Final Report

Incorporating Standards Education into Courses on Textile Protection and Comfort

For

National Institute of Standards & Technology
US Department of Commerce

Reference Number: 70NANB14H247

By the

Center for Research on Textile Protection & Comfort (T-PACC)
College of Textiles
North Carolina State University

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Executive Summary

The objective of this project was to develop course content and instructional approaches to increase the knowledge of standards for safety and performance textiles. During this phase, we incorporated instruction on standards into undergraduate and graduate courses taught at the College of Textiles at NC State University. We presented standards information in short courses, and at conferences and meetings of standards organizations. Key topics addressed include:

- Requirements for reliable reference standards for personal protective clothing and equipment (PPE); the need to quantify test precision, reproducibility, and accepted practices for validating measurement and test procedures for performance and safety textiles.

- The need for reliable reference standards for instruments and methods for testing PPE, including the calibration requirements of instrumented test methods.

- The strengths and limitations of using standardized tests to predict real world performance in safety textile applications. We address the need for hazard assessment and risk analysis as the basis for test methods and performance requirements for different PPE applications.

- The role of national and international standards development organizations, including ASTM, ANSI, NIOSH, NIJ, ISEA, CEN and ISO. We provide instruction on the processes used to develop consensus performance standards for PPE.

- The role of performance standards and certifications in product innovation and in the marketing and commercialization of safety and performance textiles.

We incorporated instruction on standards into an undergraduate course on textiles testing during this cooperative agreement. Appendix I shows the class outline for instructional modules incorporated into TE 331, a required undergraduate course for textile engineers on testing and evaluation of textile materials. The course includes a group project activity on standards. Appendix II shows a survey instrument developed to assess student knowledge about standards used in TE 331 and in an introductory survey course on Fiber Science.

We developed the syllabi for two new graduate level courses for the Textile Engineering curriculum. The focus of one graduate level course is protective gear for fire, intense heat and mechanical and ballistic hazards. The focus of the second course is on PPE for chemical, biological and medical threats. Each of these courses covers requirements for standardized tests, formation of performance criteria, and the basics of standardization processes for specific thermal or chemical hazards. These courses will use lectures and group projects to engage students in discussions and cooperative learning experiences. They incorporate opportunities for students to observe and participate in conducting laboratory-testing procedures. U-tube recordings of testing procedures are accessible for current students. These videos will be a key element of planned

distance education classes that feature standards instruction in safety and performance textiles.

In order to build mastery, assignments require students to read material on the requirements for tests methods and performance standards. Case studies are used, in which students are expected to learn about the risks and user needs for particular workers and then to become familiar with the relevant performance standards for the protective clothing used for that job. Then, students discuss the value and limitation of existing standards.

We have designed a new certificate program in protective and performance textiles that will provide additional opportunities to leverage our standards instruction modules. The certificate program will be open to students in any of NCSU's graduate curricula. The certificates requires a set of core courses (basic knowledge of textile systems, TE550 and TE551, along with a choice of at least three additional courses including the new courses on Thermal Protection and Chemical Protection. For students enrolled in traditional graduate curricula, the certificate will provide evidence of additional specialized knowledge.

We developed foundational elements for asynchronous and synchronous distance education versions of a course on the impact of clothing on human heat stress. We recorded this course in the fall of 2016 as a first step in that process.

Finally, we have developed a survey instrument for assessing student knowledge of performance standards (Appendix II). We are using this survey to accumulate these data in on-going classes.

Discussion

Our specific achievements against stated objectives include:

Development of course content on standards and standardization

During this cooperative agreement, we developed the syllabi for two new graduate courses that focus on performance and protective textile technologies. The syllabus for a new course on "Protective Clothing and Equipment for Chemical and Biological Hazards" is included in Appendix III. This course provides instruction on risk assessments and the critical need to balance threat protection with physiological strain, system comfort and functional utility/ergonomics of the protective clothing and other gear. It instructs on the basic requirements for performance standards, understanding of how materials and systems are used, the reliability of measurements (accuracy and precision), and the need for test method validation. It provides information on chemical, biological radiological or nuclear hazards and on the basics of toxicology (dosage, physical state, toxicologically relevant end-points), routes of exposure (dermal, respiratory, ingestion) and core technical content for engineering solutions to reduce exposures and need for personal protective clothing and equipment for users in hazardous situations. It covers the processes for creating consensus standards for firefighter and emergency responder PPE followed

by the National Fire Protection (NFPA), with specific discussion of PPE Standards (NFPA 1991, 1992, 1994). It covers the concept of providing graduated levels of protection for users depending on the specific environment and threat. It cover basic principles of cost/benefit analysis for protection versus functionality and for protection versus thermal burden. Students will critically examine the strengths, weakness and gaps of both current methods and performance standards. These elements have also been introduced in on-going graduate level courses in Textile Engineering: TE 550 "Principles of Human Protection and Comfort" and TE 551 "Human Physiology for Clothing and Wearables".

We have developed a second course called "Thermal and Mechanical Protection Clothing and Equipment". This course provides an in-depth treatment of topics on protection against different thermal threats. It covers mechanical hazards, fibers and fabrics used for protection, materials tests and performance standards, and the costs and benefits of different materials and design approaches. Examples include hot work industrial garments, wildlands firefighting systems, electrical shock hazards, structural firefighting and proximity firefighting. In addition, gear for Technical Rescue (Urban Search and Rescue, extrication from vehicles, mechanical hazards and other industrial hazards are presented. Students will critically evaluate current test methods and performance standards. Standards discussed in the course include ASTM Standard test methods for thermal protection, physiological protection, and other relevant procedures as well as NFPA Standards on Firefighting (NFPA 1971, NFPA 1983, NFPA 1851, NFPA 1977) and Technical Rescue (NFPA 1951). Students will learn about the trade-offs between protection, operational tactics used for responding to incidents, and the gaps in current test methods and standards. Elements of this course have been introduces in TE550 and TE551, and in short courses for industry offered by the College of Textiles.

We have incorporated new course materials on standards into TE 331, the textile-testing course required for Textile Engineering majors. This course covers the basic requirements for testing and evaluating textile materials. The instruction stresses the applicability of the test for the intended purpose and the use of testing results to set performance criteria, measurements of reliability (precision and accuracy), and the need for test method. We are implementing surveys of student knowledge of standards into two undergraduate courses (Appendix II).

Development of new pedagogical procedures

We are teaching an appreciation for the use of standards as an integral part of the process of innovation in PPE technologies. To accomplish this learning objective, we have incorporated case studies, mostly taken from our research in PPE, that demonstrate the critical connection between performance standards and the development of useful protective clothing and gear. Examples from research projects that have resulted in the development of new test methods and contributed to help establish a technical basis for standard performance requirements illustrate the central role of standards in developing innovative PPE technologies.

We are utilizing multiple methodologies for instruction to introduce information on requirements for standardized tests, formation of performance criteria, and the basics of standardization processes. We have adopted methodologies designed to address the learning styles of auditory, visual and experiential learners. A variety of instructional approaches, including traditional lectures and group projects, are used to engage students in discussions and cooperative learning experiences. Students have the opportunity to observe laboratory testing procedures and to ask questions on methods, limitations and operational details.

We employ extensive reading and interpretation assignments that require students to interpret standards and put them to use for practical applications. Internet accessible recordings of testing procedures are available for current students. These new media will be a core element of distance education classes. Students will have the opportunity to participate in the analysis and interpretation of experimental results. We will provide data obtained from experiments shown in online videos to distance education students. Students will analyze the data and interpret testing results in the same manner as if they had conducted the experiments. In some cases, group projects will permit students to share their analysis of particular experiments so that they can develop holistic evaluations of clothing systems.

In another approach, student teams identify protection or performance-related applications for high performance textiles or PPE systems. In TE551, students assume roles such as designer, manufacturer, testing body, standards organization, user, purchaser, labor union, or manufacturer. They discuss how to use tests and standards to meet the needs of the chosen application, and how to arrive at consensus standards for the products. They discuss how to account for diverse stakeholder interests, and challenges that may arise in arriving at a consensus standard. Individual students identify an application for protective clothing and equipment. They identify key standards that apply to that application. They identify key tests and performance requirements. They write a paper to discuss their findings. This exercise requires that the students have an understanding of the minimum performance to meet certification requirements. They present the results to the class in a 10-15 minute talk that includes a discussion of the protection provided because of the performance standard, as well as any limitations that they have identified.

We are in the process of developing online versions of these courses with standards content. We recorded TE551in the fall semester of 2016. We are using recordings to create internet-suitable graphics and demonstrations. Project team members, the technology support group for the College of Textiles, and DELTA (North Carolina State University's Distance Education and Learning Technology Applications) have joined to enable a distance education version of that course as a model for standards education content. We have developed videos of important test procedures, such as the Kawabata Evaluation System test method, as part of this effort.

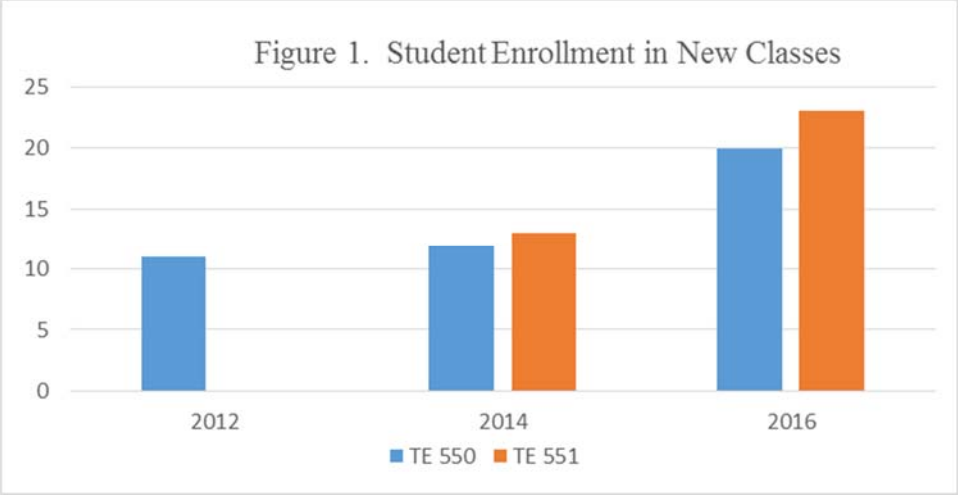
Definition of student needs and learning gaps

We have developed a survey instrument to assess undergraduate students' familiarity with testing

and performance standards (Appendix II). We have used the survey in TE331. We assess mastery of standards and standardization topics during this course through testing and through the evaluation of the group project on standards and certifications (Appendix I). The survey is also administered to student in TMS211 "Introduction to Fiber Science," to begin collecting data on the level of standards knowledge for students entering in the College of Textiles. We are analyzing the results. We will use these findings to facilitate incorporation of key standards concepts into future introductory courses.

Develop instruments to judge the effectiveness and sustainability of the new courses

Student enrollments in courses that incorporate standards instruction at the graduate level (TE550 and TE551) have doubled over the last four years, and enrollment had to be capped in 2016 (Figure 1). Based on this success, we will add standards topics to other courses taught in the College of Textiles. Many students are seeking to enroll in the new graduate courses. In addition, industry, government scientists and students at other institutions have expressed interest in enrolling through Distance Education options.



Increase awareness of Standards Education and Research Activities

One objective of this project was to expand knowledge of standards to the broader community. Faculty, graduate students and staff have presented on topics at conferences and meetings, and at NFPA project meetings.

We presented a progress reports on the Cooperative Agreement to the November 2014 and 2015 NIST Standards Education workshops. In addition, we published an article on *Integrating Standards into Courses on High Performance Garment Systems and Human Protection and Comfort at North Carolina State University [1]*. This article describes our experience

incorporating standards into our educational program. We discuss the value that this cooperative agreement has had in furthering the objective of standards education at the College of Textiles. We made a presentation on the topic of addressing important gaps in the current PPE standards at the Tenth ASTM Symposium on Performance of Protective Clothing in January 2016. In addition to the presentation on Gaps in Standards, T-PACC faculty and students presented a number of other papers related to standards and development of new test methods were presented at the January 2015 ASTM Symposium [2-6].

William Gabler, a PhD student in T-PACC, received the Second Place Award at ANSI "World Standards Day," for his paper *Building Community: Innovation through Consensus [6]*. This paper addressed the value of standards in advancing new technologies and identifying shortcomings in current technologies. William participated in the Standard Simulation Event for young professionals who are involved with standards.

We presented at numerous short courses that included standards and testing topics. These courses are offered by the NCSU College of Textiles and attended by industry, military and governmental professionals. Examples included discussions of dyeing and finishing test methods, performance and sports apparel, technical textiles (sport and performance apparel, military textiles, and PPE), and physical testing of textiles. Over the period of the Cooperative Agreement, we have delivered instruction on various aspects of standards to over 350 professionals.

Summary

This NIST Cooperative Agreement has been extremely valuable in developing course content and instructional approaches to increase the knowledge of standards for safety and performance textiles.

References:

1. Thompson, D. B., Barker, R., and DenHartog, E., "*Standards Engineering***,** v. 68, no. 1, January/February 2015, p. 1-6.
2. McQuerry, M., DenHartog, E., Barker, R., and Hummel, A., "Alternative Methodologies for Determining the Impact of Clothing Ventilation in Structural Turnout Suits," *Performance of Protective Clothing and Equipment: 10th Volume, Risk through Research and Testing*, STP 1953, Brian Shiels and Karen Lehtonen, eds., ASTM International, West Conshohocken, PA, 2016, pp. 313-330, doi:10.1520/STP159320160003.
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4. Ormond, R.B., "Considerations for Applying Man-in-Simulant Test Methodologies for the Evaluation of Fully Encapsulating Chemical Protective Ensembles," *Performance of Protective Clothing and Equipment: 10th Volume, Risk through Research and Testing*, STP 1953, Brian Shiels and Karen Lehtonen, eds., ASTM International, West Conshohocken, PA, 2016, pp. 212-232, ldoi:10.1520/STP159320160010.
5. Mekeel, C.J., and Gao, P. Development and Validation of an Alternative Chemical Permeation Test Cell," *Performance of Protective Clothing and Equipment: 10th Volume, Risk through Research and Testing*, STP 1953, Brian Shiels and Karen Lehtonen, eds., ASTM International, West Conshohocken, PA, 2016, pp. 250-271, doi:10.1520/STP159320160016.
6. Gabler, W. and Ormond, R. B., "Interlaboratory Variation for Permeation Test Standards and Considerations for Test Materials," *Performance of Protective Clothing and Equipment: 10th Volume, Risk through Research and Texting*, STP 1953, Brian Shiels and Karen Lehtonen, eds., ASTM International, West Conshohocken, PA, 2016, p. 272-284, doi:10.1520/STP159320160022.

Disclaimer:

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Appendix I: Model Assignment for TE 331

Student Assignment and Presentation Outline

TT331/EADH/20160330

Class Exercise

Standardization Committees and balancing conflicting interests

Standardization committee on safety and health of Oil Off-shore industry workers

Group Assignment TT331, Spring 2016

You will be assigned to one of the interest groups and prepare your point of view, by discussing with your fellow group students and thinking about it yourself. Prepare a set of questions for the expert that are specific to your interest group. You need to think for that specific viewpoint and be critical of the proposed method and how it might impact your interests (business, safety, complexity, …).

During the meeting we will exchange viewpoints, ask questions and discuss the issues that exist and see what the major issues are for the different groups. At the end each group will verbally present a brief statement on what they think about the proposed method, keeping all interests in mind. Then, as a group you will prepare a bulleted list of:

- Questions you still have with the proposed method

- Positive points about adding this method to the product standard – From your groups' perspective only ("Why do this"?)

- Negative points about adding this method to the product standard – From your groups' perspective only ("Why not do this" – objections)

This can be in a word document or a brief Powerpoint; make sure you state:

- Group – Stakeholder/interest group
- Name of the students
- Class TT331-Spring 2016 and date;

Background

In the off shore industry workers have to do their jobs at a wide range of climatic environments,

ranging from the Nordic/arctic seas, which can be extremely cold, to moderate regions, in which rain and chill temperatures are a main issues as well as very hot and humid conditions as in the Persian gulf (about the hottest place on earth) and the gulf of Mexico.

That might not be a huge issue but for the multiple other, additional hazards that these workers face during their work, to name some:

- Falling objects and bumping into objects (impact protection)

- Slipping and Falling of structures and heights (slip and fall protection)

- Chemicals being used in production sometimes, with chance of accidental exposure (skin protection)

- Oils, lubricants and similar substances used every day (skin protection)

- Electrostatic Discharge [ESD] (electric hazards and possible cause of fire)

- Fire and flames (fire and flame protection, limited)

- Sharp objects, on the structure or from tools (cut and puncture protection)

This committee has done quite a good job to set requirements for fabrics to be used for these workers, balancing the absolutely necessary protection with some comfort. Modern Flame Retardant (FR) fabrics are used that provide ESD protection as well as good liquid (water an oil) repellency to avoid skin contamination largely. Besides that good hygiene and cleaning instructions are given to the workers to keep them safe and healthy. At local spots (elbows, lower arms and knees some impact protection is given and they have to wear helmets.

Situation

So far no good requirements have been set to integrate a falling protection harness into the requirements for the clothing. Available commercial harnesses do protect but are very abrasive in combination with the clothing and cause skin damages and injuries (blisters, wounds, etc.). There is now a proposal in this committee to set requirements for harnesses. Safety aspects and construction have been well covered, but testing of ergonomics, comfort and prevention of skin injuries not yet. Professor Comfort from Peak University, NC, USA now has a proposal for evaluating these skin abrasive aspects. It involves an elaborate test method that uses a measurement probe, basic physical properties testing of the materials as well as a human evaluation to derive the combined performance of the clothing plus the harness. It also sets performance criteria for this. He has publications that support his work and that show that results are repeatable and the criteria prevent skin injuries in off shore workers.

The committee consists of different interest groups that have a history of fierce discussions, but coming to a consensus every time. The basic groups are:

- Off shore exploitation Industry: these are the actual employers of the workers and their interest is to make sure their work is profitable, but also have an obvious interest to reduce accidents and illnesses. They have to balance the cost of their operations, which includes everything related to their workers, with the money they receive from the oil industry, who is always trying to reduce prices;

- Oil industry: these are the customers for the off shore exploitation industry and have a very strong interest in health and safety of off shore industry as it strongly reflects on their image to society;

- Clothing industry: as the harnesses are worn over the clothing, the proposal is to sell these systems together and the requirements for that will impact what they can sell and what they need to test for. Thy will have to work with the harness manufacturers to comply with the requirements;

- Labor union of the workers: the workers are fairly organized and they have been able to push some requirements related to safety and health, which is obviously of their interest;

- Department of Labor: labor inspections are preformed regularly and their statistics do not show much of the problems that are discussed. Their statistics count mostly major accidents such that require hospitalization of workers (broken bones, severe head injuries, major burns and other very nasty things) and of course deaths;

- Test institutes: as the clothing-harness system needs to be certified to the committee standard the test institutes are present to ensure it will be possible to conduct the tests in a repeatable and reproducible way. They have standard labs for all standard tests that exist so far, but have very little experience doing human subject evaluations as they are much more variable in nature.

The Meeting

Professor Comfort of Peak University will briefly explain more on his evaluation method, but some extra information is listed below. The meeting will be divided into the different interest groups as they are described above. Make sure you prepare questions for Professor Comfort to make sure your groups' interests are well discussed and defended.

Assignment

You will be assigned to one of the interest groups and prepare your point of view, by discussing with your fellow group students and thinking about it yourself. Prepare a set of questions for the expert that are specific to your interest group. You need to think for that specific viewpoint and be

critical of the proposed method and how it might impact your interests (business, safety, complexity, …).

During the meeting we will exchange viewpoints, ask questions and discuss the issues that exist and see what the major issues are for the different groups. At the end each group will verbally present a brief statement on what they think about the proposed method, keeping all interests in mind. Then, as a group you will prepare a bulleted list of:

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This can be in a word document or a brief PowerPoint; make sure you state:
- Group – Stakeholder/interest group
- Name of the students
- Class TT331-Spring 2016 and date;
- Due Date of submitted document: Monday, April 25th, 2016, online, preferably as a pdf, 1 submission per group.

Test methods

The method that is developed combines materials physical properties test, with a new sensor and a final evaluation with a human panel. Each test has a specific minimal performance requirement. The system, the clothing plus the harness will be evaluated and would be certified together, one harness will be certified with one specific clothing type.

The physical properties tests are:

- Tensile strengths of the harness materials, standard ASTM method;

- Strength test of the opening/closure system of the harness, standard ASTM method;

- Abrasion test of harness materials separate, standard ASTM test method

- Abrasion of harness material on clothing, adapted ASTM test method

- UV degradation test of harness material, AATCC test method

- Degradation of harness materials by pollutants (oils, weather, basic chemicals), adapted AATCC test

The New Proposed Method

The new Human Evaluation method that Professor Comfort proposes is an extensive human evaluation trial with a set of 4 tribology sensors ("Artificial Finger Sensors") integrated into a measurement system between the harness and the clothing at 2 points and between the clothing and the skin at 2 points. At least 24 human subjects will be undergoing a human comfort evaluation for 4 hours wearing the equipment and being evaluated for comfort aspects as well as using the sensor data. Professor Comfort has proposed some movements that people could do and generates subjective data from questionnaires as well as objective data from physiology and the "artificial finger."

The execution of these experiments is such that with Professor Comfort's set up he can test 1 human subject per day. Therefore, the full execution takes 24 days with his proposal, plus preparation and data analysis time. In total before getting an end report it takes at least 2 months, often more than 3 months. Professor Comfort charges $25,000 per evaluation of clothing/harness system in his University Lab.

Assignment in class

You are member of 1 of the 6 stakeholders' groups that are present in the Standards Committee meeting. In preparation to the meeting you need to determine how this test proposal from Professor Comfort would impact the interests of the group that you are representing.

The questions you may ask Prof. Comfort are many, they may be directed towards collecting more information on the method itself as well as to the consequence of actually putting tis into a standard. Think widely about the consequences (economic, safety and health, selling of products, logistics, product innovation, …)

Below a list of generic questions, some of these may be applicable to your interest (stakeholder) group, some may not. You may also add very different questions, it is just meant as a starting point.

List of Possible Questions

- What problem does this solve?

- What is the cost of testing when I do more than 1 product?

- When exactly would I need to redo the testing (change to clothing, change to harness, both)?

- How would this impact safety and health of workers?

- Has this method been published?

- What is the reliability/variability?

- How many labs can execute these tests currently?

- What would be the cost of an official test lab to do these tests?

- What are the requirements for a lab to do these tests as part of certification?

- What are the qualifications for Prof. Comfort on this topic?

- Who would need to pay the cost of testing and certification for these products?

- How do the test method and the specifications connect with the work that the off shore workers need to do?

- How do we set the performance specifications?

- How much will approved products change injuries or sick leave of workers?

- Are the test results repeatable and reproducible?

- What is needed for a certified test lab to set up these tests (facilities, equipment, space, …)?

You will be graded as a group (group grade), there will be an individual reduction of your grade when you are not present in class during the group discussions, unless the absence was explicitly approved by the teacher via an email.

Appendix II: Questionnaire To Assess Student Knowledge of Standards

1. Why did standards arise? (For trade and business. *(Note: Basic ideas for suggested response in italics. To ensure that what was being traded was what was expected and was the right amount)*

2. How many standards can you identify in this room? *(Paint color, electronics, smart phones [batteries, communications, coding, information exchange….. fire and building codes, HVAC…)*

3. Why is it essential for manufacturers to have access to common standards and regulations? *(For systems to work together, everyone has to know what rules they must comply with. For example, standard voltages and frequencies must be known to make electrical devices work; and makers of computers, smart devices and applications must understand the frequencies, languages and electronic characteristics in order to make the devices work correctly. The mechanical properties of materials must meet the requirements for the intended application.……..).*

4. What is the difference between standards and regulations? *(Standards are agreed-upon by bodies with interests in a particular area; regulations are government rules established by agencies who implement laws).*

5. What is the international governing body for standards and standardization *(ISO).*

6. Who should be involved in creating standards? *(Users, manufacturers, subject matter experts, the pubic, government agencies, nations or groups of nations…. Represent all viewpoints; but participants should make known whose views they represent)*?

7. Do standards promote or reduce innovation? *(Both. Standards can be set to encourage better protection or performance; but changing factors can make them obsolete. Also, standards can prohibit entry of new technologies or be used to create unfair advantages. There is a need to continually review and update most standards; and the process must be open and fair).*

8. Why do OSHA rules require that employers conduct a risk assessment for all jobs? *(In order to keep workers safe, the employer must understand what risks accompany doing the job, and the employer is required to make workers safe when they perform their jobs).*

9. Is personal protective equipment the first response to workplace safety? *(No. The job must be designed so that it can be done with the minimum of risk. Next, engineering measures are used to reduce risk further, and then personal protective equipment is used if it is necessary).*

10. Name some characteristics of good test methods and performance standards?

---Designed with need or risk in mind
--Measures factors relevant to the performance characteristic desired
--Produces an output that can be clearly measured or defined
--Considers conditioning and environmental factors that could affect results
--Has a traceable reference standard for calibration
--Includes measure of reliability (precision and accuracy)
--For standards, establish performance criteria (minimum and maximum acceptable values)
--Certification of compliance verified through independent testing
--Ideally, performance criteria should be evaluated through field testing

Appendix III: Syllabus for Protective Clothing and Equipment for Chemical and Biological Hazards

Professor: Dr. R. Bryan Ormond
Office: 3314
E-mail: rbormond@ncsu.edu
Phone: 919-524-1569
Office Hours: By Appointment

Course Overview:
There are many different types of personal protective equipment (PPE) that may be required in response to a chemical, biological, radiological, or nuclear (CBRN) hazard. Each end-user application requires specific PPE that meets the needs and requirements for that particular hazard or scenario. This course will provide a comprehensive introduction to CBRN hazards and routes of exposure from a basic toxicological perspective. Additionally, the different types of respiratory and dermal protective equipment will be discussed in relation to their intended applications, design and protective requirements, physiological and psychological implications to the wearer, and the materials in which they are constructed. The course will also provide a thorough discussion of standard test methodologies used to evaluate different properties of CBRN PPE on the material, component, and whole ensemble levels.

Learning Objectives:
By the end of this course, students should be able to:
- Explain the basics of a variety of CBRN hazards and identify their routes of exposure
- Demonstrate a fundamental knowledge of toxicological principles including exposure dosages, toxicologically relevant end-points, dermal adsorption, and basic risk analysis
- Explain the applications and limitations for different types of respiratory protection and total body/dermal protection (including gloves and footwear)
- Explain on a fundamental level, the physiological and psychological effects on the wearer caused by use of CBRN PPE
- Determine which types of protective equipment can be used in different scenarios and explain the design and protective requirements for that equipment
- Explain the standard test methods used to evaluated different aspects of CBRN PPE including material-level tests for chemical permeation resistance, liquid penetration resistance, and whole ensemble tests such as the Man-In-Simulant-Test and the liquid-tight integrity test
- Demonstrate an understanding of how to identify weaknesses in standard test methods and how they can be addressed through professional standards committees

Course Organization and Scope:

1. Introduction to CBRN Protective Equipment
2. Historical Background on CBRN Development
3. Toxicological Principles and Routes of Exposure
4. Overview of Respiratory and Total Body Protection
5. Component/Ensemble Design for Appropriate Scenario
6. Physiological/Psychological Burden Caused by CBRN PPE
7. Setting Performance Criteria and Requirements
8. Fundamentals of Analytical Chemistry and Quality Assurance
9. Performance Evaluation and Standard Test Methods
10. Decontamination and Reuse

Suggested Texts And Reading Assignments:

1. Personal Protective Equipment for Chemical, Biological, and Radiological Hazards: Design, Evaluation, and Selection by Eva F. Gudgin Dickson
2. Chemical Protective Clothing 2nd Edition edited by Daniel H. Anna
3. National Fire Protection Association: Standards on Chemical Protective Clothing: History, Evolution, and Current Criteria

Reading assignments are to be assigned to coordinate with material covered in class. Learning objectives will be distributed to focus study and provide review for tests.

Calculation Of Course Grade:

- Exams (2) = 40%
- Course Assignments = 15%
- Final Examination = 30%
- Course Project/Presentation = 15%

The grading scale will be A, B, C, D and F. As required by the University, plus/minus grading will be used. The following +/- grading scheme will be employed:

97% = A+	87% = B+	77% = C+	67% = D+	< 60% = F
94% = A	84% = B	74% = C	64% = D	
90% = A-	80% = B-	70% = C-	60% = D-	

Missed Tests/Assignments:

If you miss a test, assignment or project deadline for a valid reason, you may take a makeup test at a designated time near the end of the semester, or make up the assignment. Excused absences require a typed memo or official notification delivered to the instructor stating the reason for the absence and a contact for verification. If you miss any test, assignment, project or the final exam without a valid excuse, a zero will be averaged into your grade. See below for notification of University policy on approved absences.

Policy on Grade Changes Or Issues With Grading:
Any student that has an issue with the grading of an assignment (homework, exam, or other) will have TWO WEEKS FROM THE DAY THE ASSIGNMENT WAS RETURNED to bring the issue to the instructor's attention.

Course Locker Information:
All class documents and PowerPoint slides will be available to TC 589 students in the course locker that can be found at https://wolfware.ncsu.edu/login/.

Attendance:
There is usually a correlation between good class participation and good course performance. Students are encouraged to attend all class sessions and attendance will be taken. If a student anticipates missing a class due to an excused or accepted reason, it is the student's responsibility to discuss the absence and any missed work as soon as possible with the instructor.
The University policy on excused absences can be found at:
http://www.ncsu.edu/policies/academic_affairs/courses_undergrad/REG02.20.3.php.

Incomplete Grade:
An IN grade will be assigned only in cases where make-up of the incomplete work is justified by an acceptable (to the instructor) excuse based on university policies (http://policies.ncsu.edu/regulation/reg-02-50-03).

Academic Dishonesty:
Students are responsible for their behavior in accordance with the Code of Student Conduct (Appendix L of Handbook for Advising and Teaching (http://policies.ncsu.edu/policy/pol-11-35-01). You should refer to the Code of Student Conduct for definitions of cheating. In this course, I expect that you will talk to each other about course material, including assignments, but when it comes to writing, including homework, it is expected that each student will write completely independently. This means that you cannot agree on what was said, construct a common statement and then both students use the same statement in an assignment. Any sign of essentially the same words being used in two or more sets of papers will constitute an academic violation. There will be no questions asked, other than do you wish to sign the Academic Integrity Form before it is submitted to the Office of Student Conduct. You obviously, cannot use words from someone else without quoting them and giving credit to them for those words. The first instance of academic dishonesty, **including plagiarism**, will result in a zero on the homework/exam AND submission of the proper paperwork to the Office of Student Conduct. A repeat offense will result in an F in the course. Your signature on any assignment, lab report, or exam indicates you are abiding by the Honor Pledge and that the work being submitted is entirely yours. To be certain that you understand the policies Academic Integrity policies of this course, you will be asked to sign a form stating that you understand them and the consequences that will ensue from any academic integrity violation.

NC State Policy on Working With Students With Disabilities:
Reasonable accommodations will be made for students with verifiable disabilities. In order to take advantage of available accommodations, student must register with the Disability Services Office (http://www.ncsu.edu/dso) located at 1900 Student Health Center, Campus Box 7509, 515-7653. For more information on NC State's policy on working with students with disabilities, please see the Academic Accommodations for Students with Disabilities Regulation at http://policies.ncsu.edu/regulation/reg-02-20-01.

Discrimination:
NC State University provides equality of opportunity in education and employment for all students and employees. Accordingly, NC State affirms its commitment to maintain a work environment for all employees and an academic environment for all students that is free from all forms of discrimination. Discrimination based on race, color, religion, creed, sex, national origin, age, disability, veteran status, or sexual orientation is a violation of state and federal law and/or NC State University policy and will not be tolerated. harassment of any person (either in the form of quid pro quo or creation of a hostile environment) based on race, color, religion, creed, sex, national origin, age, disability, veteran status, or sexual orientation also is in violation of state and federal law and/or NC State University policy and will not be tolerated. Retaliation against any person who complains about discrimination is also strictly prohibited. NC State's policies and regulations covering discrimination, harassment, and retaliation may be accessed at http://policies.ncsu.edu/policy/pol-04-25-05 or http://oied.ncsu.edu/oied/. Any person who feels that he or she has been the subject of prohibited discrimination, harassment, or retaliation should contact the Office for Equal Opportunity (OEO) at 515-3148.

Appendix IV: Syllabus for TE 589 - Thermal and Mechanical Protection Clothing and Equipment

Professor: Dr. Emiel DenHartog
Office: 3351
E-mail: eadenhar@ncsu.edu
Phone: 919-622-8985
Office Hours: By Appointment

Course Overview:
This course will describe the structures, materials, technologies, and testing that goes into the development of Personal Protective Equipment (PPE) used for thermal protection and mechanical protection. The topics to be covered in this course will be:

- **Thermal Threats and Hazards:** personnel who are required to wear fire resistant (FR) PPE can be exposed to a wide variety of thermal threats. Understanding these threats and how heat is transferred to the human body from fire, flames, and other heat sources is critical to understanding how to create/equip the proper level of protection for the wearer. This will include an overview of modes of heat and mass transfer through different media, including fabrics and the human skin.
- **Mechanical/Ballistic Threats and Hazards:** these hazards include cut, stab, puncture, impact, ballistic, and any other forces that could cause injury to the body. These threats vary in intensity and severity, but understanding the impact physics and mechanics associated with these different scenarios will help create/equip proper PPE for personnel.
- **Fibers and Fabrics:** the composition of the fibers (both inherently FR and for mechanical protection), formation of the fabrics, applied coatings/finishes and the material properties that make each of these unique and/or useful for these PPE applications
- **Textile Testing and Performance Standards:** the test methods currently used to analyze the protective properties of thermal and mechanical PPE, the theory behind their operation, and their importance to the performance standards, certification requirements, and overall clothing design.

Learning Objectives
By the end of this course, students should be able to:

- Estimate the level of protection needed based on the potential threats/hazards to first responders and other personnel at risk of thermal or mechanical injury.
- Design or Compose PPE ensembles that will provide personnel with appropriate levels of protection without overburdening them to heat stress related injuries or fatigue.
- Identify the appropriate test methods, standards, and certifying bodies needed in the design/equipping of personnel for thermal and mechanical protection.

Course Organization and Scope:

	Topic
1	Introduction to the Course
2	Thermal Threats and Hazards: Heat Transfer Fundamentals, Conduction, Convection, Radiation, Combustion, and other Fire Science.
3	FR Fibers, Fabrics, Garments and their Formation
4	FR Clothing Testing, Standards, and Certification
5	Mechanical Threats and Hazards: Mechanics, Dynamics, Impact Physics, Ballistics, and Fiber/Fabric Forces
6	Mechanical Protection Fibers, Fabrics, Garments and their Formation
7	Mechanical PPE Testing, Standards, and Certification

Reading Assignments
Reading assignments are to be assigned to coordinate with material covered in class. Learning objectives will be distributed to focus study and provide review for tests.

Calculation of Course Grade

- Exams (2) = 50%
- Final Examination = 35%
- Course Project = 15%

Score	**Grade**	**Score**	**Grade**
≥ 97	A+	76.9 - 73	C
96.9 - 93	A	72.9 - 70	C-
92.9 - 90	A-	69.9 – 67	D+
89.9 - 87	B+	66.9 - 63	D
86.9 - 83	B	62.9 - 60	D-
82.9 - 80	B-	< 60	F
79.9 - 77	C+		

Incomplete Grades, Absences, Late Assignments:
Class attendance will be required in lectures and excessive absences may affect final grade. No late assignments will be accepted and no make-up tests will be given. If, due to an emergency, you are unable to attend a test or cannot turn in an assignment, please contact me **immediately**.

Academic Integrity
Students are to comply with the NCSU Code of Student Conduct Policy (NCSU POL 11.35.1). Plagiarism and cheating are not permitted and can result in penalties up to **failure** in the course.

Electronic Course Components:
Students may be required to disclose personally identifiable information to other students in the course, via electronic tools like email or web-postings, where relevant to the course. Examples include online discussions of class topics, and posting of student coursework. All students are expected to respect the privacy of each other by not sharing or using such information outside the course.

Students With Disabilities:
Reasonable accommodations will be made for students with verifiable disabilities. In order to take advantage of available accommodations, students must register with Disability Services for Students at 1900 Student Health Center, Campus Box 7509, 919-515-7653. For more information on NC State's policy on working with students with disabilities, please see the **Academic Accommodations for Students with Disabilities Regulation (REG02.20.01).**

N.C. State Polices, Regulations, and Rules (PRR):
Students are responsible for reviewing the NC State University PRR's located at **http://oucc.ncsu.edu/course-rights-and-responsibilities** which pertains to their course rights and responsibilities.

***No additional charges are to be assessed beyond those charged by NCSU.**