INNOVATIVE TECHNOLOGY REPORT

PPE Garments CAN Reduce Heat Stress, Reduce Worker Contaminations AND Increase Productivity AND Potentially Save Costs – Interim Report

Decontamination and Decommissioning Focus Area

By Mark Dieterle

10/14/09

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PPE Garments CAN Reduce Heat Stress, Reduce Worker Contaminations AND Increase Productivity AND Potentially Save Costs – Interim Report

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Overview: IH, Radiological HP, Safety and Operations professionals often struggle with how to clothe workers in PPE garments that allow them to be productive longer, with lower heat stress issues, while reducing personal contamination events (PCEs). Various factors including comfort, fit, fabric choice and design lead to better results, and compliance. A new PPE garment called Q-Gard Quantumwear®, designed by Radcon / IH people with actual workers' input along with the suit manufacturer Quest®, helps meet those needs.

Introduction: Personal Protective Apparel is designed to protect workers in various D and D (D & D) environments from a variety of challenges, including airborne contaminants, radiological insults, water and chemical splashes and other work place hazards. Current PPE suits range from the conventional reusable laundered suits with their lower perceived per-use cost balanced against laundering, environmental impact, inspection, cross contamination and associated replacement costs, to very light weight disposable fabric or "paper" suits with their own challenges of protecting the worker.

Considerations such as the garment's fabric barrier characteristics, overall design and fit, breathability, moisture transmission, seam construction as well as industry tradition weigh into the safety professional's choice when outfitting a work crew for a particular mission, not the least being perceived comfort and attitude by the worker and his / her compliance, safety and productivity. In the nuclear weapons complex specifically and the massive D & D challenge on an accelerated timetable, the problem is how to get the workers safely and comfortably in the D & D zones longer, with higher productivity and lower cost, meeting both safety and productivity goals.

Historical Challenge and Possible New Technology Alternative: Historically, D & D activities at former weapons complex sites encompass a wide variety of challenges and issues for achieving ALARA goals and traditional IH health and safety concerns, from various decommissioning and decontaminating production facilities containing numerous chemical compound and radiological species, asbestos containing materials and other contaminants, to waste retrieval and disposition missions requiring unique designs and executions. Each mission requires the health and operations professional to protect the worker for the worst exposures anticipated through pre-work assessments, while unencumbering the worker's mobility, comfort and resultant productivity.

Traditionally, workers have been protected wearing laundered coveralls, with additional hoods, boots, shoe covers and gloves, with additional layers added to fend off various chemical, dirt and radiological exposure. Laundered suits have a long past, including the

huge fixed cost investment, distribution systems, relationships and habits among makers and launderers and users which won't be displaced easily, despite new technological advances. Disposable suits also have made inroads where chemical protection is needed, and improvement in ALARA approaches can be made or as a carry over from other industry practices as is the case in asbestos abatement and regular D & D work. Literature from both commercial power generation and weapons sites D & D activities and lessons learned points to contaminant concentration in laundered suits as a source of continued PCEs, warranting further investigation for a clean, comfortable and safe alternative.

Quest® surveyed health and operations professionals over 2 years across the weapons complex and found that despite advances in fabrics and designs, even including the new PVA dissolvable fabrics heralded to solve heat stress issues, the old issues of particulate hold-out, seam intrusion, moisture transmission, self contamination and heat stress still plague the specifiers of PPE for missions every day. A new suit design and longer term study was needed, and was conducted, to compare the latest technology (the new Q-Gard Quantumwear® design suit by Quest®), with standard suits used made of PVA or other KC / DuPont barrier type or launderable garments for a variety of missions across a number of sites.

Test Performance: Comparisons of suits were conducted in a number of phases and locations. A portion of suits were compared to traditional launderable suit use, some were compared to the Orex® Deluxe suit, some to KleenGuard® Ultra A-60 style hood and boot coveralls, and some against Tyvek® coveralls manufactured by DuPont or Lakeland. Missions and locations included waste drum repackaging, mixed waste (asbestos and radiological) abatement prior to demolition, dry waste handling, tank farm sampling activities and basin clean-up and super structure demolition.
Additional test comparisons were made in textile testing results provided by the manufacturers as published or obtained independently, and in qualitative trial comments and ratings from Radcon, HPT, and operational supervision and actual workers. Sites included were Paducah, Savannah River, part of Oak Ridge (waste treating and processing) and suit developmental trial suggestions at Hanford. Some sites have declined participation.

Workers wore baseline suits or those assigned in previous similar missions alongside the Q-Gard Quantumwear® suit for light, medium and heavy duty activities in temperatures ranging from 65 - 105°F over an 18 month period. Shifts varied similarly with heat exposure and activity level based on established heat stress WBGT protocols by site from ½ hour in-containment work sessions in high heat exposures to 4 hour shifts with standard break periods for rest and heat stress abatement. Results were quantified in tabular form, with further quantitative analysis needed for statistical analysis after a longer period of use.

Technical data review preceded approval by IH and Radcon engineering staffs prior to any trials being conducted. Of particular interest were the particle holdout data, using the Latex Particle Challenge and Staphylococcus tests as 1 to 3 micron analog tests, as well

as MVTR (Moisture Vapor Transmission Rate ASTM E-96) (Table 1). Particle hold out is particularly important in remediation of mixed waste, not so much in the case of asbestos work, as the worker decontaminates in showering, but for any radiological dirt that may penetrate or transmit through the suit from bleed through transfers. It is, however, difficult to quantify by standard test method, and easily defeated by holes in the actual suit. MVTR is critical (higher being better) for the microclimate exchange between human skin and suit fabric to transmit cooling vapor to the outside. This promotes the reduction of heat stress factors and accounts for the perceived better comfort of the Q-Gard Quantumwear® suit compared to the baseline suits. It should be noted that there are numerous methods of the MVTR test reported and those done using the inverted method report an increased MVTR due to gravimetric effect. Basic textile testing results for a variety of suits worn in radiological D & D are shown in Table 1. High MVTR with relatively high air permeability and high water hold out should make for a comfortable and protective suit.

Physical Properties Comparison							
				Orex	Standard		Kleenguard
Property	Method	Unit	Quantumwear®	Deluxe®	PVA	Tyvek®	Ultra®
Air Permeability	ASTM D737	ft3/min/ft2	33	NR	NR	NR	NR
Hydrohead	AATCC 127	cm	62	NR	NR	112	226
MVTR (50%RH@90F)*	ASTM E-96	gr/24hr/m2	5200-6200	1872	2217	1700	2725
Particle Challenge	Latex	% @ mean 1.0m	77	NR	NR	NR	NR
	Staphylococcus	% @ mean 3.0m	94.4	NR	NR	NR	NR

NR = Not Reported

*MVTR can be measured inverted or not inverted.
Results for Q-Gard Quantumwear® reported as NOT inverted. Others are unspecified.

Table 1 Physical Properties

Trial objectives included:

- Protection of the garment versus baseline for particle holdout and splash resistance.
- Donning and doffing characteristics and potential for self contamination when doffing.
- Perception of coolness and increased wear time. Will heat stress be avoided versus baseline?
- Cost similar or better than baseline garments per use (excluding unknown fixed cost investments; estimated laundry and acquisition costs).
- Willingness / preference of workers / Radcon to wear / spec a new suit (not invented here; that's not our culture, etc.)

Results: Though not statistically conclusive, performance was measured by trial interviews and tabulations on a trial process form (Figure 1) in which individual ratings and comments were recorded around eight attributes: Ease of Application (Easy to put on of don), Overall Comfort (Not comfortable versus very comfortable), Size Fit (Too tight to very comfortable), Protection (Felt not protected to very protected), Breathability (Felt Hot to Felt Cool), Durability (Tore easily to very durable), Elbows and Knees (Didn't like reinforced joints versus really liked), Overall Rating (Poor to Excellent). Ratings were recorded on a scale of 1 to 5. A rating of 5 is rated as Excellent. Additional voluntary comments were recorded and compiled.

Activities were coordinated and supervised by IH / Radcon personnel and ranged from glove bag work removing asbestos insulation in a hot zone – wet work, maintenance work in contaminated zones, survey / support, dry waste, cleaning inside enclosures, lifting and moving materials and demolition debris, removing and replacing drum rings, and jack-hammering while in respirators and suits. One engineer in South Carolina also wore the Q-Gard Quantumwear® suit in the summer to cut his grass to contrast the heat stress relief of the Q-Gard Quantumwear® suit compared to the baseline suit worn at work

To date, 4 sites and over 50 workers have participated with over 200 shift changes and over 26 volunteering to participate in the survey. (It may be noted that one worker who was described as a person who "never wears anything except cotton coveralls" participated but scored no category above a 3 or "Good", but was included in the data for completeness.) Summary ratings are shown in Table 2. No contaminations from the Q-Gard Quantumwear® suit were reported.

An example of an actual comment trial form is shown in Figure 2.

Quest® Q-Gard Quantumwear®
Comparison Trial Process

Date _____

Customer _____

Name _____
Position _____

Work / Mission Type _____
(Briefly describe the work you do in the suit)

Quantity Used _____
Size: _____ Duration of use: _____
Work Area _____

1	Poor
2	Fair
3	Good
4	V Good
5	Excellent

Instructions: Thank you for trying out our new patent-pending Q-Gard Quantumwear® protective suit. Please rate the suit for each of the categories below, with 1 being Poor to 5 being Excellent. Please feel free to add any comments or suggestions. Thanks!

	Property Rating	Poor				Excellent
1	Ease of Application (Easy to put on)	1	2	3	4	5
2	Overall comfort (not comfortable to very comfortable)	1	2	3	4	5
3	Size fit (Too tight to very comfortable)	1	2	3	4	5
4	Protection (Felt not protected to felt very protected)	1	2	3	4	5
5	Breatheability (Felt hot to felt cool)	1	2	3	4	5
6	Durability (Tore easily to very durable)	1	2	3	4	5
7	Elbows and Knees (Didn't like to Really liked)	1	2	3	4	5
8	Overall Garment Rating (Poor to Excellent)	1	2	3	4	5

Comments and suggestions: _____

Would you rate this suit better than the suit you wear today? Y / N
Why? or Why not? _____

What suit do you use today? _____

Would you suggest anyone else should use this suit? Y / N Who? _____

The Q-Gard Quantumwear® name is a registered trademark of Quest Environmental & Safety Products, Inc. and the suit design is protected under one or more US Patents-Pending.

Figure 1

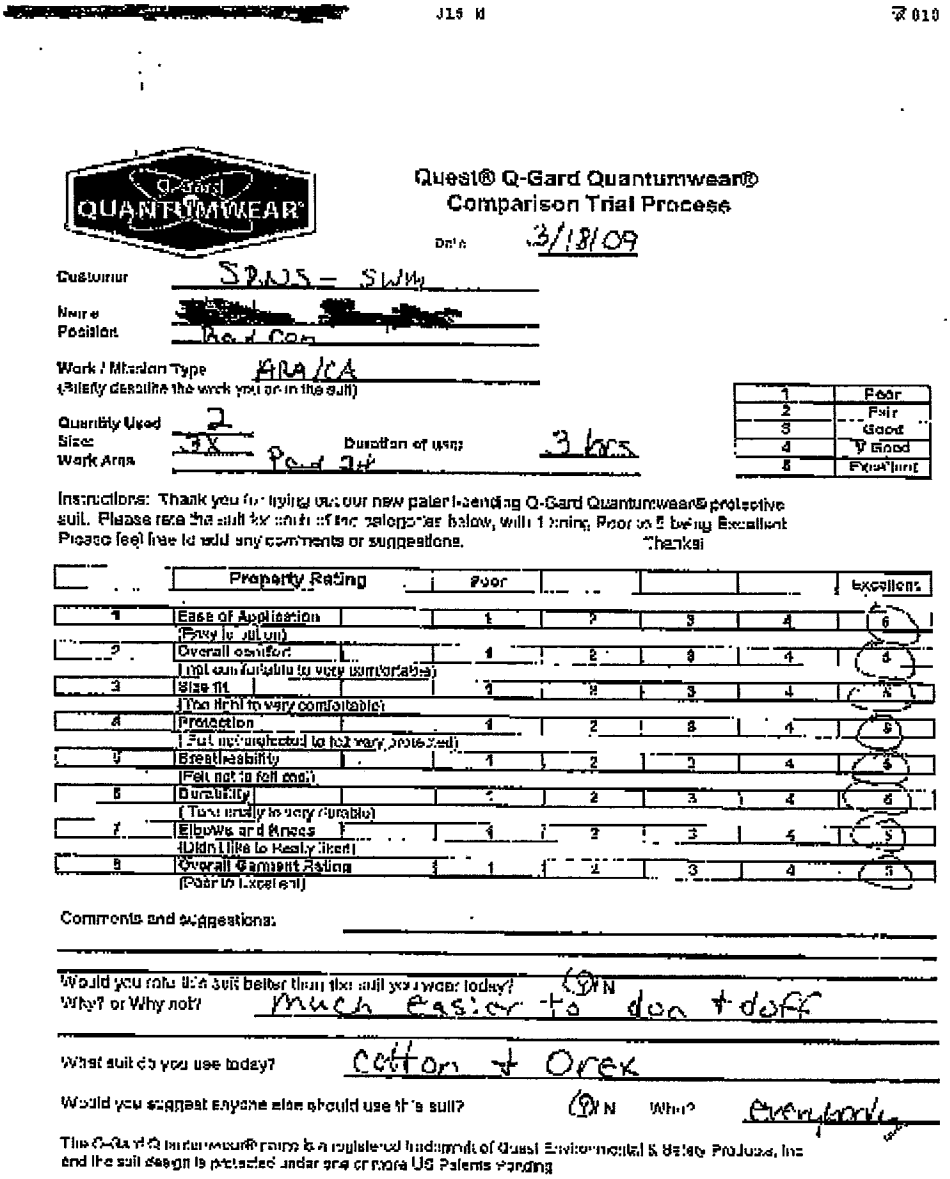
Summary of compiled surveys scores are as follows in Table 2:

Property	Rating 1-5
Ease of Application	4.69
(Easy to put on)	
Overall comfort	4.58
(not comfortable to very comfortable)	
Size fit	4.42
(Too tight to very comfortable)	
Protection	4.69
(Felt not protected to felt very protected)	
Breatheability	4.50
(Felt hot to felt cool)	
Durability	4.62
(Tore easily to very durable)	
Elbows and Knees	4.85
(Didn't like to Really liked)	
Overall Garment Rating	4.62
(Poor to Excellent)	

Table 2 - Overall Compiled Summary Results To-Date

1	"Fits better for a 6'2" man."
2	"Good for working with asbestos and zippers seem better."
3	"It doesn't seem to draw heat to the body when working in the sun."
4	"Needs Velcro on pocket and strap on chest area for EPS."
5	"White, cool and easy to don."
6	"Place some Velcro on inside of chest pocket to allow for keeping closed."
7	"Add a loop above pocket for attachment of EPD."
8	"The durability and the color doesn't draw draw heat to the body from the sun when outside."
9	"Very good for working with asbestos material."
10	"Feel very protective. Better protection from asbestos fibers."
11	"Very good for working with asbestos; zippers seem to last longer."
12	"Overall wear of the Q-Gard Quantumwear® was excellent."
13	"Special features made donning and doffing easy."
14	"Comfortable for cool conditions; haven't used for heat stress conditions yet."
15	"Everything was enclusive; hood, suit and booties."
16	"Good overall fit; Comfortable."
17	"More breathable suit."
18	"Excellent PPE."
19	"Not as heavy; Comfortable."
20	"Much easier to don and doff."
21	"Easier."
22	"It's so much easier to put on and take off; feels a whole lot more comfortable"
23	"I would like to ask if not everyone likes them (Q-Gard Quantumwear®) can we have a choice because I can tell a huge difference in the heat stress my body endures with the white(Q-Gard Quantumwear®) versus blue)
24	"Absolutely, they allow your body to breathe; I also like the toughness of the material."
25	"When I jack-hammer I get small tears in the blue suit, but not with these(Q-Gard Quantumwear®) suits.
26	"Bigger, lighter and reinforced knees and elbows."
27	"Cooler, bigger and less tape needed around the neck."
28	" A lot easier to doff."
29	"Got more protection than other coverall (PVA)."

Table 3 Comments



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Quest® Q-Gard Quantumwear®
Comparison Trial Process

Date 3/18/09

Customer SPWS - SWM

Name [redacted]
Position Lead Con

Work / Mission Type RRA/CA
(Briefly describe the work you did in the suit)

Quantity Used 2
Size 3X
Work Area Pad 3H

Duration of use: 3 hrs

1	Poor
2	Fair
3	Good
4	V Good
5	Excellent

Instructions: Thank you for trying out our new patent-pending Q-Gard Quantumwear® protective suit. Please rate the suit for each of the categories below, with 1 being Poor to 5 being Excellent. Please feel free to add any comments or suggestions. Thanks!

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6	Durability (Tore easily to very durable)	1	2	3	4	5
7	Elbows and Knees (Didn't like to Really liked)	1	2	3	4	5
8	Overall Garment Rating (Poor to Excellent)	1	2	3	4	5

Comments and suggestions:

Would you rate this suit better than the suit you wear today? (Y) N
Why? or Why not? much easier to don + doff

What suit do you use today? Cotton + Orex

Would you suggest anyone else should use this suit? (Y) N Who? everybody

The Q-Gard® Quantumwear® name is a registered trademark of Quest Environmental & Safety Products, Inc and the suit design is protected under one or more US Patents Pending

Figure 2. - Actual Comment Form

Cost Considerations: The Q-Gard Quantumwear® Hood and Boot protective suit used for these comparisons ranged from size XL to 5XL are all packaged 25 per case. Other suits used either were hood and boot attached or separate coveralls with added detached hoods and boots. Competitive suits are packaged 25, 24 or 20 suits per case dependent on size and vendor. Costs for the laundered suits, laundering costs and negative environmental cost impacts from laundering, inspection rejection rates and replacement costs were not provided for this trial and will be subject to further studies.

Based on purchase price comparisons, the Q-Gard Quantumwear® suits average cost for these trials was $5.15 per suit, and $6.00 for separate coverall, hood and boot assembly, compared to an average Orex® assembly including hood, boot cover and suit of $7.96 per dress out and $5.70 for a K-C Ultra® hood and boot suit. Based on those factors, the Q-Gard Quantumwear® suit offers a savings over the traditional baseline suits of 10% to 34% per dress out, depending on configuration (separate elements versus integral Hood and Boot Coverall).

Conclusion: Based on available selections for protective suits, the IH / Radcon and safety people at D & D operations have to make choices based on the severity of the exposure of contaminants using an ALARA approach for each mission. Where traditional bulky coveralls have been used to protect workers doing light to medium work in partly contaminated areas, or applications of abatement in full enclosures requiring hoods, boots and respirators, the Q-Gard Quantumwear® suit was designed to improve the comfort, protection and ease of use. The Q-Gard Quantumwear® suit also may serve to provide substantial cost savings based on a per-use cost.

Compliance based on worker comfort can also be impacted based on the preference for this new technology. The Q-Gard Quantumwear® suit was preferred by many workers and can provide a clean, comfortable and safe alternative to traditional choices to protect workers in many D & D environments.

About the Author: Mark Dieterle is a Division Manager for Quest Environmental & Safety Products, Inc., and co-inventor of the Q-Gard Quantumwear® protective apparel suit. He started his career in textile manufacturing, development and product management in 1980 at Milliken & Company, followed by similar responsibilities at a number of plastics and safety products companies, including AEARO, now 3M. Quest Environmental & Safety Products, Inc. is based in Indiana at 1-800-878-4872, and at www.questsafety.com