QUALIFICATION OF FIRE FIGHTERS' PROTECTIVE CLOTHING

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INTRODUCTION

In 1981 the Directorate Fire-Brigade, the Netherlands Ministry of Internal Affairs started a program to increase the general quality of the turn-out gear on the market. TNO was requested to support this program scientificly. The strategy was to do comparative operational tests with various types of clothing and to optimize the best clothing, putting it forward as a reference, to be beaten by the competition. The brigades were recommended to buy only clothing that would match the reference garment. The brigades were provided with the test reports. In a short time the reference garment became market leader and recently alternatives were submitted for testing. These appeared to be of comparable quality, proving the success of the project.

In their concept specifications of turn-out gear the Directorate demands qualities beyond the pre-European Standard (prEN 469). There were already requirements for the protective aspects of fabrics against heat and flames (1, 2, 3) and water-tightness (4, 5) of protective clothes, but these requirements do not take account of the design of the clothing. That is why a test-battery has been developed to get results of the clothed man instead of material-studies (6, 7) or manikin-studies (8). The test-battery using clothed subjects is a means to arrive at standards for the clothed man. It includes both ergonomical (9) and protective aspects (10).

In this paper the tests, typical results, and their potential to classify clothing are presented.

METHODS

The present test-battery is the result of a series of experiments with equipped fire fighters that started in 1981 (11). It consists of four parts: physiological strain test, heat-protection test, ergonomical experiments and water-tightness test.

The physiological strain test consisted of a 20 min.'s walk around propane heaters (radiation intensity 7 $kW{\cdot}m^{-2}$) in a room with an air-temperature of 60°C. The fire-fighters walked alternately clockwise and anti-clockwise around the heaters. V_{O_2}, T_{skin}, T_{core}, mass of subject and mass of clothing have been measured. From the measurements the heat balance has been calculated (Metab = W_{ext} + Sto + Dry + Evap + Resp) and the physiological strain of the subjects has been determined.

The heat-protection test was carried out in the same facility as the physiological strain test, but at an air-temperature of 120°C. The subjects walked up and down a step-bench in front of a heater till they had to leave the room, because of locally high skin temperatures. This test was done with dry and wet underwear, both for the front and the back of the subjects. Skin and clothing surface temperatures and tolerance times have been measured.

In the ergonomical test speed and coordination of the clothed fire fighter are measured. The times needed for dressing, for a 50 meter dash, for a coordination test and for a dedicated obstacle course have been measured. Loss of performance with regard to the reference-garment has been calculated by:

$$LP = \frac{\text{score - reference}}{\text{score}} * 100\ (\%)$$

The water-tightness test consisted of a 20 min. conditioned rainfall (0.33 $l{\cdot}min^{-1}{\cdot}m^{-2}$). In the rain the fire-fighters were carrying out some light tasks, which included walking, climbing and crawling. The amount of water absorbed into outer layers (water uptake) and the time to leakage have been measured.

The tests were carried out by 8 subjects, wearing 7 different garments following a Latin-square design. After each experiment questionnaires have been filled out to get an impression of the mobility, ease of use, comfort and thermal sensations.

RESULTS

In the physiological strain test the average body heat storage at the end of the exposure was 7.2 $J{\cdot}g^{-1}$ body weight. The limit of heat storage of 8 Jg^{-1} body mass (12) has been used to calculate the maximal work time. The maximal work time of the present garments varied from 21 to 30 min. with a mean of 25 min. Temperature and wetness sensations agreed with the level of measured physiological strain.

During the heat-protection test the highest skin temperatures were measured on the shoulders and thighs, because of the small air gap on the shoulders and the thinner material of the trousers. The rate of rise in skin temperature was about .06 to .12 $°Cs^{-1}$. Initial skin temperatures of 33°C and a safety-limit of 42°C lead to withdrawal times of 75s to 150s. With wet underwear tolerance times were longer than with dry underwear, as found earlier (9, 14). The results of the questionnaires supported the temperature measurements and the withdrawal times.

The ergonomic experiments showed no loss of performance compared to the reference garment, but all turn-out garments gave a loss of performance of about 5% to 10% compared to sports wear. Proper sizing of the clothing, in particular for overalls is critical. Similar sizing of all brands of clothing is a feature of practical importance, since heat protection depends on a good fit. Garments of flexible fabrics and a good fit were preferred. Since the development of a neck protecting cloth, mounted to the helmet, compatibility problems are few.

The garments had widely different water uptake and some difference in leakage, but water uptake was unrelated to leakage. The questionnaires showed that wet garments allow reduced freedom of movement.

The results allow classification of the garments according to the specific tasks they are meant for, such as assaults to search for victims, assistance in open air, forest fires, work at chemical plants, etc. Although all garments met the desired level of protection on all aspects, they excelled in specific aspects and will accordingly be advertised to the fire brigades. This will be supported by a classification mark in the clothing.

CONCLUSION

The present standards for fabrics of protective clothing have been extended with tests on made-up garments. The test battery has proven to be useful for the qualification and classification of turn-out gear and will effectively lead to a local standard. The Dutch project to push the market towards better products was successful. In the future fire-fighters' protective clothing will be labelled for its suitability for specific tasks.

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