THREE RAPID TESTS FOR THE ESTIMATION OF TROPICAL FITNESS OF FABRICS

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(With 3 Figures in the Text)

Three major factors determine the tropical fitness of fabrics: (1) thermal insulation, (2) porosity, (3) reflecting power.

Gregory (1930) was able to show that no great differences existed among different samples tested for their reflecting power of light. Thermal insulating power and porosity therefore evoke far greater interest.

Though many detailed tests have been worked out to meet the more exacting needs of the textile industry, no simple tests are available up to now to estimate thermal insulation and porosity with an accuracy sufficient for hygienic work.

(1) THERMAL INSULATION

Niven & Babbit (1938) employed a heated cylinder to test the heat transmission through fabrics. Determining the heat loss from the uncovered cylinder and the heat loss from the cylinder covered with the fabric, the thermal insulating value (%) is defined by them as

$$\left(1-\frac{\text{Heat loss from covered cylinder}}{\text{Heat loss from uncovered cylinder}}\right)\times 100.$$

Rees (1941) replaced the cylinder by a heated plate and simultaneously introduced some refinements of the method.

The procedure worked out by Niven & Babbit (1938) can be readily adapted for the kata-thermometer. A finger stall to fit the body of the kata-thermometer is prepared from the fabric to be tested. Ten to sixteen measurements are performed taking in rotation the naked kata-thermometer and the kata-thermometer covered with the finger stall. In order to exclude the action of air movement the kata-thermometer is put up in a cupboard with a glass window. The calculation of the thermal insulating value is then based on the following principles:

In still air the relationship valid for the kata-thermometer is

$$H=0\cdot27\ (36\cdot5-t),$$

where H stands for cooling rate, and t for the temperature of the ambient air (° C.). Taking t as abscissa and H as ordinate we obtain a straight line (Fig. 1, full line). Similar straight lines can be obtained for each fabric to be tested. Denoting by H_1 the cooling rate obtained with the finger stall (muslin), the relationship $H_1:H$ will be the same for each finger stall, since similar triangles are formed. Cooling rates, however, become zero at 36·5° C.; therefore the result is easier to evaluate at lower temperatures (below 20° C.). By performing in rotation measurements with the naked and the covered kata-thermometer, the effects of changes in temperature of the ambient air are cancelled out. Suppose fourteen measurements have been made, the odd numbers of this set representing the times obtained with the naked kata-thermometer, the even numbers representing the times from the covered kata-thermometer, the thermal insulating value is simply found as

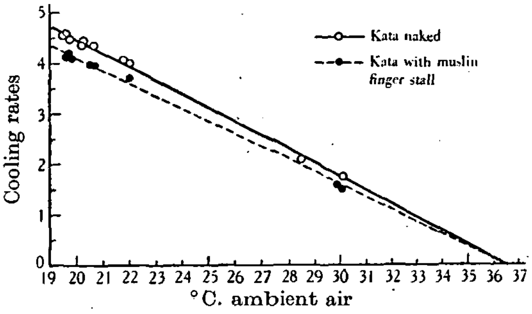


Fig. 1

$$\left(1-\frac{\text{Sum of cooling times of the naked kata}}{\text{Sum of cooling times of the covered kata}}\right)\times 100,$$

since cooling time and cooling rate are in inverse proportion.

Returning to Fig. 1 we find at 24° C. still air a cooling rate of 3·38 for the naked kata-thermometer, while the kata-thermometer with a muslin finger stall yields 3·15 at the same temperature; the thermal insulating value of muslin is therefore

$$\left(1-\frac{3\cdot15}{3\cdot38}\right)\times 100=7\%.$$

This method can also be employed when wind acts on the kata-thermometer. An electric fan is taken, the kata-thermometer put up at a distance of about 1½ m.; then the velocity of wind is determined by the kata-thermometer in the usual way. The stand of the kata-thermometer is moved until the wind speed is 1 m./sec.; again the thermal insulating value is determined as above. It will be seen that thermal insulating values increase with wind speed. It is of interest to note that measurements performed with a wet finger stall show quite similar results, and therefore do not indicate actual gain.

The criticism of the method lies in the fact that a thick layer of fabric increases appreciably the mass of the kata-thermometer, and also its surface. Further, it is often difficult to prepare a finger stall which exactly fits the kata-thermometer; thus there is introduced an additional insulating layer of air.

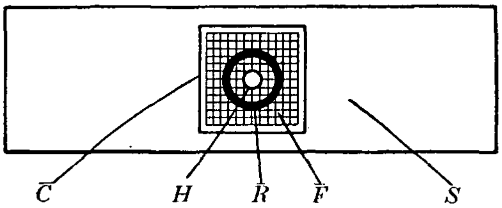
An alternative method is therefore suggested which, though indirect, yields nearly the same result. It is based on Rees's (1941) findings which have been obtained under carefully standardized conditions. From his data it follows that heat transmission through a fabric mainly depends on the thickness of the fabric. Thus the actual measurement of heat transmission can be replaced by a measurement of thickness.

Estimating the heat loss from a hot plate by measuring the thickness of the fabric covering the plate, a recalculation of Rees's (1941) data shows a mean percentage error of 5·1. For the thermal insulating value the mean percentage error is only 2·4. We thus arrive at the relationship which is shown in Table 1.

Table 1. *Corresponding values of thickness of a fabric (mm.) and thermal insulating value (tested at* 25° C., 65% R.H. *and wind speed* 2·2 *ft./sec.)*

Thickness	0·5	1·0	1·5	2·0	2·5
Thermal insulating value (%)	6	16	22	29	36
Thickness	3·0	3·5	4·0	4·5	5·0
Thermal insulating value (%)	42	48	52	56	60

Thickness of a fabric, however, is no absolute value and highly dependent on the pressure exerted during the measurement. While thick fabrics can be easily measured by means of vernier callipers, layers below 1 mm. are rather difficult to estimate. This difficulty can be overcome as follows: The micrometer drum of microscopes bears a calibration in μ; in case the scale is an arbitrary one, it can be easily calibrated by taking a blood-counting chamber, the depth of which is known to be 0·1 mm. Now focus (*a*) a line of the grid and afterwards (*b*) any mark on the lower surface of the cover-glass. When focusing by moving the micrometer screw only, we obtain what the absolute value of one part of the micrometer scale is. Then an ordinary slide is taken and a line scratched on it. A line is also scratched on a cover-glass. Then the cover-glass is weighed. Each square centimetre of the cover-glass should weigh 0·07 g. (corresponding to a pressure of 0·001 lb./sq.in. exerted on the fabric). In case the cover-glass is found to be too light, a ring is cut from cardboard or tinfoil so as to increase the weight of the cover-glass (Fig. 2). A numerical example should illustrate this: Weight of a cover-glass, size 18 × 18 mm., is found to be 0·11 g. Since its surface is 3·24 sq.cm., its weight should be 0·227 g. The ring has to weigh 0·227 − 0·11 = 0·117 g. A small hole (*H*) is punched through the fabric (*F*). The fabric is now interposed between slide and cover-glass, the ring added on top of the cover-glass, and the thickness of the fabric estimated from the readings of the micrometer drum. Assuming a thickness of 0·7 mm. was found, we now have to look up in Table 1 the corresponding thermal insulating value. The entry corresponding to 0·5 mm. is 6% thermal insulating value, while the correct value has to be found by interpolation. (To 0·1 mm. increase in thickness corresponds an increase of 2% thermal insulating value; hence 6% plus 4% = 10% thermal insulating value.)



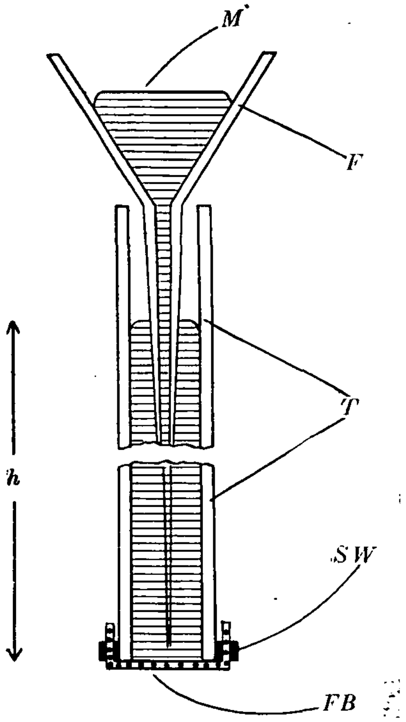
C	Cover glass	*R*	Cardboard ring
F	Fabric	*S*	Slide
H	Hole in fabric		

Fig. 2

(2) POROSITY

A standard method for testing the porosity of fabrics has been worked out by Marsh (1931). In his procedure porosity is estimated from the volume of air (ml.) passing in a second through a sample of 1 sq.cm. in size, when the pressure drop caused by the sample is 1 cm. of water. Air is aspirated through the sample by means of a fan, the difference in pressure before and after the sample is measured by a manometer, and the passing air volume determined by a gas meter. This arrangement is rather cumbersome to build up and can be replaced by the following method which we worked out and which is found to be far simpler:

A glass tube (Fig. 3, *T*) with an inner diameter of 6 mm. and about 20 cm. in height is taken. One end of the tube is heated and a layer of sealing wax (*SW*) applied to it. This layer forms a seal between the glass tube and the fabric to be tested. The seal is now reinforced by another layer of sealing wax. Then a glass funnel is drawn out so as to form a capillary (*F*). The capillary is now inserted into the tube and should nearly reach the fabric. Clean mercury* is next poured through the funnel. The mercury will now be seen to rise in the tube until a height (h) is reached which forces the holes of the fabric. When making parallel experiments with the air method and the mercury column a correlation ratio of $-0\cdot78$ between these two methods is obtained. Denoting by x the amount of air (ml.) passing through 1 sq.cm. of fabric in a second, by y the height of the mercury column (mm.) when mercury is first seen to pass the fabric, the following relationship is approximately valid:



F Funnel *FB* Fabric *h* Height of mercury
M Mercury *SW* Sealing wax *T* Glass tube

Fig. 3

$$y=31\cdot2+\frac{1108}{x^{0\cdot94}},$$

in other words both qualities are in inverse proportion to each other. This equation is only an approximation. Table 2 should be consulted for actual tests. On examining this table it will be seen that the mercury method shows a higher sensitivity in more closely woven fabrics, while its accuracy falls off for more loose fabrics.

Table 2

Height of Hg (mm.)	165	110	85	69	59	53	49	47	46
Air (ml./sec.)	10	20	30	40	50	60	70	80	90

DISCUSSION

Up to now no definite suggestions can be made as to the comfort experienced during the wear of different fabrics. In the experience of the author shirts with a mercury value of more than 85 cause a rather close feeling, especially on humid days. The role which thermal insulating value plays is far more difficult to estimate, since porosity falsifies the picture. It can, however, be shown that the thinner fabric causes greater comfort in case the mercury value is equal for two fabrics.

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* Clean mercury should not stick to glass. Cleaning mercury: Let mercury run into water through a capillary funnel as shown in Fig. 3, *F*. Repeat several times, finally using distilled water. Transfer to a funnel charged with filter-paper, which takes up the water. In case the mercury is still found to stick to glass, let the mercury run into 10% NaOH, then 10% nitric acid, wash, etc.

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(*MS. received for publication* 20. II. 1945.—Ed.)