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THE INFLUENCE OF CLOTHING AND TEMPERATURE ON SEDENTARY COMFORT

When the Chinese describe the weather, they do so in terms of the number of suits required for thermal comfort. They speak of a "one-suit" day when the weather is moderate, a "two-suit" day when it is a little cooler and a "twelve-suit" day when it is bitter cold.^{1,2} To treat this relationship between thermal environment and clothing more objectively, a modern interpretation might state that in order to maintain a condition of heat balance in the human body which would result in a thermal sensation of "comfortable" as the temperature decreases, more clothing is required. Conversely, as the temperature increases less clothing is required for man to be comfortable while engaged on any given level of activity.

To carry this axiom from the realm of the subjective into the laboratory, Gagge, Burton, and Bazett³ proposed the "clo" unit as a measure to quantify the insulative value of various clothing ensembles. Defined, one clo is the "the amount of insulation necessary to maintain comfort and mean skin temp of 92 F in a room at 70 F with air movement not over 10 ft/min, humidity not over 50% with a metabolism of 50 calories per square meter per hour" (resting condition)⁴ (p. 445).

Careful study of this definition will reveal that the clo unit is arbitrary. Nevertheless, it has been standardized with empirical evidence and has been assigned to various clothing ensembles by means of electrically-heated copper manikins. Winslow and Herrington² state that a resting nude male (zero clothing) is comfortable at 86 F when the humidity is moderate and the air movement is low. However, when one clo of insulation is worn, the air temp must be reduced to 70 F to obtain the same degree of comfort. Fanger⁵ has determined the relative effects of clothing and temp on thermal comfort by means of a comfort equation and it agrees favorably with the data in the new ASHRAE Comfort Chart^{6,7}.

New synthetic materials and styles of dress and fashion have dictated the need for additional information on the relative effects of clothing and temp on sedentary comfort and are the impetus for the present study. Its purpose is to determine the effects of various clothing ensembles on the thermal sensation on sedentary human subjects exposed to moderate temp.

METHOD

Test Conditions

For studying the effects of such corollary factors as lighting, crowding, incentive, and age on the thermal sensation, Rohles^{8,9} proposed a set of 15 temp-humidity conditions in which approximately 94% of sedentary men and women report feeling comfortable while clothed in a 0.6 clo ensemble. The Modal Comfort Envelope (MCE), as this set of conditions was called, was modified following a new determination of Effective Temperatures by Gagge *et al.*¹⁰ and served as test condition for a study of thermal comfort with

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elderly subjects.⁹ These same conditions were used in the present study and are presented in Table I.

Table I

Effective Temperature (ET), Dry Bulb Temperature (DBT), and Relative Humidity (RH), Conditions within the Modal Comfort Envelope

ET (F)	DBT (F)	RH (%)
79.7	80	45
79.1	80	35
78.9	78	65
78.6	80	25
78.3	78	55
78.2	80	15
77.9	76	85
77.8	78	45
77.4	78	35
77.2	76	75
77.0	78	25
76.7	78	15
76.6	76	65
76.2	76	55
75.8	76	45

Subjects

The subjects consisted of 75 male and 75 female college students. All were volunteers who were recruited from newspaper advertisements and each subject was paid \$15.00 for the series of tests.

Facilities

All tests were conducted in the ASHRAE Environmental Chamber which was transferred from Cleveland and placed into operation at Kansas State University, Manhattan KS, in 1963. This facility which has been described in detail elsewhere¹⁰ consists of a main chamber, 12 ft wide, 24 ft long, with an 8 ft ceiling, a 9 ft by 18 ft pre-test room, and a control room.

Clothing

Three clothing ensembles having clo values of 0.4, 0.6, and 0.8 clo were selected for study. For the male subjects, the 0.4 ensemble consisted of a cotton tank top, jeans, jockey shorts, and cotton socks; the 0.6 clo ensemble which has now become known as the Standard KSU Uniform consisted of a long-sleeve cotton twill shirt, cotton twill trousers, jockey shorts, and cotton socks; and the 0.8 clo ensemble consisted of a short-sleeve cotton shirt, a light cotton jacket, jockey shorts, jeans, and cotton socks. These three ensembles are shown in Fig. 1.

For the women subjects, the 0.4 clo ensemble consisted of a long-sleeve cotton shirt, a short, loose fitting cotton skirt, bra, panties, and cotton socks; the Standard KSU Uniform, measuring 0.6 clo was worn over bra and panties; and the 0.8 clo ensemble consisted of a short-sleeve cotton blouse, a medium weight sweater, cotton jeans, and bra, panties, and pantyhose. These ensembles for the women are shown in Fig. 2.

Procedure

The subjects reported for the test in groups of 10, 5 men and 5 women. On the first day, the purpose of the study was explained and instructions were presented concerning the garments that the subjects should bring to the second session to make up the 0.4 and 0.8 ensemble. This orientation period lasted approximately 30 minutes.

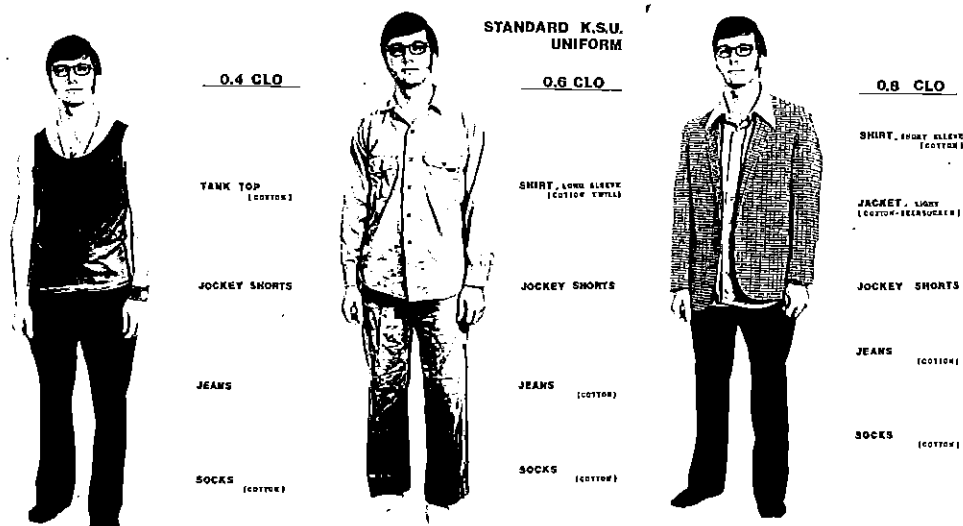


Fig. 1 Male subject dressed in three clothing ensembles

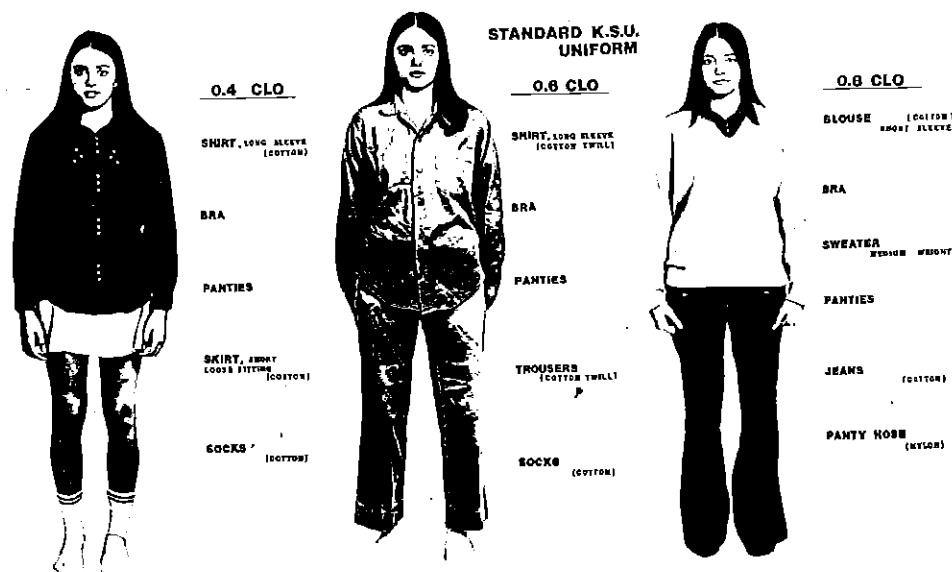


Fig. 2 Female subject dressed in three clothing ensembles

On the second day, when the subjects reported, they immediately had their temps taken orally and if their temp was within the range of $98.6\text{ F} \pm 0.2\text{ F}$ the subject was instructed to disrobe and dress in the KSU standard uniform which was provided. While this was being done, both the 0.4 and 0.8 ensembles were evaluated by a member of the staff of the Department of Clothing and Textiles, College of Home Economics, Kansas State University. If the clothing brought by the subjects met the required specifications, it was marked and held in the pre-test room. If it did not, the discrepancies were brought to the attention of the subjects concerned and the appropriate changes in the ensembles were specified; these were brought in by the subject before the third test.

After the clothing had been evaluated and the subjects instructed on the procedures for recording their thermal sensations, they entered the test chamber and the test began. The subjects sat at tables, and were permitted to read, study, or talk quietly; however, once they entered the chamber they were not allowed to leave. Exposure in the chamber was for three hours and ballots were distributed and the votes were recorded after 1.0, 1.5, 2.0, 2.5, and 3.0 hours. Immediately after each vote was taken, the ballots were collected so they could not be used as reference for subsequent votes. After recording the fifth vote at 3 hours, the subjects were free to leave.

It should be noted that the ballot employed was the same as that used in previous studies. A sample ballot is shown in Fig. 3.

The procedure of the third and fourth days was the same as on the second, with the exception of the clothing ensemble worn. For the third day the subjects were dressed in the 0.4 ensemble and the 0.8 ensemble was worn on the fourth day.

Subject: _____	
Name _____	No. _____
Circle the number that describes how you feel	
1. Cold	
2. Cool	
3. Slightly Cool	
4. Comfortable	
5. Slightly Warm	
6. Warm	
7. Hot	

Fig. 3 Sample Ballot

Results

Each of the five votes for men and women while wearing the three clothing ensembles was used in computing the analysis of variance. The results of this procedure are presented in Table II.

As indicated by the F-ratios there was no statistically significant difference in votes between men and women. This appears to be opposite to the results of earlier studies until examination is made of the sex and clothing and sex exposure (votes) interactions. Both of these F-ratios are significant at the 1% level of confidence and in the case of the S x E interaction evidence is provided that men and women exhibited different rates of sensory adaptation to the thermal environment during the three hour test period. Thus while the variance may point to the lack of sex

Table II
Analysis of Variance of the Thermal
Sensations (Votes)

Source	df	F-ratio	P
Sex (S)	1	1.921	(ns)
Individuals (I)	148	6.406	.01
Clothing (C)	2	313.679	.001
Exposure (E)	4	15.040	.001
S x C	2	6.144	.01
S x E	4	5.970	.01
C x E	8	0.646	(ns)
S x C x E	8	1.050	(ns)
Error	2072		
Total	2249		

*ns--not significant at the 5 per cent level of confidence

differences, the interactions demonstrate their presence. To illustrate these relationships more graphically, the mean thermal sensations for both men and women for each exposure period were plotted for the three clothing ensembles and are shown in Fig. 4.

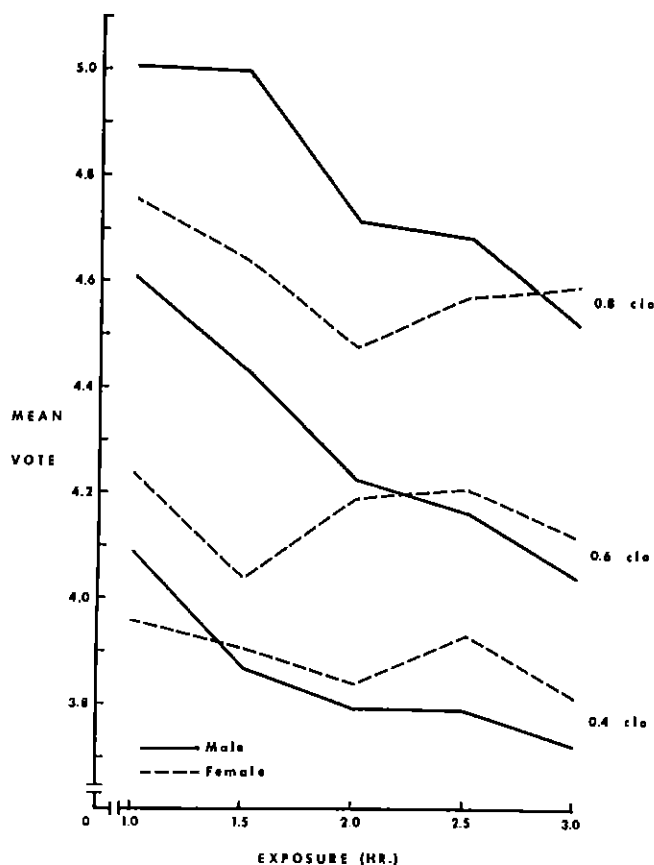


Fig. 4 Mean hourly thermal sensation of men and women while wearing ensembles having insulative values of 0.4, 0.6 and 0.8 clo.

As would be expected, the largest F-ratio was associated with the clothing variable; and adaptation to the thermal environment, similar to the sensory process of dark adaptation is evidenced by the significant F-ratio for Exposure.

In a further analysis, the thermal sensation vote was correlated with the clothing ensemble for men and women separately and for men and women combined for each of the five exposure periods. These correlations which are all statistically significant at the 1% level of confidence, together with their regression equations, are presented in Table III.

Table III

Regression Equations and Product-moment Correlations (r) for Predicting Thermal Sensations from the Clo (I_{cl}) value of Clothing Ensembles for Men, Women, and Men and Women combined after Five Exposure Periods to the Thermal Conditions within the Modal Comfort Envelope

Exposure-Sex	Regression Equation*	r
1.0 hour		
Male	$Y = 2.300 I_{cl} + 3.193$	.45
Female	$Y = 2.000 I_{cl} + 3.120$	.39
Combined	$Y = 2.150 I_{cl} + 3.157$	.41
1.5 hours		
Male	$Y = 2.833 I_{cl} + 2.736$	.54
Female	$Y = 1.833 I_{cl} + 3.096$	.36
Combined	$Y = 2.333 I_{cl} + 2.916$	.45
2.0 hours		
Male	$Y = 2.333 I_{cl} + 2.844$	.46
Female	$Y = 1.600 I_{cl} + 3.209$	.35
Combined	$Y = 1.967 I_{cl} + 3.027$	.41
2.5 hours		
Male	$Y = 2.267 I_{cl} + 2.858$	.46
Female	$Y = 1.600 I_{cl} + 3.280$	.31
Combined	$Y = 1.933 I_{cl} + 3.069$	.38
3.0 hours		
Male	$Y = 2.000 I_{cl} + 2.907$	.41
Female	$Y = 1.967 I_{cl} + 2.998$	.38
Combined	$Y = 1.983 I_{cl} + 2.952$	.39

*Y = Thermal sensation where 1 = Cold; 2 = Cool; 3 = Slightly Cool; 4 = Comfortable; 5 = Slightly Warm; 6 = Warm; 7 = Hot. I_{cl} = clo value.

In order to determine empirically the relationship between the insulative value of the clothing ensemble and the thermal environment, two equations were considered. The first equation was taken from the present study (Table III) for the men and women combined after an exposure of three hours. This is shown below:

$$Y = 1.983 I_{cl} + 2.952 \quad (1)$$

Where Y is the thermal sensation
and I_{cl} is the clo value

The second equation was taken from the research by Rohles and Nevins¹¹ and represents the multiple regression equation for predicting the thermal sensation from the temp and relative humidity for men and women combined after exposure of three hours; this is as follows:

$$Y = 0.151 T + 0.010 H - 8.371 \quad (2)$$

Where Y is the thermal sensation; T is the dry bulb temp in F; and H is the relative humidity in percent.

Since the new effective temp, ET^{*10} , was defined at relative humidities of 50%, a value of 50 was substituted for H in Eq (2):

$$Y = 0.151 T - 7.871 \quad (3)$$

The value of T in Eq (3) therefore may be considered as ET^* . Eqs (1) and (3) represent independent methods of predicting Y , the thermal sensation, and were combined as follows:

$$T = 13.13 I_{cl} + 71.68 \quad (4)$$

Eq (4) described effective temp as a function of clo values relative to the conditions of the MCE which was evaluated at 0.6 clo. Substituting 0.6 for I_{cl} in Eq (4) gives $T = 79.60$ F, and from Eq (3), $Y = 4.14$. The change in temp with respect to clo, as determined from the first derivative of Eq (4), has the value:

$$\frac{dT}{dI_{cl}} = 13.13 \text{ F/clo}$$

Therefore to maintain the same thermal sensation, Y , at various clo values, the necessary compensation in effective temp may be described as:

$$\frac{d}{dI_{cl}} (ET^*) = -13.13 \text{ F/clo} \quad (5)$$

Separating variables and integrating Eq (5):

$$ET^* = K - 13.13 I_{cl} \quad (6)$$

Since $ET^* = 79.6$ F at $I_{cl} = 0.6$ and $Y = 4.14$, the constant of intergration K was found to be 87.48, and:

$$ET^* = 87.48 - 13.13 I_{cl} \quad (7)$$

Eq (7) therefore may be used to predict the ET^* necessary to maintain a thermal sensation of $Y = 4.14$ for various clo values. This relationship is shown graphically in Fig. 5 together with similar relationships previously described in the literature.

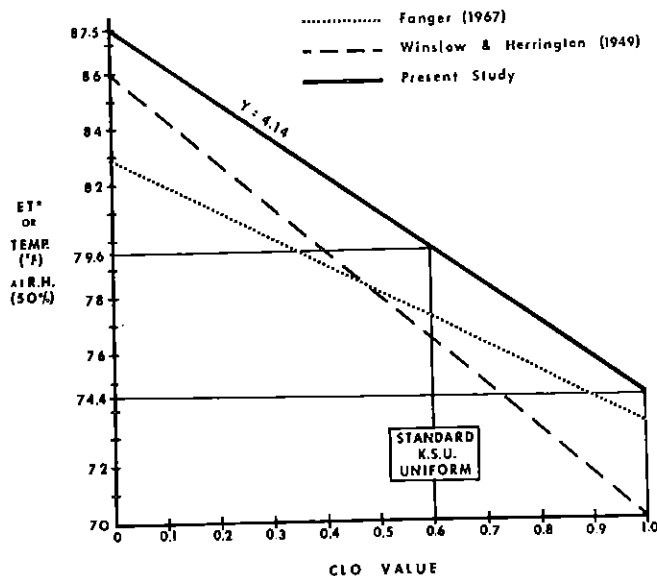


Fig. 5 Thermal comfort as affected by ambient temperature and amount of clothing.

It should be pointed out that the thermal sensation represented is a value of 4.14, slightly above the 4.0 value corresponding to "comfortable" on the seven point scale. If the thermal sensation is assumed to be 4.0, Eq (1) requires $I_{cl} = 0.528$. Substituting these conditions into Eq (4) yields $T = 78.61$ F, and from Eq (6), the predicted intercept at $I_{cl} = 0$ is 85.54 F. This agrees favorably with the finding noted above by Winslow and Herrington² which state that "with low air movement and moderate humidity, the resting nude subject is comfortable at 86 F."

Carrying this description further, in order for a subject to be comfortable while wearing a 1.0 clothing ensemble, the temp must be reduced to 74.4 F which is above the 70 F value suggested by Winslow and Herrington. But just as the nude value is higher in the present study so is the value for 1.0 clo. In other words, the two studies are in very close agreement.

Discussion

The concept of the MCE was proposed as a set of conditions which could be used to study the effects of the various constituents in the physical environment that affect the thermal sensation. Currently identified in the 1972 ASHRAE Handbook of Fundamentals⁶ as the KSU-ASHRAE Comfort Envelope, it was first used to study thermal comfort among elderly subjects. And as it proved fruitful in that study, the same was true in the present research.

From the results of the experiment several conclusions are apparent. First, the linear relationship between the three clothing ensembles demonstrates the accuracy of the clo measurements obtained from the copper manikin, and also attests to the reliability of the tests in which the subjects were attired in the KSU Standard Uniform. This afforded the opportunity to compare the results of this study with the data from the original MCE. While this will be the subject of a more detailed report, it suffices to mention that near-perfect agreement was found between the two sets of observations. The findings also support 86 F as the comfortable temp for a nude subject; however, this is reduced to 74.4 F when a 1.0 clo ensemble is worn. Eq (7) provides a means by which a comfortable effective temp can be predicted as a function of the insulation value of clothing. It can be seen from Fig. 5 that the slope of Eq (7) is slightly greater than Fanger's⁵ but less than that reported by Winslow and Herrington.² Also, the values predicted by Eq (7) agree more favorably with the data of Winslow and Herrington at clo = 0, but are in closer agreement with Fanger's data at clo = 1.0. Personal communication with Oleson¹³ from the Danish Laboratory of Heating and Air Conditioning concerning the Fanger's value of 82.9 F for nude subjects suggests that more recent data are in fact similar to the findings reported in this paper.

Perhaps the most significant finding of the experiment and one that should be considered for further study is the fact that the same clothing is responsible for different thermal sensations in men and women. This is evidenced by the significant Sex by Clothing interaction ($F = 6.1444$; $P < .01$)

The significance of both the clothing variable and the $S \times C$ interaction may be explained by two factors: (1) the permeability of the fabric to water vapor and (2) the "snugness" of fit of the ensemble itself. The former may markedly change the vapor pressure gradient between the skin and the surrounding ambient. Since 1/4 to 1/3 of the metabolic heat loss is by evaporation under normal conditions, this factor could produce responses that are warmer than comfortable. As indicated by Nishi and Gagge,¹⁴ evaporative heat loss is modified by an "efficiency factor" for moisture permeation and may vary from 1.0 to 0.8 for the KSU uniform. For "blast" jackets or garments with nylon shells, F_{pcl} could be as low as 0.2. The evaporative heat loss has been expressed by Nishi and Gagge as:

$$E = F_{pcl} W h_e (P_{sk} - P_{dp})$$

where: E = Evaporative heat loss
 F_{pcl} = permeability efficiency
 W = skin wettedness
 h_e = evaporative heat transfer coefficient
 P_{sk} = saturated vapor pressure at mean skin temp
 P_{dp} = saturated vapor pressure at ambient dew point temp

If the clothing has a low permeability, then P_{dp} approaches P_{sk} , therefore F_{pcl} , h_e , and P_{dp} must be interacting variables.

The second factor, or snugness-of-fit of a garment, influences the trapped air layer which, if not ventilated, is a major contributor to clothing insulation. One layer of fabric has negligible heat transfer resistance. If it traps a layer of air, the insulation value may increase significantly. However, the subjective reaction to a snug fitting sweater or pair of hose may be based on some other sensory input. These factors are described but currently have no experimental base. It is recommended that the latter effect should be investigated from a psychophysiological view point. The permeability question has received some study, but additional data are needed.

A third factor which can affect the insulation value of clothing is the air movement generated within the garment due to either activity or room air motion (e.g. arm-pumping during walking). In general the thermal resistance for convection heat transfer through the clothing is:

$$R = \frac{1}{h_{sk}} + \frac{X}{K_{ucl}} + \frac{1}{h_{ucl}} + \frac{X}{K_{cl}} + \frac{1}{h_{cl}}$$

where: R_t = Total convection Heat Transfer Resistance
 h_{sk} = Air film coefficient at the skin
 K_{cl} = thermal conductivity of underclothing of thickness, X
 h_{ucl} = air film coefficient between underclothing and outer garment
 K_{ucl} = thermal conductivity of clothing (outer garment) of thickness, X
 h_{cl} = air film coefficient at outer clothing surface

The terms h_{sk} and h_{ucl} are dependent on "fit" and on any pumping action which may occur and h_{cl} is a function of room air movement. Because the geometry and complexity

of this relationship are normally unworkable, the concept of the "clo" provides a lumping of these factors—a procedure which has proven useful and accurate. It must be remembered that I_{cl} is a complex function of all the parameters mentioned above.

As a general conclusion, the study provides empirical evidence on the interrelationship between clothing and temp and thermal sensation and as such identifies one of the major physical constituents that determines man's reaction to the thermal environment.

ACKNOWLEDGMENTS

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DISCUSSION

P.O. FANGER (Technical University of Denmark, Copenhagen): The authors should be complimented for having initiated the present study on the effect of clothing on man's comfort. I would like to make some comments, however. It is not mathematically correct to combine Eq (1) and Eq (2). Since Eq (1) applies for $T \sim 77.7$ F only, and Eq (2) applies for $I_{cl} = 0.6$ only, you are actually assuming that the relationship between the thermal sensation and the ambient temperature, determined at 0.6 clo in earlier studies, applies to other clo values. Heat transfer considerations make it evident that this is not correct. A change in ambient temperature of one degree has a larger effect on man's thermal sensation when he is nude than when he is heavily clothed. You need to transfer the thermal votes to preferred ambient temperature.

The problem is, however, that your present experimental data do not give you any information about the relationship between the thermal sensation vote and the ambient temperature at 0.4 and 0.8 clo, since you have not varied the ambient temperature (it was almost constant). From an earlier study you know this relationship, but only for $I_{cl} = 0.6$ clo.

I would suggest treating the data in this way. The subjects were exposed to a mean ambient temperature (ET^*) of 77.7 F. From Fig. 4 the mean votes (females + males, 3.0 hours) were 3.76, 4.08, and 4.55 corresponding to 0.4, 0.6, and 0.8 clo, respectively. This corresponds to preferred ambient temperatures of 78.8, 77.2, and 74.6 F (when using the value for $\frac{\delta T}{\delta Y}$ from Eq (3) for 0.6 clo, and

values for $\frac{\delta T}{\delta Y}$ from Fig. 23 in Ref 15 for 0.4 and 0.8 clo, corrected to constant RH). These three points and a regression line with the equation

$$T = -10.58 I_{cl} + 83.21$$

have been plotted in Fig. 6 together with the comfort equation. The slopes of the two lines are in remarkably good agreement. The main result of this study is the determination of the slope of the line, $\frac{\delta T}{\delta I_{cl}} = -10.58$ deg F/clo = -5.88 deg C/clo at constant RH.

A few years ago we determined $\frac{\delta I}{\delta I_{cl}}$ at constant vapor pressure by partial differentiation of the comfort equation.¹⁵ In Fig. 7, $\frac{\delta T}{\delta I_{cl}}$ is depicted as a function of activity,

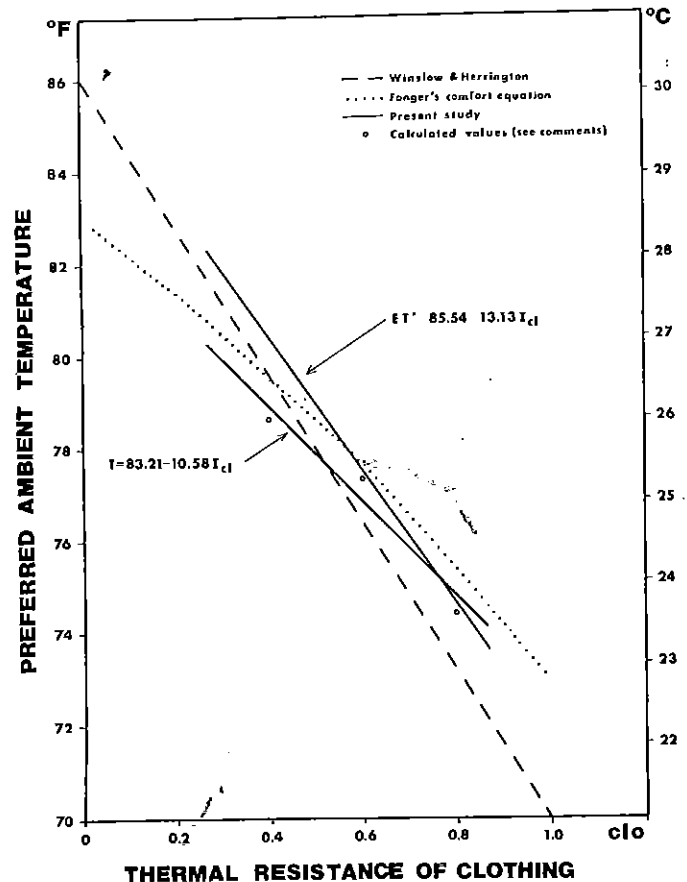


Fig. 6 Relationship between preferred ambient temperature and thermal resistance of clothing as reported by several investigators.

clo value, and air velocity. For constant vapor pressure ($p_a = 12.2$ mmHg) the regression equation for the present data was found to be

$$T = -11.50 I_{cl} + 83.67$$

The slope $\frac{\delta T}{\delta I_{cl}} = -11.50$ deg F/clo = -6.38 deg C/clo has been shown in Fig. 7 for comparison. It can be seen that there is excellent agreement between the present study and our curves from 1970.¹⁵

It should be noted from Fig. 7 that $\frac{\delta T}{\delta I_{cl}}$ is quite independent of clo value and velocity, but increases with the activity level. The experimental results of the present paper should therefore be used only at sedentary activity.

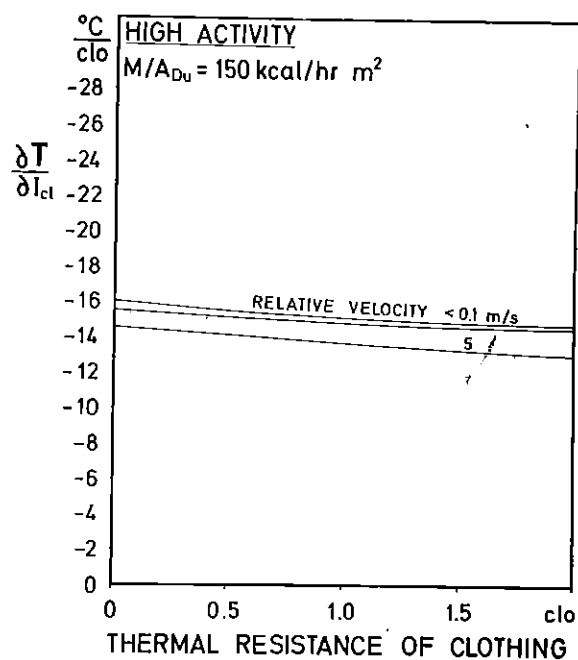
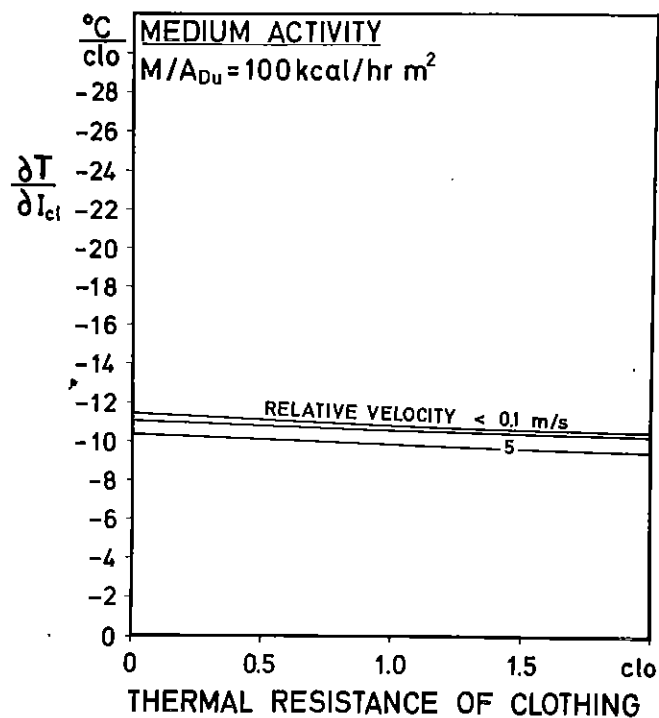
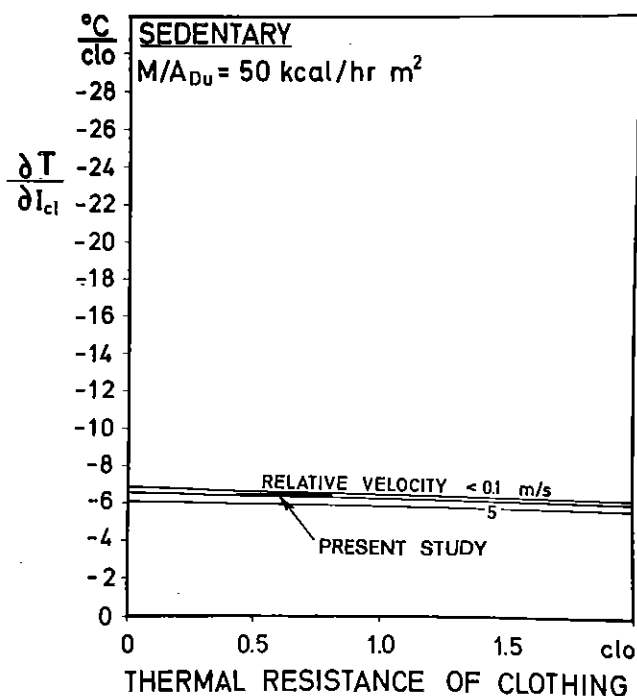


Fig. 7 $\frac{\delta T}{\delta I_{cl}}$ as a function of the clo value with rel. velocity as parameter at three different activities (constant vapor pressure). $\frac{\delta T}{\delta I_{cl}}$ indicates the change in ambient temperature necessary to maintain thermal comfort when the clo value is increased by one unit.¹⁵ Shown for comparison is the value of $\frac{\delta T}{\delta I_{cl}}$ determined in the present study.

DR. ROHLES: Before addressing our remarks to your specific comments, I would like to make an observation. By using the Modal Comfort Envelope we are employing a technique not at all unlike a partial regression analysis. In effect, then, we are determining the effects of the clothing ensemble when holding temperature constant. Therefore, instead of stating that we *need* to "transfer the thermal votes to preferred ambient temperature," I assume you mean we should specify the clothing-temperature relationship for a "4" comfortable condition. But the value of this exercise is questionable when we examine your procedures for analyzing our data and compare them with our results and find little or no difference between the two.

MR. WOODS: Dr. Fanger has suggested an alternate method of treating the data to arrive at the predicted thermal conditions necessary for comfort at various values of clothing insulation. It is true that heat transfer considerations indicate that the thermal sensation of a nude man will be affected to a greater extent by a change in ambient temperature than will the thermal sensation of a heavily clothed man. However, lacking experimental data, we assumed a constant $\partial Y/\partial T$ for the range of clo values tested, 0.4 to 0.8, not over the range 0.0 to 1.5 clo.

Comparing results of the two methods, the maximum error was approximately 0.5 deg F between "preferred ambient temperature" and "Effective Temperature". Also, the other comparisons of slope and intercept are in agreement within the accuracy of the experiments and engineering practice. The difference between the intercept of the equation you derived, 83.21 F, and the intercept of 85.54 F we have reported, which was corrected to a 4.0 (comfortable) thermal sensation, is negligible considering that the correlation coefficient for Eq (1) estimates that only 16% ($r^2 = 0.16$) of the variance in thermal sensation was attributable to the clothing insulation over the range tested. This also is evidenced in the near-identical slopes of the regression lines. Assuming you corrected your "preferred ambient temperature" to the constant relative humidity of 50%, we have superimposed the predicted ET* values of 80.3, 77.7, and 75.0 for I_{cl} values of 0.4, 0.6, and 0.8 clo, respectively, on Fig. 6, which displays the similarity graphically. The values suggested by Winslow and Herrington (i.e., 86.0, 76.4, and 70.0) shown in Fig. 5, are also shown in Fig. 6. It is interesting to note that the predicted ET* at 0.6 clo is practically identical to your original "Predicted Ambient Temperature" and varies on both sides of the line with clo, whereas the straight line fit you calculated from our data is consistently lower than your original line.

The relationship you discuss between "preferred ambient temperature" and clo at constant vapor pressure is interesting and supports the data reported by Rohles and Nevins¹² regarding the minor influence of humidity in the range of thermal comfort.

Your statement that the results from the present experiment should be used only at sedentary conditions (as noted in Fig. 7) we believe is explained in the title of the paper.

DR. FANGER: What criteria did you use for assessing and selecting the subjects' personal clothing used in the 0.4 and 0.8 clo clothing ensemble?

DR. ROHLES: The clothing ensembles for 0.4 and 0.8 clo were identified in a survey by the Department of Clothing and Textiles, Kansas State University, as common apparel in the majority of the wardrobes of the college students at Kansas State University. In order to insure uniformity of the ensembles, on the first day of the study the subjects were instructed on the clothing ensembles that they should bring with them; these were evaluated to determine if they met the criteria in terms of fit, material, and condition of wear established by the staff of the Department of Clothing and Textiles of the College of Home Economics. The paper by Seppanen et al¹⁷ identifies similar types of garments used in the study.

DR. FANGER: In three earlier KSU papers you reported the clo value of the KSU uniform as being measured at 0.52 (Nevins et al¹¹), 0.59 (McNall and Biddison¹⁶), and 0.69 (Seppanen et al¹⁷). Which value do you think is most reliable?

DR. ROHLES: The reported clo values of the KSU Standard Uniform are also a concern to us. I believe we can disregard the 0.52 clo reported in the Nevins et al study because in subsequent research the KSU Standard Uniform was reevaluated at 0.6 clo. This is the rounded value of the 0.59 reported in the McNall and Biddison study. However, it represents a difference of 0.09 clo from the value of 0.69 reported by Seppanen et al. The fact that the thermal sensations reported in Fig. 4 appear essentially equally spaced between the three clothing insulation levels leads us to believe that the 0.6 clo value is probably correct. However, your point is well taken and certainly is a question that we should address immediately for a consistent and valid evaluation of the insulation of this ensemble.

DR. FANGER: Concerning the clothing ensembles in Figs. 1 and 2, were the male subjects asked to wear the jacket unbuttoned as shown in Fig. 1? This might influence the clo value somewhat, especially for sedentary subjects. Also, of what type fiber was the sweater worn by the females made?

DR. ROHLES: The subjects were seated and the jackets were worn unbuttoned. Granted this might affect the clo value to some extent; however, if all the subjects operated under the same rules, we would expect a constant error which would not affect the results. The sweater worn by the females was constructed of lamb's wool.

DR. FANGER: You did not randomize the order in which each subject participated in the three tests (0.6, 0.4, and 0.8). Is there any experimental evidence to show that there was no order effect (the subjects being more trained in the 0.8 clo test than in the 0.6 clo test, where they were naive)?

DR. ROHLES: To employ the random wearing of the three garments, six different orders (five additional) would be required. Each of these would employ 150 subjects and would add \$11,250 to the cost of the study. Obviously, this would be prohibitive and since twenty-four hours elapsed between the tests it is difficult to imagine how any order effect could occur.

DR. FANGER: You stated "that the same clothing is responsible for different thermal sensations in men and women". This is not obvious when comparing the mean votes, which were nearly identical for males and females at all three clothing levels (3 hours).

DR. ROHLES: Your statement, as it pertains to the third hour, is valid; nevertheless, the sex by clothing interaction is significant at the 1% level of confidence and is probably brought about by the discrepancy between the sexes during the early part of the exposure. This is apparent in the

graphs themselves.

DR. FANGER: The formula for the thermal resistance, R , might give the false impression that the film coefficient at the outer clothing surface is included in the clo value.

What do you mean by the "Total Convection Heat Transfer Resistance"? I guess it should be the "total heat transfer resistance". But in that case several radiative terms are missing in the formula.

DR. NEVINS: The equation for the "total convection heat transfer resistance" is an attempt to illustrate the several series resistances in the convection pathway from the skin surface to the ambient air, excluding the parallel heat transfer paths which may exist for evaporation and radiation.

It is important to note that I_{cl} is not equal to R_t since I_{cl} *does not* contain the film coefficient, h_{cl} , at the outer surface of the garment.