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Research Study Report, BP-3

Some Effects of Absorbency of Clothing Materials

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ABSTRACT

Samples of wool and nylon fabrics were conditioned at high and low relative humidities and placed on a heated guard ring flat plate. The rate of heat loss from the plate was measured as a function of time until a steady state was reached. In the case of wool conditioned in a high humidity, this took approximately three hours. The merits of using absorbent materials in clothing is discussed in terms of the use to which it is to be put.

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1. Introduction

Other factors beside the dry insulation value of textile materials or the clo value of uniforms are important in maintaining the thermal balance of the soldier. One of these factors is the transient thermal effect caused by absorption or desorption of moisture by textile materials. When textile materials are exposed to air with a higher relative humidity, they absorb water vapor and heat is liberated similar to the heat liberated when condensation of vapor occurs. When textile materials are exposed to a lower relative humidity, the reverse occurs and cooling takes place. Different types of fibers vary greatly in the amount of moisture which they will absorb and consequently the amount of heat of absorption they will liberate. It is of considerable interest to determine whether or not the heating or cooling, due to this phenomenon, is of sufficient magnitude and duration to be important in comparison with other channels of heat flow in clothing systems. It is also of interest to determine under what conditions this may or may not be beneficial. The amount of water absorbed by textile fibers at different relative humidities (regain characteristics) is well known. Much less is known of the dynamic effects of regain as related to total heat loss from a clothed man when either environmental humidity changes or when man starts and stops sweating. This study is intended to simulate heat loss due to desorption such as might occur when a man donned clothing conditioned to high relative humidity.

2. Methods

A standard guard ring flat plate was equilibrated at 90.7°F in a small controlled condition chamber maintained at 61°F and either at 12% or 81% relative humidity. Two sets of fabrics were used, one consisting of four layers of nylon and the other of four layers of wool. These fabrics were made as similar as possible to pajama type underwear material in all respects except fiber composition.

The fabrics were conditioned in the test chamber at one of the above humidities for twenty-four hours so that their moisture content was in equilibrium with one of the above relative humidities. The fabrics were then placed on the heated flat plate and the heat loss from the plate through the fabric was measured as a function of time until a steady state of thermal transfer had been reached.

3. Results

It will be seen in Figure 1 that the initial heat loss under all conditions is initially high but gradually decreases with time until an equilibrium value is reached. The two solid lines represent the values obtained on wool fabric while those on nylon fabric are dotted. The upper line in each case represents high humidity conditions (Curves 1) and the lower line, low humidity (Curves 2). From these results it can be seen that nylon conditioned at low humidity took approximately one half hour to reach equilibrium, most of the excess heat was undoubtedly used in warming the nylon. Wool fabric conditioned at high humidity

took over three hours to reach equilibrium and in this case most of the excess heat required was due to heat used to dry the wool. The difference between excess heat loss conditioned at low humidity and high humidity must be attributed to the absorbed moisture.

The total excess heat loss is equal to the area under the curve, i.e., heat loss per unit time multiplied by time. This quantity of heat can be expressed as equivalent to the equilibrium heat loss over a period of time and is given in Table I.

TABLE I
EXCESS HEAT LOSS EXPRESSED AS TIME
EQUIVALENT OF EQUILIBRIUM HEAT LOSS

Condition	Wool Fabric	Nylon Fabric
Low Humidity	6.7 minutes	3.2 minutes
High Humidity	34.4 minutes	10.5 minutes

For nylon fabric, desorption of moisture at the higher humidity triples the total excess heat loss over that of the low humidity state (Table I). The effects with wool fabric are similar but much more marked.

4. Discussion

In the above experiments, the equilibrium rate of heat loss was 68 kg cal/m²/hr which can be taken as roughly equivalent to the heat loss for an active man. The fabric combination can, therefore, be considered as equivalent to the clothing a man would require at 60°F. If a man were in another environment with twice the temperature difference across his clothing, he would presumably require twice the clothing. Under these conditions, the equilibrium heat loss would be the same but the excess heat loss would be doubled. In addition, because vapor pressures are lower at lower temperatures, vapor pressure gradients also prevail which tend to slow up the desorption process. Thus one would expect equilibrium to be attained even more slowly at low environmental temperatures. It will be seen that, under the conditions of this experiment, the wool conditioned at high humidities took three hours to reach equilibrium and one hour to reach a point where the rate of heat loss was 20% above equilibrium. A 20% increase in heat loss is by no means physiologically insignificant. At low temperatures, therefore, absorbed moisture can be expected to be an important factor in effective insulation value for several hours.

It should be pointed out that absorption and desorption are transient effects which occur when related humidity conditions in the clothing are changed, and which tend to retard the effect of the change. In this respect they can be considered as equivalent to a greatly increased specific heat. If the change in conditions is one of environment, such

as going in and out of heated buildings, as for example a gasoline station attendant might do, then the tendency is to delay the effects of the change. Thus the impact of the changed environment is reduced by the use of absorptive clothing which might, therefore, be considered advantageous.

If, however, as is the case with a combat soldier living outdoors continually, the change in condition is not one of environment but one of activity with change in sweat rate to compensate for changed metabolism, then absorptive clothing tends to delay change in heat loss. Thus increased metabolism is not accompanied by a corresponding increased heat transfer. The absorption of moisture from sweat generates heat which would reduce heat loss from the man who might become temporarily overheated and might sweat somewhat more. On reducing activity with accompanying reduction in heat production and sweating, the moisture in his clothes continues to dry out causing excessive heat loss and after exercise chill.

Under conditions where sweat may condense in the outer layers of clothing as liquid water, this condensation will be delayed until moisture is absorbed by the textile fibers. Moisture which is absorbed into the fibers is presumed not to move, while moisture which is condensed on the fibers as liquid water may move by wicking or blotting into inner layers. Thus the absorption of moisture may be of some use in delaying blotting effects if the material is of a wicking and blotting type. However, if it is non-blotting, the absorbency is of no use in this respect and, therefore, an overall disadvantage.

5. Conclusions

From this work it can be concluded that absorbed moisture can cause transient effects in heat transfer which are appreciable for an hour or more. These transient effects may be put to advantage by using absorbent materials such as wool which stabilizes heat loss from a man who is changing his environment such as going in and out of heated buildings. However, such absorbent materials would be a disadvantage to persons like the combat soldier who remains in a relatively stable outdoor environment but changes his activity. Hence, nonabsorbent materials such as some of the synthetics may be preferable.

THE EQUILIBRATION OF WOOL AND NYLON ON A
HEATED GUARD RING FLAT PLATE

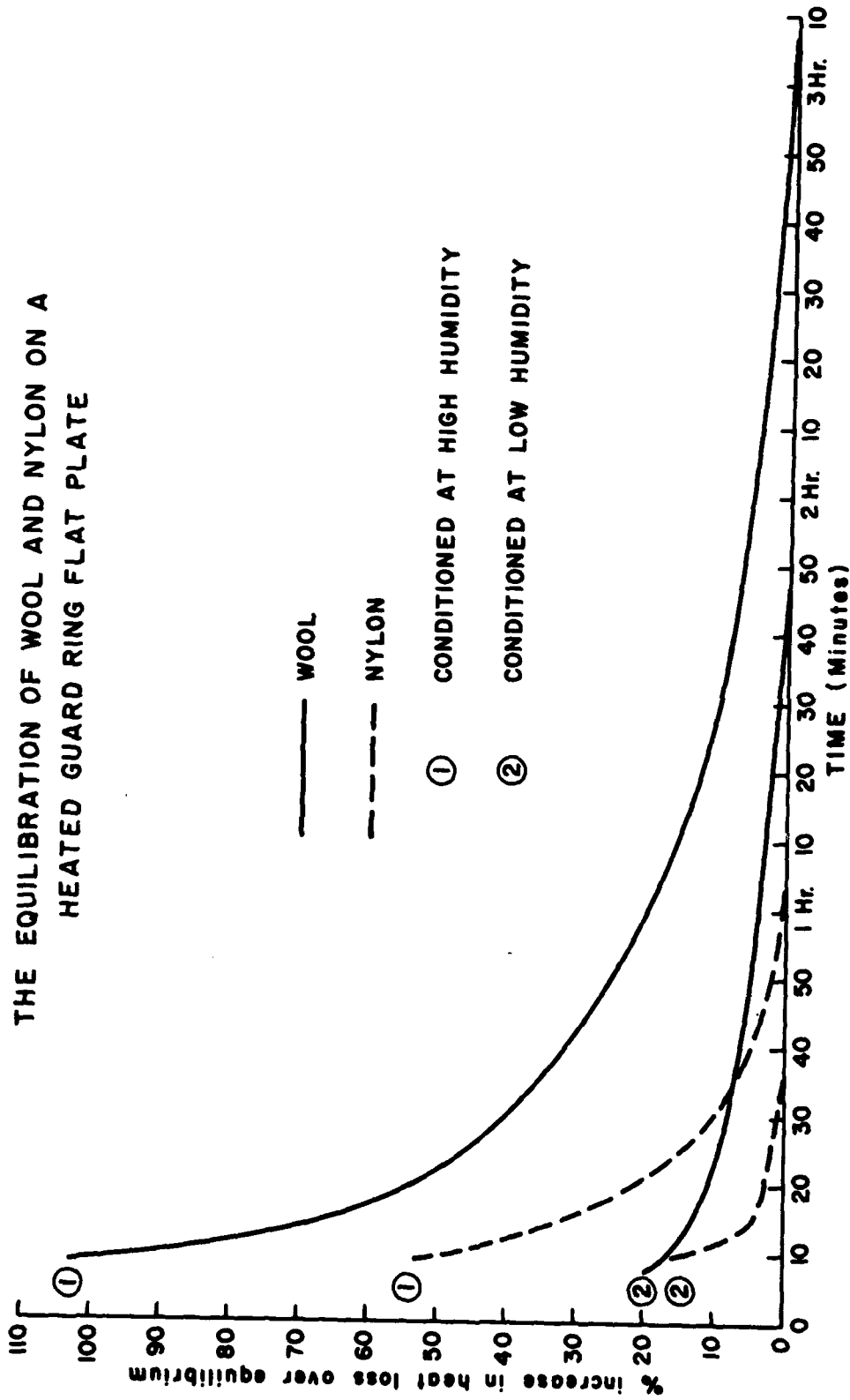


Figure 1