MODIFICATION OF A THERMAL MANIKIN FOR DETERMINATION OF WATER VAPOTJR PERMEABILITY OF AIRCREW CLOTHING ASSEMBLIES

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INTRODUCTION

Military aircrew are routinely required to wear complex clothing assemblies designed both to maintain operational effectiveness and provide personal protection during combat, emergency egress, amd post-egress survival on land and sea. Inevitably, such clothing will tend to increase the risk of thermal strain, particularly in hot climates and despite the provision of cockpit environmental conditioning. In some situations personal conditioning may even be required to maintain aircrew thermal comfort.

In studying the impact of the thermal environment on aircrew performance it is desirable to employ a standard thermal index. However, to facilitate its use the thermal properties of any clothing must be known. Data on thermal insulation of aircrew assemblies are available, for instance from manikin studies at this Centre. However, comparable water vapour permeability data are currently not available.

This paper describes the development of a technique to measure permeability of standard aircrew clothing assemblies. The approach adopted uses an anthropometric manikin, which avoids some of the problems associated with other methods such as human trials (subjective variability) and regression of 'skin model' determinations (complexity of garment fabric sampling).

MATERIALS and METHODS

Figure 1 shows a schematic of the hardware employed. A thermal manikin (TIM 3, Cord Group Ltd, Canada)' is covered in hygroscopic fabric (Nortene horticultural capillary matting). The head is excluded, and the hands are covered with cotton gloves. Annular manifolds are provided at the neck and forearms to ensure a controlled flow of water through the matting under the influence of gravity. The manikin is suspended vertically on a frame over a water supply reservoir covered with an impermeable lid. The whole assembly is mounted on a precision weighing machine (KC300, Mettler) situated in an environmental chamber (T_{db}=27°C, RH=15%, V_w=0.8ms^{-1}). The manikin is also dressed in a closely conforming water vapour permeable coverall (Musto, UK) to prevent water wicking out into any clothing under test. Drain tubes incorporated into

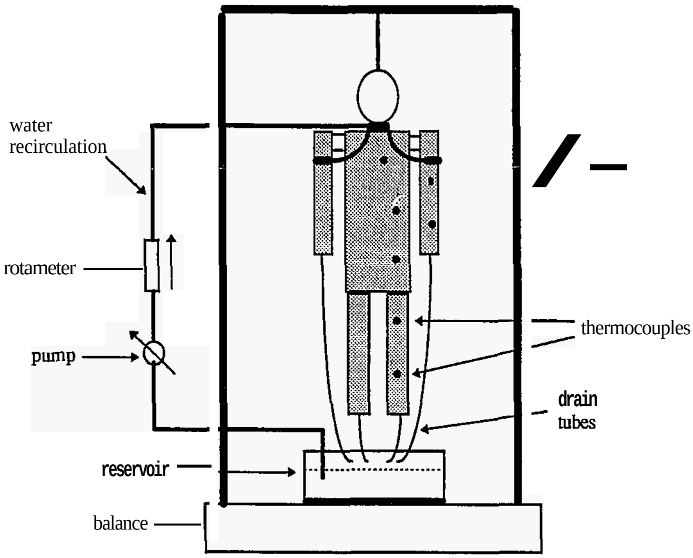

Figure 1 Schematic of sweating manikin

the hands and feet of the coverall feed through a small hole in the reservoir lid. This arrangement is designed to maintain a fully wetted surface regardless of evaporation rate, but avoid any extraneous water losses. The water supply is provided by a miniature pump which recirculates water from the reservoir to the capillary matting manifolds. Flow rate is adjusted to $0.06 l.min^{-1}$ using a rotameter. The temperature of the wetted surface is measured by means of 24 type K thermocouples distributed over one half of the symmetrical manikin. Surface area estimates are made by caliper measurements in conjunction with the known surface area of the nude manikin.

In order to determine mean evaporative resistance' (R_{cl}) of a clothing assembly, initial tests are performed both with the wetted suface exposed and with the liquid barrier suit fitted, during which the rate of evaporating mass loss, m(t) is computed by continuous weighing over an equilibrium period of 2 hours. The procedure is then repeated with the manikin dressed in the assembly under test. Boundary layer resistance (R_a), barrier suit resistance (R_g) and total resistance (R_T) are computed from the data using the relationship:

$$R = A(p_s - p_a)/\lambda.m(t)$$

where p_s is the wetted surface saturated vapour pressure at measured mean temperature, p_a is the ambient vapour pressure, A is the surface area and λ is the latent heat of vaporisation. Intrinsic clothing resistance is then given by:

$$R_{cl} = R_T - R_g - R_a/f_{cl} \qquad f_{cl} = \text{clothed area factor.}$$

RESULTS

Uniformity of surface wetting was assessed by thermal imaging of the manikin. In order to confirm stability and repeatability of the mass estimations and exclude the possibilty of unaccounted water losses, 2 hour test runs were made both with a dry manikin and with the manikin sweating but covered with an impermeable bag. Dry test weighings were stable to within ±2g. Extraneous losses during sweating tests with the impermeable bag were less than 4g.

The mean temperature of the wetted surface was typically 20°C (sd=±1°C, n=24). This suggests that uniform saturation was being achieved, and indicates that estimation of mean surface vapour pressure can be made within practically useful confidence limits.

Figure 2 is a graph of the progressive mass loss during a test with no clothing (liquid water barrier only), the uniform slope of which confirms that a saturated surface was satisfactorily maintained.

At the time of publication some test results were as follows:
$R_a = 0.005$; $R_g = 0.011$; R_{cl} (typical aircrew clothing assembly) = 0.04 $kPa.m^2.W^{-1}$.

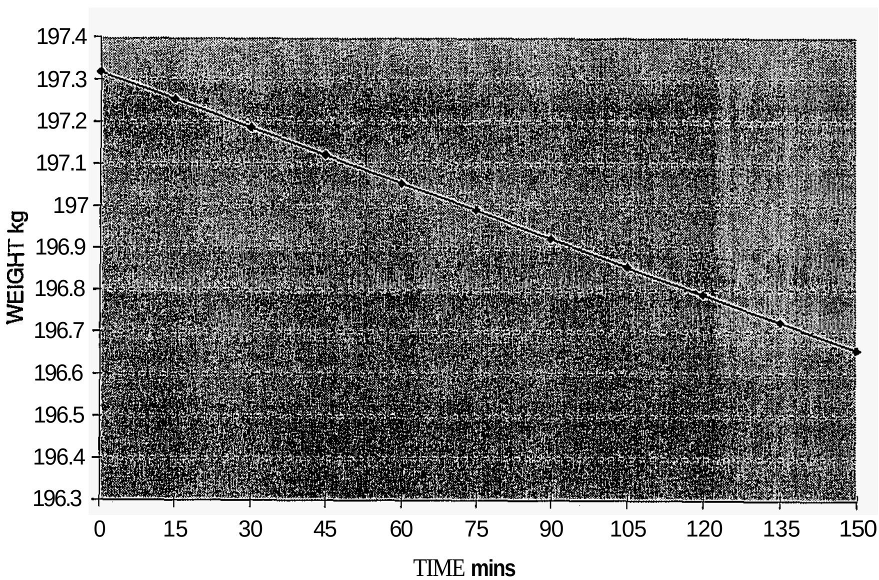

Figure 2 Unclothed evaporative loss (n=1)

CONCLUSIONS

The sweating manikin was developed to overcome the difficulty of maintaining a fully wetted surface after dressing. This is particularly important for complex military clothing assemblies where dressing may take many minutes to complete, in which case it may be impossible to ensure that an initial 'one-shot' wetting of the surface will guarantee the surface remains saturated for long enough to achieve equilibrium. This is very important, since an accurate estimate of vapour pressure gradient is essential.

The results of initial verification tests indicate that this device will be a useful tool for thermal assessment of clothing assemblies.

REFERENCES

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