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Human-mannequin comparisons in testing NBC protective clothing: a next generation mannequin system

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Abstract

A mannequin-based personal protective equipment (PPE) exposure chamber has been developed within a project sponsored by Canadian Centre for Security Science (CSS) CBRN Research and Technology Initiative (CRTI) [1], and supported by the CB^{plus} technology demonstration project of Defence Research and Development Canada (DRDC), with contribution from industry and international partners. The mannequin has been designed to address issues observed previously that can result in lack of fidelity between human and mannequin vapour protection test results. The chamber has also been designed to permit more extensive variation of chamber exposure parameters than is easily performed with human test subjects. Results are compared of system-level vapour protection obtained using a chemical warfare agent simulant, with human test subjects and this new mannequin platform. In general, this initial study indicates that the objective of a sufficiently human-like platform to be used for system testing has been achieved for vapour exposures. Future work includes more extensive validation of the performance of the mannequin test platform for a variety of exposure parameters including aerosol simulants.

Introduction

As discussed in a previous presentation at this conference [2], both human and mannequin testing have previously been used in the evaluation of the protective performance of PPE. Mannequins in test chambers are particularly useful as a reproducible platform for development and qualification work, especially using test agents that are toxic to humans, and can supplement human testing which reflects the full variability of human anthropometry and range of motion. Data were presented in the previous presentation indicating some of the important areas for improvement in mannequin design. These relate mainly to improving the human-like nature of the motion, shape and surface texture of the mannequin.

Hence, targets for the next generation mannequin system included ensuring that (i) the attachment points for the mannequin were minimally disruptive to the fit and sealing of the clothing; (ii) the mannequin is appropriately representative of human anthropometry, and the locations where closures are made to skin are constructed of a formable material; (iii) the activity routine is variable and sufficiently similar to that performed by humans, permitting reorientation with respect to the direction of the wind stream in the chamber. The new Canadian simulation-based exposure chamber was developed to include a next generation moving mannequin concept that would address some of these key points in mannequin design with the intent of achieving greater fidelity. Also developed was a mannequin articulated head and torso, that is fitted to a breathing machine to measure respirator and mask/hood fit performances; it can be used in a variety of table-top set ups for particulate, vapour and aerosol testing.

Canada

Experimental and Results

Movement

The mannequin is designed to perform a large selection of activities while able to rotate in the wind stream (Figure 1). The rate at which each of these activities is performed can be individually controlled.

The mannequin is suspended at its face, through the front of the mask facepiece, with the facepiece seal retained intact. The hands are connected to the motion platform through a leak-tight seal passing through the gloves, while the boots are clamped from the outside without modification.

Sit with back to wind

Lift weights with right side to wind

Figure 1. Example activities

The activity routine for this study mimicked the standard military routine used in Canada for human testing, consisting of 4 activities alternating with sitting periods, rotating in the wind stream, for a duration of 2 hours.

Figure 2. Sealing surface at waist

Figure 3. Passive dosimeters on back

Anthropometry and sealing surfaces

Anthropometry is approximately that of a 50th percentile male in the Canadian Forces; some exceptions exist, in particular where necessary to permit free motion of limbs without contact.

Sealing surfaces on the head, wrists and waist are constructed of a flexible, somewhat decontaminable polymer designed to simulate the "give" of human flesh (Figure 2). The remainder of the mannequin surface is hardened against vapours.

Sampling

For vapour sampling, passive adsorbent dosimeters are used, either identical to those used in human testing and adhered to the mannequin surface (Figure 3), or as dosimeter tubes inserted into the body of the mannequin.

Exposure chamber

The chamber is designed to achieve temperatures in the range of 5 to 50 °C, relative humidities between 10 an d 90%, and wind speeds up to 7 m/s. Exposure conditions of 27 °C, 55% RH, 5 m/s wind were used for this study with a vapour simulant, methyl salicylate, at 100 mg/m^3.

Each trial in this study consisted of 4 replicate tests on the Canadian in-service protective coverall (Figure 1) using humans or the next generation mannequin test platform.

Physiological protective dosage factors were calculated based on [3]. Geometric mean and standard deviation of the results are given in Figure 4 (logarithmic scale, relative data) and compared with those obtained previously [2].

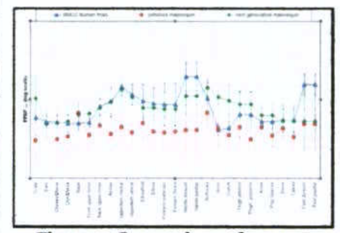

Figure 4. Comparison of vapour protection results for humans and two mannequin systems

It can be seen that the current mannequin gives results much closer to those obtained on humans. The majority of the differences that remain can be ascribed to specific anthropometric differences that remain around the neck and lower torso. Compared with the earlier mannequin, the softer sealing surfaces and improved anthropometry have improved the protection received, as a result of the better seal and fit.

Conclusions

This initial study indicates that the objective of a sufficiently human-like platform to be used for system testing has been achieved. The next step is further validation of the test platform and exposure chamber at a wider range of exposure conditions.

References

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