

CORRELATION OF RESULTS OF QUALITATIVE RESPIRATOR  
FACEPIECE FITTING TESTS USING ISOAMYL ACETATE VAPOR  
AS TEST AGENT WITH RESULTS OF QUANTITATIVE  
RESPIRATOR FACEPIECE FITTING TESTS USING POLYDISPERSE  
DIETHYLHEXYL PHTHALATE AEROSOL AS TEST AGENT

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## INTRODUCTION

If the pressure of the air inside the respiratory-inlet covering of a respirator worn by a person is less than the pressure of the air in the atmosphere surrounding the respirator wearer, then the pressure of the air inside the respiratory-inlet covering is said to be negative. If the pressure of the air inside the respiratory-inlet covering of a respirator worn by a person is greater than the pressure of the air in the atmosphere surrounding the respirator wearer, then the pressure of the air inside the respiratory-inlet covering is said to be positive. Certain types of respirators operate in a manner such that the air pressure inside the respiratory-inlet covering is negative when the respirator wearer inhales and the air pressure inside the respiratory-inlet covering is positive when the respirator wearer exhales. These types of respirators include the non-powered air-purifying respirator, the demand type airline respirator, the hose mask without blower, the hose mask with blower which sometimes supplies an inadequate amount of air when the respirator wearer inhales, the demand type open-circuit self-contained breathing respirator, and the negative pressure type closed-circuit self-contained breathing respirator. All of these types of respirators are classified as negative pressure respirators. The respiratory-inlet covering of these types of respirators is a facepiece. If the facepiece of a negative pressure respirator does not properly fit the face of the respirator wearer, then air which surrounds the respirator wearer can pass between the facepiece and the wearer's face and penetrate into the interior of the facepiece whenever the wearer inhales. This means that air containing a contaminant can penetrate into the interior of a facepiece of a negative pressure respirator worn by a person whenever the wearer inhales if the facepiece does not properly fit the face of the wearer and this contaminated air will be inhaled by the wearer.

Inasmuch as faces of persons vary greatly in size and shape, it is not possible that a particular facepiece of a specific make and model negative pressure respirator will properly fit the faces of all respirator wearers. Thus, an employer who provides negative pressure respirators to employees to protect them against inhalation of a harmful contaminant in the air of a workplace should have available several different makes and models of negative pressure respirators equipped with facepieces which have a variety of sizes and shapes, and the employer should carry out respirator facepiece fitting tests in order to select specific makes and models of negative pressure respirators for assignment to particular employees.

Two types of respirator facepiece fitting tests have been used by employers for selection of specific makes and models of negative pressure respirators for assignment to particular employees. One type is known as the qualitative respirator facepiece fitting test and the other type is known as the quantitative respirator facepiece fitting test.

In a qualitative respirator facepiece fitting test, a person wearing a negative pressure respirator is exposed to an atmosphere containing a test agent which the wearer can detect by sensation of odor, taste, or irritation. Usually, the test agent utilized in a qualitative respirator facepiece fitting test is an odorous vapor or an irritant smoke. When carrying out a qualitative respirator facepiece fitting test with an air-purifying respirator worn by a person, the respirator must be equipped with an air-purifying element(s) which effectively removes the test agent from air. During the qualitative respirator facepiece fitting test, if the respirator wearer is unable to detect the penetration of the test agent into the interior of the facepiece, then it is assumed that the facepiece satisfactorily fits the wearer's face.

In a quantitative respirator facepiece fitting test, a person wearing a negative pressure respirator is exposed to an atmosphere containing a test agent which can be accurately measured for concentration by means of an instrument. Instrumentation, which samples the air of the test atmosphere and the air inside the respirator facepiece worn by the person, is utilized to quantitatively measure the penetration of the test agent into the interior of the facepiece of the respirator worn by the person. The test agent may be an aerosol, vapor, or gas. When carrying out a quantitative respirator facepiece fitting test with an air-purifying respirator worn by a person, the respirator must be equipped with an air-purifying element(s) which effectively removes the test agent from air.

Facial movements, head movements, and body movements by a respirator wearer may affect the stability of the position of the respirator facepiece on the wearer's face. Therefore, when carrying out a qualitative or quantitative respirator facepiece fitting test, the respirator wearer should carry out a series of facial, head, and body movements which simulate movements the wearer may carry out while wearing a respirator in a workplace.

A facepiece-fitting factor is defined as the ratio of the concentration of the test agent in the test atmosphere surrounding the respirator wearer during a quantitative respirator facepiece fitting test to the concentration of the test agent in the air inside the respirator facepiece. The facepiece-fitting factor is a measure of the integrity of the fit of the facepiece to the wearer.

A quantitative respirator facepiece fitting test may be used to assign a facepiece-fitting factor to a respirator/wearer combination. The instrument which measures the penetration of the test agent into the respirator facepiece worn by a person should be connected to a fast response recorder which continuously records the values of penetration of the test agent into the interior of the facepiece. The mean of the peak values of the penetration of the test agent into the interior of the respirator facepiece which occur when the respirator wearer inhales should be determined for each type of exercise carried out by the respirator wearer. The facepiece-fitting factor for a given make and model respirator worn by the person in quantitative respirator facepiece fitting test is calculated by using the following equation:

$$\text{Facepiece-Fitting Factor} = \frac{100}{\frac{\text{Sum of mean peak penetrations for all exercises (in percent)}}{\text{Number of exercises}}}$$

An investigation was carried out to compare the results of a qualitative respirator facepiece fitting test to the results of a quantitative respirator facepiece fitting test. The investigation involved a comparison of the results of the two mentioned types of respirator facepiece fitting tests for non-powered air-purifying type negative pressure respirators equipped with half-mask facepieces worn by a human test subject. The test agent utilized in the qualitative respirator facepiece fitting test was isoamyl acetate (IAA) vapor and the test agent utilized in the quantitative respirator facepiece fitting test was a polydisperse di (2-ethylhexyl) phthalate (DEHP) aerosol.

Each respirator used in the investigation was equipped with a pair of air-purifying cartridges which would remove both the DEHP aerosol particles and the IAA vapor from air. Each cartridge contained an ultra-high efficiency particulate-filtering element and a vapor adsorbent bed of packed activated carbon granules. A metal probe penetrated the respirator facepiece in the respirator wearer's breathing zone and a flexible plastic tube attached to this probe was connected to the test agent sampling instrumentation during a quantitative respirator facepiece fitting test. This flexible tube was closed by means of a clamp during a qualitative respirator facepiece fitting test.

Penetration of the IAA vapor between the respirator facepiece and the respirator wearer's face during a qualitative respirator fitting test would be determined by the respirator wearer detecting the odor of the IAA vapor. Penetration of the polydisperse DEHP aerosol particles between the respirator facepiece and the respirator wearer's face during a quantitative respirator facepiece fitting test would be quantitatively measured by passing air sampled from within the facepiece in the respirator wearer's breathing zone through the probe and flexible plastic tube and through a forward light-scattering photometer instrument, and the penetration values in percentage of the concentration of the polydisperse DEHP aerosol particles in the test atmosphere would be recorded on a strip chart. During both the qualitative respirator facepiece fitting test and the quantitative respirator facepiece fitting test, the human test subject wearing the respirator carries out a series of exercises involving facial and head movements which simulate those a worker may carry out in a workplace.

#### TEST DETAILS

Non-powered air-purifying respirators equipped with half-mask facepieces were used in the investigation. Respirators equipped with three sizes of facepiece, large, medium, and small, were available. Each respirator contained a pair of air-purifying cartridges which would effectively remove both the DEHP aerosol particles and the IAA vapor from air passing through the cartridge during inhalation by a respirator wearer. A metal probe penetrated the wall of the facepiece in the breathing zone of the respirator wearer. A flexible plastic tube attached to the probe and connected to a forward

light-scattering photometer and pump was used to sample air from within the facepiece and to measure the penetration of the DEHP aerosol particles into the facepiece during a quantitative respirator fitting test. A fast response strip chart recorder connected to the photometer was used to make a record of this penetration continuously through a test. The flexible plastic tube was left connected to the probe in the facepiece during a qualitative respirator facepiece fitting test, but the tube was closed by means of a clamp.

Laboratory, office, and factory workers, both male and female, were used as human test subjects in the investigation. Although these persons had been trained to wear respirators, they do not normally wear respirators while performing their jobs. The group of human test subjects did not comprise an anthropometric panel having facial dimensions to represent the adult work population. Each human test subject was provided with a respirator equipped with a half-mask facepiece of a size appropriate to the size of the subject's face. After donning the respirator, the subject performed a positive air pressure type facepiece to face fit check to insure that the respirator facepiece was positioned properly on the subject's face. In a few cases, the facepiece to face fit check indicated that the subject could not get an air-tight seal of the facepiece to the face. These subjects were allowed to participate in the investigation since the purpose of the investigation was to compare the results of the qualitative respirator facepiece fitting tests with the results of the quantitative respirator facepiece fitting tests. Sixty sets of qualitative and quantitative respirator facepiece fitting tests were carried out.

A person can detect the presence of IAA vapor in air by sensing its odor which is pleasant and smells like a banana. Some persons can sense the odor of IAA vapor in air when its concentration is as low as 0.2 ppm. Prior to carrying out the qualitative respirator facepiece fitting tests which utilized IAA vapor as the test agent, each human test subject was checked to insure that the subject could detect the odor of IAA vapor in air at a concentration of approximately 1 ppm.

During both the qualitative respirator facepiece fitting test and the quantitative respirator fitting test, the human test subject wearing a respirator sequentially carried out the following five exercises: (1) normal breathing, (2) deep breathing, (3) turning head side to side, (4) nodding head up and down, and (5) normal breathing. The time period for each exercise was approximately 2 minutes.

In each set of respirator facepiece fitting tests, the IAA vapor qualitative test was carried out first and the polydisperse DEHP aerosol quantitative test was carried out second. After donning the respirator, adjusting the fit of the respirator facepiece on the face, and checking the seal of the respirator facepiece to the face, the respirator wearer entered the IAA vapor test chamber and carried out the qualitative respirator facepiece fitting test. After exiting from the IAA vapor test chamber upon completion of the qualitative respirator facepiece fitting test, the respirator wearer entered the DEHP aerosol test chamber and performed the quantitative respirator facepiece fitting test. The fit of the respirator facepiece on the respirator wearer's face was not adjusted between the two types of tests.

The concentration of the IAA vapor in the air of the test atmosphere employed in the qualitative respirator facepiece fitting test was approximately 100 ppm. The mass median aerodynamic diameter of the polydisperse DEHP aerosol particles used in the quantitative respirator facepiece fitting tests was 0.7 micrometer and the mean concentration of the particles in air of the test atmosphere was 25 milligrams per cubic meter of air. Air from within the respirator facepiece was sampled at a volumetric air flow rate of 1 liter per minute during the quantitative respirator facepiece fitting test. The volume of the test chamber utilized in the qualitative respirator facepiece fitting test is 14 cubic meters and the volume of the test chamber utilized in the quantitative respirator facepiece fitting test is 22 cubic meters.

In the Introduction, it was mentioned that the peak values of the penetration of the test agent into the interior of the respirator facepiece during a quantitative respirator facepiece fitting test are used to determine a facepiece-fitting factor. The recording of the values of penetration of the test agent into the interior of the respirator facepiece is sinusoidal in shape because of the breathing pattern of the respirator wearer. The peaks of this sinusoidal-shaped recording represent, the values of the penetration of the test agent which occur during the inhalation phase of breathing. The strip chart recording for each quantitative test was analyzed to determine the means of the peak penetrations which occurred during each exercise performed by the respirator wearer. These mean values of the peak penetrations were used in the equation given in the Introduction to calculate a facepiece-fitting factor for each quantitative test.

## TEST RESULTS

The results of the sixty sets of qualitative and quantitative respirator facepiece fitting tests are given in Table No. I.

Table No. II groups the results of the qualitative and quantitative respirator facepiece fitting tests according to the facepiece-fitting factors achieved by respirator/wearer combinations during the quantitative tests. This Table also presents the responses of the human test subjects wearing the respirators during the qualitative tests. In this Table, the results are given for all five exercises carried out by the respirator wearers and for only the initial normal breathing exercise.

The results of the quantitative respirator facepiece fitting tests are illustrated graphically in Figure No. 1. In this Figure is a graphical plot of the cumulative percentages of the respirator/wearer combinations which achieved certain facepiece-fitting factors during the quantitative tests for all five exercises carried out by the respirator wearers. Also, the figure contains a graphical plot of the cumulative percentages of the respirator/wearer combinations which achieved certain facepiece-fitting factors during the quantitative tests for only the initial normal breathing exercise performed by the respirator.

## ANALYSIS OF TEST RESULTS

When a worker wears a respirator in a workplace where the atmosphere contains a harmful **contaminant**, the respirator should insure that the concentration of the contaminant inside the respiratory-inlet covering of the respirator never exceeds the established permissible time-weighted average concentration or the established permissible ceiling concentration, whichever is applicable, for a toxic substance, or the maximum permissible airborne concentration for a radionuclide. Provided that the air-purifying element of an air-purifying respirator is effective in removing the contaminant from the air passed through it when a respirator wearer inhales, provided that an atmosphere-supplying respirator provides an adequate amount of respirable air to a respirator wearer, and provided that other components of a respirator worn by a person operate properly, the integrity of the fit of the respiratory-inlet covering of a respirator to the wearer will determine the maximum concentration of a contaminant in the air of the workplace atmosphere for which a respirator can be used for protection.

The integrity of the fit of a respirator facepiece to the face of a person can be classified as adequate or inadequate by the **facepiece-fitting** factor achieved by the respirator/wearer combination during a quantitative respirator facepiece fitting test. Generally, the **facepiece-fitting** factor of 10 has been selected for application of negative pressure respirators equipped with **quarter-mask** facepieces or half-mask facepieces when specific makes and models of these respirators have been selected for assignment to particular persons on the basis of having been found to be acceptable in regard to facepiece to fit by means of qualitative respirator facepiece fitting tests. The investigation described in this paper was carried out to determine if a **facepiece-fitting** factor of 10 is safe to use for air-purifying type negative pressure respirators equipped with half-mask facepieces.

Various statistics for evaluating the performance of the IAA vapor qualitative respirator facepiece fitting test by means of a respirator/wearer combination achieving a specific **facepiece-fitting** factor during a **polydisperse DEHP** aerosol quantitative respirator facepiece fitting test are defined in Table No. III. Using the summary of tests results given in Table No. II, the values of these statistics can be calculated.

The statistic "**lambda**", which is the fraction of the **respirator/wearer** combinations falsely accepted by the qualitative facepiece fitting tests of all respirator/wearer combinations accepted by the qualitative respirator facepiece fitting tests, is an indication of the danger of the qualitative respirator facepiece fitting test since the false acceptance of a respirator/wearer combination which actually has an inadequate fit of the respirator facepiece to the respirator **wearer's** face possibly may result in exposing the wearer to a hazardous concentration of an air contaminant. Thus, a very low value of the statistic "**lambda**" is a necessary objective for a qualitative respirator facepiece fitting test.

The statistic "alpha", which is the fraction of the respirator/wearer combinations falsely rejected by qualitative respirator facepiece fitting tests of all respirator/wearer combinations which actually achieve the desired facepiece-fitting factor, is an indication of a waste since it requires that another make and model respirator be tested on the wearer. Thus, a very high value of the statistic "alpha" results in increasing the cost of carrying out qualitative respirator fitting tests and is an economic burden on the employer. However, since a very high value of the statistic "alpha" does not result in a danger to the respirator wearer, it may be acceptable in a qualitative respirator facepiece fitting program.

Table No. IV summarizes the values of the statistics "lambda" and "alpha" for the IAA vapor qualitative respirator fitting test for various levels of facepiece-fitting factors as determined by the investigation described in this paper. In Figure No. 2 and Figure No. 3, the values of the statistics "lambda" and "alpha" for the IAA vapor qualitative respirator fitting tests for various levels of facepiece-fitting factors are graphically illustrated.

A study of Table No. 1 indicates that for certain respirator/wearer combinations, a specific exercise or specific exercises carried out by the respirator wearer during a respirator facepiece fitting test can result in a much higher penetration of the test agent into the interior of the respirator facepiece than the penetrations which occur when other exercises are carried out. The data in Table No. 1 shows that this can happen in both the polydisperse DEHP aerosol quantitative respirator facepiece fitting tests and the IAA vapor qualitative respirator facepiece fitting tests. Some persons have advocated that respirator facepiece fitting tests be carried out with the respirator wearers performing only the normal breathing exercise. The data in Table No. 1 indicates that this may be risky. The data given in Table No. II shows that the results of both the quantitative tests and the qualitative tests carried out with the use of the five exercises frequently are significantly different from the results obtained when these tests make use only of the normal breathing exercise. Figure No. 1 graphically illustrates the differences between the results of quantitative respirator facepiece fitting tests performed with the use of the five exercises and the results of quantitative respirator facepiece fitting tests performed with the use of only the normal breathing exercise.

The statistic "lambda" indicates the risk of using the IAA vapor qualitative respirator facepiece fitting test instead of the polydisperse DEHP aerosol quantitative respirator facepiece fitting test when selecting specific makes and models of air-purifying type negative pressure respirators equipped with half-mask facepieces for assignment to particular persons. A review of Table No. IV shows that there is a much greater risk of falsely accepting a specific make and model respirator for assignment to a particular person when the qualitative test employs only the normal breathing exercise than when the qualitative tests employs the five exercises. Figure No. 2 graphically illustrates this matter.

A review of the values of the statistic " $\lambda$ " in Table No. IV shows that a **facepiece-fitting** factor of 10 is safe for the application of air-purifying type negative pressure respirators equipped with half-masks facepieces when specific makes and models of these respirators are selected for assignment to particular persons on the basis of having been found to be acceptable in regard to facepiece to face fit by means of IAA vapor qualitative respirator facepiece fitting tests. This value of the facepiece fitting factor is unquestionably safe when the qualitative tests are performed with the use of exercises which simulate the movements of workers in workplaces.

The statistic " $\alpha$ " indicates the economic burden on an employer of using the IAA vapor qualitative respirator facepiece fitting test instead of the **polydisperse** DEHP aerosol quantitative respirator facepiece fitting test when selecting specific makes and models of air-purifying type negative pressure respirators equipped with half-mask facepieces for assignment to particular employees. The values of the statistic " $\alpha$ " in Table No. IV indicate that the IAA vapor qualitative respirator facepiece fitting test frequently may result in the rejection of specific makes and models of respirators for assignment to particular persons when these respirators properly fit these persons.

#### CONCLUSIONS

The IAA vapor qualitative respirator facepiece fitting test is safe to use to select specific makes and models of air-purifying type negative pressure respirators equipped with half-mask facepieces for assignment to particular persons provided that a **facepiece-fitting** factor not exceeding 10 is applied when the respirators are worn by persons for respiratory protection in contaminated atmospheres.

When carrying out an IAA vapor qualitative respirator facepiece fitting tests, the respirator wearer should perform a series of exercises which simulate movements the wearer will carry out in the workplace.

The IAA vapor qualitative respirator facepiece fitting test poses an economic burden on an employer in selecting specific makes and models of air-purifying type negative pressure respirators equipped with half-mask facepieces for assignment to particular employees since it frequently may result in the rejection of specific makes and models of respirators for assignment to particular persons when these respirators actually fit these persons properly.

TABLE NO. I

**RESULTS OF QUALITATIVE ISOAMYL ACETATE VAPOR FITTING  
TESTS AND QUANTITATIVE POLYDISPERSE DEHP AEROSOL FITTING TESTS WITH  
HUMAN TEST SUBJECTS WEARING AIR-PURIFYING RESPIRATORS EQUIPPED WITH  
WITH HALF-MASK FACEPIECES**

| Test No. | Type of Test | Detection of Odor of IAA in Qual. Test Mean Peak Penetration of DEHP |                |                |                |                | Mean of Peak DEHP Pen. | Facepiece-Fitting Factor |
|----------|--------------|----------------------------------------------------------------------|----------------|----------------|----------------|----------------|------------------------|--------------------------|
|          |              | Aerosol in NB                                                        | Quant. DB      | Test THSS      | NHVD           | NB             |                        |                          |
| 1        | Qual. Quant. | None<br>0.0032                                                       | None<br>0.0070 | None<br>0.0024 | None<br>0.0028 | None<br>0.0022 | 0.0035                 | 28,571                   |
| 2        | Qual. Quant. | None<br>0.0030                                                       | None<br>0.0040 | None<br>0.022  | Medium<br>0.12 | None<br>0.0042 | 0.031                  | 3,226                    |
| 3        | Qual. Quant. | None<br>0.0025                                                       | None<br>0.0012 | None<br>0.0045 | None<br>0.0050 | None<br>0.0030 | 0.0032                 | 31,250                   |
| 4        | Qual. Quant. | None<br>0.030                                                        | None<br>0.052  | None<br>0.060  | None<br>0.082  | None<br>0.042  | 0.053                  | 1,887                    |
| 5        | Qual. Quant. | Large<br>12                                                          | Large<br>10    | Large<br>24    | Large<br>15    | Large<br>11    | 14.4                   | 6.9                      |
| 6        | Qual. Quant. | None<br>0.0016                                                       | None<br>0.0032 | Large<br>3.2   | Large<br>4.4   | None<br>0.0046 | 1.5                    | 67                       |
| 7        | Qual. Quant. | None<br>0.18                                                         | None<br>0.18   | None<br>0.20   | None<br>0.18   | None<br>0.18   | 0.18                   | 556                      |
| 8        | Qual. Quant. | Small<br>1.8                                                         | None<br>0.90   | Medium<br>8.5  | Medium<br>12.5 | Small<br>3.2   | 5.4                    | 18.5                     |
| 9        | Qual. Quant. | None<br>0.50                                                         | None<br>0.32   | None<br>0.56   | None<br>0.52   | None<br>0.30   | 0.44                   | 227                      |
| 10       | Qual. Quant. | Medium<br>9.9                                                        | Medium<br>8.4  | Large<br>30    | Large<br>29    | Large<br>28    | 21.1                   | 4.7                      |
| 11       | Qual. Quant. | None<br>2.6                                                          | None<br>2.5    | None<br>2.1    | None<br>2.1    | None<br>2.3    | 2.3                    | 43                       |
| 12       | Qual. Quant. | None<br>0.020                                                        | None<br>0.028  | None<br>0.26   | None<br>0.22   | None<br>0.047  | 0.12                   | 833                      |
| 13       | Qual. Quant. | Small<br>0.35                                                        | Small<br>0.30  | Small<br>0.34  | Small<br>0.34  | Small<br>0.32  | 0.33                   | 303                      |
| 14       | Qual. Quant. | Medium<br>3.8                                                        | Medium<br>3.8  | Medium<br>5.0  | Medium<br>5.0  | Medium<br>4.0  | 4.3                    | 23                       |
| 15       | Qual. Quant. | Large<br>20                                                          | Large<br>9     | Large<br>24    | Large          | Large          | 18.6                   | 5.4                      |
| 16       | Qual. Quant. | None<br>0.015                                                        | None<br>0.010  | None<br>0.022  | None<br>0.022  | None<br>0.018  | 0.017                  | 5,882                    |
| 17       | Qual. Quant. | None<br>0.0038                                                       | None<br>0.0029 | None<br>0.014  | None<br>0.0030 | None<br>0.0048 | 0.0057                 | 17,544                   |
| 18       | Qual. Quant. | None<br>0.0010                                                       | None<br>0.0020 | None<br>0.0014 | None<br>0.0080 | None<br>0.0022 | 0.0047                 | 21,277                   |
| 19       | Qual. Quant. | Small<br>2.4                                                         | Small<br>2.0   | Small<br>2.2   | Small<br>2.2   | Small<br>2.0   | 2.2                    | 45                       |
| 20       | Qual. Quant. | Small<br>4.4                                                         | Small<br>4.3   | Medium<br>5.4  | Medium<br>4.9  | Small<br>4.0   | 4.6                    | 22                       |

TABLE NO. I (continued)

RESULTS OF QUALITATIVE ISOAMYL ACETATE VAPOR FITTING  
 TESTS AND QUANTITATIVE POLYDISPERSE DEHP AEROSOL FITTING TESTS WITH  
 HUMAN TEST SUBJECTS WEARING AIR-PURIFYING RESPIRATORS EQUIPPED WITH  
 WITH HALF-MASK FACEPIECES

| Test<br>No. | Type of<br>Test | Detection of Odor of IAA in Qual.<br>Test Mean Peak Penetration of DEHP<br>Aerosol in Quant. Test |                |                |                |                | Mean of<br>PEAK DEHP.<br>Pen. | Facepiece-<br>Fitting<br>Factor |
|-------------|-----------------|---------------------------------------------------------------------------------------------------|----------------|----------------|----------------|----------------|-------------------------------|---------------------------------|
|             |                 | NB                                                                                                | DB             | THSS           | NHVD           | NB             |                               |                                 |
|             |                 |                                                                                                   |                |                |                |                |                               |                                 |
| 21          | Qual.<br>Quant. | Large<br>3.6                                                                                      | Large<br>4.1   | Large<br>1.4   | Large<br>4.6   | Large<br>4.2   | 3.6                           | 28                              |
| 22          | Qual.<br>Quant. | None<br>0.0040                                                                                    | None<br>0.0040 | Large<br>40    | Medium<br>0.20 | None<br>0.0040 | 8.0                           | 12.5                            |
| 23          | Qual.<br>Quant. | Medium<br>1.8                                                                                     | Medium<br>1.4  | Medium<br>2.4  | Medium<br>0.64 | Medium<br>1.1  | 1.5                           | 67                              |
| 24          | Qual.<br>Quant. | None<br>0.19                                                                                      | None<br>0.17   | None<br>0.18   | None<br>0.19   | None<br>0.15   | 0.18                          | 556                             |
| 25          | Qual.<br>Quant. | Small<br>4.0                                                                                      | Small<br>4.0   | Small<br>5.0   | Small<br>4.8   | Small<br>4.0   | 4.4                           | 23                              |
| 26          | Qual.<br>Quant. | None<br>2.0                                                                                       | None<br>1.2    | Medium<br>14   | Small<br>10    | None<br>1.0    | 5.6                           | 18                              |
| 27          | Qual.<br>Quant. | Large<br>5.8                                                                                      | Large<br>8.2   | Large<br>6.8   | Large<br>10.0  | Large<br>12.0  | 8.6                           | 12                              |
| 28          | Qual.<br>Quant. | None<br>0.42                                                                                      | None<br>0.68   | Small<br>1.4   | Small<br>1.2   | Small<br>1.0   | 0.94                          | 106                             |
| 29          | Qual.<br>Quant. | None<br>0.040                                                                                     | None<br>0.028  | None<br>0.044  | None<br>0.040  | None<br>0.038  | 0.038                         | 2,632                           |
| 30          | Qual.<br>Quant. | None<br>0.040                                                                                     | None<br>0.030  | None<br>0.034  | None<br>0.032  | None<br>0.032  | 0.034                         | 2,941                           |
| 31          | Qual.<br>Quant. | None<br>2.5                                                                                       | None<br>2.4    | None<br>3.0    | None<br>2.8    | None<br>2.7    | 2.7                           | 37                              |
| 32          | Qual.<br>Quant. | Small<br>4.0                                                                                      | Small<br>3.8   | Small<br>6.0   | Small<br>5.4   | Small<br>4.8   | 4.8                           | 21                              |
| 33          | Qual.<br>Quant. | None<br>0.0030                                                                                    | None<br>0.0020 | None<br>0.0035 | None<br>0.0035 | None<br>0.0025 | 0.0029                        | 34,483                          |
| 34          | Qual.<br>Quant. | Small<br>0.78                                                                                     | Small<br>0.62  | Small<br>0.84  | Small<br>0.78  | Small<br>0.70  | 0.74                          | 133                             |
| 35          | Qual.<br>Quant. | None<br>0.0020                                                                                    | None<br>0.0012 | None<br>0.0024 | None<br>0.0010 | None<br>0.0026 | 0.0018                        | 55,556                          |
| 36          | Qual.<br>Quant. | Small<br>0.50                                                                                     | Small<br>0.40  | Small<br>0.55  | Small<br>0.40  | Small<br>0.30  | .043                          | 233                             |
| 37          | Qual.<br>Quant. | Large<br>1.2                                                                                      | Large<br>1.6   | Medium<br>0.52 | Medium<br>0.50 | Large<br>6.4   | 2.0                           | 50                              |
| 38          | Qual.<br>Quant. | None<br>0.28                                                                                      | None<br>0.26   | None<br>0.28   | None<br>0.28   | None<br>0.26   | 0.27                          | 371                             |
| 39          | Qual.<br>Quant. | Small<br>2.4                                                                                      | Small<br>2.2   | Small<br>2.4   | Small<br>2.4   | Small<br>2.0   | 2.3                           | 43                              |
| 40          | Qual.<br>Quant. | None<br>0.20                                                                                      | None<br>0.18   | None<br>0.26   | None<br>0.22   | None<br>0.20   | 0.21                          | 476                             |

TABEL NO. I (continued)

RESULTS OF QUALITATIVE ISOAMYL ACETATE VAPOR FITTING  
TESTS AND QUANTITATIVE POLYDISPERSE DEHP AEROSOL FITTING TESTS WITH  
HUMAN TEST SUBJECTS WEARING AIR-PURIFYING RESPIRATORS EQUIPPED WITH  
WITH HALF-MASK FACEPIECES

| Test<br>No. | Type of<br>Test | Detection of Odor of IAA in Qual.<br>Test Mean Peak Penetration of DEHP<br>Detection in Quant. Test |                |                |                |                | Mean of<br>Peak DEHP.<br>Pen. | Facepiece-<br>Fitting<br>Factor |
|-------------|-----------------|-----------------------------------------------------------------------------------------------------|----------------|----------------|----------------|----------------|-------------------------------|---------------------------------|
|             |                 | NB                                                                                                  | DB             | THSS           | NHVD           | NB             |                               |                                 |
|             |                 |                                                                                                     |                |                |                |                |                               |                                 |
| 41          | Qual.<br>Quant. | None<br>0.32                                                                                        | None<br>0.18   | Small<br>1.8   | Small<br>1.0   | None<br>0.55   | 0.77                          | 130                             |
| 42          | Qual.<br>Quant. | None<br>0.028                                                                                       | None<br>0.030  | None<br>0.032  | None<br>0.027  | None<br>0.032  | 0.030                         | 3,333                           |
| 43          | Qual.<br>Quant. | None<br>0.80                                                                                        | None<br>0.42   | Small<br>1.4   | Small<br>1.0   | None<br>0.78   | 0.88                          | 114                             |
| 44          | Qual.<br>Quant. | None<br>1.4                                                                                         | Small<br>2.5   | None<br>1.8    | None<br>1.9    | None<br>1.5    | 1.8                           | 56                              |
| 45          | Qual.<br>Quant. | None<br>0.032                                                                                       | None<br>0.022  | None<br>0.040  | None<br>0.053  | None<br>0.043  | 0.038                         | 2,632                           |
| 46          | Qual.<br>Quant. | None<br>0.0054                                                                                      | None<br>0.0070 | None<br>0.0070 | None<br>0.0070 | None<br>0.0068 | 0.0066                        | 15,152                          |
| 47          | Qual.<br>Quant. | None<br>0.0034                                                                                      | None<br>0.0050 | None<br>0.0052 | None<br>0.0056 | None<br>0.0050 | 0.0048                        | 20,833                          |
| 48          | Qual.<br>Quant. | Medium<br>2.0                                                                                       | Medium<br>1.6  | Large<br>2.2   | Large<br>2.4   | Medium<br>1.4  | 1.9                           | 53                              |
| 49          | Qual.<br>Quant. | None<br>0.52                                                                                        | None<br>0.18   | None<br>0.90   | None<br>0.92   | None<br>0.60   | 0.62                          | 161                             |
| 50          | Qual.<br>Quant. | None<br>0.0026                                                                                      | None<br>0.0046 | Small<br>0.14  | Medium<br>1.4  | None<br>0.0040 | 0.31                          | 323                             |
| 51          | Qual.<br>Quant. | None<br>0.0024                                                                                      | None<br>0.0022 | None<br>0.094  | None<br>0.0026 | None<br>0.0024 | 0.021                         | 4,761                           |
| 52          | Qual.<br>Quant. | None<br>0.32                                                                                        | None<br>0.14   | Large<br>24.0  | Large<br>12.4  | None<br>1.4    | 7.7                           | 13                              |
| 53          | Qual.<br>Quant. | Medium<br>10                                                                                        | Medium<br>6.2  | Large<br>22    | Large<br>15    | Medium<br>10   | 13                            | 7.7                             |
| 54          | Qual.<br>Quant. | None<br>0.0056                                                                                      | None<br>0.0060 | None<br>0.0018 | None<br>0.0026 | None<br>0.0030 | 0.0038                        | 26,316                          |
| 55          | Qual.<br>Quant. | None<br>0.0044                                                                                      | None<br>0.0070 | None<br>0.024  | None<br>0.020  | None<br>0.016  | 0.014                         | 7,143                           |
| 56          | Qual.<br>Quant. | None<br>0.0052                                                                                      | None<br>0.0074 | None<br>0.0052 | None<br>0.0064 | None<br>0.0064 | 0.0061                        | 16,393                          |
| 57          | Qual.<br>Quant. | None<br>0.070                                                                                       | None<br>0.060  | None<br>0.076  | None<br>0.070  | None<br>0.070  | 0.069                         | 1,449                           |
| 58          | Qual.<br>Quant. | None<br>0.040                                                                                       | None<br>0.044  | Large<br>5.6   | Large<br>18    | Large<br>5.0   | 5.7                           | 18                              |
| 59          | Qual.<br>Quant. | Small<br>1.2                                                                                        | Small<br>0.80  | Large<br>28    | Large<br>20    | Large<br>10    | 12                            | 8.3                             |
| 60          | Qual.<br>Quant. | None<br>0.34                                                                                        | None<br>0.22   | None<br>0.48   | None<br>0.42   | None<br>0.36   | 0.36                          | 278                             |

SUMMARY OF RESULTS OF ISOAMYL ACETATE VAPOR ODOR QUALITATIVE RESPIRATOR  
FACEPIECE FITTING TESTS AND POLYDISPERSE DEHP AEROSOL PENETRATION TYPE  
QUANTITATIVE RESPIRATOR FITTING TESTS

| Test No. | Mean of Peaks of DEHP Aerosol Penetrations |                           | Facepiece-Fitting Factor |                           | Subject Response During Isoamyl Acetate Vapor. Qualitative Test. |                           |
|----------|--------------------------------------------|---------------------------|--------------------------|---------------------------|------------------------------------------------------------------|---------------------------|
|          | For All Exercises                          | For First N. Br. Ex. Only | For All Ex.              | For First N. Br. Ex. Only | For Any Ex.                                                      | For First N. Br. Ex. Only |
|          | (%)                                        | (%)                       |                          |                           |                                                                  |                           |
| 10       | 21.1                                       | 9.9                       | 4.7                      | 10.1                      | +                                                                | +                         |
| 15       | 18.6                                       | 20                        | 5.4                      | 5                         | +                                                                | +                         |
| 5        | 14.4                                       | 12                        | 6.9                      | 8.3                       | +                                                                | +                         |
| 53       | 13                                         | 10                        | 7.7                      | 10                        | +                                                                | +                         |
| 59       | 12                                         | 1.2                       | 8.3                      | 83                        | +                                                                | +                         |
| 27       | 8.6                                        | 5.8                       | 12                       | 17                        | +                                                                | +                         |
| 22       | 8.0                                        | 0.0040                    | 12.5                     | 25,000                    | +                                                                | -                         |
| 52       | 7.7                                        | 0.32                      | 13                       | 312                       | +                                                                | -                         |
| 26       | 5.6                                        | 2.0                       | 18                       | 50                        | +                                                                | -                         |
| 58       | 5.7                                        | 0.040                     | 18                       | 2,500                     | +                                                                | -                         |
| 8        | 5.4                                        | 1.8                       | 18.5                     | 56                        | +                                                                | +                         |
| 32       | 4.8                                        | 4.0                       | 21                       | 25                        | +                                                                | +                         |
| 20       | 4.6                                        | 4.4                       | 22                       | 23                        | +                                                                | +                         |
| 14       | 4.3                                        | 3.8                       | 23                       | 26                        | +                                                                | +                         |
| 25       | 4.4                                        | 4.0                       | 23                       | 25                        | +                                                                | +                         |
| 21       | 3.6                                        | 3.6                       | 28                       | 28                        | +                                                                | +                         |
| 31       | 2.7                                        | 2.5                       | 37                       | 40                        | -                                                                | -                         |
| 11       | 2.3                                        | 2.6                       | 43                       | 38                        | -                                                                | -                         |
| 39       | 2.3                                        | 2.4                       | 43                       | 42                        | +                                                                | +                         |
| 19       | 2.2                                        | 2.4                       | 45                       | 42                        | +                                                                | +                         |
| 37       | 2.0                                        | 1.2                       | 50                       | 83                        | +                                                                | +                         |
| 48       | 1.9                                        | 2.0                       | 53                       | 50                        | +                                                                | +                         |
| 44       | 1.8                                        | 1.4                       | 56                       | 71                        | +                                                                | -                         |
| 23       | 1.5                                        | 1.8                       | 67                       | 56                        | +                                                                | +                         |
| 6        | 1.5                                        | 0.0016                    | 67                       | 62,500                    | +                                                                | -                         |
| 28       | 0.94                                       | 0.42                      | 106                      | 238                       | +                                                                | -                         |
| 43       | 0.88                                       | 0.80                      | 114                      | 125                       | +                                                                | -                         |
| 41       | 0.77                                       | 0.32                      | 130                      | 312                       | +                                                                | -                         |
| 34       | 0.74                                       | 0.78                      | 135                      | 128                       | +                                                                | +                         |
| 49       | 0.62                                       | 0.52                      | 161                      | 192                       | -                                                                | -                         |
| 9        | 0.44                                       | 0.50                      | 227                      | 200                       | -                                                                | -                         |
| 36       | 0.43                                       | 0.50                      | 233                      | 200                       | +                                                                | +                         |
| 60       | 0.36                                       | 0.34                      | 278                      | 294                       | -                                                                | -                         |
| 13       | 0.33                                       | 0.35                      | 303                      | 286                       | +                                                                | +                         |
| 50       | 0.31                                       | 0.0026                    | 323                      | 38,462                    | +                                                                | -                         |
| 38       | 0.27                                       | 0.28                      | 371                      | 357                       | -                                                                | -                         |
| 40       | 0.21                                       | 0.20                      | 476                      | 500                       | -                                                                | -                         |
| 24       | 0.18                                       | 0.19                      | 556                      | 526                       | -                                                                | -                         |
| 9        | 0.18                                       | 0.18                      | 556                      | 556                       | -                                                                | -                         |
| 12       | 0.12                                       | 0.020                     | 833                      | 5,000                     | -                                                                | -                         |
| 57       | 0.069                                      | 0.070                     | 1,449                    | 1,429                     | -                                                                | -                         |
| 4        | 0.053                                      | 0.030                     | 1,887                    | 3,333                     | -                                                                | -                         |
| 29       | 0.038                                      | 0.040                     | 2,632                    | 2,500                     | -                                                                | -                         |
| 45       | 0.038                                      | 0.032                     | 2,632                    | 3,125                     | -                                                                | -                         |
| 30       | 0.034                                      | 0.040                     | 2,941                    | 2,500                     | -                                                                | -                         |
| 2        | 0.031                                      | 0.0030                    | 3,226                    | 33,333                    | +                                                                | -                         |
| 42       | 0.030                                      | 0.028                     | 3,333                    | 3,571                     | -                                                                | -                         |
| 51       | 0.021                                      | 0.0024                    | 4,761                    | 41,667                    | -                                                                | -                         |
| 16       | 0.017                                      | 0.015                     | 5,882                    | 6,667                     | -                                                                | -                         |
| 55       | 0.014                                      | 0.0044                    | 7,143                    | 22,727                    | -                                                                | -                         |
| 46       | 0.0066                                     | 0.0054                    | 15,152                   | 18,519                    | -                                                                | -                         |
| 56       | 0.0061                                     | 0.0052                    | 16,393                   | 19,230                    | -                                                                | -                         |
| 17       | 0.0057                                     | 0.0038                    | 17,544                   | 26,316                    | -                                                                | -                         |
| 47       | 0.0048                                     | 0.0034                    | 20,833                   | 29,412                    | -                                                                | +                         |
| 18       | 0.0047                                     | 0.010                     | 21,277                   | 10,000                    | -                                                                | -                         |
| 54       | 0.0038                                     | 0.0056                    | 26,316                   | 17,857                    | -                                                                | -                         |
| 1        | 0.0035                                     | 0.0032                    | 28,571                   | 31,250                    | -                                                                | -                         |
| 3        | 0.0032                                     | 0.0025                    | 31,250                   | 40,000                    | -                                                                | -                         |
| 33       | 0.0029                                     | 0.0030                    | 34,483                   | 33,333                    | -                                                                | -                         |
| 35       | 0.0018                                     | 0.0020                    | 55,556                   | 50,000                    | -                                                                | -                         |

STATISTIC DEFINITIONS FOR EVALUATING ISOAMYL ACETATE VAPOR ODOR TYPE QUALITATIVE RESPIRATOR FIT TEST BY MEANS OF ACHIEVING SPECIFIC RESPIRATOR FACEPIECE-FITTING FACTOR DURING POLYDISPERSE DEHP AEROSOL PENETRATION TYPE QUANTITATIVE RESPIRATOR FIT TEST

| STATISTIC                   | DEFINITION                                                                                                                                                                                                       |
|-----------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| a                           | Number of respirator/subject combinations which are rejected by qualitative fit tests and which fail to achieve desired facepiece-fitting factor in quantitative fit tests.                                      |
| b                           | Number of respirator/subject combinations which are accepted by qualitative fit tests but which fail to achieve desired facepiece-fitting factor in quantitative fit tests.                                      |
| c                           | Number of respirator/subject combinations which are rejected by qualitative fit tests but which achieve desired facepiece-fitting factor in quantitative fit tests.                                              |
| d                           | Number of respirator/subject combinations which are accepted by qualitative fit tests and which achieve desired facepiece-fitting factor in quantitative fit tests.                                              |
| $\alpha = \frac{c}{c + d}$  | Fraction of respirator/subject combinations falsely rejected by qualitative fit tests of all respirator/subject combinations which achieve desired facepiece-fitting factor in quantitative fit tests.           |
| $\beta = \frac{c}{a + c}$   | Fraction of respirator/subject combinations falsely rejected by qualitative fit tests of all respirator/subject combinations rejected by qualitative fit tests.                                                  |
| $\psi = \frac{a}{a + b}$    | Fraction of respirator/subject combinations correctly rejected by qualitative fit tests of all respirator/subject combinations which fail to achieve desired facepiece-fitting factor in quantitative fit tests. |
| $\delta = \frac{a}{a + c}$  | Fraction of respirator/subject combinations correctly rejected by qualitative fit tests of all respirator/subject combinations which are rejected by qualitative fit tests.                                      |
| $A = \frac{b}{a + b}$       | Fraction of respirator/subject combinations falsely accepted by qualitative fit tests of all respirator/subject combinations which fail to achieve desired facepiece-fitting factor in quantitative fit tests.   |
| $\lambda = \frac{b}{b + d}$ | Fraction of respirator/subject combination falsely accepted by qualitative fit tests of all respirator/subject combinations accepted by qualitative fit tests.                                                   |
| $\phi = \frac{d}{c + d}$    | Fraction of respirator/subject combinations correctly accepted by qualitative fit tests of all respirator/subject combinations which achieve desired facepiece-fitting factor in quantitative fit tests.         |
| $\psi = \frac{d}{b + d}$    | Fraction of respirators/subject combinations correctly accepted by qualitative fit tests of all respirator/subject combinations accepted by qualitative fit tests.                                               |

RESULTS OF QUANTITATIVE FIT TESTS  
BASED ON RESPIRATORY SUBJECT/  
COMBINATION ACHIEVING DESIRED  
FACEPIECE-FITTING FACTOR OR  
FAILING TO ACHIEVE DESIRED FACE-  
PIECE-FITTING FACTOR

RESULTS OF QUALITATIVE FIT TESTS BASED  
ON SUBJECT DETECTING ODOR OF ISOAMYL  
ACETATE VAPOR OR FAILING TO DETECT ODOR  
OF ISOAMYL ACETATE VAPOR

|                                                                  | (+) Reject (Detects Odor of IAA) | (-) Accept (No Detection of Odor of IAA) | Total         |
|------------------------------------------------------------------|----------------------------------|------------------------------------------|---------------|
| (+) <u>Reject</u> (Failure to Achieve Desired Protection Factor) | a                                | b                                        | a + b         |
| (-) <u>Accept</u> (Achieve Desired Protection Factor)            | c                                | d                                        | c + d         |
|                                                                  | a + c                            | b + d                                    | a + b + c + d |

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TABLE IV

SUMMARY of A AND a FOR ISOAMYL ACETATE VAPOR ODOR TYPE QUALITATIVE RESPIRATOR FACEPIECE TEST WHICH INDICATE DANGER AND ECONOMIC BURDEN OF THIS TESTING

| Facepiece -<br>Fitting<br>Factor | $\lambda$<br>(Possible Danger to Wearer)                                                                                                                                        |                                                                    | $\alpha$<br>(Economic Burden to Employer)                                                                                                                                                         |                                                                    |
|----------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------|
|                                  | Percent of Respirator/Subject<br>Combinations Falsely Accepted<br>by Qualitative Fit Tests of<br>All Respirator/Subject Combination<br><u>Accepted by Qualitative Fit Tests</u> |                                                                    | Percent of Respirator/Subject<br>Combinations Falsely Rejected<br>by Qualitative Fit Tests of<br>All Respirator/Subject<br>Combinations Which Achieve<br>or Exceed Desired Face Fitting<br>Factor |                                                                    |
|                                  | For Qual. Fit<br>Test Response<br>in Any of 5 Ex.<br>(%)                                                                                                                        | For Qual. Fit<br>Test Response<br>in Initial NB<br>Ex. Only<br>(%) | For Qual. Fit<br>Test Response<br>in Any of 5 Ex.<br>(%)                                                                                                                                          | For Qual. Fit<br>Test Response<br>in Initial NB<br>Ex. Only<br>(%) |
| 20,000+                          | 75.9                                                                                                                                                                            | 82.5                                                               | 0.0                                                                                                                                                                                               | 0.0                                                                |
| 10,000+                          | 65.5                                                                                                                                                                            | 75.0                                                               | 0.0                                                                                                                                                                                               | 0.0                                                                |
| 5,000+                           | 58.6                                                                                                                                                                            | 70.0                                                               | 0.0                                                                                                                                                                                               | 0.0                                                                |
| 1,000+                           | 34.5                                                                                                                                                                            | 50.0                                                               | 5.0                                                                                                                                                                                               | 0.0                                                                |
| 500+                             | 24.1                                                                                                                                                                            | 42.5                                                               | 4.6                                                                                                                                                                                               | 0.0                                                                |
| 200+                             | 10.3                                                                                                                                                                            | 30.0                                                               | 13.3                                                                                                                                                                                              | 6.7                                                                |
| 100+                             | 6.9                                                                                                                                                                             | 20.0                                                               | 22.9                                                                                                                                                                                              | 9.4                                                                |
| 50+                              | 6.9                                                                                                                                                                             | 15.0                                                               | 30.8                                                                                                                                                                                              | 12.8                                                               |
| 20+                              | 0.0                                                                                                                                                                             | 10.0                                                               | 40.8                                                                                                                                                                                              | 26.5                                                               |
| 10+                              | 0.0                                                                                                                                                                             | 0.0                                                                | 47.3                                                                                                                                                                                              | 27.3                                                               |
| 5+                               | 0.0                                                                                                                                                                             | 0.0                                                                | 50.9                                                                                                                                                                                              | 32.2                                                               |

Note: The facepiece-fitting factors listed are for quantitative fit tests which utilized all five exercises.





