HUMAN FACTORS PERFORMANCE OF A PROTOTYPE FIREFIGHTER SUIT WITH DEPLOYABLE CBRN FEATURES

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INTRODUCTION

Studies were conducted to determine the impact of a prototype firefighter turnout suit with deployable CBRN features on ergonomic functionality in structural fire fighting. This aspect of evaluation was considered to be an important performance factor in view of firefighter expectation for CBRN protection incorporated into a turnout ensemble that would primarily function in conventional structural fire fighting operations. The CBRN prototype turnout suit consists of a uniquely designed jacket and pants system with a CB protective hood integrated into the jacket collar.

The turnout system is fitted with deployable innovative interface and closure systems to provide resistance to chemical vapor infiltration into the suit. It incorporates constructional features designed to provide enhanced ergonomic function in fire fighting and greater range of body motion in wear. Ergonomic features constructed into the jacket include full-length expansion pleats on the outer jacket to provide unrestricted movement with or without an SCBA. Pleats and darts in the outer and inner jacket sleeve provide extra length when reaching. Curved sleeves in the turnout jacket follow the natural shape of the arm to provide decreased resistance when working.

Systematically designed laboratory based human subject wear trials indicated no significant effects related to deploying the CBRN features of the prototype turnout suit on firefighter heat stress and wear comfort [1]. This paper will focus on the effects of these CBRN features on firefighter ergonomic performance evaluated in laboratory based and field wear evaluations. Priority was placed on assessing the effects of CB prototype design features on the ability of the suit design to function in routine fire fighting operations.

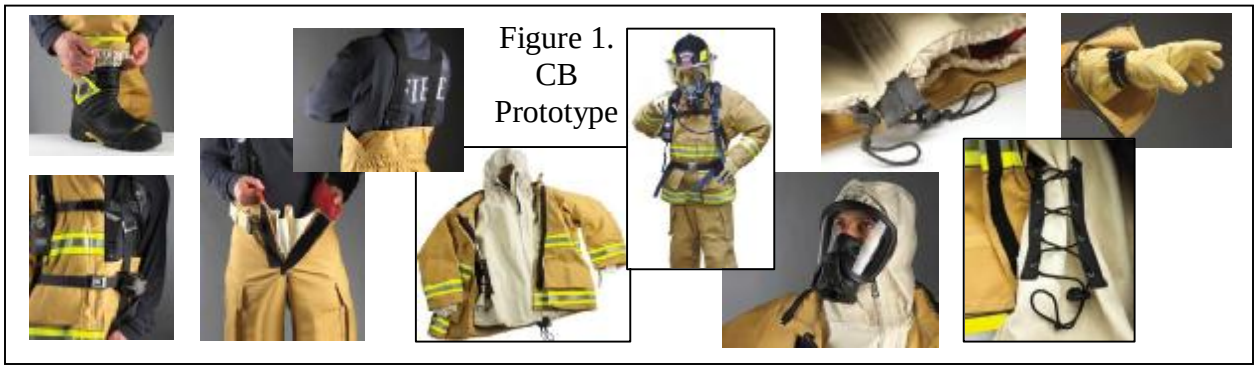

Figure 1. CB Prototype

METHODS

Laboratory Studies of Ergonomic Function: Specially designed controlled laboratory tests were used to evaluate the ergonomic function of a CB prototype, configured both with and without deployable CB closure features in place during the test. The ergonomic protocols used were adapted from procedures specified in ASTM F 1154 and a Candidate Physical Aptitude Test (CPAT) used by fire departments in the U.S. for firefighter assessments [2, 3].

The laboratory test protocol, summarized in Table1, involved the participation of eight male firefighters from the City of Raleigh Fire Department. The ergonomic regiment was designed to simulate common fire fighting activities in a controlled setting.

Table 1. Ergonomic Functional Utility Testing Protocol

Test Period	Time (min)	Activity (exercise/ task)	Rate: Difficulty Performing Exercise/ Task	Rate: Comfort Qualities
1	~15	3X Don/Doff Garment: 1-show; 2-on own; 3timed	Yes	No
2	~15	Rest/ instrumentation	No	No
3	~15	a. Stair climbing (≈ 50 steps/ min) b. Crawling (≈ 65 ft.) c. Ladder Climb using Versa Climber (1 min with no resistance setting) d. Kneeling (4X - left, both right, stand) e. Box lifts (2 - 20 lbs each: floor - table 2X) f. Overhead/ cross body arm movements* (4X: raise arms overhead, bend, extend forward, bend, down. Followed by 4X of crossing arms around chest (self hug) and down) g. Uncoil and coil hose	Yes After each exercise/task	Yes After completing all exercises/tasks
4	~10	Timed Exercise Routine	No	Yes

* This activity was modified to accommodate an overhead arm movement during the timed routine.

Figure 2. Laboratory Evaluation of Ergonomic Function of CB Turnout.

The ergonomic data enabled useful performance comparisons between the CBRN prototype design and a conventionally configured turnout. Donning and doffing times of the undeployed CB prototype were only slightly slower when compared to the control turnout (Table 2) while

the deployed prototype showed an increase in these times due to additional activities required to engage the chemical resistance features built into the suit. A difference is also observed in the perceived ease of getting into and out of the CBRN prototype, as compared to the conventional turnout suit. These differences can be expected to decrease, however, with increased firefighter familiarity with the CBRN turnout and its deployable features.

Table 2. Donning and Doffing Times and Ratings* (n = 6)

	---------- Turnout Type ----------		
Activity/ Firefighter Rating	Conventional	CB Undeployed	CB Deployed
Donning Time (seconds)	71	94	196
Doffing Time (seconds)	30	36	55
Ease of "Getting Into"	1.4	4.6	5.0
Ease of "Getting Out Of"	1.4	3.7	4.6
Routine Time (seconds)	361	391	380

* 1 = Extremely Easy; 5 = Extremely Difficult

Results of evaluator assessments of functionality, while performing job related exercises and tasks show most of the tasks are judged to be more difficult while wearing the deployed CB garment (Table 3). The control turnout is slightly favored when compared to the undeployed CB suit. Regardless, the slight advantage of one garment over another is not large for any of the activities performed.

Table 3. Difficulty Ratings* of Exercises and Tasks

	---------- Turnout Type ----------		
Activity	Conventional	CB Undeployed	CB Deployed
Stair Climb	1.9	1.9	2.1
Crawling	1.9	1.8	2.3
Ladder Climbing	2.5	2.6	3.1
Kneeling	1.9	1.8	2.3
Box Lifts	1.6	2.1	1.9
Overhead Arm & Cross Body	1.4	1.6	1.8
Hose Uncoil & Coil	2.4	2.4	2.8
Dragging	3.8	3.9	3.9
Overall Rating	2.2	2.3	2.5

* 1 = Extremely Easy; 5 = Extremely Difficult

Field Evaluations: Characterizing firefighter response to CB turnout designs when deployed in field settings was an important part of this research. This was accomplished using short duration field exercises conducted at selected firefighter training facilities. Exercises were carried out at three different major metropolitan fire departments including the Fire Department of New York (FDNY), Fairfax County Fire and Rescue (FCFR), and the Philadelphia Fire Department (PFD). These evaluations were not extended field trials. The objective was to obtain firefighter response to the CB features incorporated into the prototype turnout with respect to their perceived utility

of a turnout suit to be used for both routine firefighter activities and in escape and rescue activities in a CB incident.

Evaluation protocols enabled CB design features to be evaluated by professional firefighters while wearing prototype turnout suits along with a full complement of structural fire fighting gear, including appropriate SCBA equipment, hood, boots and gloves. Evaluations occurred as firefighter participants performed prescribed regiments of physical activity routines tailored for each fire department test site.

Regiments used at FCFR and PFD were based on activities called for by the CPAT routines employed by the individual fire departments. These activities permitted various evaluations, including assessment of the turnout impact on walking, carrying heavy objects, dummy dragging and hose, hammer and ladder work. For example, FDNY activities included climbing, forced door entry using a Halligan tool and axe, operation of a saw, hose and Hurst tool, dummy drag, and exiting and descending from a window.

Evaluations of the CB turnout design were based on obtaining qualitative descriptions of the perceived or the potential effects of the test turnout system on task performance, wear comfort, and on practicality for use in structural fire fighting or for deployment in escape and rescue. In addition, systematically designed questionnaires were used to obtain quantitative data in these same critical categories of performance. Summary of the quantitative results on performance ratings are shown in Table 4.

Table 4. Average Performance Rating of Prototype Suit (n = 6)

Question	New York	Fairfax	Philadelphia	Overall
CBRN Performance:				
Importance of CB protection?	2.8	3.5	4.0	
Deploy for escape and rescue?	3.3	3.8	3.3	
Deploy in a timely manner?	2.2	3.7	3.2	
Practicality of deployment?	3.2	4.0	3.7	
Average	2.9	3.8	3.6	3.4
Structural Fire fighting Performance:				
Perform as expect a turnout?	3.1	3.7	3.6	
Complete all tasks?	4.0	3.9	4.0	
Degree of mobility and flexibility?	3.8	4.0	3.9	
How comfortable?	3.0	3.9	3.7	
Appearance?	3.0	4.0	3.8	
Practicality for everyday use?	2.7	3.9	3.5	
Average	3.3	3.9	3.8	3.7
Overall Rating:				
Overall Impression	2.8	4.0	3.7	3.5
Evaluation Average	3.1	3.9	3.7	3.6

* 4 = very; 3 = Likely or somewhat; 2 = not very; 1 = not at all.

Figure 3. Fire Department Evaluations of CB Prototype Turnout.

CONCLUSIONS

These studies show that the CB turnout deployable design features can be expected to have minimal negative impact on factors related to performing the physical tasks typically associated with structural fire fighting operations. The CB suit design received generally high marks for comfort, ease of motion and deployment, and can be donned in only slightly longer time compared to a conventional turnout system. These results indicate that the deployable CB suit design concepts can be accepted by firefighters for use as structural fire fighting gear.

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