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Cholesteric Liquid Crystals: Ambient Temperature Effects

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Cholesteric Liquid Crystals: Ambient Temperature Effects

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Abstract—The effect of ambient temperature on a liquid crystal tape system was investigated. The data indicate that when the temperature of the object being measured is controllable, the crystal tape system is not affected by ambient temperature changes. However, if the temperature of the object tends toward equilibrium with the ambient temperature, the liquid crystal tape system records intermediate values between ambient and source temperatures.

1. Introduction

Early investigators[1,2] had observed that certain cholesterol esters when heated pass from white crystalline form through a highly colored phase to clear colorless liquid. While the exact nature of this phenomenon has not been satisfactorily explained in spite of intensive investigation,[3,4] these compounds, referred to as "liquid crystals,"[5,6] have been used to develop sensitive temperature measuring systems. Mixtures of the temperature sensitive cholesterol crystals are encapsulated in a protective coating and laminated to tape. By choosing the proper mixture to give color changes in a desired temperature range, the temperature of an object can be correlated accurately with a color and variations in temperature of the object result in specific color changes.

Temperature measuring systems employing liquid crystals easily and accurately measure thermal changes both *in vivo*[7,8] and *in vitro*.[9] They are stable, simple to use and inexpensive. However, the effect of the ambient temperature on this system, when this temperature is sufficiently different from that of the object being measured, has not been investigated. Obviously, if the environmental temperature sufficiently alters the reaction of the tape (i.e., produced a color change based on a temperature intermediate between the object and environment) the application of these temperature measuring systems will be severely limited. The present report describes the results of experiments carried out to determine whether ambient temperature effects the accuracy of the liquid crystal tapes.

2. Materials and Methods

Two types of liquid crystal tapes for temperature measurement were employed in this study. The standard liquid crystal esters, highly purified, were used in the approximate ratios of cholesterol nonanoate 75% W/W, cholesterol oleyl carbonate 15% W/W, and cholesterol chloride 10% W/W. The following are thermochromic responses:

Liquid crystal tape 970–81	*Temperature range*	*Color of tape*
	32.8 °C to 35.0°C	Red
	35.0 °C to 35.6 °C	Yellow
	35.6 °C to 37.1 °C	Green
	37.1 °C and above	Blue

Liquid crystal tape 706–01	*Temperature range*	*Color of tape*
	30.4 °C to 31.6 °C	Red
	31.6 °C to 32.0 °C	Yellow
	32.0 °C to 34.7 °C	Green
	34.7 °C and above	Blue

A Yellow Springs Instrument Telethermometer Model 42SC, fitted with 409 and 401 thermistor probes, was used to measure the surface temperature of the flask and the core temperature of the 3000 ml of water in the flask (Fig. 1). Ambient humidity was determined using a Bacharach Thermometer/Hygrometer. It was monitored only as a control, used to avoid any possible severe humidity conditions. Ambient temperature, measured using both a mercury thermometer and a telethermometer was altered by placing the flask (for the desired time interval) in constant-temperature stability rooms maintained at selected temperatures.

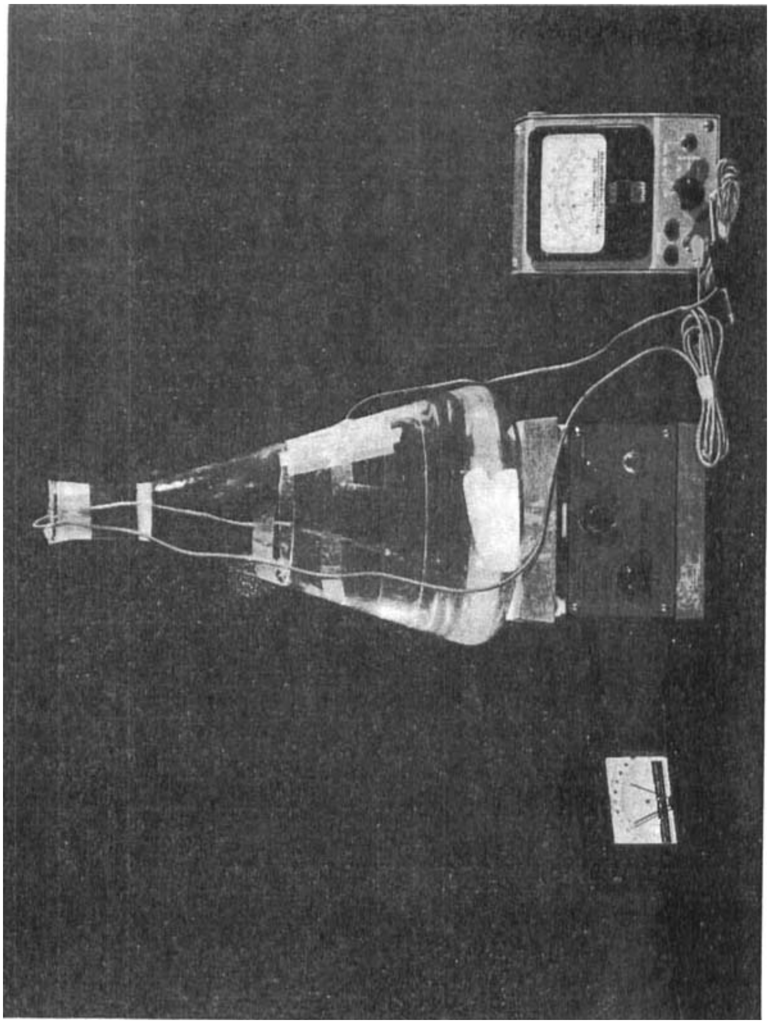

FIGURE 1

In the initial experiment, the flask was filled with 3000 ml of water which had been heated to 37 °C and a 401 probe inserted to measure the water temperature. A 2.5 cm^2 piece of 970–81 liquid crystal tape was placed on the exterior flask surface with Scotch tape several cm below the water line. The flask was then incubated at 5 °C, 27 °C, 37 °C and 45 °C for 2 minutes of each ambient temperature, and the color of the tape was recorded independently by three observers.

In the second experiment, 3000 ml of water heated to 33.5 °C was added to the flask containing a magnetic stirrer. The temperature of the water was maintained by agitating the water in the flask on a Thermolyne Model SP-A1025B stir-hot plate. As the water temperature rose above 33.5 °C, ice was added, and as the water temperature fell below 33.5 °C, the heater was activated automatically to maintain temperature. The water, now in a dynamic temperature condition, served as a true heat source being able to increase or reduce its thermal output. A 2.5 cm^2 piece of 706–01 liquid crystal tape was applied to the flask as in the first experiment. A 409 thermistor probe coated with Dow Corning silicone heat sink compound on the measuring surface was taped to the flask next to the liquid crystal tape and a 401 thermistor probe was inserted to approximately the geometric center of the flask. The entire apparatus with water temperature maintained at approximately 33.5 °C was placed in constant temperature rooms at 3 °C, 29 °C and 37 °C respectively for 15 minutes at each temperature. The relative humidity, temperature of the water, temperature at the surface of the flask and ambient temperature were recorded at 2, 5, 10 and 15 minutes following incubation at the ambient temperature. The color readings on the tape were independently noted by four observers at each time interval.

There is the possibility of error when a thermistor probe is used to measure surface temperature. Since the probe is omnidirectional in function, it measures the temperature on all of its surface although to a smaller extent on its insulated surface which is exposed to the environment. To further insulate this surface a few layers of scotch tape were applied over it. Another possible source of error will depend on the degree of intimacy achieved between the probe and the surface being monitored. Heat sink compound was used to reduce this error to a minimum. Using a " Temperature controller and readout " device to investigate these two sources of error resulted in ±0.2 °C as a maximum potential error. The greatest potential source of error is the accuracy associated with the combination of thermistor probe and telethermometer (±0.5 °C in the instrument specifications). Using a temperature standard (YSI Thermilinear Thermometer Model 777) our instrumentation accuracy was determined to be ±0.2 °C.

3. Results

In the initial experiment, the internal temperature of the water was 37 °C and at this temperature the color of the liquid crystal tape (970–81) was green. No attempt was made to maintain this temperature when the flask was placed at the different ambient temperatures. In the 27 °C and 37 °C constant-temperature rooms the tape remained green. In the 5 °C room, the tape became yellow/green indicating either the water in the flask was cooling or the tape was reacting to a temperature compromise between the external ambient temperature and the water temperature. The tape turned green/blue at the 45 °C ambient temperature, indicating similar possibilities. To obviate changes in the internal water temperature, the second experiment was conducted whereby the water was maintained at a constant 33.5 °C. In this experiment exposure to ambient temperature of the constant temperature rooms was carried out for 15 minutes. The results presented in Table 1 show that at the ambient temperature of 3 °C, the surface temperature dropped within 2 min to 30.2 °C and remained between this temperature and 31.0 °C over the 15 min period. The temperature of the water remained between

TABLE 1 Effect of Ambient Temperature on the Thermochromic Response of Liquid Crystal Tape (706–01) in Contact with a Constant Heat Source

Incubation time (min)	Temperature of H_2O in the flask	Temperature at the surface of the flask	Ambient temperature	Color change of tape from expected green (32.0 °C to 34.7 °C)
2	33.5 °C	30.2 °C	3 °C	None
5	33.7 °C	30.5 °C	3 °C	None
10	34.0 °C	31.0 °C	3 °C	None
15	33.9 °C	30.5 °C	3 °C	None

33.5 °C and 34.0 °C. The liquid crystal tape color remained green throughout indicating that the source temperature and not the surface temperature was actually being measured by the tape. At 29 °C and 37 °C ambient temperatures the surface temperature remained essentially the same as that of the H_2O heat source and as expected no change in the color of the tape was observed.

4. Conclusions

The data indicate that the tape is accurately reflecting the temperature of the object, whether this temperature be dynamic or static. If the temperature of the object cannot be maintained when exposed to a drastically different ambient temperature, the color of the tape will change in response to the changing temperature of the object. The color of the tape will continue to change until the object temperature has been equilibrated with its environment. Conversely, if the temperature of the object is maintained when exposed to a drastically different ambient temperature, the color response of the tape will not change. Thus, when the ambient temperature is close to that of the object, the data show that the liquid crystal tape will accurately reflect the temperature of the object. The data also show that when the ambient temperature is much higher or lower than that of the object, the thermal state of the object must be considered before interpreting the thermochromic response of the tape.

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