Central Fire Brigades Advisory Council
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Measurements of the Firefighting Environment Summary Report

The Fire Experimental Unit (FEU) has carried out measurements during training exercises and in specifically designed tests. The limited number of tests means that the firefighting environment cannot be fully defined but far more information has been obtained than was available previously. The various conditions under which firefighters and their equipment may have to operate have been classified into four groups ranging from 'routine' to 'critical'.

Information on the firefighting environment was required in support of standards work for firefighters' clothing and equipment. There was insufficient knowledge of the temperatures they would be likely to reach. These are governed by the time they are exposed to the ambient air temperature and humidity, the incident thermal radiation, and the air flow past the firefighter.

The most relevant previous work was research by Coletta and Abott which is summarised in Reference 1. They produced a convenient way of defining zones for routine, hazardous and emergency conditions, but measurements were not available to support the definitions used.

To obtain these measurements, the FEU arranged for a firefighter to carry specially designed instrumentation whilst taking part in fire training exercises. In these exercises, no attempt was made to determine the limits of exposure that could be tolerated; the conditions encountered by the firefighter were simply recorded. As a subsequent activity the effects of specific combinations of thermal radiation and temperature were measured in an attempt to identify safe working limits.

INSTRUMENTATION

An instrument package was developed to collect the data which could be attached to the harness of a breathing apparatus set and carried into fire conditions (Figures 1 and 2 [see page 2]). This included a portable datalogger and transducers to measure the following parameters on and around a firefighter dressed in firefighting kit with breathing apparatus (BA):

- Air temperature at several points on the outside of the tunic
- Air flow past the firefighter
- Thermal radiation
- Humidity

The major parts of the instrument package were a case and an instrumented sash. The case housed the data logger and interfaces to some of the transducers. The sash was fitted to the BA harness (Figure 1) and carried the temperature probes, humidity probe and an event switch. For environmental protection, a jacket was fitted around the case. This had an outer cover of Nomex and was lined with insulation. The radiometer (to measure thermal radiation) and air flow probe were fitted with mounting brackets which located on the BA harness.

In some tests, thermocouples, a humidity probe and radiometers were installed in the buildings and connected to a datalogger in a control room. These fixed transducers gave additional data to that from the instrument package.

MEASUREMENT DETAILS

- **Exercises**

The training exercises included the more severe of those used for regular training of firefighters at the Fire Service College. Tests were also carried out at the Controlled Ventilation Simulator of Essex County Fire and Rescue Service and in the fire house of Suffolk County Fire Service.

Most tests used crib fires which were built in crib stands using wood, straw and paper.

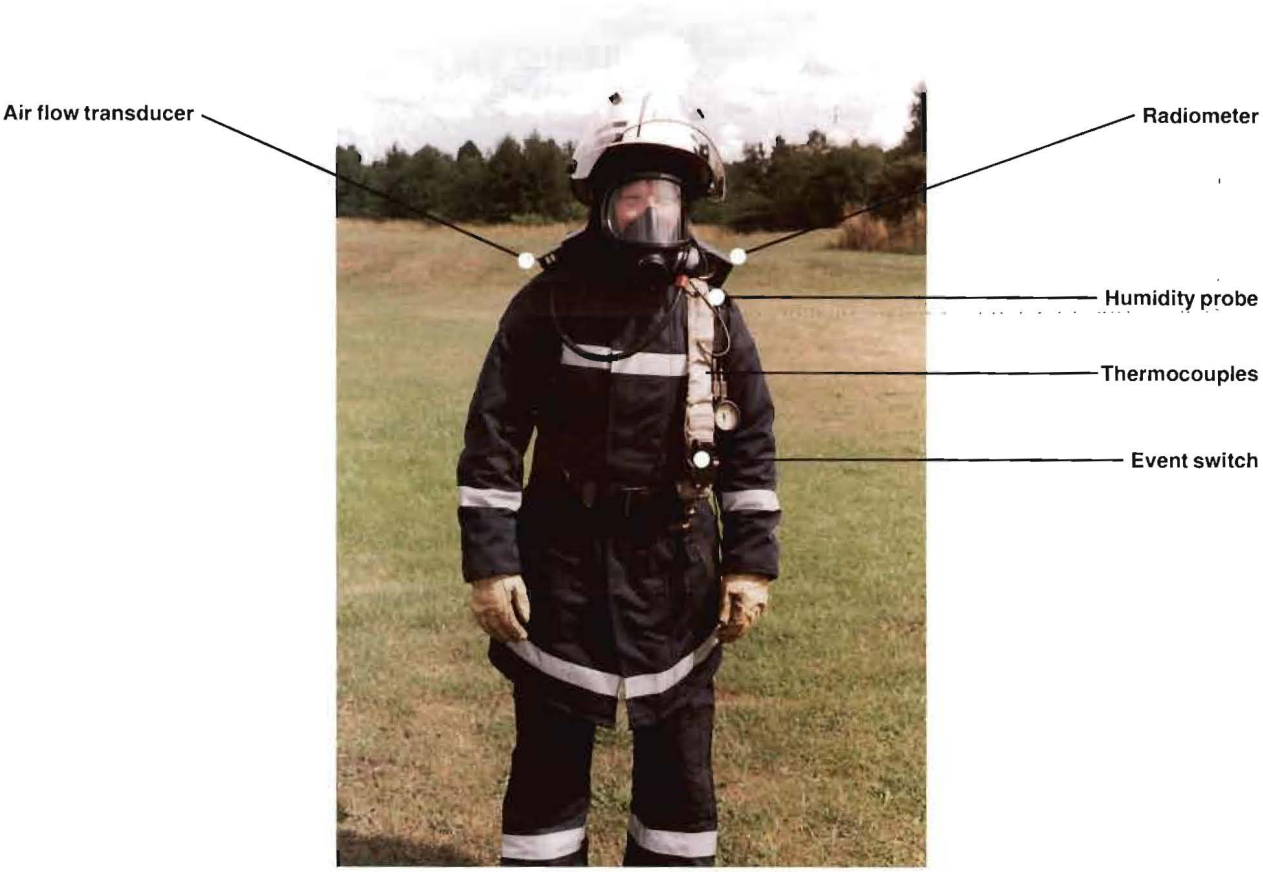

Figure 1: Package on BA wearer showing positions of the sensors.

Figure 2: Package mounted on BA cylinder.

In the later tests the wearer of the instrument package was asked to report his comfort level during the exercise on a scale of one to ten. Scale point one was defined as normal room conditions and ten as the limit of acceptable working conditions.

- **Exposure to Thermal Radiation at Ambient Temperature**

Tests were carried out under the north hood of the FEU still air facility at Hangar 97 Little Rissington, to explore the time for which firefighters could tolerate various thermal radiation levels.

A 2.4 metre diameter tray was filled with heptane on a water base and ignited. Two firefighters dressed in standard BA kit were asked to move to a predetermined position near the fire and beside a radiometer and to remain there until they felt discomfort.

Cooling sprays were available which could be applied to firefighters if requested. The time limits were taken to be the times at which the firefighters moved away from the fire or when they asked for cooling sprays to be applied.

- **Exposure to Combinations of Temperature and Thermal Radiation**

Tests were carried out in the Fire Service College Commercial Building to investigate the ability of firefighters in standard BA kit to tolerate combinations of high air temperatures and thermal radiation.

The conditions in the room were varied by changing the number of cribs (two or three) and the quantity of wood. When the required conditions had been established, the BA team was asked to enter the room and proceed to a predetermined location near the fire and adjacent to fixed transducers, where they were asked to remain standing until they felt discomfort. The instrumentation package was worn by one of the BA team.

In two tests, the BA wearer carrying the instrument package stood behind a plywood screen faced with aluminium foil to shield him from the direct thermal radiation from the fire. This allowed the tolerance to high temperature in the absence of thermal radiation to be assessed.

SUMMARY OF RESULTS

The details and data from all the tests are given in FRDG Publication 4/93. Figure 3 shows a typical graph from the instrumentation package and includes the comfort levels reported by the firefighters during the tests.

A summary of the results is given in Figure 4. This is based on Reference 1 with the FEU results added as follows:

- The air temperatures and thermal radiation levels experienced by the firefighters. (The tolerance times are noted where these were available).
- The maximum temperature measured on a firefighter. (This was 235°C, although it was only experienced for about 5 seconds).
- The results of tests carried out in the FEU fire test room in 1987 in support of work on low and high pressure pumps (Reference 2). (The results shown in Figure 4 reflect the conditions measured in the test room at a stage where it was deemed unsafe to

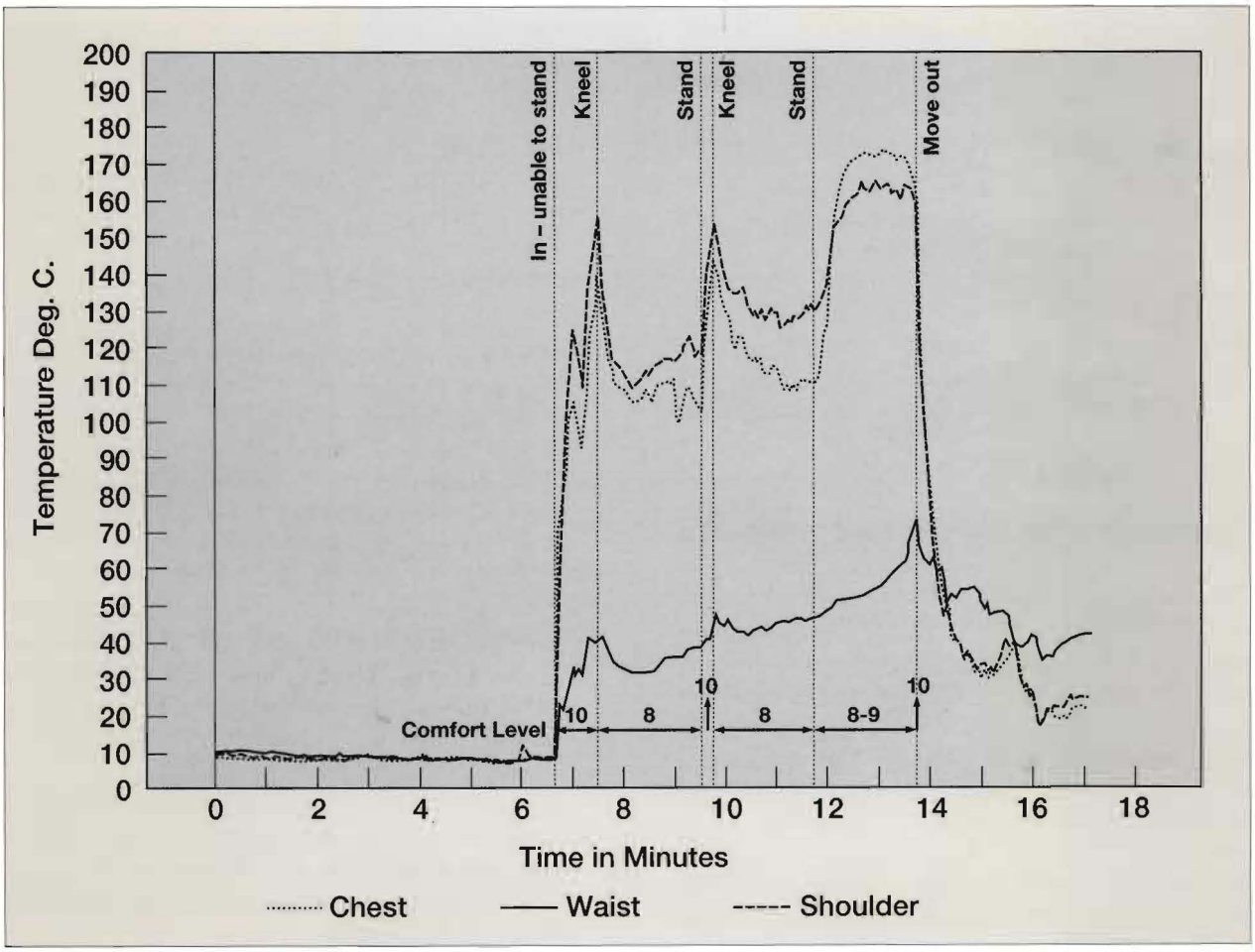

Figure 3: Typical graph from the instrumentation package.

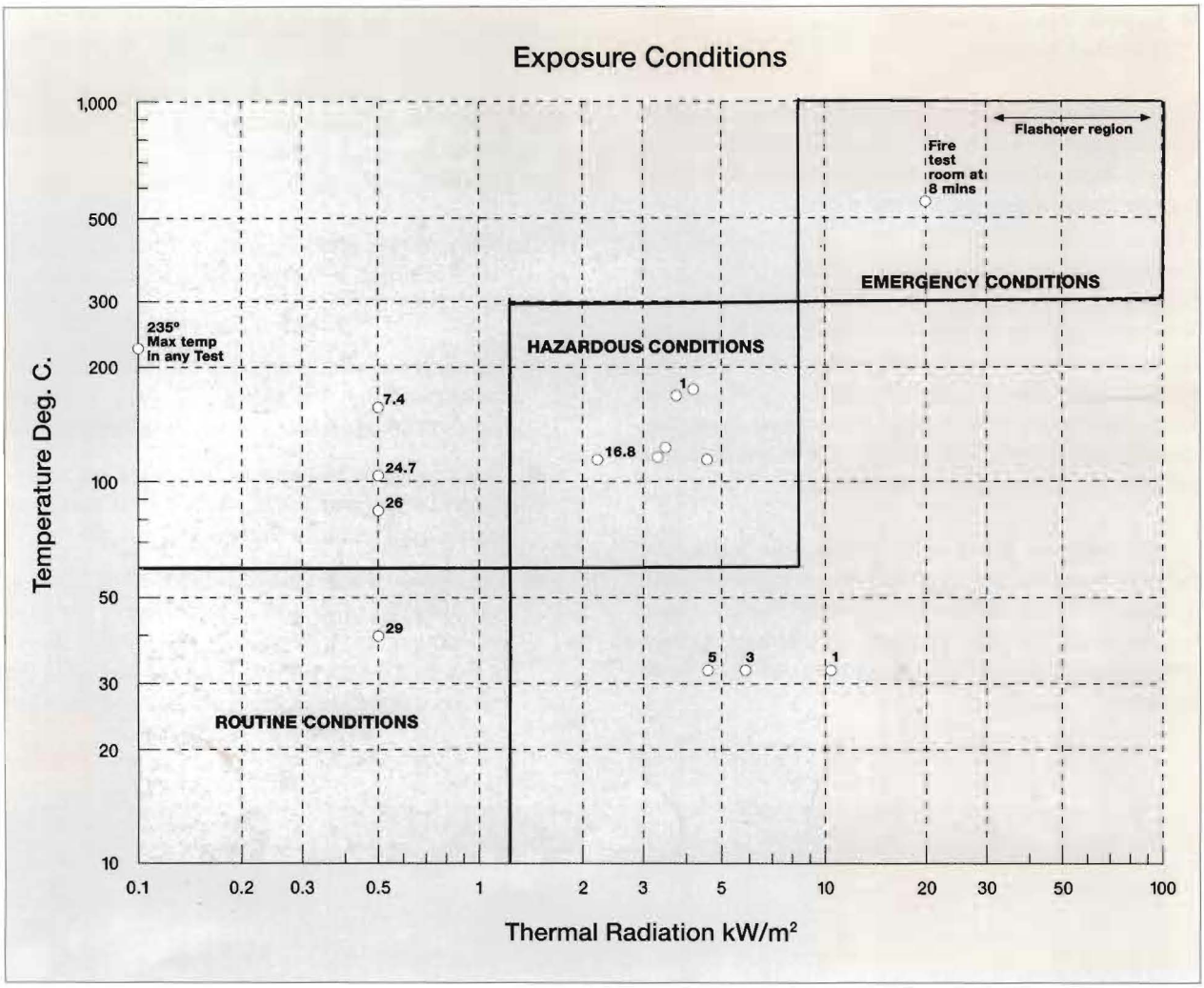

Figure 4: Firefighters exposure conditions including FEU results.
Zones are based on Colleta & Abbot.
Numbers next to points refer to time periods, in minutes, for which conditions have been tolerated.

enter the room in the judgement of the participating fire officer. In his view, had he done so he would have sustained injury and/or equipment damage.)

FIREFIGHTERS' EXPOSURE CONDITIONS

The reason for measuring the firefighting environment is to determine its effect on firefighters and their equipment. The relevant data required are the air temperature, humidity, thermal radiation, air velocity past the firefighter, and the time for which the equipment was exposed to the conditions. Most of the data collected in this work have been measurements of air temperatures and thermal radiation.

In Figure 5 an attempt has been made to give a simplified summary of the results for temperature, thermal radiation and time of exposure. It has not been, and probably never will be, possible completely to define the firefighting environment. However the information collected in this work has extended knowledge of the firefighting environment to include a range of conditions which has not previously been reported. The effect on the firefighter depends on many physical, physiological and psychological factors and any conclusions must bear all these factors in mind. A major project would be required to refine and further explore the results.

The classifications used in Figure 5 are Routine, Hazardous, Extreme and Critical. These are described in more detail below:

- **Routine Conditions**

Routine conditions would be expected to apply to most of the operating conditions experienced by a firefighter. This will include elevated temperatures but not direct thermal radiation from fires.

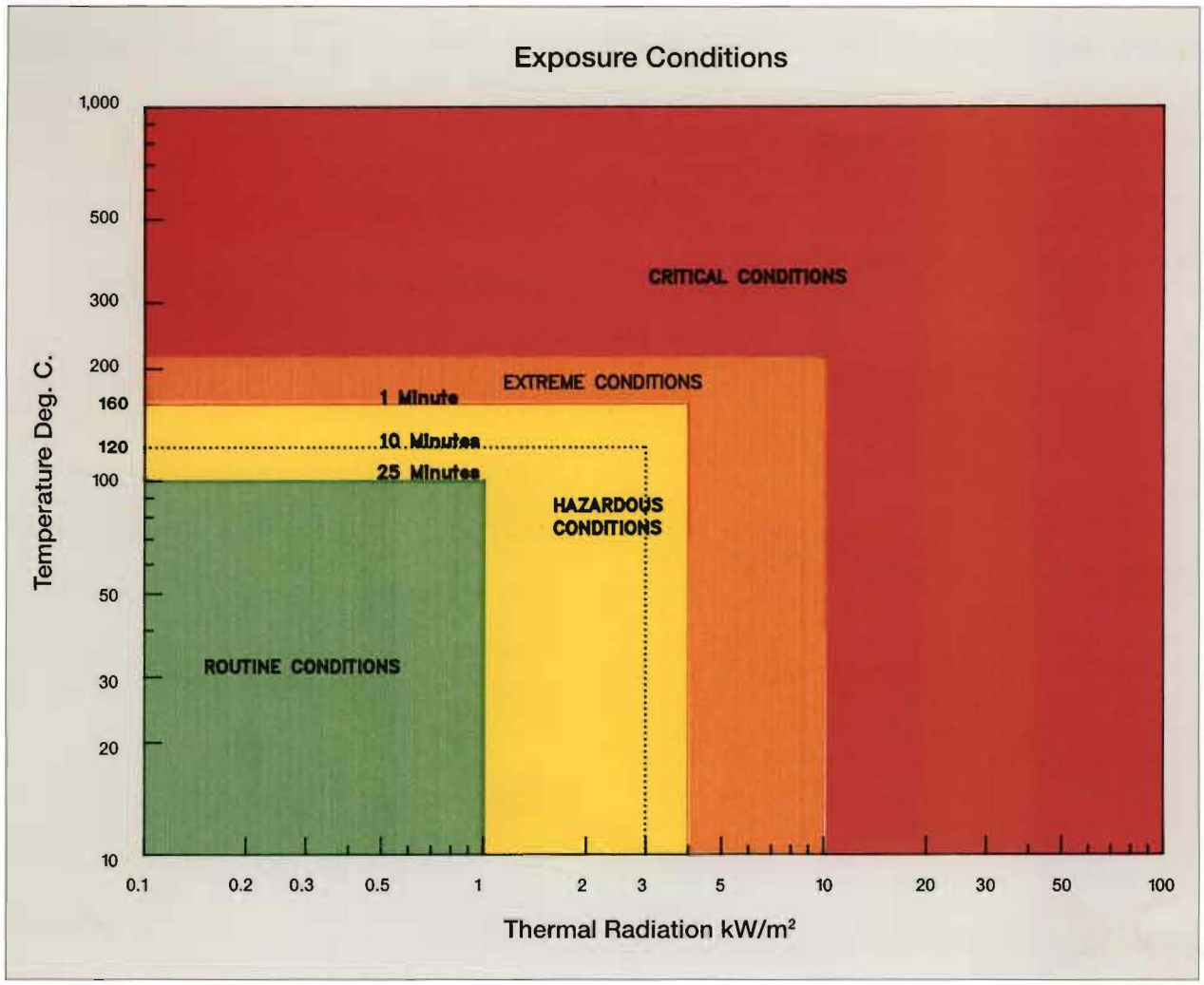

Figure 5: Firefighters exposure conditions in standard BA kit with proposed time limits.

The limits proposed for routine conditions are 25 minutes at 100°C and a thermal radiation limit of 1 kW/m².

There will be a lower temperature limit within the routine conditions which can be tolerated for the full duration of the BA cylinder, but this was not determined in the present work.

Where the FEU were monitoring firefighters in Fire Service College exercises, none of these firefighters was committed for more than 30 minutes. In all of these exercises, none of the firefighters was exposed to temperatures above 100°C for longer than 7 minutes.

The humidity will have a significant effect on the tolerance times for routine conditions but the combined effects of temperature and humidity were not explored.

- **Hazardous Conditions**

Hazardous conditions would apply where a firefighter would be expected to operate for only a short period in high temperatures in combination with thermal radiation.

The limits proposed for hazardous conditions are 1 minute at 160°C and a thermal radiation limit of 4 kW/m². Above the upper limit for thermal radiation of 4kW/m², damage or injury is likely to result.

A subsidiary limit has been added in the hazardous zone to represent the conditions which could be tolerated for 10 minutes.

Humidity is not a significant factor above 100°C because it decreases rapidly to low relative humidity values.

- **Extreme Conditions**

Typically this would include snatch rescue situations or, at worst, retreat from a flashover condition.

Extreme conditions have been taken to be above the

160°C and 4 kW/m² limit of hazardous conditions but not exceeding 235°C and 10 kW/m².

In the tests at ambient temperature, 10 kW/m² was tolerated for 1 minute but damage was sustained to equipment and these conditions would not be acceptable operationally. It may be possible to tolerate a higher value for a short time but injury to the firefighter and damage to equipment would occur.

- **Critical Conditions**

These are conditions beyond the 235°C and 10 kW/m² limit for extreme conditions and could be life threatening. The firefighter would not be expected to operate in these conditions.

DISCUSSION

Although the physical size of the environmental package developed for this work makes it unsuitable for use operationally, its value as a research tool for measuring the firefighting environment has been proved. It is much simpler to allow the wearer of the package to move around a large area rather than to instrument the area at numerous fixed positions. A further advantage is that the temperatures and other parameters recorded are those actually experienced by the wearer.

Humidity proved difficult to measure and analyse but generally, as expected, the humidity was found to decrease to low relative humidity values at high temperatures. No useful data was obtained on air velocity because the conditions encountered have not produced significant air flow.

The data collected has been limited to training scenarios and to the exercises described above, the latter being intended to establish the tolerance limits of the firefighter. FEU consider that there is little merit in carrying out further tests using the FSC exercises since the most severe have been explored.

If further tests were required then closer control of the test conditions would be necessary than can be achieved using wood cribs. The conditions obtained with the type of crib fires used are not repeatable and do not remain constant throughout a test.

Future tests would require a large controlled environmental chamber for close control of the relevant combinations of thermal radiation, temperature, humidity and air flow. Input from physiologists and psychologists would be required to consider the human factors that could influence the results. Combinations of clothing and other protective equipment would also require assessment.

The health and safety of the firefighters taking part in any such trials would have to be carefully considered.

CONCLUSIONS

The results have produced a better definition of the firefighting environment than was previously available. Four conditions, ranging from routine to critical have been proposed as a basis for discussion and, possibly, for further elaboration. However, the limited number of tests carried out does not enable the firefighting environment to be fully defined or absolute answers to be given.

Significant data has been collected on air temperatures and thermal radiation, but the effect of humidity requires further assessment. Further work using more closely controlled conditions would be necessary to make further progress.

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REFERENCES

1. B.N. Hoschke, "Specifications for Firefighters Clothing", Fire Safety Journal 4(1981) 125-137.

2. SRDB Publication 34/88, "The Use of High Pressure and Low Pressure Pumps with Hose Reel Systems", J Rimen, 1988.

FURTHER INFORMATION

The following reports provide more detail of the work carried out in this project:

SRDB Publication 35/89, "Measurements of Air Temperatures Experienced During Exercises at the Fire Service College", J Foster, B Johnson and R Lock, 1989.

FRDG Report 12/92, "Measurements of Temperatures in the Fire Training Building of Suffolk Fire Service", J A Foster and G V Roberts, 1992.

FRDG Publication 4/93, "An Instrument Package to measure the Firefighting Environment: The Development and Results", J A Foster and G V Roberts.

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