Designing and testing a prototype respirator to accommodate individuals wearing articles of faith

Aliya Hilmi
Mentored by Mr. Steven Yurechko

Introduction

In recent years the Army has enlisted a more diverse population of recruits who wear articles of faith (hijab, turban, etc.). Results from a 2016 study conducted by the Army performed at the U.S. Army Combat Capabilities Development Command Chemical Biological Center (CCDC) demonstrated that certain articles of faith (AOF) interfere with the chemical and biological seal that respirators provide. According to the CCDC (2017), these results indicated that the protection factor (PF) from the AOF did not achieve a score of 1,000 and therefore failed. The Army is investigating ways to increase the safety for soldiers by redesigning a respirator, without using a seal, that ensures the same level of protection as traditional masks. This will allow the Army to recruit from a diverse pool of soldiers that require religious accommodation. This mask is a new design from past respirators, therefore this project is aiding CCDC in researching methods before prototype creation, designing the prototype, and testing the protection afforded by the respirator. It was hypothesized that the prototype will experience a passing score (PF ≥ 1,000) during the test.

Materials and Methods

This project was completed in four stages: design research, prototype design, prototype one testing, and prototype two testing. In research testing, the optimal configuration of velocity and distance to filter air between hoses was investigated. Several configurations of velocity and distance with two and three hoses were connected to filtered blowers. These configurations were used to find the highest protection level between hoses. These hoses faced each other to blow directly at an equidistant point (Figure 1). The midpoint between the hoses were tested to determine the protection factor (PF). The PF was calculated by a laser photometer, comparing the background aerosol concentration in the chamber to the concentration of particles being sampled in the air. Each configuration consisted of the blue blower (BB) or C420 (with high and low speeds), two or more hoses, and distances between hose openings of 0.50″, 0.75″, and 1.00″ (Figures 1 and 2). The chamber was filled with a corn oil aerosol as a biological agent simulant for testing. Each test configuration calculated a PF, then the configurations were analyzed determine the highest PF value, shown in Table 1. The highest PF score was used for the design of the first prototype.

In the prototype design, a face scan was completed with an Artec EVA Handheld Camera, which encircled the face from a one meter distance to create the digital model of the face. The mask design was created using computer design software, using the facial scan as a model. The conclusions from the design research stage were considered while creating the final design.

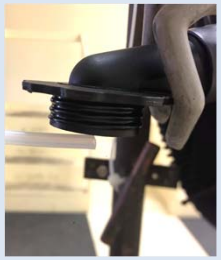
Materials and Methods (cont.)

Prototype one was set up in the same aerosol chamber as the design research for testing. The protection level was calculated with the PF taken where the respirator covered the mouth and nose (Figure 3). Prototype one was tested in five trials, each with three data points. All scores were below five.

After a base test of prototype one, modifications were made and tested for a second prototype. Modifications were mouth coverage, and full face and neck coverage. Each of these modifications were tested for three trials, with four data points. Based on these results, determinations can be made on how to improve the respirator to better serve the needs of the military.

Figure 1 (left): One out of 20 configurations are shown from the design research stage of this project. This shows BB-2-0.50″.

Figure 2 (right): Displays a configuration with one sampling hose 0.25″ under the air opening (BB-1-0.25″).



Research testing configuration protection factor scores

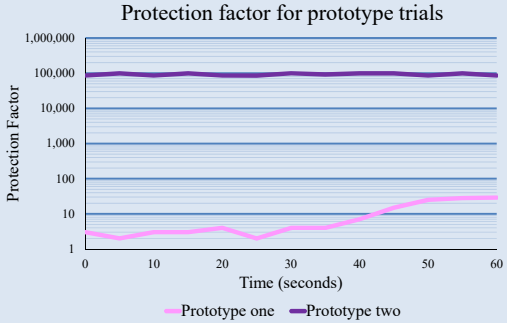
Blower Type	Sample 1	Sample 2	Sample 3	Overall PF
C420-1-0.25″	86	88	87	88
C420-2-0.50″	991	1,047	1,051	1,032
BB-1-0.50″	108	105	100	105
BB-2-0.50″	2,367	2,936	3,184	4,196
BB-2-0.50″/low	59,448	79,188	83,114	67,258
BB-2-0.50″/high	3,949	4,414	4,186	6,198
BB/C420-3-1.00″	4,380	3,981	4,254	5,322
BB/C420-3-0.50″	446	466	452	461

Table 1 (above): Results of configurations tested are shown. Highlighted in purple shows the blue blower with two hoses at a distance of 0.50″ apart, displaying the highest PF value (BB-2-0.50″/low).

Figure 3 (right): Displays prototype one during the PF testing. The sampling hose is shown near the wearer's mouth, at the equidistant point between air streams for the blower. The prototype was tested with both standard and blue blowers.

Results

The testing of prototype one showed that it was not successful. Graph 1 shows the overall PF scores for the two prototypes. The first prototype produced PF scores below the Army standard score (PF ≥ 1,000), failing minimum safety levels. After the lack of success from prototype one, modifications were made to solve issues with air flow. Modifications of full face and neck coverage enabled the second prototype to be more effective, yielding PF scores of over 10,000.



Graph 1 (above): Shows protection factors of the prototypes. The first prototypes shows a failing score, below the Army standard (1,000). While prototype two shows the ideal score (PF ≥ 1,000).

Conclusions

The purpose of this project was to create a prototype mask that does not use a rubber seal in order to accommodate religious artifacts. By using filtered air streams to act as the mechanism to prevent polluted breathing, two prototypes were developed and tested. Given the results from prototype one testing, alterations were made based on air escaping from the mouth nose area. Modifications made for prototype two showed that with coverage of the full face and neck, adequate protection is provided for an individual. Since not all requirements from design research were met, such as the fixed distance between air openings, improvements could be made to increase the effectiveness of the respirator. Further testing should examine the effects of additional facial coverage. Final improvements to the respirator should be tested with a model wearing different articles of faith to test the effectiveness of the prototype in comparison to standard respirators.

References

U.S. Army Combat Capabilities Development Command Chemical Biological Center. (2017). *Quantitative fit factor study on the effects of articles of faith on military respirator performance report* (TREB-PF- R010117). Aberdeen, MD: U.S. Government Printing Office.