Design and Evaluation of a Garment System for Protection Against Steam and Hot Water

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People working in the western Canadian oil industry are exposed to extreme environments and hazardous equipment. With a focus on functional clothing and user-centred design this paper reports on a study that took place over five years, that involving the design and evaluation of a garment system to protect from steam and hot water. A multi-method approach was taken in the overall project: field observations, focus groups (Strickfaden et al., 2010), precedent research (Yu et al., 2011), photographic analysis, developing recommendations (Yu et al., 2012a), mock-up evaluation (Yu et al., 2012b), textile analysis, prototype development and wear trials. This paper reports on the last two phases.

Background: Steam and hot water are used in extracting, refining and producing heavy oil in oilfields, oil sands and plants. Workers are protected against flash fire and radiant thermal exposures through aramid coveralls. However, these garments offer no protection from exposure to steam or hot water. Field research identified six typical tasks that expose workers to these hazards, e.g., loading hot water, opening high-pressure valves and spraying on wellheads. Based on anecdotal and documented industry reports, there has been an increase in incidents of steam and hot water injuries over the past eight years. This prompted the collaboration herein between an industry consortium and researchers at the University of Alberta to develop a garment system.

Purpose & Objectives: The functional apparel design process is used to develop a full-scale prototype of a proposed garment system by working directly in consultation with workers, safety supervisors, and manufacturers. The prototypes are then evaluated in actual workplaces for functional fit, mobility, subjective comfort and acceptability.

Methods*:* Four workers tested the garment system by wearing it during two shifts of 14 days and 12 hours per day. Details about the design were reported daily through questionnaires and one focus group meeting their safety supervisor at the mid-point. The questionnaires were: a pre-trial fit assessment, garment daily use record, wear acceptability scales with open-ended questions, and a post-trail fit assessment.

Garment System: The resulting two-part garment system is worn over coveralls. Design features are: 1) a standing collared jacket with triangulated venting on the back, cinched waist, extended shoulders and widened armhole, dropped hem at the back, and cuffs that interface well with gloves; and 2) high-waist pants with a vest, inseam panel at crotch, wide-legs to allow donning and doffing while wearing boots, knee pad pocket, and venting at the back of the leg. Also included are ample pockets for worker's personal and work effects. A need for functional fit and mobility resulted in design details such as construction lines, the set of the garment, garment balance and garment ease. There are two separate garments to improve mobility and fit in terms of body shapes. Optimal ease is added for maximum flexibility of movement and work activities—including stretching, climbing, bending, crawling. A fabric is selected that is semi-

permeable and ventilation added in order to better regulate heat dissipation from the skin to the environment, which enhances physiological comfort and reduces the risk of heat stress. Finally, the garment is aesthetically pleasing, culturally acceptable and identifies the wearer with safety, meaning the design has the look of hard-wearing work wear along with sporty features.

Wear Trials: The workers were four males between 21-49 years old with experience between 1.5-15 years. One works in an extraction plant, two in the field and one in maintenance. The garment was worn in winter conditions between -10ºC/14ºF to -35ºC/-31Fº. Workers wore coveralls with long johns or shirt, jeans and FR hoodies under the garment system. All the workers gave the prototype high ratings with respect to most categories. One worker said that it was "non-constricting" and another indicated that he "could not feel steam when working in steam situations". They felt the garments were lightweight and one especially liked being able to wear the jacket and pants separately. Critical remarks were that they felt the pant legs were "way too big" and the straps on the pants were too loose with ineffective buckles and fasteners. The top venting on the jacket was drafty especially in the wind. Most surprising is that even though the garment system was designed to only be worn when workers were working with steam and hot water they instead wore the garments all day because they felt it was more comfortable than their current coverall.

Conclusion & Future work: The design of our garment system was evaluated based on visual design and aesthetics (design look), function (cuff closures, ability to don and doff), movement, fit and thermal qualities (venting system). On the most part the overall design look was considered to be neutral, the function was very good, ability to move and the feelings of and actual protection were superior. Overall, the garment system passed with only a few design changes to implemented. Even so, as the wear trial took place in the winter it is necessary to perform wear trials under summer conditions before manufacture.

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