INTRODUCTION

This training note is intended to provide information to students attending the programme on the subject of Working in Hot and Humid Atmospheres. This training note should be read in conjunction with other notes, such as Physiology of Respiration and Working in Smoke.

AIM

To ensure that students understand how performance levels and wearing durations can be adversely affected in hot and humid atmospheres.

OBJECTIVES

At the end of the instructional session dealing with this subject, and after detailed study of this note, you will be able to:

- State the four main mechanisms of heat loss
- State the effects of heat and humidity

CONTENTS

This subject will be dealt with under the following headings

- Introduction
- Four mechanisms of heat loss
- The effects of heat and humidity
- Summary
INTRODUCTION

Firefighters often fail to understand and consider the physiological effects of heat when it is associated with humidity. These can have serious implications with regard to health and decision making.

Performance levels can deteriorate, skills become increasingly more difficult to perform and mental agility can be less efficient. There are many factors to consider and not all of these will result in producing the symptoms.

HEAT STRESS

Components of heat stress are

- Metabolic Heat
- Air Temperature
- Humidity
- Air Movement
- Radiant Temperature
- Clothing
- Individual Performance Level (Fitness)
- Age

The normal body temperature is around 37°C and must be maintained to avoid heat strain. There are four mechanisms by which the body loses heat; they are

- Radiation (surface temperatures)
- Convection (passages of air)
- Evaporation (sweating)
- Vaporisation (lungs)

Radiation

Loss of heat by radiation is due to the temperature of surrounding surfaces (walls, etc) being lower than that of the body. If the body temperature is increased, for example by working, then the radiant heat given off will also increase. However, this loss will be counteracted by heat gain from other radiative surfaces until, when structural temperatures exceed body temperatures, there will be a net heat gain through this process. Other radiative sources, such as the sun or fires, will also contribute to heat gain. As with convection, covering the body surface will disrupt this avenue for heat loss. In these situations, external radiative sources will warm the outside of the clothing and, as this heat is conducted inwards, will eventually contribute to body warming.

Convection

It is well known that hot air is lighter than cold air. Therefore hot air rises as it expands. Convection currents around a resting nude body account for about 25% of its heat loss. As air becomes warmed by the body it rises and is replaced by cooler air. In hotter climates, the temperature difference between the skin and the air becomes smaller and the effectiveness of this heat loss mechanism is reduced until, at temperatures greater than skin temperature, it becomes a means of heat gain. Any clothing which prevents or reduces air exchange will disrupt this mechanism.

Clothing worn by firefighters, including standard issue protective clothing, but especially chemical suits designed to prevent contamination, will reduce the amount of body heat lost by this process to negligible levels. On a more positive note, until heat is conducted through to the inner clothing surface, it will also prevent heat gain from the environment.
Evaporation

Vaporisation of water is the main element of the loss of heat through breathing. This process also provides a further mechanism through the evaporation of sweat. At rest, sweat production is minimal and only accounts for around 10-15% of heat loss.

In hot climates, or when working (or both), sweat production is considerably increased. Under these circumstances sweat evaporation becomes the main route for heat loss, now accounting for some 80% of total heat loss, with the other avenues combined representing the remaining 20%. For this sweat to be an effective heat loss mechanism, it must be evaporated. The proportion of heat lost by warm sweat dripping off the body is minimal. It follows therefore that, for sweat to be evaporated, the surrounding air must be capable of receiving it. Humid air (air which already contains a lot of moisture) cannot take up as much sweat as dry air. When water is used on a fire, the air temperature may be reduced but the evaporation of that water will increase the humidity and can therefore increase the apparent temperature. In evaporating, sweat takes up heat from the surface it is in contact with. Sweat soaked into clothing will cool the clothing and only indirectly therefore cool the underlying skin.

Vaporisation

When we breathe, air drawn into the lungs is warmed to close to body temperature and becomes saturated with water vapour. These processes provide an avenue for heat loss, depending upon the temperature and humidity of the inhaled air. The most important element of this is the evaporation of water. Even at air temperatures slightly above that of the body, if the incoming air is fairly dry, there will still be a net loss of heat through this route - about 15% of the total for the resting male.

With ‘open’ circuit breathing apparatus, the process of expansion of air from the cylinder cools and dries it, so this is potentially an important avenue of heat loss for the firefighter. Heat pick-up through tubing and in the facemask will counteract this slightly but there will still be a net heat loss through this procedure.

THE EFFECTS OF HEAT AND HUMIDITY

As previously mentioned, there are physiological effects of heat when it is associated with humidity.

When the body is subjected to heat there is a general reddening of the skin due to an increased blood flow in the vessels of the skin. This reaction increases the heat loss due to radiation but, if the external temperature is actually higher than that of the body, then the body may absorb heat from outside through the increased blood flow.

Another effect of heat is to increase thermal sweating so that the whole trunk, forehead, backs of hands and legs become moist. This affects the consumption rate of the firefighter and ultimately symptoms of distress and illness appear.

These symptoms may be classed under three separate headings

- Heat exhaustion
- Heat syncope
- Heat stroke

Heat exhaustion

Heat exhaustion is probably the most common reaction among firefighters. In hot moist environments, heat exhaustion develops even more quickly than in dry conditions since evaporation is reduced. The pain thresholds seem to be approached more quickly in moist heat than in dry, possibly because of the cooling effect still exerted under dry conditions. Heat exhaustion is due to excessive sweating; the body temperature remains more or less normal while the excess heat is given off in the evaporation of sweat from the body. Sweat consists of salt and water and during heavy and prolonged sweating, the body loses an appreciable amount of both. Salt deficiency can cause:
• cramps
• headaches
• weakness
• fainting and collapse

Heat syncope

This is due to temperatures above normal body temperatures dilating the skin vessels which fill with blood. The blood will take heat in instead of giving heat off. If this condition becomes extreme, the blood pressure will drop so that insufficient blood reaches the brain. Less blood means less oxygen, thus fainting occurs.

Heat stroke

This is the most serious disorder due to exposure to environmental or climatic heat. The fundamental feature of the disorder is an extreme and uncontrolled elevation of body temperature. This exerts its harmful effect chiefly on the central nervous system.

SUMMARY

Firefighters should not be allowed to operate or remain in hot and humid atmospheres for any longer than absolutely necessary. If a firefighter in these environments is experiencing dizziness, nausea, abdominal pain or a burning sensation of the skin, the Officer in Charge should withdraw the whole team to fresh air.

Dry clothing and liquid refreshment should be considered after working in hot and humid atmospheres.