

Developing a Quantitative-Fit-Test Program for the Clark County Fire Department

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Abstract

To comply with the recommendations of ANSI Z.88.5-1981, "Respiratory Protection for the Fire Service," 294 combat firefighters were tested quantitatively for facepiece fit of self-contained breathing apparatus (SCBA), in both "demand" and "pressure demand" modes (Scott Pressure Pac 11-A equipped with Scottoramic masks). Test panel personnel were wearing full combat equipment (bunker coats, pants, boots, Nomex hoods, and helmets). The challenge atmosphere was a corn oil aerosol. Leakage was measured by a forward light-scattering photometer. To reflect actual usage and protection factors on the fire ground, a test scenario including breathing, talking and exercise was performed in the "demand" and "pressure demand" modes (designated as the "cold" test). Following the "cold" test, each subject removed the facepiece and jogged 0.32 km in full combat equipment followed by a climb up and down 12 stairs. This exercise was followed by a test for facepiece fit ("hot test"). Following the "cold" test, all personnel were able to obtain acceptable protection factors using multiple size or shape facepieces; however, significant differences in protection factors were observed between "hot" and "cold" test results. This range was attributed to high breathing rates and high sweating rates during the exercise segment, and the subsequent post-exercise donning technique. Results demonstrated (1) the need for multiple sizes of facepieces for SCBA and (2) the desirability of individually issued facepieces for fire-service personnel. We concluded that the use of "positive-pressure" (pressure-demand) breathing may not, on its own, guarantee acceptable protection factors. Furthermore, it was noted that an annual fit-test program was of value to the fire service as a means of documenting wearer success in obtaining an acceptable level of protection, in addition to providing a goal for the training program.

Introduction

In order to comply with the mandates of the American National Standards Institute (ANSI) recommendation, Z88.5-1981, and the Occupational Safety and Health Administration (OSHA) CFR 1910.134, we developed a quantitative-fit-test pilot program for the Clark County Fire Depart-

ment (CCFD), Las Vegas, Nevada.* This program required us to perform fit tests on all personnel with

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the standard medium-size facepiece, evaluate the performance, and, if necessary, retest using smaller or larger facepieces based upon leak rates and physical characteristics. The goal of the fit tests was to issue masks individually in the proper size to ensure maximum fire-ground protection factors. Subsequently, we anticipated developing a "Fire Service End User" annual test for CCFD and being able to provide a training baseline for firefighters in the use of self-contained breathing apparatus (SCBA).

Methods and Procedures

Test Equipment

All testing was conducted in a mobile van (International Harvester/Boyertown) especially equipped for testing respirator fit. The van was equipped with air-conditioning/heating, storage cabinets, test equipment, an aerosol test booth and air lock. Fuel capacity was increased to 75 gallons for travel to various work areas on and off the Nevada Test Site (NTS). Test equipment included an aerosol generator/detection system (forward light-scattering photometer, Frontier 259H) and a strip-chart recorder (Williams, 1978). The test aerosol was USP corn oil, measured gravimetrically at a concentration of 22-25 mg/m³ in the test booth. Weekly maintenance consisted of checking vehicle safety, cleaning the generator and impactor bowls and nozzles, changing the corn oil, flushing the vacuum pump, and checking hose connections. During this weekly maintenance, special attention was required on the generator orifice, and the upstream/downstream solenoids in the detection system, while the light-scattering chamber was reblacked.

Respirators

The test SCBAs were Scott Pac II-A. All test respirators were performance-validated each week using a Flow Bench (Scott) to ensure compliance with manufacturer's standards and specifications of operation.

Facepiece Mask

In order to use as many of the in-service facepieces of the CCFD as possible (a total of 350 were available), a measurement survey was performed to determine the physical dimensions of the facepiece as compared to new, unused masks (Scottoramic). It was found that through elastomeric change (due apparently to heat and age), three facepiece mask sizes were identified. The "A" mask was a new medium-size facepiece.

"Probe masks" were developed with modifying the facepiece by penetrating the lens at the bottom/center and attaching a short metal probe (1/4" i.d.) [Fig. 1]. The probe was sealed in place with silastic compound. After curing, the "probe mask" was leak-tested on a standard mannikin head using a Q-237 DOP Penetrometer (Air Techniques, Inc.).

All firefighting personnel were initially fit-tested using the "B" size facepiece mask. If they failed to meet the minimum protection for fit (1,000 in "demand" and 10,000 in "pressure demand"), they were retested and fitted with an "A" or "C" size facepiece depending on their facial characteristics. The effect of nose cups was not evaluated during this testing.

Test Procedures

All firefighting personnel reported to the testing site by company and battalion. Before testing began, each fire company was instructed in the objectives of the program, the testing procedures, and the proper facepiece techniques. The firefighter to be tested would then dress in full combat firefighting equipment including the SCBA with a full cylinder at 2216 psig. The facepiece mask was donned with the supervision and assistance of the test personnel.

The industrial standard exercise test and sequencing were modified to reflect fire-ground usage. Upon entering the booth, the following sequence of exercises was performed: normal breathing, deep breathing, movement of the head from side to side, movement of the head up and down, talking, running in place, deep breathing (following running), and yelling for help (Fig. 2). These exercises were initially performed in the "demand" mode. Following completion of the exercises in the "demand" mode, the regulator was switched to the "pressure-demand" mode, and the exercises were repeated. At the end of the test, the subject switched back to the "demand" and broke the face mask seal. This completed the "cold" test portion of the fitting. The firefighter would then exit the booth. If the firefighter did not meet the minimum protection for fit factor, the "cold" test was repeated with a different-sized mask.

After the minimum protection for fit factor had been achieved, another test sequence, the "hot" test, was initiated. After removing only the facepiece and exiting the van, the firefighter jogged 0.32 km (0.2 mile), then walked up and down a flight of 12 steps (Figs. 3 and 4). Upon re-entering the van, the firefighter would don the facepiece without assistance, re-enter the booth, and repeat the test exercises, first in "demand" and then in



Figure 1. Probe mask.

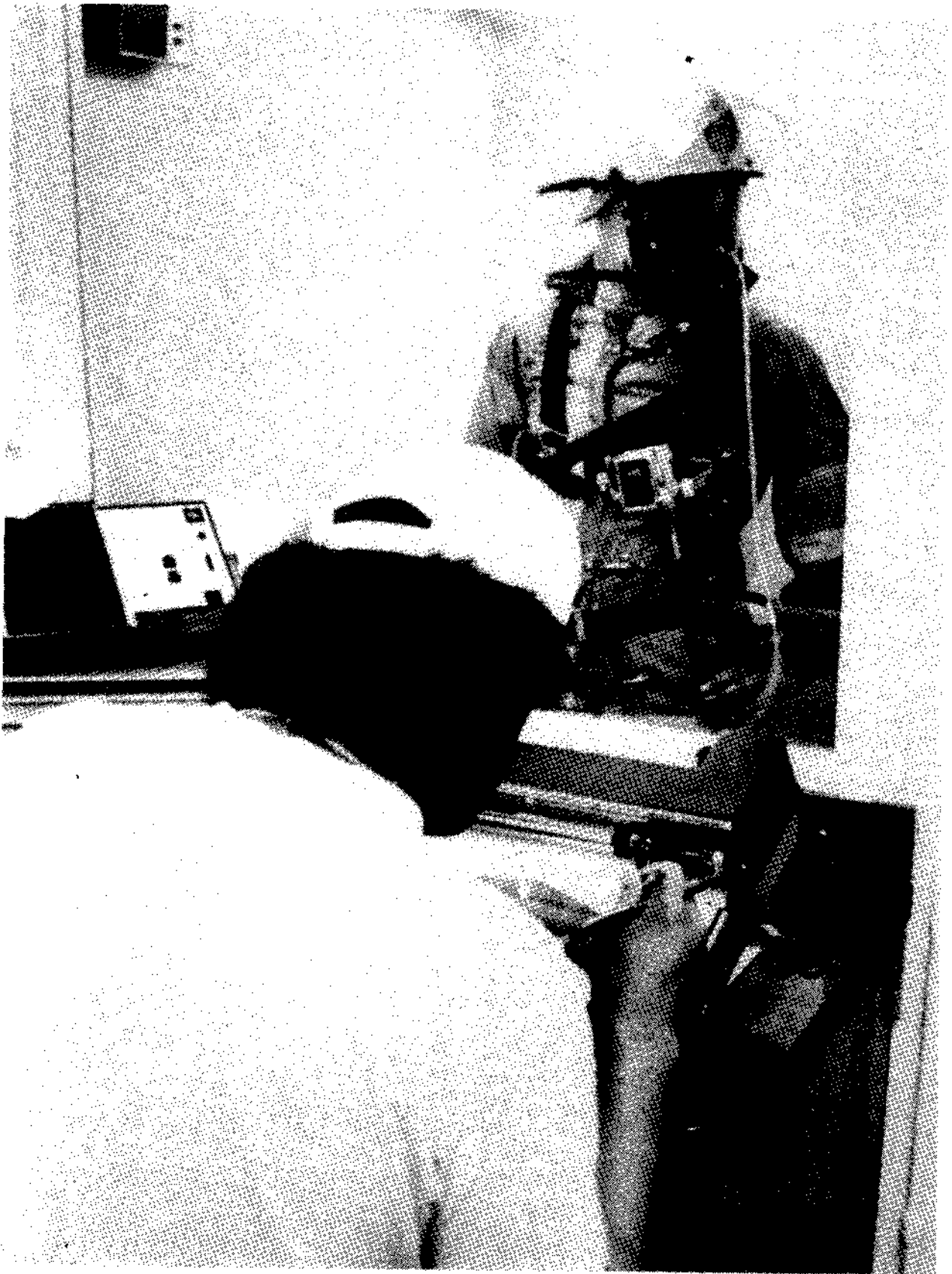


Figure 2. Side-to-side movement in the test booth.

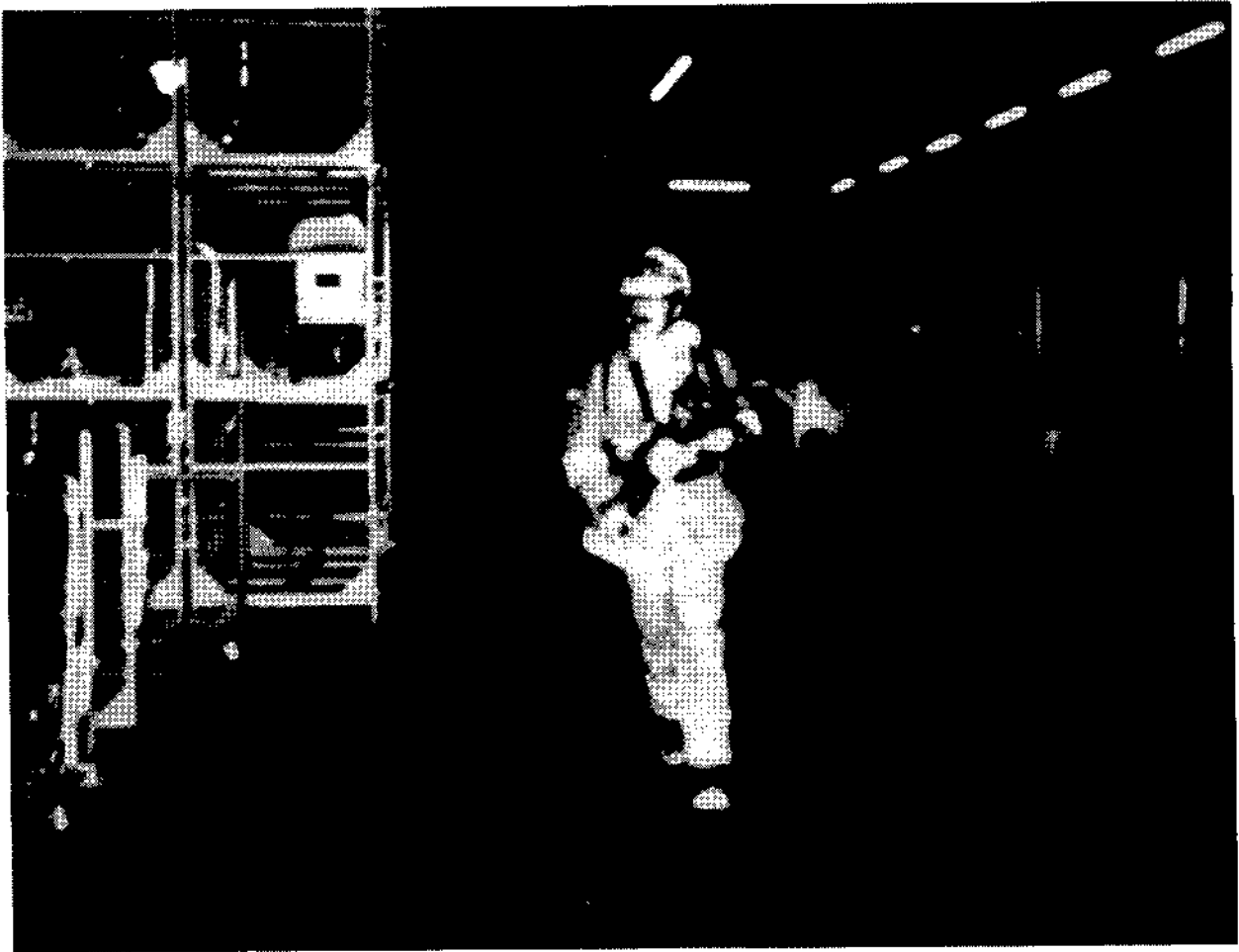


Figure 3. Running portion of exercise segment.

"pressure-demand," as in the "cold" test. This fit test was designated the "hot" test. All test exercises were used with the exception of normal breathing. Protection for fit factors was determined by mid-

point peak averaging on a straight line of peaks, or by triangulation of non-straight line peaks, then selecting the mid-point of the enclosed area (Williams, 1978).

Results

All 294 firefighters were individually fit-tested. Nine firefighters are permanently assigned to duty at the airport station. These nine firefighters were required to use different firefighting clothes, hence, they were not subjected to the full firefighting equipment requirements during testing. Table 1 summarizes the data obtained from 285 firefighters. As can be seen, 244 (85.6%) firefighters were able to obtain a successful first-time fit. Of the remaining 41 firefighters, 36 required changes to a new "A" size facepiece and 5 of the 41

required changes to the new "C" type facepiece. Following the exercise intervention, 95 firefighters (or 33.3% of the 285) obtained a protection fit factor of $>10,000$ while only 50 (or 17.5%) of the total achieved $>20,000$ protection fit factor using "pressure demand" following the exercise.

Table 2 summarizes the results from all 294 firefighters and compares the "hot" versus the "cold" fit testing, as well as "demand" versus "pressure-demand" breathing modes. Following the "hot" test, only 18 firefighters (or 6.3%) had an



Figure 4. Stair portion of exercise segment.

Table 1. Quantitative-fit-test results from 285 firefighters.

	Number of firefighters	Percent
First-time fit with "B" size mask	244	85.6
Change in size needed total:	41	14.4
Change to new "A" size mask	36	12.6
Change to new "C" size mask	5	1.8
Hot test reproducibility	145	50.8
Able to reach 10 K		
Protection fit factor	95	33.3
Able to reach 20 K		
Protection fit factor	50	17.5

improvement in protection fit factor regardless of breathing mode. Furthermore, 215 (or 72.3%) had lower protection fit factors regardless of the breathing mode following the exercise challenge. In contrast, following the exercise challenge, 38 firefighters (or 13.4%) evidenced greater protection fit factor in the "demand" as compared to the "pressure-demand" breathing mode. Only 23 (or

Table 2. Quantitative-fit-test results from all 294 firefighters.

	Number of firefighters	Percent
Improved fit with "pressure demand" and decreased fit with "demand"	23	8.1
Improved fit with "demand" and decreased fit with "pressure demand"	18	6.3
10 K "pressure-demand"—minimum passing	31	10.9
10 K "pressure-demand"—minimum failing	7	2.5
Decreased fit for both "pressure-demand" and "demand"		
10 K "pressure-demand"—minimum passing	73	25.6
10 K "pressure-demand"—minimum failing	142	46.7

8.1%) had better facepiece sealing in "pressure demand" and yet had worse seals in "demand" following the exercise test.

Discussion

As a result of employee dissension to qualitative fit testing, the Clark County Fire Department has instituted a program of quantitative fit testing. Our results here represent the first report from an in-the-field use of a quantitative-fit-test program for the fire service. Future SCBA protection studies using this firefighter panel are planned.

This study confirms the need to ensure that the individual firefighter is issued a correct-sized facepiece mask before being required to use the SCBA. It was significant that approximately 15% (or 41 of 285) of the firefighters tested were unable to obtain an adequate protection fit factor regardless of the breathing mode during first-time fitting. Of these 41 firefighters, 36 required smaller facepieces while 5 required larger facepieces. This data confirms the earlier findings of Hyatt (1982) and the recent work of Hack et al. (1982) at the Los Alamos National Laboratory who identified 6 different face structures as representative of the population at large. These findings further emphasize the need for all firefighters to ensure correct fit by using a quantitative fit test as well as possibly requiring that the facepiece respirator mask be regarded as a personalized piece of equipment.

Subsequently, our data identifies the field problems associated with intermittent wearing of the facepiece while actually performing work. After removing the facepiece and performing an exercise task, some 46.7% of the 294 firefighters tested were unable to re-don the facepiece and achieve the required 10,000 protection fit factor in "pressure-demand." Also, 214 (or 72.3%) of the total population recorded less protection following the exercise bout regardless of the breathing mode. These data suggest that, because of facial sweating or other work-related changes in physiognomy, it was difficult to achieve the same seal. This has significant importance concerning the work practices of the firefighter and other emergency personnel. Furthermore, it verifies the concern raised by Raven et al. (1982) in their recent suggestion that, during heavy work (50% of maximal capacity), the "pressure-demand" regulators of today may not provide any greater protection than "demand." This is of major importance if the face seal is in any way disturbed.

Despite the apparent expense in both time and money, it was rewarding to note that, in those persons who were unable to obtain fit during the

first fitting session, the use of quantitative fitting procedures was helpful in training the firefighter. Subsequent demonstration of poor fit following the exercise test was also a good training experience and enabled the instructor to re-emphasize the problems associated with fitting. Many of these points have been documented by Pritchard (1977) in the Los Alamos guide. These include face structure and size, and facial hair.

In conclusion, the quantitative-fit-test program appears to be a feasible requirement for all emergency personnel. Despite its apparent large start-up costs, the benefits obtained in training and the safety of personnel on a continued basis would outweigh these costs.

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