WEARING THE RIGHT clos

A complexly instrumented copper manikin provides insulation values—expressed in "clo" units—to aid in choosing comfortable apparel for any climate

BY JULIE ANN MILLER

With President Jimmy Carter's recent extension of the voluntary temperature controls to conserve energy, most businessmen can look forward to a sweaty summer, and most businesswomen can expect to shiver next winter. The federal program directs that thermostats in nonresidential buildings be set to cool no lower than 78° F and to heat no higher than 65° F. But following the guidelines does not eliminate all hope of comfort indoors. By adjusting what clothes they wear, people can be comfortable at the prescribed temperatures, Elizabeth McCollough of Kansas State University told the recent meeting in Houston of the American Chemical Society.

"Changing the insulation value of clothing is the most economical and effective way of providing thermal comfort under these conditions," she says. "Although people cannot be compelled to alter their clothing habits drastically, dress codes should be modified to allow people to adjust their clothing more effectively."

"Men are in a bind in the summer unless they radically change what they're wearing," says McCollough. "A male executive is way overdressed." She calculates that a short-sleeved shirt, bermuda shorts, socks and sandals would be more appropriate summer office wear.

On the other hand, women have more trouble keeping warm in the winter. McCollough has determined that it takes a long-sleeved blouse, vest, jacket, pants, socks and boots to get into the comfort range at 65°F.

A manikin named Sam the Copper Man adds the weight of scientific measurements to common clothes sense. McCollough, Frederick H. Rohles and other colleagues at Kansas have measured the insulation values of dozens of individual garments and complete outfits. The result so far is some practical, if unfashionable, advice.

The Kansas manikin is the only U.S. civilian copper manikin in the thermal comfort business. There is one in Copenhagen, Denmark, and another in Hohenstein, Germany, but the only other copper manikins instrumented for thermal comfort research in this country belong to the military. The army uses them to design appropriate uniforms for various climates.

Sam is made of black anodized copper in the form of a man, although he is often decked out in ladies' garments. Heating wires in a cloth carrier are bound to the inside of the copper skin, and sixteen thermistors monitor skin temperature. The researchers record how much power is needed to maintain a constant skin temperature of a comfortable 92° F. From that power measurement, with equations that take into account the air layer around the manikin, the investigators calculate the insulation value of a garment or an outfit. That value is given in a unit called a "clo."

The Kansas researchers have measured clo values for a variety of men's and women's garments and clothing ensembles. They developed, and then simplified, equations to be used to estimate the clo value of an outfit from the values of its parts. The standard, expected to be adopted soon by the American Society of Heating, Refrigeration and Air Conditioning Engineers, estimates that the insulation value of an ensemble is 0.8 times the sum of the values of the individual items. The factor 0.8 reflects the compressibility of garments; two sweaters of equal warmth worn together, for instance, are not twice as warm as one worn alone.

Over the last 50 years, winter clothing has become lighter and the temperatures at which people feel comfortable have risen, McCollough says. In 1930, people were comfortable when sedentary at 65° F; today that temperature is 72° F to 78° F.

Now, to conserve energy, the time may have come to reverse the trend, with the help of data from Sam. McCollough says, for instance, a person engaged in seden-

Intrinsic Insulation (CLO)

FOR WOMEN'S CLOTHING ITEMS

Bra and Panties:		0.05		
Slip:	Full	0.19	Half	0.13
Dress:	Light	0.20	Heavy	0.63
	Add	10% for long sleeves		
	Deduct	5% for above knee		
	Add	5% for below knee		
Blouse:	Light	0.20	Heavy	0.29
	Deduct	10% for short or no sleeves		
Skirt:	Light	0.10	Heavy	0.22
	Deduct	5% for above knee		
	Add	5% for below knee		
Slacks:	Light	0.26	Heavy	0.44
Jacket:	Light	0.17	Heavy	0.37
Sweater:	Light	0.17	Heavy	0.37
	Deduct	10% for short or no sleeves		
Stockings:	Short	0.01	Panty Hose	0.01
Shoes:	Sandals	0.02	Boots	0.08
	Pumps	0.04		

FOR MEN'S CLOTHING ITEMS

Underpants:		0.05		
Undershirt:	Sleeveless	0.06	"T"	0.09
Trousers:	Light	0.26	Heavy	0.32
Shorts:	Short	0.15	Long	0.22
Shirt:	Light		Heavy	
	Short sleeves	0.14	Short sleeves	0.25
	Long sleeves	0.22	Long sleeves	0.29
	Add: 5% for turtle neck			
	Add: 5% for tie			
Sweater:	Light	0.20	Heavy	0.37
	Deduct 10% for short or no sleeves			
Vest	Light	0.15	Heavy	0.29
Jacket:	Light	0.22	Heavy	0.49
Socks:	Ankle	0.04	Knee High	0.10
Shoes:	Sandals	0.02	Boots	0.08
	Oxfords	0.04		

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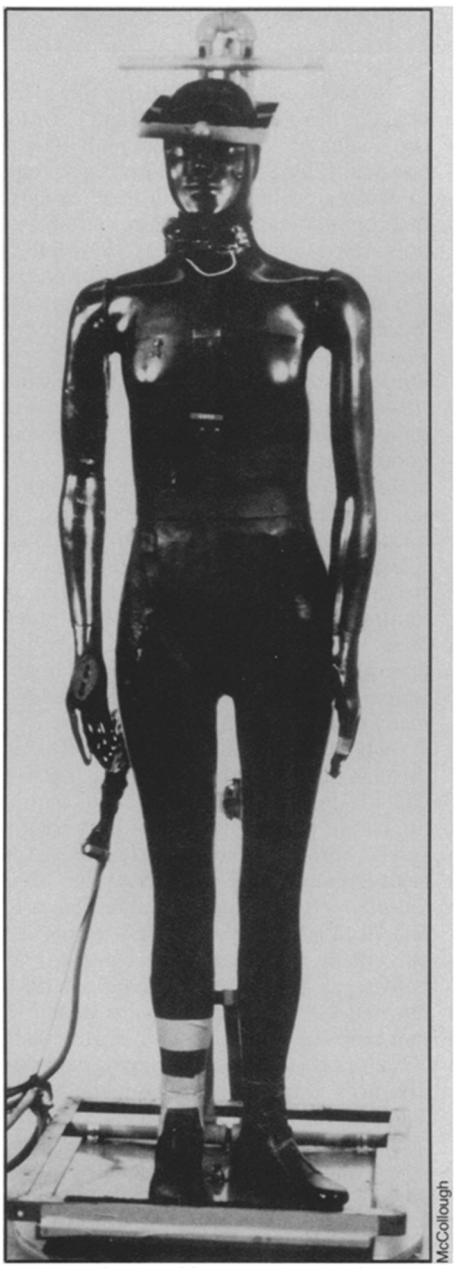
tary work at an air temperature of 65°F should wear between 1.2 and 1.5 clo. From the tables, a woman's outfit consisting of a heavy suit jacket, slacks, sweater, light blouse, bra, panties, stockings and boots has a clo value of 1.24. But for practical reasons it would be difficult to boost an outfit's insulation value much higher. "Although convective heat loss is largely a function of fabric thickness, there is a limit to how much bulk and weight a person can add. Thick cumbersome clothing can restrict mobility and contribute to a less attractive appearance according to current fashion standards," McCollough says.

In summer, a person's clothing insulation should be reduced to between 0.2 and 0.5 clo to provide comfort at 78°F. Men wearing a short-sleeved shirt, tie, light long trousers, underwear, socks and shoes are just at the comfort limit with a clo value of 0.5. Shorts and sandals would make more sense, but that little clothing may be socially unacceptable in indoor environments, McCollough admits. She says, "In addition some people are reluctant to wear shorts and reveal their legs."

McCollough and other researchers have suggested that consumers would benefit from clothes in the stores being labeled with clo values. Such labels could help shoppers select appropriate clothing for different environments.

Because there are practical limits to the number of garments that can be tested on Sam, and because such a specialized manikin would be too expensive for individual clothing manufacturers to obtain, McCollough suggests that researchers develop a table of clothing items described by design and fabric properties such as weight, thickness and air permeability. Manufacturers who want to label their products could estimate the insulation value from the tables.

Jackets and other outerwear are already labeled, in some cases, by the manufacturer with a "comfort range." McCollough has performed tests on jackets for a manufacturer who wanted to evaluate a new insulation material. Her results convinced her that many of the claims now being made are based on inadequate testing or no testing at all. While she wouldn't give specific results, McCollough says that as a general rule, the fiber content of a material is not as important in determining its warmth as are the thickness and weight of the fabric. In short, the thicker and heavier the garment, the warmer.


McCollough

Sam the Copper Man is lined with heating wires and studded with thermal sensors.

A multitude of questions about clothing warmth still face Sam. The next large project McCollough has planned is to dress the manikin in a variety of styles of clothes made from the same fabric to see how design — for example, a full, pleated, wrap-around or straight skirt—influences insulation values.

Of course the clo value doesn't tell everything about thermal comfort. For instance, the moisture permeability of a garment influences its comfort at high temperatures or high activity levels. Another table of values can be assigned to that parameter. To determine a moisture permeability index the researchers make Sam sweat by garbing him in a wet cotton skin before dressing him. The value of moisture permeability is determined from equations, again using the power required to maintain the manikin's skin temperature at 92° F.

Another area that is now opening is the role of psychological factors in the perception of thermal comfort, McCollough says. Brainless Sam, unfortunately, cannot contribute here. However, in studies of human subjects, the surroundings have been found to play a significant role in a person's comfort. Lighting and furnishings of a room, as well as the setting of a dummy thermostat, influence whether people report being chilly or warm. Even the textiles and design of the chair in which a person sits can be an influence, McCollough adds. So keeping warm or cool while conserving energy may eventually involve the talents of interior decorators and psychologists, as well as of architects and fashion designers. □