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Effect of Facial Hair on the Face Seal of Negative-Pressure Respirators

O.T. SKRETVEDT[A] and J.G. LOSCHIAVO[B]
[A]E.I. du Pont de Nemours & Company, Inc., Spruance Plant, P.O. Box 27001, Richmond, VA 23261;
[B]E.I. du Pont de Nemours & Company, Inc., Washington Works, Box 1217, Parkersburg, WV 26102

The effect of facial hair on the face seal of negative-pressure respirators, both half-masks and full facepieces, has been investigated. Three hundred and seventy (370) male employees were fit tested both qualitatively and quantitatively. Of these, sixty-seven (67) had fully established beards varying in length, shape, density and texture. Bearded subjects consistently failed the qualitative fit test protocol. Quantitative fit testing with half-mask respirators indicated that bearded employees had a median fit factor of 12 (8% leakage). A median fit factor of 2950 (0.03% leakage) was obtained on clean-shaven employees. An average two hundred and forty-six (246) fold drop in protection was experienced by bearded employees. With full facepiece respirators, the bearded employees had a median fit factor of 30 (3% leakage). A median fit factor of > 10 000 (<0.01% leakage) was obtained on clean-shaven employees. At least a three hundred and thirty (330) fold drop in protection was experienced by bearded employees. Results indicate that the presence of a beard greatly increases the leakage through the respirator face seal, and this leakage should not be permitted when employees are required to wear respirators.

Introduction

With today's emphasis on personal rights, it is difficult to mandate any practice a person might consider to be an infringement on those rights. Policies dictating hair length, style of clothing, facial hair, etc., usually become subjective, rather than objective, issues. When these "personal preferences" influence or interfere with job safety or health, responsibilities must be assumed by both employer and employee. Both parties have the same goal: the assurance of proper protection from a hazardous environment.

The Occupational Safety and Health Standards, Title 29 CFR 1910.134, Subpart I, Personal Protective Equipment, spells out the obligations of both employer and employee concerning respirator use. Subparagraph (a)(3) lists the responsibilities of the employee. This section states that: "The employee shall use the provided respiratory protection in accordance with instruction and training received." The respirator user is obligated to wear the respirator in a responsible manner as directed by the respirator manufacturer and by the employer's respirator program director. The remaining requirements of 1910.134 are the obligation of the employer.

Section 1910.134(e)(5)(i) lists conditions which prevent a respirator from fitting adequately. This section states: "Every respirator wearer shall receive fitting instructions including demonstrations and practice in how the respirator should be worn, how to adjust it, and how to determine if it fits properly. Respirators shall not be worn when conditions prevent a good face seal. Such conditions *may be* a growth of beard, sideburns, a skull cap that projects under the facepiece, or temple pieces on glasses." The last sentence can be interpreted two ways. The words "may be" could be synonomous with "might". In other words, a beard might prevent an adequate face seal. The words "may be" could also be synonomous with "including but not limited to". In other words, a beard will prevent an adequate face seal and there may be other things which will create a similar situation. Considerable confusion has arisen over the intent of this Standard. As a result, many persons question whether beards will prevent an adequate face seal.

Several investigators have reported on the effects of facial hair on the face seal of respirators. The data from one study indicate that even one day's beard growth is enough to reduce the fit factor seventeen fold.[1] Other investigators also emphasize the importance of being clean-shaven.[2-6] However, there are limited published data on this subject, particularly concerning half-mask respirators. A respirator program director, who must develop and enforce a facial hair policy, should have sufficient data to make a decision and to justify a policy to employees.

We have investigated the effect of facial hair upon the face seal of both half-mask and full facepiece negative-pressure respirators. Male employees from many ethnic backgrounds, in various geographical locations, served as the test population. A variety of beard lengths, shapes, densities, and textures were tested. Only individuals with fully established beards were included in this investigation. The effect of sideburns, goatees, and Van Dykes on respirator fit was not studied. The data in this investigation were collected at various manufacturing sites in the course of conducting a fit test. The actual protection provided in the workplace by a properly functioning respirator when worn or used, *i.e.* working protection factors, may be different.

Methodology

The effect of facial hair on respirator face seal was assessed by performing a qualitative fit test, followed immediately by

a quantitative fit test. Because many of the subjects had not worn respirators previously, training was included to demonstrate proper donning procedures. Half-mask data are based on selection from an array of five facepieces: Three sizes from one manufacturer and two sizes from another. The full facepiece data are based largely on the availability of one mask.

The qualitative fit test uses isoamyl acetate as the test agent.[7,8] To make sure the test subject can detect a low concentration of the test agent, he is asked to smell a 1 ppm concentration of isoamyl acetate. The person is then asked to choose a respirator, from an array of facepieces, which fits snugly but comfortably on his face. Once a respirator is chosen, the individual dons it and performs a negative and a positive pressure test. If both tests are passed, the wearer proceeds to the qualitative fit test chamber. The chamber is a clear polyethylene drum liner with a plywood disc ceiling and is suspended from the test room ceiling. An individual enters the chamber wearing a respirator equipped with combination organic vapor/high-efficiency filter cartridges. By wearing a respirator equipped with these combination cartridges, no switching of respirator cartridges is needed when the person proceeds from the qualitative fit test chamber to the quantitative fit test chamber. Using these combination cartridges prevents the possibility of altering the orientation of the facepiece on the person's face. The test conductor hands the wearer a single-ply paper towel wetted with 0.5 cc isoamyl acetate. The paper towel is hung from a hook in the chamber ceiling. The wearer is instructed that, if at any time the odor of isoamyl acetate is detected, he is to immediately notify the test conductor. If the odor of isoamyl acetate is detected inside the facepiece, this constitutes a test failure. By following our test protocol, a test concentration of 150 ppm can be maintained inside the chamber. It takes two minutes for the test concentration to build up after the paper towel is hung in the chamber.

A series of fit test exercises is performed by the wearer. Each exercise lasts at least thirty seconds and the exercises are performed in the following order: Normal breathing, deep breathing, turning head from side to side, nodding head up and down, talking, and normal breathing. For the deep breathing exercise, the breaths are deep and regular. The turning of the head from side to side is done making complete movements with one turn made about every second. The test subject is alerted not to bump the respirator on the shoulders. Nodding the head up and down is done making complete movements with one nod made about every second. The talking exercise is done by reading the Rainbow Passage aloud and distinctly. The Rainbow Passage is a paragraph containing six sentences obtained from a speech articulation drill book.[9] A qualitative fit test lasts approximately five minutes. This includes the two minutes it takes for the isoamyl acetate concentration to reach equilibrium. Obtain reference 7 or 8 for further detail on the qualitative fit test protocol.

If a person wearing a half-mask respirator fails the qualitative fit test, he chooses another respirator from the array. The individual is again asked to smell the 1 ppm concentration of isoamyl acetate to make sure his olfactory sense is not fatigued as a result of the earlier qualitative fit test. Only those individuals passing this odor sensitivity test are allowed to don the facepiece, perform the positive and negative pressure tests, and be qualitatively fit tested. This entire procedure is repeated until a facepiece is found, if there is one, that will provide a passing fit. Repetition of this procedure was not done, for the most part, for individuals wearing full facepiece respirators since only one full facepiece was usually available in the array. For clean-shaven test subjects, once a facepiece is found that provides a passing fit according to the qualitative fit test, the subjects proceed immediately to the quantitative fit test chamber. Those clean-shaven test subjects who cannot obtain a passing fit on any of the respirators chosen are not quantitatively fit tested. See Results and Discussion section for further detail.

Unlike the clean-shaven test subjects, none of the bearded test subjects could obtain a passing fit on any respirator they chose even though they were given the same opportunity as the clean-shaven subjects to find a respirator that provided them with a passing fit. Therefore, it was important that the respirator worn for the quantitative fit test be the best fitting respirator in the array. For this reason, the test conductors spent extra time with the bearded test subjects to make sure that the respirator chosen for quantitative fit testing conformed to the bearded test subject's facial contours. This would assure that the measured leakage was due to the presence of a beard and not to a respirator which didn't conform to a subject's face.

A Dynatech-Frontier Model FE250A System is used to conduct the quantitative fit tests. In this System, polydispersed di(2-ethylhexyl) phthalate (DOP) is used as the test aerosol. Relative DOP concentrations were measured inside the test chamber and inside the respirator facepiece using a forward light scattering photometer. Concentrations of DOP aerosol inside the facepiece relative to the chamber concentration were continuously monitored during each fit test. Persons being fit tested were asked to perform the same exercise regimen as described for the qualitative fit test.

Results and Discussion

Three hundred seventy (370) male employees participated in the study. Of these, sixty-seven (67) had fully-established beards. Data were collected on subjects wearing both half-mask and full facepiece negative-pressure respirators. Test subjects completed the qualitative fit test protocol before quantitative testing began.

All clean-shaven individuals that were quantitatively fit tested are those who passed the qualitative fit test protocol. Only about 2% of the clean-shaven individuals could not pass the qualitative fit test with a half-mask respirator. There were no clean-shaven individuals who could not pass the qualitative fit tests with a full facepiece respirator. Therefore, not including quantitative fit test data on those clean-shaven individuals who *could not pass* the qualitative fit test has no significant effect on the results. This population really represents fitting-program failures and should not be per-

TABLE I
Fit Factors Obtained for Negative-Pressure Respirators

Sample size		Fit Factor Median	Minimum	Maximum
Half-mask				
Clean shaven	188	2950	95	> 10 000
Bearded	54	12	2	185
Full facepiece				
Clean shaven	115	> 10 000	95	> 10 000
Bearded	13	30	5	75

TABLE II
Cumulative Fit Factors Obtained with Negative-Pressure Respirators

	Percent of sample with: F.F. < 10	F.F. < 50	F.F. < 100
Half-mask			
Clean shaven	0	0	2
Bearded	43	85	89
Full facepiece			
Clean shaven	0	0	0
Bearded	23	77	100

mitted to wear a respirator in the workplace until they have passed the qualitative fit test using an alternate half-mask or full facepiece respirator.

As previously mentioned, none of the bearded test subjects could pass the qualitative fit test. Quantitative fit test data were therefore collected on the respirator chosen from the array which was judged by the test conductors and the subjects themselves to be the best fitting.

The results of the quantitative fit tests are shown in Table I. For bearded subjects wearing half-mask respirators, the median face seal leakage was two hundred forty-six (246) times greater than the median face seal leakage for the clean-shaven individuals. Bearded subjects wearing full facepiece respirators experienced a median leakage that was more than three hundred thirty (330) times greater than that for clean-shaven individuals. The lowest fit factors measured on bearded individuals wearing half-mask and full facepiece respirators were 2 and 5 respectively. (NOTE: A fit factor of 1 indicates that a respirator is providing no protection.)

Table II indicates that 43% of the bearded individuals wearing half-mask respirators achieved fit factors below OSHA's minimum requirement of 10. Also, 89% of the bearded individuals wearing half-mask respirators achieved fit factors below 100. On the other hand, none of the clean shaven half-mask respirator wearers achieved fit factors below 10 and only 2% achieved fit factors below 100. The fit factors determined on this 2%, however, were only slightly below 100 with none falling below 94. Table II also indicates that 77% of bearded individuals wearing full facepiece respirators achieved fit factors below OSHA's minimum requirement of 50. Also, 100% of the bearded individuals wearing full facepiece respirators achieved fit factors below 100. On the other hand, none of the clean-shaven full facepiece respirator wearers obtained fit factors below 100.

Figure 1 is a plot of the cumulative frequency versus the log of the fit factors for subjects wearing half-mask respirators. This plot clearly illustrates the lower range of fit factors achieved by bearded users. Figure 2 is a similar plot for subjects wearing full facepiece respirators, and again illustrates the very large difference in fit factors obtained for the two populations.

Even though a number of bearded individuals did obtain fit factors *above* OSHA's minimum requirement for half-mask and full facepiece respirators, they all failed the qualitative fit test. No relationship was found between the length, shape, density and texture of beards and the amount of face seal leakage. Therefore, the only way to identify bearded negative-pressure respirator wearers obtaining fit factors above OSHA's minimum requirements would be by performing a quantitative fit test on them. However, even if quantitative fit tests are performed on all bearded individuals, another problem must be faced. The drop in the fit factor

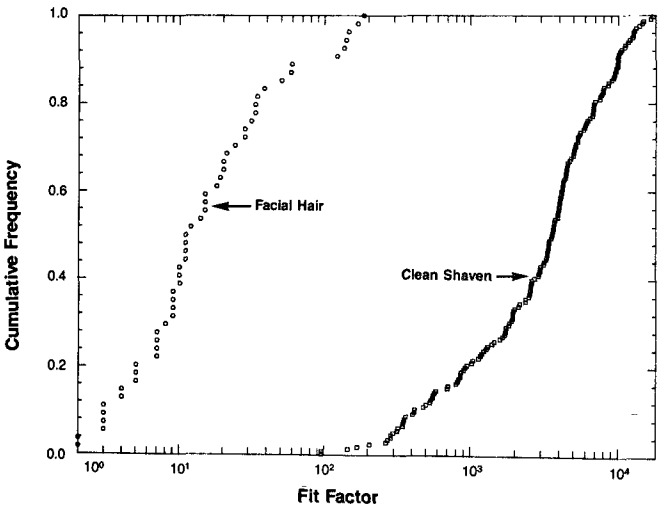

Figure 1 — Cumulative frequency versus the log of the fit factors obtained for wearers tested with half-mask respirators.

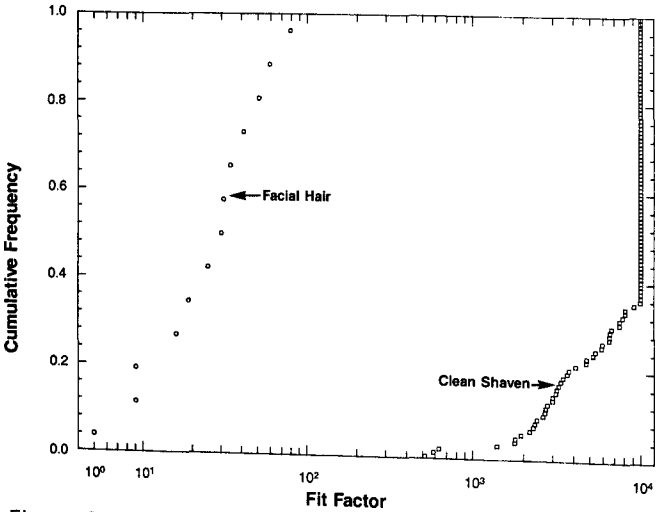

Figure 2 — Cumulative frequency versus the log of the fit factors obtained for wearers tested with full facepiece.

experienced when a beard is present is of such magnitude that no confidence can be placed in the protection the respirator will provide either in the workplace or in future donnings. All respirator users experience variability of fit from one donning to the next. This fit variability from donning to donning occurs due to changes in strap tension, positioning on the face, and a host of other variables. Donning-to-donning fit variability for bearded individuals will be even greater since additional variables will be introduced. A beard is a dynamically changing thing. The hair length constantly changes as well as the orientation of the hair in the sealing surface. Beards also accumulate moisture, natural oils, and debris from the workplace. Even though a percentage of bearded respirator wearers obtain fit factors slightly above OSHA's minimum requirements, the tremendous drop in fit factor resulting from the presence of a beard is such that the safety factor necessary to accommodate the variability of fit no longer exists. In summary, although bearded individuals may be able to achieve fit factors above OSHA's minimum requirements during a specific quantitative fit test, the drop in protection caused by a beard coupled with the large fit variability from donning to donning makes it quite likely that the individual will not obtain the minimum required protection in the workplace.

Conclusions

The popularity of beards in recent years has become a subject of concern for respirator program directors. Our data show that a beard protruding into the face seal of a negative-pressure respirator greatly reduces the effectiveness of the respirator. A person having facial hair which protrudes into the face seal of a negative-pressure respirator is substantially more at risk than a clean-shaven worker. Therefore, facial hair must not be permitted if adequate respiratory protection is to be provided.

The original intent of the authors of ANSI Standard Z88.2-1969 was made clear in their rewrite of this Standard called Z88.2-1980. Section 3.5.8 of Z88.2-1980 states: "A respirator equipped with a facepiece shall not be worn if facial hair comes between the sealing periphery of the facepiece and the face or if facial hair interferes with valve function." Section 7.3.1 of the same Standard states: "A person who has hair (stubble, moustache, sideburns, beard, low hairline, bangs) which passes between the face and the sealing surface of the facepiece of the respirator shall not be permitted to wear such type of respirator." It is evident that the original intent of the authors was to state that beards will prevent an adequate face seal. The results of this research investigation support this claim.

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