The effects of environmental stresses simulating those encountered by downed air crew wearing anti-exposure garments were evaluated. Test conditions were: water temperature = 7.2°C; air temperature = 0.0°C; and an air velocity of 7.8 M/S litres per second. All testing was performed in calm water. Fourteen subjects aged 21 to 40 were studied in eight configurations for maximum 120 minute exposures. The eight configurations consisted of intact and damaged polytetraflurethylene (PTFE) anti-exposure suits worn with various combinations of cotton/polypropylene and olefin liners. Parameters used to assess physiological effects were: duration (DUR), rectal temperature (Tsk), body temperature (Tbd), heart rate (HR), total body heat loss (S), and subjective comfort.

Mean duration of all configurations were greater than 109 minutes, with no significant differences observed. Signficant differences were observed among configurations for the Tsk, Tbd, HR, and S, values being most extreme when a two inch tear was present in the PTFE suits were with a wet cotton/polypropylene liner.

When intact, the vapour permeable PTFE anti-exposure suits appears to provide effective protection during cold water immersion, independent of underlying insulative garments. Since leakage reduced the protection provided by the suits, further study of its impact on protection appears just fine.

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43 Physiological tests and evaluation models for the optimization of the performance of protective clothing

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Clothing in general, but protective clothing in particular, must possess a biophysical function. Thermal insulation and moisture permeability have to be adapted to specific climatic and activity conditions in order to give thermal comfort to the wearer. For the manufacturer of protective clothing it is essential to evaluate the physiological characteristics of his products. Because for the textile and garment industry today time-consuming and expensive wear trials are no longer a suitable means for testing, a system of laboratory measurements has been developed, by which specific quantities of textiles and garments can be determined, which directly show their physiological performance.

In this system with a thermoregulatory model of human skin (Skin Model), simulating heat and moisture exchange from the skin, the thermal insulation as well as the moisture permeability of fabrics are measured. These quantities are not only determined under stationary ("normal") wear conditions but also under transient situations, characterized by sweat pulses resulting from strenuous body activity. Thus, a complete set of specific fabric quantities can be measured, which are inserted in predictive formulae, yielding the physiological comfort of fabrics.

However, the wear properties of a clothing ensemble consisting of several garments are not only determined by the fabrics but also by the interspaced air layers' contribution to thermal regulation. Thus, for the evaluation of total clothing ensembles a life-sized movable manikin has been developed. With this manikin the thermal insulation and moisture transport of garments, as they become effective for the wearer, can be measured. Because the manikin can perform body movements, ventilation effects in the microclimate between the garments and their influence on thermal comfort can be evaluated. Thus, the effects of garment patterns on thermoregulation can be made visible.

With the manikin again a set of physiological quantities, now specific for the total clothing system, is resulting, which inserted in a predictive model shows the system's range of utility. This range is limited on the one hand by a minimum ambient temperature, where the wearer performing a certain kind of activity is just not suffering from hypothermia. With this minimum temperature wind-chill effects are also considered. On the other hand, the range of utility is limited by a maximum ambient temperature and air humidity, where hyperthermia is just prevented.

Furthermore, the model can predict thermal comfort of garments under all possible climate and activity conditions. In particular, tolerance times, for which clothing near its very limit of utility can protect its wearer from health damage, can be determined. Thus, this laboratory evaluation of garments has proceeded into a region which could never be covered by wear trials with human subjects.

Due to the broad physiological basis on which this evaluation model has been developed, its predictions are highly consistent with the wear performance of the clothing experienced in actual use by persons. For an example this is demonstrated by a cold-weather protective suit, designed to possess an outstandingly broad range of utility.

Thus, for the manufacturer the physiological apparati and measurements described represent a reliable means to optimize the functionality of his products. They really should be used during the development and design of protective clothing.

44 Measurement and estimation of Indoor clothing insulation

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Standards and handbooks have been developed by organizations such as the American Society of Heating, Refrigerating, and Air-Conditioning Engineers and the International Standardization Organization which specify the environmental conditions that are thermally acceptable to most people at different levels of clothing insulation and metabolic activity. For example, ISO 7730, ASHRAE 55-1981, and Chapter 8 of ASHRAE Handbook - 1981 Fundamentals are documents concerning the thermal comfort of people in indoor environments.

It is necessary for users of these documents to determine what types of clothing provide different amounts of insulation. In addition, researchers who study man/environment systems often need to control or vary clothing insulation levels experimentally. The purpose of this study was: (1) to expand the current data base of insulation (clo) values for garments and clothing ensembles commonly worn in indoor environments, and (2) to develop and compare different methods for estimating clothing insulation.

The clo values of 115 different garments and 60 representative ensembles were measured using a standing, electrically-heated manikin in a climate-controlled chamber. Regression analysis was used to relate a number of variables to garments and ensemble insulation. A new computer model which calculates local and total body heat loss (or clothing insulation) was also developed. The model divides the body into 12 main segments which may be further divided into subsegments so that each one represents a uniformly clothed area of the body surface.

Results indicated that garment insulation values can be predicted with accuracy from fabric thickness and the amount of body surface area covered by the garment. Together, ensemble weight (without shoes) and the amount of body surface area covered by different numbers of fabric layers are fairly good predictors of ensemble insulation. Summation formulas which estimate ensemble insulation from the sum of the clo values of the component garments give relatively accurate predictions of ensemble clo values -- when the garment clo values are measured on a manikin or predicted with accuracy (this does not include estimating garment clo values from a prepared list).

The relative accuracy of the predictive equations and model was determined by calculating the standard deviation of error between measured and predicted insulation values. Standard deviations ranged from 0.06 to 0.20 clo for equations used to estimate garment insulation and from 0.09 to 0.22 clo for predicting ensemble insulation. The computer model provided the most accurate prediction of clothing insulation ($\bar{S} = 0.09$).