EVALUATION OF TWO THERMO-METAL NEOPRENES

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INTRODUCTION

Recently, a new type of diving suit fabric called thermo-metal neoprene was introduced on the market It consists of a closed-cell neoprene with the inner cloth lining coated with metal. The metal-coated lining is claimed to act as a reflective barrier that minimises radiative heat loss from the body and hence, improves the thermal properties of the fabric by 25% over uncoated neoprene. The objective of the present study was to verify the claims of the manufacturer by comparing the insulation of two thermo-metal neoprenes (titanium and stainless steel coated) to the current Canadian Forces (CF) Arctic diving suit neoprene in a dry environment at 1 atmosphere and in a wet environment under pressures to simulate dives up to 100 m.

MATERIALS AND METHODS

Neoprene samples. Three 28.7 x 28.7 cm samples of closed-cell neoprene were tested: a sample of the current CF Arctic diving suit neoprene (CF-N; Rubatex G-231, 6.4 mm thick, Rubatex Corporation, Bedford, Virginia, U.S.A.), and samples of the titanium (TT-M; 7.1 mm thick) and the stainless steel (SS-M, 7.7 mm thick) coated thermo-metal neoprenes (Yamamoto Corporation, Osaka, Japan).

Thermal resistance measurements. To compare the thermal insulative values of the three neoprene materials, we evaluated their thermal resistances (R_d) in a dry environment at 1 atmosphere and in a wet environment during dives to five different depths ranging from 0 to 100m (R_w). The thermal resistances of the neoprene materials were measured in the dry environment (dry test) using a Rapid-k instrument (Dynatech R/O Company, Mass). The heat flow meter of the Rapid-k was previously calibrated against 2 thermal resistance standards (MDGB Transfer Standards #357-172-A,B, NRC). The R_d values (in °C•m^{2}•W^{-1}) for the different neoprene materials were calculated using the Fourier linear heat flow equation as follows: $R_d = (T_u - T_l) / H_{rapid\text{-}k}$, where T_l is the average temperature (in °C) of the lower face of the neoprene sample (in contact with the cold copper plate of the Rapid-k), T_u is the average temperature (in "C) of the upper face of the neoprene sample (in contact with the hot copper plate of the Rapid-k), and $H_{rapid\text{-}k}$ is the average heat transfer from the upper to the lower face of the sample (in W•m^{-2}). The reported values of R_d are averages of resistances measured for two heat fluxes (~80 and 250 W•m^{-2}) for every neoprene material. A constant pressure of 60 pounds was applied on the samples during the testing to assure good contact with the copper plates of the Rapid-k. The pressure was not sufficient to create noticeable compression of the neoprenes. The objective of measuring R_w was to investigate the effect of pressure and wetness on the thermal performance of the neoprene materials (wet tests). The tests were conducted in a hyperbaric chamber partially filled with stirred water maintained at 5°C in which a custom made temperature conrrolled water bath was partially immersed and maintained at 35°C to allow a transfer of heat through the test material fixed to the bottom of the bath. The neoprene test sample was sandwiched between the bottom part of the bath (acting as a hot plate) and the "test bed" (acting as a cold plate). The test bed, in contact with the water at 5°C consisted of a 1 cm thick aluminium plate (40 x 40 cm) and a 0.6 cm Teflon® bed (30 x 30 cm) on which were fixed four recalibrated heat flux transducers (HFTs; model HA13-18-10-P(C), Thermonetics Corporation, San Diego, CA). Three calibrated thermocouples (AWG 40) were fixed on the upper face of the neoprene sample and three on the lower face. The thermal resistances of the neoprene samples were measured using the same formula as for the dry tests. The heat flux used for the measurement of R_w varied with the depth of the dives due to changes in the thickness of the neoprene samples with pressure (–150 W•m^{-2} at 0 m to –500 W•m^{-2} at 100 m). All data reported were collected at thermal steady state which was considered established when the R values changed less than 1% over a 20-min period.

Experimental procedures. Only one sample of each neoprene material was used for the dry and wet tests. The wet tests consisted of a series of dives, each dive lasted about 4 days, starting with a dry test at 1 atmosphere performed with the wet apparatus. The objective of this dry test was to verify that wet test apparatus could reproduce the results of the dry test performed with the Rapid-k. This was followed by a 12 h period to wet the samples (the samples were sandwiched between the test bed and the bottom of the brass bath) and by a step dive at 0, 10, 25, 50, and 100m.

RESULTS

Thermal resistances in dry environment. Figure 1 shows that the two thermo-metal neoprenes have R_d values significantly higher than that of the CF-N, the TT-M being 25% better and the SS-M 53% better than the CF-N.

Thermal resistance in wet environment. Only the thermo-metal neoprene having the best resistance during the dry test (SS-M) was chosen for the wet test. The thermal resistance values measured with the wet test apparatus in a dry environment were very close to the R_d values measured with the Rapid-k (see Figs 1 and 2). These results confirm the validity of the wet test apparatus for the measurement of the thermal resistances of the neoprenes. Figure 2 shows that the R_w values decreased exponentially for both neoprenes with an increase of immersion depth. On average, for all depths tested, the R_w values were 60% higher for the SS-M neoprene than for the CF-N. The difference decreased with depth from 70% at 0 m to 34% at 100 m.

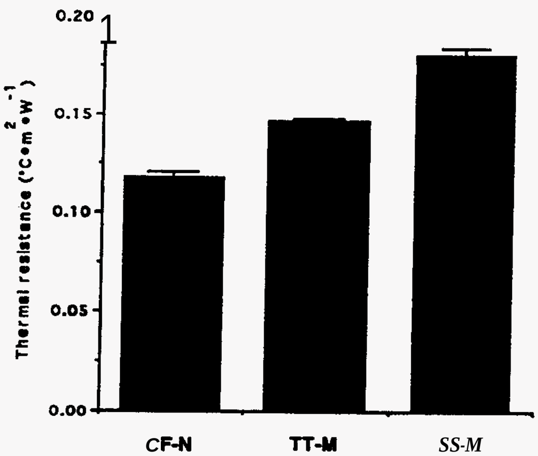

Fig.1 Thermal resistance of two thermo-metal neoprenes [titanium (TT-M); stainless steel (SS-M)] and of CF Arctic diving suit neoprene (CF-N) during the Dry Test.

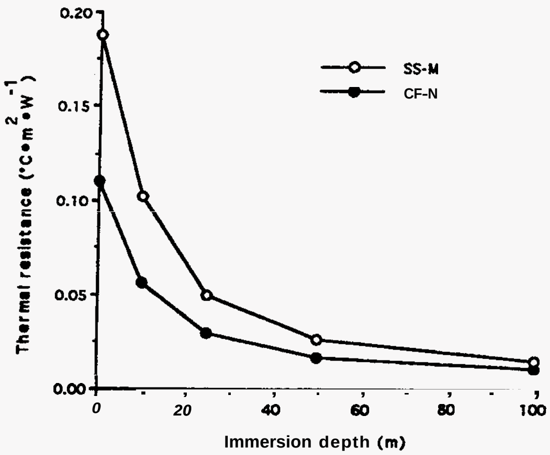

Fig2 Thermal resistance of a thermo-metal neoprene (stainless steel: SS-M) and of the current CF Arctic diving suit neoprene (CF-N) during the Wet Test at five different pressures.

DISCUSSION

The results of the present study clearly show that the thermal resistances of the two thermo-metal neoprenes tested are significantly higher than that of the CF Arctic diving suit neoprene, and that the better thermo-metal neoprene is the stainless steel (SS-M) coated neoprene (53% better in a dry environment). While studies reported by Fourt and Harris (1968) showed that exposed metallic surfaces can act as a thermal barrier and significantly increase the thermal resistance of clothing, the present study cannot separate the effect of neoprene thickness and /or structure from fabric metal coating on insulation improvement. It was observed under magnification that the size of the gas bubbles in the CF-N is much larger than in the ***Yamamoto*** neoprene due to different methods of expansion of the neoprene materials. The difference in the structure of the neoprenes could be responsible for much of the difference observed in the resistance values.

The tests performed in the wet environment show that the insulative properties of the SS-M neoprene were more affected by the depth of the dives than the CF-N. This is in agreement with recent observations comparing the thicknesses of the two neoprenes during real dives which showed that Yamamoto neoprene compresses more than Rubatex G-231 neoprene at the same depth (Frew, 1993; unpublished observations). Despite this compression, the thermal resistance of the SS-M neoprene remains higher than that of the CF-N for the whole range of depths tested. Again, the present study can not attribute the difference in thermal resistances to either the reflective barrier or the neoprene material. It is well known, however, that water absorbs infrared radiation (Adkins, 1987), and if water was present inside the woven reflective layer of the SS-M, then it should have nullified any advantages provided by the metal reflective barrier. Because the thermal resistance of the SS-M was greater than that of the CF-N even in wet conditions, it is possible that the difference in thermal resistance was due to the difference in the neoprene materials. Another possibility is that the neoprenes were not completely soaked with water during the wet tests and, therefore, the reflective barrier was still effective.

CONCLUSION

This study shows that these neoprene materials have higher thermal resistance values than the current CF Arctic diving suit neoprene in dry and wet environments and under pressures simulating dives up to 100 m.

REFERENCES

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2- Adkins C.J. 1987, An introduction to thermal physics, Cambridge University Press, Cambridge, 134p.