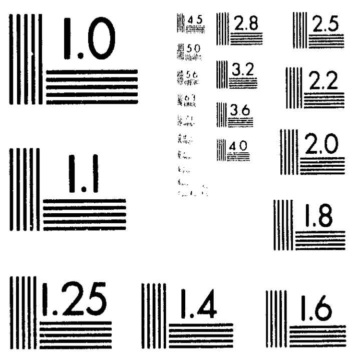
1.0
2.8
2.5
3.2
2.2
3.6
4.0
2.0
1.1
1.8
1.25
1.4
1.6

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FIBER-OPTIC TEMPERATURE SENSOR (U)

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DISCLAIMER

FIBER OPTIC TEMPERATURE SENSOR

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ABSTRACT

Researchers at the Savannah River Technology Center (SRTC) have developed a class of fiber-optic temperature sensors based upon temperature induced changes in the absorption spectrum of selected materials. For example, a neodymium (Nd) doped glass sensor can be used over a very broad temperature range (-196 to 500°C) and provide good precision and accuracy (± 1°C). This type temperature probe is constructed so that light from a fiber optic cable shines through the Nd glass and is reflected onto a second fiber optic cable. Light from this second fiber optic is measured by a diode array spectrophotometer, and the absorption spectrum of the Nd glass used to compute temperature.

INTRODUCTION

Fiber-optic sensors based on absorption spectrophotometry are proposed for use in many environmental measurements. These measurements can be made in wells, high radiation areas, and other inaccessible locations by transmitting the light used to monitor effects on these sensors over fiber-optic cables. The use of absorption spectrophotometry to monitor temperature, in addition to the chemical concentrations, can further increase the utility of a fiber-optic spectrophotometer for remote monitoring.

Fiber-optic temperature sensors are often used in applications where electromagnetic interference causes a problem for RTDs and thermocouples. These systems typically operate in one of two common modes: 1) measuring changes in the fluoresence spectra of rare earth oxides or 2) measuring the change in light intensity through a temperature sensitive structure. Using absorption spectrophotometry to measure temperature has several advantages not found in these commercial systems:

absorption based systems are tolerant of multiple fiber-optic junctions and insensitive to fiber length or type because absorption involves ratios of intensity instead of raw intensity measurements

sensor elements are inexpensive to manufacture because precision machining is not required and sensors do not require individual calibration

EXPERIMENTAL

Equipment required to make fiber-optic temperature measurements include a fiber-optic diode array spectrometer, computer, duplex fiber-optic cable, light source, and sensor element (see figure 1). With the use of a multiplexer, up to 50 temperature probes can be measured sequentially with one spectrometer and computer. A measurement from each probe requires about 2 seconds.

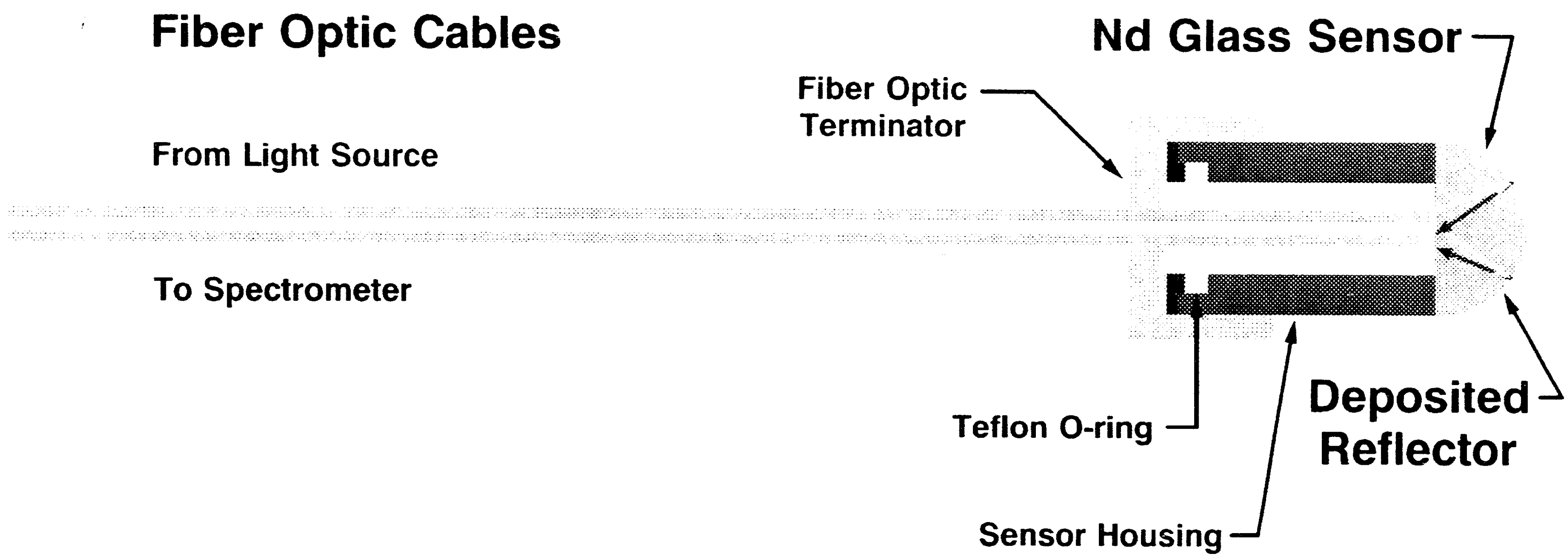
Currently the temperature sensing material of choice is Nd doped (3-5 wt%) borosilicate glass. The absorption spectrum of this glass at near infrared wavelengths is sharp and temperature sensitive (see figure 2). Temperature is calculated from the absorption spectrum by computing a first derivative (see figure 3), decomposing the derivative spectrum using a two component principal component regression (PCR) model based on data from a calibration experiment, and then calculating temperature using a polynomial equation relating temperature to the ratio of PCR components (see figure 4). The first derivative provides a baseline correction for shifts due to fiber coupling losses. The first component of the PCR model correlates to Nd concentration in the sensor while the second PCR component correlates to both Nd concentration and temperature. Using the ratio of the two PCR components in a polynomial equation removes the effect of Nd concentration on the temperature prediction and provides a linear temperature response. Our testing has shown that individual sensors made from the same type glass, use the same calibration equations, except for the constant offset term. This term is determined by measuring on known temperature with each sensor.

RESULTS AND DISCUSSION

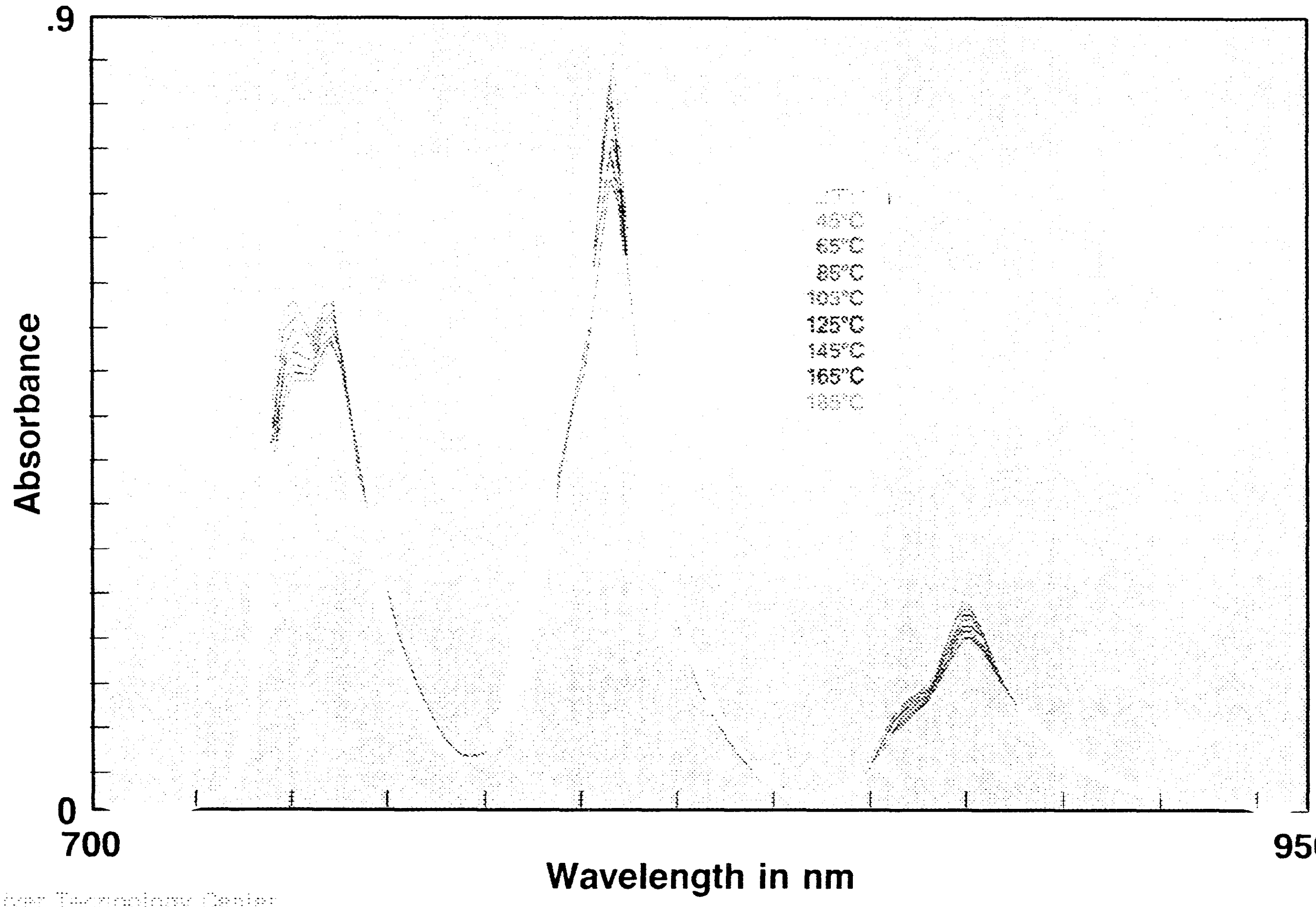
Sensors made and tested by SRTC show that absorption based fiber-optic temperature sensors have very good dynamic range (see figure 5) and very little drift(< 1^{o}C per month). Currently, a Nd doped glass sensor is being used over a very broad temperature range (-196 to 500^{o}C) and provides good precision and accuracy (± 1^{o}C). Work is continuing to develop glass compositions that will allow extension of this useful range up to 1000^{o}C, if higher temperature fibers can be found.

Applications for this type temperature sensor include use in monitoring radio frequency (RF) and microwave heating, measuring temperature of high voltage equipment like generators and transfer switches, and other applications where a single device is required over a very broad temperature range.

SRTC Fiber Optic Temperature Sensor



Temperature Effect on Absorbance of Nd Glass



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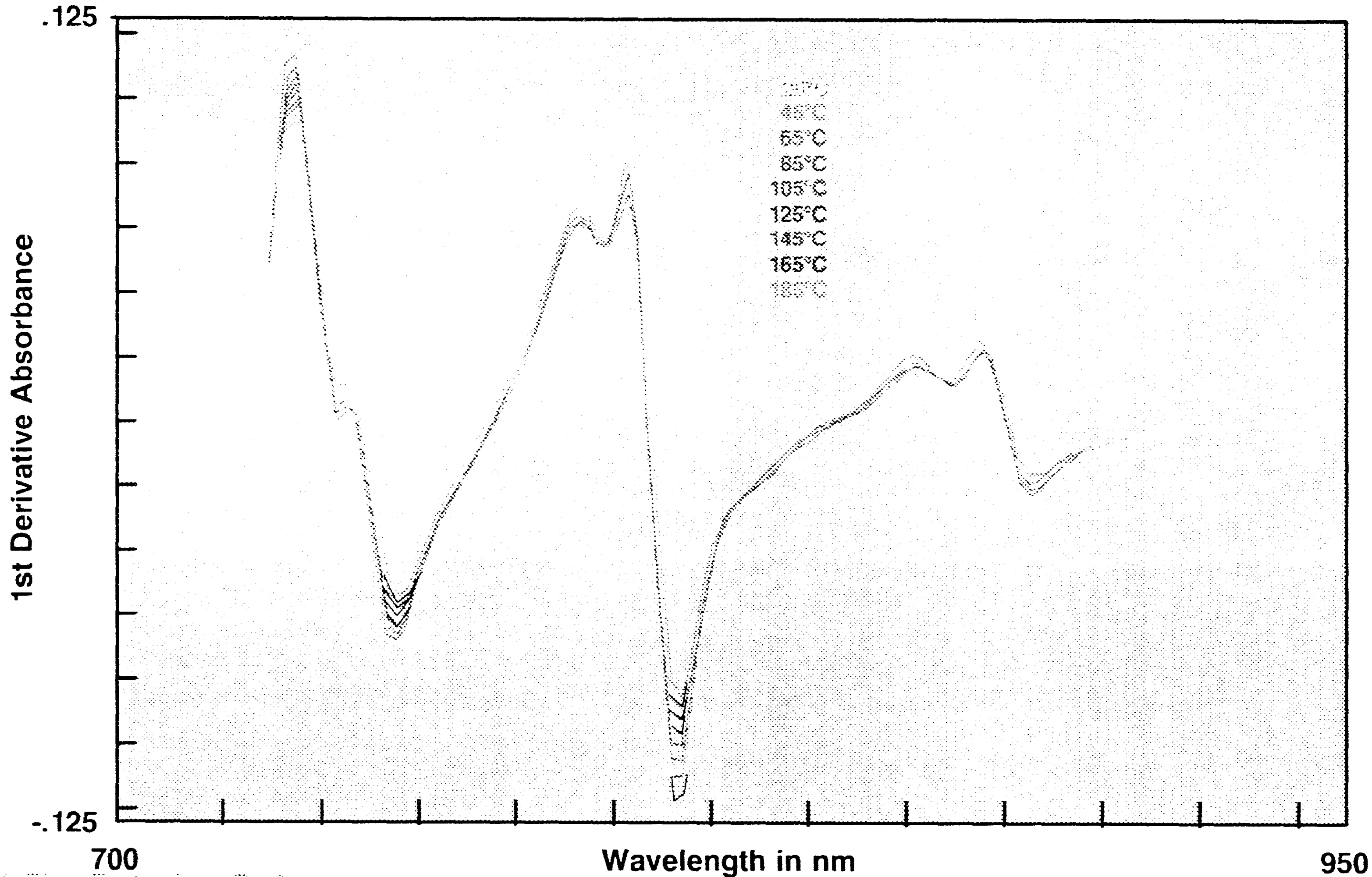
Temperature Effect on 1st Derivative Absorbance



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Fit of Eigenvalue Ratio to Temperature

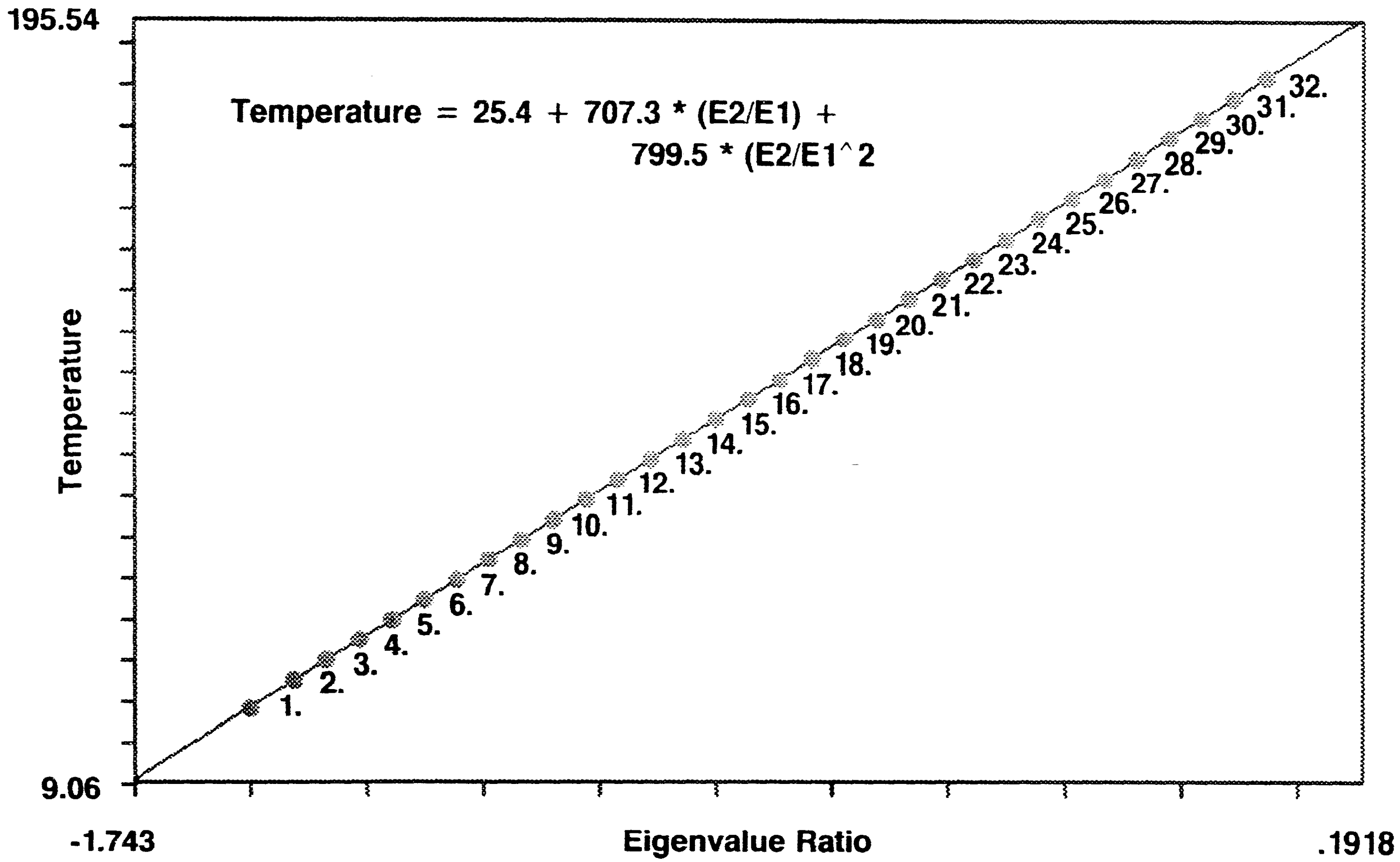

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FIG 4

Wide Range Temperature Calibration

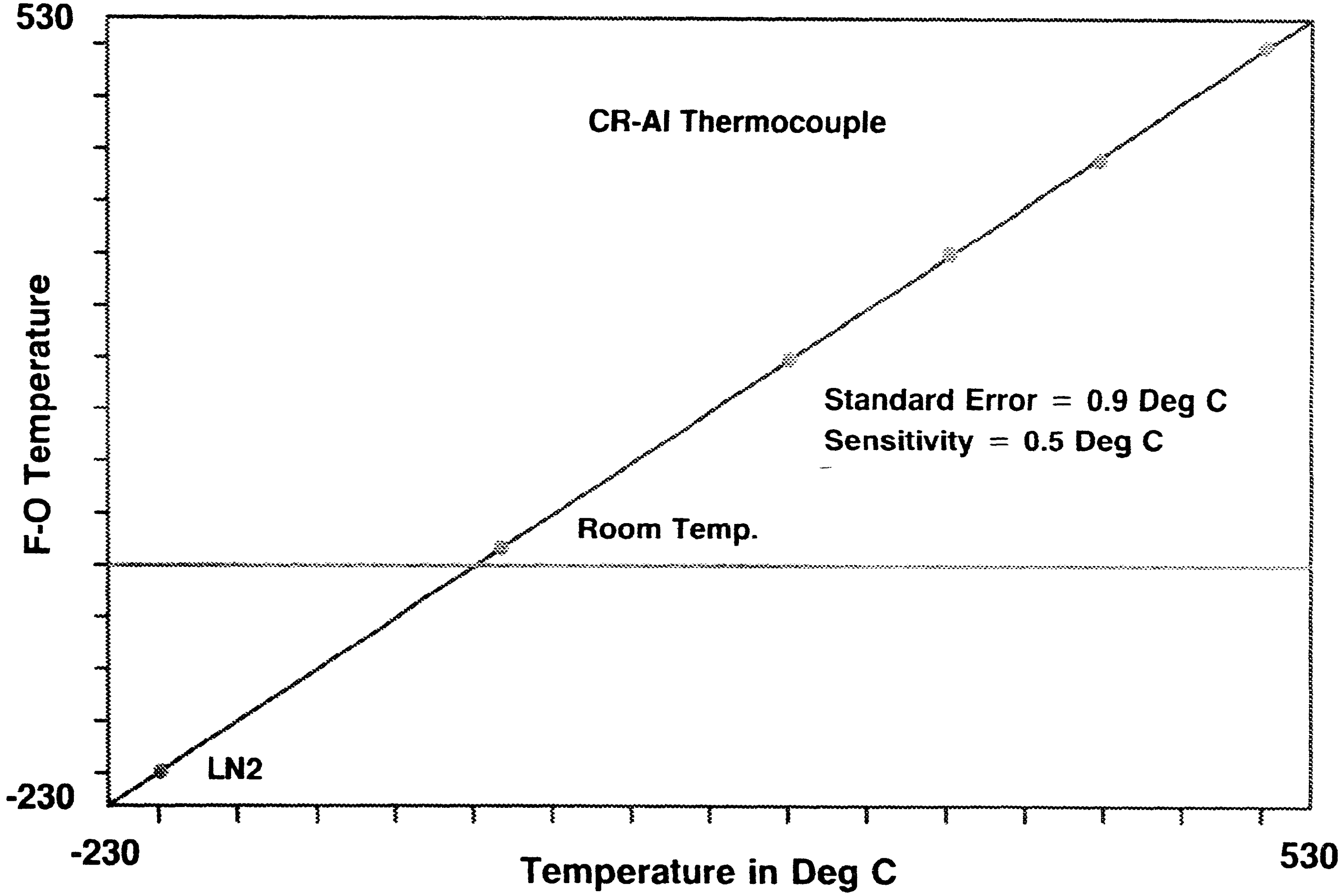

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FIG 5

DATE

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