PERSONAL PROTECTIVE EQUIPMENT FOR FIREFIGHTERS:
COMPLETE SUIT TEST IN HAZARDOUS CONDITIONS

Key words: Personal Protective Equipment, fire fighting, hazardous conditions

1 SCOPE

This is a test method for testing the combined performance of a complete assembly of Personal Protective Equipment (PPE), worn by a test person.

2 FIELD OF APPLICATION

The purpose of this test method is to offer a test of the combined performance of a complete assembly of Personal Protective Equipment (PPE) [1], worn by a test person under exposure to reproducible hazardous conditions consisting of high air temperature and radiant heat, as encountered by a fire fighter [2, 3], see ANNEX A.

The intention of this standard is not to replace the relevant standards for testing various parts of the PPE. All parts of PPE used in this test should fulfill the applicable parts of the relevant EN-standards [5–13].

This standard does not cover the testing of special clothing for use in high risk situations e.g. fire entry suits or protection against other hazards, e.g. chemical, biological, radiological and electrical hazards.

3 REFERENCES


4 NORMATIVE REFERENCES


5 DEFINITIONS

5.1 Personal protective equipment (PPE)
All the equipment described in normative references, to be used during heat exposure.

5.2 Test person
The person wearing the PPE during test.

5.3 Test leader
The person in charge of test procedure and safety precautions.

5.4 Test
The time period from conditioning of PPE until the test person starts to take the PPE off after heat exposure.

5.5 Heat exposure
The time period during which the test person is inside the heated test room.
6 TEST PERFORMANCE SUMMARY

The exposure is performed under hazardous conditions in a heated test room. The temperature in the room and under the PPE is monitored while the test person is following a scheme of different body positions during a 5 minute period. The performance is evaluated from the temperature measurements and the observations is made by the test person.

7 TEST FACILITY

7.1 Test room

The test room shall have a length of 6.5 ± 0.2 m, a height of 2.3 ± 0.1 m and a width of 2.25 ± 0.15 m. It can be an ordinary 40 foot container divided into three sections. For construction details, see ANNEX B.

Means shall be provided so that the test person has the head at the right height, based on the height of a person 1.75 m tall. One way of doing this is to hang a chain from the ceiling.

7.2 Test Conditions

7.2.1 Air temperature

During the test the air temperature at the level of 1.2 m above the floor shall be 250 ± 10°C. The average temperature during the test should be 250 ± 5°C.

During the test the air temperature at the level of 2.2 m above the floor shall be 320 ± 20°C. The average temperature during the test should be 320 ± 10°C.

7.2.2 Heat flux

During the test the heat flux at the level of 1.2 m above the floor shall be 5.0 ± 1 kW/m². The average heat flux during the test should be 5.0 ± 1 kW/m².

7.3 Heat Sources

The test room should be heated by 2 gas burners at different locations. The construction of the burners is described in ANNEX B.

8 INSTRUMENTATION AND CALIBRATION

8.1 Measuring requirements

Registration shall be made every 5th second according to the following specifications.

8.2 Sensors

- Air temperature at 2.2 m and 1.2 m height above the floor. The measuring points should be placed 12 cm from the wall, see ANNEX B. An informative measurement of the air temperature also at 0.5 m height above the floor is recommended.

- Thermocouples should be of type K, of quality class 2 according to IEC 584-2 with a nominal lead diameter of 0.81 mm. The lead ends shall be welded together. The measuring step shall be no less than 1 °C. The thermocouples should be changed at least every year.

- The heat flux sensor at 1.2 m height above the floor measuring the upper half spherical, see ANNEX B. Accuracy of measurement ±0.1 kW/m² measuring step 0.1 kW/m².

- The heat flux meter shall be of the Schmidt-Boelter type with a suitable metering range, e.g. 0–20 kW/m². The heat flux meter shall be calibrated by a certified laboratory or testing house before installation and thereafter at least once a year.

- Temperature next to the skin with standardised skin sensors, see ANNEX C.

8.3 Positioning of skin sensors

- One on the outer side of each arm. The sensors should be positioned where the extra insulation ends.

- One on each calf.

- One at the back of each thigh.

Other positions may be relevant depending on the situation, e.g. between outer and inner garment or between glove and garment.

9 ACCEPTANCE CRITERIA TO FULFIL THE TEST

9.1 The test person shall not feel pain during the test.

9.2 After the test the PPE shall be inspected in the same way as after any fire fighting operation by a firebrigade, as specified in the manufacturer's care and maintenance advices. Any deviations should be recorded.

9.3 The temperature measured by the skin sensors (arms) may not exceed 47 °C, either when the test person is in the test room or after he/she leaves the test room [4].

10 PREPARATION BEFORE TEST

10.1 Test person

Users of this method should observe the following warning:

SAFETY WARNING – To all concerned in the test. The safety of the test person must be specially considered and suitable precautions should accordingly, be taken to prevent injury.
The test person shall be in good health, and qualified according to national requirements for training or working with a breathing apparatus.

The test person should be instructed to terminate the test if pain is experienced or if the test person is feeling uncomfortable for any other reason. It is recommended that the test person should drink half a litre of water before the test.

10.2 Personal Protective Equipment (PPE)

Only PPE which has satisfied the minimum requirements in the normative references [5–13] should be used in the test. The PPE should be conditioned at 20 ± 5°C for 24 hours before the test. The PPE should also be clean and dry.

10.3 Test leader

The test leader has to check that:

- all parts of the PPE fulfill the relevant standards, and that essential parts and functions of the PPE on the test person are in proper condition before the test, and that the PPE is of a suitable size for the test person,
- the test person is aware of the procedure during the test, ANNEX D and that the signalling system is fully understood,
- the burner gas system, the ignition source and the burners are in proper condition, to avoid any risk of explosion,
- waterspray is available for immediate emergency cooling,
- a trained firefighter, fully equipped with breathing apparatus and PPE is in position for emergency rescue,
- the measurement system is in functional order, and
- test conditions, such as temperature and heat flux, are steady at the proper levels.

11 TEST PROCEDURE

11.1 Safety

The test leader is in charge of safety and shall at all times observe both the test person and the temperature measurements. The test leader shall be able to instruct the test person to leave the test room by use of a signalling system or a loudspeaker.

The test leader shall also be in immediate contact with the fully equipped firefighter outside the test facility. In this way, the test leader can decide to interrupt the test or give an order for a quick rescue operation.

A heart rate sensor can be used for safety reasons.

11.2 Test procedure

The skin sensors shall be attached next to the skin of the test person.

When the test conditions are within the ranges of Section 7.2, the test person can put on the conditioned PPE.

When the test leader is convinced that the test person is properly dressed and that the requirements of Chapter 10 are fulfilled, the test person can enter the test room for exposure. The start time shall be recorded.

The test person follows the procedure in ANNEX D during exposure by observing the signal lamps.

After the end of exposure, the test person leaves the test room. The end time shall be recorded.

The test person shall stay in the start room wearing the PPE and temperature measurements shall continue until the skin temperature starts to decrease. The time when the temperature starts to decrease shall be recorded.

12 TEST REPORT

The test report should contain the following information.

a) Name and address of the testing facility.
b) Date and identification number of the report.
c) Name and address of the client.
d) Date of test.
e) Purpose of the test.
f) Name of the manufacturer or supplier of the products.
g) Name or other identification marks and description of the product. It is recommended to also include the weight per square metre and thickness of the outer and inner garment.
h) Method of sampling.
i) Date of supply of the product(s).
j) Date when the PPE was certified.
k) Conditioning of the PPE products.
l) Status, e.g. age, wear, cleanness and number of washes of the PPE products.
m) Test person information, e.g. name, age, height, weight.
p) Information on positions of skin sensors.
q) Table of all data from measurements during the exposure period, until the skin temperature starts to decrease.
r) Observations of the test person e.g. of pain.
s) Observations of damage to PPE during the test.
FIRE FIGHTING HEAT EXPOSURE CHARACTERISTICS
Graph from Hoeschke

Figure A1. Firefighter’s exposure conditions (N. Hoschke, Fire Safety Journal 4(1981)125-137.)
TEST ROOM MATERIAL

1. Cross bars R 45 galvanized steel profile, nominal material thickness 4.5 mm, in the ceiling and on the walls.
2. Nominally 1 mm thick hot dip galvanized steel on the walls up to 1.2 m from the floor.
3. Nominally 1 mm thick stainless steel in the ceiling and on the walls down to 1.2 m from the floor.
4. Insulation of at least 35 mm mineral wool.
5. Toughened glass as inspection window.

Energy source

The energy source should consist of two gas burners that each consume approximately 100 kW.

The use of flammable gas can be hazardous, attention is therefore drawn to the following. The system shall be built by an expert. All equipment such as tubes, couplings etc. shall be approved for the gas used. The installations shall be constructed according to nationally accepted regulations.

A ventilation procedure before ignition shall be followed in order to prevent explosion in case of accidental leakage.

For safety reasons the burner shall be equipped with a remote controlled ignition device for example a pilot flame or a glow wire. There shall be a system for immediate and automatic cut off of the gas supply in case of extinguishment of the ignition flame. There shall also be a system for manual emergency cut off of the gas supply from the control room.

The gas shall be supplied centrally through the bottom of the burner. The top surface of the burner shall consist of non combustible material. The construction shall be such that an even gas flow is achieved over the entire opening area.

Burner descriptions

The stove is placed 330 mm from the long wall and 600 mm from the short wall outside the start room. The inner cylinder, $\varnothing$ 220 mm, should have three “legs” with a height of 130 mm. The total height of the cylinder with legs is 1030 mm. On top of the cylinder there shall be a cone of sheet steel, 50 mm deep, $\varnothing$ 230 mm upside down and 100 mm above the open stove area.

The second cylinder, $\varnothing$ 450 mm, hangs on three 200 mm long “arms” from the ceiling. It shall have a height of 1000 mm.

The burner is placed 450 mm from the long wall and 1500 mm from the short wall outside the control cabin under the inspection window. There should be a safety screen to prevent the test person from entering or falling into the flames.

A general length scale tolerance of ±5% is allowed for the burner design.
SKIN SENSORS

Type 1:
Semiconductor transmitter: a transmitter that converts the temperature to a linear voltage using semiconductor technology.

In this case, the LM35 DZ is used. When the response times are too high, this sensor has now been replaced by type 2.

Metering range: $-55 - +150^\circ C$
Accuracy: ±1.0% or guaranteed 0.5°C at 25°C
Output voltage: 10 mV/°C linear
Cap: TO-92
Operating voltage: 4–30 V DC
Power consumption <60 µA
Output impedance: 0.1 ohm at 1 mA load
Heat generation: <0.1°C in still air
Response time: approx. 5 secs in oil bath; 40 secs in still air.

Type 2:
NTC resistance: a non-linear resistor, the resistance strength of which depends on the temperature of the resistor body. NTC (Negative Temperature Coefficient) has a negative temperature coefficient, i.e. the resistance decreases with increasing temperature. A potential-divider is built up using an NTC resistor and a normal resistor as reference. The temperature is taken from the data table depending on the resistance.

Type: Rhopoint UUT 45J1 (ACW-006) from Fenwall Electronics
Metering range: $-80 - +150^\circ C$
Accuracy: ±0.2°C (within 0–70°C)
Resistance: 50 kOhm at 25°C (non-linear)
Cap: Epoxy insulated
Heat generation: 1 mW (increases the temperature in the resistor by 1°C in still air)
Response time: approx. 10 secs in still air.
PHYSICAL EXCERCISE PROGRAM TO BE FOLLOWED BY TEST PERSON

The test person shall follow the following scheme. First from up to down, and then from down to up, a total of 5 minutes.

- Stand upright on floor: 30 s
- Sit down: 15 s
- Stand up on 2 pallets: 15 s
- Lay down: 30 s
- Stand up on 1 pallet: 15 s
- Kneel down: 30 s
- Stand upright on floor: 15 s