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An Examination and Critique of the Simulated Workplace Protection Factor Studies Conducted in December of 2003 and July of 2004 at the Aberdeen Proving Ground Using Bullard Powered Air-Purifying and Supplied-Air Respirators

The following is my critique of the simulated workplace protection factor studies that were conducted on December 6, 2003 and July 17, 2004 on Bullard powered air-purifying respirators (PAPRs) and supplied-air respirators (SARs) at the Department of the Army's Aberdeen Proving Ground facilities in Maryland. I have examined the draft reports containing the results from both tests. While I was not present for the testing on December 6, I was present for all of the testing conducted on July 17. A similar protocol was used during both of these test dates.

Test Facility

Testing took place in Building E5604 at the Aberdeen Proving Ground. This is a large building that houses a number of offices, an area where the test subjects can relax when they are not involved in testing, and an area where respirators can be assembled for testing.

All testing occurred in a large test chamber that was 20 feet by 32 feet by 10 feet high. The chamber allowed for up to 12 subjects to be tested simultaneously. The chamber had 600 CFM of air that was brought into it, and air from the chamber exited through a filter bank. The chamber was not airtight, and it was estimated that up to 100 CFM may have exited through leaks at the edges of the chamber (this had no effect on the chamber concentration or on the ability to test respirators). There were several wall fans mounted near the ceiling that facilitated mixing of the air.

A challenge aerosol of corn oil was generated at room temperature above the chamber using a Laskin nozzle. This aerosol was directed into an impaction plate that yielded an aerosol of 0.4-0.6 μ m at a concentration of 20 ± 3 mg/m³. The aerosol concentration was monitored continuously with a Dust Trak unit (total aerosol), and recorded once or twice during each test for documentation purposes.

TSI model 8587 light-scattering laser photometers were used to sample both upstream and downstream aerosol concentrations. The photometers were calibrated approximately every six months at the facility. A single photometer was used for each test subject. The photometers took 10 readings/sec from either outside or inside the respirator worn by the test subject. The inlet for the outside concentration was located approximately six to eight inches from the wall of the chamber in the same general location as where the test subject conducted his/her exercises. The photometer measured the outside concentration for approximately 5 seconds prior to each test. The average was then used to calculate the protection factor. Data from all photometers were sent to a single computer. This displayed in real-time what the photometers were measuring. The computer output recorded the protection factor and not the actual concentration being measured. The computer was calibrated to give a maximum protection factor value of 100,000. This value was the recommended maximum value from TSI that the unit could reliably determine (a six-decade difference between the maximum and minimum value measured). For each exercise a computer recorded the geometric mean protection factor value. A geometric standard deviation for the 1200 readings was not generated for each two-

minute exercise, and this did not allow for an examination of the variability of the respirator fit during each two-minute exercise.

The facility was ISO 17,025 certified (certification for laboratory testing) and maintained records according to ISO certification.

Personnel

The testing was conducted and assisted by a number of civilian individuals. Several of these individuals had numerous years of experience in the design of military respirators and/or their testing. These individuals had also conducted several similar protection factor studies for manufacturers of commercial respirators. There were also several summer interns (college students) who assisted with the testing that I observed. Alex G. Pappas was the host during the July 17 testing, and my discussions with him confirmed that he was very knowledgeable about the design and performance of respirators.

All of the test subjects were from the Army and were newer recruits who had completed their basic training and were at the facility to complete their next level of specialized training. Recruits were all volunteers, and those that were under 18 years of age were not allowed to participate in the studies. All of the test subjects received instructions as to the nature of the study and why it was being conducted. Those that chose to participate were required to fill out forms designed by the Human Use Committee of the Army. These included the rights of the subjects such as confidentiality and access to their records along with possible risks, discomforts and inconveniences.

Anthropometric measurements were taken of each recruit (e.g. face length, width, neck circumference). The subjects' sex, height and weight were also recorded for the July 17 test. Thirty volunteers reported for the December 6th test and 15 of these were selected to represent the widest variety of anthropometric facial measurements. Four of the 15 test subjects were female. Twenty one subjects were chosen for the July 17 test. Two of these subjects had anthropometric values that fell outside of the NIOSH standard test panel. This had no material impact on the study design except to represent a robust group of test subjects, with respect to facial dimensions, that participated in the testing.

Test subjects were given minimal information regarding the donning of the respirators. Each subject was familiar with military respirators, but not the Bullard respirators being tested. All subjects received assistance in donning the respirators. An explanation of the test exercises was given to all of the subjects prior to their entering the test chamber.

Respirators

A total of eight different Bullard respirators were tested during the December and July tests. All respirators were hooded with neck seals and bibs, and they were new and furnished by the manufacturer. Two of these respirators were supplied-air units and the difference was only the hood material (RT1 and RT2). Each of these respirators were tested with 25 feet of hose and with 14-15 psi of air, as recommended by the manufacturer.

The other six respirators were PAPRs and consisted of four different hoods (RT1, RT2, 20TIC and 20SIC) and two different blowers (PA1 and PA3). The results of the PAPR testing using the PA1 blower are described in a separate report. PAPRs had batteries charged prior to their use and all

devices were checked with the manufacturer's rotometer that was included with the respirator to insure adequate airflow.

All respirators were probed in the face lens midpoint between the nose and mouth by the test facility personnel using a specially designed probe designed to minimize particle loss. A ten foot silicon tube was attached to the probe and then connected by the subject to a fixed hose in the test facility leading to the inlet of the aerosol photometer.

Test Protocol

Subjects donned respirators prior to entering the chamber. As previously mentioned, subjects received some assistance in ensuring that their respirators were properly donned. The subjects entered the test chamber and connected the silicon hose from their respirator probe to the fixed hose inside the chamber that led to the photometer. The subjects stood still and waited for air to purge from the respirator for several minutes. Air was drawn from the inside of the respirator at a rate of 1-2 L/min.

A series of ten two-minute exercises was then performed by each of the test subjects. The exercises included: normal breathing, moving the head from side to side, moving the head up and down, bending forward and touching the toes, climbing a stepladder, moving a 3-lb box from the floor to a table at waist height and back down, standing with arms folded in the front of the chest and twisting the torso from side to side, raising arms above head and looking upward, loosening bolts on a table and then tightening them again, and a second normal breathing.

Several of the facility's test personnel observed the entire test procedure from outside of the chamber where they could monitor the real-time results on a computer. A speaker system allowed for test personnel to inform the test subjects when to begin each exercise.

At the end of the ten exercises, subjects left the chamber and removed their respirators. They then relaxed for several minutes and were offered water prior to re-donning the respirator. They then entered the chamber and repeated the exercises. After the subjects had completed the second series of exercises, they left the chamber, removed the respirator and were allowed to relax or have some food prior to their next tests.

Results

Draft reports issued by Adam Seiple of the US Army's Engineering Directorate at the Aberdeen Proving Ground are attached that include all the tabulated data from these studies. The testing conducted in December of 2003 included the PAPR PA3 blower with RT1 and RT2 hoods and the SAR with RT1 and RT2 hoods. The testing in July of 2004 included the PAPR PA3 blower with 20TIC and 20SIC hoods and the PAPR PA1 blower with RT1 and 20TIC hoods.

SAR with RT1 Hood

Fifteen test subjects were each tested once with this respirator. Thirteen of the test subjects had an average PF of over 100,000, while the other two had PFs of over 75,000. Only two of the 150 measurements detected any leakage into the respirator, and these had PFs above 20,000. An estimated lower 5th percentile for these tests was 100,000.

SAR with RT2 Hood

Fifteen test subjects were each tested with this respirator; seven of these subjects were tested twice and the other eight were tested once. Twenty of the 22 average results were over 100,000, and the other two had PFs over 65,000. Only two of the 220 measurements detected leakage, with the lowest PF value being above 16,000. An estimated lower 5th percentile for these tests was 100,000.

PAPR PA3 with RT1 Hood

Fifteen test subjects were each tested once with this respirator. Nine of the subjects received an average PF above 100,000 and the lowest average PF for the other subjects was above 85,000. Nineteen of the 150 results had detectable leakage inside the respirator, with the lowest PF detected being approximately 50,000. An estimated lower 5th percentile for these tests was above 90,000.

PAPR PA3 with RT2 Hood

Fifteen test subjects were each tested with this respirator; seven of these subjects were tested twice and the other eight were tested once. Seventeen of the 22 average results were over 100,000 and the others were above 85,000. Twenty nine of the 220 measurements detected leakage, with the lowest PF value being above 60,000. An estimated lower 5th percentile for these tests was above 90,000.

PAPR PA3 with 20TIC Hood

Twelve test subjects were each tested twice with this respirator. Twenty of the 24 average PFs recorded were above 100,000 and the others were above 14,000. Twenty three of the 240 measurements detected leakage, with the lowest PF value being 8,800. An estimated lower 5th percentile was above 30,000. One subject was responsible for 20 of the 26 detectable measurements.

PAPR PA3 with 20SIC Hood

Nine test subjects were each tested twice with this respirator. Thirteen of the 18 average PFs recorded were above 100,000 and the others were above 14,000. Twenty seven of the 180 measurements detected leakage, with the lowest PF value being 22,000. An estimated lower 5th percentile was above 35,000. One subject was responsible for 20 of the 27 detectable measurements.

Discussion

My observations of the test protocol and individuals conducting the test indicated that these were high quality simulated protection factors studies conducted at least as well, if not better, than a previous study sponsored by Organization Resource Counselors (ORC) and published in the *AIHA Journal* in 2001. One major advantage of this study, over the ORC study, was that the same photometer was used for both outside and inside concentrations, eliminating concerns with minor calibration changes and zero drift.

The results indicate that the Bullard SAR respirators performed exceptionally well and certainly can be assumed to provide protection factors well in excess of 1000, based on these results. The Bullard PAPRs with the PA-3 blower and RT1 and RT2 hoods also performed exceptionally well and should provide protection factors in excess of 1000.

The Bullard PAPRs with the PA-3 blower and 20TIC and 20SIC hoods did not perform quite as well as those with the RT1 and RT2 hoods, but certainly could be expected to provide protection factor in excess of 1000.

There are several limitations imposed by the study design, some of which are similar to problems encountered with the ORC PAPR and SAR study. First, this study did not have test subjects don their

own respirators without assistance. Therefore, any problems with donning that can affect the respirator's performance could not be identified in this study. This is an identical limitation of the previously published ORC PAPR and SAR study. During the July testing, I found it very difficult to separate differences between subject variability and respirator performance. This is because all of the repeat studies that were done used the same individual wearing the exact same respirator (this was done to avoid having to disinfect respirators between each series of tests). For the SARs and PAPRs using the PA-3 blower, this is a minor issue given the high degree of performance of these devices.

Both the Army's draft report and my report consider each test result in determining the lower 5th percentile and range of protection factors. Some of these tests represent the same test subject and some represent different test subjects. It is likely that the variability in respirator performance among the same individual with multiple donnings and different individuals are not the same. This point is raised simply for accuracy purposes. For the purposes of identifying whether the respirator can provide a minimum protection factor of 1000, this potential difference in variability is not significant.

The SAR respirators were tested with 25 feet of hose and they are approved by NIOSH for up to 300 feet of hose. It is possible that with different flow rates, different performance may be achieved. However, with a hose length of approximately 25 feet and pressures of 14-15 psi of air, workers wearing these respirators would be expected to experience similar performance as the test subjects in this study.

The test subjects used in this study were all healthy young military subjects. The workforce would be expected to have a wider variety of subjects in terms of their age and sex (few female subjects were tested). It is unclear what, if any, effect these differences would have on respirator performance. Furthermore, the results of this simulated protection factor study demonstrated excellent performance, and suggest that an assigned protection factor of only 1000 is very conservative for these respirators.

The choice of test exercises were designed to simulate activities for many routine situations encountered by workers. The limitation of any simulated protection factor study (or even workplace protection factor studies) is that the actual activities of some workers are going to be different than the exercises performed in this study. It certainly is possible that some unusual work activities might challenge the fit of the respirator more aggressively than was conducted in this study. I would expect that this would be the exception rather than the rule, and that the exercises conducted by these test subjects were very appropriate in measuring the performance of these respirators.

Conclusions

This study was very well executed, comparable and perhaps even superior to a previously published simulated protection factor study sponsored by ORC. The ORC study is the basis for OSHA allowing an assigned protection factor of 1,000 for SAR and PAPR hood and helmet model respirators that were specifically tested in that study. Based on these results, I would endorse an assigned protection factor of 1,000 for all of the SAR and PAPR (using PA-3 blowers) respirators tested in this study.

Submitted by,

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