The Thermal Insulation of Caribou Pelts

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Abstract

The thermal insulation of samples of three caribou pelts, six other pelts, and one pile fabric was measured in still air and in winds up to about 26 mph. In still air the values, including ambient air layer, ranged from 2.0 clos for the pile fabric to 5.4 clos for the winter caribou. In a 25-mph wind the insulation afforded by most of the samples dropped to about 50% of the still-air value; notable exceptions were winter caribou, which dropped to only 58%, and winter deer, which dropped as low as 38%.

Introduction

The study of arctic clothing has of recent years become a subject of some importance, and it is natural that those who were first interested in this field of investigation should have attached considerable significance to the means by which the Eskimo clothed himself to face the elements, namely, the caribou skin. A certain school of thought arose which believed that caribou clothing had exceptional qualities extremely difficult if not impossible to duplicate by other means.

The work described in this communication was undertaken to decide whether caribou really did differ particularly from any other skin which was thickly covered with hair or if availability was the reason for its use by the Eskimo. The investigation therefore was not planned with a view to comparing the thermal insulation required by different animals in different climates, which is of course a subject of great interest to biologists [9]; the aim of the work was rather to find out if caribou skin used as a material for garments was superior to any other kind of fur.

The investigation comprised essentially the measurement of the thermal conductance of the various samples in still air and in winds up to about 26 mph, with the hair side of the pelt in the wind. The thickness and weight of each sample were measured later in order to aid in the general assessment of caribou as an insulator.

Methods

The hot-plate apparatus used for measuring the thermal conductances was similar to that described by Cleveland [2]. It was constructed by the Textile Section, Division of Chemistry (N.R.C., Canada), and has been described by Larose [7]. It

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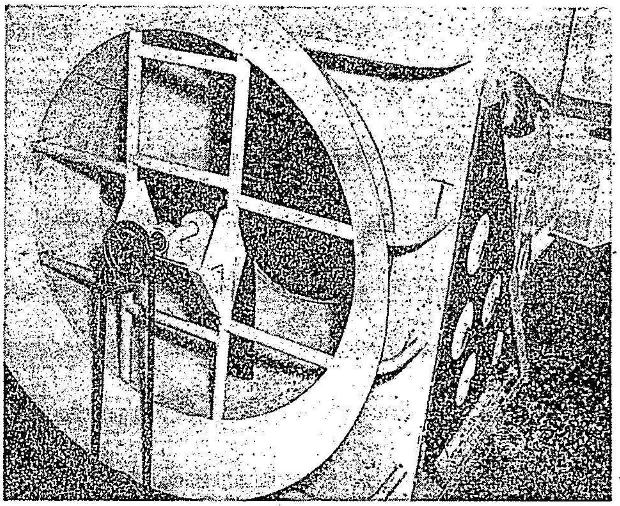

Fig. 1. Full-length view of wind tunnel, showing fan, controls for regulating speed of fan, outlet of tunnel above the apparatus, and the wind screen for still air tests.

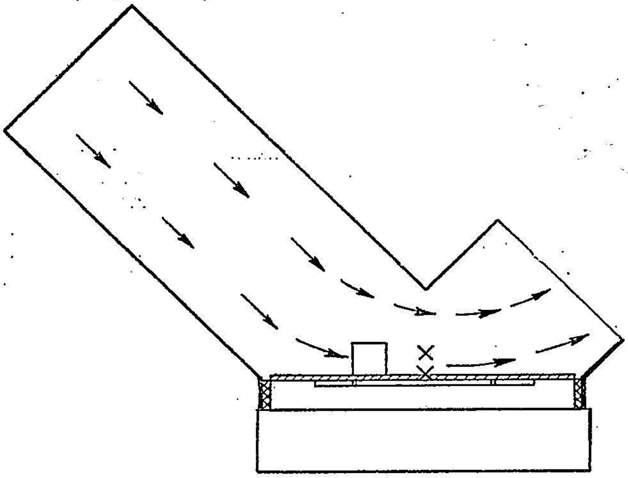

Fig. 2. Longitudinal section of that part of the wind tunnel over the apparatus, showing the air flow over the sample, the anemometer at one station, and the thermocouples at the surface of the sample and in the air above it.

consisted, briefly, of an electrically heated brass plate 10 in. square surrounded by a 2-in. guard ring with a lower plate to prevent heat flow downward. Thermocouples on the central plate, guard ring, and lower plate enabled the operator to keep the guard ring and lower plate to within 0.02°C of the central plate, while the latter was held at a temperature of around 37°C.

The apparatus stood in a wind tunnel, a photograph of which is shown in Figure 1. The wind was generated by a powerful 36-in. fan running in the cylindrical part of the tunnel, and air was forced into a rectangular cross-section 22½ in. wide by 12 in. deep, which was arranged at an angle of 45° to the surface of the plate, as illustrated in Figure 2. The fan was driven by a dc motor and speeds could thus be varied from 5 to 26 mph. To measure the wind velocity a Negretti and Zambra vane anemometer was used. It was placed on the surface of the sample at five positions, shown by circles in Figure 3. The average of the readings was taken as the wind-velocity value. The crosses in Figure 3 indicate the positions of the thermocouples.

Since very slight air movement in a "still air" measurement of conductance makes an appreciable change in value, special provision had to be made to shield the sample from draughts. The last portion of the wind tunnel was therefore constructed to lift off and permit a wooden frame covered with two layers of cheesecloth to be placed over the plate.

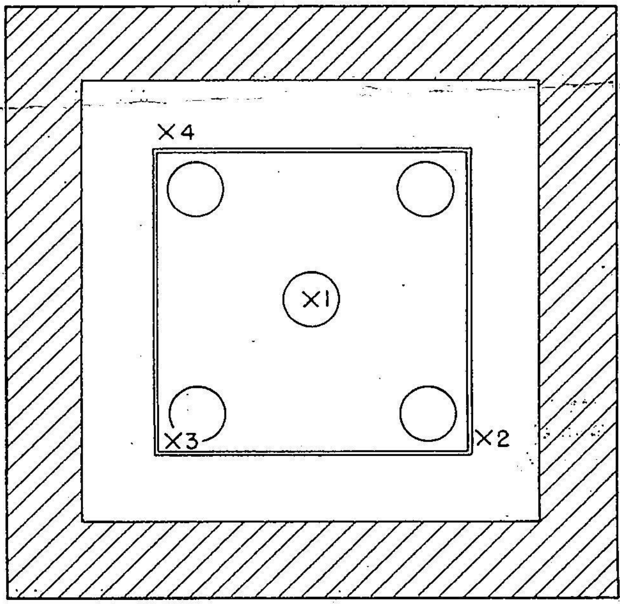

Fig. 3. Top view of the apparatus showing by crosses the positions of the thermocouples in the hot plate and guard ring and by circles the five stations for measuring wind velocity.

This screen can be seen in Figure 1, standing near the hot plate but not in use. The room in which the wind tunnel was situated was controlled at approximately 75°F.

Since there are wide differences in the thermal insulation values of caribou skins, three samples

TABLE I. Description of the Fur Samples

Type of Fur	Part of Pelt Used	Skin	Hair Structure	Hair Density
Caribou (Winter)	Neck and back	Chrome tanned, thick	Cellular and brittle, fairly coarse,	Very great
Caribou (Summer)	Back and flank	Untanned, a bit stiff, thinner than winter caribou	Cellular, not brittle and finer	Somewhat less than that of winter caribou
Caribou (Thin summer)	Back and flanks	Untanned, quite stiff, not flat, very thin	Cellular, not brittle and finer	Less than summer caribou
Deer (Winter)	Back	Chrome tanned, thick	Cellular, brittle and coarse	About half that of winter caribou
Arctic Wolf	Back and flanks	Tanned, quite thin and soft	Solid, not brittle, guard hairs coarse, underfur soft and fine	Guard hairs not very dense, underfur very dense
Raccoon	Back and flanks	Commercially tanned and stitched	Solid, guard hairs coarse, underfur soft and fine	Guard hairs not very dense, underfur very dense
Beaver	Back and flanks	Commercially tanned, very soft and thick	Solid, both guard hairs (very few) and underfur sheared	Underfur very dense on flanks, much less dense on back
Muskrat	Back and flanks of four pelts	Commercially tanned and stitched together	Solid, guard hairs less coarse, and underfur very soft and fine	Less dense than the other furs
Rabbit	Many small pieces	Commercially tanned and stitched together	Solid, no guard hairs, underfur sheared and dyed black	Same as muskrat
Pile fabric		Cotton ground fabric	Single mohair pile woven on ground fabric	50 tufts per square inch

were taken, a winter pelt, a summer pelt, and a light summer pelt presumably from a young animal. Taking several samples of each of the other furs was not important provided that pelts from a variety of species were used and provided the sample of each was of normal commercial grade. These pelts included deer, arctic wolf, raccoon, beaver, muskrat, and rabbit. The beaver was sheared and lacked the guard hairs; the rabbit was sheared and dyed black and actually came off an old worn coat. A sample of mohair pile fabric was included in the tests. Some details of the actual samples used are given in Tables I and II.

A sample for test was placed, with the fur side upward, flat on the hot plate and tacked in position, usually with the hair pointing downwind. One thermocouple was placed near the center of the surface of the sample and another one in the air $1\frac{1}{2}$ in. directly above it. This height seemed reasonable since Larose [7] found that the temperature of the ambient air layer did not vary significantly from heights of 0.6 in. to 8.0 in. above the surface. Thermal equilibrium was considered to have been reached if, with constant current in the central plate circuit, no appreciable change was observed in No. 1 thermocouple for a period of 1 hr. The conductance could then be calculated from the equation

$$C = \frac{I^2R}{JA(t_1 - t_2)}$$

where I and R are respectively current and resistance of central plate; J, the mechanical equivalent of heat; A, area of central plate; t_1, the temperature of the central plate; and t_2, the temperature either at the surface of the sample or $1\frac{1}{2}$ in. above, depending on whether the resistance of the ambient air film

TABLE II. Some Physical Properties of the Fur Samples

Type of Fur	Thickness in Inches under Pressure of 0.10 lb/in.²	Thickness in Inches under Pressure of 0.0 lb/in.²	Weight (oz)	Length of Hair (in.) Guard	Length of Hair (in.) Under-fur
Caribou (Winter)	1.13	1.29	15.2	—	2.0
Caribou (Summer)	0.30	0.47	7.8	1.8	0.7
Caribou (Thin summer)	0.22	0.29	5.3	1.6	0.5
Deer (Winter)	0.82	0.94	12.5	—	2.2
Arctic Wolf	0.47	1.08	9.3	3.6	1.3
Raccoon	0.24	0.52	9.3	2.3	1.2
Beaver	0.31	0.66	10.0	0.6*	0.6*
Muskrat	0.13	0.27	7.1	1.5	0.7
Rabbit	0.17	0.37	8.6	0.6*	0.6*
Mohair Pile Fabric	0.42	0.50	11.2	0.5	0.5

* Hair sheared to an even length.

was to be excluded or included. When the heat is measured in calories, the temperature in degrees centigrade, the area in square meters, and the time in seconds, the thermal resistance (R) in clo units [6] can be calculated directly from the equation $CR = 1.543$.

Results and Discussion

In plotting the results resistance rather than conductance values have been used. Figures 4 and 5 show resistance plotted against wind velocity when the ambient air film is included. Winter caribou is clearly shown to be the best of all the samples tested. However, Figure 5, in which the three caribou samples are compared, shows that summer caribou is only about half as good as winter caribou. Comparing the two diagrams it is easy to see that summer caribou only rated about as high as sheared beaver while the light summer caribou was about as good as muskrat. The comparison of caribou with deer in Figure 4 is of interest, because the resistance values in still air differed only slightly, but in wind the pelt of the forest animal was much inferior to the pelt of the animal of wind-swept arctic wastes. By examining the pelts one can see quite easily why this is so: the caribou hair stands up like soft close-packed bristles, while the hair on the deerskin can be pressed down with the hand much more readily. Raccoon and arctic wolf both turned out to be better than summer caribou.

In Figure 6 the effect of wind on the ambient air layer is illustrated. Broken lines refer to resistance calculations excluding the air layer and solid lines, those including the air layer. As one might expect, the air layer exerts a negligible effect at high wind velocities. It is at low wind velocities that the air layer is important, and some rather puzzling results were obtained, indicating a rise of resistance with wind velocity if the velocity was low and the resistance excluded the air layer. This effect was quite pronounced for a sample of raccoon measured with the fur lying "upwind." All the other samples referred to in Figure 6 were measured with the fur

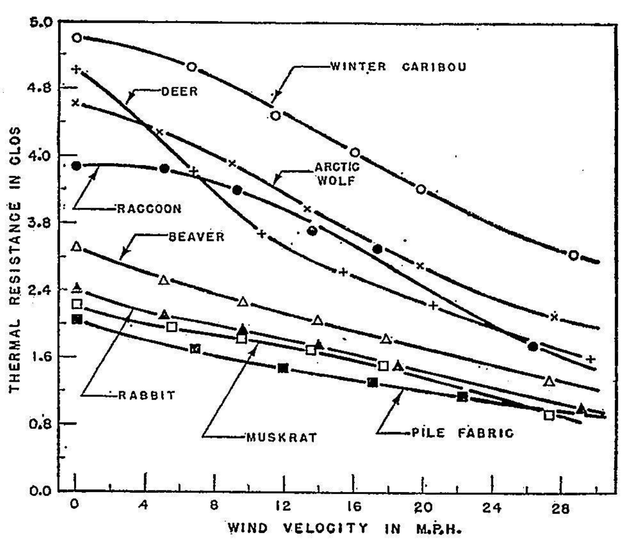

Fig. 4. Thermal resistance of the fur samples plus ambient air plotted against wind velocity.

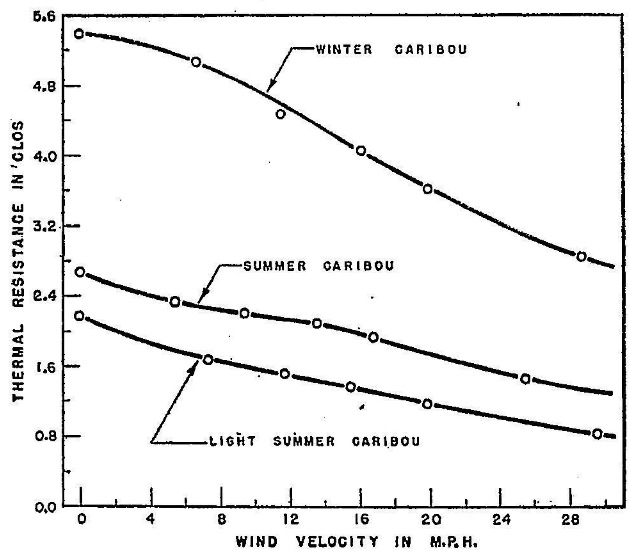

Fig. 5. Thermal resistance of the three caribou samples plus ambient air plotted against wind velocity.

lying downwind. The author suggests that the explanation of this finding is that the wind blows the hair out so that the depth of the fur is actually increased and the thermocouple is then below the surface. Too definite conclusions must not, however, be drawn about this rather academic point, since the exact position of the surface of an unsheared fur is somewhat indefinite.

While the graphs in Figures 4 and 5 give a fairly good estimate of caribou, there are some special aspects which possibly warrant consideration in making a comparison with other furs: namely, (a) the effect which wind has in decreasing thermal resistance, (b) the thermal resistance when thickness is taken into account, and (c) the thermal resistance when weight is taken into account.

a. The effect of wind in decreasing the insulation of a fur can be judged superficially from the slopes of the graphs. Table III gives this comparison in actual figures and shows that winter caribou stands out as superior to any of the others; winter deer is very poor.

b. When thickness is taken into account, Table IV indicates that caribou should be rated as poor. Of course, it must be conceded that the measurement of thickness is difficult and an error in this factor can give a misleading impression, but the evidence that caribou is superior to other furs on this basis of comparison is certainly lacking.

It is of interest to note in passing that the average of the nine natural fur samples which were tested gives a figure of 4.4 for the clo value per inch of pelt thickness using an uncompressed thickness value. The average of clo values per inch found by several investigators [3, 4, 8] for the resistance of fabrics when the thickness was measured under a pressure of 0.1 lb/in.^{2} is about 4. Using thickness values measured under 0.1 lb/in.^{2} pressure in the calculations for the furs led to impossible values for muskrat and raccoon, which were much higher than the value for still air at 25°C given by Fourt and Harris [5] at 6.8 clo/in. The ruling of the Canadian Government Purchasing Standards Committee [1] that thickness of pile fabrics should be measured under 0.10 lb/in.^{2} pressure cannot then be applied to furs unless the thermal conductivity tests are also to be carried out under a 0.10 lb/in.^{2} pressure.

c. When weight is taken into account the third column of Table V again fails to show any superiority for caribou. The figures in this column were obtained by dividing the clo value by the weight per square yard, and they give a measure of the insulation which a wearer gets for the weight of clothing he carries. In the fourth column of the table percentage of fur to total weight of hide plus hair is given: caribou shows up poorly.

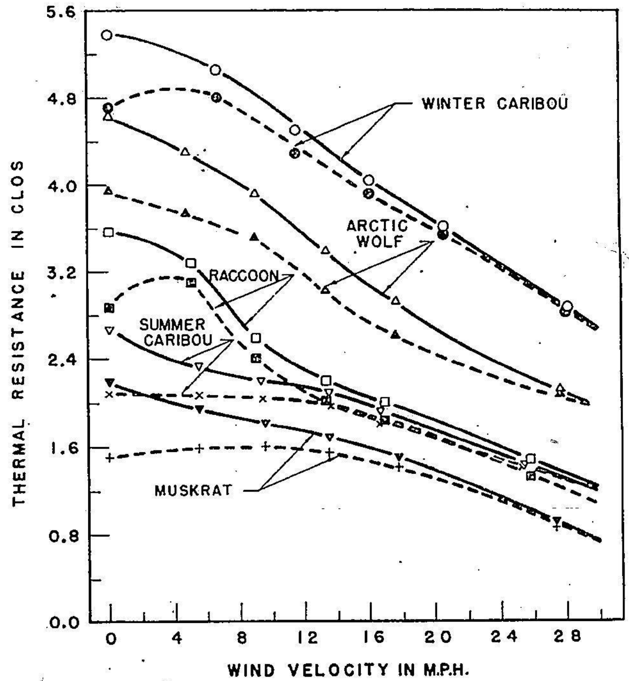

Fig. 6. Comparison of the thermal resistance of the sample only and of the sample plus the ambient air for five of the furs.
O——O Thermal resistance of sample plus ambient air vs. wind velocity.
⊕- - - - -⊕ Thermal resistance of sample only vs. wind velocity.

Altogether these more specific ways of rating caribou with the exception of (a) fail to demonstrate its superiority over other pelts. Where caribou has special quality is in the wind-resistant nature of its close-packed hair and in the high thermal resistance of the winter pelt. Since, however, Stefansson [10] distinctly states that Eskimos prefer pelts from animals killed in July, August, or September rather than in the last three months of the year one cannot account for the use of caribou skin for clothing by the insulation value of the winter pelt.

On the whole the work described above leads one to the conclusion that availability rather than superiority accounts for the use of caribou skins for clothing by the natives of the Arctic.

The exceptional wind resistance of caribou fur which this investigation has brought to light is a

TABLE III. Ratio of Thermal Resistance in Following Wind Velocities to the Thermal Resistance in Still Air in Per Cent

Type of Fur	10 Mph	25 Mph	30 Mph
Caribou (Winter)	89	58	50
Caribou (Summer)	81	55	47
Caribou (Thin summer)	72	44	37
Deer (Winter)	64	38	32
Arctic Wolf	83	50	42
Raccoon	90	49	40
Beaver	78	50	41
Muskrat	82	50	33
Rabbit	79	50	42
Pile Fabric	78	51	42

TABLE IV. Thermal Resistance per Unit Thickness

Type of Fur	Resistance* in Clos	Under Pressure of 0.0 lb/in.^{2} Thickness (in.)	Clo/in.
Caribou (Winter)	4.72	1.29	3.7
Caribou (Summer)	2.09	0.47	4.5
Caribou (Thin summer)	1.33	0.29	4.6
Deer (Winter)	4.33	0.94	4.6
Arctic Wolf	3.94	1.08	3.7
Raccoon	3.09	0.52	5.9
Beaver	2.23	0.66	3.4
Muskrat	1.51	0.27	5.6
Rabbit	1.37	0.37	3.7
Pile Fabric	1.50	0.50	3.0

* Thermal resistance in still air of sample only.

point of interest in the design of pile fabrics because apparently for good wind resistance the hair must be close packed and moderately stiff. From a purely utilitarian viewpoint where it is not necessary to simulate fur in appearance, wind resistance can be far more easily accomplished by means of a thin flexible windproof fabric on the outside of the insulation.

Acknowledgment

The author wishes to make grateful acknowledgment to Dr. C. D. Niven under whose direction this work has been carried out and who has given helpful criticism in the writing of this paper.

TABLE V. Thermal Resistance per Unit Weight

Type of Fur	Resistance* in Clos	Weight (oz/yd^2)	Clo/oz/yd^2	Weight of Fur (% of total weight)
Caribou (Winter)	4.72	52	0.091	48
Caribou (Summer)	2.09	26	0.080	44
Caribou (Thin summer)	1.33	17	0.078	39
Deer (Winter)	4.33	42	0.103	56
Arctic Wolf	3.94	31	0.127	66
Raccoon	3.09	32	0.097	61
Beaver	2.23	34	0.066	41
Muskrat	1.51	24	0.063	51
Rabbit	1.37	29	0.047	52
Pile Fabric	1.50	38	0.039	49

* Thermal resistance in still air of sample only.

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