THERMAL CONDUCTIVITY SYSTEMS FOR MEASUREMENTS
ON ROCKS UNDER APPLIED STRESS

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ABSTRACT

A simple, unguarded-plate apparatus has been shown effective for medium-precision measurements of thermal conductivity with applied uniaxial pressures. Measurements on Minnekahta limestone samples have been made at 20°C under pressures of 1.2 to 18.3 MPa. Both the low pressure values and the pressure dependence of the thermal conductivity are dependent upon the sample. An unjointed sample had a conductivity of 2.57 Wm⁻¹K⁻¹ at 1.2 MPa which increased to 2.73 Wm⁻¹K⁻¹ at 18.3 MPa; while a jointed sample had an initial conductivity of 3.19 Wm⁻¹K⁻¹ which decreased to 3.12 Wm⁻¹K⁻¹ upon loading to 18.3 MPa and then further decreased to 2.78 Wm⁻¹K⁻¹ upon unloading to 1.2 MPa. A nylon sample used for calibration initially showed an increase in thermal conductivity of 7% as the pressure was increased from 1.2 to 18.3 MPa, but this pressure dependence disappeared after repeated pressure cycling.

INTRODUCTION

A number of current important problems in areas of mining technology would benefit from the greater availability of thermal conductivity data for rocks under stress. Examples include nuclear waste disposal in either salt domes or granite, underground power stations, ventilation systems in deep mines, in situ gasification of lignites, retorting of oil shales, and geothermal applications. Available data is scarce and must be used with some care. Factors, such as moisture content and temperature gradient (which lead to fluid migration) and differential expansion effects, have not always been correctly accounted for.
Measurement of thermophysical properties under pressure is not simple. Primarily, the measurement scheme must allow for heat transfer to and through the medium used to apply the stress. Other considerations include the modification of the material by the procedures necessary to fabricate the test sample, the temperature gradients, nonuniform stress, moisture migration within the sample, and the capability of the system to perform differential measurements.

There exists no ideal system for these measurements. However, in our opinion, two systems have significant advantages over other options. These are a cylindrical heat-flow configuration, used in the transient mode to compensate for thermal resistance between heater and sample with applied hydrostatic pressure,1 2 and a simple, double-sampled plate configuration, used in steady state, differential mode with applied uniaxial stress.3 Cylindrical systems have the disadvantages that large, nonuniform temperature gradients exist, and in the transient mode of operation, they cannot be used in a differential mode. With a plate system, the main disadvantage is heat loss from the edges of the sample discs and heater. Thus, these two measuring techniques are complimentary in that their drawbacks are of a different nature.

EXPERIMENTAL DETAILS

In view of the pros and cons discussed above, we undertook to explore the suitability of a simple, unguarded apparatus. This choice was influenced partly by the availability of a stiff testing machine for provision of uniaxial loading, partly by the facilities available for sample fabrication, and partly by our experiences with this type of system. Since the pressure plates of the testing machine could not be thermally isolated from the samples, they were used as heat sinks. This dictated that a configuration be used with either samples on both sides of the heater or a sample on one side and a reference material on the other, as shown in Figure 1.

Ruggedness and simplicity of design and assembly were of considerable importance. In the past we have used differential thermocouples to measure temperature differences. In this application thermistors* were tried and found suitable. They were carefully mounted in copper plates with silicone rubber. This allowed the device to be slightly prominent and thereby acquire direct intimate contact with the sample, but the mounting yielded so the thermistor was not subjected to significant stress. With a thermistor, pins for soldered connections could be used without concern about spurious e.m.f.'s. Most of the thermometers were located axially, but some

*SensiChips, Model 31SC1A704 manufactured by Victory Engineering Corporation, Springfield, New Jersey.