GLR-44

QUARTERLY REPORT ON
THERMAL AND ELECTRICAL CONDUCTIVITIES
OF BIOLOGICAL FLUIDS AND TISSUES

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SUMMARY

Experimental changes in the electrical conductivity of bovine liver were determined after both slow and rapid freeze-thaw exposures. The ratio of conductivities for exposed to unexposed specimen varied from 1.2 to 2.0 after freezing to a little below 32°F and slowly thawing to room temperature. The ratio of conductivities for exposed to unexposed samples was 1.04 after freezing to -320°F and rapidly thawing in warm water.

In the current research program, thermal and electrical conductivities both increased after freeze-thaw stressing. Cryogenic freezing and rapid thawing cause minimum changes in the conductivities for the materials studied (liver, kidney, brain, and muscle).

On the basis of the present thermal and electrical conductivity research, it is felt that changes in these properties can be used as indices for biochemical and morphological changes in exposed biological specimens.

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I. TISSUE ELECTRICAL CONDUCTIVITY CHANGES AFTER SLOW AND RAPID FREEZE-THAW PROCESSES

A. Slow Freeze-Thaw Rate Studies

The relative differences in electrical conductivity between unstressed and slowly frozen and thawed, homogenized bovine liver were determined from room temperature to 33°C. Four different samples of liver were homogenized in equal volumes of isotonic sodium chloride solution. The suspension was washed in three volumes of the same solution and then divided into two equal portions. One portion was frozen at -7°C and the remaining fraction was packed into the conductivity cell with a uniform pressure. Figure 1 depicts the horizontal and vertical cells which were used in this series of experiments. The equipment was equilibrated in an isothermal bath at a number of temperature levels between 21°C and 33°C and then conductivity measurements were made; all temperatures were established within ± 0.05°C. The frozen specimens were each maintained for 24 hours at -7°C and subsequently thawed to room temperature.

Typical electrical conductivity measurements for slowly frozen and thawed samples of liver in comparison to those for unexposed samples can be found in Figures 2 and 3. These measurements were obtained in the horizontal conductivity cell. In all cases, it may be noted that the electrical conductivities of the samples that have been frozen and thawed are greater than the corresponding values for unexposed specimens. The ratio of the conductivities for exposed to unexposed samples vary from 1.2 to 2.0. It is also noted that the average values for unstressed liver samples were about a factor of two lower than those reported in the literature[(1)] for whole tissue; however, some differences between homogenized and whole tissue would be expected.

B. Rapid Freeze-Thaw Rate Studies

A homogenized sample of liver in the form of a 1/16 inch thick slab covered by a thin plastic envelope was quickly immersed in a bath of liquid nitrogen. The liver sample was agitated with the aid of a pair of tongs. After the liver remained

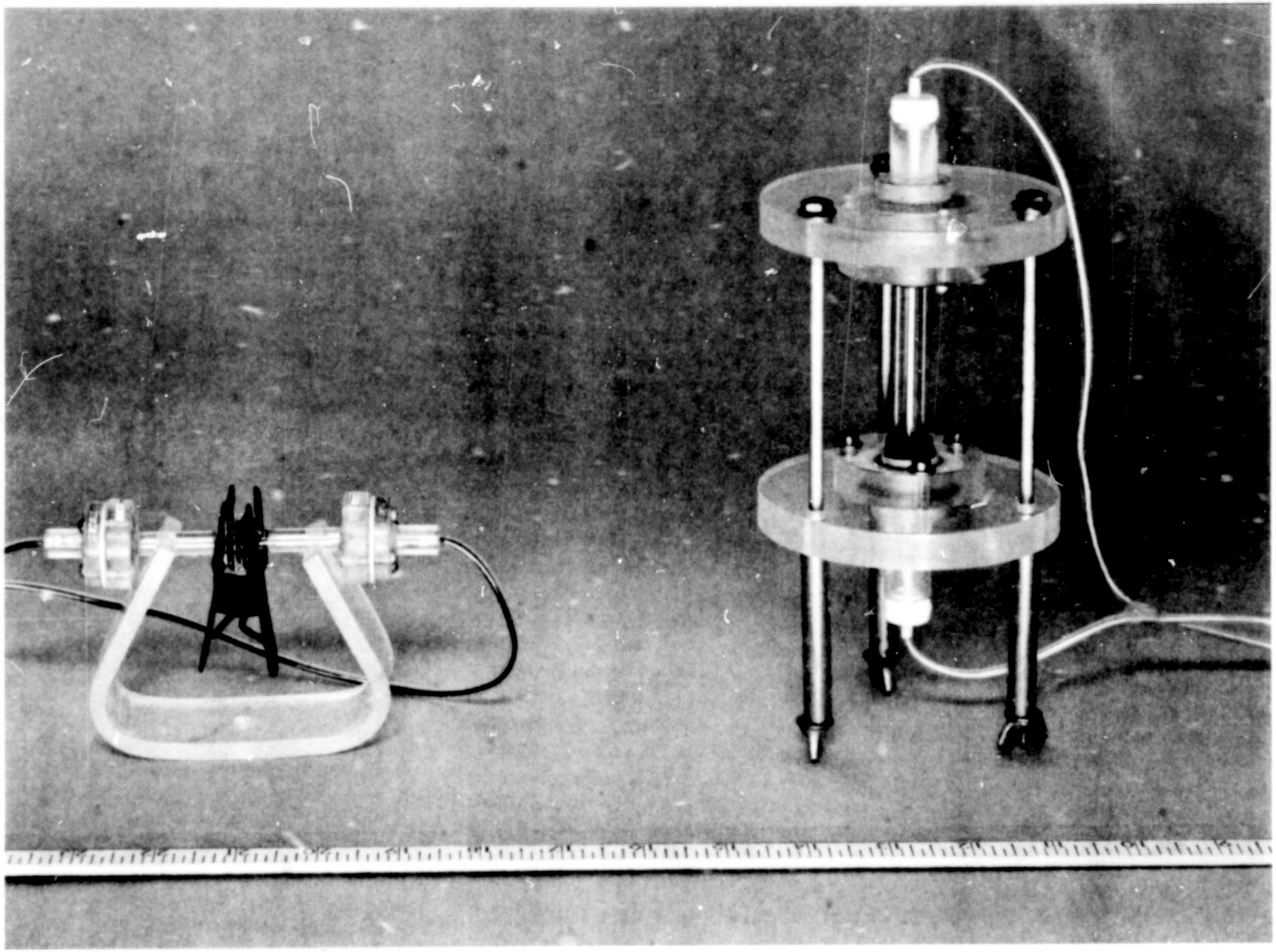

Figure 1. Tissue conductivity cells.

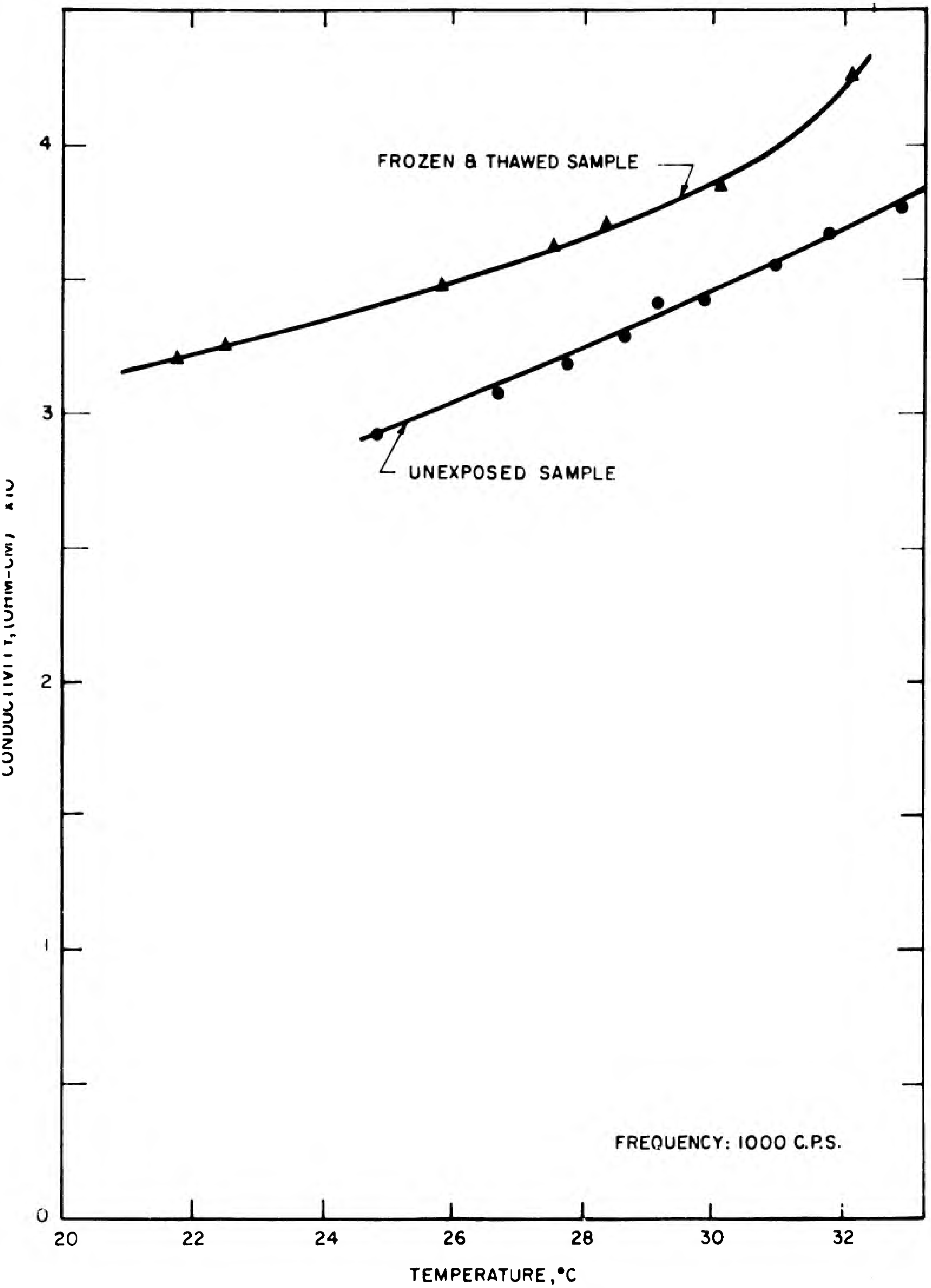

Figure 2. Comparison of electrical conductivities of liver samples that have been slowly frozen and thawed with unexposed samples (No. 4).

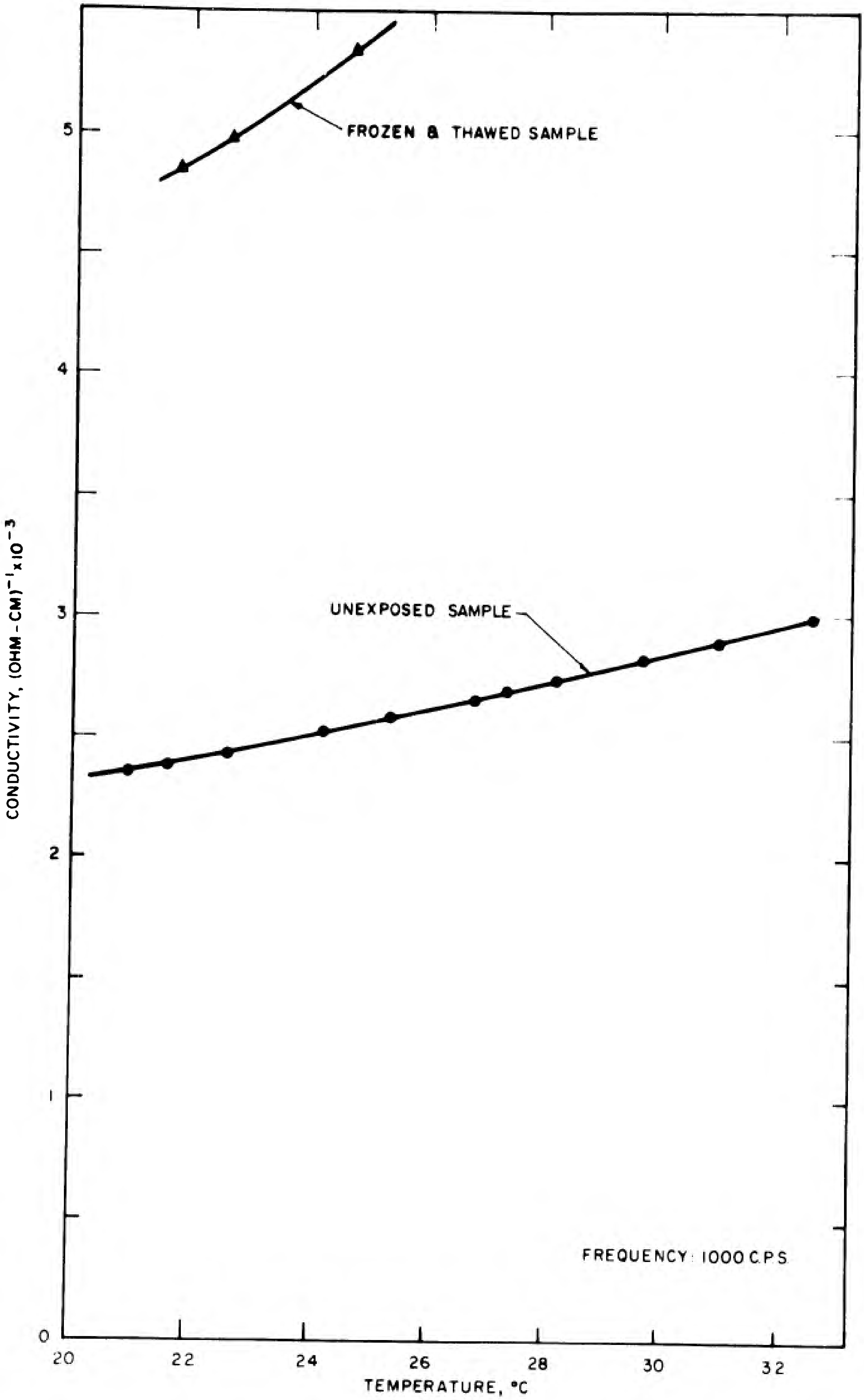

Figure 3. Comparison of electrical conductivities of liver samples that have been slowly frozen and thawed with unexposed samples (No. 5).

in the frozen state for a short period of time, it was removed and thawed in warm water using vigorous agitation. The sample of liver was then put into the vertical conductivity cell and measurements were made; the conductivity results are shown in Figure 4 together with corresponding values for an unexposed sample. It can be seen that although the electrical conductivity of the stressed sample again fell above the values for an unstressed sample, the conductivity ratio (stressed to unstressed values) was only about 1.04.

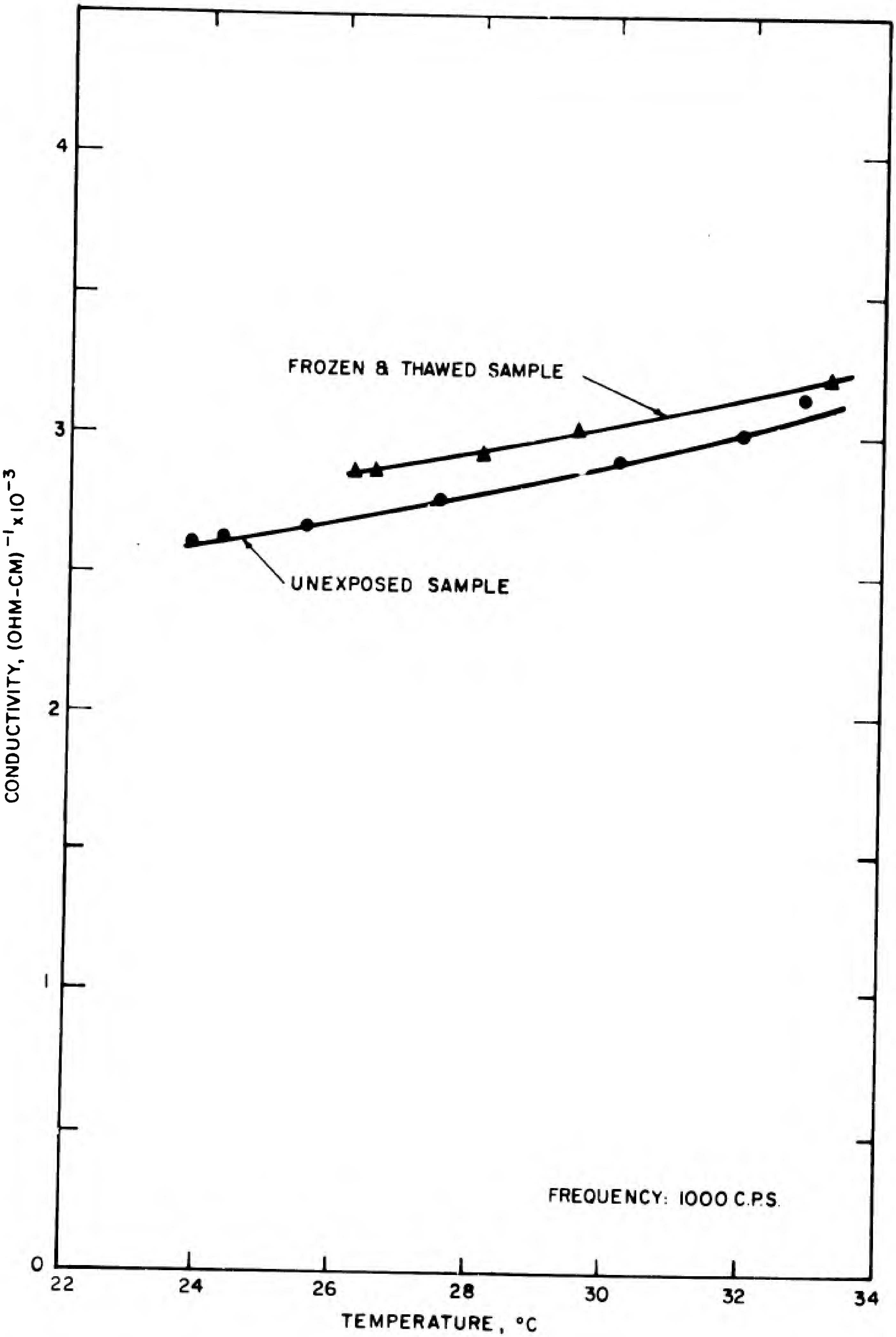

Figure 4. Comparison of electrical conductivities of liver samples that have been rapidly frozen and thawed with unexposed samples (No. 1).

II. COMPARISON OF TISSUE ELECTRICAL AND THERMAL CONDUCTIVITY CHANGES WITH FREEZE-THAW RATES

As a result of the thermal and electrical conductivity measurements of stressed and unstressed samples of biological materials under the present research program,it has been found that the freezing and thawing processes apparently caused some morpholrgical and biochemical changes; the thermal and electrical conductivities both increase after the freeze-thaw stressing. Further, cryogenic freezing and rapid thawing appear to cause minimum changes in the conductivities. A comparison of such results can be found in Table 1.

It is recognized that the length of time that a specimen remains in the frozen state also is a parameter that influences biochemical and property changes. For example, when specimens were frozen to a little below 32°F, larger thermal conductivity increases occurred in five days of storage than in one day.

No electrical conductivity measurements have been made of whole blood (without PVP additive) that was first unstressed and then frozen and thawed. Electrical conductivity measurements of blood plasma with various percentages of hemoglobin content have been made however[5]; for example, a 10 weight percent hemoglobin addition decreased the conductivity of the plasma by about 25 percent. Consequently, freeze-thaw damage to whole blood can be detected by working with the plasma and perhaps also with the whole blood itself.

Table 1

COMPARISON OF THERMAL AND ELECTRICAL CONDUCTIVITY CHANGES AFTER SLOW AND RAPID FREEZE-THAW EXPOSURES

Specimen	Conductivity	Ratio of Exposed to Unexposed Conductivities	
		Slow Freeze-Thaw Rate (freezing to a little below 32° F and slow thawing to room temperature)	Rapid Freeze-Thaw Rate (freezing to -320° F and rapid thawing in warm water)
Bovine Liver (ground) $70<t<90°$ F	electrical	0.2 to 2.0	1.04
Bovine Liver (ground) $75<t<100°$ F	thermal	1.12 to 1.27 Reference 2	1.05 Reference 3
Bovine Kidney (ground) $75<t<100°$ F	thermal	1.12 Reference 2	
Bovine Brain (ground) $75<t<100°$ F	thermal	1.21 Reference 2	
Bovine Muscle $75<t<100°$ F	thermal	1.15 Reference 4	

III. RELATION OF THERMAL AND ELECTRICAL CONDUCTIVITY CHANGES TO MORPHOLOGICAL AND BIOCHEMICAL CHANGES IN BIOLOGICAL MATERIALS

On the basis of the results presented in Table 1, there are definite, measurable changes in thermal and electrical conductivities of biological materials after freeze-thaw exposure. Further, it appears that after rapid freeze-thaw exposures, smaller changes in these properties were observed suggesting that less changes in chemical structure had occurred. Therefore, it is believed that these property changes could be used as indices for biochemical and morphological changes in exposed biological materials. Because of 1) the greater accuracy involved in electrical conductivity measurements and 2) the rapidity with which this measurement can be made, it is suggested that this property be the one used. The present electrical conductivity cells could be miniaturized so that very small samples of biological materials, say about 0.5 cc, could be used to make the conductivity determinations.

IV. REFERENCES

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relation of thermal and electrical conductivity changes to morphological and biochemical changes in biological materials						