A STUDY ON

FIREFIGHTERS' PROTECTIVE CLOTHING

SUPRIYO CHAKRABORTY

DEPARTMENT OF TEXTILE TECHNOLOGY

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A STUDY ON

FIREFIGHTERS' PROTECTIVE CLOTHING

by

SUPRIYO CHAKRABORTY

Department of Textile Technology

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CERTIFICATE

This is to certify that the thesis titled **"A study on firefighter's protective clothing"**, being submitted by **Mr. Supriyo Chakraborty** to the **Indian Institute of Technology Delhi**, for the award of the degree of **Doctor of Philosophy**, is a record of bonafide research work carried out by him. He has worked under my guidance and supervision and fulfilled the requirements for the submission of the thesis, which has attained the standard required for a Ph.D. degree of this institute.

The results contained in this thesis have not been submitted, in part or in full, to any other University or Institute for the award of any degree or diploma.

Dr. V. K Kothari

Emeritus Professor
Department of Textile Technology,
Indian Institute of Technology, Delhi,
New Delhi - 110016,
India

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ABSTRACT

Firefighters are exposed to various levels of radiant heat and flame hazards. Inspite of introduction of different heat resistant fibres and clothing, firefighters receive severe burn injuries. Hence heat protective performance of firefighters' protective clothing is always a critical issue as the life of the person involved is in question. Many studies had been carried to understand and characterise firefighters' and other protective clothing exposed to similar hazards. Various evaluation methodologies have been developed to estimate protective clothing assemblies, designed for protecting the person from a specific sort of hazard. A firefighters' protective clothing usually consists of three clothing layers, typically an outer shell, a thermal liner, and an inner layer. Characteristics of the constituent fibres, constructional features of clothing layers, properties of the yarns used greatly influence heat protective performance.

Radiant heat of various intensities is the main category of thermal hazard faced by a firefighter. The focus of the thesis is to develop an understanding of various physical, dimensional, thermal and optical properties of protective clothing assemblies that affect protection from radiant heat. An instrument for evaluating heat protective performance of clothing assemblies against radiant heat has been developed, based on principles given in ASTM standards. Various commercial woven fabrics made of heat resistant fibres, needle punched nonwoven thermal liners has been used to prepare multilayered assemblies and investigated for radiant heat protection. Heat protective performance of such clothing assemblies has been analysed using statistical techniques and explained from fundamental fabric properties. All the components of a multilayered clothing assembly significantly influence protection. Areal density, air permeability and porosity, optical properties, fibre fineness, bulk density of clothing

layers has been found to be critical. Effect of various constructional properties of clothing assemblies on radiant heat protection has been investigated using woven clothes of varying cover and nonwoven fabrics of different compactness. Empirical relationship for estimated protection time with constructional parameters and heat fluxes was obtained. It was observed that constructional parameter of outer layer cloth most significantly affects protection. Thickness of thermal liners appeared to be another crucial parameter. Protection time has been found to vary nonlinearly with incident heat flux. Effect of preconditioning of protective clothing in different atmospheric conditions, and effect of added water on outer shell in presence and absence of a barrier has been investigated. Moisture in clothing layers and its quantity found to significantly affecting thermal response. Use of a barrier layer was found to be advantageous.

Mathematical modelling can be useful in predicting thermal behaviour of firefighters' clothing assemblies exposed to radiant heat fluxes. A conduction-radiation heat transfer model for firefighters' protective clothing, subjected to high intensity thermal irradiations, has been developed. Experimentally measured physical, thermal and optical properties of multilayered clothing assemblies has been used in the model. Specific heat capacity and thermal conductivity of clothing layers has been considered as function of temperature. Predicted thermal response has been obtained for various incident heat fluxes and clothing assemblies. Predicted thermal behaviour obtained from the numerical solution of the model has been found to be close to the experimentally obtained response. Role of different clothing properties on protection time has been studied from the numerical solution of the model equations. It revealed that fabric reflectance and thickness are the most crucial parameters. Thermal conductivity of fabric and presence of moisture in clothing layers are also found to affect protection significantly. Effect of air gap between fabric layers has also been studied using the model. Protection time has been found to increase linearly with increasing air gap between fabric layers, both experimentally and from the model.

A new insulating material, namely aerogel-nonwoven composite structures has been studied and their effectiveness in heat protective clothing has been evaluated. Aerogel-nonwoven composites were produced in Laboratory, from two different precursors, using suitable methods of preparation. Aerogel-nonwoven insulation fabric has been found to offer more than 100% protection against radiant heat compared to normal Nomex nonwoven insulations. Higher levels of protection has been achieved at the cost of small increase in fabric areal density.

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