Testing Seams for use in Apparel Designed for Protection Against Steam

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While developing apparel with semi-permeable fabric systems that are able to withstand hazards invoked by steam it is critical to examine the seams. Seams are the ubiquitous part of apparel where two or more fabric pieces are joined by stitching, thermal bonding, stapling or adhering (ASTM D7722-11). Seams can be seen as the 'Achilles heel' of apparel because the entire garment system can collapse when seams fail. The work herein is part of broader research project intended to address issues around injury from steam and hot water including: 1) developing a laboratory test apparatus (Ackerman et al, 2012); 2) modeling parameters to test fabric properties and optimize the existing evaluation protocols; and 3) proposing design recommendations for garment systems that protect from steam and hot water (Yu et al., 2012).

Background & Purpose: Seams are of various types and complexity: concealed, functional or decorative. The construction of seams must fit with the function of the garment, which is dependent on thickness and weight of the fabric and desired durability and longevity of seams. The standards ASTM 6193-11, ASTM D 5646-11, ISO 4915 and ISO 4916 define and classify types of seams with general names, systematic diagrams and a written description of each seam. Several tests have been done that focus on seam strength with different fabric types (e.g., ASTM D 4884-09, EN ISO 10321) and seam tensile strength (e.g., ASTM D 123-12); however, to date no tests have been done on the effects of steam on seams. The purpose of the research reported here is to ascertain the ideal seam structure(s) that can be used on a semi-permeable fabric that performs well enough to withstand steam at a pressure of 30 psig in a controlled environment.

Methods*:* Fabric specimens of 150 mm/59 inches diameter are created with basic seams typically used for constructing apparel typical to the protective clothing industry. The specimens are tested at the Protective Clothing and Equipment Research Facility (PCERF) at the University of Alberta using a bench scale apparatus designed to test the effects of steam. The apparatus offers a method for evaluating low pressurized steam on the protective properties of material composites (Ackerman et al., 2012). The apparatus is a 3 KW boiler connected to a super heater that produces saturated steam at a controlled pressure releasing steam through a nozzle about 4.6 mm/0.2 inch in diameter positioned above a test specimen (ibid). A computer controls the time and pressure through a solenoid valve and a skin simulant sensor is at the centre of a platen where the fabric specimen is placed. During the experiment the computer records 10 readings per second, to a total of 600 readings for one test sequence of 1 minute. Six specimens were tested with five repetitions of each to verify accuracy. The specimens were placed in a conditioning chamber following the standard CAN/CGSB-4.2 No.2-M88 at 65% (+/-2%) relative humidity and at 20°C (+/-2°C). The order of the tests was randomized using a computer generated randomized list and the same computer organized and analyzed the data.

Fabric & Seams: A tri-laminate fabric—exterior, vapor barrier, insulation—is used that was deemed to protect from steam and hot water. The weight of the fabric is 490 g/m and 14.5 oz/yd squared. The fiber content is 93% Nomex© and 7% PU membrane. The exterior woven layer is made of a plain weave and the insulating layer is made of knitted fleece. Six different seam types are tested. Five from the standards ASTM D 6193-11, ASTM 5646-11 and ISO 4916 (flat felled, serged, lapped, two types of piping seams) and a bound seam designed by author 1. An Edmonton manufacturer of protective clothing produced the seam specimens. The thread used for construction is a Nomex© thread (30 tex) normally used in manufacturing protective clothing and the stitch length was 2.76 stitches/cm or 6.65 stitches/inch for all specimens.

Results: Of the seams tested the piping seam without top stitching did the best. This seam registered a second degree burn at an average of 23.6 seconds (SD 19.1 seconds) and did not register a third degree burn. It is speculated that the piping seam fold created an air gap above the sensor, proving additional insulation compared to the other seams. Also, the seam allowance 2.4 cm/1 inch in length at the back of the garment rests over the skin simulation sensor. These layers created by the construction of seam, including the piping itself, provided additional layers of insulation thereby preventing steam penetration. The second piping seam and the flat felled seam each had two rows of top stitching which breaks the membrane on the tri-laminate through perforation. The lapped seam compared closely with the flat felled seam; however, the additional layers of fabric provided extra insulation to help minimize the degree of burns registered. The serged seam had a similar issue but with only a single top stitch. The bound seam also had a stitch that ran through the entire fabric structure that punctured the membrane.

Conclusion: From the review of literature it is clear that no established method for testing seams against steam existed previously. The bench-scale apparatus developed by PCERF is used in this application for the first time. Even so, this first test of seams against steam impingement provides valuable research to hone research protocols, improve apparatus design and allow designers to select better seams for to be used in apparel design that protects from steam injuries.

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