

A Final Report

on the

**Incorporating Standards Education into Courses on Textile Protection and Comfort**

for

**National Institute of Standards and Technology  
US Department of Commerce**

Reference Number: 70NANB13H205

by the

**Center for Research on Textile Protection & Comfort**  
College of Textiles  
North Carolina State University

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## **Executive Summary**

The College of Textiles at North Carolina State University (NCSU) has developed new course materials and pedagogical approaches to incorporate standards principles into courses on comfort and protective performance of personal protective ensembles and equipment. Project goals have been successfully addressed during the project: 1) content on standards and standardization were incorporated in two special topics courses; 2) new pedagogical procedures were used, and additional ones are under development for planned distance education; 3) instruments were devised to judge the effectiveness of the new curriculum materials; and 4) two course action forms were approved both at the College level and by the University Graduate Course and Curriculum Committee. The two courses, TE 550 “Principles of Human Protection and Comfort” and TE 551 “Human Physiology for Clothing and Wearables” will be offered annually. Both TE 550 and TE 551 will be offered in the fall of 2015. Exemplars of course materials are found in the appendices.

The project team began development of asynchronous and synchronous distance education versions of these courses and is working with NCSU’s Distance Education and Learning Technologies Applications (DELTA) toward online class offering for those courses. Administrative changes related to the funding formula for online courses, including new procedures for funding distance courses, are impacting the timing for beginning to offer courses. The Provost office is projecting that those issues will be resolved prior to fall 2015.

NCSU Administration has granted Permission to Plan for an Institute for Human Protection and Comfort Science (IHPCS) that will include these courses in its curriculum. When new administrative procedures mentioned above have been implemented, the project team plans to move forward with the online courses, the Professional Sciences Masters’ degree program, and the Institute.

## **Discussion of Project Accomplishments**

A course entitled “Clothing Comfort and Personal Protection Science” was offered by Professor Roger Barker in the fall of 2013. The course included a number of class modules about standards and standardization. Topics addressed included the basics of standards and standardization including the role of standards; risk assessment and analysis of the level of

performance as a basis for tests and standards; the processes used to create test methods; identification of standards organizations relevant to personal protective technologies; and the procedures used to propose and adopt test methods within standards. Class lectures and discussions addressed the need to have reliable reference standards, the requirements for reference standards, discussion of important consensus standards and regulatory organizations (ASTM, ANSI, NIOSH, NIJ, ISEA, CEN and ISO), specific test methods and standards relevant to personal protective technologies, and the role of standards in innovation and certification of the performance of materials, ensembles and personal protective technologies.

In addition to lectures and discussions, students visited testing laboratories located in the Textile Protection and Comfort Center to observe laboratory tests being performed according to ASTM, NIO/SH, and NFPA standards requirements. Students were also asked to choose one user application where protective clothing and equipment are required, and the students were required to present to the class regarding risks and risk mitigation for that application and the standards that are required. Students were assessed on their knowledge through questions during the presentation, through the written report, and through class discussions and written exams.

Appendix I, which describes one of the class sessions along with explanatory notes, is attached as part of this final report. Examples of some of the information presented in the course are shown in Figures 1 and 2:

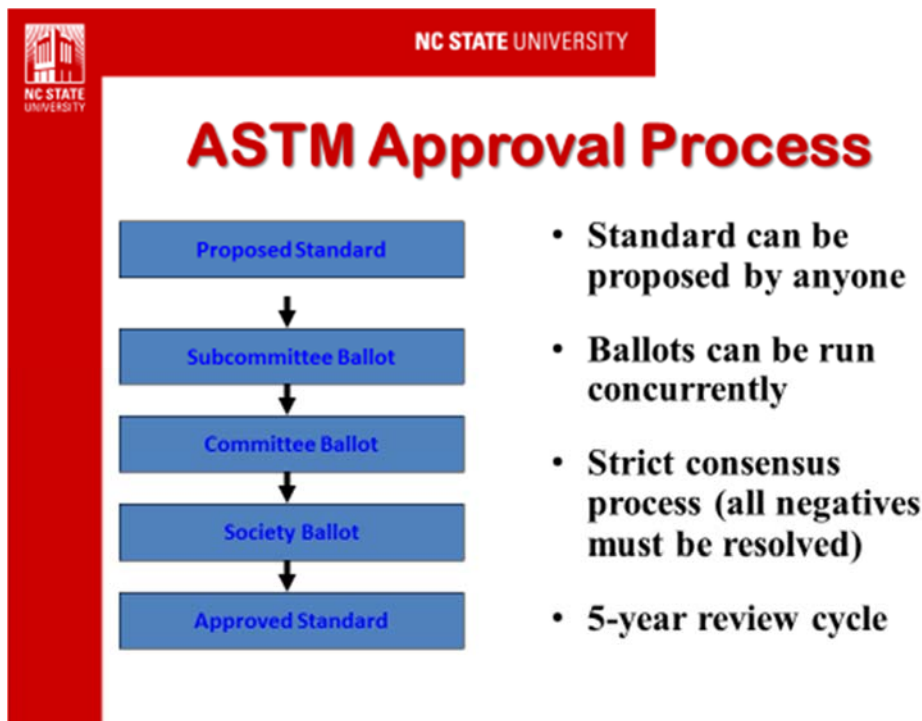



Figure 1: Description of ASTM Approval Process



**NC STATE UNIVERSITY**

## Comparison of Standards Organizations

<i>Organization</i>	<i>Membership</i>	<i>Development Process</i>	<i>Consensus Type</i>	<i>Focus</i>
<b>ASTM</b>	Open	Open-ended (3 years)	Full	Test methods
<b>NFPA</b>	By appt. (limited)	Fixed length (2 ½ years)	2/3 majority	Product specs.
<b>CGSB</b>	By appt. (limited)	Open-ended (3 years)	2/3 majority	Product specs.
<b>CEN</b>	By EEC or EFTA nation	Fixed length (3 years)	based on ballot	Product specs.
<b>ISO</b>	By country	Fixed length (4 years)	based on ballot	Methods & specs.

Figure 2: Comparison of Processes for Key Consensus Standards Organizations

Dr. Emiel DenHartog offered the course on “Human Physiology for Clothing and Wearables” in the spring of 2014. The course used a number of approaches to emphasize the importance of standardized testing methods and performance requirements. Further, the limitations of laboratory tests in predicting typical physiological burdens and performance limitations in the field were discussed. In one exercise, students created groups to decide how to investigate impacts of particular activities on bodily systems, including what standards and testing procedures would apply to that research. Standards topics discussed during the course included:

- Human testing limits
  - ISO9886 (Physiological Monitoring)
  - ISO8996 (Metabolic Heat Production)
  - ISO7933 (Predicted Heat Strain)
- ASTM procedures for ergonomics/functionality
  - F1154 Standard Practices for Qualitatively Evaluating the Comfort, Fit, Function,

and Durability of Protective Ensembles and Ensemble Components

- F2371 Standard Test Method for Measuring the Heat Removal Rate of Personal Cooling Systems Using a Sweating Heated Manikin
- F1291 Test Method for Measuring the Thermal Insulation of Clothing Using a Heated Manikin
- F2370 Test Method for Measuring the Evaporative Resistance of Clothing Using a Sweating Manikin
- F1868-12 Standard Test Method for Thermal and Evaporative Resistance of Clothing Materials Using a Sweating Hot Plate)
- ISO/EU methods
  - ISO7730 Ergonomics of the thermal environment - Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria
  - ISO 9920 Ergonomics of the thermal environment - Estimation of thermal insulation and water vapor resistance of a clothing ensemble
  - ISO 11079 Ergonomics of the thermal environment - Determination and interpretation of cold stress when using required clothing insulation (IREQ) and local cooling effects
  - ISO 8559 Garment construction and anthropometric surveys - Body dimensions
  - ISO 11092 Textiles - Physiological effects - Measurement of thermal and water vapor resistance under steady-state conditions (sweating guarded-hotplate test)
  - ISO 15265 Ergonomics of the thermal environment - Risk assessment strategy for the prevention of stress or discomfort in thermal working conditions
- OSHA Standard 1910.269

Other instructional activities included observation of laboratory instrumental tests, as well as manikin and human tests. To assess learning, students were asked to describe the tests being performed, what the tests were designed to measure, the strengths and limitations of the tests, and how the results obtained could be interpreted. In addition to the group and laboratory activities, students were asked to discuss the topics during lectures, and questions were included on tests and homework assignments. Two examples of topical slides on human subject performance testing are shown in Figures 3 and 4:



## Clothing Standards – Human Subjects

- **Physiology:**
  - ASTM: ASTM F 2668 & ASTM F 2300
  - EU: EU469 – Annex F (Protective clothing for fire fighting)
- **Ergonomics:**
  - ASTM: F1154 – limited usability test
  - NFPA: Limited Usability tests in some standards (HazMat suits)
  - EU - Ergonomics: prEN14876-1

11/24/2014

Human Physiology

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Figure 3: Human Subject Physiological and Ergonomic Testing Standards



## Clothing Standards – Human Subjects

- **Efforts in EU:**
  - ballistic police vests (2002-2004)
  - Fire fighters (EN469)
  - NL Mil. Specs for EOD
- **US:**
  - Various ASTM standards part of NFPA (ASTM F-1154)
  - CB-FF gear : Antropometry, static & dynamic ROM (Coca, et al., 2008)
  - EOD suits (NIJ)



11/24/2014

Human Physiology

Figure 4: Additional Clothing Standards for Human Subjects

The project team also prepared documentation to submit the courses for inclusion in the regular curriculum of the College of Textiles graduate program. The course action forms and syllabi have been considered at the College level and the University Graduate Course and Curriculum Committee, and they have received final approval.

The courses are intended to be a part of the educational program of the new Institute for Human Protection and Comfort Science (IHPCS) and the Professional Sciences Master's (PSM) Degree program. A detailed submission was prepared for the Institute and submitted to the NCSU administration. The University has granted formal Permission to Plan for the Institute, a process expected to require a year or longer. The documentation for permission to plan the PSM has nearly been completed, and it will be submitted in the near future.

Professor Barker and Dr. Don Thompson presented a description of the project to the November 2013 and 2014 meetings of the NIST Standards Education program awardees. In addition, the team presented the progress made to that time to the NIST program managers in a February, 2014, site visit to NCSU. A series of slides describing our project in detail was sent to the NIST program managers following that meeting.

Dr. Barker, Dr. DenHartog and Dr. Thompson have begun to work with the DELTA group and the new NCSU cluster on Digital Transformation of Education to develop the distance education versions of the first two courses. The course syllabi will be shared with the DELTA Educational Technologies unit, Instructional Innovations unit and the Instructional Support Services unit. Together with the College of Textiles digital services group, DELTA and the project team will collaborate on effective distance education approaches as those are developed. In addition, we will engage with new cluster on Digital Transformation of Education about the most effective approaches to deliver content. Currently, the new curriculum and the proposed Institute for Human Protection and Comfort Sciences are delayed due to UNC system-level approvals processes, and due to the pending changes in course support models for traditional education and distance education. Nevertheless, the IPHCS received "permission to plan," and the PSM will be submitted for approval of Permission to Plan as soon as the administrative process is once again open to us.

## **Progress to Achieve the Project Plan of Work**

**Task 1:** Develop complete course outlines and syllabi including modules on standards and Standardization modules for two courses (*Principles of Comfort and Personal Protection and Comfort and Physiology of Performance Wear and Protective Clothing and Equipment*)

Status: *Complete.* Course syllabi and learning objectives completed.

**Task 2:** Write instruction materials on standards to be included in course. (Months 3-6)

Status: *Complete.* Courses have been delivered to 12 students each. Submission of courses to the University Graduate Course and Curriculum Committee has been made, and approval for inclusion in regular curriculum anticipated in the near future.

**TASK 3:** Develop distance education and virtual laboratory materials based on the outcomes of. Develop tools for assessing learning outcomes. (Months 6-18).

Status: *Partially complete.* The project team is involved in discussions with the DELTA program and the College of Textiles digital support group on development of the distance education modules. Note: Based on the scheduling available from the DELTA program, the active work on finalizing the distance education courses will begin in the in 2015. In anticipation of the future distance education courses, TE 550 and TE 551 lectures and supporting materials will be recorded; and the parts that are appropriate will be retained for the distance education courses. The delays are a result of factors outside of the control of the project team, but the objective is a critical part of our plans for an Institute and PSM. The learning outcome assessments for the residential courses have been completed, and those for the distance education module will be part of the process for our course development. Completion of this work will depend on the NCSU and UNC system action.

**Task 4:** Create summary report and prepare journal article on integration of standards into courses about human protection and comfort sciences. (Month 18).



Status: *Partially complete*. An article has been requested by *Standards Engineering*, has been completed and is in final internal review. In addition, the presentation and paper for the January, 2016 ASTM symposium has been accepted. The topic of the presentation and paper will be gaps in standards related to personal protection, and an important part will be addressing the need to educate developers of new technologies and standards groups on the importance of validated test methods, standardization procedures, and performance standards.

Project team members are working with faculty in other Colleges with regards to integrating standards in their courses related to personal protection topics. Examples include courses in cognition and stress (College of Humanities and Social Sciences, Psychology Department), Environment and workplace and agricultural exposures to chemical and biological toxins (Center for Human Health and Environment and Veterinary Medicine--Center for Chemical Toxicology Research and Pharmacokinetics), as well as Wildlands Firefighting and Forestry Operations (College of Natural Resources, Forestry Department).

Two TPACC students have submitted papers to the ANSI student completion for contributions on how Standards enable innovation.

Finally, as a result of an invitation generated from the intervention of the NIST Standards office, Dr. Thompson attended the March, 2015 meeting of the Interagency Board steering group, and several key members from ANSI, the Underwriters Laboratory Standards group, the Combatting Terrorism Technical Support Office (DoD), the Fire Prevention Research Foundation, and the NFPA Government Affairs Office expressed interest in developing a joint short course for their users, experts and customers on standards and standardization processes. Other key SMEs including Jeffrey Stull of International Personnel Protection and Robert Tutterow of F.I.E.R.O. have also expressed an interest in participating. We hope to proceed with that effort and to capture the materials for use both as U-tube educational offerings by the agencies and for inclusion in the courses and short course offerings at N. C. State University.