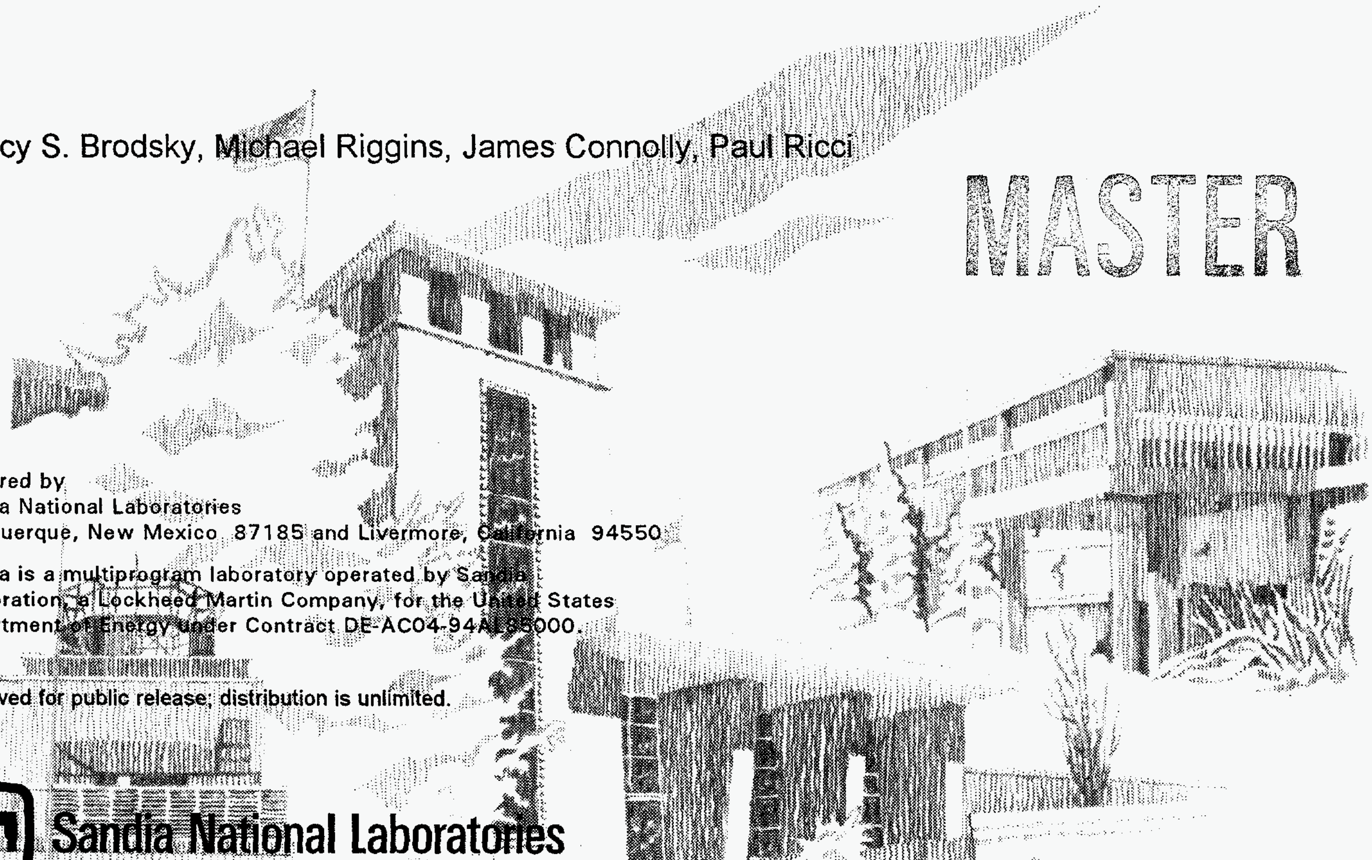
SANDIA REPORT

SAND95-1955 • UC-814
Unlimited Release
Printed September 1997

Yucca Mountain Site Characterization Project

Thermal Expansion, Thermal Conductivity, and Heat Capacity Measurements for Boreholes UE25 NRG-4, UE25 NRG-5, USW NRG-6, and USW NRG-7/7A

Nancy S. Brodsky, Michael Riggins, James Connolly, Paul Ricci



Prepared by
Sandia National Laboratories
Albuquerque, New Mexico 87185 and Livermore, California 94550

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under Contract DE-AC04-94AL85000.

Sandia National Laboratories

SF2900Q(8-81)

"Prepared by Yucca Mountain Site Characterization Project (YMSCP) participants as part of the Civilian Radioactive Waste Management Program (CRWM). The YMSCP is managed by the Yucca Mountain Project Office of the U.S. Department of Energy, DOE Field Office, Nevada (DOE/NV). YMSCP work is sponsored by the Office of Geologic Repositories (OGR) of the DOE Office of Civilian Radioactive Waste Management (OCRWM)."

Issued by Sandia National Laboratories, operated for the United States Department of Energy by Sandia Corporation.

Printed in the United States of America. This report has been reproduced directly from the best available copy.

Available to DOE and DOE contractors from
Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37831

Prices available from (615) 576-8401, FTS 626-8401

Available to the public from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Rd
Springfield, VA 22161

NTIS price codes
Printed copy: A17
Microfiche copy: A01

Distribution
Category UC-814

SAND95-1955
Unlimited Release
Printed September 1997

THERMAL EXPANSION, THERMAL CONDUCTIVITY, AND HEAT CAPACITY MEASUREMENTS FOR BOREHOLES UE25 NRG-4, UE25 NRG-5, USW NRG-6, and USW NRG-7/7A

Nancy S. Brodsky and Michael Riggins
Sandia National Laboratories
P.O. Box 5800
Albuquerque, NM 87185-1325

James Connolly
Department of Geology and Institute
of Meteoritics
University of New Mexico
Albuquerque, NM 87131

Paul Ricci
Holometrix, Inc.
Bedford, MA 01730

ABSTRACT

Cores from boreholes UE25 NRG-4, UE25 NRG-5, USW NRG-6, and USW NRG-7/7A were tested to determine mineralogy and thermal properties, including conductivity, the coefficient of thermal expansion, and heat capacity. Specimens were tested from four thermal-mechanical units, namely Tiva Canyon (TCw), Paintbrush Tuff (PTn), and two Topopah Spring units (TSw1 and TSw2), and from two lithologies, i.e., welded devitrified (TCw, TSw1, TSw2) and nonwelded vitric tuff (PTn). Petrologic data were obtained from 97 samples, all from USW NRG-6. A total of 95 specimens were tested for thermal conductivity and 143 thermal conductivity tests were run. Many specimens were tested at multiple saturation states including

vacuum saturated, partially saturated, air dried, and oven dried conditions. Each thermal conductivity test comprised between three and seven individual conductivity determinations, performed at different temperatures. Similarly, 120 specimens were tested for thermal expansion and 132 thermal expansion tests were run under either vacuum saturated, air dried, or oven dried conditions. Each thermal expansion test comprised between 10 and 22 determinations of mean and instantaneous coefficient of thermal expansion at different temperatures. Tests were conducted at room pressure and at temperatures between 30°C and 300°C. Specific heat was measured for 10 air-dried specimens at 5°C intervals between 25°C and 300°C. Thermal conductivities were highest for saturated specimens and lowest for dried specimens. Thermal conductivities, averaged over all boreholes, ranged (depending upon temperature and saturation state) from $1.2 \cdot W(mK)^{-1}$ to $1.9 \cdot W(mK)^{-1}$ for TCw, from $0.4 \cdot W(mK)^{-1}$ to $0.9 \cdot W(mK)^{-1}$ for PTn, from $1.0 \cdot W(mK)^{-1}$ to $1.7 \cdot W(mK)^{-1}$ for TSw1, and from $1.5 \cdot W(mK)^{-1}$ to $2.3 \cdot W(mK)^{-1}$ for TSw2. Mean coefficients of thermal expansion were highly temperature dependent and values, averaged over all boreholes, ranged (depending upon temperature and saturation state) from $6.6 \times 10^{-6} \cdot {}^{\circ}C^{-1}$ to $49 \times 10^{-6} \cdot {}^{\circ}C^{-1}$ for TCw, from the negative range to $16 \times 10^{-6} \cdot {}^{\circ}C^{-1}$ for PTn, from $6.3 \times 10^{-6} \cdot {}^{\circ}C^{-1}$ to $44 \times 10^{-6} \cdot {}^{\circ}C^{-1}$ for TSw1, and from $6.7 \times 10^{-6} \cdot {}^{\circ}C^{-1}$ to $37 \times 10^{-6} \cdot {}^{\circ}C^{-1}$ for TSw2. Mean values of thermal capacitance (averaged overall specimens) ranged from $1.6\ J \cdot cm^{-3} \cdot K^{-1}$ to $2.1\ J \cdot cm^{-3} \cdot K^{-1}$ for TSw1 and from $1.8\ J \cdot cm^{-3} \cdot K^{-1}$ to $2.5\ J \cdot cm^{-3} \cdot K^{-1}$ for TSw2. In general, the lithostratigraphic classifications of rock assigned by the USGS (Geslin et. al., 1995) are consistent with the mineralogical data presented in this report.

This report was prepared under Yucca Mountain Project W.B.S. Numbers 1.2.3.2.7.1.1 and 1.2.3.2.7.1.2, and under Work Agreements (WA) 0153, 0154, 0124, 0125, 0081, 0083, 0159, 0160, 0113, and 0088. The Site Characterization Plan, Sections 8.3.1.15.1.1 and 8.3.1.15.1.2, served as the planning document that guided the work. The information and data documented in this report were collected under a fully qualified Quality Assurance (QA) program and may be used in the licensing process. The data have been submitted to the Sandia National Laboratories Participant Data Archive (PDA) and are indexed in the Automated Technical Data Tracking System (ATDT). The data packages have the following Data Tracking Numbers (DTN): SNL01A05059301.005, SNL01B05059301.006, SNL01C12159302.002, and SNL04050593.001.002 for thermal conductivity, thermal expansion, heat capacity, and mineralogical data, respectively. This work was performed under the direction of Sandia National Laboratories supported by the U.S. Department of Energy under Contract Number DE-AC04-94AL8500.

DISCLAIMER

Acknowledgments:

The authors would like to acknowledge the substantial contributions made to this work by Connie S. Chocas. Ms. Chocas served as a project manager for the thermal testing program through its early stages, supervised development of the thermal properties test equipment, and oversaw much of the planning and testing reported here. Without her diligent efforts, this work could not have been accomplished.

The authors would like also like to recognize Agapito and Associates for providing the tables in Appendix H.

CONTENTS

Figures

Tables

ACRONYMS

A/D	Analog-to-digital
CTE	Coefficient of thermal expansion
MCTE	Mean coefficient of thermal expansion
ICTE	Instantaneous coefficient of thermal expansion
DOE	U.S. Department of Energy
GHFM	Guarded heat flow meter
HFT	Heat flux transducer
LVDT	Linear variable differential transformer
NIST	National Institute of Standards and Technology
NTS	Nevada Test Site
QAIP	Quality Assurance Implementation Procedure
SNL	Sandia National Laboratories
STA	Saturation test apparatus
SRM	Standard Reference Material
T/M	Thermal/mechanical

1.0 INTRODUCTION

1.1 Background

The U.S. Department of Energy (DOE) is investigating Yucca Mountain, Nevada as a potential site for the disposal of high-level nuclear waste. The site is located near the southwest corner of the Nevada Test Site (NTS) in southern Nye County, Nevada. The proposed repository boundary and the Exploratory Studies Facility ramp are shown in Figure 1-1. The engineering design for the high-level nuclear waste repository is unique because large quantities of heat will be generated by the waste packages. It is therefore essential that heat transfer properties such as thermal conductivity, thermal expansion, and thermal heat capacity be measured so that repository performance can be assessed. Thermal properties are largely a function of mineralogy, and so a phenomenological understanding of these properties requires that mineralogy be determined. Four boreholes shown in Figure 1-1 as UE25 NRG-4, UE25 NRG-5, USW NRG-6, and USW NRG-7/7A were drilled along the North Ramp of the Exploratory Studies Facility to guide construction. These borehole designations will be abbreviated in the text as NRG-4, NRG-5, NRG-6, and NRG-7, respectively. Sample materials were obtained from these boreholes and used for measuring mechanical and thermal properties of the stratigraphic units and for petrologic characterization. Additional boreholes shown in Figure1-1 are referred to later in the text. The thickness of each unit is shown in Table 1-1 for each borehole. A correlation between the thermal/mechanical (T/M) and lithostratigraphic units is given in Figure 1-2. Data are grouped by T/M unit for statistical analyses because this is consistent with the study plan; however information is also given by lithostratigraphic unit.

1.2 Scope

This report documents experimental measurements of thermal properties obtained by Sandia National Laboratories (SNL) for Fiscal Years 1994 and 1995 for boreholes NRG-4, NRG-5, NRG-6, and NRG-7. The thermal properties testing was performed by Holometrix, Inc., of Bedford, MA. Petrographic and mineral characterizations were performed by the University of New Mexico in Albuquerque.

Tables 1-2, 1-3 and 1-4, respectively show the numbers of thermal conductivity, thermal expansion and specific heat tests performed for each T/M unit and each borehole. A total of 143 thermal conductivity tests, 132 thermal expansion tests, and 10 specific heat tests were conducted. For thermal conductivity measurements, four saturation levels were used: vacuum saturated, partially saturated, air dried, and oven dried. Thermal expansion test specimens were either air dried, oven dried, or vacuum saturated. All specific heat measurements were made on air-dried specimens. Tests were conducted at room pressure and at temperatures between 25°C and 300°C. Because many specimens were tested at multiple saturation states, there are more tests than test specimens. The number of specimens tested are shown in Tables 1-5, 1-6, and 1-7 for thermal conductivity, thermal expansion, and heat capacity, respectively. The distributions of test specimens within each borehole are shown in Figures 1-3, 1-4, and 1-5 for thermal expansion and specific heat, respectively. Petrologic data were obtained for 97 samples from borehole NRG-6. Hand sample descriptions were obtained for 95 of these samples and more detailed analyses (e.g., microscopic examination of thin sections, X-ray diffraction (XRD), major-element chemical determinations) were performed for 32 samples.

Table 1-1. Depth of Thermal/Mechanical Rock Units for Each Borehole[a]

Thermal/ Mechanical Rock Unit	Approximate Depth to Base of Thermal/Mechanical Unit							
	NRG-4		NRG-5		NRG-6		NRG-7	
	(m)	(ft)	(m)	(ft)	(m)	(ft)	(m)	(ft)
TCw Tiva Canyon	95.4	313.0	42.5	139.3	45.8	150.2	21.2	69.7
PTn Paintbrush, Nonwelded	147.8	485.0	100.6	330.0	77.6	254.5	90.3	296.2
TSw1 Topopah Spring	221.3[b]	726.0[b]	242.6	796.0	217.3	713.0	234.2	768.5
TSw2 Topopah Spring			411.5[b]	1350.0[b]	335.3[b]	1100.0[b]	431.2	1414.8
TSw3 Topopah Spring							444.1	1457.0
CHn1 Calico Hills							461.3[b]	1513.4[b]

[a] Data from Brechtel et al., 1995.
[b] Total Depth of Borehole.

Table 1-2. Numbers of Thermal Conductivity Tests.

T/M Unit	NRG-4	NRG-5	NRG-6	NRG-7	Total
TCw	0	0	12	9	21
PTn	4	0	10	17	31
TSw1	10	4	32	3	49
TSw2	0	18	24	0	42
Total	14	22	78	29	143

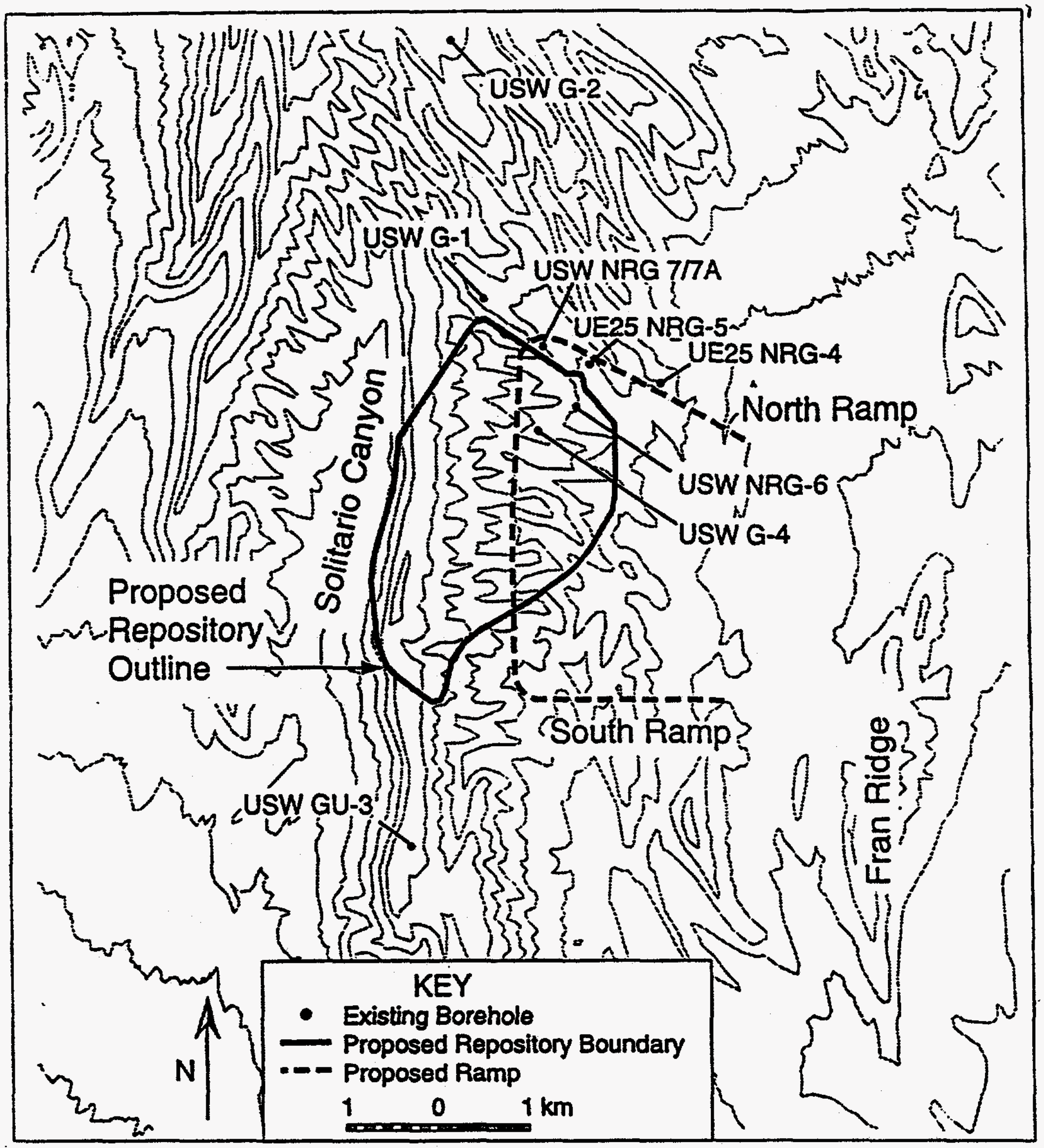


Figure 1-1. Approximate Locations of Drillholes Relative To Proposed Repository Boundary and Exploratory Studies Facilities Ramp. Drillholes and Ramp Locations Were Taken from U.S. Department of Energy (1995).

Geologic Unit (from Sawyer and others, 1994)		Older hydrologic zonation (modified after Scott and Bonk, 1984)			Proposed zonation of Buesch and others (USGS, written comm., 1994)	Thermal/mechanical unit (Ortiz and others, 1985)
Paintbrush Group	Tiva Canyon Tuff	Paintbrush Tuff	Tiva Canyon Member	ccr - caprock	Tpcrv	TCw
				cuc - upper cliff	Tpcrn	
				cul - upper lithophysal	Tpcrl	
					Tpcpul	
				cks - clinkstone	Tpcpmn	
				cll - lower lithophysal	Tpcpll	
				ch - hackly	Tpcplnh	
				cc - columnar	Tpcplnc	
					Tpcpv3	
				ccs - shardy base	Tpcpv2	PTn
					Tpcpv1	
	Yucca Mtn. Tuff		Yucca Mtn. Mbr.			
	Pah Cyn. Tuff		Pah Cyn. Mbr.			
	Topopah Spring Tuff		Topopah Spring Member	upper nonwelded	Tptrv3	
					Tptrv2	
				tc - caprock	Tptrv1	TSw1
				tr - rounded	Tptrn	
				tul - upper lithophysal	Tptrl	
					Tptpul	
				tn - nonlithophysal	Tptpmn	TSw2
				tll - lower lithophysal	Tptpll	
				tm - mottled	Tptpln	
				tv - basal vitrophyre	Tptpv3	TSw3
				nonwelded base	Tptpv2	CHn1
					Tptpv1	
Calico Hills Formation		Tuffaceous Beds of Calico Hills		(not subdivided)	Unit 5 Unit 4 Unit 3 Unit 2 Unit 1	
					bedded tuff unit basal sandstone unit	CHn2
Crater Flat Group	Prow Pass Tuff	Crater Flat Tuff	Prow Pass Member	Not subdivided	Unit 4	CHn3
					Unit 3	PPw
					Unit 2 Unit 1	CFUn
	"bedded tuff"		"bedded tuff"		bedded tuff unit	
	Bullfrog Tuff		Bullfrog Member		Not subdivided (?)	BFw
						CFMn1
	"bedded tuff"		"bedded tuff"			CFMn2
	Tram Tuff		Tram Member			CFMn3
						TRw
						Not Recognized

Figure 1-2. Correlation Between Thermal/Mechanical and Lithostratigraphic Units (Rautman and Engstrom, 1996).

Table 1-3. Numbers of Thermal Expansion Tests.

T/M Unit	NRG-4	NRG-5	NRG-6	NRG-7	Total
TCw	0	0	13	3	16
PTn	1	0	5	8	14
TSw1	6	1	26	10	43
TSw2	0	11	38	10	59
Total	7	12	82	31	132

Table 1-4. Numbers of Specific Heat Tests

T/M Unit	NRG-4	NRG-5	NRG-6	NRG-7	Total
TCw	0	0	0	0	0
PTn	0	0	0	0	0
TSw1	3	0	0	0	3
TSw2	0	7	0	0	7
Total	3	7	0	0	10

1.3 Organization

This report comprises six chapters including this introductory chapter. Chapter 2 discusses specimen preparation procedures. A description of the test equipment and procedures is given in Chapter 3. Results are presented and discussed in Chapter 4, and the summary and conclusions are given in Chapter 5. Chapter 6 contains cited references. Appendices A, B and C are summary data tables for thermal conductivity, thermal expansion, and thermal capacitance tests respectively, and Appendices D, E and F are complete data sets for thermal conductivity, thermal expansion, and thermal capacitance tests, respectively. Appendix G provides a description of each specimen in terms of the lithostratigraphic nomenclature used by the U. S. Geologic Survey (USGS), and Apendix H gives the thermal properties data sorted by lithostratigraphic unit.

Table 1-5. Numbers of Thermal Conductivity Test Specimens

T/M Unit	NRG-4	NRG-5	NRG-6	NRG-7	Total
TCw	0	0	6	6	12
PTn	4	0	6	11	21
TSw1	10	3	19	2	34
TSw2	0	12	16	0	28
Total	14	15	47	19	95

Table 1-6. Numbers of Thermal Expansion Test Specimens

T/M Unit	NRG-4	NRG-5	NRG-6	NRG-7	Total
TCw	0	0	8	3	11
PTn	1	0	4	8	13
TSw1	6	1	20	10	36
TSw2	0	11	38	10	59
Total	7	12	70	31	120

Table 1-7. Numbers of Heat Capacity Test Specimens

T/M Unit	NRG-4	NRG-5	NRG-6	NRG-7	Total
TCw	0	0	0	0	0
PTn	0	0	0	0	0
TSw1	3	0	0	0	3
TSw2	0	7	0	0	7
Total	3	7	0	0	10

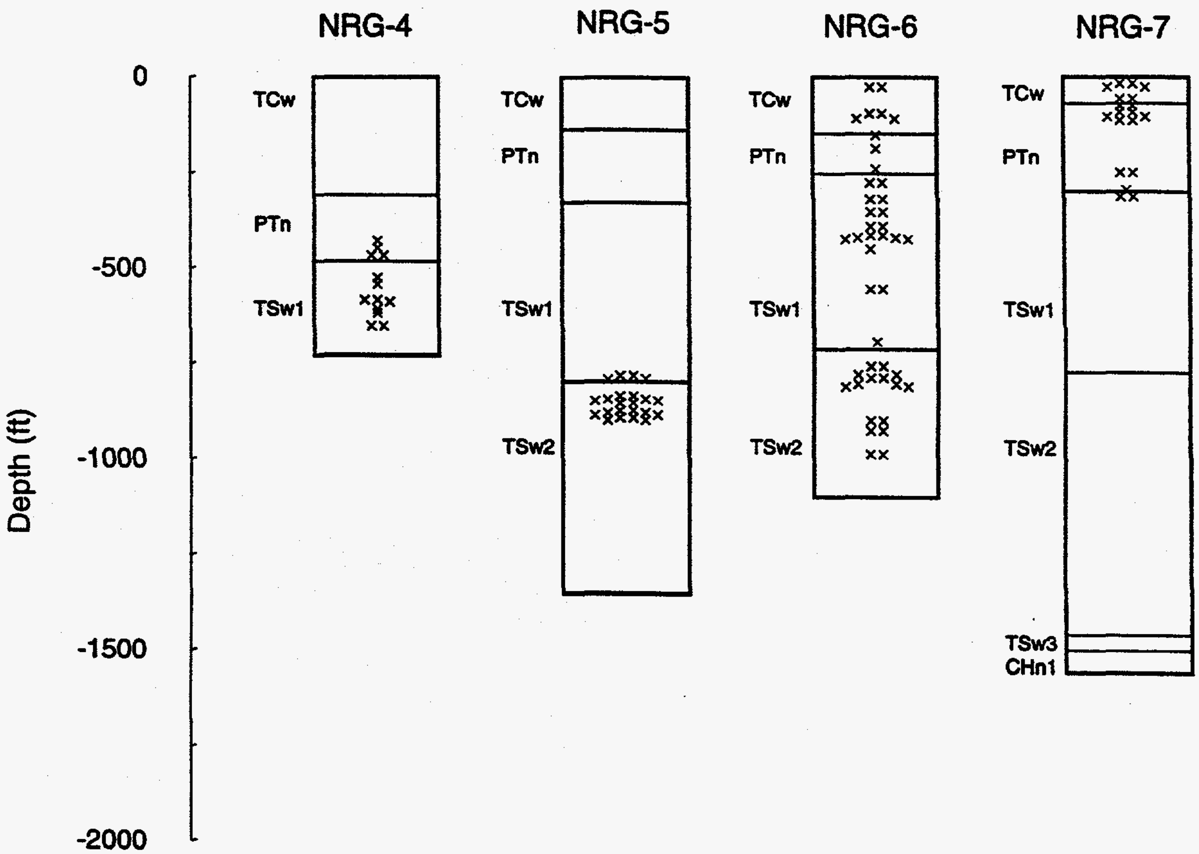


Figure 1-3. Spatial Distribution of Thermal Conductivity Specimens.

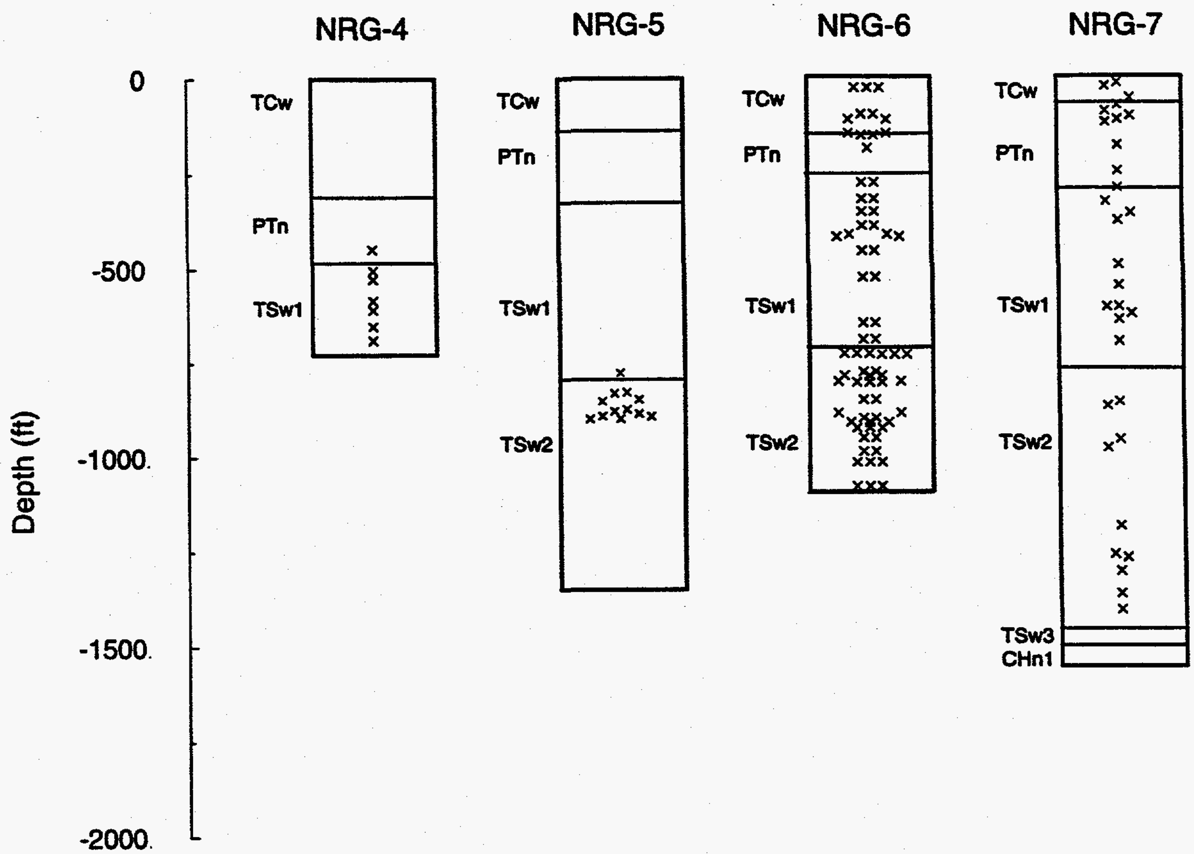


Figure 1-4. Spatial Distribution of Thermal Expansion Specimens.

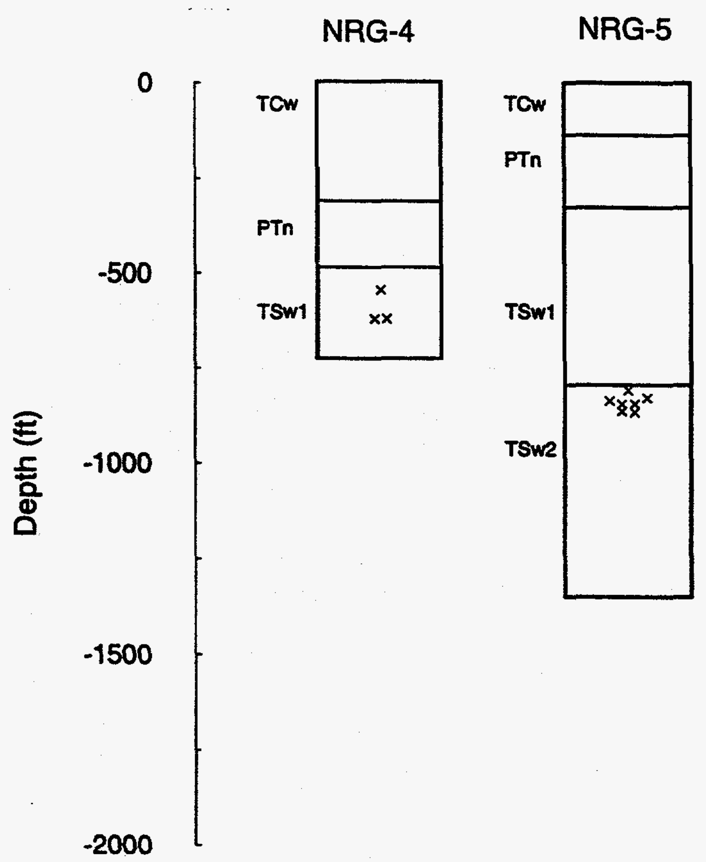


Figure 1-5. Spatial Distribution of Heat Capacity Specimens.

2.0 SPECIMEN PREPARATION

2.1 Thermal Properties Testing

Test specimens were prepared by New England Research, Inc. of White River Junction, VT, according to Sandia National Laboratories (SNL) Technical Procedure SNL TP-200 entitled "Inspection of Samples Used in Thermal Properties Measurements." All specimens were ground, right circular cylinders with nominal specimen dimensions as given in Table 2-1. The exact dimensions were checked and verified according to SNL TP-200.

Specimens were assigned identification numbers according to SNL Quality Assurance Implementation Procedure (QAIP) 20-3 entitled "Sample Control". The specimen identification number begins with the designation of the borehole, e.g., NRG-4, followed by the depth of the top of the piece of core from which the specimen was prepared. "SNL" in the specimen ID denotes that the specimen was prepared for Sandia National Laboratories. If multiple test specimens were prepared from a single piece of core, then the specimens were sequentially labeled A - Z.

Table 2-1. Nominal Dimensions of Test Specimens.

	Thermal Conductivity Test Specimens	Thermal Expansion Test Specimens	Specific Heat Test Specimens[a]
Length (m)	0.0127	0.0508	0.057
Diameter (m)	0.0508	0.0254	0.051

[a]Each specimen contained a 0.0105 m hole drilled along the specimen axis to accommodate the electrical energy source.

Specimens were tested at different saturation states. Air dried specimens were tested in the as-received condition with no effort made to preserve or alter the moisture content. Saturation and drying procedures were performed by Holometrix according to SNL TP-64, "Procedure for Vacuum Saturation of Geologic Core Samples" and SNL TP-65, "Drying Geologic Samples to Constant Weight," respectively. Vacuum saturated test specimens were submerged in distilled water and a vacuum of 10^{-3} Torr was applied for 30 hours. Specimens then equilibrated to ambient pressure for 16 hours before mass was measured. This process was repeated until subsequent weighings showed that mass was stable to within ± 0.05 percent. Partial saturation states were achieved by allowing the saturated specimens to dehydrate at room temperature. The level of partial saturation varies from specimen to specimen. This moisture condition is simply intermediate between air dried and saturated. Oven dried specimens were placed in an oven and heated at ≤ 2°C per minute until the oven reached 110°C. They were dried until subsequent weighings 120 to 128 hours apart showed that masses were stable to within

± 0.05 percent. For specimens that were tested under multiple saturation states, the order in which moisture conditions were imposed was as follows:

- air dried;
- vacuum saturated;
- partially saturated;
- oven dried.
-

2.2 Petrographic Analysis

Specimen preparation is described in Section 3.4 in the context of the analytical methods used.

3.0 TEST METHODS

3.1 Thermal Conductivity

3.1.1 Definition

The flow of heat across a material per unit time is proportional to the temperature gradient. The constant of proportionality, k, is the thermal conductivity and is a property of the material. This proportionality can be written as follows (Feynman et al., 1964)

$$\vec{h} = -k\nabla T \qquad (3\text{-}1)$$

where $\vec{h}$ is a vector and represents the flow of heat across a material of unit cross sectional area per unit time, and ∇T is the temperature gradient. For one dimensional flow this equation can be written as (Halliday and Resnick, 1974):

$$\frac{\Delta Q}{\Delta t} = -kA\frac{\Delta T}{\Delta x} \qquad (3\text{-}2)$$

where: ΔQ = heat (J)
Δt = time (s)
k = thermal conductivity (W/(mK)),
A = cross sectional area (m^2),
ΔT = temperature difference across material (K), and
Δx = thickness of material (m).

3.1.2 Test Equipment

Thermal conductivity measurements were made by the Testing Services Division of Holometrix, Inc. using the guarded heat flow meter (GHFM). This apparatus is appropriate for measurements of thermal conductivity between 0.1 W/(mK) and 10 W/(mK) and for temperatures between -120°C and 300°C. The apparatus is shown schematically in Figure 3-1. The test specimen was located between two heater plates controlled at different temperatures, producing heat flow through the specimen. The heat flow was measured by a heat flux transducer (HFT) located between the specimen and one heater plate. Radial heat flow losses were minimized in two ways. First, a cylindrical guard heater surrounded the specimen and was maintained at the mean specimen temperature, and second, specimens with lengths less than 20 mm were used. Low temperature tests (below 100°C) were performed on a Holometrix TCA-200-LT GHFM and data were acquired and analyzed with Holometrix TCA-200-LT software. High temperature tests (above 100°C) were conducted on a Holometrix TCA-300 GHFM and data were acquired and analyzed with Holometrix TCA-YMP software.

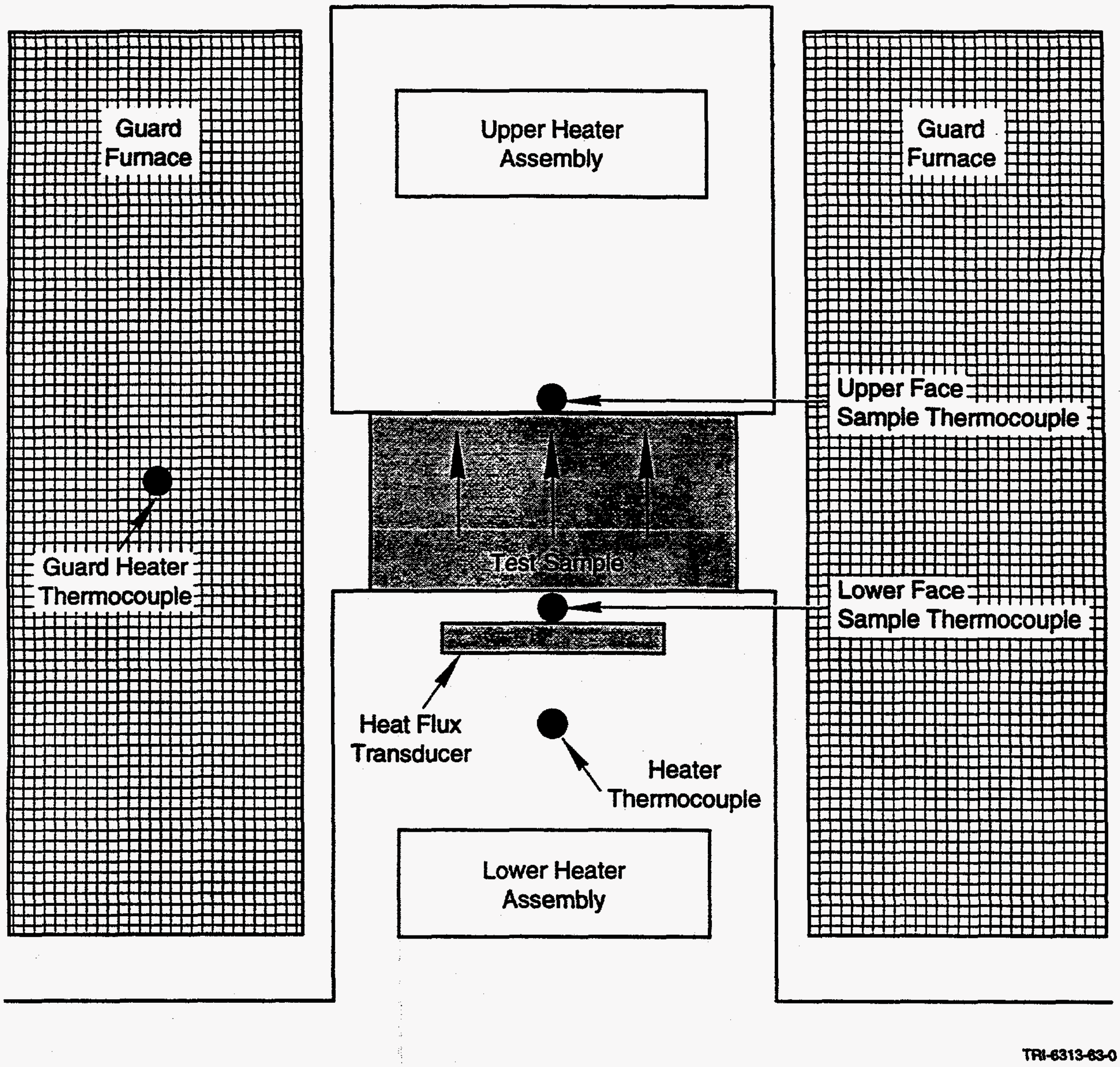


Figure 3-1. Schematic of Guarded Heat Flow Meter Test Section.

3.1.3 Calibration/Data Reduction

The GHFM is calibrated by comparing results obtained using specimens of known thermal conductivity with theoretical values. A single calibration is performed to determine both the contact resistance between the specimen and heater plates, and the proportionality constant relating the output of the heat flux transducer to the actual heat flux.

The total thermal resistance of the specimen and contact area is given by:

$$R_t = \frac{N\Delta T}{q} \tag{3-3}$$

where: R_t = total thermal resistance (m^2K/W),
N = sensitivity of the heat flux transducer (m^2V/W),
ΔT = the measured temperature difference between thermocouples (K), and
q = heat flow transducer output (V).

The total thermal resistance comprises the thermal resistance of the specimen and the residual value associated with the interfaces:

$$R_t = R_s + R_0 \tag{3-4}$$

where: R_s = thermal resistance of the specimen (m^2K/W) and
R_0 = residual thermal resistance (m^2K/W).

Substituting Equation 3-3 into 3-4 gives

$$R_s = \frac{N\Delta T}{q} - R_0 \tag{3-5}$$

Calibrations, discussed later in this section, are performed to determine N and R_0. This equation is then used to determine R_s from measured values of q and ΔT.

The next equations relate R_s to thermal conductivity. The thermal resistance of the specimen is given by:

$$R_s = \frac{\Delta T}{(\Delta Q / \Delta t)A} \tag{3-6}$$

Substituting Equation 3-2 into equation 3-6 gives

$$k = \frac{-\Delta x}{R_s} \tag{3-7}$$

This final equation is used to calculate thermal conductivity from R_s. Equations 3-5 and 3-7 are cited in TP-202, "Measurement of Thermal Conductivity of Geologic Samples by the Guarded-Heat-Flow-Meter Method." Equations 3-3, 3-4 and 3-6 show the derivation of equations 3-5 and 3-7.

Calibrations were performed on reference samples of Pyrex 7740. A range of thermal resistance values was obtained using specimens of different thicknesses (6 mm, 12 mm, and 18 mm). Thermal resistance measurements were made at three temperatures spanning the operating range. Separate calibrations were obtained for the low temperature range (20°C to 100°C) and the high temperature range (100°C to 300°C). Values of ΔT and q were obtained from the thermocouples and the HFT, respectively. A straight line fit to Equation 3-5 was used to determine the calibration constants N and R_0. A typical calibration curve is shown in Figure 3-2. Calibrations were verified by performing measurements on reference specimens of high-purity fused quartz. Verifications were obtained using one specimen size and testing at each of the three temperatures. Recommended thermal conductivity values for Pyrex 7740 and high purity fused quartz are published by the National Institute of Standards and Technology (NIST). These were chosen as reference materials since no NIST Standard Reference Materials of suitable conductivity were available. Calibration verifications were performed periodically throughout the testing program. If the error in thermal conductivity calculated for the standard material exceeded four percent at any temperature, then the equipment was recalibrated and all tests conducted since the last successful verification were repeated.

Additional components of the system requiring calibration included thermocouples and an analog-to-digital (A/D) converter. The thermocouple cold junction electronic ice reference was calibrated with an ice bath and a NIST-traceable thermocouple, and the analog-to-digital (A/D) converter was calibrated with a NIST-traceable precision voltage source. The calibration was performed using SNL TP-207, "Calibration of Temperature Sensors Used for Thermal Properties Testing."

3.1.4 Procedure

Once the instrument was calibrated, the test specimens were tested in the same manner as the reference materials. This procedure is given in SNL TP-202, "Measurement of Thermal Conductivity of Geologic Samples by the Guarded-Heat-Flow-Meter Method" and is summarized here. Data were obtained after the instrument had reached steady state thermal equilibrium as determined by taking readings of the thermocouples and HFT as a function of time until the readings were constant. Five readings were taken per minute and were considered to be stable when they were constant to within ± 0.25 percent for 10 minutes. This is within the stability criteria given in ASTM F433, "Standard Practice for Evaluating Thermal Conductivity of Gasket Materials," an ASTM standard based on use of the GHFM. The measured ratio, $\Delta T/q$, was then used to determine the thermal resistance of the specimen. Thermal conductivity was calculated from R_s and specimen thickness. Separate test cycles in separate apparatus were run at low temperature (<100°C) and at high temperature (>100°C).

Specimens tested at less than 100°C were placed in moisture containment cells to preserve saturation during testing (see Figure 3-3). These cells are composed of aluminum face plates that contact the specimen faces, and a low conductivity ring manufactured from thermally stable, moisture resistant, thermoplastic (Kel-F 81). A rubber o-ring and gasket improve the seal.

Reference specimens were run in the moisture containment cells to calibrate for the resistance of the face plates and additional interfaces.

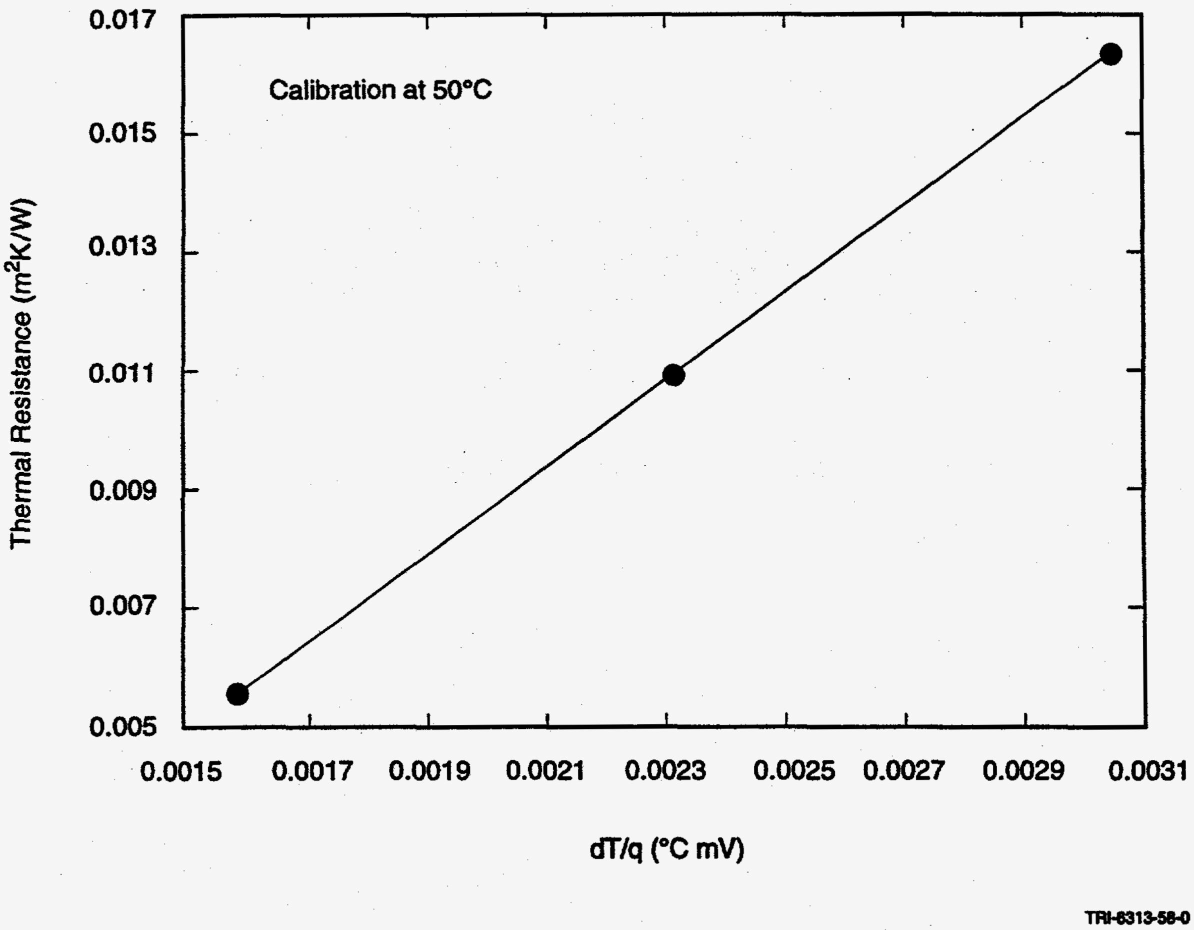


Figure 3-2. Typical Calibration Curve.

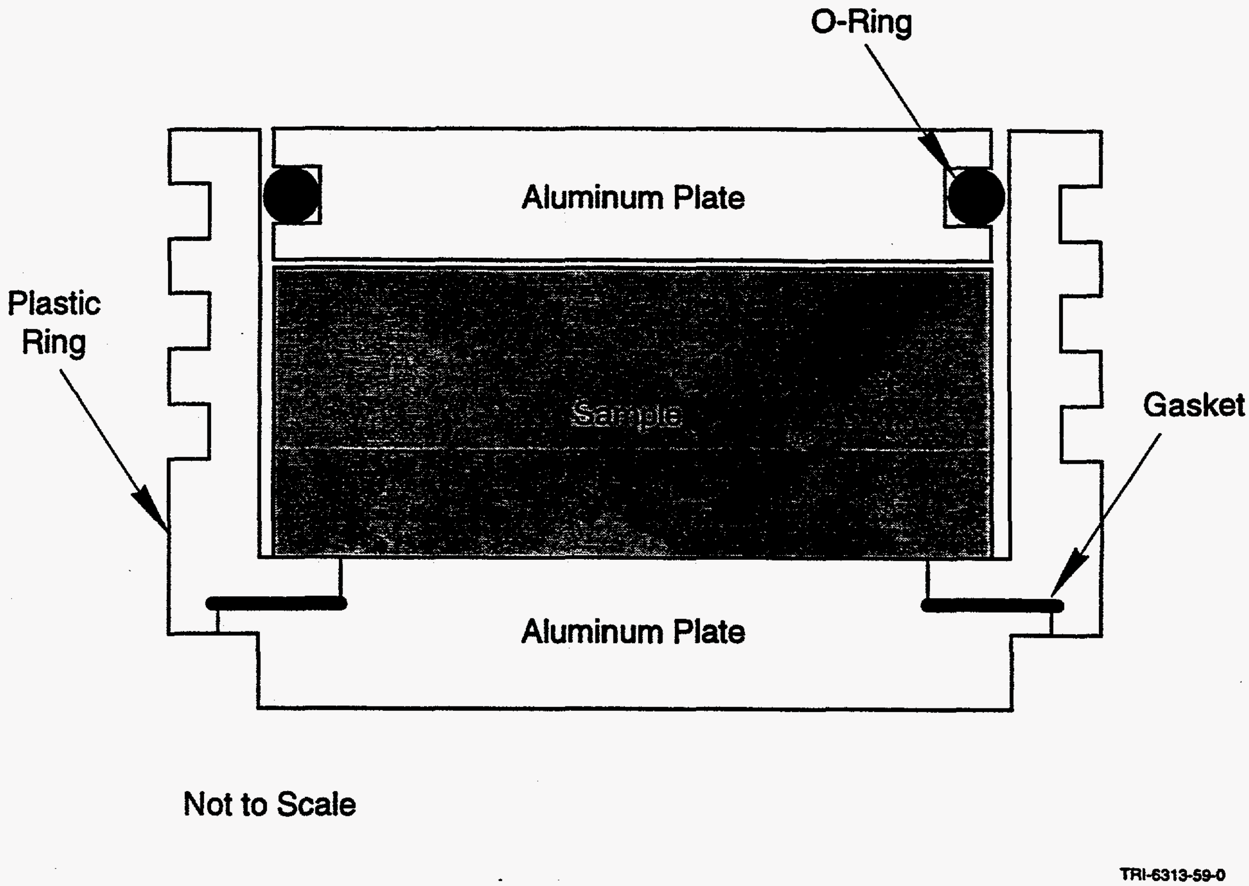


Figure 3-3. Moisture Containment Cell.

3.2 Thermal Expansion

3.2.1 Definition

The coefficient of linear thermal expansion, α, is the ratio of change in specimen length per degree Centigrade to the length at 0°C and is given by (Weast, 1974):

$$l_t = l_0(1 + \alpha T) \tag{3-8a}$$

where: l_0 = length at 0°C and

l_t = length at T °C.

Thermal expansion is temperature sensitive, and the more general equation is

$$l_t = l_0\left(1 + \alpha T + \beta T^2 + \gamma T^3 + ...\right) \qquad (3\text{-}8b)$$

where α, β, and γ are empirically determined constants.

3.2.2 Test Equipment

All of the thermal expansion data were obtained from experiments using one of two identical push-rod dilatometer instruments manufactured by Harrop Industries. The push-rod dilatometer is one of several instruments for measuring the linear coefficient of thermal expansion of materials. The specimen is placed in a receptacle at the end of a tube made of fused silica (Figure 3-4). The tube, or specimen holder, containing the specimen and push rod slides into a cylindrical furnace such that the specimen is positioned near the center of the furnace. As the temperature of the specimen changes, its length changes and this motion is transmitted to the push rod. The change in length is continuously measured by a linear variable differential transformer (LVDT) located outside of the heated area of the specimen. A type K thermocouple near the surface of the specimen monitors specimen temperature. The specimen can be maintained in an environment such as inert gas, high humidity, or a vacuum by placing an "environmental tube" around the entire specimen holder and controlling the environment through apertures in the end of the tube. The entire assembly of environmental tube and specimen holder is then inserted into the furnace.

Specimens were tested up to 100°C under saturated conditions by maintaining an atmosphere in the environmental tube consisting of moist air with a partial pressure of water equal to that of the water in the specimen. This was done with a Saturation Test Apparatus (STA). The required atmosphere was obtained by heating a pool of water in the vicinity of the specimen to the same temperature as the specimen itself. The water and specimen temperatures were held to within 1°C of each other up to a temperature of 95°C.

3.2.3 Calibration/Data Reduction

The dilatometer system expansion was calibrated and then verified by running Standard Reference Materials (SRMs) certified as traceable to NIST and comparing data with expected results. Calibration was performed using a specimen of fused silica (SRM 739), and verification was provided by measuring the expansion of either SRM 731 (borosilicate glass) or SRM 738 (stainless steel). The LVDT and associated electronics were calibrated with a micrometer using an 11-point calibration. The measurement error associated with thermal expansion is $\pm 2 \times 10^{-6} \cdot C^{-1}$ if the STA was used and $\pm 1 \times 10^{-6} \cdot C^{-1}$ if the STA was not used. These measurements are repeatable to within ± 5 percent. The system calibration was reverified once each month using the glass or stainless steel standard. If the calculated CTE was in error by more than 5 percent, then the system was recalibrated and all tests conducted since the last successful verification were repeated.

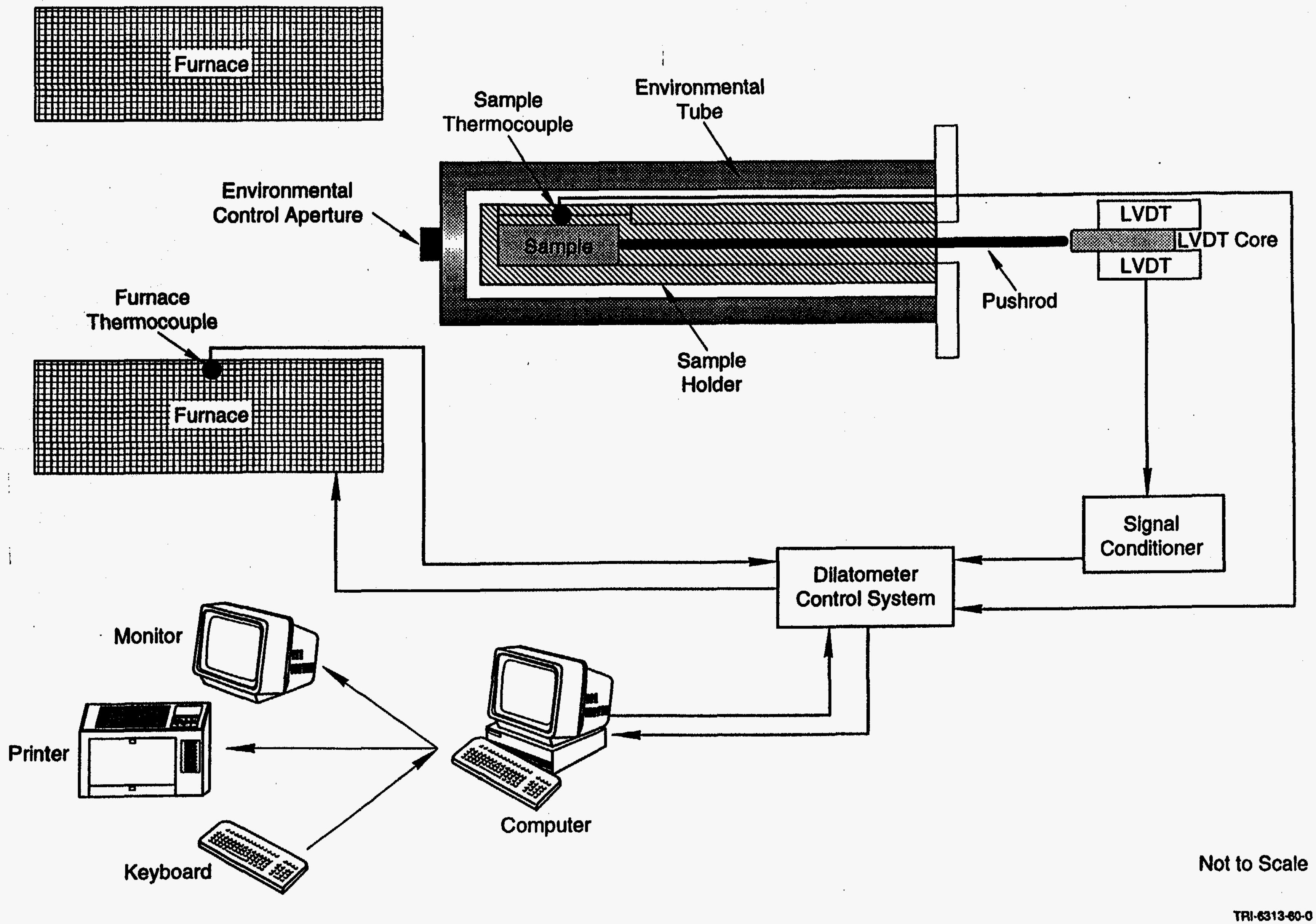


Figure 3-4. Schematic of dilatometer system.

The thermal expansion data were corrected for system expansion using calibration data obtained as previously described. These data were then used to calculate thermal strain resulting from temperature changes (ε_T), starting at 25°C, during the heating and cooling phases as follows (Jaegar and Cook, 1976):

$$\varepsilon_T = \frac{L_{Tn} - L_0}{L_0} \qquad (3\text{-}9)$$

where: L_{Tn} = specimen length (m) at a particular temperature (Tn), i.e., Tn = 25°C, 50°C, 75°C, ... 300°C, 275°C, 250°C, ... 35°C, and

L_0 = specimen length (m) at the reference temperature.

The mean coefficient of thermal expansion ($\overline{\alpha}$ or MCTE) is the linear thermal expansion per unit change in temperature. It was calculated in 25°C intervals, starting at 25°C, i.e., 25°C - 50°C, 50°C - 75°C, 75°C - 100°C, ... 275°C - 300°C, 300°C - 275°C, ... 50°C - 35°C (note the last interval is over a 15°C interval), during heating and cooling. The MCTE must be accompanied by the values of the two temperatures used in the calculation. The MCTE is defined (following equations 3-8a and also as given in Halliday and Resnick, 1974) as:

$$\overline{\alpha} = \frac{1}{L_0}\left\{\frac{L_{T2} - L_{T1}}{(T_2 - T_1)}\right\} \qquad (3\text{-}10a)$$

or

$$\overline{\alpha} = \frac{1}{L_0}\left(\frac{\Delta L}{\Delta T}\right) \qquad (3\text{-}10b)$$

where: L_{T1} = specimen length (m) at temperature T_1,
L_{T2} = specimen length (m) at temperature T_2,
L_0 = specimen length (m) at reference temperature,
$\Delta L = L_{T2} - L_{T1}$ = specimen displacement due to temperature increment (m) and
ΔT = $T_2 - T_1$ = temperature increment, 25°C or 15°C.

Because data were not always collected at exact 25°C intervals, a linear least squares fit was used to calculate the specimen lengths L_{T1} and L_{T2} at temperatures T_1 and T_2, respectively. In most cases the data were fit within a window of approximately 5°C, symmetric about temperatures T_1 or T_2. Equation 3-10b was then used to calculate the MCTE for each 25°C interval.

The instantaneous coefficient of thermal expansion (α_T or ICTE) is the slope of the linear thermal expansion curve at temperature T. The calculation was made at specified temperatures 25°C apart starting at 50°C, i.e., 50°, 75°, 100°, ... 300°, 300°, 275°, ... 50°C, during heat-up and cool-down. It was calculated using a linear least square fit to the strain versus temperature data over a 5°C window centered over the specified temperature T, and is therefore not truly instantaneous. The ICTE must be accompanied by the temperature at which it is determined. The ICTE is defined following equation 3-10b as:

$$\alpha_T = \frac{1}{L_0}\frac{dL}{dT} \qquad (3\text{-}11)$$

3.2.4 Procedure

The test procedure is given in SNL TP-203, "Measurement of Thermal Expansion of Geologic Supplies Using a Push Rod Dilatometer". The test specimen was placed in the notched-out end of a fused silica tube and the test apparatus set up as described in Section 3.2.2. The furnace temperature was ramped up and down at a constant rate of 1°C per minute. The rate at which the specimen temperature changed was therefore always ≤ 1°C per minute. Displacement and temperature data were acquired continuously throughout the heat-up and cool-down phases of the test and recorded by a computerized data acquisition system.

3.3 Specific Heat

3.3.1 Definitions

Heat capacity is the amount of heat required to change the temperature of a substance by a given amount. It is defined as (Halliday and Resnick, 1974):

$$H = \frac{\Delta J}{\Delta T} \qquad (3\text{-}12)$$

where ΔJ = Quantity of heat (J)

ΔT = Change in temperature (K)

The specific heat of a substance is its heat capacity per unit mass[a] (Halliday and Resnick, 1974), i.e.,

$$C = \frac{H}{m} = \frac{\Delta J}{m \cdot \Delta T} \qquad (3\text{-}13)$$

where m = mass (kg).

Generally, specific heat is measured under isobaric (constant pressure) or isochoric (constant volume) conditions. In this study, specific heat was measured under isobaric conditions and will

[a] Weast (1974) defines specific heat of a substance as the ratio of its $\Delta J/(m\Delta T)$, to that of water at 15°C.

be represented by the symbol C_p. In this report, thermal capacitance will be defined as heat capacity per unit volume, i.e.,

$$\rho \cdot C_p = \frac{H}{v} = \frac{\Delta J}{v \cdot \Delta T} \tag{3-14}$$

where v = volume (m^3).

3.3.2 Test Equipment

The ASTM procedure for measurement of specific heat of geologic materials is ASTM D4611, "Standard Test Method for Specific Heat of Rock and Soil". This ASTM standard is based on drop calorimetry and reports a precision and bias error of up to 10 percent based on a limited amount of round-robin testing. As shown in Section 3.3.3, the error associated with the procedure used in this study, SNL-TP-204 entitled "Measurement of Specific Heat of Geologic Samples by Adiabatic Pulse Calorimetry", is less than 5 percent.

The specific heat data reported here were obtained using an adiabatic pulse calorimeter shown schematically in Figure 3-5. This instrument applies a known quantity of electrical energy to a specimen and measures the resulting rise in specimen temperature. The specimen is placed inside a removable container which is located in the center of a low-mass adiabatic guard. The guard is located inside a small test chamber in which the air temperature is controlled while the air is circulated past the outside surface of the adiabatic guard. All temperatures are measured with type-K thermocouples. The adiabatic guard heater is controlled at the same temperature as the specimen holder to minimize heat flow and ensure that the measurement is adiabatic. Heat exchange between the specimen holder and the guard, due to small temperature differences during operation, is reduced by low density fibrous insulation on the inside of the guard wall, as well as by a series of radiation shields. As a result, almost all heat input to the specimen is used for raising its temperature and that of the specimen holder, or for converting the specimen material from one physical state to another.

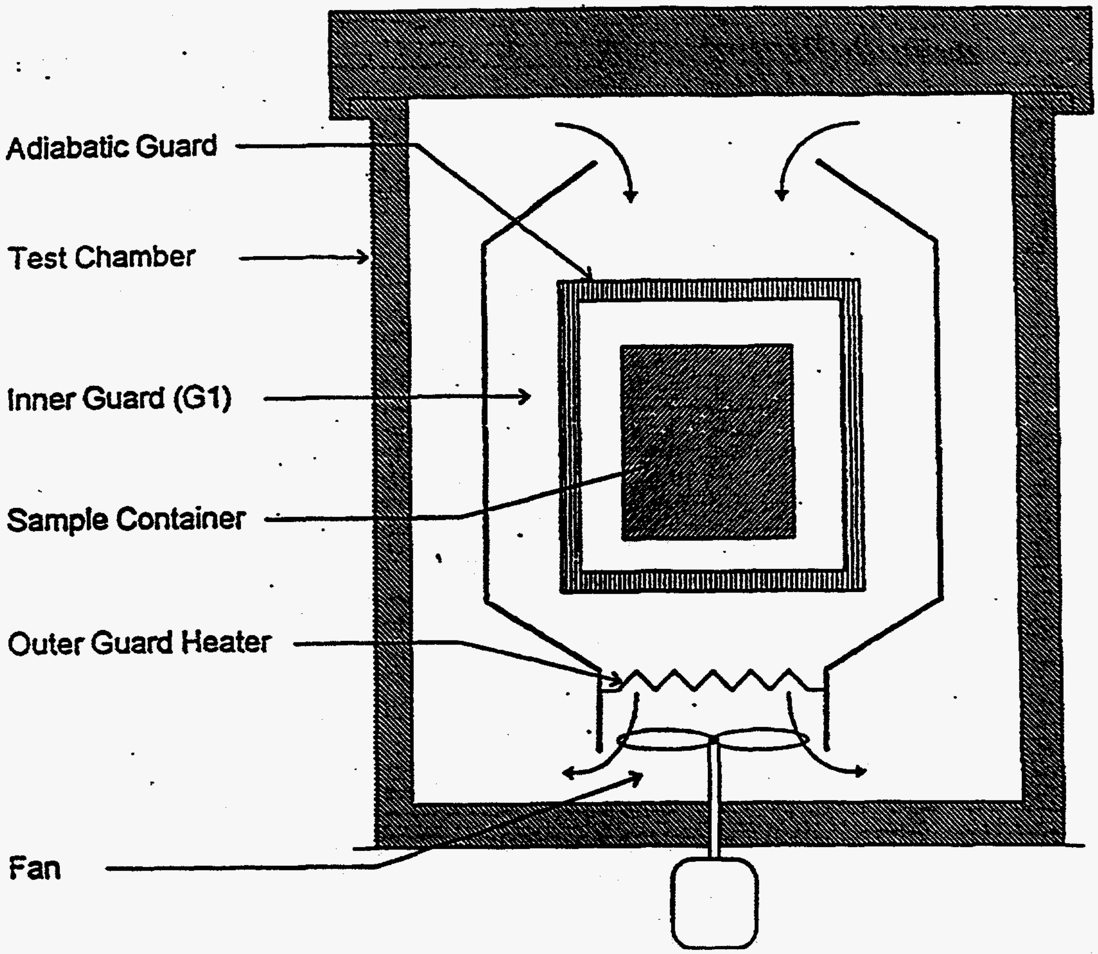


Figure 3-5. Schematic of QTA Adiabatic Calorimeter.

3.3.3 Calibration/Data Reduction

The test system was calibrated by determining the heat lost to the specimen container. A test was conducted on the empty specimen container to determine its ''apparent specific heat'' over the test temperature range. The apparent specific heat values included both the true heat capacity of the container and the effect, if any, of departures from adiabatic conditions. The apparent specific heat was then used to correct the data for the heat required to increase the temperature of the container while running a test.

Tests were verified with NIST Standard Reference Material No 720, synthetic sapphire. Measurement error, initially projected to be better than 5 percent, was found to be actually better than 2.5 percent.

Data were reduced using equations 3-13 and 3-14. The specimen mass was determined by weighing the empty and filled specimen container, and specimen volume was determined from its measurements and geometry. The incremental heat, ΔJ, was found from measurements of voltage and current and the duration of the electrical power pulse, as follows (TP-204, "Measurements of Specific Heat of Geologic Samples by Adiabatic Pulse Calorimetry"):

$$\Delta J = \sum_{i=1}^{N} (V \cdot I \cdot dt)_i \tag{3-15}$$

where

N = Number of time intervals during which, for a given pulse, current is applied to the sample heater

V = Voltage across the sample heater (V)

I = Current through the sample heater (A)

i = Index taking on values from 1 to N

dt = time interval (s)

Specific heat values reported here were determined from polynomial fits to the raw data. Specific heat was measured every five degrees Celsius from 25°C to 300°C. These raw data were smoothed using a two-segment, least squares polynomial curve-fit. The equations for the polynomial fit were then used to determine C_p at 25°C intervals.

3.3.4 Procedure

The test procedure is given in SNL TP-204 and is summarized here. The adiabatic calorimeter is controlled by a built-in micro-computer. Once the specimen and container have been installed in the calorimeter, the testing proceeds under computer control. When the test is started, the computer scans the temperatures of the specimen container, adiabatic guard, and chamber air. The air temperature is maintained at a constant 5°C below the adiabatic guard, which significantly improves the guard temperature control. Electrical power is supplied to a small heater in the specimen container in precisely timed pulses lasting from 1 to 2 minutes. This results in typical temperature steps of 5°C if the specimen is stable. During phase changes, some or all of the energy is used for conversion until the process is complete. After each pulse, the computer monitors the specimen and guard temperatures until thermal equilibrium is established. This usually takes about 12 minutes depending upon specimen thermal conductivity.

3.4 Petrographic and Mineralogical Characterization

3.4.1 Introduction

Petrologic data were obtained from 97 samples from borehole NRG-6. Hand samples were described for all but two of these samples and for 32 samples detailed data were obtained. Methods used to obtain these detailed data include: microscopic examination of thin sections (to identify visible mineral and petrographic constituents, estimate the modal or volumetric proportions of those constituents, and describe their textural and spatial arrangement), X-ray diffraction (XRD) analysis (to identify minerals too finely-crystalline to identify optically, which are generally the majority of mineral components in these samples, and estimate their proportions), and major-element chemical analysis (to identify bulk rock chemistry and water content).

3.4.2 Analytical Methods

Hand samples were examined using an 8x hand lens, and the following characteristics noted: colors and distribution of colors in the sample; degree of welding; presence and abundance of pumice or fiamme; presence and abundance of glass; presence and abundance of vesicles and pores; presence, abundance and shape of lithophysae and associated cavities; identification, estimated abundance and maximum size of phenocrysts.

Two 2.5 cm diameter polished thin sections were made of each of the 32 samples studied in greater detail following procedures detailed in SNL TP-60, ''Procedures for Preparation of Polished Thin Sections''. For each sample, one section was oriented approximately parallel to the core axis (approximately to perpendicular to layering) and the second oriented perpendicular to the core axis. Descriptive petrographic data were obtained utilizing an optical petrographic microscope following procedures detailed in SNL TP-59 ''Procedures for Laboratory Sample Petrology Determination'', and quantitative point counts of components were obtained by counting approximately 900 to 1600 points on the sections using a 1mm x 1mm grid.

The XRD data used to identify mineral phases were obtained in the X-ray diffraction laboratory in the Department of Earth and Planetary Sciences at the University of New Mexico using the Scintag Pad V XRD system following procedures detailed in SNL TP-62, ''Laboratory Procedures for Mineralogic Analysis by X-Ray Powder Diffraction Part 1: Data Gathering''. Sample powders were prepared using a Spex (Brand) shatterbox and Retch-Brinkmann automated mortar and pestle following procedures which insured a uniform sample powder size of approximately 1 to 10 microns. All of the 32 samples for which XRD data were obtained were scanned over an angular interval of 2° to 52° 2-Theta (2θ) at a rate of 1° 2θ per minute. The mineral phases were identified following procedures detailed in SNL TP-102, ''Laboratory

Procedures for Mineralogic Analysis by X-Ray Powder Diffraction Part 2: Data Analysis''. The proportions of mineral phases were estimated using a spreadsheet-based modification of the matrix flushing method of Chung (1974a, 1974b) developed utilizing Excel 5.0 for Microsoft Windows on a personal computer using reference intensity ratios determined and published by Bish and Chipera (1989).

Whole-rock analyses were obtained in the Geochemistry Laboratory in the Department of Earth and Planetary Sciences at UNM. Analyses were obtained on powdered samples prepared using the same SPEX Brand shatterbox used to prepare powders for XRD analysis. Various analytical techniques were used to obtain the data including X-ray fluorescence spectroscopy (XRF) for most elements, gravimetric and volumetric analysis (for H_2O and the proportion of ferrous and ferric iron reported as FeO and Fe_2O_3, and for some analyses of SiO_2), atomic absorption spectrophotometry for one CaO analysis, and colorimetric analysis (for P_2O_5). These techniques are described in detail in SNL TP-61, ''Procedures for Laboratory Sample Bulk Chemical Determination''. Accuracy was checked by simultaneously analyzing laboratory standards traceable to NIST rock standards, and comparison with certified values.

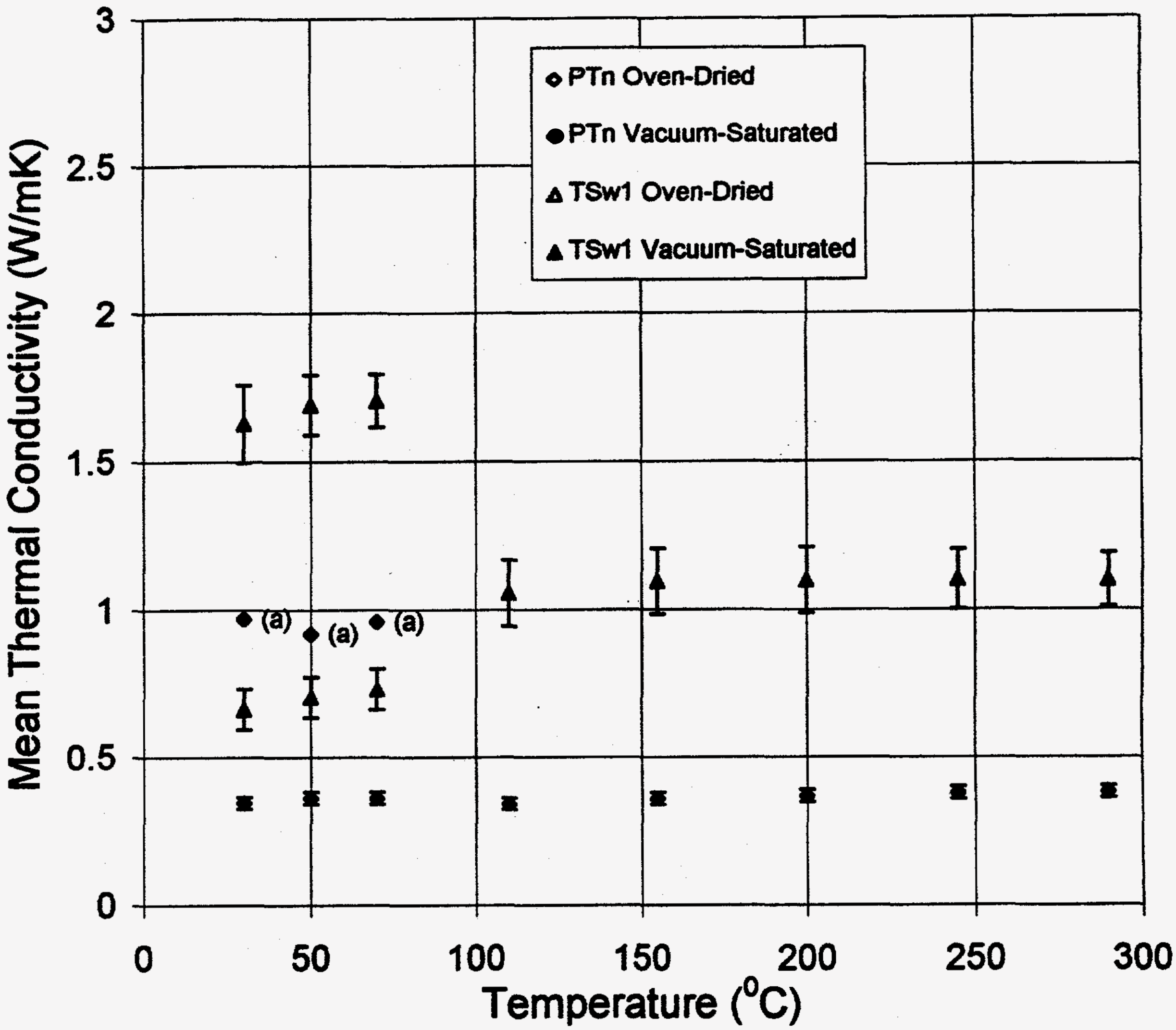
4.0 RESULTS

4.1 Thermal Conductivity

4.1.1 Summary of Data

The thermal conductivity data are summarized in Appendix A, Tables A-1 through A-4, for NRG-4, NRG-5, NRG-6, and NRG-7, respectively. The information in each table is grouped according to T/M unit and moisture content. The mean thermal conductivity and standard deviation about the mean are given at each temperature for each T/M unit and moisture content. The mean thermal conductivities are plotted in Figures 4-1 through 4-4 as a function of temperature for NRG-4, NRG-5, NRG-6, and NRG-7, respectively. To simplify the plots, only data obtained under saturated and oven dried conditions are shown, but the complete data set is given in Appendix D. Generally, thermal conductivity for oven dried specimens either increases or remains constant with increasing temperature. Thermal conductivity increases with temperature for plagioclase and glasses; however, it decreases with temperature for quartz (Lappin, 1980). Decreases in conductivity with increasing temperature as observed in saturated specimens are attributed to dehydration. Sharp increases in thermal conductivity are observed near 100°C for several oven dried specimens (TSw1 in NRG-4 and NRG-7, and TCw from NRG-7). These increases are as yet unexplained, but may be associated with a change in instrumentation at 100°C or with the vaporization of remaining water.

Mean thermal conductivities as a function of temperature for oven dried specimens from all four boreholes are shown in Figure 4-5. Each T/M unit is represented by a different symbol, and each borehole is represented by a different line type. This plot can be used to assess the lateral consistency of thermal conductivity values. PTn consistently shows the lowest conductivities while the TCw and TSw2 units have the highest conductivity values. TSw1 specimens span a larger range of thermal conductivity and are intermediate in value.



(a) Insufficient data to calculate standard deviation.

Figure 4-1. Summary of Average Thermal Conductivities for Borehole NRG-4. Error bars indicate ± one standard deviation.

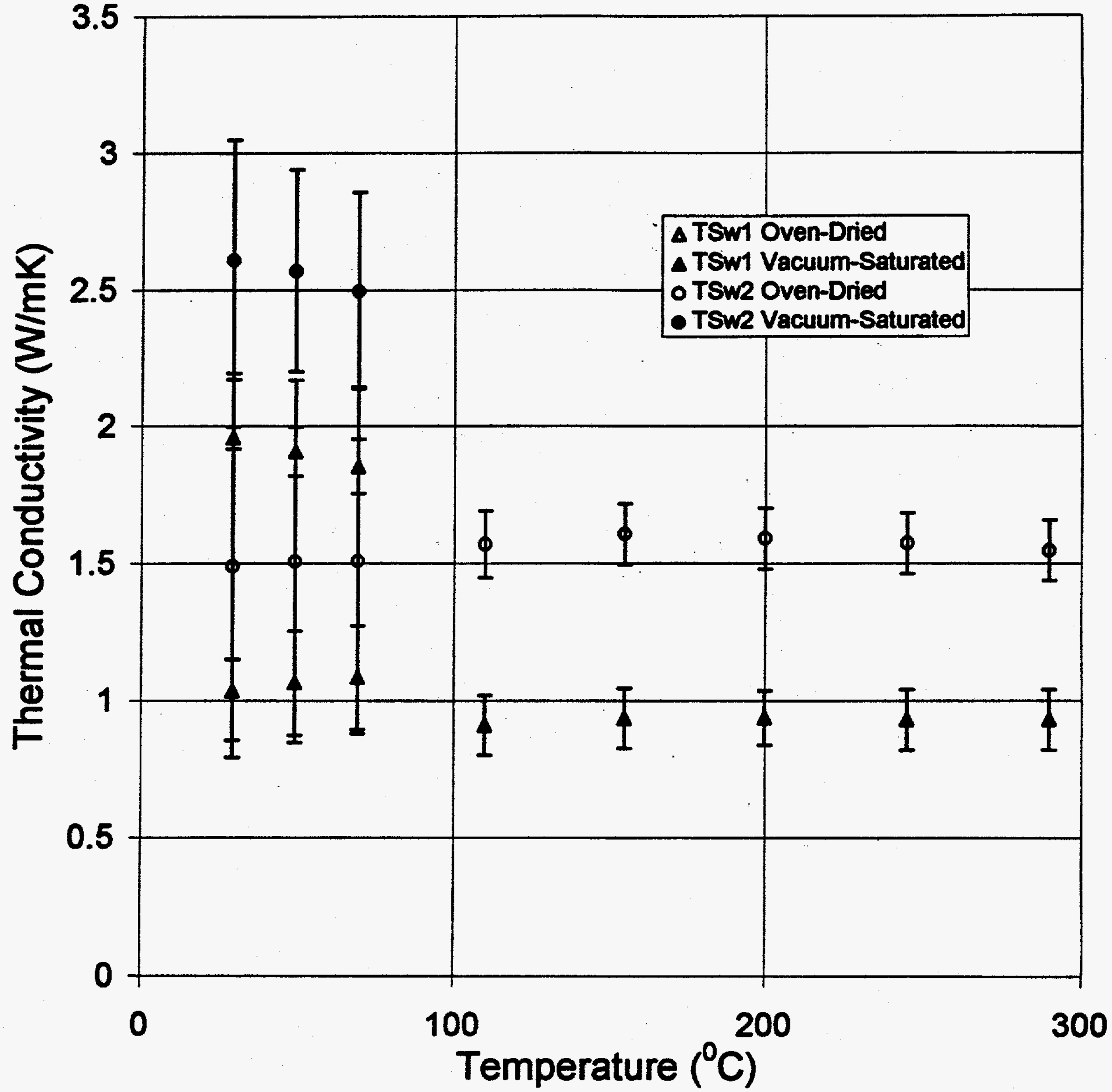


Figure 4-2. Summary of Average Thermal Conductivities for Borehole NRG-5. Error bars indicate ± one standard deviation.

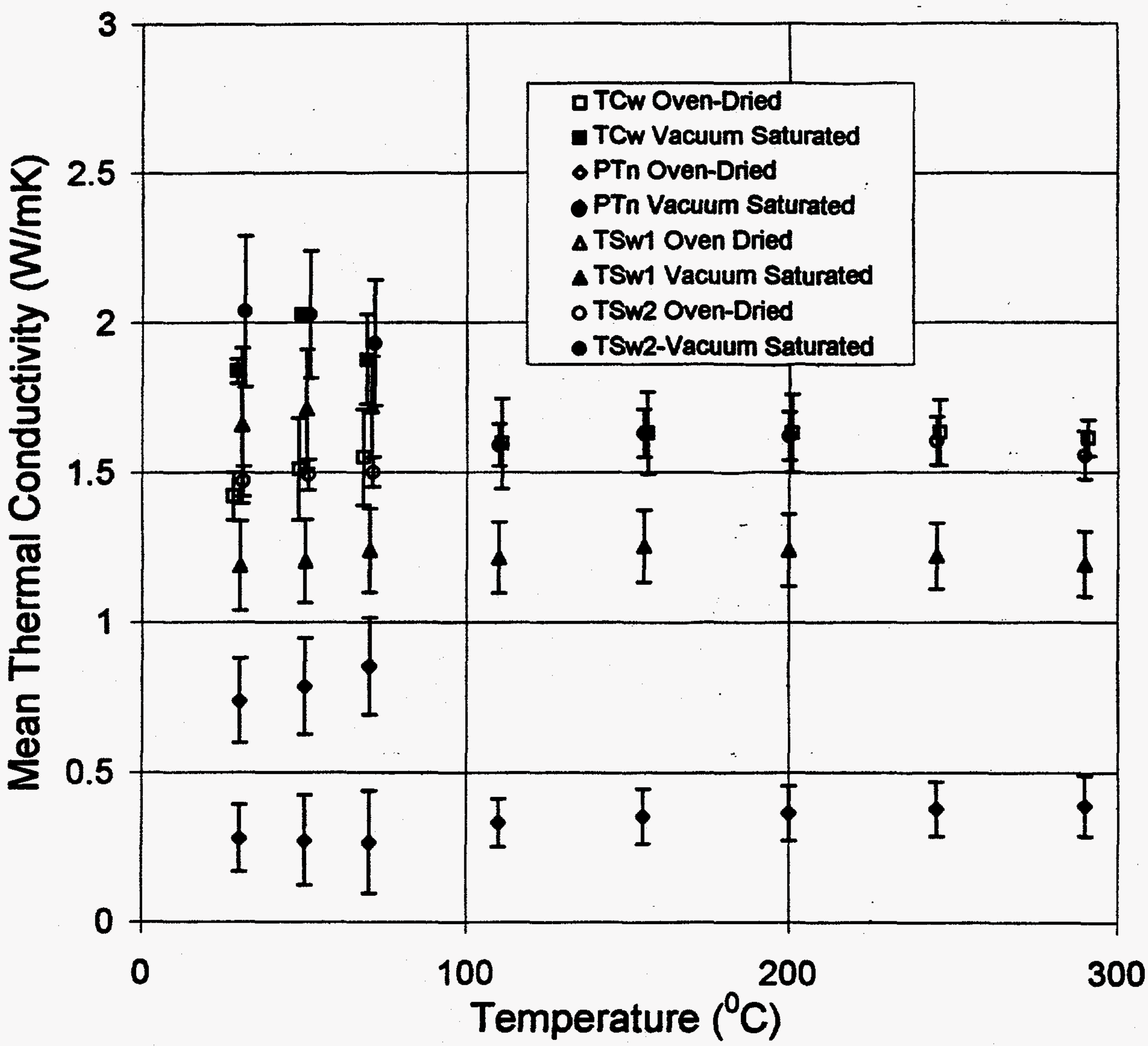
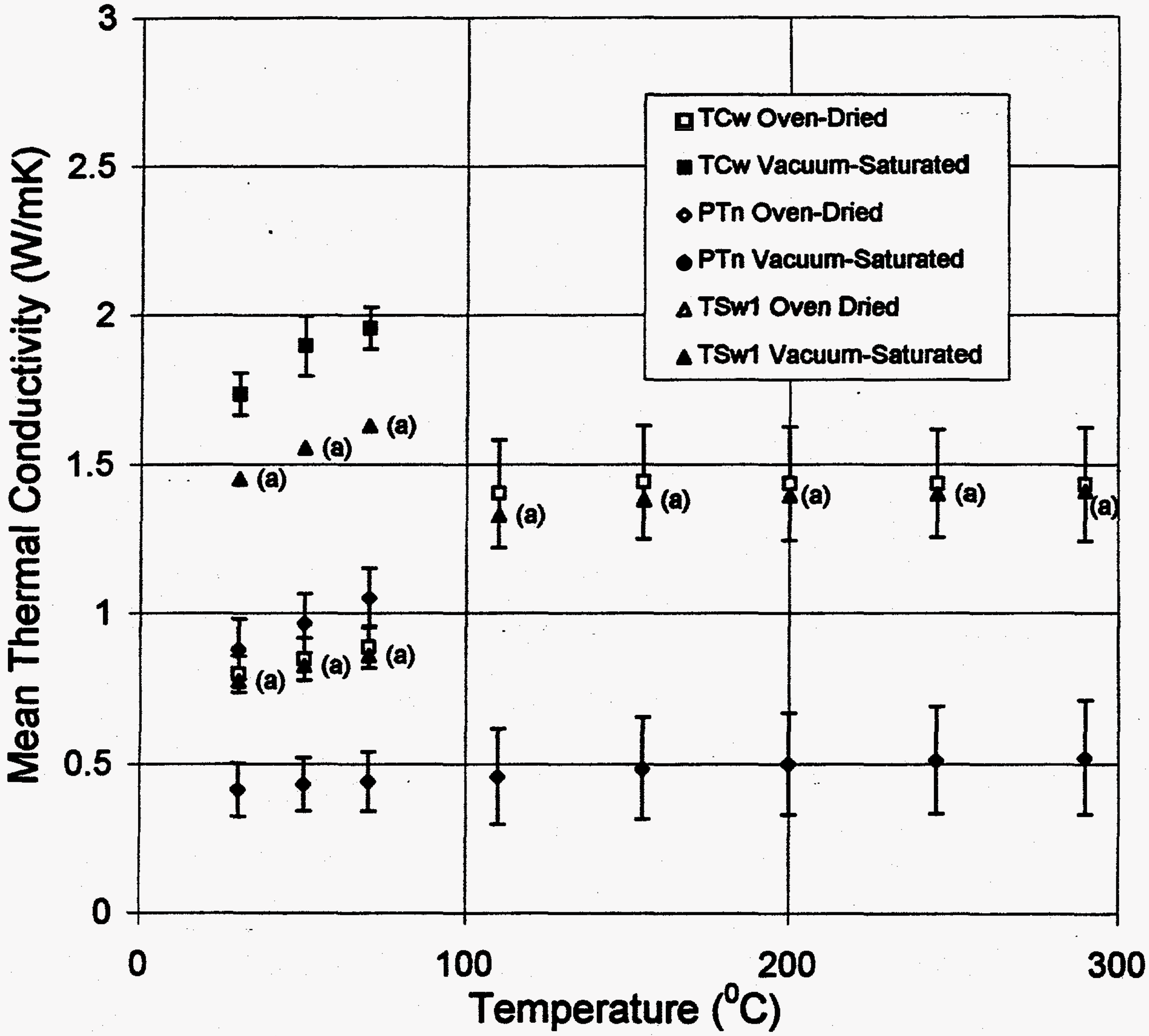


Figure 4-3. Summary of Average Thermal Conductivities for Borehole NRG-6. Error bars indicate ± one standard deviation.



(a) Insufficient data to calculate standard deviation

Figure 4-4. Summary of Average Thermal Conductivities for Borehole NRG-7. Error bars indicate ± one standard deviation.

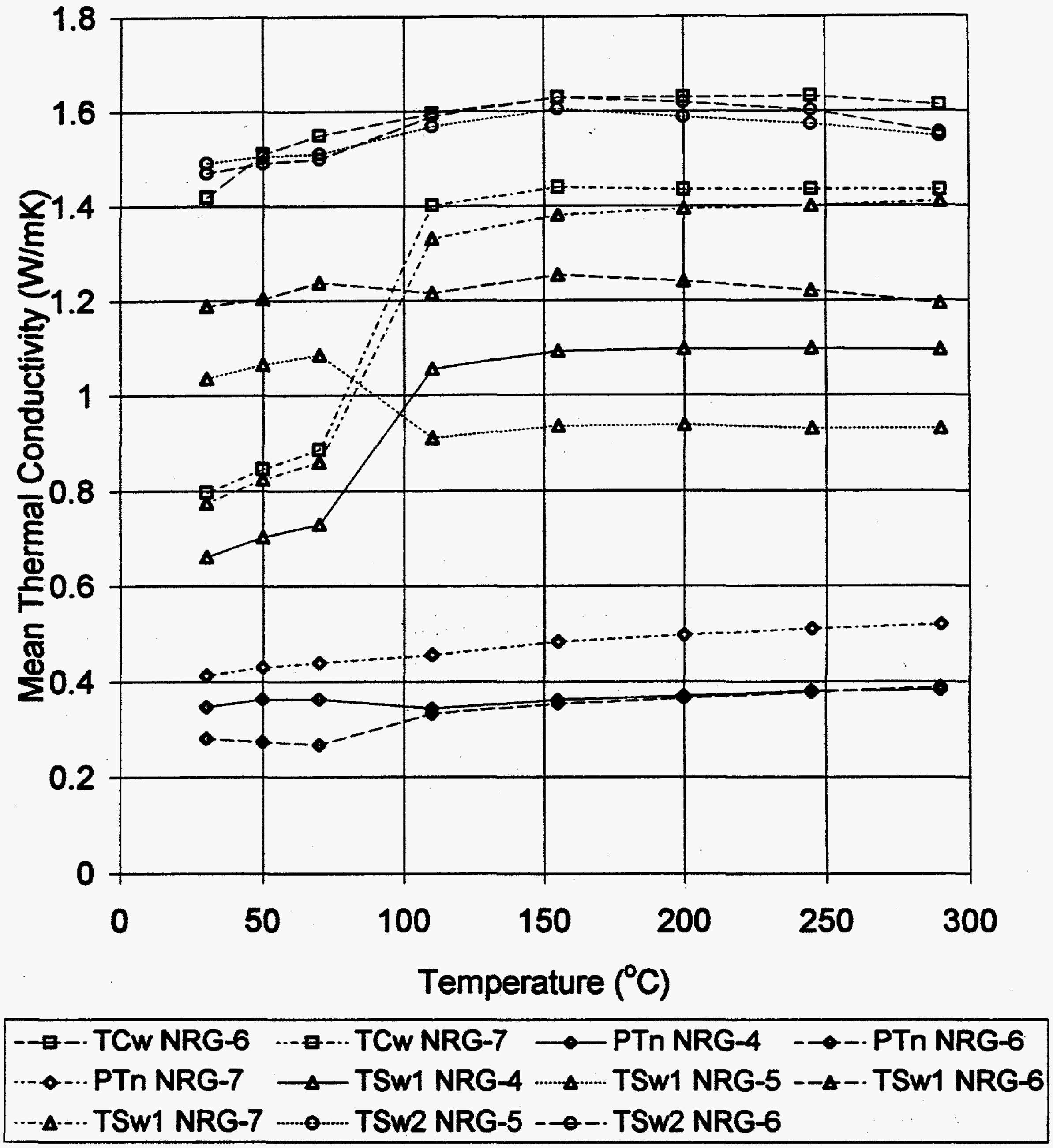


Figure 4-5. Thermal Conductivity for Oven-Dried Specimens From Four Boreholes

The mean values of thermal conductivity are given for each T/M unit in Tables 4-1 and 4-2 for low temperature and high temperature data, respectively. Each test measurement was weighted equally. These tables are included primarily for the purpose of summarizing a large data set. Thermal conductivity is actually temperature sensitive and shows some borehole-to-borehole variation; both of these factors are obscured by the data averaging used in these tables. Thermal conductivities were highest for saturated specimens and lowest for dried specimens. Thermal conductivities, averaged over all boreholes, ranged (depending upon temperature and saturation state) from $1.2 \cdot W(mK)^{-1}$ to $1.9 \cdot W(mK)^{-1}$ for TCw, from $0.4 \cdot W(mK)^{-1}$ to $0.9 \cdot W(mK)^{-1}$ for PTn, from $1.0 \cdot W\,(mK)^{-1}$ to $1.7 \cdot W(mK)^{-1}$ for TSw1, and from $1.5 \cdot W(mK)^{-1}$ to $2.3 \cdot W(mK)^{-1}$ for TSw2.

Table 4-1. Low Temperature (<100°C) Rock Thermal Conductivities.[a]

Thermal/ Mechanical Unit	Thermal Conductivity (W/mK)											
	Saturated			Partially Saturated			Air Dry			Dry		
	Sample Mean	Sample Standard Deviation	Sample Count	Sample Mean	Sample Standard Deviation	Sample Count	Sample Mean	Sample Standard Deviation	Sample Count	Sample Mean	Sample Standard Deviation	Sample Count
TCw	1.89	0.12	18	1.39	0.56	18	1.58	0.16	9	1.17	0.35	18
PTn	0.92	0.13	42	0.57	0.12	33	0.35	0.13	12	0.38	0.10	49
TSw1	1.70	0.19	50	1.23	0.46	11	1.21	0.12	30	0.98	0.26	59
TSw2	2.29	0.42	51	ND	ND	ND	1.66	0.10	24	1.50	0.44	48

[a] ND: No Data. "Sample" refers to the number of test measurements, not the number of specimens tested. Measurements were made during both heating and cooling for some specimens.

Table 4-2. High Temperature (>100°C) Rock Thermal Conductivities. [a]

Thermal/ Mechanical Unit	Thermal Conductivity (W/mK)		
	Dry		
	Sample Mean	Sample Standard Deviation	Sample Count
TCw	1.53	0.17	57
PTn	0.42	0.14	102
TSw1	1.15	0.15	173
TSw2	1.59	0.10	125

[a] "Sample" refers to the number of test measurements, not the number of specimens tested. Measurements were made during both heating and cooling for some specimens.

4.1.2 Comparison with Existing Data

Table 4-3 compares the thermal conductivity data presented here with existing data from boreholes USW G-1, USW G-2, USW GU-3, and USW G-4 (shown in Figure 1-1). Data reported in Nimick (1989) include both published and previously unpublished results for which supporting documentation is available. Only data obtained on saturated specimens at 20°C to 30°C are presented in Table 4-3 so that data are compared at comparable conditions. As shown in Table 4-3, mean values of thermal conductivity for TSw2 reported in this study compare very well with Nimick's results. For TSw1, Nimick's database comprises only three tests; however, the reported mean thermal conductivity is within one standard deviation of the mean for data reported in this study. The largest discrepancy is in the PTn data for which values of thermal

Table 4-3. Thermal Conductivities: Comparison with Existing Data

	Thermal Conductivity ($W(mK)^{-1}$)	
	This Study	Nimick (1989)[a]
Ptn		
Mean	0.85	1.73
Standard Deviation	0.13	0.06
Number of Tests	10	2[b]
TSw1		
Mean	1.69	1.82
Standard Deviation	0.26	0.06
Number of Tests	13	3[c]
TSw2		
Mean	2.23	2.24
Standard Deviation	0.50	0.17
Number of Tests	20	10[d]

(a) These data were all either NQ or QA III. They are used in this report for comparative purposes and are not used to derive any numerical results.

(b) All test data from USW G-2.

(c) Test data from USW G-1, USW G-2, and USW GU-3.

(d) Four tests from G-1, three tests from USW G-2, one test from USW GU-3, and two tests from USW G-4.

conductivity differ by a factor of 2. Because Nimick's database comprises only two tests, this discrepancy may not be significant. Additionally, Nimick's PTn data were all from borehole USW G-2, which is almost 3 km from the nearest NRG borehole.

4.1.3 ASTM Reporting Requirements

ASTM procedures generally list reporting requirements. The ASTM procedure that invokes use of the guarded heat flow meter is ASTM F433 - 77, "Standard Practice for Evaluating Thermal Conductivity of Gasket Materials". The reporting requirements are given below:

- *Sample Conditioning Procedure*: All specimen preparation and conditioning information is given in Chapter 2 of this report. See Appendix G for lithostratigraphic unit assignments.
- *Ambient Temperature*: Tests were conducted at room temperature. The precise temperature values are recorded in the Scientific Notebooks.[b]
- *Sample Hot Side Temperature (T_h)*: These data are recorded in the Scientific Notebooks.[b]
- *Sample Cold Side Temperature (T_c)*: These data are recorded in the Scientific Notebooks.[b]
- *Sample Temperature Drop ($T_h - T_c$)*: Calculated from items listed above and given in the Scientific Notebooks.[b]
- *Average Sample Temperature ($(T_h + T_c)/2$)*: Calculated from items listed above and given in the Scientific Notebooks.[b]
- *Sample Thickness*: These data are recorded in the Scientific Notebooks.[b]
- *Thermal Conductivity*: These data are presented in Appendix D and summarized in Section 4.1.1 of this report.
- *Compressive Load*: No compressive load was applied.

4.2 Coefficient of Thermal Expansion

4.2.1 Summary of Data

The mean coefficients of thermal expansion (MCTE) are summarized in Appendix B, Tables B-1 through B-4 for NRG-4, NRG-5, NRG-6, and NRG-7, respectively. The instantaneous coefficients of thermal expansion (ICTE) are given in Appendix B, Tables B-5 through B-8 for each of the four boreholes. Within each table, the information is grouped according to T/M unit and moisture content. The mean MCTE and ICTE and standard deviation about the mean are given at each temperature for each T/M unit and moisture content. The complete data set is given in Appendix E.

The mean MCTEs are given for each T/M unit in Tables 4-4 and 4-5 for heating and cooling phases, respectively. Mean values of ICTE are given in Tables 4-6 and 4-7 for heating

[b] The Scientific Notebooks are available through the Sandia National Laboratories Participant Data Archive under the following dataset identification numbers: NRG4: 51/L01A-04/25/94; NRG5: 51/L01A-12/12/93; NRG6: 51/L01A-05/05/93; NRG7: 51/L01A-07/01/94.

and cooling, respectively. Similar to the conductivity data, each test was weighted equally. The table is included primarily for the purpose of summarizing a large data set. The coefficient of thermal expansion shows some borehole-to-borehole variation which is obscured by the data averaging used in these tables. Mean coefficients of thermal expansion were highly temperature dependent and ranged (depending upon temperature and saturation state) from $6.6 \times 10^{-6} \cdot °C^{-1}$ to $49 \times 10^{-6} \cdot °C^{-1}$ for TCw, from the negative range to $16 \times 10^{-6} \cdot °C^{-1}$ for PTn, from $6.3 \times 10^{-6} \cdot °C^{-1}$ to $44 \times 10^{-6} \cdot °C^{-1}$ for TSw1, and from $6.7 \times 10^{-6} \cdot °C^{-1}$ to $37 \times 10^{-6} \cdot °C^{-1}$ for Tsw2.

4.2.2 Welded Versus Nonwelded Specimens

4.2.2.1 Saturation State

Thermal expansion was independent of saturation state for welded specimens but did depend upon saturation state for the nonwelded specimens. This is illustrated in Figure 4-6 for specimens from NRG-6 (only NRG-6 specimens were tested at multiple saturation states). This figure shows MCTE versus temperature for welded and nonwelded tuffs at three saturation states: oven dried, air dried, and vacuum saturated. Each curve represents the average of multiple test specimens. The nonwelded specimens which have high moisture contents contracted during testing near 100°C, causing the temporary sharp decrease in MCTE seen at approximately 100°C. This is presumed to be due to reduction of pore water and dehydration of hydrated glass; however, there is insufficient information to determine a mechanism for the shrinkage. The expansion characteristics of the welded specimens, on the other hand, seemed to be independent of saturation state; i.e., the curves for different saturation states are similar.

For nonwelded specimens, initial testing showed that the thermal expansion characteristics changed significantly depending upon the amount of time required to drive off interstitial water near 100°C. Because of this, nonwelded specimens were tested with a "thermal soak period" (i.e., an extended period of time at 100°C) to drive off water in the specimen before proceeding with the test. For early tests, the duration of the thermal soak was 30 hours; however, it became apparent that 20 hours were sufficient and the soak time was reduced. For welded specimens, the thermal soak did not significantly affect the results; therefore, welded specimens were tested without a thermal soak period. When it was not clear what effect the thermal soak period would have on the test results, the specimen was tested with a thermal soak period to be sure the results would be representative of anticipated conditions.

Table 4-4. Mean Coefficient of Thermal Expansion during Heat-up.

T/M Unit	Saturation State	Statistics[a]	Mean CTE on Heat-up ($10^{-6}/^{\circ}C$)										
			25-50°C	50-75°C	75-100°C	100-125°C	125-150°C	150-175°C	175-200°C	200-225°C	225-250°C	250-275°C	275-300°C
TCw	Saturated	Mean	7.09	7.62	8.08	10.34	13.17	15.20	16.99	18.99	21.38	27.42	42.99
		Std. Dev.	0.43	0.15	0.50	1.52	1.23	1.57	1.41	0.96	1.23	1.94	37.35
		Count	4	4	4	4	4	4	4	3	3	3	3
	Dry	Mean	6.60	8.29	9.62	10.53	12.69	14.90	17.03	20.68	29.64	36.49	49.15
		Std. Dev.	1.49	0.99	1.06	1.60	1.55	1.91	2.31	5.41	21.88	16.97	34.24
		Count	10	10	10	7	7	7	7	7	7	7	7
			25-50°C	50-75°C	75-100°C	100-125°C	125-150°C	150-175°C	175-200°C	200-225°C	225-250°C	250-275°C	275-300°C
PTn	Saturated	Mean	4.46	4.28	-1.45	-30.42	5.54	4.47	0.64	-4.65	-9.79	-13.46	-12.96
		Std. Dev.	0.38	1.61	3.63	21.47	0.41	0.79	1.03	4.05	7.85	11.12	12.90
		Count	4	4	4	4	3	3	3	2	2	2	2
	Dry	Mean	4.55	4.24	3.36	-4.78	6.46	5.69	3.61	0.56	-2.98	-5.81	-7.25
		Std. Dev.	0.74	1.46	2.40	11.12	0.98	1.41	2.58	5.81	9.12	11.36	10.80
		Count	12	12	12	10	10	10	10	10	10	10	10
			25-50°C	50-75°C	75-100°C	100-125°C	125-150°C	150-175°C	175-200°C	200-225°C	225-250°C	250-275°C	275-300°C
TSw1	Saturated	Mean	6.56	7.32	6.83	6.92	10.72	14.28	20.98	36.82	41.64	42.76	43.81
		Std. Dev.	1.16	0.60	1.60	3.28	1.74	3.26	7.01	20.49	17.35	13.19	13.65
		Count	10	10	10	10	10	9	9	8	8	8	8
	Dry	Mean	6.29	7.60	8.39	8.96	10.37	15.51	23.67	34.24	34.00	36.07	38.74
		Std. Dev.	1.22	1.02	0.89	1.20	1.38	4.53	11.07	20.30	13.70	13.23	13.78
		Count	33	33	33	28	28	27	26	25	25	25	25
			25-50°C	50-75°C	75-100°C	100-125°C	125-150°C	150-175°C	175-200°C	200-225°C	225-250°C	250-275°C	275-300°C
TSw2	Saturated	Mean	7.14	7.47	7.46	9.07	9.98	11.74	13.09	15.47	19.03	25.28	37.19
		Std. Dev.	0.65	1.51	1.21	2.41	0.77	1.28	1.40	1.75	3.09	6.87	14.27
		Count	19	19	19	19	19	19	19	16	16	16	16
	Dry	Mean	6.67	8.31	8.87	9.37	10.10	10.96	12.22	14.52	20.79	25.13	35.13
		Std. Dev.	1.20	0.42	0.40	0.55	0.88	1.16	1.50	2.57	17.03	10.07	14.56
		Count	40	40	40	40	40	38	38	35	35	35	35

[a] Std. Dev. is the standard deviation.

Table 4-5. Mean Coefficient of Thermal Expansion during Cool-down.

T/M Unit	Saturation State	Statistics[a]	Mean CTE on Cool-down ($10^{-6}/^{\circ}C$)										
			300-275°C	275-250°C	250-225°C	225-200°C	200-175°C	175-150°C	150-125°C	125-100°C	100-75°C	75-50°C	50-35°C
TCw	Saturated	Mean	14.72	21.97	33.53	37.01	23.81	18.48	15.72	13.51	12.09	10.78	10.85
		Std. Dev.	3.76	6.79	16.44	26.18	10.01	3.25	1.96	1.48	1.28	1.36	1.96
		Count	3	3	3	3	4	4	4	4	4	4	4
	Dry	Mean	17.46	26.34	36.95	33.72	22.86	17.58	13.89	11.77	10.21	9.35	6.59
		Std. Dev.	3.70	6.88	11.50	14.21	3.16	2.00	2.39	2.22	1.56	1.15	2.20
		Count	7	7	7	7	7	7	7	7	9	9	9
			300-275°C	275-250°C	250-225°C	225-200°C	200-175°C	175-150°C	150-125°C	125-100°C	100-75°C	75-50°C	50-35°C
PTn	Saturated	Mean	15.58	9.12	7.20	6.39	6.98	6.29	5.93	5.36	5.12	4.33	1.94
		Std. Dev.	1.04	0.84	0.29	0.17	1.51	0.78	0.47	0.36	0.34	0.84	2.93
		Count	2	2	2	2	3	3	3	4	4	4	4
	Dry	Mean	11.22	7.91	6.78	6.45	6.47	6.53	6.11	5.80	5.52	4.82	2.41
		Std. Dev.	2.46	1.00	0.81	0.90	1.14	1.35	1.30	1.16	0.89	0.84	0.86
		Count	10	10	10	10	10	10	10	10	12	12	12
			300-275°C	275-250°C	250-225°C	225-200°C	200-175°C	175-150°C	150-125°C	125-100°C	100-75°C	75-50°C	50-35°C
TSw1	Saturated	Mean	15.07	19.87	24.05	26.15	27.57	26.66	28.19	19.89	11.46	9.92	9.35
		Std. Dev.	4.68	7.82	9.85	7.37	8.36	9.91	18.04	8.05	2.01	1.54	1.06
		Count	8	8	8	8	9	9	10	10	10	10	10
	Dry	Mean	16.68	20.71	24.16	23.26	26.74	25.34	25.55	17.78	10.53	9.22	6.95
		Std. Dev.	4.13	7.78	10.61	7.29	9.32	9.35	14.94	8.53	2.15	1.51	2.49
		Count	25	25	25	25	26	27	28	28	33	33	33
			300-275°C	275-250°C	250-225°C	225-200°C	200-175°C	175-150°C	150-125°C	125-100°C	100-75°C	75-50°C	50-35°C
TSw2	Saturated	Mean	21.89	27.83	26.55	21.38	17.31	14.06	12.49	11.52	10.27	9.48	8.81
		Std. Dev.	6.16	10.36	10.01	5.70	3.07	1.38	1.32	2.00	0.62	0.63	0.62
		Count	16	16	16	16	19	19	19	19	19	19	19
	Dry	Mean	20.57	24.31	24.20	21.16	18.45	14.34	11.74	10.51	9.54	8.87	7.48
		Std. Dev.	4.88	7.55	8.08	6.24	9.36	4.23	3.03	2.26	1.79	1.56	1.99
		Count	35	35	35	35	38	38	40	40	40	40	40

[a] Std. Dev. is the standard deviation.

Table 4-6. Instantaneous Coefficient of Thermal Expansion during Heat-up.

T/M Unit	Saturation State	Statistics[a]	Instantaneous CTE on Heat-up ($10^{-6}/^{\circ}C$)										
			50°C	75°C	100°C	125°C	150°C	175°C	200°C	225°C	250°C	275°C	300°C
TCw	Saturated	Mean	7.10	7.10	6.49	12.29	14.36	15.65	16.75	19.15	24.12	29.91	80.77
		Std. Dev.	0.73	0.36	1.59	1.54	2.40	1.75	0.98	0.42	2.42	4.91	110.14
		Count	4	4	4	4	4	4	4	3	3	3	3
	Dry	Mean	8.03	8.42	9.70	10.69	14.00	15.49	16.91	19.71	26.26	47.79	63.28
		Std. Dev.	1.21	1.67	1.67	1.44	1.88	1.94	1.53	1.01	7.09	29.78	74.09
		Count	10	10	10	7	7	7	7	7	7	7	7
			50°C	75°C	100°C	125°C	150°C	175°C	200°C	225°C	250°C	275°C	300°C
PTn	Saturated	Mean	4.90	2.29	-4.35	5.71	5.37	2.58	-2.80	-7.77	-11.32	-14.30	-12.65
		Std. Dev.	1.90	4.09	16.80	0.63	0.47	1.23	2.59	6.68	11.18	12.23	11.15
		Count	4	4	4	3	3	3	3	2	2	2	2
	Dry	Mean	5.08	3.43	2.65	5.74	6.55	5.01	1.89	-1.49	-4.63	-6.81	-8.91
		Std. Dev.	1.14	1.90	4.09	1.76	1.45	1.75	4.01	7.80	10.66	11.63	11.10
		Count	12	12	12	10	10	10	10	10	10	10	10
			50°C	75°C	100°C	125°C	150°C	175°C	200°C	225°C	250°C	275°C	300°C
TSw1	Saturated	Mean	6.90	7.52	7.72	10.44	12.54	17.78	25.56	44.45	42.83	43.87	41.74
		Std. Dev.	1.35	1.16	6.82	2.10	3.84	4.86	11.35	26.33	13.08	14.13	14.24
		Count	10	10	10	10	10	9	9	8	8	8	8
	Dry	Mean	7.58	7.69	8.45	9.34	11.37	19.88	27.43	34.14	34.97	38.07	38.82
		Std. Dev.	0.98	1.10	1.18	1.13	2.23	8.28	15.17	18.36	12.82	14.47	13.72
		Count	33	33	33	28	28	27	26	25	25	25	25
			50°C	75°C	100°C	125°C	150°C	175°C	200°C	225°C	250°C	275°C	300°C
TSw2	Saturated	Mean	7.58	7.82	6.29	9.79	10.55	12.69	14.20	17.18	21.50	31.02	41.58
		Std. Dev.	1.22	1.16	5.27	2.26	1.11	2.09	1.48	2.94	4.04	9.98	16.39
		Count	19	19	19	19	19	19	19	16	16	16	16
	Dry	Mean	8.18	8.61	8.99	9.01	10.45	10.80	13.38	17.44	21.65	29.28	39.23
		Std. Dev.	0.68	0.69	0.77	1.15	1.32	1.34	2.03	7.25	9.38	10.47	15.33
		Count	40	40	40	40	40	38	38	35	35	35	35

[a] Std. Dev. is the standard deviation.

Table 4-7. Instantaneous Coefficient of Thermal Expansion during Cool-down.

T/M Unit	Saturation State	Statistics[a]	Instantaneous CTE on Cool-down ($10^{-6}/^{\circ}C$)										
			300°C	275°C	250°C	225°C	200°C	175°C	150°C	125°C	100°C	75°C	50°C
TCw	Saturated	Mean	10.24	17.96	28.54	38.26	26.81	20.24	16.83	14.45	12.38	11.07	10.23
		Std. Dev.	2.19	5.50	9.56	25.83	15.98	4.53	1.92	1.54	1.36	1.30	1.27
		Count	3	3	3	3	4	4	4	4	4	4	4
	Dry	Mean	13.68	21.28	34.15	38.19	25.58	19.32	15.82	12.63	10.43	9.47	8.54
		Std. Dev.	2.74	6.18	10.34	17.30	4.48	2.37	1.43	2.42	1.76	1.51	1.03
		Count	7	7	7	7	7	7	7	7	9	9	9
			300°C	275°C	250°C	225°C	200°C	175°C	150°C	125°C	100°C	75°C	50°C
PTn	Saturated	Mean	22.00	11.08	8.25	6.29	6.91	5.99	5.69	5.78	5.71	4.63	3.42
		Std. Dev.	0.71	1.65	0.07	0.22	2.47	1.44	0.78	0.37	0.75	0.66	1.59
		Count	2	2	2	2	3	3	3	4	4	4	4
	Dry	Mean	13.12	8.73	7.35	6.58	6.06	6.22	6.03	5.45	5.59	4.97	4.30
		Std. Dev.	3.90	1.27	0.87	0.67	1.05	1.52	1.58	1.25	1.17	1.01	1.01
		Count	10	10	10	10	10	10	10	10	12	12	12
			300°C	275°C	250°C	225°C	200°C	175°C	150°C	125°C	100°C	75°C	50°C
TSw1	Saturated	Mean	12.45	18.44	22.62	25.25	26.74	26.31	26.52	28.55	12.43	10.39	9.57
		Std. Dev.	3.66	6.68	9.61	8.98	8.22	9.05	13.27	21.21	2.77	1.66	1.33
		Count	8	8	8	8	9	9	10	10	10	10	10
	Dry	Mean	14.02	18.55	22.99	23.92	24.70	26.42	24.48	25.86	11.29	9.63	8.47
		Std. Dev.	3.30	5.05	10.44	9.06	7.23	10.07	10.53	19.50	2.90	1.65	1.47
		Count	25	25	25	25	26	27	28	28	33	33	33
			300°C	275°C	250°C	225°C	200°C	175°C	150°C	125°C	100°C	75°C	50°C
TSw2	Saturated	Mean	18.51	25.86	28.55	23.50	18.64	15.27	13.42	11.93	11.00	9.70	9.03
		Std. Dev.	4.97	8.67	11.00	8.29	4.06	1.92	1.24	1.43	1.11	0.63	0.61
		Count	16	16	16	16	19	19	19	19	19	19	19
	Dry	Mean	17.61	22.85	25.43	22.97	19.07	16.34	13.16	11.28	10.22	9.39	8.40
		Std. Dev.	3.81	6.69	9.12	8.30	5.46	9.29	4.84	3.21	2.36	1.99	1.85
		Count	35	35	35	35	38	38	40	40	40	40	40

[a] Std. Dev. is the standard deviation.

4.2.2.2 Transition Temperature

There are additional differences in expansion characteristics between welded and nonwelded tuffs. As shown in Figure 4-6, at a "transition temperature" of 150°C to 200°C, the MCTE increases more steeply for the welded tuff but decreases for the nonwelded tuff. A transition is expected in the welded devitrified specimens due to phase changes in tridymite and cristobalite. These minerals occur, with or without quartz, as primary devitrification products in many samples of Yucca Mountain welded tuffs. Phase transitions in synthetic tridymite occur at approximately 117°C and 163°C, and in synthetic cristobalite at approximately 272°C (Papike and Cameron, 1976), and involve notable changes in volume. Phase transition temperatures have been shown to vary significantly due to lattice variations found in natural occurrences of these minerals which are usually mixed phase material (Thompson and Wennemer, 1979). Previous and current work on the mineralogy of welded tuff from TCw, TSw1, TSw2, and TSw3 suggest that these mixed phase assemblages are dominant. Hysteresis is associated with the phase changes because the phases invert at higher temperature during heating than during cooling.

Strains measured during one temperature cycle for a specimen of welded and a specimen of nonwelded tuff are shown in Figure 4-7. The strains increase (expansion is positive) for both tuffs until a "transition temperature" of approximately 175° to 225°C is reached. In both cases, the strain-versus-temperature curves then become more highly nonlinear; however, the slope increases for the welded specimen while it decreases for the nonwelded specimen. For the welded specimen, the strain is likely to be the result of phase transformations; the irreversible expansion may be a consequence of incomplete phase inversion on cooling. For the nonwelded specimen, some of the strain decrease (near 100°C) is attributable to loss of pore water, but most of the irreversible strain is probably a consequence of dehydration of perlitic volcanic glass and clay minerals at elevated temperatures which results in a permanent volume decrease. It should be noted that not all specimens show this type of behavior, and that analysis of mineralogical and petrologic data on the tested specimens will be necessary to fully understand the cause of the behavior and its variations.

Transition temperatures, as described in this report, were defined as the temperature regions over which the slopes of the strain-versus-time curves substantially changed, as determined by visual inspection. The transition temperatures reported here are considered to be approximate.

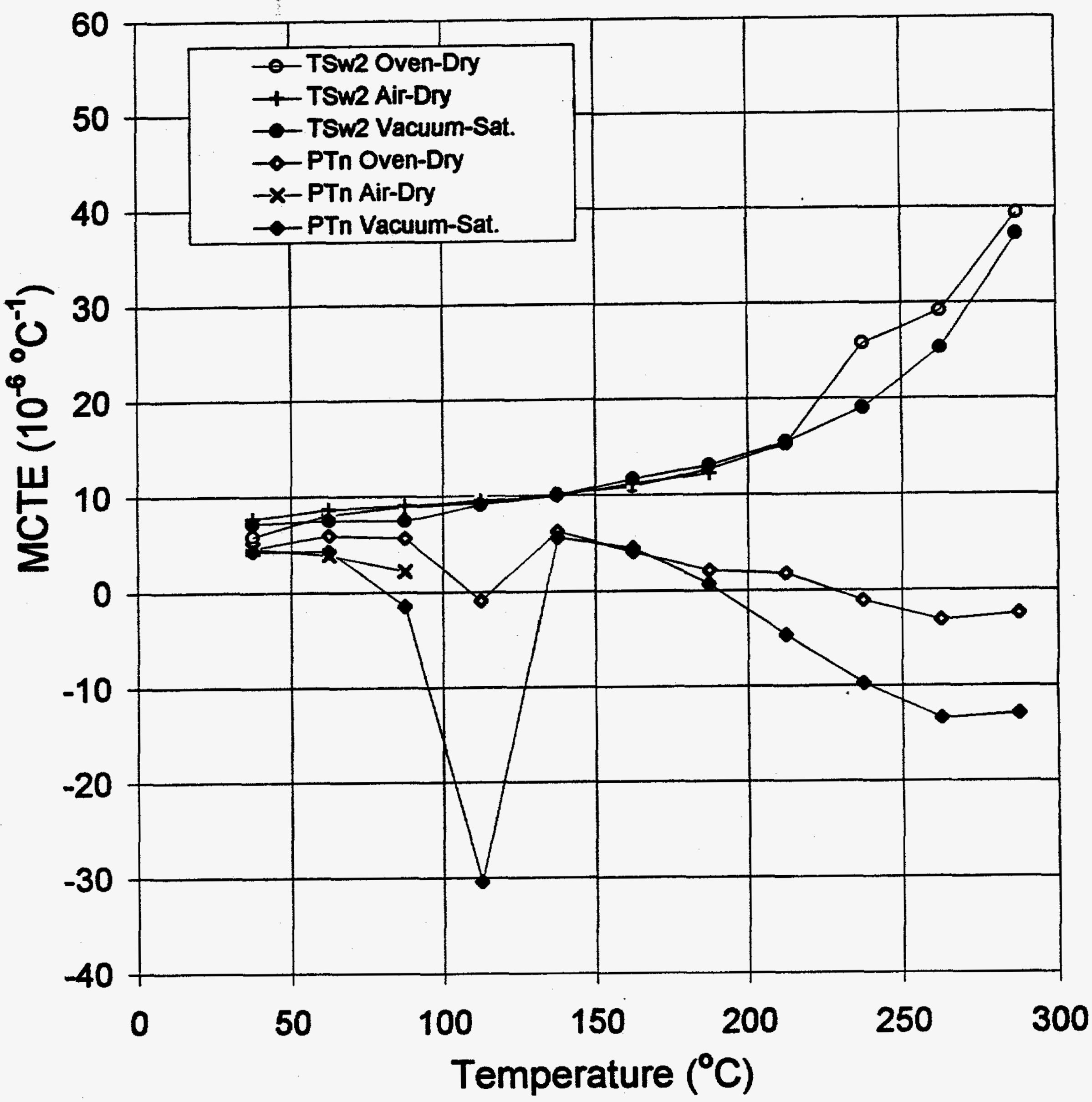


Figure 4-6. Moisture Dependence of MCTE in Welded (TSw2) and Non-Welded (Ptn) Tuff.

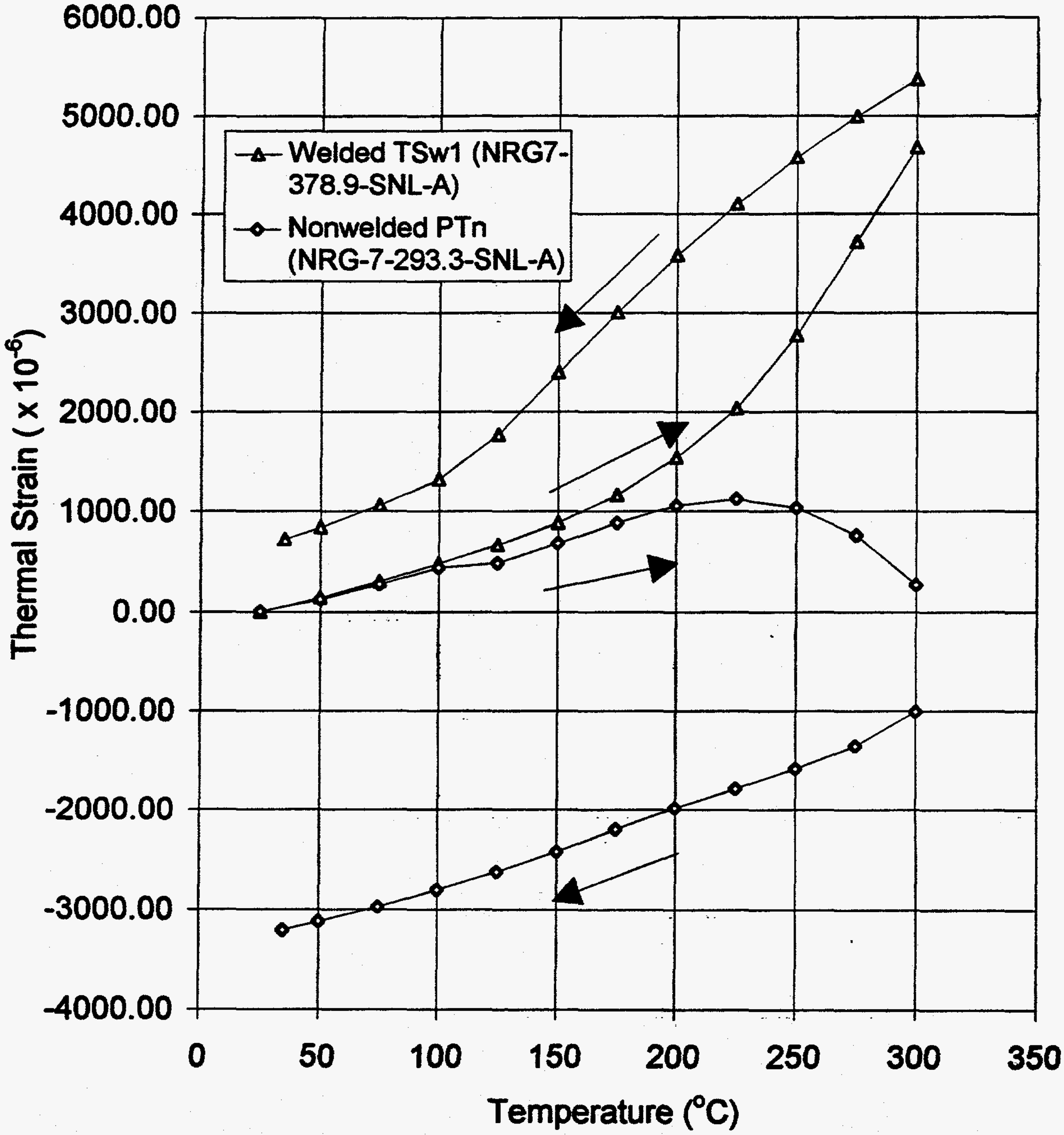


Figure 4-7. Thermal Strains Versus Temperature for Welded and Non-welded Air-dried Tuffs. Data above 300°C are not included in this plot.

Some specimens that displayed sensitivity to transition temperature were analyzed to assess the role of the maximum test temperature. Specimens from approximately the same depth (i.e., from the same piece of original core) were tested to different temperatures. The results (e.g., see Appendix E specimens NRG-6-28.8 D and F vacuum saturated) showed that as long as the maximum test temperature remained below the transition temperature, the specimens did not permanently change dimension (i.e., no hysteresis was evident). The specimens expanded during the heating phase along a nearly linear curve and contracted during cooling along the same curve, with no discontinuity. These tests indicated that the transition temperatures probably caused physical changes in tuff that altered the expansion characteristics. The maximum temperature to which the specimens were exposed affected the magnitude of the hysteresis in the strain-versus-temperature curves.

The transition temperature effects varied slightly among the T/M units and the boreholes. Several T/M units (e.g., PTn from NRG-4, and TSw2 from NRG-7 at depths between 384.4 and 428.9 m) showed no temperature transition effects. This is illustrated by the strain-versus-temperature data for NRG-7-1269.9-SNL-A shown in Figure 4-8. Other specimens and T/M units showed not only large hysteresis, but thermal expansion data characteristic of a phase change. Figure 4-9 shows data for TSw1 specimen NRG-7-625.7-SNL-A. The strain increases until a transition temperature of approximately 250°C is reached. The slope then increases steeply but levels off again above 300°C, presumably after the phase change is completed. During cooling, the phase change inverts between 250° and 200°C.

4.2.3 Directional Anisotropy Tests

Some NRG-6 specimens were tested for directional anisotropy. Two specimens from the same depth (i.e., the same piece of original core) were prepared so that their longitudinal axes were mutually orthogonal. In general, these tests showed that within the accuracy of the instrumentation there was no significant difference between specimens (e.g., see Appendix E, specimens NRG-6-729.2A and NRG-6-729.2-B, vacuum saturated).

4.2.4 ASTM Reporting Requirements

ASTM procedures generally list reporting requirements. The ASTM procedure that invokes use of the Silica Dilatometer is ASTM E228 - 85, "Standard Test Method for Linear Thermal Expansion of Solid Materials With a Vitreous Silica Dilatometer." According to this Standard, the items summarized below may be reported if available and applicable:

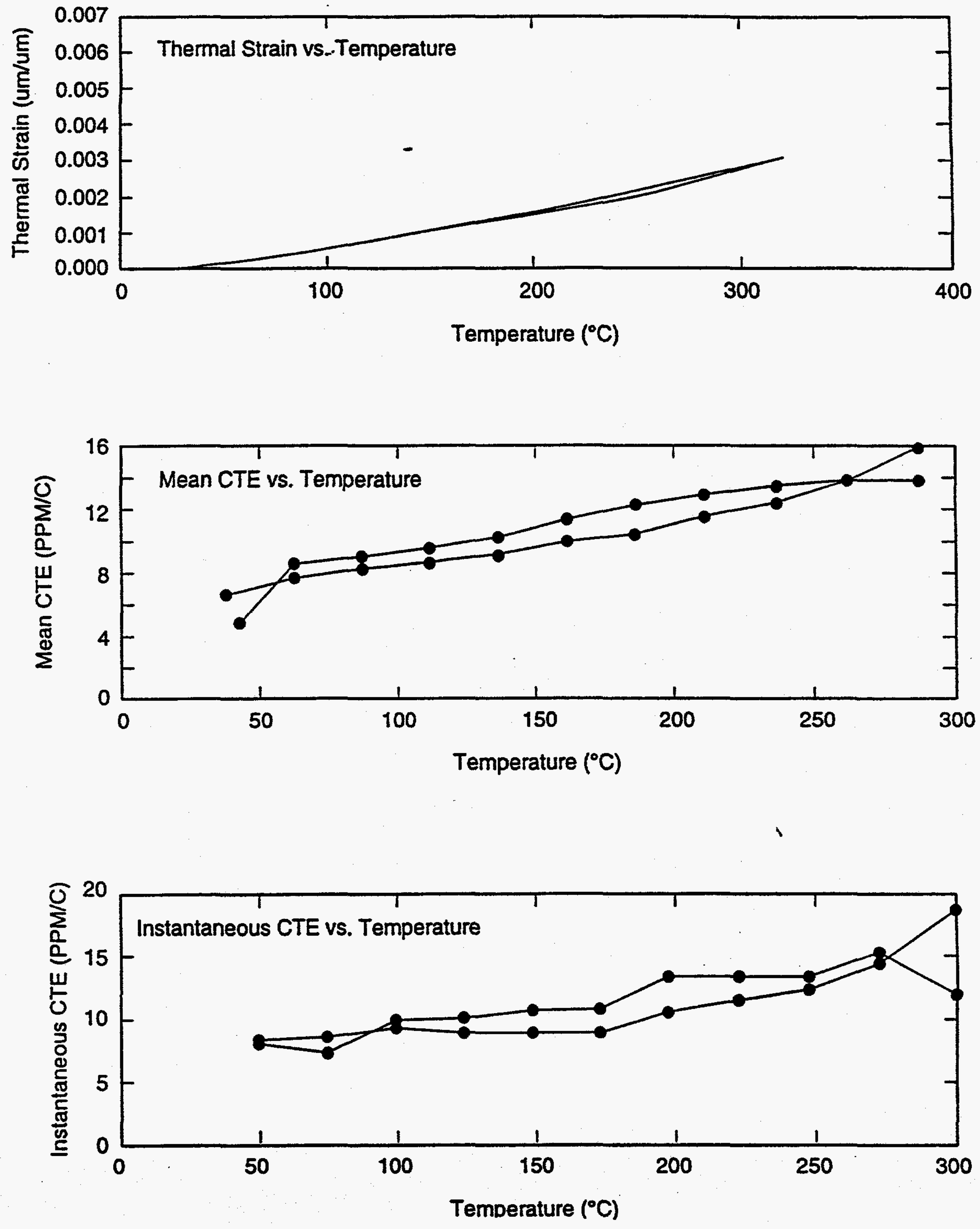


Figure 4-8. Thermal Expansion Data for Welded TSw2 Specimen NRG-7-1269.9-SNL-A Showing Essentially No Hysteresis.

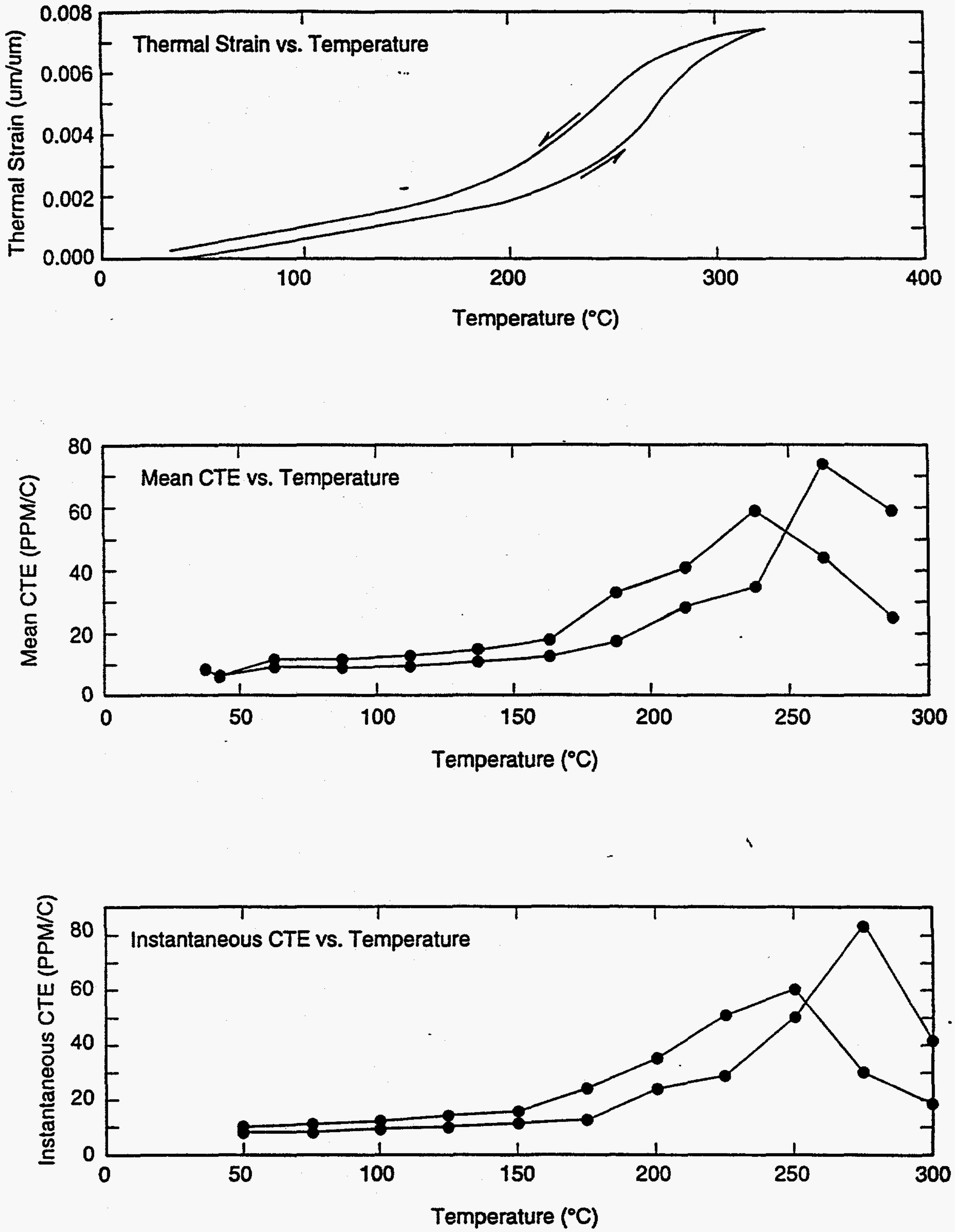


Figure 4-9. Thermal Expansion Data for Welded TSw1 Specimen NRG-7-625.7-SNL-A Showing a Probable Phase Change.

- *Description of Material, Chemical Composition, Thermal and Mechanical History, Moisture Content, and Other Conditioning History*: Chapters 1 and 2 of this report specify the specimen origins, preparation, and conditioning. Chemical or mineralogical compositions are discussed in Section 4.4. Lithostratigraphic Unit Assignments are given in Appendix G.

- *Method of Test Specimen Preparation, Specimen Dimensions and Orientation if Anisotropic*: This information is given in Chapter 2. Specimen axes were parallel to the borehole axes unless otherwise specified in Appendix E.

- *Description of Apparatus including Displacement and Temperature Measuring Systems, Estimate of Precision, Heating and Cooling Rates, Temperature Controls, and any Protective Gas Other Than Air*: This information is given in Chapter 3 of this report.

- *Listing of Reference Materials and Procedure used for Calibrations*: This information is given in Chapter 3 of this report.

- *Tabulation of Data, Including Initial Length at Reference Temperature, Showing Test Temperatures and Linear Thermal Expansion*: Data are provided in Appendix E for each test specimen and summarized in Chapter 4 of this report.

- *Tabulation or Curves for Thermal Strain-Versus-Temperature, MCTE-Versus-Temperature, ICTE-Versus-Temperature*: These data are given in Appendix E for each test specimen.

- *Complete Description of Any Unusual Behavior Such as Permanent Length Change, Visual Observations of Physical Changes*: Unusual behavior is described in Chapter 4 of this report.

4.3 Specific Heat

4.3.1 Summary of Data

Thermal capacitance data are summarized in Table 4-8 and plotted in Figure 4-10. Thermal capacitance is given at each temperature for each specimen in Appendix C; Table C-1 contains data for TSw1 specimens from NRG-4, and Table C-2 contains data for TSw2 specimens from NRG-5. Appendix F contains more detailed summary data for each tested specimen including plots of specific heat versus temperature.

Thermal capacitance is higher for TSw2 than for TSw1. Mean thermal capacitance ranges from 1.6 $J\cdot cm^{-3}\cdot K^{-1}$ to 2.1 $J\cdot cm^{-3}\cdot K^{-1}$ for TSw1 and from 1.8 $J\cdot cm^{-3}\cdot K^{-1}$ to 2.5 $J\cdot cm^{-3}\cdot K^{-1}$ for TSw2. All specimens show a localized peak in thermal capacitance at 150°C - 170°C. In general, thermal capacitance increases monotonically until this temperature range is reached. For all TSw1 specimens and some TSw2 specimens, thermal capacitance then decreases with increasing temperature as illustrated in Figure 4-11 for TSw1 specimen NRG-4-619.9-C. Above 150°C - 170°C, other TSw2 specimens show initial decreases in thermal capacitance followed by increases or perhaps by additional broad peaks as illustrated in Figure 4-12 for TSw2 specimen NRG-5-808.5-C. Additional plots are given for each specimen in Appendix F.

Table 4-8 Thermal Capacitance ($\rho\cdot Cp$) of Topopah Spring Tuff

TSw1				TSw2			
Temper -ature (°C)	Mean $\rho\cdot Cp$ ($J\cdot cm^{-3}\cdot K^{-1}$)	Standard Deviation ($J\cdot cm^{-3}\cdot K^{-1}$)	No. of Tests	Temper -ature (°C)	Mean $\rho\cdot Cp$ ($J\cdot cm^{-3}\cdot K^{-1}$)	Standard Deviation ($J\cdot cm^{-3}\cdot K^{-1}$)	No. of Tests
25	1.58	0.05	3	25	1.79	0.11	7
50	1.68	0.05	3	50	1.88	0.11	7
75	1.80	0.05	3	75	1.97	0.11	7
100	1.91	0.05	3	100	2.16	0.11	7
125	2.03	0.06	3	125	2.32	0.11	7
150	2.14	0.11	3	150	2.45	0.13	7
175	2.13	0.10	3	175	2.43	0.18	7
200	2.09	0.07	3	200	2.40	0.16	7
225	2.07	0.06	3	225	2.39	0.17	7
250	2.05	0.05	3	250	2.39	0.19	7
275	2.03	0.05	3	275	2.39	0.22	7
300	2.03	0.06	3	300	2.43	0.26	7

As noted in Section 3.3.2, heat supplied to the specimen either causes its temperature to rise or is used to convert specimen material from one physical state to another. A phase change that absorbs heat will cause the measured value of heat capacity (effective heat capacity) to rise. Once the phase change is completed, the effective heat capacity will return to its baseline value. Nimick and Connolly (1991) calculated theoretical values of effective specific heat based on mineralogical data for tuffs from Yucca Mountain. Their results, given in Figure 4-13 for devitrified Topopah Spring tuff, show theoretical changes in effective specific heat (labelled as heat capacity in their plot) with temperature. Two phase transformations are shown. The tridymite and crystobalite phase transformations shown here are centered at 163°C (436K) and 225°C (498K), respectively, and both are are arbitrarily assumed to occur over 20°C intervals.

As noted in Section 4.2.2.2, phase transitions in synthetic tridymite also occur at 117°C, and at approximately 272°C in synthetic crystobalite.

We believe that the peaks in specific heat shown in Figures 4-11 and 4-12 are related to phase changes; however, the data presented here are insufficient to correlate these peaks more specifically with mineralogy. It is worth noting that the peaks in specific heat at 150°C - 170°C occur at a temperature range associated with the phase change in tridymite (163°C). It is also evident that there were no significant changes in specific heat for these air-dried specimens at 100°C, indicating that dehydration effects were minor.

4.3.2 Comparison With Existing Data

Values of thermal capacitance were calculated by Nimick and Connolly (1991) from chemical and mineralogical data and published heat capacity data for the constituent minerals. Their values of thermal capacitance are given in Figure 4-10 along with the experimental data. For both the theoretical and experimental data, values for TSw2 are higher than for TSw1. The two sets of data roughly coincide, which is very encouraging considering the many assumptions inherent in Nimick and Connolly's work. Measurements of heat capacity are very sensitive to moisture content and to the types of water present. The experimental data were obtained on air-dried specimens containing 0.3 percent to 0.7 percent water by weight, whereas the calculated data were based on a water content of 5.5 percent by weight. Additionally, Nimick and Connolly believed that calculated values above 100°C would probably be high because they assumed that all H_2O^+ remained in the glass during heating. Calculated values near 100°C were omitted from the plot because they were highly influenced by heat of vaporization of water.

4.3.3 ASTM Reporting Requirements

The ASTM procedure for determination of specific heat that pertains to geologic materials is ASTM D 4611, "Standard Practice for Specific Heat of Rock and Soil". That procedure is based on the drop calorimeter rather than the adiabatic calorimeter and so the reporting requirements will be addressed as applicable.

- *Sample description including size, form, and mass.* Chapters 1 and 2 of this report specify the specimen origins, form, preparation, and conditioning. Specimen dimensions and masses are given in Appendix F. Chemical and mineralogical data for these specific specimens are currently unavailable. Lithostratigraphic unit assignments are given in Appendix G.

- *The enthalpy change and drop temperatures*. The enthalpy change and temperature change corresponding to a single determination of specific heat are collected using a microprocessor and stored on electronic media using dual storage. In addition, all computer printouts of data generated during testing are collected and become part of the Scientific Notebooks.[c]

- *The calculated mean or instantaneous specific heat, or both.* These data are provided in Appendix F.
- *Type of calorimeter fluid used (if any).* Not applicable. No calorimeter fluid was used.
- *The contribution of the capsule to the total enthalpy change for each drop (percent).* The most analogous information under the procedure used in this study would be the contribution of the sample container to the total heat loss. This information is recorded in the Scientific Notebooks.[c]
- *Type of temperature readout used (both on the calorimeter and sample).* All temperatures were measured with type-K thermocouples. All data collection was performed by a microprocessor.
- *Any deviation from test procedure.* The test procedure used here is documented in detail in SNL TP-204, *Measurement of Specific Heat of Geologic Samples by Adiabatic Pulse Calorimetry.*

4.4 Petrographic and Mineralogical Characterization

4.4.1 Summary of Data

All data presented for the samples are summarized in Table 4-9. These data are presented to facilitate comparison of mineralogy and petrology characteristics with the laboratory thermal conductivity, thermal expansion, and heat capacity test results presented in this report. Samples are identified by depth (in feet).

4.4.2 Colors and Arrangements.

Colors shown in Table 4-9 are those observed in examination of hand samples. Color names do not utilize a standard color chart, but are names routinely used in field descriptions of rock samples. An attempt was made to identify different colors present and estimate their relative modal proportions. Most samples are composed of many discrete areas of different colors, and are notably inhomogeneous in appearance. In the row labeled "Color" an attempt was made to qualify this inhomogeneity. If colors were sufficiently blended to give a generally uniform appearance in hand sample, it was designated as "uniform". If colors appeared splotchy

[c] The Scientific Notebooks are under review and will be available through the Sandia National Laboratories Participant Data Archive under the following dataset identification number: SNL01C12159302.002.

in a generally regular manner, the sample was designated as "mottled". If colors gave an irregular appearance in the hand sample, the sample was designated as "irregular". If colors gave a splotchy appearance overall and also showed a strong preferred elongation fabric, it was

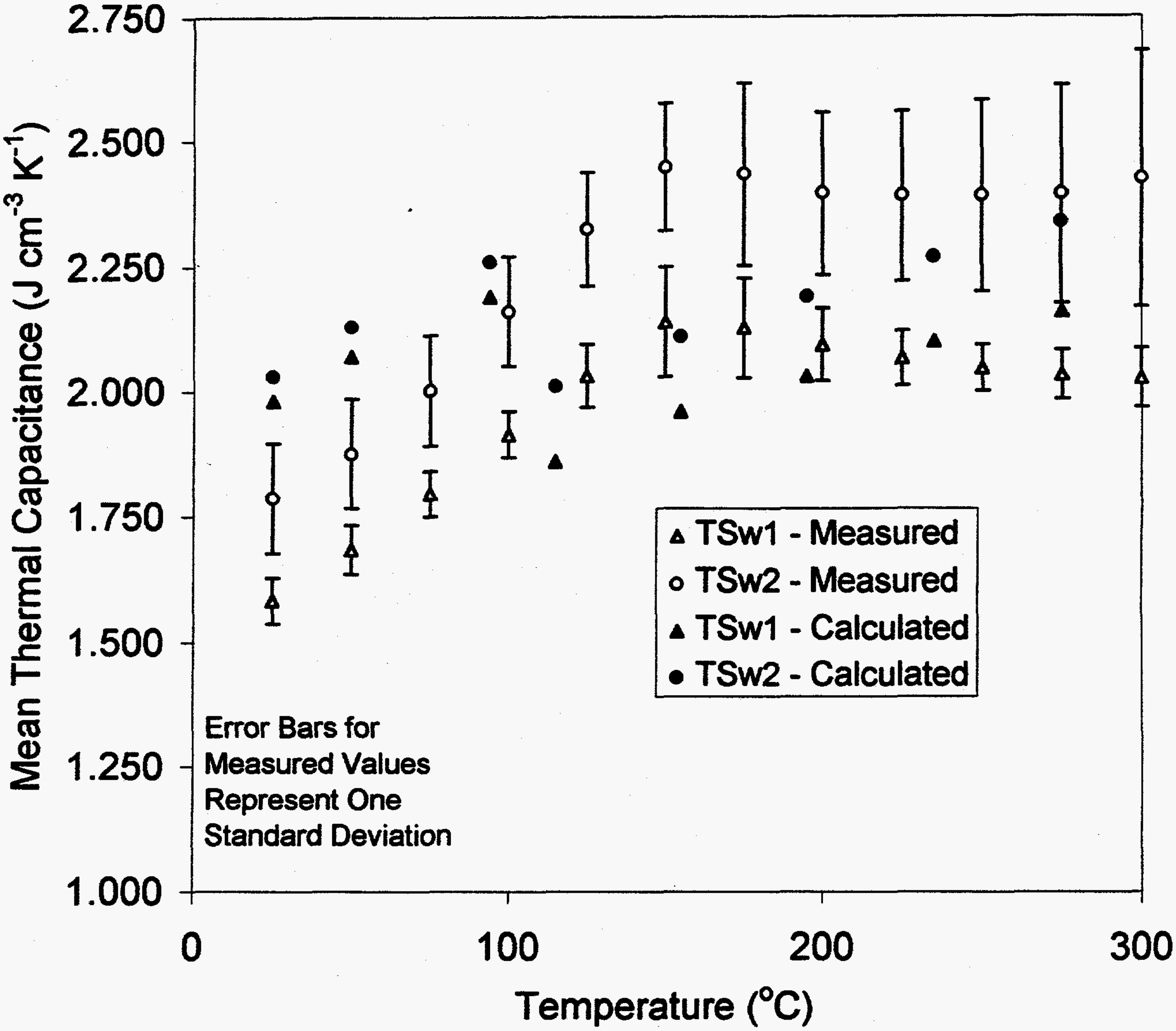


Figure 4-10. Mean Thermal Capacitance and Standard Deviations for Three TSw1 Specimens And Seven TSw2 Specimens. Values calculated by Nimick and Connolly (1991) for TSw1 and TSw2 using In Situ Saturation Levels are also shown. Data from Nimick and Connolly (1991) are either NQ or QAIII. They are used in this report for comparative purposes and are not used to derive any numerical results.

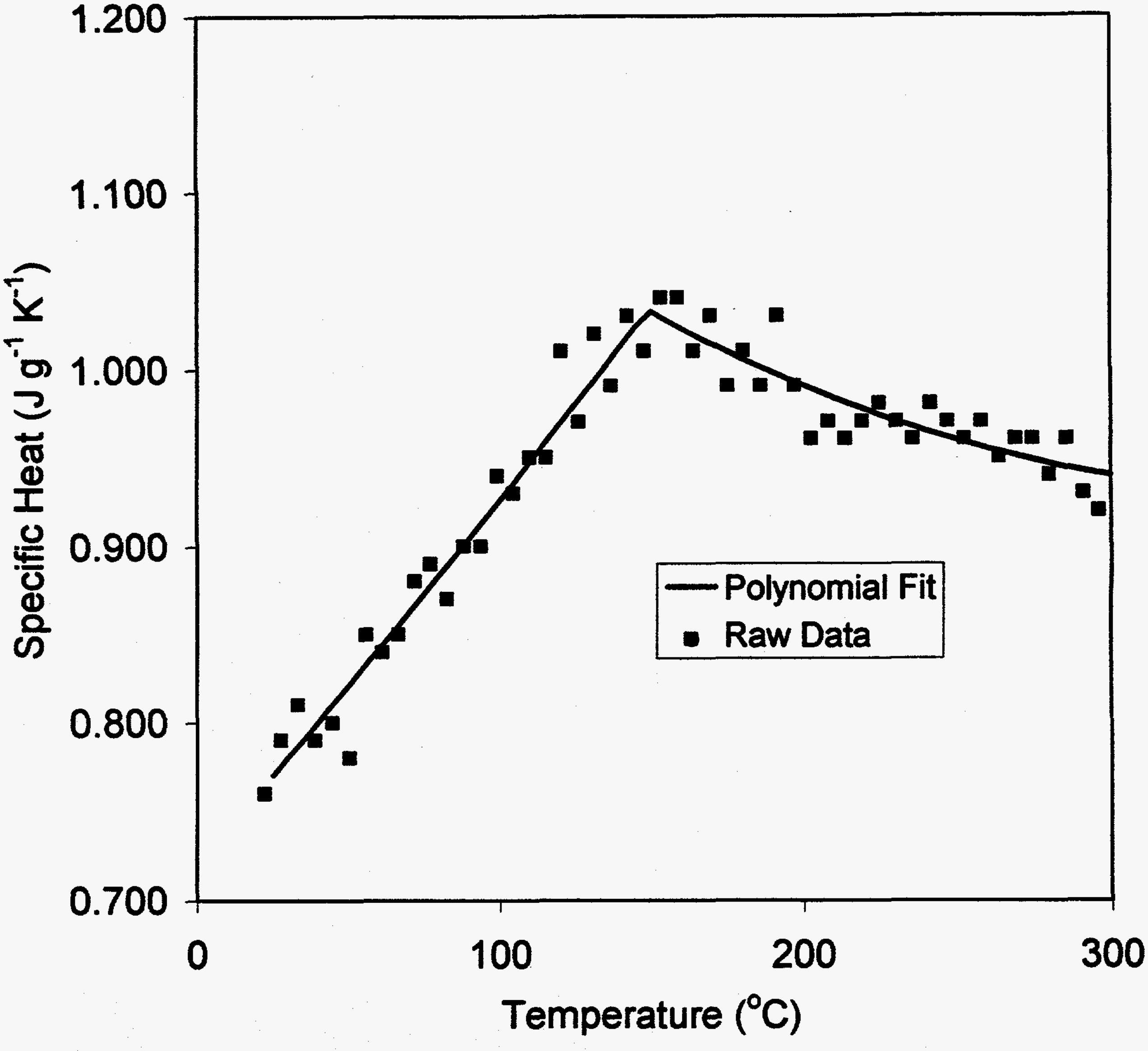


Figure 4-11. Specific Heat - Versus- Temperature During Heating of TSw1 Specimen NRG-4-619.9-SNL-C

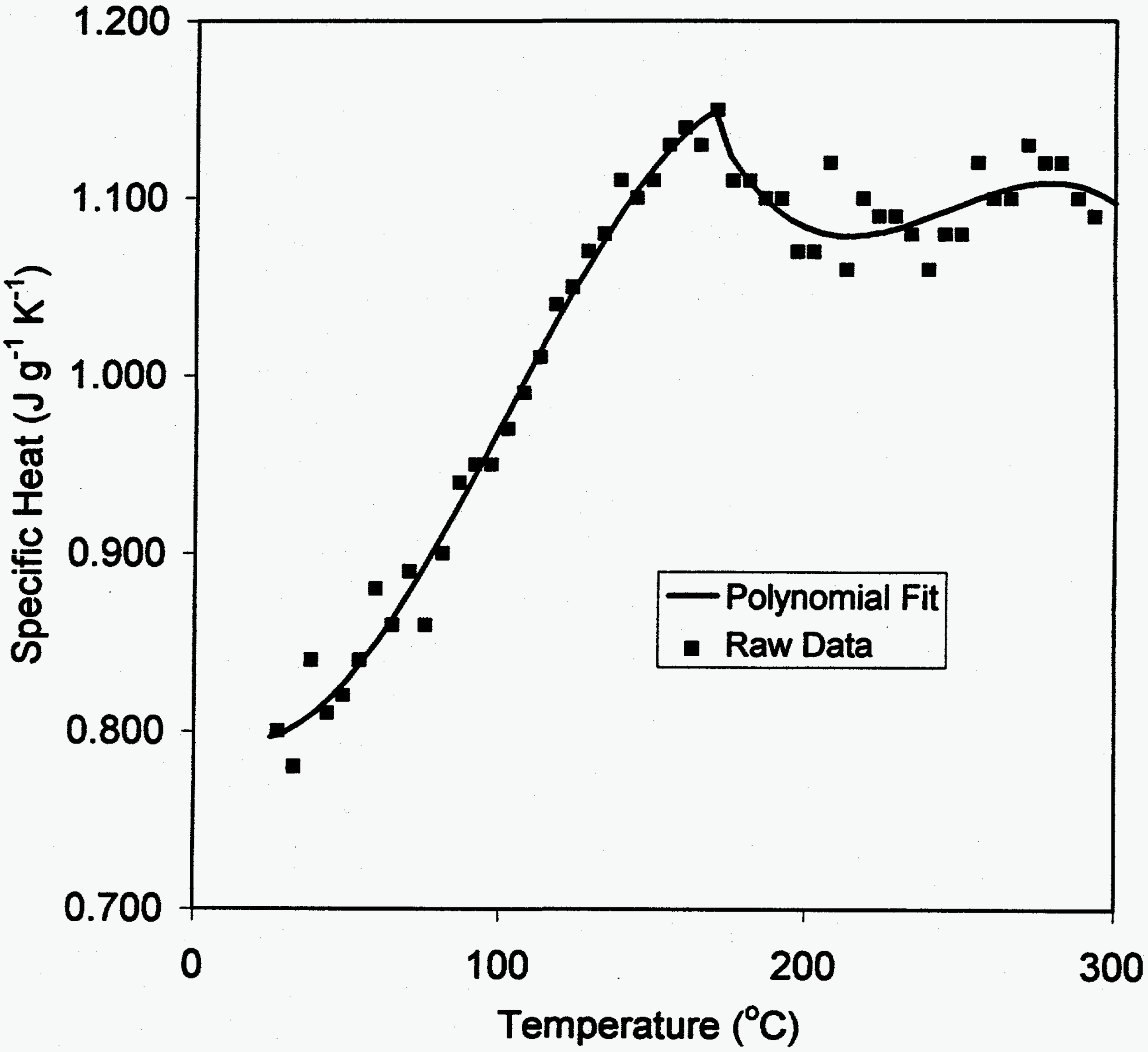


Figure 4-12. Specific Heat - Versus- Temperature During Heating of TSw2 Specimen NRG-5-808.5-SNL-C

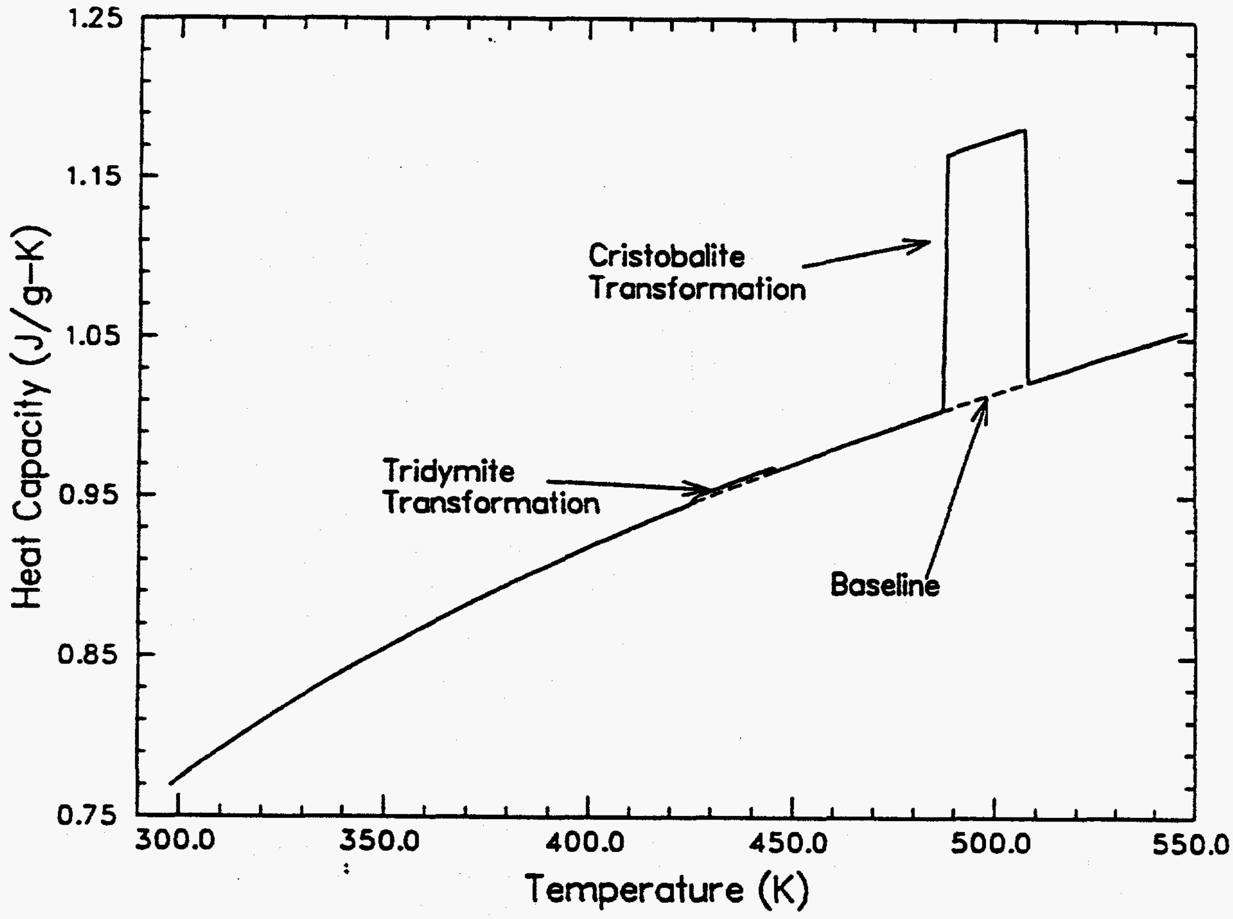


Figure 4-13 Average Specific Heat for The Devitrified Portion of The Topopah Spring Member, Including Tridymite and Cristobalite Phase Transformations. (From Nimick and Connolly, 1991)

designated as "streaked". It is important to remember that these descriptive qualifiers are on the scale of a hand-sized sample (generally 2 cm to 10 cm across) and will not reflect larger-scale variations in color components.

4.4.3 Welding

The absence, presence, and degree of welding was estimated based on visual observations of hand samples and thin sections. Weak and moderate welding reflects compaction of the original components of the tuff in vertical compression as a consequence of loading of a thick section of hot ash-flow. Strong welding (as defined here) usually reflects some flow in the compacting material in addition to extreme compression.

Non-welded samples (Designated 0 in Table 4-9) show the presence of undeformed pumice and shards. Weakly welded samples (Designated 1) show the presence of some flattening of pumice and preferred orientation of shard components. Moderately welded samples (Designated 2) show strong flattening of pumice, and notable deformation and preferred alignment of shard components. Strongly welded samples (Designated 3) show extreme flattening of pumice (usually losing all primary textures and appearing as highly elongate fiamme) and destruction of most primary shard textures.

4.4.4 Pumice and Fiamme content

Pumice is a major component of all of the tuffs examined. In nonwelded samples, it appears in its primary textural state as volcanic glass with abundant gas bubbles present as pores, either open or partially filled with clays or other minerals. In welded devitrified samples pumice is generally present as fiamme (from the Italian for flame whose structure they often resemble); these are elongated pumice fragments which have been strongly flattened as a consequence of compaction during welding. Fiamme loose their porous pumice structure with increasing degree of welding.

Pumice is present in all samples examined. The qualitative abundance estimates are based on visual estimates for hand samples and point counts for thin sections. "Rare" (Designated 1) indicates under about 10 percent pumice, "Common" (Designated 2) indicates under about 50 percent pumice, and "Abundant" (Designated 3) indicates significantly more than 50 percent of the rock is pumice.

4.4.5 Glass Abundance

Glass is only present in samples from the non-welded interval (samples between 143.5 ft and 241.5 ft) and glassy components dominate most samples in this interval. Abundance estimates for glass are very qualitative and based on the recognition of visibly glassy fragments in hand samples and isotropic optical properties in thin sections. Very fine-grained components which may be glassy are commonly not recognizable as such because of the very fine grain size. Examination of X-ray diffraction data (not presented in Table 4-9 because mineralogical analysis is incomplete) suggests that glass (as pumice, shards, and fine-grained matrix) comprises perhaps 50 percent to 70 percent of these samples.

4.4.6 Lithophysal Zones and Consistency

Lithophysae are ovoid to flattened zones of vapor-phase alteration, generally showing a light gray color, with or without a central porous zone which occur within devitrified welded ash-flow tuff. As defined here, lithophysae include both the central lithophysal cavity and the surrounding zone of vapor-phase alteration. In Table 4-9, relative abundance of lithophysae are estimated in a manner similar to that used for pumice, however the absolute abundance is much lower. Due to the small size of hand samples and thin-sections examined and the inhomogeneous occurrence of lithophysae, abundance estimates cannot be taken to be absolutely representative of samples. "None" (Designated 0) indicates no lithophysae were noted, "Rare" (Designated 1) indicates no more than 1 percent to 3 percent lithophysae, "Common" (Designated 2) indicates under about 3 percent to 15 percent lithophysae, and "Abundant" (Designated 3) indicates more than 15 percent to 25 percent (or more) lithophysae. These estimates do not include only the central porous zone, but also include the surrounding zone of vapor-phase alteration. The maximum size of lithophysae and related cavities as observed in the samples, as well as description of the shape of the features are included in Table 4-9.

Lithophysae are recognized intermittently in samples from depths greater than 354 ft, but are most abundant and consistently present between samples at 416.0 ft and 693.1 ft. Lithophysae are notably absent in most samples from greater than 792.2 ft depth.

It should be noted that zones with a significant content of large lithophysae generally show very poor core recovery in drill holes, and that our sample suite in some intervals may be significantly biased toward nonlithophysal samples because of this.

4.4.7 Lithic Fragment Abundance

Lithic fragments are defined as fragments of pre-existing volcanic or other crystalline rock which have been incorporated into the rock examined. Lithic fragments are rare (under 1 percent - 2 percent of the mode) in almost all samples with the exception of the sample from 488.0 ft which contains several large lithic fragments.

4.4.8 Modal Analysis

Detailed modal analyses were made only for samples for which thin sections were available. For hand samples, a visual estimate of total phenocryst content is the only modal data presented. It should be noted that point counts made on thin sections, while very accurate for the thin section area, may significantly under- or over-estimate amounts of certain components in the sample as a whole (chiefly large components such as lithophysae or large lithic fragments) if these fragments are absent or present in the thin section being counted.

The primary phenocrysts present in the samples are quartz, plagioclase, alkali-feldspar, and biotite and iron-titanium oxides (combined as "Mafic" in Table 4-9). The interval between 169.5 ft and 458.7 ft shows total phenocryst percentage of generally over 5 percent, with the highest amounts (> 15 percent) between 276.2 ft and 392.6 ft. Samples from 488 ft and below are all extremely low in phenocrysts, generally well under 2 percent.

The major components of tuffaceous rocks are shards, pumice and matrix, and point count data for these components are included in Table 4-9. Shards are angular fragments, generally 1 mm - 2 mm or less in long dimension, which are formed by explosive eruption of the gas-rich magma, and are a major component of most volcanic ash. While shards are a major component of most explosive silicic eruptions, their primary textures may be destroyed by crystallization or other alteration as the ash is turned into rock by welding and devitrification. In the point count data, shards were only counted as such when the primary texture was recognizable in the rock. Matrix is the fine-grained component of the ash, generally in a size range under 10 μm. Much of the matrix counted in the devitrified samples (all samples but those in the interval 143.5 ft to 241.5 ft) is probably in-part the result of the process of welding and devitrification. Pumice or fiamme (described previously) can show significant variation depending on the actual eruptive source, but also commonly have their primary textures obscured or destroyed by welding and devitrification.

Porosity visible in thin section includes only those pores which are larger than 15 μm to 20 μm and are clearly visible as pore space. Pores in the matrix smaller than what is visible in thin section can contribute significantly to the bulk porosity of the rock, but cannot be identified by optical techniques (since they are significantly smaller than the 30μm thickness of the thin section). It is important to note that the point count results for visible porosity include areas of the thin sections which are also included in the count of shards, pumice and matrix, i.e., these areas have been counted twice so that areas of shards, pumice, and matrix which include pores are still included in the count area for those components. In general, most visible porosity is counted within pumice and shards.

In general, the qualitative estimates of porosity of hand samples show positive correlation with the porosity visible in thin sections, but in some cases (chiefly in the welded interval between 276.2 ft and 648.6 ft, including most of the lithophysal zone) the porosity visible in the hand samples is more abundant that that in the thin sections. This is primarily a result of the irregular occurrence of pores in lithophysae and fiamme with may be under-represented in the thin sections.

4.4.9 Estimates of Primary Mineralogy and Proportions Utilizing X-ray Diffraction

Most of the XRD data for these samples were gathered in 1994. Major mineral phases present in the samples were identified by comparison of X-ray diffraction (XRD) patterns for the powdered rock samples with patterns for standard minerals in the International Center for Diffraction Data Powder Diffraction File. Primarily because of the difficulties in evaluating the amounts of glass present, mineral proportions were not estimated for the nonwelded samples (between 143.4 ft and 241.5 ft).

The integrated intensities of the characteristic XRD peaks for the minerals identified were calculated from the data and, using reference intensity rations (RIRs) published by Bish and Chipera (1989), estimates of the proportions of the mineral phases were calculated using the "Matrix-Flushing" method of Chung (1974a, 1974b). These results are presented in Table 4-9, and must be considered qualitative. The data upon which these analyses were based was gathered without using an internal standard, and this is the primary factor limiting the results as qualitative. Factors compromising the absolute accuracy of the results are:

1. The published RIRs were obtained using other XRD equipment and may not be exactly correct for the XRD system upon which these data were obtained.
2. The resultant amounts are normalized to 100 percent, thus any unidentified minerals are not represented in the results. The detection limit for most mineral phases is estimated to be about 3 to 5 wt percent depending on the particular mineral. Porosity is also not included in this estimate. The result is that all other things being correct, the actual amounts of the minerals reported will be reduced by the amount of unidentified material present.
3. RIR's may not be accurate for some mineral phases, particularly feldspar and possibly tridymite where the values may vary somewhat with variations in chemical composition.

All of the above error-inducing factors may be minimized by mixing a known proportion of a mineral standard (such as corundum) with the sample powders as an internal standard, and by determination of RIRs for mineral standards on the same equipment with the same internal standard. In addition to eliminating most problems with RIR determinations, the presence of an internal standard also eliminates the problems connected with normalization and the presence of a significant amount of material (such as glass) which cannot be accurately determined by XRD; in an internal-standard method, the amount of each mineral is determined against the standard independently of other minerals in the sample. These techniques have been developed over the past year, and application to the samples included in this report require another round of data collection and analysis.

The minerals identified by X-ray diffraction in the devitrified samples from NRG-6 include the silica phases cristobalite, quartz, tridymite, feldspar (plagioclase and sodium- and potassium-rich alkali feldspar), and a clay mineral (primarily illite). The following points are noted about the minerals identified and their occurrence:

1. Cristobalite is present in virtually all devitrified samples, and is the dominant silica phase in most samples.
2. Quartz is absent in all samples shallower than 458.7 ft, and does not appear abundantly until 648.6 ft. Note that the "phenocryst" quartz is not identified in the XRD patterns; this is attributed to its low abundance and probably its relatively large grain size in the powders analyzed which tends to suppress the XRD peak intensity.
3. Tridymite is intermittently present in samples at 425.3 ft or less depth, and was not identified in any quartz-bearing samples.
4. Clay (Illite) is identified from many (but not all) samples in the same interval from which Tridymite was identified.

Some further discussion of mineralogical results is included in section 4.4.11 in relation to the USGS lithologic classification scheme.

4.4.10 Water Content and Significance

The total water content in weight percent for all samples analyzed chemically is included in Table 4-9. The total water content is obtained by adding the H_2O- (water lost under 110°C) with H_2O+ (water lost on ignition at 1000°C) from the chemical analysis.

Water content is consistently high (between 4 percent and 7 percent) in the nonwelded interval. Most tuffs containing only perlitic glass show water contents around 3 percent, and tuffs which have significant zeolitic alteration typically show water contents of 9 percent to 15 percent. These samples show water contents which are typical of tuffs with perlitic alteration of volcanic glass and some clay alteration.

Water content is consistently lower in the welded and devitrified tuffs, but shows significant variation. A devitrified rhyolitic tuff which contains no clay minerals or other alteration will typically have a total water content between 0.5 percent and 1.0 percent. A devitrified quartz-latite tuff will typically show a total water content somewhat less than a rhyolite. Upward deviations from these averages generally will be due to the presence of hydrated mineral phases such as clays, and the samples which show this deviation are at 416.0 ft, 425.3 ft, 458.7 ft, and 802.7 ft. For the shallower samples, there appears to a clear correlation with identified clay minerals; a clear mineralogical correlation for the deeper sample is not evident.

4.4.11 Comparison with Existing Data

The USGS has applied a lithostratigraphic classification to rocks from drill hole NRG-6 (Geslin et al., 1995), and their unit designations have been included in Table 4-9. In general, the lithologic units are consistent with the data presented in this report, with some variations as discussed below.

- Eight samples from the Tiva Canyon Tuff (Tpc) include three from the devitrified lower lithophysal zone (pll) and one from the devitrified lower nonlithophysal zone (plnc), and four from the crystal-poor vitric zone (pv). In the devitrified samples, total phenocryst content is somewhat lower than determined by point count (2 percent - 3 percent versus our 3 percent - 6 percent), and no clay minerals were identified although clay is reported to be "abundant" in the interval between 106 ft and 125.2 ft. Although in the moderately welded subzone (pv2), the sample at 143.5 ft does not show textural evidence of welding in thin section, but does show low porosity which could suggest some welding.
- Three samples of Bedded tuffs (Tpb) from subzones 3 (161.4 ft) and 4 (169.5 ft and 174.0 ft) are highly variable texturally as is characteristic of tuffaceous fall deposits, however the subzone 4 samples show significantly higher phenocryst contents than is implied by the description given by Geslin et al. (1995).
- Three samples from the Pah Canyon Tuff (Tpp) all have higher phenocryst contents, and higher pumice contents than implied by the descriptions of Geslin et al. (1995).
- Two samples of Bedded tuffs (Tpbt2) have high pumice and low shard contents typical of tuffaceous fall deposits as described by Geslin et al. (1995).
- Twenty-seven samples (between 276.2 ft and 427.0 ft) are Topopah Spring Tuff (Tpt) from the crystal-rich nonlithophysal zone (rn). Variations are noted within our detailed data which are not noted in the descriptions of Geslin et al. (1995) as follows:

    1. Lithophysae are noted intermittently beginning at 354.9 ft, and are abundant beginning at 416.0 ft, suggesting the boundary with the lower lithophysal zone might be moved upward by 10 ft - 15 ft.

2. There is a break in total phenocryst abundance somewhere between 390 ft and 395 ft indicated by a notable drop by about half of total phenocryst content.

3. The lower part of the zone in which lithophysae begin to be abundant also contains clay minerals.

- The crystal transition subzone (Tpt-rl1) of Geslin et al. (1995) is represented two samples in our data (458.7 ft and 462.3 ft), and our samples show the described decrease in phenocryst content.

- Fifteen samples (between 488.0 ft and 693.1 ft) represent the crystal-poor upper lithophysal zone (Tpt-pul2 and pul1) of Geslin et al. (1995). The zone is characterized by abundant large lithophysae, and under 2 percent total phenocryst content. Geslin et al. (1995) indicate considerably less pumice than our point count data suggesting that they did not include fiamme in their estimation of pumice content, but overall their lithologic description agrees well with our observations. Mineralogically, the first significant amount of quartz as a devitrification product occurs within this zone.

- Fifteen samples (between 720.6 ft and 806.8 ft) represent the crystal-poor middle nonlithophysal zone (Tpt-pmn) of Geslin et al. (1995). This interval is crystal poor, nonlithophysal (with the exception of the sample at 773.5 ft in agreement with the descriptive data of Geslin et al.).

- Twenty-three samples (between 848.0 ft and 1085.0 ft) represent the crystal-poor lower lithophysal zone (Tpt-pll) of Geslin et al. (1995). Geslin et al. (1995) identify "numerous cavernous (greater than 10 cm) lithophysae in downhole videotape" which are poorly to non-represented in most of the samples examined. Lithophysae were only identified in five samples (926.3 ft, 934.0 ft, 940.5 ft, 952.2 ft, and 1081.0 ft), however our ability to recognize lithophysae may have been inhibited by the relatively small size of the samples. These observations suggest that this is an interval in which thermal and mechanical testing of laboratory samples may not accurately predict the behavior of the rock mass as a whole. Previous work on lithophysal samples (Price et al., 1985) have noted the correlation between tridymite and lithophysae. It is noted here that tridymite is present in most samples from the upper lithophysal zone (Tpt-pul), but is notably absent in samples from the lower lithophysal zone (Tpt-pll).

Table 4-9. Petrographic Characterization of NRG-6 Samples

Yucca Mountain Project NRG-6 Drillcore	Mineralogy Petrology Description Summary																				
Depth	22.2	23.4	28.8	111.0	143.5	145.7	151.2	152.9	161.4	169.5	174.0	182.2	187.0	220.0	227.9	241.5	276.2	277.5	316.3	318.2	321.1
In-depth analysis for this sample? (Note 1)	Y		X	Y	Y			Y	Y	Y	Y	Y	Y	Y	Y	Y		Y			Y
USGS Stratigraphic Unit Designation	Tpc	Tpc	Tpc	Tpc	Tpc	Tpc	Tpc	Tpc	Tpb	Tpb	Tpb	Tpp	Tpp	Tpp	Tpbt	Tpbt	Tpt	Tpt	Tpt	Tpt	Tpt
USGS Subzone	pll	pll	pll	plnc	pv	pv	pv	pv	3	4	4				2	2	m	m	m	m	m
USGS Subzone Division					2	2	1	1													
Colors White			See						15	15					50	10	10	5		10	5
Light Yellowish-Brown			Note		80	75	55	80				20	20	50	10	80					
Black			4			15	25	10			10										
Gray		15		20	20		5	10	10		90			10	40	10	10		15	10	
Purple-Gray	20	85		80													20	15		15	15
Light-Pink-Gray																					
Orange																					
Rust-Reddish Brown																					
Pale Orangish-Red																					
Gray Brick-Red	80								75	85				40			40	80	85	65	80
Reddish-pink						10	15					80	80								
Color (0=uniform, 1=mottled, 2=irregular, 3=streaked)	0	3		3	1	0	1	1	1	1	1	2	2	2	0	2	1	1	1	1	1
Welding (0=none,1=weak,2=moderate,3=strong)	2	2		3	0	0	0	0	0	0	0	0	0	0	0	0	1	2	1	1	2
Fiamme or Pumice (maximum size in mm)	5	20		10	5	15	10	15	20	5	10	25	10	15	10	10	20	5	20	15	30
Pumice Abundance (Note 2)	3	2		1	1	1	2	1	2	2	3	2	2	2	3	2	2	2	2	2	2
Glass Abundance (Note 2)	0	0		0	2	2	2	2	1	2	2	2	2	2	2	2	0	0	0	0	0
Vesicles Abundance (Note 2)	0	0		0	0	2	2	0	0	0	0	0	0	0	0	0	2	0	2	2	0
Pore Abundance (Note 2)	1	1		1	1	2	2	2	1	1	2	2	2	2	2	2	2	1	2	2	2
Lithophysae (maximum size in mm)																					
Abundance (Note 2)	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Shaped: 1=Flattened, 2=Irregular, 3=Ovoid																					
Lithophysal Caviites (maximum size in mm)																					
Abundance of Cavities(Note 2)	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Shape: 1=flattened or arcuate, 2=ovoid																					
Lithics (maximum size in mm)	1	2		2	0.5	4	7	0.5	1	2	2	2	1.5	1	2	10	3	5	2	2	2
Abundance (Note 2)	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Modal Petrographic Data (See Note 3)																					
Component / Approximate Percentages																					
Phenocrysts (est. total modal %)	4.1	3		6	4	4	4	2	3	8	11	5.5	6.5	12	4.5	9.5	15	17	15	20	23
Alkali-Feldspar (est. modal %)	2			4	2			1	2	2	2	1.5	1.5	1.5	4	2		6			9
(size in mm)	1.5			1	0.5			1.5	1	1	1	1		0.5				1			
Quartz (est. modal %)	1.5			1.5	1.5			1	1	2	2	1	3.5	3	0.3	2.5		4			5
(size in mm)	1			1	0.5			1	0.5	0.5	1	0.5		0.5				1			
Plagioclase (est. modal %)	0.1			0	0.5			0	0	3	6	2.5	1	5	0.2	3		6			6
(size in mm)	1				0.5					1.5	1	1		0.5				1			
Mafic (est. modal %)	0.5			0.5	0			0	0	1	1	0.5	0.5	2	0	2		1			2.5
(size in mm)	0.2			1						0.5	1	0.5		0.5				1			
Matrix	7.0			21.0	49.7			26.6	22.0	23.3	10.7	16.0	15.7	26.4	17.2	14.5		29.3			18.2
Shards	82.5			63.8	36.3			62.0	6.0	19.1	0.5	25.9	31.3	21.0	8.8	19.6		20.7			21.7
Pumice or Fiamme	63.8			7.9	8.8			8.4	50.9	33.1	75.7	51.3	45.8	38.5	67.2	55.5		33.8			37.1
Porosity Visible in Thin Section				0.1	1.3			11.4	16.1	5.8	36.4	31.5	23.5	24.5	35.8	24.2		0.8			0.9
Semi Quantitative XRD Results (Note 5)																					
Mineral / Approximate Percentages																					
Quartz																					
Cristobalite	25		25	17														8			6
Tridymite	5																				3
Feldspar	71		75	83														87			85
Clay (Illite)																		5			6
Total	100		100	100														100			100
Total H2O in wt. % (from Chemical analysis)	0.46		0.45	0.70				4.81	4.96	6.48	4.23		3.87	5.58	7.11	4.87		0.15			0.18
Notes: See End of Table																					

Table 4-9. Petrographic Characterization of NRG-6 Samples

Yucca Mountain Project NRG-6 Drillcore																					
Depth	328.7	354.4	354.9	355.4	372.6	373.1	391.6	392.1	392.6	395.0	395.2	397.0	397.5	407.0	407.2	416.0	420.8	421.5	421.8	425.3	427.0
In-depth analysis for this sample? (Note 1)			Y			Y		Y								Y				Y	
USGS Stratigraphic Unit Designation	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt
USGS Subzone	m	m	m	m	m	m	m	m	m	m	m	m	m	m	m	m	m	m	m	m	m
USGS Subzone Division																					
Colors White	5	5	5	5	5	5	10	5	5	5	10	10	10	10	10	10	15	15	20	5	10
Light Yellowish-Brown																					
Black															5						
Gray	25	15		15	10	5	20	20	10	10	15	20	10	20	20	15	10	5	10	5	10
Purple-Gray			15		20	40	20	40	40	30	10	20	25	20	20		20	25		20	40
Light-Pink-Gray																					
Orange																					
Rust-Reddish Brown		5		10	15		10			20		15	20	10	10		10	10			
Pale Orangish-Red																					
Gray Brick-Red	70	75	80	70	50	50	40	35	45	35	65	35	35	40	35	75	45	45	70	60	40
Reddish-pink																				10	
Color (0=uniform, 1=mottled, 2=irregular, 3=streaked)	3	3	1	3	3	1	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Welding (0=none,1=weak,2=moderate,3=strong)	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	3	3
Fiamme or Pumice (maximum size in mm)	30	40	20	25	40	15	25	20	30	30	20	30	25	35	50	15	20	20	50	40	25
Pumice Abundance (Note 2)	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3
Glass Abundance (Note 2)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vesicles Abundance (Note 2)	1	1	0	2	2	0	2	0	1	1	1	1	1	1	1	0	1	1	0	0	0
Pore Abundance (Note 2)	2	2	2	2	2	1	2	1	2	1	1	1	1	2	1	1	1	1	2	1	1
Lithophysae (maximum size in mm)			3	15	10	3		10	7			5		20	8	10	25	10	12	20	10
Abundance (Note 2)	0	0	1	1	1	1	0	1	1	0	0	1	0	1	1	2	2	2	1	2	1
Shaped: 1=Flattened, 2=Irregular, 3=Ovoid			1	1	1	1		1	1			1		1	1	1	1	1	3	1	1
Lithophysal Caviites (maximum size in mm)			1	12	6	2		5	4			2		10	4	3	10	5	10	3	4
Abundance of Cavities(Note 2)	0	0	1	1	1	1	0	1	1	0	0	1	0	1	1	2	2	1	1	2	1
Shape: 1=flattened or arcuate, 2=ovoid			1	1	1	1		1	1			1		1	1	1	1	1	2	1	1
Lithics (maximum size in mm)	3	1	1	1	8		1		2	2	8	5	3	1	25		2	2	2	2	2
Abundance (Note 2)	1	1	1	1	1	0	1	0	1	1	1	1	1	1	1	0	1	1	1	1	1
Modal Petrographic Data (See Note 3)																					
Component / Approximate Percentages																					
Phenocrysts (est. total modal %)	20	15	17	15	15	17	15	20	15	10	10	10	10	10	10	13	10	10	10	10	10
Alkali-Feldspar (est. modal %)			8.5			8		8.5								5				3.5	
(size in mm)			2			2		1								1				2	
Quartz (est. modal %)			3.5			5		4.5								3.5				2.5	
(size in mm)			2			2		0.5								0.5				4	
Plagioclase (est. modal %)			3.5			2.5		4								3.5				3	
(size in mm)			2			2		1								1				3	
Mafic (est. modal %)			1.5			1.5		2.5								1				1	
(size in mm)			1			1		0.5								0.5				2	
Matrix			25.3			28.3		35.9								29.7				27.2	
Shards			17.7			16.1		11.6								11.8				13.7	
Pumice or Fiamme			41.8			38.6		33.9								38.2				48.0	
Porosity Visible in Thin Section			1.3			1.2		0.7								2.5				0.2	
Semi Quantitative XRD Results (Note 5)																					
Mineral / Approximate Percentages																					
Quartz																					
Cristobalite			9			7		8								8				8	
Tridymite			5			8		9								9				13	
Feldspar			79			85		77								80				75	
Clay (Illite)			7					6								3				4	
Total			100			100		100								100				100	
Total H2O in wt. % (from Chemical analysis)			0.26			0.53		0.48								1.23				1.20	
Notes: See End of Table																					

Table 4-9. Petrographic Characterization of NRG-6 Samples

Yucca Mountain Project NRG-6 Drillcore																					
Depth	458.7	462.3	488.0	495.0	502.8	528.4	539.2	539.8	554.0	564.9	640.0	648.6	649.6	662.2	673.4	687.5	693.1	720.6	729.2	742.3	742.9
In-depth analysis for this sample? (Note 1)	Y					Y						Y					Y		Y		
USGS Stratigraphic Unit Designation	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt
USGS Subzone	rl	rl	pul	pul	pul	pul	pul	pul	pul	pul	pul	pul	pul	pul	pul	pul	pul	pmn	pmn	pmn	pmn
USGS Subzone Division	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	3	3	3	3
Colors White	5	10	20	10	10	See							5	5	5		5		5		
Light Yellowish-Brown						Note															
Black						4															
Gray	25	20		50	40		50	40	40	30	35	45	35	20	40	25	35	10		15	10
Purple-Gray	70	50	70	20	10		10	10	20	50	35	35	50	50	30	50	20	70	70		
Light-Pink-Gray																					
Orange																					
Rust-Reddish Brown		20	10		20		20	40	40								40		25		
Pale Orangish-Red																				85	90
Gray Brick-Red										20	30	20	10	25	25	25		20			
Reddish-pink				20	20		20	10													
Color (0=uniform, 1=mottled, 2=irregular, 3=streaked)	1	3	3	1	1		1	1	1	1	2	1	1	1	3	3	2	3	2	1	3
Welding (0=none,1=weak,2=moderate,3=strong)	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	2	2	2	2
Fiamme or Pumice (maximum size in mm)	25	25	15	10	5	4	25	5	5	5	5	3	10	40	10	10	3	10	5	15	8
Pumice Abundance (Note 2)	3	2	2	2	2	2	2	1	1	1	1	2	1	1	1	1	2	2	2	2	2
Glass Abundance (Note 2)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vesicles Abundance (Note 2)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pore Abundance (Note 2)	2	2	1	2	2	1	2	2	2	2	2	2	1	1	1	1	1	0	0	0	1
Lithophysae (maximum size in mm)	30	20	12	25	40		35	30	30	30	40	40	30	30	50	10	40	7			
Abundance (Note 2)	2	1	1	3	3		3	3	2	2	2	3	2	2	3	2	3	1	0	0	0
Shaped: 1=Flattened, 2=Irregular, 3=Ovoid	1	1	1	3	3		3	3	3	3	3	2	3	3	1	1	2	3			
Lithophysal Caviites (maximum size in mm)	8	6	5	10	8		10	10	25	15	10	10	10	8	25		15	2			
Abundance of Cavities(Note 2)	2	1	2	3	2		3	3	3	3	2	2	1	1	2	1	2	1	0	0	0
Shape: 1=flattened or arcuate, 2=ovoid	1	1	1	2	2		1	1	2	1	1	1	1	1	1		1	3			
Lithics (maximum size in mm)	2	3	3	3				2		1		2	2	8		3		0	0		
Abundance (Note 2)	1	1	2	1	0		0	1	0	1	0	1	1	1	0	1	0		1	0	0
Modal Petrographic Data (See Note 3)																					
Component / Approximate Percentages																					
Phenocrysts (est. total modal %)	7.5	3	2	2	1	1.7	2	1	2	1	1	1.2	1	1	1	1	1.6	1	1.5	2	1
Alkali-Feldspar (est. modal %)	3					0.5						0.5					0.5		0.4		
(size in mm)	1					0.5						1					0.5		0.5		
Quartz (est. modal %)	2					0.2						0.1					0.1		0.4		
(size in mm)	0.5					0.2						0.5					0.2		0.5		
Plagioclase (est. modal %)	2					0.5						0.5					0.5		0.4		
(size in mm)	1					0.7						1					0.5		0.5		
Mafic (est. modal %)	0.5					0.5						0.1					0.5		0.3		
(size in mm)	0.5					0.5						1					1		0.3		
Matrix	29.3					47.0						51.6					42.7		21.2		
Shards	5.6					12.8						16.7					27.5		42.0		
Pumice or Fiamme	58.0					25.2						22.3					26.0		32.9		
Porosity Visible in Thin Section	2.7					0.2															
Semi Quantitative XRD Results (Note 5)																					
Mineral / Approximate Percentages																					
Quartz	2											12					7		2		
Cristobalite	11					18						11					13		17		
Tridymite																					
Feldspar	83					82						78					80		81		
Clay (Illite)	4																				
Total	100					100						100					100		100		
Total H2O in wt. % (from Chemical analysis)	1.38					0.77						0.86					0.60		0.69		
Notes: See End of Table																					

Table 4-9. Petrographic Characterization of NRG-6 Samples

Yucca Mountain Project NRG-6 Drillcore																					
Depth	757.0	762.9	773.5	777.8	784.8	785.6	788.3	802.4	802.7	806.0	806.8	848.0	849.9	886.5	900.4	906.0	908.2	911.2	926.3	934.0	940.5
In-depth analysis for this sample? (Note 1)	Y			Y					Y				Y		Y				Y		
USGS Stratigraphic Unit Designation	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt
USGS Subzone	pmn	pmn	pmn	pmn	pmn	pmn	pmn	pmn	pmn	pmn	pmn	pll	pll	pll	pll	pll	pll	pll	pll	pll	pll
USGS Subzone Division	3	3	2	2	1	1	1	1	1	1	1										
Colors White	5		5	2	2											5			5	5	5
Light Yellowish-Brown																					
Black																					
Gray	10	10	20	15	10	10	30	15	15	15	10	10	15	15	5	15	10	15			5
Purple-Gray		40	60	83	88	80	70	60	75	85	90	10		10				45	20	15	60
Light-Pink-Gray													85			65			40		
Orange																				45	
Rust-Reddish Brown			15			10		25	10			50		75			50	40		35	15
Pale Orangish-Red	85	50																			
Gray Brick-Red												30			95	15	40		35		15
Reddish-pink																					
Color (0=uniform, 1=mottled, 2=irregular, 3=streaked)	1	1	2	1	2	2	1	1	3	3	1	2	3	3	2	2	1	3	2	2	2
Welding (0=none,1=weak,2=moderate,3=strong)	3	2	2	2	2	2	2	2	2	2	2	2	2	3	3	2	2	2	2	2	2
Fiamme or Pumice (maximum size in mm)	8	20	4	30	5	5	10	6	15	30	3	40	35	20	3	50	15	25	20	50	10
Pumice Abundance (Note 2)	2	2	1	2	2	2	2	2	2	2	2	2	2	0	2	2	2	2	2	3	1
Glass Abundance (Note 2)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vesicles Abundance (Note 2)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pore Abundance (Note 2)	0	1	1	1	1	0	0	0	1	0	0	0	1	1	0	1	1	1	2	1	1
Lithophysae (maximum size in mm)			30																60	20	10
Abundance (Note 2)	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	1
Shaped: 1=Flattened, 2=Irregular, 3=Ovoid			1																1	1	1
Lithophysal Caviites (maximum size in mm)			15																12	15	6
Abundance of Cavities(Note 2)	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
Shape: 1=flattened or arcuate, 2=ovoid																			1	1	1
Lithics (maximum size in mm)	0	0	0	0		1	5	1	0	4	2	8	0	15	3	1	1	10	0	15	5
Abundance (Note 2)	1			1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2
Modal Petrographic Data (See Note 3)																					
Component / Approximate Percentages																					
Phenocrysts (est. total modal %)	0.9	1	1	1.1	1	1	1	1	1.2	1	1	1	2.1	1	1.2	1	2	1	1.7	2	2
Alkali-Feldspar (est. modal %)	0.2			0.4					0.2				0.3		0.3				0.1		
(size in mm)	0.5			0.5					0.5				1		1				0.5		
Quartz (est. modal %)	0.2			0.2					0.3				0.3		0.4				0.2		
(size in mm)	0.5			0.5					0.5				0.5		0.5				0.5		
Plagioclase (est. modal %)	0.4			0.4					0.5				0.5		0.3				1.2		
(size in mm)	0.5			0.5					1				0.5		1				0.5		
Mafic (est. modal %)	0.1			0.1					0.2				1		0.2				0.2		
(size in mm)	0.2			0.2					0.3				0.5		0.1				0.2		
Matrix	19.8			2.5					10.8				20.0		13.0				10.3		
Shards	40.5			51.3					39.9				19.4		33.2				27.8		
Pumice or Fiamme	32.1			40.2					42.6				51.8		51.1				58.1		
Porosity Visible in Thin Section																					
Semi Quantitative XRD Results (Note 5)																					
Mineral / Approximate Percentages																					
Quartz	6			2					3				25		20				16		
Cristobalite	18			20					21										9		
Tridymite																					
Feldspar	76			77					76				75		80				75		
Clay (Illite)																					
Total	100			100					100				100		100				100		
Total H2O in wt. % (from Chemical analysis)	0.89			0.65					1.30				0.62		0.50				0.72		
Notes: See End of Table																					

Table 4-9. Petrographic Characterization of NRG-6 Samples

Yucca Mountain Project NRG-6 Drillcore													
Depth	952.2	953.2	956.8	963.3	969.3	971.4	972.4	985.7	987.6	1016.6	1017.8	1081.0	1085.0
In-depth analysis for this sample? (Note 1)										Y		Y	
USGS Stratigraphic Unit Designation	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt
USGS Subzone	pll	pll	pll	pll	pll	pll	pll	pll	pll	pll	pll	pll	pll
USGS Subzone Division													
Colors White	2		10	10			5	5	5	5		5	
Light Yellowish-Brown													
Black													
Gray	8			5	10	5	5	10	25	5	15		10
Purple-Gray	40	10	5	35	40	30	50	50	40			35	20
Light-Pink-Gray		15	30				20			40		50	50
Orange		25											
Rust-Reddish Brown	50	50	55	40	50	65	20	15	30				20
Pale Orangish-Red													
Gray Brick-Red								20		50	85	15	
Reddish-pink													
Color (0=uniform, 1=mottled, 2=irregular, 3=streaked)	2	2	2	2	2	2	2	2	3	3	2	2	2
Welding (0=none,1=weak,2=moderate,3=strong)	2	2	2	2	2	2	2	2	3	3	2	2	2
Fiamme or Pumice (maximum size in mm)	40	25	20	25	15	15	40	10	20	20		50	50
Pumice Abundance (Note 2)	3	3	3	3	3	2	2	2	2	2	2	3	3
Glass Abundance (Note 2)	0	0	0	0	0	0	0	0	0	0	0	0	0
Vesicles Abundance (Note 2)	0	0	0	0	0	0	0	0	0	0	0	0	0
Pore Abundance (Note 2)	1	1	1	1	1	1	1	1	1	2	1	2	2
Lithophysae (maximun size in mm)	8											35	
Abundance (Note 2)	1	0	0	0	0	0	0	0	0	0	0	2	0
Shaped: 1=Flattened, 2=Irregular, 3=Ovoid	3											1	
Lithophysal Caviites (maximum size in mm)	4											12	
Abundance of Cavities(Note 2)	1	0	0	0	0	0	0	0	0	0	0	2	0
Shape: 1=flattened or arcuate, 2=ovoid	2						1					1	
Lithics (maximum size in mm)	20	10	4	3	15	10	3	15	15	0	17	3	8
Abundance (Note 2)	2	2	2	1	2	1	1	2	1	1	1	1	2
Modal Petrographic Data (See Note 3)													
Component / Approximate Percentages													
Phenocrysts (est. total modal %)	2	2	1	1	2	1	1	1	1	1.1	1	1.1	1
Alkali-Feldspar (est. modal %)										0.3		0.1	
(size in mm)										0.5		0.5	
Quartz (est. modal %)										0.3		0.3	
(size in mm)										0.5		1	
Plagioclase (est. modal %)										0.4		0.4	
(size in mm)										0.5		0.5	
Mafic (est. modal %)										0.1		0.3	
(size in mm)										0.5		0.3	
Matrix										11.9		13.0	
Shards										33.3		21.1	
Pumice or Fiamme										51.4		61.6	
Porosity Visible in Thin Section												0.2	
Semi Quantitative XRD Results (Note 5)													
Mineral / Approximate Percentages													
Quartz										15		18	
Cristobalite										6		10	
Tridymite													
Feldspar										79		72	
Clay (Illite)													
Total										100		100	
Total H2O in wt. % (from Chemical analysis)										0.86		0.79	
Notes: See End of Table													

Note 1: Y Indicates thin section and XRD Mineralogy data acquired for sample. X indicates XRD Mineralogy data only.

Note 2: For all Abundance estimates, 0 or Blank=not noted, 1=rare, 2=common, 3=abundant. Estimates are qualitative.

Note 3: Percentage Estimates for samples with "in depth" analyses are from point counts of thin sections. For hand samples, only total phenocryst percentage was estimated qualitatively by visual examination. "Porosity Visible in Thin Section" occurs in fiamme and shards and is counted with these components as well as individually.

Note 4: No hand sample description. Listed data are from thin-section. For these samples either all of sample was crushed for laboratory analysis, or remainder was too small for representative description.

Note 5: Proportions are approximate, and normalized to 100% excluding unidentified minor components. See text for explanation. No XRD mineralogy data given for glass interval (152.9 through 241.5).

4.5 Preliminary Comparison of Mineralogical Data with Thermal Properties

Mineralogies were examined to determine if correlations exist between thermal properties and the presence of certain minerals. In this section, correlations between the petrographic and thermal expansion data are discussed. Thermal conductivity data are not discussed in this section because these data did not indicate any apparent mineral phase changes. Heat capacity data are also omitted because these data were obtained for NRG-4 and NRG-5 while the petrographic characterizations were obtained for NRG-6.

Section 4.2.2.2 contained a discussion of transition temperatures and hysteresis observed during thermal expansion testing. These characteristics of the thermal expansion curves were discussed in light of phase changes expected in tridymite and cristobalite. Two characteristics of the thermal expansion curves are examined here. First, strain hysteresis (the difference in measured strains between the initial value at 25°C and the final value at 35°C) was tabulated for oven-dried specimens that had been cycled to 310°C - 320°C. Second, the MCTEs determined at 300°C during the heating cycle were tabulated for these same oven-dried specimens. A linear least squares regression was performed to correlate each of these thermal expansion characteristics with each of the petrographic characteristics listed in Table 4-9. The resulting correlation coefficient (r^2) indicates the proportion of variability in a thermal expansion characteristic that can be explained by a linear relationship with a petrographic characteristic. Of the 97 samples that were petrographically analyzed, 18 were for welded specimens that were originally adjacent to thermal expansion test specimens and 13 of these were used for semi-quantitative XRD analyses of silica components. All 18 samples were used for correlations of thermal properties with color and welding characteristics. The subset of 13 samples was used for correlations of thermal properties with lithophysae characteristics, lithics, modal percentages of minerals, major components, porosity, silica phase components, and water content. The correlation coefficients determined for each linear regression are shown in Table 4-10. The petrographic characteristics are listed sequentially in the table. For each petrographic characteristic two correlation coefficients are given; the first shows the correlation with strain hysteresis, and the second shows the correlation with MCTE at 300°C.

It is evident from the data in Table 4-10 that the correlation coefficients are generally low. The highest value corresponds to strain hysteresis versus lithophysae (or cavity) shape ($r^2 = 0.741$), and the next highest value corresponds to strain hysteresis versus lithophysae (or cavity) abundance ($r^2=0.540$). Strain hysteresis is plotted versus lithophysae shape and abundance in Figures 4-14 and 4-15, respectively. The plots are identical for cavity shape and abundance and so these are not shown.

High correlation coefficients were expected for tridymite and cristobalite contents and these data are plotted in Figures 4-16 through 4-19. Strain hysteresis and MCTE are plotted versus tridymite content in Figures 4-16 and 4-17, respectively, and plotted versus cristobalite content in Figures 4-18 and 4-19, respectively. The highest correlation coefficient is for strain hysteresis versus tridymite content ($r^2 = 0.367$). It is interesting to note that for specimen NRG-6-900.4, there is no tridymite or cristobalite present, yet thermal expansion testing resulted in a hysteresis of over 1100 microstrain.

The poor correlation between thermal properties and mineralogical composition may be explained in several ways. First, the data set is very limited. Thermal expansion data and detailed mineralogical data are both available for only 14 specimens. Second, the mineralogical analyses were not performed on the test specimens themselves, but on pieces of rock taken from near the test specimens. Compositional inhomogeneity within the rock mass may add variability to these results. Third, hysteresis in the thermal expansion data may be influenced by more than just mineralogy (e.g., lithophysae) and a larger database and/or further analyses may be required to separate the influences of each of these variables.

Table 4-10. Correlation Coefficients for Petrographic and Thermal Expansion Data

Core Characteristic	Correlation Coefficients[a]			
	All Samples (18)		Samples with in Depth Analyses (13)	
	Net Strain Hysteresis	MCTE at 300C (Heating Cycle)	Net Strain Hysteresis	MCTE at 300C (Heating Cycle)
Colors: White	0.325	0.000	N/A	N/A
Light Yellowish-Brown	-	-	N/A	N/A
Black	-	-	N/A	N/A
Gray	0.066	0.009	N/A	N/A
Purple-Gray	0.100	0.030	N/A	N/A
Light-Pink-Gray	0.049	0.211	N/A	N/A
Orange	-	-	N/A	N/A
Rust-Reddish Brown	0.009	0.017	N/A	N/A
Pale Orangish-Red	-	-	N/A	N/A
Gray Brick-Red	0.204	0.037	N/A	N/A
Reddish-pink	-	-	N/A	N/A
Color Uniformity	0.009	0.115	N/A	N/A
Extent of Welding	0.052	0.000	N/A	N/A
Fiamme or Pumice (maximum size in mm)	0.109	0.005	N/A	N/A
Pumice Abundance	0.169	0.048	N/A	N/A
Glass Abundance	-	-	N/A	N/A
Vesicles Abundance	-	-	N/A	N/A
Pore Abundance	0.123	0.130	N/A	N/A
Lithophysae (maximun size in mm)	N/A	N/A	0.227	0.001
Abundance	N/A	N/A	0.540	0.011
Shaped: 1=Flattened, 2=Irregular, 3=Ovoid	N/A	N/A	0.741	0.022
Lithophysal Caviites (maximum size in mm)	N/A	N/A	0.256	0.002
Abundance of Cavities	N/A	N/A	0.540	0.011
Shape: 1=flattened or arcuate, 2=ovoid	N/A	N/A	0.741	0.022
Lithics (maximum size in mm)	N/A	N/A	0.001	0.008
Abundance	N/A	N/A	0.191	0.015
Phenocrysts (est. total modal %)	N/A	N/A	0.138	0.010
Alkali-Feldspar (est. modal %)	N/A	N/A	0.180	0.005
(size in mm)	N/A	N/A	0.272	0.000
Quartz (est. modal %)	N/A	N/A	0.140	0.009
(size in mm)	N/A	N/A	0.194	0.013
Plagioclase (est. modal %)	N/A	N/A	0.061	0.021
(size in mm)	N/A	N/A	0.398	0.072
Mafic (est. modal %)	N/A	N/A	0.107	0.007
(size in mm)	N/A	N/A	0.001	0.313
Matrix	N/A	N/A	0.156	0.092
Shards	N/A	N/A	0.303	0.005
Pumice or Fiamme	N/A	N/A	0.056	0.039
Porosity Visible in Thin Section	N/A	N/A	0.143	0.164
Quartz	N/A	N/A	0.035	0.002
Cristobalite	N/A	N/A	0.029	0.006
Tridymite	N/A	N/A	0.430	0.031
Feldspar	N/A	N/A	0.032	0.019
Clay (Illite)	N/A	N/A	0.260	0.001
Total H2O in wt. % (from Chemical analysis)	N/A	N/A	0.000	0.001

[a] N/A = Not Applicable. For many petrographic characteristics data were only available for the 13 samples with in-depth analyses. If data were available for all 18 samples, then correlation coefficients were not calculated for the subset of 13 samples.

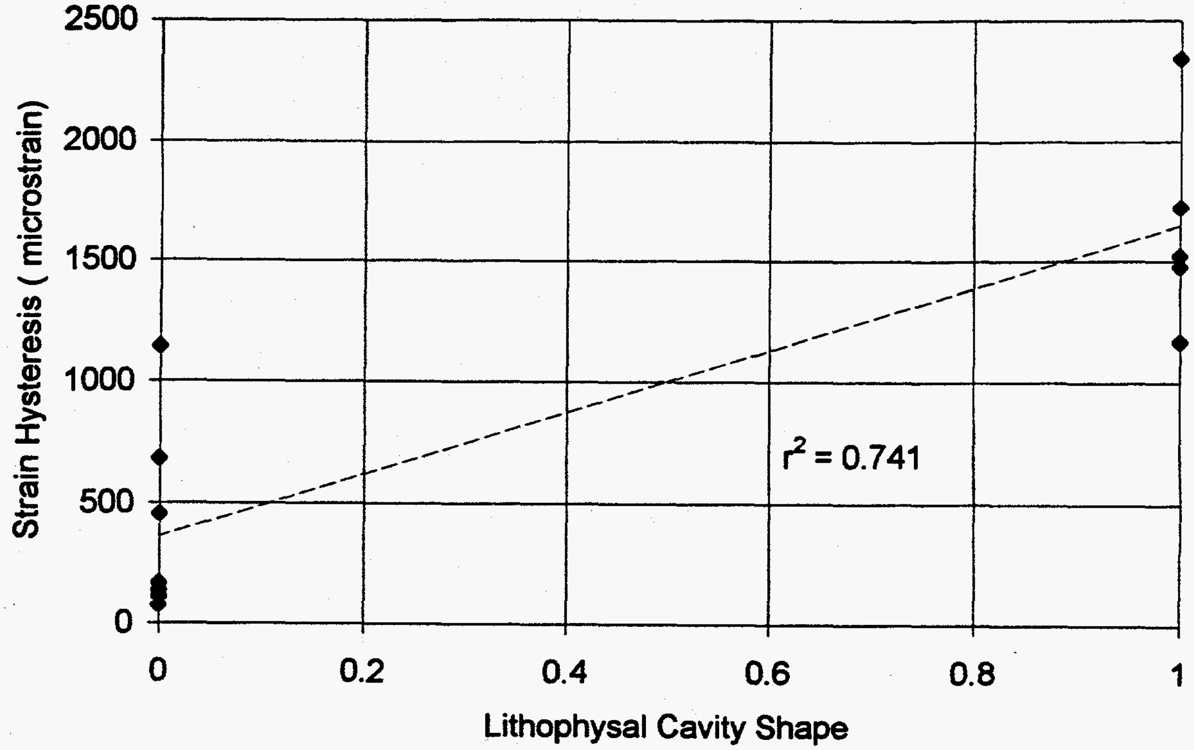


Figure 4-14. Strain Hysteresis Versus Lithophysae Shape for NRG-6

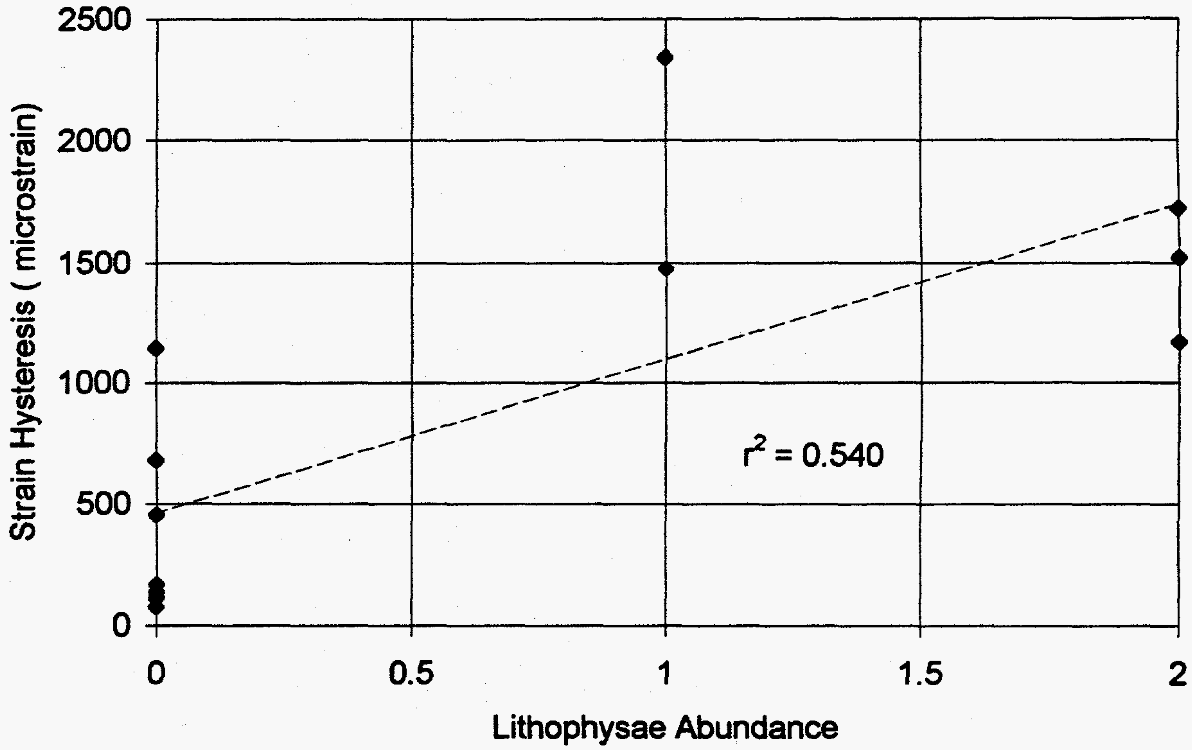


Figure 4-15. Strain Hysteresis Versus Lithophysae Abundance for NRG-6

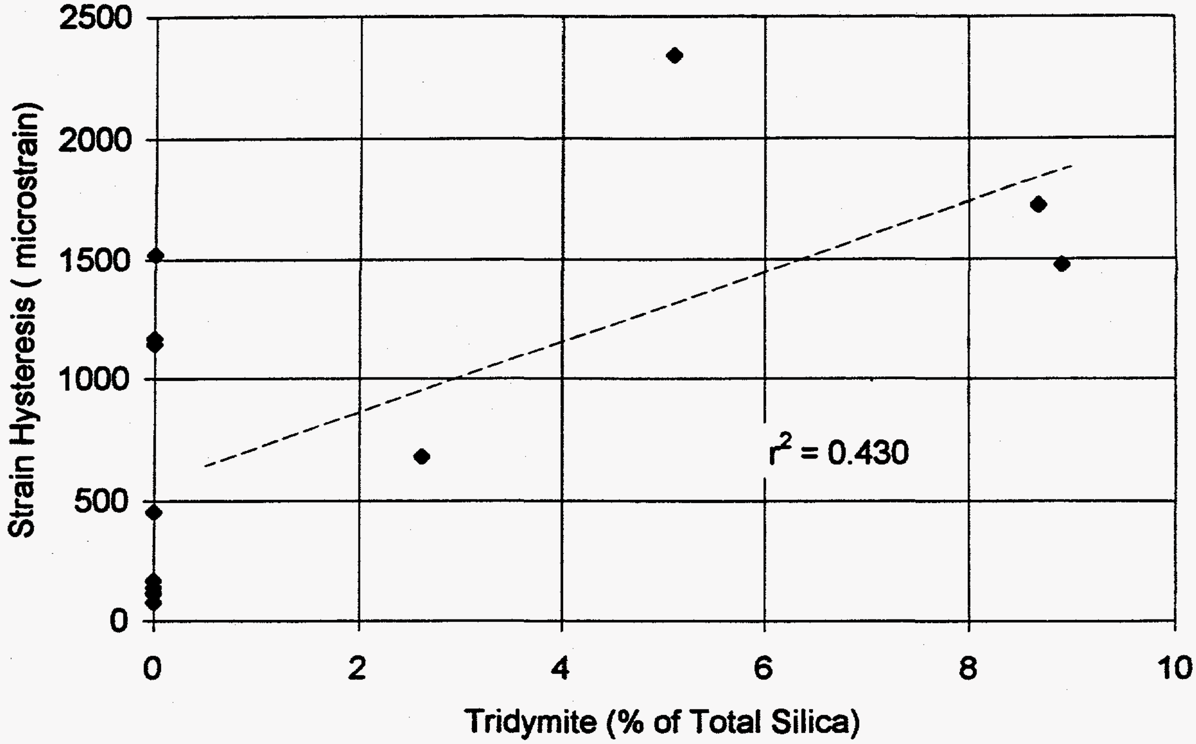


Figure 4-16. Strain Hysteresis Versus Tridymite Content for NRG-6

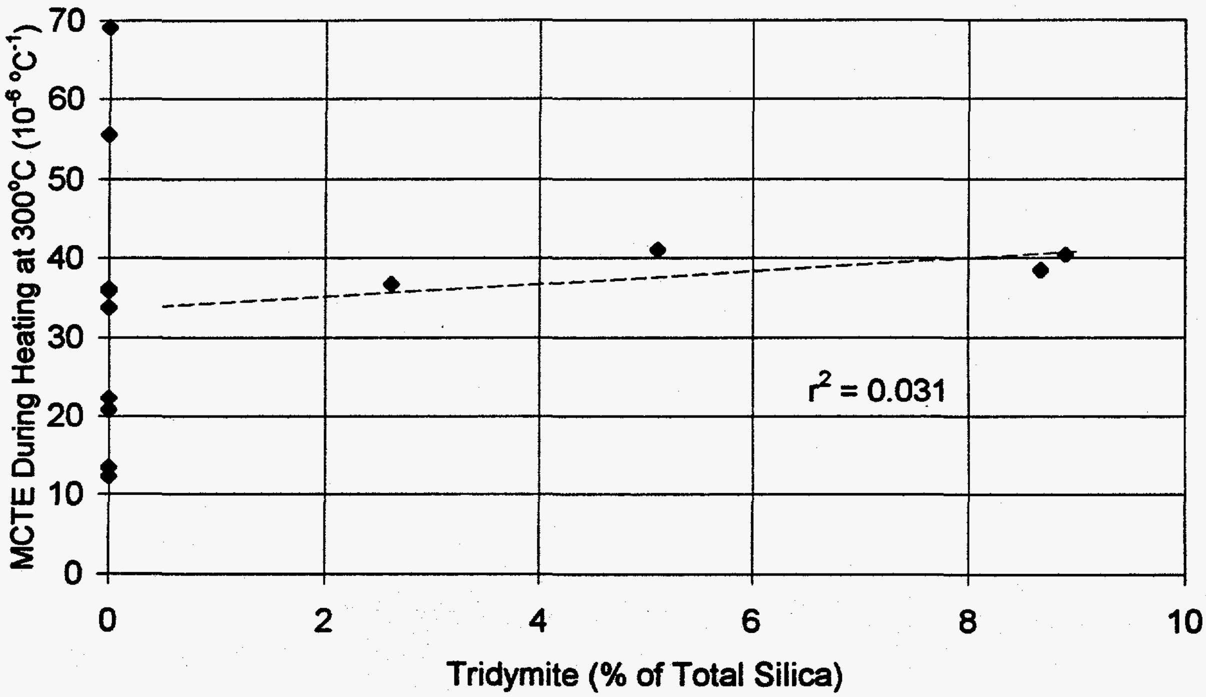


Figure 4-17. MCTE at 300°C (Heating Cycle only) Versus Tridymite Content for NRG-6

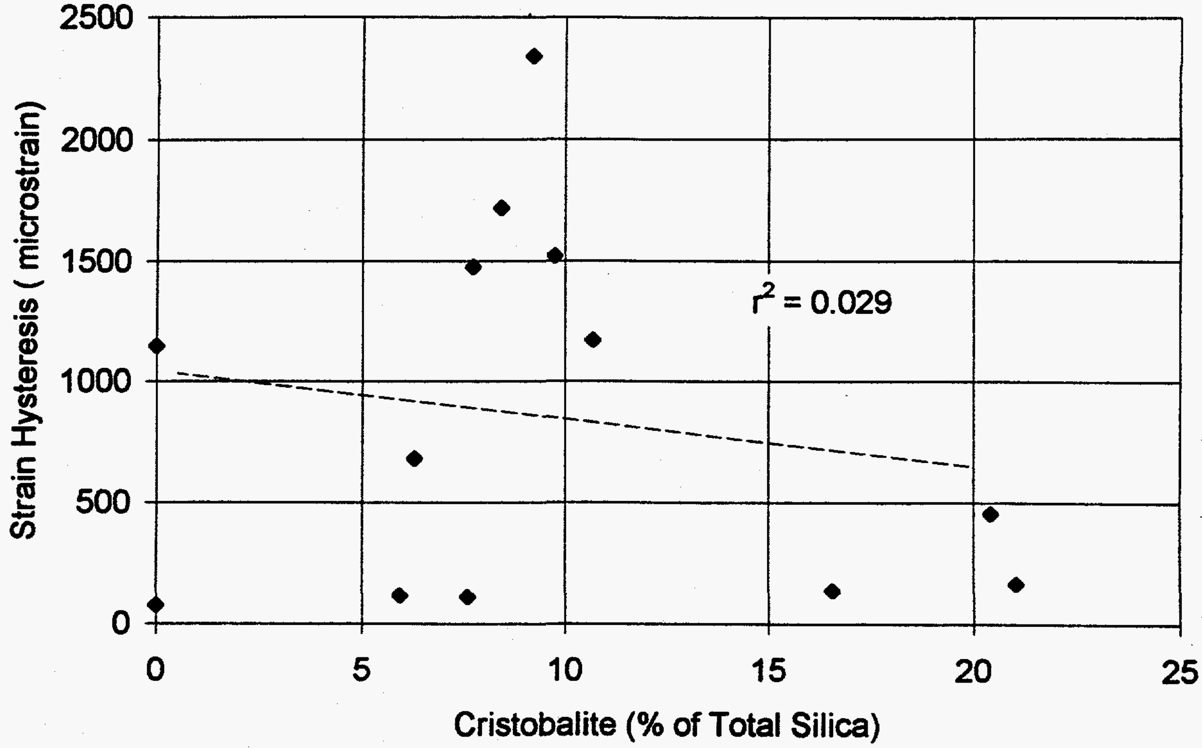


Figure 4-18. Strain Hysteresis Versus Crystobalite Content for NRG-6

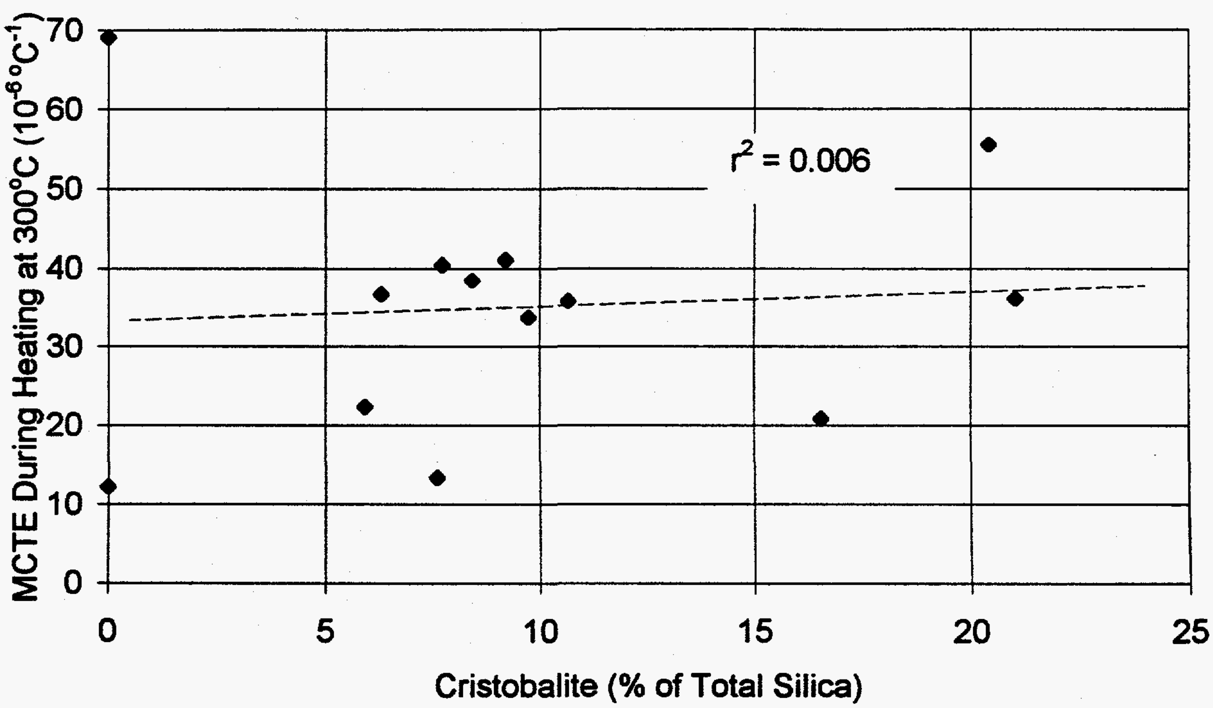


Figure 4-19. MCTE at 300°C (Heating Cycle only) Versus Crystobalite Content for NRG-6

5.0 SUMMARY AND CONCLUSIONS

A very extensive data set for thermal conductivity and thermal expansion has been presented for boreholes UE25 NRG-5, UE25 NRG-5, USW NRG-6, and USW NRG-7/7A. A total of 143 thermal conductivity tests were conducted on 95 test specimens, 132 thermal expansion tests were conducted on 120 specimens, and 10 specific heat tests were conducted on 10 specimens. Specimens were tested at several saturation states including oven dried, air dried, partially saturated, and vacuum saturated. Tests were conducted at room pressure and at temperatures up to 300°C. Petrologic data were obtained from 97 NRG-6 samples.

Thermal conductivities were highest for saturated specimens and lowest for dried specimens. Thermal conductivities, averaged over all boreholes, ranged (depending upon temperature and saturation state) from $1.2 \cdot W(mK)^{-1}$ to $1.9 \cdot W(mK)^{-1}$ for TCw, from $0.4 \cdot W(mK)^{-1}$ to $0.9\ W \cdot (mK)^{-1}$ for PTn, from $1.0 \cdot W(mK)^{-1}$ to $1.7\ W \cdot (mK)^{-1}$ for TSw1, and from $1.5 \cdot W(mK)^{-1}$ to $2.3\ W \cdot (mK)^{-1}$ for TSw2. Thermal conductivity results showed that for oven dried specimens, thermal conductivities increased slightly or remained constant as temperature increased from 25°C to 300°C. The PTn T/M unit consistently showed the lowest thermal conductivities while the TCw and TSw2 units had the highest conductivity values. TSw1 specimens spanned a large range of thermal conductivities and were intermediate in value.

Mean coefficients of thermal expansion were highly temperature dependent and values, averaged over all boreholes, ranged (depending upon temperature and saturation state) from $6.6 \times 10^{-6} \cdot °C^{-1}$ to $49 \times 10^{-6} \cdot °C^{-1}$ for TCw, from the negative range to $16 \times 10^{-6} \cdot °C^{-1}$ for PTn, from $6.3 \times 10^{-6} \cdot °C^{-1}$ to $44 \times 10^{-6} \cdot °C^{-1}$ for TSw1, and from $6.7 \times 10^{-6} \cdot °C^{-1}$ to $37 \times 10^{-6} \cdot °C^{-1}$ for TSw2. Thermal expansion coefficients showed substantive differences between welded and nonwelded specimens. Moisture effects were apparent in nonwelded specimens. Even for oven dried specimens, the nonwelded PTn T/M unit showed dehydration and volume loss at 100°C. At more elevated temperatures, these specimens generally continued to shorten as bound water was released. Thermal expansion of the welded specimens showed no moisture dependence. At temperatures near 200°C, hysteresis in the strain-versus-temperature curves became apparent in most specimens. Most of this was probably caused by phase changes in trydimite and cristobalite, however, this was not clear from comparison of thermal expansion and mineralogical data. Although most expansion reversed during cooling, substantial permanent elongations (up to 200 microns or 0.4 percent strain) were observed.

Thermal capacitance values were lower for TSw1 specimens from NRG-4 than for TSw2 specimens from NRG5. Mean values of thermal capacitance (averaged over all specimens) ranged from $1.6\ J \cdot cm^{-3} \cdot K^{-1}$ to $2.1\ J \cdot cm^{-3} \cdot K^{-1}$ for TSw1 and from $1.8\ J \cdot cm^{-3} \cdot K^{-1}$ to $2.5\ J \cdot cm^{-3} \cdot K^{-1}$ for TSw2. The irregular slopes of the specific heat - versus - temperature curves are most likely related to phase changes. No mineralogical data were obtained for NRG-4 and NRG-5 specimens.

The data presented here suggest relationships between measured thermal properties and composition; however, the relationships are not well understood. Additional data and correlation analyses between composition (including presence and amounts of tridymite, cristobalite, clay, zeolites, tightly and loosely bound H_2O, and textural arrangement of these components) and the thermal behavior of the samples should lead to a more systemic understanding of the observed variations. This should be particularly helpful in understanding the source of the hysteresis and permanent deformations in the thermal expansion data and the source of peaks in the thermal capacitance curves. The mineralogical phase changes discussed in this report are pressure sensitive, and the temperature at which the transition occurs increases with pressure. Dilation associated with the heating of fractures and pore volumes may also be suppressed by elevated pressures. Additional work includes examination of transition temperature effects at elevated confining pressure.

6.0 REFERENCES

American Society for Testing and Materials, *Standard Practice for Evaluating Thermal Conductivity of Gasket Materials*, Standard F433 - 77, Philadelphia, PA: American Society for Testing and Materials, 1993.

American Society for Testing and Materials, *Standard Practice for Specific Heat of Rock and Soil*, Standard D4611-86, Philadelphia, PA: American Society for Testing and Materials, 1993.

American Society for Testing and Materials, *Standard Test Method for Linear Thermal Expansion of Solid Materials With a Vitreous Silica Dilatometer*, Standard E228 - 85, Philadelphia, PA: American Society for Testing and Materials, 1989.

Bish, D.L. and S.J. Chipera, *Revised Mineralogic Summary of Yucca Mountain, Nevada*, Los Alamos, NM: Los Alamos National Laboratory, Report LA-11497-MS, 68 p., 1989.

Brechtel, C.E., M. Lin, E. Martin, and D.S. Kessel, *Geotechnical Characterization of the North Ramp of the Exploratory Studies Facility Volume I of II Data Summary*, SAND95-0488/1, Albuquerque, NM: Sandia National Laboratories, 304 pp., 1995.

Buesch, D.C., R.W. Spengler, T.C. Moyer, and J.K. Geslin, *Proposed Stratigraphic Nomenclature and Macroscopic Identification of Lithostratigraphic Units of the Paintbrush Group Exposed at Yucca Mountain, Nevada*, Open-File Report 94-469, Denver, CO: U. S. Geological Survey, 47 p., 1996.

Chung, F.H., Quantitative Interpretation of X-ray Diffraction Patterns of Mixtures. I. Matrix-Flushing Method for Quantitative Multicomponent Analysis, *Journal of Applied Crystallography*, vol. 7, pt. 6, pp. 519-525, 1974a.

Chung, F.H., Quantitative Interpretation of X-ray Diffraction Patterns of Mixtures. II. Adiabatic Principle of X-Ray Diffraction Analysis of Mixtures, *Journal of Applied Crystallography*, vol. 7, pt. 6, pp. 526-531, 1974b.

Feynman, R.P., R.B. Leighton, and M. Sands, *The Feynman Lectures on Physics,* Reading, MA: Addison-Wesley Publishing Company, vol. II , p. 12-2, 1964.

Geslin, J.K. and T.C. Moyer, *Summary of Lithologic Logging of New and Existing Boreholes at Yucca Mountain, Nevada, March 1994 to June 1994,* U.S. Geologic Survey Open-File Report 94-451, Denver, CO: U.S. Department of the Interior, U. S. Geologic Survey, 16 p., 1995a.

Geslin, J.K., T.C. Moyer, and D.C. Buesch, *Summary of Lithologic Logging of New and Existing Boreholes at Yucca Mountain, Nevada, August 1993 to February, 1994,* U.S. Geologic Survey Open-File Report 94-342, Denver, CO: U.S. Department of the Interior, U. S. Geological Survey, 39 p., 1995b.

Halliday, D. and R. Resnick, *Fundamentals of Physics,* Rev. ed., New York, NY: John Wiley and Sons, Inc., pp. 351, 359, 360, 1974.

Jaeger, J.C. and N.G.W. Cook, *Fundamentals of Rock Mechanics,* London: Chapman and Hall Ltd., p. 35, 1976.

Lappin, A.R., *Thermal Conductivity of Silicic Tuffs: Predictive Formalism and Comparison with Preliminary Experimental Results*, SAND80-0769, Albuquerque, NM: Sandia National Laboratories, 51 p., 1980.

Nimick, F.B., *Thermal-Conductivity Data for Tuffs From the Unsaturated Zone at Yucca Mountain, Nevada*, SAND88-0624, Albuquerque, NM: Sandia National Laboratories, 87 p., 1989.

Nimick, F.B. and J.R. Connolly, *Calculation of Heat Capacities for Tuffaceous Units from the Unsaturated Zone at Yucca Mountain, Nevada*, SAND88-3050, Albuquerque, NM: Sandia National Laboratories, 79 p., 1991.

Ortiz, T.S., R.L. Williams, F.B. Nimick, B.C. Whittet, and D.L. South, *A Three-Dimensional Model of Reference Thermal-Mechanical and Hydrological Stratigraphy at Yucca Mountain, Southern Nevada,* SAND84-1076, Albuquerque, NM: Sandia National Laboratories, 79 p., 1985.

Papike, J.J. and M. Cameron, Crystal Chemistry of Silicate Minerals of Geophysical Interest, *Reviews of Geophysics and Space Physics*, vol. 14, no. 1, pp. 37-80, 1976.

Price, R.H., F.B. Nimick, J.R. Connolly, K. Keil, B.M. Schwartz, and S.J. Spence, *Preliminary Characterization of the Petrologic, Bulk, and Mechanical Properties of a Lithophysal Zone Within the Topopah Spring Member of the Paintbrush Tuff*, SAND84-0860, 115 p., Albuquerque, NM: Sandia National Laboratories, 1985.

Rautman, C.A. and D.A. Engstrom, *Geology of the USW SD-7 Drill Hole Yucca Mountain, Nevada,* SAND96-1474, Albuquerque,NM: Sandia National Laboratories, 164 p., 1996.

Sawyer, D.A., R.J. Fleck, M.A. Lanphere, R.G. Warren, D.E. Broxton, and M.R. Hudson, Episodic Caldera Volcanism in the Miocene Southwestern Nevada Volcanic Field: Revised Stratigraphic Framework, $^{40}Ar/^{39}Ar$ Geochronology, and Implications for Magmatism and Extension, *Geological Society of America Bulletin*, vol. 106, no. 10, pp. 1304-1318, 1994.

Scott, R.B. and J. Bonk, *Preliminary Geologic Map of Yucca Mountain with Geologic Sections, Nye County, Nevada*, U.S. Geological Survey Open-File Report 84-494, 10 p., 3 sheets, 1984.

Thompson, A.B. and M. Wennemer, Heat Capacities and Inversions in Trydimite, Cristobalite, and Tridymite-Cristobalite Mixed Phases, *American Mineralogist*, vol. 64, no. 9-10, pp. 1018-1026, 1979.

U.S. Department of Energy, *Yucca Mountain Site Characterization Project Site Atlas 1995, Vol. 1, Yucca Mountain Nye County, Nevada,* prepared by U. S. Department of Energy Remote Sensing Laboratory operated by EG&G Energy Measurements, 1995.

Weast, R.C., ed., *CRC Handbook of Chemistry and Physics*, 55th ed., Cleveland, OH: CRC Press, pp. F109, F-112, 1974.

APPENDIX A

Summary of Thermal Conductivity Test Results

This page intentionally left blank

Table A-1. Thermal Conductivity Values for Borehole NRG-4.

Thermal/mechanical Unit PTn: Nonwelded, Vitric: Oven dried

Sample ID	Low Temperature Thermal Conductivity Cycle[a] (W/(m K))			High Temperature Thermal Conductivity Cycle[a] (W/(m K))				
Depth (ft) ID	30°C	50°C	70°C	110°C	155°C	200°C	245°C	290°C
431.3 B	0.32 0.33	0.34 0.34	0.34	0.32 0.31	0.34 0.33	0.35 0.34	0.36 0.35	0.36
450.6 B	0.35 0.36	0.37 0.37	0.37	0.36 0.36	0.39 0.37	0.39 0.39	0.40 0.40	0.40
470.0 B	0.36 0.36	0.38 0.38	0.38	0.36 0.35	0.37 0.37	0.37 0.38	0.38 0.39	0.39
N[b] =	6	6	3	6	6	6	6	3
Mean =	0.35	0.36	0.36	0.34	0.36	0.37	0.38	0.38
STD[b] =	0.018	0.019	0.021	0.023	0.022	0.021	0.021	0.021

Thermal/mechanical Unit TSw1: Welded, Devitrified: Oven dried

Sample ID	Low Temperature Thermal Conductivity Cycle[a] (W/(m K))			High Temperature Thermal Conductivity Cycle[a] (W/(m K))				
Depth (ft) ID	30°C	50°C	70°C	110°C	155°C	200°C	245°C	290°C
529.0 A	0.72	0.76	0.80	1.18 1.14	1.22 1.17	1.23 1.18	1.23 1.17	1.19
545.0 G	0.63	0.67	0.69	0.90 0.89	0.94 0.92	0.95 0.93	0.96 0.95	0.97
586.2 B	0.63	0.67	0.69	0.95 0.94	1.00 0.98	1.01 0.99	1.02 1.00	1.02
590.5 B	0.65	0.69	0.71	1.01 0.98	1.05 1.02	1.06 1.02	1.06 1.03	1.05
610.5 B	0.73	0.77	0.80	1.14 1.05	1.18 1.07	1.16 1.07	1.13 1.07	1.09
619.9 B	0.55	0.59	0.62	1.17 1.11	1.21 1.15	1.22 1.15	1.21 1.16	1.17
654.0 B	0.72	0.77	0.80	1.18 1.13	1.22 1.17	1.23 1.17	1.22 1.17	1.19
N[b] =	7	7	7	14	14	14	14	7
Mean =	0.66	0.70	0.73	1.06	1.09	1.10	1.10	1.10
STD[b] =	0.066	0.068	0.071	0.108	0.108	0.106	0.097	0.088

[a] Data were taken as temperature cycled up to peak value and then ramped down
[b] N = Number of samples; STD = Standard deviation

Table A-1 (continued). Thermal Conductivity Values for Borehole NRG-4.

Thermal/mechanical Unit PTn:
Nonwelded, Vitric: Vacuum saturated

Sample ID	Low Temperature Thermal Conductivity (W/(m K))		
Depth ID (ft)	30°C	50°C	70°C
470.0 A	0.97	0.92	0.96
N[a] =	1	1	1
Mean =	0.97	0.92	0.96
STD[a] =	NA	NA	NA

Thermal/mechanical Unit TSw1:
Welded, Devitrified: Vacuum saturated

Sample ID	Low Temperature Thermal Conductivity (W/(m K))		
Depth ID (ft)	30°C	50°C	70°C
529.0 A	1.61	1.66	1.67
586.2 A	1.51	1.61	1.64
654.0 A	1.76	1.80	1.80
N[a] =	3	3	3
Mean =	1.63	1.69	1.70
STD[a] =	0.126	0.098	0.085

[a] N = Number of samples; STD = Standard deviation

Table A-2. Thermal Conductivity Values for Borehole NRG-5.

Thermal/mechanical Unit TSw1: Welded, Devitrified: Oven dried

Sample ID	Low Temperature Thermal Conductivity Cycle[a] (W/(m K))			High Temperature Thermal Conductivity Cycle[a] (W/(m K))				
Depth ID (ft)	30°C	50°C	70°C	110°C	155°C	200°C	245°C	290°C
781.8 A	1.16	1.20	1.22	1.02	1.05	1.05	1.04	1.01
				0.98	1.00	1.00	1.00	
791.6 A	0.91	0.93	0.95	0.84	0.87	0.87	0.85	0.85
				0.80	0.82	0.83	0.83	
N[b] =	2	2	2	4	4	4	4	2
Mean =	1.04	1.07	1.09	0.91	0.94	0.94	0.93	0.93
STD[b] =	0.177	0.191	0.191	0.106	0.108	0.104	0.106	0.113

Thermal/mechanical Unit TSw2: Welded, Devitrified: Oven dried

Sample ID	Low Temperature Thermal Conductivity Cycle[a] (W/(m K))			High Temperature Thermal Conductivity Cycle[a] (W/(m K))				
Depth ID (ft)	30°C	50°C	70°C	110°C	155°C	200°C	245°C	290°C
834.8 B	2.15	2.13	2.07	1.65	1.68	1.68	1.66	1.64
				1.66	1.69	1.66	1.64	
843.5 A	2.02	2.01	1.97	1.65	1.69	1.68	1.67	1.63
				1.65	1.69	1.66	1.64	
848.0 B	0.81	0.86	0.90	1.51	1.55	1.55	1.52	1.46
				1.49	1.52	1.49	1.47	
853.8 A	2.20	2.17	2.14	1.71	1.74	1.73	1.72	1.67
				1.70	1.73	1.71	1.68	
874.9 B	2.19	2.18	2.20	1.68	1.72	1.71	1.69	1.64
				1.67	1.70	1.67	1.65	
879.6 A	ND	ND	ND	1.63	1.66	1.64	1.63	1.58
				1.62	1.65	1.63	1.60	
886.5 B	0.80	0.85	0.88	1.38	1.42	1.42	1.42	1.39
				1.36	1.40	1.39	1.39	
893.3 B	0.90	0.94	0.97	1.44	1.51	1.50	1.50	1.47
				1.48	1.51	1.49	1.48	
899.8 B	0.86	0.91	0.95	1.49	1.53	1.52	1.50	1.44
				1.46	1.49	1.47	1.45	
N[b] =	8	8	8	18	18	18	18	9
Mean =	1.49	1.51	1.51	1.57	1.60	1.59	1.57	1.55
STD[b] =	0.696	0.661	0.629	0.115	0.112	0.109	0.105	0.106

[a] Data were taken as temperature cycled up to peak value and then ramped down

[b] N = Number of samples; STD = Standard deviation; ND = No data

Table A-2 (continued): Thermal Conductivity Values for Borehole NRG-5

Thermal/mechanical Unit TSw1:
Welded, Devitrified: Vacuum saturated

Sample ID	Low Temperature Thermal Conductivity (W/(m K))		
Depth (ft) ID	30°C	50°C	70°C
781.8 A	1.98	1.97	1.92
791.3 A	1.93	1.84	1.78
N[a] =	2	2	2
Mean =	1.96	1.91	1.85
STD[a] =	0.035	0.092	0.099

Thermal/mechanical Unit TSw2:
Welded, Devitrified: Vacuum saturated

Sample ID	Low Temperature Thermal Conductivity (W/(m K))		
Depth (ft) ID	30°C	50°C	70°C
834.8 A	2.12	2.12	1.92
843.5 A	2.17	2.25	2.20
848.0 B	2.71	2.66	2.61
852.5 B	2.34	2.32	2.26
874.3 B	2.36	2.35	2.32
879.6 A	3.57	3.36	3.09
886.5 B	2.62	2.56	2.53
893.3 B	2.81	2.73	2.75
899.8 B	2.77	2.75	2.77
N[a] =	9	9	9
Mean =	2.61	2.57	2.49
STD[a] =	0.442	0.372	0.356

[a] N = Number of samples; STD = Standard deviation

Table A-3. Thermal Conductivity Values for Borehole NRG-6.

Thermal/mechanical Unit TCw: Welded, Devitrified: Oven dried

Sample ID		Low Temperature Thermal Conductivity Cycle[a] (W/(m K))			High Temperature Thermal Conductivity Cycle[a] (W/(m K))				
Depth (ft)	ID	30°C	50°C	70°C	110°C	155°C	200°C	245°C	290°C
28.8	C	1.48	1.70	1.73	1.79	1.82	1.81	1.80	1.63
					1.71	1.75	1.73	1.66	1.60
98.1	I	1.45	1.47	1.51	1.62	1.65	1.66	1.68	1.69
					1.58	1.60	1.61	1.64	1.67
111.0	I	1.33	1.36	1.41	1.46	1.50	1.50	1.52	1.55
					1.41	1.46	1.47	1.49	1.54
N[b] =		3	3	3	6	6	6	6	6
Mean =		1.42	1.51	1.55	1.60	1.63	1.63	1.63	1.61
STD[b] =		0.079	0.173	0.164	0.145	0.140	0.131	0.113	0.062

Thermal/mechanical Unit PTn: Nonwelded, Vitric: Oven dried

Sample ID		Low Temperature Thermal Conductivity Cycle[a] (W/(m K))			High Temperature Thermal Conductivity Cycle[a] (W/(m K))				
Depth (ft)	ID	30°C	50°C	70°C	110°C	155°C	200°C	245°C	290°C
152.9	E	0.41	0.44	0.46	0.43	0.46	0.47	0.49	0.51
					0.43	0.46	0.47	0.49	0.51
187.0	F	0.23	0.20	0.18	0.32	0.34	0.35	0.36	0.36
					0.31	0.33	0.35	0.36	0.36
241.5	E	0.20	0.18	0.16	0.26	0.27	0.28	0.29	0.30
					0.24	0.26	0.27	0.28	0.29
N[b] =		3	3	3	6	6	6	6	6
Mean =		0.28	0.27	0.27	0.33	0.35	0.37	0.38	0.39
STD[b] =		0.114	0.145	0.168	0.082	0.088	0.088	0.093	0.099

[a] Data were taken as temperature cycled up to peak value and then ramped down

[b] N = Number of samples; STD = Standard deviation

Table A-3 (continued). Thermal Conductivity Values for Borehole NRG-6.

Thermal/mechanical Unit TSw1: Welded, Devitrified: Oven dried

Sample ID	Low Temperature Thermal Conductivity Cycle[a] (W/(m K))			High Temperature Thermal Conductivity Cycle[a] (W/(m K))				
Depth ID (ft)	30°C	50°C	70°C	110°C	155°C	200°C	245°C	290°C
277.5 E	1.29	1.18	1.21	1.27	1.32	1.33	1.35	1.36
				1.24	1.29	1.31	1.33	1.36
321.1 E	1.00	1.09	1.08	1.17	1.23	1.24	1.23	1.21
				1.16	1.20	1.20	1.19	1.19
354.9 C	1.08	1.12	1.21	1.17	1.20	1.20	1.17	1.11
				1.10	1.12	1.11	1.10	1.10
392.1 D	1.12	1.18	1.20	1.24	1.27	1.21	1.15	1.11
				1.13	1.15	1.12	1.11	1.11
416.0 K	1.43	1.49	1.54	1.36	1.39	1.36	1.28	1.23
				1.21	1.26	1.23	1.21	1.21
421.8 D	1.40	1.35	1.38	1.25	1.30	1.28	1.21	1.17
				1.13	1.15	1.14	1.15	
425.3 B	1.09	1.13	1.19	1.26	1.32	1.29	1.21	1.17
451.2 B	1.20	1.22	1.24	1.29	1.33	1.34	1.31	1.26
556.1 B	1.08	1.07	1.09	0.91	0.94	0.97	0.97	0.95
				1.40	1.43	1.44	1.42	1.36
693.1 C				1.37	1.39	1.38	1.37	
N[b] =	9	9	9	17	17	17	17	15
Mean =	1.19	1.20	1.24	1.22	1.25	1.24	1.22	1.19
STD[b] =	0.153	0.136	0.143	0.117	0.120	0.117	0.113	0.113

[a] Data were taken as temperature cycled up to peak value and then ramped down

[b] N = Number of samples; STD = Standard deviation

Table A-3 (continued). Thermal Conductivity Values for Borehole NRG-6.

Thermal/mechanical Unit TSw2: Welded, Devitrified: Oven dried

Sample ID	Low Temperature Thermal Conductivity Cycle[a] (W/(m K))			High Temperature Thermal Conductivity Cycle[a] (W/(m K))				
Depth (ft) ID	30°C	50°C	70°C	110°C	155°C	200°C	245°C	290°C
757.0 B	1.48	1.48	1.52	1.61	1.65	1.65	1.63	1.55
778.1 B	1.52	1.57	1.58	1.71	1.78	1.75	1.73	1.67
787.5 B	1.48	1.49	1.49	1.60	1.64	1.64	1.63	1.56
802.7 D	1.49	1.47	1.48	1.67	1.71	1.70	1.69	1.63
809.4 B	1.55	1.57	1.58	1.64	1.69	1.7	1.68	1.62
900.4 D	1.41	1.45	1.49	1.50	1.53	1.51	1.50	1.44
926.3 E	1.44	1.47	1.47	1.55 1.53	1.58 1.55	1.57 1.54	1.55 1.52	1.50
987.0 B	1.39	1.43	1.46	1.55	1.60	1.59	1.57	1.54
N[b] =	8	8	8	8	8	8	8	7
Mean =	1.47	1.49	1.51	1.59	1.63	1.62	1.60	1.56
STD[b] =	0.054	0.052	0.047	0.072	0.084	0.081	0.082	0.077

[a] Data were taken as temperature cycled up to peak value and then ramped down
[b] N = Number of samples; STD = Standard deviation

Table A-3 (continued). Thermal Conductivity Values for Borehole NRG-6.

Thermal/mechanical Unit TCw:
Welded, Devitrified: Vacuum saturated

Sample ID		Low Temperature Thermal Conductivity (W/(m K))		
Depth (ft)	ID	$30^{o}C$	$50^{o}C$	$70^{o}C$
28.8	B	1.82	2.04	1.91
98.1	H	1.81	2.04	1.71
111.0	H	1.89	2.00	2.01
	N[a] =	3	3	3
	Mean =	1.84	2.03	1.88
	STD[a] =	0.044	0.023	0.153

Thermal/mechanical Unit PTn:
Non-welded, Vitric: Vacuum saturated

Sample ID		Low Temperature Thermal Conductivity (W/(m K))		
Depth (ft)	ID	$30^{o}C$	$50^{o}C$	$70^{o}C$
152.9	E	0.90	0.97	1.04
187.0	F	0.70	0.72	0.79
241.5	E	0.62	0.67	0.73
	N[a] =	3	3	3
	Mean =	0.74	0.79	0.85
	STD[a] =	0.144	0.161	0.164

[a] N = Number of samples; STD = Standard deviation

Table A-3 (continued). Thermal Conductivity Values for Borehole NRG-6.

Thermal/mechanical Unit TSw1:
Welded, Devitrified: Vacuum saturated

Sample ID	Low Temperature Thermal Conductivity (W/(m K))		
Depth ID (ft)	30°C	50°C	70°C
277.5 D	1.47	1.61	1.68
321.1 D	1.65	1.67	1.71
354.9 B	1.37	1.45	1.49
392.1 C	1.34	1.52	1.55
416.0 J	1.48	1.68	1.55
421.8 C	1.72	1.66	1.70
425.3 A	1.76	1.76	1.82
451.2 A	1.64	1.69	1.70
556.1 A	2.17	2.12	2.04
693.1 C	1.97	1.95	1.93
N[a] =	10	10	10
Mean =	1.66	1.71	1.72
STD[a] =	0.264	0.196	0.173

Thermal/mechanical Unit TSw2:
Welded, Devitrified: Vacuum saturated

Sample ID	Low Temperature Thermal Conductivity (W/(m K))		
Depth ID (ft)	30°C	50°C	70°C
757.0 A	2.16	2.22	2.02
778.1 A	2.30	2.18	1.85
787.5 A	1.90	2.00	1.72
802.7 C	1.96	1.79	1.78
809.4 A	1.56	1.65	1.66
900.4 C	1.94	2.01	2.23
926.3 D	2.35	2.25	2.15
987.0 A	2.13	2.11	2.04
N[a] =	8	8	8
Mean =	2.04	2.03	1.93
STD[a] =	0.254	0.213	0.209

[a] N = Number of samples; STD = Standard deviation

Table A-3 (continued). Thermal Conductivity Values for Borehole NRG-6.

Thermal/mechanical Unit TCw:
Welded, Devitrified: Partially saturated

Sample ID		Low Temperature Thermal Conductivity (W/(m K))		
Depth (ft)	ID	30°C	50°C	70°C
28.8	B	2.06	2.08	2.11
98.1	H	1.90	1.90	1.92
111.0	H	1.74	1.80	1.85
	N[a] =	3	3	3
	Mean =	1.90	1.93	1.96
	STD[a] =	0.160	0.142	0.135

Thermal/mechanical Unit PTn:
Non-welded, Vitric: Partially saturated

Sample ID		Low Temperature Thermal Conductivity (W/(m K))		
Depth (ft)	ID	30°C	50°C	70°C
152.9	E	0.76	0.87	1.03
	N[a] =	1	1	1
	Mean =	0.76	0.87	1.03
	STD[a] =	NA	NA	NA

Thermal/mechanical Units TSw1 (354.9') and TCw (416.0')
Welded, Devitrified: Partially saturated

Sample ID		Low Temperature Thermal Conductivity (W/(m K))		
Depth (ft)	ID	30°C	50°C	70°C
354.9	B	1.53	1.55	1.62
416.0	J	1.65	1.71	1.72
	N[a] =	2	2	2
	Mean =	1.59	1.63	1.67
	STD[a] =	0.085	0.113	0.071

[a] N = Number of samples; STD = Standard deviation

Table A-3 (continued). Thermal Conductivity Values for Borehole NRG-6.

Thermal/mechanical Unit TCw:
Welded, Devitrified: Air dried

Sample ID	Low Temperature Thermal Conductivity (W/(m K))		
Depth (ft) ID	30°C	50°C	70°C
28.8 C	1.74	1.71	1.71
98.1 I	1.66	1.64	1.63
111.0 I	1.36	1.39	1.38
N[a] =	3	3	3
Mean =	1.59	1.58	1.57
STD[a] =	0.200	0.168	0.172

Thermal/mechanical Unit PTn:
Nonwelded, Vitric: Air dried

Sample ID	Low Temperature Thermal Conductivity (W/(m K))		
Depth (ft) ID	30°C	50°C	70°C
152.9 E	0.47	0.51	0.50
	0.41	0.46	0.49
187.0 F	0.21	0.19	0.15
241.5 E	0.27	0.29	0.29
N[a] =	4	4	4
Mean =	0.34	0.36	0.36
STD[a] =	0.121	0.149	0.169

[a] N = Number of samples; STD = Standard deviation

Table A-3 (continued). Thermal Conductivity Values for Borehole NRG-6.

Thermal/mechanical Unit TSw1:
Welded, Devitrified: Air dried

Sample ID	Low Temperature Thermal Conductivity (W/(m K))		
Depth ID (ft)	30°C	50°C	70°C
277.5 E	1.21	1.23	1.24
321.1 E	1.04	1.10	1.13
354.9 C	1.10	1.15	1.20
392.1 D	1.28	1.29	1.31
416.0 K	1.33	1.34	1.36
421.8 D	1.30	1.31	1.31
425.3 B	1.17	1.20	1.21
451.2 B	1.10	1.11	1.14
556.1 B	1.00	1.01	1.01
693.1 C	1.40	1.39	1.38
N[(a)] =	10	10	10
Mean =	1.19	1.21	1.23
STD[(a)] =	0.133	0.121	0.116

Thermal/mechanical Unit TSw2:
Welded, Devitrified: Air dried

Sample ID	Low Temperature Thermal Conductivity (W/(m K))		
Depth ID (ft)	30°C	50°C	70°C
757.0 B	1.57	1.53	1.49
778.1 B	1.79	1.77	1.72
787.5 B	1.59	1.58	1.57
802.7 D	1.70	1.62	1.80
809.4 B	1.87	1.79	1.78
900.4 D	1.69	1.61	1.58
926.3 E	1.66	1.57	1.55
987.0 B	1.81	1.71	1.67
N[(a)] =	8	8	8
Mean =	1.71	1.65	1.65
STD[(a)] =	0.106	0.097	0.114

[(a)] N = Number of samples; STD = Standard deviation

Table A-4. Thermal Conductivity Values for Borehole NRG-7.

Thermal/mechanical Unit TCw: Welded, Devitrified: Oven dried

Sample ID		Low Temperature Thermal Conductivity Cycle[a] (W/(m K))			High Temperature Thermal Conductivity Cycle[a] (W/(m K))				
Depth (ft)	ID	30°C	50°C	70°C	110°C	155°C	200°C	245°C	290°C
18.6	D	0.85	0.90	0.94	1.55	1.61	1.60	1.59	1.56
					1.55	1.59	1.57	1.55	
27.0	B	0.81	0.87	0.91	1.47	1.52	1.52	1.53	1.53
					1.49	1.52	1.52	1.52	
56.8	D	0.73	0.77	0.81	1.19	1.22	1.22	1.23	1.21
					1.16	1.18	1.18	1.19	
N[b] =		3	3	3	6	6	6	6	3
Mean =		0.80	0.85	0.89	1.40	1.44	1.44	1.44	1.43
STD[b] =		0.061	0.068	0.068	0.179	0.190	0.185	0.176	0.194

Thermal/mechanical Unit PTn: Nonwelded, Vitric: Oven dried

Sample ID		Low Temperature Thermal Conductivity Cycle[a] (W/(m K))			High Temperature Thermal Conductivity Cycle[a] (W/(m K))				
Depth (ft)	ID	30°C	50°C	70°C	110°C	155°C	200°C	245°C	290°C
75.0	D	0.56	0.59	0.60	0.75	0.80	0.82	0.83	0.85
		0.57	0.59		0.74	0.78	0.80	0.83	
91.6	D	0.41	0.43	0.44	0.44	0.47	0.49	0.50	0.50
		0.42	0.43		0.43	0.46	0.47	0.49	
104.1	C	0.34	0.35	0.36	0.32	0.33	0.35	0.36	0.37
		0.34	0.35		0.32	0.33	0.35	0.36	
113.1	B	0.38	0.41	0.42	0.45	0.48	0.49	0.50	0.48
		0.39	0.41		0.42	0.45	0.46	0.47	
248.5	D	0.35	0.37	0.38	0.35	0.37	0.38	0.39	0.40
		0.36	0.37		0.34	0.36	0.37	0.38	
N[b] =		10	10	5	10	10	10	10	5
Mean =		0.41	0.43	0.44	0.46	0.48	0.50	0.51	0.52
STD[b] =		0.085	0.089	0.095	0.160	0.172	0.174	0.177	0.192

[a] Data were taken as temperature cycled up to peak value and then ramped down

[b] N = Number of samples; STD = Standard deviation

Table A-4 (Continued). Thermal Conductivity Values for Borehole NRG-7.

Thermal/mechanical Unit TSw1: Welded, Devitrified: Oven dried

Sample ID	Low Temperature Thermal Conductivity Cycle[a] (W/(m K))			High Temperature Thermal Conductivity Cycle[a] (W/(m K))				
Depth ID (ft)	30°C	50°C	70°C	110°C	155°C	200°C	245°C	290°C
312.8 D	0.76	0.82	0.86	1.32	1.38	1.40	1.40	1.41
	0.79	0.83		1.34	1.38	1.39	1.40	
N[b] =	2	2	1	2	2	2	2	1
Mean =	0.78	0.83	0.86	1.33	1.38	1.40	1.40	1.41
STD[b] =	0.021	0.007	NA	0.014	0.000	0.007	0.000	NA

[a] Data were taken as temperature cycled up to peak value and then ramped down

[b] N = Number of samples; STD = Standard deviation

Table A-4 (continued): Thermal Conductivity Values for Borehole NRG-7.

Thermal/mechanical Unit TCw:
Welded, Devitrified: Vacuum saturated

Sample ID		Low Temperature Thermal Conductivity (W/(m K))		
Depth (ft)	ID	30°C	50°C	70°C
18.6	C	1.66	1.81	1.90
27.0	A	1.77	1.88	1.93
56.8	C	1.78	2.00	2.04
	N[a] =	3	3	3
	Mean =	1.74	1.90	1.96
	STD[a] =	0.067	0.096	0.074

Thermal/mechanical Unit PTn:
Nonwelded, Vitric: Vacuum saturated

Sample ID		Low Temperature Thermal Conductivity (W/(m K))		
Depth (ft)	ID	30°C	50°C	70°C
75.0	C	1.03	1.13	1.20
		1.03	1.12	
91.6	C	0.79	0.90	1.01
		0.80	0.88	
104.1	B	0.77	0.86	0.95
		0.80	0.88	
113.1	C	0.91	0.98	1.04
		0.91	0.99	
248.5	C	0.78	0.90	0.98
		0.79	0.86	
293.3	C	0.97	1.05	1.13
		0.98	1.05	
	N[a] =	12	12	6
	Mean =	0.88	0.97	1.05
	STD[a] =	0.103	0.101	0.095

[a] N = Number of samples; STD = Standard deviation

Table A-4 (continued): Thermal Conductivity Values for Borehole NRG-7.

Thermal/mechanical Unit TSw1:
Welded, Devitrified: Vacuum saturated

Sample ID	Low Temperature Thermal Conductivity (W/(m K))		
Depth ID (ft)	30°C	50°C	70°C
312.8 C	1.45	1.57	1.63
N[a] =	1	1	1
Mean =	1.45	1.57	1.63
STD[a] =	NA	NA	NA

Thermal/mechanical Unit TCw:
Welded, Devitrified: Partially saturated

Sample ID	Low Temperature Thermal Conductivity (W/(m K))		
Depth ID (ft)	30°C	50°C	70°C
18.6 C	0.79	0.85	0.90
27.0 A	0.81	0.87	0.91
56.8 C	0.78	0.83	0.88
N[a] =	3	3	3
Mean =	0.79	0.85	0.90
STD[a] =	0.015	0.020	0.015

[a] N = Number of samples; STD = Standard deviation

Table A-4 (continued): Thermal Conductivity Values for Borehole NRG-7.

Thermal/mechanical Unit PTn:
Nonwelded, Vitric: Partially saturated

Sample ID		Low Temperature Thermal Conductivity (W/(m K))		
Depth (ft)	ID	30°C	50°C	70°C
75.0	C	0.59	0.63	0.67
		0.61	0.64	
91.6	C	0.47	0.52	0.57
		0.48	0.53	
104.1	B	0.45	0.52	0.58
		0.45	0.51	
113.1	C	0.49	0.55	0.60
		0.50	0.54	
248.5	C	0.44	0.50	0.54
		0.45	0.50	
293.3	C	0.52	0.57	0.63
		0.53	0.58	
N[a] =		12	12	6
Mean =		0.50	0.55	0.60
STD[a] =		0.056	0.047	0.046

Thermal/mechanical Unit TSw1:
Welded, Devitrified: Partially saturated

Sample ID		Low Temperature Thermal Conductivity (W/(m K))		
Depth (ft)	ID	30°C	50°C	70°C
312.8	C	0.71	0.76	0.80
		0.74	0.78	
N[a] =		2	2	1
Mean =		0.73	0.77	0.80
STD[a] =		0.021	0.014	NA

[a] N = Number of samples; STD = Standard deviation

This page intentionally left blank

APPENDIX B

Summary of Thermal Expansion Test Results

This page intentionally left blank

Table B-1. Mean Thermal Expansion Coefficients for Borehole NRG-4

Thermal/mechanical Unit PTn[a]: Nonwelded, Vitric: Air dried: Heat-up

Sample ID			Mean CTE on Heat-up ($10^{-6}/^{\circ}C$)										
Depth (ft)	ID	Max. Temp. (°C)	25-50	50-75	75-100	100-125	125-150	150-175	175-200	200-225	225-250	250-275	275-300
450.6	D	300	4.37	2.00	-0.84	-6.6	5.56	4.64	4.15	4.39	4.46	4.15	1.72
		N[b] =	1	1	1	1	1	1	1	1	1	1	1
		Mean =	4.37	2.00	-0.84	-6.57	5.56	4.64	4.15	4.39	4.46	4.15	1.72
		STD[b] =	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Thermal/mechanical Unit PTn[a]: Nonwelded, Vitric: Air dried: Cool-down

Sample ID			Mean CTE on Cool-down ($10^{-6}/^{\circ}C$)										
Depth (ft)	ID	Max. Temp. (°C)	300-275	275-250	250-225	225-200	200-175	175-150	150-125	125-100	100-75	75-50	50-35
450.6	D	300	8.56	6.54	5.95	5.74	5.70	5.80	5.53	5.18	4.75	3.74	1.58
		N[b] =	1	1	1	1	1	1	1	1	1	1	1
		Mean =	8.56	6.54	5.95	5.74	5.70	5.80	5.53	5.18	4.75	3.74	1.58
		STD[b] =	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

[a] PTn samples were subjected to a thermal soaking period prior to testing.
[b] N = Number of samples; STD = Standard deviation; NA = Not Applicable

Table B-1 (Continued). Mean Thermal Expansion Coefficients for Borehole NRG-4

Thermal/mechanical Unit TSw1: Welded, Devitrified: Air dried: Heat-up

Sample ID			Mean CTE on Heat-up ($10^{-6}/^{o}C$)										
Depth (ft)	ID	Max. Temp. (^{o}C)	25-50	50-75	75-100	100-125	125-150	150-175	175-200	200-225	225-250	250-275	275-300
506.0	D	300	6.16	7.11	7.60	8.23	9.23	10.95	12.32	14.57	16.31	16.92	16.88
529.0	C	300	7.16	8.13	8.70	9.32	10.39	13.23	17.82	20.45	26.01	34.60	40.40
586.2	D	300	5.05	5.89	6.29	6.73	7.42	10.79	13.83	13.59	14.84	19.60	33.55
610.5	D	300	5.96	6.71	7.35	8.21	9.67	19.64	35.80	37.08	37.22	36.39	38.77
654.5	A	300	6.57	7.64	8.20	8.80	10.04	21.14	21.88	21.77	23.61	29.65	39.21
690.6	A	300	6.60	7.32	8.08	8.91	9.92	16.61	23.67	28.82	31.38	31.52	35.57
		N[a] =	6	6	6	6	6	6	6	6	6	6	6
		Mean =	6.25	7.13	7.70	8.37	9.44	15.39	20.89	22.71	24.89	28.12	34.06
		STD[a] =	0.72	0.78	0.84	0.91	1.07	4.43	8.53	8.94	8.62	8.03	8.79

Thermal/mechanical Unit TSw1: Welded, Devitrified: Air dried: Cool-down

Sample ID			Mean CTE on Cool-down ($10^{-6}/^{o}C$)										
Depth (ft)	ID	Max. Temp. (^{o}C)	300-275	275-250	250-225	225-200	200-175	175-150	150-125	125-100	100-75	75-50	50-35
506.0	D	300	12.90	14.47	16.23	16.97	15.06	12.76	11.14	9.69	8.67	7.84	7.41
529.0	C	300	18.62	22.26	25.38	25.32	25.40	24.00	22.80	17.72	12.04	10.50	9.67
586.2	D	300	16.24	18.99	19.79	17.64	14.59	14.50	14.33	10.41	8.24	7.32	4.18
610.5	D	300	15.47	18.51	20.75	21.40	23.18	25.83	36.25	26.60	11.77	9.73	8.77
654.5	A	300	19.68	22.62	22.05	21.31	22.10	23.02	25.10	16.85	10.67	9.39	8.47
690.6	A	300	17.14	20.79	23.25	26.27	34.86	27.13	17.10	11.71	10.17	9.24	8.59
		N[a] =	6	6	6	6	6	6	6	6	6	6	6
		Mean =	16.67	19.61	21.24	21.48	22.53	21.21	21.12	15.50	10.26	9.00	7.85
		STD[a] =	2.41	3.01	3.14	3.81	7.48	6.06	9.05	6.39	1.56	1.20	1.94

[a] N = Number of samples; STD = Standard deviation

Table B-2. Mean Thermal Expansion Coefficients for Borehole NRG-5.

Thermal/mechanical Unit TSw1: Welded, Devitrified: Air dried: Heat-up

Sample ID			Mean CTE on Heat-up ($10^{-6}/^{o}C$)										
Depth (ft)	ID	Max. Temp. (^{o}C)	25-50	50-75	75-100	100-125	125-150	150-175	175-200	200-225	225-250	250-275	275-300
779.8	A	300	6.93	8.15	8.65	9.05	10.04	12.40	14.61	23.44	29.90	41.14	64.54
		N[(a)] =	1	1	1	1	1	1	1	1	1	1	1
		Mean =	6.93	8.15	8.65	9.05	10.04	12.40	14.61	23.44	29.90	41.14	64.54
		STD[(a)] =	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Thermal/mechanical Unit TSw1: Welded, Devitrified: Air dried: Cool-down

Sample ID			Mean CTE on Cool-down ($10^{-6}/^{o}C$)										
Depth (ft)	ID	Max. Temp. (^{o}C)	300-275	275-250	250-225	225-200	200-175	175-150	150-125	125-100	100-75	75-50	50-35
779.8	A	300	26.07	35.83	40.06	33.49	33.55	17.44	14.03	12.59	11.46	10.56	10.44
		N[(a)] =	1	1	1	1	1	1	1	1	1	1	1
		Mean =	26.07	35.83	40.06	33.49	33.55	17.44	14.03	12.59	11.46	10.56	10.44
		STD[(a)] =	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

[(a)] N = Number of samples; STD = Standard deviation; NA = Not Applicable

Table B-2 (continued). Mean Thermal Expansion Coefficients for Borehole NRG-5.

Thermal/mechanical Unit TSw2: Welded, Devitrified: Air dried: Heat-up

Sample ID			Mean CTE on Heat-up ($10^{-6}/^{\circ}C$)										
Depth (ft)	ID	Max. Temp. ($^{\circ}C$)	25-50	50-75	75-100	100-125	125-150	150-175	175-200	200-225	225-250	250-275	275-300
829.0	A	300	7.18	8.29	8.69	9.30	9.87	10.47	11.04	12.67	15.81	21.37	32.25
831.8	A	300	7.35	8.39	8.78	9.32	9.85	10.32	10.74	10.93	12.58	11.97	36.46
848.0	A	300	7.25	8.30	8.87	9.30	9.94	10.71	11.82	15.87	23.03	27.97	37.82
852.5	A	300	6.54	8.31	8.80	9.39	9.93	10.64	12.34	15.25	19.40	25.77	37.36
874.9	A	300	7.18	8.35	8.64	9.37	9.89	10.90	11.61	14.34	22.35	29.10	38.44
879.6	D	300	7.35	8.58	9.16	9.73	10.42	11.14	11.83	13.75	18.58	27.21	38.68
886.5	A	300	7.39	8.48	9.00	9.65	10.34	11.62	14.48	17.69	21.33	25.06	29.53
892.8	A	300	7.64	8.63	8.85	9.52	10.04	10.80	11.72	13.52	18.27	27.14	39.03
893.3	A	300	7.32	8.28	8.89	9.32	9.79	10.38	10.97	13.55	19.46	29.34	46.33
899.5	A	300	7.16	8.62	9.03	9.41	10.11	11.08	12.34	15.75	22.09	29.41	50.20
899.8	A	300	7.11	8.20	8.53	8.89	9.37	9.99	10.87	12.18	14.71	24.58	43.04
		N[a] =	11	11	11	11	11	11	11	11	11	11	11
		Mean =	7.22	8.40	8.84	9.38	9.96	10.73	11.80	14.14	18.87	25.36	39.01
		STD[a] =	0.27	0.15	0.18	0.22	0.28	0.45	1.05	1.91	3.36	5.06	5.85

Thermal/mechanical Unit TSw2: Welded, Devitrified: Air dried: Cool-down

Sample ID			Mean CTE on Cool-down ($10^{-6}/^{\circ}C$)										
Depth (ft)	ID	Max. Temp. ($^{\circ}C$)	25-50	50-75	75-100	100-125	125-150	150-175	175-200	200-225	225-250	250-275	275-300
829.0	A	300	23.27	26.16	22.13	18.08	14.91	13.24	11.66	10.59	9.89	9.15	8.75
831.8	A	300	21.08	22.40	20.75	16.64	13.41	12.22	11.09	10.19	9.62	9.01	8.74
848.0	A	300	25.43	26.56	23.89	22.71	24.26	15.07	12.41	10.96	10.09	9.31	8.96
852.5	A	300	27.17	28.49	25.61	22.37	19.31	14.87	12.44	11.14	10.31	9.52	9.15
874.9	A	300	22.64	25.85	26.57	23.12	21.88	16.73	14.43	13.21	10.95	9.71	9.08
879.6	D	300	25.48	28.70	26.69	22.52	17.77	13.96	11.99	10.92	10.11	9.72	9.11
886.5	A	300	20.44	22.74	23.32	22.01	20.45	17.36	14.05	11.68	10.16	9.16	8.81
892.8	A	300	24.26	31.39	29.00	22.72	17.35	13.93	12.20	10.93	10.19	9.46	8.86
893.3	A	300	25.72	32.98	31.33	24.48	20.22	13.56	12.07	10.94	10.14	9.40	8.78
899.5	A	300	23.73	30.09	32.26	27.88	23.20	18.51	14.91	12.47	10.99	9.86	9.34
899.8	A	300	27.89	35.84	29.59	18.60	13.97	12.39	11.44	10.64	9.93	9.35	8.92
		N[a] =	11	11	11	11	11	11	11	11	11	11	11
		Mean =	24.28	28.29	26.47	21.92	18.79	14.71	12.61	11.24	10.22	9.42	8.96
		STD[a] =	2.35	4.14	3.77	3.15	3.67	2.05	1.27	0.89	0.41	0.26	0.19

[a] N = Number of samples; STD = Standard deviation

Table B-3. Mean Thermal Expansion Coefficients for Borehole NRG-6

Thermal/mechanical Unit TCw: Welded, Devitrified: Vacuum saturated: Heat-up

Sample ID			Mean CTE on Heat-up ($10^{-6}/^{\circ}C$)										
Depth (ft)	ID	Max. Temp. (°C)	25-50	50-75	75-100	100-125	125-150	150-175	175-200	200-225	225-250	250-275	275-300
28.8	D	300	7.32	7.79	7.76	10.35	11.94	13.54	15.38	18.10	22.35	29.66	86.02
	F	200	7.58	7.42	8.47	11.59	12.28	14.20	16.23	ND	ND	ND	ND
98.1	F	300	6.77	7.63	7.55	11.21	14.18	16.35	18.10	20.00	21.80	26.40	24.00
111.0	G	300	6.70	7.64	8.56	8.20	14.28	16.73	18.24	18.86	20.00	26.21	18.95
		N[a] =	4	4	4	4	4	4	4	3	3	3	3
		Mean =	7.09	7.62	8.08	10.34	13.17	15.20	16.99	18.99	21.38	27.42	42.99
		STD[a] =	0.43	0.15	0.50	1.52	1.23	1.57	1.41	0.96	1.23	1.94	37.35

Thermal/mechanical Unit TCw: Welded, Devitrified: Vacuum saturated: Cool-down

Sample ID			Mean CTE on Cool-down ($10^{-6}/^{\circ}C$)										
Depth (ft)	ID	Max. Temp. (°C)	300-275	275-250	250-225	225-200	200-175	175-150	150-125	125-100	100-75	75-50	50-35
28.8	D	300	18.78	29.72	52.48	67.23	38.15	22.57	18.09	15.42	13.95	12.76	12.06
	F	200	ND	ND	ND	ND	14.94	14.64	13.29	11.81	11.02	10.00	12.88
98.1	F	300	14.04	19.17	23.03	22.37	21.80	18.71	15.88	13.52	11.71	10.58	9.80
111.0	G	300	11.35	17.02	25.07	21.42	20.32	18.00	15.63	13.31	11.68	9.78	8.65
		N[a] =	3	3	3	3	4	4	4	4	4	4	4
		Mean =	14.72	21.97	33.53	37.01	23.81	18.48	15.72	13.51	12.09	10.78	10.85
		STD[a] =	3.76	6.79	16.44	26.18	10.01	3.25	1.96	1.48	1.28	1.36	1.96

[a] N = Number of samples; STD = Standard deviation; ND = No Data

Table B-3 (Continued). Mean Thermal Expansion Coefficients for Borehole NRG-6

Thermal/mechanical Units TCw (Welded, Devitrified) and PTn (Nonwelded, Vitric): Vacuum saturated: Heat-up

Sample ID			Mean CTE on Heat-up ($10^{-6}/^{\circ}C$)										
Depth (ft)	ID	Max. Temp. (°C)	25-50	50-75	75-100	100-125	125-150	150-175	175-200	200-225	225-250	250-275	275-300
148.4[a]	A	125	4.66	5.16	2.68	-53.0	ND	ND	ND	ND	ND	ND	ND
148.4[a]	A	225	4.64	5.27	-0.90	-44.0	6.00	5.12	1.22	ND	ND	ND	ND
152.9[b]	B	300	4.64	4.79	-1.41	-16.3	5.26	4.70	1.24	-1.79	-4.24	-5.60	-3.84
187.0[b]	D	300	3.89	1.87	-6.16	-8.35	5.35	3.59	-0.54	-7.51	-15.3	-21.3	-22.1
		N[c] =	4	4	4	4	3	3	3	2	2	2	2
		Mean =	4.46	4.28	-1.45	-30.4	5.54	4.47	0.64	-4.65	-9.79	-13.5	-13.0
		STD[c] =	0.38	1.61	3.63	21.47	0.41	0.79	1.03	4.05	7.85	11.12	12.90

Thermal/mechanical Units TCw (Welded, Devitrified) and PTn (Nonwelded, Vitric): Vacuum saturated: Cool-down

Sample ID			Mean CTE on Cool-down ($10^{-6}/^{\circ}C$)										
Depth (ft)	ID	Max. Temp. (°C)	300-275	275-250	250-225	225-200	200-175	175-150	150-125	125-100	100-75	75-50	50-35
148.4[a]	A	125	ND	ND	ND	ND	ND	ND	ND	4.94	5.53	4.65	3.04
148.4[a]	A	225	ND	ND	ND	ND	8.71	7.18	6.46	5.78	4.71	3.11	-2.41
152.9[b]	B	300	16.31	9.72	7.41	6.51	6.34	5.98	5.79	5.50	5.04	4.57	3.17
187.0[b]	D	300	14.84	8.52	6.99	6.27	5.90	5.70	5.55	5.21	5.20	4.99	3.98
		N[c] =	2	2	2	2	3	3	3	4	4	4	4
		Mean =	15.58	9.12	7.20	6.39	6.98	6.29	5.93	5.36	5.12	4.33	1.94
		STD[c] =	1.04	0.84	0.29	0.17	1.51	0.78	0.47	0.36	0.34	0.84	2.93

[a] Based on depth this specimen is classified as a TCw T/M Unit, however, based on physical properties and thermal expansion behavior the sample behaved as a PTn T/M Unit and was considered as such for statistical purposes.

[b] These specimens are PTn

[c] N = Number of samples; STD = Standard deviation; ND = No Data

Table B-3 (Continued). Mean Thermal Expansion Coefficients for Borehole NRG-6

Thermal/mechanical Unit TSw1: Welded, Devitrified: Vacuum saturated: Heat-up

Sample ID			Mean CTE on Heat-up ($10^{-6}/^{o}C$)										
Depth (ft)	ID	Max. Temp. (°C)	25-50	50-75	75-100	100-125	125-150	150-175	175-200	200-225	225-250	250-275	275-300
277.5	B	300	4.21	7.68	7.02	3.67	8.91	11.74	12.86	13.43	13.88	14.02	12.87
321.1	C	300	5.45	7.97	7.00	7.37	8.64	10.18	14.71	24.66	39.34	42.50	42.27
354.9	E	300	5.44	6.26	7.15	8.33	9.30	14.33	30.44	66.64	61.50	51.62	42.45
392.1	F	300	6.82	7.11	7.77	6.90	11.20	17.17	27.45	49.47	62.45	53.38	46.98
416.0	M	300	6.57	7.47	6.37	6.23	11.10	20.61	29.67	63.57	57.44	48.62	44.10
421.8	B	175	7.29	7.41	2.65	-0.09	14.86	ND	ND	ND	ND	ND	ND
458.7	A	200	7.02	8.28	6.61	6.12	10.91	15.61	23.50	ND	ND	ND	ND
528.4	A	300	7.58	6.68	7.16	9.60	10.41	12.05	17.90	32.90	35.89	54.36	56.73
648.6	A	300	7.60	6.98	8.26	10.09	11.02	14.98	19.17	25.14	33.36	38.54	55.07
693.1	A	300	7.59	7.33	8.32	10.96	10.86	11.82	13.13	18.76	29.25	39.05	50.02
		N[(a)] =	10	10	10	10	10	9	9	8	8	8	8
		Mean =	6.56	7.32	6.83	6.92	10.72	14.28	20.98	36.82	41.64	42.76	43.81
		STD[(a)] =	1.16	0.60	1.60	3.28	1.74	3.26	7.01	20.49	17.35	13.19	13.65

Thermal/mechanical Unit TSw1: Welded, Devitrified: Vacuum saturated: Cool-down

Sample ID			Mean CTE on Cool-down ($10^{-6}/^{o}C$)										
Depth (ft)	ID	Max. Temp. (°C)	300-275	275-250	250-225	225-200	200-175	175-150	150-125	125-100	100-75	75-50	50-35
277.5	B	300	8.29	8.63	10.00	13.04	11.78	9.22	7.88	18.45	7.01	6.20	7.74
321.1	C	300	13.37	15.66	18.02	21.36	25.91	31.35	27.71	16.14	10.40	9.14	9.22
354.9	E	300	11.51	12.81	16.09	25.76	26.34	34.28	54.64	29.26	11.73	9.75	8.48
392.1	F	300	12.18	17.81	23.03	25.19	29.72	36.95	51.30	33.78	14.04	10.98	11.08
416.0	M	300	15.63	18.66	20.80	23.49	29.04	38.49	54.03	30.45	13.93	11.48	10.57
421.8	B	175	ND	ND	ND	ND	ND	ND	18.76	16.33	11.61	10.00	8.57
458.7	A	200	ND	ND	ND	ND	19.45	18.84	16.17	12.67	10.18	9.12	8.36
528.4	A	300	17.45	26.67	38.12	36.62	40.89	28.97	17.36	13.54	11.52	10.54	9.83
648.6	A	300	19.82	28.22	34.96	32.84	34.36	24.40	19.63	15.39	12.34	10.98	9.84
693.1	A	300	22.33	30.48	31.37	30.91	30.59	17.47	14.42	12.87	11.86	11.00	9.84
		N[(a)] =	8	8	8	8	9	9	10	10	10	10	10
		Mean =	15.07	19.87	24.05	26.15	27.57	26.66	28.19	19.89	11.46	9.92	9.35
		STD[(a)] =	4.65	7.82	9.85	7.37	8.36	9.91	18.04	8.05	2.01	1.54	1.06

[(a)] N = Number of samples; STD = Standard deviation; ND = No Data

Table B-3 (Continued). Mean Thermal Expansion Coefficients for Borehole NRG-6

Thermal/mechanical Unit TSw2: Welded, Devitrified: Vacuum saturated: Heat-up

Sample ID			Mean CTE on Heat-up ($10^{-6}/^{o}C$)										
Depth (ft)	ID	Max. Temp. (°C)	25-50	50-75	75-100	100-125	125-150	150-175	175-200	200-225	225-250	250-275	275-300
729.2	A	300	7.52	8.61	8.91	5.77	10.19	11.84	13.16	16.56	22.75	36.80	63.58
	B	300	7.68	9.06	8.71	8.34	10.71	12.50	13.42	15.65	20.49	31.82	51.59
732.6	A	300	7.13	8.51	7.68	6.65	10.22	11.65	12.72	15.85	21.08	31.99	54.96
	C	300	7.72	8.89	7.77	8.32	10.51	12.20	13.16	15.36	19.80	29.24	49.15
777.8	A	200	7.34	7.28	6.98	10.95	10.61	11.59	14.05	ND	ND	ND	ND
788.3	A	200	7.60	7.49	6.85	11.17	10.38	11.60	13.03	ND	ND	ND	ND
802.7	A	175	5.02	2.98	8.82	11.17	7.87	10.81	11.44	13.51	16.73	24.43	39.58
806.0	A	200	7.54	8.76	8.94	7.02	10.47	11.92	13.08	16.46	22.73	31.68	45.66
	B	300	7.22	8.40	6.72	9.14	10.03	11.58	12.63	15.30	20.65	32.62	48.19
849.9	A	300	6.42	6.46	6.11	9.80	9.59	16.20	17.39	16.31	17.99	18.19	18.63
886.5	A	300	6.83	4.81	5.40	12.36	9.10	9.61	10.03	10.43	10.98	11.35	12.51
911.2	A	300	6.57	7.61	6.24	7.58	9.31	11.18	13.48	18.01	21.49	24.35	30.72
	B	300	7.04	8.21	7.56	6.65	9.32	10.77	12.02	14.36	15.97	17.71	20.72
926.3	A	300	6.88	7.14	4.87	3.28	9.12	10.62	12.93	17.62	21.84	27.69	37.34
	B	300	7.42	8.80	7.56	10.19	10.19	11.65	12.70	15.02	17.61	21.77	32.57
952.2	A	200	7.89	7.50	8.59	11.49	11.03	12.57	14.24	ND	ND	ND	ND
987.6	A	300	7.01	7.39	7.45	11.23	10.54	11.56	13.49	16.26	18.27	21.54	29.25
1016.6	A	300	7.45	7.49	7.88	9.85	9.89	11.43	12.56	14.97	16.21	18.81	25.44
1081.5	B	300	7.43	6.58	8.67	11.32	10.58	11.73	13.18	15.83	19.84	24.41	35.21
		N[a] =	19	19	19	19	19	19	19	16	16	16	16
		Mean =	7.14	7.47	7.46	9.07	9.98	11.74	13.09	15.47	19.03	25.28	37.19
		STD[a] =	0.65	1.51	1.21	2.41	0.77	1.28	1.40	1.75	3.09	6.87	14.27

[a] N = Number of samples; STD = Standard deviation; ND = No Data

Table B-3 (Continued). Mean Thermal Expansion Coefficients for Borehole NRG-6

Thermal/mechanical Unit TSw2: Welded, Devitrified: Vacuum saturated: Cool-down

Sample ID			Mean CTE on Cool-down ($10^{-6}/^{\circ}C$)										
Depth (ft)	ID	Max. Temp. (°C)	300-275	275-250	250-225	225-200	200-175	175-150	150-125	125-100	100-75	75-50	50-35
729.2	A	300	26.58	41.03	46.65	35.48	24.60	17.17	14.44	12.65	11.49	10.41	9.85
	B	300	29.52	39.22	35.72	24.86	18.25	15.19	13.17	11.85	11.05	10.28	9.67
732.6	A	300	27.60	39.94	37.22	25.82	19.31	15.14	13.06	11.75	10.83	9.91	9.18
	C	300	30.14	38.77	33.91	24.22	18.14	14.87	13.15	11.93	10.97	10.17	9.62
777.8	A	200	ND	ND	ND	ND	14.35	13.13	11.92	10.75	10.04	9.25	8.57
788.3	A	200	ND	ND	ND	ND	14.43	12.74	11.73	10.72	10.27	9.54	8.47
802.7	A	175	26.75	34.91	31.17	22.07	16.99	13.69	11.97	10.94	10.23	9.47	8.67
806.0	A	200	27.23	36.12	32.75	23.56	17.28	14.29	12.72	11.42	10.54	9.87	9.40
	B	300	26.69	37.96	35.95	24.90	17.99	14.33	12.58	11.36	10.45	9.61	8.88
849.9	A	300	12.01	12.60	13.12	14.12	14.51	15.05	16.44	19.24	9.89	8.47	7.59
886.5	A	300	10.81	11.60	11.32	11.12	11.06	10.38	10.02	9.45	9.08	8.57	8.05
911.2	A	300	19.05	21.80	21.75	20.77	19.53	14.89	11.95	10.54	9.34	8.36	7.81
	B	300	15.22	16.62	16.12	16.42	15.80	13.39	11.86	10.70	9.61	8.71	8.09
926.3	A	300	21.00	26.66	25.18	23.32	21.41	14.65	11.93	10.53	9.68	8.92	8.78
	B	300	22.09	24.60	22.85	19.94	17.89	13.96	12.31	11.29	10.41	9.62	9.07
952.2	A	200	ND	ND	ND	ND	14.32	13.39	12.41	11.22	10.53	9.74	8.94
987.6	A	300	19.08	20.84	19.23	17.91	17.47	14.20	12.17	10.89	10.29	9.92	9.05
1016.6	A	300	16.75	18.48	17.57	15.88	15.27	12.56	11.04	10.13	9.67	9.20	8.54
1081.5	B	300	19.72	24.18	24.25	21.75	20.28	14.17	12.49	11.63	10.72	10.06	9.09
		N[a] =	16	16	16	16	19	19	19	19	19	19	19
		Mean =	21.89	27.83	26.55	21.38	17.31	14.06	12.49	11.52	10.27	9.48	8.81
		STD[a] =	6.16	10.36	10.01	5.70	3.07	1.38	1.32	2.00	0.62	0.63	0.62

Thermal/mechanical Unit TCw: Welded, Devitrified: Oven dried: Heat-up

Sample ID			Mean CTE on Heat-up ($10^{-6}/^{\circ}C$)										
Depth (ft)	ID	Max. Temp. (°C)	25-50	50-75	75-100	100-125	125-150	150-175	175-200	200-225	225-250	250-275	275-300
28.8	G	350	7.54	9.59	11.21	12.85	13.87	16.40	19.98	32.41	79.19	73.37	37.10
	G	300	6.74	8.63	10.05	11.93	11.89	13.67	15.51	17.64	21.97	30.65	121.4
98.1	G	300	7.31	8.66	10.33	8.37	14.12	16.49	18.34	20.83	22.86	28.12	25.33
111.0	F	300	7.27	8.88	10.66	10.98	14.52	17.09	18.92	19.25	20.63	27.83	20.83
		N[a] =	4	4	4	4	4	4	4	4	4	4	4
		Mean =	7.21	8.94	10.56	11.03	13.60	15.91	18.19	22.53	36.16	39.99	51.16
		STD[a] =	0.34	0.45	0.50	1.94	1.17	1.53	1.91	6.71	28.70	22.29	47.32

[a] N = Number of samples: STD = Standard deviation: ND = No Data

Table B-3 (Continued). Mean Thermal Expansion Coefficients for Borehole NRG-6

Thermal/mechanical Unit TCw: Welded, Devitrified: Oven dried: Cool-down

Sample ID			Mean CTE on Cool-down ($10^{-6}/^{o}C$)										
Depth (ft)	ID	Max. Temp. (°C)	300-275	275-250	250-225	225-200	200-175	175-150	150-125	125-100	100-75	75-50	50-35
28.8	G	350	15.58	21.70	39.94	44.94	24.85	14.49	10.39	8.78	7.98	6.88	6.62
	G	300	19.99	30.89	52.48	59.55	21.20	17.60	11.18	8.70	7.86	8.66	8.93
98.1	G	300	13.88	19.23	22.84	23.43	22.91	18.83	15.58	13.79	11.56	10.13	9.99
111.0	F	300	12.48	18.41	26.72	22.23	20.80	18.70	15.97	13.34	11.73	10.57	8.98
		N[a] =	4	4	4	4	4	4	4	4	4	4	4
		Mean =	15.48	22.56	35.50	37.54	22.44	17.40	13.28	11.15	9.78	9.06	8.63
		STD[a] =	3.26	5.73	13.48	18.01	1.85	2.02	2.90	2.79	2.15	1.67	1.42

Thermal/mechanical Unit PTn: Nonwelded, Vitric: Oven dried: Heat-up

Sample ID			Mean CTE on Heat-up ($10^{-6}/^{o}C$)										
Depth (ft)	ID	Max. Temp. (°C)	25-50	50-75	75-100	100-125	125-150	150-175	175-200	200-225	225-250	250-275	275-300
152.9	C	300	4.57	5.89	5.60	-0.92	6.22	4.01	2.06	1.72	-1.02	-3.11	-2.46
		N[a] =	1	1	1	1	1	1	1	1	1	1	1
		Mean =	4.57	5.89	5.60	-0.92	6.22	4.01	2.06	1.72	-1.02	-3.11	-2.46
		STD[a] =	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Thermal/mechanical Unit PTn: Nonwelded, Vitric: Oven dried: Cool-down

Sample ID			Mean CTE on Cool-down ($10^{-6}/^{o}C$)										
Depth (ft)	ID	Max. Temp. (°C)	300-275	275-250	250-225	225-200	200-175	175-150	150-125	125-100	100-75	75-50	50-35
152.9	C	300	12.29	6.85	5.15	4.57	4.55	4.55	4.26	4.01	4.39	4.12	3.77
		N[a] =	1	1	1	1	1	1	1	1	1	1	1
		Mean =	12.29	6.85	5.15	4.57	4.55	4.55	4.26	4.01	4.39	4.12	3.77
		STD[a] =	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

[a] N = Number of samples: STD = Standard deviation: ND = No Data: NA = Not Applicable

Table B-3 (Continued). Mean Thermal Expansion Coefficients for Borehole NRG-6

Thermal/mechanical Unit TSw1: Welded, Devitrified: Oven dried: Heat-up

Sample ID			Mean CTE on Heat-up ($10^{-6}/^{\circ}C$)										
Depth (ft)	ID	Max. Temp. (°C)	25-50	50-75	75-100	100-125	125-150	150-175	175-200	200-225	225-250	250-275	275-300
277.5	C	300	6.63	7.47	8.50	5.77	10.32	11.94	13.11	14.03	14.01	13.91	13.42
321.1	B	300	4.16	6.04	7.10	9.65	8.31	10.21	12.60	16.57	30.59	38.65	36.71
354.9	D	300	4.38	5.82	8.62	11.24	10.52	18.50	37.38	78.97	55.78	45.94	41.09
392.1	E	300	5.70	7.88	8.98	8.86	10.42	21.92	32.26	49.84	55.10	46.98	40.39
416.0	L	300	2.80	8.49	9.54	8.59	11.41	24.02	47.35	70.85	52.38	44.18	38.46
421.8	B	300	6.23	8.54	9.34	9.79	11.89	21.70	40.89	71.95	49.49	46.19	43.53
458.7	B	300	6.00	8.13	9.02	9.63	11.14	19.77	34.99	49.86	46.86	41.92	35.81
528.4	B	200	7.30	8.88	9.54	10.36	11.29	16.78	ND	ND	ND	ND	ND
648.6	B	175	7.35	8.43	8.82	9.75	14.32	ND	ND	ND	ND	ND	ND
693.1	B	225	7.71	8.71	9.09	9.50	10.12	11.15	13.07	ND	ND	ND	ND
		N[a] =	10	10	10	10	10	9	8	7	7	7	7
		Mean =	5.83	7.84	8.86	9.32	10.97	17.33	28.96	50.30	43.46	39.68	35.63
		STD[a] =	1.59	1.09	0.71	1.44	1.53	5.13	13.99	26.35	15.53	11.73	10.14

Thermal/mechanical Unit TSw1: Welded, Devitrified: Oven dried: Cool-down

Sample ID			Mean CTE on Cool-down ($10^{-6}/^{\circ}C$)										
Depth (ft)	ID	Max. Temp. (°C)	300-275	275-250	250-225	225-200	200-175	175-150	150-125	125-100	100-75	75-50	50-35
277.5	C	300	10.70	11.85	13.19	14.38	14.18	12.76	11.45	9.97	8.96	7.92	7.75
321.1	B	300	12.11	13.33	16.35	20.95	23.94	25.49	20.35	14.90	9.93	9.73	7.05
354.9	D	300	11.26	13.33	28.63	10.49	26.51	33.05	57.22	32.57	11.96	9.85	11.21
392.1	E	300	13.41	16.83	19.01	21.83	25.93	31.75	50.09	37.14	14.33	10.81	9.73
416.0	L	300	14.76	17.04	19.00	21.96	27.11	35.15	57.38	40.88	14.28	11.48	10.57
421.8	B	300	16.05	19.60	22.93	23.83	30.27	40.47	53.00	27.05	13.52	11.47	9.89
458.7	B	300	13.97	17.82	22.76	27.04	44.01	40.23	33.61	18.55	11.94	9.85	8.89
528.4	B	200	ND	ND	ND	ND	ND	24.17	18.26	11.83	9.67	9.00	8.72
648.6	B	175	ND	ND	ND	ND	ND	ND	15.47	18.25	10.52	8.58	7.87
693.1	B	225	ND	ND	ND	ND	14.86	12.50	11.22	10.15	9.40	8.80	8.42
		N[a] =	7	7	7	7	8	9	10	10	10	10	10
		Mean =	13.18	15.69	20.27	20.07	25.85	28.40	32.81	22.13	11.45	9.75	9.01
		STD[a] =	1.93	2.85	5.03	5.69	9.35	10.53	19.71	11.49	2.05	1.22	1.32

[a] N = Number of samples: STD = Standard deviation: ND = No Data

Table B-3 (Continued). Mean Thermal Expansion Coefficients for Borehole NRG-6

Thermal/mechanical Unit TSw2: Welded, Devitrified: Oven dried: Heat-up

Sample ID			Mean CTE on Heat-up ($10^{-6}/^{\circ}C$)										
Depth (ft)	ID	Max. Temp. ($^{\circ}C$)	25-50	50-75	75-100	100-125	125-150	150-175	175-200	200-225	225-250	250-275	275-300
777.8	B	300	8.49	8.90	9.38	10.03	11.00	12.05	14.00	17.48	25.10	39.18	55.54
788.3	B	300	6.62	8.68	9.34	9.75	10.67	11.56	13.13	16.55	23.88	39.73	57.35
789.4	A	300	2.12	7.97	9.10	9.73	10.52	11.06	12.25	14.05	19.00	28.52	47.55
802.7	B	300	4.04	7.71	8.94	9.30	9.95	10.60	11.59	12.64	15.99	22.27	36.06
849.9	B	300	5.90	7.17	7.69	7.90	8.59	9.04	10.02	10.16	10.66	11.56	12.19
886.5	B	300	5.77	7.85	8.50	8.92	9.81	10.42	12.03	13.90	16.53	21.31	28.12
900.4	A	300	6.56	8.21	8.84	9.26	9.90	10.42	11.90	13.88	18.77	34.13	69.10
	B	300	5.33	8.27	9.01	9.46	10.21	10.80	11.89	13.66	17.49	29.79	73.20
952.2	B	300	6.29	8.52	9.46	9.95	11.13	12.88	16.47	21.69	26.08	30.79	39.62
987.6	B	300	6.56	8.25	9.05	9.37	10.41	11.30	13.97	18.23	20.62	22.94	28.26
1016.6	B	300	6.09	8.39	9.01	9.36	10.08	10.91	12.49	13.95	15.57	17.53	22.32
1017.2	A	300	5.72	7.34	7.81	8.06	8.83	9.38	10.78	12.46	15.01	18.41	24.71
1081.0	A	300	6.56	8.59	9.36	9.52	10.50	11.61	14.08	16.85	20.27	25.68	33.73
1081.5	A	300	5.24	7.91	8.94	8.92	9.86	10.82	13.09	18.53	116.2	66.56	23.06
		N[(a)] =	14	14	14	14	14	14	14	14	14	14	14
		Mean =	5.81	8.13	8.89	9.25	10.10	10.92	12.69	15.29	25.80	29.17	39.34
		STD[(a)] =	1.44	0.50	0.55	0.63	0.72	0.99	1.61	3.04	26.35	13.47	18.57

[(a)] N = Number of samples: STD = Standard deviation

Table B-3 (Continued). Mean Thermal Expansion Coefficients for Borehole NRG-6

Thermal/mechanical Unit TSw2: Welded, Devitrified: Oven dried: Cool-down

Sample ID			Mean CTE on Cool-down ($10^{-6}/^{\circ}C$)										
Depth (ft)	ID	Max. Temp. (°C)	300-275	275-250	250-225	225-200	200-175	175-150	150-125	125-100	100-75	75-50	50-35
777.8	B	300	24.60	38.80	43.40	31.56	22.04	16.09	13.78	11.39	9.71	8.37	8.34
788.3	B	300	25.61	38.52	38.91	28.18	20.28	15.28	12.85	11.39	10.80	10.15	8.84
789.4	A	300	26.51	24.95	19.72	14.09	1.24	1.39	1.06	3.54	5.75	8.52	5.57
802.7	B	300	26.15	34.49	33.34	24.42	18.18	15.21	13.05	11.73	10.42	9.81	9.54
849.9	B	300	10.77	11.17	10.69	10.32	10.67	10.35	9.54	8.85	7.83	7.45	6.99
886.5	B	300	14.98	15.15	15.43	15.09	14.83	12.70	10.83	9.76	8.58	7.93	7.77
900.4	A	300	20.29	29.91	37.67	32.90	21.56	16.92	13.38	11.36	9.72	7.57	5.63
	B	300	19.71	26.46	40.22	39.55	22.91	15.99	13.47	12.02	10.23	9.88	9.34
952.2	B	300	15.55	21.31	24.22	23.66	24.60	18.58	15.08	12.45	10.27	9.44	9.03
987.6	B	300	18.19	20.30	20.08	20.57	21.85	15.88	12.56	11.13	9.68	8.89	8.58
1016.6	B	300	16.98	18.10	17.31	16.27	15.76	13.49	11.67	10.57	9.32	8.87	8.43
1017.2	A	300	17.40	18.40	18.02	16.02	15.13	12.81	10.66	9.52	8.38	7.79	7.47
1081.0	A	300	20.53	23.49	23.24	22.03	22.20	14.55	0.97	1.03	0.40	0.14	0.38
1081.5	A	300	15.93	18.97	21.08	30.10	67.16	32.45	17.66	13.78	11.03	9.32	9.40
		N[a] =	14	14	14	14	14	14	14	14	14	14	14
		Mean =	19.51	24.29	25.95	23.20	21.31	15.12	11.18	9.90	8.72	8.15	7.52
		STD[a] =	4.77	8.49	10.58	8.45	14.56	6.47	4.74	3.49	2.77	2.47	2.42

[a] N = Number of samples: STD = Standard deviation

Table B-3 (Continued). Mean Thermal Expansion Coefficients for Borehole NRG-6

Thermal/mechanical Unit TCw: Welded, Devitrified: Air dried: Heat-up

Sample ID			Mean CTE on Heat-up ($10^{-6}/^{o}C$)										
Depth (ft)	ID	Max. Temp. (^{o}C)	25-50	50-75	75-100	100-125	125-150	150-175	175-200	200-225	225-250	250-275	275-300
28.8	G	110	2.71	5.85	8.08	ND	ND	ND	ND	ND	ND	ND	ND
98.1	G	110	6.85	8.43	10.00	ND	ND	ND	ND	ND	ND	ND	ND
111.0	G	110	5.58	7.92	9.39	ND	ND	ND	ND	ND	ND	ND	ND
		N[a] =	3	3	3	NA	NA	NA	NA	NA	NA	NA	NA
		Mean =	5.04	7.40	9.16	NA	NA	NA	NA	NA	NA	NA	NA
		STD[a] =	2.12	1.37	0.98	NA	NA	NA	NA	NA	NA	NA	NA

Thermal/mechanical Unit TCw: Welded, Devitrified: Air dried: Cool-down

Sample ID			Mean CTE on Cool-down ($10^{-6}/^{o}C$)										
Depth (ft)	ID	Max. Temp. (^{o}C)	300-275	275-250	250-225	225-200	200-175	175-150	150-125	125-100	100-75	75-50	50-35
28.8	G	110	ND	ND	ND	ND	ND	ND	ND	ND	9.02	8.89	4.28
98.1	G	110	ND	ND	ND	ND	ND	ND	ND	ND	10.84	9.64	3.97
111.0	G	110	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
		N[a] =	NA	NA	NA	NA	NA	NA	NA	NA	2	2	2
		Mean =	NA	NA	NA	NA	NA	NA	NA	NA	9.93	9.26	4.12
		STD[a] =	NA	NA	NA	NA	NA	NA	NA	NA	1.29	0.53	0.22

Thermal/mechanical Unit PTn: Nonwelded, Vitric: Air dried: Heat-up

Sample ID			Mean CTE on Heat-up ($10^{-6}/^{o}C$)										
Depth (ft)	ID	Max. Temp. (^{o}C)	25-50	50-75	75-100	100-125	125-150	150-175	175-200	200-225	225-250	250-275	275-300
152.9	C	110	4.64	3.96	0.96	ND	ND	ND	ND	ND	ND	ND	ND
187.0	D	110	4.49	3.71	3.27	ND	ND	ND	ND	ND	ND	ND	ND
		N[a] =	2	2	2	NA	NA	NA	NA	NA	NA	NA	NA
		Mean =	4.57	3.83	2.12	NA	NA	NA	NA	NA	NA	NA	NA
		STD[a] =	0.11	0.18	1.64	NA	NA	NA	NA	NA	NA	NA	NA

[a] N = Number of samples; STD = Standard deviation; ND = No Data; NA = Not Applicable

Table B-3 (Continued). Mean Thermal Expansion Coefficients for Borehole NRG-6

Thermal/mechanical Unit PTn: Nonwelded, Vitric: Air dried: Cool-down

Sample ID			Mean CTE on Cool-down ($10^{-6}/^{\circ}C$)										
Depth (ft)	ID	Max. Temp. (°C)	300-275	275-250	250-225	225-200	200-175	175-150	150-125	125-100	100-75	75-50	50-35
152.9	C	110	ND	ND	ND	ND	ND	ND	ND	ND	6.24	5.46	2.28
187.0	D	110	ND	ND	ND	ND	ND	ND	ND	ND	5.93	4.45	1.19
		N[a] =	NA	NA	NA	NA	NA	NA	NA	NA	2	2	2
		Mean =	NA	NA	NA	NA	NA	NA	NA	NA	6.08	4.95	1.74
		STD[a] =	NA	NA	NA	NA	NA	NA	NA	NA	0.22	0.72	0.77

Thermal/mechanical Unit TSw1: Welded, Devitrified: Air dried: Heat-up

Sample ID			Mean CTE on Heat-up ($10^{-6}/^{\circ}C$)										
Depth (ft)	ID	Max. Temp. (°C)	25-50	50-75	75-100	100-125	125-150	150-175	175-200	200-225	225-250	250-275	275-300
277.5	C	110	5.33	5.26	7.95	ND	ND	ND	ND	ND	ND	ND	ND
321.1	C	110	4.13	6.17	6.79	ND	ND	ND	ND	ND	ND	ND	ND
354.9	D	110	6.29	7.03	7.87	ND	ND	ND	ND	ND	ND	ND	ND
392.1	E	110	5.45	7.62	8.52	ND	ND	ND	ND	ND	ND	ND	ND
416.0	L	110	6.96	7.65	8.79	ND	ND	ND	ND	ND	ND	ND	ND
421.8	A	300	6.50	8.26	9.16	7.86	11.24	20.45	35.64	60.54	56.39	49.02	44.23
		N[a] =	6	6	6	1	1	1	1	1	1	1	1
		Mean =	5.78	7.00	8.18	7.86	11.24	20.45	35.64	60.54	56.39	49.02	44.23
		STD[a] =	1.02	1.10	0.84	NA	NA	NA	NA	NA	NA	NA	NA

Thermal/mechanical Unit TSw1: Welded, Devitrified: Air dried: Cool-down

Sample ID			Mean CTE on Cool-down ($10^{-6}/^{\circ}C$)										
Depth (ft)	ID	Max. Temp. (°C)	300-275	275-250	250-225	225-200	200-175	175-150	150-125	125-100	100-75	75-50	50-35
277.5	C	110	ND	ND	ND	ND	ND	ND	ND	ND	8.26	7.49	4.23
321.1	C	110	ND	ND	ND	ND	ND	ND	ND	ND	6.29	7.48	3.76
354.9	D	110	ND	ND	ND	ND	ND	ND	ND	ND	7.80	6.94	2.98
392.1	E	110	ND	ND	ND	ND	ND	ND	ND	ND	6.64	5.57	2.76
416.0	L	110	ND	ND	ND	ND	ND	ND	ND	ND	9.21	8.17	3.54
421.8	A	300	11.94	14.30	15.83	18.02	30.33	37.63	44.43	22.47	11.15	9.64	10.43
		N[a] =	1	1	1	1	1	1	1	1	6	6	6
		Mean =	11.94	14.30	15.83	18.02	30.33	37.63	44.43	22.47	8.22	7.55	4.62
		STD[a] =	NA	NA	NA	NA	NA	NA	NA	NA	1.79	1.34	2.90

[a] N = Number of samples: STD = Standard deviation: ND = No Data: NA = Not Applicable

Table B-3 (Continued). Mean Thermal Expansion Coefficients for Borehole NRG-6

Thermal/mechanical Unit TSw2: Welded, Devitrified: Air dried: Heat-up

Sample ID			Mean CTE on Heat-up ($10^{-6}/^{\circ}C$)										
Depth (ft)	ID	Max. Temp. ($^{\circ}C$)	25-50	50-75	75-100	100-125	125-150	150-175	175-200	200-225	225-250	250-275	275-300
729.2	C	225	7.69	8.81	9.05	9.59	10.18	11.08	12.10	ND	ND	ND	ND
732.6	B	225	7.54	8.81	9.20	10.02	10.17	11.27	12.23	ND	ND	ND	ND
806.0	C	225	8.53	8.82	9.23	9.55	10.35	11.29	12.42	ND	ND	ND	ND
911.2	C	175	6.98	7.91	8.42	8.86	9.15	ND	ND	ND	ND	ND	ND
926.3	C	175	7.79	8.85	9.32	9.57	9.99	ND	ND	ND	ND	ND	ND
		N[a] =	5	5	5	5	5	3	3	NA	NA	NA	NA
		Mean =	7.71	8.64	9.04	9.52	9.97	11.21	12.25	NA	NA	NA	NA
		STD[a] =	0.56	0.41	0.37	0.42	0.48	0.11	0.16	NA	NA	NA	NA

Thermal/mechanical Unit TSw2: Welded, Devitrified: Air dried: Cool-down

Sample ID			Mean CTE on Cool-down ($10^{-6}/^{\circ}C$)										
Depth (ft)	ID	Max. Temp. ($^{\circ}C$)	300-275	275-250	250-225	225-200	200-175	175-150	150-125	125-100	100-75	75-50	50-35
729.2	C	225	ND	ND	ND	ND	13.22	12.14	11.16	10.07	9.54	8.97	8.48
732.6	B	225	ND	ND	ND	ND	13.51	12.27	11.30	10.20	9.73	8.99	8.65
806.0	C	225	ND	ND	ND	ND	13.78	12.49	11.30	10.27	9.59	9.08	8.53
911.2	C	175	ND	ND	ND	ND	ND	ND	9.94	9.12	8.71	8.26	7.97
926.3	C	175	ND	ND	ND	ND	ND	ND	10.95	9.93	9.53	8.97	8.70
		N[a] =	NA	NA	NA	NA	3	3	5	5	5	5	5
		Mean =	NA	NA	NA	NA	13.50	12.30	10.93	9.92	9.42	8.85	8.47
		STD[a] =	NA	NA	NA	NA	0.28	0.18	0.57	0.46	0.40	0.33	0.29

[a] N = Number of samples; STD = Standard deviation; ND = No Data; NA = Not Applicable

Table B-4. Mean Thermal Expansion Coefficients for Borehole NRG-7.

Thermal/mechanical Unit TCw: Welded, Devitrified: Air dried: Heat-up

Sample ID			Mean CTE on Heat-up ($10^{-6}/^{\circ}C$)										
Depth (ft)	ID	Max. Temp. (°C)	25-50	50-75	75-100	100-125	125-150	150-175	175-200	200-225	225-250	250-275	275-300
18.6	A	300	7.53	8.55	9.29	10.18	11.66	13.79	15.69	18.63	22.01	29.76	55.70
27.3	A	300	7.53	8.66	9.36	10.56	12.45	15.06	17.44	20.07	21.32	25.22	33.16
56.8	A	300	6.96	7.76	7.84	8.81	10.28	11.82	13.31	15.95	19.50	40.47	50.54
		N[a] =	3	3	3	3	3	3	3	3	3	3	3
		Mean =	7.34	8.32	8.83	9.85	11.46	13.56	15.48	18.22	20.94	31.82	46.46
		STD[a] =	0.33	0.49	0.86	0.92	1.10	1.63	2.08	2.09	1.30	7.83	11.81

Thermal/mechanical Unit TCw: Welded, Devitrified: Air dried: Cool-down

Sample ID			Mean CTE on Cool-down ($10^{-6}/^{\circ}C$)										
Depth (ft)	ID	Max. Temp. (°C)	300-275	275-250	250-225	225-200	200-175	175-150	150-125	125-100	100-75	75-50	50-35
18.6	A	300	22.69	34.50	44.47	36.90	28.72	19.79	16.02	13.68	11.76	10.52	5.99
27.3	A	300	20.11	25.54	26.55	24.82	22.47	18.49	15.23	12.72	11.03	9.77	5.43
56.8	A	300	17.45	34.13	45.62	24.18	19.05	15.14	12.85	11.40	10.11	9.08	5.15
		N[a] =	3	3	3	3	3	3	3	3	3	3	3
		Mean =	20.09	31.39	38.88	28.64	23.41	17.81	14.70	12.60	10.97	9.79	5.52
		STD[a] =	2.62	5.07	10.69	7.16	4.90	2.40	1.65	1.15	0.83	0.72	0.43

[a] N = Number of samples; STD = Standard deviation

Table B-4 (Continued). Mean Thermal Expansion Coefficients for Borehole NRG-7.

Thermal/mechanical Unit PTn: Nonwelded, Vitric: Air dried: Heat-up

Sample ID			Mean CTE on Heat-up ($10^{-6}/^{o}C$)										
Depth (ft)	ID	Max. Temp. (°C)	25-50	50-75	75-100	100-125	125-150	150-175	175-200	200-225	225-250	250-275	275-300
75.0	B	300	6.67	6.71	5.54	-33.6	8.54	7.51	3.03	-2.57	-6.88	-9.00	-9.13
91.6	A	300	4.08	3.87	3.93	3.46	5.86	5.95	5.91	5.82	5.66	4.34	1.71
104.1	A	300	3.95	2.66	-0.01	-6.66	5.57	4.85	5.37	6.20	6.57	6.07	4.26
113.1	A	300	4.12	4.74	5.28	5.43	6.11	6.38	6.28	6.15	5.85	4.41	1.90
120.9	A	300	4.44	5.05	4.94	1.11	6.59	6.17	3.53	-0.92	-6.00	-6.04	-5.16
181.7	A	300	3.98	2.86	2.58	-3.93	6.36	4.95	-0.13	-9.33	-18.6	-25.4	-22.1
248.5	A	300	4.21	3.42	2.45	-7.7	5.96	4.21	-0.68	-8.52	-16.2	-22.7	-23.7
293.3	A	300	5.09	5.98	6.63	1.66	7.82	8.26	6.62	2.65	-3.6	-10.7	-19.5
		N[(a)] =	8	8	8	8	8	8	8	8	8	8	8
		Mean =	4.57	4.41	3.92	-5.03	6.60	6.03	3.74	-0.07	-4.15	-7.39	-8.97
		STD[(a)] =	0.92	1.46	2.15	12.50	1.04	1.37	2.86	6.37	9.84	12.16	11.48

Thermal/mechanical Unit PTn: Nonwelded, Vitric: Air dried: Cool-down

Sample ID			Mean CTE on Cool-down ($10^{-6}/^{o}C$)										
Depth (ft)	ID	Max. Temp. (°C)	300-275	275-250	250-225	225-200	200-175	175-150	150-125	125-100	100-75	75-50	50-35
75.0	B	300	11.18	8.40	7.54	7.44	8.03	8.71	8.68	8.21	7.39	6.51	3.45
91.6	A	300	9.38	7.36	6.52	6.32	6.26	6.25	5.83	5.66	5.57	4.84	2.30
104.1	A	300	8.31	7.37	7.10	6.91	6.53	6.22	5.52	5.27	4.63	3.77	1.07
113.1	A	300	10.92	8.06	6.81	6.51	6.39	6.47	6.00	5.90	5.48	5.23	2.89
120.9	A	300	16.26	9.68	7.51	6.60	6.15	6.19	5.83	5.60	5.12	4.66	2.92
181.7	A	300	10.20	7.69	6.69	6.29	6.21	6.04	5.69	5.50	5.12	4.61	2.10
248.5	A	300	11.08	7.84	6.68	6.30	6.26	5.98	5.65	5.43	4.96	4.52	2.18
293.3	A	300	14.00	9.32	7.90	7.84	8.65	9.04	8.08	7.24	6.64	5.97	3.23
		N[(a)] =	8	8	8	8	8	8	8	8	8	8	8
		Mean =	11.42	8.21	7.09	6.78	6.81	6.86	6.41	6.10	5.61	5.01	2.52
		STD[(a)] =	2.56	0.87	0.50	0.58	0.97	1.26	1.24	1.05	0.93	0.87	0.77

[(a)] N = Number of samples; STD = Standard deviation

Table B-4 (Continued). Mean Thermal Expansion Coefficients for Borehole NRG-7.

Thermal/mechanical Unit TSw1: Welded, Devitrified: Air dried: Heat-up

Sample ID			Mean CTE on Heat-up ($10^{-6}/^{o}C$)										
Depth (ft)	ID	Max. Temp. (°C)	25-50	50-75	75-100	100-125	125-150	150-175	175-200	200-225	225-250	250-275	275-300
329.2	A	300	6.34	7.48	8.03	8.71	10.43	12.51	13.38	15.37	20.18	23.63	26.61
359.1	A	300	5.62	6.27	6.76	7.11	8.26	10.19	13.08	15.87	18.17	19.04	18.97
378.9	A	300	5.69	6.54	6.99	7.55	8.59	11.18	14.91	19.80	29.55	37.97	38.07
496.3	A	300	7.81	9.17	9.80	10.77	12.59	22.36	39.52	50.78	45.75	44.53	45.09
550.9	A	300	7.73	8.56	9.09	10.02	11.17	17.89	29.89	47.18	43.38	40.13	47.47
606.4	A	300	7.22	8.45	8.75	9.00	10.06	12.92	19.74	26.07	32.84	30.60	34.52
608.1	A	300	7.70	8.44	8.97	9.71	11.02	15.49	29.41	37.87	36.83	33.21	35.02
625.7	A	300	7.36	8.45	8.82	9.55	10.64	12.22	17.43	28.32	35.07	74.14	59.53
641.0	A	300	8.13	8.63	9.08	9.69	10.54	12.05	18.89	29.11	32.90	43.51	75.58
699.0	A	300	6.70	7.56	8.05	8.58	9.45	10.70	11.97	13.42	15.51	18.41	25.17
		N[(a)] =	10	10	10	10	10	10	10	10	10	10	10
		Mean =	7.03	7.95	8.44	9.07	10.27	13.75	20.82	28.38	31.02	36.52	40.60
		STD[(a)] =	0.90	0.96	0.97	1.12	1.27	3.81	9.13	13.23	10.29	16.29	17.08

Thermal/mechanical Unit TSw1: Welded, Devitrified: Air dried: Cool-down

Sample ID			Mean CTE on Cool-down ($10^{-6}/^{o}C$)										
Depth (ft)	ID	Max. Temp. (°C)	300-275	275-250	250-225	225-200	200-175	175-150	150-125	125-100	100-75	75-50	50-35
329.2	A	300	15.78	18.16	19.72	19.78	18.59	16.76	14.75	12.05	9.32	8.35	4.60
359.1	A	300	13.08	13.93	14.92	15.21	15.30	15.67	13.56	10.05	8.11	7.20	3.97
378.9	A	300	15.20	16.84	18.81	20.77	23.11	24.50	25.01	17.87	10.31	8.78	4.68
496.3	A	300	17.84	22.44	25.86	28.00	38.11	43.14	41.58	27.28	15.72	12.60	6.76
550.9	A	300	18.25	23.96	28.69	31.22	47.18	34.81	22.82	14.82	11.86	10.46	6.03
606.4	A	300	20.78	23.00	22.30	23.13	29.03	26.38	18.77	13.96	11.31	9.78	5.51
608.1	A	300	19.25	21.72	22.66	26.52	34.23	29.91	23.95	15.80	11.55	9.96	5.57
625.7	A	300	25.42	44.63	59.62	40.52	32.55	17.94	13.94	12.48	11.01	10.37	5.94
641.0	A	300	23.02	36.32	47.91	39.31	36.83	24.00	15.76	13.21	11.67	10.55	6.07
699.0	A	300	18.12	19.20	18.19	16.20	14.39	13.26	12.08	10.95	9.79	8.78	4.89
		N[(a)] =	10	10	10	10	10	10	10	10	10	10	10
		Mean =	18.67	24.02	27.87	26.07	28.93	24.64	20.22	14.85	11.06	9.68	5.40
		STD[(a)] =	3.68	9.40	14.46	8.86	10.85	9.39	8.83	4.94	2.03	1.49	0.85

[(a)] N = Number of samples: STD = Standard deviation

Table B-4 (Continued). Mean Thermal Expansion Coefficients for Borehole NRG-7.

Thermal/mechanical Unit TSw2: Welded, Devitrified: Air dried: Heat-up

Sample ID			Mean CTE on Heat-up ($10^{-6}/^{\circ}C$)										
Depth (ft)	ID	Max. Temp. (°C)	25-50	50-75	75-100	100-125	125-150	150-175	175-200	200-225	225-250	250-275	275-300
856.5	A	300	6.03	8.21	8.87	9.44	10.20	11.53	13.16	17.84	22.00	28.21	34.26
867.8	A	300	7.24	8.59	8.70	9.33	9.90	10.41	11.11	13.55	17.16	26.29	46.63
956.6	A	300	7.32	8.55	8.90	9.41	9.92	10.41	11.37	13.15	15.06	19.33	25.70
979.2	A	300	7.21	8.56	9.05	9.61	10.44	11.73	14.43	18.18	20.85	24.27	31.40
1187.4	A	300	6.90	7.89	8.22	8.71	9.24	10.04	10.70	12.13	14.42	17.59	22.76
1261.8	A	300	4.32	7.55	8.44	8.99	9.66	10.28	10.58	11.79	13.15	14.66	17.16
1269.9	A	300	6.72	7.86	8.45	8.87	9.37	9.93	10.47	11.51	12.45	13.81	15.72
1305.7	A	300	7.06	8.33	8.69	9.24	9.72	10.29	11.05	12.59	13.83	16.59	20.64
1364.6	A	300	7.02	8.44	8.80	9.32	10.00	10.85	11.35	12.66	14.96	17.97	23.34
1407.4	A	300	7.63	9.03	9.59	11.47	14.52	16.45	16.06	15.36	14.95	13.38	12.04
		N[(a)] =	10	10	10	10	10	10	10	10	10	10	10
		Mean =	6.74	8.30	8.77	9.44	10.30	11.19	12.03	13.87	15.88	19.21	24.97
		STD[(a)] =	0.95	0.43	0.38	0.77	1.53	1.94	1.90	2.43	3.19	5.29	10.21

Thermal/mechanical Unit TSw2: Welded, Devitrified: Air dried: Cool-down

Sample ID			Mean CTE on Cool-down ($10^{-6}/^{\circ}C$)										
Depth (ft)	ID	Max. Temp. (°C)	300-275	275-250	250-225	225-200	200-175	175-150	150-125	125-100	100-75	75-50	50-35
856.5	A	300	23.23	26.70	25.15	22.00	18.33	14.33	12.28	11.19	10.27	9.66	5.58
867.8	A	300	28.69	36.69	31.05	21.91	16.70	13.35	12.14	11.15	10.34	9.67	5.51
956.6	A	300	17.40	19.61	19.07	17.04	14.55	12.49	10.76	9.81	9.37	8.87	5.26
979.2	A	300	19.76	21.99	21.75	21.68	21.64	17.14	13.83	12.10	10.75	9.78	5.55
1187.4	A	300	15.51	17.21	18.71	16.81	13.87	12.02	10.80	10.11	9.38	8.60	4.89
1261.8	A	300	15.52	15.23	14.48	14.20	13.15	12.20	11.28	10.46	9.74	9.31	5.44
1269.9	A	300	13.80	13.72	13.46	12.84	12.19	11.20	10.27	9.56	9.11	8.62	4.96
1305.7	A	300	16.91	17.51	16.46	15.04	13.33	11.67	10.76	9.92	9.52	8.94	5.15
1364.6	A	300	17.85	19.19	18.86	16.61	14.22	12.47	11.11	10.17	9.53	8.88	5.12
1407.4	A	300	11.05	11.96	13.66	16.68	17.53	17.61	16.50	14.15	11.85	10.24	5.52
		N[(a)] =	10	10	10	10	10	10	10	10	10	10	10
		Mean =	17.97	19.98	19.27	17.48	15.55	13.45	11.97	10.86	9.99	9.26	5.30
		STD[(a)] =	5.00	7.22	5.54	3.30	2.94	2.25	1.90	1.39	0.84	0.56	0.26

[(a)] N = Number of samples: STD = Standard deviation

Table B-5. Instantaneous Thermal Expansion Coefficients for Borehole NRG-4.

Thermal/mechanical Unit PTn[a]: Nonwelded, Vitric: Air dried: Heat-up

Sample ID			Instantaneous CTE on Heat-up ($10^{-6}/^{o}C$)										
Depth (ft)	ID	Max. Temp. (^{o}C)	50	75	100	125	150	175	200	225	250	275	300
450.6	D	300	4.24	-0.29	-1.42	6.8	4.03	2.62	3.31	4.53	3.74	2.46	0.31
		N[b] =	1	1	1	1	1	1	1	1	1	1	1
		Mean =	4.24	-0.29	-1.42	6.81	4.03	2.62	3.31	4.53	3.74	2.46	0.31
		STD[b] =	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Thermal/mechanical Unit PTn[a]: Nonwelded, Vitric: Air dried: Cool-down

Sample ID			Instantaneous CTE on Cool-down ($10^{-6}/^{o}C$)										
Depth (ft)	ID	Max. Temp. (^{o}C)	300	275	250	225	200	175	150	125	100	75	50
450.6	D	300	10.01	6.70	6.36	6.20	5.11	5.72	5.29	4.73	5.21	3.78	3.41
		N[b] =	1	1	1	1	1	1	1	1	1	1	1
		Mean =	10.01	6.70	6.36	6.20	5.11	5.72	5.29	4.73	5.21	3.78	3.41
		STD[b] =	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

[a] PTn samples were subjected to a thermal soaking period prior to testing.
[b] N = Number of samples: STD = Standard deviation: NA = Not Applicable

Table B-5 (Continued). Instantaneous Thermal Expansion Coefficients for Borehole NRG-4.

Thermal/mechanical Unit TSw1: Welded, Devitrified: Air dried: Heat-up

Sample ID			Instantaneous CTE on Heat-up ($10^{-6}/^{\circ}C$)										
Depth (ft)	ID	Max. Temp. (°C)	50	75	100	125	150	175	200	225	250	275	300
506.0	D	300	6.96	7.52	8.39	7.58	9.75	11.72	13.24	15.66	16.95	17.15	17.54
529.0	C	300	7.80	8.00	8.71	9.43	10.14	16.65	19.75	22.11	28.32	38.17	40.73
586.2	D	300	6.37	5.66	6.26	7.07	7.05	15.19	13.74	14.16	15.79	29.84	37.67
610.5	D	300	6.93	6.92	7.01	8.77	10.13	29.96	39.40	35.51	36.95	38.93	36.74
654.5	A	300	7.95	8.44	8.62	8.83	12.33	24.07	21.92	23.38	24.83	32.98	43.67
690.6	A	300	7.45	7.28	8.60	9.57	10.70	24.38	24.96	31.17	31.22	32.45	37.93
		N[(a)] =	6	6	6	6	6	6	6	6	6	6	6
		Mean =	7.24	7.30	7.93	8.54	10.02	20.33	22.17	23.66	25.68	31.59	35.71
		STD[(a)] =	0.60	0.97	1.04	1.01	1.72	6.89	9.60	8.41	8.24	7.89	9.26

Thermal/mechanical Unit TSw1: Welded, Devitrified: Air dried: Cool-down

Sample ID			Instantaneous CTE on Cool-down ($10^{-6}/^{\circ}C$)										
Depth (ft)	ID	Max. Temp. (°C)	300	275	250	225	200	175	150	125	100	75	50
506.0	D	300	11.35	14.50	14.70	17.81	17.49	13.62	12.18	10.44	8.72	8.27	7.12
529.0	C	300	16.03	20.83	24.30	26.31	25.81	24.26	22.99	23.51	12.77	10.67	9.58
586.2	D	300	13.69	18.27	19.88	18.14	15.71	14.59	14.35	13.84	8.05	7.75	6.34
610.5	D	300	15.28	16.32	19.65	20.98	22.50	25.04	31.94	29.06	11.62	9.35	9.12
654.5	A	300	16.78	21.45	22.85	21.59	21.92	22.33	23.06	27.33	11.51	10.01	8.18
690.6	A	300	14.65	18.60	23.80	24.02	31.29	34.29	21.07	13.71	10.38	9.80	8.38
		N[(a)] =	6	6	6	6	6	6	6	6	6	6	6
		Mean =	14.63	18.33	20.86	21.48	22.45	22.35	20.93	19.65	10.51	9.31	8.12
		STD[(a)] =	1.93	2.64	3.60	3.31	5.65	7.62	7.07	7.95	1.82	1.10	1.21

[(a)] N = Number of samples: STD = Standard deviation

Table B-6. Instantaneous Thermal Expansion Coefficients for Borehole NRG-5.

Thermal/mechanical Unit TSw1: Welded, Devitrified: Air dried: Heat-up

Sample ID			Instantaneous CTE on Heat-up ($10^{-6}/^{o}C$)										
Depth (ft)	ID	Max. Temp. (^{o}C)	50	75	100	125	150	175	200	225	250	275	300
779.8	A	300	8.06	8.17	9.16	10.25	10.20	12.98	17.54	26.38	33.00	50.59	73.71
		N[(a)] =	1	1	1	1	1	1	1	1	1	1	1
		Mean =	8.06	8.17	9.16	10.25	10.20	12.98	17.54	26.38	33.00	50.59	73.71
		STD[(a)] =	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Thermal/mechanical Unit TSw1: Welded, Devitrified: Air dried: Cool-down

Sample ID			Instantaneous CTE on Cool-down ($10^{-6}/^{o}C$)										
Depth (ft)	ID	Max. Temp. (^{o}C)	300	275	250	225	200	175	150	125	100	75	50
779.8	A	300	21.77	30.21	39.32	40.96	33.70	22.68	15.26	13.40	11.54	10.75	9.93
		N[(a)] =	1	1	1	1	1	1	1	1	1	1	1
		Mean =	21.77	30.21	39.32	40.96	33.70	22.68	15.26	13.40	11.54	10.75	9.93
		STD[(a)] =	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

[(a)] N = Number of samples; STD = Standard deviation; NA = Not Applicable

Table 4-13 (Continued). Instantaneous Thermal Expansion Coefficients for Borehole NRG-5

Thermal/mechanical Unit TSw2: Welded, Devitrified: Air dried: Heat-up

Sample ID			Instantaneous CTE on Heat-up ($10^{-6}/^{\circ}C$)										
Depth (ft)	ID	Max. Temp. ($^{\circ}C$)	50	75	100	125	150	175	200	225	250	275	300
829.0	A	300	8.49	8.51	9.36	9.17	9.50	9.16	12.35	13.78	17.32	24.96	36.44
831.8	A	300	7.88	8.41	8.49	10.21	8.99	10.03	11.44	12.67	14.54	20.74	36.21
848.0	A	300	8.15	8.60	8.75	9.29	9.07	12.25	13.60	19.13	25.62	31.66	43.73
852.5	A	300	8.38	7.70	9.03	9.07	9.54	11.00	13.33	16.54	20.64	30.50	45.19
874.9	A	300	8.99	8.12	8.73	9.82	9.90	11.20	12.95	16.72	25.21	32.35	47.60
879.6	D	300	8.22	8.57	9.86	10.20	10.52	10.37	12.03	15.57	22.11	34.39	44.34
886.5	A	300	8.26	9.02	8.48	10.55	10.55	11.57	16.29	18.99	22.94	27.34	32.62
892.8	A	300	8.78	7.95	9.21	10.21	9.76	11.33	12.26	14.54	20.71	34.14	44.45
893.3	A	300	8.21	8.01	8.79	9.60	10.02	10.44	12.51	16.07	23.73	35.83	53.98
899.5	A	300	7.90	8.52	10.25	10.11	10.17	11.52	13.57	20.03	24.43	35.72	64.02
899.8	A	300	8.09	8.35	9.05	8.66	9.04	9.69	12.42	13.18	17.16	33.80	50.26
		N[a] =	11	11	11	11	11	11	11	11	11	11	11
		Mean =	8.30	8.34	9.09	9.72	9.73	10.78	12.98	16.11	21.31	31.04	45.35
		STD[a] =	0.34	0.37	0.56	0.60	0.56	0.92	1.29	2.49	3.64	4.82	8.84

Thermal/mechanical Unit TSw2: Welded, Devitrified: Air dried: Cool-down

Sample ID			Instantaneous CTE on Cool-down ($10^{-6}/^{\circ}C$)										
Depth (ft)	ID	Max. Temp. ($^{\circ}C$)	300	275	250	225	200	175	150	125	100	75	50
829.0	A	300	21.53	23.47	24.81	20.99	16.35	13.52	12.38	11.09	9.95	9.21	8.50
831.8	A	300	19.31	22.10	22.24	18.80	15.49	12.47	11.97	10.25	10.16	9.25	8.30
848.0	A	300	22.19	27.16	26.01	21.77	25.30	18.77	13.33	11.56	10.78	9.28	8.50
852.5	A	300	23.75	28.81	27.57	23.95	22.23	16.53	13.26	12.61	10.44	9.40	9.02
874.9	A	300	18.79	24.81	26.46	24.06	23.65	19.39	15.33	14.02	11.86	9.89	8.68
879.6	D	300	20.82	28.15	29.66	25.31	20.41	14.78	13.27	11.82	10.39	9.62	8.80
886.5	A	300	17.24	21.88	23.82	22.41	21.34	17.96	15.78	12.30	10.68	9.27	8.63
892.8	A	300	18.83	27.36	31.38	25.73	20.82	14.40	13.44	11.89	10.56	9.30	8.57
893.3	A	300	19.57	30.74	34.80	27.65	22.90	14.33	12.48	11.51	10.03	9.41	8.68
899.5	A	300	19.95	26.23	32.63	29.50	26.79	20.15	16.99	13.80	11.61	9.95	9.02
899.8	A	300	21.31	33.23	36.43	22.15	16.33	12.54	11.65	10.95	10.47	9.35	8.37
		N[a] =	11	11	11	11	11	11	11	11	11	11	11
		Mean =	20.30	26.72	28.71	23.85	21.06	15.89	13.63	11.98	10.63	9.45	8.64
		STD[a] =	1.84	3.53	4.63	3.08	3.72	2.79	1.70	1.15	0.60	0.26	0.23

[a] N = Number of samples; STD = Standard deviation

Table B-7. Instantaneous Thermal Expansion Coefficients for Borehole NRG-6.

Thermal/mechanical Unit TCw: Welded, Devitrified: Vacuum saturated: Heat-up

Sample ID			Instantaneous CTE on Heat-up ($10^{-6}/^{o}C$)										
Depth (ft)	ID	Max. Temp. (°C)	50	75	100	125	150	175	200	225	250	275	300
28.8	D	300	7.99	7.21	4.59	10.60	12.99	13.36	15.40	18.77	26.40	35.48	207.9
	F	200	7.37	6.88	7.67	13.97	11.72	15.19	17.68	ND	ND	ND	ND
98.1	F	300	6.36	6.75	5.76	13.16	15.88	17.04	17.18	19.60	24.37	28.03	20.47
111.0	G	300	6.68	7.56	7.94	11.44	16.84	17.01	16.74	19.08	21.58	26.22	13.95
		N[(a)] =	4	4	4	4	4	4	4	3	3	3	3
		Mean =	7.10	7.10	6.49	12.29	14.36	15.65	16.75	19.15	24.12	29.91	80.77
		STD[(a)] =	0.73	0.36	1.59	1.54	2.40	1.75	0.98	0.42	2.42	4.91	110.1

Thermal/mechanical Unit TCw: Welded, Devitrified: Vacuum saturated: Cool-down

Sample ID			Instantaneous CTE on Cool-down ($10^{-6}/^{o}C$)										
Depth (ft)	ID	Max. Temp. (°C)	300	275	250	225	200	175	150	125	100	75	50
28.8	D	300	10.97	24.01	39.58	68.08	50.35	26.24	19.35	16.29	14.32	13.00	12.13
	F	200	ND	ND	ND	ND	14.86	15.32	14.83	12.53	11.40	10.24	9.73
98.1	F	300	11.97	16.62	22.79	22.96	21.98	20.23	17.13	14.65	12.33	10.74	9.66
111.0	G	300	7.78	13.26	23.26	23.72	20.04	19.16	16.01	14.32	11.46	10.32	9.40
		N[(a)] =	3	3	3	3	4	4	4	4	4	4	4
		Mean =	10.24	17.96	28.54	38.26	26.81	20.24	16.83	14.45	12.38	11.07	10.23
		STD[(a)] =	2.19	5.50	9.56	25.83	15.98	4.53	1.92	1.54	1.36	1.30	1.27

[(a)] N = Number of samples: STD = Standard deviation: ND = No Data

Table B-7 (Continued). Instantaneous Thermal Expansion Coefficients for Borehole NRG-6.

Thermal/mechanical Units TCw (Welded, Devitrified) and PTn (Nonwelded, Vitric): Vacuum saturated: Heat-up

Sample ID			Instantaneous CTE on Heat-up ($10^{-6}/^{o}C$)										
Depth (ft)	ID	Max. Temp. (°C)	50	75	100	125	150	175	200	225	250	275	300
148.4[(a)]	A	125	4.63	5.05	6.03	ND	ND	ND	ND	ND	ND	ND	ND
148.4[(a)]	A	225	4.54	5.34	-2.91	6.0	5.49	3.50	-1.50	ND	ND	ND	ND
152.9[(b)]	B	300	7.50	2.25	8.00	5.0	5.77	3.07	-1.12	-3.05	-3.42	-5.65	-4.77
187.0[(b)]	D	300	2.94	-3.48	-28.5	6.14	4.86	1.18	-5.79	-12.5	-19.2	-22.9	-20.5
		N[(c)] =	4	4	4	3	3	3	3	2	2	2	2
		Mean =	4.90	2.29	-4.35	5.7	5.37	2.58	-2.80	-7.77	-11.3	-14.3	-12.7
		STD[(c)] =	1.90	4.09	16.80	0.63	0.47	1.23	2.59	6.68	11.18	12.23	11.15

Thermal/mechanical Units TCw (Welded, Devitrified) and PTn (Nonwelded, Vitric): Vacuum saturated: Cool-down

Sample ID			Instantaneous CTE on Cool-down ($10^{-6}/^{o}C$)										
Depth (ft)	ID	Max. Temp. (°C)	300	275	250	225	200	175	150	125	100	75	50
148.4[(a)]	A	125	ND	ND	ND	ND	ND	ND	ND	6.26	6.66	4.90	4.01
148.4[(a)]	A	225	ND	ND	ND	ND	9.55	7.63	6.43	5.85	5.91	3.63	1.08
152.9[(b)]	B	300	22.51	12.25	8.29	6.13	6.54	5.44	5.77	5.38	5.33	4.98	3.92
187.0[(b)]	D	300	21.50	9.91	8.20	6.44	4.66	4.91	4.87	5.66	4.94	4.99	4.64
		N[(c)] =	2	2	2	2	3	3	3	4	4	4	4
		Mean =	22.00	11.08	8.25	6.29	6.91	5.99	5.69	5.78	5.71	4.63	3.42
		STD[(c)] =	0.71	1.65	0.07	0.22	2.47	1.44	0.78	0.37	0.75	0.66	1.59

[(a)] Based on depth this specimen is classified as a TCw T/M Unit, however, based on physical properties and thermal expansion behavior the sample behaved as a PTn T/M Unit and was considered as such for statistical purposes.

[(b)] These specimens are PTn

[(c)] N = Number of samples; STD = Standard deviation; ND = No Data

Table B-7 (Continued). Instantaneous Thermal Expansion Coefficients for Borehole NRG-6.

Thermal/mechanical Unit TSw1: Welded, Devitrified: Vacuum saturated: Heat-up

Sample ID			Instantaneous CTE on Heat-up ($10^{-6}/°C$)										
Depth (ft)	ID	Max. Temp. (°C)	50	75	100	125	150	175	200	225	250	275	300
277.5	B	300	4.15	6.30	6.40	7.30	11.44	13.70	10.85	13.89	16.22	13.70	12.09
321.1	C	300	5.33	6.69	8.81	8.70	9.71	12.41	15.95	31.88	44.15	40.79	41.21
354.9	E	300	6.48	6.23	11.51	8.24	10.33	20.16	43.90	91.50	45.40	51.69	36.03
392.1	F	300	6.53	9.62	8.99	9.60	12.46	22.87	32.35	56.14	60.64	50.75	41.20
416.0	M	300	7.12	8.32	5.19	10.49	13.59	25.31	37.63	71.44	54.20	45.22	41.78
421.8	B	175	6.89	7.70	3.73	13.72	22.93	ND	ND	ND	ND	ND	ND
458.7	A	200	8.04	9.01	-8.30	9.70	12.42	21.02	31.82	ND	ND	ND	ND
528.4	A	300	7.90	6.82	14.09	11.72	11.30	14.02	22.85	33.39	43.83	62.81	47.79
648.6	A	300	8.56	6.84	16.20	12.31	10.99	18.20	19.73	34.25	37.36	44.99	58.65
693.1	A	300	7.93	7.66	10.58	12.63	10.21	12.29	14.92	23.09	40.86	41.01	55.46
		N[(a)] =	10	10	10	10	10	9	9	8	8	8	8
		Mean =	6.90	7.52	7.72	10.44	12.54	17.78	25.56	44.45	42.83	43.87	41.78
		STD[(a)] =	1.35	1.16	6.82	2.10	3.84	4.86	11.35	26.33	13.08	14.13	14.26

Thermal/mechanical Unit TSw1: Welded, Devitrified: Vacuum saturated: Cool-down

Sample ID			Instantaneous CTE on Cool-down ($10^{-6}/°C$)										
Depth (ft)	ID	Max. Temp. (°C)	300	275	250	225	200	175	150	125	100	75	50
277.5	B	300	8.36	8.71	9.04	12.46	12.88	8.96	8.49	7.83	7.18	6.43	7.16
321.1	C	300	9.39	15.75	17.19	19.91	22.79	28.34	33.91	21.96	11.75	9.69	9.05
354.9	E	300	10.00	12.22	14.31	19.60	32.50	28.61	40.16	58.09	13.28	10.51	9.04
392.1	F	300	11.22	16.81	19.61	25.21	26.48	29.21	42.21	61.11	17.05	11.40	10.72
416.0	M	300	12.11	17.98	20.50	21.59	24.20	33.00	47.18	56.91	15.95	12.26	11.22
421.8	B	175	ND	ND	ND	ND	ND	ND	16.77	20.85	12.48	10.43	9.29
458.7	A	200	ND	ND	ND	ND	17.12	20.61	16.48	12.86	9.95	9.31	8.08
528.4	A	300	12.77	21.52	33.10	41.17	35.09	40.94	22.93	14.80	12.06	10.74	10.10
648.6	A	300	17.21	25.87	33.69	32.92	35.62	27.46	20.88	17.20	12.29	11.38	11.29
693.1	A	300	18.56	28.65	33.48	29.17	33.96	19.68	16.20	13.87	12.34	11.77	9.74
		N[(a)] =	8	8	8	8	9	9	10	10	10	10	10
		Mean =	12.45	18.44	22.62	25.25	26.74	26.31	26.52	28.55	12.43	10.39	9.57
		STD[(a)] =	3.66	6.68	9.61	8.98	8.22	9.05	13.27	21.21	2.77	1.66	1.33

[(a)] N = Number of samples: STD = Standard deviation: ND = No Data

Table B-7 (Continued). Instantaneous Thermal Expansion Coefficients for Borehole NRG-6.

Thermal/mechanical Unit TSw2: Welded, Devitrified: Vacuum saturated: Heat-up

Sample ID			Instantaneous CTE on Heat-up ($10^{-6}/^{o}C$)										
Depth (ft)	ID	Max. Temp. (°C)	50	75	100	125	150	175	200	225	250	275	300
729.2	A	300	7.47	8.77	5.81	8.94	12.21	12.26	14.38	20.60	27.88	48.64	72.72
	B	300	8.55	10.00	4.86	9.90	12.09	13.02	14.91	17.68	24.61	40.35	56.19
732.6	A	300	7.49	9.19	5.25	8.18	10.79	12.81	13.91	17.56	24.71	39.98	63.02
732.6	C	300	9.29	8.67	4.69	8.72	11.54	12.12	15.06	17.31	23.13	37.82	55.52
777.8	A	200	8.50	7.31	5.78	12.25	10.25	11.91	13.83	ND	ND	ND	ND
788.3	A	200	7.95	6.95	6.83	12.15	10.93	12.24	14.32	ND	ND	ND	ND
802.7	A	175	4.06	5.11	***	1.67	10.02	12.09	12.57	14.24	20.49	30.87	47.60
806.0	A	200	8.76	8.79	3.79	10.19	11.30	11.67	14.80	21.14	25.72	42.10	49.89
	B	300	8.93	8.45	3.63	8.23	11.24	12.23	13.74	17.24	25.47	40.88	45.51
849.9	A	300	6.82	7.22	5.95	11.24	9.47	20.63	16.52	16.59	19.59	19.75	18.47
886.5	A	300	5.88	6.59	0.97	10.61	8.39	10.44	9.74	9.86	12.27	12.13	12.15
911.2	A	300	7.34	7.78	-2.22	8.32	9.85	12.71	16.67	20.95	22.09	28.00	34.94
	B	300	8.02	7.90	4.40	9.00	9.30	11.83	13.35	15.23	17.00	20.50	22.50
926.3	A	300	7.83	7.52	1.54	8.46	10.02	11.29	14.88	20.98	24.12	33.58	46.81
	B	300	8.51	8.91	5.70	9.28	10.78	11.78	13.52	16.95	18.06	26.47	36.93
952.2	A	200	6.46	8.17	11.58	12.83	12.31	14.52	15.45	ND	ND	ND	ND
987.6	A	300	7.37	6.75	13.39	12.21	10.82	12.55	13.90	15.28	19.74	24.66	33.34
1016.6	A	300	7.74	8.04	13.10	10.11	8.81	12.08	13.85	15.61	17.53	22.75	29.58
1081.5	B	300	7.02	6.47	21.12	12.32	10.25	12.99	14.34	17.68	21.65	27.80	40.08
		N[(a)] =	19	19	18	19	19	19	19	16	16	16	16
		Mean =	7.58	7.82	6.45	9.72	10.55	12.69	14.20	17.18	21.50	31.02	41.58
		STD[(a)] =	1.22	1.16	5.38	2.51	1.11	2.09	1.48	2.94	4.04	9.98	16.39

[(a)] N = Number of samples: STD = Standard deviation: ND = No Data

Table B-7 (Continued). Instantaneous Thermal Expansion Coefficients for Borehole NRG-6.

Thermal/mechanical Unit TSw2: Welded, Devitrified: Vacuum saturated: Cool-down

Sample ID			Instantaneous CTE on Cool-down ($10^{-6}/^{o}C$)										
Depth (ft)	ID	Max. Temp. (°C)	300	275	250	225	200	175	150	125	100	75	50
729.2	A	300	21.05	32.93	45.84	43.94	29.39	19.52	15.96	13.40	12.17	10.84	9.76
	B	300	26.62	36.95	37.70	27.96	20.25	15.21	12.85	11.83	11.41	10.13	9.52
732.6	A	300	22.57	34.23	41.34	31.29	21.21	16.01	14.12	12.66	12.69	10.03	9.53
	C	300	24.36	38.19	38.48	28.83	20.65	15.56	14.05	12.95	11.81	10.47	9.65
777.8	A	200	ND	ND	ND	ND	14.97	13.95	13.23	10.75	9.85	9.77	8.59
788.3	A	200	ND	ND	ND	ND	14.68	13.45	12.59	10.66	10.17	10.09	9.05
802.7	A	175	21.49	33.65	34.18	23.66	18.73	14.43	13.20	12.17	11.38	9.60	8.95
806.0	A	200	22.31	32.81	37.78	27.75	19.08	15.26	14.22	12.45	11.60	9.94	9.55
	B	300	22.44	32.70	41.43	30.24	21.29	15.63	13.34	12.51	11.74	9.68	9.10
849.9	A	300	10.64	13.11	13.35	12.87	14.29	14.84	16.39	16.56	12.86	9.48	7.77
886.5	A	300	9.17	11.73	12.10	10.61	11.44	10.44	10.72	10.13	8.41	8.94	8.31
911.2	A	300	17.45	22.35	21.74	22.11	20.60	16.97	12.93	11.19	10.62	8.52	7.87
	B	300	14.22	16.52	15.41	15.82	15.63	14.55	12.53	11.31	10.83	8.83	8.33
926.3	A	300	17.80	24.68	26.94	23.95	22.50	17.73	13.22	11.42	10.74	8.75	9.13
	B	300	20.44	24.28	24.78	21.30	19.27	16.20	13.35	11.72	11.60	9.64	8.99
952.2	A	200	ND	ND	ND	ND	14.89	14.03	13.10	11.86	10.75	10.28	9.28
987.6	A	300	15.87	19.60	21.00	17.88	17.07	16.47	13.69	11.24	9.87	10.09	9.42
1016.6	A	300	13.92	18.67	19.47	15.67	16.29	13.41	12.29	10.20	9.66	9.17	8.93
1081.5	B	300	15.82	21.36	25.22	22.21	21.94	16.47	13.27	11.59	10.78	10.17	9.84
		N[(a)] =	16	16	16	16	19	19	19	19	19	19	19
		Mean =	18.51	25.86	28.55	23.50	18.64	15.27	13.42	11.93	11.00	9.70	9.03
		STD[(a)] =	4.97	8.67	11.00	8.29	4.06	1.92	1.24	1.43	1.11	0.63	0.61

Thermal/mechanical Unit TCw: Welded, Devitrified: Oven dried: Heat-up

Sample ID			Instantaneous CTE on Heat-up ($10^{-6}/^{o}C$)										
Depth (ft)	ID	Max. Temp. (°C)	50	75	100	125	150	175	200	225	250	275	300
28.8	G	350	9.30	10.43	11.90	8.52	13.89	16.13	17.43	20.30	41.89	109.5	30.78
	G	300	7.80	9.28	6.34	10.21	13.64	14.57	15.05	19.15	25.54	37.22	224.0
98.1	G	300	8.26	8.72	8.59	12.67	15.61	17.34	18.43	20.02	26.11	29.04	19.81
111.0	F	300	8.51	10.83	10.20	12.06	17.04	18.08	17.08	19.60	22.61	28.94	14.76
		N[(a)] =	4	4	4	4	4	4	4	4	4	4	4
		Mean =	8.47	9.82	9.26	10.87	15.05	16.53	17.00	19.77	29.04	51.17	72.33
		STD[(a)] =	0.63	0.98	2.37	1.88	1.59	1.53	1.42	0.51	8.70	39.06	101.3

[(a)] N = Number of samples: STD = Standard deviation: ND = No Data

Table B-7 (Continued). Instantaneous Thermal Expansion Coefficients for Borehole NRG-6.

Thermal/mechanical Unit TCw: Welded, Devitrified: Oven dried: Cool-down

Sample ID			Instantaneous CTE on Cool-down ($10^{-6}/^{o}C$)										
Depth (ft)	ID	Max. Temp. (°C)	300	275	250	225	200	175	150	125	100	75	50
28.8	G	350	11.29	15.63	32.70	47.06	26.96	16.60	13.82	9.68	8.14	7.28	6.36
28.8	G	300	14.98	27.88	39.86	71.03	27.43	21.26	15.41	9.08	7.63	7.48	8.00
98.1	G	300	10.73	15.83	22.90	23.93	22.89	19.83	16.39	14.80	12.12	10.15	9.25
111.0	F	300	11.25	14.41	25.35	24.77	21.22	19.18	17.24	14.33	12.42	11.40	9.35
		N[(a)] =	3	3	4	4	4	4	4	4	4	4	4
		Mean =	12.32	19.37	30.20	41.70	24.62	19.22	15.72	11.97	10.08	9.08	8.24
		STD[(a)] =	2.32	7.41	7.67	22.30	3.05	1.95	1.47	3.01	2.55	2.03	1.39

Thermal/mechanical Unit PTn: Nonwelded, Vitric: Oven dried: Heat-up

Sample ID			Instantaneous CTE on Heat-up ($10^{-6}/^{o}C$)										
Depth (ft)	ID	Max. Temp. (°C)	50	75	100	125	150	175	200	225	250	275	300
152.9	C	300	5.70	4.73	5.15	1.11	6.24	6.95	1.84	0.25	-0.25	-2.21	-3.80
		N[(a)] =	1	1	1	1	1	1	1	1	1	1	1
		Mean =	5.70	4.73	5.15	1.11	6.24	6.95	1.84	0.25	-0.25	-2.21	-3.80
		STD[(a)] =	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Thermal/mechanical Unit PTn: Nonwelded, Vitric: Oven dried: Cool-down

Sample ID			Instantaneous CTE on Cool-down ($10^{-6}/^{o}C$)										
Depth (ft)	ID	Max. Temp. (°C)	300	275	250	225	200	175	150	125	100	75	50
152.9	C		17.48	8.80	5.77	5.27	3.92	3.63	3.16	3.78	3.37	4.11	4.44
		N[(a)] =	1	1	1	1	1	1	1	1	1	1	1
		Mean =	17.48	8.80	5.77	5.27	3.92	3.63	3.16	3.78	3.37	4.11	4.44
		STD[(a)] =	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

[(a)] N = Number of samples: STD = Standard deviation: NA = Not Applicable

Table B-7 (Continued). Instantaneous Thermal Expansion Coefficients for Borehole NRG-6.

Thermal/mechanical Unit TSw1: Welded, Devitrified: Oven dried: Heat-up

Sample ID			Instantaneous CTE on Heat-up ($10^{-6}/^{o}C$)										
Depth (ft)	ID	Max. Temp. (^{o}C)	50	75	100	125	150	175	200	225	250	275	300
277.5	C	300	6.77	8.13	6.52	9.51	11.86	12.53	11.27	12.99	15.16	14.04	13.63
321.1	B	300	7.31	6.00	6.12	7.73	9.07	11.73	12.09	19.91	40.40	35.70	35.58
354.9	D	300	5.38	5.98	8.16	9.70	12.27	29.36	39.24	85.32	47.04	43.00	39.20
392.1	E	300	8.09	7.52	6.36	9.40	13.88	28.69	36.70	54.85	51.95	42.85	37.20
416.0	L	300	8.62	8.59	9.32	10.24	15.15	32.09	65.25	58.90	48.78	41.36	36.84
421.8	B	300	8.22	9.30	9.63	8.42	14.22	30.14	63.01	51.32	49.35	45.71	41.17
458.7	B	300	8.11	9.72	8.76	8.27	7.90	13.36	31.22	41.20	53.30	42.74	38.13
528.4	B	200	8.40	9.09	9.51	10.43	12.63	36.56	ND	ND	ND	ND	ND
648.6	B	175	8.32	8.44	9.80	10.00	15.95	ND	ND	ND	ND	ND	ND
693.1	B	225	8.28	9.20	9.35	10.14	10.40	11.62	15.98	ND	ND	ND	ND
		N[a] =	10	10	10	10	10	9	8	7	7	7	7
		Mean =	7.75	8.20	8.35	9.38	12.33	22.90	34.34	46.36	43.71	37.91	34.54
		STD[a] =	1.00	1.32	1.47	0.93	2.61	10.30	21.32	24.53	13.26	10.96	9.39

Thermal/mechanical Unit TSw1: Welded, Devitrified: Oven dried: Cool-down

Sample ID			Instantaneous CTE on Cool-down ($10^{-6}/^{o}C$)										
Depth (ft)	ID	Max. Temp. (^{o}C)	300	275	250	225	200	175	150	125	100	75	50
277.5	C	300	9.14	11.53	12.58	13.90	14.09	13.15	11.13	10.84	8.99	8.54	7.55
321.1	B	300	9.14	12.42	15.65	20.79	21.53	26.21	22.58	19.82	11.00	9.14	11.08
354.9	D	300	8.84	14.01	14.30	18.59	23.01	30.66	40.05	67.37	13.61	10.35	9.26
392.1	E	300	9.20	16.09	19.18	19.30	23.74	28.48	35.81	63.15	16.38	12.55	9.06
416.0	L	300	12.87	16.24	18.47	20.65	24.10	32.01	39.37	85.89	16.69	12.11	10.31
421.8	B	300	13.86	17.49	21.33	22.84	25.36	33.94	47.52	49.48	15.46	12.09	10.03
458.7	B	300	12.64	15.84	20.01	25.80	33.34	48.92	36.03	24.73	13.32	10.98	9.08
528.4	B	200	ND	ND	ND	ND	ND	19.85	25.73	13.71	10.62	9.45	9.04
648.6	B	175	ND	ND	ND	ND	ND	ND	13.90	18.53	15.15	9.16	8.18
693.1	B	225	ND	ND	ND	ND	15.06	12.72	12.03	10.73	9.98	9.23	8.75
		N[a] =	7	7	7	7	8	9	10	10	10	10	10
		Mean =	10.81	14.80	17.36	20.27	22.53	27.33	28.41	36.42	13.12	10.36	9.23
		STD[a] =	2.20	2.20	3.23	3.70	6.06	11.27	13.13	27.59	2.81	1.48	1.03

[a] N = Number of samples: STD = Standard deviation: ND = No Data

Table B-7 (Continued). Instantaneous Thermal Expansion Coefficients for Borehole NRG-6.

Thermal/mechanical Unit TSw2: Welded, Devitrified: Oven dried: Heat-up

Sample ID			Instantaneous CTE on Heat-up ($10^{-6}/^{o}C$)										
Depth (ft)	ID	Max. Temp. (°C)	50	75	100	125	150	175	200	225	250	275	300
777.8	B	300	8.82	9.68	9.37	8.74	12.08	11.99	15.62	21.38	31.74	49.10	55.46
788.3	B	300	9.30	9.85	9.17	8.27	12.95	11.02	15.01	19.86	29.09	51.48	53.60
789.4	A	300	7.78	8.66	9.54	7.74	10.98	9.84	13.01	16.70	20.84	33.72	58.65
802.7	B	300	6.49	8.84	7.50	7.97	10.06	10.21	12.12	15.30	18.61	26.70	45.26
849.9	B	300	7.80	8.12	7.58	6.41	7.37	8.61	7.88	10.10	11.85	10.87	12.46
886.5	B	300	7.81	8.66	7.91	8.15	11.09	9.97	13.56	15.53	18.51	25.19	32.86
900.4	A	300	8.14	8.77	8.66	8.65	10.52	9.55	12.95	17.62	25.80	46.83	74.16
	B	300	8.50	9.30	8.89	7.77	11.90	10.47	13.08	16.41	20.51	46.02	67.98
952.2	B	300	9.00	9.82	9.49	9.15	12.73	13.75	18.44	25.50	27.72	34.08	36.76
987.6	B	300	8.23	9.94	8.76	8.21	11.09	10.77	16.49	20.85	21.59	25.45	31.14
1016.6	B	300	8.58	9.00	8.75	8.44	11.10	10.70	13.66	16.03	17.09	20.00	25.59
1017.2	A	300	7.44	8.09	7.48	6.05	9.44	9.41	11.89	14.61	16.32	22.01	29.42
1081.0	A	300	7.93	9.18	8.65	8.23	11.23	11.27	15.87	19.63	22.53	30.06	38.97
1081.5	A	300	8.33	8.67	8.60	7.62	10.57	10.34	14.47	54.61	68.2	46.08	33.83
		N[a] =	14	14	14	14	14	14	14	14	14	14	14
		Mean =	8.15	9.04	8.60	7.96	10.94	10.57	13.86	20.29	25.03	33.40	42.58
		STD[a] =	0.71	0.61	0.72	0.84	1.41	1.25	2.51	10.54	13.55	12.64	17.35

[a] N = Number of samples: STD = Standard deviation

Table B-7 (Continued). Instantaneous Thermal Expansion Coefficients for Borehole NRG-6.

Thermal/mechanical Unit TSw2: Welded, Devitrified: Oven dried: Cool-down

Sample ID			Instantaneous CTE on Cool-down ($10^{-6}/^{o}C$)										
Depth (ft)	ID	Max. Temp. (°C)	300	275	250	225	200	175	150	125	100	75	50
777.8	B	300	19.67	30.23	44.85	38.09	25.56	18.08	14.93	12.67	10.36	9.43	8.43
788.3	B	300	20.31	30.51	41.73	33.40	24.28	15.56	14.12	12.28	10.29	10.61	9.10
789.4	A	300	23.43	33.59	38.93	30.38	2.32	1.71	1.61	0.74	10.73	7.72	5.05
802.7	B	300	22.20	33.24	36.39	25.65	20.06	16.93	14.00	12.58	10.98	10.79	9.60
849.9	B	300	10.46	11.30	11.62	9.87	10.90	10.75	10.32	8.91	8.16	8.19	7.37
886.5	B	300	15.88	20.88	15.92	15.65	15.65	14.10	11.72	11.21	9.82	8.17	9.03
900.4	A	300	17.48	23.97	37.83	37.09	27.56	18.56	15.70	11.80	10.37	9.13	5.64
	B	300	17.82	23.06	31.72	52.62	28.38	17.82	15.02	12.89	11.28	10.57	9.62
952.2	B	300	13.55	18.11	24.08	24.49	26.47	20.50	17.10	13.29	11.48	10.46	9.22
987.6	B	300	18.02	19.27	20.82	19.06	22.88	18.46	14.15	11.81	10.11	9.79	8.65
1016.6	B	300	16.56	18.43	18.52	15.95	16.51	14.56	12.46	11.53	9.38	9.67	8.68
1017.2	A	300	16.89	17.65	18.47	15.66	16.51	14.09	11.58	9.98	8.79	8.68	7.56
1081.0	A	300	18.98	21.31	23.70	22.46	20.97	19.67	4.74	0.35	-0.04	1.02	-0.14
1081.5	A	300	8.91	11.08	13.52	15.94	24.58	67.86	36.87	21.44	19.30	17.37	13.91
		N[a] =	14	14	14	14	14	14	14	14	14	14	14
		Mean =	17.15	22.33	27.01	25.45	20.19	19.19	13.88	10.82	10.07	9.40	7.98
		STD[a] =	4.05	7.31	11.26	11.73	7.27	14.79	7.86	5.19	3.91	3.35	3.11

[a] N = Number of samples: STD = Standard deviation

Table B-7 (Continued). Instantaneous Thermal Expansion Coefficients for Borehole NRG-6.

Thermal/mechanical Unit TCw: Welded, Devitrified: Air dried: Heat-up

Sample ID			Instantaneous CTE on Heat-up ($10^{-6}/^{o}C$)										
Depth (ft)	ID	Max. Temp. (°C)	50	75	100	125	150	175	200	225	250	275	300
28.8	G	110	4.91	5.16	10.35	ND	ND	ND	ND	ND	ND	ND	ND
98.1	G	110	8.24	8.81	11.55	ND	ND	ND	ND	ND	ND	ND	ND
111.0	G	110	8.04	7.97	10.49	ND	ND	ND	ND	ND	ND	ND	ND
		N[a] =	3	3	3	NA	NA	NA	NA	NA	NA	NA	NA
		Mean =	7.06	7.31	10.79	NA	NA	NA	NA	NA	NA	NA	NA
		STD[a] =	1.87	1.91	0.66	NA	NA	NA	NA	NA	NA	NA	NA

Thermal/mechanical Unit TCw: Welded, Devitrified: Air dried: Cool-down

Sample ID			Instantaneous CTE on Cool-down ($10^{-6}/^{o}C$)										
Depth (ft)	ID	Max. Temp. (°C)	300	275	250	225	200	175	150	125	100	75	50
28.8	G	110	ND	ND	ND	ND	ND	ND	ND	ND	9.40	8.27	8.33
98.1	G	110	ND	ND	ND	ND	ND	ND	ND	ND	10.01	10.74	8.22
111.0	G	110	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
		N[a] =	NA	NA	NA	NA	NA	NA	NA	NA	2	2	2
		Mean =	NA	NA	NA	NA	NA	NA	NA	NA	9.70	9.51	8.28
		STD[a] =	NA	NA	NA	NA	NA	NA	NA	NA	0.44	1.74	0.08

Thermal/mechanical Unit PTn: Nonwelded, Vitric: Air dried: Heat-up

Sample ID			Instantaneous CTE on Heat-up ($10^{-6}/^{o}C$)										
Depth (ft)	ID	Max. Temp. (°C)	50	75	100	125	150	175	200	225	250	275	300
152.9	C	110	5.48	1.88	-7.65	ND	ND	ND	ND	ND	ND	ND	ND
187.0	D	110	5.56	2.72	3.99	ND	ND	ND	ND	ND	ND	ND	ND
		N[a] =	2	2	2	NA	NA	NA	NA	NA	NA	NA	NA
		Mean =	5.52	2.30	-1.83	NA	NA	NA	NA	NA	NA	NA	NA
		STD[a] =	0.06	0.59	8.23	NA	NA	NA	NA	NA	NA	NA	NA

[a] N = Number of samples; STD = Standard deviation; ND = No Data; NA = Not Applicable

Table B-7 (Continued). Instantaneous Thermal Expansion Coefficients for Borehole NRG-6.

Thermal/mechanical Unit PTn: Nonwelded, Vitric: Air dried: Cool-down

Sample ID			Instantaneous CTE on Cool-down ($10^{-6}/^{\circ}C$)										
Depth (ft)	ID	Max. Temp. (°C)	300	275	250	225	200	175	150	125	100	75	50
152.9	C	110	ND	ND	ND	ND	ND	ND	ND	ND	5.90	6.42	4.75
187.0	D	110	ND	ND	ND	ND	ND	ND	ND	ND	5.98	5.40	3.81
		N[(a)] =	NA	NA	NA	NA	NA	NA	NA	NA	2	2	2
		Mean =	NA	NA	NA	NA	NA	NA	NA	NA	5.94	5.91	4.28
		STD[(a)] =	NA	NA	NA	NA	NA	NA	NA	NA	0.05	0.72	0.66

Thermal/mechanical Unit TSw1: Welded, Devitrified: Air dried: Heat-up

Sample ID			Instantaneous CTE on Heat-up ($10^{-6}/^{\circ}C$)										
Depth (ft)	ID	Max. Temp. (°C)	50	75	100	125	150	175	200	225	250	275	300
277.5	C	110	5.19	5.82	8.79	ND	ND	ND	ND	ND	ND	ND	ND
321.1	C	110	5.69	6.08	7.91	ND	ND	ND	ND	ND	ND	ND	ND
354.9	D	110	7.73	6.38	9.68	ND	ND	ND	ND	ND	ND	ND	ND
392.1	E	110	7.83	7.37	8.85	ND	ND	ND	ND	ND	ND	ND	ND
416.0	L	110	8.02	7.71	8.27	ND	ND	ND	ND	ND	ND	ND	ND
421.8	A	300	8.47	8.17	8.16	10.78	14.44	26.60	43.22	62.11	54.94	45.80	40.90
		N[(a)] =	6	6	6	1	1	1	1	1	1	1	1
		Mean =	7.16	6.92	8.61	10.78	14.44	26.60	43.22	62.11	54.94	45.80	40.90
		STD[(a)] =	1.36	0.96	0.64	NA	NA	NA	NA	NA	NA	NA	NA

Thermal/mechanical Unit TSw1: Welded, Devitrified: Air dried: Cool-down

Sample ID			Instantaneous CTE on Cool-down ($10^{-6}/^{\circ}C$)										
Depth (ft)	ID	Max. Temp. (°C)	300	275	250	225	200	175	150	125	100	75	50
277.5	C	110	ND	ND	ND	ND	ND	ND	ND	ND	7.48	8.07	7.57
321.1	C	110	ND	ND	ND	ND	ND	ND	ND	ND	6.19	7.86	5.58
354.9	D	110	ND	ND	ND	ND	ND	ND	ND	ND	7.35	7.84	6.44
392.1	E	110	ND	ND	ND	ND	ND	ND	ND	ND	6.14	5.80	5.12
416.0	L	110	ND	ND	ND	ND	ND	ND	ND	ND	9.12	9.05	7.48
421.8	A	300	10.91	13.57	16.99	16.98	20.74	32.94	37.88	43.80	12.82	8.90	8.92
		N[(a)] =	1	1	1	1	1	1	1	1	6	6	6
		Mean =	10.91	13.57	16.99	16.98	20.74	32.94	37.88	43.80	8.18	7.92	6.85
		STD[(a)] =	NA	NA	NA	NA	NA	NA	NA	NA	2.52	1.16	1.41

[(a)] N = Number of samples: STD = Standard deviation: ND = No Data: NA = Not Applicable

Table B-7 (Continued). Instantaneous Thermal Expansion Coefficients for Borehole NRG-6.

Thermal/mechanical Unit TSw2: Welded, Devitrified: Air dried: Heat-up

Sample ID			Instantaneous CTE on Heat-up ($10^{-6}/^{o}C$)										
Depth (ft)	ID	Max. Temp. (°C)	50	75	100	125	150	175	200	225	250	275	300
729.2	C	225	7.89	8.93	9.71	9.53	11.21	11.75	13.68	ND	ND	ND	ND
732.6	B	225	9.58	8.68	9.93	10.61	11.45	10.82	13.90	ND	ND	ND	ND
806.0	C	225	8.92	9.07	10.63	9.45	11.40	10.85	14.72	ND	ND	ND	ND
911.2	C	175	7.31	8.61	8.25	8.53	9.93	ND	ND	ND	ND	ND	ND
926.3	C	175	9.02	9.06	9.01	8.78	10.53	ND	ND	ND	ND	ND	ND
		N[a] =	5	5	5	5	5	3	3	NA	NA	NA	NA
		Mean =	8.54	8.87	9.51	9.38	10.90	11.14	14.10	NA	NA	NA	NA
		STD[a] =	0.92	0.22	0.91	0.81	0.66	0.53	0.55	NA	NA	NA	NA

Thermal/mechanical Unit TSw2: Welded, Devitrified: Air dried: Cool-down

Sample ID			Instantaneous CTE on Cool-down ($10^{-6}/^{o}C$)										
Depth (ft)	ID	Max. Temp. (°C)	300	275	250	225	200	175	150	125	100	75	50
729.2	C	225	ND	ND	ND	ND	12.85	13.33	11.00	10.62	10.02	9.58	8.87
732.6	B	225	ND	ND	ND	ND	13.36	11.68	11.34	10.84	10.30	8.73	8.60
806.0	C	225	ND	ND	ND	ND	13.98	12.92	11.77	11.15	10.10	9.81	8.88
911.2	C	175	ND	ND	ND	ND	ND	ND	9.76	9.55	9.74	8.44	8.37
926.3	C	175	ND	ND	ND	ND	ND	ND	11.44	10.92	9.82	10.17	9.07
		N[a] =	NA	NA	NA	NA	3	3	5	5	5	5	5
		Mean =	NA	NA	NA	NA	13.39	12.64	11.06	10.62	10.00	9.34	8.76
		STD[a] =	NA	NA	NA	NA	0.56	0.86	0.78	0.62	0.22	0.73	0.27

[a] N = Number of samples: STD = Standard deviation: ND = No Data: NA = Not Applicable

Table B-8. Instantaneous Thermal Expansion Coefficients for Borehole NRG-7.

Thermal/mechanical Unit TCw: Welded, Devitrified: Air dried: Heat-up

Sample ID			Instantaneous CTE on Heat-up ($10^{-6}/^{o}C$)										
Depth (ft)	ID	Max. Temp. (°C)	50	75	100	125	150	175	200	225	250	275	300
18.6	A	300	9.10	8.00	9.71	10.49	12.50	14.29	17.41	19.90	23.79	39.31	81.37
27.3	A	300	8.38	8.34	9.95	11.31	13.94	15.62	18.40	21.11	21.96	27.73	34.76
56.8	A	300	7.71	6.64	7.96	9.54	11.37	12.38	14.57	17.87	21.92	62.82	37.48
		N[(a)] =	3	3	3	3	3	3	3	3	3	3	3
		Mean =	8.40	7.66	9.21	10.44	12.61	14.10	16.80	19.63	22.56	43.29	51.21
		STD[(a)] =	0.69	0.90	1.08	0.88	1.29	1.63	1.99	1.64	1.07	17.88	26.16

Thermal/mechanical Unit TCw: Welded, Devitrified: Air dried: Cool-down

Sample ID			Instantaneous CTE on Cool-down ($10^{-6}/^{o}C$)										
Depth (ft)	ID	Max. Temp. (°C)	300	275	250	225	200	175	150	125	100	75	50
18.6	A	300	17.52	29.74	40.03	44.63	34.22	22.54	17.42	14.98	11.87	10.89	9.96
27.3	A	300	16.57	23.24	26.46	26.62	24.30	19.92	16.36	13.36	11.64	9.85	8.97
56.8	A	300	13.40	22.24	51.73	29.31	22.05	15.93	14.10	12.15	10.60	9.13	8.39
		N[(a)] =	3	3	3	3	3	3	3	3	3	3	3
		Mean =	15.83	25.07	39.41	33.52	26.86	19.46	15.96	13.49	11.37	9.96	9.11
		STD[(a)] =	2.16	4.07	12.65	9.72	6.47	3.33	1.69	1.42	0.68	0.89	0.79

[(a)] N = Number of samples: STD = Standard deviation

Table B-8 (Continued). Instantaneous Thermal Expansion Coefficients for Borehole NRG-7.

Thermal/mechanical Unit PTn: Nonwelded, Vitric: Air dried: Heat-up

Sample ID			Instantaneous CTE on Heat-up ($10^{-6}/^{o}C$)										
Depth (ft)	ID	Max. Temp. (°C)	50	75	100	125	150	175	200	225	250	275	300
75.0	B	300	7.12	5.41	4.28	7.4	9.34	5.69	0.11	-5.56	-8.31	-9.42	-9.61
91.6	A	300	4.66	4.01	4.46	5.31	6.68	5.64	5.58	5.50	4.54	3.29	-0.49
104.1	A	300	4.45	1.56	-1.19	5.31	5.49	4.49	6.22	6.39	6.82	5.57	1.79
113.1	A	300	4.98	4.52	5.77	6.03	6.72	5.52	5.34	5.79	5.08	3.42	0.58
120.9	A	300	5.39	5.18	5.31	6.49	6.23	5.46	1.20	-2.59	-7.53	-6.61	-5.21
181.7	A	300	2.82	2.85	3.28	6.31	6.52	3.14	-4.77	-15.0	-23.5	-25.6	-23.8
248.5	A	300	4.09	2.31	3.28	5.8	5.91	2.77	-4.63	-13.4	-20.2	-25.4	-22.7
293.3	A	300	6.42	6.23	6.49	6.78	8.31	7.84	4.71	-0.75	-6.7	-13.6	-26.1
		N[(a)] =	8	8	8	8	8	8	8	8	8	8	8
		Mean =	4.99	4.01	3.96	6.19	6.90	5.07	1.72	-2.46	-6.22	-8.54	-10.7
		STD[(a)] =	1.34	1.63	2.37	0.73	1.29	1.61	4.51	8.46	11.42	12.46	11.79

Thermal/mechanical Unit PTn: Nonwelded, Vitric: Air dried: Cool-down

Sample ID			Instantaneous CTE on Cool-down ($10^{-6}/^{o}C$)										
Depth (ft)	ID	Max. Temp. (°C)	300	275	250	225	200	175	150	125	100	75	50
75.0	B	300	12.49	8.92	8.37	7.32	7.39	8.05	8.89	8.16	8.27	6.51	5.85
91.6	A	300	11.30	7.66	7.09	6.85	6.04	4.85	5.74	5.80	5.36	4.84	4.25
104.1	A	300	8.24	8.30	8.16	6.31	6.66	6.37	6.19	5.10	5.01	3.69	2.07
113.1	A	300	11.21	8.71	7.76	7.08	5.86	6.36	5.55	5.39	5.63	5.10	4.70
120.9	A	300	20.32	10.47	8.18	6.36	6.51	6.08	5.84	4.71	5.40	4.53	5.10
181.7	A	300	10.96	7.84	7.26	6.25	6.20	6.29	5.90	4.57	5.25	4.55	3.96
248.5	A	300	11.76	8.85	6.67	6.49	5.53	5.78	5.52	5.39	4.87	4.37	3.83
293.3	A	300	17.41	11.02	7.91	7.64	7.39	9.09	8.23	6.82	6.81	6.39	5.48
		N[(a)] =	8	8	8	8	8	8	8	8	8	8	8
		Mean =	12.96	8.97	7.68	6.79	6.45	6.61	6.48	5.74	5.82	5.00	4.41
		STD[(a)] =	3.92	1.19	0.60	0.52	0.68	1.34	1.31	1.20	1.15	0.98	1.18

[(a)] N = Number of samples: STD = Standard deviation

Table B-8 (Continued). Instantaneous Thermal Expansion Coefficients for Borehole NRG-7.

Thermal/mechanical Unit TSw1: Welded, Devitrified: Air dried: Heat-up

Sample ID			Instantaneous CTE on Heat-up ($10^{-6}/^{o}C$)										
Depth (ft)	ID	Max. Temp. (°C)	50	75	100	125	150	175	200	225	250	275	300
329.2	A	300	7.55	7.54	7.89	8.5	11.56	12.89	13.64	18.07	22.45	25.43	27.97
359.1	A	300	6.20	6.43	6.44	7.20	8.50	12.39	14.73	16.88	18.13	19.10	19.33
378.9	A	300	6.69	6.88	7.29	8.73	9.04	13.86	16.72	23.81	35.76	40.18	36.77
496.3	A	300	9.16	9.06	10.03	11.97	14.33	31.92	46.60	48.82	42.02	46.78	41.20
550.9	A	300	7.81	8.41	10.07	10.35	12.73	25.83	35.88	49.03	40.17	43.84	53.30
606.4	A	300	8.08	8.51	8.51	9.37	10.80	14.97	22.90	28.40	29.37	29.71	37.59
608.1	A	300	8.74	8.72	9.75	9.44	11.52	20.34	34.63	38.73	34.98	32.01	38.38
625.7	A	300	8.32	7.79	9.45	10.26	11.11	12.11	23.74	29.09	50.46	84.01	40.48
641.0	A	300	8.55	7.75	9.65	10.14	10.55	13.11	22.61	31.23	35.57	57.94	75.41
699.0	A	300	7.04	7.26	7.78	9.31	10.09	11.70	13.21	14.40	17.46	21.39	29.28
		N[a] =	10	10	10	10	10	10	10	10	10	10	10
		Mean =	7.81	7.84	8.69	9.53	11.02	16.91	24.47	29.84	32.64	40.04	39.97
		STD[a] =	0.95	0.84	1.29	1.28	1.69	6.92	11.20	12.44	10.76	19.68	15.41

Thermal/mechanical Unit TSw1: Welded, Devitrified: Air dried: Cool-down

Sample ID			Instantaneous CTE on Cool-down ($10^{-6}/^{o}C$)										
Depth (ft)	ID	Max. Temp. (°C)	300	275	250	225	200	175	150	125	100	75	50
329.2	A	300	12.65	16.30	18.90	20.37	19.16	18.26	16.28	14.61	9.51	8.90	7.18
359.1	A	300	12.16	13.50	15.36	14.82	15.67	14.76	15.52	12.19	8.36	7.39	6.54
378.9	A	300	13.01	16.20	17.59	19.32	21.71	23.16	24.82	24.13	11.64	8.71	7.84
496.3	A	300	14.81	20.31	25.67	26.34	30.98	44.13	40.93	41.69	17.33	13.91	11.11
550.9	A	300	15.11	19.80	26.69	28.68	37.79	46.47	28.09	17.36	12.60	10.86	9.71
606.4	A	300	18.01	21.93	22.61	22.65	26.11	30.27	21.75	16.24	11.59	10.36	8.78
608.1	A	300	16.80	20.81	21.66	23.49	32.32	33.06	28.07	19.71	12.81	10.32	9.03
625.7	A	300	18.42	29.86	59.92	50.67	34.73	23.54	15.38	13.53	11.23	10.36	9.37
641.0	A	300	18.06	28.77	43.84	45.43	37.73	30.30	18.91	13.78	12.31	10.58	9.79
699.0	A	300	15.45	18.84	19.50	17.46	16.72	13.81	12.90	11.44	10.33	8.77	7.93
		N[a] =	10	10	10	10	10	10	10	10	10	10	10
		Mean =	15.45	20.63	27.17	26.92	27.29	27.77	22.26	18.47	11.77	10.02	8.73
		STD[a] =	2.34	5.23	13.99	11.91	8.56	11.31	8.50	9.00	2.41	1.76	1.37

[a] N = Number of samples: STD = Standard deviation

Table B-8 (Continued). Instantaneous Thermal Expansion Coefficients for Borehole NRG-7.

Thermal/mechanical Unit TSw2: Welded, Devitrified: Air dried: Heat-up

Sample ID			Mean CTE on Heat-up ($10^{-6}/^{o}C$)										
Depth (ft)	ID	Max. Temp. (°C)	50	75	100	125	150	175	200	225	250	275	300
856.5	A	300	7.46	6.47	8.81	9.21	10.31	12.14	14.45	20.29	23.77	34.26	32.78
867.8	A	300	7.97	8.74	9.82	9.26	9.63	10.17	11.10	16.24	19.64	33.62	56.98
956.6	A	300	8.27	8.38	9.65	9.18	9.32	10.96	12.23	13.60	18.16	21.30	29.18
979.2	A	300	8.36	8.81	9.47	9.86	10.75	11.92	17.50	19.62	22.10	27.04	35.63
1187.4	A	300	7.94	8.46	8.11	8.35	9.54	9.83	11.52	13.67	16.05	21.06	26.40
1261.8	A	300	6.05	7.65	8.32	9.23	9.49	10.07	11.04	12.33	15.74	13.50	17.12
1269.9	A	300	8.24	7.38	9.82	9.05	9.05	9.17	10.64	11.69	12.57	14.77	18.65
1305.7	A	300	8.02	8.45	9.03	8.85	10.10	9.34	13.04	12.03	14.13	18.26	23.82
1364.6	A	300	8.97	7.74	8.01	9.82	9.95	10.98	12.37	13.54	17.15	19.74	26.16
1407.4	A	300	7.80	9.48	10.53	12.57	15.06	15.90	15.60	16.01	13.77	12.13	11.50
		N[a] =	10	10	10	10	10	10	10	10	10	10	10
		Mean =	7.91	8.16	9.16	9.54	10.32	11.05	12.95	14.90	17.31	21.57	27.82
		STD[a] =	0.76	0.86	0.84	1.15	1.74	1.98	2.24	3.07	3.65	7.83	12.58

Thermal/mechanical Unit TSw2: Welded, Devitrified: Air dried: Cool-down

Sample ID			Mean CTE on Cool-down ($10^{-6}/^{o}C$)										
Depth (ft)	ID	Max. Temp. (°C)	300	275	250	225	200	175	150	125	100	75	50
856.5	A	300	17.88	25.47	26.24	23.11	20.89	15.15	12.49	11.76	10.37	9.60	8.98
867.8	A	300	22.70	34.84	36.18	27.23	19.40	13.69	12.66	11.84	10.35	9.91	9.16
956.6	A	300	14.41	19.25	20.01	18.37	16.11	13.28	11.26	10.29	8.74	8.97	8.19
979.2	A	300	17.07	21.27	21.73	21.67	21.78	19.16	15.05	12.82	10.71	10.11	9.18
1187.4	A	300	14.13	15.49	18.02	18.92	15.68	12.58	11.64	10.44	9.43	8.70	7.96
1261.8	A	300	13.64	13.63	12.40	15.35	13.46	12.67	11.92	11.32	9.71	9.12	8.70
1269.9	A	300	12.83	15.30	13.62	13.51	13.33	11.00	10.83	9.97	9.18	8.55	7.76
1305.7	A	300	14.26	17.92	17.39	15.59	15.31	11.74	11.46	10.50	9.57	9.02	8.39
1364.6	A	300	16.42	18.59	18.06	17.45	16.24	12.88	11.40	10.44	9.72	8.66	7.83
1407.4	A	300	9.66	11.39	12.36	14.19	17.90	17.38	18.08	15.57	12.93	10.75	9.12
		N[a] =	10	10	10	10	10	10	10	10	10	10	10
		Mean =	15.30	19.32	19.60	18.54	17.01	13.95	12.68	11.49	10.07	9.34	8.53
		STD[a] =	3.49	6.76	7.25	4.35	2.92	2.56	2.24	1.68	1.17	0.73	0.57

[a] N = Number of samples; STD = Standard deviation

APPENDIX C

Summary of Thermal Capacitance Test Results

This page intentionally left blank

Table of Thermal Capacitance (ρCp) for Borehole NRG-4

Sample ID					Test Conditions		Thermal Capacitance (J/cm³-K)														
No	Depth (ft)	ID	T/M Unit	Lith	Testing State	Max Temp (°C)	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
1	545.0	B	TSw1	WD	Air-dried	300	1.537	1.554	1.573	1.593	1.614	1.636	1.658	1.681	1.704	1.727	1.751	1.774	1.797	1.820	1.842
2	619.9	C	TSw1	WD	Air-dried	300	1.626	1.647	1.669	1.690	1.712	1.733	1.755	1.777	1.799	1.821	1.843	1.865	1.887	1.910	1.932
3	619.9	D	TSw1	WD	Air-dried	300	1.588	1.605	1.624	1.643	1.662	1.683	1.704	1.726	1.748	1.772	1.795	1.820	1.845	1.871	1.897
						N =	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
						Mean =	1.583	1.602	1.622	1.642	1.663	1.684	1.706	1.728	1.750	1.773	1.796	1.820	1.843	1.867	1.890
						Sample Std. Dev. =	0.045	0.046	0.048	0.048	0.049	0.049	0.049	0.048	0.048	0.047	0.046	0.046	0.045	0.045	0.045

Sample ID					Test Conditions		Thermal Capacitance (J/cm³-K)														
No	Depth (ft)	ID	T/M Unit	Lith	Testing State	Max Temp (°C)	100	105	110	115	120	125	130	135	140	145	150	155	160	165	170
1	545.0	B	TSw1	WD	Air-dried	300	1.864	1.885	1.905	1.924	1.942	1.958	1.973	1.986	1.998	2.008	2.015	2.021	2.024	2.025	2.025
2	619.9	C	TSw1	WD	Air-dried	300	1.955	1.977	2.000	2.022	2.045	2.068	2.091	2.114	2.137	2.160	2.178	2.169	2.159	2.149	2.140
3	619.9	D	TSw1	WD	Air-dried	300	1.924	1.952	1.980	2.009	2.038	2.068	2.098	2.129	2.161	2.193	2.225	2.280	2.265	2.251	2.237
						N =	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
						Mean =	1.914	1.938	1.961	1.985	2.008	2.031	2.054	2.077	2.099	2.120	2.140	2.157	2.149	2.142	2.134
						Sample Std. Dev. =	0.046	0.048	0.050	0.053	0.058	0.063	0.070	0.079	0.088	0.099	0.110	0.130	0.121	0.113	0.106

Sample ID					Test Conditions		Thermal Capacitance (J/cm³-K)														
No	Depth (ft)	ID	T/M Unit	Lith	Testing State	Max Temp (°C)	175	180	185	190	195	200	205	210	215	220	225	230	235	240	245
1	545.0	B	TSw1	WD	Air-dried	300	2.025	2.024	2.024	2.023	2.022	2.022	2.021	2.020	2.020	2.019	2.018	2.017	2.016	2.016	2.015
2	619.9	C	TSw1	WD	Air-dried	300	2.131	2.122	2.114	2.106	2.098	2.090	2.082	2.075	2.068	2.061	2.054	2.048	2.042	2.036	2.030
3	619.9	D	TSw1	WD	Air-dried	300	2.224	2.212	2.200	2.189	2.178	2.168	2.159	2.150	2.142	2.134	2.127	2.121	2.115	2.109	2.105
						N =	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
						Mean =	2.127	2.119	2.113	2.106	2.099	2.093	2.087	2.082	2.076	2.071	2.066	2.062	2.058	2.054	2.050
						Sample Std. Dev. =	0.100	0.094	0.088	0.083	0.078	0.073	0.069	0.065	0.061	0.058	0.055	0.053	0.051	0.049	0.048

Table of Thermal Capacitance (ρCp) for Borehole NRG-4 (Continued)

Sample ID					Test Conditions		Thermal Capacitance (J/cm^3-K)										
No	Depth (ft)	ID	T/M Unit	Lith	Testing State	Max Temp (°C)	250	255	260	265	270	275	280	285	290	295	300
1	545.0	B	TSw1	WD	Air-dried	300	2.014	2.013	2.012	2.011	2.010	2.009	2.008	2.007	2.006	2.004	2.003
2	619.9	C	TSw1	WD	Air-dried	300	2.025	2.019	2.014	2.010	2.005	2.001	1.997	1.993	1.990	1.986	1.983
3	619.9	D	TSw1	WD	Air-dried	300	2.101	2.098	2.095	2.093	2.091	2.090	2.090	2.090	2.091	2.092	2.094
						N =	3	3	3	3	3	3	3	3	3	3	3
						Mean =	2.046	2.043	2.040	2.038	2.035	2.033	2.031	2.030	2.029	2.028	2.027
						Sample Std. Dev. =	0.047	0.047	0.047	0.047	0.048	0.049	0.051	0.052	0.054	0.057	0.059

Table of Thermal Capacitance (ρCp) for Borehole NRG-5

Sample ID					Test Conditions		Thermal Capacitance (J/cm^3-K)														
No	Depth (ft)	ID	T/M Unit	Lith	Testing State	Max Temp (°C)	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
1	808.5	C	TSw2	WD	Air-dried	300	1.856	1.864	1.875	1.891	1.910	1.932	1.957	1.985	2.014	2.046	2.080	2.115	2.151	2.189	2.226
2	828.2	C	TSw2	WD	Air-dried	300	1.898	1.913	1.929	1.947	1.966	1.986	2.008	2.032	2.056	2.083	2.110	2.139	2.169	2.200	2.232
3	834.8	E	TSw2	WD	Air-dried	300	1.778	1.797	1.814	1.831	1.849	1.867	1.887	1.909	1.932	1.958	1.986	2.016	2.048	2.082	2.117
4	843.5	D	TSw2	WD	Air-dried	300	1.914	1.930	1.948	1.968	1.988	2.009	2.032	2.055	2.080	2.105	2.131	2.157	2.184	2.212	2.240
5	844.0	C	TSw2	WD	Air-dried	300	1.740	1.758	1.777	1.796	1.816	1.837	1.858	1.881	1.904	1.928	1.952	1.977	2.003	2.030	2.058
6	864.0	C	TSw2	WD	Air-dried	300	1.710	1.726	1.742	1.760	1.779	1.799	1.821	1.846	1.872	1.899	1.929	1.961	1.994	2.028	2.062
7	866.7	C	TSw2	WD	Air-dried	300	1.609	1.623	1.639	1.657	1.677	1.698	1.721	1.745	1.771	1.799	1.828	1.858	1.889	1.921	1.953
						N =	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
						Mean =	1.786	1.802	1.818	1.836	1.855	1.876	1.898	1.922	1.947	1.974	2.002	2.032	2.063	2.094	2.127
						Sample Std. Dev. =	0.110	0.110	0.110	0.110	0.110	0.110	0.110	0.110	0.110	0.110	0.110	0.110	0.110	0.110	0.110

Sample ID					Test Conditions		Thermal Capacitance (J/cm^3-K)														
No	Depth (ft)	ID	T/M Unit	Lith	Testing State	Max Temp (°C)	100	105	110	115	120	125	130	135	140	145	150	155	160	165	170
1	808.5	C	TSw2	WD	Air-dried	300	2.264	2.302	2.340	2.378	2.414	2.449	2.483	2.516	2.546	2.574	2.600	2.623	2.642	2.659	2.671
2	828.2	C	TSw2	WD	Air-dried	300	2.264	2.296	2.329	2.361	2.393	2.425	2.455	2.483	2.510	2.534	2.556	2.575	2.589	2.600	2.606
3	834.8	E	TSw2	WD	Air-dried	300	2.154	2.191	2.228	2.264	2.299	2.331	2.360	2.384	2.403	2.415	2.418	2.411	2.402	2.398	2.394
4	843.5	D	TSw2	WD	Air-dried	300	2.269	2.298	2.328	2.358	2.388	2.418	2.449	2.480	2.511	2.543	2.574	2.606	2.638	2.670	2.655
5	844.0	C	TSw2	WD	Air-dried	300	2.086	2.115	2.145	2.175	2.206	2.238	2.271	2.304	2.339	2.374	2.387	2.379	2.372	2.365	2.359
6	864.0	C	TSw2	WD	Air-dried	300	2.098	2.133	2.167	2.200	2.231	2.260	2.285	2.305	2.320	2.329	2.330	2.323	2.306	2.293	2.285
7	866.7	C	TSw2	WD	Air-dried	300	1.986	2.020	2.053	2.085	2.117	2.148	2.178	2.206	2.232	2.255	2.275	2.292	2.244	2.214	2.191
						N =	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
						Mean =	2.160	2.194	2.227	2.260	2.293	2.324	2.354	2.383	2.409	2.432	2.449	2.458	2.456	2.457	2.452
						Sample Std. Dev. =	0.110	0.111	0.111	0.112	0.112	0.113	0.114	0.116	0.118	0.122	0.128	0.140	0.165	0.185	0.192

Table of Thermal Capacitance (ρCp) for Borehole NRG-5 (Continued)

Sample ID					Test Conditions		Thermal Capacitance (J/cm³-K)														
No	Depth (ft)	ID	T/M Unit	Lith	Testing State	Max Temp (°C)	175	180	185	190	195	200	205	210	215	220	225	230	235	240	245
1	808.5	C	TSw2	WD	Air-dried	300	2.620	2.592	2.570	2.552	2.538	2.528	2.522	2.518	2.518	2.520	2.523	2.529	2.535	2.543	2.551
2	828.2	C	TSw2	WD	Air-dried	300	2.608	2.600	2.591	2.584	2.577	2.571	2.565	2.560	2.556	2.552	2.549	2.547	2.545	2.544	2.544
3	834.8	E	TSw2	WD	Air-dried	300	2.392	2.390	2.390	2.389	2.389	2.389	2.389	2.389	2.389	2.389	2.388	2.387	2.387	2.386	2.386
4	843.5	D	TSw2	WD	Air-dried	300	2.615	2.588	2.569	2.559	2.554	2.555	2.558	2.564	2.572	2.580	2.587	2.594	2.601	2.606	2.611
5	844.0	C	TSw2	WD	Air-dried	300	2.352	2.347	2.341	2.336	2.331	2.327	2.322	2.319	2.315	2.312	2.309	2.307	2.305	2.303	2.301
6	864.0	C	TSw2	WD	Air-dried	300	2.279	2.273	2.268	2.264	2.260	2.256	2.253	2.250	2.247	2.244	2.241	2.238	2.235	2.232	2.229
7	866.7	C	TSw2	WD	Air-dried	300	2.175	2.163	2.155	2.150	2.147	2.146	2.145	2.145	2.144	2.143	2.140	2.136	2.131	2.124	2.116
						N =	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
						Mean =	2.434	2.422	2.412	2.405	2.400	2.396	2.394	2.392	2.391	2.391	2.391	2.391	2.391	2.391	2.391
						Sample Std. Dev. =	0.182	0.175	0.170	0.167	0.165	0.163	0.163	0.164	0.165	0.167	0.170	0.173	0.177	0.181	0.186

Sample ID					Test Conditions		Thermal Capacitance (J/cm³-K)										
No	Depth (ft)	ID	T/M Unit	Lith	Testing State	Max Temp (°C)	250	255	260	265	270	275	280	285	290	295	300
1	808.5	C	TSw2	WD	Air-dried	300	2.559	2.567	2.574	2.581	2.586	2.589	2.590	2.589	2.585	2.578	2.568
2	828.2	C	TSw2	WD	Air-dried	300	2.544	2.545	2.546	2.549	2.551	2.555	2.559	2.564	2.570	2.576	2.583
3	834.8	E	TSw2	WD	Air-dried	300	2.386	2.387	2.389	2.392	2.396	2.402	2.410	2.421	2.435	2.452	2.473
4	843.5	D	TSw2	WD	Air-dried	300	2.615	2.619	2.623	2.628	2.635	2.646	2.661	2.681	2.709	2.747	2.795
5	844.0	C	TSw2	WD	Air-dried	300	2.300	2.300	2.299	2.299	2.299	2.300	2.301	2.302	2.304	2.306	2.308
6	864.0	C	TSw2	WD	Air-dried	300	2.227	2.224	2.221	2.219	2.217	2.215	2.214	2.214	2.214	2.215	2.218
7	866.7	C	TSw2	WD	Air-dried	300	2.106	2.096	2.085	2.073	2.062	2.051	2.041	2.034	2.030	2.029	2.034
						N =	7	7	7	7	7	7	7	7	7	7	7
						Mean =	2.391	2.391	2.391	2.391	2.392	2.394	2.397	2.401	2.407	2.415	2.425
						Sample Std. Dev. =	0.191	0.196	0.201	0.207	0.212	0.218	0.224	0.231	0.238	0.246	0.256

APPENDIX D

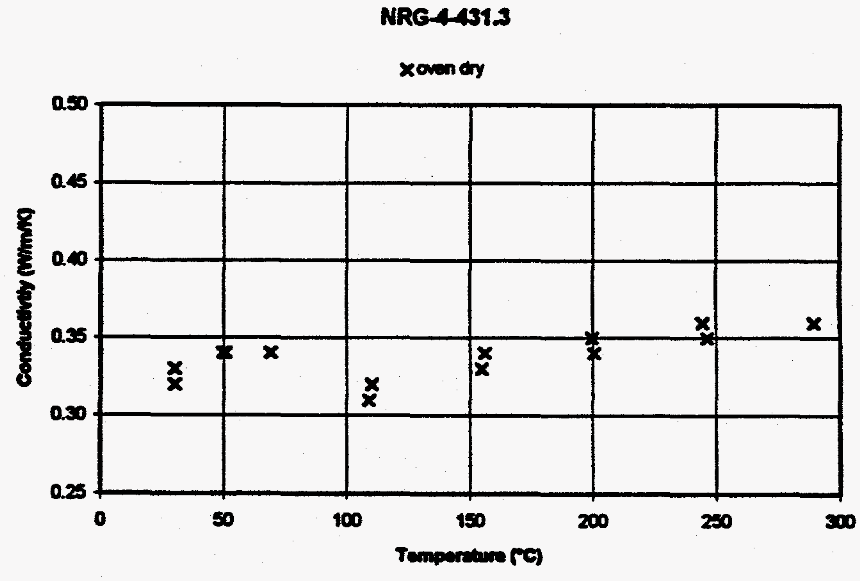
Thermal Conductivity Test Data

This page intentionally left blank

Data Summary

Hole & Depth NRG-4-431.3
Lithology: Vitric Nonwelded
TMU: PTn

Sample ID	Saturation (%)	Weight (g) pre-test	Weight (g) post-test	Weight (g) average	Density (g/cc)	Temperature (°C)	Conductivity (W/(mK))
NRG-4-431.3-SNL-B	oven dry	27.970	27.969	27.970	1.10	30.2	0.32
						49.8	0.34
						69.2	0.34
						50.8	*0.34*
						30.2	*0.33*
NRG-4-431.3-SNL-B	oven dry	27.958	27.411	27.685	1.09	110.2	0.32
						156.0	0.34
						199.7	0.35
						244.5	0.36
						289.4	0.36
						246.4	*0.35*
						200.6	*0.34*
						154.8	*0.33*
						109.2	*0.31*

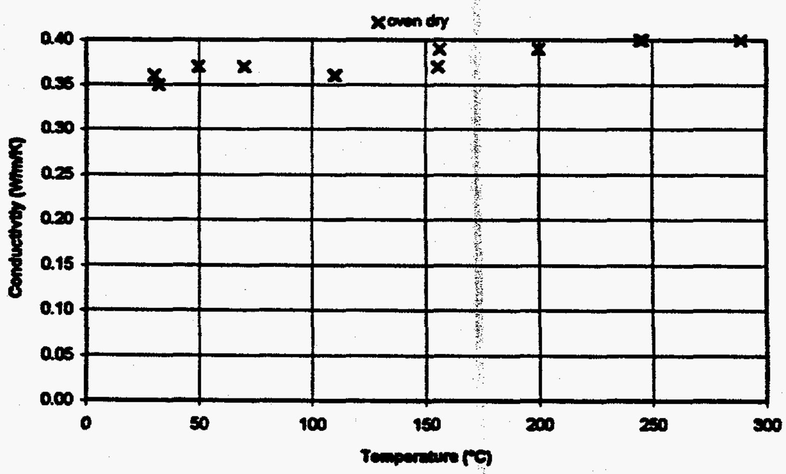


Data Summary

Hole & Depth	NRG-4-450.6
Lithology:	Vitric Nonwelded
TMU:	PTn

Sample ID	Saturation (%)	Weight (g) pre-test	Weight (g) post-test	Weight (g) average	Density (g/cc)	Temperature (°C)	Conductivity (W/(mK))
						32.0	0.35
NRG-4-450.6-SNL-B	oven dry	29.454	29.454	29.454	1.13	49.7	0.37
						70.0	0.37
						49.6	*0.37*
						29.9	*0.36*
						110.3	0.36
NRG-4-450.6-SNL-B	oven dry	29.414	28.792	29.103	1.12	156.1	0.39
						199.8	0.39
						244.7	0.40
						288.8	0.40
						245.8	*0.40*
						200.1	*0.39*
						155.3	*0.37*
						109.5	*0.36*

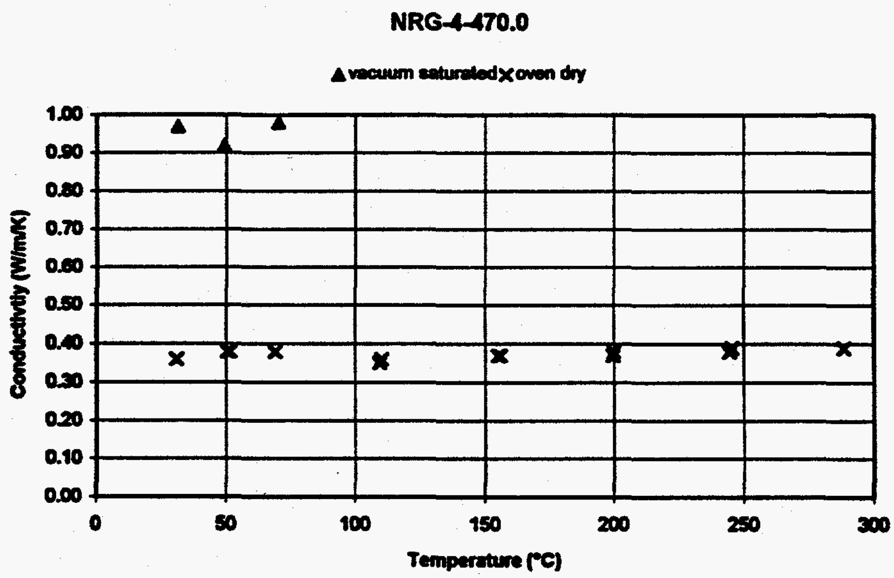
NRG-4-431.3



Data Summary

0	Hole & Depth	NRG-4-470.0
	Lithology:	Vitric Nonwelded
	TMU:	PTn

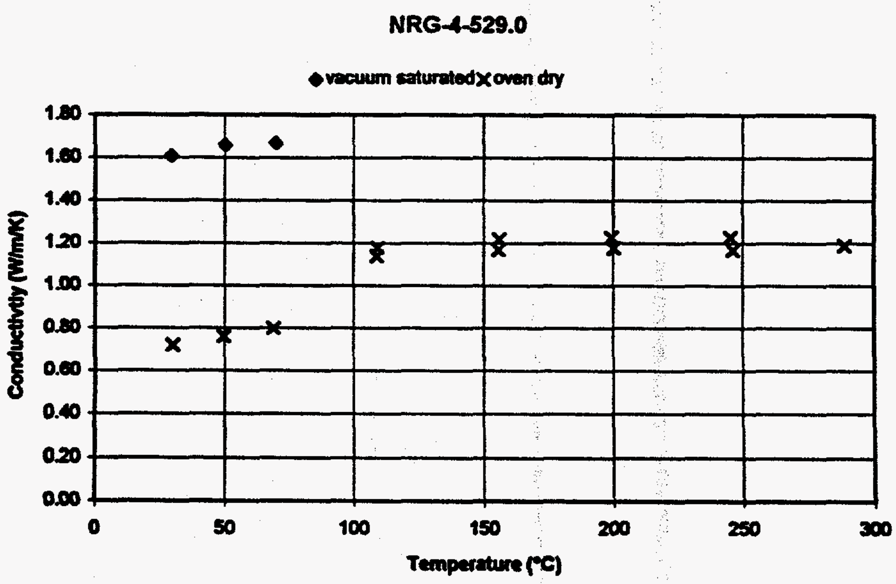
Sample ID		Weight (g)			Density	Temperature	Conductivity
	Saturation (%)	pre-test	post-test	average	(g/cc)	(°C)	(W/(mK))
NRG-4-470.0-SNL-A	vacuum sat.	43.745	43.340	43.543	1.70	31.3	0.97
						49.4	0.92
						70.4	0.98
NRG-4-470.0-SNL-B	oven dry	33.410	33.405	33.408	1.29	30.9	0.36
						50.6	0.38
						69.0	0.38
						51.6	*0.38*
						31.0	*0.36*
NRG-4-470.0-SNL-B	oven dry	33.305	32.019	32.662	1.26	110.3	0.36
						156.1	0.37
						199.8	0.37
						244.6	0.38
						288.6	0.39
						245.6	*0.39*
						199.9	*0.38*
						155.2	*0.37*
						109.4	*0.35*



Data Summary

0 Hole & Depth NRG-4-529.0
Lithology: Welded Devitrified
TMU: TSw1

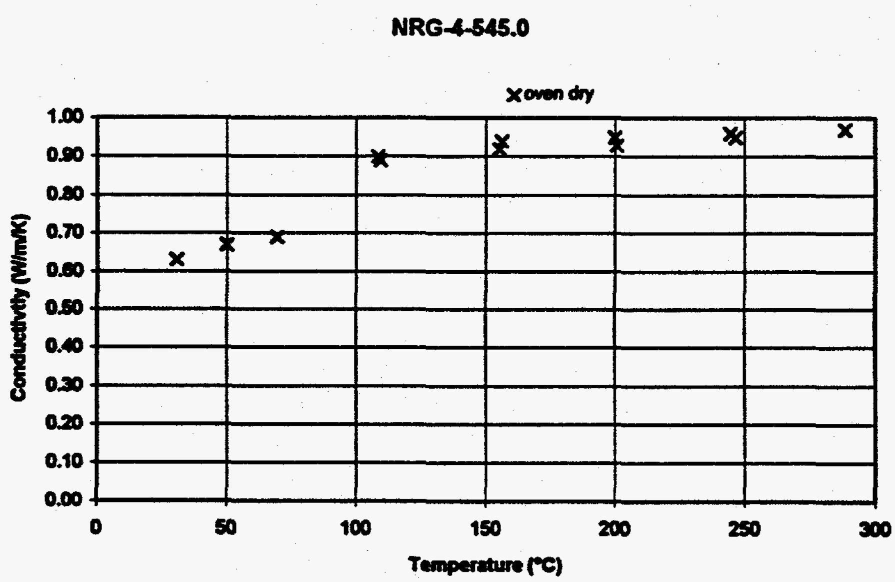
Sample ID	Saturation (%)	Weight (g) pre-test	Weight (g) post-test	Weight (g) average	Density (g/cc)	Temperature (°C)	Conductivity (W/(mK))
NRG-4-529.0-SNL-A	vacuum sat.	57.514	57.346	57.430	2.22	29.3	1.61
						50.4	1.66
						70.1	1.67
NRG-4-529.0-SNL-B	oven dry	54.264	54.262	54.263	2.12	30.2	0.72
						49.8	0.76
						69.1	0.80
NRG-4-529.0-SNL-B	oven dry	54.246	54.175	54.211	2.12	109.1	1.18
						155.9	1.22
						199.4	1.23
						245.1	1.23
						288.8	1.19
						246.1	*1.17*
						200.3	*1.18*
						155.7	*1.17*
						109.0	*1.14*



Data Summary

0	Hole & Depth	NRG-4-545.0
	Lithology:	Welded Devitrified
	TMU:	TSw1

Sample ID	Saturation (%)	Weight (g) pre-test	Weight (g) post-test	Weight (g) average	Density (g/cc)	Temperature (°C)	Conductivity (W/(mK))
						30.5	0.63
NRG-4-545.0-SNL-G	oven dry	51.515	51.517	51.516	1.96	50.0	0.67
						69.3	0.69
						108.5	0.90
NRG-4-545.0-SNL-G	oven dry	51.511	51.478	51.495	1.97	156.3	0.94
						199.9	0.95
						244.6	0.96
						288.5	0.97
						246.5	*0.95*
						200.7	*0.93*
						155.2	*0.92*
						109.4	*0.89*

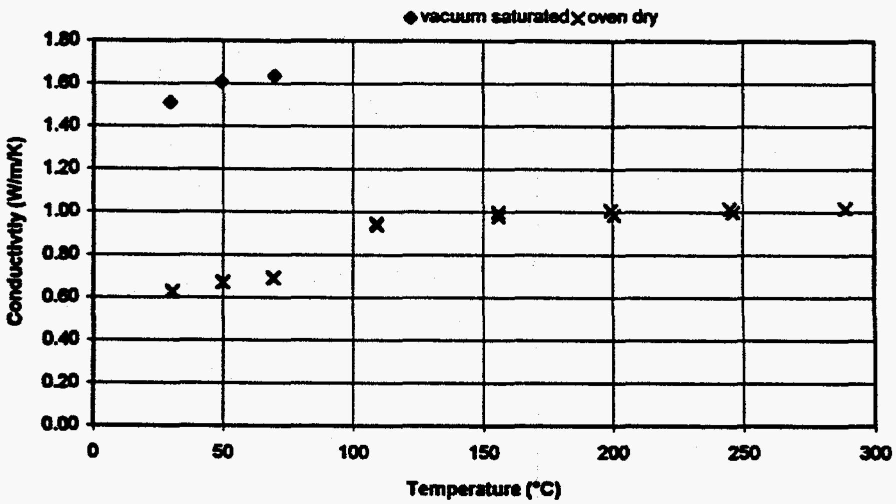


Data Summary

0	Hole & Depth	NRG-4-586.2
	Lithology:	Welded Devitrified
	TMU:	TSw1

Sample ID	Saturation (%)	Weight (g) pre-test	post-test	average	Density (g/cc)	Temperature (°C)	Conductivity (W/(mK))
NRG-4-586.2-SNL-A	vacuum sat.	58.572	58.368	58.470	2.26	29.6	1.51
						49.5	1.61
						70.0	1.64
NRG-4-586.2-SNL-B	oven dry	53.117	53.117	53.117	2.08	30.5	0.63
						50.0	0.67
						69.3	0.69
NRG-4-586.2-SNL-B	oven dry	53.108	53.019	53.064	2.08	109.0	0.95
						155.7	1.00
						199.3	1.01
						245.1	1.02
						289.0	1.02
						246.2	*1.00*
						200.5	*0.99*
						155.9	*0.98*
						109.1	*0.94*

NRG-4-586.2

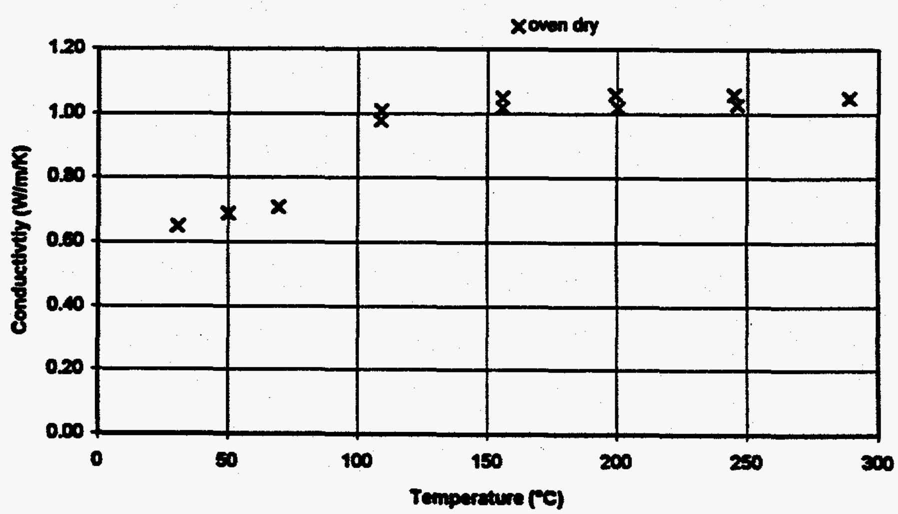


Data Summary

0	Hole & Depth	NRG-4-590.5
	Lithology:	Welded Devitrified
	TMU:	TSw1

Sample ID	Saturation (%)	Weight (g) pre-test	post-test	average	Density (g/cc)	Temperature (°C)	Conductivity (W/(mK))
NRG-4-590.5-SNL-B	oven dry	55.040	55.039	55.040	2.09	30.5	0.65
						50.0	0.69
						69.3	0.71
NRG-4-590.5-SNL-B	oven dry	54.996	54.910	54.953	2.09	108.9	1.01
						155.7	1.05
						199.2	1.06
						244.9	1.06
						288.7	1.05
						245.9	*1.03*
						200.2	*1.02*
						155.6	*1.02*
						108.9	*0.98*

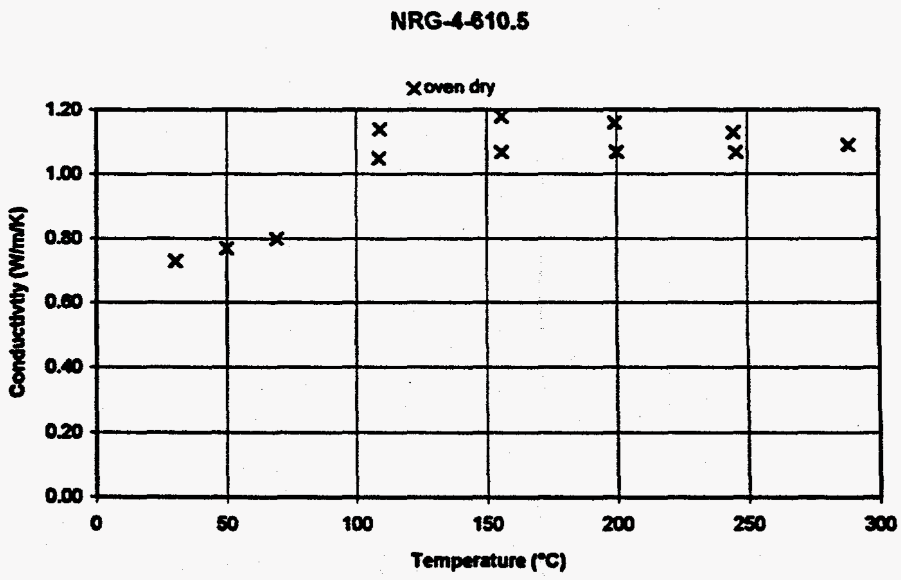
NRG-4-590.5



Data Summary

0	Hole & Depth	NRG-4-610.5
	Lithology:	Welded Devitrified
	TMU:	TSw1

Sample ID	Saturation (%)	Weight (g) pre-test	post-test	average	Density (g/cc)	Temperature (°C)	Conductivity (W/(mK))
NRG-4-610.5-SNL-B	oven dry	57.237	57.234	57.236	2.20	30.4	0.73
						49.9	0.77
						69.2	0.80
NRG-4-610.5-SNL-B	oven dry	57.221	57.115	57.168	2.20	109.1	1.14
						155.8	1.18
						199.3	1.16
						244.9	1.13
						288.6	1.09
						245.8	*1.07*
						200.1	*1.07*
						155.6	*1.07*
						108.8	*1.05*

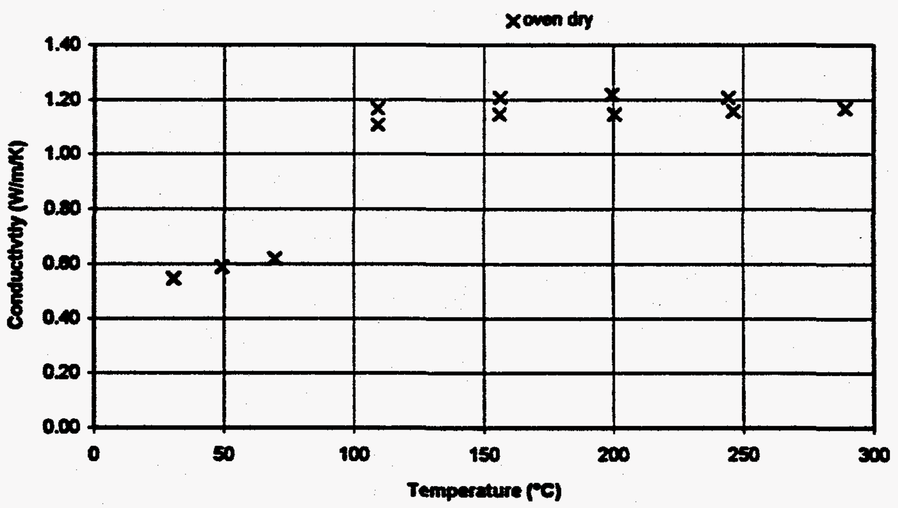


Data Summary

0	Hole & Depth	NRG-4-619.9
	Lithology:	Welded Devitrified
	TMU:	TSw1

Sample ID	Saturation (%)	Weight (g) pre-test	Weight (g) post-test	Weight (g) average	Density (g/cc)	Temperature (°C)	Conductivity (W/(mK))
NRG-4-619.9-SNL-B	oven dry	52.901	52.901	52.901	2.24	30.7	0.55
						49.3	0.59
						69.7	0.62
NRG-4-619.9-SNL-B	oven dry	52.881	52.781	52.831	2.23	109.3	1.17
						156.1	1.21
						199.6	1.22
						244.2	1.21
						289.0	1.17
						246.2	*1.16*
						200.5	*1.15*
						155.9	*1.15*
						109.1	*1.11*

NRG-4-619.9

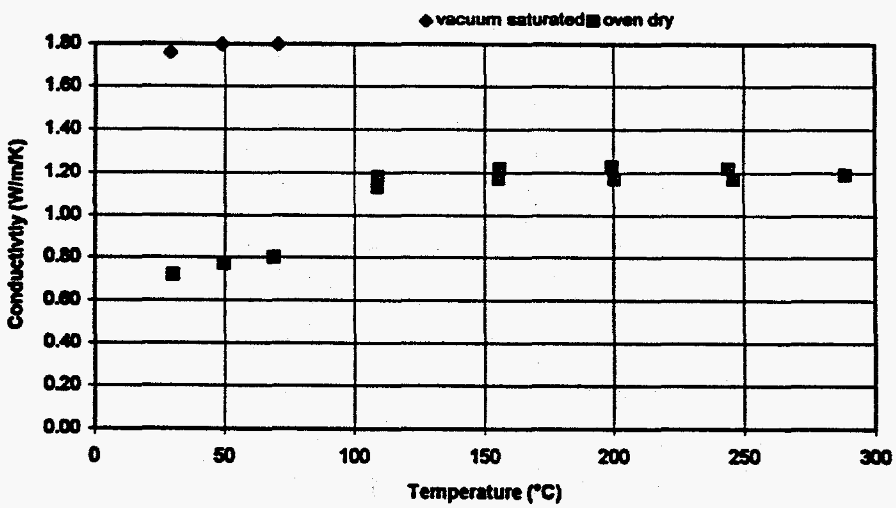


Data Summary

0	Hole & Depth	NRG-4-654.0
	Lithology:	Welded Devitrified
	TMU:	TSw1

Sample ID	Saturation (%)	Weight (g) pre-test	Weight (g) post-test	Weight (g) average	Density (g/cc)	Temperature (°C)	Conductivity (W/(mK))
NRG-4-654.0-SNL-A	vacuum sat.	59.946	59.865	59.906	2.32	29.1	1.76
						49.1	1.80
						70.7	1.80
NRG-4-654.0-SNL-B	oven dry	56.776	56.774	56.775	2.20	30.1	0.72
						49.7	0.77
						69.0	0.80
NRG-4-654.0-SNL-B	oven dry	56.737	56.505	56.621	2.20	109.2	1.18
						156.0	1.22
						199.5	1.23
						244.2	1.22
						288.9	1.19
						246.1	*1.17*
						200.4	*1.17*
						155.7	*1.17*
						109.1	*1.13*

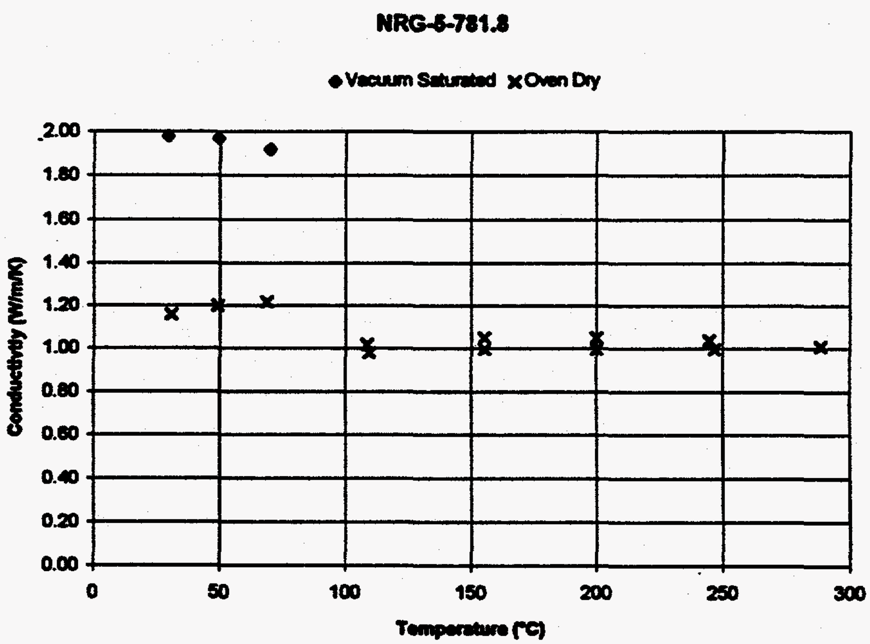
NRG-4-654.0



Data Summary

Hole & Depth:	NRG-5-781.8
Lithology:	Welded Devitrified
TMU:	TSw1

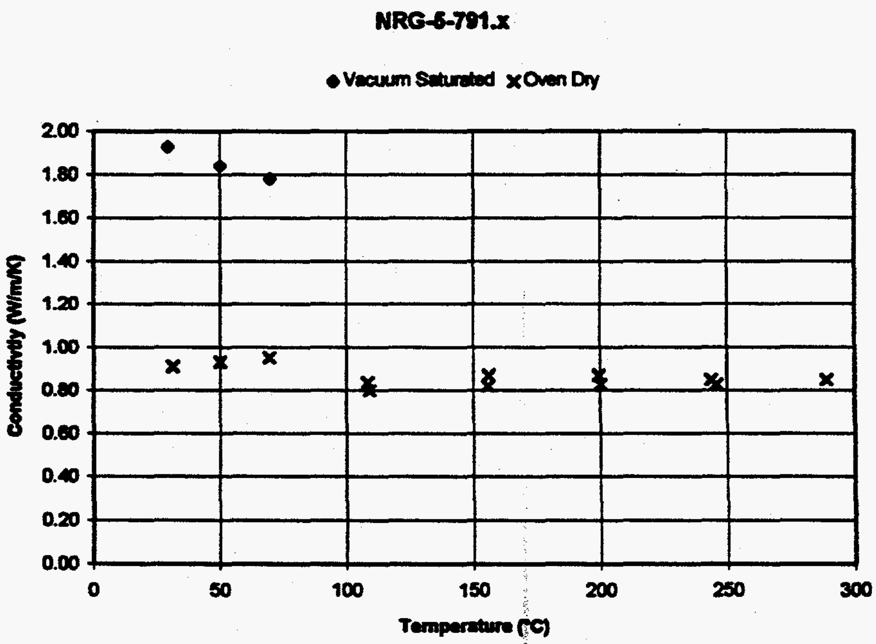
Sample ID	Saturation (%)	Weight (g) pre-test	post-test	average	Density (g/cc)	Temperature (°C)	Conductivity (W/(mK))
NRG-5-781.8-SNL-A	vacuum	59.525	59.484	59.505	2.29	29.6	1.98
						49.5	1.97
						70.1	1.92
NRG-5-781.8-SNL-A	oven dry	55.834	55.830	55.832	2.14	30.8	1.16
						49.3	1.20
						68.9	1.22
NRG-5-781.8-SNL-A	oven dry	55.836	55.697	55.767	2.14	108.6	1.02
						155.3	1.05
						199.9	1.05
						244.6	1.04
						288.4	1.01
						246.5	*1.00*
						199.9	*1.00*
						155.3	*1.00*
						109.7	*0.98*



Data Summary

Hole & Depth: NRG-5-791.x
Lithology: Welded Devitrified
TMU: TSw1

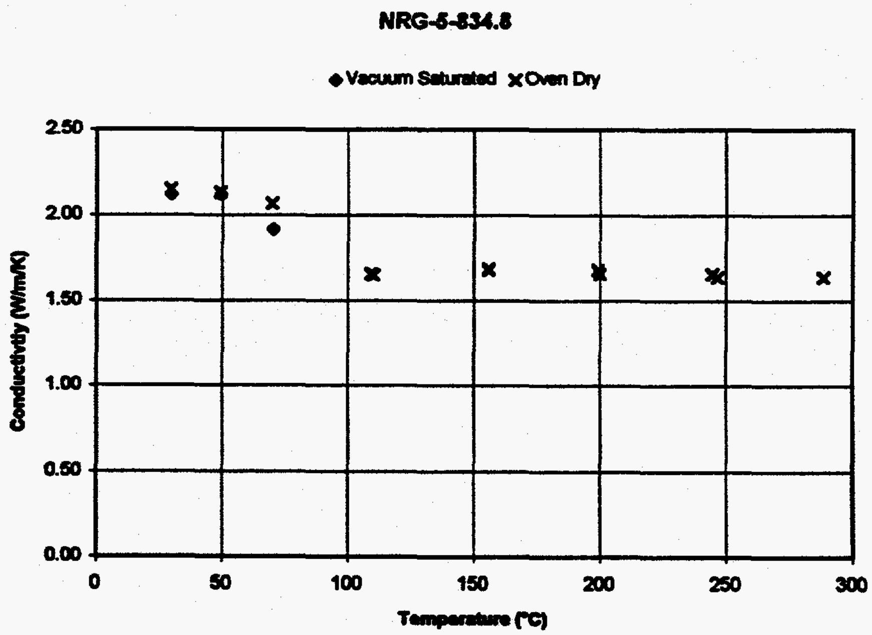
Sample ID	Saturation (%)	Weight (g) pre-test	post-test	average	Density (g/cc)	Temperature (°C)	Conductivity (W/(mK))
NRG-5-791.3-SNL-A	vacuum	59.753	59.668	59.711	2.29	29.5	1.93
						50.3	1.84
						70.0	1.78
NRG-5-791.6-SNL-A	oven dry	50.201	50.196	50.199	1.92	31.2	0.91
						49.9	0.93
						69.5	0.95
NRG-5-791.6-SNL-A	oven dry	50.183	50.106	50.145	1.92	108.3	0.84
						156.0	0.87
						199.5	0.87
						244.0	0.85
						288.9	0.85
						245.9	*0.83*
						200.3	*0.83*
						155.8	*0.82*
						109.1	*0.80*



Data Summary

Hole & Depth: NRG-5-834.8
Lithology: Welded Devitrified
TMU: TSw2

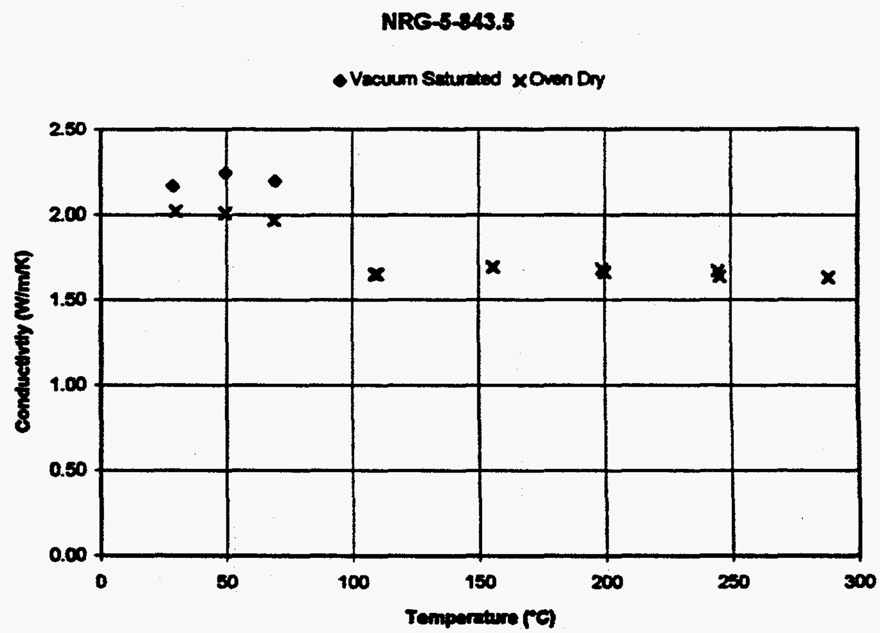
Sample ID	Saturation (%)	Weight (g) pre-test	Weight (g) post-test	Weight (g) average	Density (g/cc)	Temperature (°C)	Conductivity (W/(mK))
NRG-5-834.8-SNL-A	vacuum	61.973	61.901	61.937	2.39	29.3	2.12
						50.1	2.12
						69.8	1.92
NRG-5-834.8-SNL-B	oven dry	60.283	60.281	60.282	2.32	29.5	2.15
						49.1	2.13
						69.6	2.07
NRG-5-834.8-SNL-B	oven dry	60.284	60.114	60.199	2.31	110.1	1.65
						155.7	1.68
						199.2	1.68
						244.7	1.66
						288.5	1.64
						246.7	*1.64*
						200.2	*1.66*
						155.7	*1.69*
						109.1	*1.66*



Data Summary

Hole & Depth:	NRG-5-843.5
Lithology:	Welded Devitrified
TMU:	TSw2

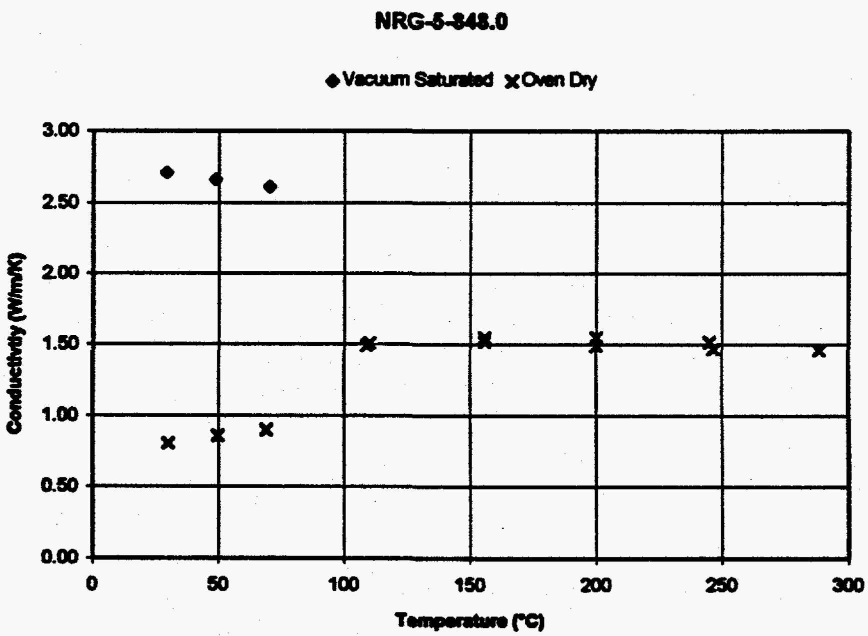
Sample ID	Saturation (%)	Weight (g) pre-test	Weight (g) post-test	Weight (g) average	Density (g/cc)	Temperature (°C)	Conductivity (W/(mK))
NRG-5-843.5-SNL-A	vacuum	62.543	62.509	62.526	2.39	28.7	2.17
						49.7	2.25
						69.4	2.20
NRG-5-843.5-SNL-A	oven dry	60.391	60.392	60.392	2.31	29.7	2.02
						49.4	2.01
						68.9	1.97
NRG-5-843.5-SNL-A	oven dry	60.391	60.238	60.315	2.31	109.9	1.65
						155.5	1.69
						199.1	1.68
						244.8	1.67
						288.5	1.63
						245.8	*1.64*
						200.2	*1.66*
						155.7	*1.69*
						109.0	*1.65*



Data Summary

Hole & Depth: NRG-5-848.0
Lithology: Welded Devitrified
TMU: TSw2

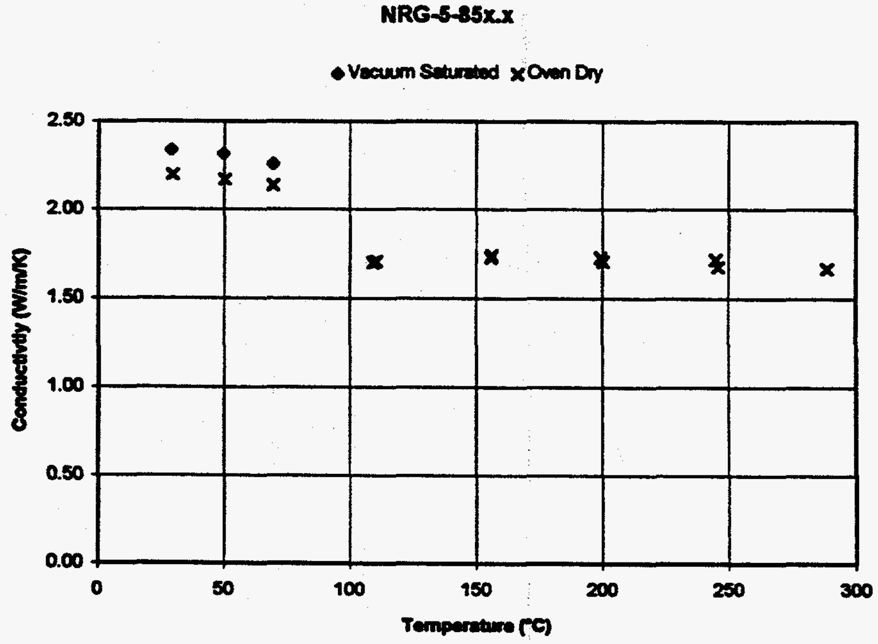
Sample ID	Saturation (%)	Weight (g) pre-test	Weight (g) post-test	Weight (g) average	Density (g/cc)	Temperature (°C)	Conductivity (W/(mK))
						29.1	2.71
NRG-5-848.0-SNL-B	vacuum	61.410	61.383	61.397	2.34	48.6	2.66
						70.1	2.61
						30.0	0.81
NRG-5-848.0-SNL-B	oven dry	58.549	58.548	58.549	2.23	49.6	0.86
						68.9	0.90
						109.9	1.51
NRG-5-848.0-SNL-B	oven dry	58.552	58.452	58.502	2.23	155.5	1.55
						200.1	1.55
						244.8	1.52
						288.5	1.46
						246.7	*1.47*
						200.0	*1.49*
						155.6	*1.52*
						108.8	*1.49*



Data Summary

Hole & Depth:	NRG-5-85x.x
Lithology:	Welded Devitrified
TMU:	TSw2

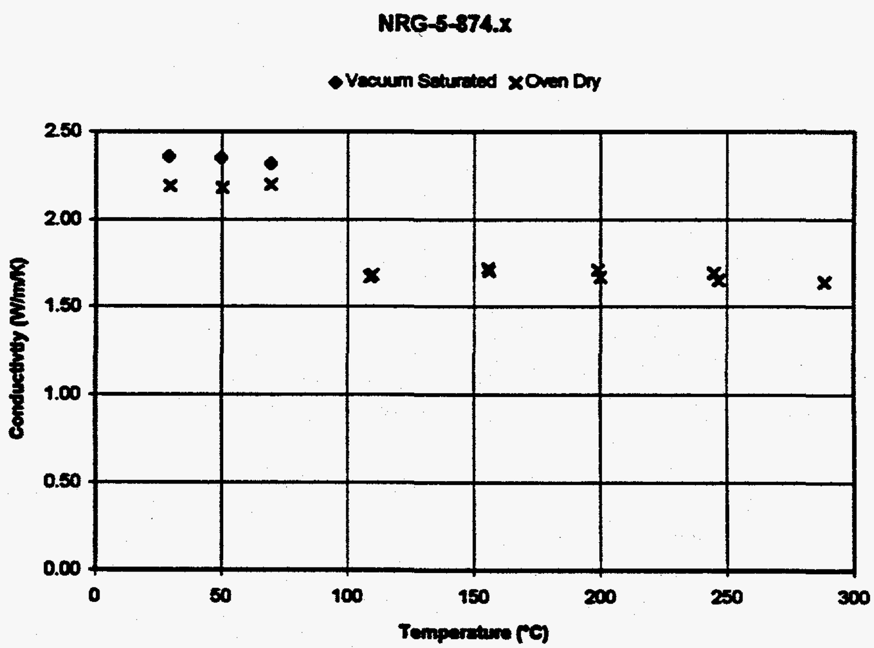
Sample ID	Saturation (%)	Weight (g) pre-test	Weight (g) post-test	Weight (g) average	Density (g/cc)	Temperature (°C)	Conductivity (W/(mK))
NRG-5-852.5-SNL-B	vacuum	61.245	61.205	61.225	2.35	28.9	2.34
						49.7	2.32
						69.5	2.26
NRG-5-853.8-SNL-A	oven dry	59.701	59.701	59.701	2.31	29.5	2.20
						50.1	2.17
						69.5	2.14
NRG-5-853.8-SNL-A	oven dry	59.702	59.549	59.626	2.31	110.3	1.71
						155.9	1.74
						199.4	1.73
						245.0	1.72
						288.7	1.67
						245.9	*1.68*
						200.3	*1.71*
						155.8	*1.73*
						109.1	*1.70*



Data Summary

Hole & Depth: NRG-5-874.x
Lithology: Welded Devitrified
TMU: TSw2

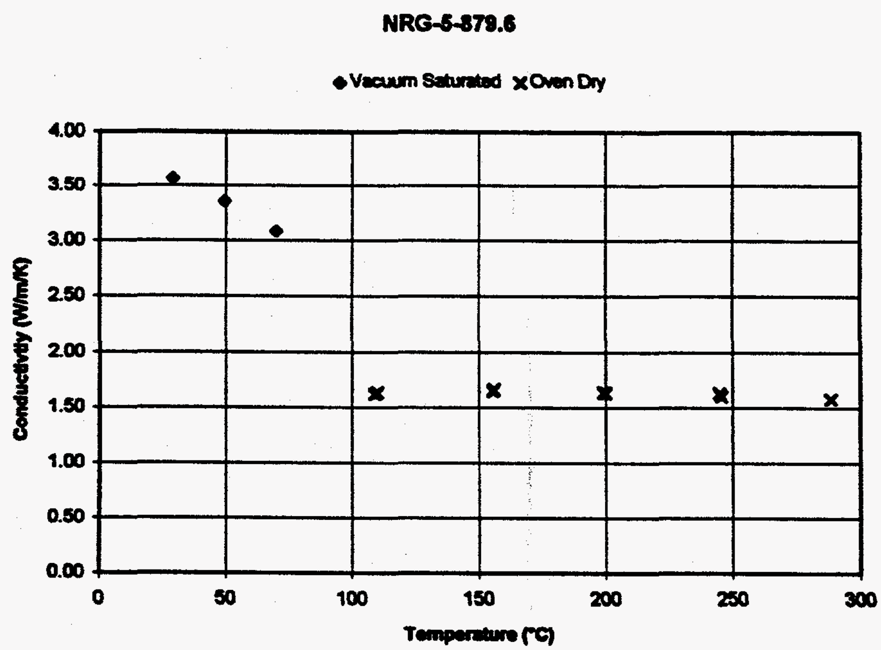
Sample ID	Saturation (%)	Weight (g) pre-test	Weight (g) post-test	Weight (g) average	Density (g/cc)	Temperature (°C)	Conductivity (W/(mK))
NRG-5-874.3-SNL-B	vacuum	61.220	61.174	61.197	2.35	28.9	2.36
						49.8	2.35
						69.5	2.32
NRG-5-874.9-SNL-B	oven dry	59.301	59.296	59.299	2.31	29.5	2.19
						50.1	2.18
						69.5	2.20
NRG-5-874.9-SNL-B	oven dry	59.305	59.067	59.186	2.31	109.8	1.68
						155.6	1.72
						199.1	1.71
						244.8	1.69
						288.5	1.64
						246.8	*1.65*
						200.2	*1.67*
						155.7	*1.70*
						109.0	*1.67*



Data Summary

Hole & Depth: NRG-5-879.6
Lithology: Welded Devitrified
TMU: TSw2

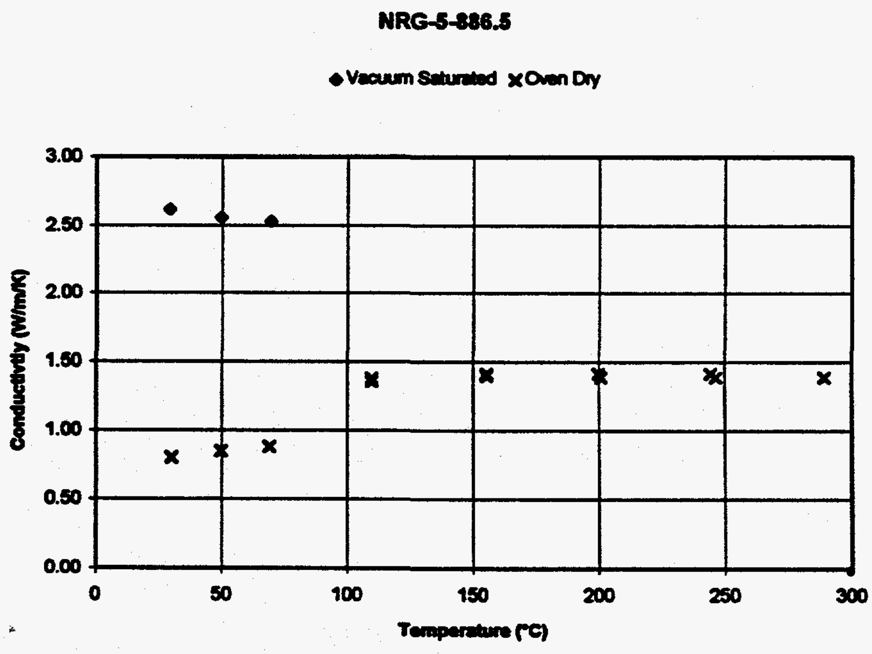
Sample ID	Saturation (%)	Weight (g) pre-test	post-test	average	Density (g/cc)	Temperature (°C)	Conductivity (W/(mK))
						29.0	3.57
NRG-5-879.6-SNL-A	vacuum	63.545	63.314	63.430	2.41	49.5	3.36
						70.0	3.09
						110.0	1.63
NRG-5-879.6-SNL-A	oven dry	60.925	60.789	60.857	2.31	155.7	1.66
						199.2	1.64
						244.8	1.63
						288.5	1.58
						245.7	*1.60*
						200.1	*1.63*
						155.5	*1.65*
						108.9	*1.62*



Data Summary

Hole & Depth: NRG-5-886.5
Lithology: Welded Devitrified
TMU: TSw2

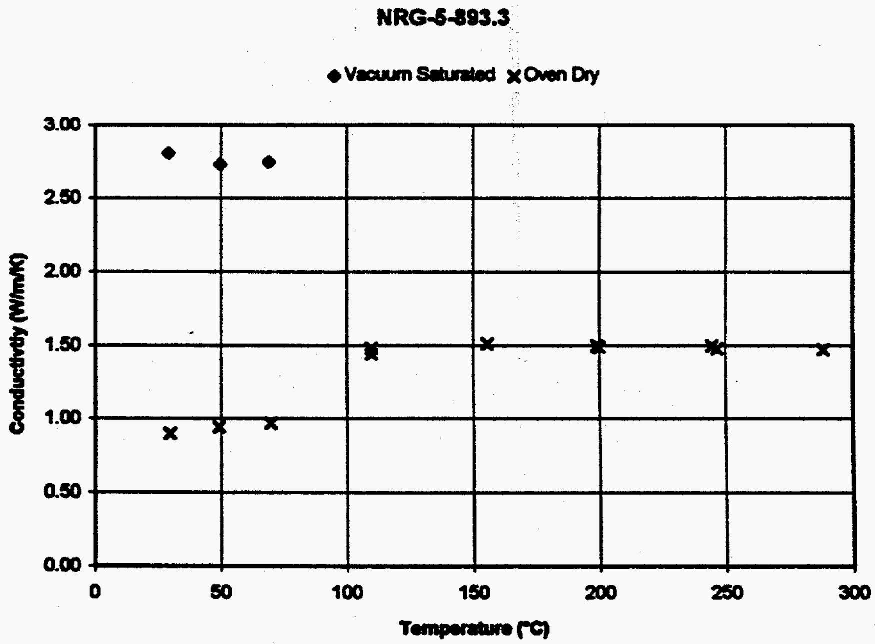
Sample ID	Saturation (%)	Weight (g) pre-test	Weight (g) post-test	Weight (g) average	Density (g/cc)	Temperature (°C)	Conductivity (W/(mK))
NRG-5-886.5-SNL-B	vacuum	61.526	61.466	61.496	2.35	29.3	2.62
						49.8	2.56
						69.3	2.53
NRG-5-886.5-SNL-B	oven dry	58.199	58.198	58.199	2.23	30.1	0.80
						49.6	0.85
						68.9	0.88
NRG-5-886.5-SNL-B	oven dry	58.195	58.081	58.138	2.22	109.6	1.38
						155.3	1.42
						199.9	1.42
						244.5	1.42
						289.2	1.39
						246.4	*1.39*
						200.8	*1.39*
						155.2	*1.40*
						109.6	*1.36*



Data Summary

Hole & Depth: NRG-5-893.3
Lithology: Welded Devitrified
TMU: TSw2

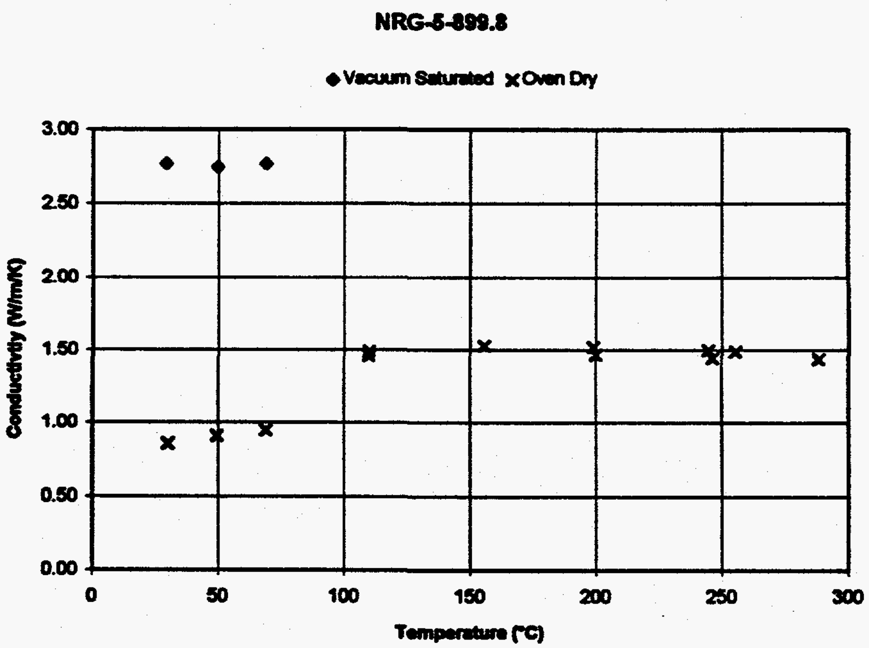
Sample ID	Saturation (%)	Weight (g) pre-test	post-test	average	Density (g/cc)	Temperature (°C)	Conductivity (W/(mK))
NRG-5-893.3-SNL-B	vacuum	62.020	61.967	61.994	2.36	29.1	2.81
						49.6	2.73
						69.0	2.75
NRG-5-893.3-SNL-B	oven dry	58.970	58.966	58.968	2.24	29.8	0.90
						49.3	0.94
						69.6	0.97
NRG-5-893.3-SNL-B	oven dry	58.969	58.791	58.880	2.24	109.7	1.44
						155.5	1.51
						199.0	1.50
						244.7	1.50
						288.4	1.47
						246.6	*1.48*
						200.0	*1.49*
						155.4	*1.51*
						109.7	*1.48*



Data Summary

Hole & Depth: NRG-5-899.8
Lithology: Welded Devitrified
TMU: TSw2

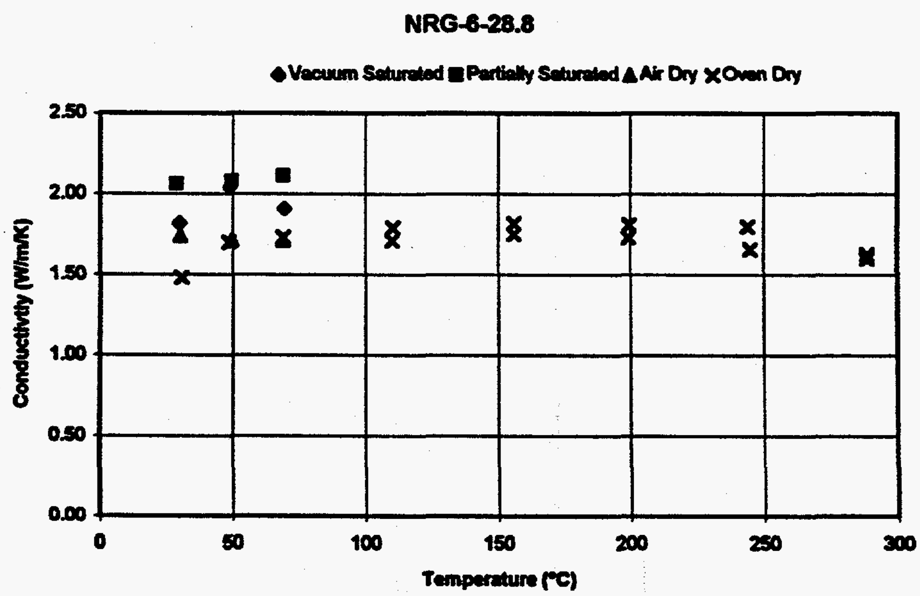
Sample ID	Saturation (%)	Weight (g) pre-test	Weight (g) post-test	Weight (g) average	Density (g/cc)	Temperature (°C)	Conductivity (W/(mK))
NRG-5-899.8-SNL-B	vacuum	61.681	61.601	61.641	2.35	29.1	2.77
						49.6	2.75
						69.0	2.77
NRG-5-899.8-SNL-B	oven dry	58.785	58.784	58.785	2.24	30.0	0.86
						49.5	0.91
						68.8	0.95
NRG-5-899.8-SNL-B	oven dry	58.784	58.504	58.644	2.24	109.9	1.49
						155.6	1.53
						199.1	1.52
						244.7	1.50
						288.3	1.44
						246.5	*1.45*
						200.0	*1.47*
						255.4	*1.49*
						109.8	*1.46*



Data Summary

Hole & Depth: NRG-6-28.8
Lithology: Welded Devitrified
TMU: TCw

Sample ID	Saturation (%)	Weight (g) pre-test	Weight (g) post-test	Weight (g) average	Density (g/cc)	Temperature (°C)	Conductivity (W/(mK))
NRG-6-28.8-SNL-B	vacuum	58.627	58.435	58.531	2.38	30.0 49.0 69.7	1.82 2.04 1.91
NRG-6-28.8-SNL-B	partial	57.965	57.920	57.943	2.36	28.8 49.7 69.2	2.06 2.08 2.11
NRG-6-28.8-SNL-C	air dry	60.465	60.449	60.457	2.35	30.2 49.7 69.2	1.74 1.71 1.71
NRG-6-28.8-SNL-C	oven dry	60.465	60.449	60.457	2.35	30.7 48.7 69.1	1.48 1.70 1.73
NRG-6-28.8-SNL-C	oven dry	60.411	60.218	60.315	2.35	110.5 156.1 199.7 244.3 288.9	1.79 1.82 1.81 1.80 1.63
NRG-6-28.8-SNL-C	oven dry	60.252	60.218	60.235	2.34	110.4 156.0 199.5 245.1 288.9	1.71 1.75 1.73 1.66 1.60

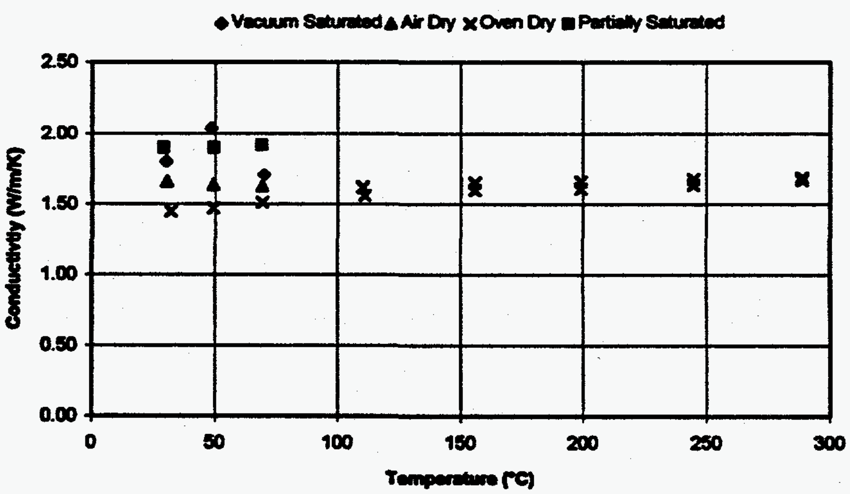


Data Summary

Hole & Depth:	NRG-6-98.1
Lithology:	Welded Devitrified
TMU:	TCw

Sample ID	Saturation (%)	Weight (g) pre-test	Weight (g) post-test	Weight (g) average	Density (g/cc)	Temperature (°C)	Conductivity (W/(mK))
						30.3	1.81
NRG-6-98.1-SNL-H	vacuum sat.	61.273	61.097	61.185	2.37	48.6	2.04
						70.0	1.71
						29.2	1.90
NRG-6-98.1-SNL-H	partial	60.576	60.528	60.552	2.34	49.7	1.90
						69.1	1.92
						30.4	1.66
NRG-6-98.1-SNL-I	air dry	59.514	59.490	59.502	2.31	49.3	1.64
						69.2	1.63
						32.0	1.45
NRG-6-98.1-SNL-I	oven dry	59.501	59.464	59.483	2.31	49.4	1.47
						69.2	1.51
						110.3	1.62
NRG-6-98.1-SNL-I	oven dry	59.433	59.214	59.324	2.30	155.9	1.65
						199.1	1.66
						245.0	1.68
						288.8	1.69
						111.1	1.56
NRG-6-98.1-SNL-I	oven dry	59.229	59.200	59.215	2.30	155.8	1.60
						199.3	1.61
						244.9	1.64
						288.8	1.67

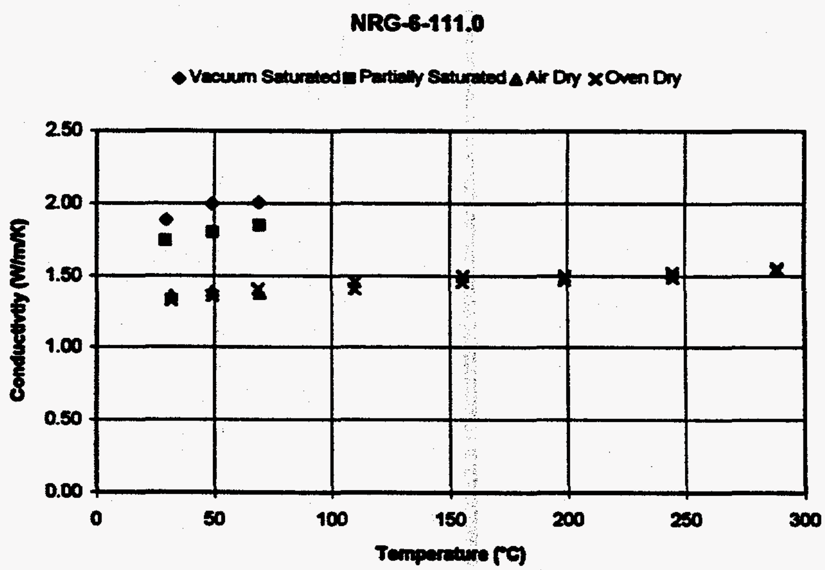
NRG-6-98.1



Data Summary

Hole & Depth:	NRG-6-111.0
Lithology:	Welded Devitrified
TMU:	TCw

Sample ID	Saturation (%)	Weight (g) pre-test	Weight (g) post-test	Weight (g) average	Density (g/cc)	Temperature (°C)	Conductivity (W/(mK))
NRG-6-111.0-SNL-H	vacuum	60.800	60.634	60.717	2.34	29.7 49.2 69.0	1.89 2.00 2.01
NRG-6-111.0-SNL-H	partial	59.632	59.579	59.606	2.29	29.5 49.5 69.3	1.74 1.80 1.85
NRG-6-111.0-SNL-I	air dry	58.162	58.140	58.151	2.25	31.7 49.4 69.4	1.36 1.39 1.38
NRG-6-111.0-SNL-I	oven dry	58.169	58.127	58.148	2.25	31.7 49.2 68.9	1.33 1.36 1.41
NRG-6-111.0-SNL-I	oven dry	58.087	57.962	58.025	2.24	110.1 155.7 199.2 244.8 288.7	1.46 1.50 1.50 1.52 1.55
NRG-6-111.0-SNL-I	oven dry	58.00	57.958	57.978	2.24	109.9 155.6 199.1 244.9 288.7	1.41 1.46 1.47 1.49 1.54

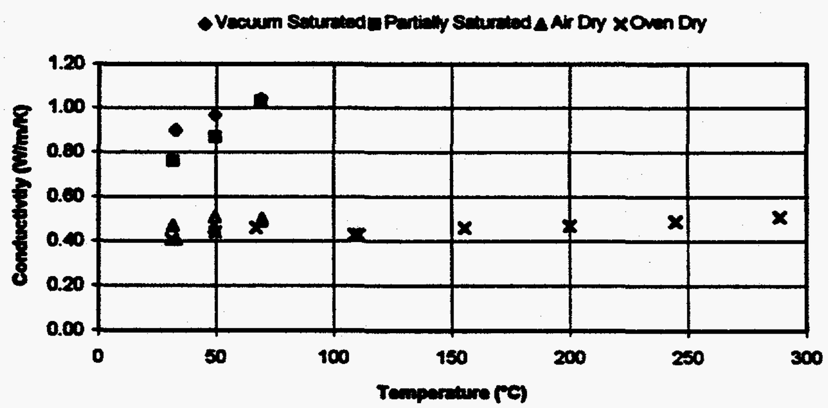


Data Summary

Hole & Depth:	NRG-6-152.9
Lithology:	Vitric Nonwelded
TMU:	PTn

Sample ID	Saturation (%)	Weight (g) pre-test	Weight (g) post-test	Weight (g) average	Density (g/cc)	Temperature (°C)	Conductivity (W/(mK))
NRG-6-152.9-SNL-D	vacuum	45.976	45.765	45.871	1.77	32.7 49.5 69.0	0.90 0.97 1.04
NRG-6-152.9-SNL-D	partial	41.083	40.969	41.026	1.58	31.8 49.3 69.0	0.76 0.87 1.03
NRG-6-152.9-SNL-E	air dry	17.051	16.917	16.984	1.37	31.6 49.3 69.4	0.47 0.51 0.50
NRG-6-152.9-SNL-E	air dry	16.959	16.890	16.925	1.36	33.0 49.1 69.3	0.41 0.46 0.49
NRG-6-152.9-SNL-E	oven dry	16.690	16.669	16.680	1.34	31.1 49.7 66.9	0.41 0.44 0.46
NRG-6-152.9-SNL-E	oven dry	16.351	16.324	16.338	1.31	110.6 155.4 200.1 244.9 288.8	0.43 0.46 0.47 0.49 0.51
NRG-6-152.9-SNL-E	oven dry	16.351	16.302	16.327	1.31	108.6 155.4 200.1 244.9 288.7	0.43 0.46 0.47 0.49 0.51

NRG-6-152.9

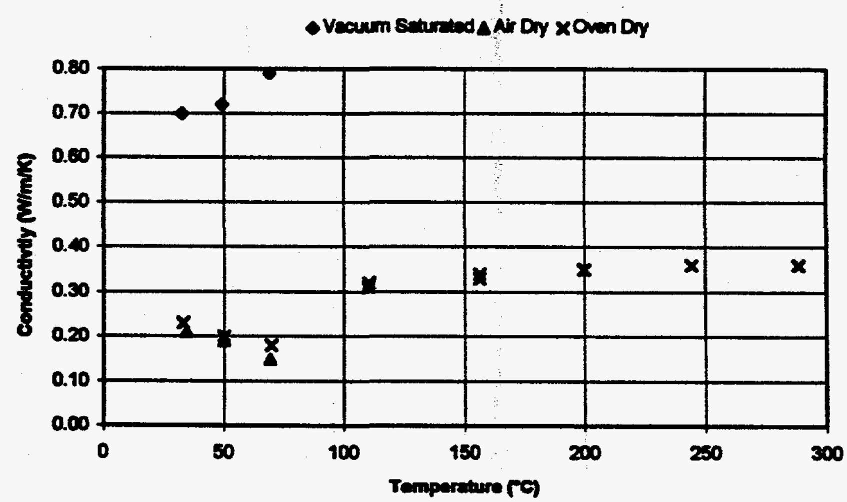


Data Summary

Hole & Depth: NRG-6-187.0
Lithology: Vitric Nonwelded
TMU: PTn

Sample ID	Saturation (%)	Weight (g) pre-test	Weight (g) post-test	Weight (g) average	Density (g/cc)	Temperature (°C)	Conductivity (W/(mK))
NRG-6-187.0-SNL-E	vacuum sat.	39.821	39.578	39.700	1.54	32.7	0.70
						49.4	0.72
						69.1	0.79
NRG-6-187.0-SNL-F	air dry	27.688	27.622	27.655	1.06	34.6	0.21
						50.0	0.19
						69.4	0.15
NRG-6-187.0-SNL-F	oven dry	27.406	27.368	27.387	1.05	33.2	0.23
						50.2	0.20
						69.7	0.18
NRG-6-187.0-SNL-F	oven dry	27.204	26.677	26.941	1.04	110.5	0.32
						156.2	0.34
						199.7	0.35
						244.5	0.36
						288.6	0.36
NRG-6-187.0-SNL-F	oven dry	26.702	26.602	26.652	1.03	110.2	0.31
						156.2	0.33
						199.9	0.35
						244.5	0.36
						288.5	0.36

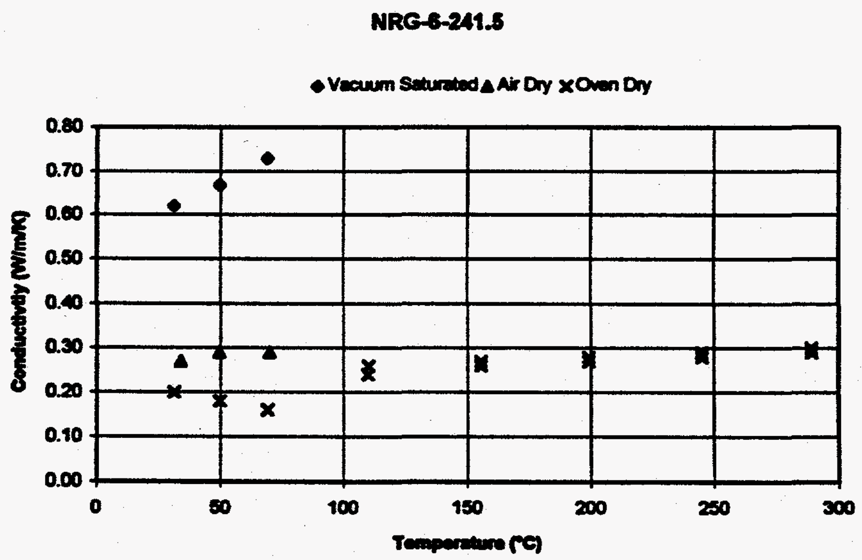
NRG-6-187.0



Data Summary

Hole & Depth:	NRG-6-241.5
Lithology:	Vitric Nonwelded
TMU:	PTn

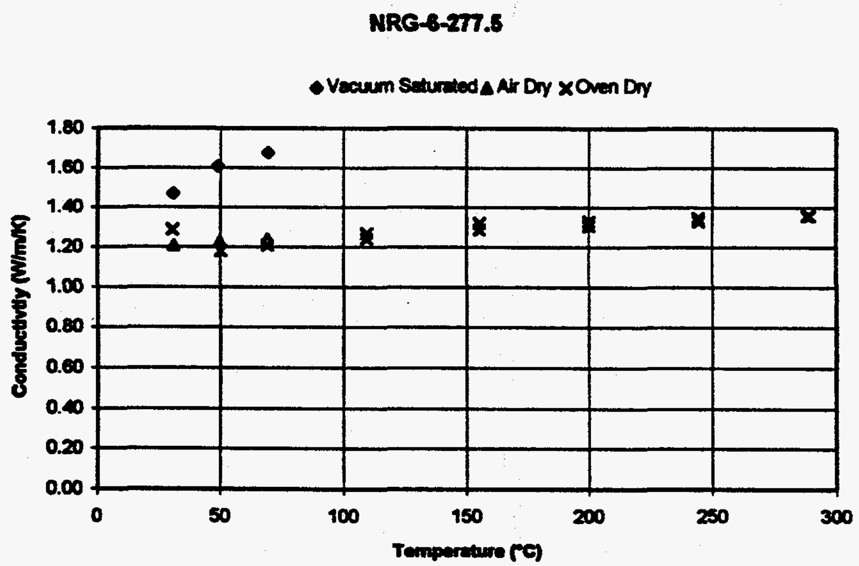
Sample ID	Saturation (%)	Weight (g) pre-test	Weight (g) post-test	Weight (g) average	Density (g/cc)	Temperature (°C)	Conductivity (W/(mK))
NRG-6-241.5-SNL-D	vacuum sat.	39.408	39.130	39.269	1.52	31.2	0.62
						49.8	0.67
						69.1	0.73
NRG-6-241.5-SNL-E	air dry	24.742	24.328	24.535	0.95	33.8	0.27
						49.6	0.29
						69.8	0.29
NRG-6-241.5-SNL-E	oven dry	24.419	24.278	24.349	0.94	31.3	0.20
						49.9	0.18
						69.1	0.16
NRG-6-241.5-SNL-E	oven dry	24.128	23.494	23.811	0.92	110.0	0.26
						155.8	0.27
						199.2	0.28
						244.9	0.29
						289.1	0.30
NRG-6-241.5-SNL-E	oven dry	23.522	23.440	23.481	0.91	109.9	0.24
						155.6	0.26
						199.4	0.27
						245.2	0.28
						289.2	0.29



Data Summary

Hole & Depth:	NRG-6-277.5
Lithology:	Welded Devitrified
TMU:	TSw1

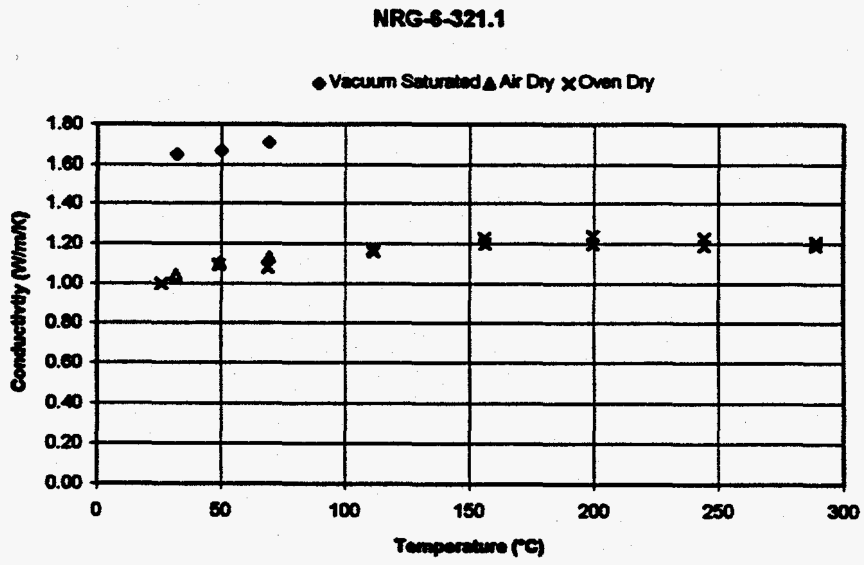
Sample ID	Saturation (%)	Weight (g) pre-test	post-test	average	Density (g/cc)	Temperature (°C)	Conductivity (W/(mK))
NRG-6-277.5-SNL-D	vacuum sat.	61.122	60.740	60.931	2.36	30.8 48.8 69.3	1.47 1.61 1.68
NRG-6-277.5-SNL-E	air dry	57.871	57.856	57.864	2.26	31.1 49.7 69.2	1.21 1.23 1.24
NRG-6-277.5-SNL-E	oven dry	57.884	57.861	57.873	2.26	30.5 50.1 69.2	1.29 1.18 1.21
NRG-6-277.5-SNL-E	oven dry	57.837	57.780	57.809	2.26	109.6 155.2 199.8 244.4 289.3	1.27 1.32 1.33 1.35 1.36
NRG-6-277.5-SNL-E	oven dry	57.81	57.776	57.793	2.26	109.6 155.3 199.8 244.5 288.4	1.24 1.29 1.31 1.33 1.36



Data Summary

Hole & Depth:	NRG-6-321.1
Lithology:	Welded Devitrified
TMU:	TSw1

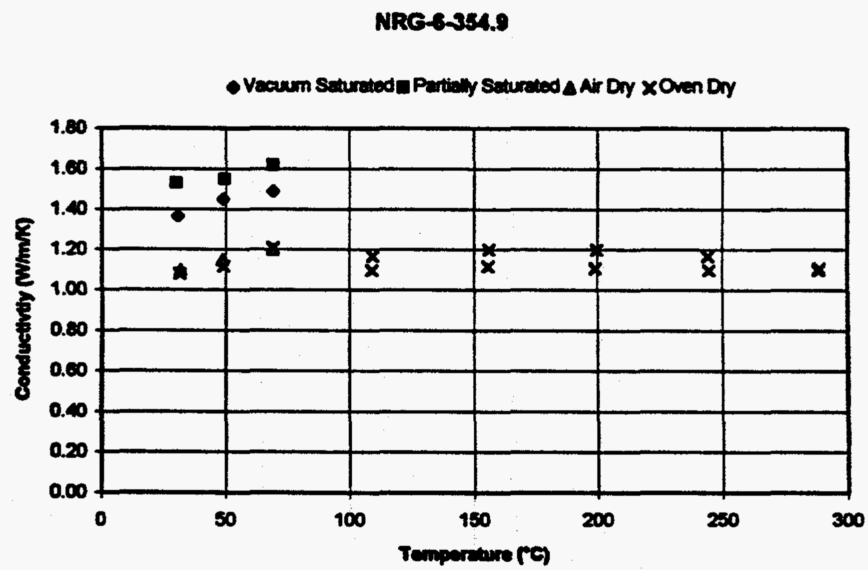
Sample ID	Saturation (%)	Weight (g) pre-test	post-test	average	Density (g/cc)	Temperature (°C)	Conductivity (W/(mK))
NRG-6-321.1-SNL-D	vacuum sat.	60.527	60.364	60.446	2.33	31.9 49.9 69.1	1.65 1.67 1.71
NRG-6-321.1-SNL-E	air dry	56.179	56.150	56.165	2.19	31.4 49.2 69.1	1.04 1.10 1.13
NRG-6-321.1-SNL-E	oven dry	56.164	56.139	56.152	2.19	25.8 49.0 68.7	1.00 1.09 1.08
NRG-6-321.1-SNL-E	oven dry	56.125	56.068	56.097	2.19	111.2 155.9 199.5 244.3 289.0	1.17 1.23 1.24 1.23 1.21
NRG-6-321.1-SNL-E	oven dry	56.09	56.063	56.077	2.18	111.3 156.0 199.6 244.2 289.0	1.16 1.20 1.20 1.19 1.19



Data Summary

Hole & Depth: NRG-6-354.9
Lithology: Welded Devitrified
TMU: TSw1

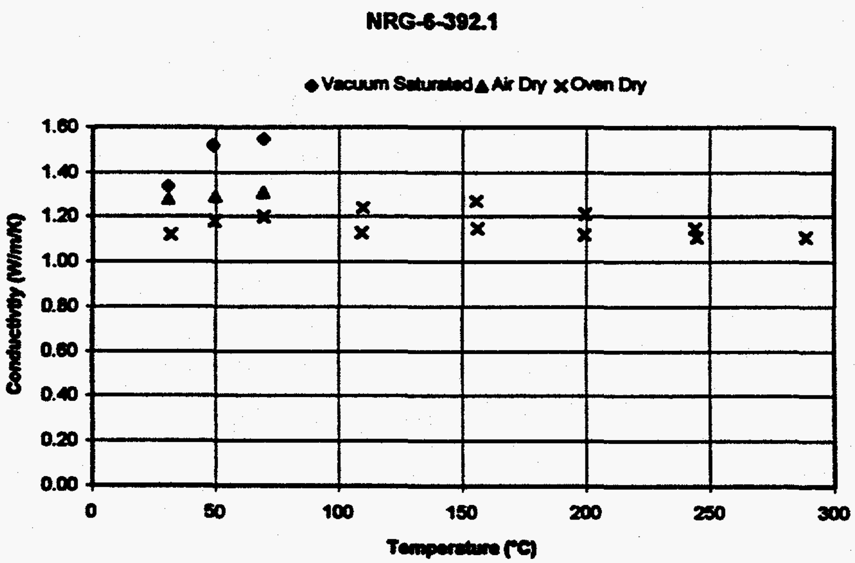
Sample ID	Saturation (%)	Weight (g) pre-test	Weight (g) post-test	Weight (g) average	Density (g/cc)	Temperature (°C)	Conductivity (W/(mK))
NRG-6-354.9-SNL-B	vacuum sat.	60.382	60.137	60.260	2.34	30.9	1.37
						49.2	1.45
						69.2	1.49
NRG-6-354.9-SNL-B	partial	58.813	58.701	58.757	2.19	30.1	1.53
						49.5	1.55
						69.2	1.62
NRG-6-354.9-SNL-C	air dry	57.028	57.000	57.014	2.19	31.8	1.10
						48.9	1.15
						69.3	1.20
NRG-6-354.9-SNL-C	oven dry	57.036	57.010	57.023	2.19	31.5	1.08
						49.3	1.12
						69.1	1.21
NRG-6-354.9-SNL-C	oven dry	56.971	56.907	56.939	2.19	109.4	1.17
						156.1	1.20
						199.7	1.20
						244.3	1.17
						288.9	1.11
NRG-6-354.9-SNL-C	oven dry	56.928	56.909	56.919	2.19	109.1	1.10
						155.8	1.12
						199.3	1.11
						244.9	1.10
						288.6	1.10



Data Summary

Hole & Depth:	NRG-6-392.1
Lithology:	Welded Devitrified
TMU:	TSw1

Sample ID	Saturation (%)	Weight (g) pre-test	post-test	average	Density (g/cc)	Temperature (°C)	Conductivity (W/(mK))
NRG-6-392.1-SNL-C	vacuum sat.	57.542	57.346	57.444	2.24	30.7 49.0 69.2	1.34 1.52 1.55
NRG-6-392.1-SNL-D	air dry	57.455	57.435	57.445	2.21	30.7 49.7 69.1	1.28 1.29 1.31
NRG-6-392.1-SNL-D	oven dry	57.5	57.467	57.484	2.21	31.6 49.5 69.2	1.12 1.18 1.20
NRG-6-392.1-SNL-D	oven dry	57.364	57.230	57.297	2.20	109.7 155.3 199.6 244.0 288.7	1.24 1.27 1.21 1.15 1.11
NRG-6-392.1-SNL-D	oven dry	57.262	57.230	57.246	2.20	109.1 155.8 199.2 244.9 288.8	1.13 1.15 1.12 1.11 1.11

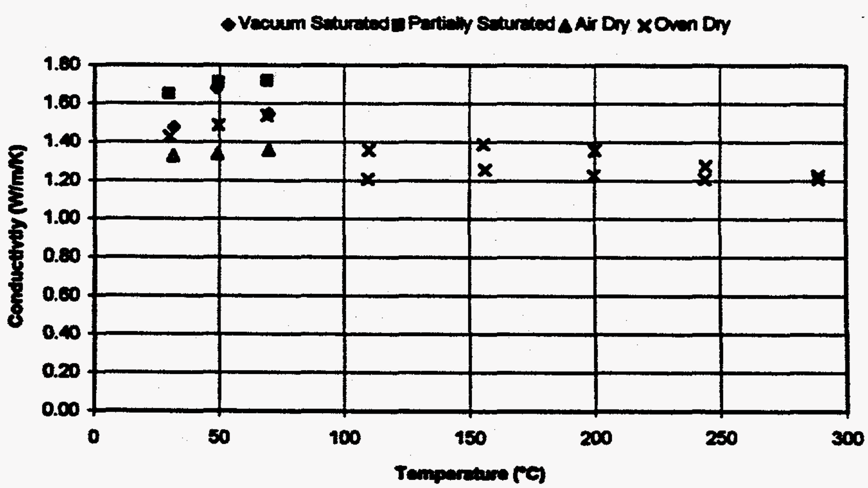


Data Summary

Hole & Depth: NRG-6-416.0
Lithology: Welded Devitrified
TMU: TSw1

Sample ID	Saturation (%)	Weight (g) pre-test	post-test	average	Density (g/cc)	Temperature (°C)	Conductivity (W/(mK))
NRG-6-416.0-SNL-J	vacuum sat.	60.059	59.942	60.001	2.33	31.8 48.8 70.0	1.48 1.68 1.55
NRG-6-416.0-SNL-J	partial	59.109	59.011	59.060	2.29	29.8 49.5 69.1	1.65 1.71 1.72
NRG-6-416.0-SNL-K	air dry	58.232	58.150	58.191	2.25	31.2 49.3 69.5	1.33 1.34 1.36
NRG-6-416.0-SNL-K	oven dry	57.874	57.868	57.871	2.24	30.1 49.6 69.1	1.43 1.49 1.54
NRG-6-416.0-SNL-K	oven dry	57.875	57.676	57.776	2.24	109.8 155.4 200.0 244.4 289.1	1.36 1.39 1.36 1.28 1.23
NRG-6-416.0-SNL-K	oven dry	57.726	57.665	57.696	2.24	109.5 156.2 199.7 244.2 289.0	1.21 1.26 1.23 1.21 1.21

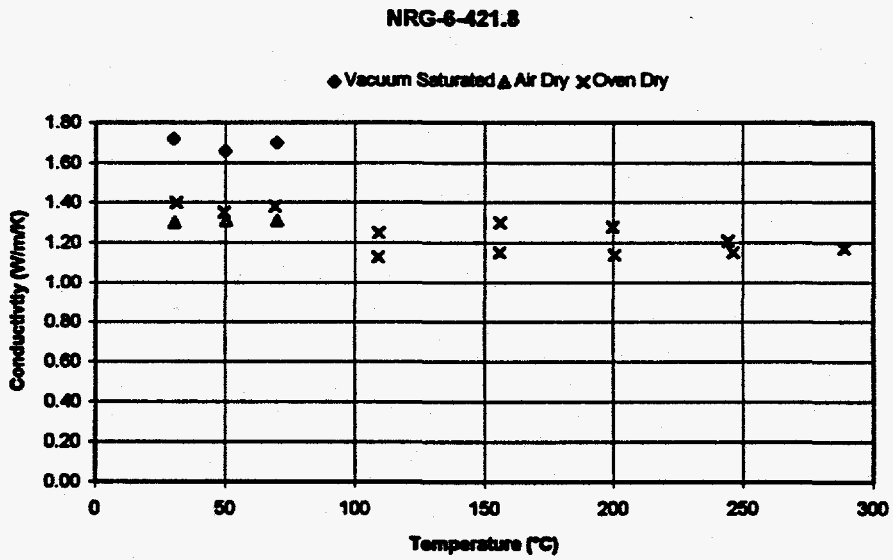
NRG-6-416.0



Data Summary

Hole & Depth:	NRG-6-421.8
Lithology:	Welded Devitrified
TMU:	TSw1

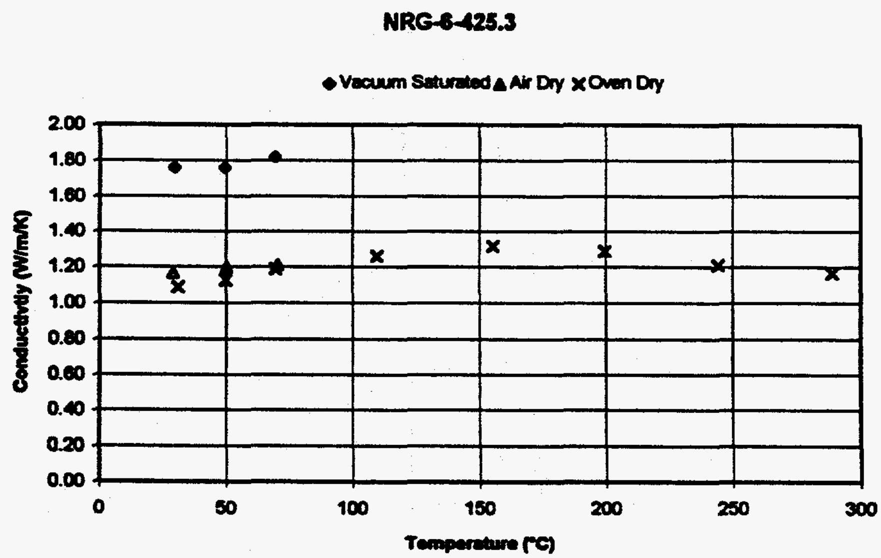
Sample ID	Saturation (%)	Weight (g) pre-test	post-test	average	Density (g/cc)	Temperature (°C)	Conductivity (W/(mK))
NRG-6-421.8-SNL-C	vacuum sat.	60.539	60.433	60.486	2.30	30.2	1.72
						50.1	1.66
						69.9	1.70
NRG-6-421.8-SNL-D	air dry	58.264	58.252	58.258	2.24	30.4	1.30
						50.2	1.31
						70.0	1.31
NRG-6-421.8-SNL-D	oven dry	57.911	57.903	57.907	2.22	31.0	1.40
						49.5	1.35
						69.2	1.38
NRG-6-421.8-SNL-D	oven dry	57.929	57.716	57.823	2.22	109.4	1.25
						156.2	1.30
						199.7	1.28
						244.2	1.21
						288.9	1.17
						246.1	*1.15*
						200.3	*1.14*
						155.9	*1.15*
						109.1	*1.13*



Data Summary

Hole & Depth: NRG-6-425.3
Lithology: Welded Devitrified
TMU: TSw1

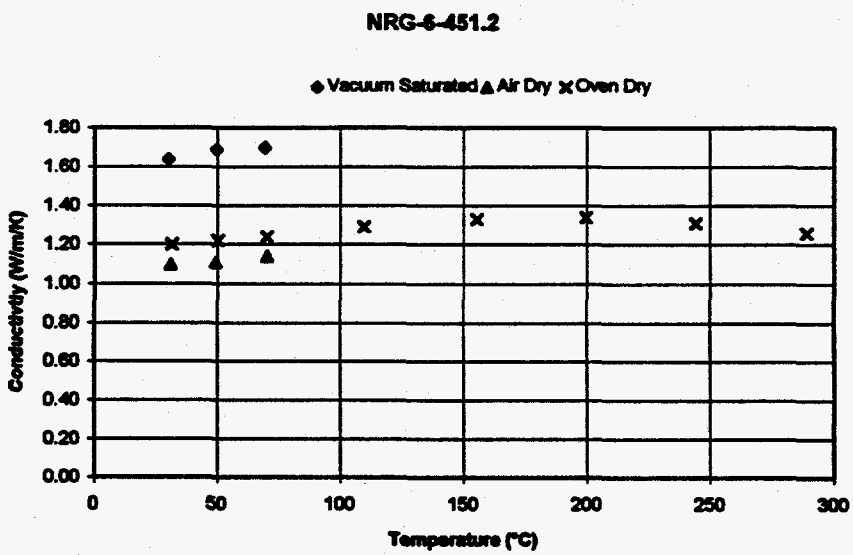
Sample ID	Saturation (%)	Weight (g) pre-test	post-test	average	Density (g/cc)	Temperature (°C)	Conductivity (W/(mK))
NRG-6-425.3-SNL-A	vacuum sat.	58.550	58.468	58.509	2.31	29.7	1.76
						49.6	1.76
						69.4	1.82
NRG-6-425.3-SNL-B	air dry	56.997	56.984	56.991	2.20	29.1	1.17
						50.2	1.20
						70.4	1.21
NRG-6-425.3-SNL-B	oven dry	56.658	56.655	56.657	2.18	31.0	1.09
						49.9	1.13
						69.6	1.19
NRG-6-425.3-SNL-B	oven dry	56.527	56.487	56.507	2.18	109.7	1.26
						155.4	1.32
						199.8	1.29
						244.3	1.21
						289.0	1.17



Data Summary

Hole & Depth:	NRG-6-451.2
Lithology:	Welded Devitrified
TMU:	TSw1

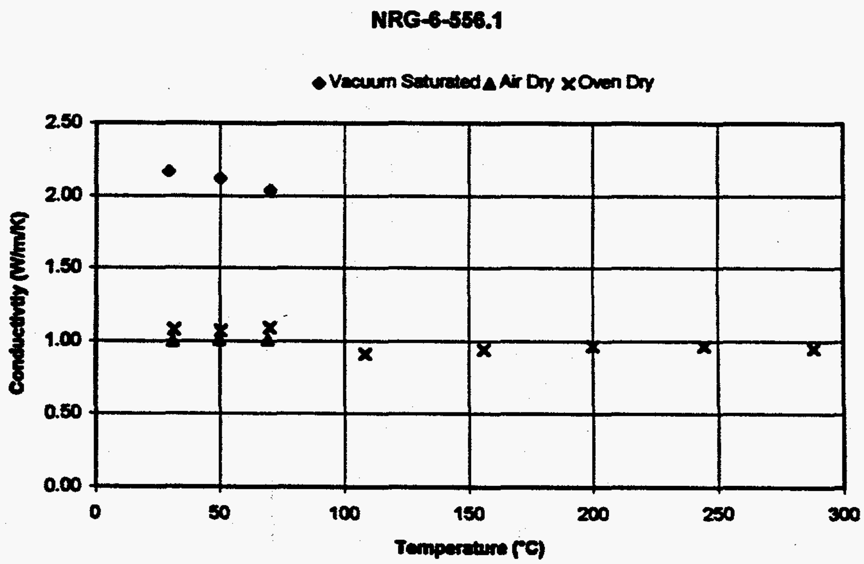
Sample ID	Saturation (%)	Weight (g) pre-test	post-test	average	Density (g/cc)	Temperature (°C)	Conductivity (W/(mK))
NRG-6-451.2-SNL-A	vacuum sat.	56.045	56.025	56.035	2.22	30.0	1.64
						49.7	1.69
						69.4	1.70
NRG-6-451.2-SNL-B	air dry	53.988	53.978	53.983	2.07	30.9	1.10
						49.1	1.11
						70.0	1.14
NRG-6-451.2-SNL-B	oven dry	53.687	53.678	53.683	2.05	31.4	1.20
						50.2	1.22
						70.0	1.24
NRG-6-451.2-SNL-B	oven dry	53.557	53.517	53.537	2.05	109.6	1.29
						155.3	1.33
						199.8	1.34
						244.4	1.31
						289.1	1.26



Data Summary

Hole & Depth: NRG-6-556.1
Lithology: Welded Devitrified
TMU: TSw1

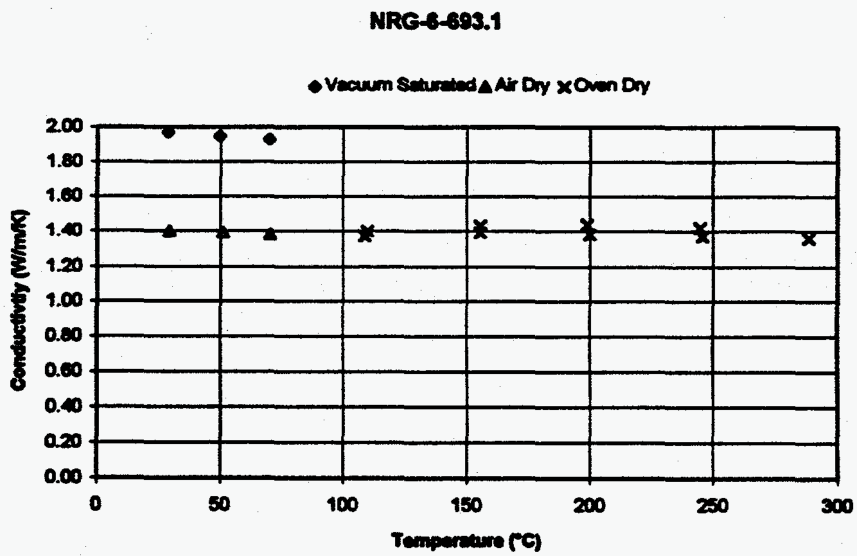
Sample ID	Saturation (%)	Weight (g) pre-test	Weight (g) post-test	Weight (g) average	Density (g/cc)	Temperature (°C)	Conductivity (W/(mK))
NRG-6-556.1-SNL-A	vacuum sat.	59.688	59.580	59.634	2.26	29.3	2.17
						50.3	2.12
						70.2	2.04
NRG-6-556.1-SNL-B	air dry	48.159	48.131	48.145	1.82	30.9	1.00
						49.6	1.01
						69.2	1.01
NRG-6-556.1-SNL-B	oven dry	47.947	47.941	47.944	1.82	31.4	1.08
						50.2	1.07
						70.0	1.09
NRG-6-556.1-SNL-B	oven dry	47.817	47.784	47.801	1.81	108.4	0.91
						156.1	0.94
						199.8	0.97
						244.5	0.97
						288.3	0.95



Data Summary

Hole & Depth:	NRG-6-693.1
Lithology:	Welded Devitrified
TMU:	TSw1

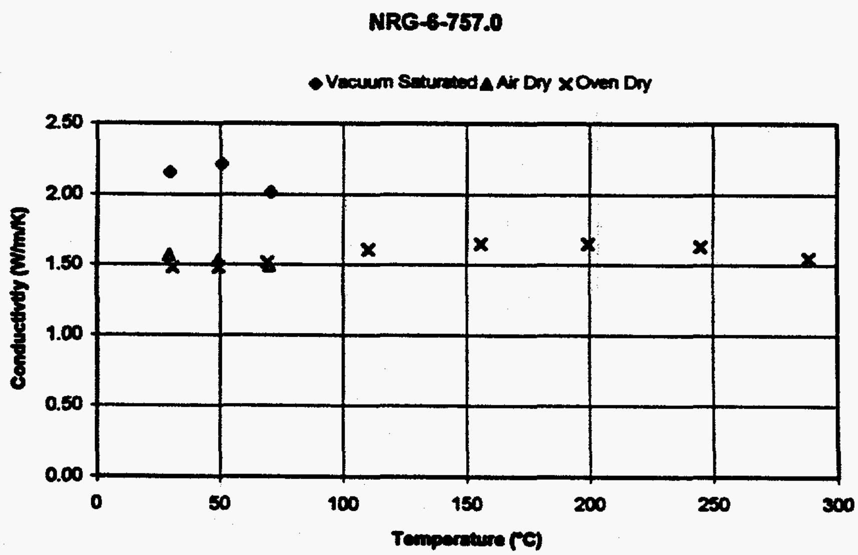
Sample ID	Saturation (%)	Weight (g) pre-test	Weight (g) post-test	Weight (g) average	Density (g/cc)	Temperature (°C)	Conductivity (W/(mK))
						28.8	1.97
NRG-6-693.1-SNL-C	vacuum sat.	60.661	60.596	60.629	2.31	49.8	1.95
						69.9	1.93
						29.4	1.40
NRG-6-693.1-SNL-C	air dry	57.385	57.374	57.380	2.19	51.2	1.39
						70.2	1.38
NRG-6-693.1-SNL-C	oven dry	57.201	57.052	57.127	2.18	109.8	1.40
						155.5	1.43
						199.1	1.44
						244.7	1.42
						288.5	1.36
						245.7	*1.37*
						200.1	*1.38*
						155.6	*1.39*
						108.9	*1.37*



Data Summary

Hole & Depth:	NRG-6-757.0
Lithology:	Welded Devitrified
TMU:	TSw2

Sample ID	Saturation (%)	Weight (g) pre-test	post-test	average	Density (g/cc)	Temperature (°C)	Conductivity (W/(mK))
NRG-6-757.0-SNL-A	vacuum sat.	62.729	62.671	62.700	2.38	29.4	2.16
						50.4	2.22
						70.4	2.02
NRG-6-757.0-SNL-B	air dry	56.944	56.937	56.941	2.29	29.1	1.57
						49.2	1.53
						69.9	1.49
NRG-6-757.0-SNL-B	oven dry	56.778	56.762	56.770	2.28	30.7	1.48
						49.6	1.48
						69.3	1.52
NRG-6-757.0-SNL-B	oven dry	56.779	56.617	56.698	2.28	110.2	1.61
						155.9	1.65
						199.4	1.65
						245.1	1.63
						288.8	1.55

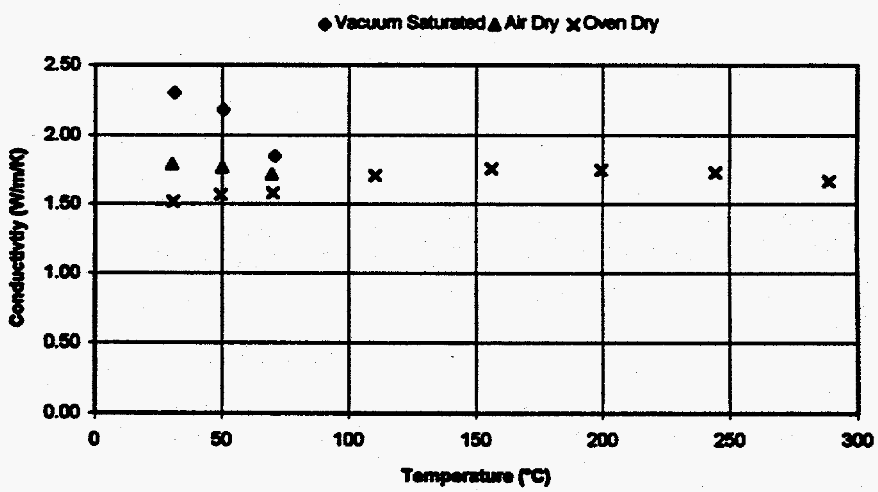


Data Summary

Hole & Depth: NRG-6-778.1
Lithology: Welded Devitrified
TMU: TSw2

Sample ID	Saturation (%)	Weight (g) pre-test	Weight (g) post-test	Weight (g) average	Density (g/cc)	Temperature (°C)	Conductivity (W/(mK))
NRG-6-778.1-SNL-A	vacuum sat.	59.485	59.415	59.450	2.30	31.3 50.4 70.7	2.30 2.18 1.85
NRG-6-778.1-SNL-B	air dry	59.711	59.705	59.708	2.30	30.1 50.0 69.6	1.79 1.77 1.72
NRG-6-778.1-SNL-B	oven dry	59.612	59.606	59.610	2.29	30.6 49.4 70.1	1.52 1.57 1.58
NRG-6-778.1-SNL-B	oven dry	59.619	59.511	59.565	2.29	110.3 156.0 199.5 244.3 289.0	1.71 1.76 1.75 1.73 1.67

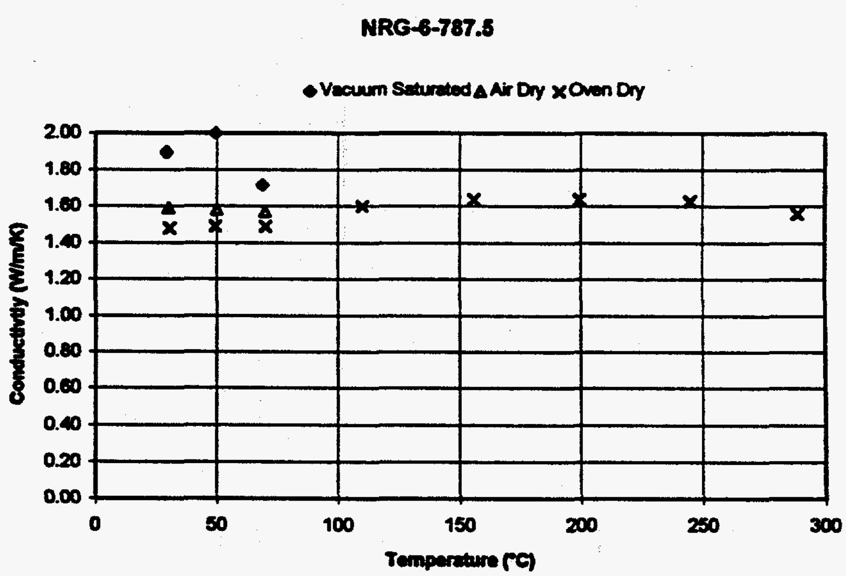
NRG-6-778.1



Data Summary

Hole & Depth: NRG-6-787.5
Lithology: Welded Devitrified
TMU: TSw2

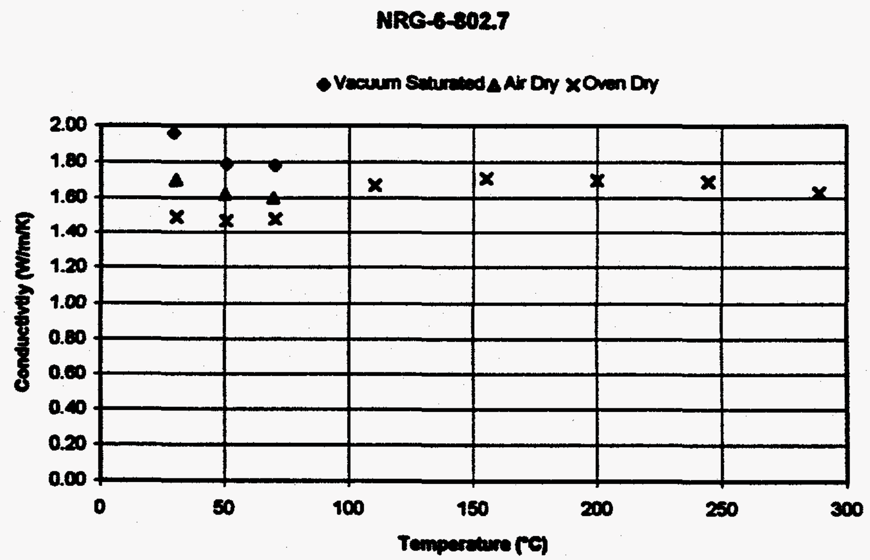
Sample ID	Saturation (%)	Weight (g) pre-test	Weight (g) post-test	Weight (g) average	Density (g/cc)	Temperature (°C)	Conductivity (W/(mK))
NRG-6-787.5-SNL-A	vacuum sat.	61.538	61.469	61.504	2.34	29.2	1.90
						49.5	2.00
						68.9	1.72
NRG-6-787.5-SNL-B	air dry	58.581	58.575	58.578	2.24	30.1	1.59
						50.1	1.58
						69.9	1.57
NRG-6-787.5-SNL-B	oven dry	58.469	58.462	58.466	2.23	30.6	1.48
						49.4	1.49
						70.1	1.49
NRG-6-787.5-SNL-B	oven dry	58.476	58.355	58.416	2.23	110.2	1.60
						155.9	1.64
						199.4	1.64
						245.0	1.63
						288.7	1.56



Data Summary

Hole & Depth: NRG-6-802.7
Lithology: Welded Devitrified
TMU: TSw2

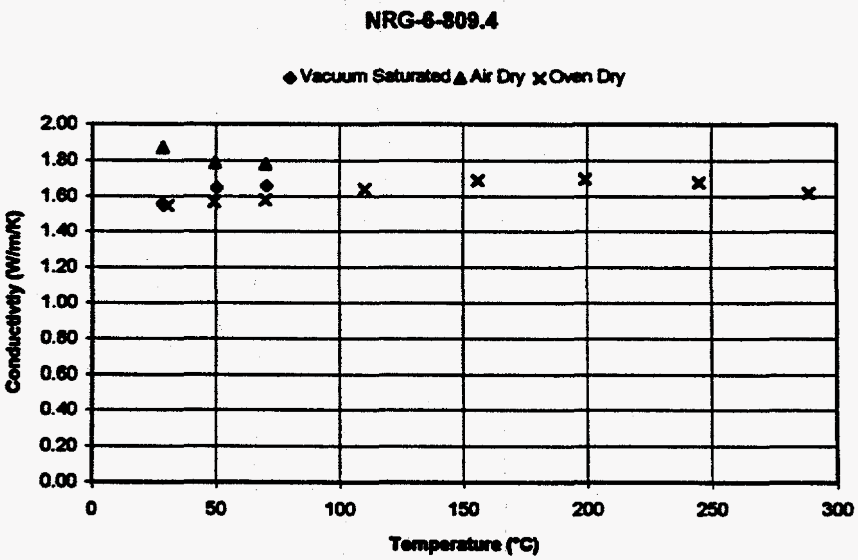
Sample ID	Saturation (%)	Weight (g) pre-test	Weight (g) post-test	Weight (g) average	Density (g/cc)	Temperature (°C)	Conductivity (W/(mK))
NRG-6-802.7-SNL-C	vacuum sat.	61.154	61.053	61.104	2.32	29.4	1.96
						50.8	1.79
						70.2	1.78
NRG-6-802.7-SNL-D	air dry	52.788	52.779	52.784	2.27	30.2	1.70
						49.9	1.62
						69.5	1.60
NRG-6-802.7-SNL-D	oven dry	52.701	52.693	52.697	2.27	30.4	1.49
						50.4	1.47
						70.2	1.48
NRG-6-802.7-SNL-D	oven dry	52.709	52.622	52.666	2.27	110.6	1.67
						155.3	1.71
						199.8	1.70
						244.5	1.69
						289.2	1.63



Data Summary

Hole & Depth: **NRG-6-809.4**
Lithology: **Welded Devitrified**
TMU: **TSw2**

Sample ID	Saturation (%)	Weight (g) pre-test	Weight (g) post-test	Weight (g) average	Density (g/cc)	Temperature (°C)	Conductivity (W/(mK))
NRG-6-809.4-SNL-A	vacuum sat.	60.395	60.372	60.384	2.36	28.4	1.56
						50.4	1.65
						70.7	1.66
NRG-6-809.4-SNL-B	air dry	60.071	60.062	60.067	2.29	28.6	1.87
						49.8	1.79
						70.1	1.78
NRG-6-809.4-SNL-B	oven dry	59.922	59.922	59.922	2.28	30.5	1.55
						49.4	1.57
						70.2	1.58
NRG-6-809.4-SNL-B	oven dry	59.944	59.811	59.878	2.28	110.2	1.64
						155.9	1.69
						199.4	1.70
						245.1	1.68
						288.9	1.62

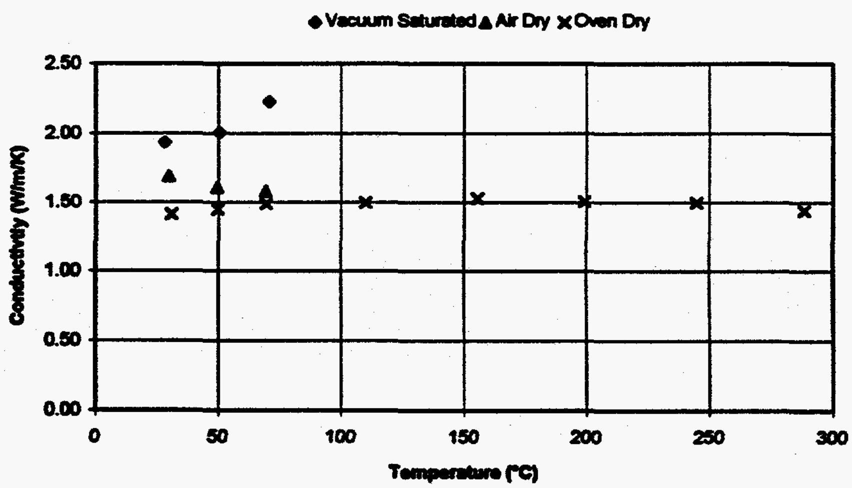


<u>Data Summary</u>

Hole & Depth: NRG-6-900.4
Lithology: Welded Devitrified
TMU: TSw2

Sample ID	Saturation (%)	Weight (g) pre-test	Weight (g) post-test	Weight (g) average	Density (g/cc)	Temperature (°C)	Conductivity (W/(mK))
NRG-6-900.4-SNL-C	vacuum sat.	60.664	60.607	60.636	2.33	28.1 50.6 70.8	1.94 2.01 2.23
NRG-6-900.4-SNL-D	air dry	57.445	57.440	57.443	2.20	29.8 49.6 69.2	1.69 1.61 1.58
NRG-6-900.4-SNL-D	oven dry	57.368	57.362	57.365	2.20	30.9 49.8 69.5	1.41 1.45 1.49
NRG-6-900.4-SNL-D	oven dry	57.379	57.279	57.329	2.19	109.9 155.6 199.1 244.8 288.5	1.50 1.53 1.51 1.50 1.44

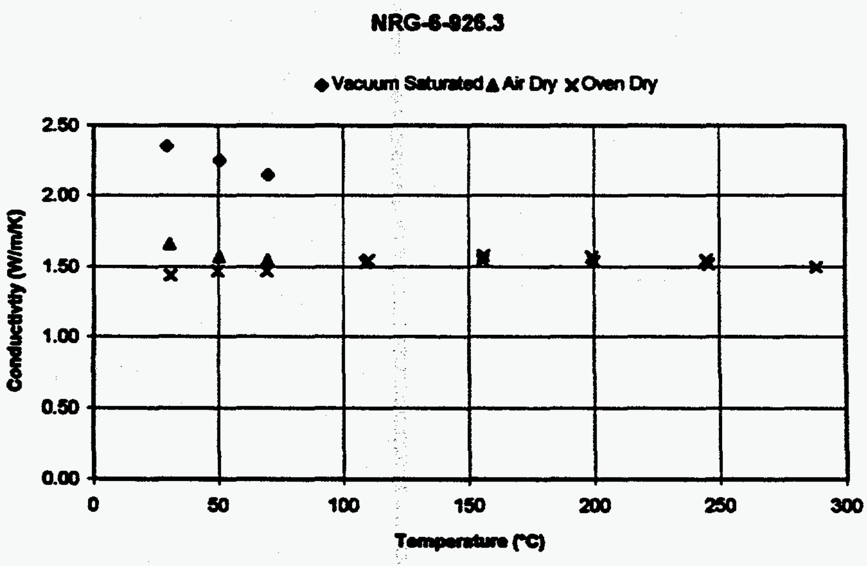
NRG-6-900.4



Data Summary

Hole & Depth:	NRG-6-926.3
Lithology:	Welded Devitrified
TMU:	TSw2

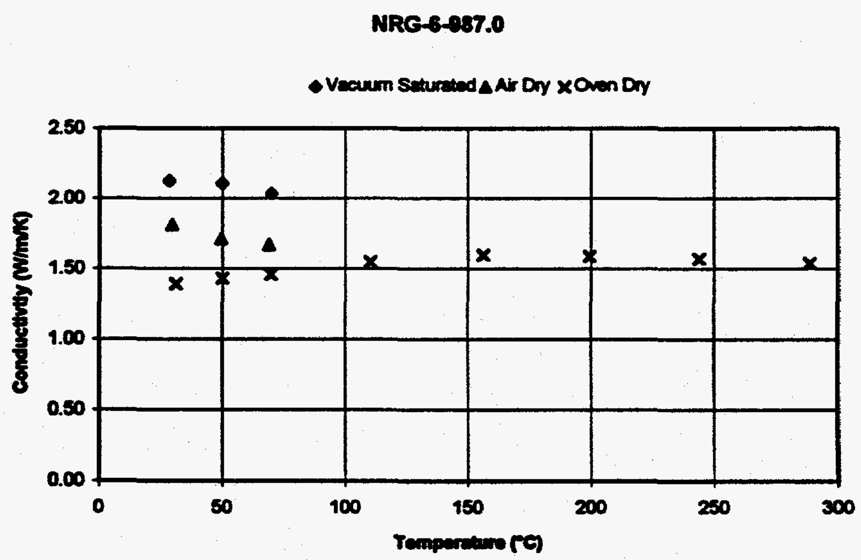
Sample ID	Saturation (%)	Weight (g) pre-test	Weight (g) post-test	Weight (g) average	Density (g/cc)	Temperature (°C)	Conductivity (W/(mK))
NRG-6-926.3-SNL-D	vacuum sat.	58.159	58.124	58.142	2.40	29.3	2.35
						50.5	2.25
						69.9	2.15
NRG-6-926.3-SNL-E	air dry	58.631	58.620	58.626	2.25	30.2	1.66
						50.1	1.57
						69.7	1.55
NRG-6-926.3-SNL-E	oven dry	58.499	58.499	58.499	2.24	30.7	1.44
						49.6	1.47
						69.4	1.47
NRG-6-926.3-SNL-E	oven dry	58.515	58.393	58.454	2.24	110.1	1.55
						155.7	1.58
						199.2	1.57
						244.8	1.55
						288.7	1.50
						245.8	*1.52*
						200.1	*1.54*
						155.6	*1.55*
						108.9	*1.53*



Data Summary

Hole & Depth:	NRG-6-987.0
Lithology:	Welded Devitrified
TMU:	TSw2

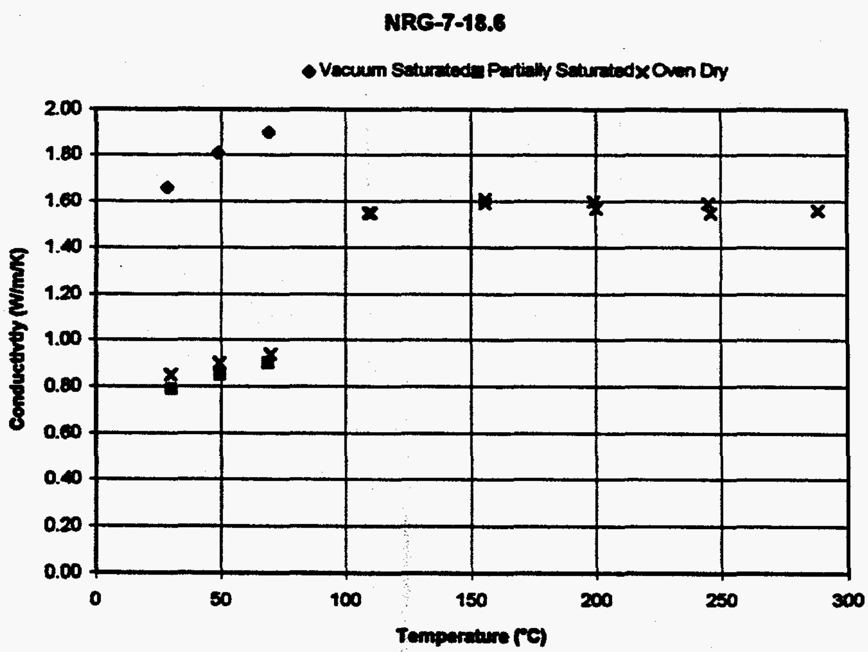
Sample ID	Saturation (%)	Weight (g) pre-test	post-test	average	Density (g/cc)	Temperature (°C)	Conductivity (W/(mK))
NRG-6-987.0-SNL-A	vacuum sat.	57.723	57.654	57.689	2.35	28.4	2.13
						50.0	2.11
						70.0	2.04
NRG-6-987.0-SNL-B	air dry	58.959	58.950	58.955	2.27	29.5	1.81
						49.3	1.71
						68.9	1.67
NRG-6-987.0-SNL-B	oven dry	58.822	58.816	58.819	2.26	30.9	1.39
						49.9	1.43
						69.6	1.46
NRG-6-987.0-SNL-B	oven dry	58.838	58.713	58.776	2.26	110.2	1.55
						156.1	1.60
						199.6	1.59
						244.1	1.57
						288.8	1.54



Data Summary

Hole & Depth: NRG-7-18.6
Lithology: Welded Devitrified
TMU: TCw

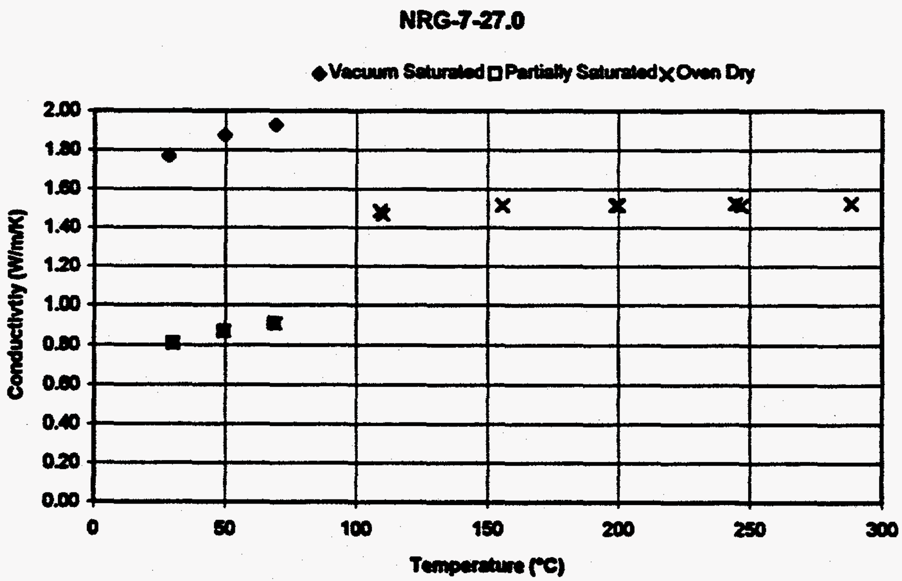
Sample ID	Saturation (%)	Weight (g) pre-test	Weight (g) post-test	Weight (g) average	Density (g/cc)	Temperature (°C)	Conductivity (W/(mK))
NRG-7-18.6-SNL-C	vacuum sat.	61.941	61.904	61.923	2.39	28.5	1.66
						48.9	1.81
						69.1	1.90
NRG-7-18.6-SNL-C	partial	60.798	60.795	60.797	2.35	30.0	0.79
						49.5	0.85
						68.8	0.90
NRG-7-18.6-SNL-D	oven dry	60.562	60.560	60.561	2.33	29.9	0.85
						49.4	0.90
						69.7	0.94
NRG-7-18.6-SNL-D	oven dry	60.561	60.523	60.542	2.33	110.2	1.55
						155.8	1.61
						199.4	1.60
						245.0	1.59
						288.6	1.56
						245.9	*1.55*
						200.3	*1.57*
						155.8	*1.59*
						109.2	*1.55*



Data Summary

Hole & Depth	NRG-7-27.0
Lithology:	Welded Devitrified
TMU:	TCw

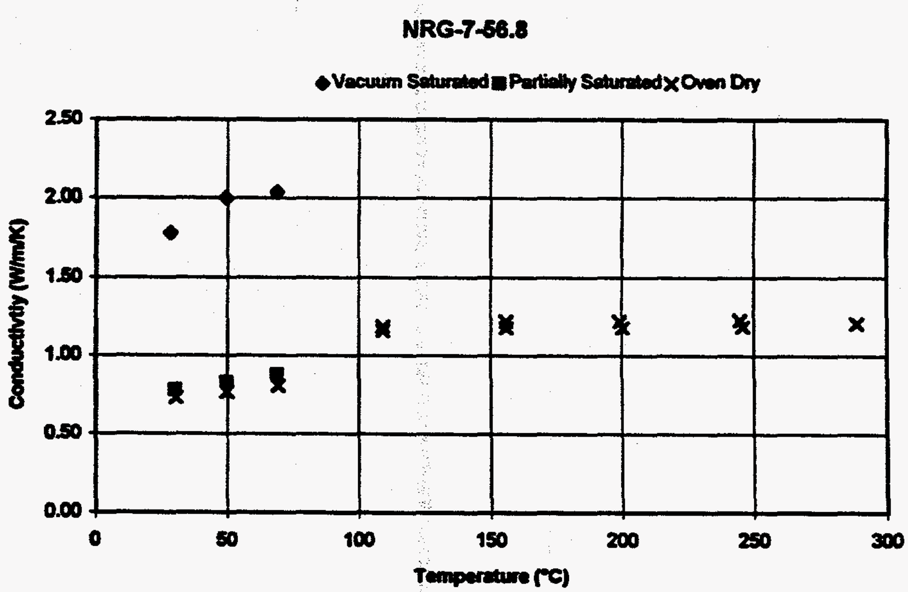
Sample ID	Saturation (%)	Weight (g) pre-test	Weight (g) post-test	Weight (g) average	Density (g/cc)	Temperature (°C)	Conductivity (W/(mK))
NRG-7-27.0-SNL-A	vacuum sat.	62.140	62.076	62.108	2.39	28.4	1.77
						49.8	1.88
						69.1	1.93
NRG-7-27.0-SNL-A	partial	61.085	61.084	61.085	2.35	30.0	0.81
						49.5	0.87
						68.8	0.91
NRG-7-27.0-SNL-B	oven dry	60.789	60.787	60.788	2.33	30.0	0.81
						49.5	0.87
						68.9	0.91
NRG-7-27.0-SNL-B	oven dry	60.787	60.750	60.769	2.33	110.0	1.47
						155.6	1.52
						199.1	1.52
						244.7	1.53
						288.4	1.53
						246.7	*1.52*
						200.1	*1.52*
						155.6	*1.52*
						109.0	*1.49*



Data Summary

Hole & Depth	NRG-7-56.8
Lithology:	Welded Devitrified
TMU:	TCw

Sample ID	Saturation (%)	Weight (g) pre-test	Weight (g) post-test	Weight (g) average	Density (g/cc)	Temperature (°C)	Conductivity (W/(mK))
NRG-7-56.8-SNL-C	vacuum sat.	58.080	58.031	58.056	2.23	28.3	1.78
						49.6	2.00
						68.9	2.04
NRG-7-56.8-SNL-C	partial	54.665	54.659	54.662	2.10	30.1	0.78
						49.7	0.83
						68.9	0.88
NRG-7-56.8-SNL-D	oven dry	54.290	54.289	54.290	2.07	30.2	0.73
						49.8	0.77
						69.1	0.81
NRG-7-56.8-SNL-D	oven dry	54.290	54.289	54.290	2.07	109.0	1.19
						155.8	1.22
						199.3	1.22
						244.8	1.23
						288.6	1.21
						245.8	*1.19*
						200.2	*1.18*
						155.8	*1.18*
						109.0	*1.16*

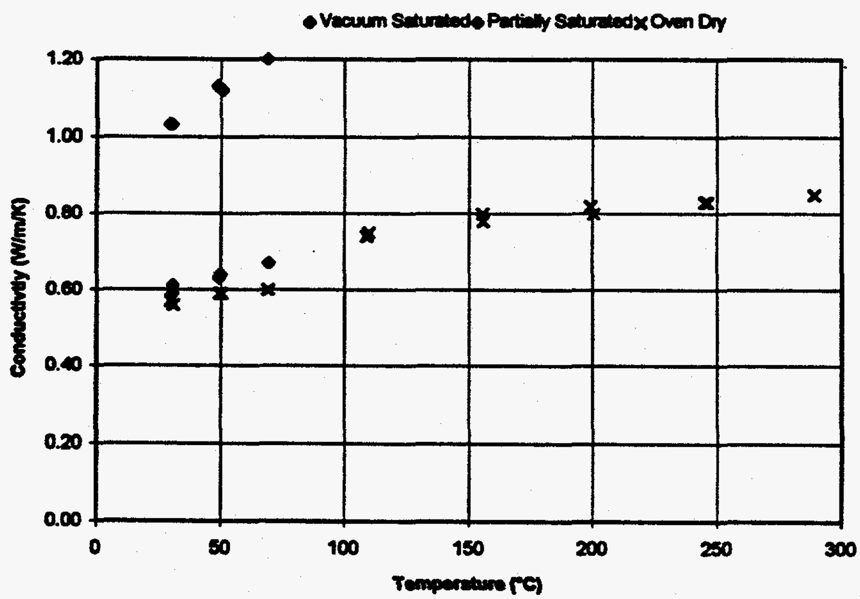


Data Summary

Hole & Depth	NRG-7-75.0
Lithology:	Vitric Nonwelded
TMU:	PTn

Sample ID	Saturation (%)	Weight (g) pre-test	post-test	average	Density (g/cc)	Temperature (°C)	Conductivity (W/(mK))
						29.6	1.03
NRG-7-75.0-SNL-C	vacuum sat.	51.507	51.436	51.472	1.96	49.0	1.13
						69.2	1.20
						50.9	1.12
						30.4	1.03
						30.7	0.59
NRG-7-75.0-SNL-C	partial	47.880	47.877	47.879	1.84	49.3	0.63
						69.5	0.67
						50.2	*0.64*
						30.7	*0.61*
						30.9	0.56
NRG-7-75.0-SNL-D	oven dry	45.338	45.338	45.338	1.74	49.6	0.59
						69.0	0.60
						50.5	*0.59*
						29.9	*0.57*
						109.9	0.75
NRG-7-75.0-SNL-D	oven dry	45.413	44.437	44.925	1.72	155.7	0.80
						199.3	0.82
						245.1	0.83
						289.1	0.85
						246.2	*0.83*
						200.4	*0.80*
						155.8	*0.78*
						109.0	*0.74*

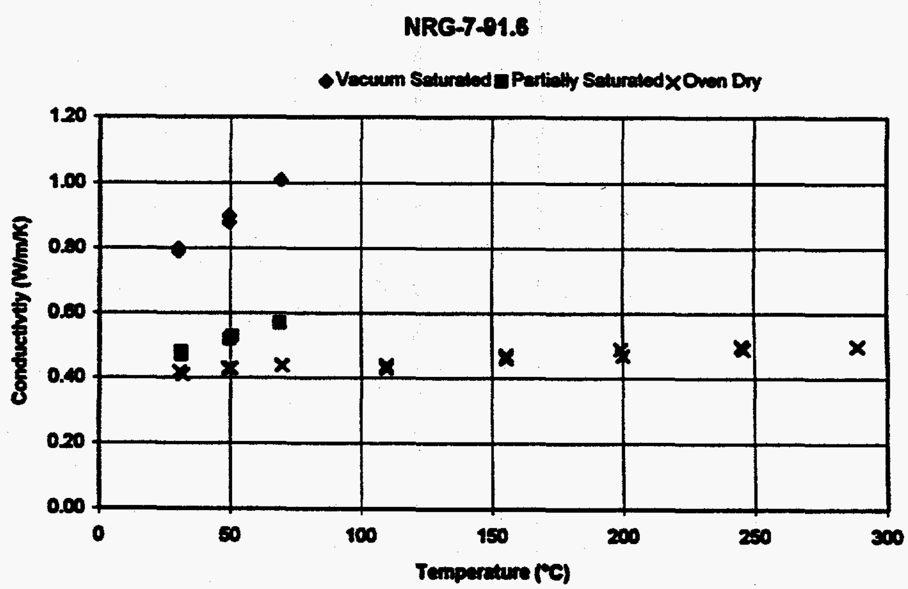
NRG-7-75.0



Data Summary

Hole & Depth	NRG-7-91.6
Lithology:	Vitric Nonwelded
TMU:	PTn

Sample ID	Saturation (%)	Weight (g) pre-test	post-test	average	Density (g/cc)	Temperature (°C)	Conductivity (W/(mK))
NRG-7-91.6-SNL-C	vacuum sat.	45.618	45.541	45.580	1.74	30.0	0.79
						49.5	0.90
						69.5	1.01
						49.5	*0.88*
						30.0	*0.80*
NRG-7-91.6-SNL-C	partial	37.919	37.916	37.918	1.45	31.4	0.47
						49.8	0.52
						69.0	0.57
						50.8	*0.53*
						31.3	*0.48*
NRG-7-91.6-SNL-D	oven dry	35.007	35.004	35.006	1.35	31.7	0.41
						49.3	0.43
						69.7	0.44
						50.3	*0.43*
						30.6	*0.42*
NRG-7-91.6-SNL-D	oven dry	35.004	34.465	34.735	1.34	109.7	0.44
						155.5	0.47
						199.2	0.49
						245.0	0.50
						288.8	0.50
						245.8	*0.49*
						200.1	*0.47*
						155.5	*0.46*
						109.7	*0.43*

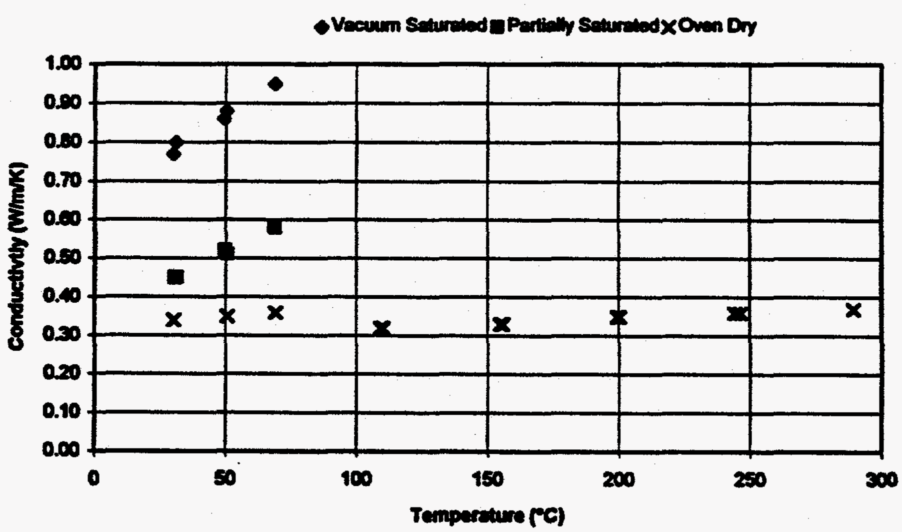


Data Summary

Hole & Depth NRG-7-104.1
Lithology: Vitric Nonwelded
TMU: PTn

Sample ID	Saturation (%)	Weight (g) pre-test	post-test	average	Density (g/cc)	Temperature (°C)	Conductivity (W/(mK))
NRG-7-104.1-SNL-B	vacuum sat.	38.396	38.382	38.389	1.49	30.1	0.77
						49.5	0.86
						68.8	0.95
						50.5	*0.88*
						31.0	*0.80*
NRG-7-104.1-SNL-B	partial	28.779	28.774	28.777	1.12	31.3	0.45
						49.7	0.52
						68.9	0.58
						50.8	*0.51*
						30.4	*0.45*
NRG-7-104.1-SNL-C	oven dry	27.023	27.022	27.023	1.01	31.2	0.34
						50.8	0.35
						69.2	0.36
						50.8	*0.35*
						30.2	*0.34*
NRG-7-104.1-SNL-C	oven dry	27.019	26.436	26.728	1.00	110.2	0.32
						155.9	0.33
						199.7	0.35
						244.4	0.36
						289.3	0.37
						246.5	*0.36*
						200.6	*0.35*
						154.9	*0.33*
						109.2	*0.32*

NRG-7-104.1

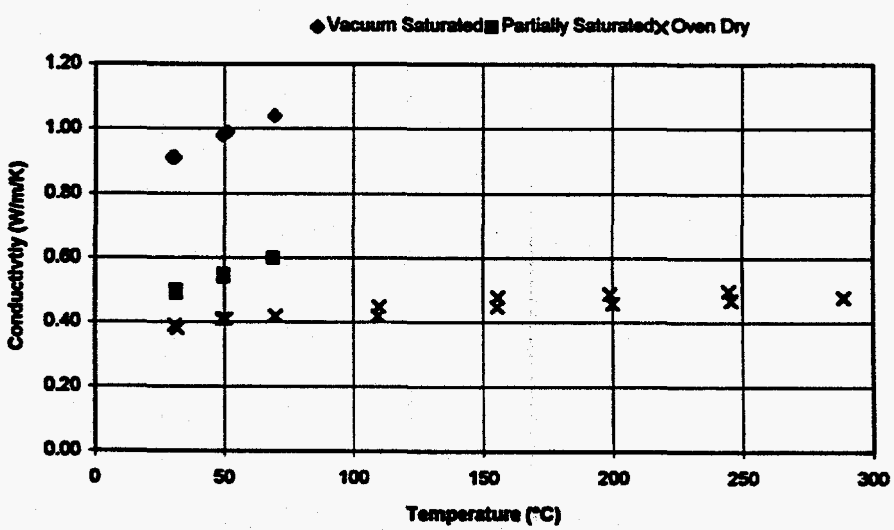


Data Summary

Hole & Depth	NRG-7-113.1
Lithology:	Vitric Nonwelded
TMU:	PTn

Sample ID	Saturation (%)	Weight (g) pre-test	Weight (g) post-test	Weight (g) average	Density (g/cc)	Temperature (°C)	Conductivity (W/(mK))
NRG-7-113.1-SNL-C	vacuum sat.	43.474	43.449	43.462	1.70	29.7	0.91
						49.2	0.98
						69.4	1.04
						51.1	*0.99*
						30.6	*0.91*
NRG-7-113.1-SNL-C	20% sat.	36.172	36.170	36.171	1.41	31.3	0.49
						49.7	0.55
						68.9	0.60
						49.7	*0.54*
						31.2	*0.50*
NRG-7-113.1-SNL-B	oven dry	34.670	34.670	34.670	1.33	31.7	0.38
						50.4	0.41
						69.7	0.42
						49.3	*0.41*
						30.7	*0.39*
NRG-7-113.1-SNL-B	oven dry	34.663	34.211	34.437	1.32	109.8	0.45
						155.6	0.48
						199.2	0.49
						244.8	0.50
						288.7	0.48
						245.7	*0.47*
						200.0	*0.46*
						155.3	*0.45*
						109.5	*0.42*

NRG-7-113.1

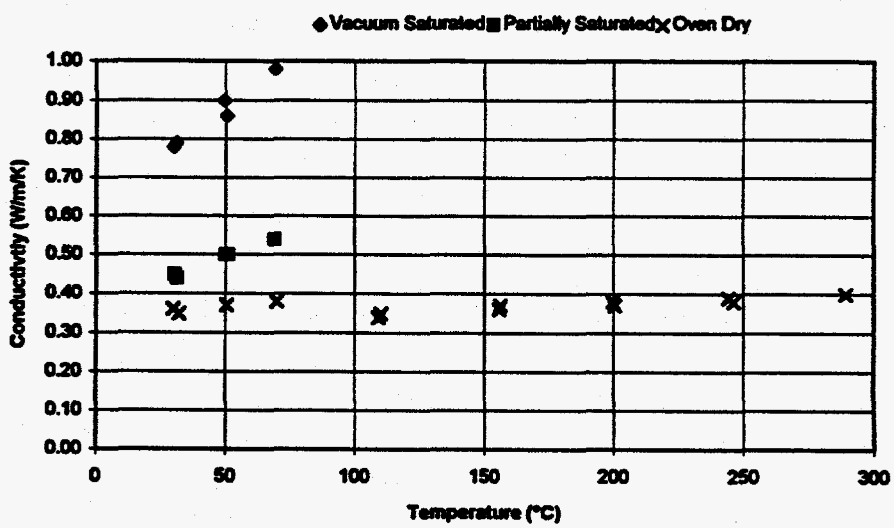


Data Summary

Hole & Depth	NRG-7-248.5
Lithology:	Vitric Nonwelded
TMU:	PTn

Sample ID	Saturation (%)	Weight (g) pre-test	Weight (g) post-test	Weight (g) average	Density (g/cc)	Temperature (°C)	Conductivity (W/(mK))
						30.1	0.78
NRG-7-248.5-SNL-C	vacuum sat.	43.001	42.901	42.951	1.65	49.5	0.90
						69.5	0.98
						50.5	*0.86*
						31.1	*0.79*
						31.4	0.44
NRG-7-248.5-SNL-C	partial	34.030	34.028	34.029	1.30	49.9	0.50
						69.1	0.54
						50.9	*0.50*
						30.4	*0.45*
						32.0	0.35
NRG-7-248.5-SNL-D	oven dry	30.521	30.521	30.521	1.18	50.6	0.37
						69.9	0.38
						50.6	*0.37*
						29.9	*0.36*
						110.3	0.35
NRG-7-248.5-SNL-D	oven dry	30.507	29.918	30.213	1.17	156.1	0.37
						199.7	0.38
						244.4	0.39
						289.4	0.40
						246.2	*0.38*
						200.4	*0.37*
						155.8	*0.36*
						109.2	*0.34*

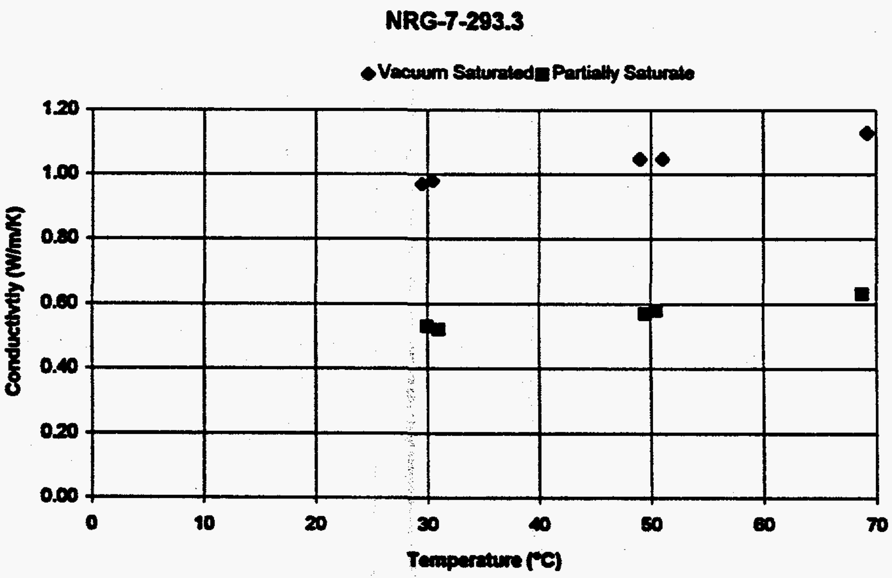
NRG-7-248.5



Data Summary

Hole & Depth	NRG-7-293.3
Lithology:	Vitric Nonwelded
TMU:	PTn

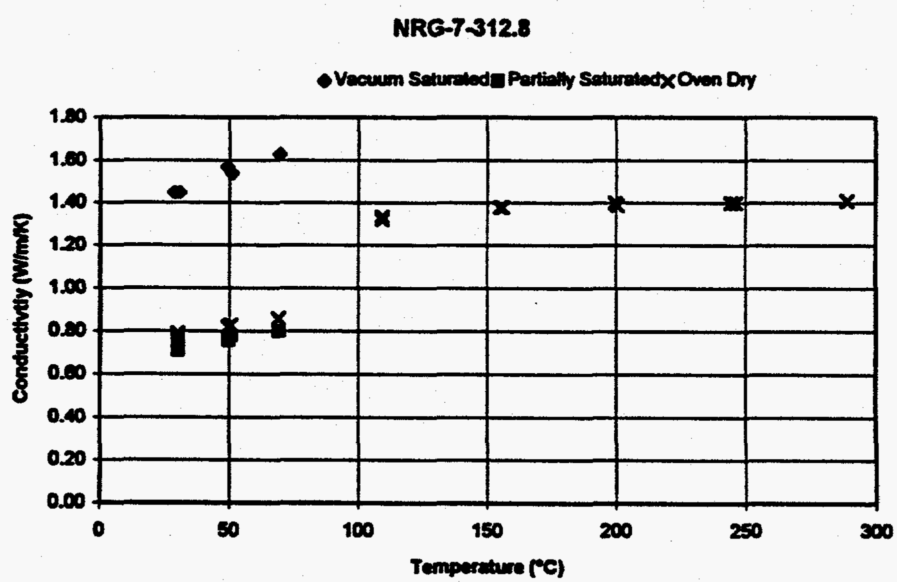
Sample ID	Saturation (%)	Weight (g) pre-test	post-test	average	Density (g/cc)	Temperature (°C)	Conductivity (W/(mK))
NRG-7-293.3-SNL-C	vacuum sat.	46.410	46.331	46.371	1.78	29.5	0.97
						49.0	1.05
						69.2	1.13
						51.0	1.05
						30.5	0.98
NRG-7-293.3-SNL-C	partial	40.769	40.768	40.769	1.57	31.0	0.52
						49.5	0.57
						68.8	0.63
						50.5	0.58
						30.0	0.53



Data Summary

Hole & Depth NRG-7-312.8
Lithology: Welded Devitrified
TMU: TSw1

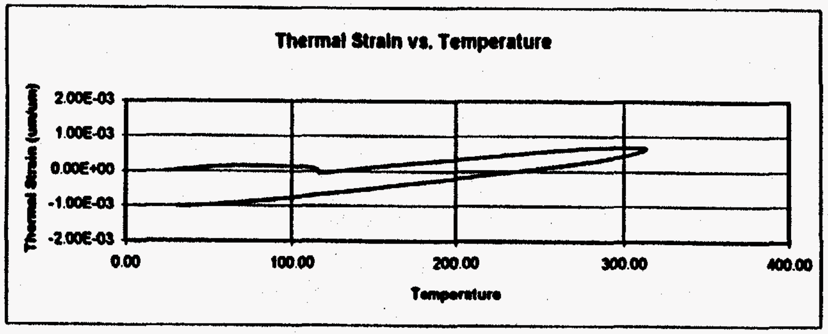
Sample ID	Saturation (%)	Weight (g) pre-test	post-test	average	Density (g/cc)	Temperature (°C)	Conductivity (W/(mK))
						28.8	1.45
NRG-7-312.8-SNL-C	vacuum sat.	62.679	62.552	62.616	2.39	49.2	1.57
						69.4	1.63
						51.1	*1.54*
						30.7	*1.45*
						30.3	0.71
NRG-7-312.8-SNL-C	partial	61.115	61.113	61.114	2.33	49.8	0.76
						69.2	0.80
						50.8	*0.78*
						30.2	*0.74*
						30.1	0.76
NRG-7-312.8-SNL-D	oven dry	59.868	59.867	59.868	2.30	49.6	0.82
						68.9	0.86
						50.6	*0.83*
						30.0	*0.79*
						109.3	1.32
NRG-7-312.8-SNL-D	oven dry	59.868	59.825	59.847	2.30	156.0	1.38
						199.5	1.40
						244.3	1.40
						288.9	1.41
						246.2	*1.40*
						200.5	*1.39*
						155.0	*1.38*
						109.3	*1.34*

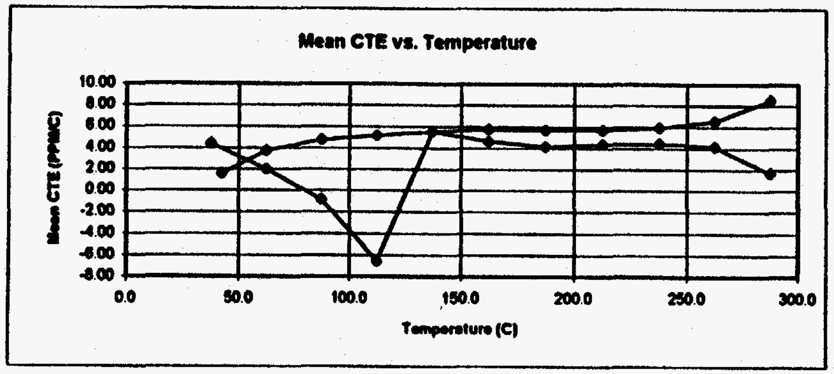


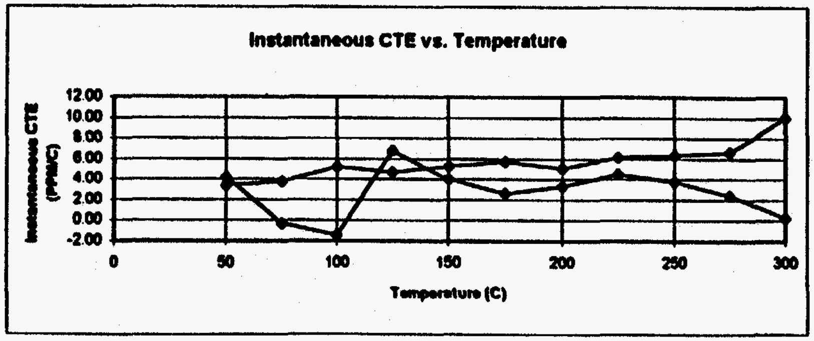
APPENDIX E

Thermal Expansion Test Data

This page intentionally left blank







Data Summary

Sample ID: NRG-4-450.6-SNL-D
Lithology: Nonwelded Vitric
TMU: PTn

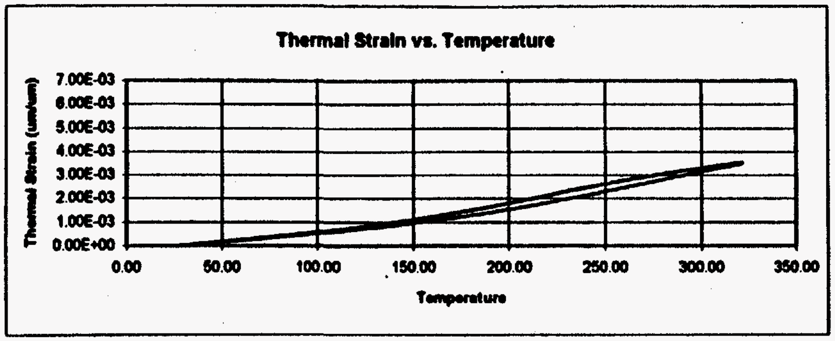
Test condition: AIR DRIED
Sample Size: 2" (l) x 1" (d)

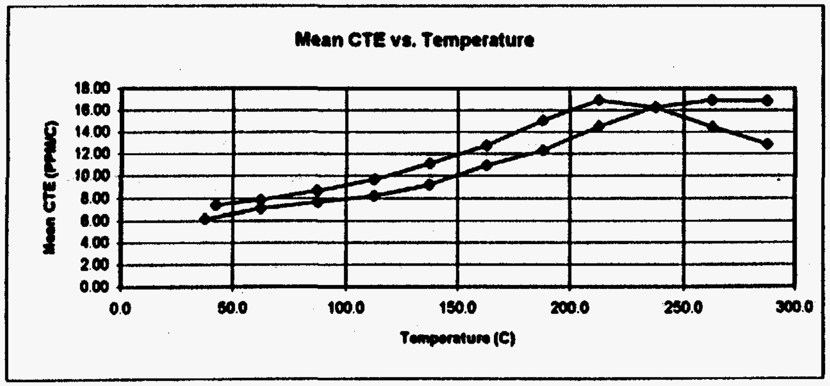
Sample Data:

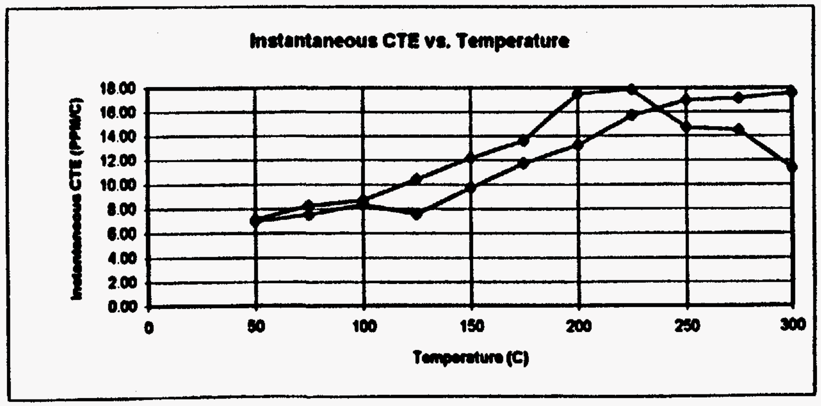
	mass (g)	length (mm)	volume (cc)	density (g/cc)
Initial:	27.30	50.52	25.60	1.07
Final:	26.96	50.47	25.57	1.05

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
Heat up	25	-0.66	***	***	
	50	106.68	4.37	4.24	37.5
	75	158.60	2.00	-0.29	62.5
	100	137.58	-0.84	-1.42	87.5
	125	-26.74	-6.57	6.81	112.5
	150	112.27	5.56	4.03	137.5
	175	228.33	4.64	2.62	162.5
	200	332.20	4.15	3.31	187.5
	225	441.93	4.39	4.53	212.5
	250	553.32	4.46	3.74	237.5
	275	657.05	4.15	2.46	262.5
	300	700.05	1.72	0.31	287.5
Cool down	300	459.19	8.56	10.01	287.5
	275	245.26	6.54	6.70	262.5
	250	81.74	5.95	6.36	237.5
	225	-66.95	5.74	6.20	212.5
	200	-210.46	5.70	5.11	187.5
	175	-353.07	5.80	5.72	162.5
	150	-498.17	5.53	5.29	137.5
	125	-636.31	5.18	4.73	112.5
	100	-765.90	4.75	5.21	87.5
	75	-884.68	3.74	3.78	62.5
	50	-978.18	1.58	3.41	42.5
	35	-1017.62	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

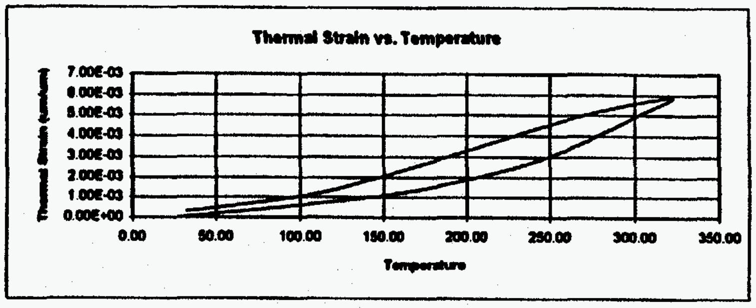
Sample ID: NRG-4-506.0-SNL-D
Lithology: Welded Devitrified
TMU: TSw1

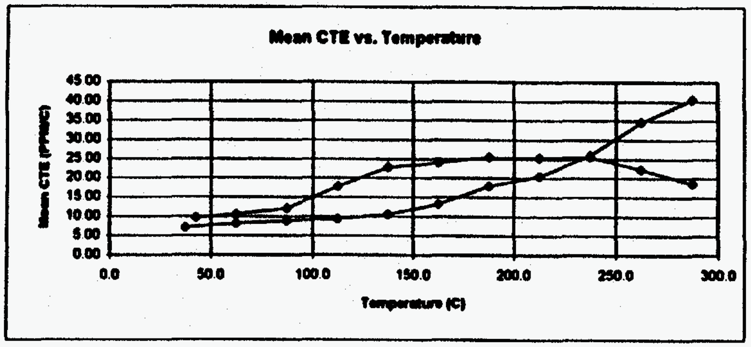
Test condition: AIR DRIED
Sample Size: 2" (l) x 1" (d)

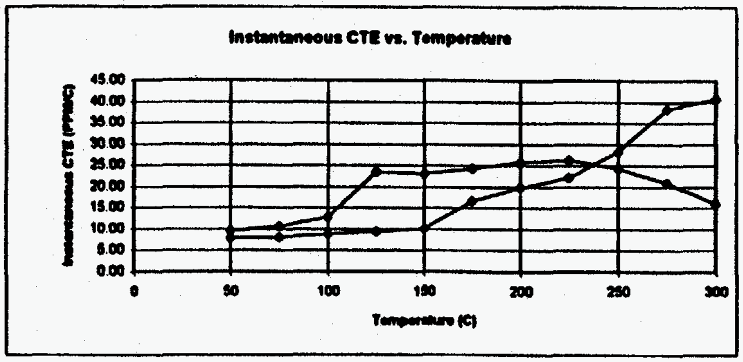
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	56.502	50.9	25.79	2.19
post-test:	56.43	50.9	25.79	2.19

Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
25	1.85	***	***	
50	155.87	6.16	6.96	37.5
75	333.60	7.11	7.52	62.5
100	523.54	7.60	8.39	87.5
125	729.34	8.23	7.58	112.5
150	959.97	9.23	9.75	137.5
175	1233.66	10.95	11.72	162.5
200	1541.57	12.32	13.24	187.5
225	1905.72	14.57	15.66	212.5
250	2313.38	16.31	16.95	237.5
275	2736.49	16.92	17.15	262.5
300	3158.48	16.88	17.54	287.5
300	3323.73	12.90	11.35	287.5
275	3001.34	14.47	14.50	262.5
250	2639.53	16.23	14.70	237.5
225	2233.83	16.97	17.81	212.5
200	1809.63	15.06	17.49	187.5
175	1433.12	12.76	13.62	162.5
150	1114.06	11.14	12.18	137.5
125	835.50	9.69	10.44	112.5
100	593.34	8.67	8.72	87.5
75	376.68	7.84	8.27	62.5
50	180.79	7.41	7.12	42.5
35	69.58	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







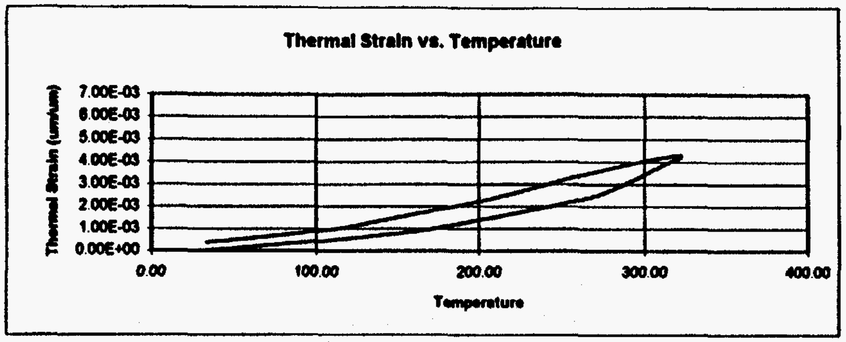
Data Summary

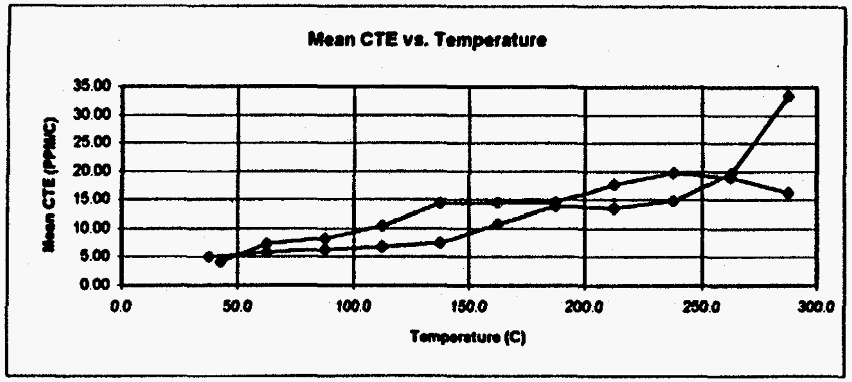
Sample ID:	NRG-4-529.0-SNL-C
Lithology:	Welded Devitrified
TMU:	TSw1
Test condition:	AIR DRIED
Sample Size:	2" (l) x 1" (d)

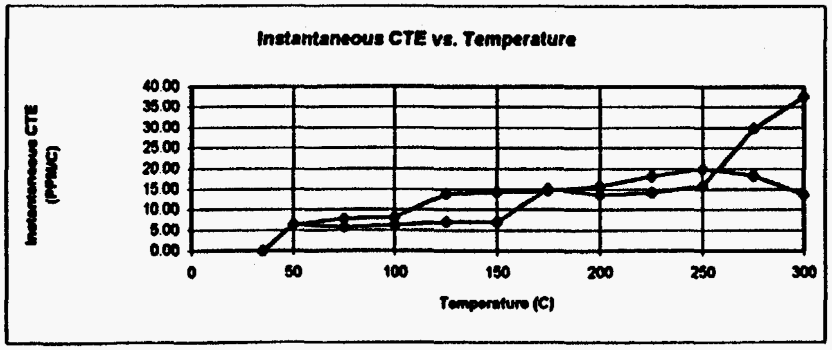
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	53.676	50.85	25.77	2.08
post-test:	53.535	50.88	25.78	2.08

Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
25	1.08	***	***	
50	180.01	7.16	7.80	37.5
75	383.24	8.13	8.00	62.5
100	600.62	8.70	8.71	87.5
125	833.71	9.32	9.43	112.5
150	1093.52	10.39	10.14	137.5
175	1424.16	13.23	16.65	162.5
200	1869.55	17.82	19.75	187.5
225	2380.82	20.45	22.11	212.5
250	3031.07	26.01	28.32	237.5
275	3896.13	34.60	38.17	262.5
300	4906.04	40.40	40.73	287.5
300	5574.29	18.62	16.03	287.5
275	5108.92	22.26	20.83	262.5
250	4562.47	25.38	24.30	237.5
225	3918.08	25.32	28.31	212.5
200	3285.10	25.40	25.81	187.5
175	2650.10	24.00	24.26	162.5
150	2050.11	22.80	22.99	137.5
125	1480.11	17.72	23.51	112.5
100	1037.16	12.04	12.77	87.5
75	736.24	10.50	10.67	62.5
50	473.81	9.67	9.58	42.5
35	328.74	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







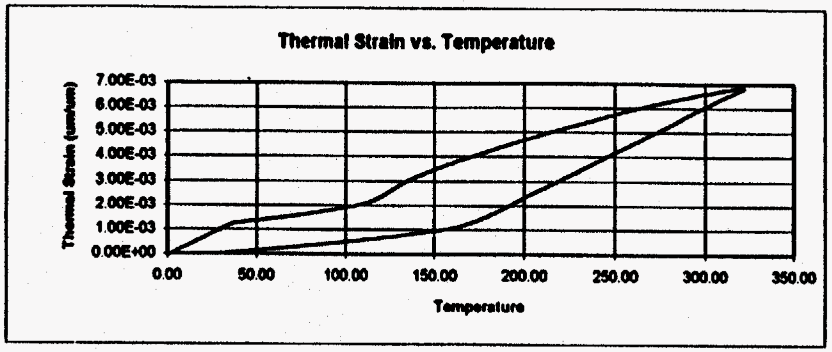
Data Summary

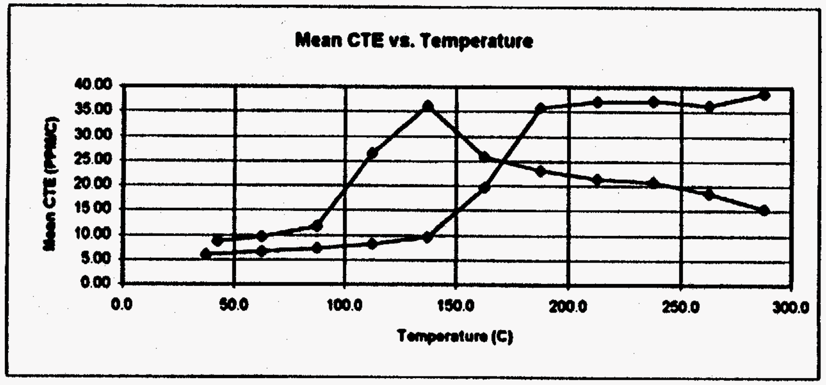
Sample ID:	NRG-4-586.2-SNL-D
Lithology:	Welded Devitrified
TMU:	TSw1
Test condition:	AIR DRIED
Sample Size:	2" (l) x 1" (d)

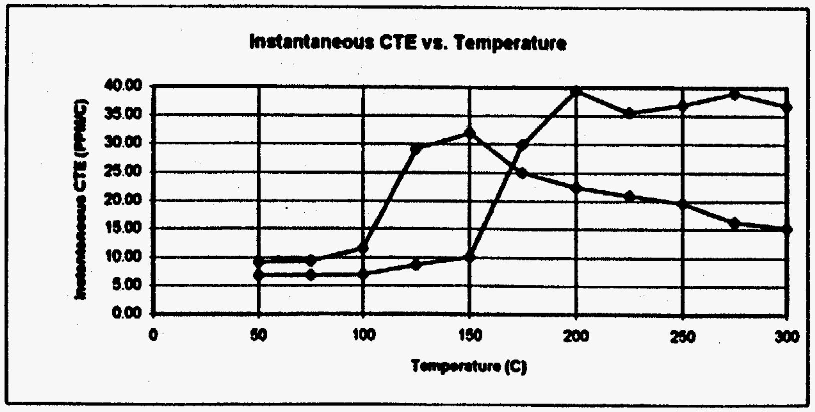
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
Initial:	53.961	50.83	25.76	2.10
Final:	53.813	50.83	25.76	2.09

Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (^oC)
25	2.06	***	***	
50	128.26	5.05	6.37	37.5
75	275.59	5.89	5.66	62.5
100	432.78	6.29	6.26	87.5
125	601.00	6.73	7.07	112.5
150	786.47	7.42	7.05	137.5
175	1056.32	10.79	15.19	162.5
200	1402.19	13.83	13.74	187.5
225	1742.06	13.59	14.16	212.5
250	2113.00	14.84	15.79	237.5
275	2603.09	19.60	29.84	262.5
300	3441.72	33.55	37.67	287.5
300	4053.16	16.24	13.69	287.5
275	3647.21	18.99	18.27	262.5
250	3172.42	19.79	19.88	237.5
225	2677.73	17.64	18.14	212.5
200	2236.63	14.59	15.71	187.5
175	1871.98	14.50	14.59	162.5
150	1509.52	14.33	14.35	137.5
125	1151.17	10.41	13.84	112.5
100	890.89	8.24	8.05	87.5
75	684.77	7.32	7.75	62.5
50	501.87	4.18	6.34	42.5
35	397.38	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

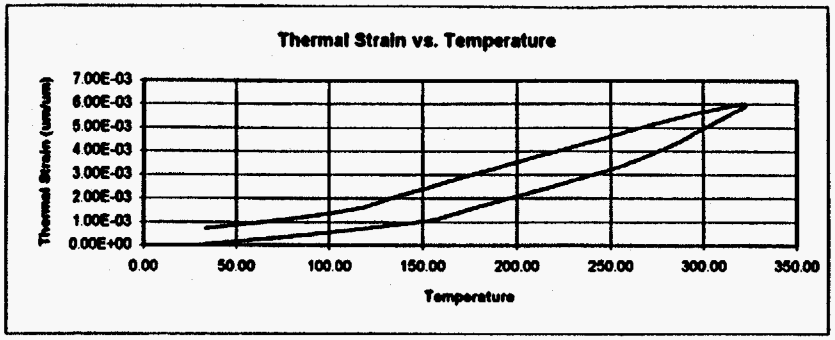
Sample ID: NRG-4-610.5-SNL-D
Lithology: Welded Devitrified
TMU: TSw1

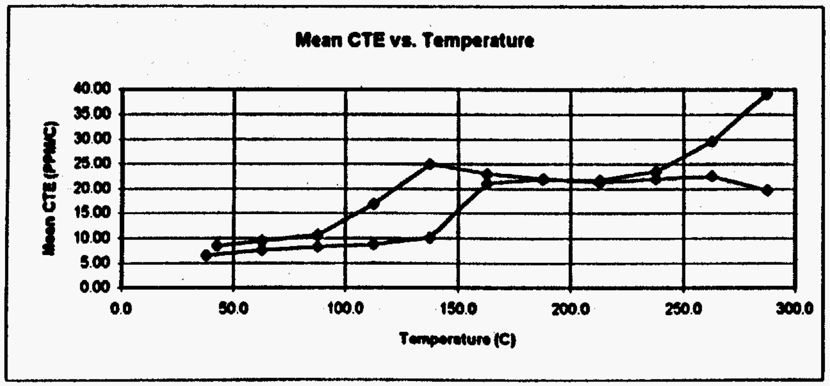
Test condition: AIR DRIED
Sample Size: 2" (l) x 1" (d)

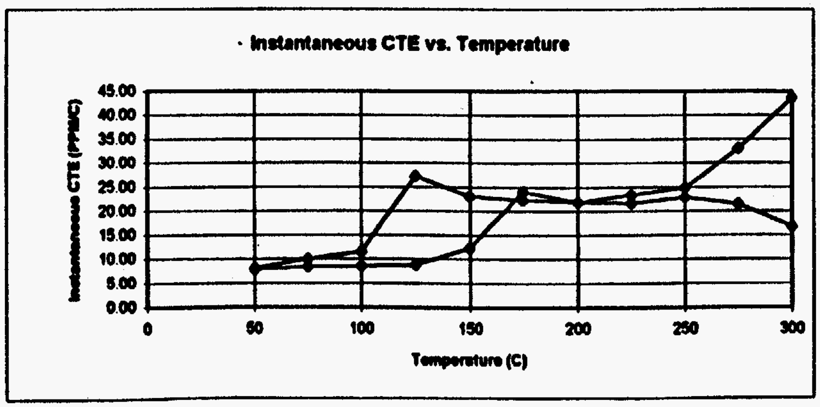
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	55.775	50.88	25.78	2.16
post-test:	55.613	50.93	25.81	2.15

Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
25	0.41	***	***	
50	149.48	5.96	6.93	37.5
75	317.19	6.71	6.92	62.5
100	500.98	7.35	7.01	87.5
125	706.31	8.21	8.77	112.5
150	948.12	9.67	10.13	137.5
175	1439.06	19.64	29.96	162.5
200	2333.99	35.80	39.40	187.5
225	3260.96	37.08	35.51	212.5
250	4191.44	37.22	36.95	237.5
275	5101.30	36.39	38.93	262.5
300	6070.57	38.77	36.74	287.5
300	6603.94	15.47	15.28	287.5
275	6217.16	18.51	16.32	262.5
250	5754.52	20.75	19.65	237.5
225	5235.71	21.40	20.98	212.5
200	4700.65	23.18	22.50	187.5
175	4121.22	25.63	25.04	162.5
150	3475.37	36.25	31.94	137.5
125	2569.11	26.60	29.06	112.5
100	1904.20	11.77	11.62	87.5
75	1610.04	9.73	9.35	62.5
50	1366.74	8.77	9.12	42.5
35	1235.18	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







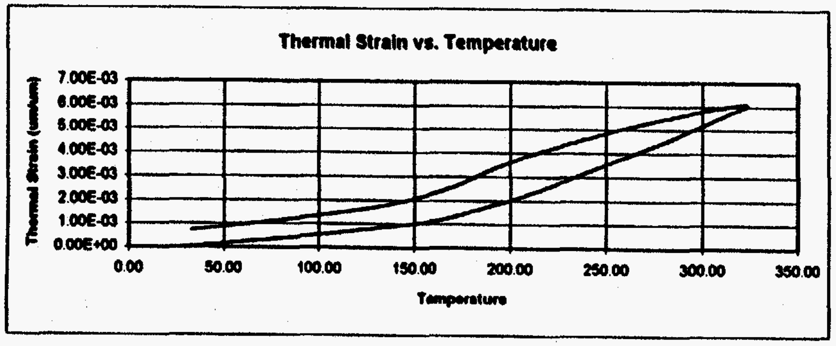
Data Summary

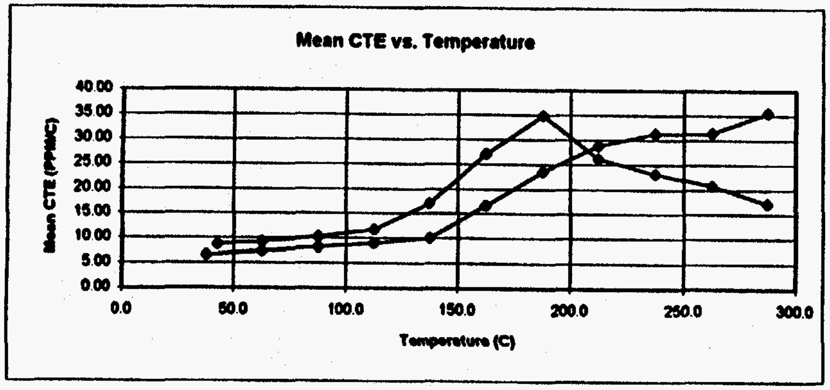
Sample ID:	NRG-4-654.5-SNL-A
Lithology:	Welded Devitrified
TMU:	TSw1
Test condition:	AIR DRIED
Sample Size:	2" (l) x 1" (d)

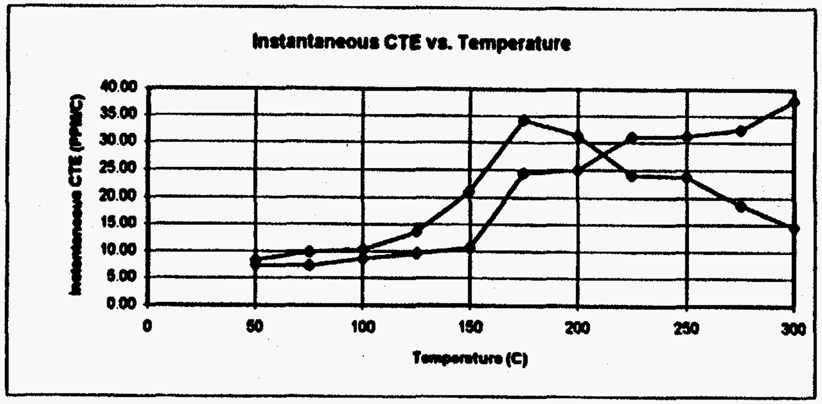
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	56.227	50.85	25.77	2.18
post-test:	55.785	50.88	25.78	2.16

Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (^{o}C)
25	1.36	***	***	
50	165.69	6.57	7.95	37.5
75	356.73	7.64	8.44	62.5
100	561.68	8.20	8.62	87.5
125	781.62	8.80	8.83	112.5
150	1032.57	10.04	12.33	137.5
175	1561.05	21.14	24.07	162.5
200	2108.07	21.88	21.92	187.5
225	2652.21	21.77	23.38	212.5
250	3242.40	23.61	24.83	237.5
275	3983.67	29.65	32.98	262.5
300	4963.92	39.21	43.67	287.5
300	5686.62	19.68	16.78	287.5
275	5194.66	22.62	21.45	262.5
250	4629.22	22.05	22.85	237.5
225	4078.00	21.31	21.59	212.5
200	3545.35	22.10	21.92	187.5
175	2992.96	23.02	22.33	162.5
150	2417.51	25.10	23.06	137.5
125	1790.10	16.85	27.33	112.5
100	1368.84	10.67	11.51	87.5
75	1102.15	9.39	10.01	62.5
50	867.45	8.47	8.18	42.5
35	740.36	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

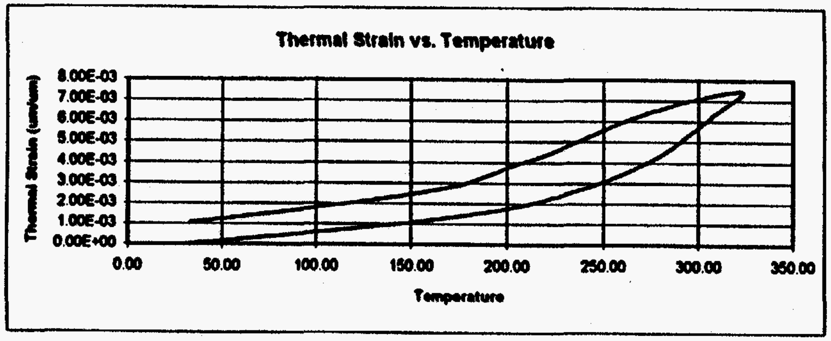
Sample ID:	NRG-4-690.6-SNL-A
Lithology:	Welded Devitrified
TMU:	TSw1
Test condition:	AIR DRIED
Sample Size:	2" (l) x 1" (d)

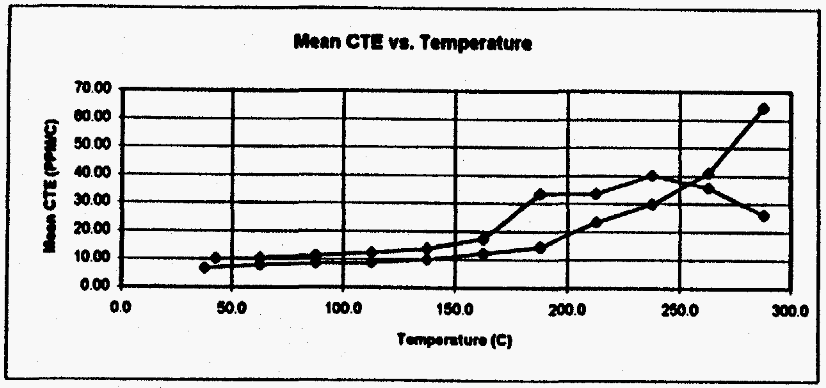
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	46.847	50.77	25.73	1.82
post-test:	46.631	50.8	25.74	1.81

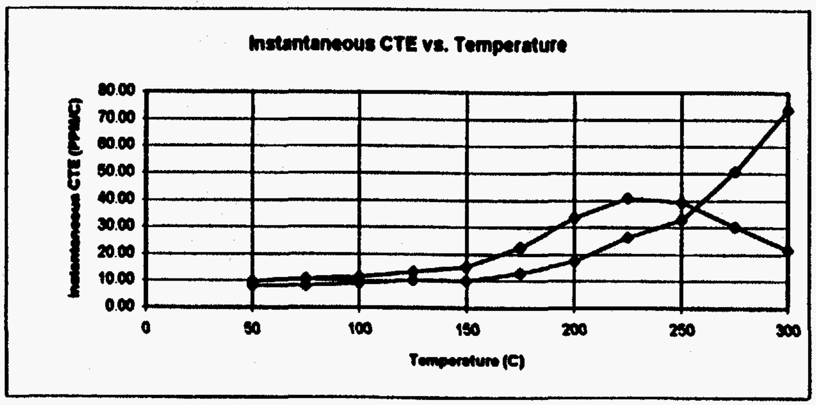
Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
25	2.68	***	***	
50	167.78	6.60	7.45	37.5
75	350.87	7.32	7.28	62.5
100	552.93	8.08	8.60	87.5
125	775.68	8.91	9.57	112.5
150	1023.56	9.92	10.70	137.5
175	1438.79	16.61	24.38	162.5
200	2030.47	23.67	24.96	187.5
225	2751.01	28.82	31.17	212.5
250	3535.42	31.38	31.22	237.5
275	4323.53	31.52	32.45	262.5
300	5212.67	35.57	37.93	287.5
300	5813.07	17.14	14.65	287.5
275	5384.50	20.79	18.60	262.5
250	4864.70	23.25	23.80	237.5
225	4283.40	26.27	24.02	212.5
200	3626.72	34.86	31.29	187.5
175	2755.24	27.13	34.29	162.5
150	2076.93	17.10	21.07	137.5
125	1649.48	11.71	13.71	112.5
100	1356.68	10.17	10.38	87.5
75	1102.38	9.24	9.80	62.5
50	871.46	8.59	8.38	42.5
35	742.57	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.

<u>Data Summaries for NRG-5</u>







Data Summary

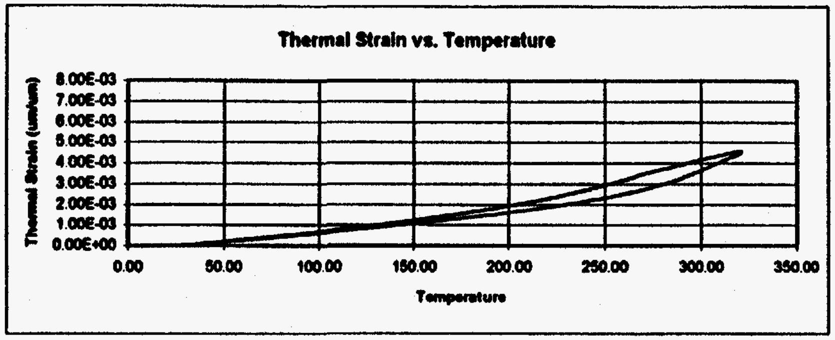
Sample ID: NRG-5-779.8-SNL-A
Lithology: Welded Devitrified
TMU: TSw1

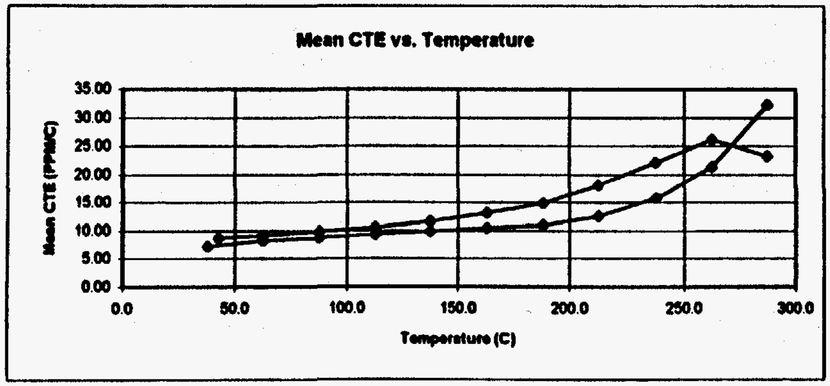
Test condition: AIR DRIED
Sample Size: 2" (l) x 1" (d)

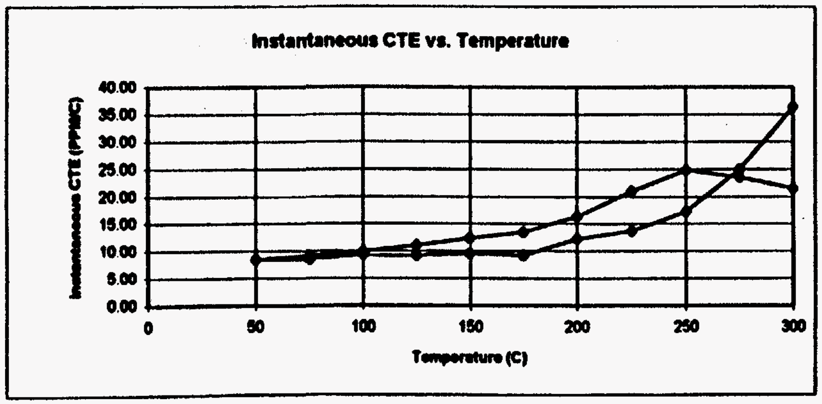
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	55.195	50.93	25.81	2.14
post-test:	54.969	50.98	25.83	2.13

Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
25	7.88	***	***	
50	181.03	6.93	8.06	37.5
75	384.70	8.15	8.17	62.5
100	601.02	8.65	9.16	87.5
125	827.27	9.05	10.25	112.5
150	1078.21	10.04	10.20	137.5
175	1388.09	12.40	12.98	162.5
200	1753.31	14.61	17.54	187.5
225	2339.29	23.44	26.38	212.5
250	3086.83	29.90	33.00	237.5
275	4115.45	41.14	50.59	262.5
300	5729.02	64.54	73.71	287.5
300	7122.02	26.07	21.77	287.5
275	6470.17	35.83	30.21	262.5
250	5574.41	40.06	39.32	237.5
225	4572.81	33.49	40.96	212.5
200	3735.53	33.55	33.70	187.5
175	2896.67	17.44	22.68	162.5
150	2460.78	14.03	15.26	137.5
125	2110.02	12.59	13.40	112.5
100	1795.18	11.46	11.54	87.5
75	1508.65	10.56	10.75	62.5
50	1244.58	10.44	9.93	42.5
35	1088.00	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







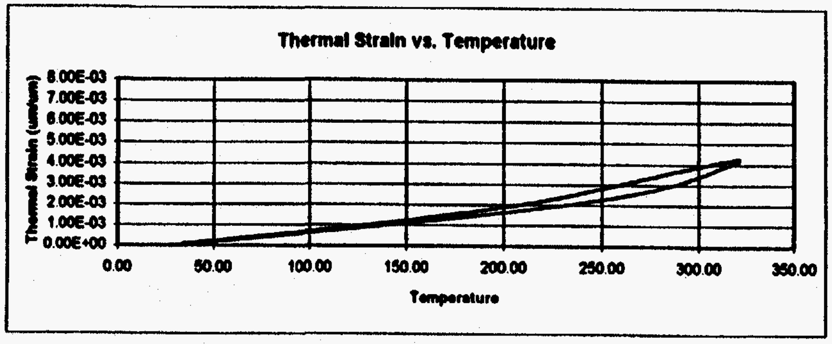
Data Summary

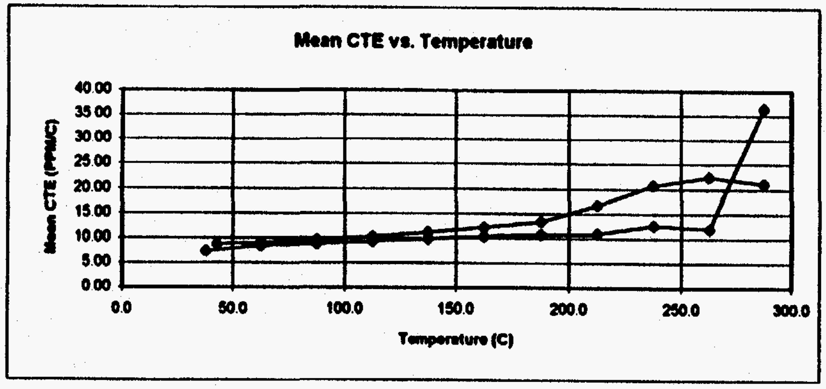
Sample ID:	NRG-5-829.0-SNL-A
Lithology:	Welded Devitrified
TMU:	TSw2
Test condition:	AIR DRIED
Sample Size:	2" (l) x 1" (d)

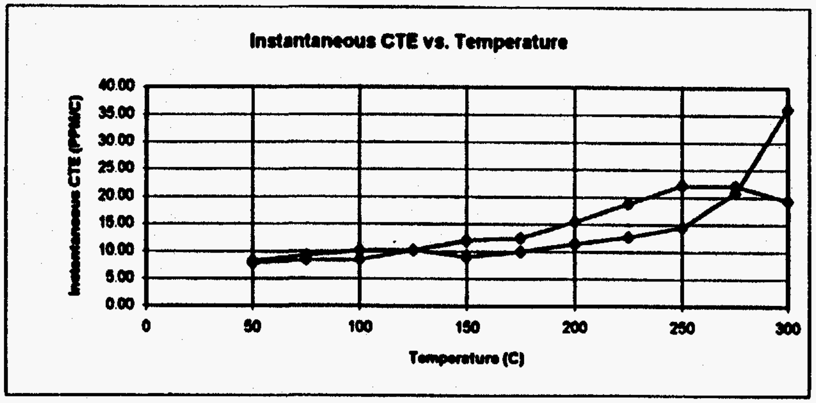
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	58.302	50.88	25.78	2.26
post-test:	57.977	50.88	25.78	2.25

Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
25	1.29	***	***	
50	180.89	7.18	8.49	37.5
75	388.24	8.29	8.51	62.5
100	605.50	8.69	9.36	87.5
125	838.08	9.30	9.17	112.5
150	1084.83	9.87	9.50	137.5
175	1346.68	10.47	9.16	162.5
200	1622.66	11.04	12.35	187.5
225	1939.38	12.67	13.78	212.5
250	2334.67	15.81	17.32	237.5
275	2868.97	21.37	24.96	262.5
300	3675.23	32.25	36.44	287.5
300	4165.10	23.27	21.53	287.5
275	3603.35	26.16	23.47	262.5
250	2949.33	22.13	24.81	237.5
225	2396.17	18.08	20.99	212.5
200	1944.16	14.91	16.35	187.5
175	1571.43	13.24	13.52	162.5
150	1240.39	11.66	12.38	137.5
125	948.93	10.59	11.09	112.5
100	684.07	9.89	9.95	87.5
75	436.75	9.15	9.21	62.5
50	207.96	8.75	8.50	42.5
35	76.66	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

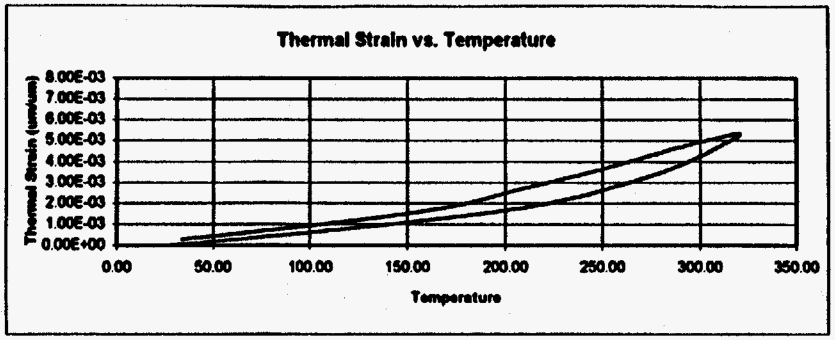
Sample ID:	NRG-5-831.8-SNL-A
Lithology:	Welded Devitrified
TMU:	TSw2
Test condition:	AIR DRIED
Sample Size:	2" (l) x 1" (d)

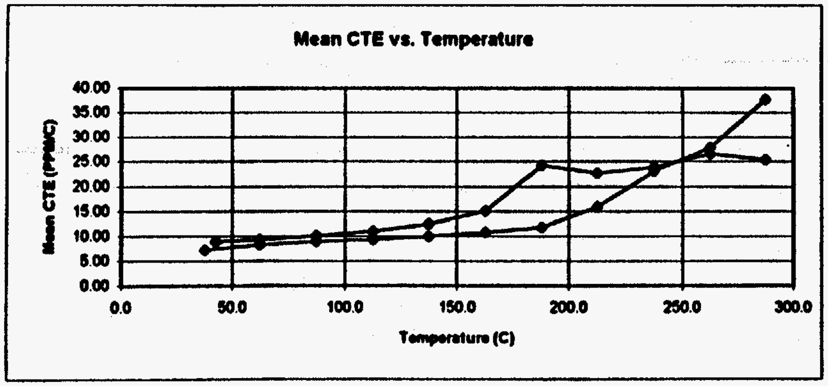
Sample Data:

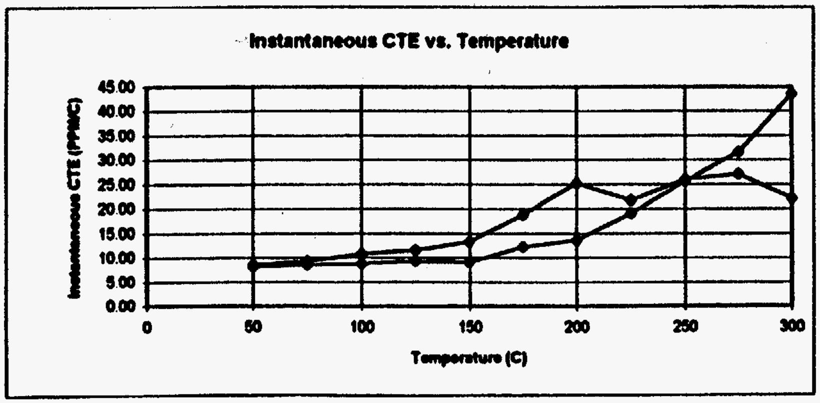
	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	58.742	50.88	25.78	2.28
post-test:	58.448	50.85	25.77	2.27

Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
25	2.25	***	***	
50	185.94	7.35	7.88	37.5
75	395.81	8.39	8.41	62.5
100	615.37	8.78	8.49	87.5
125	848.33	9.32	10.21	112.5
150	1094.50	9.85	8.99	137.5
175	1352.52	10.32	10.03	162.5
200	1620.95	10.74	11.44	187.5
225	1894.16	10.93	12.67	212.5
250	2208.60	12.58	14.54	237.5
275	2507.80	11.97	20.74	262.5
300	3419.27	36.46	36.21	287.5
300	3901.04	21.08	19.31	287.5
275	3373.98	22.40	22.10	262.5
250	2814.04	20.75	22.24	237.5
225	2295.23	16.64	18.80	212.5
200	1879.34	13.41	15.49	187.5
175	1544.05	12.22	12.47	162.5
150	1238.55	11.09	11.97	137.5
125	961.25	10.19	10.25	112.5
100	706.45	9.62	10.16	87.5
75	465.96	9.01	9.25	62.5
50	240.62	8.74	8.30	42.5
35	109.59	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







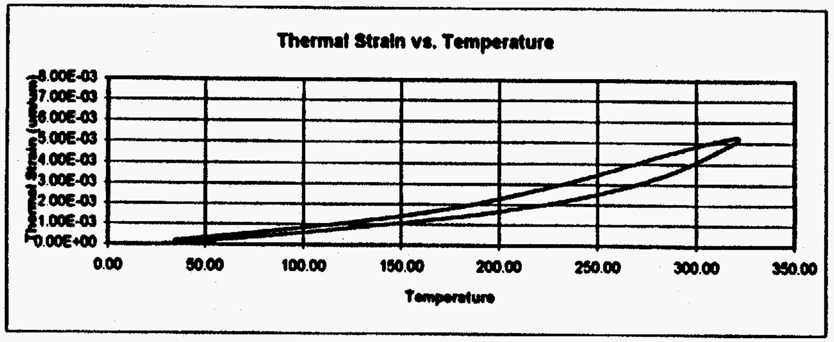
<u>**Data Summary**</u>

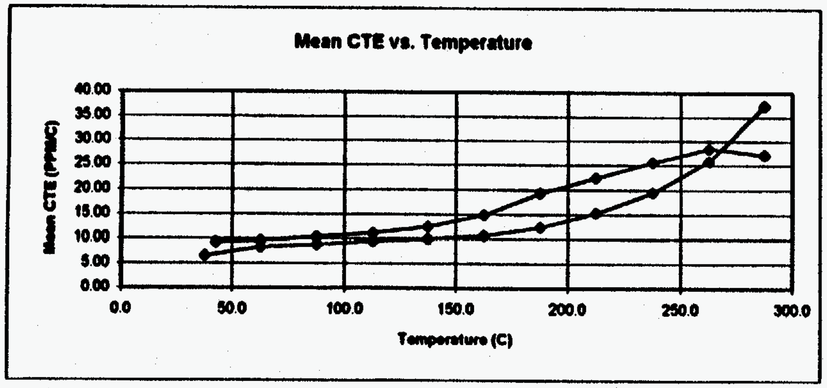
Sample ID:	**NRG-5-848.0-SNL-A**
Lithology:	**Welded Devitrified**
TMU:	**TSw2**
Test condition:	**AIR DRIED**
Sample Size:	**2" (l) x 1" (d)**

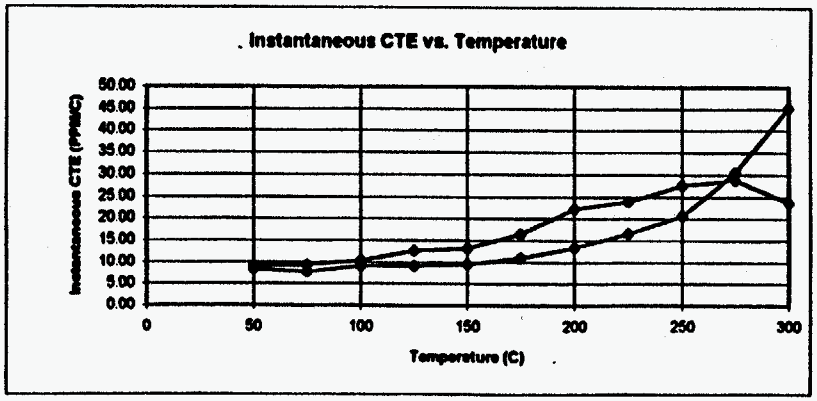
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	57.198	50.85	25.77	2.22
post-test:	56.996	50.85	25.77	2.21

Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
25	2.60	***	***	
50	183.85	7.25	8.15	37.5
75	391.35	8.30	8.60	62.5
100	613.19	8.87	8.75	87.5
125	845.69	9.30	9.29	112.5
150	1094.10	9.94	9.07	137.5
175	1361.76	10.71	12.25	162.5
200	1657.34	11.82	13.60	187.5
225	2054.15	15.87	19.13	212.5
250	2629.82	23.03	25.62	237.5
275	3329.09	27.97	31.66	262.5
300	4274.49	37.82	43.73	287.5
300	4960.15	25.43	22.19	287.5
275	4324.37	26.56	27.16	262.5
250	3660.32	23.89	26.01	237.5
225	3063.18	22.71	21.77	212.5
200	2495.36	24.26	25.30	187.5
175	1888.88	15.07	18.77	162.5
150	1512.09	12.41	13.33	137.5
125	1201.95	10.96	11.56	112.5
100	927.90	10.09	10.78	87.5
75	675.62	9.31	9.28	62.5
50	442.96	8.96	8.50	42.5
35	308.59	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

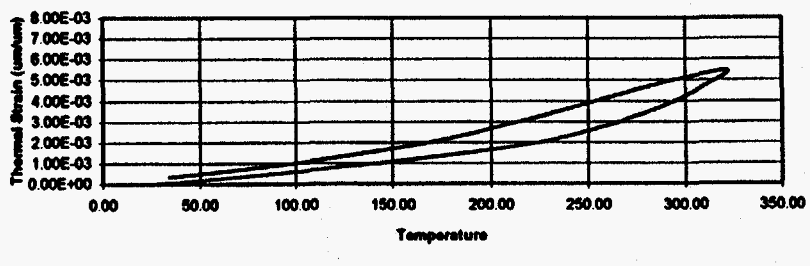
Sample ID:	NRG-5-852.5-SNL-A
Lithology:	Welded Devitrified
TMU:	TSw2
Test condition:	AIR DRIED
Sample Size:	2" (l) x 1" (d)

Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	57.913	50.85	25.77	2.25
post-test:	57.752	50.85	25.77	2.24

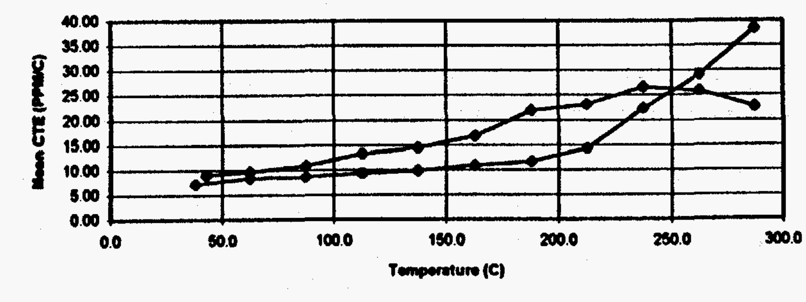
Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (^{o}C)
25	2.62	***	***	
50	166.17	6.54	8.38	37.5
75	373.82	8.31	7.70	62.5
100	593.85	8.80	9.03	87.5
125	826.68	9.39	9.07	112.5
150	1076.95	9.93	9.54	137.5
175	1343.06	10.64	11.00	162.5
200	1651.63	12.34	13.33	187.5
225	2032.84	15.25	16.54	212.5
250	2517.93	19.40	20.64	237.5
275	3162.29	25.77	30.50	262.5
300	4096.30	37.36	45.19	287.5
300	4864.54	27.17	23.75	287.5
275	4185.40	28.49	28.81	262.5
250	3473.06	25.61	27.57	237.5
225	2832.93	22.37	23.95	212.5
200	2273.77	19.31	22.23	187.5
175	1790.95	14.87	16.53	162.5
150	1419.09	12.44	13.26	137.5
125	1108.04	11.14	12.61	112.5
100	829.59	10.31	10.44	87.5
75	571.91	9.52	9.40	62.5
50	333.82	9.15	9.02	42.5
35	196.60	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.

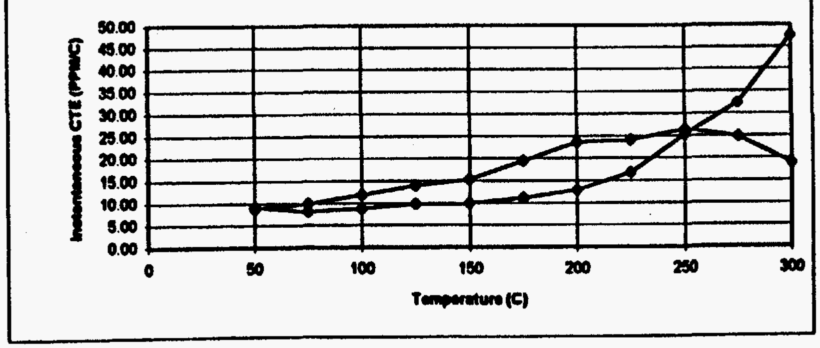
Thermal Strain vs. Temperature



Mean CTE vs. Temperature



Instantaneous CTE vs. Temperature



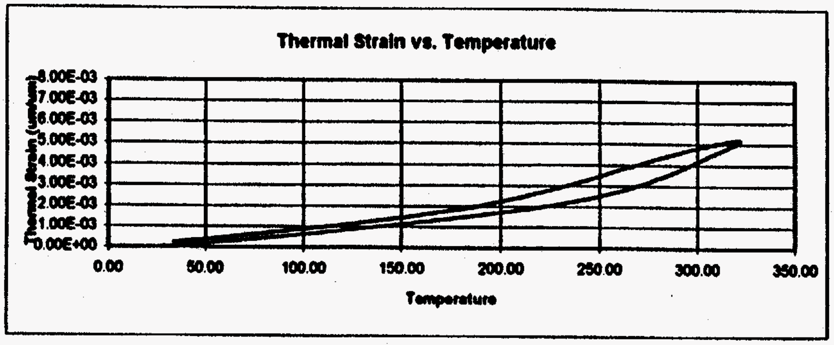
Data Summary

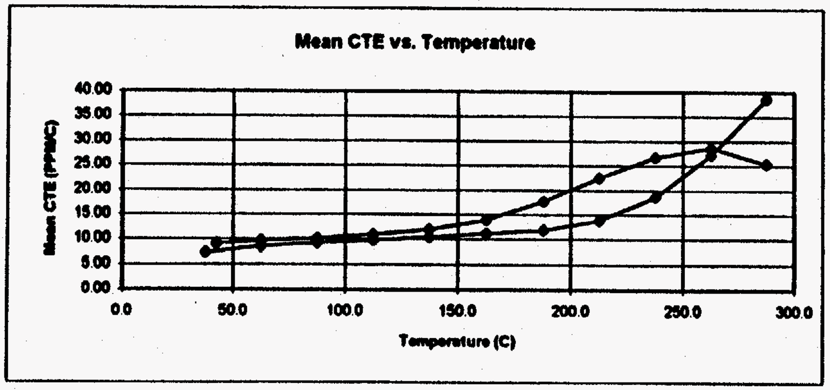
Sample ID:	NRG-5-874.9-SNL-A
Lithology:	Welded Devitrified
TMU:	TSw2
Test condition:	AIR DRIED
Sample Size:	2" (l) x 1" (d)

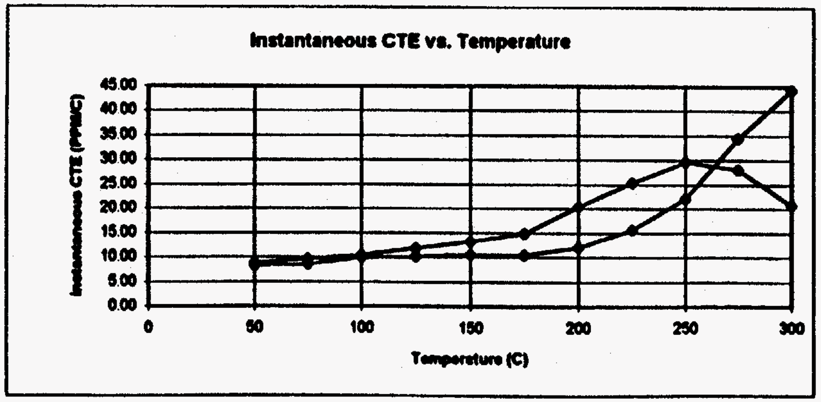
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	57.762	50.83	25.76	2.24
post-test:	57.465	50.85	25.77	2.23

Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (^oC)
25	1.57	***	***	
50	181.00	7.18	8.99	37.5
75	389.73	8.35	8.12	62.5
100	605.71	8.64	8.73	87.5
125	840.07	9.37	9.82	112.5
150	1087.23	9.89	9.90	137.5
175	1359.64	10.90	11.20	162.5
200	1649.89	11.61	12.95	187.5
225	2008.44	14.34	16.72	212.5
250	2567.07	22.35	25.21	237.5
275	3294.64	29.10	32.35	262.5
300	4255.62	38.44	47.60	287.5
300	5128.48	22.64	18.79	287.5
275	4562.37	25.85	24.81	262.5
250	3916.15	26.67	26.46	237.5
225	3251.90	23.12	24.06	212.5
200	2673.88	21.88	23.65	187.5
175	2126.90	16.73	19.39	162.5
150	1708.64	14.43	15.33	137.5
125	1347.84	13.21	14.02	112.5
100	1017.56	10.95	11.86	87.5
75	743.90	9.71	9.89	62.5
50	501.20	9.08	8.68	42.5
35	364.96	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

Sample ID: NRG-5-879.6-SNL-D
Lithology: Welded Devitrified
TMU: TSw2

Test condition: AIR DRIED
Sample Size: 2" (l) x 1" (d)

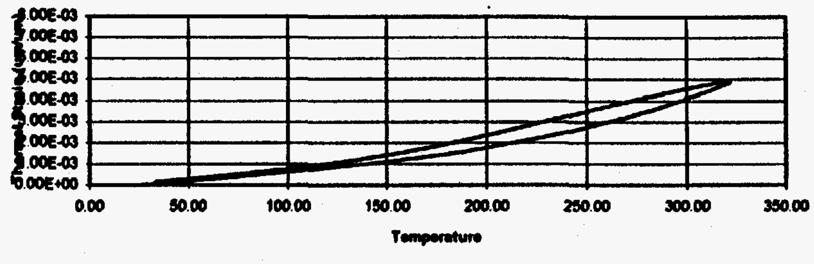
Sample Data:

	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	59.013	50.88	25.78	2.29
post-test:	58.664	50.88	25.78	2.28

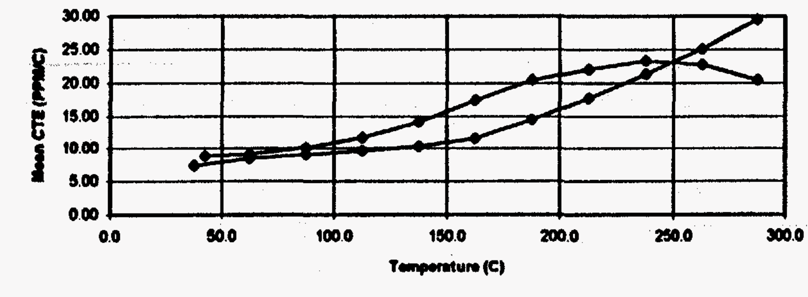
Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
25	2.28	***	***	
50	186.02	7.35	8.22	37.5
75	400.62	8.58	8.57	62.5
100	629.63	9.16	9.86	87.5
125	872.95	9.73	10.20	112.5
150	1133.53	10.42	10.52	137.5
175	1412.03	11.14	10.37	162.5
200	1707.79	11.83	12.03	187.5
225	2051.58	13.75	15.57	212.5
250	2516.04	18.58	22.11	237.5
275	3196.39	27.21	34.39	262.5
300	4163.39	38.68	44.34	287.5
300	4829.38	25.48	20.82	287.5
275	4192.31	28.70	28.15	262.5
250	3474.78	26.69	29.66	237.5
225	2807.52	22.52	25.31	212.5
200	2244.50	17.77	20.41	187.5
175	1800.32	13.96	14.78	162.5
150	1451.38	11.99	13.27	137.5
125	1151.74	10.92	11.82	112.5
100	878.67	10.11	10.39	87.5
75	625.89	9.72	9.62	62.5
50	382.95	9.11	8.80	42.5
35	246.26	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.

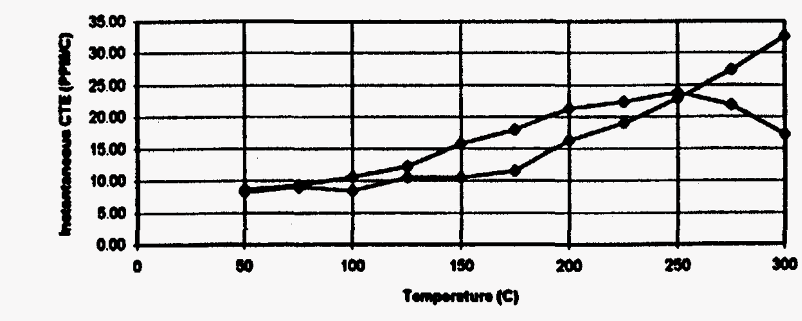
Thermal Strain vs. Temperature



Mean CTE vs. Temperature



Instantaneous CTE vs. Temperature



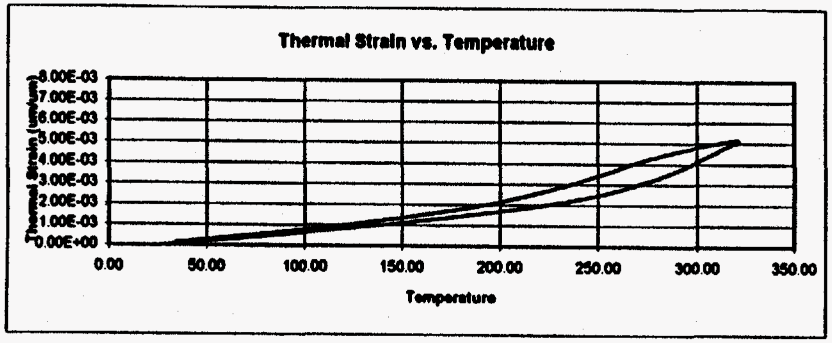
Data Summary

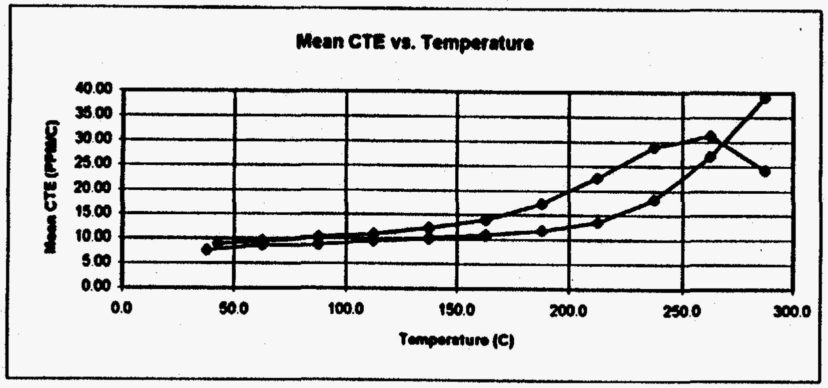
Sample ID:	NRG-5-886.5-SNL-A
Lithology:	Welded Devitrified
TMU:	TSw2
Test condition:	AIR DRIED
Sample Size:	2" (l) x 1" (d)

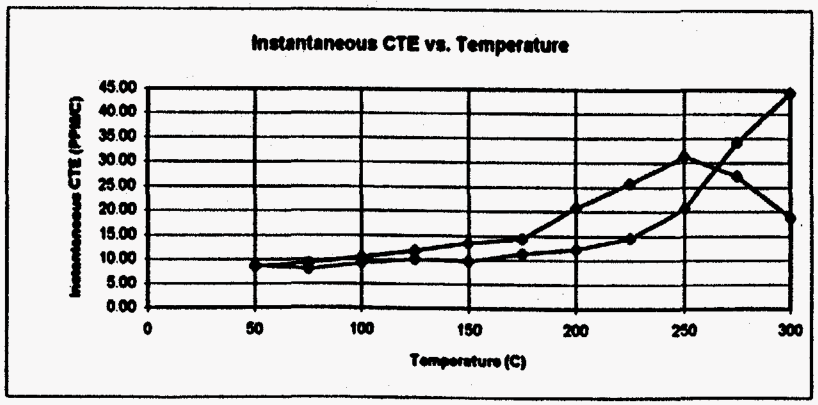
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	58.242	50.72	25.70	2.27
post-test:	57.995	50.72	25.70	2.26

Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
25	0.93	***	***	
50	185.72	7.39	8.26	37.5
75	397.63	8.48	9.02	62.5
100	622.71	9.00	8.48	87.5
125	863.94	9.65	10.55	112.5
150	1122.33	10.34	10.55	137.5
175	1412.86	11.62	11.57	162.5
200	1774.75	14.48	16.29	187.5
225	2216.92	17.69	18.99	212.5
250	2750.10	21.33	22.94	237.5
275	3376.65	25.06	27.34	262.5
300	4114.86	29.53	32.62	287.5
300	4586.39	20.44	17.24	287.5
275	4075.50	22.74	21.88	262.5
250	3507.07	23.32	23.82	237.5
225	2924.17	22.01	22.41	212.5
200	2373.80	20.45	21.34	187.5
175	1862.65	17.36	17.96	162.5
150	1428.56	14.05	15.78	137.5
125	1077.29	11.68	12.30	112.5
100	785.28	10.16	10.68	87.5
75	531.31	9.16	9.27	62.5
50	302.37	8.81	8.63	42.5
35	170.25	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

Sample ID: NRG-5-892.8-SNL-A
Lithology: Welded Devitrified
TMU: TSw2

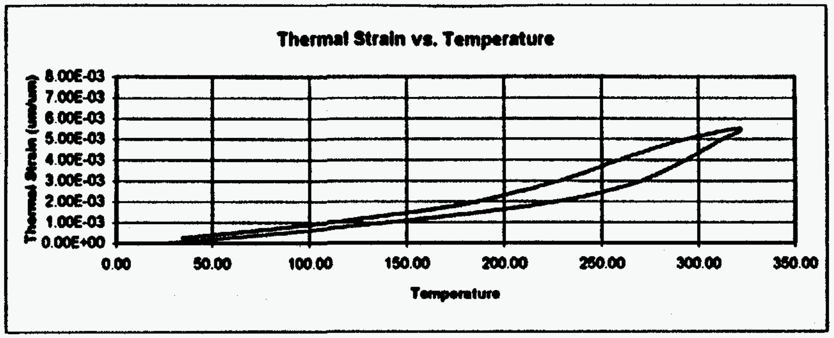
Test condition: AIR DRIED
Sample Size: 2" (l) x 1" (d)

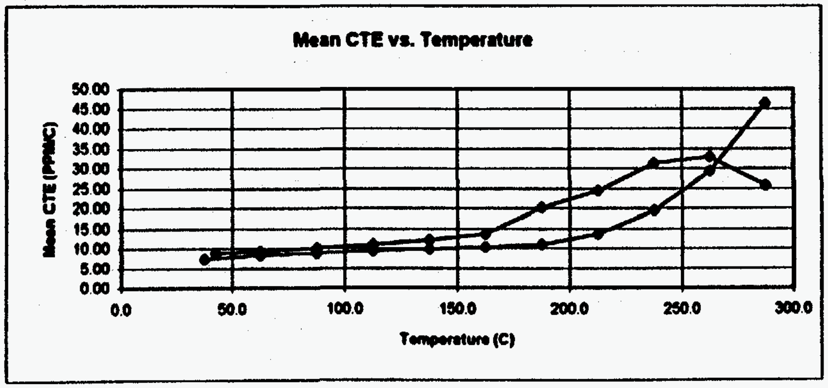
Sample Data:

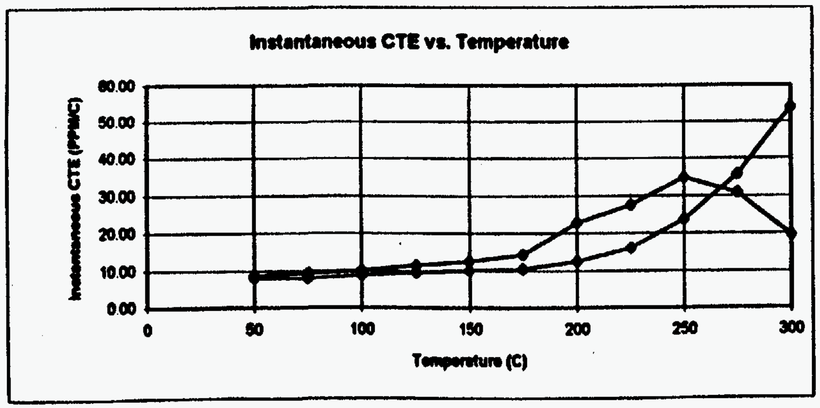
	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	57.191	50.17	25.42	2.25
post-test:	56.813	50.17	25.42	2.23

Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
25	0.71	***	***	
50	191.71	7.64	8.78	37.5
75	407.43	8.63	7.95	62.5
100	628.57	8.85	9.21	87.5
125	866.67	9.52	10.21	112.5
150	1117.73	10.04	9.76	137.5
175	1387.79	10.80	11.33	162.5
200	1680.71	11.72	12.26	187.5
225	2018.83	13.52	14.54	212.5
250	2475.47	18.27	20.71	237.5
275	3153.96	27.14	34.14	262.5
300	4129.77	39.03	44.45	287.5
300	4829.73	24.26	18.83	287.5
275	4223.12	31.39	27.36	262.5
250	3438.34	29.00	31.38	237.5
225	2713.30	22.72	25.73	212.5
200	2145.22	17.35	20.82	187.5
175	1711.43	13.93	14.40	162.5
150	1363.25	12.20	13.44	137.5
125	1058.24	10.93	11.89	112.5
100	785.11	10.19	10.56	87.5
75	530.39	9.46	9.30	62.5
50	293.88	8.86	8.57	42.5
35	160.91	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







<u>**Data Summary**</u>

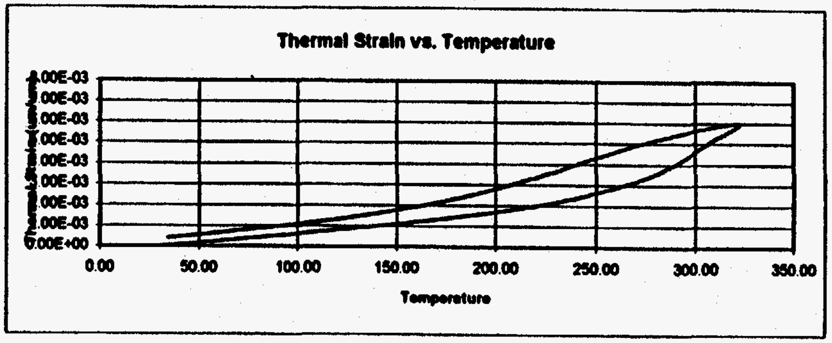
Sample ID: NRG-5-893.3-SNL-A
Lithology: Welded Devitrified
TMU: TSw2

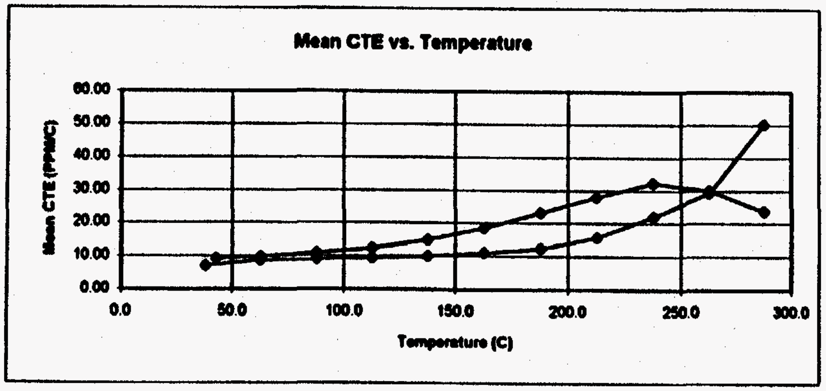
Test condition: AIR DRIED
Sample Size: 2" (l) x 1" (d)

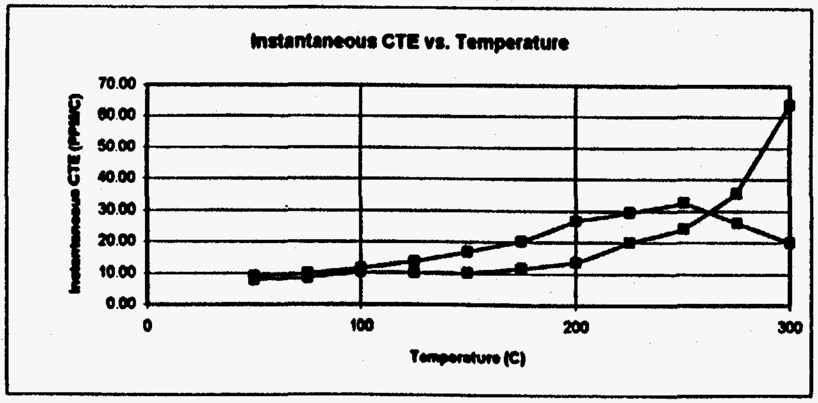
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	57.046	50.88	25.78	2.21
post-test:	56.69	50.9	25.79	2.20

Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (^oC)
25	2.83	***	***	
50	185.78	7.32	8.21	37.5
75	392.60	8.26	8.01	62.5
100	615.09	8.69	8.79	87.5
125	848.10	9.32	9.60	112.5
150	1092.69	9.79	10.02	137.5
175	1352.45	10.38	10.44	162.5
200	1626.74	10.97	12.51	187.5
225	1965.42	13.55	16.07	212.5
250	2452.02	19.46	23.73	237.5
275	3165.55	29.34	35.63	262.5
300	4343.72	46.33	53.98	287.5
300	5166.33	25.72	19.57	287.5
275	4525.27	32.98	30.74	262.5
250	3700.76	31.33	34.80	237.5
225	2917.61	24.48	27.65	212.5
200	2305.60	20.22	22.90	187.5
175	1800.20	13.56	14.33	162.5
150	1461.24	12.07	12.48	137.5
125	1159.37	10.94	11.51	112.5
100	885.88	10.14	10.03	87.5
75	632.43	9.40	9.41	62.5
50	397.30	8.78	8.66	42.5
35	265.54	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

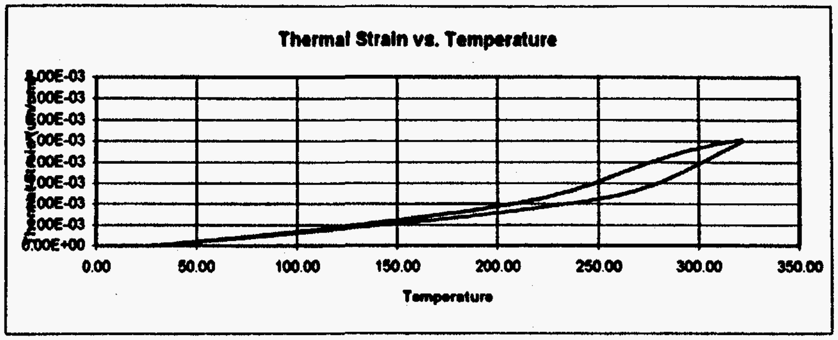
Sample ID: NRG-5-899.5-SNL-A
Lithology: Welded Devitrified
TMU: TSw2

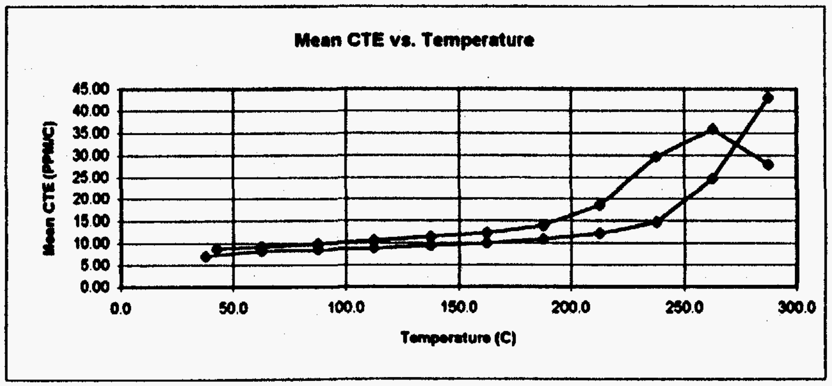
Test condition: AIR DRIED
Sample Size: 2" (l) x 1" (d)

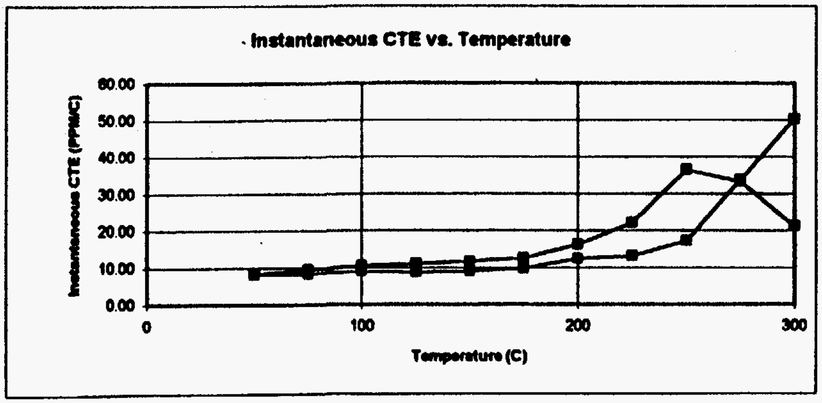
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	57.554	50.9	25.79	2.23
post-test:	57.263	50.93	25.61	2.22

Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
25	1.97	***	***	
50	161.07	7.16	7.90	37.5
75	396.48	8.62	8.52	62.5
100	622.22	9.03	10.25	87.5
125	857.39	9.41	10.11	112.5
150	1110.08	10.11	10.17	137.5
175	1387.00	11.08	11.52	162.5
200	1695.46	12.34	13.57	187.5
225	2089.25	15.75	20.03	212.5
250	2641.58	22.09	24.43	237.5
275	3376.73	29.41	35.72	262.5
300	4631.80	50.20	64.02	287.5
300	5662.64	23.73	19.95	287.5
275	5069.43	30.09	26.23	262.5
250	4317.30	32.26	32.63	237.5
225	3510.89	27.88	29.50	212.5
200	2813.94	23.20	26.79	187.5
175	2233.88	18.51	20.15	162.5
150	1771.17	14.91	16.99	137.5
125	1398.50	12.47	13.80	112.5
100	1086.88	10.99	11.61	87.5
75	812.18	9.86	9.95	62.5
50	565.76	9.34	9.02	42.5
35	425.61	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







<u>Data Summary</u>

Sample ID:	NRG-5-899.8-SNL-A
Lithology:	Welded Devitrified
TMU:	TSw2
Test condition:	AIR DRIED
Sample Size:	2" (l) x 1" (d)

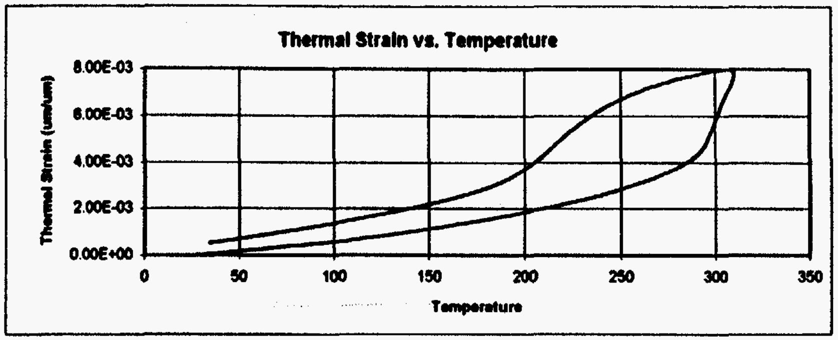
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	56.056	50.47	25.57	2.19
post-test:	55.675	50.47	25.57	2.18

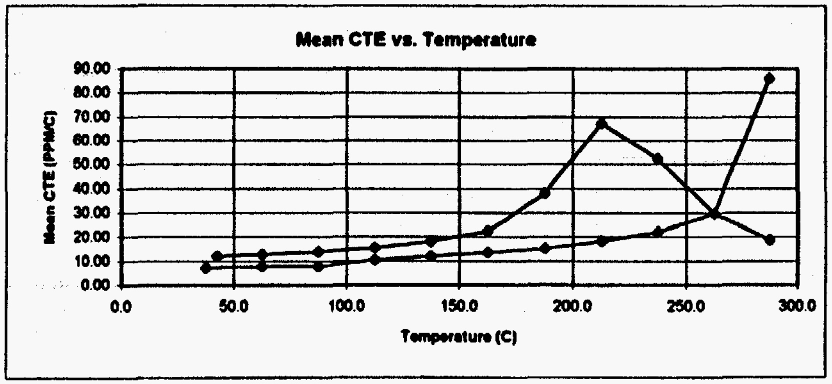
Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
25	1.52	***	***	
50	179.25	7.11	8.09	37.5
75	384.24	8.20	8.35	62.5
100	597.47	8.53	9.05	87.5
125	819.73	8.89	8.66	112.5
150	1054.09	9.37	9.04	137.5
175	1303.95	9.99	9.69	162.5
200	1575.63	10.87	12.42	187.5
225	1880.25	12.18	13.18	212.5
250	2248.03	14.71	17.16	237.5
275	2862.62	24.58	33.80	262.5
300	3938.49	43.04	50.26	287.5
300	4684.57	27.89	21.31	287.5
275	3987.36	35.84	33.23	262.5
250	3091.35	29.59	36.43	237.5
225	2351.67	18.60	22.15	212.5
200	1886.72	13.97	16.33	187.5
175	1537.55	12.39	12.54	162.5
150	1227.70	11.44	11.65	137.5
125	941.67	10.64	10.95	112.5
100	675.65	9.93	10.47	87.5
75	427.35	9.35	9.35	62.5
50	193.51	8.92	8.37	42.5
35	59.69	***	***	

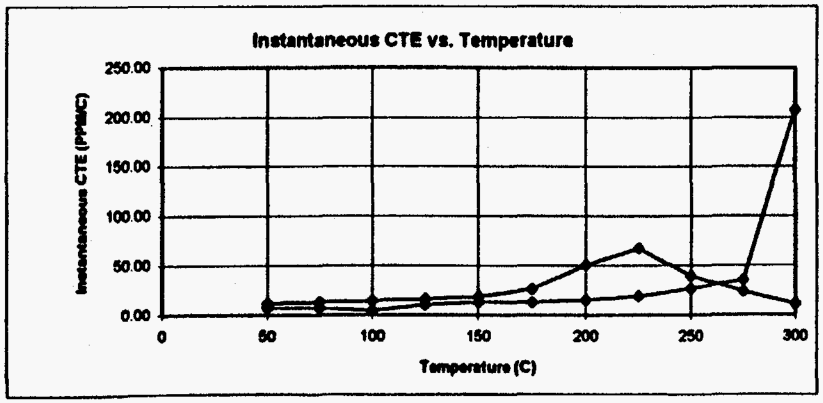
* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.

Data Summaries for NRG-6

(Vacuum Saturated)







Data Summary

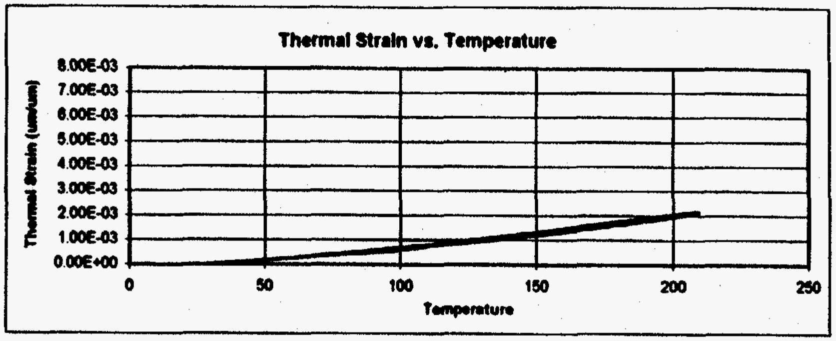
Sample ID:	NRG-6-28.8-SNL-D
Lithology:	Welded Devitrified
TMU:	TCw
Test condition:	Vacuum-Saturated
Sample Size:	2" (l) x 1" (d)

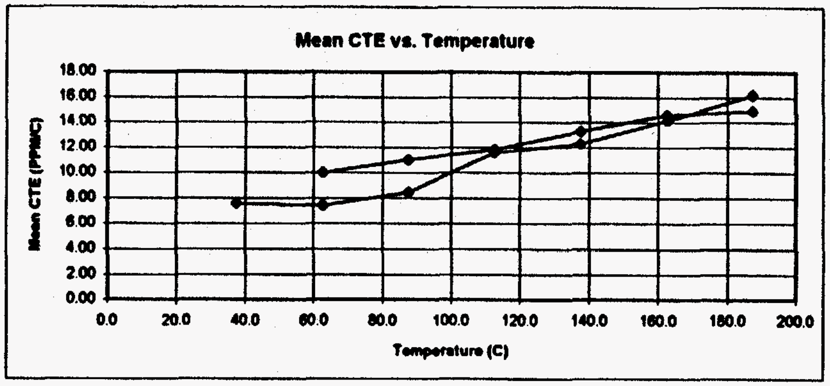
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	60.56	50.82	25.75	2.35
post-test:	59.05	50.82	25.75	2.29

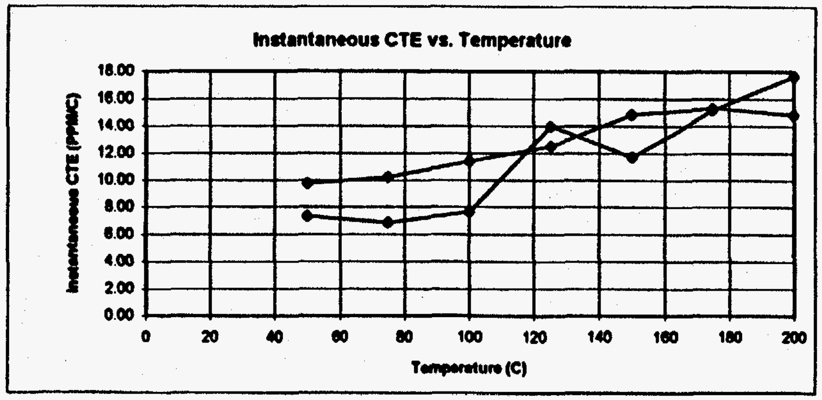
	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (^{o}C)
Heat-up	25	-1.45	***	***	
	50	181.57	7.32	7.99	37.5
	75	376.32	7.79	7.21	62.5
	100	570.24	7.76	4.59	87.5
	125	829.10	10.35	10.60	112.5
	150	1127.63	11.94	12.99	137.5
	175	1466.18	13.54	13.36	162.5
	200	1850.60	15.38	15.40	187.5
	225	2303.06	18.10	18.77	212.5
	250	2861.74	22.35	26.40	237.5
	275	3603.29	29.66	35.48	262.5
	300	5753.83	86.02	207.89	287.5
Cool-down	300	7933.16	18.78	10.97	287.5
	275	7463.74	29.72	24.01	262.5
	250	6720.83	52.48	39.58	237.5
	225	5408.84	67.23	68.08	212.5
	200	3728.10	38.15	50.35	187.5
	175	2774.30	22.57	26.24	162.5
	150	2210.16	18.09	19.35	137.5
	125	1757.95	15.42	16.29	112.5
	100	1372.48	13.95	14.32	87.5
	75	1023.71	12.76	13.00	62.5
	50	704.67	12.06	12.13	42.5
	35	523.73	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.

E-25







Data Summary

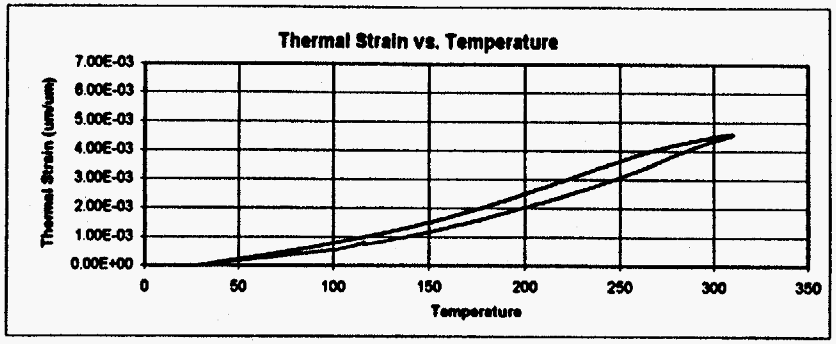
Sample ID: NRG-6-28.8-SNL-F
Lithology: Welded Devitrified
TMU: TCw

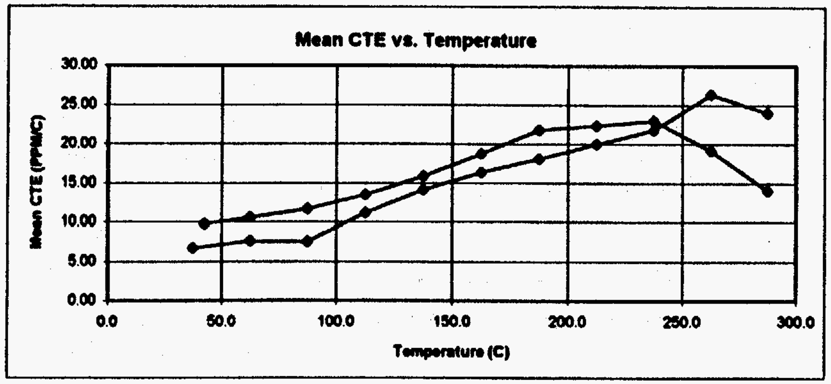
Test condition: Vacuum-Saturated
Sample Size: 2" (l) x 1" (d)

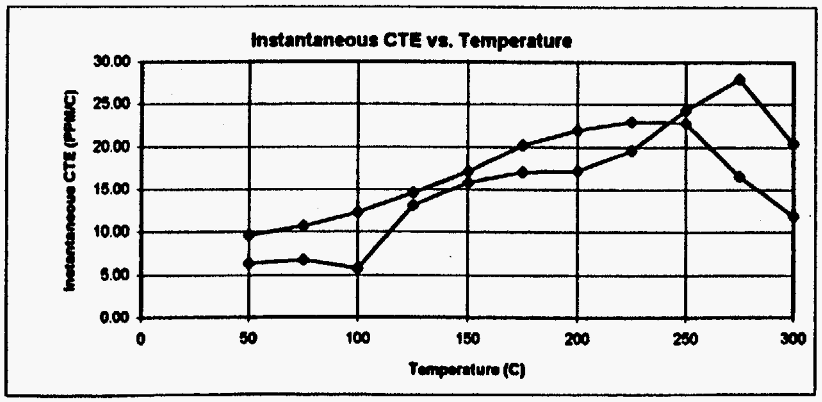
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	60.63	50.80	25.74	2.36
post-test:	59.21	50.83	25.76	2.30

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
Heat-up	25	-0.80	***	***	
	50	188.64	7.58	7.37	37.5
	75	374.24	7.42	6.88	62.5
	100	585.98	8.47	7.67	87.5
	125	875.71	11.59	13.97	112.5
	150	1182.81	12.28	11.72	137.5
	175	1537.73	14.20	15.19	162.5
	200	1943.37	16.23	17.68	187.5
Cool-down	200	2064.07	14.94	14.86	187.5
	175	1690.50	14.64	15.32	162.5
	150	1324.61	13.29	14.83	137.5
	125	992.44	11.81	12.53	112.5
	100	697.26	11.02	11.40	87.5
	75	421.75	10.00	10.24	62.5
	50	171.75	12.88	9.73	42.5
	35	-21.52	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







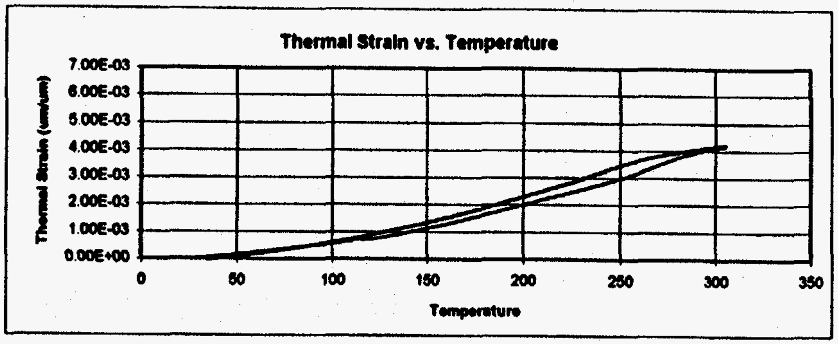
Data Summary

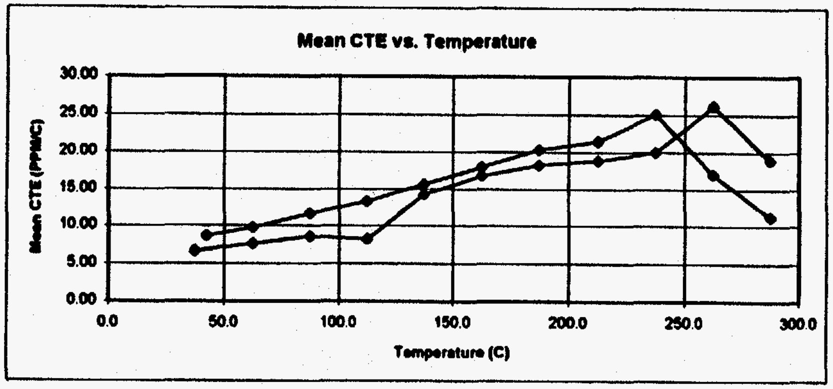
Sample ID:	NRG-6-98.1-SNL-F
Lithology:	Welded Devitrified
TMU:	TCw
Test condition:	Vacuum-Saturated
Sample Size:	2" (l) x 1" (d)

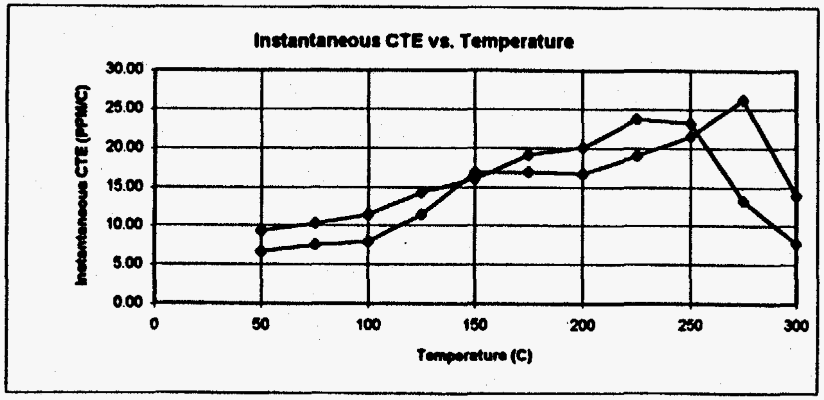
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	59.76	50.72	25.70	2.33
post-test:	58.17	50.72	25.70	2.26

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (^{o}C)
Heat-up	25	0.87	***	***	
	50	170.15	6.77	6.36	37.5
	75	360.89	7.63	6.75	62.5
	100	549.71	7.55	5.76	87.5
	125	829.86	11.21	13.16	112.5
	150	1184.25	14.18	15.88	137.5
	175	1592.97	16.35	17.04	162.5
	200	2045.52	18.10	17.18	187.5
	225	2545.64	20.00	19.60	212.5
	250	3090.67	21.80	24.37	237.5
	275	3750.61	26.40	28.03	262.5
	300	4350.49	24.00	20.47	287.5
Cool-down	300	4494.88	14.04	11.97	287.5
	275	4143.93	19.17	16.62	262.5
	250	3664.58	23.03	22.79	237.5
	225	3088.86	22.37	22.96	212.5
	200	2529.66	21.80	21.98	187.5
	175	1984.54	18.71	20.23	162.5
	150	1516.79	15.88	17.13	137.5
	125	1119.85	13.52	14.65	112.5
	100	781.90	11.71	12.33	87.5
	75	489.20	10.58	10.74	62.5
	50	224.73	9.80	9.66	42.5
	35	77.72	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

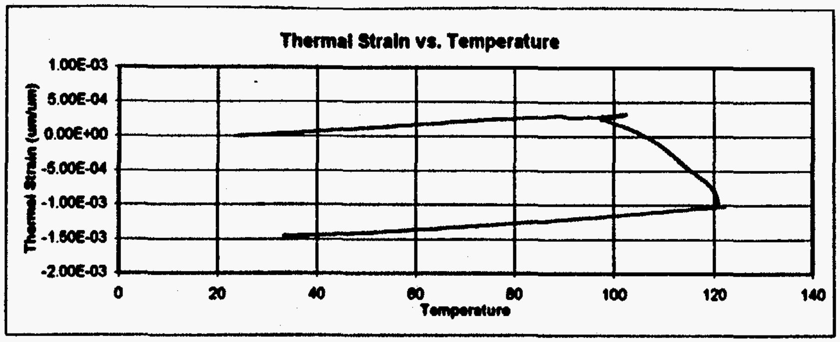
Sample ID: NRG-6-111.0-SNL-G
Lithology: Welded Devitrified
TMU: TCw

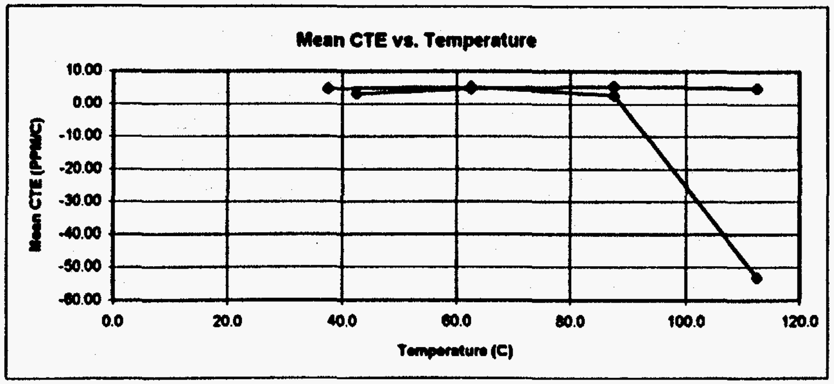
Test condition: Vacuum-Saturated
Sample Size: 2" (l) x 1" (d)

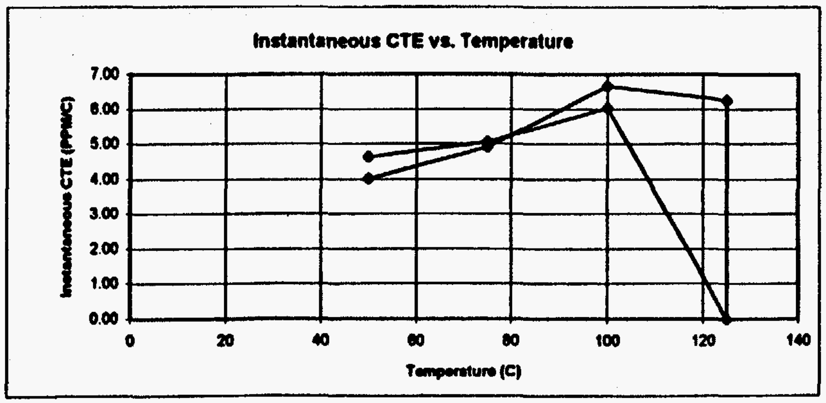
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	59.12	50.88	25.78	2.29
post-test:	56.69	50.88	25.78	2.20

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (^{o}C)
Heat-up	25	1.17	***	***	
	50	168.67	6.70	6.68	37.5
	75	359.61	7.64	7.56	62.5
	100	573.50	8.56	7.94	87.5
	125	778.39	8.20	11.44	112.5
	150	1135.28	14.28	16.84	137.5
	175	1553.53	16.73	17.01	162.5
	200	2009.62	18.24	16.74	187.5
	225	2481.03	18.86	19.08	212.5
	250	2981.05	20.00	21.58	237.5
	275	3636.24	26.21	26.22	262.5
	300	4110.01	18.95	13.95	287.5
Cool-down	300	4178.97	11.35	7.78	287.5
	275	3895.34	17.02	13.26	262.5
	250	3469.87	25.07	23.26	237.5
	225	2843.00	21.42	23.72	212.5
	200	2307.38	20.32	20.04	187.5
	175	1789.28	18.00	19.16	162.5
	150	1349.25	15.63	16.01	137.5
	125	958.55	13.31	14.32	112.5
	100	625.72	11.68	11.46	87.5
	75	333.82	9.78	10.32	62.5
	50	89.19	8.65	9.40	42.5
	35	-40.50	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







<u>**Data Summary**</u>

Sample ID:	NRG-6-148.4-SNL-A
Lithology:	Welded Devitrified *
TMU:	TCw *

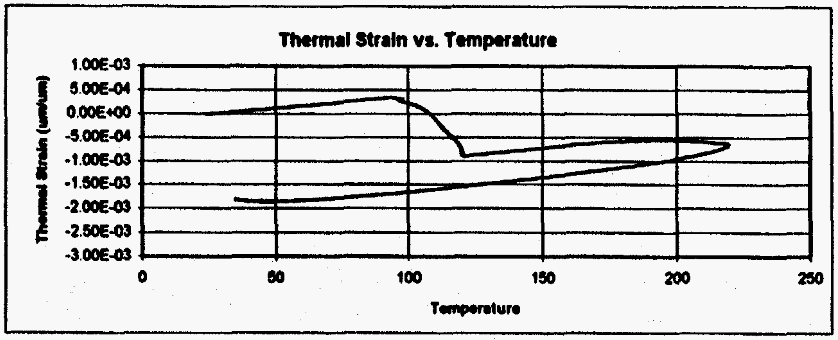
* This sample was identified as shown above, but its behavior appears to be typical of a nonwelded vitric sample.

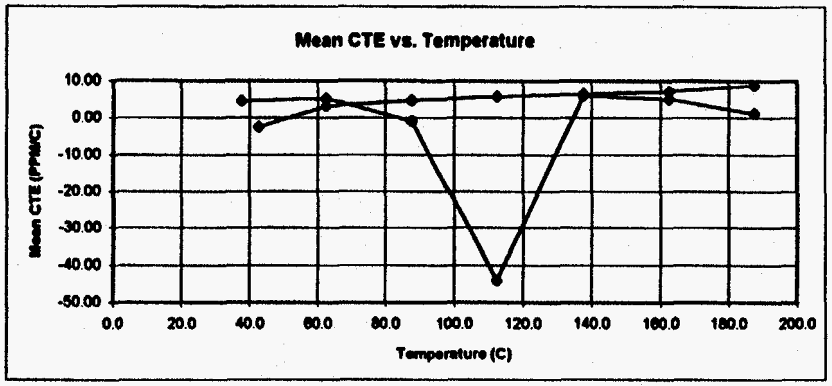
Test condition:	Vacuum-Saturated
Sample Size:	2" (l) x 1" (d)

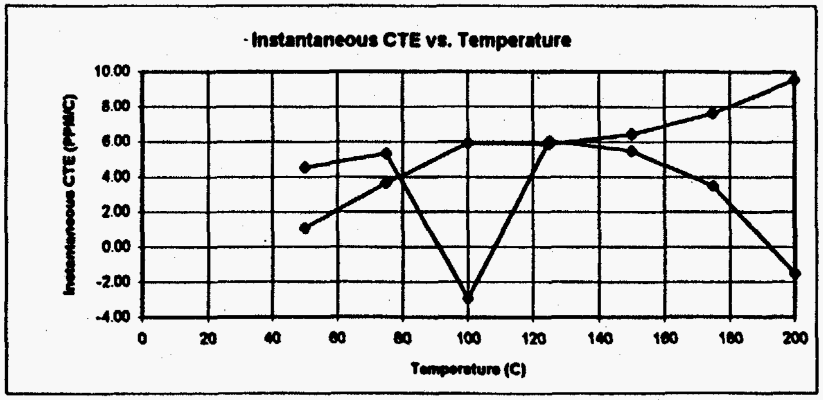
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	47.49	50.88	25.78	1.84
post-test:	38.38	50.80	25.74	1.49

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
Heat-up	25	-0.16	***	***	
	50	116.45	4.66	4.63	37.5
	75	245.53	5.16	5.05	62.5
	100	312.45	2.68	6.03	87.5
	125	-1013.79	-53.05	***	112.5
Cool-down	125	-1026.31	4.94	6.26	112.5
	100	-1149.76	5.53	6.66	87.5
	75	-1288.11	4.65	4.90	62.5
	50	-1404.40	3.04	4.01	42.5
	35	-1450.06	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

Sample ID: NRG-6-148.4-SNL-A
Lithology: Welded Devitrified *
TMU: TCw *

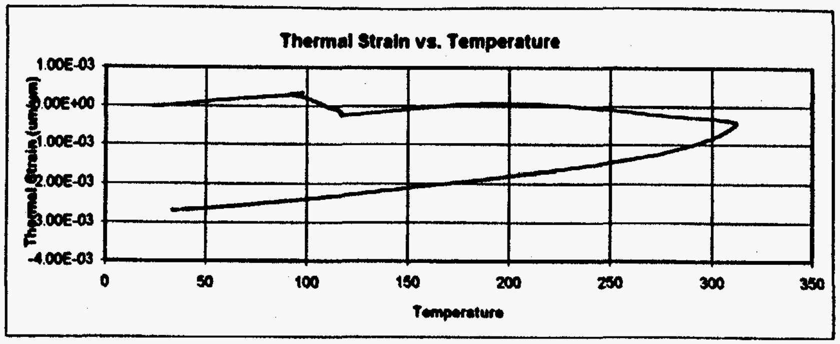
* This sample was identified as shown above, but its behavior appears to be typical of a nonwelded vitric sample.

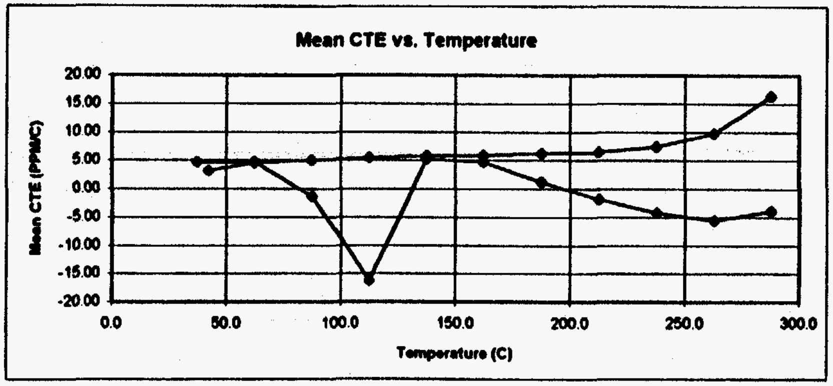
Test condition: Vacuum-Saturated
Sample Size: 2" (l) x 1" (d)

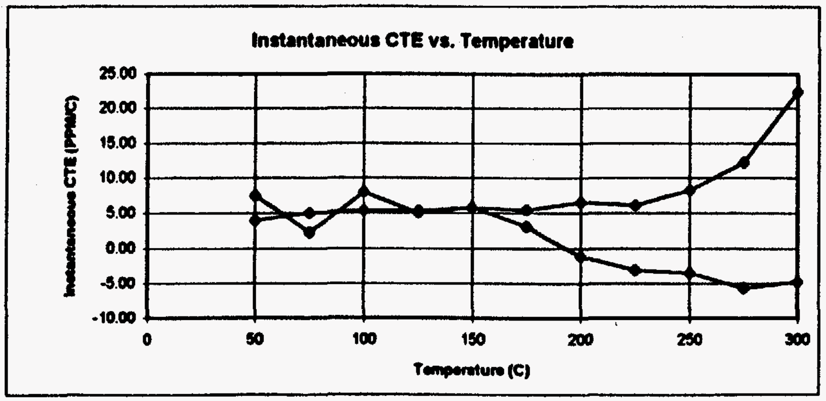
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	47.33	50.85	25.77	1.84
post-test:	38.19	50.77	25.73	1.48

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (^{o}C)
Heat-up	25	0.00	***	***	
	50	115.96	4.64	4.54	37.5
	75	247.82	5.27	5.34	62.5
	100	225.28	-0.90	-2.91	87.5
	125	-874.52	-43.99	6.01	112.5
	150	-724.45	6.00	5.49	137.5
	175	-596.48	5.12	3.50	162.5
	200	-565.92	1.22	-1.50	187.5
Cool-down	200	-953.82	8.71	9.55	187.5
	175	-1171.63	7.18	7.63	162.5
	150	-1351.04	6.46	6.43	137.5
	125	-1512.50	5.78	5.85	112.5
	100	-1657.02	4.71	5.91	87.5
	75	-1774.65	3.11	3.63	62.5
	50	-1852.31	-2.41	1.08	42.5
	35	-1816.14	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

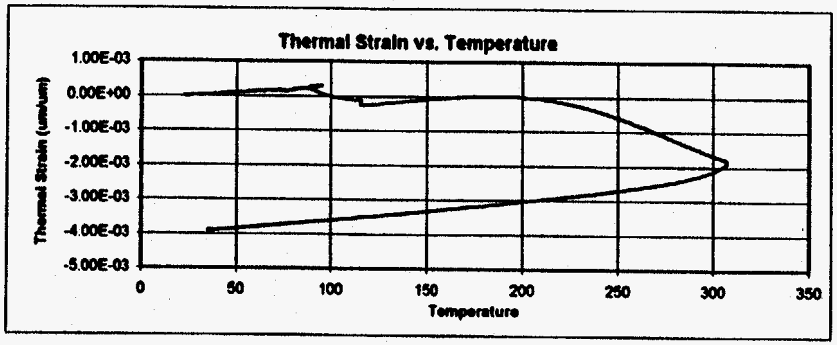
Sample ID: NRG-6-152.9-SNL-B
Lithology: Nonwelded Vitric
TMU: PTn

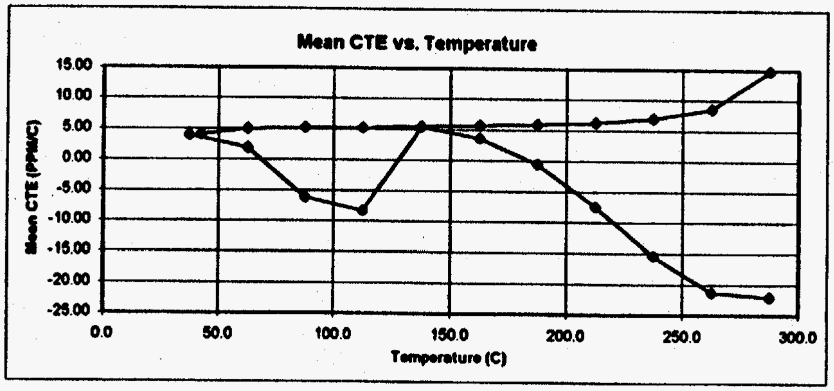
Test condition: Vacuum Saturated
Sample Size: 2" (l) x 1" (d)

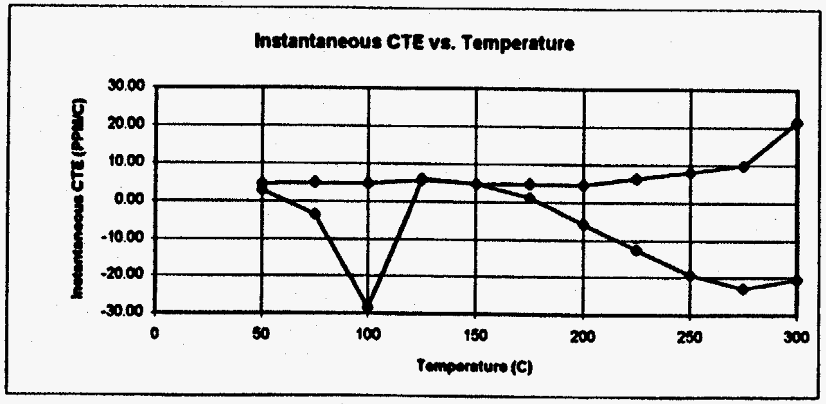
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	44.62	50.72	25.70	1.74
post-test:	34.21	50.72	25.70	1.33

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (^{0}C)
Heat-up	25	-1.06	***	***	
	50	114.95	4.64	7.50	37.5
	75	234.72	4.79	2.25	62.5
	100	199.58	-1.41	8.00	87.5
	125	-207.37	-16.28	4.98	112.5
	150	-75.94	5.26	5.77	137.5
	175	41.56	4.70	3.07	162.5
	200	72.65	1.24	-1.12	187.5
	225	27.87	-1.79	-3.05	212.5
	250	-78.22	-4.24	-3.42	237.5
	275	-218.30	-5.60	-5.65	262.5
	300	-314.34	-3.84	-4.77	287.5
Cool-down	300	-810.65	16.31	22.51	287.5
	275	-1218.68	9.72	12.25	262.5
	250	-1461.58	7.41	8.29	237.5
	225	-1646.81	6.51	6.13	212.5
	200	-1809.57	6.34	6.54	187.5
	175	-1968.13	5.98	5.44	162.5
	150	-2117.58	5.79	5.77	137.5
	125	-2262.34	5.50	5.38	112.5
	100	-2399.66	5.04	5.33	87.5
	75	-2525.95	4.57	4.98	62.5
	50	-2640.23	3.17	3.92	42.5
	35	-2687.72	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







E-31

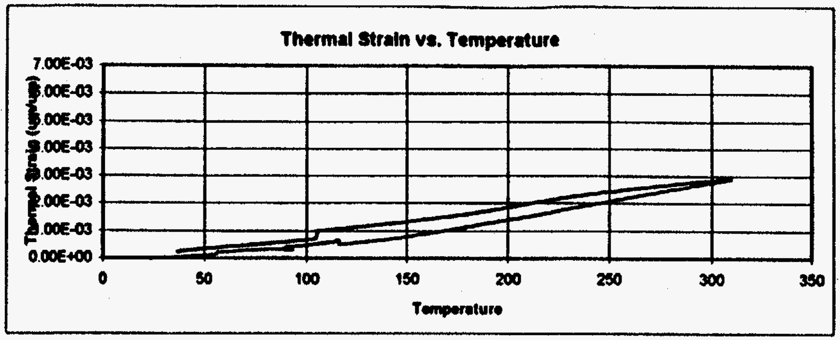
Data Summary

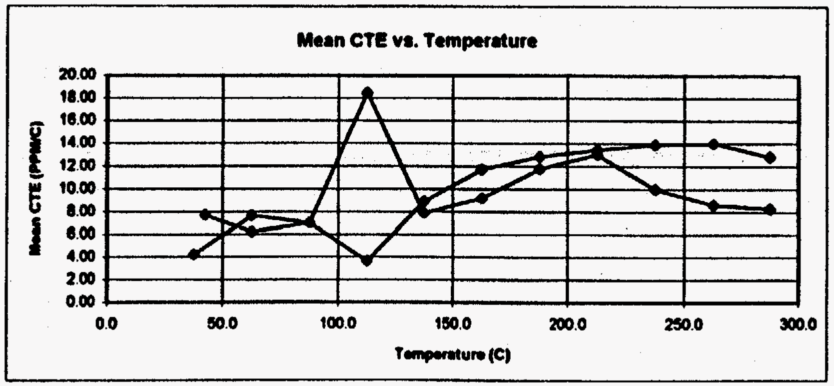
Sample ID:	NRG-6-187.0-SNL-D
Lithology:	Nonwelded Vitric
TMU:	PTn
Test condition:	Vacuum-Saturated
Sample Size:	2" (l) x 1" (d)

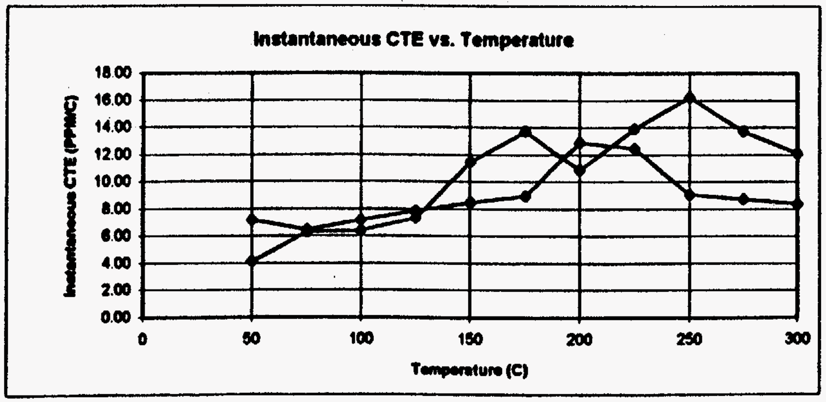
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	36.88	50.93	25.81	1.43
post-test:	24.29	50.72	25.70	0.95

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (^oC)
Heat-up	25	-0.63	***	***	
	50	96.50	3.89	2.94	37.5
	75	143.34	1.87	-3.48	62.5
	100	-10.77	-6.16	-28.52	87.5
	125	-219.44	-8.35	6.14	112.5
	150	-85.76	5.35	4.86	137.5
	175	3.89	3.59	1.18	162.5
	200	-9.72	-0.54	-5.79	187.5
	225	-197.53	-7.51	-12.50	212.5
	250	-581.11	-15.34	-19.23	237.5
	275	-1114.21	-21.32	-22.95	262.5
	300	-1666.30	-22.08	-20.54	287.5
Cool-down	300	-2121.80	14.84	21.50	287.5
	275	-2492.74	8.52	9.91	262.5
	250	-2705.85	6.99	8.20	237.5
	225	-2880.70	6.27	6.44	212.5
	200	-3037.44	5.90	4.66	187.5
	175	-3184.94	5.70	4.91	162.5
	150	-3327.55	5.55	4.87	137.5
	125	-3466.21	5.21	5.66	112.5
	100	-3596.54	5.20	4.94	87.5
	75	-3726.50	4.99	4.99	62.5
	50	-3851.32	3.98	4.64	42.5
	35	-3910.98	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

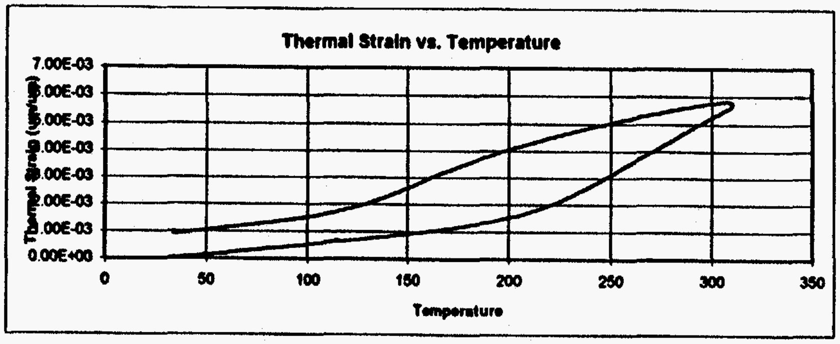
Sample ID: NRG-6-277.5 -SNL-B
Lithology: Welded Devitrified
TMU: TSw1

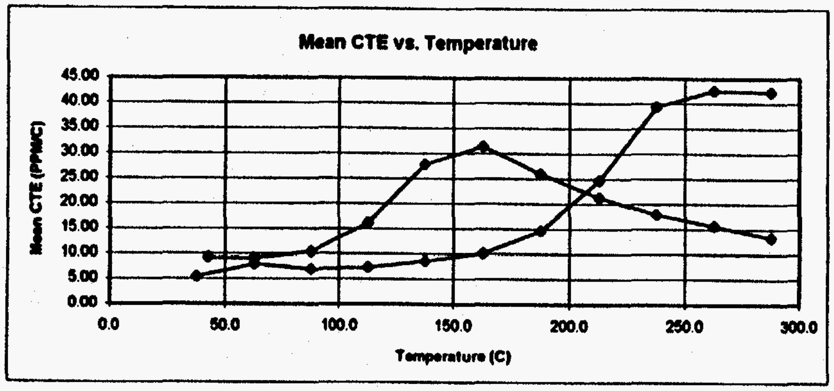
Test condition: Vacuum-Saturated
Sample Size: 2" (l) x 1" (d)

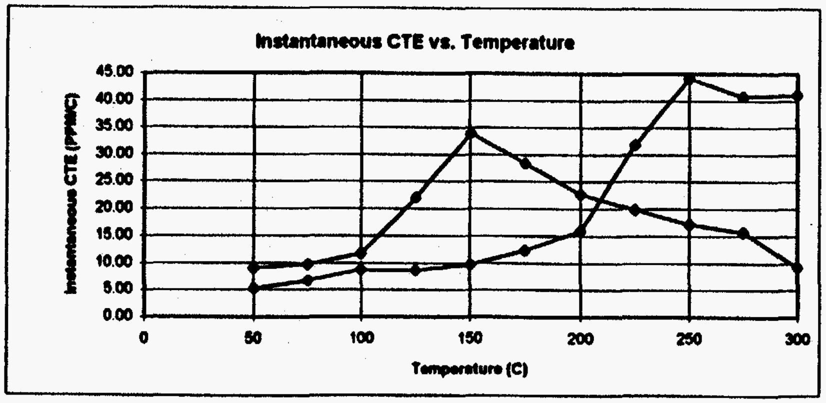
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	60.21	50.75	25.72	2.34
post-test:	57.56	50.75	25.72	2.24

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (^{0}C)
Heat-up	25	3.41	•••	•••	
	50	108.75	4.21	4.15	37.5
	75	300.75	7.68	6.30	62.5
	100	476.13	7.02	6.40	87.5
	125	567.81	3.67	7.30	112.5
	150	790.49	8.91	11.44	137.5
	175	1083.97	11.74	13.70	162.5
	200	1405.46	12.86	10.85	187.5
	225	1741.12	13.43	13.89	212.5
	250	2088.21	13.88	16.22	237.5
	275	2438.63	14.02	13.70	262.5
	300	2760.48	12.87	12.09	287.5
Cool-down	300	2859.98	8.29	8.36	287.5
	275	2652.72	8.63	8.71	262.5
	250	2436.99	10.00	9.04	237.5
	225	2186.88	13.04	12.46	212.5
	200	1860.81	11.78	12.88	187.5
	175	1566.19	9.22	8.96	162.5
	150	1335.72	7.88	8.49	137.5
	125	1138.77	18.45	7.83	112.5
	100	677.44	7.01	7.18	87.5
	75	502.25	6.20	6.43	62.5
	50	347.24	7.74	7.16	42.5
	35	269.89	•••	•••	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







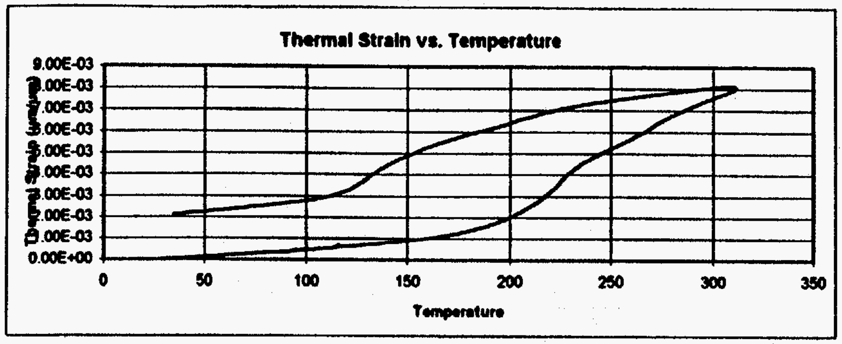
Data Summary

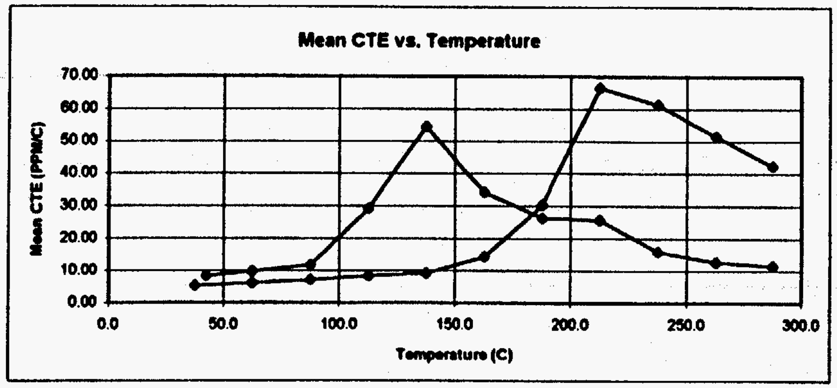
Sample ID:	NRG-6-321.1-SNL-C
Lithology:	Welded Devitrified
TMU:	TSw1
Test condition:	Vacuum Saturated
Sample Size:	2" (l) x 1" (d)

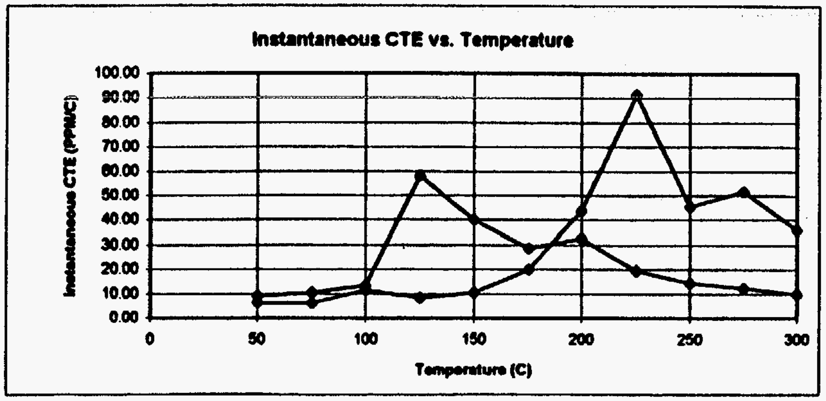
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	58.34	50.83	25.76	2.27
post-test:	54.20	50.88	25.78	2.10

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
Heat-up	25	0.72	***	***	
	50	136.96	5.45	5.33	37.5
	75	336.11	7.97	6.69	62.5
	100	511.07	7.00	8.81	87.5
	125	695.39	7.37	8.70	112.5
	150	911.39	8.64	9.71	137.5
	175	1166.02	10.18	12.41	162.5
	200	1533.75	14.71	15.95	187.5
	225	2150.18	24.66	31.88	212.5
	250	3133.64	39.34	44.15	237.5
	275	4196.06	42.50	40.79	262.5
	300	5252.78	42.27	41.21	287.5
Cool-down	300	5765.12	13.37	9.39	287.5
	275	5430.92	15.66	15.75	262.5
	250	5039.31	18.02	17.19	237.5
	225	4588.91	21.36	19.91	212.5
	200	4055.03	25.91	22.79	187.5
	175	3407.26	31.35	28.34	162.5
	150	2623.62	27.71	33.91	137.5
	125	1930.89	16.14	21.96	112.5
	100	1527.43	10.40	11.75	87.5
	75	1267.40	9.14	9.69	62.5
	50	1038.85	9.22	9.05	42.5
	35	900.51	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







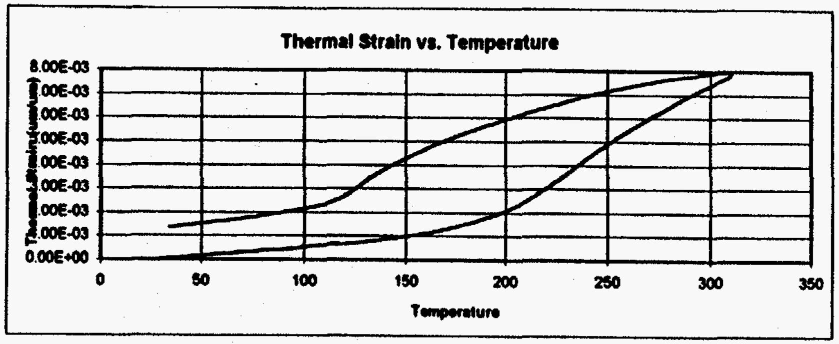
Data Summary

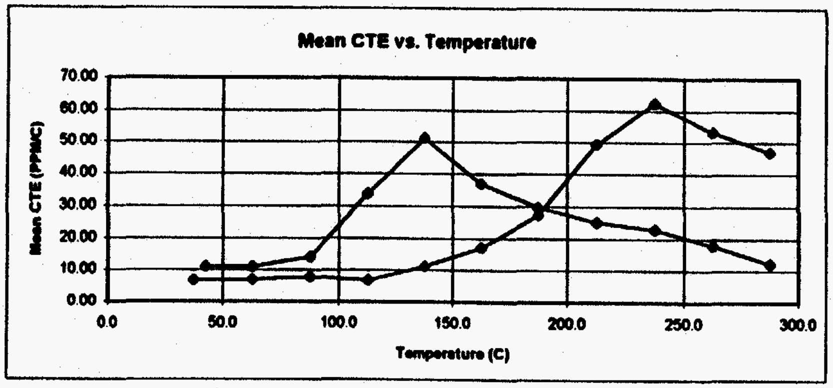
Sample ID:	NRG-6-354.9-SNL-E
Lithology:	Welded Devitrified
TMU:	TSw1
Test condition:	VACUUM SATURATED
Sample Size:	2" (l) x 1" (d)

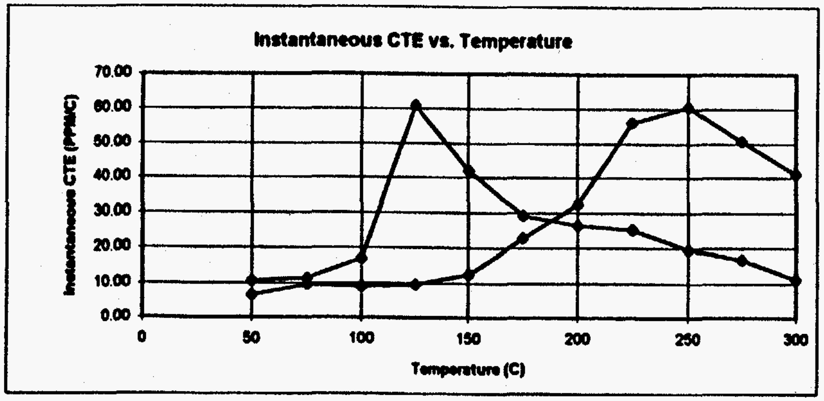
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	57.88	50.88	25.78	2.25
post-test:	53.47	50.98	25.83	2.07

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (^{o}C)
Heat-up	25	2.14	***	***	
	50	138.13	5.44	6.48	37.5
	75	294.52	6.26	6.23	62.5
	100	473.32	7.15	11.51	87.5
	125	681.55	8.33	8.24	112.5
	150	913.95	9.30	10.33	137.5
	175	1272.26	14.33	20.16	162.5
	200	2033.17	30.44	43.90	187.5
	225	3699.06	66.64	91.50	212.5
	250	5236.54	61.50	45.40	237.5
	275	6527.05	51.62	51.69	262.5
	300	7588.28	42.45	36.03	287.5
Cool-down	300	8066.50	11.51	10.00	287.5
	275	7778.65	12.81	12.22	262.5
	250	7458.59	16.09	14.31	237.5
	225	7056.32	25.76	19.60	212.5
	200	6412.31	26.34	32.50	187.5
	175	5753.73	34.28	28.61	162.5
	150	4896.82	54.64	40.16	137.5
	125	3530.88	29.26	58.09	112.5
	100	2799.46	11.73	13.28	87.5
	75	2506.11	9.75	10.51	62.5
	50	2262.26	8.48	9.04	42.5
	35	2135.13	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

Sample ID: NRG-6-392.1-SNL-F
Lithology: Welded Devitrified
TMU: TSw1

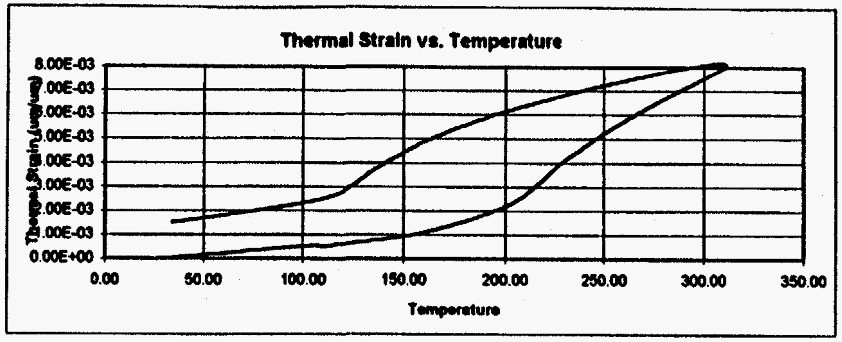
Test condition: Vacuum Saturated
Sample Size: 2" (l) x 1" (d)

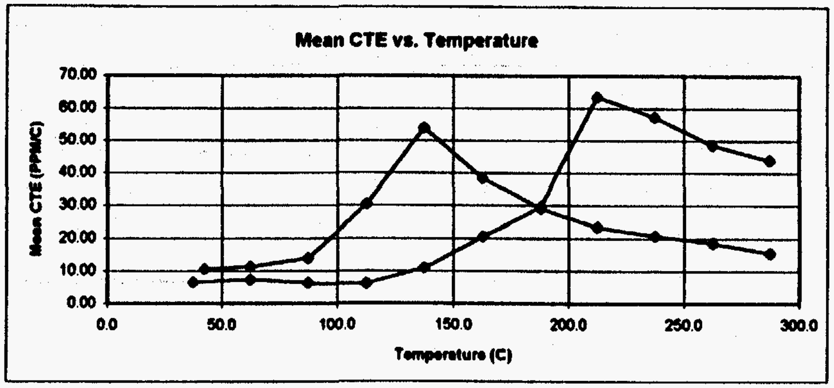
Sample Data:

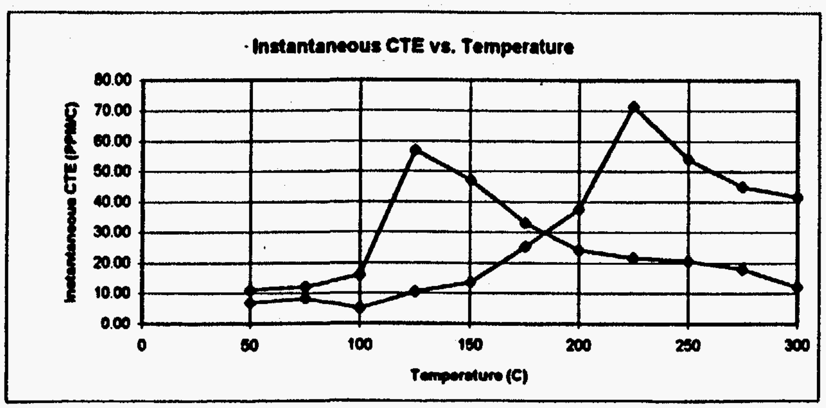
	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	59.57	50.85	25.77	2.31
post-test:	56.66	50.90	25.79	2.20

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
Heat-up	25	-1.56	***	***	
	50	168.88	6.82	6.53	37.5
	75	346.65	7.11	9.62	62.5
	100	540.85	7.77	8.99	87.5
	125	713.47	6.90	9.60	112.5
	150	993.44	11.20	12.46	137.5
	175	1422.62	17.17	22.87	162.5
	200	2108.97	27.45	32.35	187.5
	225	3345.81	49.47	56.14	212.5
	250	4907.04	62.45	60.64	237.5
	275	6241.65	53.38	50.75	262.5
	300	7416.26	46.98	41.20	287.5
Cool-down	300	7905.31	12.18	11.22	287.5
	275	7600.93	17.81	16.81	262.5
	250	7155.77	23.03	19.61	237.5
	225	6580.06	25.19	25.21	212.5
	200	5950.30	29.72	26.46	187.5
	175	5207.37	36.95	29.21	162.5
	150	4283.60	51.30	42.21	137.5
	125	3001.09	33.78	61.11	112.5
	100	2156.59	14.04	17.05	87.5
	75	1805.70	10.98	11.40	62.5
	50	1531.28	11.08	10.72	42.5
	35	1365.14	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







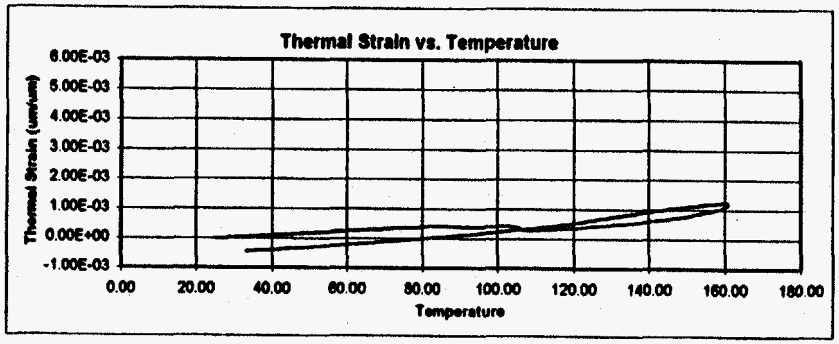
Data Summary

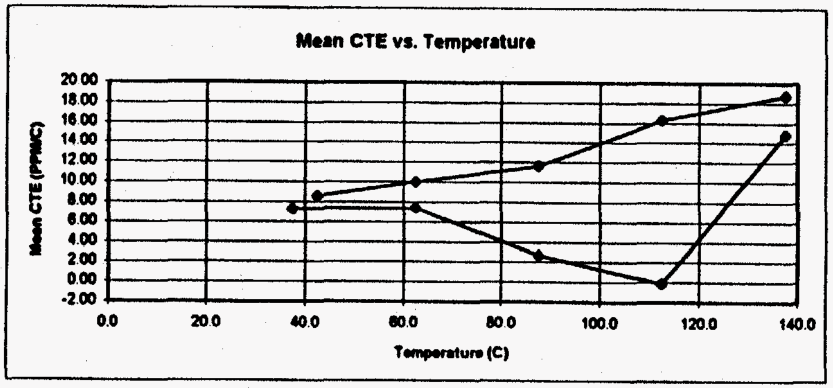
Sample ID:	NRG-6-416.0-SNL-M
Lithology:	Welded Devitrified
TMU:	TSw1
Test condition:	Vacuum-Saturated
Sample Size:	2" (l) x 1" (d)

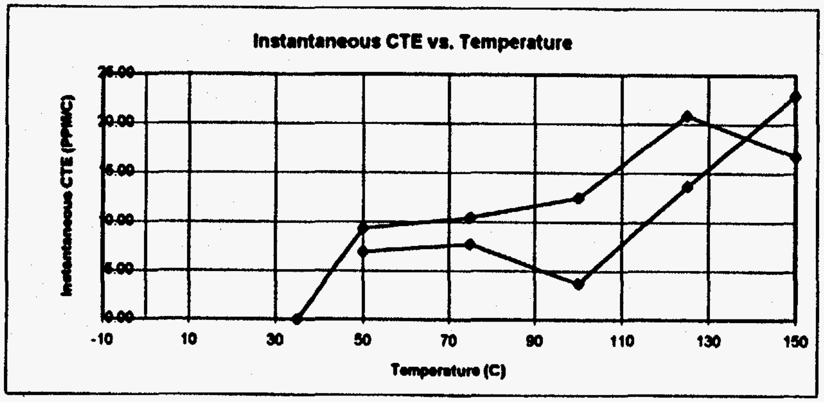
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	59.68	50.85	25.77	2.32
post-test:	56.89	50.93	25.81	2.20

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
Heat-up	25	-1.88	***	***	
	50	162.43	6.57	7.12	37.5
	75	349.29	7.47	8.32	62.5
	100	508.53	6.37	5.19	87.5
	125	664.22	6.23	10.49	112.5
	150	941.67	11.10	13.59	137.5
	175	1456.91	20.61	25.31	162.5
	200	2198.67	29.67	37.63	187.5
	225	3767.89	63.57	71.44	212.5
	250	5223.91	57.44	54.20	237.5
	275	6439.37	48.62	45.22	262.5
	300	7541.85	44.10	41.78	287.5
Cool-down	300	8097.21	15.63	12.11	287.5
	275	7706.37	18.66	17.98	262.5
	250	7239.93	20.80	20.50	237.5
	225	6719.84	23.49	21.59	212.5
	200	6132.67	29.04	24.20	187.5
	175	5406.69	38.49	33.00	162.5
	150	4444.36	54.03	47.18	137.5
	125	3093.51	30.45	56.91	112.5
	100	2332.22	13.93	15.95	87.5
	75	1983.88	11.48	12.26	62.5
	50	1696.94	10.57	11.22	42.5
	35	1538.42	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







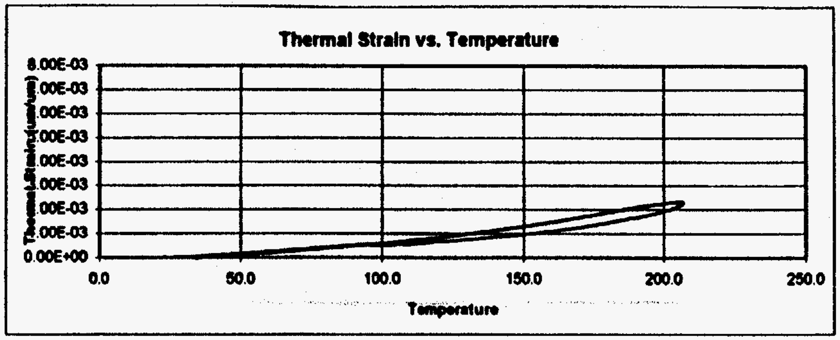
Data Summary

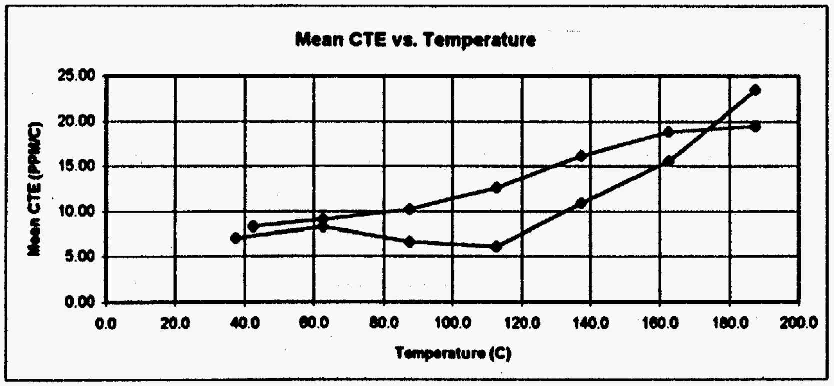
Sample ID:	NRG-6-421.8-SNL-B
Lithology:	Welded Devitrified
TMU:	TSw1
Test condition:	Vacuum-Saturated
Sample Size:	2" (l) x 1" (d)

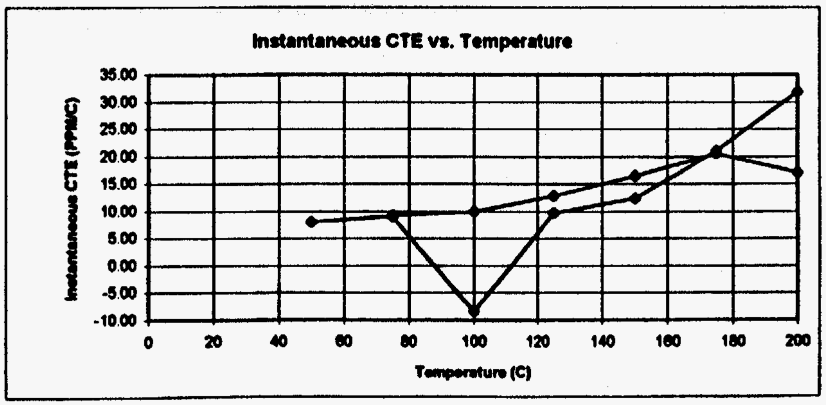
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	59.16	50.95	25.82	2.29
post-test:	56.01	50.93	25.81	2.17

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
Heat-up	25	-1.88	***	***	
	50	180.39	7.29	6.89	37.5
	75	365.73	7.41	7.70	62.5
	100	432.03	2.65	3.73	87.5
	125	429.81	-0.09	13.72	112.5
	150	801.33	14.86	22.93	137.5
Cool-down	150	1115.17	18.76	16.77	137.5
	125	646.19	16.33	20.65	112.5
	100	237.97	11.61	12.48	87.5
	75	-52.22	10.00	10.43	62.5
	50	-302.18	8.57	9.29	42.5
	35	-430.70	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







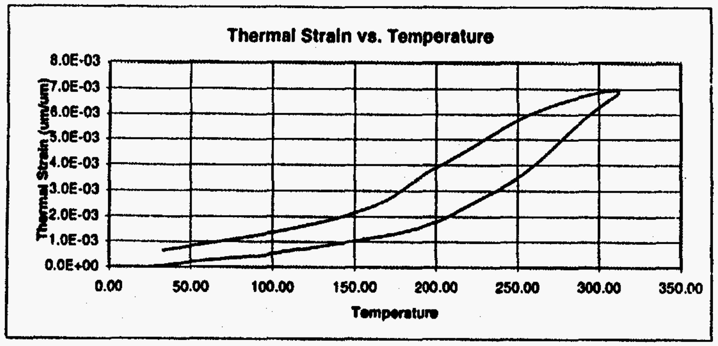
Data Summary

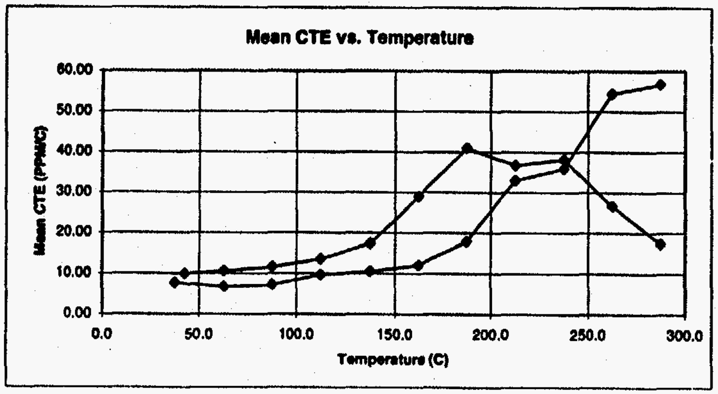
Sample ID:	NRG-6-458.7-SNL-A
Lithology:	Welded Devitrified
TMU:	TSw1
Test condition:	VACUUM SATURATED
Sample Size:	2" (l) x 1" (d)

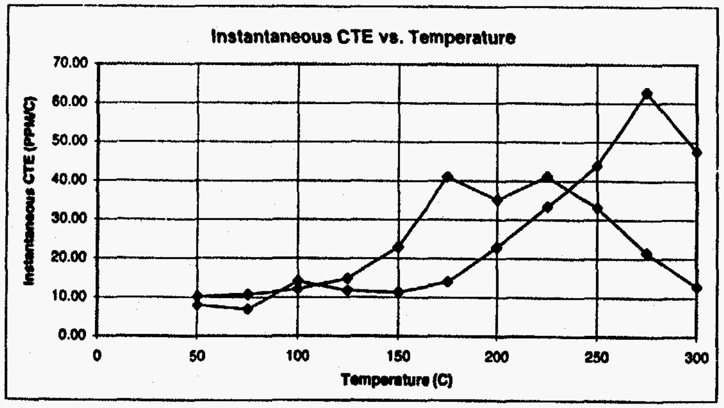
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	55.08	50.95	25.82	2.13
post-test:	50.43	50.95	25.82	1.95

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
Heat-up	25	1.98	***	***	
	50	177.53	7.02	8.04	37.5
	75	384.47	8.28	9.01	62.5
	100	549.72	6.61	-8.30	87.5
	125	702.84	6.12	9.70	112.5
	150	975.48	10.91	12.42	137.5
	175	1365.79	15.61	21.02	162.5
	200	1953.34	23.50	31.82	187.5
Cool-down	200	2269.49	19.45	17.12	187.5
	175	1783.30	18.84	20.61	162.5
	150	1312.34	16.17	16.48	137.5
	125	908.12	12.67	12.86	112.5
	100	591.29	10.18	9.95	87.5
	75	336.75	9.12	9.31	62.5
	50	108.67	8.36	8.08	42.5
	35	-16.67	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

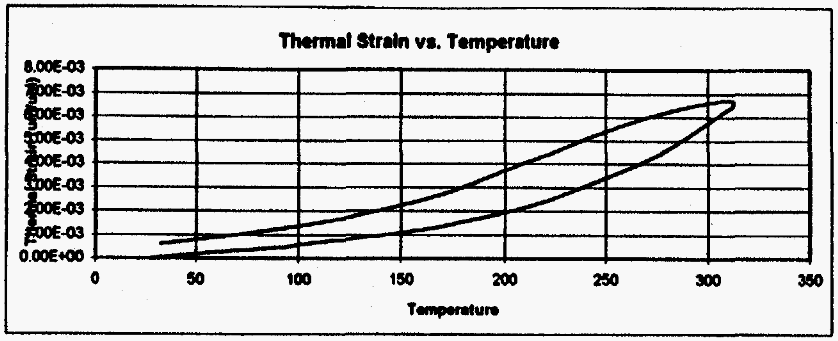
Sample ID: NRG-6-528.4-SNL-A
Lithology: Welded Devitrified
TMU: TSw1

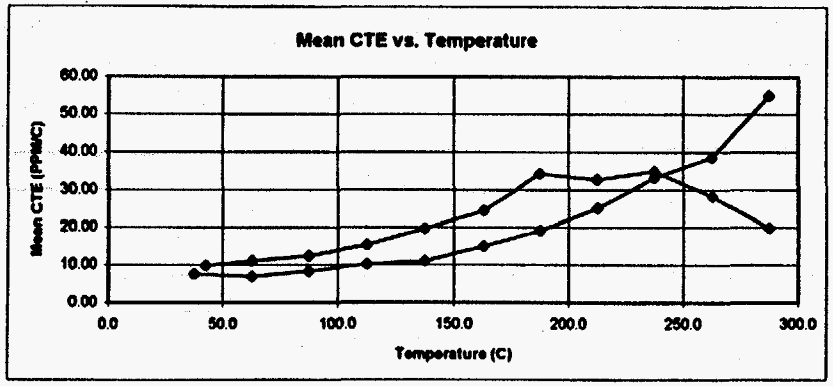
Test condition: Vacuum-Saturated
Sample Size: 2" (l) x 1" (d)

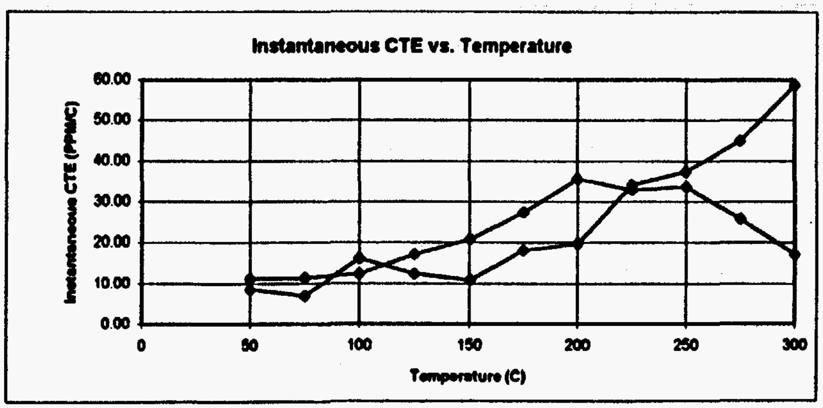
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	59.96	50.85	25.77	2.33
post-test:	53.10	50.88	25.78	2.06

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
Heat-up	25	-1.36	***	***	
	50	188.08	7.58	7.90	37.5
	75	355.08	6.68	6.82	62.5
	100	534.15	7.16	14.09	87.5
	125	774.14	9.60	11.72	112.5
	150	1034.42	10.41	11.30	137.5
	175	1335.60	12.05	14.02	162.5
	200	1783.15	17.90	22.85	187.5
	225	2605.56	32.90	33.39	212.5
	250	3502.85	35.89	43.83	237.5
	275	4861.97	54.36	62.81	262.5
	300	6280.21	56.73	47.49	287.5
Cool-dowr	300	6862.23	17.45	12.77	287.5
	275	6425.98	26.67	21.52	262.5
	250	5759.28	38.12	33.10	237.5
	225	4806.32	36.62	41.17	212.5
	200	3890.71	40.89	35.09	187.5
	175	2868.49	28.97	40.94	162.5
	150	2144.29	17.36	22.93	137.5
	125	1710.30	13.54	14.80	112.5
	100	1371.69	11.52	12.06	87.5
	75	1083.73	10.54	10.74	62.5
	50	820.34	9.83	10.10	42.5
	35	672.90	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

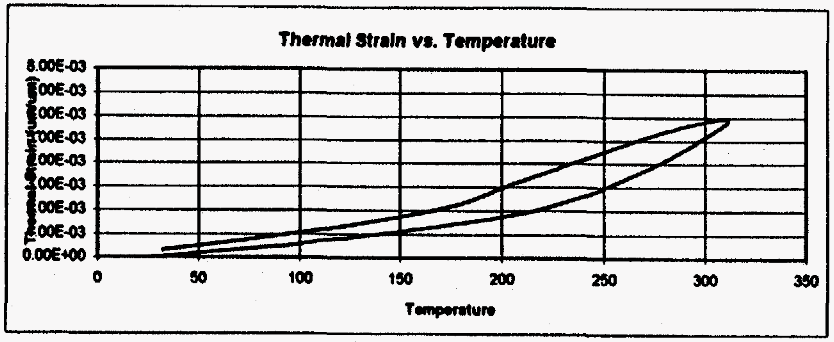
Sample ID: NRG-6-648.6-SNL-A
Lithology: Welded Devitrified
TMU: TSw1

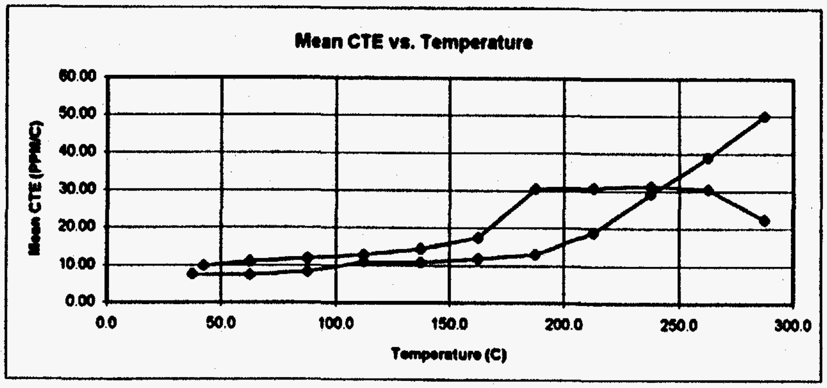
Test condition: Vacuum-Saturated
Sample Size: 2" (l) x 1" (d)

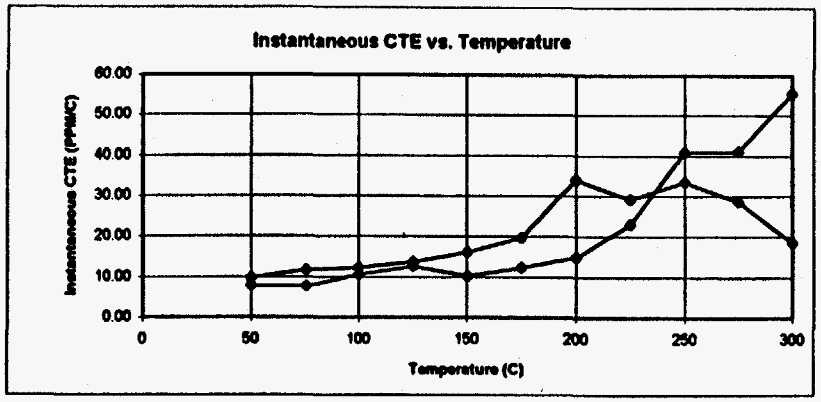
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	56.28	50.85	25.77	2.18
post-test:	51.66	50.88	25.78	2.00

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
Heat-up	25	-0.14	***	***	
	50	189.98	7.60	8.56	37.5
	75	364.41	6.98	6.84	62.5
	100	570.90	8.26	16.20	87.5
	125	823.14	10.09	12.31	112.5
	150	1098.60	11.02	10.99	137.5
	175	1473.19	14.98	18.20	162.5
	200	1952.38	19.17	19.73	187.5
	225	2580.97	25.14	34.25	212.5
	250	3415.02	33.36	37.36	237.5
	275	4378.40	38.54	44.99	262.5
	300	5755.08	55.07	58.65	287.5
Cool-down	300	6613.08	19.82	17.21	287.5
	275	6117.46	28.22	25.87	262.5
	250	5411.97	34.96	33.69	237.5
	225	4538.01	32.84	32.92	212.5
	200	3717.00	34.36	35.62	187.5
	175	2857.89	24.40	27.46	162.5
	150	2247.78	19.63	20.88	137.5
	125	1757.00	15.39	17.20	112.5
	100	1372.27	12.34	12.29	87.5
	75	1063.66	10.98	11.38	62.5
	50	789.28	9.84	11.29	42.5
	35	641.67	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

Sample ID: NRG-6-693.1-SNL-A
Lithology: Welded Devitrified
TMU: TSw1

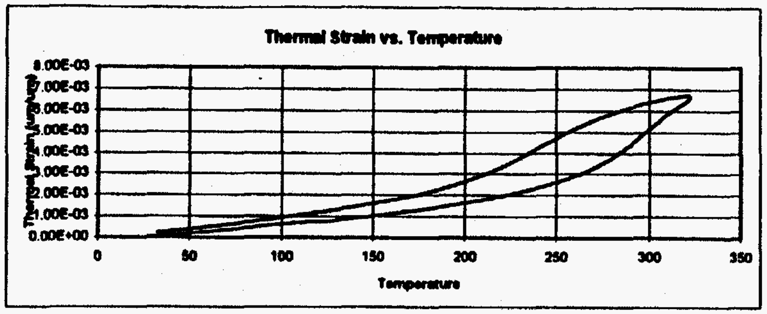
Test condition: Vacuum-Saturated
Sample Size: 2" (l) x 1" (d)

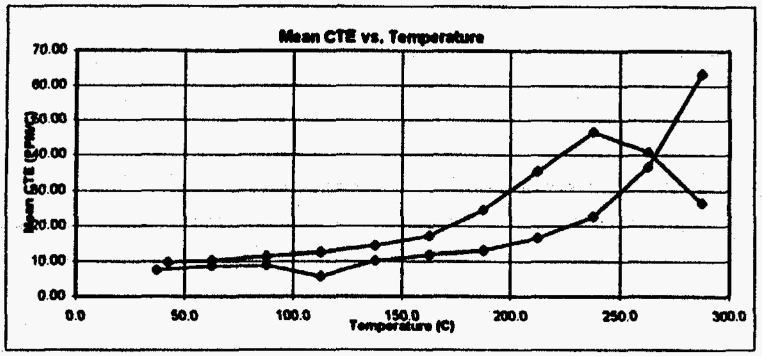
Sample Data:

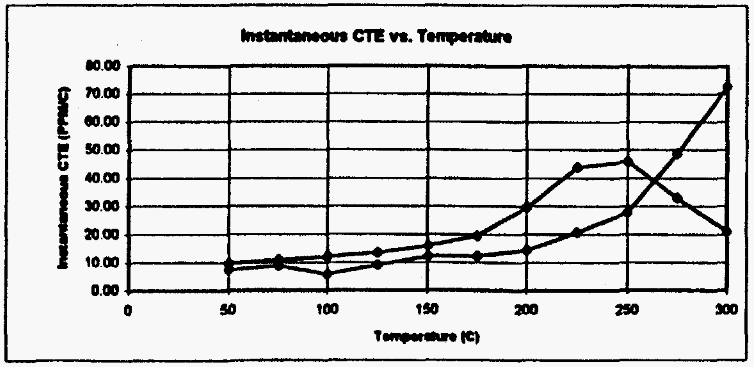
	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	59.90	50.85	25.77	2.32
post-test:	57.37	50.85	25.77	2.23

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (^oC)
Heat-up	25	-0.98	***	***	
	50	188.79	7.59	7.93	37.5
	75	372.16	7.33	7.66	62.5
	100	580.23	8.32	10.58	87.5
	125	854.17	10.96	12.63	112.5
	150	1125.76	10.86	10.21	137.5
	175	1421.30	11.82	12.29	162.5
	200	1749.46	13.13	14.92	187.5
	225	2218.40	18.76	23.09	212.5
	250	2949.62	29.25	40.86	237.5
	275	3925.79	39.05	41.01	262.5
	300	5176.39	50.02	55.46	287.5
Cool-down	300	5827.76	22.33	18.56	287.5
	275	5269.57	30.48	28.65	262.5
	250	4507.56	31.37	33.48	237.5
	225	3723.44	30.91	29.17	212.5
	200	2950.66	30.59	33.96	187.5
	175	2185.84	17.47	19.68	162.5
	150	1749.10	14.42	16.20	137.5
	125	1388.57	12.87	13.87	112.5
	100	1066.79	11.86	12.34	87.5
	75	770.37	11.00	11.77	62.5
	50	495.39	9.84	9.74	42.5
	35	347.72	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







E-42

Data Summary

Sample ID: NRG-6-729.2-SNL-A
Lithology: Welded Devitrified
TMU: TSw2

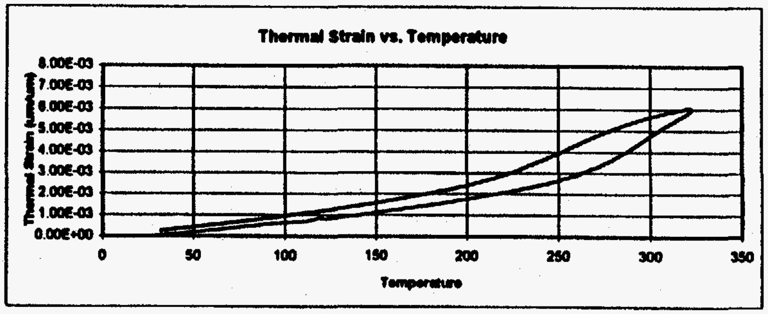
This sample is part of a pair tested for anisotropy
The other sample is: NRG-6-729.2-SNL-B

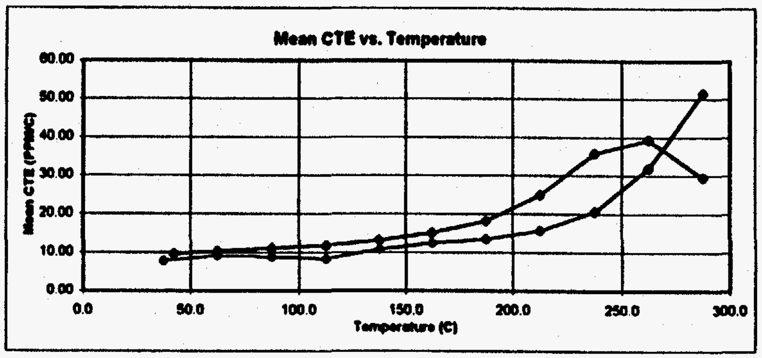
Test condition: Vacuum-Saturated
Sample Size: 2" (l) x 1" (d)

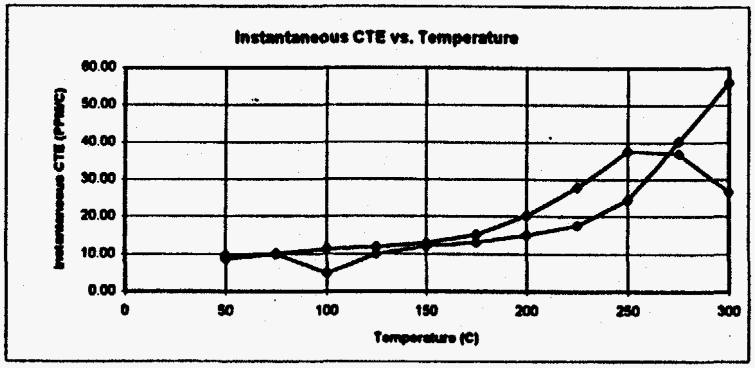
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	60.24	50.88	25.78	2.34
post-test:	58.04	50.88	25.78	2.25

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
Heat-up	25	0.92	***	***	
	50	188.92	7.52	7.47	37.5
	75	404.08	8.61	8.77	62.5
	100	626.72	8.91	5.81	87.5
	125	770.94	5.77	8.94	112.5
	150	1025.68	10.19	12.21	137.5
	175	1321.71	11.84	12.26	162.5
	200	1650.63	13.16	14.38	187.5
	225	2064.63	16.56	20.60	212.5
	250	2633.28	22.75	27.88	237.5
	275	3553.20	36.80	48.64	262.5
	300	5142.63	63.58	72.72	287.5
Cool-down	300	6409.36	26.58	21.05	287.5
	275	5744.79	41.03	32.93	262.5
	250	4719.08	46.65	45.84	237.5
	225	3552.74	35.48	43.94	212.5
	200	2665.76	24.60	29.39	187.5
	175	2050.87	17.17	19.52	162.5
	150	1621.63	14.44	15.96	137.5
	125	1260.54	12.65	13.40	112.5
	100	944.40	11.49	12.17	87.5
	75	657.19	10.41	10.84	62.5
	50	396.88	9.85	9.76	42.5
	35	249.16	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

Sample ID:	NRG-6-729.2-SNL-B
Lithology:	Welded Devitrified
TMU:	TSw2

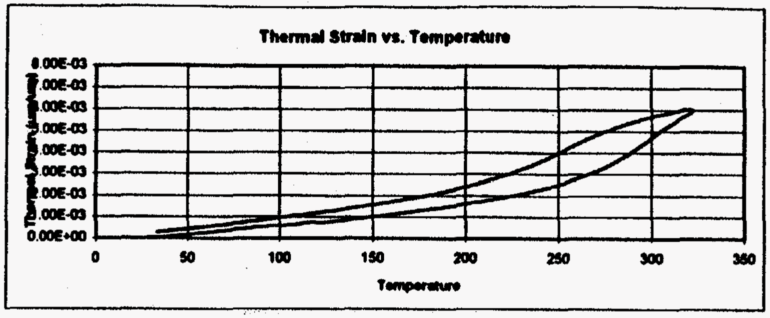
This sample is part of a pair tested for anisotropy
The other sample is: NRG-6-729.2-SNL-A

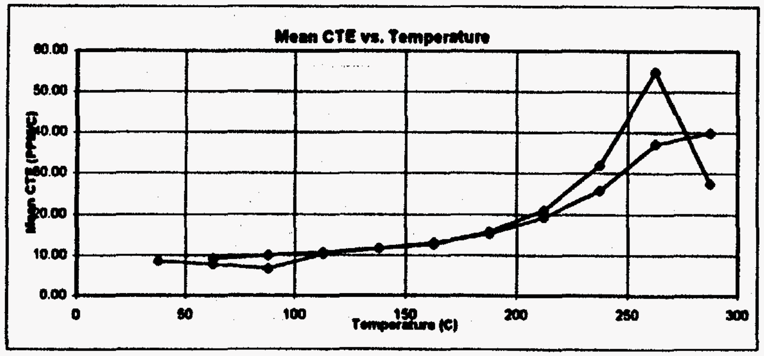
Test condition:	Vacuum-Saturated
Sample Size:	2" (l) x 1" (d)

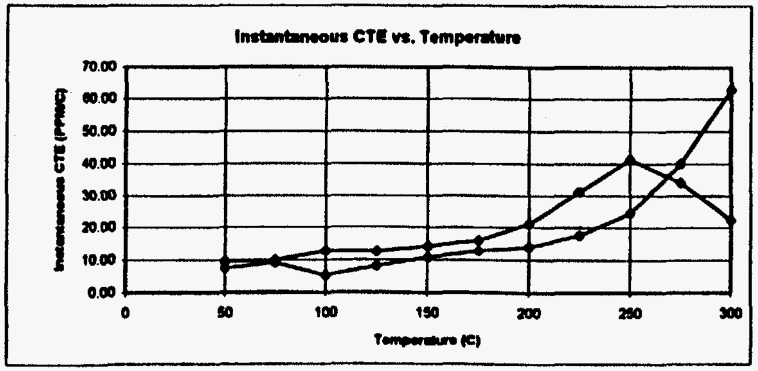
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	60.56	50.88	25.78	2.35
post-test:	58.71	50.88	25.78	2.28

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
Heat-up	25	4.40	***	***	
	50	196.37	7.68	8.55	37.5
	75	422.99	9.06	10.00	62.5
	100	640.82	8.71	4.86	87.5
	125	849.32	8.34	9.90	112.5
	150	1117.15	10.71	12.09	137.5
	175	1429.72	12.50	13.02	162.5
	200	1765.16	13.42	14.91	187.5
	225	2156.31	15.65	17.68	212.5
	250	2668.60	20.49	24.61	237.5
	275	3464.12	31.82	40.35	262.5
	300	4753.90	51.59	56.19	287.5
Cool-down	300	5658.62	29.52	26.62	287.5
	275	4920.68	39.22	36.95	262.5
	250	3940.27	35.72	37.70	237.5
	225	3047.40	24.86	27.96	212.5
	200	2425.79	18.25	20.25	187.5
	175	1969.54	15.19	15.21	162.5
	150	1589.69	13.17	12.85	137.5
	125	1260.41	11.85	11.83	112.5
	100	964.16	11.05	11.41	87.5
	75	687.96	10.28	10.13	62.5
	50	430.91	9.67	9.52	42.5
	35	265.82	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

Sample ID: NRG-6-732.6-SNL-A
Lithology: Welded Devitrified
TMU: TSw2

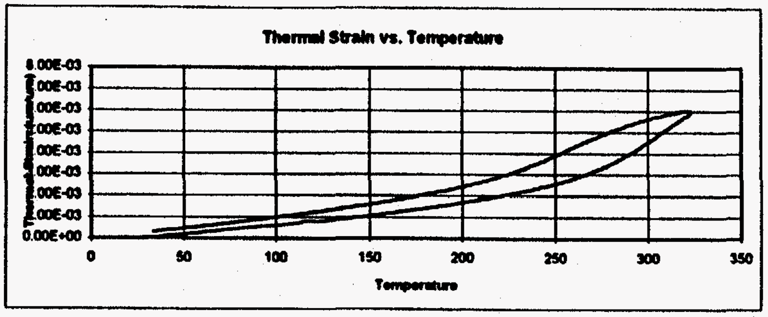
This sample is part of a pair tested for anisotropy
The other sample is: NRG-6-732.6-SNL-C

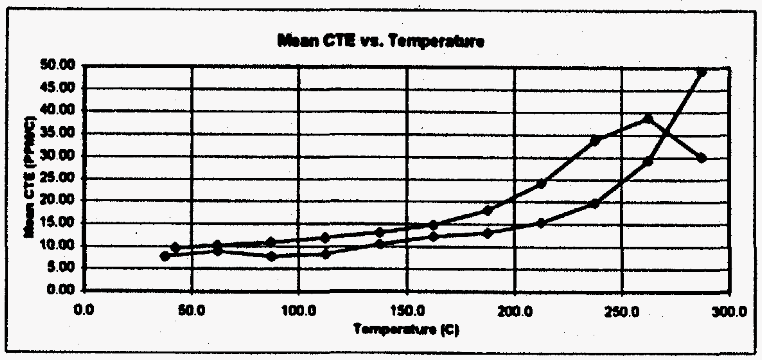
Test condition: Vacuum-Saturated
Sample Size: 2" (l) x 1" (d)

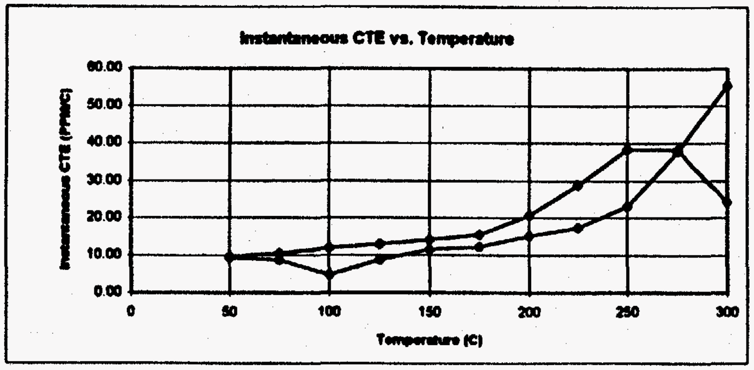
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	59.89	50.83	25.76	2.33
post-test:	57.69	50.83	25.76	2.24

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
Heat-up	25	2.15	***	***	
	50	180.37	7.13	7.49	37.5
	75	393.24	8.51	9.19	62.5
	100	585.35	7.68	5.26	87.5
	125	751.70	6.65	8.18	112.5
	150	1007.30	10.22	10.79	137.5
	175	1298.47	11.65	12.81	162.5
	200	1616.48	12.72	13.91	187.5
	225	2012.63	15.86	17.56	212.5
	250	2539.61	21.08	24.71	237.5
	275	3339.41	31.99	39.98	262.5
	300	4713.43	54.96	63.02	287.5
Cool-down	300	5698.91	27.60	22.57	287.5
	275	5008.96	39.94	34.23	262.5
	250	4010.53	37.22	41.34	237.5
	225	3080.12	25.82	31.29	212.5
	200	2434.59	18.31	21.21	187.5
	175	1951.77	15.14	16.01	162.5
	150	1573.19	13.06	14.12	137.5
	125	1246.66	11.75	12.66	112.5
	100	953.00	10.83	12.69	87.5
	75	682.28	9.91	10.03	62.5
	50	434.56	9.18	9.53	42.5
	35	296.84	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

Sample ID: NRG-6-732.6-SNL-C
Lithology: Welded Devitrified
TMU: TSw2

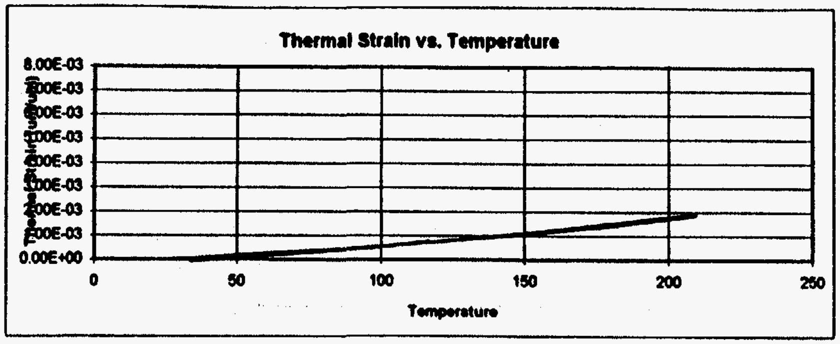
This sample is part of a pair tested for anisotropy
The other sample is: NRG-6-732.6-SNL-A

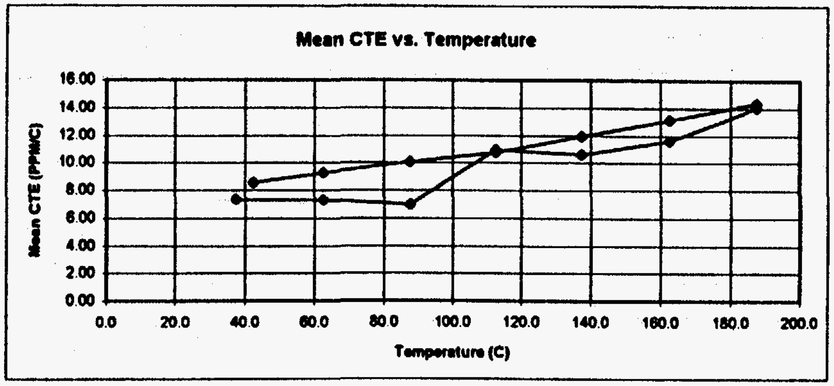
Test condition: Vacuum-Saturated
Sample Size: 2" (l) x 1" (d)

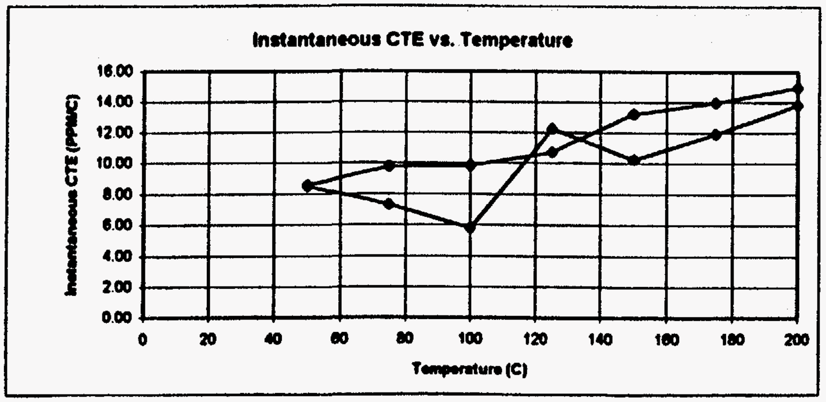
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	60.43	50.77	25.73	2.35
post-test:	58.26	50.80	25.74	2.26

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (^{o}C)
Heat-up	25	-0.01	***	***	
	50	193.09	7.72	9.29	37.5
	75	415.43	8.89	8.67	62.5
	100	609.78	7.77	4.69	87.5
	125	817.68	8.32	8.72	112.5
	150	1080.40	10.51	11.54	137.5
	175	1385.31	12.20	12.12	162.5
	200	1714.26	13.16	15.06	187.5
	225	2098.29	15.36	17.31	212.5
	250	2593.35	19.80	23.13	237.5
	275	3324.46	29.24	37.82	262.5
	300	4553.26	49.15	55.52	287.5
Cool-down	300	5627.42	30.14	24.36	287.5
	275	4873.86	38.77	38.19	262.5
	250	3904.70	33.91	38.48	237.5
	225	3056.91	24.22	28.83	212.5
	200	2451.48	18.14	20.65	187.5
	175	1998.01	14.87	15.56	162.5
	150	1626.26	13.15	14.06	137.5
	125	1297.43	11.93	12.95	112.5
	100	999.15	10.97	11.81	87.5
	75	724.97	10.17	10.47	62.5
	50	470.76	9.62	9.65	42.5
	35	326.52	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







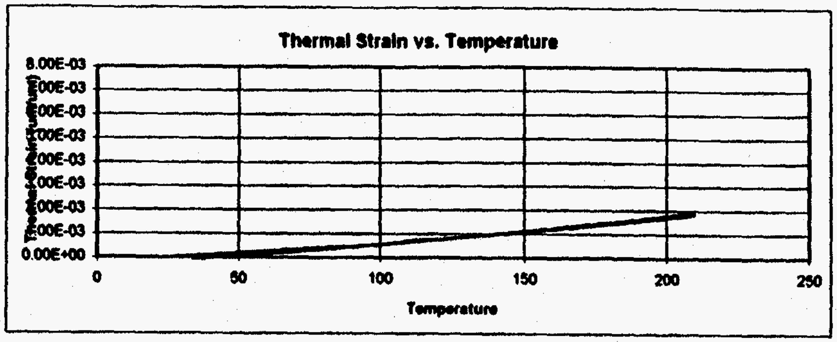
Data Summary

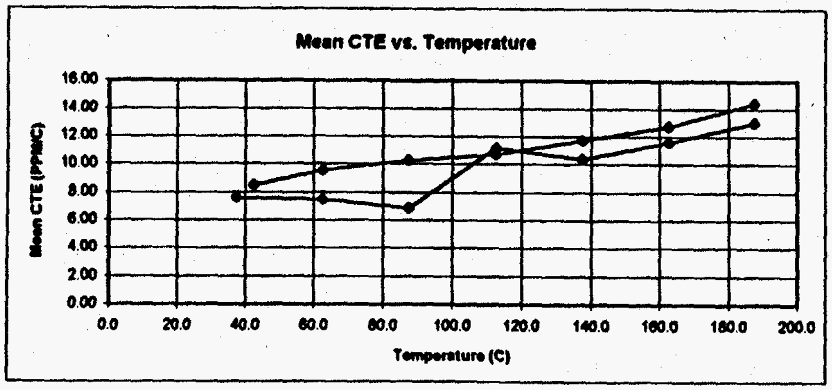
Sample ID:	NRG-6-777.8-SNL-A
Lithology:	Welded Devitrified
TMU:	TSw2
Test condition:	Vacuum-Saturated
Sample Size:	2" (l) x 1" (d)

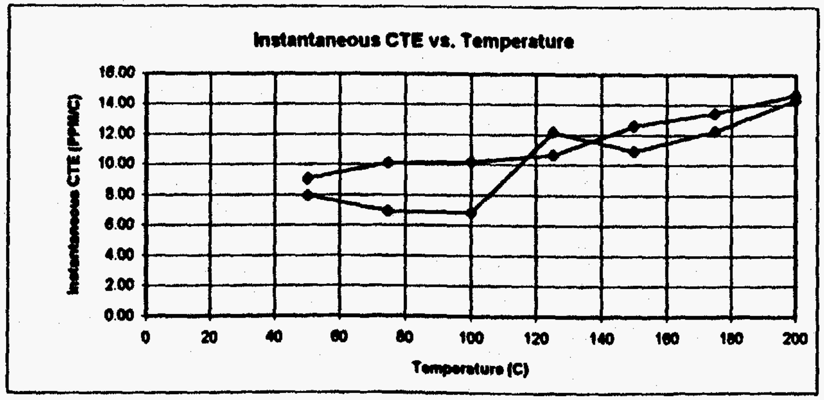
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	60.07	50.85	25.77	2.33
post-test:	57.84	50.85	25.77	2.24

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (^{o}C)
Heat-up	25	-1.18	***	***	
	50	182.39	7.34	8.50	37.5
	75	364.37	7.28	7.31	62.5
	100	538.81	6.98	5.78	87.5
	125	812.53	10.95	12.25	112.5
	150	1077.90	10.61	10.25	137.5
	175	1367.55	11.59	11.91	162.5
	200	1718.71	14.05	13.83	187.5
Cool-down	200	1805.53	14.35	14.97	187.5
	175	1446.66	13.13	13.95	162.5
	150	1118.51	11.92	13.23	137.5
	125	820.40	10.75	10.75	112.5
	100	551.66	10.04	9.85	87.5
	75	300.54	9.25	9.77	62.5
	50	69.40	8.57	8.59	42.5
	35	-59.10	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

Sample ID: NRG-6-788.3-SNL-A
Lithology: Welded Devitrified
TMU: TSw2

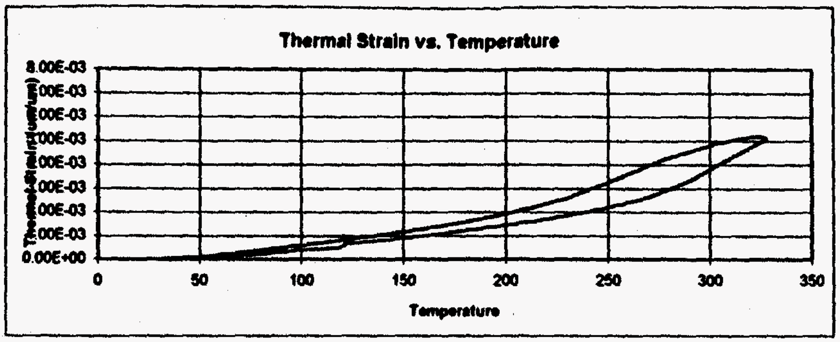
Test condition: Vacuum-Saturated
Sample Size: 2" (l) x 1" (d)

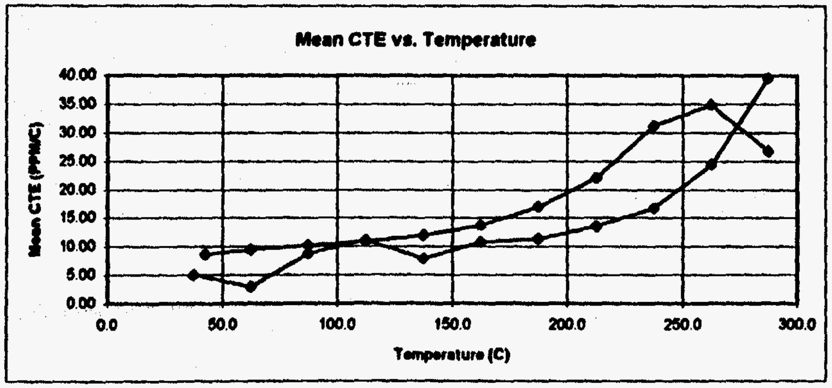
Sample Data:

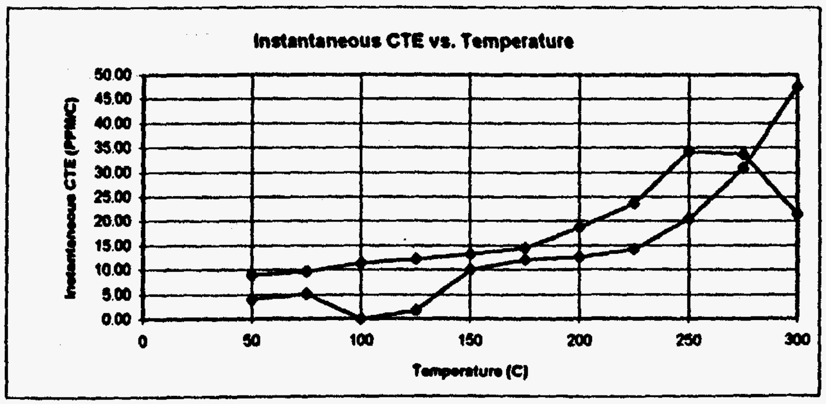
	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	59.44	50.80	25.74	2.31
post-test:	56.81	50.77	25.73	2.21

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
Heat-up	25	0.65	***	***	
	50	190.65	7.60	7.95	37.5
	75	377.86	7.49	6.95	62.5
	100	549.01	6.85	6.83	87.5
	125	828.33	11.17	12.15	112.5
	150	1087.85	10.38	10.93	137.5
	175	1377.94	11.60	12.24	162.5
	200	1703.62	13.03	14.32	187.5
Cool-down	200	1793.62	14.43	14.68	187.5
	175	1432.79	12.74	13.45	162.5
	150	1114.40	11.73	12.59	137.5
	125	821.06	10.72	10.66	112.5
	100	553.02	10.27	10.17	87.5
	75	296.38	9.54	10.09	62.5
	50	57.63	8.47	9.05	42.5
	35	-69.24	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







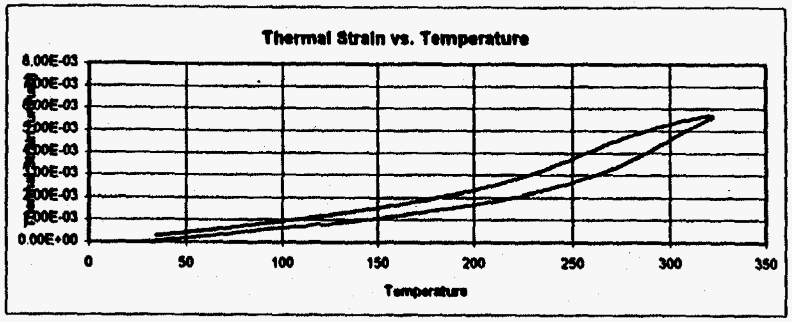
Data Summary

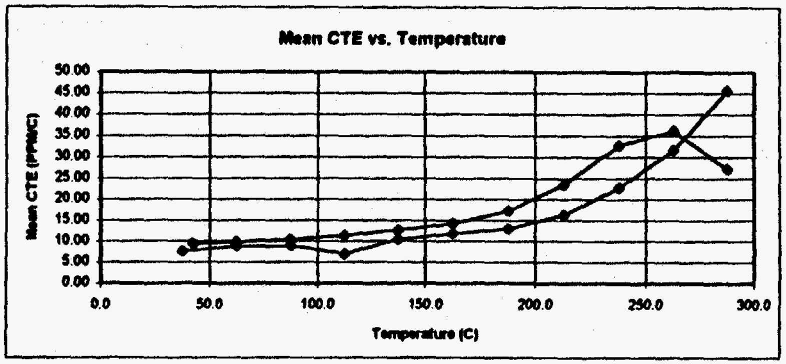
Sample ID:	NRG-6-802.7-SNL-A
Lithology:	Welded Devitrified
TMU:	TSw2
Test condition:	Vacuum-Saturated
Sample Size:	2" (l) x 1" (d)

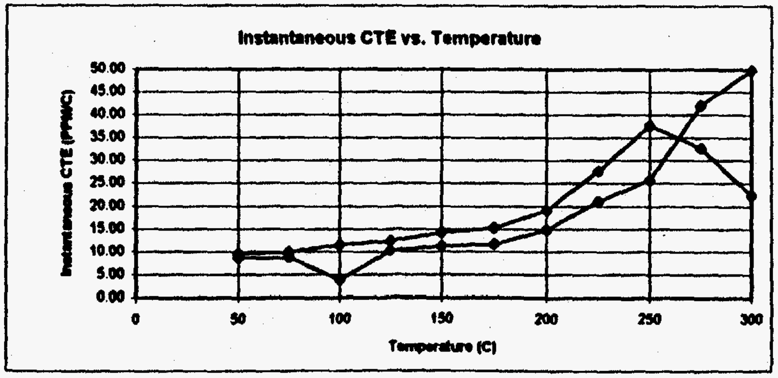
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	60.21	50.90	25.79	2.33
post-test:	58.08	50.90	25.79	2.25

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
Heat-up	25	-1.86	***	***	
	50	123.62	5.02	4.06	37.5
	75	198.19	2.98	5.11	62.5
	100	418.72	8.82	***	87.5
	125	698.04	11.17	1.67	112.5
	150	894.67	7.87	10.02	137.5
	175	1164.81	10.81	12.09	162.5
	200	1450.86	11.44	12.57	187.5
	225	1788.55	13.51	14.24	212.5
	250	2206.70	16.73	20.49	237.5
	275	2817.56	24.43	30.87	262.5
	300	3806.97	39.58	47.60	287.5
Cool-down	300	4811.60	26.75	21.49	287.5
	275	4142.75	34.91	33.65	262.5
	250	3269.97	31.17	34.18	237.5
	225	2490.59	22.07	23.66	212.5
	200	1938.91	16.99	18.73	187.5
	175	1514.07	13.69	14.43	162.5
	150	1171.79	11.97	13.20	137.5
	125	872.54	10.94	12.17	112.5
	100	599.02	10.23	11.38	87.5
	75	343.29	9.47	9.60	62.5
	50	106.47	8.67	8.95	42.5
	35	-23.63	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

Sample ID: NRG-6-806.0-SNL-A
Lithology: Welded Devitrified
TMU: TSw2

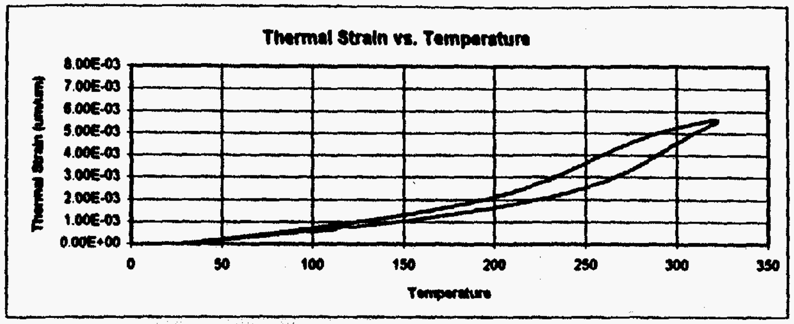
**** This sample is part of a pair tested for anisotropy ****
The other sample is: NRG-6-806.0-SNL-B

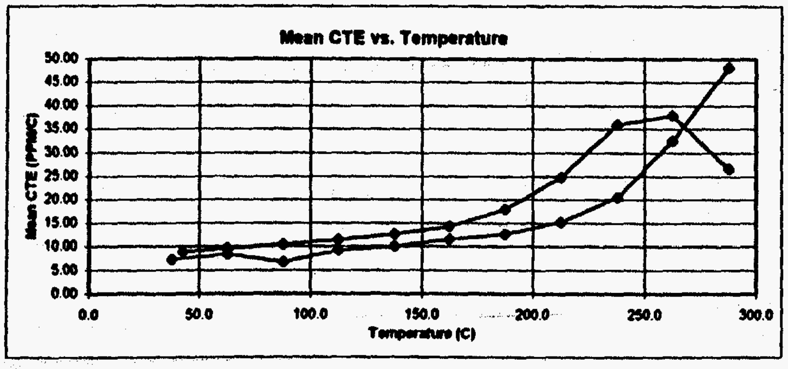
Test condition: Vacuum-Saturated
Sample Size: 2" (l) x 1" (d)

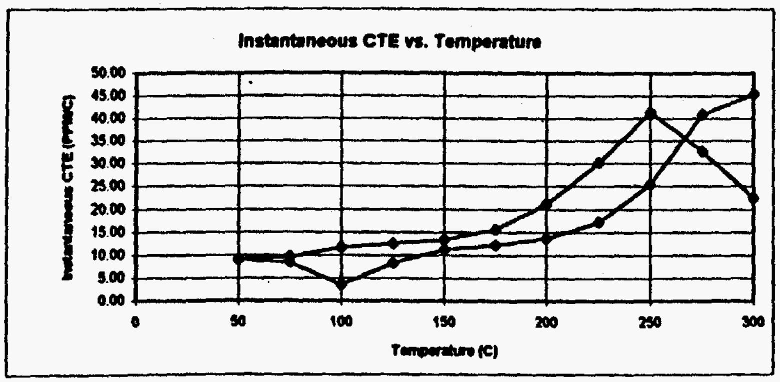
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	60.36	50.85	25.77	2.34
post-test:	58.47	50.85	25.77	2.27

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (^{0}C)
Heat-up	25	1.94	***	***	
	50	190.37	7.54	8.76	37.5
	75	409.26	8.76	8.79	62.5
	100	632.80	8.94	3.79	87.5
	125	808.35	7.02	10.19	112.5
	150	1070.08	10.47	11.30	137.5
	175	1368.13	11.92	11.67	162.5
	200	1695.01	13.08	14.80	187.5
	225	2106.48	16.46	21.14	212.5
	250	2674.72	22.73	25.72	237.5
	275	3466.74	31.68	42.10	262.5
	300	4608.16	45.66	49.89	287.5
Cool-down	300	5324.48	27.23	22.31	287.5
	275	4643.75	36.12	32.81	262.5
	250	3740.74	32.75	37.78	237.5
	225	2922.00	23.56	27.75	212.5
	200	2332.94	17.28	19.08	187.5
	175	1900.89	14.29	15.26	162.5
	150	1543.70	12.72	14.22	137.5
	125	1225.67	11.42	12.45	112.5
	100	940.30	10.54	11.60	87.5
	75	676.71	9.87	9.94	62.5
	50	429.84	9.40	9.55	42.5
	35	288.91	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

Sample ID:	NRG-6-906.0-SNL-B
Lithology:	Welded Devitrified
TMU:	TSw2

**** This sample is part of a pair tested for anisotropy****

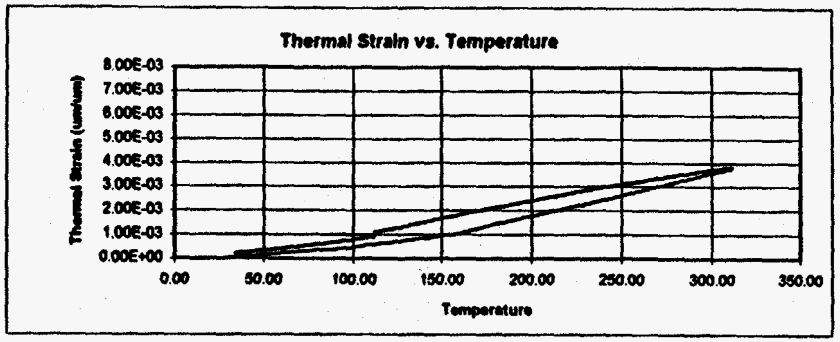
The other sample is: NRG-6-906.0-SNL-A

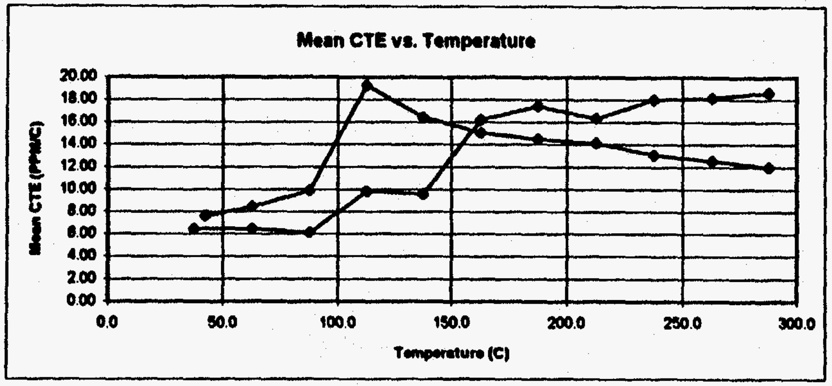
Test condition:	Vacuum-Saturated
Sample Size:	2" (l) x 1" (d)

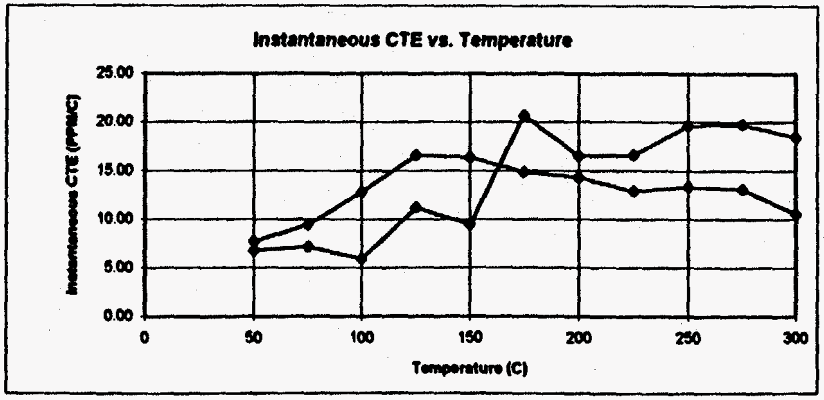
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	60.46	50.85	25.77	2.35
post-test:	58.40	50.85	25.77	2.27

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (^{0}C)
Heat-up	25	2.82	***	***	
	50	183.33	7.22	8.93	37.5
	75	393.35	8.40	8.45	62.5
	100	561.36	6.72	3.63	87.5
	125	789.94	9.14	8.23	112.5
	150	1040.74	10.03	11.24	137.5
	175	1330.32	11.58	12.23	162.5
	200	1646.18	12.63	13.74	187.5
	225	2028.70	15.30	17.24	212.5
	250	2545.03	20.65	25.47	237.5
	275	3360.55	32.62	40.88	262.5
	300	4565.22	48.19	45.51	287.5
Cool-down	300	5262.84	26.69	22.44	287.5
	275	4595.66	37.96	32.70	262.5
	250	3646.71	35.95	41.43	237.5
	225	2747.89	24.90	30.24	212.5
	200	2125.39	17.99	21.29	187.5
	175	1675.59	14.33	15.63	162.5
	150	1317.32	12.58	13.34	137.5
	125	1002.73	11.36	12.51	112.5
	100	718.69	10.45	11.74	87.5
	75	457.54	9.61	9.66	62.5
	50	217.37	8.88	9.10	42.5
	35	84.20	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







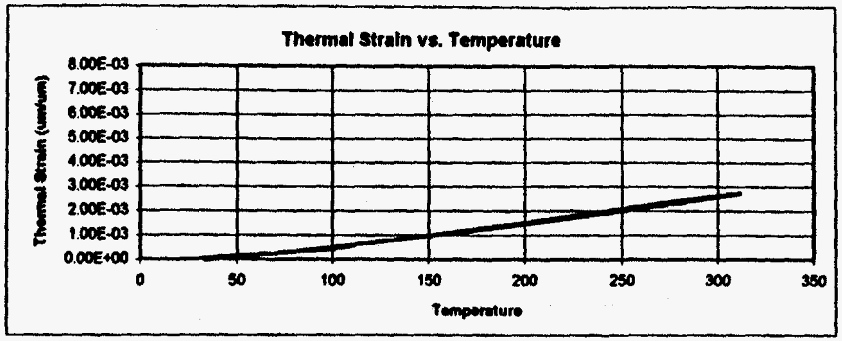
Data Summary

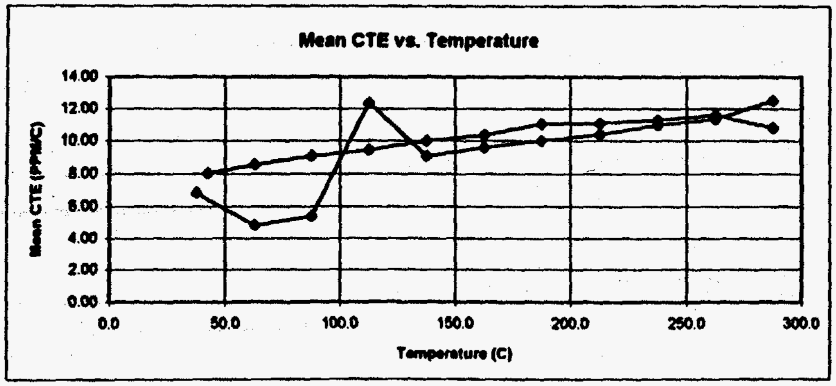
Sample ID:	NRG-6-849.9-SNL-A
Lithology:	Welded Devitrified
TMU:	TSw2
Test condition:	Vacuum-Saturated
Sample Size:	2" (l) x 1" (d)

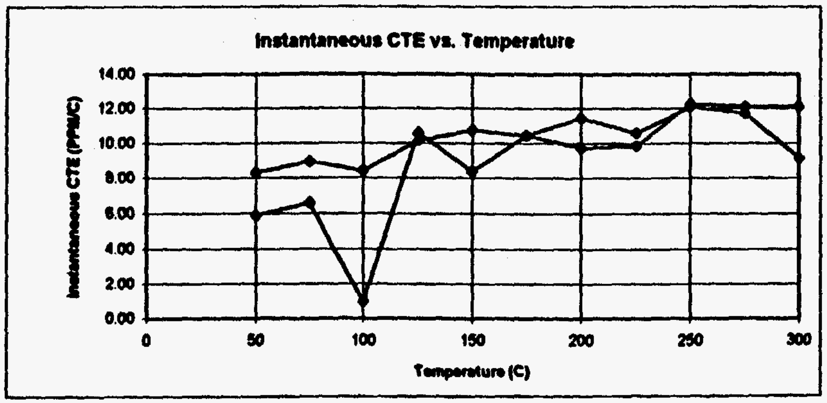
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	60.30	50.93	25.81	2.34
post-test:	57.34	50.83	25.76	2.23

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
Heat-up	25	-0.34	***	***	
	50	160.26	6.42	6.82	37.5
	75	321.67	6.46	7.22	62.5
	100	474.39	6.11	5.95	87.5
	125	719.43	9.80	11.24	112.5
	150	959.16	9.59	9.47	137.5
	175	1364.17	16.20	20.63	162.5
	200	1798.64	17.39	16.52	187.5
	225	2206.54	16.31	16.59	212.5
	250	2656.27	17.99	19.59	237.5
	275	3110.98	18.19	19.75	262.5
	300	3576.67	18.63	18.47	287.5
Cool-down	300	3728.79	12.01	10.64	287.5
	275	3428.62	12.60	13.11	262.5
	250	3113.71	13.12	13.35	237.5
	225	2785.60	14.12	12.87	212.5
	200	2432.62	14.51	14.29	187.5
	175	2069.93	15.05	14.84	162.5
	150	1693.72	16.44	16.39	137.5
	125	1282.81	19.24	16.56	112.5
	100	801.90	9.89	12.86	87.5
	75	554.54	8.47	9.48	62.5
	50	342.66	7.59	7.77	42.5
	35	228.75	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

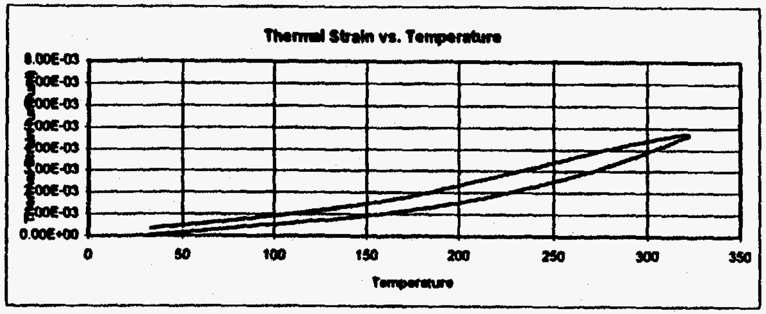
Sample ID: NRG-6-886.5-SNL-A
Lithology: Welded Devitrified
TMU: TSw2

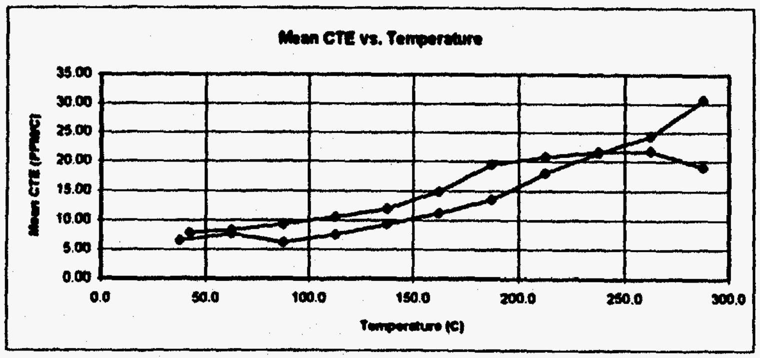
Test condition: Vacuum-Saturated
Sample Size: 2" (l) x 1" (d)

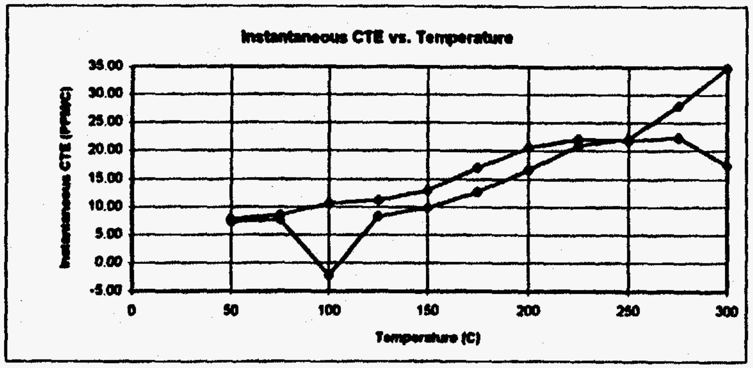
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	59.10	48.82	24.74	2.39
post-test:	56.86	48.82	24.74	2.30

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (^{o}C)
Heat-up	25	-3.09	***	***	
	50	167.57	6.83	5.88	37.5
	75	287.90	4.81	6.59	62.5
	100	422.87	5.40	0.97	87.5
	125	731.84	12.36	10.61	112.5
	150	959.33	9.10	8.39	137.5
	175	1199.54	9.61	10.44	162.5
	200	1450.37	10.03	9.74	187.5
	225	1711.25	10.43	9.86	212.5
	250	1985.77	10.98	12.27	237.5
	275	2269.62	11.35	12.13	262.5
	300	2582.36	12.51	12.15	287.5
Cool-down	300	2666.22	10.81	9.17	287.5
	275	2396.01	11.60	11.73	262.5
	250	2106.05	11.32	12.10	237.5
	225	1823.07	11.12	10.61	212.5
	200	1545.06	11.06	11.44	187.5
	175	1268.62	10.38	10.44	162.5
	150	1009.24	10.02	10.72	137.5
	125	758.72	9.45	10.13	112.5
	100	522.41	9.08	8.41	87.5
	75	295.53	8.57	8.94	62.5
	50	81.33	8.05	8.31	42.5
	35	-39.38	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

Sample ID: NRG-6-911.2-SNL-A
Lithology: Welded Devitrified
TMU: TSw2

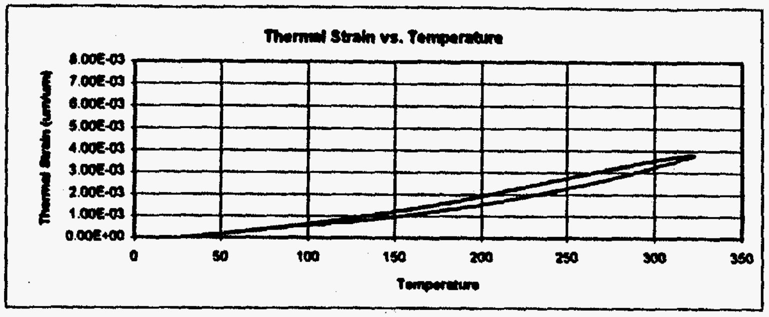
This sample is part of a pair tested for anisotropy
The other sample is: NRG-6-911.2-SNL-B

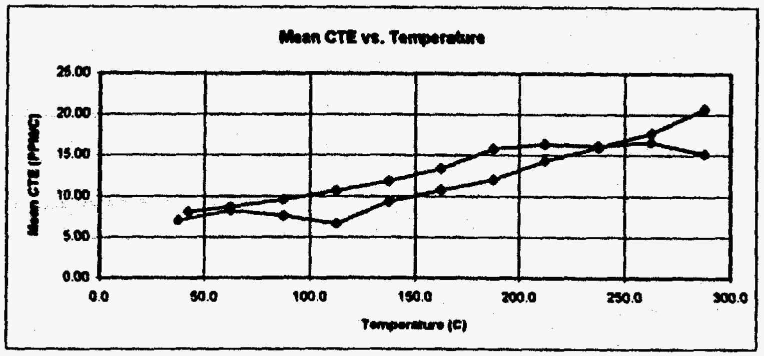
Test condition: Vacuum-Saturated
Sample Size: 2" (l) x 1" (d)

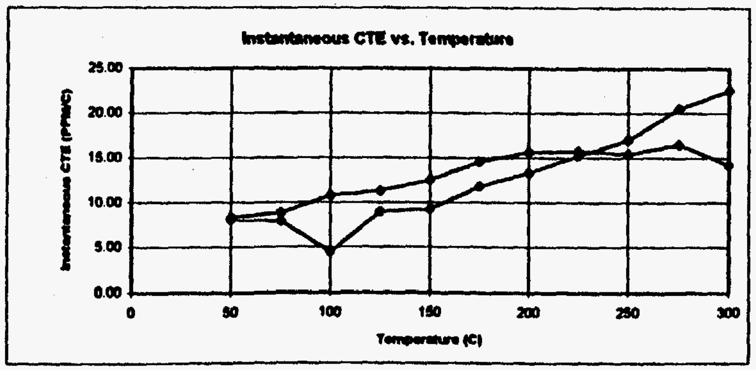
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	61.50	50.80	25.74	2.39
post-test:	59.06	50.80	25.74	2.29

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
Heat-up	25	-0.38	***	***	
	50	163.95	6.57	7.34	37.5
	75	354.22	7.61	7.78	62.5
	100	510.25	6.24	-2.22	87.5
	125	699.67	7.58	8.32	112.5
	150	932.43	9.31	9.85	137.5
	175	1212.01	11.19	12.71	162.5
	200	1549.06	13.49	16.67	187.5
	225	1999.22	18.01	20.95	212.5
	250	2536.48	21.49	22.09	237.5
	275	3145.21	24.35	28.00	262.5
	300	3913.13	30.72	34.94	287.5
Cool-down	300	4431.85	19.05	17.45	287.5
	275	3955.54	21.80	22.35	262.5
	250	3410.49	21.75	21.74	237.5
	225	2866.66	20.77	22.11	212.5
	200	2347.42	19.53	20.60	187.5
	175	1859.16	14.89	16.97	162.5
	150	1486.96	11.95	12.93	137.5
	125	1188.21	10.54	11.19	112.5
	100	924.81	9.34	10.62	87.5
	75	691.30	8.38	8.52	62.5
	50	492.30	7.91	7.87	42.5
	35	365.10	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

Sample ID: NRG-6-911.2-SNL-B
Lithology: Welded Devitrified
TMU: TSw2

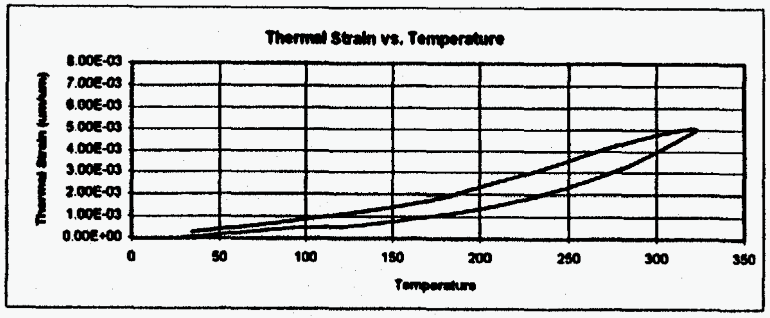
This sample is part of a pair tested for anisotropy
The other sample is: NRG-6-911.2-SNL-A

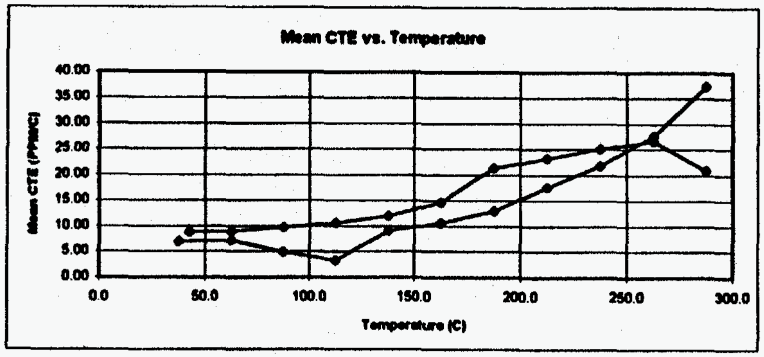
Test condition: Vacuum-Saturated
Sample Size: 2" (l) x 1" (d)

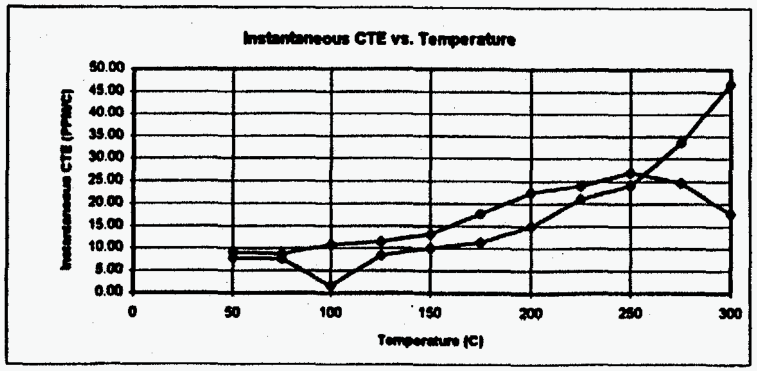
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	61.06	50.83	25.76	2.37
post-test:	58.51	50.83	25.76	2.27

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
Heat-up	25	1.21	***	***	
	50	177.20	7.04	8.02	37.5
	75	382.56	8.21	7.90	62.5
	100	571.49	7.56	4.40	87.5
	125	737.70	6.65	9.00	112.5
	150	970.69	9.32	9.30	137.5
	175	1238.93	10.77	11.83	162.5
	200	1540.42	12.02	13.35	187.5
	225	1899.30	14.36	15.23	212.5
	250	2298.46	15.97	17.00	237.5
	275	2741.27	17.71	20.50	262.5
	300	3259.33	20.72	22.50	287.5
Cool-down	300	3550.67	15.22	14.22	287.5
	275	3170.18	16.62	16.52	262.5
	250	2754.77	16.12	15.41	237.5
	225	2351.69	16.42	15.82	212.5
	200	1941.31	15.80	15.63	187.5
	175	1546.23	13.39	14.55	162.5
	150	1211.48	11.88	12.53	137.5
	125	915.09	10.70	11.31	112.5
	100	647.51	9.61	10.83	87.5
	75	407.22	8.71	8.83	62.5
	50	189.50	8.09	8.33	42.5
	35	68.21	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

Sample ID: NRG-6-926.3-SNL-A
Lithology: Welded Devitrified
TMU: TSw2

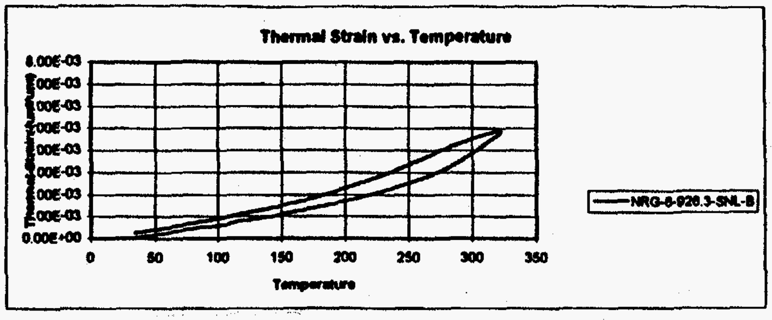
*** This sample is part of a pair tested for anisotropy***
The other sample is: NRG-6-926.3-SNL-B

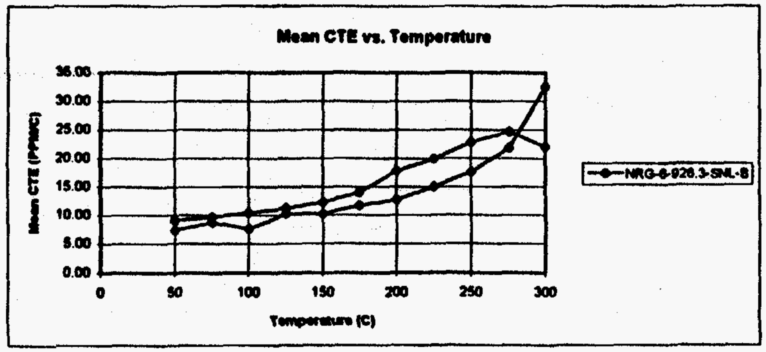
Test condition: Vacuum-Saturated
Sample Size: 2" (l) x 1" (d)

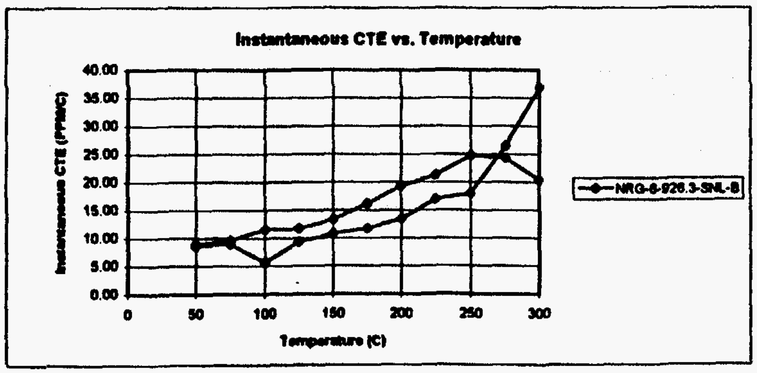
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	59.88	50.93	25.81	2.32
post-test:	56.45	50.93	25.81	2.19

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
Heat-up	25	1.60	***	***	
	50	173.49	6.88	7.83	37.5
	75	351.87	7.14	7.52	62.5
	100	473.51	4.87	1.54	87.5
	125	555.57	3.28	8.46	112.5
	150	783.53	9.12	10.02	137.5
	175	1048.91	10.62	11.29	162.5
Cool-down	200	1372.17	12.93	14.88	187.5
	225	1812.75	17.62	20.98	212.5
	250	2358.81	21.84	24.12	237.5
	275	3051.11	27.69	33.58	262.5
	300	3984.70	37.34	46.81	287.5
	300	4748.78	21.00	17.80	287.5
	275	4223.68	26.66	24.68	262.5
	250	3557.20	25.19	26.94	237.5
	225	2927.66	23.32	23.95	212.5
	200	2344.60	21.41	22.50	187.5
	175	1809.38	14.65	17.73	162.5
	150	1443.19	11.93	13.22	137.5
	125	1144.87	10.53	11.42	112.5
	100	881.69	9.68	10.74	87.5
	75	639.65	8.92	8.75	62.5
	50	416.58	8.78	9.13	42.5
	35	284.86	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

Sample ID: NRG-6-926.3-SNL-B
Lithology: Welded Devitrified
TMU: TSw2

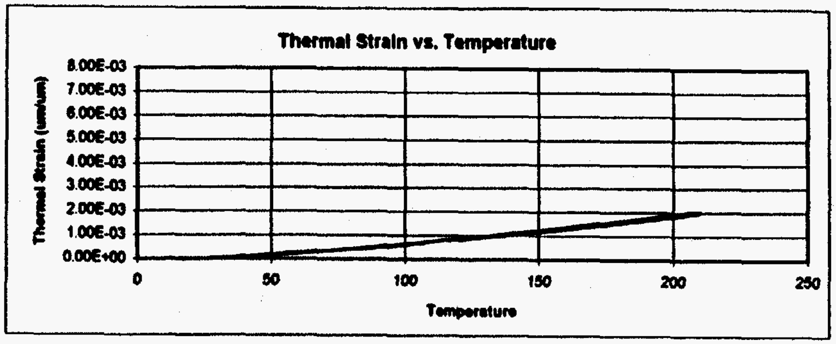
This sample is part of a pair tested for anisotropy
The other sample is: NRG-6-926.3-SNL-A

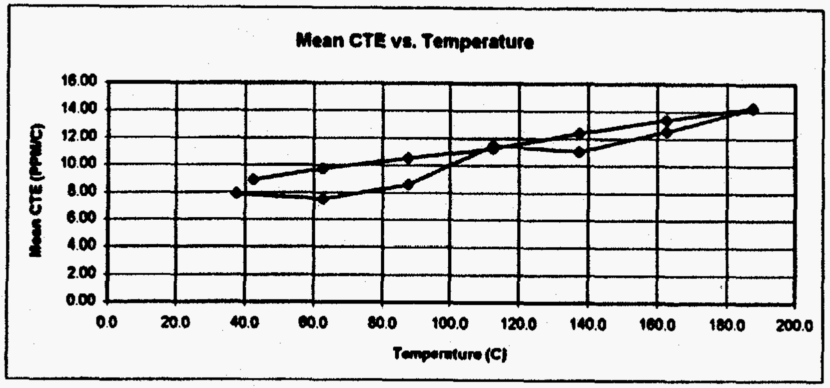
Test condition: Vacuum-Saturated
Sample Size: 2" (l) x 1" (d)

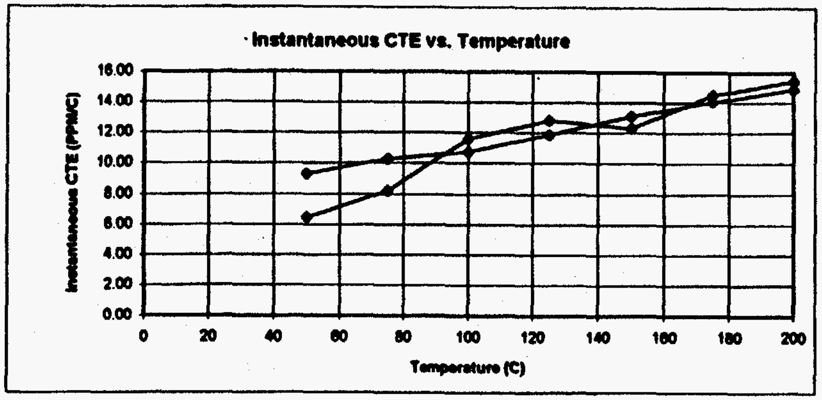
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	60.57	50.85	25.77	2.35
post-test:	57.77	50.85	25.77	2.24

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)
Heat-up	25	3.48	***	***
	50	189.10	7.42	8.51
	75	409.04	8.80	9.91
	100	597.99	7.56	5.70
	125	852.66	10.19	9.28
	150	1107.52	10.19	10.78
	175	1398.82	11.66	11.79
	200	1716.37	12.70	13.52
	225	2091.78	15.02	16.95
	250	2532.04	17.61	18.06
	275	3076.36	21.77	26.47
	300	3890.68	32.57	36.93
Cool-down	300	4539.48	22.09	20.44
	275	3987.19	24.60	24.28
	250	3372.12	22.85	24.78
	225	2800.87	19.94	21.30
	200	2302.41	17.89	19.27
	175	1855.16	13.96	16.20
	150	1506.18	12.31	13.35
	125	1198.45	11.29	11.72
	100	916.21	10.41	11.60
	75	655.86	9.62	9.64
	50	415.29	9.07	8.99
	35	279.26	***	***

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

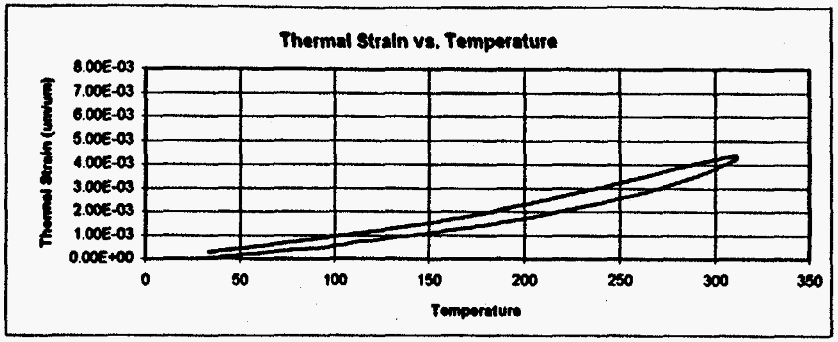
Sample ID: NRG-6-952.2-SNL-A
Lithology: Welded Devitrified
TMU: TSw2

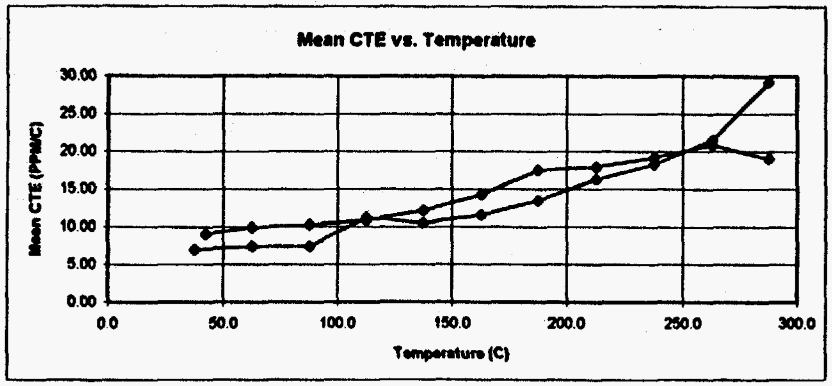
Test condition: Vacuum-Saturated
Sample Size: 2" (l) x 1" (d)

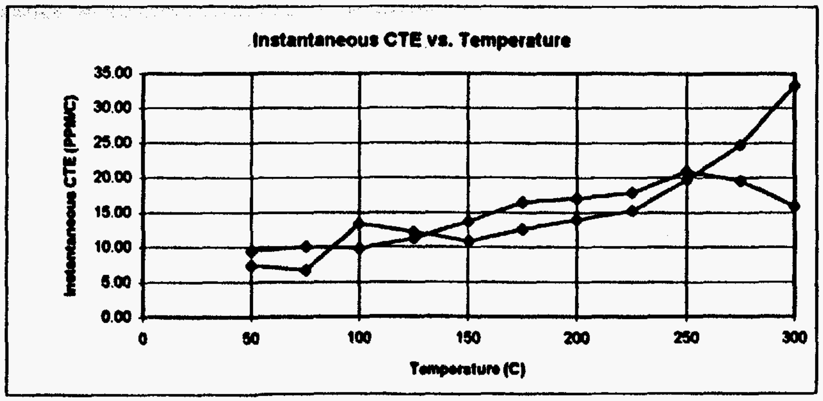
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	59.78	50.93	25.81	2.32
post-test:	56.93	50.93	25.81	2.21

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
Heat-up	25	-3.70	***	***	
	50	193.55	7.89	6.46	37.5
	75	381.00	7.50	8.17	62.5
	100	595.63	8.59	11.58	87.5
	125	882.86	11.49	12.83	112.5
	150	1158.64	11.03	12.31	137.5
	175	1472.85	12.57	14.52	162.5
	200	1828.75	14.24	15.45	187.5
Cool-down	200	1933.09	14.32	14.89	187.5
	175	1575.13	13.39	14.03	162.5
	150	1240.41	12.41	13.10	137.5
	125	930.23	11.22	11.86	112.5
	100	649.85	10.53	10.75	87.5
	75	386.68	9.74	10.28	62.5
	50	143.10	8.94	9.28	42.5
	35	8.98	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







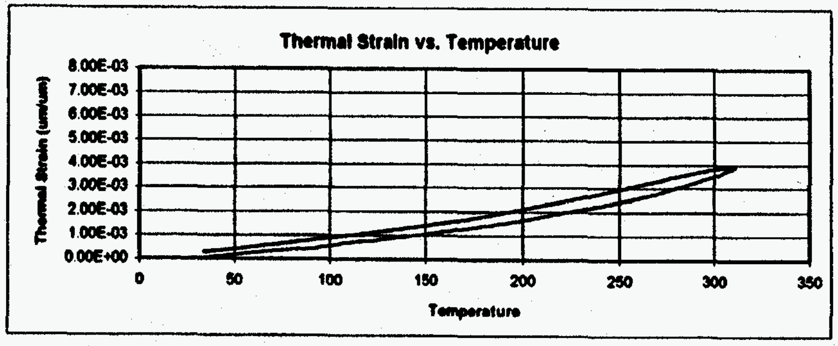
Data Summary

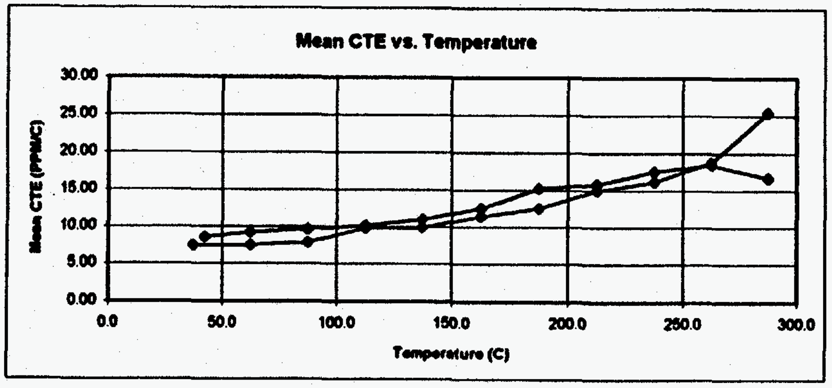
Sample ID:	NRG-6-987.6-SNL-A
Lithology:	Welded Devitrified
TMU:	TSw2
Test condition:	Vacuum-Saturated
Sample Size:	2" (l) x 1" (d)

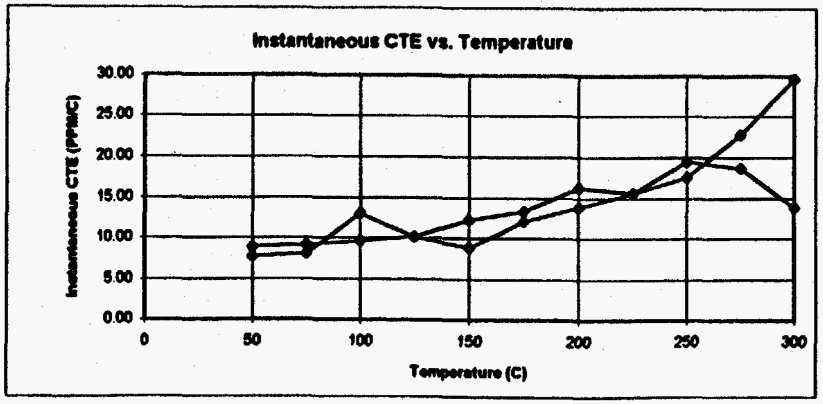
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	61.00	50.90	25.79	2.37
post-test:	58.32	50.90	25.79	2.26

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
Heat-up	25	1.54	•••	•••	
	50	176.75	7.01	7.37	37.5
	75	361.58	7.39	6.75	62.5
	100	547.79	7.45	13.39	87.5
	125	828.58	11.23	12.21	112.5
	150	1092.17	10.54	10.82	137.5
	175	1381.27	11.56	12.55	162.5
	200	1718.47	13.49	13.90	187.5
	225	2125.04	16.26	15.28	212.5
	250	2581.89	18.27	19.74	237.5
	275	3120.43	21.54	24.66	262.5
	300	3851.67	29.25	33.34	287.5
Cool-down	300	4244.72	19.08	15.87	287.5
	275	3767.77	20.84	19.60	262.5
	250	3246.81	19.23	21.00	237.5
	225	2765.98	17.91	17.88	212.5
	200	2318.11	17.47	17.07	187.5
	175	1881.29	14.20	16.47	162.5
	150	1526.23	12.17	13.69	137.5
	125	1221.90	10.89	11.24	112.5
	100	949.61	10.29	9.87	87.5
	75	692.24	9.92	10.09	62.5
	50	444.36	9.05	9.42	42.5
	35	308.67	•••	•••	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

Sample ID: NRG-6-1016.6-SNL-A
Lithology: Welded Devitrified
TMU: TSw2

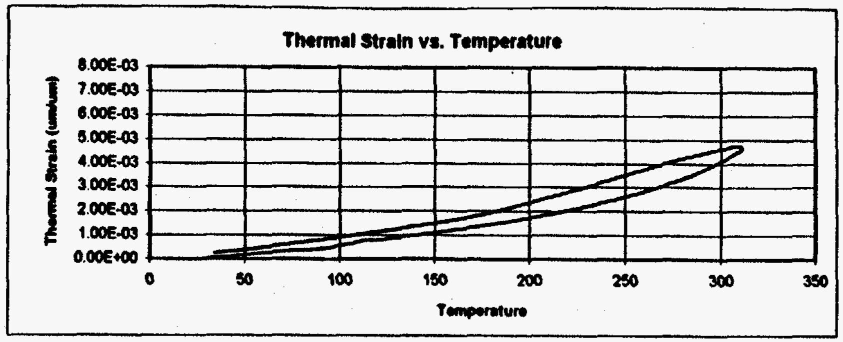
Test condition: Vacuum-Saturated
Sample Size: 2" (l) x 1" (d)

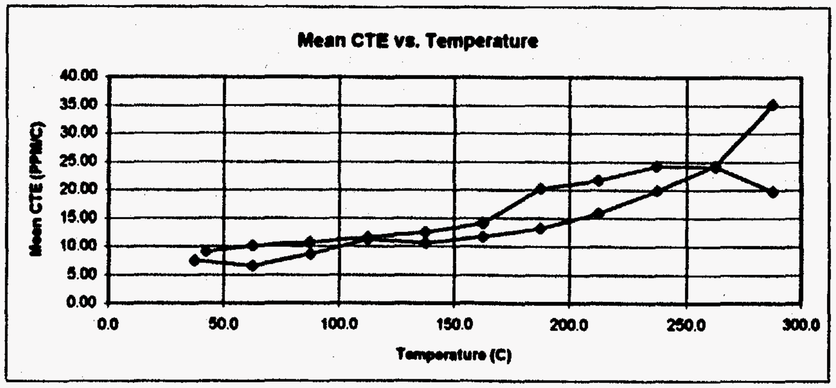
Sample Data:

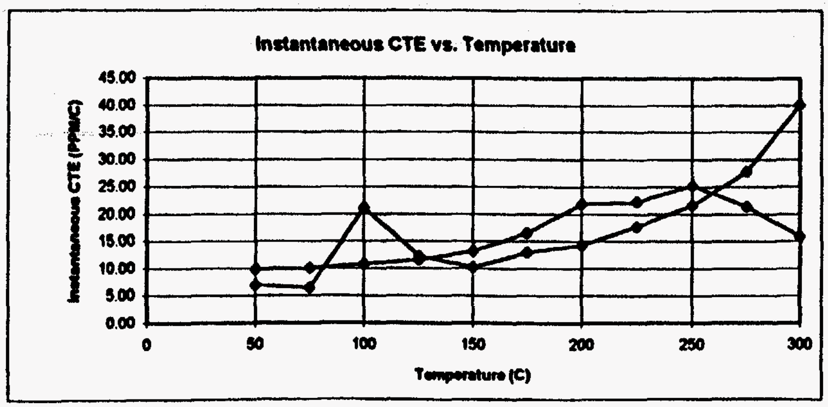
	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	60.79	50.88	25.78	2.36
post-test:	57.95	50.88	25.78	2.25

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
Heat-up	25	0.09	***	***	
	50	186.23	7.45	7.74	37.5
	75	373.39	7.49	8.04	62.5
	100	570.40	7.88	13.10	87.5
	125	816.76	9.85	10.11	112.5
	150	1063.98	9.89	8.81	137.5
	175	1349.72	11.43	12.08	162.5
	200	1663.81	12.56	13.85	187.5
	225	2038.05	14.97	15.61	212.5
	250	2443.36	16.21	17.53	237.5
	275	2913.64	18.81	22.75	262.5
	300	3549.63	25.44	29.58	287.5
Cool-down	300	3841.91	16.75	13.92	287.5
	275	3423.04	18.48	18.67	262.5
	250	2961.11	17.57	19.47	237.5
	225	2521.90	15.88	15.67	212.5
	200	2124.86	15.27	16.29	187.5
	175	1743.11	12.56	13.41	162.5
	150	1429.23	11.04	12.29	137.5
	125	1153.12	10.13	10.20	112.5
	100	899.78	9.67	9.66	87.5
	75	657.95	9.20	9.17	62.5
	50	427.89	8.54	8.93	42.5
	35	299.73	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

Sample ID: NRG-6-1081.5-SNL-8
Lithology: Welded Devitrified
TMU: TSw2

Test condition: Vacuum-Saturated
Sample Size: 2" (l) x 1" (d)

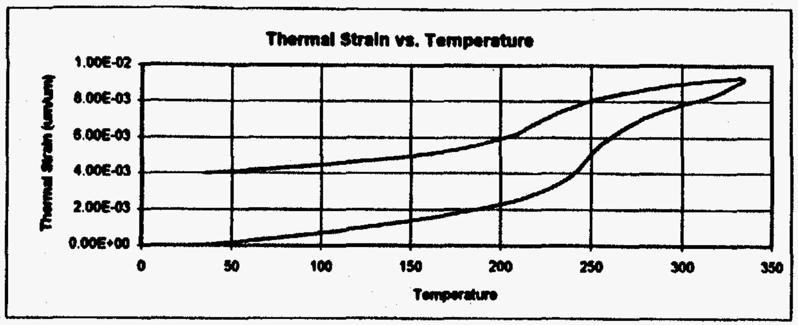
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	61.18	50.90	25.79	2.37
post-test:	58.71	50.90	25.79	2.28

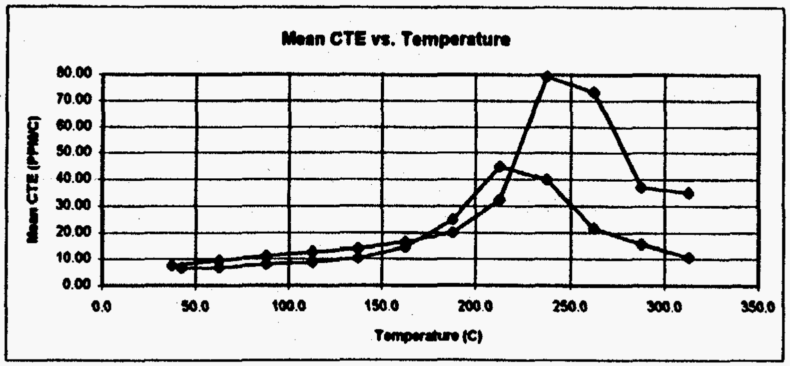
	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (^oC)
Heat-up	25	-0.85	***	***	
	50	184.96	7.43	7.02	37.5
	75	349.46	6.58	6.47	62.5
	100	566.10	8.67	21.12	87.5
	125	849.00	11.32	12.32	112.5
	150	1113.52	10.58	10.25	137.5
	175	1406.80	11.73	12.99	162.5
	200	1736.33	13.18	14.34	187.5
	225	2132.13	15.83	17.68	212.5
	250	2628.03	19.84	21.65	237.5
	275	3238.28	24.41	27.80	262.5
	300	4118.62	35.21	40.08	287.5
Cool-down	300	4624.02	19.72	15.82	287.5
	275	4131.03	24.18	21.36	262.5
	250	3526.63	24.25	25.22	237.5
	225	2920.27	21.75	22.21	212.5
	200	2376.48	20.28	21.94	187.5
	175	1869.47	14.17	16.47	162.5
	150	1515.12	12.49	13.27	137.5
	125	1202.80	11.63	11.59	112.5
	100	912.17	10.72	10.78	87.5
	75	644.11	10.06	10.17	62.5
	50	392.65	9.09	9.84	42.5
	35	256.24	***	***	

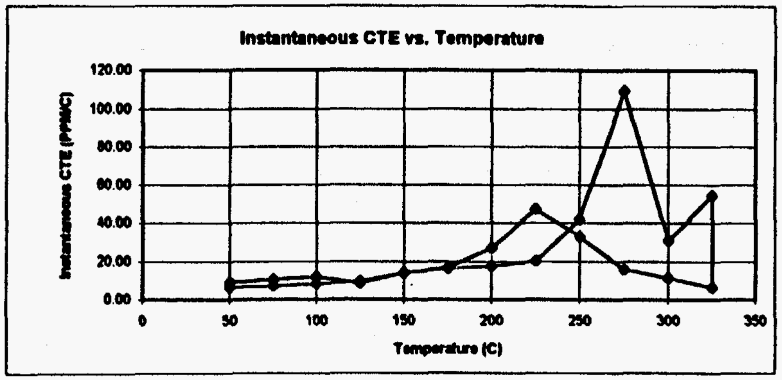
* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.

Data Summaries for NRG-6

(Oven-Dried)







Data Summary

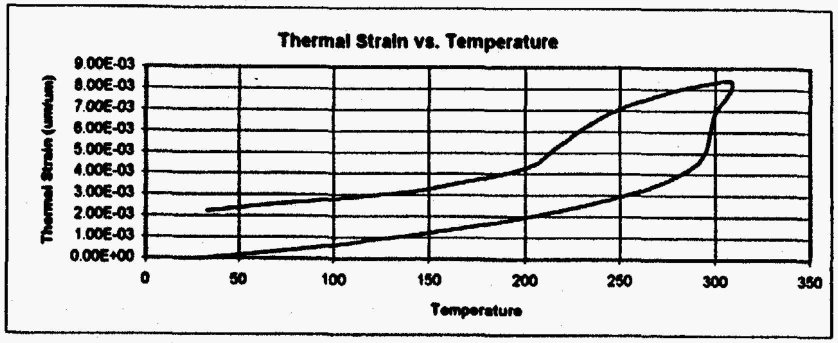
Sample ID: NRG-6-28.8-SNL-G
Lithology: Welded Devitrified
TMU: TCw

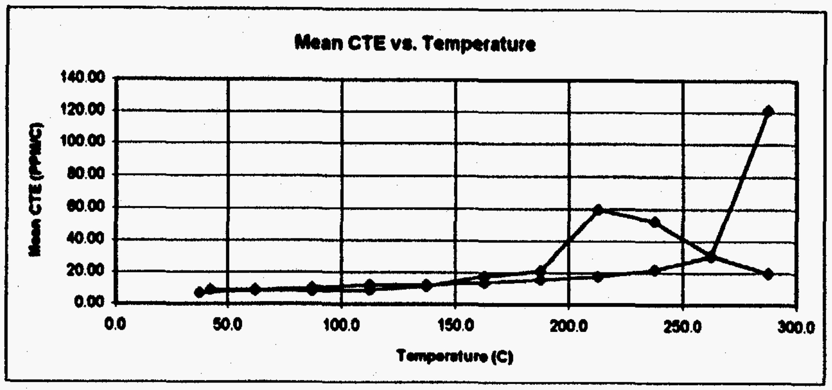
Test condition: OVEN DRIED
Sample Size: 2" (l) x 1" (d)

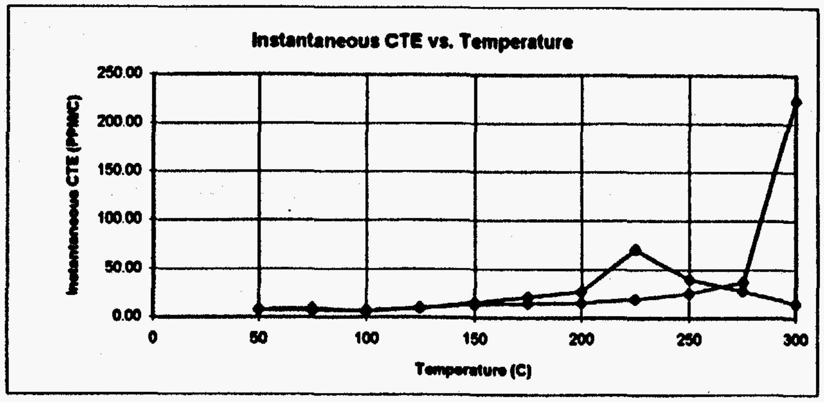
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	59.18	50.85	25.77	2.30
post-test:	59.16	50.88	25.78	2.29

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (^{0}C)
Heat-up	25	2.84	***	***	
	50	191.40	7.54	9.30	37.5
	75	431.20	9.59	10.43	62.5
	100	711.38	11.21	11.90	87.5
	125	1032.73	12.85	8.52	112.5
	150	1379.44	13.87	13.89	137.5
	175	1789.35	16.40	16.13	162.5
	200	2288.86	19.98	17.43	187.5
	225	3099.10	32.41	20.30	212.5
	250	5078.79	79.19	41.89	237.5
	275	6912.98	73.37	109.46	262.5
	300	7840.52	37.10	30.78	287.5
	325	8714.82	34.97	54.40	312.5
Cool-down	325	9262.17	10.75	6.63	312.5
	300	8993.33	15.58	11.29	287.5
	275	8603.74	21.70	15.63	262.5
	250	8061.28	39.94	32.70	237.5
	225	7062.83	44.94	47.06	212.5
	200	5939.32	24.85	26.96	187.5
	175	5318.17	14.49	16.60	162.5
	150	4955.97	10.39	13.82	137.5
	125	4696.26	8.78	9.68	112.5
	100	4476.69	7.98	8.14	87.5
	75	4277.15	6.88	7.28	62.5
	50	4105.09	6.62	6.36	42.5
	35	4005.74	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







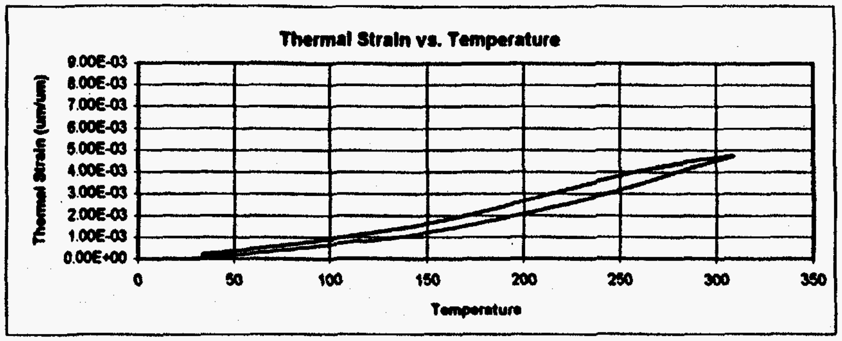
Data Summary

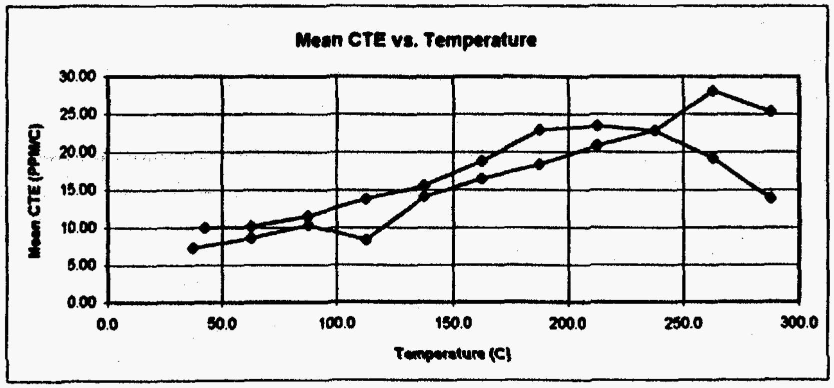
Sample ID:	NRG-6-28.8-SNL-G
Lithology:	Welded Devitrified
TMU:	TCw
Test condition:	OVEN DRIED
Sample Size:	2" (l) x 1" (d)

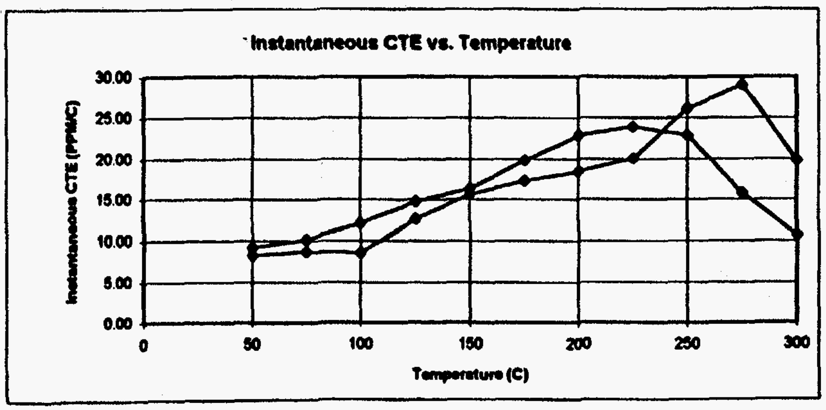
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	59.25	50.83	25.76	2.30
post-test:	59.17	50.85	25.77	2.30

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
Heat-up	25	3.58	***	***	
	50	171.99	6.74	7.60	37.5
	75	387.71	8.63	9.28	62.5
	100	638.97	10.05	6.34	87.5
	125	937.29	11.93	10.21	112.5
	150	1234.50	11.89	13.64	137.5
	175	1576.15	13.67	14.57	162.5
	200	1963.90	15.51	15.05	187.5
	225	2404.78	17.64	19.15	212.5
	250	2953.96	21.97	25.54	237.5
	275	3720.31	30.65	37.22	262.5
	300	6755.15	121.39	224.00	287.5
Cool-down	300	8343.57	19.99	14.98	287.5
	275	7843.74	30.89	27.88	262.5
	250	7071.51	52.48	39.86	237.5
	225	5759.57	59.55	71.03	212.5
	200	4270.92	21.20	27.43	187.5
	175	3740.81	17.60	21.26	162.5
	150	3300.69	11.18	15.41	137.5
	125	3021.26	8.70	9.08	112.5
	100	2803.70	7.86	7.63	87.5
	75	2607.19	8.66	7.48	62.5
	50	2390.72	8.93	8.00	42.5
	35	2256.70	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

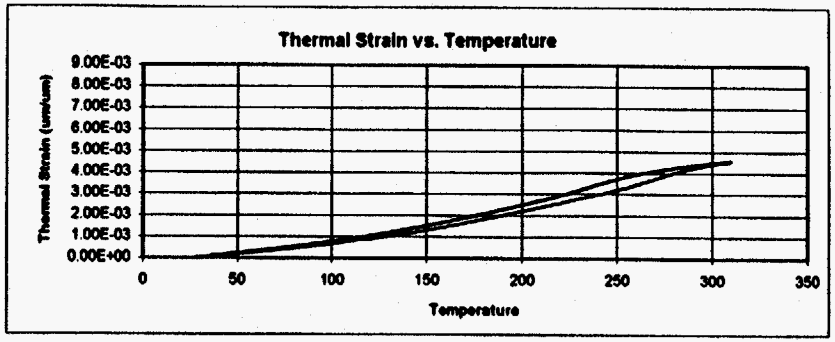
Sample ID: NRG-6-98.1-SNL-G
Lithology: Welded Devitrified
TMU: TCw

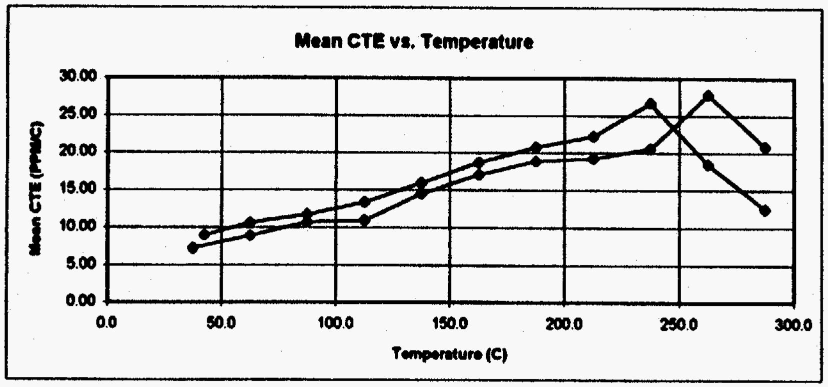
Test condition: OVEN DRIED
Sample Size: 2" (l) x 1" (d)

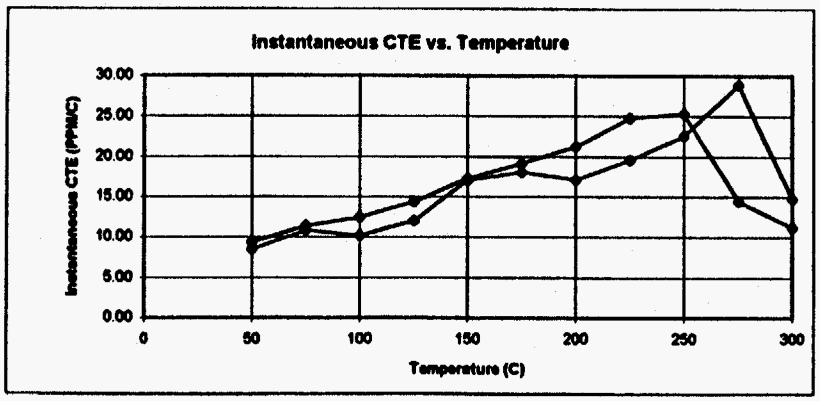
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	58.45	50.83	25.76	2.27
post-test:	58.31	50.83	25.76	2.26

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
Heat-up	25	-0.46	***	***	
	50	182.20	7.31	8.26	37.5
	75	398.59	8.66	8.72	62.5
	100	656.95	10.33	8.59	87.5
	125	866.13	8.37	12.67	112.5
	150	1219.14	14.12	15.61	137.5
	175	1631.31	16.49	17.34	162.5
	200	2089.75	18.34	18.43	187.5
	225	2610.60	20.83	20.02	212.5
	250	3182.22	22.86	26.11	237.5
	275	3885.20	28.12	29.04	262.5
	300	4518.62	25.33	19.81	287.5
Cool-down	300	4670.59	13.88	10.73	287.5
	275	4323.63	19.23	15.83	262.5
	250	3842.96	22.84	22.90	237.5
	225	3271.88	23.43	23.93	212.5
	200	2686.13	22.91	22.89	187.5
	175	2113.39	18.83	19.83	162.5
	150	1642.71	15.58	16.39	137.5
	125	1253.33	13.79	14.80	112.5
	100	908.60	11.56	12.12	87.5
	75	619.69	10.13	10.15	62.5
	50	366.34	9.99	9.25	42.5
	35	216.50	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

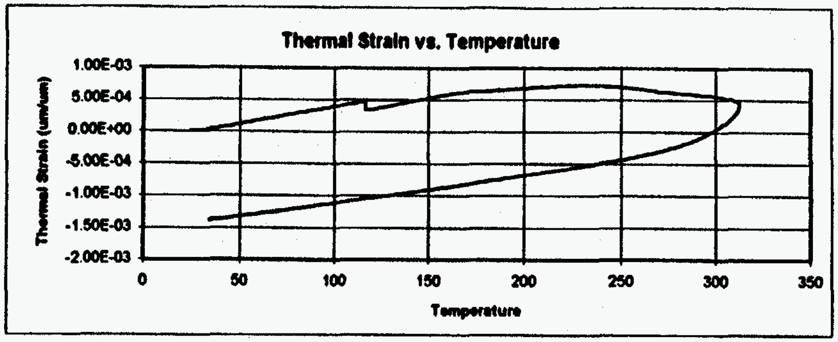
Sample ID: NRG-6-111.0-SNL-F
Lithology: Welded Devitrified
TMU: TCw

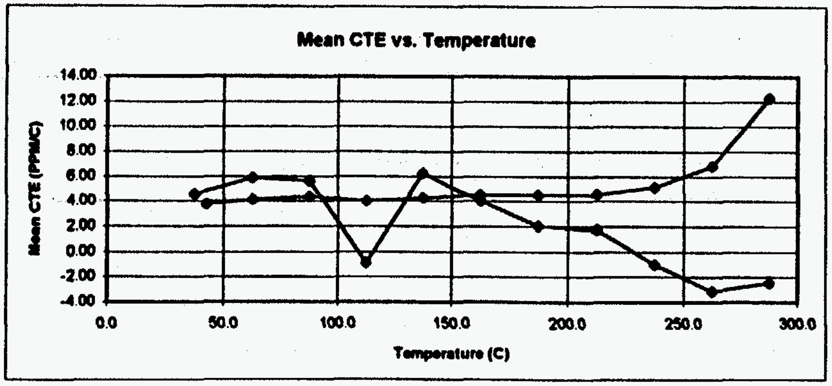
Test condition: OVEN DRIED
Sample Size: 2" (l) x 1" (d)

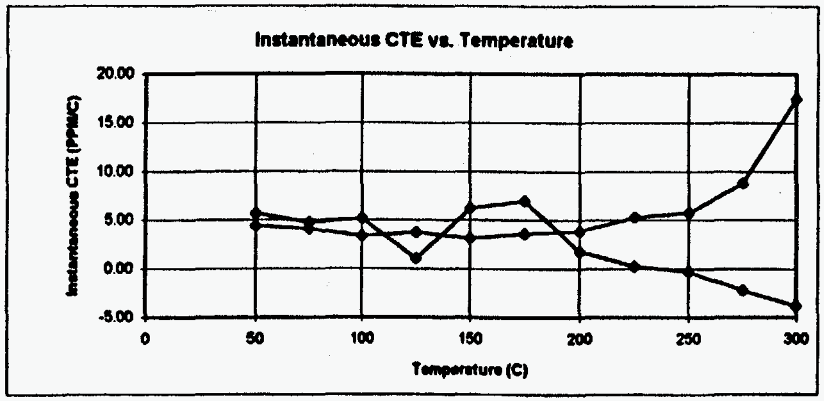
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	56.45	50.83	25.76	2.19
post-test:	56.36	50.83	25.76	2.19

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (^oC)
Heat-up	25	-0.42	***	***	
	50	181.38	7.27	8.51	37.5
	75	403.48	8.88	10.83	62.5
	100	669.86	10.66	10.20	87.5
	125	944.39	10.98	12.06	112.5
	150	1307.50	14.52	17.04	137.5
	175	1734.78	17.09	18.08	162.5
	200	2207.73	18.92	17.08	187.5
	225	2688.93	19.25	19.60	212.5
	250	3204.71	20.63	22.61	237.5
	275	3900.53	27.83	28.94	262.5
	300	4421.21	20.83	14.76	287.5
Cool-down	300	4500.72	12.48	11.25	287.5
	275	4188.70	18.41	14.41	262.5
	250	3728.40	26.72	25.35	237.5
	225	3060.33	22.23	24.77	212.5
	200	2504.62	20.80	21.22	187.5
	175	1984.66	18.70	19.18	162.5
	150	1517.22	15.97	17.24	137.5
	125	1117.96	13.34	14.33	112.5
	100	784.51	11.73	12.42	87.5
	75	491.29	10.57	11.40	62.5
	50	226.97	8.98	9.35	42.5
	35	137.20	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







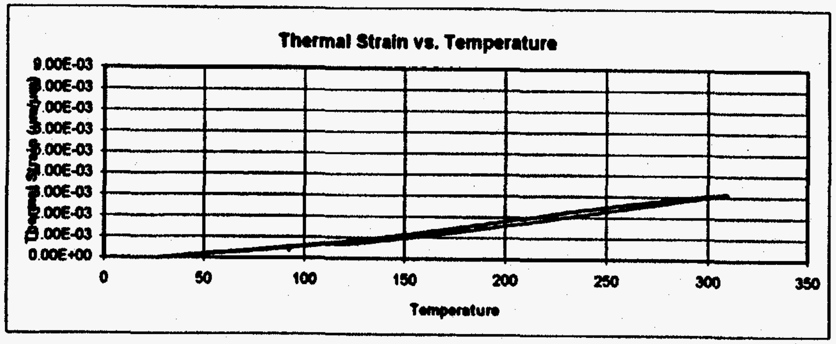
Data Summary

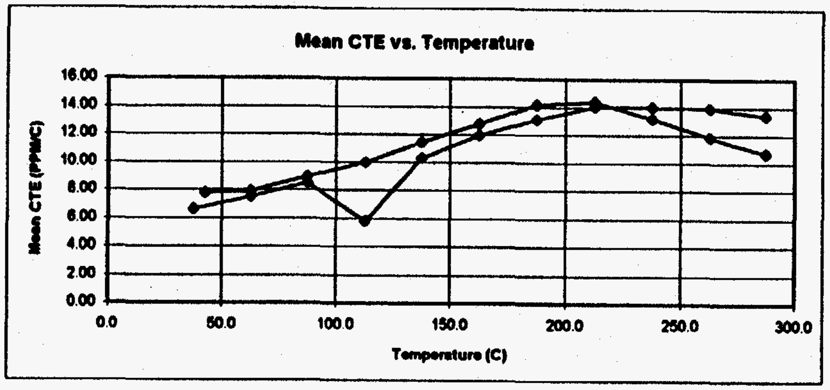
Sample ID:	NRG-6-152.9-SNL-C
Lithology:	Nonwelded Vitric
TMU:	PTn
Test condition:	OVEN DRIED
Sample Size:	2" (l) x 1" (d)

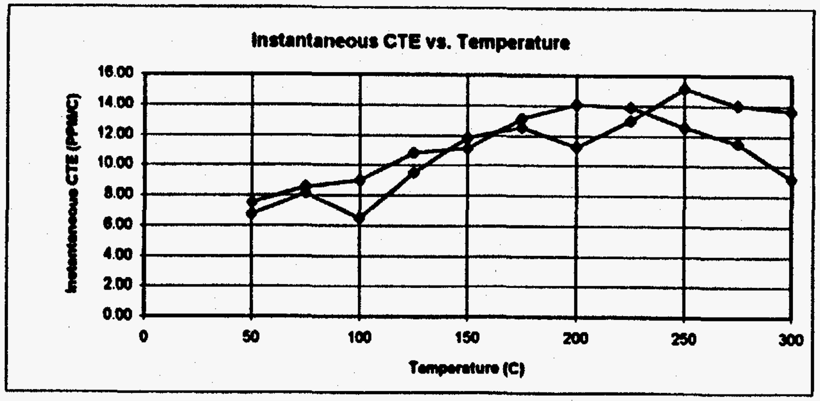
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	34.24	50.22	25.45	1.35
post-test:	33.69	50.14	25.41	1.33

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
Heat-up	25	2.85	•••	•••	
	50	117.14	4.57	5.70	37.5
	75	264.30	5.89	4.73	62.5
	100	404.26	5.60	5.15	87.5
	125	381.27	-0.92	1.11	112.5
	150	536.69	6.22	6.24	137.5
	175	637.00	4.01	6.95	162.5
	200	688.59	2.06	1.84	187.5
	225	731.70	1.72	0.25	212.5
	250	706.13	-1.02	-0.25	237.5
	275	628.29	-3.11	-2.21	262.5
	300	566.91	-2.46	-3.80	287.5
Cool-down	300	44.96	12.29	17.48	287.5
	275	-262.18	6.85	8.80	262.5
	250	-433.54	5.15	5.77	237.5
	225	-562.32	4.57	5.27	212.5
	200	-676.57	4.55	3.92	187.5
	175	-790.29	4.55	3.63	162.5
	150	-904.09	4.26	3.16	137.5
	125	-1010.69	4.01	3.78	112.5
	100	-1110.84	4.39	3.37	87.5
	75	-1220.57	4.12	4.11	62.5
	50	-1323.66	3.77	4.44	42.5
	35	-1380.15	•••	•••	

• Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







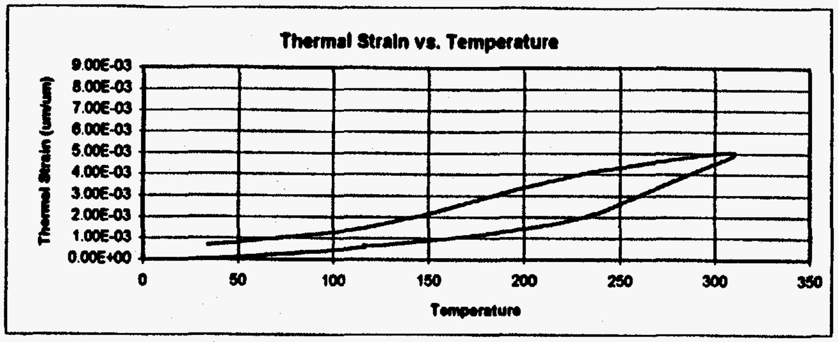
Data Summary

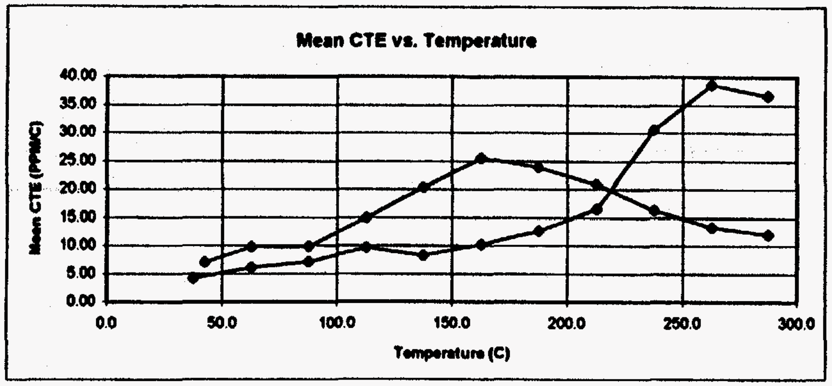
Sample ID:	NRG-6-277.5-SNL-C
Lithology:	Welded Devitrified
TMU:	TSw1
Test condition:	OVEN DRIED
Sample Size:	2" (l) x 1" (d)

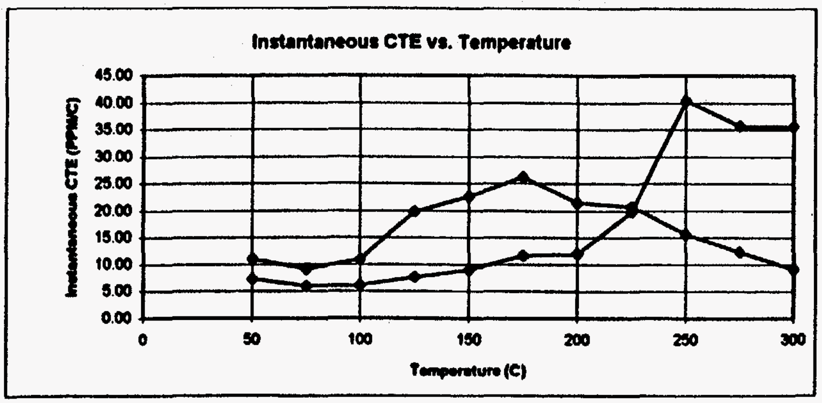
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	57.96	50.83	25.76	2.25
post-test:	57.93	50.83	25.76	2.25

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
Heat-up	25	0.80	***	***	
	50	166.66	6.63	6.77	37.5
	75	353.45	7.47	8.13	62.5
	100	566.02	8.50	6.52	87.5
	125	710.35	5.77	9.51	112.5
	150	968.37	10.32	11.86	137.5
	175	1266.90	11.94	12.53	162.5
	200	1594.68	13.11	11.27	187.5
	225	1945.51	14.03	12.99	212.5
	250	2295.77	14.01	15.16	237.5
	275	2643.53	13.91	14.04	262.5
	300	2979.11	13.42	13.63	287.5
Cool-down	300	3073.02	10.70	9.14	287.5
	275	2805.63	11.65	11.53	262.5
	250	2509.51	13.19	12.58	237.5
	225	2179.83	14.38	13.90	212.5
	200	1820.26	14.18	14.09	187.5
	175	1465.74	12.76	13.15	162.5
	150	1146.63	11.45	11.13	137.5
	125	860.43	9.97	10.84	112.5
	100	611.13	8.96	8.99	87.5
	75	387.20	7.92	8.54	62.5
	50	189.24	7.75	7.55	42.5
	35	111.76	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

Sample ID: NRG-6-321.1-SNL-B
Lithology: Welded Devitrified
TMU: TSw1

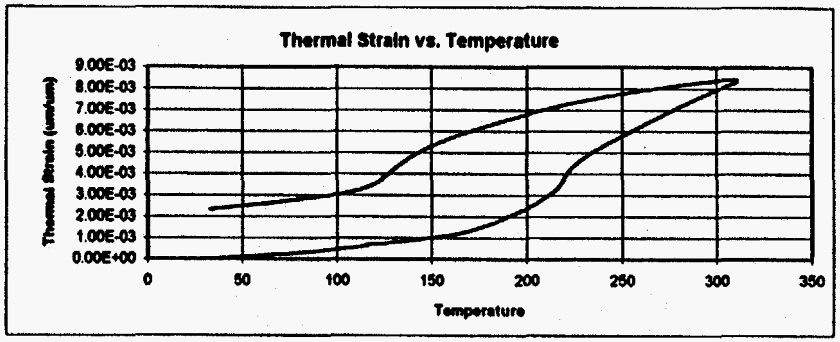
Test condition: OVEN DRIED
Sample Size: 2" (l) x 1" (d)

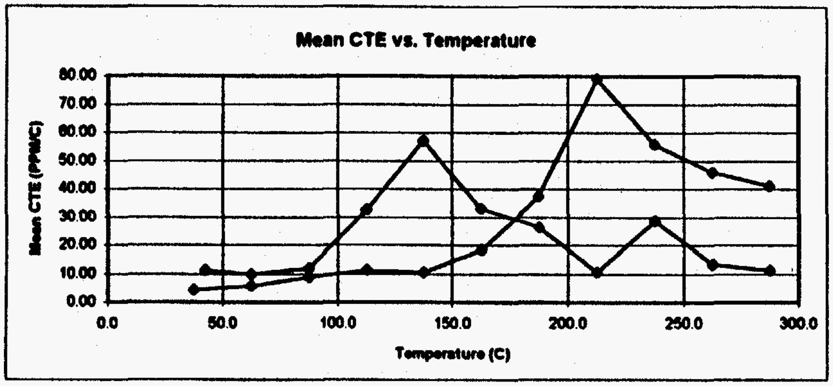
Sample Data:

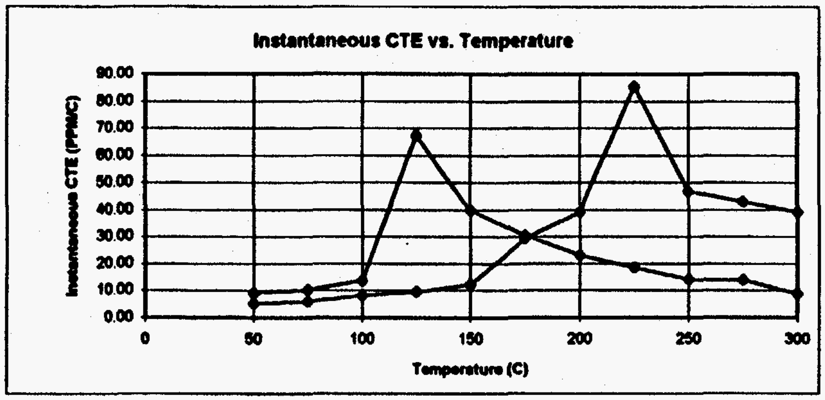
	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	55.21	50.70	25.69	2.15
post-test:	55.20	50.72	25.70	2.15

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (^{o}C)
Heat-up	25	12.68	***	***	
	50	116.79	4.16	7.31	37.5
	75	267.89	6.04	6.00	62.5
	100	445.32	7.10	6.12	87.5
	125	686.59	9.65	7.73	112.5
	150	894.35	8.31	9.07	137.5
	175	1149.67	10.21	11.73	162.5
	200	1464.56	12.60	12.09	187.5
	225	1878.75	16.57	19.91	212.5
	250	2643.61	30.59	40.40	237.5
	275	3609.74	38.65	35.70	262.5
	300	4527.59	36.71	35.58	287.5
Cool-down	300	4976.93	12.11	9.14	287.5
	275	4674.08	13.33	12.42	262.5
	250	4340.74	16.35	15.65	237.5
	225	3931.89	20.95	20.79	212.5
	200	3408.02	23.94	21.53	187.5
	175	2809.60	25.49	26.21	162.5
	150	2172.24	20.35	22.58	137.5
	125	1663.40	14.90	19.82	112.5
	100	1290.86	9.93	11.00	87.5
	75	1042.65	9.73	9.14	62.5
	50	799.48	7.06	11.08	42.5
	35	693.79	***	***	

• Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







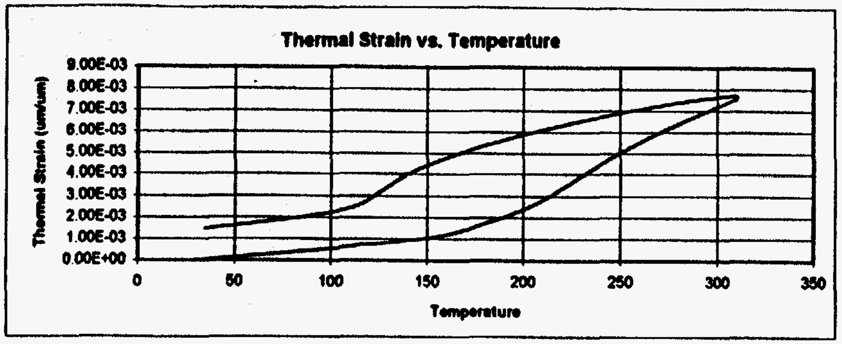
Data Summary

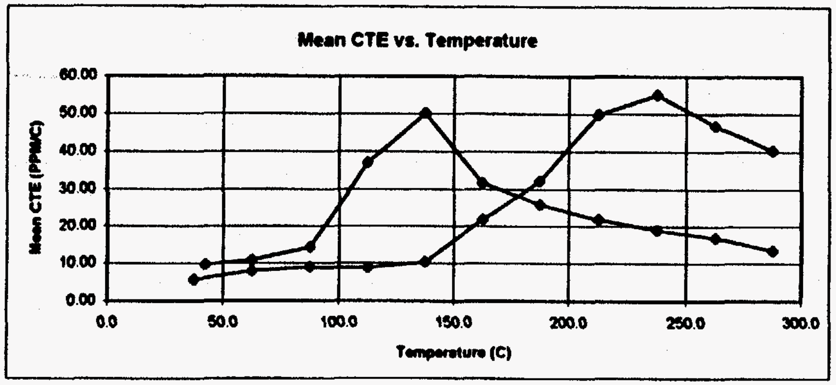
Sample ID:	NRG-6-354.9-SNL-D
Lithology:	Welded Devitrified
TMU:	TSw1
Test condition:	OVEN DRIED
Sample Size:	2" (l) x 1" (d)

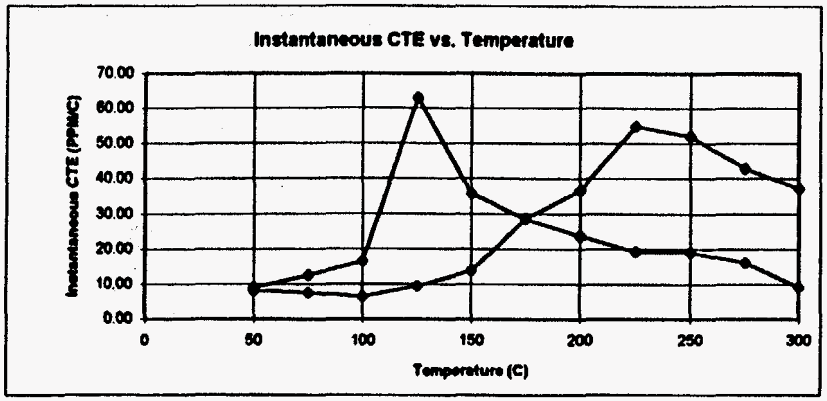
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	52.11	50.90	25.79	2.02
post-test:	52.09	51.00	25.84	2.02

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
Heat-up	25	3.29	***	***	
	50	112.86	4.38	5.38	37.5
	75	258.32	5.82	5.98	62.5
	100	473.86	8.62	8.16	87.5
	125	754.88	11.24	9.70	112.5
	150	1017.91	10.52	12.27	137.5
	175	1480.43	18.50	29.36	162.5
	200	2415.04	37.38	39.24	187.5
	225	4389.27	78.97	85.32	212.5
	250	5783.65	55.78	47.04	237.5
	275	6932.19	45.94	43.00	262.5
	300	7959.39	41.09	39.20	287.5
Cool-down	300	8384.07	11.26	8.84	287.5
	275	8102.55	13.33	14.01	262.5
	250	7769.32	28.63	14.30	237.5
	225	7053.59	10.49	18.59	212.5
	200	6791.37	28.51	23.01	187.5
	175	6128.55	33.05	30.66	162.5
	150	5302.29	57.22	40.05	137.5
	125	3871.82	32.57	67.37	112.5
	100	3057.62	11.96	13.61	87.5
	75	2758.69	9.65	10.35	62.5
	50	2512.32	11.21	9.26	42.5
	35	2344.12	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







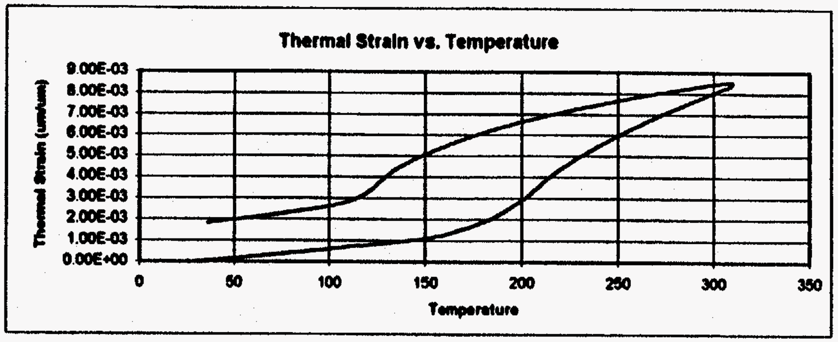
Data Summary

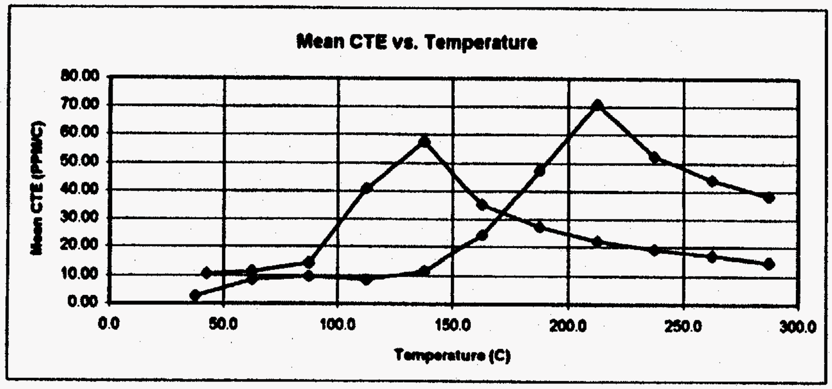
Sample ID:	NRG-6-392.1-SNL-E
Lithology:	Welded Devitrified
TMU:	TSw1
Test condition:	OVEN DRIED
Sample Size:	2" (l) x 1" (d)

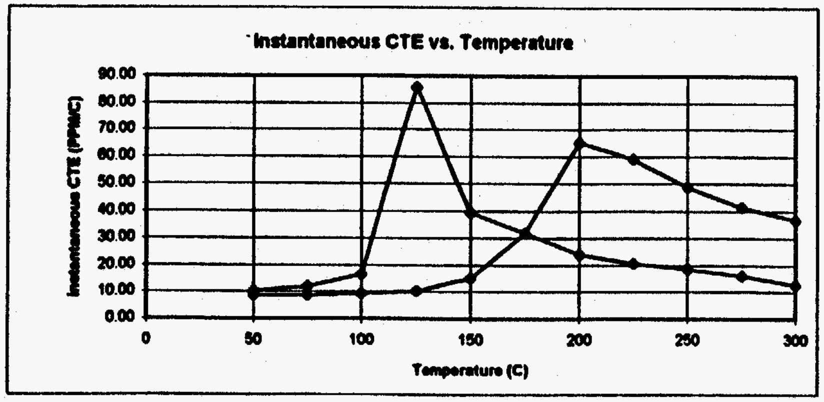
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	56.03	50.85	25.77	2.17
post-test:	55.98	50.93	25.81	2.17

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (^oC)
Heat-up	25	4.88	***	***	
	50	147.34	5.70	8.09	37.5
	75	344.38	7.88	7.52	62.5
	100	568.78	8.98	6.36	87.5
	125	790.40	8.86	9.40	112.5
	150	1050.86	10.42	13.88	137.5
	175	1598.87	21.92	28.69	162.5
	200	2405.30	32.26	36.70	187.5
	225	3651.26	49.84	54.85	212.5
	250	5028.66	55.10	51.95	237.5
	275	6203.10	46.98	42.85	262.5
	300	7212.94	40.39	37.20	287.5
Cool-down	300	7655.24	13.41	9.20	287.5
	275	7320.06	16.83	16.09	262.5
	250	6899.20	19.01	19.18	237.5
	225	6423.90	21.83	19.30	212.5
	200	5878.23	25.93	23.74	187.5
	175	5229.98	31.75	28.48	162.5
	150	4436.10	50.09	35.81	137.5
	125	3183.80	37.14	63.15	112.5
	100	2255.18	14.33	16.38	87.5
	75	1896.94	10.81	12.55	62.5
	50	1626.69	9.73	9.06	42.5
	35	1480.76	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







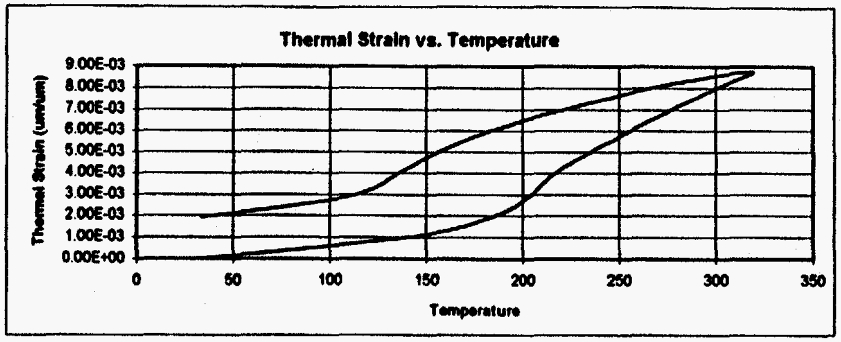
Data Summary

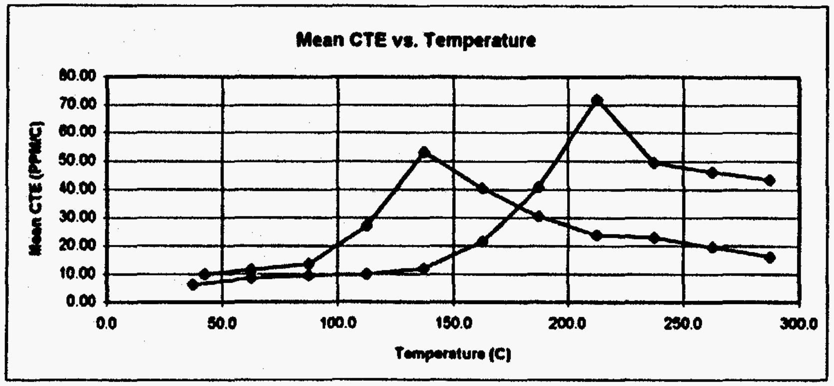
Sample ID:	NRG-6-416.0-SNL-L
Lithology:	Welded Devitrified
TMU:	TSw1
Test condition:	OVEN DRIED
Sample Size:	2" (l) x 1" (d)

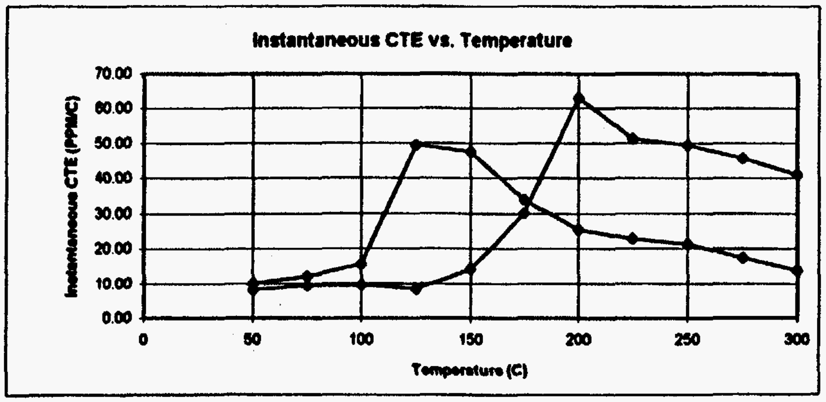
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	55.03	50.88	25.78	2.13
post-test:	54.96	50.95	25.82	2.13

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (^oC)
Heat-up	25	102.26	***	***	
	50	172.31	2.80	8.62	37.5
	75	384.55	8.49	8.59	62.5
	100	623.15	9.54	9.32	87.5
	125	838.01	8.59	10.24	112.5
	150	1123.17	11.41	15.15	137.5
	175	1723.79	24.02	32.09	162.5
	200	2907.55	47.35	65.25	187.5
	225	4678.67	70.85	58.90	212.5
	250	5988.46	52.38	48.78	237.5
	275	7092.96	44.18	41.36	262.5
	300	8054.56	38.46	36.84	287.5
Cool-down	300	8457.13	14.76	12.87	287.5
	275	8088.17	17.04	16.24	262.5
	250	7662.16	19.00	18.47	237.5
	225	7187.17	21.96	20.65	212.5
	200	6638.17	27.11	24.10	187.5
	175	5960.34	35.15	32.01	162.5
	150	5081.63	57.38	39.37	137.5
	125	3647.08	40.88	85.89	112.5
	100	2625.09	14.28	16.69	87.5
	75	2268.13	11.48	12.11	62.5
	50	1981.15	10.57	10.31	42.5
	35	1822.62	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

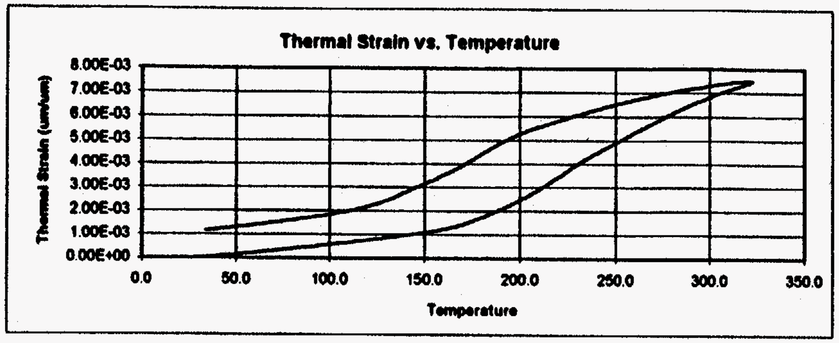
Sample ID: NRG-6-421.8-SNL-B
Lithology: Welded Devitrified
TMU: TSw1

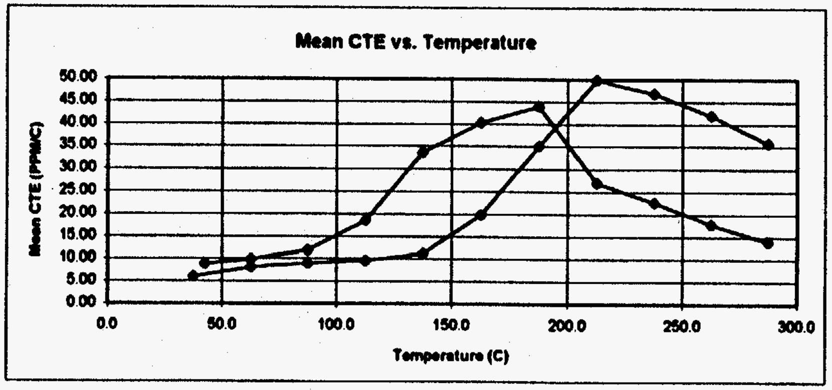
Test condition: Oven-Dried
Sample Size: 2" (l) x 1" (d)

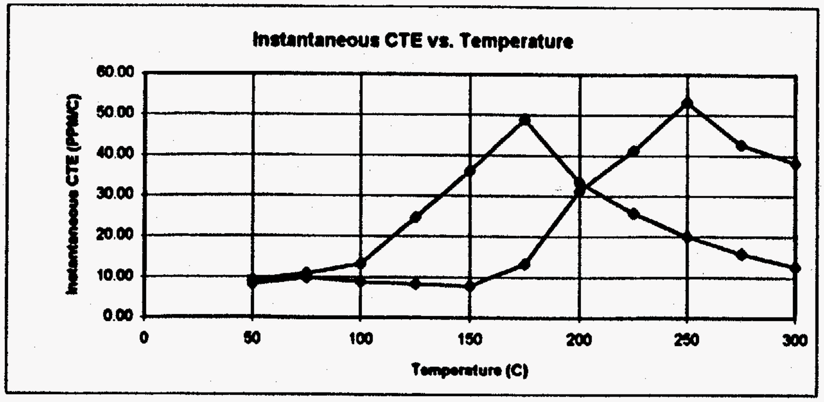
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	55.96	50.88	25.78	2.17
post-test:	55.80	50.98	25.83	2.16

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (^{o}C)
Heat-up	25	-0.94	***	***	
	50	154.89	6.23	8.22	37.5
	75	368.41	8.54	9.30	62.5
	100	602.00	9.34	9.63	87.5
	125	846.64	9.79	8.42	112.5
	150	1143.83	11.89	14.22	137.5
	175	1686.41	21.70	30.14	162.5
	200	2708.75	40.89	63.01	187.5
	225	4507.56	71.95	51.32	212.5
	250	5744.75	49.49	49.35	237.5
	275	6899.52	46.19	45.71	262.5
	300	7987.77	43.53	41.17	287.5
Cool-down	300	8561.93	16.05	13.86	287.5
	275	8160.74	19.60	17.49	262.5
	250	7670.76	22.93	21.33	237.5
	225	7097.64	23.83	22.84	212.5
	200	6501.88	30.27	25.36	187.5
	175	5745.24	40.47	33.94	162.5
	150	4733.39	53.00	47.52	137.5
	125	3408.44	27.05	49.48	112.5
	100	2732.20	13.52	15.46	87.5
	75	2394.14	11.47	12.09	62.5
	50	2107.29	9.89	10.03	42.5
	35	1958.87	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







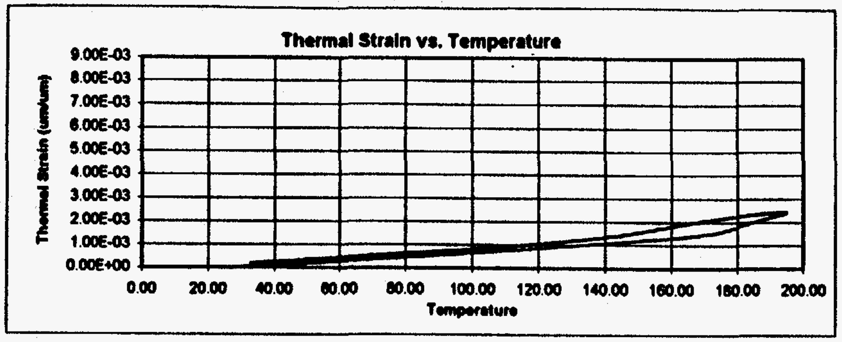
Data Summary

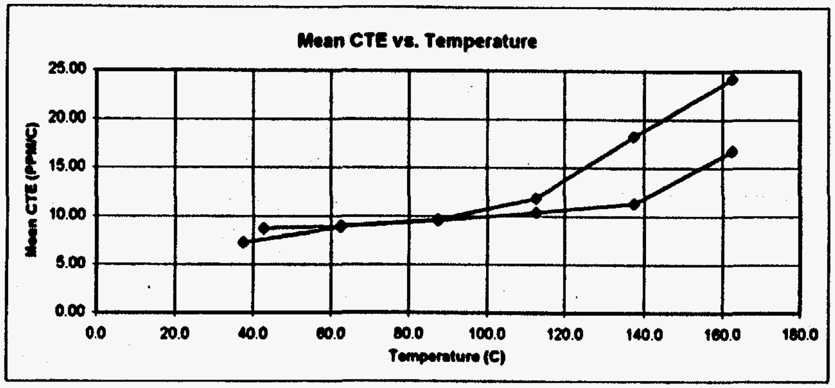
Sample ID:	NRG-6-458.7-SNL-S
Lithology:	Welded Devitrified
TMU:	TSw1
Test condition:	OVEN DRIED
Sample Size:	2" (l) x 1" (d)

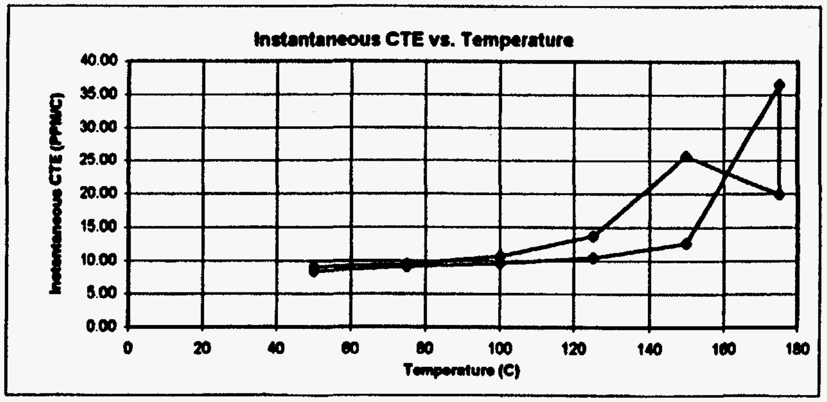
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	50.16	50.90	25.79	1.94
post-test:	50.14	50.95	25.82	1.94

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
Heat-up	25	6.85	***	***	
	50	156.79	6.00	8.11	37.5
	75	360.05	8.13	9.72	62.5
	100	565.49	9.02	8.76	87.5
	125	826.17	9.63	8.27	112.5
	150	1104.77	11.14	7.90	137.5
	175	1599.11	19.77	13.36	162.5
	200	2473.95	34.99	31.22	187.5
	225	3720.43	49.86	41.20	212.5
	250	4891.82	46.86	53.30	237.5
	275	5939.87	41.92	42.74	262.5
	300	6835.23	35.81	38.13	287.5
Cool-down	300	7304.48	13.97	12.64	287.5
	275	6955.34	17.82	15.84	262.5
	250	6509.87	22.76	20.01	237.5
	225	5940.92	27.04	25.80	212.5
	200	5265.04	44.01	33.34	187.5
	175	4164.83	40.23	48.92	162.5
	150	3159.06	33.61	36.03	137.5
	125	2318.75	18.55	24.73	112.5
	100	1854.92	11.94	13.32	87.5
	75	1556.33	9.85	10.98	62.5
	50	1309.98	8.89	9.08	42.5
	35	1176.60	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

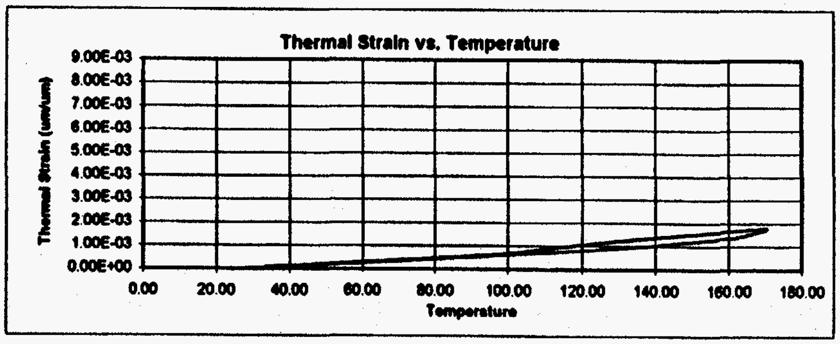
Sample ID: NRG-6-528.4-SNL-B
Lithology: Welded Devitrified
TMU: TSw1

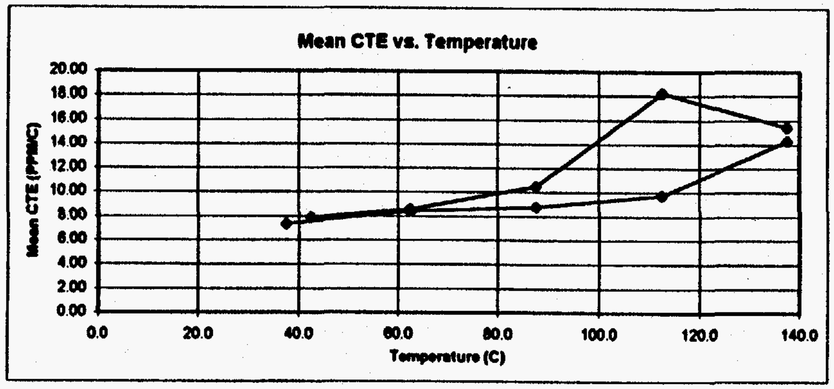
Test condition: OVEN DRIED
Sample Size: 2" (l) x 1" (d)

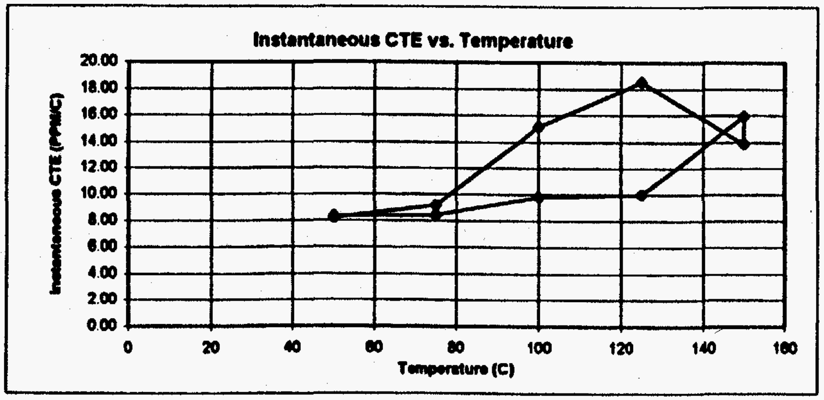
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	51.95	50.85	25.77	2.02
post-test:	52.05	50.85	25.77	2.02

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
Heat-up	25	4.20	***	***	
	50	186.65	7.30	8.40	37.5
	75	408.56	8.88	9.09	62.5
	100	647.15	9.54	9.51	87.5
	125	906.06	10.36	10.43	112.5
	150	1188.43	11.29	12.63	137.5
	175	1608.01	16.78	36.56	162.5
Cool-down	175	2170.65	24.17	19.85	162.5
	150	1566.35	18.26	25.73	137.5
	125	1109.77	11.83	13.71	112.5
	100	813.98	9.67	10.62	87.5
	75	572.24	9.00	9.45	62.5
	50	347.11	8.72	9.04	42.5
	35	216.37	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

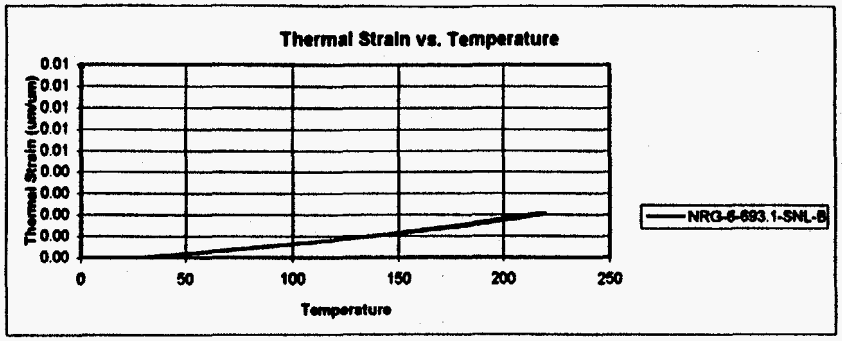
Sample ID: NRG-6-648.6-SNL-B
Lithology: Welded Devitrified
TMU: TSw1

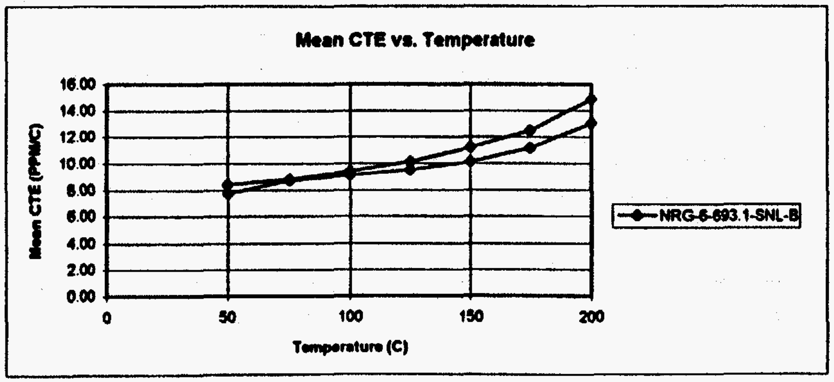
Test condition: OVEN DRIED
Sample Size: 2" (l) x 1" (d)

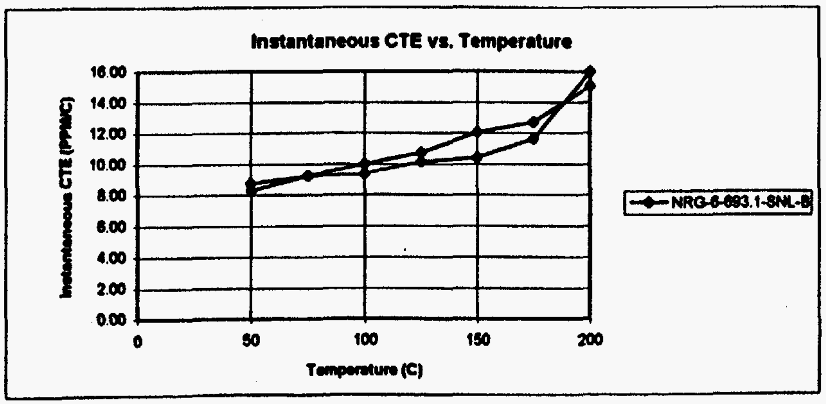
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	51.05	50.55	25.61	1.99
post-test:	51.05	50.55	25.61 ·	1.99

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (^oC)
Heat-up	25	-0.45	***	***	
	50	183.28	7.35	8.32	37.5
	75	394.07	8.43	8.44	62.5
	100	614.57	8.82	9.80	87.5
	125	858.43	9.75	10.00	112.5
	150	1216.39	14.32	15.95	137.5
Cool-down	150	1527.89	15.47	13.90	137.5
	125	1141.20	18.25	18.53	112.5
	100	684.92	10.52	15.15	87.5
	75	421.80	8.58	9.16	62.5
	50	207.39	7.87	8.18	42.5
	35	89.38	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

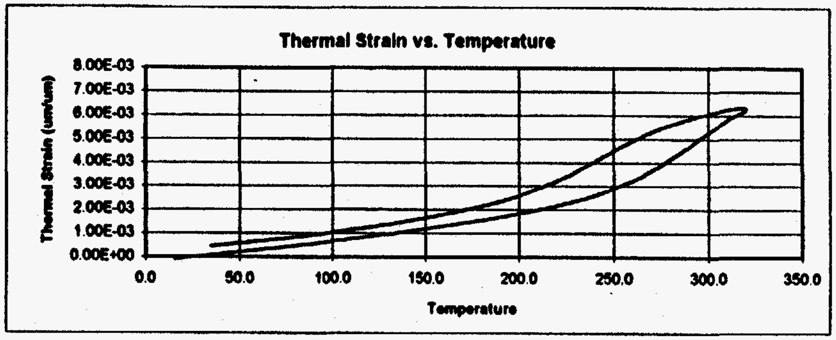
Sample ID: NRG-6-693.1-SNL-B
Lithology: Welded Devitrified
TMU: TSw1

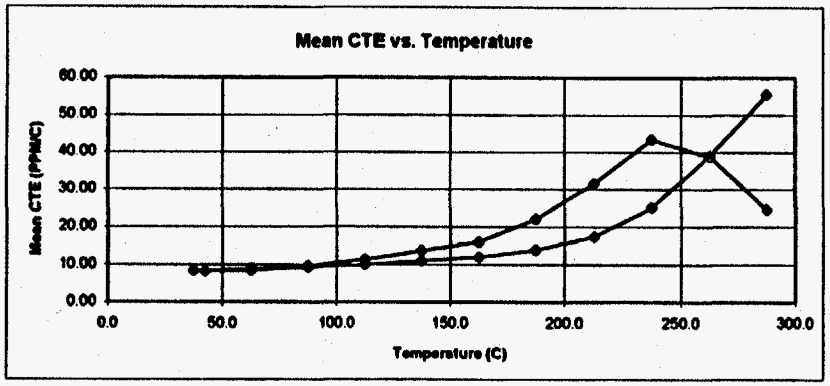
Test condition: OVEN DRIED
Sample Size: 2" (l) x 1" (d)

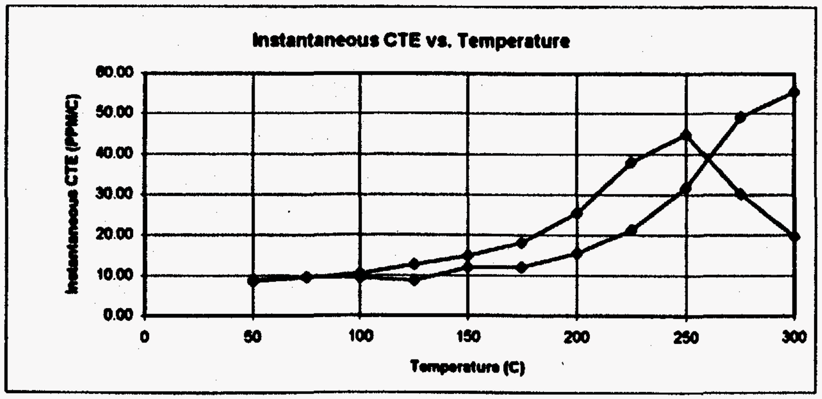
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	55.39	50.85	25.77	2.15
post-test:	55.30	50.85	25.77	2.15

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)
Heat-up	25	0.98	***	***
	50	193.69	7.71	8.28
	75	411.46	8.71	9.20
	100	638.82	9.09	9.35
	125	876.38	9.50	10.14
	150	1129.38	10.12	10.40
	175	1408.16	11.15	11.62
	200	1734.90	13.07	15.98
Cool-down	200	1843.25	14.86	15.06
	175	1471.81	12.50	12.72
	150	1159.36	11.22	12.03
	125	876.83	10.15	10.73
	100	625.15	9.40	9.98
	75	390.22	8.80	9.23
	50	170.17	8.42	8.75
	35	43.91	***	***

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

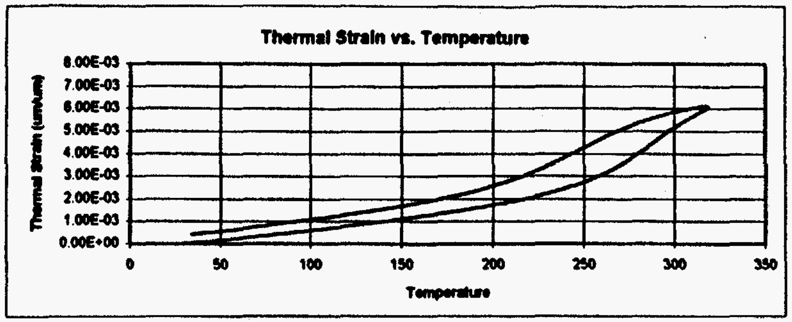
Sample ID: NRG-6-777.8-SNL-B
Lithology: Welded Devitrified
TMU: TSw2

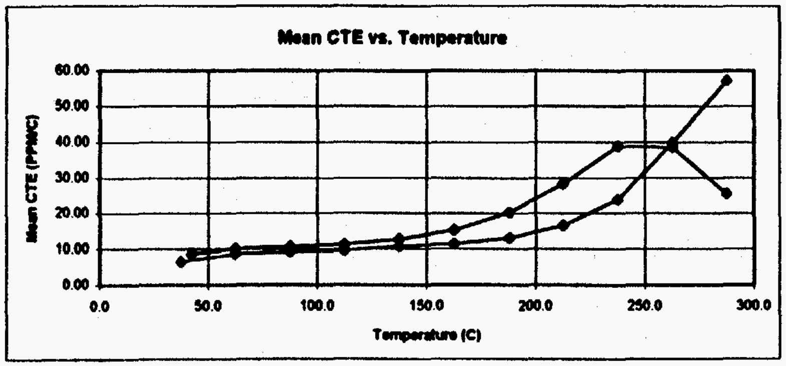
Test condition: OVEN DRIED
Sample Size: 2" (l) x 1" (d)

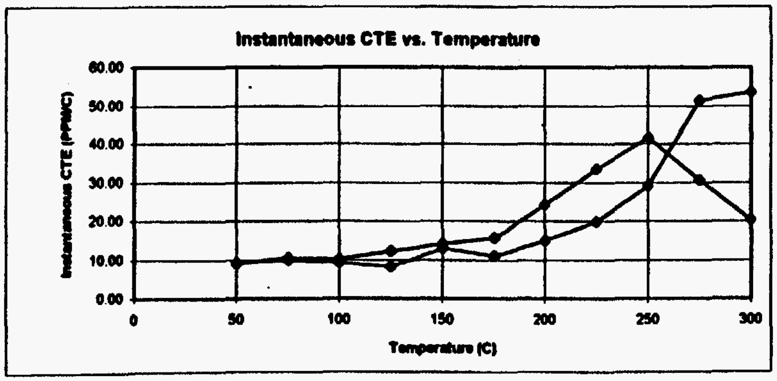
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	58.11	50.83	25.76	2.26
post-test:	58.04	50.85	25.77	2.25

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
Heat-up	25	3.69	***	***	
	50	215.91	8.49	8.82	37.5
	75	438.35	8.90	9.68	62.5
	100	672.97	9.38	9.37	87.5
	125	923.63	10.03	8.74	112.5
	150	1198.69	11.00	12.08	137.5
	175	1499.99	12.05	11.99	162.5
	200	1849.98	14.00	15.62	187.5
	225	2286.98	17.48	21.38	212.5
	250	2914.48	25.10	31.74	237.5
	275	3893.97	39.18	49.10	262.5
	300	5282.57	55.54	55.46	287.5
Cool-down	300	6078.19	24.60	19.67	287.5
	275	5463.25	38.80	30.23	262.5
	250	4493.32	43.40	44.85	237.5
	225	3408.27	31.56	38.09	212.5
	200	2619.32	22.04	25.56	187.5
	175	2068.31	16.09	18.08	162.5
	150	1665.98	13.78	14.93	137.5
	125	1321.41	11.39	12.67	112.5
	100	1036.57	9.71	10.36	87.5
	75	793.73	8.37	9.43	62.5
	50	584.58	8.34	8.43	42.5
	35	459.48	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

Sample ID: NRG-6-788.3-SNL-B
Lithology: Welded Devitrified
TMU: TSw2

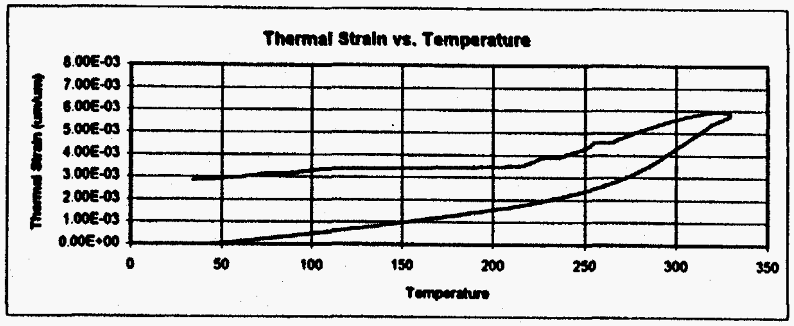
This sample is part of a pair tested for anisotropy
The other sample is: NRG-6-789.4-SNL-A

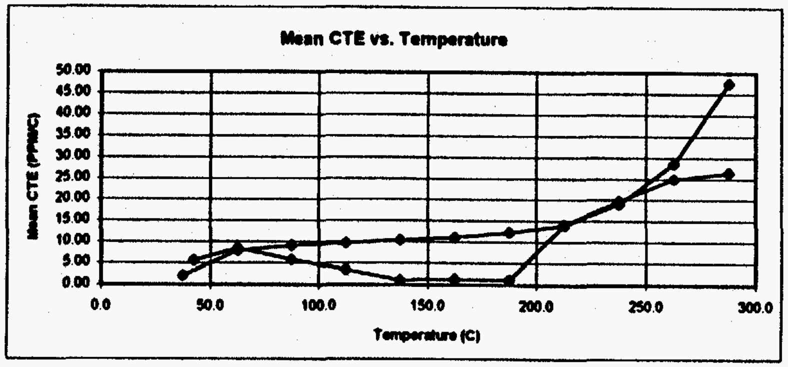
Test condition: Oven-Dried
Sample Size: 2" (l) x 1" (d)

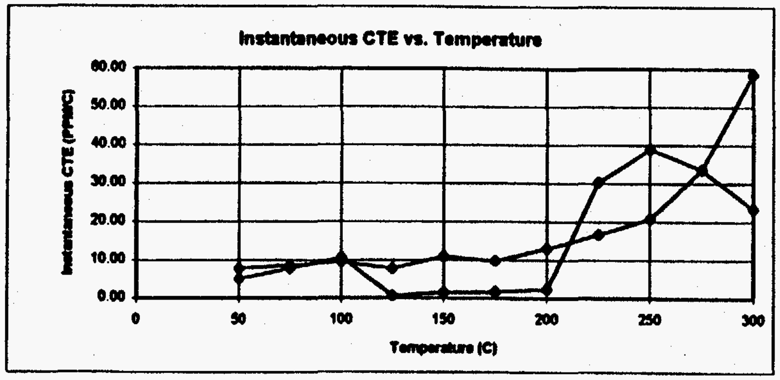
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	57.25	50.93	25.81	2.22
post-test:	57.16	50.93	25.81	2.21

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (^{o}C)
Heat-up	25	0.09	***	***	
	50	165.48	6.62	9.30	37.5
	75	382.53	8.68	9.85	62.5
	100	616.09	9.34	9.17	87.5
	125	859.72	9.75	8.27	112.5
	150	1126.57	10.67	12.95	137.5
	175	1415.57	11.56	11.02	162.5
	200	1743.83	13.13	15.01	187.5
	225	2157.53	16.55	19.86	212.5
	250	2754.43	23.88	29.09	237.5
	275	3747.64	39.73	51.48	262.5
	300	5181.41	57.35	53.60	287.5
Cool-down	300	5872.95	25.61	20.31	287.5
	275	5232.79	38.52	30.51	262.5
	250	4269.74	38.91	41.73	237.5
	225	3297.06	28.18	33.40	212.5
	200	2592.48	20.28	24.28	187.5
	175	2085.37	15.28	15.56	162.5
	150	1703.34	12.85	14.12	137.5
	125	1382.03	11.39	12.28	112.5
	100	1097.28	10.80	10.29	87.5
	75	827.36	10.15	10.61	62.5
	50	573.62	8.84	9.10	42.5
	35	441.06	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







E-79

Data Summary

Sample ID: NRG-6-789.4-SNL-A
Lithology: Welded Devitrified
TMU: TSw2

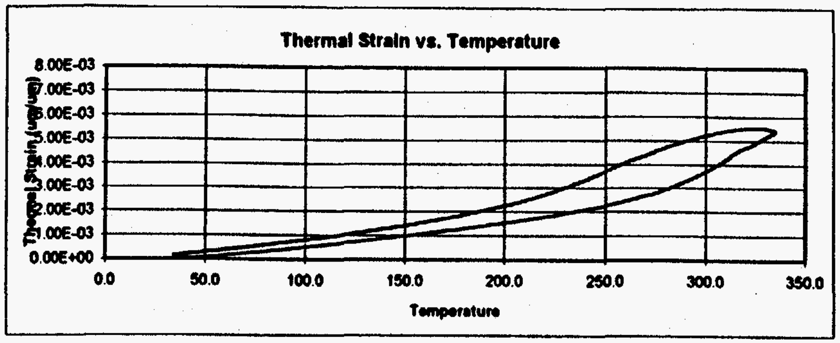
This sample is part of a pair tested for anisotropy
The other sample is: NRG-6-788.3-SNL-B

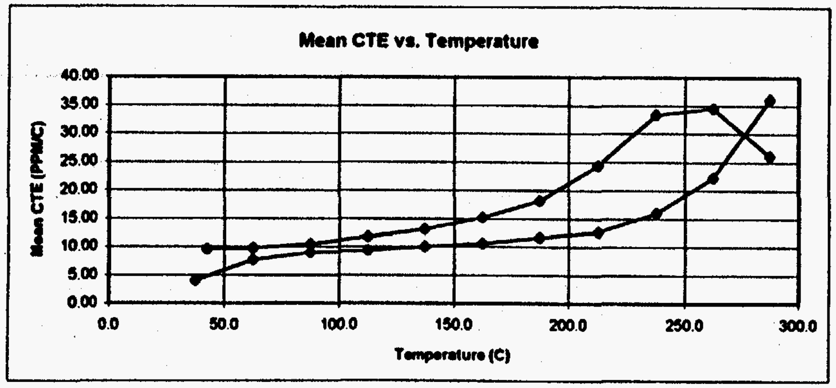
Test condition: OVEN-DRIED
Sample Size: 2" (l) x 1" (d)

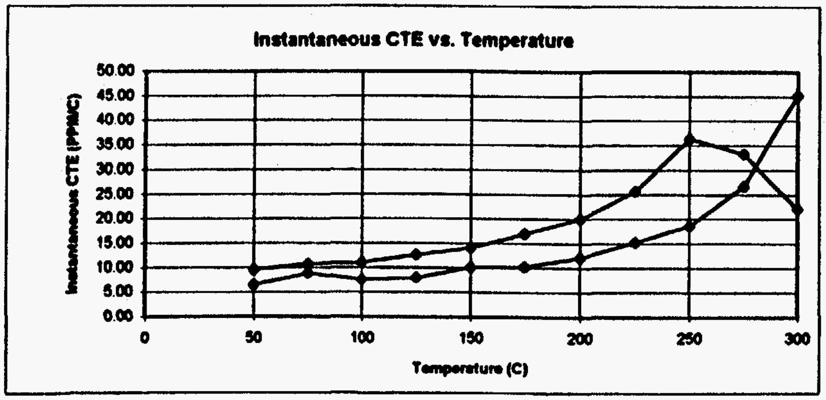
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	56.45	50.80	25.74	2.19
post-test:	56.37	50.83	25.76	2.19

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (^{0}C)
Heat-up	25	1.18	***	***	
	50	54.26	2.12	7.78	37.5
	75	253.47	7.97	8.66	62.5
	100	481.00	9.10	9.54	87.5
	125	724.37	9.73	7.74	112.5
	150	987.38	10.52	10.98	137.5
	175	1263.99	11.06	9.84	162.5
	200	1570.36	12.25	13.01	187.5
	225	1921.55	14.05	16.70	212.5
	250	2396.48	19.00	20.84	237.5
	275	3109.52	28.52	33.72	262.5
	300	4298.29	47.55	58.65	287.5
Cool-down	300	5597.19	26.51	23.43	287.5
	275	4934.41	24.95	33.59	262.5
	250	4310.54	19.72	38.93	237.5
	225	3817.43	14.09	30.38	212.5
	200	3465.23	1.24	2.32	187.5
	175	3434.34	1.39	1.71	162.5
	150	3399.67	1.06	1.61	137.5
	125	3373.26	3.54	0.74	112.5
	100	3284.64	5.75	10.73	87.5
	75	3140.96	8.52	7.72	62.5
	50	2927.91	5.57	5.05	42.5
	35	2844.29	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







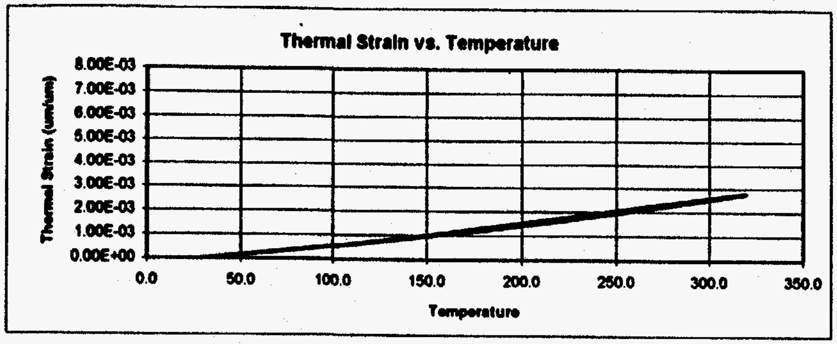
Data Summary

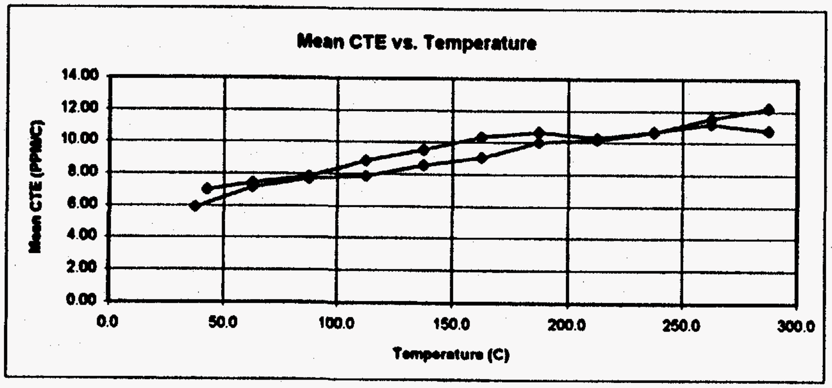
Sample ID:	NRG-6-802.7-SNL-B
Lithology:	Welded Devitrified
TMU:	TSw2
Test condition:	OVEN DRIED
Sample Size:	2" (l) x 1" (d)

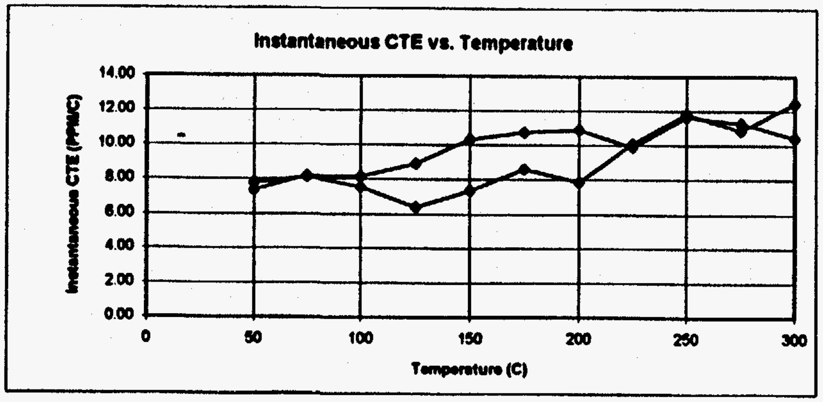
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	58.12	50.93	25.81	2.25
post-test:	58.04	50.93	25.81	2.25

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
Heat-up	25	-1.46	***	***	
	50	99.59	4.04	6.49	37.5
	75	292.46	7.71	8.84	62.5
	100	515.95	8.94	7.50	87.5
	125	748.52	9.30	7.97	112.5
	150	997.38	9.95	10.06	137.5
	175	1262.34	10.60	10.21	162.5
	200	1552.02	11.59	12.12	187.5
	225	1867.89	12.64	15.30	212.5
	250	2267.62	15.99	18.61	237.5
	275	2824.42	22.27	26.70	262.5
	300	3725.97	36.06	45.26	287.5
Cool-down	300	5226.34	26.15	22.20	287.5
	275	4572.66	34.49	33.24	262.5
	250	3710.41	33.34	36.39	237.5
	225	2876.97	24.42	25.65	212.5
	200	2266.56	18.18	20.06	187.5
	175	1812.02	15.21	16.93	162.5
	150	1431.79	13.05	14.00	137.5
	125	1105.57	11.73	12.58	112.5
	100	812.31	10.42	10.98	87.5
	75	551.70	9.81	10.79	62.5
	50	306.46	9.54	9.60	42.5
	35	163.32	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







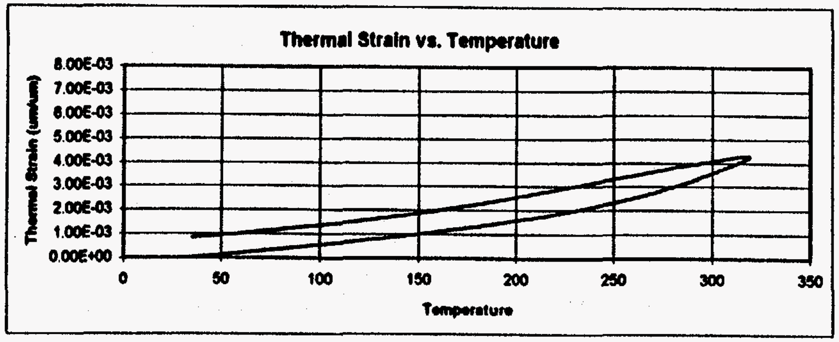
Data Summary

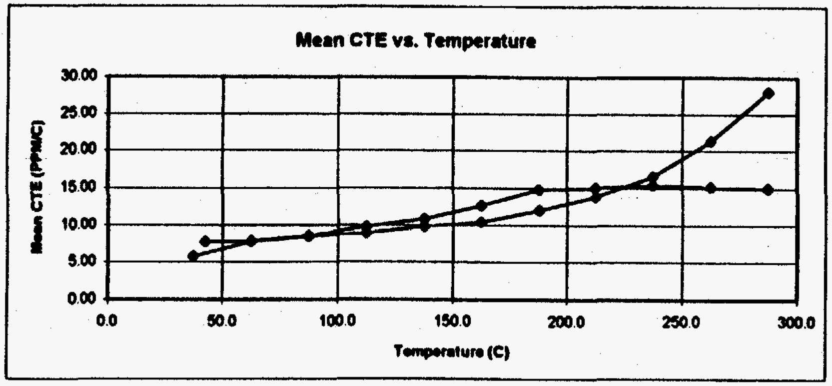
Sample ID:	NRG-6-849.9-SNL-B
Lithology:	Welded Devitrified
TMU:	TSw2
Test condition:	OVEN DRIED
Sample Size:	2" (l) x 1" (d)

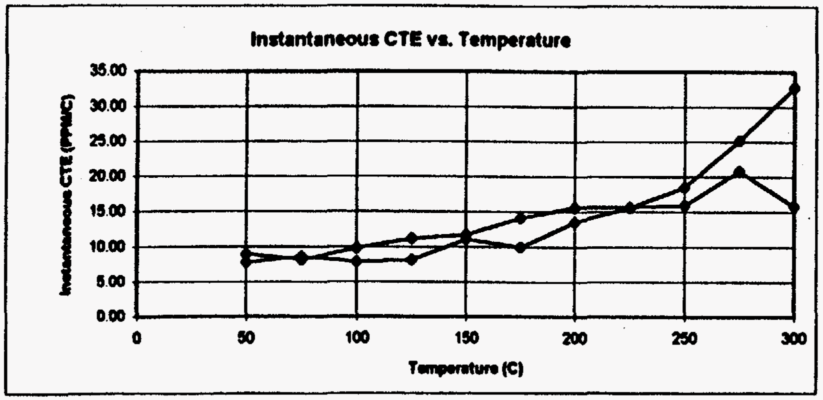
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	58.97	50.90	25.79	2.29
post-test:	58.90	50.90	25.79	2.28

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
Heat-up	25	-0.38	***	***	
	50	147.14	5.90	7.80	37.5
	75	326.37	7.17	8.12	62.5
	100	518.58	7.69	7.58	87.5
	125	716.00	7.90	6.41	112.5
	150	930.72	8.59	7.37	137.5
	175	1156.77	9.04	8.61	162.5
	200	1407.18	10.02	7.88	187.5
	225	1661.30	10.16	10.10	212.5
	250	1927.76	10.66	11.85	237.5
	275	2216.79	11.56	10.87	262.5
	300	2521.52	12.19	12.46	287.5
Cool-down	300	2621.92	10.77	10.46	287.5
	275	2352.73	11.17	11.30	262.5
	250	2073.52	10.69	11.62	237.5
	225	1806.38	10.32	9.87	212.5
	200	1548.43	10.67	10.90	187.5
	175	1281.66	10.35	10.75	162.5
	150	1022.99	9.54	10.32	137.5
	125	784.44	8.85	8.91	112.5
	100	563.18	7.83	8.16	87.5
	75	367.31	7.45	8.19	62.5
	50	180.93	6.99	7.37	42.5
	35	76.04	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

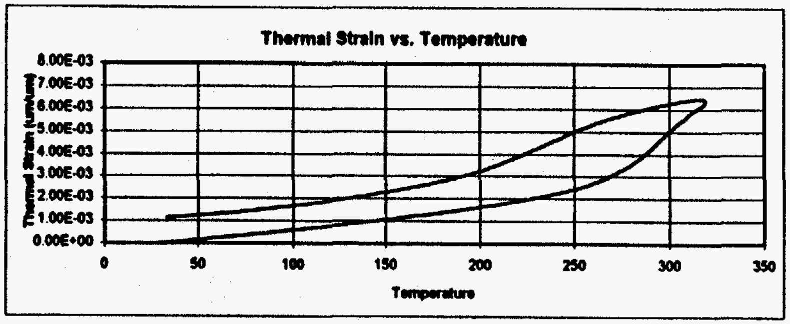
Sample ID: NRG-6-886.5-SNL-B
Lithology: Welded Devitrified
TMU: TSw2

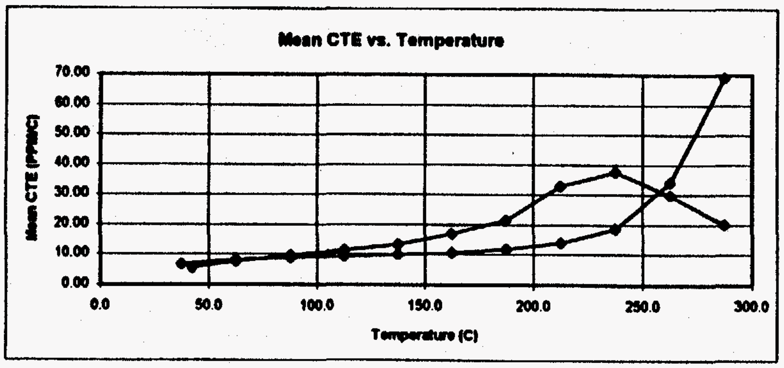
Test condition: Oven-Dried
Sample Size: 2" (l) x 1" (d)

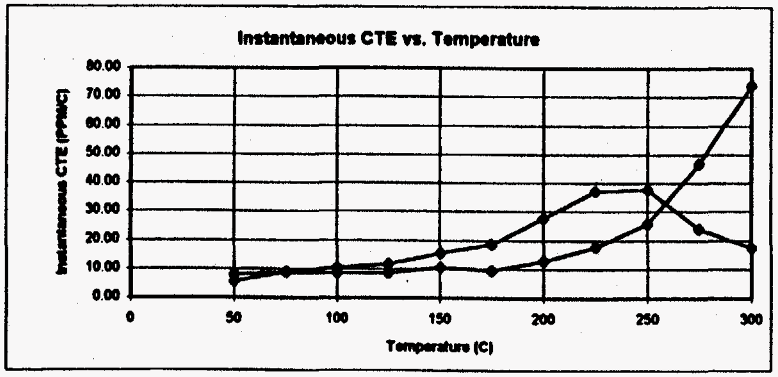
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	59.01	50.85	25.77	2.29
post-test:	58.92	50.88	25.78	2.29

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (^{o}C)
Heat-up	25	1.33	***	***	
	50	145.49	5.77	7.81	37.5
	75	341.64	7.85	8.66	62.5
	100	554.03	8.50	7.91	87.5
	125	777.07	8.92	8.15	112.5
	150	1022.26	9.81	11.09	137.5
	175	1282.79	10.42	9.97	162.5
	200	1583.51	12.03	13.56	187.5
	225	1931.06	13.90	15.53	212.5
	250	2344.37	16.63	18.51	237.5
	275	2877.06	21.31	25.19	262.5
	300	3580.03	28.12	32.86	287.5
Cool-down	300	4081.53	14.98	15.88	287.5
	275	3707.02	15.15	20.88	262.5
	250	3328.23	15.43	15.92	237.5
	225	2942.53	15.09	15.65	212.5
	200	2565.36	14.83	15.65	187.5
	175	2194.49	12.70	14.10	162.5
	150	1876.94	10.83	11.72	137.5
	125	1606.19	9.76	11.21	112.5
	100	1362.21	8.58	9.82	87.5
	75	1147.65	7.93	8.17	62.5
	50	949.45	7.77	9.03	42.5
	35	832.87	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

Sample ID: NRG-6-900.4-SNL-A
Lithology: Welded Devitrified
TMU: TSw2

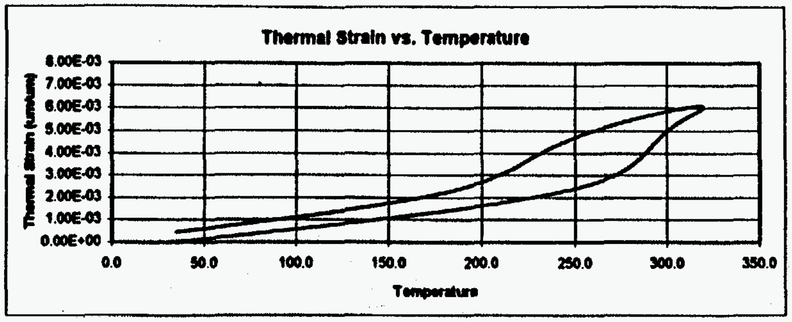
This sample is part of a pair tested for anisotropy
The other sample is: NRG-6-900.4-SNL-B

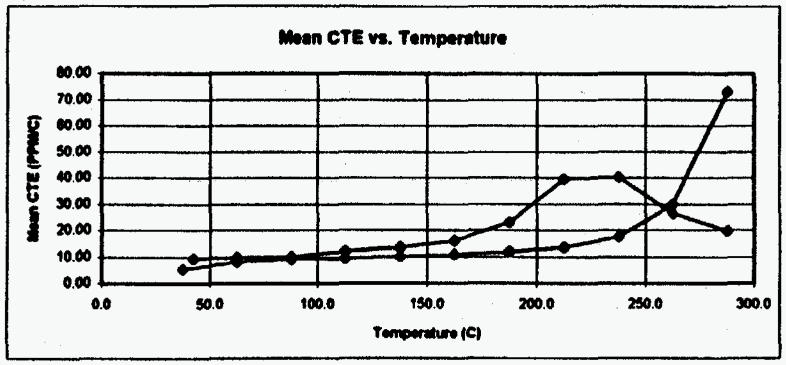
Test condition: Oven-Dried
Sample Size: 2" (l) x 1" (d)

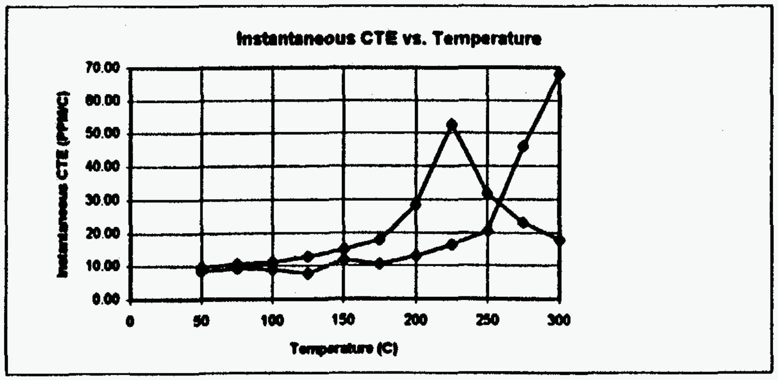
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	54.73	50.80	25.74	2.13
post-test:	54.71	50.85	25.77	2.12

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (^{0}C)
Heat-up	25	2.17	***	***	
	50	166.21	6.56	8.14	37.5
	75	371.47	8.21	8.77	62.5
	100	592.42	8.84	8.66	87.5
	125	823.83	9.26	8.65	112.5
	150	1071.36	9.90	10.52	137.5
	175	1331.92	10.42	9.55	162.5
	200	1629.33	11.90	12.95	187.5
	225	1976.23	13.88	17.62	212.5
	250	2445.39	18.77	25.80	237.5
	275	3298.56	34.13	46.83	262.5
	300	5026.04	69.10	74.16	287.5
Cool-down	300	6263.38	20.29	17.48	287.5
	275	5756.18	29.91	23.97	262.5
	250	5008.52	37.67	37.83	237.5
	225	4066.83	32.90	37.09	212.5
	200	3244.37	21.56	27.56	187.5
	175	2705.46	16.92	18.56	162.5
	150	2282.36	13.38	15.70	137.5
	125	1947.78	11.36	11.80	112.5
	100	1663.86	9.72	10.37	87.5
	75	1420.95	7.57	9.13	62.5
	50	1231.68	5.63	5.64	42.5
	35	1147.22	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

Sample ID:	NRG-6-900.4-SNL-B
Lithology:	Welded Devitrified
TMU:	TSw2

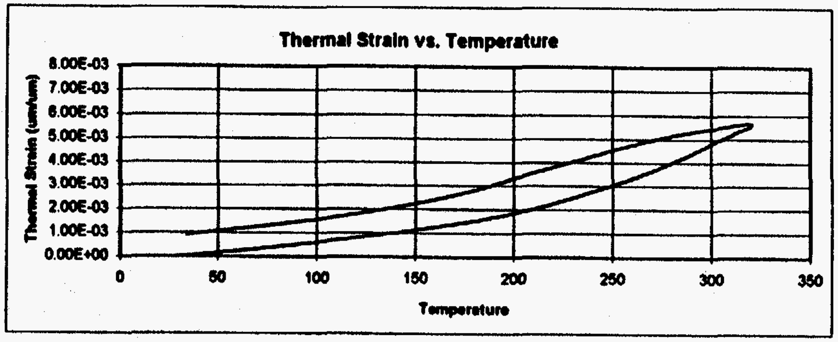
This sample is part of a pair tested for anisotropy
The other sample is: NRG-6-900.4-SNL-A

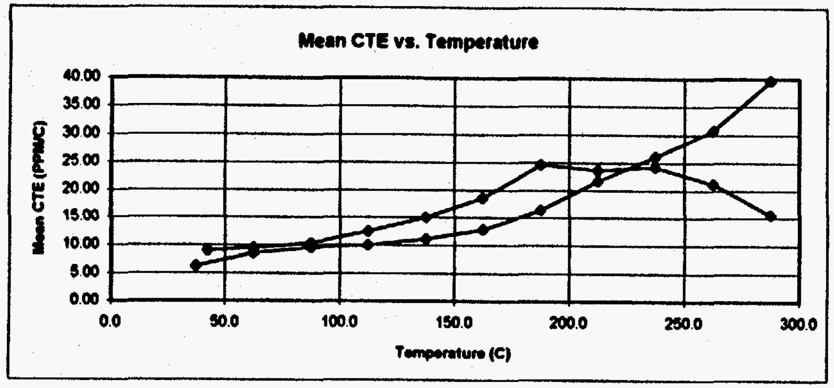
Test condition:	OVEN DRIED
Sample Size:	2" (l) x 1" (d)

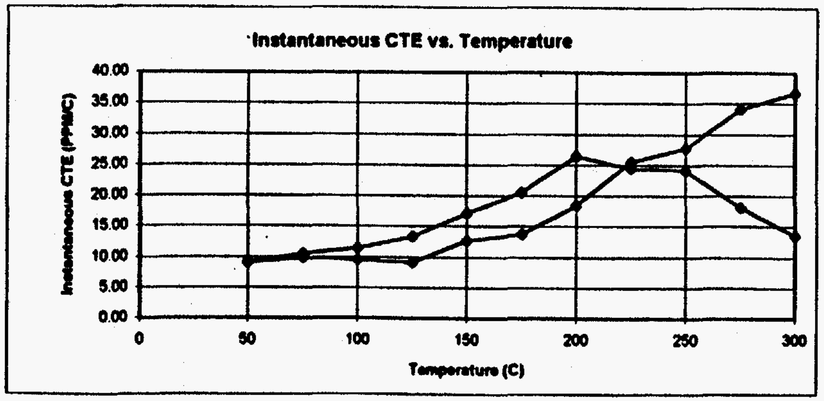
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	57.53	50.80	25.74	2.23
post-test:	57.47	50.83	25.76	2.23

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (^{0}C)
Heat-up	25	20.52	***	***	
	50	153.65	5.33	8.50	37.5
	75	360.41	8.27	9.30	62.5
	100	585.79	9.01	8.89	87.5
	125	822.21	9.46	7.77	112.5
	150	1077.46	10.21	11.90	137.5
	175	1347.54	10.80	10.47	162.5
	200	1644.69	11.89	13.08	187.5
	225	1986.28	13.66	16.41	212.5
	250	2423.53	17.49	20.51	237.5
	275	3168.18	29.79	46.02	262.5
	300	4998.30	73.20	67.98	287.5
Cool-down	300	5866.37	19.71	17.82	287.5
	275	5373.63	26.46	23.06	262.5
	250	4712.13	40.22	31.72	237.5
	225	3706.66	39.55	52.62	212.5
	200	2717.96	22.91	28.38	187.5
	175	2145.21	15.99	17.82	162.5
	150	1745.44	13.47	15.02	137.5
	125	1408.66	12.02	12.89	112.5
	100	1108.06	10.23	11.28	87.5
	75	852.27	9.88	10.57	62.5
	50	605.22	9.34	9.62	42.5
	35	465.15	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







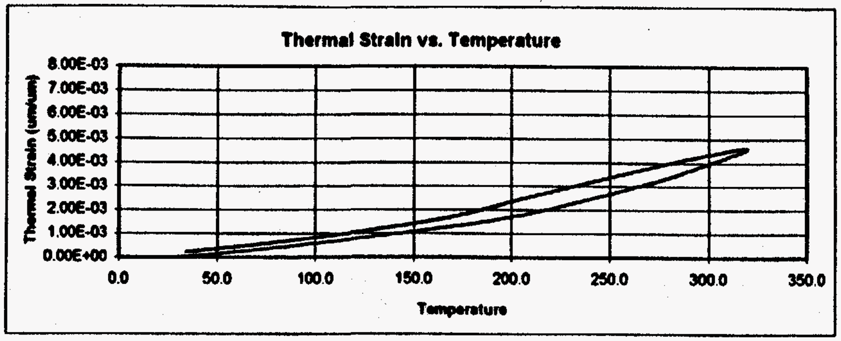
Data Summary

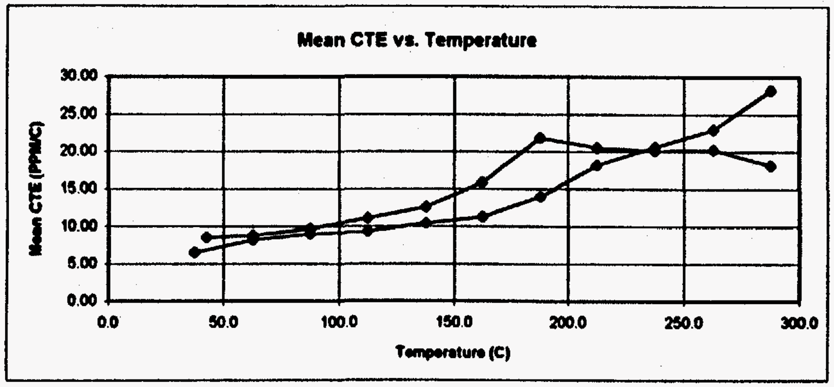
Sample ID:	NRG-6-952.2-SNL-8
Lithology:	Welded Devitrified
TMU:	TSw2
Test condition:	Oven-Dried
Sample Size:	2" (l) x 1" (d)

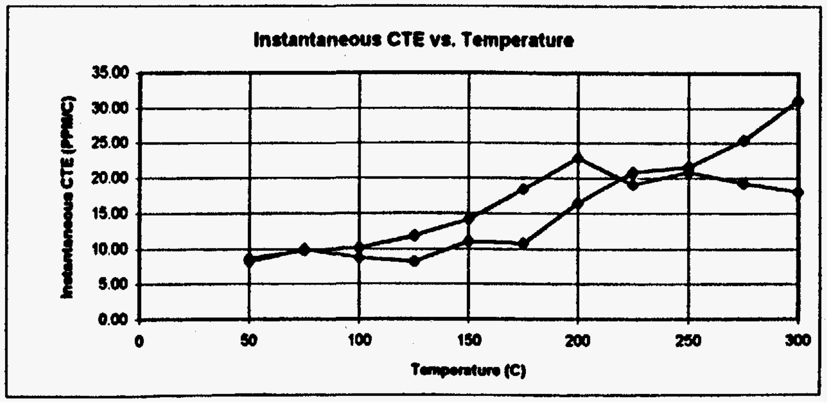
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	53.50	50.88	25.78	2.08
post-test:	53.43	50.88	25.78	2.07

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (^oC)
Heat-up	25	4.80	***	***	
	50	162.05	6.29	9.00	37.5
	75	375.17	8.52	9.82	62.5
	100	611.74	9.46	9.49	87.5
	125	860.38	9.95	9.15	112.5
	150	1138.68	11.13	12.73	137.5
	175	1460.63	12.88	13.75	162.5
	200	1872.32	16.47	18.44	187.5
	225	2414.60	21.69	25.50	212.5
	250	3066.66	26.08	27.72	237.5
	275	3836.45	30.79	34.08	262.5
	300	4827.02	39.62	36.76	287.5
Cool-down	300	5452.36	15.55	13.55	287.5
	275	5063.55	21.31	18.11	262.5
	250	4530.70	24.22	24.08	237.5
	225	3925.12	23.66	24.49	212.5
	200	3333.67	24.60	26.47	187.5
	175	2718.79	18.58	20.50	162.5
	150	2254.31	15.08	17.10	137.5
	125	1877.26	12.45	13.29	112.5
	100	1565.93	10.27	11.48	87.5
	75	1309.17	9.44	10.46	62.5
	50	1073.23	9.03	9.22	42.5
	35	937.79	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

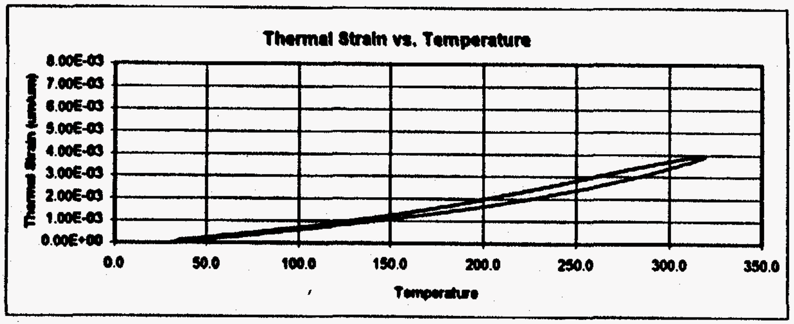
Sample ID: NRG-6-987.6-SNL-8
Lithology: Welded Devitrified
TMU: TSw2

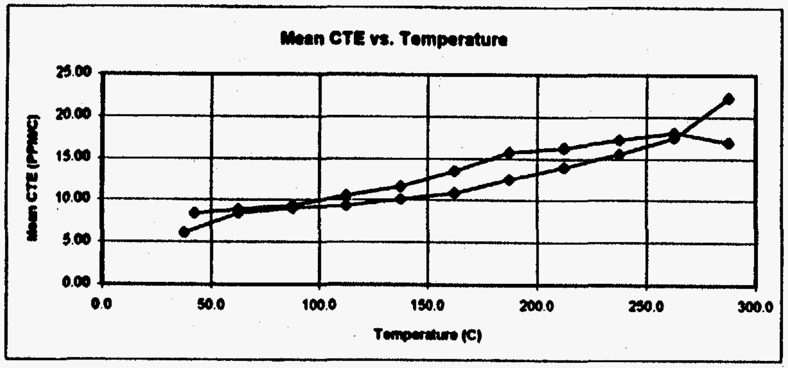
Test condition: OVEN DRIED
Sample Size: 2" (l) x 1" (d)

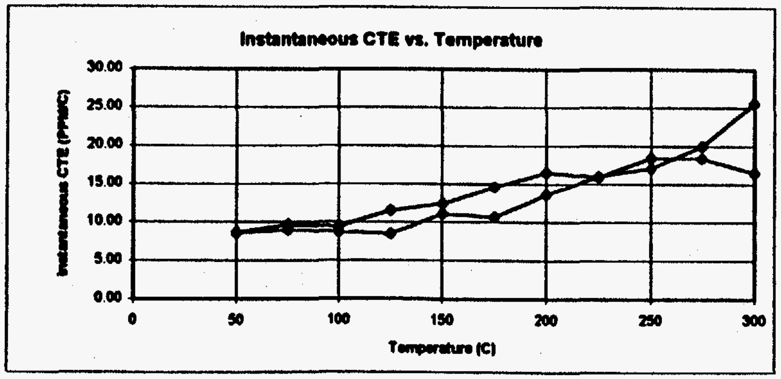
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	58.31	50.95	25.82	2.26
post-test:	58.28	50.93	25.81	2.26

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
Heat-up	25	-0.03	***	***	
	50	163.88	6.56	8.23	37.5
	75	370.01	8.25	9.94	62.5
	100	596.18	9.05	8.76	87.5
	125	830.51	9.37	8.21	112.5
	150	1090.69	10.41	11.09	137.5
	175	1373.29	11.30	10.77	162.5
	200	1722.49	13.97	16.49	187.5
	225	2178.18	18.23	20.85	212.5
	250	2693.67	20.62	21.59	237.5
	275	3267.08	22.94	25.45	262.5
	300	3973.54	28.26	31.14	287.5
Cool-down	300	4348.93	18.19	18.02	287.5
	275	3894.14	20.30	19.27	262.5
	250	3386.71	20.08	20.82	237.5
	225	2884.81	20.57	19.06	212.5
	200	2370.57	21.85	22.88	187.5
	175	1824.32	15.88	18.46	162.5
	150	1427.40	12.56	14.15	137.5
	125	1113.45	11.13	11.81	112.5
	100	835.17	9.68	10.11	87.5
	75	593.11	8.89	9.79	62.5
	50	370.95	8.58	8.65	42.5
	35	242.24	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

Sample ID: NRG-6-1016.6-SNL-B
Lithology: Welded Devitrified
TMU: TSw2

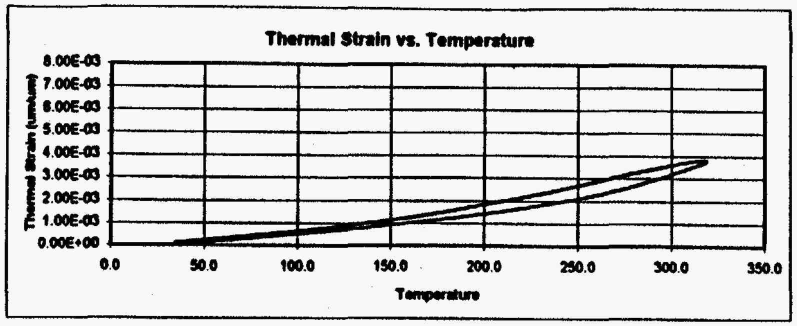
This sample is part of a pair tested for anisotropy
The other sample is: NRG-6-1017.2-SNL-A

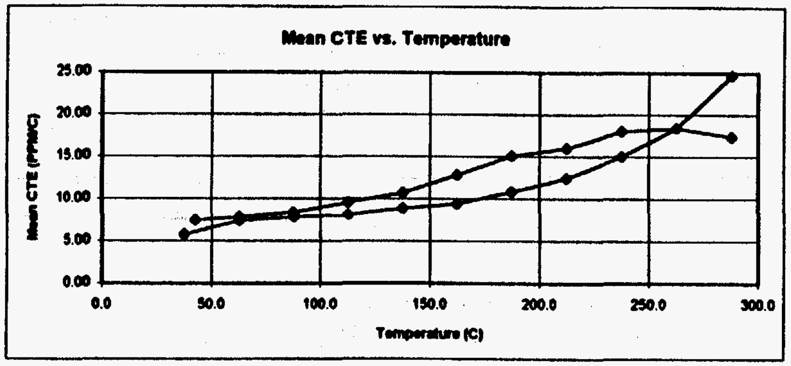
Test condition: OVEN DRIED
Sample Size: 2" (l) x 1" (d)

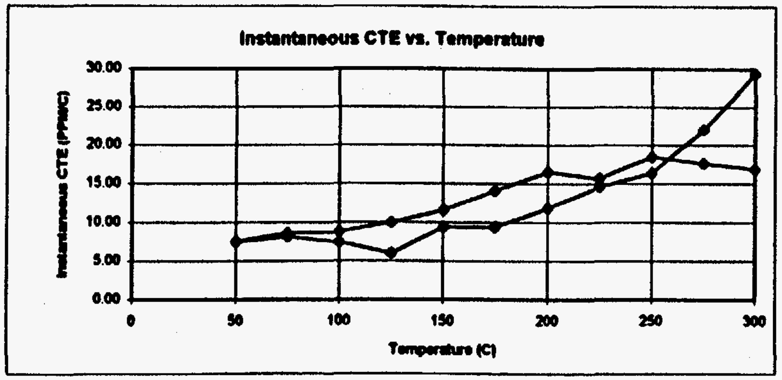
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	58.74	50.83	25.76	2.28
post-test:	58.63	50.83	25.76	2.28

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (^{0}C)
Heat-up	25	6.27	***	***	
	50	158.62	6.09	8.58	37.5
	75	368.43	8.39	9.00	62.5
	100	593.73	9.01	8.75	87.5
	125	827.66	9.36	8.44	112.5
	150	1079.60	10.08	11.10	137.5
	175	1352.45	10.91	10.70	162.5
	200	1664.72	12.49	13.66	187.5
	225	2013.58	13.95	16.03	212.5
	250	2402.87	15.57	17.09	237.5
	275	2841.11	17.53	20.00	262.5
	300	3399.16	22.32	25.59	287.5
Cool-down	300	3707.11	16.98	16.56	287.5
	275	3282.53	18.10	18.43	262.5
	250	2830.03	17.31	18.52	237.5
	225	2397.32	16.27	15.95	212.5
	200	1990.47	15.76	16.51	187.5
	175	1596.42	13.49	14.56	162.5
	150	1259.21	11.67	12.46	137.5
	125	967.43	10.57	11.53	112.5
	100	703.30	9.32	9.38	87.5
	75	470.37	8.87	9.67	62.5
	50	248.55	8.43	8.68	42.5
	35	122.14	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

Sample ID:	NRG-6-1017.2-SNL-A
Lithology:	Welded Devitrified
TMU:	TSw2

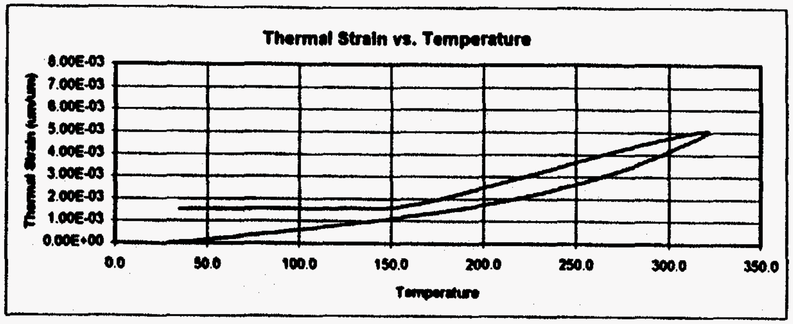
This sample is part of a pair tested for anisotropy

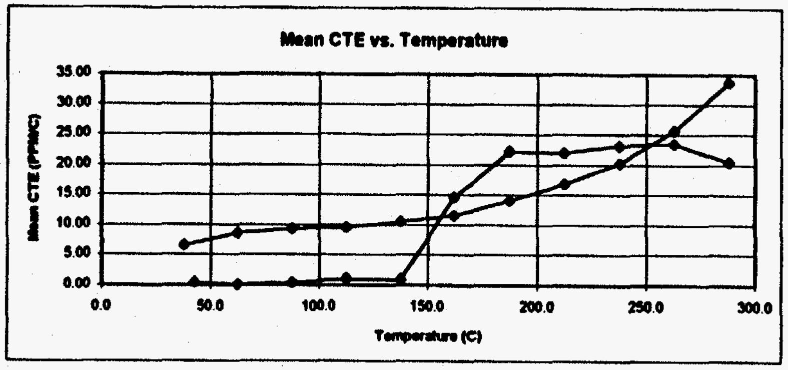
The other sample is:	NRG-6-1016.6-SNL-B
Test condition:	Oven-Dried
Sample Size:	2" (l) x 1" (d)

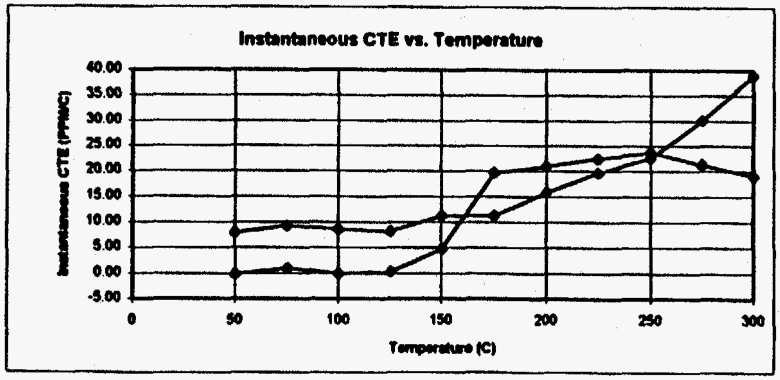
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	56.92	50.72	25.70	2.21
post-test:	56.81	50.72	25.70	2.21

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (^{0}C)
Heat-up	25	-0.19	***	***	
	50	142.84	5.72	7.44	37.5
	75	326.43	7.34	8.09	62.5
	100	521.69	7.81	7.48	87.5
	125	723.19	8.06	6.05	112.5
	150	943.88	8.83	9.44	137.5
	175	1178.31	9.38	9.41	162.5
	200	1447.69	10.78	11.89	187.5
	225	1759.22	12.46	14.61	212.5
	250	2134.53	15.01	16.32	237.5
	275	2594.88	18.41	22.01	262.5
	300	3212.56	24.71	29.42	287.5
Cool-down	300	3603.81	17.40	16.89	287.5
	275	3168.72	18.40	17.65	262.5
	250	2708.82	18.02	18.47	237.5
	225	2258.22	16.02	15.66	212.5
	200	1857.84	15.13	16.51	187.5
	175	1479.55	12.81	14.09	162.5
	150	1159.37	10.66	11.58	137.5
	125	892.85	9.52	9.98	112.5
	100	654.80	8.38	8.79	87.5
	75	445.31	7.79	8.68	62.5
	50	250.46	7.47	7.56	42.5
	35	138.41	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

Sample ID: NRG-6-1081.0-SNL-A
Lithology: Welded Devitrified
TMU: TSw2

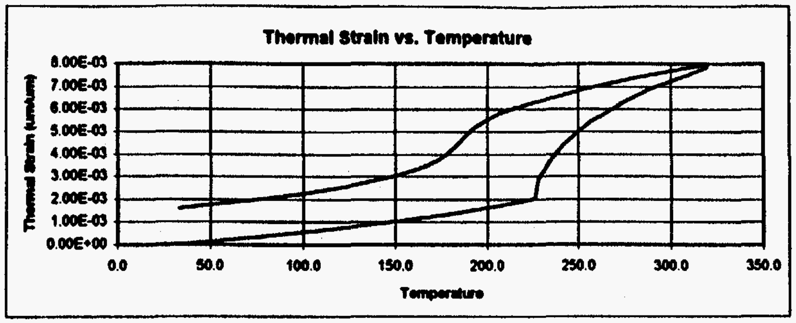
This sample is part of a pair tested for anisotropy
The other sample is: NRG-6-1081.5-SNL-A

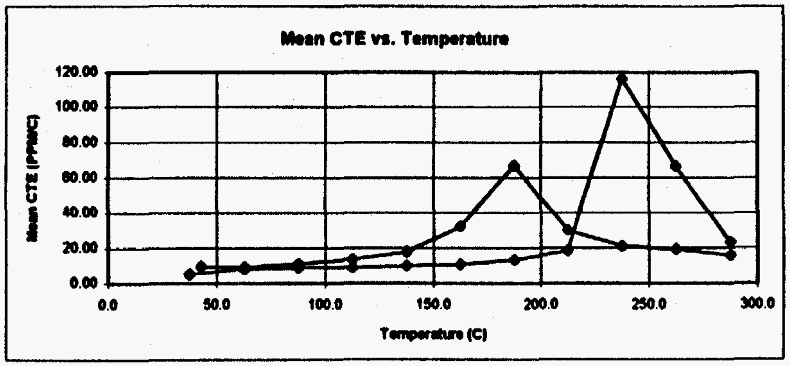
Test condition: OVEN DRIED
Sample Size: 2" (l) x 1" (d)

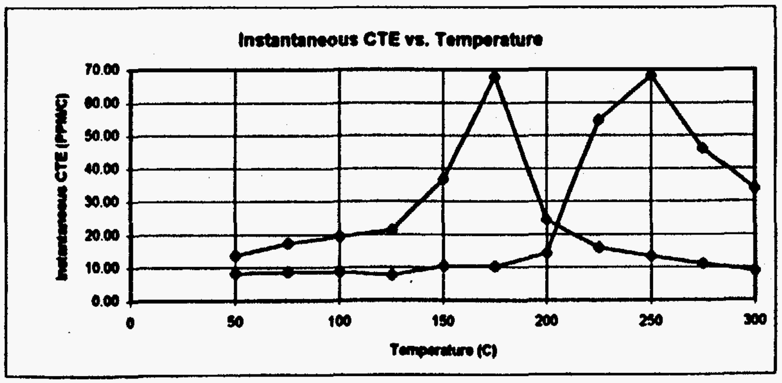
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	56.77	50.83	25.76	2.20
post-test:	56.69	50.83	25.76	2.20

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (^{0}C)
Heat-up	25	-1.95	***	***	
	50	161.99	6.56	7.93	37.5
	75	376.74	8.59	9.18	62.5
	100	610.80	9.36	8.65	87.5
	125	848.84	9.52	8.23	112.5
	150	1111.33	10.50	11.23	137.5
	175	1401.57	11.61	11.27	162.5
	200	1753.52	14.08	15.87	187.5
	225	2174.84	16.85	19.63	212.5
	250	2681.62	20.27	22.53	237.5
	275	3323.68	25.68	30.06	262.5
	300	4167.00	33.73	38.97	287.5
Cool-down	300	4760.61	20.53	18.98	287.5
	275	4247.24	23.49	21.31	262.5
	250	3660.09	23.24	23.70	237.5
	225	3079.14	22.03	22.46	212.5
	200	2528.36	22.20	20.97	187.5
	175	1973.33	14.55	19.67	162.5
	150	1609.47	0.97	4.74	137.5
	125	1585.28	1.03	0.35	112.5
	100	1559.46	0.40	-0.04	87.5
	75	1549.37	0.14	1.02	62.5
	50	1545.86	0.38	-0.14	42.5
	35	1540.10	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

Sample ID: NRG-6-1081.5-SNL-A
Lithology: Welded Devitrified
TMU: TSw2

This sample is part of a pair tested for anisotropy
The other sample is: NRG-6-1081.0-SNL-A

Test condition: OVEN DRIED
Sample Size: 2" (l) x 1" (d)

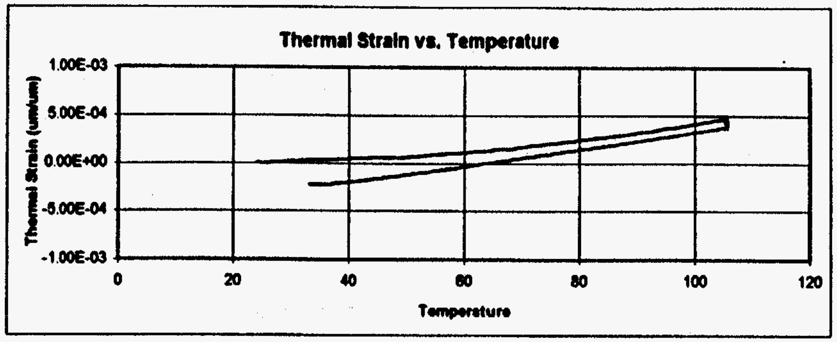
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	56.15	50.85	25.77	2.18
post-test:	56.10	50.93	25.81	2.17

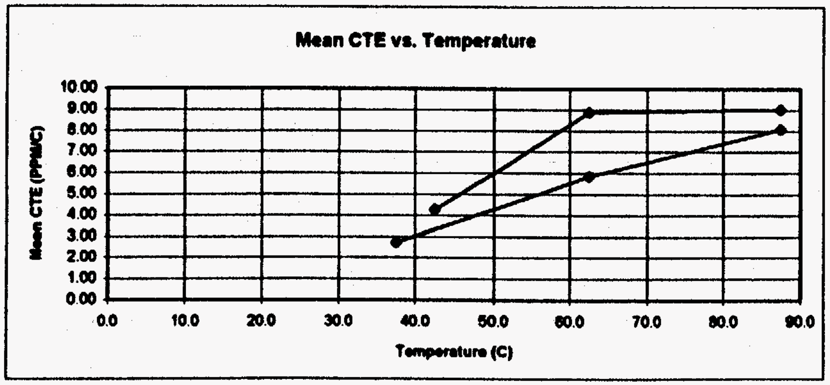
	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (^{0}C)
Heat-up	25	19.69	***	***	
	50	150.74	5.24	8.33	37.5
	75	348.61	7.91	8.67	62.5
	100	572.22	8.94	8.60	87.5
	125	795.30	8.92	7.62	112.5
	150	1041.78	9.86	10.57	137.5
	175	1312.28	10.82	10.34	162.5
	200	1639.56	13.09	14.47	187.5
	225	2102.85	18.53	54.61	212.5
	250	5007.33	116.18	68.21	237.5
	275	6671.43	66.56	46.08	262.5
	300	7248.02	23.06	33.83	287.5
Cool-down	300	7697.50	15.93	8.91	287.5
	275	7299.26	18.97	11.08	262.5
	250	6825.03	21.08	13.52	237.5
	225	6298.12	30.10	15.94	212.5
	200	5545.57	67.16	24.58	187.5
	175	3866.67	32.45	67.86	162.5
	150	3055.46	17.66	36.87	137.5
	125	2614.07	13.78	21.44	112.5
	100	2269.62	11.03	19.30	87.5
	75	1993.78	9.32	17.37	62.5
	50	1760.69	9.40	13.91	42.5
	35	1619.75	***	***	

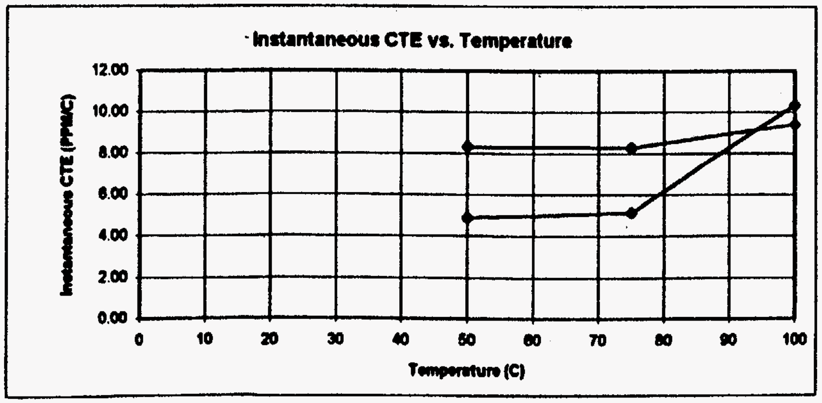
* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.

Data Summaries for NRG-6

(Air-Dried)







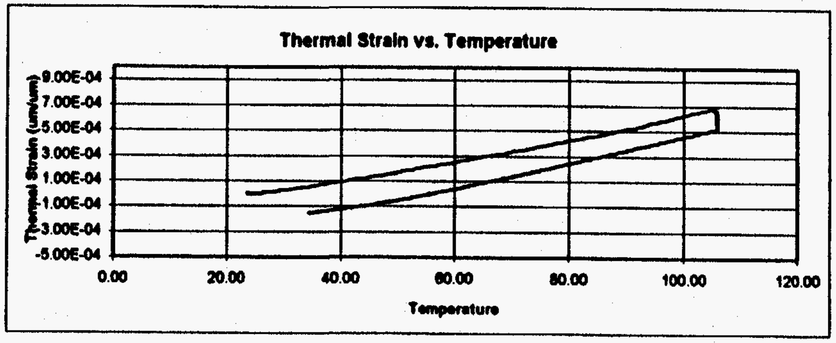
Data Summary

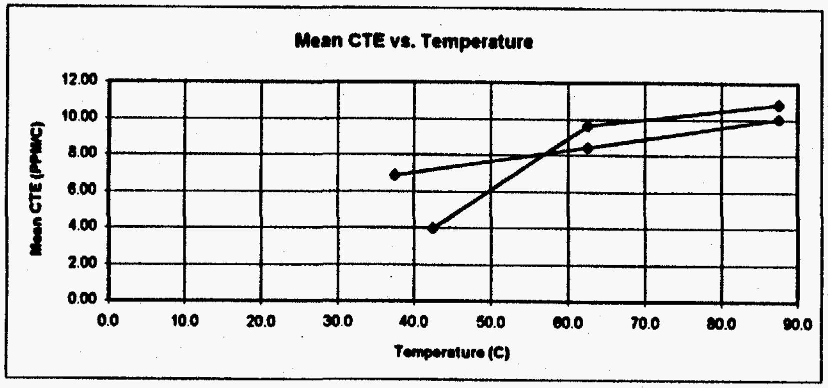
Sample ID:	NRG-6-28.8-SNL-G
Lithology:	Welded Devitrified
TMU:	TCw
Test condition:	Air-Dry
Sample Size:	2" (l) x 1" (d)

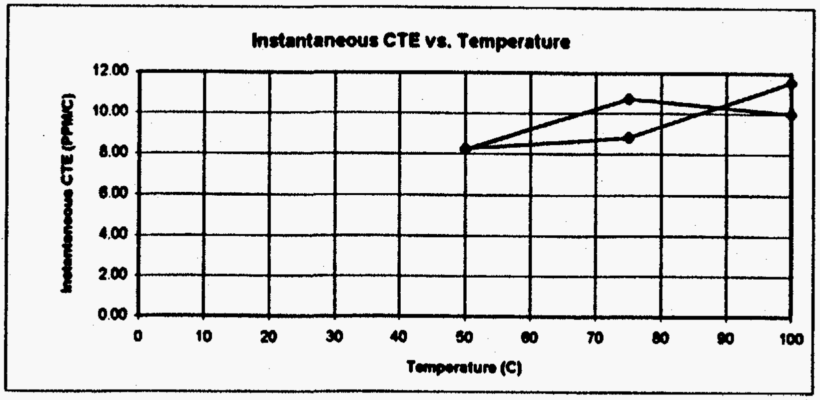
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	59.21	50.83	25.76	2.30
post-test:	59.22	50.83	25.76	2.30

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (^{o}C)
Heat-up	25	-1.09	***	***	
	50	66.57	2.71	4.91	37.5
	75	212.86	5.85	5.16	62.5
	100	414.89	8.08	10.35	87.5
Cool-down	100	327.41	9.02	9.40	87.5
	75	101.88	8.89	8.27	62.5
	50	-120.26	4.28	8.33	42.5
	35	-227.16	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

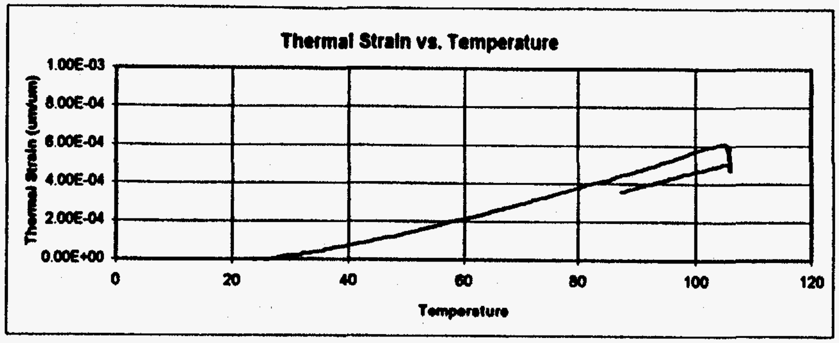
Sample ID: NRG-6-98.1-SNL-G
Lithology: Welded Devitrified
TMU: TCw

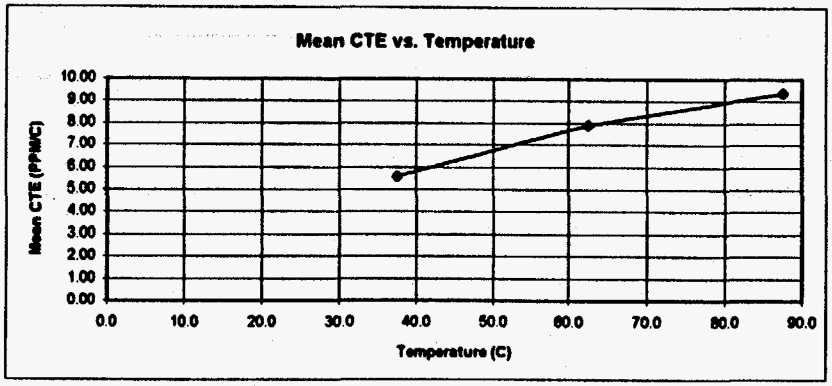
Test condition: Air-Dry
Sample Size: 2" (l) x 1" (d)

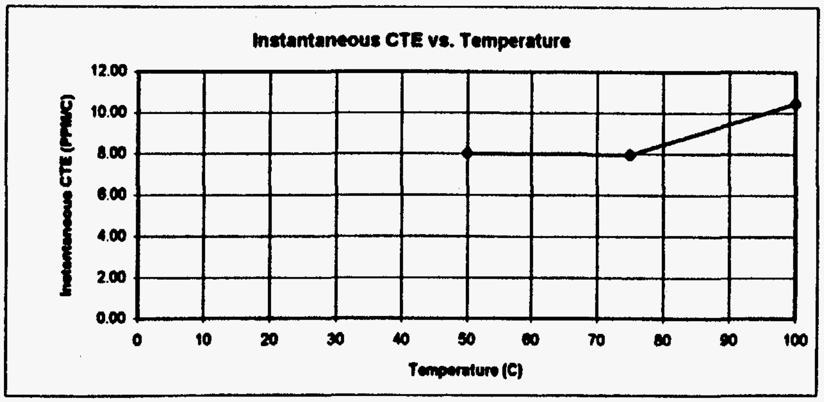
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	58.61	50.83	25.76	2.28
post-test:	58.41	50.82	25.75	2.27

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
Heat-up	25	-0.90	***	***	
	50	170.38	6.85	8.24	37.5
	75	381.22	8.43	8.81	62.5
	100	631.29	10.00	11.55	87.5
Cool-down	100	460.54	10.84	10.01	87.5
	75	189.53	9.64	10.74	62.5
	50	-51.50	3.97	8.22	42.5
	35	-150.67	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

Sample ID: NRG-6-111.0-SNL-G
Lithology: Welded Devitrified
TMU: TCw

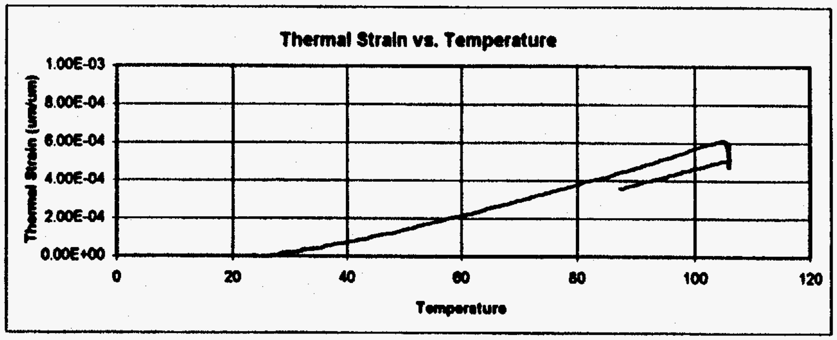
Test condition: Air-Dry
Sample Size: 2" (l) x 1" (d)

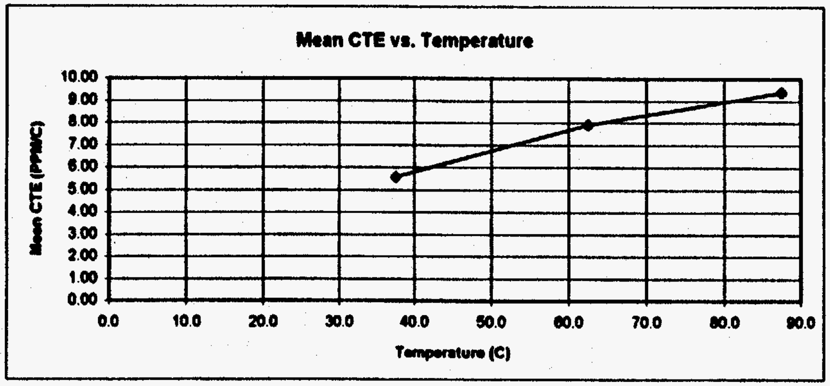
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	56.91	50.90	25.79	2.21
post-test:	56.76	50.88	25.78	2.20

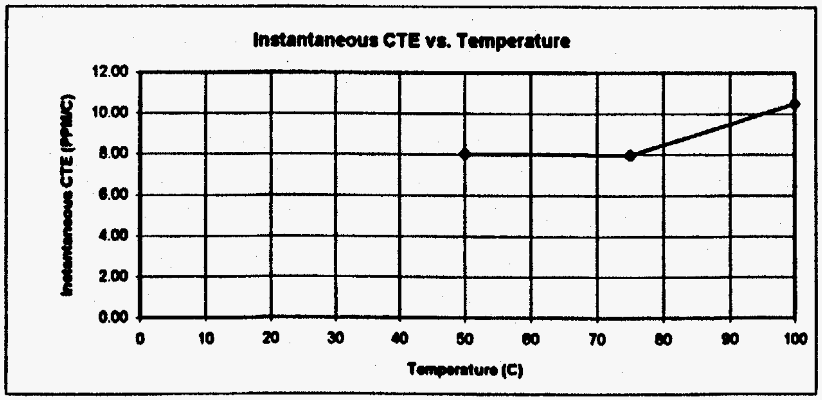
	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
Heat-up	25	-0.37	* * *	* * *	
	50	139.05	5.58	8.04	37.5
	75	336.93	7.92	7.97	62.5
	100	571.74	9.39	10.49	87.5
Cool-down	100	**	**	**	87.5
	75	**	**	**	62.5
	50	**	**	**	42.5
	35	**	**	**	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.

** No data is presented for the cool-down on this sample because the test program crashed during this range.







Data Summary

Sample ID: NRG-6-111.0-SNL-G
Lithology: Welded Devitrified
TMU: TCw

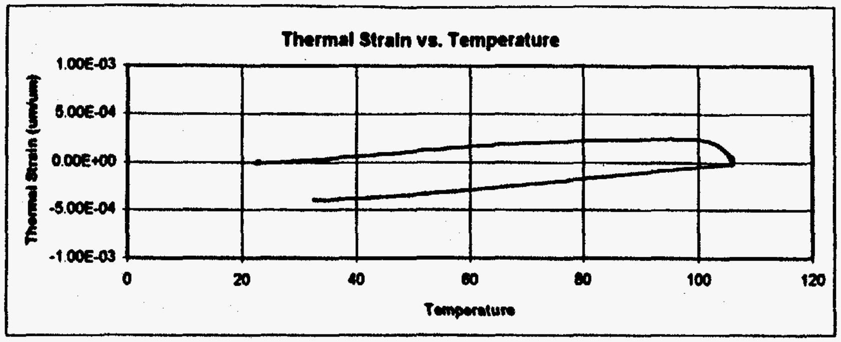
Test condition: Air-Dry
Sample Size: 2" (l) x 1" (d)

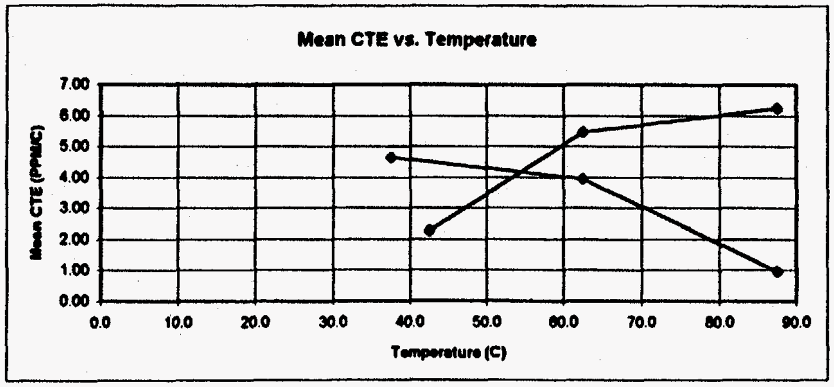
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	56.91	50.90	25.79	2.21
post-test:	56.76	50.88	25.78	2.20

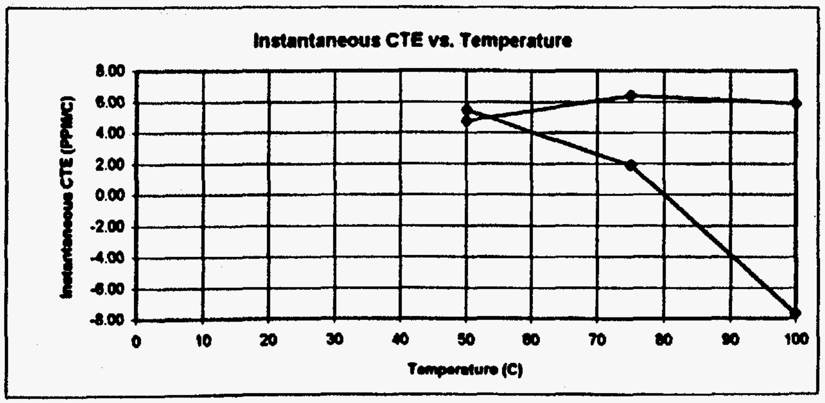
	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
Heat-up	25	-0.37	***	***	
	50	139.05	5.58	8.04	37.5
	75	336.93	7.92	7.97	62.5
	100	571.74	9.39	10.49	87.5
Cool-down	100	**	**	**	87.5
	75	**	**	**	62.5
	50	**	**	**	42.5
	35	**	**	**	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.

** No data is presented for the cool-down on this sample because the test program crashed during this range.







Data Summary

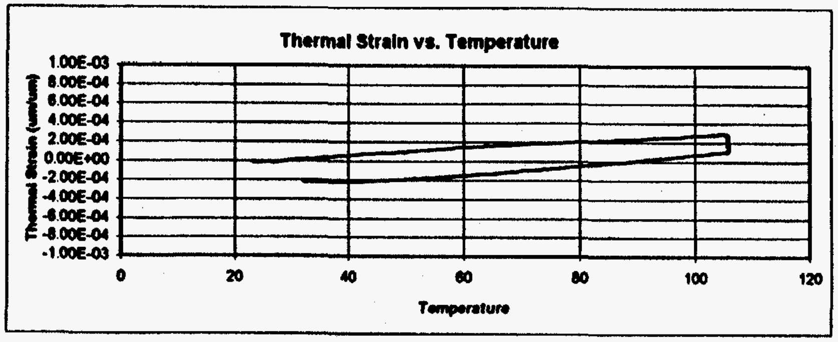
Sample ID: NRG-6-152.9-SNL-C
Lithology: Nonwelded Vitric
TMU: PTn

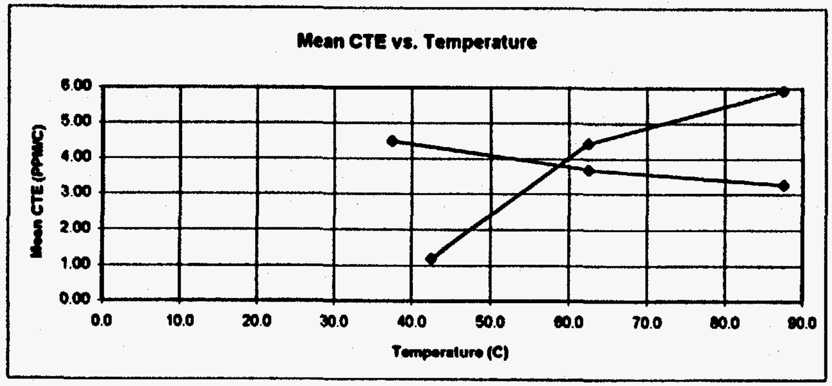
Test condition: Air-Dry
Sample Size: 2" (l) x 1" (d)

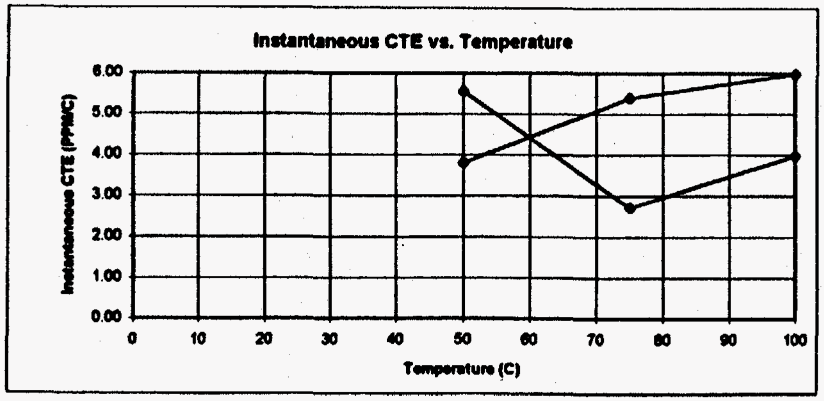
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	34.93	50.24	25.46	1.37
post-test:	34.56	50.23	25.45	1.36

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
Heat-up	25	-3.72	***	***	
	50	112.38	4.64	5.48	37.5
	75	211.43	3.96	1.88	62.5
	100	235.46	0.96	-7.65	87.5
Cool-down	100	-46.56	6.24	5.90	87.5
	75	-202.60	5.46	6.42	62.5
	50	-339.09	2.28	4.75	42.5
	35	-396.10	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







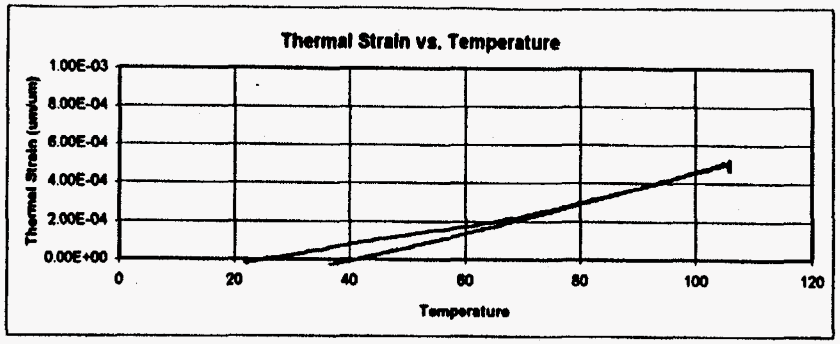
Data Summary

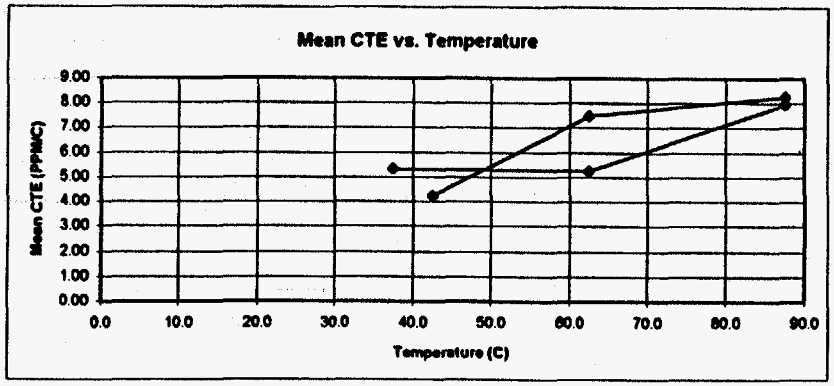
Sample ID:	NRG-6-187.0-SNL-D
Lithology:	Nonwelded Vitric
TMU:	PTn
Test condition:	Air-Dry
Sample Size:	2" (l) x 1" (d)

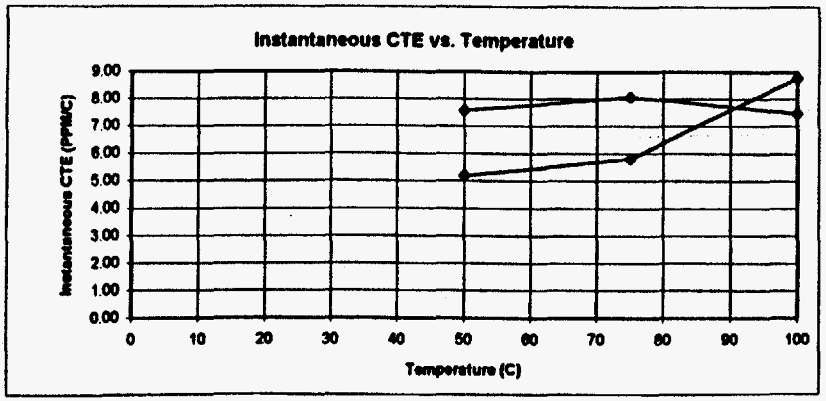
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	25.41	50.83	25.76	0.99
post-test:	25.35	50.83	25.76	0.98

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (^oC)
Heat-up	25	-13.12	***	***	
	50	99.09	4.49	5.56	37.5
	75	191.71	3.71	2.72	62.5
	100	273.58	3.27	3.99	87.5
Cool-down	100	70.81	5.93	5.98	87.5
	75	-77.35	4.45	5.40	62.5
	50	-188.56	1.19	3.81	42.5
	35	-218.42	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

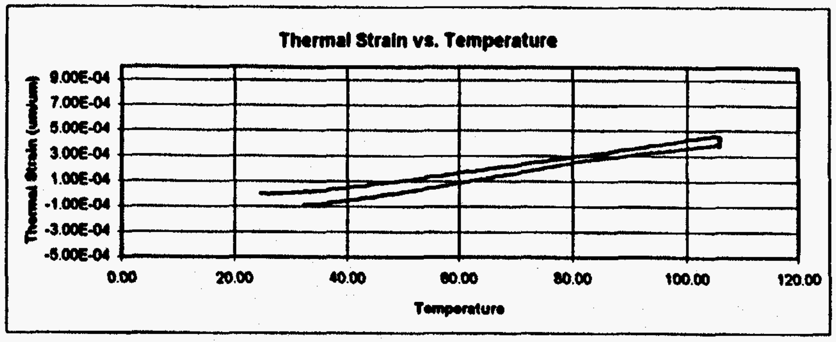
Sample ID: NRG-6-277.5-SNL-C
Lithology: Welded Devitrified
TMU: TSw1

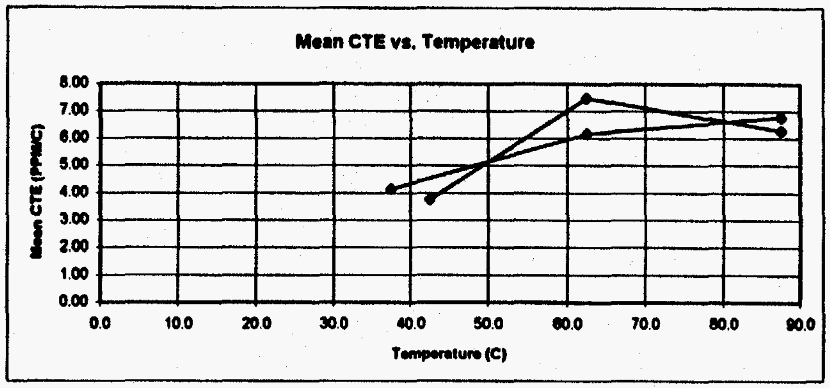
Test condition: Air-Dry
Sample Size: 2" (l) x 1" (d)

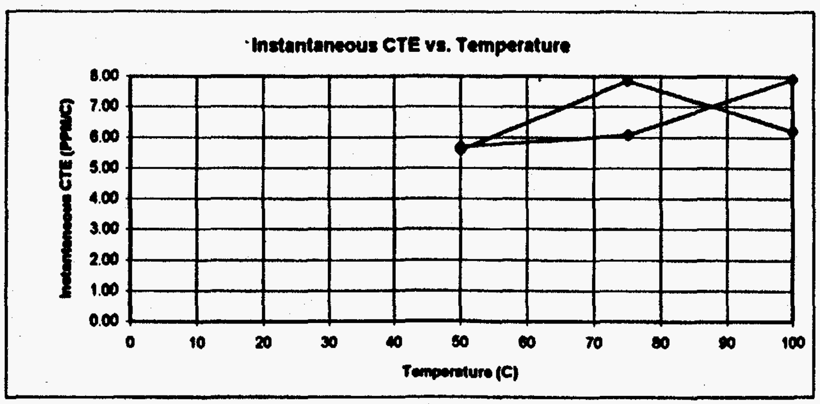
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	58.00	50.82	25.75	2.25
post-test:	57.99	50.82	25.75	2.25

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (^{o}C)
Heat-up	25	-1.25	***	***	
	50	131.99	5.33	5.19	37.5
	75	263.59	5.26	5.82	62.5
	100	462.27	7.95	8.79	87.5
Cool-down	100	456.91	8.26	7.48	87.5
	75	250.44	7.49	8.07	62.5
	50	63.24	4.23	7.57	42.5
	35	-42.46	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







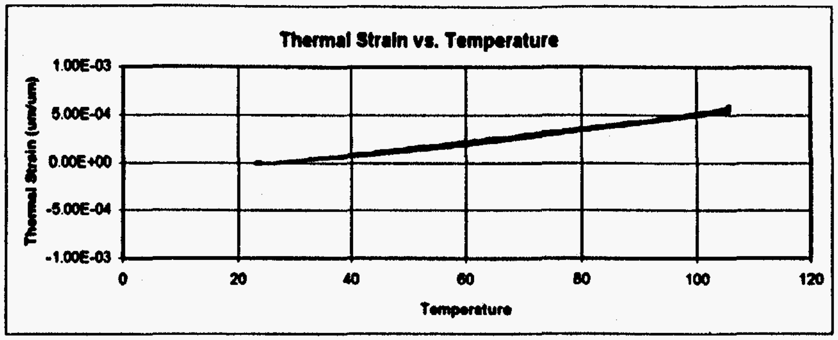
Data Summary

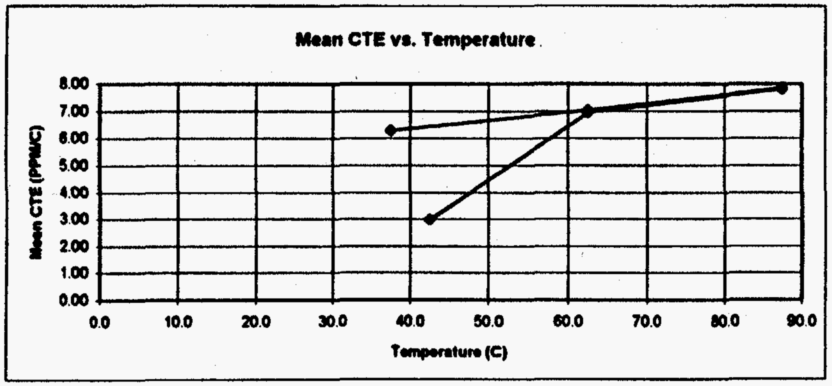
Sample ID:	NRG-6-321.1-SNL-C
Lithology:	Welded Devitrified
TMU:	TSw1
Test condition:	Air-Dry
Sample Size:	2" (l) x 1" (d)

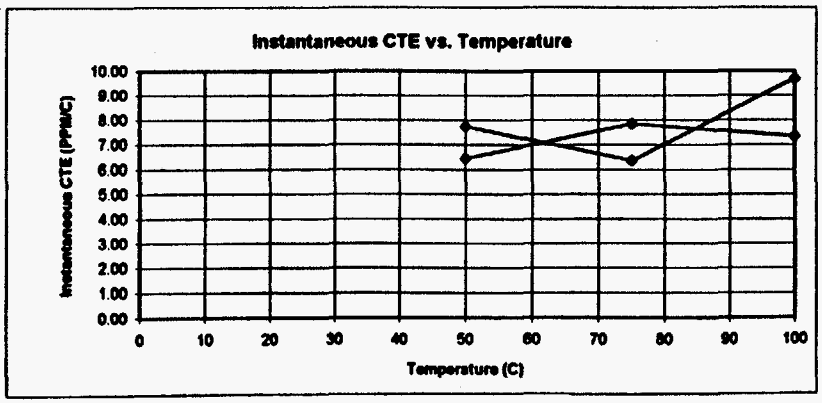
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	54.32	50.83	25.76	2.11
post-test:	54.29	50.83	25.76	2.11

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
Heat-up	25	2.79	***	***	
	50	105.97	4.13	5.69	37.5
	75	260.26	6.17	6.08	62.5
	100	429.99	6.79	7.91	87.5
Cool-down	100	360.17	6.29	6.19	87.5
	75	202.94	7.48	7.86	62.5
	50	15.81	3.76	5.58	42.5
	35	-76.06	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

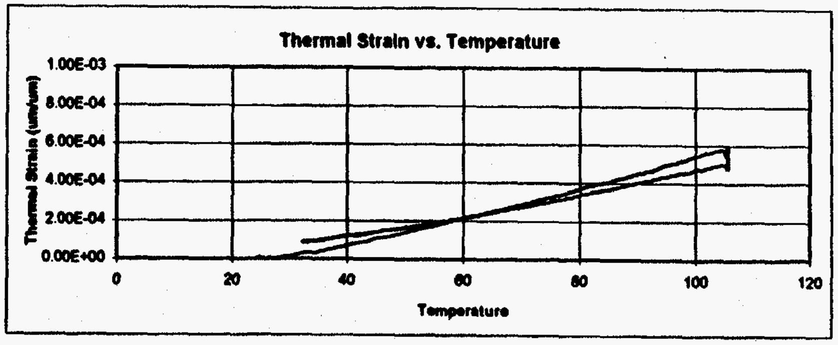
Sample ID: NRG-6-354.9-SNL-D
Lithology: Welded Devitrified
TMU: TSw1

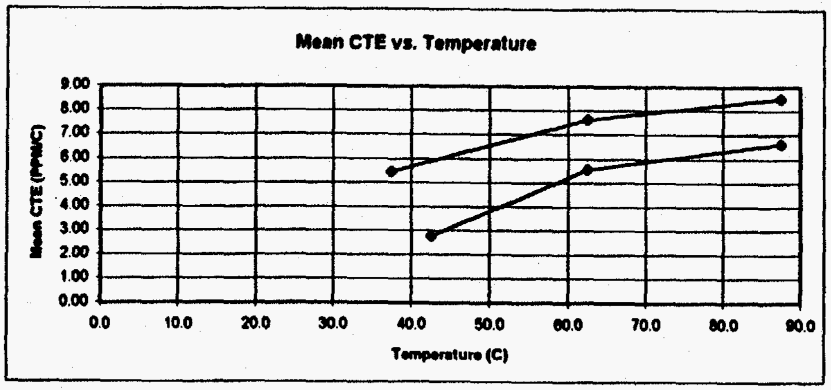
Test condition: Air-Dry
Sample Size: 2" (l) x 1" (d)

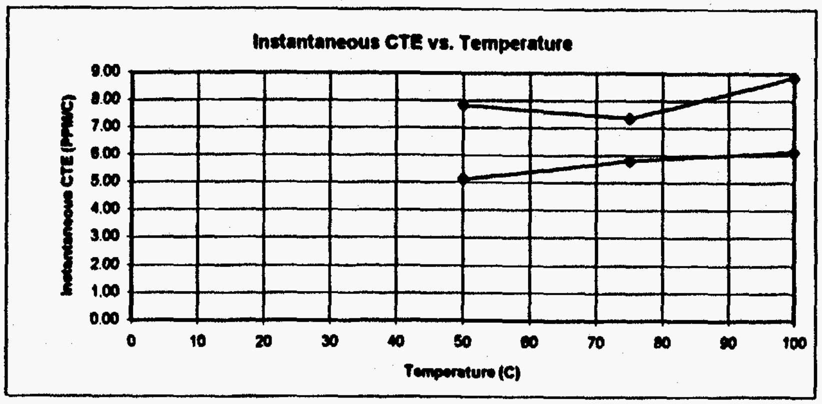
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	52.16	50.91	25.80	2.02
post-test:	52.16	50.92	25.80	2.02

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (^{0}C)
Heat-up	25	-4.70	***	***	
	50	152.67	6.29	7.73	37.5
	75	328.42	7.03	6.38	62.5
	100	525.10	7.87	9.68	87.5
Cool-down	100	488.72	7.80	7.35	87.5
	75	293.82	6.94	7.84	62.5
	50	120.38	2.98	6.44	42.5
	35	45.76	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







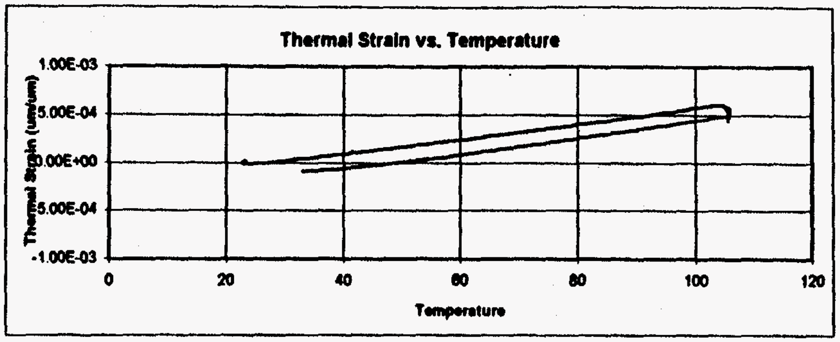
Data Summary

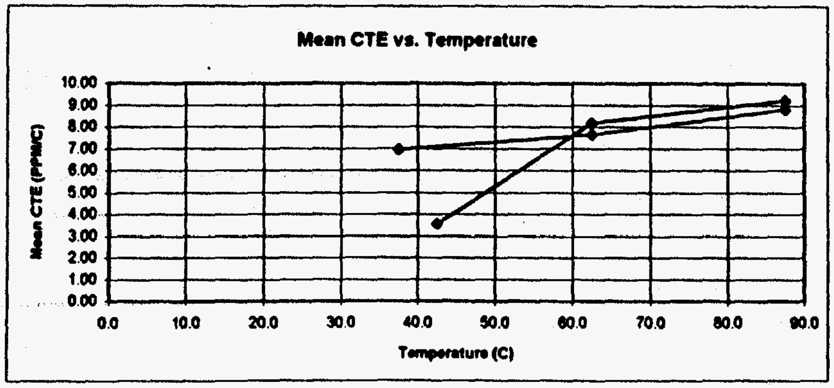
Sample ID:	NRG-6-392.1-SNL-E
Lithology:	Welded Devitrified
TMU:	TSw1
Test condition:	Air-Dry
Sample Size:	2" (l) x 1" (d)

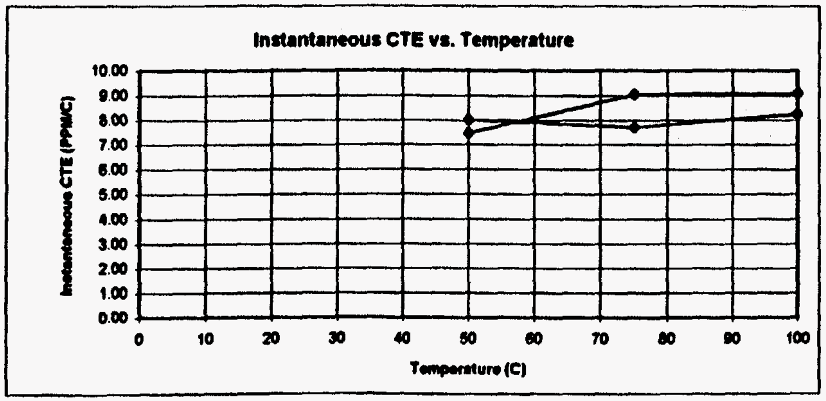
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	56.30	50.86	25.77	2.18
post-test:	56.07	50.86	25.77	2.18

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (^{o}C)
Heat-up	25	3.27	***	***	
	50	139.65	5.45	7.83	37.5
	75	330.14	7.62	7.37	62.5
	100	543.14	8.52	8.85	87.5
Cool-down	100	470.94	6.64	6.14	87.5
	75	304.89	5.57	5.80	62.5
	50	165.66	2.76	5.12	42.5
	35	96.76	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







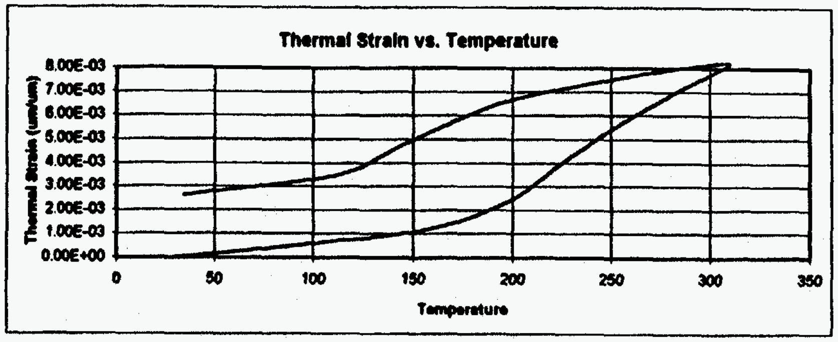
Data Summary

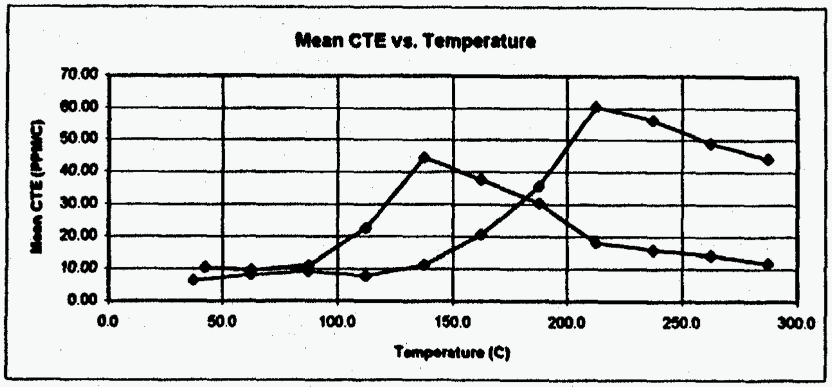
Sample ID:	NRG-6-416.0-SNL-L
Lithology:	Welded Devitrified
TMU:	TSw1
Test condition:	Air-Dry
Sample Size:	2" (l) x 1" (d)

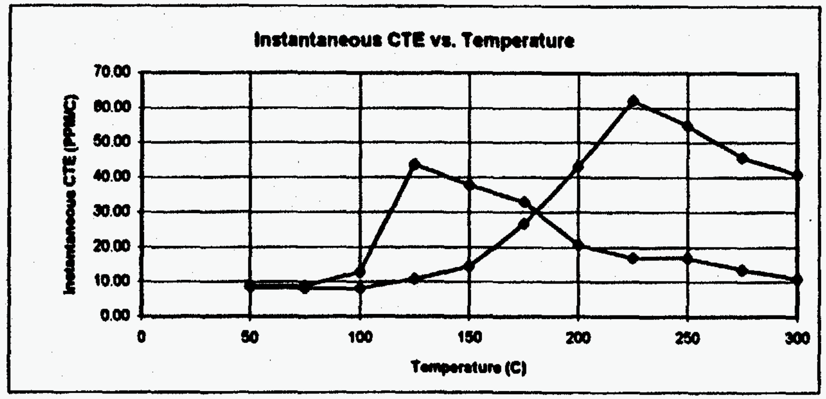
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	55.48	50.88	25.78	2.15
post-test:	55.10	50.87	25.78	2.14

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
Heat-up	25	-6.42	***	***	
	50	167.66	6.96	8.02	37.5
	75	358.89	7.65	7.71	62.5
	100	578.67	8.79	8.27	87.5
Cool-down	100	441.48	9.21	9.12	87.5
	75	211.24	8.17	9.05	62.5
	50	7.06	3.54	7.48	42.5
	35	-81.47	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

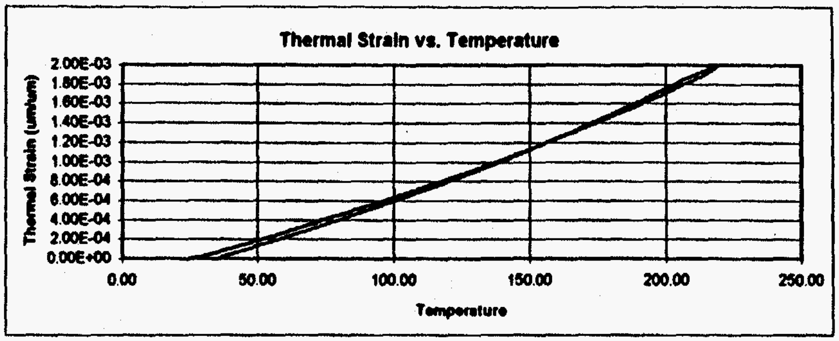
Sample ID: NRG-6-421.8-SNL-A
Lithology: Welded Devitrified
TMU: TSw1

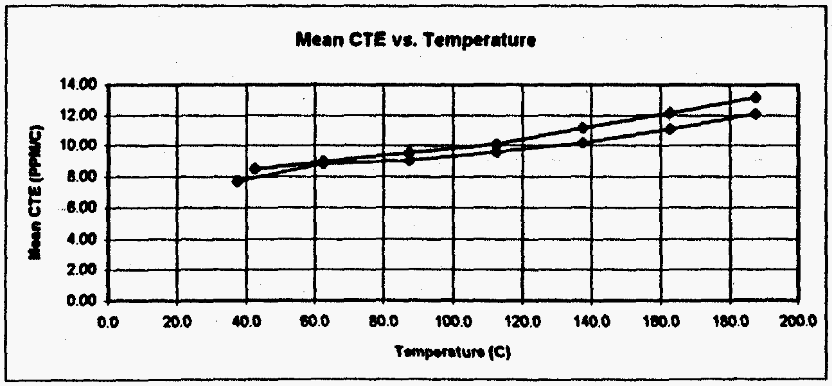
Test condition: AIR DRY
Sample Size: 2" (l) x 1" (d)

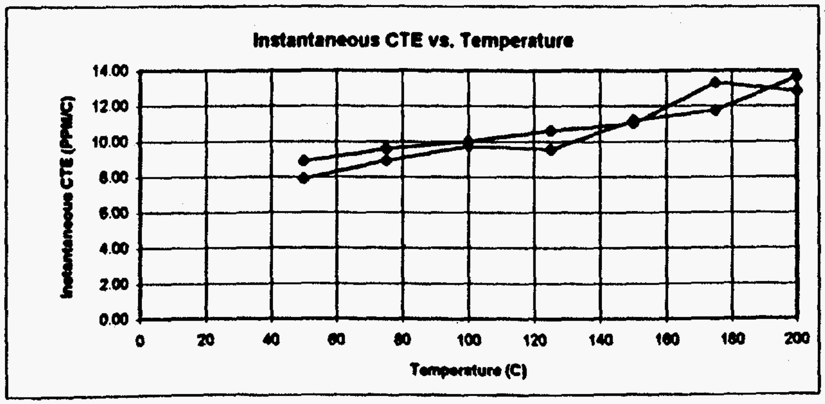
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	56.09	50.88	25.78	2.18
post-test:	55.55	50.95	25.82	2.15

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
Heat-up	25	4.79	***	***	
	50	167.34	6.50	8.47	37.5
	75	373.85	8.26	8.17	62.5
	100	602.76	9.16	8.16	87.5
	125	799.21	7.86	10.78	112.5
	150	1080.30	11.24	14.44	137.5
	175	1591.58	20.45	26.60	162.5
	200	2482.69	35.64	43.22	187.5
	225	3996.12	60.54	62.11	212.5
	250	5405.88	56.39	54.94	237.5
	275	6631.30	49.02	45.80	262.5
	300	7737.04	44.23	40.90	287.5
Cool-down	300	8176.58	11.94	10.91	287.5
	275	7677.98	14.30	13.57	262.5
	250	7520.47	15.63	16.99	237.5
	225	7124.71	18.02	16.98	212.5
	200	6674.17	30.33	20.74	187.5
	175	5915.92	37.63	32.94	162.5
	150	4975.21	44.43	37.88	137.5
	125	3864.51	22.47	43.80	112.5
	100	3302.82	11.15	12.82	87.5
	75	3024.13	9.64	8.90	62.5
	50	2783.25	10.43	8.92	42.5
	35	2626.77	***	***	

** Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.*







Data Summary

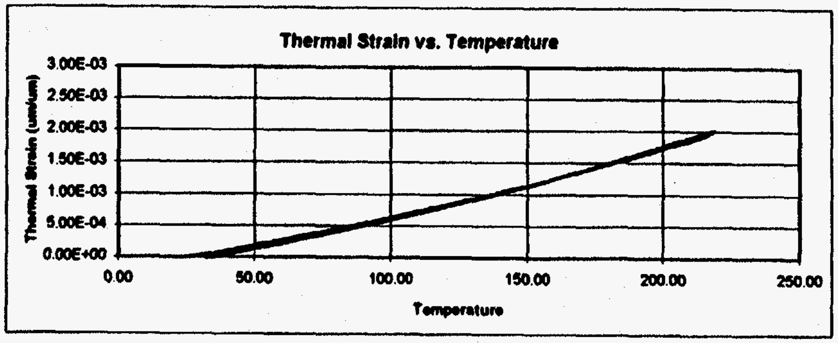
Sample ID: NRG-6-729.2-SNL-C
Lithology: Welded Devitrified
TMU: TSw2

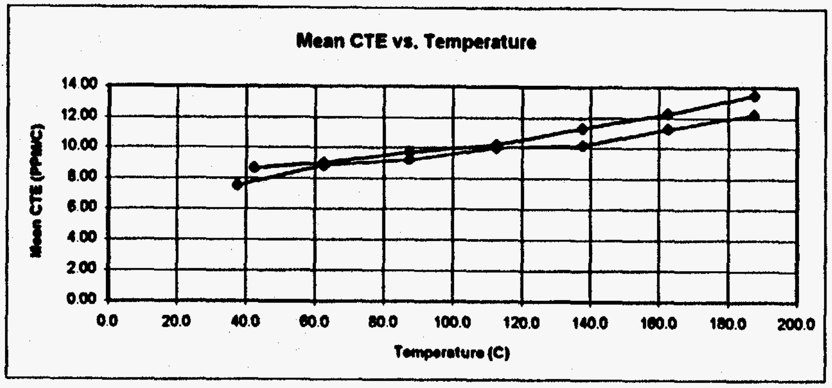
Test condition: Air-Dried
Sample Size: 2" (l) x 1" (d)

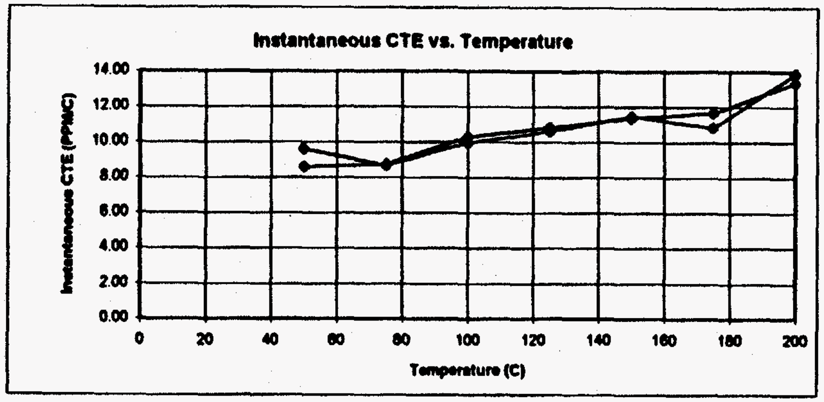
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	58.70	50.90	25.79	2.28
post-test:	58.35	50.88	25.78	2.26

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (^{o}C)
Heat-up	25	0.27	***	***	
	50	192.43	7.69	7.89	37.5
	75	412.79	8.81	8.93	62.5
	100	639.06	9.05	9.71	87.5
	125	878.80	9.59	9.53	112.5
	150	1133.32	10.18	11.21	137.5
	175	1410.41	11.08	11.75	162.5
	200	1712.97	12.10	13.68	187.5
Cool-down	200	1760.83	13.22	12.85	187.5
	175	1430.32	12.14	13.33	162.5
	150	1126.91	11.16	11.00	137.5
	125	847.81	10.07	10.62	112.5
	100	596.05	9.54	10.02	87.5
	75	357.58	8.97	9.58	62.5
	50	133.45	8.48	8.87	42.5
	35	6.31	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

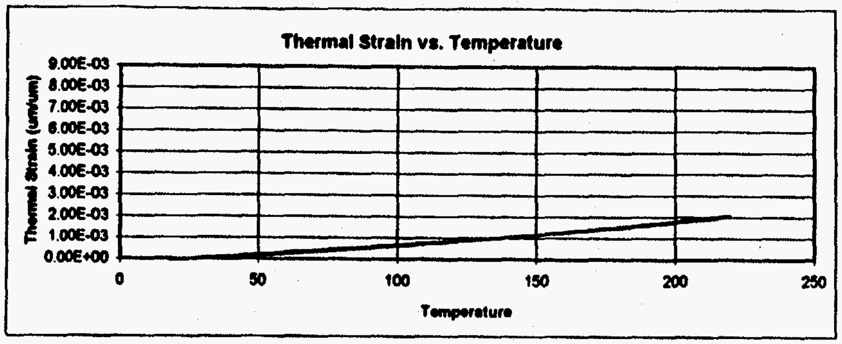
Sample ID: NRG-6-732.6-SNL-B
Lithology: Welded Devitrified
TMU: TSw2

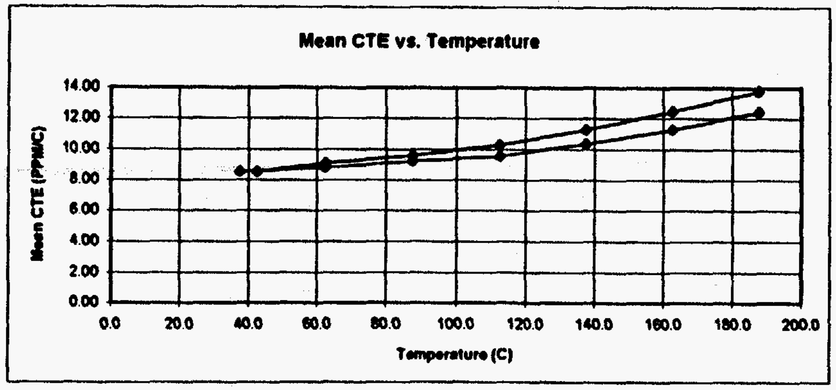
Test condition: AIR-DRIED
Sample Size: 2" (l) x 1" (d)

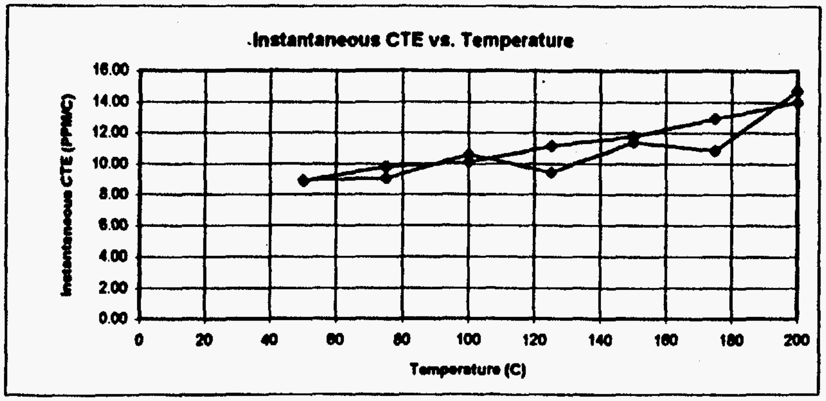
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	58.11	50.85	25.77	2.26
post-test:	57.86	50.85	25.77	2.25

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (^oC)
Heat-up	25	0.15	***	***	
	50	188.71	7.54	9.58	37.5
	75	409.06	8.81	8.68	62.5
	100	639.04	9.20	9.93	87.5
	125	889.57	10.02	10.61	112.5
	150	1143.72	10.17	11.45	137.5
	175	1425.50	11.27	10.82	162.5
	200	1731.21	12.23	13.90	187.5
Cool-down	200	1776.69	13.51	13.36	187.5
	175	1438.93	12.27	11.68	162.5
	150	1132.10	11.30	11.34	137.5
	125	849.72	10.20	10.84	112.5
	100	594.62	9.73	10.30	87.5
	75	351.40	8.99	8.73	62.5
	50	126.54	8.65	8.60	42.5
	35	-3.16	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







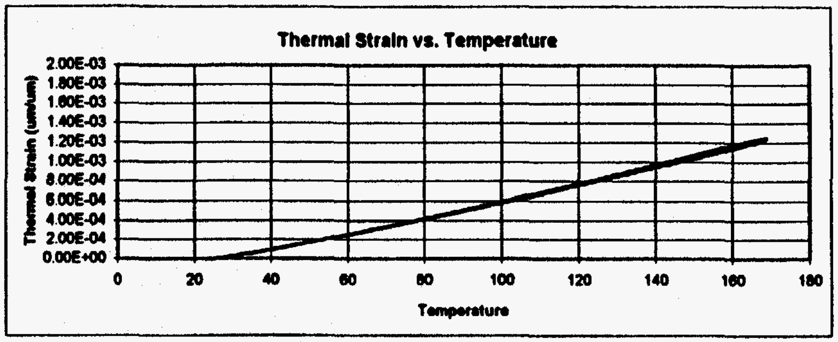
Data Summary

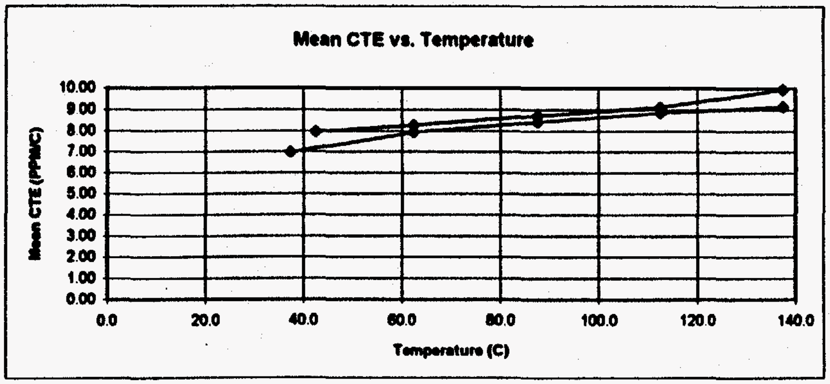
Sample ID:	NRG-6-806.0-SNL-C
Lithology:	Welded Devitrified
TMU:	TSw2
Test condition:	Air-Dried
Sample Size:	2" (l) x 1" (d)

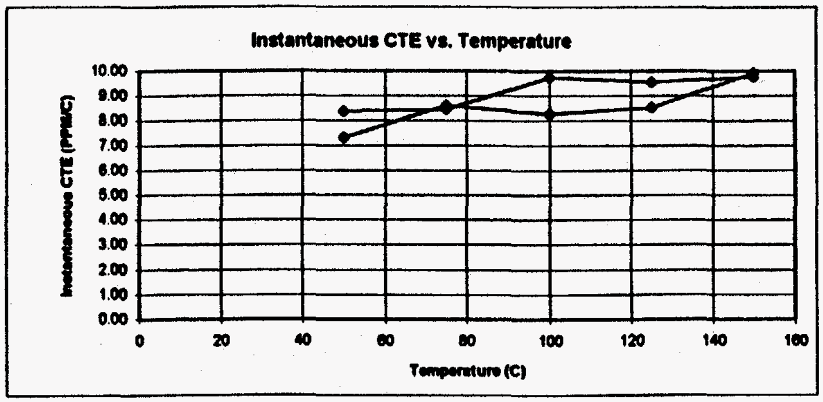
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	58.63	50.90	25.79	2.27
post-test:	58.46	50.90	25.79	2.27

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (^{0}C)
Heat-up	25	0.59	***	***	
	50	213.87	8.53	8.92	37.5
	75	434.24	8.82	9.07	62.5
	100	664.99	9.23	10.63	87.5
	125	903.66	9.55	9.45	112.5
	150	1162.41	10.35	11.40	137.5
	175	1444.53	11.29	10.85	162.5
	200	1755.15	12.42	14.72	187.5
Cool-down	200	1813.72	13.78	13.98	187.5
	175	1469.28	12.49	12.92	162.5
	150	1157.00	11.30	11.77	137.5
	125	874.63	10.27	11.15	112.5
	100	617.94	9.59	10.10	87.5
	75	378.15	9.08	9.81	62.5
	50	151.14	8.53	8.68	42.5
	35	23.12	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







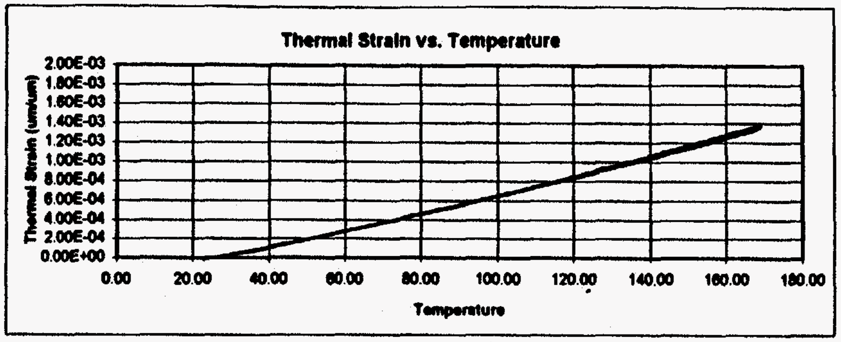
Data Summary

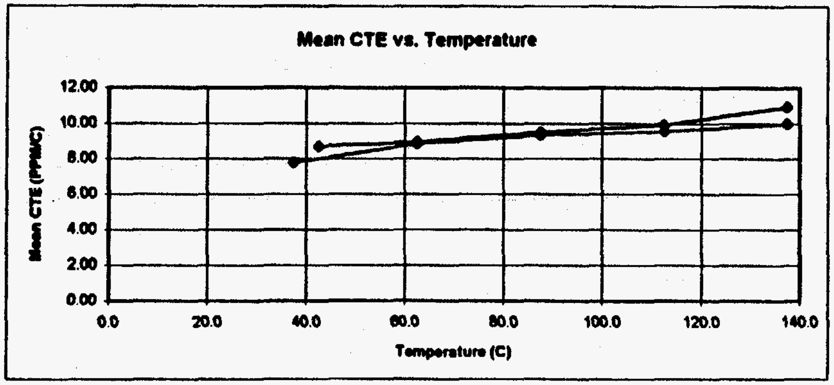
Sample ID:	NRG-6-911.2-SNL-C
Lithology:	Welded Devitrified
TMU:	TSw2
Test condition:	Air-Dried
Sample Size:	2" (l) x 1" (d)

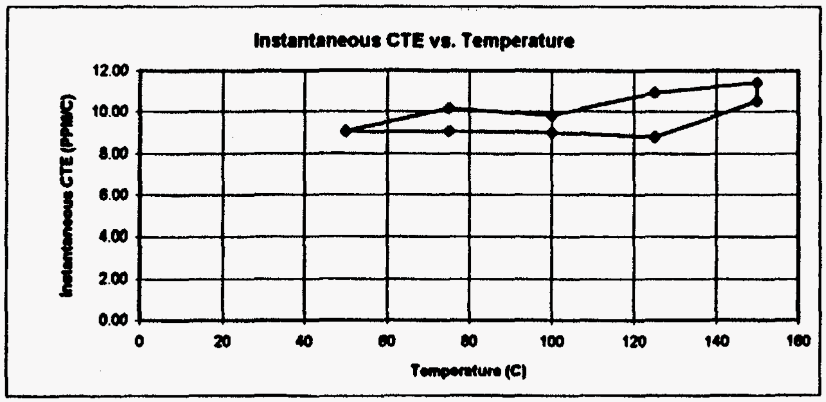
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	59.38	50.88	25.78	2.30
post-test:	59.20	50.88	25.78	2.30

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (^oC)
Heat-up	25	-0.16	***	***	
	50	174.25	6.98	7.31	37.5
	75	372.07	7.91	8.61	62.5
	100	582.44	8.42	8.25	87.5
	125	803.83	8.86	8.53	112.5
	150	1032.52	9.15	9.93	137.5
Cool-down	150	1073.48	9.94	9.76	137.5
	125	824.97	9.12	9.55	112.5
	100	596.89	8.71	9.74	87.5
	75	379.13	8.26	8.44	62.5
	50	172.58	7.97	8.37	42.5
	35	53.05	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

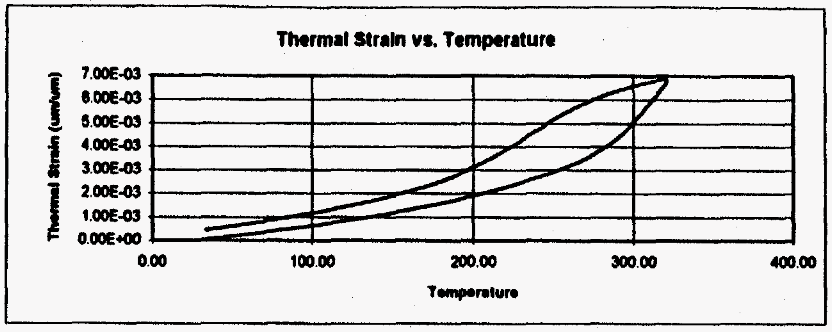
Sample ID:	NRG-6-926.3-SNL-C
Lithology:	Welded Devitrified
TMU:	TSw2
Test condition:	Air-dried
Sample Size:	2" (l) x 1" (d)

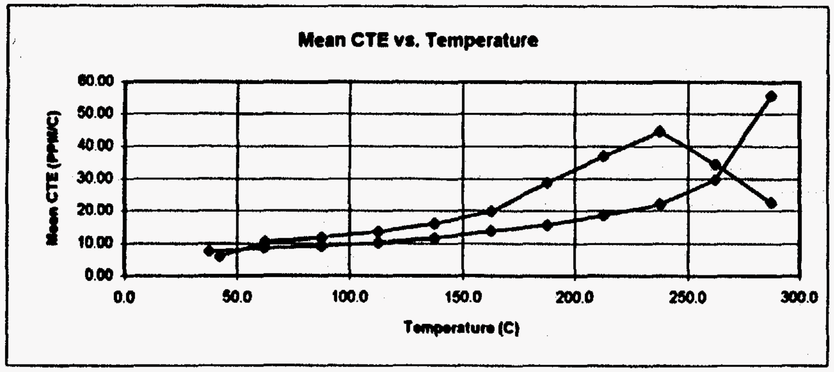
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
pre-test:	57.62	50.85	25.77	2.24
post-test:	57.44	50.83	25.76	2.23

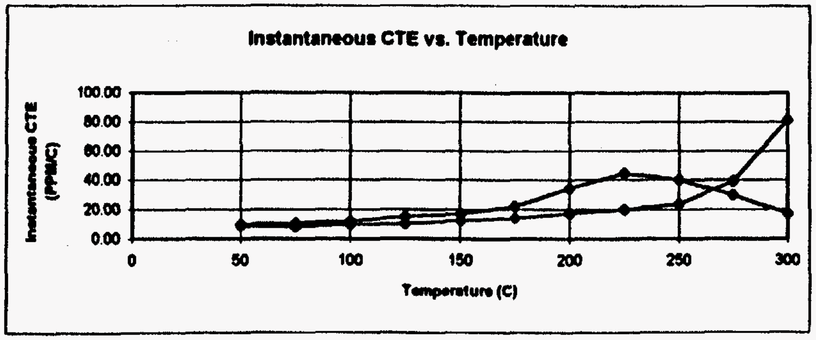
	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (^{o}C)
Heat-up	25	0.47	***	***	
	50	195.20	7.79	9.02	37.5
	75	416.49	8.85	9.06	62.5
	100	649.60	9.32	9.01	87.5
	125	888.73	9.57	8.78	112.5
	150	1138.57	9.99	10.53	137.5
Cool-down	150	1176.04	10.95	11.44	137.5
	125	902.23	9.93	10.92	112.5
	100	654.01	9.53	9.82	87.5
	75	415.63	8.97	10.17	62.5
	50	191.55	8.70	9.07	42.5
	35	61.00	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.

<u>Data Summaries for NRG-7</u>







Data Summary

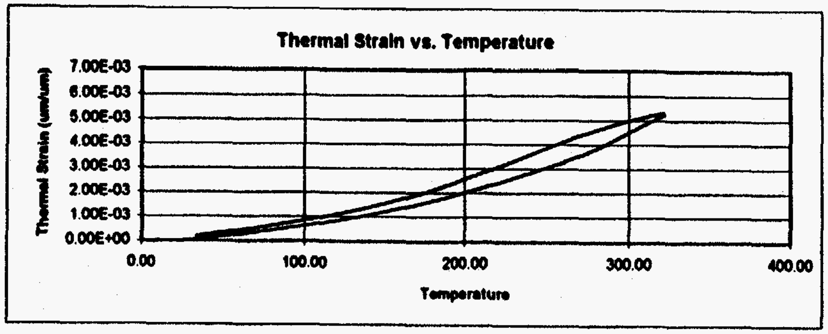
Sample ID: NRG-7-18.6-SNL-A
Lithology: Welded Devitrified
TMU: TCw

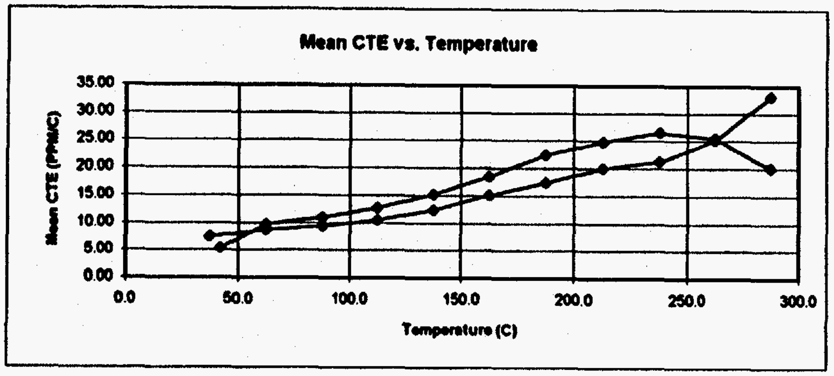
Test condition: AIR DRIED
Sample Size: 2" (l) x 1" (d)

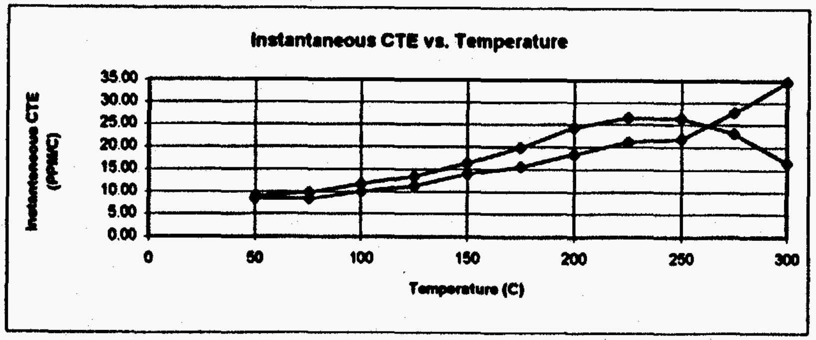
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
Initial:	59.64	50.88	25.78	2.31
Final:	59.59	50.90	25.79	2.31

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
Heat up	25	1.74	***	***	
	50	189.99	7.53	9.10	37.5
	75	403.74	8.55	8.00	62.5
	100	636.02	9.29	9.71	87.5
	125	890.55	10.18	10.49	112.5
	150	1182.15	11.66	12.50	137.5
	175	1526.95	13.79	14.29	162.5
	200	1919.12	15.69	17.41	187.5
	225	2384.79	18.63	19.90	212.5
	250	2934.96	22.01	23.79	237.5
	275	3679.07	29.76	39.31	262.5
	300	5071.56	55.70	81.37	287.5
Cool down	300	6593.20	22.69	17.52	287.5
	275	6025.93	34.50	29.74	262.5
	250	5163.51	44.47	40.03	237.5
	225	4051.66	36.90	44.63	212.5
	200	3129.17	28.72	34.22	187.5
	175	2411.13	19.79	22.54	162.5
	150	1916.35	16.02	17.42	137.5
	125	1515.83	13.68	14.98	112.5
	100	1173.88	11.76	11.87	87.5
	75	879.79	10.52	10.89	62.5
	50	616.82	5.99	9.96	42.5
	35	467.05	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

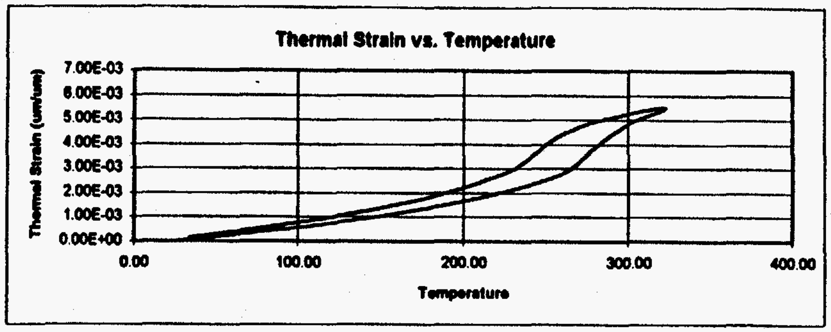
Sample ID:	NRG-7-27.3-SNL-A
Lithology:	Welded Devitrified
TMU:	TCw
Test condition:	AIR DRIED
Sample Size:	2" (l) x 1" (d)

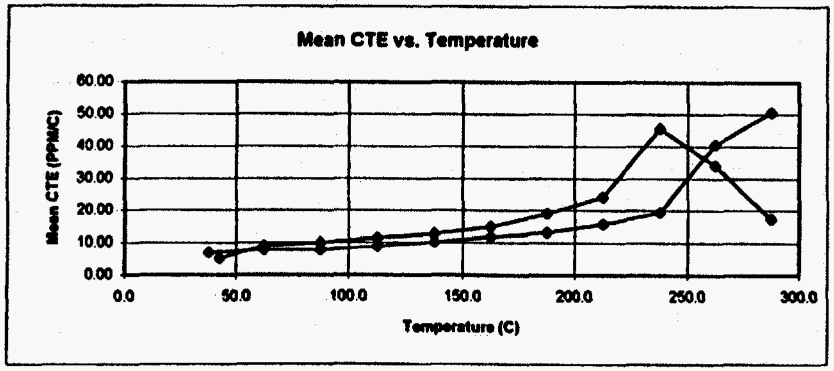
Sample Data:

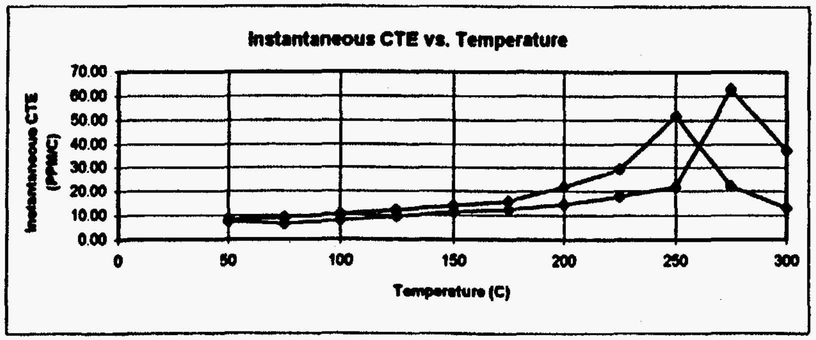
	mass (g)	length (mm)	volume (cc)	density (g/cc)
Initial:	60.23	50.80	25.74	2.34
Final:	60.18	50.80	25.74	2.34

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (^oC)
Heat up	25	0.46	***	***	
	50	188.69	7.53	8.38	37.5
	75	405.29	8.66	8.34	62.5
	100	639.26	9.36	9.95	87.5
	125	903.25	10.56	11.31	112.5
	150	1214.47	12.45	13.94	137.5
	175	1590.97	15.06	15.62	162.5
	200	2027.06	17.44	18.40	187.5
	225	2528.80	20.07	21.11	212.5
	250	3061.84	21.32	21.96	237.5
	275	3692.36	25.22	27.73	262.5
	300	4521.27	33.16	34.76	287.5
Cool down	300	5007.52	20.11	16.57	287.5
	275	4504.72	25.54	23.24	262.5
	250	3866.22	26.55	26.46	237.5
	225	3202.53	24.82	26.62	212.5
	200	2581.97	22.47	24.30	187.5
	175	2020.27	18.49	19.92	162.5
	150	1558.06	15.23	16.36	137.5
	125	1177.24	12.72	13.36	112.5
	100	859.29	11.03	11.64	87.5
	75	583.56	9.77	9.65	62.5
	50	339.32	5.43	8.97	42.5
	35	203.57	***	***	

* Mean CTE's [redacted] calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

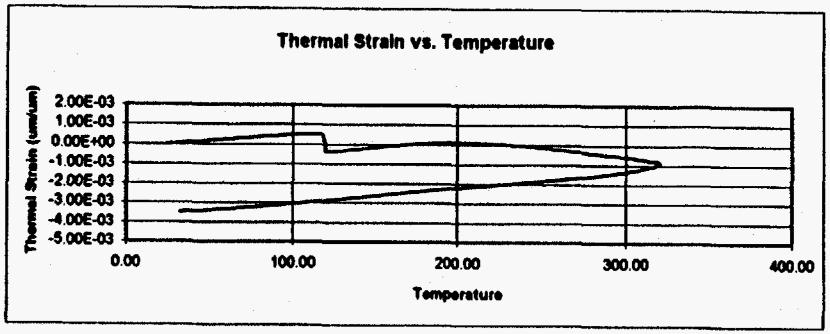
Sample ID: NRG-7-56.8-SNL-A
Lithology: Welded Devitrified
TMU: TCw

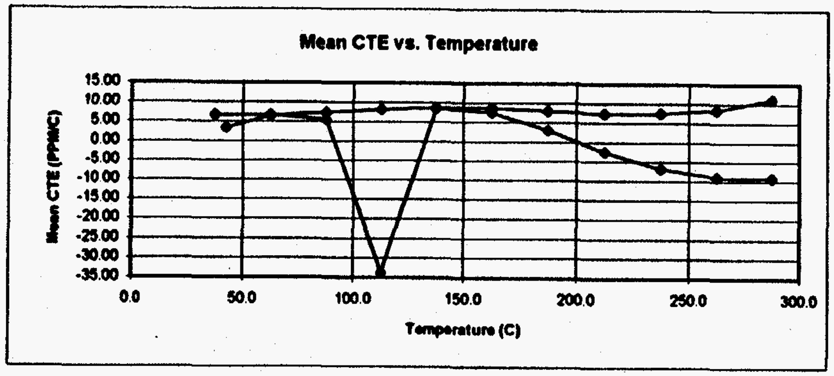
Test condition: AIR DRIED
Sample Size: 2" (l) x 1" (d)

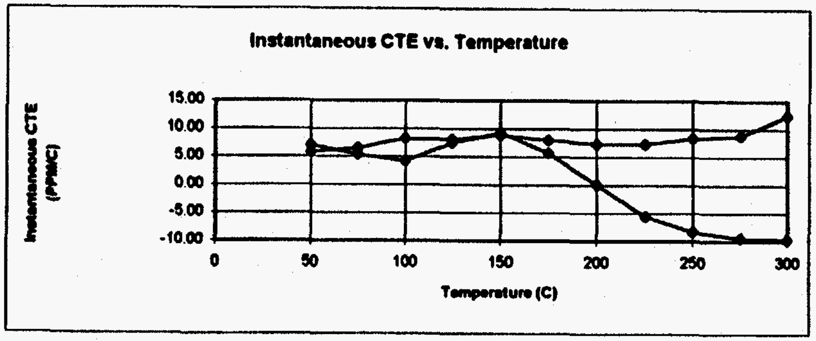
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
Initial:	53.28	50.88	25.78	2.07
Final:	53.21	50.88	25.78	2.06

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (^oC)
Heat up	25	0.35	***	***	
	50	174.38	6.96	7.71	37.5
	75	368.30	7.76	6.64	62.5
	100	564.40	7.84	7.96	87.5
	125	784.58	8.81	9.54	112.5
	150	1041.62	10.28	11.37	137.5
	175	1337.07	11.82	12.38	162.5
	200	1669.78	13.31	14.57	187.5
	225	2068.53	15.95	17.87	212.5
	250	2555.96	19.50	21.92	237.5
	275	3567.63	40.47	62.82	262.5
	300	4831.03	50.54	37.48	287.5
Cool down	300	5267.43	17.45	13.40	287.5
	275	4831.12	34.13	22.24	262.5
	250	3977.78	45.62	51.73	237.5
	225	2837.40	24.18	29.31	212.5
	200	2232.79	19.05	22.05	187.5
	175	1756.45	15.14	15.93	162.5
	150	1377.86	12.85	14.10	137.5
	125	1056.56	11.40	12.15	112.5
	100	771.68	10.11	10.60	87.5
	75	518.87	9.06	9.13	62.5
	50	291.80	5.15	8.39	42.5
	35	163.11	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







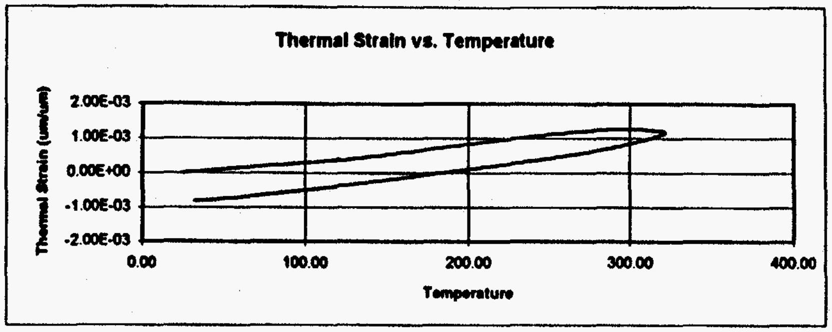
Data Summary

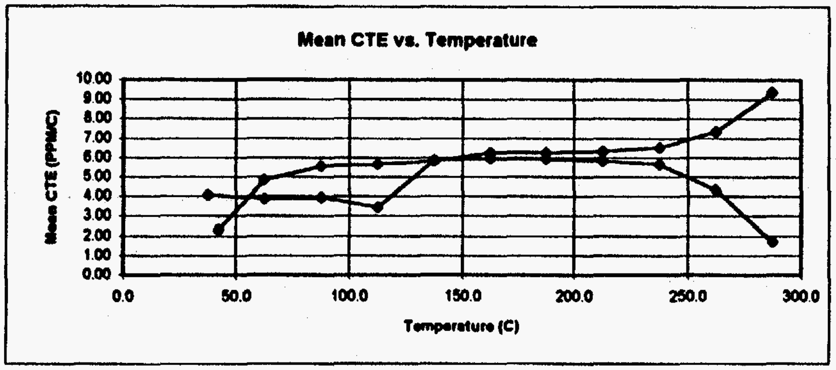
Sample ID:	NRG-7-75.0-SNL-B
Lithology:	Nonwelded Vitric
TMU:	PTn
Test condition:	AIR DRIED
Sample Size:	2" (l) x 1" (d)

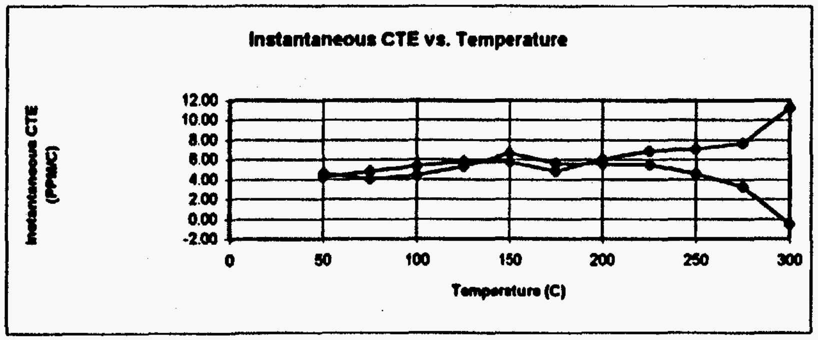
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
Initial:	45.60	50.80	25.74	1.77
Final:	43.47	50.65	25.66	1.69

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (^oC)
Heat up	25	3.29	***	***	
	50	169.93	6.67	7.12	37.5
	75	337.66	6.71	5.41	62.5
	100	476.20	5.54	4.28	87.5
	125	-364.90	-33.64	7.45	112.5
	150	-151.42	8.54	9.34	137.5
	175	36.24	7.51	5.69	162.5
	200	111.88	3.03	0.11	187.5
	225	47.58	-2.57	-5.56	212.5
	250	-124.48	-6.88	-8.31	237.5
	275	-349.47	-9.00	-9.42	262.5
	300	-577.77	-9.13	-9.61	287.5
Cool down	300	-1327.48	11.18	12.49	287.5
	275	-1606.99	8.40	8.92	262.5
	250	-1816.93	7.54	8.37	237.5
	225	-2005.38	7.44	7.32	212.5
	200	-2191.44	8.03	7.39	187.5
	175	-2392.21	8.71	8.05	162.5
	150	-2610.02	8.68	8.89	137.5
	125	-2827.07	8.21	8.16	112.5
	100	-3032.40	7.39	8.27	87.5
	75	-3217.03	6.51	6.51	62.5
	50	-3379.87	3.45	5.85	42.5
	35	-3466.01	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







E-114

Data Summary

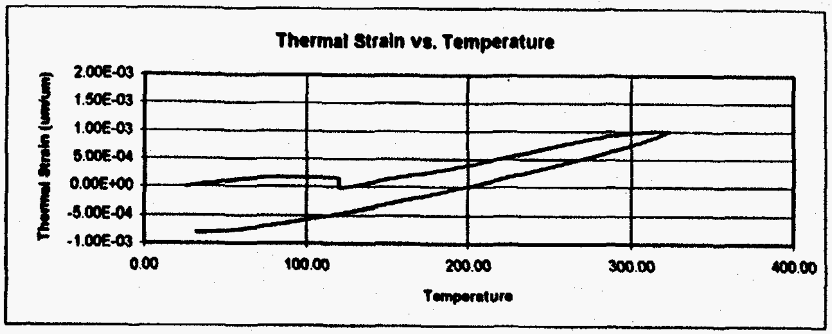
Sample ID: NRG-7-91.6-SNL-A
Lithology: Nonwelded Vitric
TMU: PTn

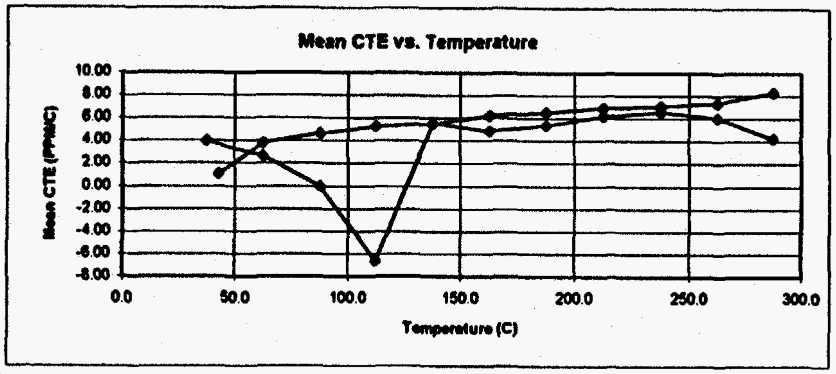
Test condition: AIR DRIED
Sample Size: 2" (l) x 1" (d)

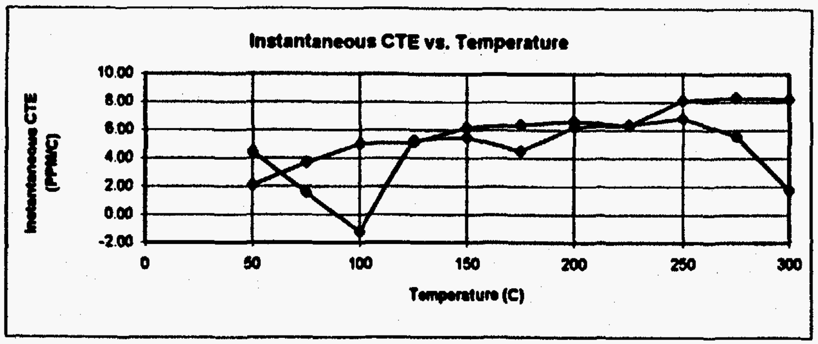
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
Initial:	34.29	50.70	25.69	1.33
Final:	34.15	50.67	25.67	1.33

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
Heat up	25	5.16	***	***	
	50	107.19	4.08	4.66	37.5
	75	204.04	3.87	4.01	62.5
	100	302.33	3.93	4.46	87.5
	125	388.82	3.46	5.31	112.5
	150	535.36	5.86	6.68	137.5
	175	684.03	5.95	5.64	162.5
	200	831.81	5.91	5.58	187.5
	225	977.23	5.82	5.50	212.5
	250	1118.72	5.66	4.54	237.5
	275	1227.26	4.34	3.29	262.5
	300	1270.02	1.71	-0.49	287.5
Cool down	300	850.74	9.38	11.30	287.5
	275	616.23	7.36	7.66	262.5
	250	432.26	6.52	7.09	237.5
	225	269.25	6.32	6.85	212.5
	200	111.21	6.26	6.04	187.5
	175	-45.27	6.25	4.85	162.5
	150	-201.44	5.83	5.74	137.5
	125	-347.20	5.66	5.80	112.5
	100	-488.77	5.57	5.36	87.5
	75	-627.91	4.84	4.84	62.5
	50	-748.84	2.30	4.25	42.5
	35	-806.42	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

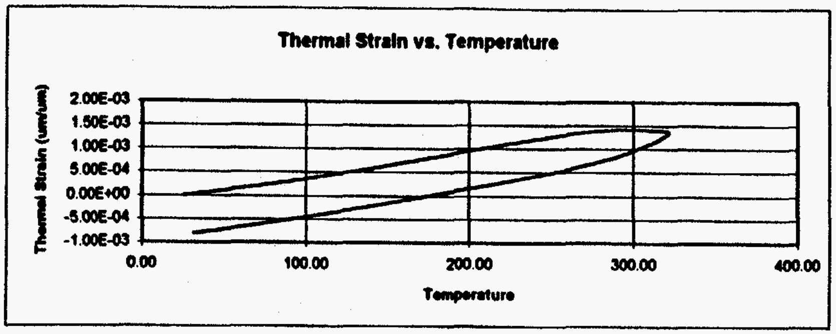
Sample ID: NRG-7-104.1-SNL-A
Lithology: Nonwelded Vitric
TMU: PTn

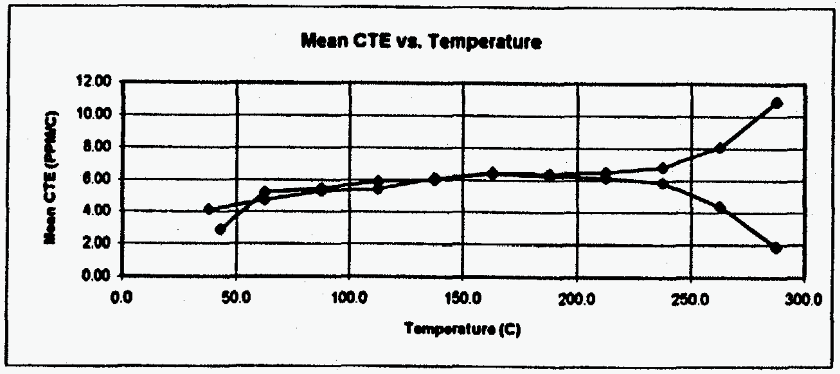
Test condition: AIR DRIED
Sample Size: 2" (l) x 1" (d)

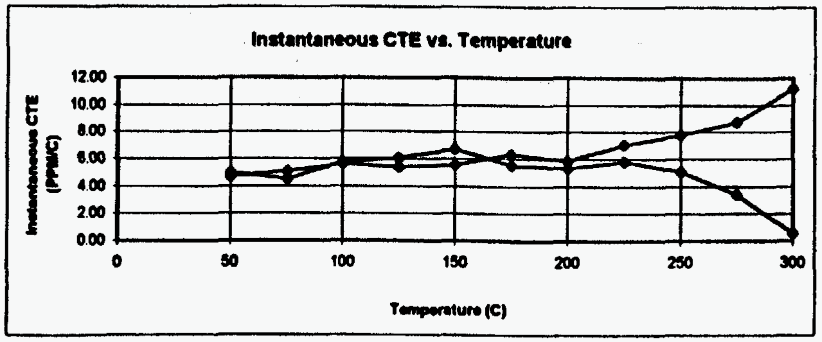
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
Initial:	23.91	50.83	25.76	0.93
Final:	23.64	50.77	25.73	0.92

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
Heat up	25	0.01	***	***	
	50	98.71	3.95	4.45	37.5
	75	165.17	2.66	1.56	62.5
	100	164.90	-0.01	-1.19	87.5
	125	-1.56	-6.66	5.31	112.5
	150	137.75	5.57	5.49	137.5
	175	259.11	4.85	4.49	162.5
	200	393.25	5.37	6.22	187.5
	225	548.34	6.20	6.39	212.5
	250	712.48	6.57	6.82	237.5
	275	864.15	6.07	5.57	262.5
	300	970.69	4.26	1.79	287.5
Cool down	300	756.16	8.31	8.24	287.5
	275	548.41	7.37	8.30	262.5
	250	364.27	7.10	8.16	237.5
	225	186.75	6.91	6.31	212.5
	200	13.91	6.53	6.66	187.5
	175	-149.35	6.22	6.37	162.5
	150	-304.79	5.52	6.19	137.5
	125	-442.81	5.27	5.10	112.5
	100	-574.62	4.63	5.01	87.5
	75	-690.32	3.77	3.69	62.5
	50	-784.61	1.07	2.07	42.5
	35	-811.28	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. *For example, the value for the range 25 - 50, is given in the 50 row.*







Data Summary

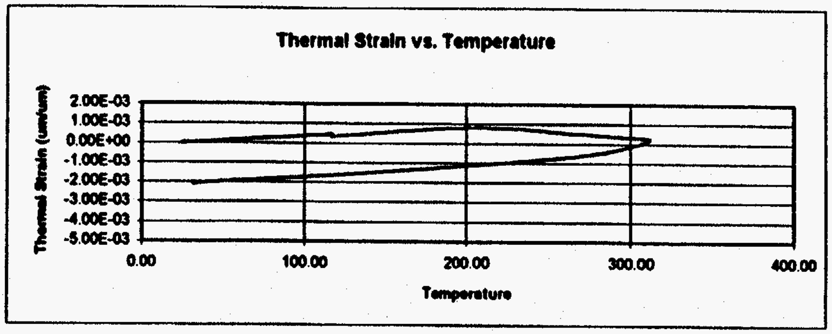
Sample ID: NRG-7-113.1-SNL-A
Lithology: Nonwelded Vitric
TMU: PTn

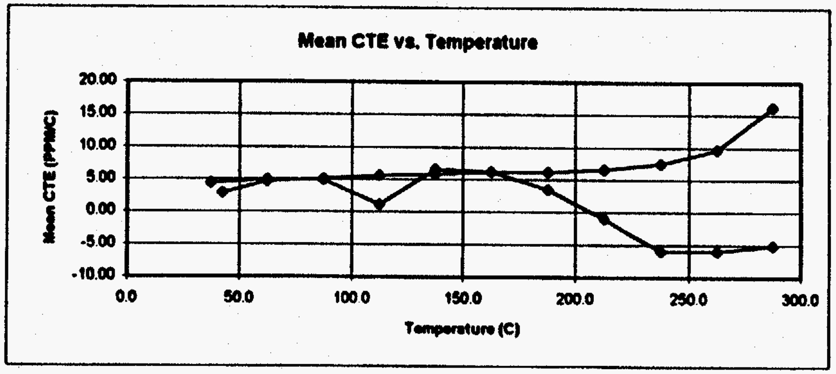
Test condition: AIR DRIED
Sample Size: 2" (l) x 1" (d)

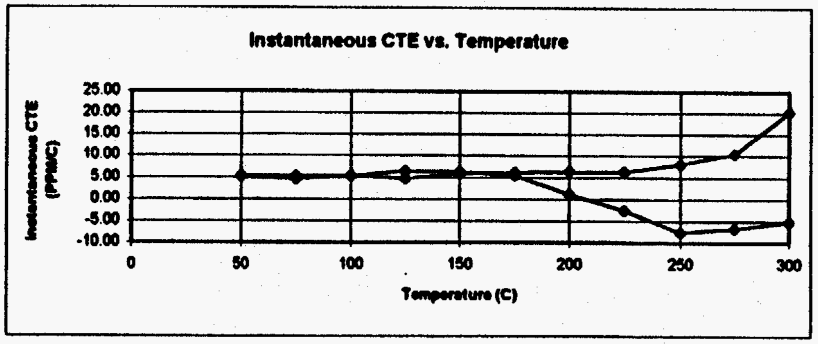
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
Initial:	32.90	50.75	25.72	1.28
Final:	32.73	50.72	25.70	1.27

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (^oC)
Heat up	25	7.86	***	***	
	50	110.81	4.12	4.98	37.5
	75	229.31	4.74	4.52	62.5
	100	361.42	5.28	5.77	87.5
	125	497.19	5.43	6.03	112.5
	150	649.91	6.11	6.72	137.5
	175	809.40	6.38	5.52	162.5
	200	966.39	6.28	5.34	187.5
	225	1120.07	6.15	5.79	212.5
	250	1266.32	5.85	5.08	237.5
	275	1376.57	4.41	3.42	262.5
	300	1424.18	1.90	0.58	287.5
Cool down	300	974.58	10.92	11.21	287.5
	275	701.68	8.06	8.71	262.5
	250	500.21	6.81	7.76	237.5
	225	329.95	6.51	7.06	212.5
	200	167.11	6.39	5.86	187.5
	175	7.49	6.47	6.36	162.5
	150	-154.38	6.00	5.55	137.5
	125	-304.35	5.90	5.39	112.5
	100	-451.84	5.48	5.63	87.5
	75	-588.75	5.23	5.10	62.5
	50	-719.41	2.89	4.70	42.5
	35	-791.56	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

Sample ID: NRG-7-120.9-SNL-A
Lithology: Nonwelded Vitric
TMU: PTn

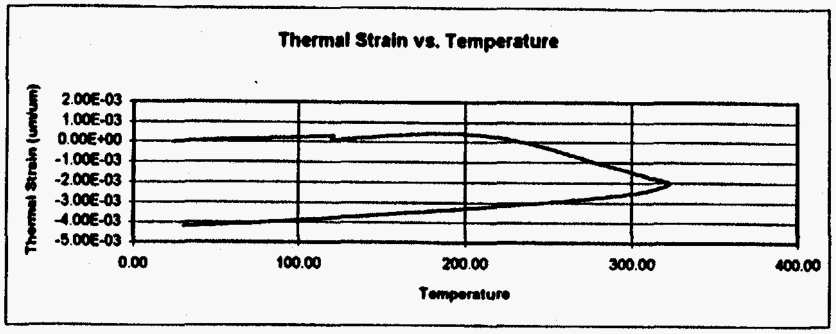
Test condition: AIR DRIED
Sample Size: 2" (l) x 1" (d)

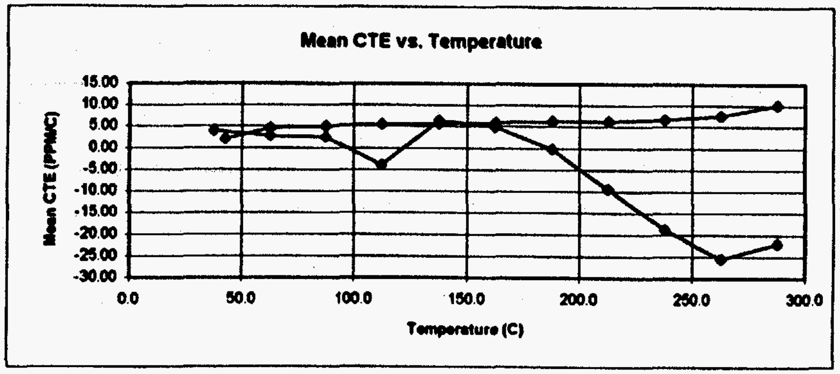
Sample Data:

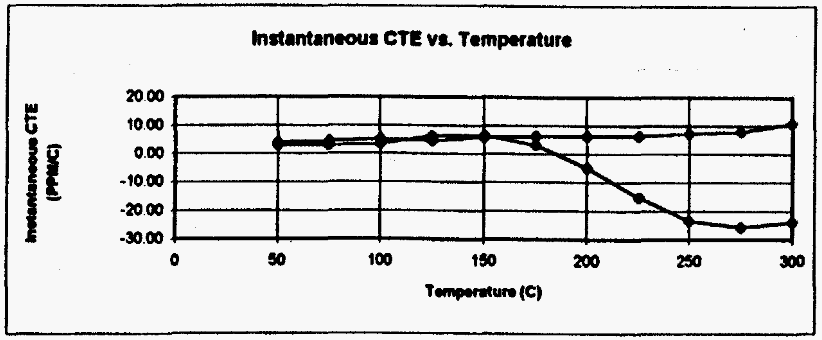
	mass (g)	length (mm)	volume (cc)	density (g/cc)
Initial:	37.76	50.80	25.74	1.47
Final:	37.08	50.67	25.67	1.44

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
Heat up	25	1.43	***	***	
	50	112.36	4.44	5.39	37.5
	75	238.51	5.05	5.18	62.5
	100	361.98	4.94	5.31	87.5
	125	389.86	1.11	6.49	112.5
	150	554.63	6.59	6.23	137.5
	175	708.90	6.17	5.46	162.5
	200	797.13	3.53	1.20	187.5
	225	774.22	-0.92	-2.59	212.5
	250	624.10	-6.00	-7.53	237.5
	275	473.00	-6.04	-6.61	262.5
	300	343.90	-5.16	-5.21	287.5
Cool down	300	-132.12	16.26	20.32	287.5
	275	-538.53	9.68	10.47	262.5
	250	-780.56	7.51	8.18	237.5
	225	-968.22	6.60	6.36	212.5
	200	-1133.19	6.15	6.51	187.5
	175	-1286.91	6.19	6.08	162.5
	150	-1441.63	5.83	5.84	137.5
	125	-1587.35	5.60	4.71	112.5
	100	-1727.23	5.12	5.40	87.5
	75	-1855.15	4.66	4.53	62.5
	50	-1971.60	2.92	5.10	42.5
	35	-2044.61	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

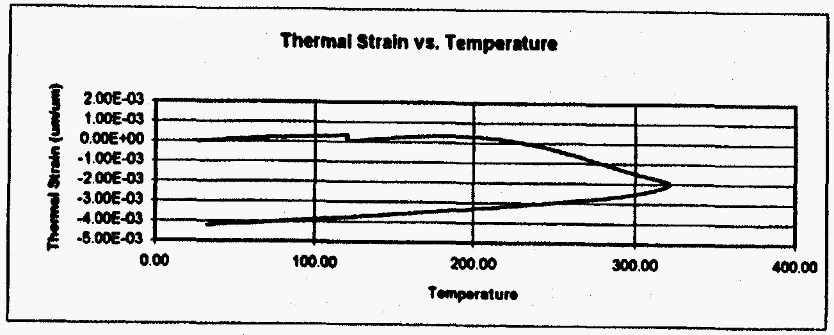
Sample ID: NRG-7-181.7-SNL-A
Lithology: Nonwelded Vitric
TMU: PTn

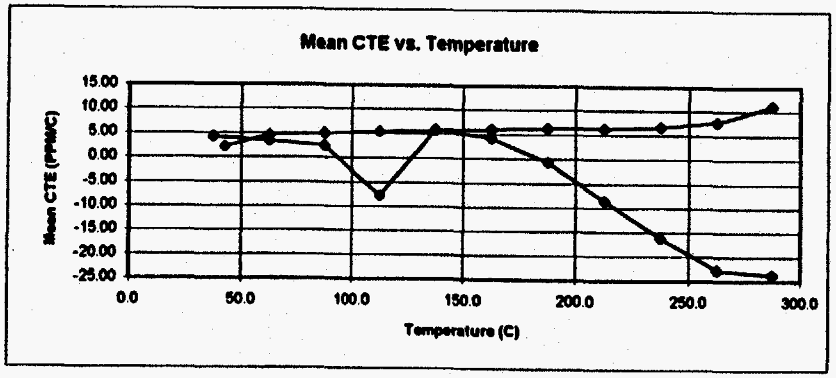
Test condition: AIR DRIED
Sample Size: 2" (l) x 1" (d)

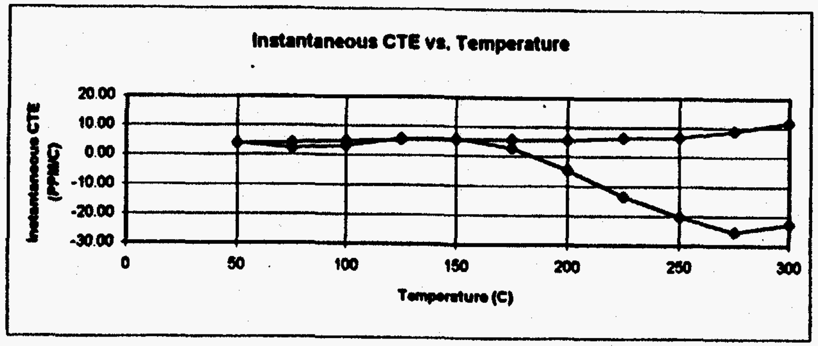
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
Initial:	27.84	51.00	25.84	1.08
Final:	27.01	50.80	25.74	1.05

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
Heat up	25	0.84	***	***	
	50	100.36	3.98	2.82	37.5
	75	171.83	2.86	2.85	62.5
	100	236.23	2.58	3.28	87.5
	125	138.02	-3.93	6.31	112.5
	150	296.91	6.36	6.52	137.5
	175	420.70	4.95	3.14	162.5
	200	417.51	-0.13	-4.77	187.5
	225	184.25	-9.33	-15.06	212.5
	250	-281.91	-18.65	-23.49	237.5
	275	-918.16	-25.45	-25.61	262.5
	300	-1469.55	-22.06	-23.80	287.5
Cool down	300	-2528.27	10.20	10.96	287.5
	275	-2783.30	7.69	7.84	262.5
	250	-2975.64	6.69	7.26	237.5
	225	-3142.83	6.29	6.25	212.5
	200	-3299.96	6.21	6.20	187.5
	175	-3455.19	6.04	6.29	162.5
	150	-3606.25	5.69	5.90	137.5
	125	-3748.45	5.50	4.57	112.5
	100	-3885.87	5.12	5.25	87.5
	75	-4013.78	4.61	4.55	62.5
	50	-4129.15	2.10	3.96	42.5
	35	-4181.67	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

Sample ID: NRG-7-248.5-SNL-A
Lithology: Nonwelded Vitric
TMU: PTn

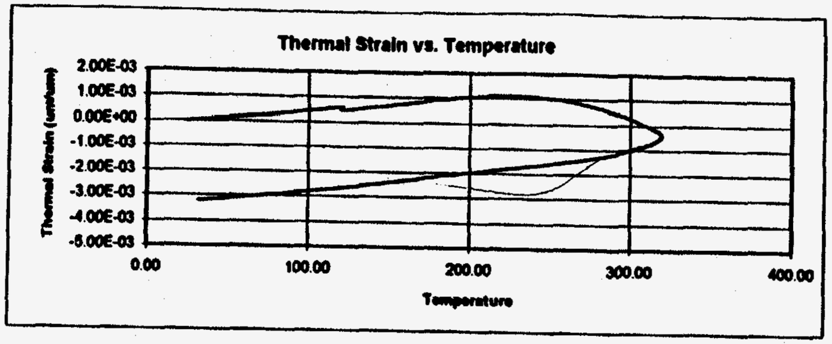
Test condition: AIR DRIED
Sample Size: 2" (l) x 1" (d)

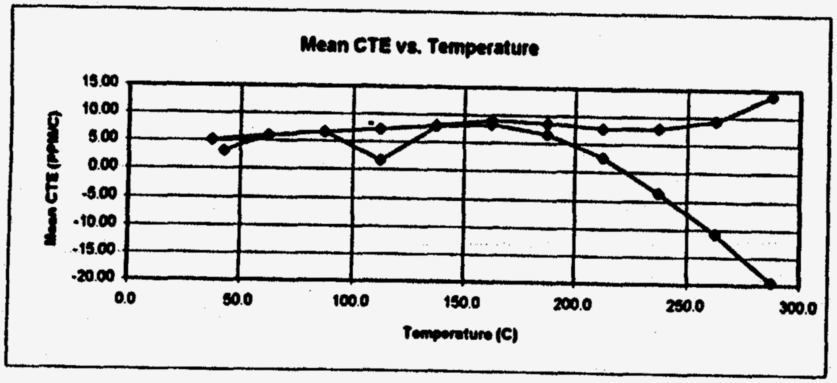
Sample Data:

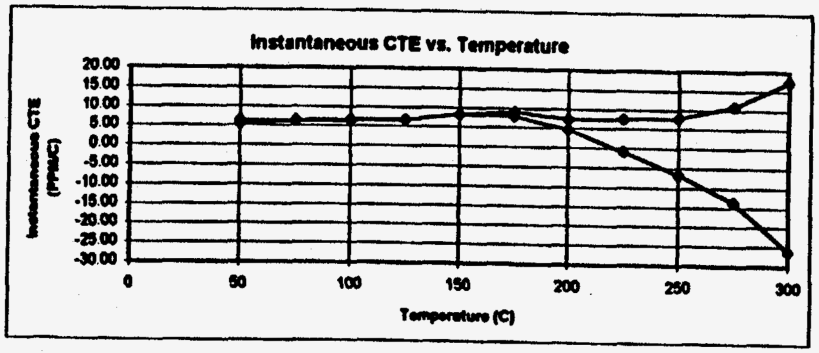
	mass (g)	length (mm)	volume (cc)	density (g/cc)
Initial:	30.29	50.80	25.74	1.18
Final:	29.43	50.57	25.62	1.15

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
Heat up	25	4.29	***	***	
	50	109.56	4.21	4.09	37.5
	75	195.06	3.42	2.31	62.5
	100	256.20	2.45	3.28	87.5
	125	63.81	-7.70	5.84	112.5
	150	212.69	5.96	5.91	137.5
	175	317.99	4.21	2.77	162.5
	200	300.87	-0.68	-4.63	187.5
	225	67.74	-8.52	-13.40	212.5
	250	-317.93	-16.23	-20.17	237.5
	275	-885.66	-22.71	-25.39	262.5
	300	-1478.61	-23.72	-22.74	287.5
Cool down	300	-2506.66	11.08	11.76	287.5
	275	-2783.77	7.84	8.85	262.5
	250	-2979.73	6.68	6.67	237.5
	225	-3146.65	6.30	6.49	212.5
	200	-3304.41	6.26	5.53	187.5
	175	-3460.87	5.98	5.78	162.5
	150	-3610.32	5.65	5.52	137.5
	125	-3751.45	5.43	5.39	112.5
	100	-3887.10	4.96	4.87	87.5
	75	-4011.01	4.52	4.37	62.5
	50	-4124.11	2.18	3.83	42.5
	35	-4178.70	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

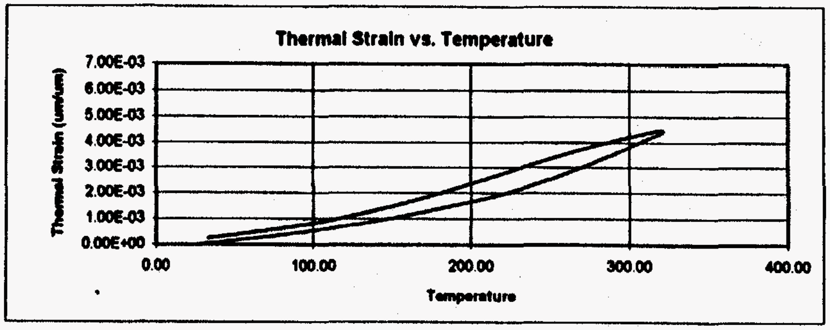
Sample ID: NRG-7-293.3-SNL-A
Lithology: Nonwelded Vitric
TMU: PTn

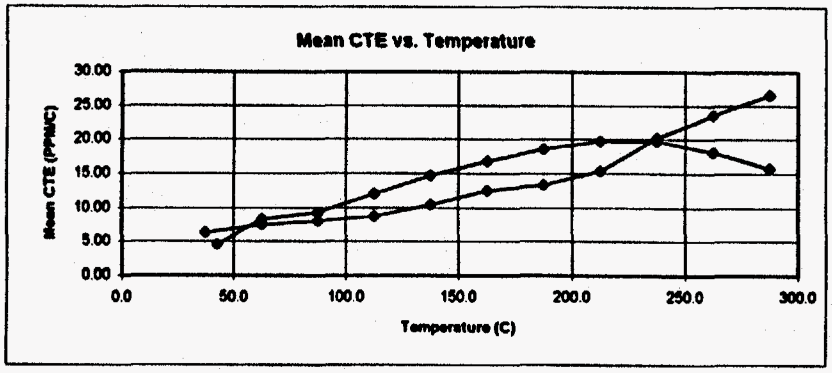
Test condition: AIR DRIED
Sample Size: 2" (l) x 1" (d)

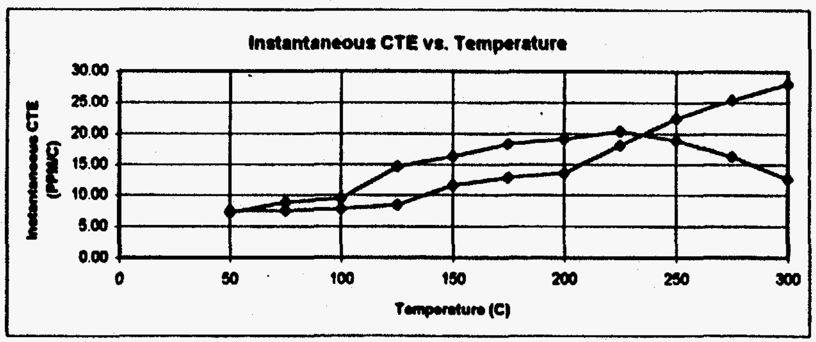
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
Initial:	36.36	50.98	25.83	1.41
Final:	35.52	50.80	25.74	1.38

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
Heat up	25	3.69	•••	•••	
	50	130.99	5.09	6.42	37.5
	75	280.52	5.98	6.23	62.5
	100	446.26	6.63	6.49	87.5
	125	487.71	1.66	6.78	112.5
	150	683.19	7.82	8.31	137.5
	175	889.61	8.26	7.84	162.5
	200	1055.19	6.62	4.71	187.5
	225	1121.44	2.65	-0.75	212.5
	250	1032.64	-3.55	-6.74	237.5
	275	763.99	-10.75	-13.56	262.5
	300	275.56	-19.54	-26.11	287.5
Cool down	300	-1003.95	14.00	17.41	287.5
	275	-1353.89	9.32	11.02	262.5
	250	-1586.93	7.90	7.91	237.5
	225	-1784.46	7.84	7.64	212.5
	200	-1980.35	8.65	7.39	187.5
	175	-2196.55	9.04	9.09	162.5
	150	-2422.60	8.08	8.23	137.5
	125	-2624.52	7.24	6.82	112.5
	100	-2805.53	6.64	6.81	87.5
	75	-2971.50	5.97	6.39	62.[illegible]
	50	-3120.70	3.23	5.48	42.5
	35	-3201.43	•••	•••	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

Sample ID: NRG-7-329.2-SNL-A
Lithology: Welded Devitrified
TMU: TSw1

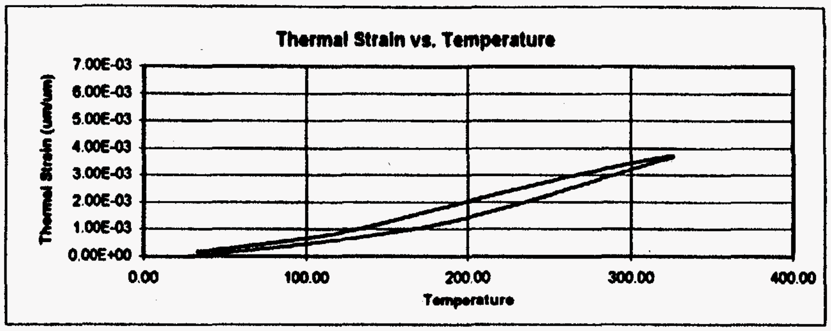
Test condition: AIR DRIED
Sample Size: 2" (l) x 1" (d)

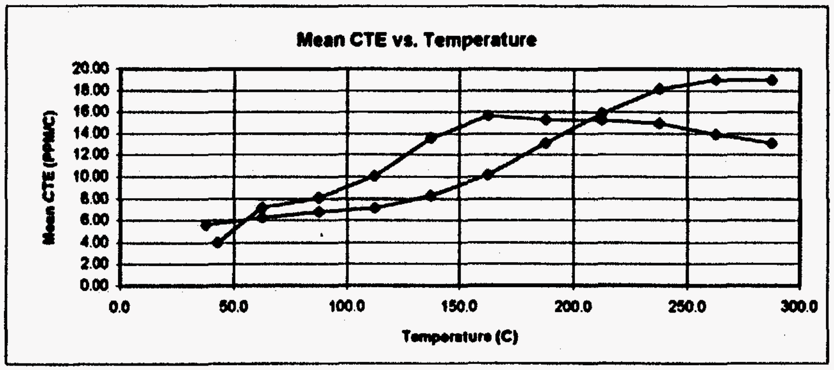
Sample Data:

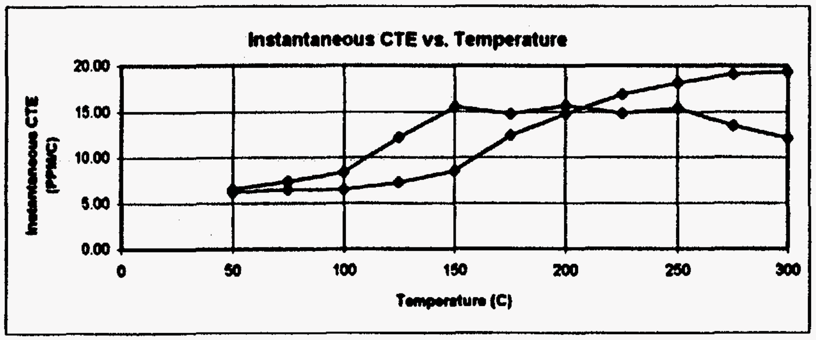
	mass (g)	length (mm)	volume (cc)	density (g/cc)
Initial:	59.17	50.88	25.78	2.30
Final:	59.17	50.88	25.78	2.29

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
Heat up	25	4.26	***	***	
	50	162.84	6.34	7.55	37.5
	75	349.71	7.48	7.54	62.5
	100	550.52	8.03	7.89	87.5
	125	768.32	8.71	8.51	112.5
	150	1029.09	10.43	11.56	137.5
	175	1341.73	12.51	12.89	162.5
	200	1676.23	13.38	13.64	187.5
	225	2060.39	15.37	18.07	212.5
	250	2564.92	20.18	22.45	237.5
	275	3155.70	23.63	25.43	262.5
	300	3821.04	26.61	27.97	287.5
Cool down	300	4216.45	15.78	12.65	287.5
	275	3821.83	18.16	16.30	262.5
	250	3367.72	19.72	18.90	237.5
	225	2874.64	19.78	20.37	212.5
	200	2380.17	18.59	19.16	187.5
	175	1915.52	16.76	18.26	162.5
	150	1496.49	14.75	16.28	137.5
	125	1127.80	12.05	14.61	112.5
	100	826.67	9.32	9.51	87.5
	75	593.62	8.35	8.90	62.5
	50	384.79	4.60	7.18	42.5
	35	269.87	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







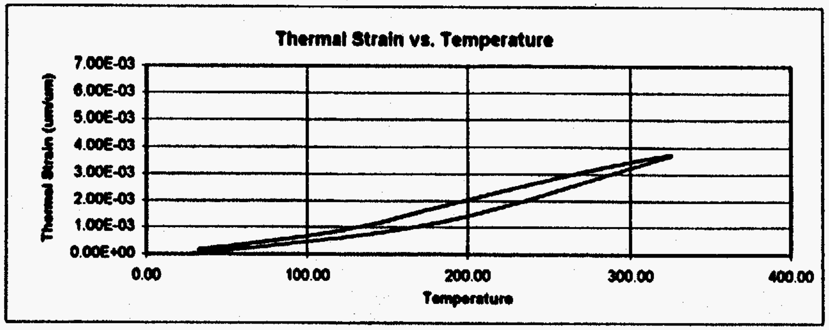
Data Summary

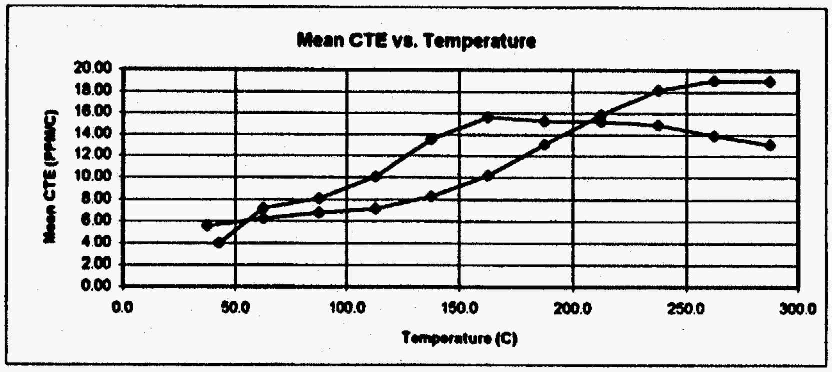
Sample ID:	NRG-7-359.1-SNL-A
Lithology:	Welded Devitrified
TMU:	TSw1
Test condition:	AIR DRIED
Sample Size:	2" (l) x 1" (d)

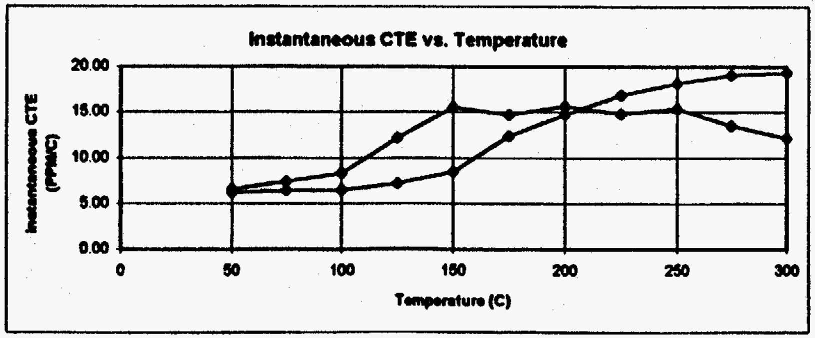
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
Initial:	53.02	50.90	25.79	2.06
Final:	52.99	50.90	25.79	2.05

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
Heat up	25	1.45	***	***	
	50	142.06	5.62	6.20	37.5
	75	298.90	6.27	6.43	62.5
	100	467.81	6.76	6.44	87.5
	125	645.65	7.11	7.20	112.5
	150	852.09	8.26	8.50	137.5
	175	1106.92	10.19	12.39	162.5
	200	1434.02	13.08	14.73	187.5
	225	1830.75	15.87	16.88	212.5
	250	2284.91	18.17	18.13	237.5
	275	2761.02	19.04	19.10	262.5
	300	3235.27	18.97	19.33	287.5
Cool down	300	3466.38	13.08	12.16	287.5
	275	3139.43	13.93	13.50	262.5
	250	2791.20	14.92	15.36	237.5
	225	2418.20	15.21	14.82	212.5
	200	2037.84	15.30	15.67	187.5
	175	1655.31	15.67	14.76	162.5
	150	1263.62	13.56	15.52	137.5
	125	924.74	10.05	12.19	112.5
	100	673.41	8.11	8.36	87.5
	75	470.67	7.20	7.39	62.5
	50	290.65	3.97	6.54	42.5
	35	191.35	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

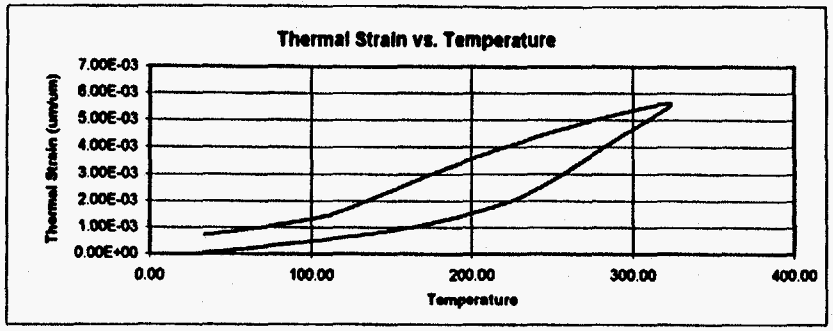
Sample ID: NRG-7-359.1-SNL-A
Lithology: Welded Devitrified
TMU: TSw1

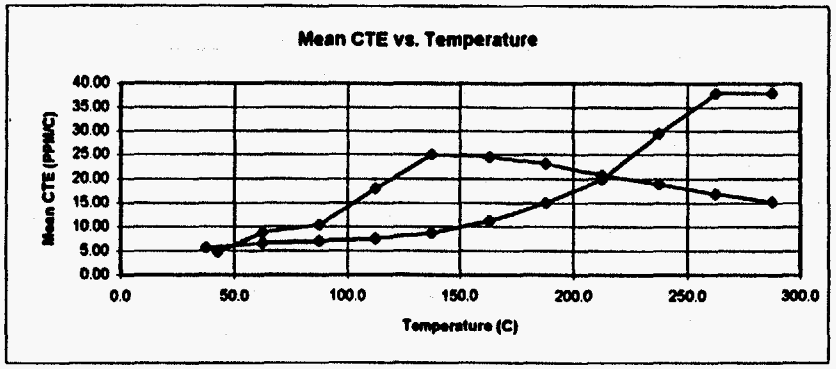
Test condition: AIR DRIED
Sample Size: 2" (l) x 1" (d)

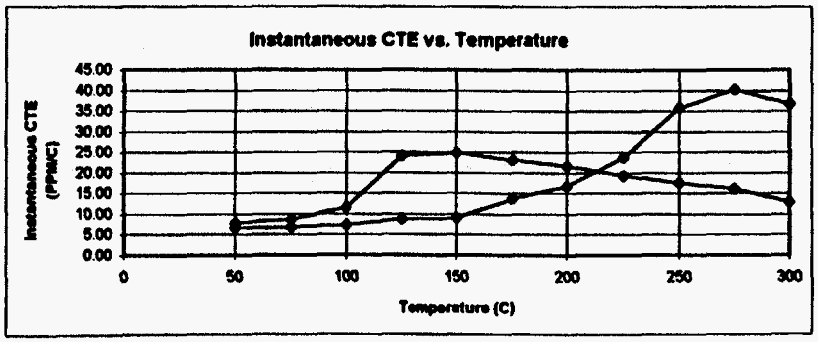
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
Initial:	53.02	50.90	25.79	2.06
Final:	52.99	50.90	25.79	2.05

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
Heat up	25	1.45	***	***	
	50	142.06	5.62	6.20	37.5
	75	298.90	6.27	6.43	62.5
	100	467.81	6.76	6.44	87.5
	125	645.65	7.11	7.20	112.5
	150	852.09	8.26	8.50	137.5
	175	1106.92	10.19	12.39	162.5
	200	1434.02	13.08	14.73	187.5
	225	1830.75	15.87	16.88	212.5
	250	2284.91	18.17	18.13	237.5
	275	2761.02	19.04	19.10	262.5
	300	3235.27	18.97	19.33	287.5
Cool down	300	3466.38	13.08	12.16	287.5
	275	3139.43	13.93	13.50	262.5
	250	2791.20	14.92	15.36	237.5
	225	2418.20	15.21	14.82	212.5
	200	2037.84	15.30	15.67	187.5
	175	1655.31	15.67	14.76	162.5
	150	1263.62	13.56	15.52	137.5
	125	924.74	10.05	12.19	112.5
	100	673.41	8.11	8.36	87.5
	75	470.67	7.20	7.39	62.5
	50	290.65	3.97	6.54	42.5
	35	191.35	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

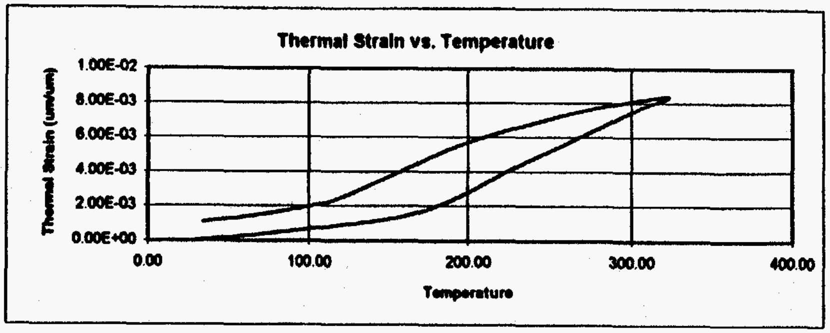
Sample ID: NRG-7-378.9-SNL-A
Lithology: Welded Devitrified
TMU: TSw1

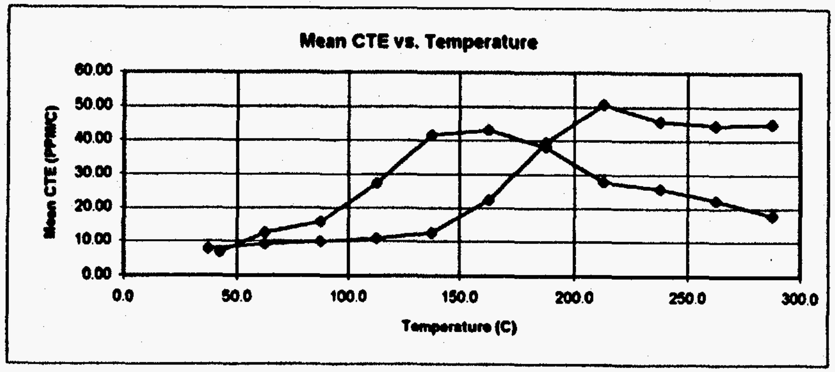
Test condition: AIR DRIED
Sample Size: 2" (l) x 1" (d)

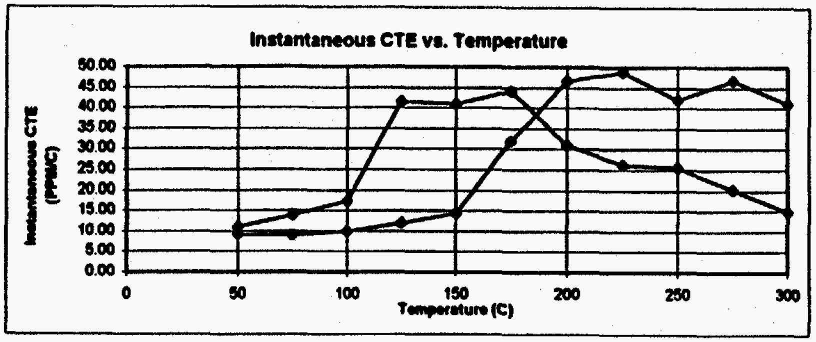
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
Initial:	54.60	50.83	25.76	2.12
Final:	54.57	50.85	25.77	2.12

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (^oC)
Heat up	25	1.29	***	***	
	50	143.52	5.69	6.69	37.5
	75	307.02	6.54	6.88	62.5
	100	481.75	6.99	7.29	87.5
	125	670.54	7.55	8.73	112.5
	150	885.25	8.59	9.04	137.5
	175	1164.87	11.18	13.86	162.5
	200	1537.62	14.91	16.72	187.5
	225	2032.52	19.80	23.81	212.5
	250	2771.37	29.55	35.76	237.5
	275	3720.57	37.97	40.18	262.5
	300	4672.32	38.07	36.77	287.5
Cool down	300	5373.10	15.20	13.01	287.5
	275	4993.07	16.64	16.20	262.5
	250	4572.15	18.81	17.59	237.5
	225	4101.97	20.77	19.32	212.5
	200	3582.64	23.11	21.71	187.5
	175	3004.95	24.50	23.16	162.5
	150	2392.53	25.01	24.82	137.5
	125	1767.20	17.87	24.13	112.5
	100	1320.52	10.31	11.64	87.5
	75	1062.81	8.78	8.71	62.5
	50	843.31	4.68	7.84	42.5
	35	726.34	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

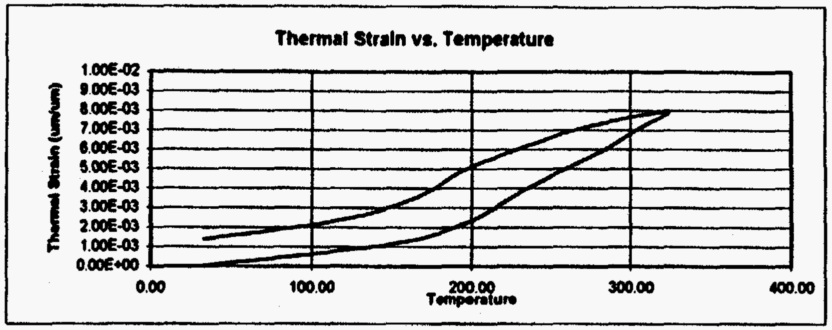
Sample ID: NRG-7-496.3-SNL-A
Lithology: Welded Devitrified
TMU: TSw1

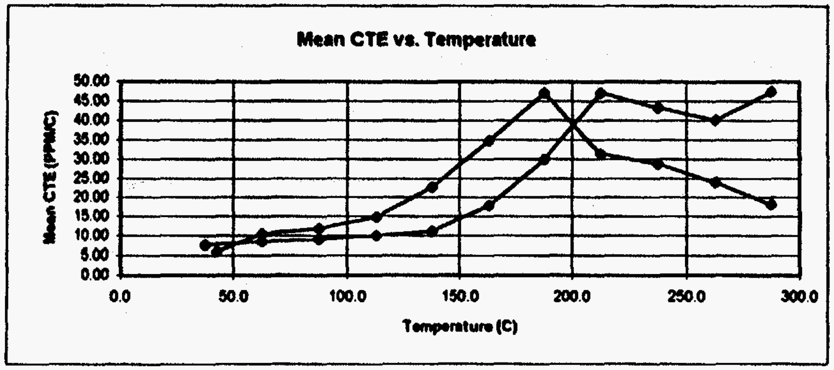
Test condition: AIR DRIED
Sample Size: 2" (l) x 1" (d)

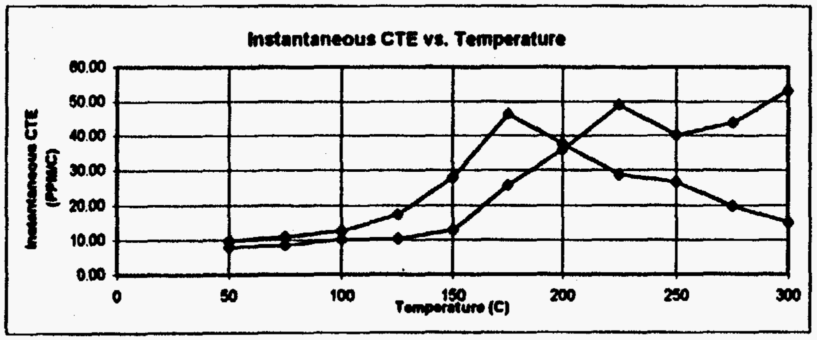
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
Initial:	54.84	50.85	25.77	2.13
Final:	54.40	50.90	25.79	2.11

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
Heat up	25	2.78	***	***	
	50	198.01	7.81	9.16	37.5
	75	427.28	9.17	9.06	62.5
	100	672.35	9.80	10.03	87.5
	125	941.52	10.77	11.97	112.5
	150	1256.34	12.59	14.33	137.5
	175	1815.29	22.36	31.92	162.5
	200	2803.30	39.52	46.60	187.5
	225	4072.84	50.76	46.82	212.5
	250	5216.67	45.75	42.02	237.5
	275	6329.84	44.53	46.78	262.5
	300	7457.15	45.09	41.20	287.5
Cool down	300	8081.04	17.84	14.81	287.5
	275	7635.02	22.44	20.31	262.5
	250	7074.05	25.86	25.67	237.5
	225	6427.57	28.00	26.34	212.5
	200	5727.51	38.11	30.98	187.5
	175	4774.79	43.14	44.13	162.5
	150	3696.32	41.58	40.93	137.5
	125	2656.76	27.28	41.69	112.5
	100	1974.84	15.72	17.33	87.5
	75	1581:76	12.60	13.91	62.5
	50	1266.86	6.76	11.11	42.5
	35	1097.83	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

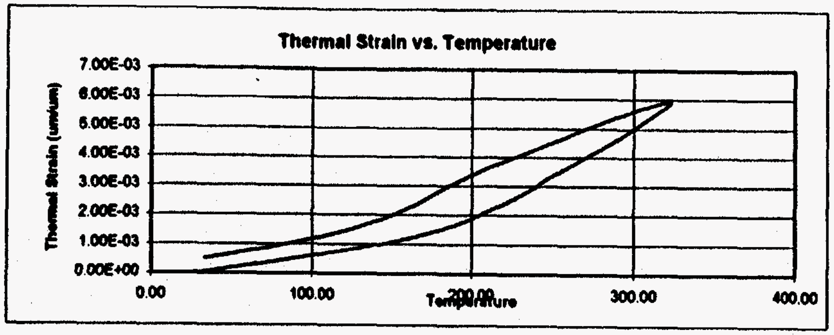
Sample ID: NRG-7-550.9-SNL-A
Lithology: Welded Devitrified
TMU: TSw1

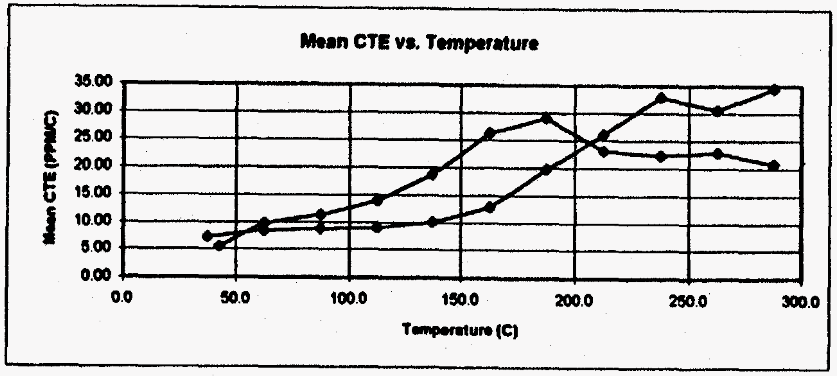
Test condition: AIR DRIED
Sample Size: 2" (l) x 1" (d)

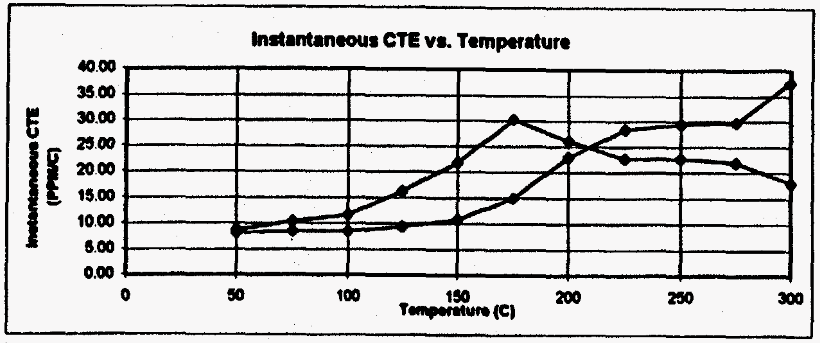
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
Initial:	45.56	50.85	25.77	1.77
Final:	45.35	50.90	25.79	1.76

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (^oC)
Heat up	25	-3.16	***	***	
	50	189.98	7.73	7.81	37.5
	75	403.91	8.56	8.41	62.5
	100	631.20	9.09	10.07	87.5
	125	881.76	10.02	10.35	112.5
	150	1160.90	11.17	12.73	137.5
	175	1608.16	17.89	25.83	162.5
	200	2355.38	29.89	35.88	187.5
	225	3534.79	47.18	49.03	212.5
	250	4619.38	43.38	40.17	237.5
	275	5622.67	40.13	43.84	262.5
	300	6809.38	47.47	53.30	287.5
Cool down	300	7673.08	18.25	15.11	287.5
	275	7216.77	23.96	19.80	262.5
	250	6617.86	28.69	26.69	237.5
	225	5900.72	31.22	28.68	212.5
	200	5120.13	47.18	37.79	187.5
	175	3940.66	34.81	46.47	162.5
	150	3070.30	22.82	28.09	137.5
	125	2499.73	14.82	17.38	112.5
	100	2129.26	11.86	12.60	87.5
	75	1832.79	10.46	10.86	62.5
	50	1571.28	6.03	9.71	42.5
	35	1420.61	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

Sample ID: NRG-7-606.4-SNL-A
Lithology: Welded Devitrified
TMU: TSw1

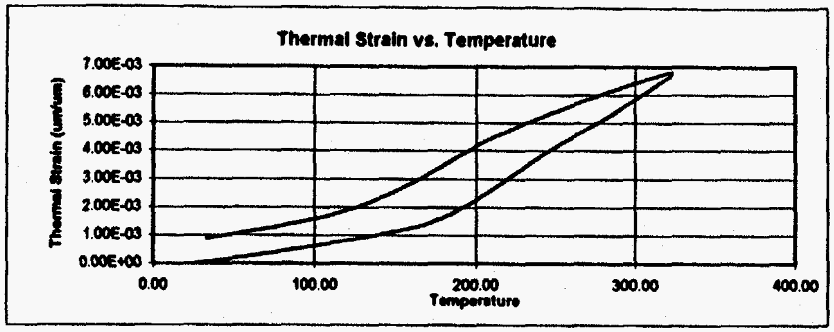
Test condition: AIR DRIED
Sample Size: 2" (l) x 1" (d)

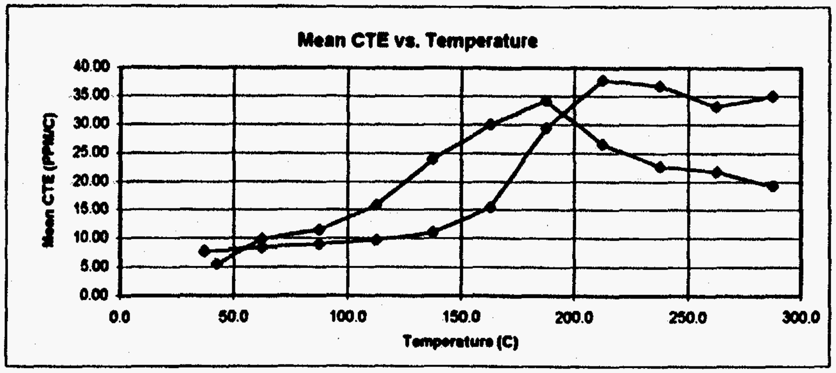
Sample Data:

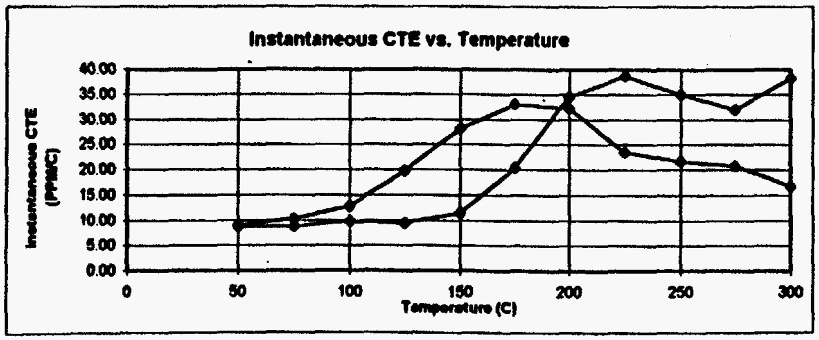
	mass (g)	length (mm)	volume (cc)	density (g/cc)
Initial:	52.35	50.85	25.77	2.03
Final:	52.17	50.85	25.77	2.02

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
Heat up	25	1.09	***	***	
	50	181.55	7.22	8.08	37.5
	75	392.69	8.45	8.51	62.5
	100	611.53	8.75	8.51	87.5
	125	836.45	9.00	9.37	112.5
	150	1088.01	10.06	10.80	137.5
	175	1410.89	12.92	14.97	162.5
	200	1904.45	19.74	22.90	187.5
	225	2556.20	26.07	28.40	212.5
	250	3377.08	32.84	29.37	237.5
	275	4142.02	30.60	29.71	262.5
	300	5005.09	34.52	37.59	287.5
Cool down	300	5616.32	20.78	18.01	287.5
	275	5096.86	23.00	21.93	262.5
	250	4521.84	22.30	22.61	237.5
	225	3964.26	23.13	22.65	212.5
	200	3385.90	29.03	26.11	187.5
	175	2660.24	26.38	30.27	162.5
	150	2000.68	18.77	21.75	137.5
	125	1531.40	13.96	16.24	112.5
	100	1182.36	11.31	11.59	87.5
	75	899.54	9.78	10.36	62.5
	50	655.09	5.51	8.78	42.5
	35	517.31	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

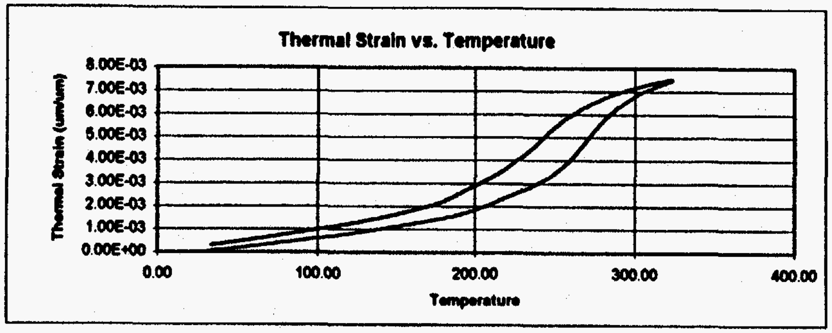
Sample ID:	NRG-7-608.1-SNL-A
Lithology:	Welded Devitrified
TMU:	TSw1
Test condition:	AIR DRIED
Sample Size:	2" (l) x 1" (d)

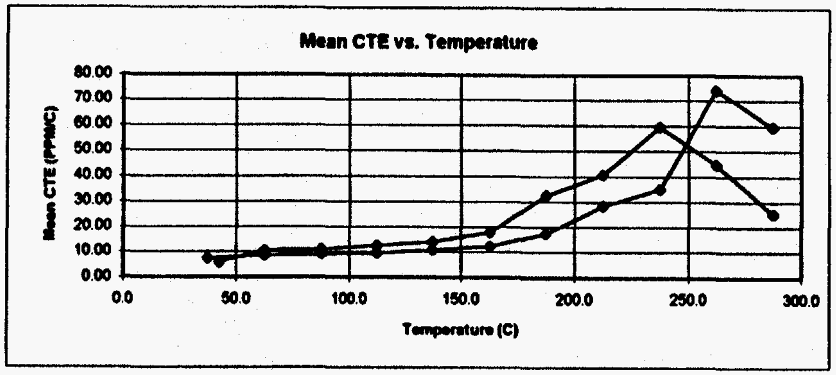
Sample Data:

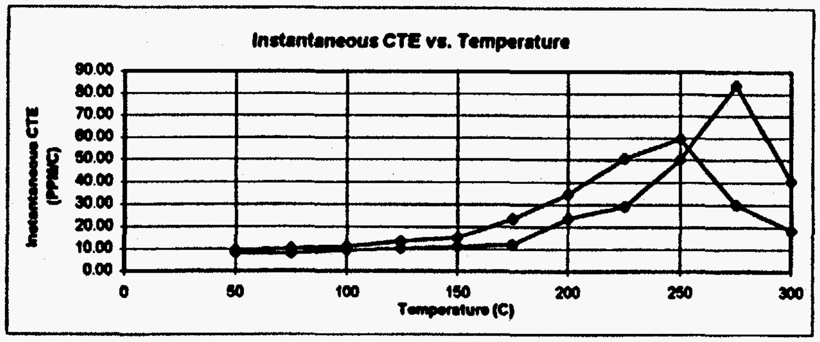
	mass (g)	length (mm)	volume (cc)	density (g/cc)
Initial:	49.04	50.75	25.72	1.91
Final:	48.83	50.80	25.74	1.90

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (^oC)
Heat up	25	-0.04	***	***	
	50	192.45	7.70	8.74	37.5
	75	403.57	8.44	8.72	62.5
	100	627.79	8.97	9.75	87.5
	125	870.54	9.71	9.44	112.5
	150	1146.07	11.02	11.52	137.5
	175	1533.36	15.49	20.34	162.5
	200	2268.66	29.41	34.63	187.5
	225	3215.28	37.87	38.73	212.5
	250	4135.95	36.83	34.98	237.5
	275	4966.30	33.21	32.01	262.5
	300	5841.69	35.02	38.38	287.5
Cool down	300	6432.73	19.25	16.80	287.5
	275	5951.52	21.72	20.81	262.5
	250	5408.62	22.66	21.66	237.5
	225	4842.14	26.52	23.49	212.5
	200	4179.04	34.23	32.32	187.5
	175	3323.32	29.91	33.06	162.5
	150	2575.44	23.95	28.07	137.5
	125	1976.67	15.80	19.71	112.5
	100	1581.62	11.55	12.81	87.5
	75	1292.97	9.96	10.32	62.5
	50	1044.03	5.57	9.03	42.5
	35	904.74	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

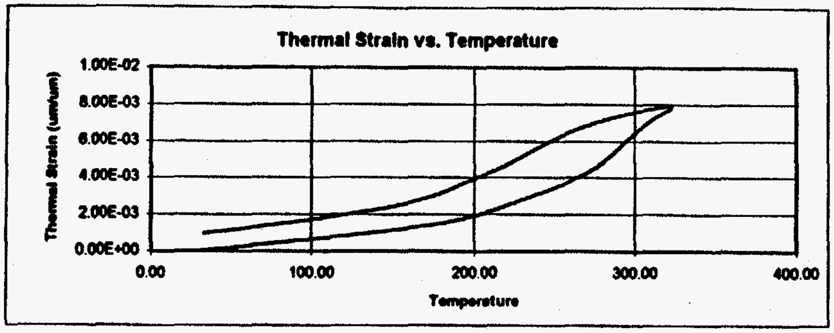
Sample ID: NRG-7-625.7-SNL-A
Lithology: Welded Devitrified
TMU: TSw1

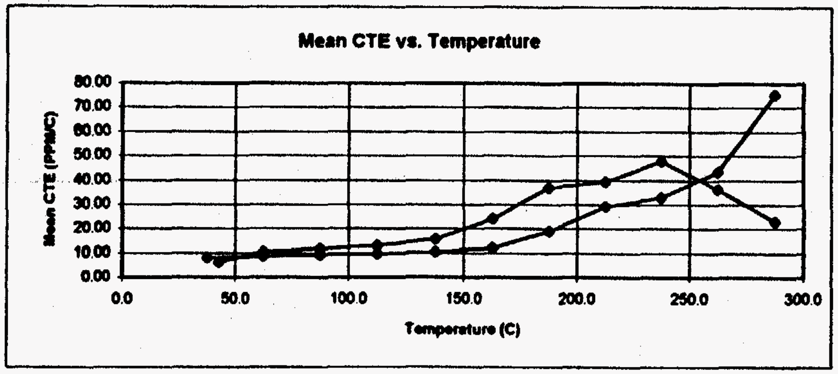
Test condition: AIR DRIED
Sample Size: 2" (l) x 1" (d)

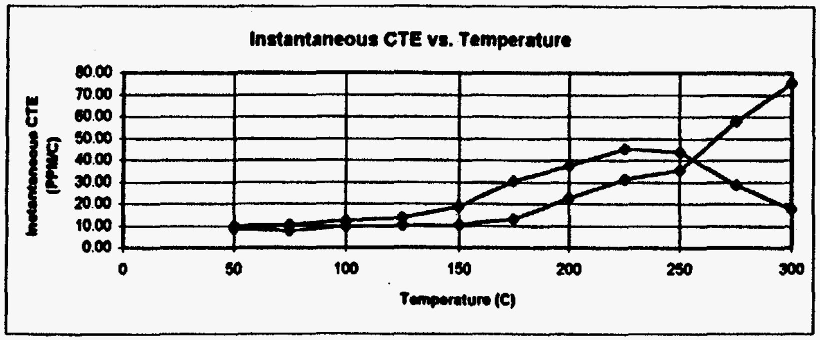
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
Initial:	52.73	50.85	25.77	2.05
Final:	52.70	50.88	25.78	2.04

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
Heat up	25	2.40	***	***	
	50	186.51	7.36	8.32	37.5
	75	397.86	8.45	7.79	62.5
	100	618.46	8.82	9.45	87.5
	125	857.10	9.55	10.26	112.5
	150	1123.00	10.64	11.11	137.5
	175	1428.46	12.22	12.11	162.5
	200	1864.26	17.43	23.74	187.5
	225	2572.31	28.32	29.09	212.5
	250	3448.97	35.07	50.46	237.5
	275	5302.48	74.14	84.01	262.5
	300	6790.63	59.53	40.48	287.5
Cool down	300	7173.11	25.42	18.42	287.5
	275	6537.56	44.63	29.86	262.5
	250	5421.87	59.62	59.92	237.5
	225	3931.37	40.52	50.67	212.5
	200	2918.40	32.55	34.73	187.5
	175	2104.57	17.94	23.54	162.5
	150	1656.12	13.94	15.38	137.5
	125	1307.62	12.48	13.53	112.5
	100	995.54	11.01	11.23	87.5
	75	720.38	10.37	10.36	62.5
	50	461.23	5.94	9.37	42.5
	35	312.85	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

Sample ID: NRG-7-641.0-SNL-A
Lithology: Welded Devitrified
TMU: TSw1

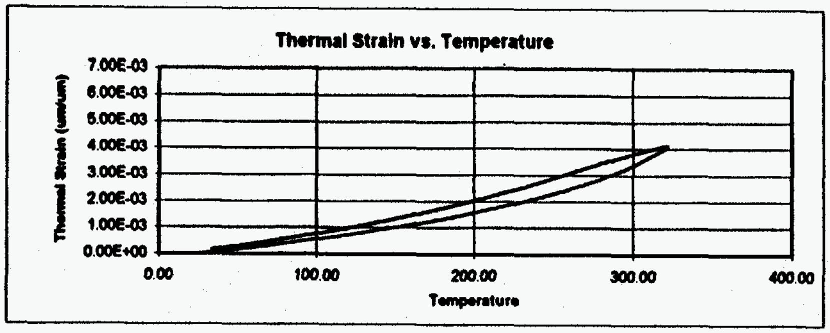
Test condition: AIR DRIED
Sample Size: 2" (l) x 1" (d)

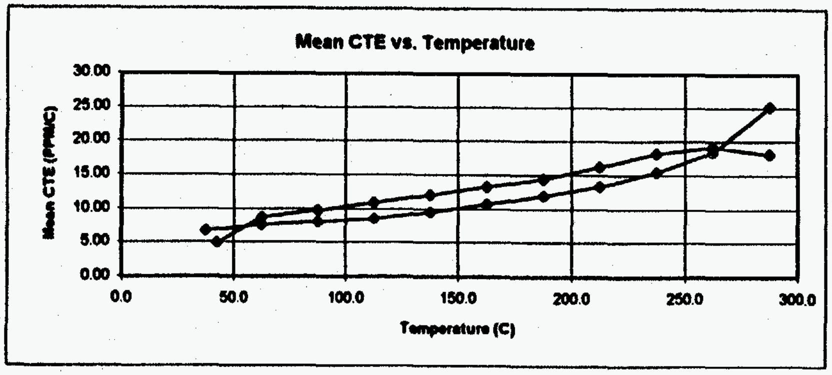
Sample Data:

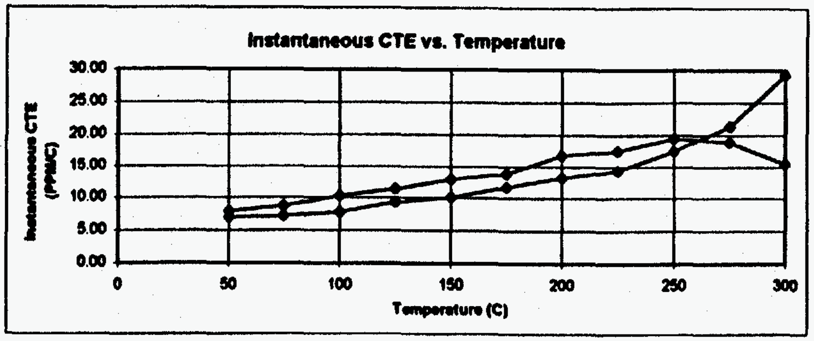
	mass (g)	length (mm)	volume (cc)	density (g/cc)
Initial:	51.63	51.28	25.98	1.99
Final:	51.46	51.31	26.00	1.98

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
Heat up	25	-2.91	***	***	
	50	200.39	8.13	8.55	37.5
	75	416.02	8.63	7.75	62.5
	100	643.10	9.08	9.65	87.5
	125	885.34	9.69	10.14	112.5
	150	1148.90	10.54	10.55	137.5
	175	1450.03	12.05	13.11	162.5
	200	1922.22	18.89	22.61	187.5
	225	2649.99	29.11	31.23	212.5
	250	3472.48	32.90	35.57	237.5
	275	4560.16	43.51	57.94	262.5
	300	6449.78	75.58	75.41	287.5
Cool down	300	7612.04	23.02	18.06	287.5
	275	7036.57	36.32	28.77	262.5
	250	6128.50	47.91	43.84	237.5
	225	4930.72	39.31	45.43	212.5
	200	3947.96	36.83	37.73	187.5
	175	3027.28	24.00	30.30	162.5
	150	2427.35	15.76	18.91	137.5
	125	2033.29	13.21	13.78	112.5
	100	1703.10	11.67	12.31	87.5
	75	1411.44	10.55	10.58	62.5
	50	1147.64	6.07	9.79	42.5
	35	995.78	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

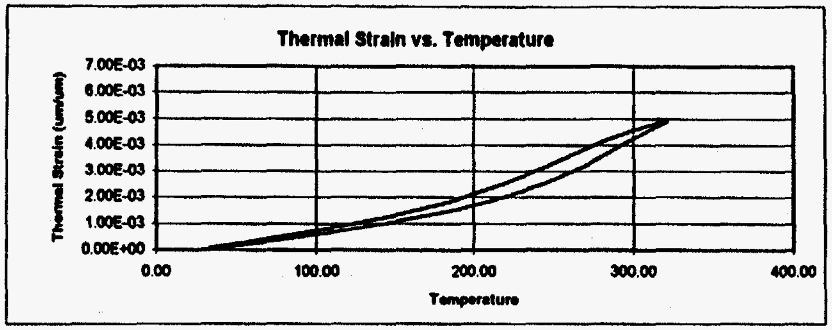
Sample ID: NRG-7-899.0-SNL-A
Lithology: Welded Devitrified
TMU: TSw1

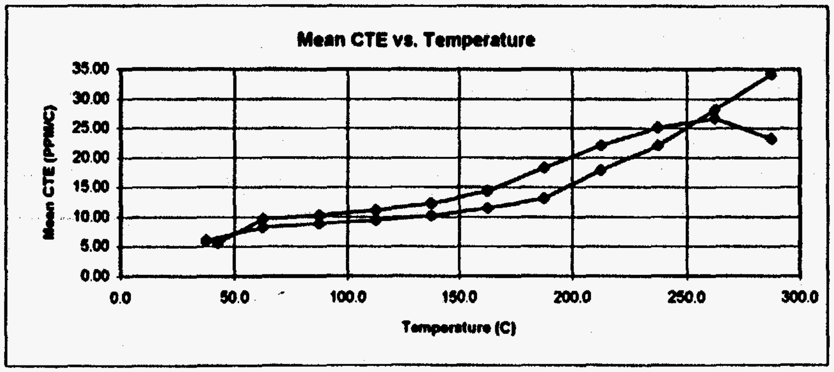
Test condition: AIR DRIED
Sample Size: 2" (l) x 1" (d)

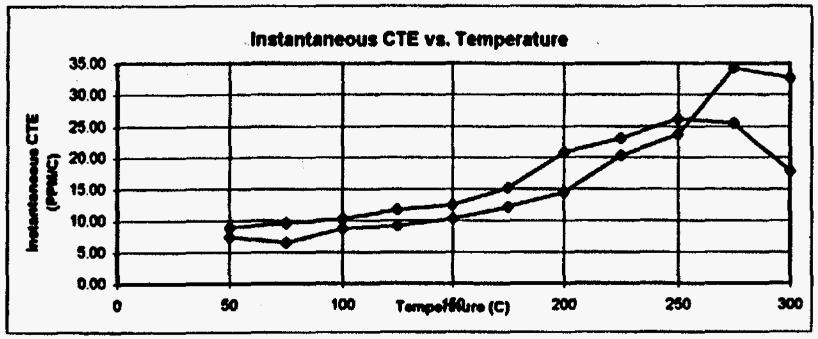
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
Initial:	55.46	50.93	25.81	2.15
Final:	55.29	50.93	25.81	2.14

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (^{o}C)
Heat up	25	0.25	***	***	
	50	167.72	6.70	7.04	37.5
	75	356.65	7.56	7.26	62.5
	100	557.88	8.05	7.78	87.5
	125	772.44	8.58	9.31	112.5
	150	1008.73	9.45	10.09	137.5
	175	1276.21	10.70	11.70	162.5
	200	1575.38	11.97	13.21	187.5
	225	1910.81	13.42	14.40	212.5
	250	2298.54	15.51	17.46	237.5
	275	2758.81	18.41	21.39	262.5
	300	3388.11	25.17	29.28	287.5
Cool down	300	3821.96	18.12	15.45	287.5
	275	3368.86	19.20	18.84	262.5
	250	2888.85	18.19	19.50	237.5
	225	2434.21	16.20	17.46	212.5
	200	2029.24	14.39	16.72	187.5
	175	1669.39	13.26	13.81	162.5
	150	1337.88	12.08	12.90	137.5
	125	1035.96	10.95	11.44	112.5
	100	762.16	9.79	10.33	87.5
	75	517.32	8.78	8.77	62.5
	50	297.86	4.89	7.93	42.5
	35	175.50	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







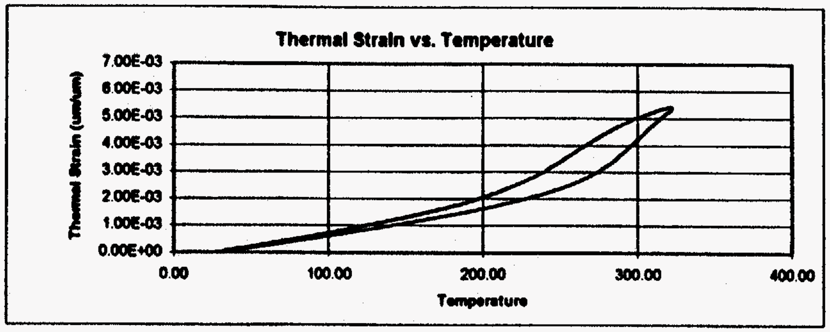
Data Summary

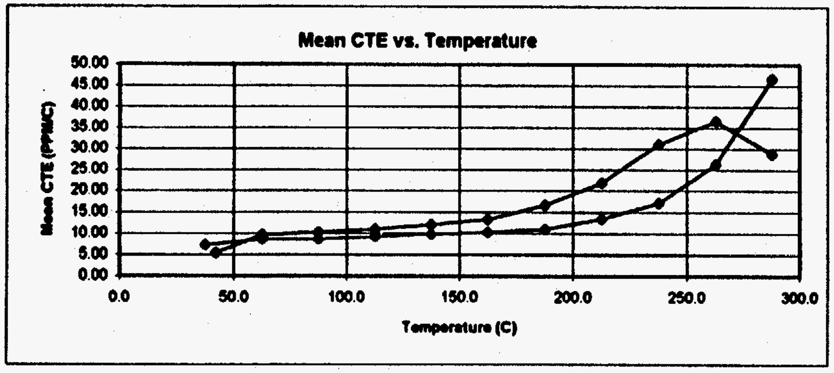
Sample ID:	NRG-7-856.5-SNL-A
Lithology:	Welded Devitrified
TMU:	TSw2
Test condition:	AIR DRIED
Sample Size:	2" (l) x 1" (d)

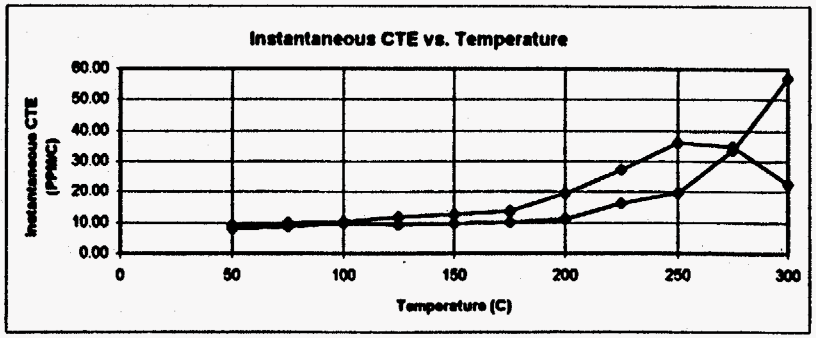
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
Initial:	57.56	50.85	25.77	2.23
Final:	57.51	50.85	25.77	2.23

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (^oC)
Heat up	25	12.77	***	***	
	50	163.51	6.03	7.46	37.5
	75	368.64	8.21	6.47	62.5
	100	590.30	8.87	8.81	87.5
	125	826.35	9.44	9.21	112.5
	150	1081.32	10.20	10.31	137.5
	175	1369.46	11.53	12.14	162.5
	200	1698.35	13.16	14.45	187.5
	225	2144.47	17.64	20.29	212.5
	250	2694.57	22.00	23.77	237.5
	275	3399.80	28.21	34.26	262.5
	300	4256.35	34.26	32.78	287.5
Cool down	300	4570.72	23.23	17.88	287.5
	275	3989.86	26.70	25.47	262.5
	250	3322.43	25.15	26.24	237.5
	225	2693.65	22.00	23.11	212.5
	200	2143.54	18.33	20.89	187.5
	175	1685.29	14.33	15.15	162.5
	150	1327.03	12.28	12.49	137.5
	125	1020.06	11.19	11.76	112.5
	100	740.20	10.27	10.37	87.5
	75	483.55	9.66	9.60	62.5
	50	241.94	5.58	8.98	42.5
	35	102.38	***	***	

‡ Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

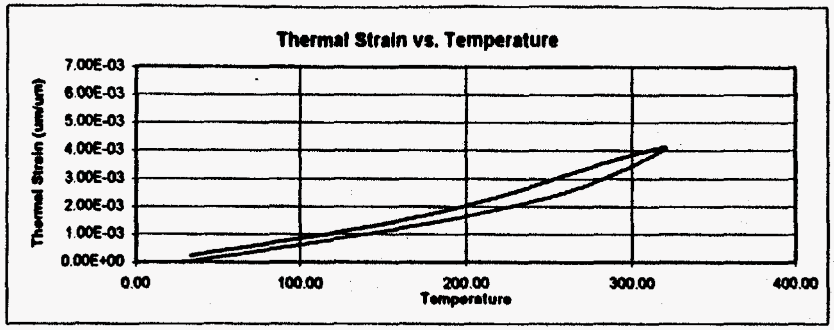
Sample ID: NRG-7-867.8-SNL-A
Lithology: Welded Devitrified
TMU: TSw2

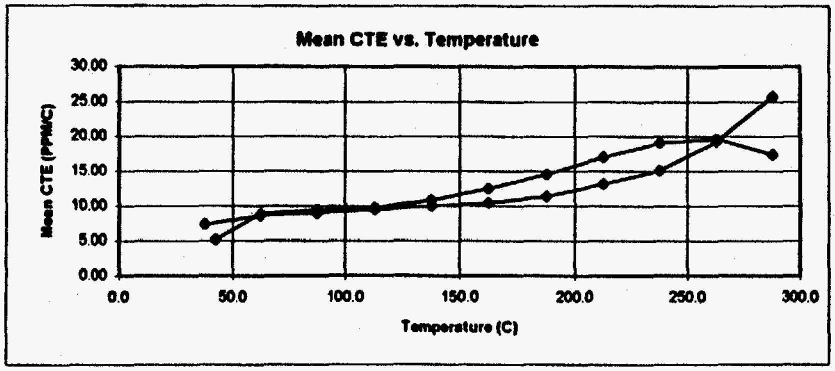
Test condition: AIR DRIED
Sample Size: 2" (l) x 1" (d)

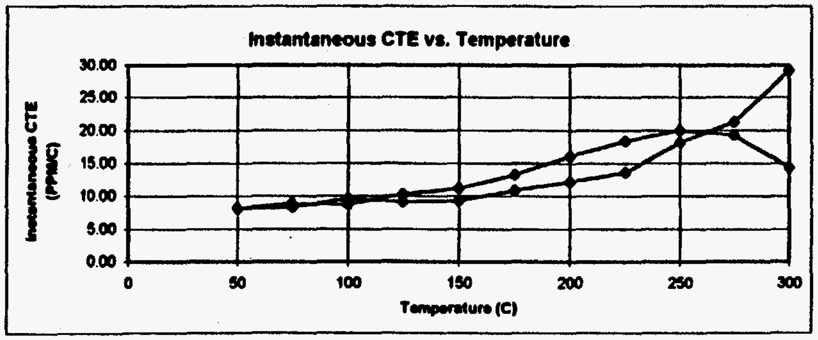
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
Initial:	54.10	48.26	24.45	2.21
Final:	53.85	48.26	24.45	2.20

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (^oC)
Heat up	25	2.00	***	***	
	50	182.89	7.24	7.97	37.5
	75	397.65	8.59	8.74	62.5
	100	615.08	8.70	9.82	87.5
	125	848.26	9.33	9.26	112.5
	150	1095.84	9.90	9.63	137.5
	175	1356.08	10.41	10.17	162.5
	200	1633.81	11.11	11.10	187.5
	225	1972.45	13.55	16.24	212.5
	250	2401.43	17.16	19.64	237.5
	275	3058.68	26.29	33.62	262.5
	300	4224.53	46.63	56.98	287.5
Cool down	300	5027.25	28.69	22.70	287.5
	275	4310.10	36.69	34.84	262.5
	250	3392.97	31.05	36.18	237.5
	225	2616.73	21.91	27.23	212.5
	200	2068.93	16.70	19.40	187.5
	175	1651.53	13.35	13.69	162.5
	150	1317.85	12.14	12.66	137.5
	125	1014.30	11.15	11.84	112.5
	100	735.58	10.34	10.35	87.5
	75	476.96	9.67	9.91	62.5
	50	235.17	5.51	9.16	42.5
	35	97.31	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

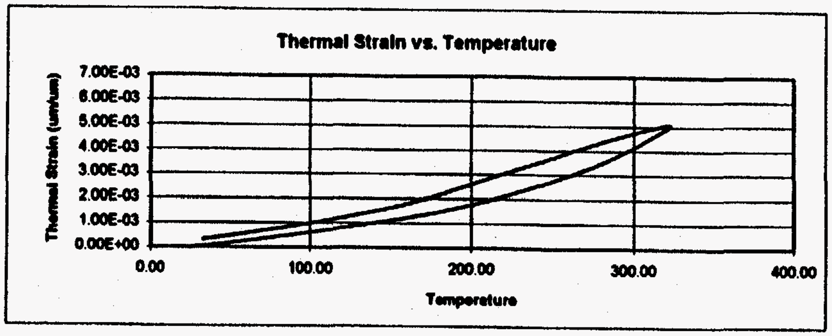
Sample ID: NRG-7-956.6-SNL-A
Lithology: Welded Devitrified
TMU: TSw2

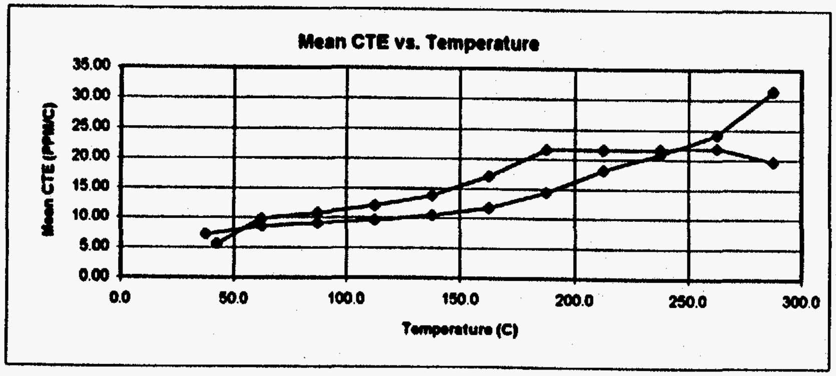
Test condition: AIR DRIED
Sample Size: 2" (l) x 1" (d)

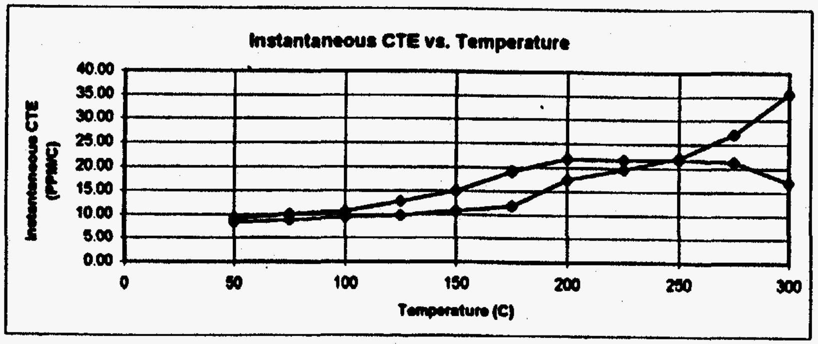
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
Initial:	56.52	47.90	24.27	2.33
Final:	56.32	47.90	24.27	2.32

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
Heat up	25	3.45	***	***	
	50	166.40	7.32	8.27	37.5
	75	400.13	8.55	8.38	62.5
	100	622.71	8.90	9.65	87.5
	125	858.01	9.41	9.18	112.5
	150	1106.08	9.92	9.32	137.5
	175	1366.35	10.41	10.96	162.5
	200	1650.59	11.37	12.23	187.5
	225	1979.37	13.15	13.60	212.5
	250	2355.78	15.06	18.16	237.5
	275	2839.02	19.33	21.30	262.5
	300	3481.60	25.70	29.18	287.5
Cool down	300	3869.16	17.40	14.41	287.5
	275	3434.06	19.61	19.25	262.5
	250	2943.72	19.07	20.01	237.5
	225	2467.04	17.04	18.37	212.5
	200	2041.00	14.55	16.11	187.5
	175	1677.33	12.49	13.28	162.5
	150	1365.20	10.76	11.26	137.5
	125	1096.15	9.81	10.29	112.5
	100	850.83	9.37	8.74	87.5
	75	616.56	8.67	8.97	62.5
	50	394.87	5.26	8.19	42.5
	35	263.36	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

Sample ID: NRG-7-979.2-SNL-A
Lithology: Welded Devitrified
TMU: TSw2

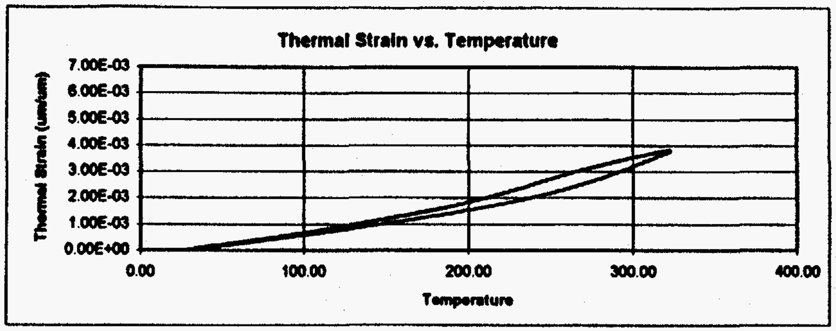
Test condition: AIR DRIED
Sample Size: 2" (l) x 1" (d)

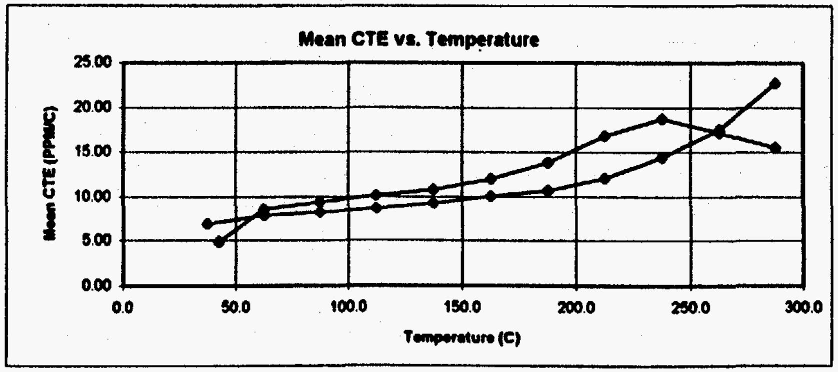
Sample Data:

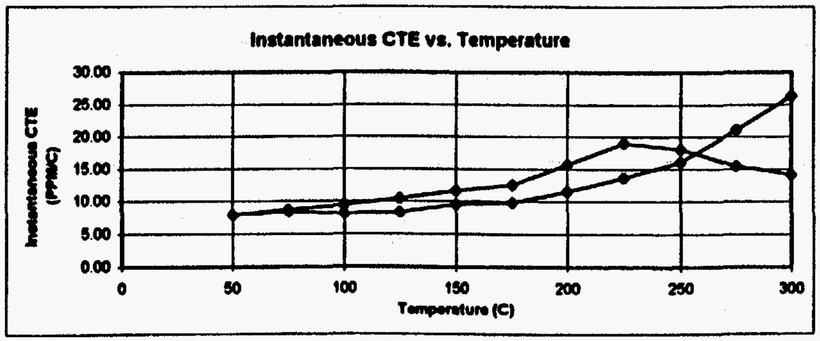
	mass (g)	length (mm)	volume (cc)	density (g/cc)
Initial:	57.55	50.90	25.79	2.23
Final:	57.40	50.90	25.79	2.23

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
Heat up	25	4.70	***	***	
	50	184.91	7.21	8.36	37.5
	75	398.81	8.56	8.81	62.5
	100	625.12	9.05	9.47	87.5
	125	865.26	9.61	9.86	112.5
	150	1126.24	10.44	10.75	137.5
	175	1419.57	11.73	11.92	162.5
	200	1780.27	14.43	17.50	187.5
	225	2234.74	18.18	19.62	212.5
	250	2755.91	20.85	22.10	237.5
	275	3362.59	24.27	27.04	262.5
	300	4147.68	31.40	35.63	287.5
Cool down	300	4745.67	19.76	17.07	287.5
	275	4251.67	21.99	21.27	262.5
	250	3701.92	21.75	21.73	237.5
	225	3158.12	21.68	21.67	212.5
	200	2616.00	21.64	21.78	187.5
	175	2074.97	17.14	19.16	162.5
	150	1646.59	13.83	15.05	137.5
	125	1300.72	12.10	12.82	112.5
	100	998.11	10.75	10.71	87.5
	75	729.32	9.78	10.11	62.5
	50	484.70	5.55	9.18	42.5
	35	345.83	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

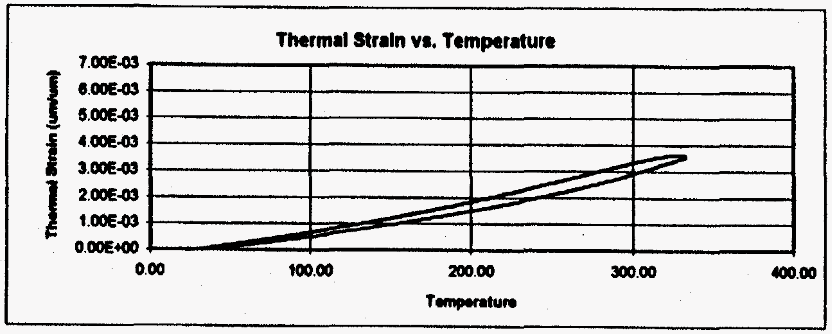
Sample ID:	NRG-7-1187.4-SNL-A
Lithology:	Welded Devitrified
TMU:	TSw2
Test condition:	AIR DRIED
Sample Size:	2" (l) x 1" (d)

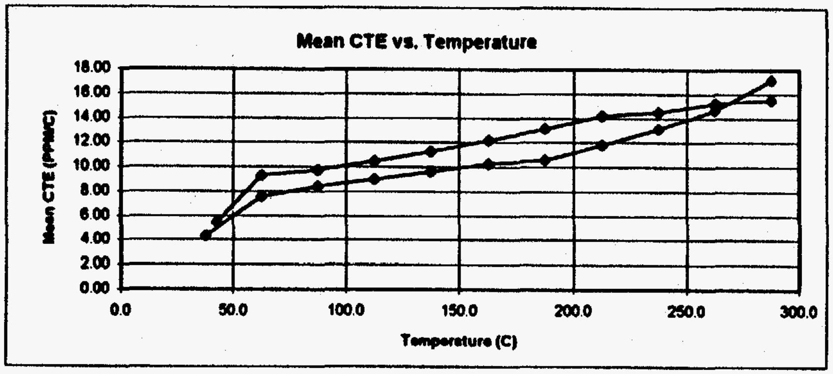
Sample Data:

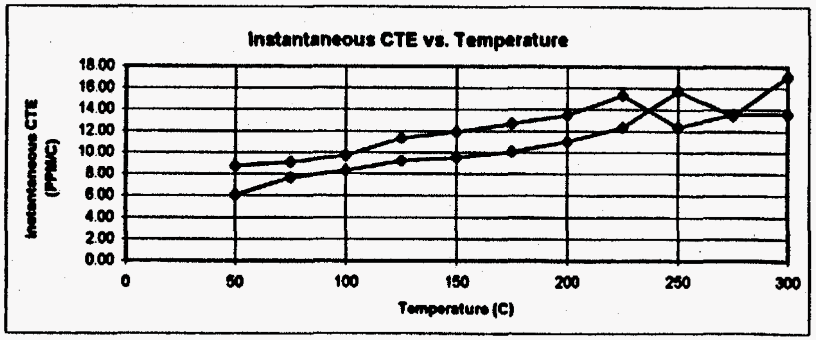
	mass (g)	length (mm)	volume (cc)	density (g/cc)
Initial:	54.66	50.93	25.81	2.12
Final:	54.53	50.93	25.81	2.11

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (^{o}C)
Heat up	25	-0.54	***	***	
	50	172.02	6.90	7.94	37.5
	75	369.28	7.89	8.46	62.5
	100	574.67	8.22	8.11	87.5
	125	792.36	8.71	8.35	112.5
	150	1023.39	9.24	9.54	137.5
	175	1274.35	10.04	9.83	162.5
	200	1541.73	10.70	11.52	187.5
	225	1845.06	12.13	13.67	212.5
	250	2205.66	14.42	16.05	237.5
	275	2645.41	17.59	21.06	262.5
	300	3214.35	22.76	26.40	287.5
Cool down	300	3551.84	15.51	14.13	287.5
	275	3164.21	17.21	15.49	262.5
	250	2734.05	18.71	18.02	237.5
	225	2266.29	16.81	18.92	212.5
	200	1846.13	13.87	15.68	187.5
	175	1499.25	12.02	12.58	162.5
	150	1198.63	10.90	11.64	137.5
	125	928.56	10.11	10.44	112.5
	100	675.73	9.38	9.43	87.5
	75	441.35	8.60	8.70	62.5
	50	226.42	4.89	7.96	42.5
	35	104.23	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

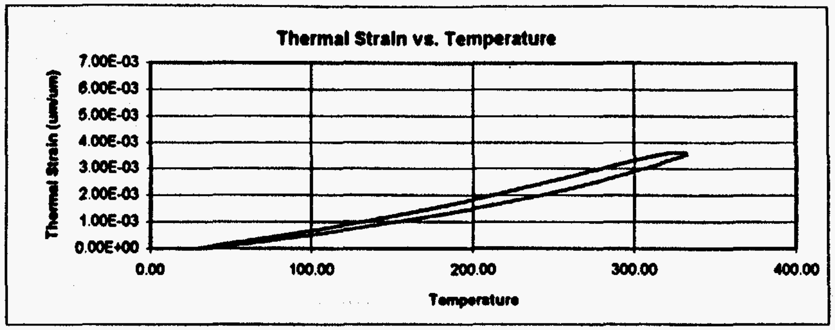
Sample ID: NRG-7-1261.8-SNL-A
Lithology: Welded Devitrified
TMU: TSw2

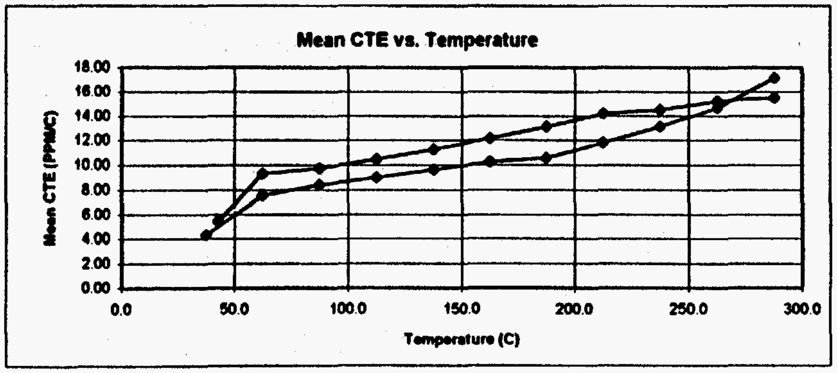
Test condition: AIR DRIED
Sample Size: 2" (l) x 1" (d)

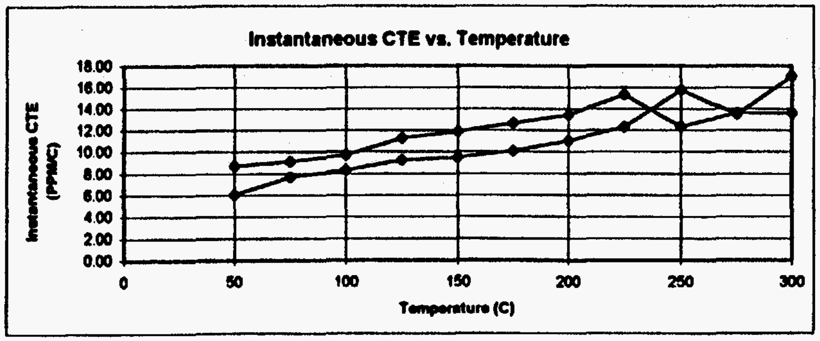
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
Initial:	59.74	50.90	25.79	2.32
Final:	59.63	50.90	25.79	2.31

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
Heat up	25	1.82	***	***	
	50	109.70	4.32	6.05	37.5
	75	298.40	7.55	7.65	62.5
	100	509.35	8.44	8.32	87.5
	125	734.04	8.99	9.23	112.5
	150	975.46	9.66	9.49	137.5
	175	1232.38	10.28	10.07	162.5
	200	1496.77	10.58	11.04	187.5
	225	1791.43	11.79	12.33	212.5
	250	2120.22	13.15	15.74	237.5
	275	2486.66	14.66	13.50	262.5
	300	2915.54	17.16	17.12	287.5
Cool down	300	3331.80	15.52	13.64	287.5
	275	2943.71	15.23	13.63	262.5
	250	2563.03	14.48	12.40	237.5
	225	2200.99	14.20	15.35	212.5
	200	1845.96	13.15	13.46	187.5
	175	1517.14	12.20	12.67	162.5
	150	1212.17	11.28	11.92	137.5
	125	930.29	10.46	11.32	112.5
	100	668.88	9.74	9.71	87.5
	75	425.42	9.31	9.12	62.5
	50	192.74	5.44	8.70	42.5
	35	56.68	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

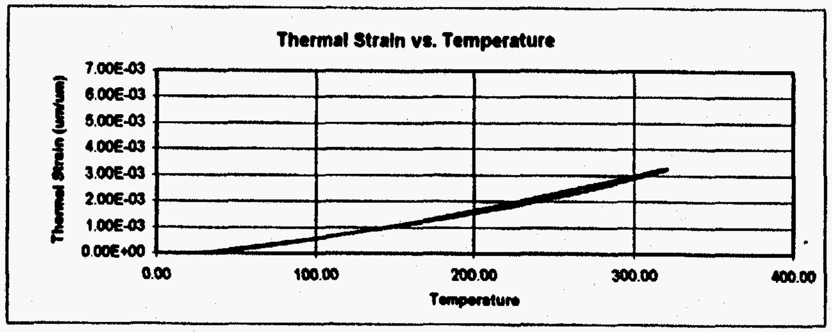
Sample ID:	NRG-7-1261.8-SNL-A
Lithology:	Welded Devitrified
TMU:	TSw2
Test condition:	AIR DRIED
Sample Size:	2" (l) x 1" (d)

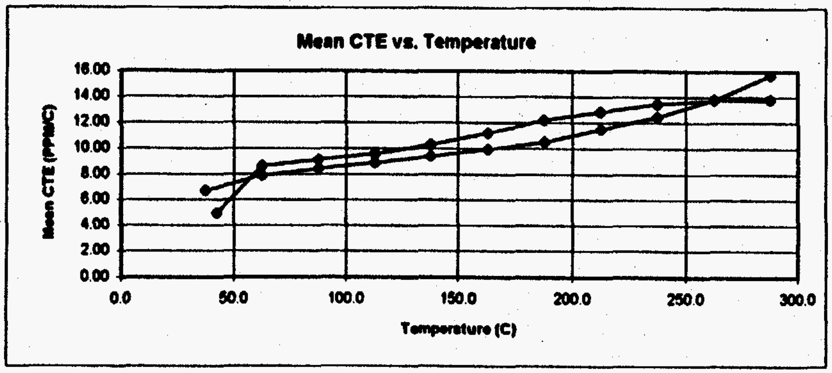
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
Initial:	59.74	50.90	25.79	2.32
Final:	59.63	50.90	25.79	2.31

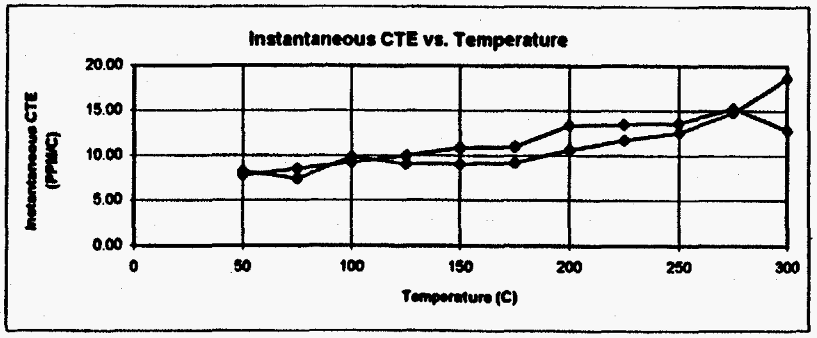
	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
Heat up	25	1.82	***	***	
	50	109.70	4.32	6.05	37.5
	75	298.40	7.55	7.65	62.5
	100	509.35	8.44	8.32	87.5
	125	734.04	8.99	9.23	112.5
	150	975.46	9.66	9.49	137.5
	175	1232.38	10.28	10.07	162.5
	200	1496.77	10.58	11.04	187.5
	225	1791.43	11.79	12.33	212.5
	250	2120.22	13.15	15.74	237.5
	275	2486.66	14.66	13.50	262.5
	300	2915.54	17.16	17.12	287.5
Cool down	300	3331.80	15.52	13.64	287.5
	275	2943.71	15.23	13.63	262.5
	250	2563.03	14.48	12.40	237.5
	225	2200.99	14.20	15.35	212.5
	200	1845.96	13.15	13.46	187.5
	175	1517.14	12.20	12.67	162.5
	150	1212.17	11.28	11.92	137.5
	125	930.29	10.46	11.32	112.5
	100	668.88	9.74	9.71	87.5
	75	425.42	9.31	9.12	62.5
	50	192.74	5.44	8.70	42.5
	35	56.68	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.

E-139







Data Summary

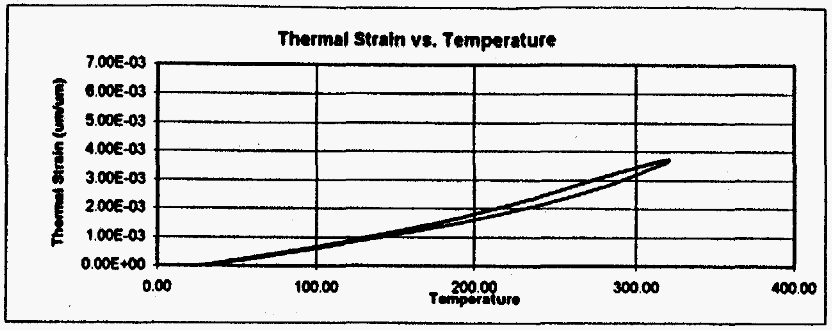
Sample ID: NRG-7-1269.9-SNL-A
Lithology: Welded Devitrified
TMU: TSw2

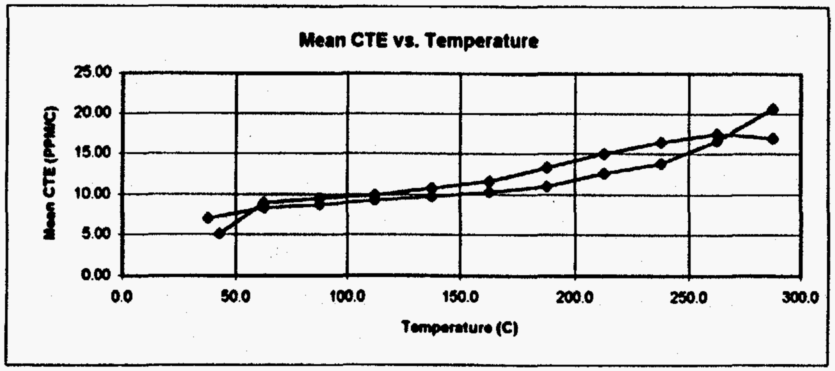
Test condition: AIR DRIED
Sample Size: 2" (l) x 1" (d)

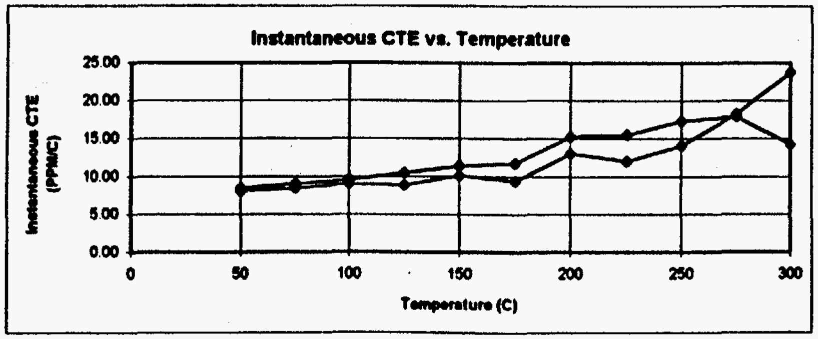
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
Initial:	59.80	50.83	25.76	2.32
Final:	59.63	50.83	25.76	2.32

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
Heat up	25	3.53	• • •	• • •	
	50	171.62	6.72	8.24	37.5
	75	368.06	7.86	7.38	62.5
	100	579.21	8.45	9.82	87.5
	125	801.05	8.87	9.05	112.5
	150	1035.37	9.37	9.05	137.5
	175	1283.74	9.93	9.17	162.5
	200	1545.58	10.47	10.64	187.5
	225	1833.21	11.51	11.69	212.5
	250	2144.40	12.45	12.57	237.5
	275	2489.66	13.81	14.77	262.5
	300	2882.63	15.72	18.65	287.5
Cool down	300	2991.69	13.80	12.83	287.5
	275	2646.81	13.72	15.30	262.5
	250	2303.71	13.46	13.62	237.5
	225	1967.25	12.84	13.51	212.5
	200	1646.19	12.19	13.33	187.5
	175	1341.47	11.20	11.00	162.5
	150	1061.59	10.27	10.83	137.5
	125	804.85	9.56	9.97	112.5
	100	565.90	9.11	9.18	87.5
	75	338.26	8.62	8.55	62.5
	50	122.76	4.96	7.76	42.5
	35	-1.15	• • •	• • •	

• Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

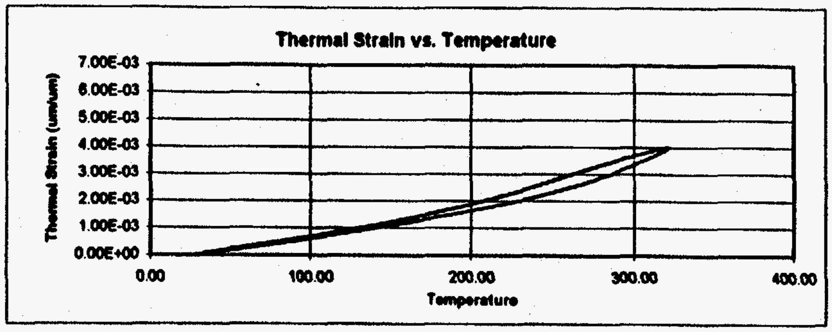
Sample ID: NRG-7-1305.7-SNL-A
Lithology: Welded Devitrified
TMU: TSw2

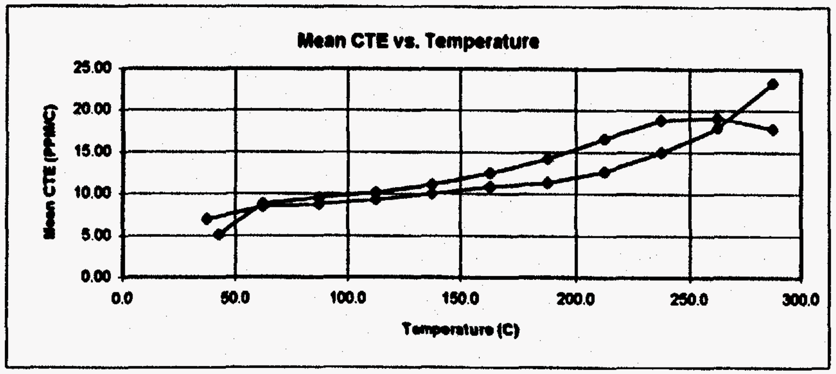
Test condition: AIR DRIED
Sample Size: 2" (l) x 1" (d)

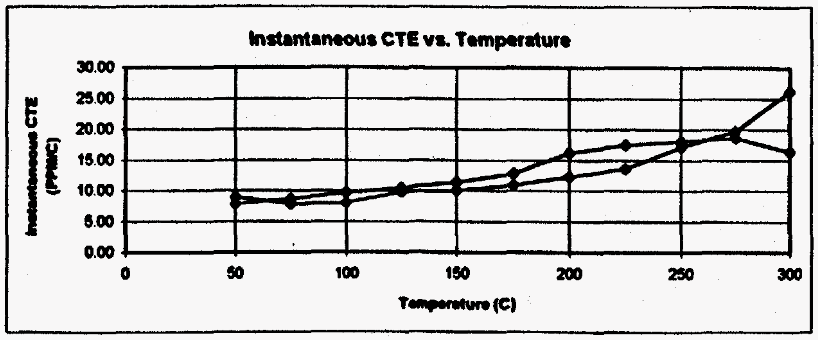
Sample Data:	mass (g)	length (mm)	volume (cc)	density (g/cc)
Initial:	58.93	50.85	25.77	2.29
Final:	58.77	50.85	25.77	2.28

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (^{o}C)
Heat up	25	2.46	***	***	
	50	178.87	7.06	8.02	37.5
	75	387.00	8.33	8.45	62.5
	100	604.26	8.69	9.03	87.5
	125	835.28	9.24	8.65	112.5
	150	1078.38	9.72	10.10	137.5
	175	1335.67	10.29	9.34	162.5
	200	1611.65	11.05	13.04	187.5
	225	1926.51	12.59	12.03	212.5
	250	2272.34	13.83	14.13	237.5
	275	2687.02	16.59	16.26	262.5
	300	3203.13	20.64	23.82	287.5
Cool down	300	3457.99	16.91	14.26	287.5
	275	3035.16	17.51	17.92	262.5
	250	2597.32	16.46	17.39	237.5
	225	2185.78	15.04	15.59	212.5
	200	1809.70	13.33	15.31	187.5
	175	1476.43	11.67	11.74	162.5
	150	1184.77	10.76	11.46	137.5
	125	915.82	9.92	10.50	112.5
	100	667.86	9.52	9.57	87.5
	75	429.91	8.94	9.02	62.5
	50	206.37	5.15	8.39	42.5
	35	77.61	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

Sample ID: NRG-7-1364.6-SNL-A
Lithology: Welded Devitrified
TMU: TSw2

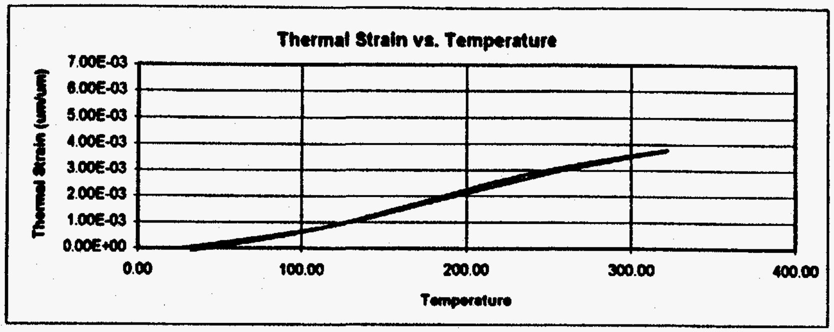
Test condition: AIR DRIED
Sample Size: 2" (l) x 1" (d)

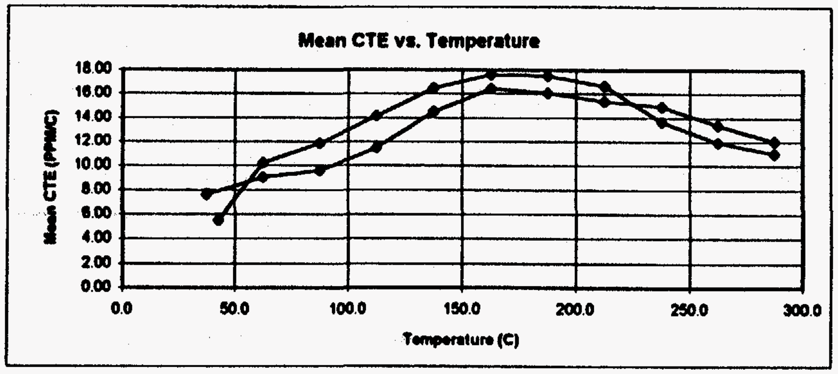
Sample Data:

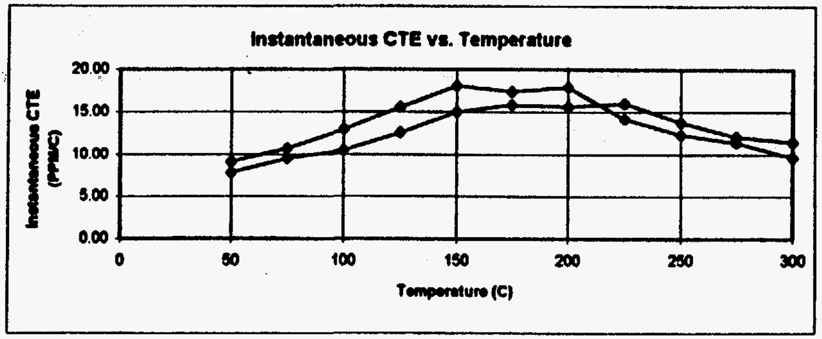
	mass (g)	length (mm)	volume (cc)	density (g/cc)
Initial:	59.30	49.73	25.20	2.35
Final:	59.09	49.73	25.20	2.34

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (°C)
Heat up	25	4.19	***	***	
	50	179.73	7.02	8.97	37.5
	75	390.81	8.44	7.74	62.5
	100	610.75	8.80	8.01	87.5
	125	843.65	9.32	9.82	112.5
	150	1093.66	10.00	9.95	137.5
	175	1364.92	10.85	10.98	162.5
	200	1648.59	11.35	12.37	187.5
	225	1965.02	12.66	13.54	212.5
	250	2339.04	14.96	17.15	237.5
	275	2788.24	17.97	19.74	262.5
	300	3371.76	23.34	26.16	287.5
Cool down	300	3706.74	17.85	16.42	287.5
	275	3262.61	19.19	18.59	262.5
	250	2782.81	18.86	18.06	237.5
	225	2311.32	16.61	17.45	212.5
	200	1896.07	14.22	16.24	187.5
	175	1540.52	12.47	12.88	162.5
	150	1228.70	11.11	11.40	137.5
	125	950.84	10.17	10.44	112.5
	100	696.50	9.53	9.72	87.5
	75	458.24	8.88	8.66	62.5
	50	236.32	5.12	7.83	42.5
	35	106.23	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.







Data Summary

Sample ID: NRG-7-1407.4-SNL-A
Lithology: Welded Devitrified
TMU: TSw2

Test condition: AIR DRIED
Sample Size: 2" (l) x 1" (d)

Sample Data:

	mass (g)	length (mm)	volume (cc)	density (g/cc)
Initial:	57.08	50.75	25.72	2.22
Final:	56.37	50.75	25.72	2.19

	Temp	Thermal Strain (um/m)	+/- 12.5 C Mean CTE (PPM/C)	+/- 2.5 C Inst. CTE (PPM/C)	Mean Temp (^{o}C)
Heat up	25	1.79	***	***	
	50	192.62	7.63	7.80	37.5
	75	418.33	9.03	9.48	62.5
	100	658.06	9.59	10.53	87.5
	125	944.82	11.47	12.57	112.5
	150	1307.77	14.52	15.06	137.5
	175	1719.11	16.45	15.90	162.5
	200	2120.70	16.06	15.60	187.5
	225	2504.67	15.36	16.01	212.5
	250	2878.44	14.95	13.77	237.5
	275	3212.84	13.38	12.13	262.5
	300	3513.96	12.04	11.50	287.5
Cool down	300	3590.54	11.05	9.66	287.5
	275	3314.41	11.96	11.39	262.5
	250	3015.32	13.66	12.36	237.5
	225	2673.73	16.68	14.19	212.5
	200	2256.84	17.53	17.90	187.5
	175	1818.66	17.61	17.38	162.5
	150	1378.31	16.50	18.08	137.5
	125	965.75	14.15	15.57	112.5
	100	612.11	11.85	12.93	87.5
	75	315.85	10.24	10.75	62.5
	50	59.86	5.52	9.12	42.5
	35	-78.11	***	***	

* Mean CTE's are calculated over 25 degree ranges, so that the value in the table for the range is reported at the end of the range. For example, the value for the range 25 - 50, is given in the 50 row.

APPENDIX F

Heat Capacity Test Data

This page intentionally left blank

Data Summary

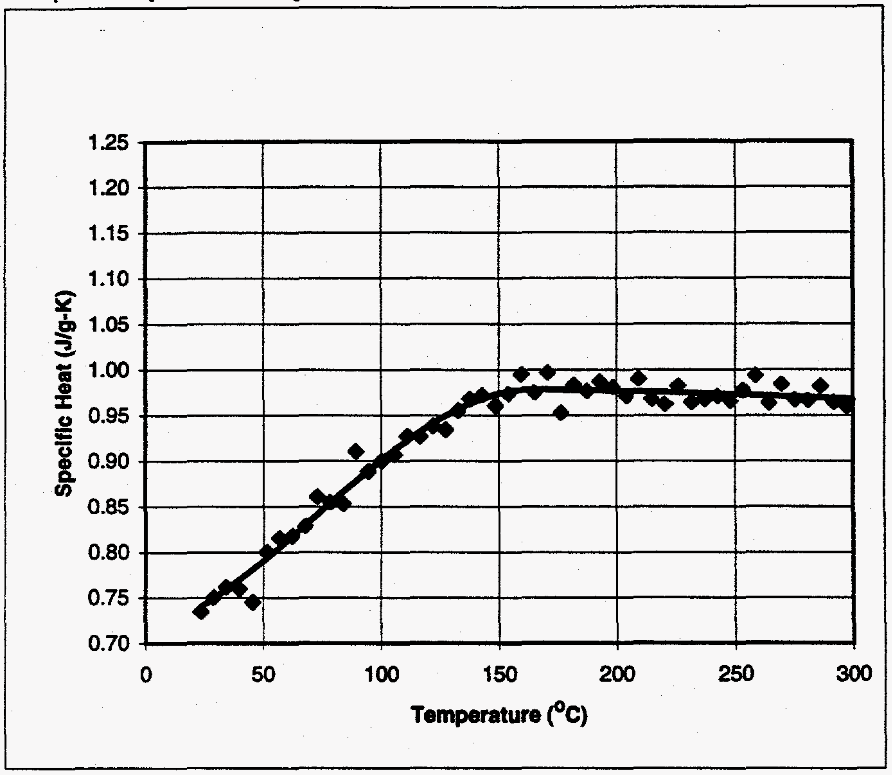
Sample ID	NRG-4-545.0-SNL-B
Borehole	USW-NRG-4
Depth (ft)	545.0
Lithology	Welded Devitrified
T/M Unit	TSw1

Test Conditions

Saturation State	Air Dry

Sample Data

Initial Mass	225.35 g
Final Mass	224.68 g
Sample Size	49.58 mm OD 10.49 mm ID 58.93 mm Len
Sample Volume	108.68 cc
Sample Density	2.07 g/cc



Original Data		Curve-fit Data		
Temp	C_p	Temp	Cp	ρC_p
23.7	0.73	25	0.74	1.54
29.0	0.75	30	0.75	1.55
34.3	0.76	35	0.76	1.57
39.9	0.76	40	0.77	1.59
45.7	0.75	45	0.78	1.61
51.4	0.80	50	0.79	1.64
56.9	0.82	55	0.80	1.66
62.3	0.82	60	0.81	1.68
67.7	0.83	65	0.82	1.70
73.1	0.86	70	0.83	1.73
78.6	0.85	75	0.85	1.75
84.1	0.85	80	0.86	1.77
89.3	0.91	85	0.87	1.80
94.7	0.89	90	0.88	1.82
100.2	0.90	95	0.89	1.84
105.7	0.91	100	0.90	1.86
111.2	0.93	105	0.91	1.88
116.6	0.93	110	0.92	1.90
122.0	0.94	115	0.93	1.92
127.4	0.93	120	0.94	1.94
132.7	0.95	125	0.95	1.96
137.9	0.97	130	0.95	1.97
143.2	0.97	135	0.96	1.99
148.6	0.96	140	0.97	2.00
154.2	0.97	145	0.97	2.01
159.8	0.99	150	0.97	2.02
165.3	0.98	155	0.98	2.02
170.9	1.00	160	0.98	2.02
176.4	0.95	165	0.98	2.02
182.0	0.98	170	0.98	2.03
187.6	0.98	175	0.98	2.02
193.1	0.99	180	0.98	2.02
198.5	0.98	185	0.98	2.02
204.0	0.97	190	0.98	2.02
209.5	0.99	195	0.98	2.02
215.0	0.97	200	0.98	2.02
220.6	0.96	205	0.98	2.02
226.1	0.98	210	0.98	2.02
231.6	0.96	215	0.98	2.02
237.1	0.97	220	0.98	2.02
242.6	0.97	225	0.97	2.02
248.1	0.97	230	0.97	2.02
253.5	0.98	235	0.97	2.02
259.0	0.99	240	0.97	2.02
264.4	0.96	245	0.97	2.01
269.9	0.98	250	0.97	2.01
275.4	0.97	255	0.97	2.01
280.8	0.97	260	0.97	2.01
286.3	0.98	265	0.97	2.01
291.7	0.96	270	0.97	2.01
297.2	0.96	275	0.97	2.01
		280	0.97	2.01
		285	0.97	2.01
		290	0.97	2.01
		295	0.97	2.00
		300	0.97	2.00

Temperature Interval and Regression Equations

25 to 169 $Cp = -9.0717E\text{-}08 \times T^3 + 1.9782E\text{-}05 \times T^2 + 8.2616E\text{-}04 \times T + 0.71073$

$r^2 = 0.98$

170 to 300 $Cp = -2.4663E\text{-}07 \times T^2 + 3.4208E\text{-}05 \times T + 0.97969$

$r^2 = 0.80$

Data Summary

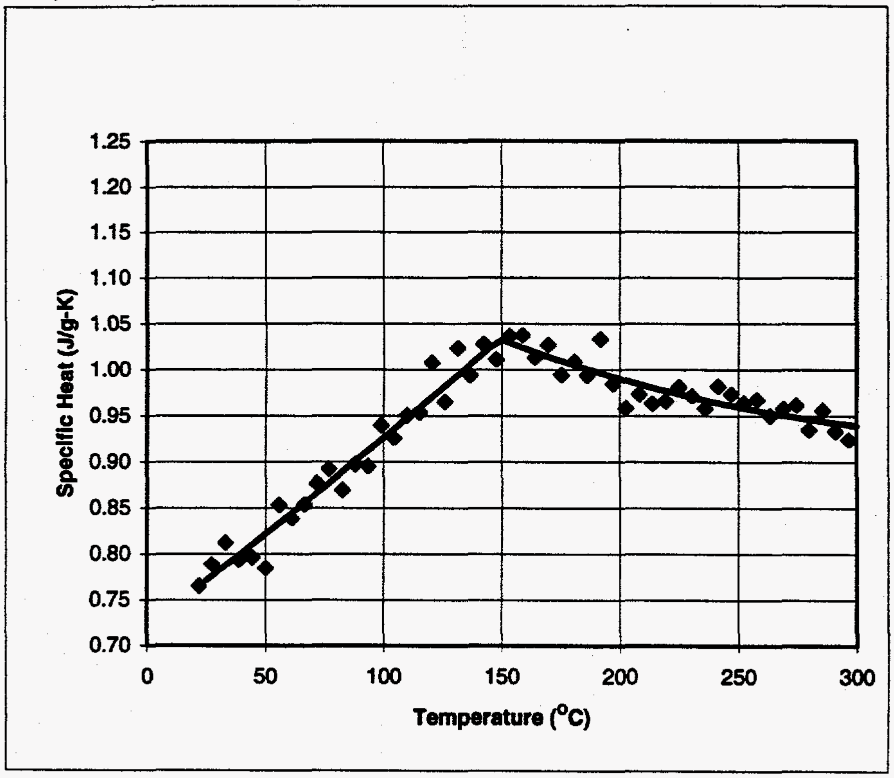
Sample ID	NRG-4-619.9-SNL-C
Borehole	USW-NRG-4
Depth (ft)	619.9
Lithology	Welded Devitrified
T/M Unit	TSw1

Test Conditions

Saturation State	Air Dry

Sample Data

Initial Mass	218.01 g		
Final Mass	217.20 g		
Sample Size	49.56 mm OD	10.54 mm ID	56.16 mm Len
Sample Volume	103.44 cc		
Sample Density	2.11 g/cc		



Original Data		Curve-fit Data		
Temp	C_p	Temp	Cp	ρC_p
22.1	0.76	25	0.77	1.63
27.5	0.79	30	0.78	1.65
33.2	0.81	35	0.79	1.67
38.8	0.79	40	0.80	1.69
44.5	0.80	45	0.81	1.71
50.1	0.78	50	0.82	1.73
55.6	0.85	55	0.83	1.76
61.0	0.84	60	0.84	1.78
66.4	0.85	65	0.85	1.80
71.7	0.88	70	0.86	1.82
76.9	0.89	75	0.87	1.84
82.4	0.87	80	0.88	1.87
88.0	0.90	85	0.89	1.89
93.6	0.90	90	0.91	1.91
99.1	0.94	95	0.92	1.93
104.5	0.93	100	0.93	1.95
109.9	0.95	105	0.94	1.98
115.3	0.95	110	0.95	2.00
120.5	1.01	115	0.96	2.02
126.0	0.97	120	0.97	2.05
131.4	1.02	125	0.98	2.07
136.8	0.99	130	0.99	2.09
142.3	1.03	135	1.00	2.11
147.8	1.01	140	1.01	2.14
153.3	1.04	145	1.02	2.16
158.8	1.04	150	1.03	2.18
164.3	1.01	155	1.03	2.17
169.7	1.03	160	1.02	2.16
175.2	0.99	165	1.02	2.15
180.7	1.01	170	1.01	2.14
186.2	0.99	175	1.01	2.13
191.7	1.03	180	1.01	2.12
197.2	0.99	185	1.00	2.11
202.7	0.96	190	1.00	2.11
208.2	0.97	195	0.99	2.10
213.7	0.96	200	0.99	2.09
219.3	0.97	205	0.99	2.08
224.8	0.98	210	0.98	2.07
230.3	0.97	215	0.98	2.07
235.8	0.96	220	0.98	2.06
241.4	0.98	225	0.97	2.05
246.9	0.97	230	0.97	2.05
252.4	0.96	235	0.97	2.04
257.9	0.97	240	0.96	2.04
263.5	0.95	245	0.96	2.03
269.0	0.96	250	0.96	2.02
274.5	0.96	255	0.96	2.02
280.0	0.94	260	0.95	2.01
285.6	0.96	265	0.95	2.01
291.1	0.93	270	0.95	2.01
296.7	0.92	275	0.95	2.00
		280	0.95	2.00
		285	0.94	1.99
		290	0.94	1.99
		295	0.94	1.99
		300	0.94	1.98

Temperature Interval and Regression Equations

25 to 149 $Cp = 7.6690E\text{-}07 \times T^2 + 1.9814E\text{-}03 \times T + 0.72050$
$r^2 = 0.97$

150 to 300 $Cp = 2.2372E\text{-}06 \times T^2 - 1.6239E\text{-}03 \times T + 1.2257$
$r^2 = 0.76$

Data Summary

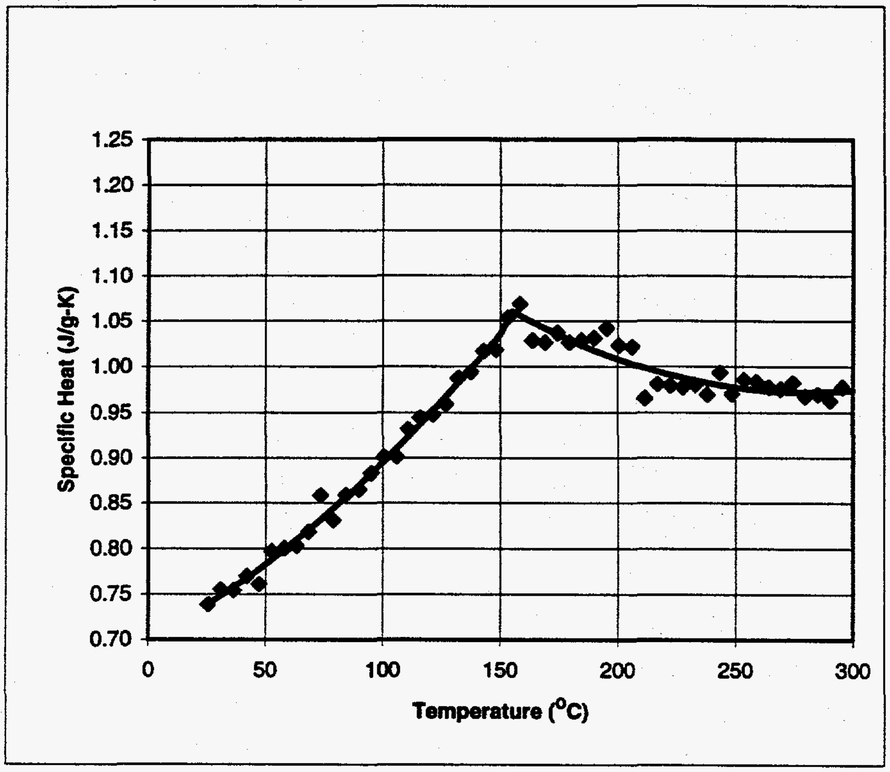
Sample ID	NRG-4-619.9-SNL-D
Borehole	USW-NRG-4
Depth (ft)	619.9
Lithology	Welded Devitrified
T/M Unit	TSw1

Test Conditions

Saturation State	Air Dry

Sample Data

Initial Mass	229.34 g		
Final Mass	228.44 g		
Sample Size	49.58 mm OD	10.41 mm ID	57.84 mm Len
Sample Volume	106.75 cc		
Sample Density	2.15 g/cc		



Original Data		Curve-fit Data		
Temp	C_p	Temp	Cp	ρC_P
25.5	0.74	25	0.74	1.59
31.0	0.75	30	0.75	1.61
36.5	0.75	35	0.76	1.62
42.0	0.77	40	0.76	1.64
47.4	0.76	45	0.77	1.66
52.7	0.80	50	0.78	1.68
58.0	0.80	55	0.79	1.70
63.2	0.80	60	0.80	1.73
68.4	0.82	65	0.81	1.75
73.6	0.86	70	0.82	1.77
78.9	0.83	75	0.84	1.80
84.4	0.86	80	0.85	1.82
89.8	0.86	85	0.86	1.84
95.2	0.88	90	0.87	1.87
100.5	0.90	95	0.88	1.90
105.8	0.90	100	0.89	1.92
111.0	0.93	105	0.91	1.95
116.1	0.94	110	0.92	1.98
121.4	0.95	115	0.93	2.01
126.9	0.96	120	0.95	2.04
132.3	0.99	125	0.96	2.07
137.6	0.99	130	0.98	2.10
142.8	1.02	135	0.99	2.13
148.0	1.02	140	1.01	2.16
153.2	1.05	145	1.02	2.19
158.4	1.07	150	1.04	2.23
163.7	1.03	155	1.06	2.28
169.1	1.03	160	1.05	2.27
174.3	1.04	165	1.05	2.25
179.4	1.03	170	1.04	2.24
184.6	1.03	175	1.03	2.22
189.9	1.03	180	1.03	2.21
195.2	1.04	185	1.02	2.20
200.6	1.02	190	1.02	2.19
206.1	1.02	195	1.01	2.18
211.7	0.97	200	1.01	2.17
217.2	0.98	205	1.00	2.16
222.4	0.98	210	1.00	2.15
227.6	0.98	215	1.00	2.14
232.9	0.98	220	0.99	2.13
238.1	0.97	225	0.99	2.13
243.4	0.99	230	0.99	2.12
248.6	0.97	235	0.98	2.11
253.8	0.99	240	0.98	2.11
259.0	0.98	245	0.98	2.10
264.2	0.98	250	0.98	2.10
269.4	0.98	255	0.98	2.10
274.6	0.98	260	0.97	2.09
279.8	0.97	265	0.97	2.09
285.1	0.97	270	0.97	2.09
290.3	0.96	275	0.97	2.09
295.5	0.98	280	0.97	2.09
		285	0.97	2.09
		290	0.97	2.09
		295	0.97	2.09
		300	0.97	2.09

Temperature Interval and Regression Equations

25 to 154 $Cp = -5.4079E\text{-}09xT^3 + 7.2200E\text{-}06xT^2 + 1.2555E\text{-}03xT + 0.70257$

$r^2 = 0.99$

155 to 300 $Cp = 5.6298E\text{-}06xT^2 - 3.1584E\text{-}03xT + 1.4149$

$r^2 = 0.80$

Data Summary

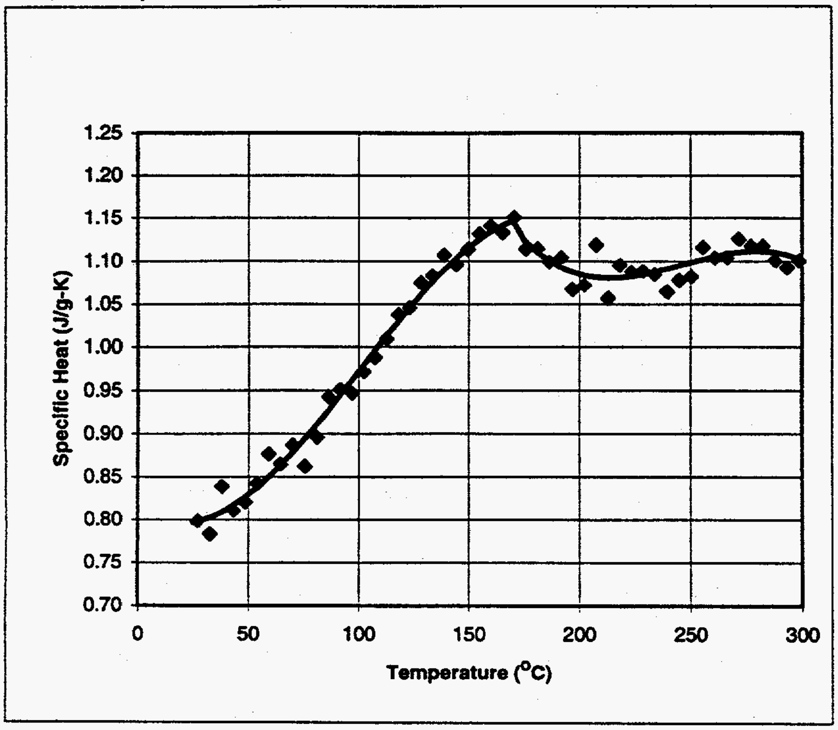
Sample ID	NRG-5-808.5-SNL-C
Borehole	USW-NRG-5
Depth (ft)	808.5
Lithology	Welded Devitrified
T/M Unit	TSw2

Test Conditions

Saturation State	Air Dry

Sample Data

Initial Mass	252.82 g
Final Mass	251.01 g
Sample Size	49.56 mm OD 10.59 mm ID 59.00 mm Len
Sample Volume	108.62 cc
Sample Density	2.33 g/cc



Original Data		Curve-fit Data		
Temp	C_p	Temp	Cp	ρC_p
27.2	0.80	25	0.80	1.86
32.7	0.78	30	0.80	1.86
38.1	0.84	35	0.80	1.88
43.4	0.81	40	0.81	1.89
48.7	0.82	45	0.82	1.91
54.0	0.84	50	0.83	1.93
59.2	0.88	55	0.84	1.96
64.6	0.86	60	0.85	1.98
70.1	0.89	65	0.86	2.01
75.6	0.86	70	0.88	2.05
81.1	0.90	75	0.89	2.08
86.4	0.94	80	0.91	2.12
91.6	0.95	85	0.92	2.15
96.9	0.95	90	0.94	2.19
102.3	0.97	95	0.96	2.23
107.5	0.99	100	0.97	2.26
112.9	1.01	105	0.99	2.30
118.1	1.04	110	1.00	2.34
123.3	1.05	115	1.02	2.38
128.4	1.07	120	1.04	2.41
133.7	1.08	125	1.05	2.45
139.1	1.11	130	1.07	2.48
144.4	1.10	135	1.08	2.52
149.7	1.11	140	1.09	2.55
155.0	1.13	145	1.10	2.57
160.2	1.14	150	1.12	2.60
165.4	1.13	155	1.13	2.62
170.6	1.15	160	1.13	2.64
175.9	1.11	165	1.14	2.66
181.3	1.11	170	1.15	2.67
186.5	1.10	175	1.12	2.62
191.8	1.10	180	1.11	2.59
197.1	1.07	185	1.10	2.57
202.4	1.07	190	1.10	2.55
207.7	1.12	195	1.09	2.54
213.0	1.06	200	1.09	2.53
218.3	1.10	205	1.08	2.52
223.6	1.09	210	1.08	2.52
228.8	1.09	215	1.08	2.52
234.1	1.08	220	1.08	2.52
239.5	1.06	225	1.08	2.52
244.9	1.08	230	1.09	2.53
250.2	1.08	235	1.09	2.54
255.5	1.12	240	1.09	2.54
260.8	1.10	245	1.09	2.55
266.3	1.10	250	1.10	2.56
271.7	1.13	255	1.10	2.57
277.1	1.12	260	1.10	2.57
282.5	1.12	265	1.11	2.58
288.0	1.10	270	1.11	2.59
293.4	1.09	275	1.11	2.59
298.6	1.10	280	1.11	2.59
		285	1.11	2.59
		290	1.11	2.59
		295	1.11	2.58
		300	1.10	2.57

Temperature Interval and Regression Equations

25 to 170 $Cp = -1.5870E\text{-}07xT^3 + 4.8271E\text{-}05xT^2 - 1.6165E\text{-}03xT + 0.80931$

$r^2 = 0.98$

171 to 300 $Cp = -2.1604E\text{-}07xT^3 + 1.5982E\text{-}04xT^2 - 3.8721E\text{-}02xT + 4.1635$

$r^2 = 0.40$

Data Summary

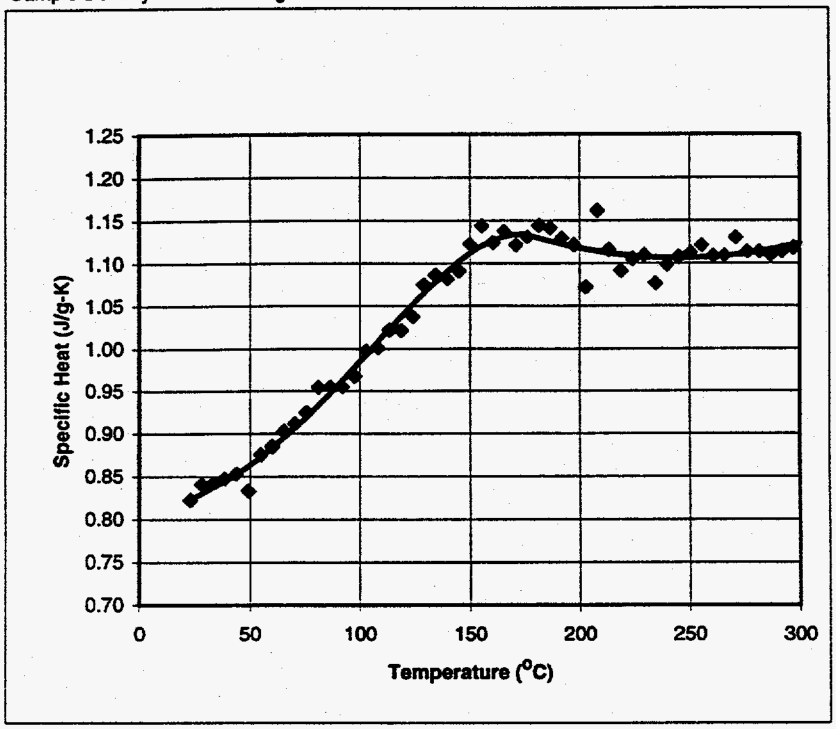
Sample ID	NRG-5-828.2-SNL-C
Borehole	USW-NRG-5
Depth (ft)	828.2
Lithology	Welded Devitrified
T/M Unit	TSw2

Test Conditions

Saturation State	Air Dry

Sample Data

Initial Mass	250.80 g		
Final Mass	249.05 g		
Sample Size	49.61 mm OD	10.57 mm ID	58.95 mm Len
Sample Volume	108.78 cc		
Sample Density	2.30 g/cc		



Original Data		Curve-fit Data		
Temp	C_p	Temp	Cp	ρC_P
23.1	0.82	25	0.83	1.90
28.3	0.84	30	0.83	1.91
33.4	0.84	35	0.84	1.93
38.6	0.85	40	0.85	1.95
43.8	0.85	45	0.85	1.97
49.3	0.83	50	0.86	1.99
54.8	0.88	55	0.87	2.01
60.1	0.89	60	0.88	2.03
65.4	0.90	65	0.89	2.06
70.6	0.91	70	0.91	2.08
75.8	0.92	75	0.92	2.11
81.2	0.95	80	0.93	2.14
86.7	0.95	85	0.94	2.17
92.1	0.95	90	0.96	2.20
97.6	0.97	95	0.97	2.23
102.9	1.00	100	0.98	2.26
108.3	1.00	105	1.00	2.30
113.5	1.02	110	1.01	2.33
118.8	1.02	115	1.03	2.36
124.0	1.04	120	1.04	2.39
129.1	1.07	125	1.05	2.42
134.3	1.09	130	1.07	2.45
139.6	1.08	135	1.08	2.48
144.9	1.09	140	1.09	2.51
150.2	1.12	145	1.10	2.53
155.3	1.14	150	1.11	2.56
160.5	1.12	155	1.12	2.57
165.8	1.14	160	1.13	2.59
171.0	1.12	165	1.13	2.60
176.2	1.13	170	1.13	2.61
181.4	1.14	175	1.13	2.61
186.6	1.14	180	1.13	2.60
192.0	1.13	185	1.13	2.59
197.4	1.12	190	1.12	2.58
203.0	1.07	195	1.12	2.58
208.3	1.16	200	1.12	2.57
213.5	1.12	205	1.12	2.56
219.0	1.09	210	1.11	2.56
224.4	1.10	215	1.11	2.56
229.6	1.11	220	1.11	2.55
234.8	1.08	225	1.11	2.55
240.0	1.10	230	1.11	2.55
245.2	1.11	235	1.11	2.54
250.4	1.11	240	1.11	2.54
255.6	1.12	245	1.11	2.54
260.8	1.11	250	1.11	2.54
266.0	1.11	255	1.11	2.54
271.1	1.13	260	1.11	2.55
276.4	1.11	265	1.11	2.55
281.7	1.11	270	1.11	2.55
286.9	1.11	275	1.11	2.56
292.0	1.11	280	1.11	2.56
297.2	1.12	285	1.11	2.56
		290	1.12	2.57
		295	1.12	2.58
		300	1.12	2.58

Temperature Interval and Regression Equations

25 to 174 $Cp = -6.7444E\text{-}10xT^4 + 1.3430E\text{-}07xT^3 + 3.0995E\text{-}06xT^2 + 8.6536E\text{-}04xT + 0.79993$

$r2 = 1.00$

175 to 300 $Cp = 5.6847E\text{-}06xT^2 - 2.7903E\text{-}03xT + 1.4483$

$r^2 = 0.22$

Data Summary

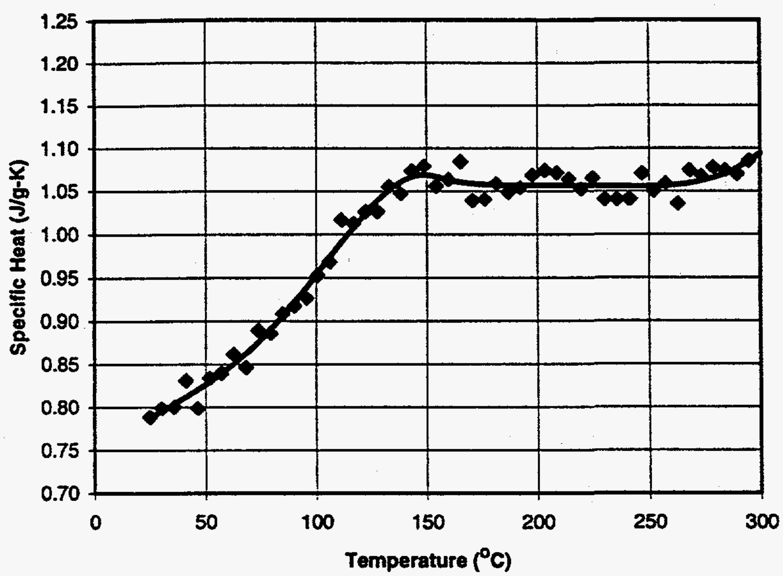
Sample ID	NRG-5-834.8-SNL-E
Borehole	USW-NRG-5
Depth (ft)	834.8
Lithology	Welded Devitrified
T/M Unit	TSw2

Test Conditions

Saturation State	Air Dry

Sample Data

Initial Mass	242.82 g		
Final Mass	241.35 g		
Sample Size	49.53 mm OD	10.62 mm ID	58.47 mm Len
Sample Volume	107.48 cc		
Sample Density	2.26 g/cc		



Original Data		Curve-fit Data		
Temp	C_p	Temp	Cp	ρC_p
25.1	0.79	25	0.79	1.78
30.5	0.80	30	0.79	1.80
35.9	0.80	35	0.80	1.81
41.3	0.83	40	0.81	1.83
46.6	0.80	45	0.82	1.85
51.9	0.83	50	0.83	1.87
57.2	0.84	55	0.84	1.89
62.6	0.86	60	0.84	1.91
68.2	0.85	65	0.86	1.93
73.8	0.89	70	0.87	1.96
79.3	0.89	75	0.88	1.99
84.7	0.91	80	0.89	2.02
90.1	0.92	85	0.91	2.05
95.4	0.93	90	0.92	2.08
100.7	0.95	95	0.94	2.12
106.1	0.97	100	0.95	2.15
111.6	1.02	105	0.97	2.19
117.1	1.01	110	0.99	2.23
122.5	1.03	115	1.00	2.26
127.8	1.03	120	1.02	2.30
133.1	1.06	125	1.03	2.33
138.3	1.05	130	1.04	2.36
143.5	1.07	135	1.06	2.38
148.8	1.08	140	1.06	2.40
154.4	1.06	145	1.07	2.41
160.0	1.06	150	1.07	2.42
165.4	1.08	155	1.07	2.41
170.9	1.04	160	1.06	2.40
176.5	1.04	165	1.06	2.40
181.8	1.06	170	1.06	2.39
187.1	1.05	175	1.06	2.39
192.6	1.05	180	1.06	2.39
198.0	1.07	185	1.06	2.39
203.4	1.07	190	1.06	2.39
208.9	1.07	195	1.06	2.39
214.3	1.06	200	1.06	2.39
219.7	1.05	205	1.06	2.39
225.1	1.07	210	1.06	2.39
230.6	1.04	215	1.06	2.39
236.0	1.04	220	1.06	2.39
241.5	1.04	225	1.06	2.39
246.9	1.07	230	1.06	2.39
252.3	1.05	235	1.06	2.39
257.7	1.06	240	1.06	2.39
263.0	1.04	245	1.06	2.39
268.4	1.07	250	1.06	2.39
273.7	1.07	255	1.06	2.39
279.0	1.08	260	1.06	2.39
284.3	1.07	265	1.06	2.39
289.6	1.07	270	1.06	2.40
294.9	1.09	275	1.06	2.40
300.1	1.09	280	1.07	2.41
		285	1.07	2.42
		290	1.08	2.43
		295	1.08	2.45
		300	1.09	2.47

Temperature Interval and Regression Equations

0 to 159 $Cp = -2.8397E\text{-}09 x T^4 + 8.0502E\text{-}07 x T^3 - 6.6032E\text{-}05 x T^2 + 3.6767E\text{-}03 x T + 0.72467$

$r^2 = 0.99$

160 to 300 $Cp = 9.4102E\text{-}10 x T^4 - 8.0985E\text{-}07 x T^3 + 2.6004E\text{-}04 x T^2 - 3.6944E\text{-}02 x T + 3.0175$

$r^2 = 0.36$

Data Summary

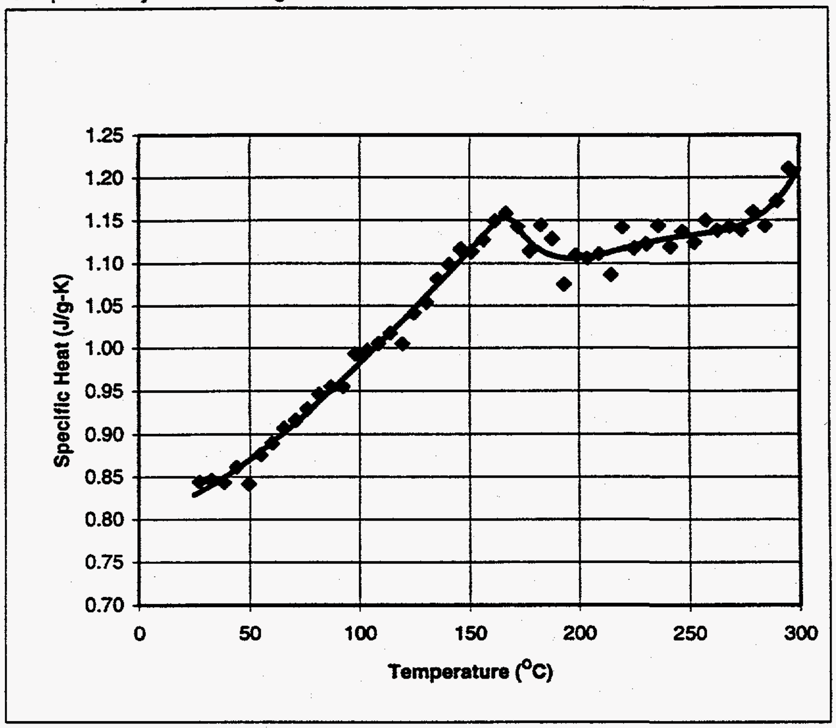
Sample ID	NRG-5-843.5-SNL-D
Borehole	USW-NRG-5
Depth (ft)	843.5
Lithology	Welded Devitrified
T/M Unit	TSw2

Test Conditions

Saturation State	Air Dry

Sample Data

Initial Mass	249.16 g		
Final Mass	247.76 g		
Sample Size	49.56 mm OD	10.49 mm ID	58.57 mm Len
Sample Volume	107.93 cc		
Sample Density	2.31 g/cc		



Temperature Interval and Regression Equations

0 to 169 $Cp = 9.3840E-11xT^4 - 6.2494E-08xT^3 + 1.6805E-05xT^2 + 6.4565E-04xT + 0.80279$

$r^2 = 0.99$

170 to 300 $Cp = 4.9236E-09xT^4 - 4.6386E-06xT^3 + 1.6307E-03xT^2 - 2.5301E-01xT + 15.711$

$r^2 = 0.78$

Original Data		Curve-fit Data		
Temp	C_p	Temp	Cp	ρC_P
27.2	0.84	25	0.83	1.91
32.9	0.85	30	0.84	1.93
38.5	0.84	35	0.84	1.95
44.1	0.86	40	0.85	1.97
49.7	0.84	45	0.86	1.99
55.0	0.88	50	0.87	2.01
60.3	0.89	55	0.88	2.03
65.6	0.91	60	0.89	2.06
71.0	0.92	65	0.90	2.08
76.3	0.93	70	0.91	2.10
81.6	0.95	75	0.92	2.13
87.0	0.95	80	0.93	2.16
92.5	0.95	85	0.95	2.18
98.0	0.99	90	0.96	2.21
103.4	1.00	95	0.97	2.24
108.8	1.01	100	0.98	2.27
114.0	1.02	105	0.99	2.30
119.4	1.00	110	1.01	2.33
124.8	1.04	115	1.02	2.36
130.3	1.05	120	1.03	2.39
135.5	1.08	125	1.05	2.42
140.6	1.10	130	1.06	2.45
145.9	1.12	135	1.07	2.48
151.1	1.11	140	1.09	2.51
156.4	1.13	145	1.10	2.54
161.7	1.15	150	1.11	2.57
166.9	1.16	155	1.13	2.61
172.2	1.14	160	1.14	2.64
177.6	1.11	165	1.16	2.67
182.8	1.14	170	1.15	2.65
188.0	1.13	175	1.13	2.62
193.4	1.08	180	1.12	2.59
198.8	1.11	185	1.11	2.57
204.0	1.11	190	1.11	2.56
209.4	1.11	195	1.11	2.55
214.8	1.09	200	1.11	2.55
220.0	1.14	205	1.11	2.56
225.3	1.12	210	1.11	2.56
230.8	1.12	215	1.11	2.57
236.2	1.14	220	1.12	2.58
241.7	1.12	225	1.12	2.59
247.2	1.14	230	1.12	2.59
252.6	1.12	235	1.13	2.60
257.7	1.15	240	1.13	2.61
263.0	1.14	245	1.13	2.61
268.4	1.14	250	1.13	2.61
273.8	1.14	255	1.13	2.62
279.3	1.16	260	1.14	2.62
284.7	1.14	265	1.14	2.63
290.1	1.17	270	1.14	2.64
295.4	1.21	275	1.15	2.65
300.9	1.21	280	1.15	2.66
		285	1.16	2.68
		290	1.17	2.71
		295	1.19	2.75
		300	1.21	2.80

Data Summary

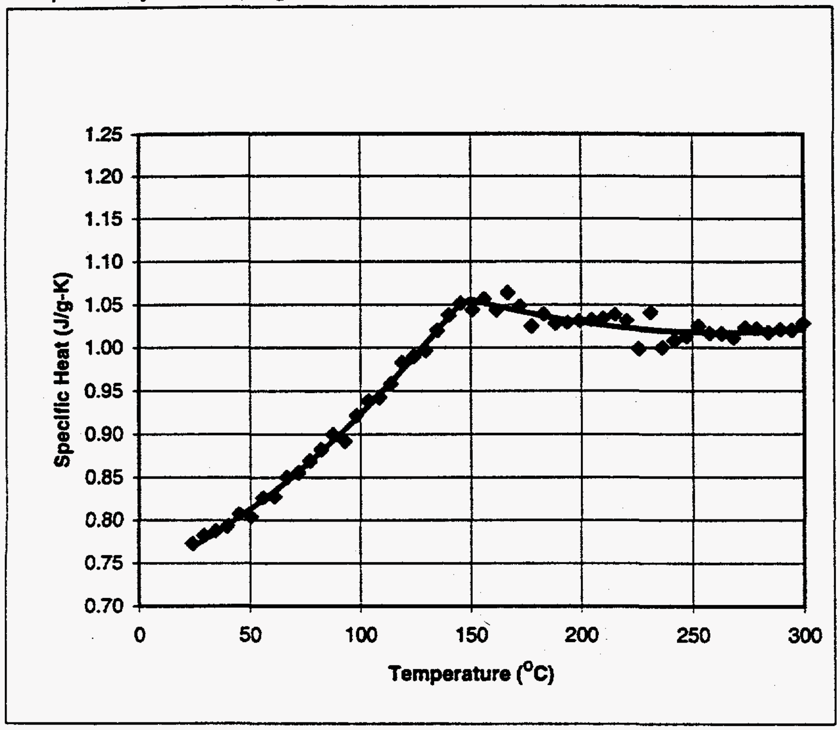
Sample ID	NRG-5-844.0-SNL-C
Borehole	USW-NRG-5
Depth (ft)	844.0
Lithology	Welded Devitrified
T/M Unit	TSw2

Test Conditions

Saturation State	Air Dry

Sample Data

Initial Mass	245.89 g
Final Mass	244.57 g
Sample Size	49.73 mm OD 10.59 mm ID 58.7 mm Len
Sample Volume	108.85 cc
Sample Density	2.26 g/cc



Temperature Interval and Regression Equations

0 to 149 $Cp = -1.7799E\text{-}10xT^3 + 6.6157E\text{-}06xT^2 + 1.2153E\text{-}03xT + 0.73549$
$r^2 = 1.00$

150 to 300 $Cp = 3.0043E\text{-}06xT^2 - 1.5836E\text{-}03xT + 1.2260$
$r^2 = 0.57$

Original Data		Curve-fit Data		
Temp	C_p	Temp	Cp	ρC_P
24.3	0.77	25	0.77	1.74
29.5	0.78	30	0.78	1.76
34.7	0.79	35	0.79	1.78
39.9	0.79	40	0.79	1.80
45.1	0.81	45	0.80	1.82
50.3	0.80	50	0.81	1.84
55.8	0.83	55	0.82	1.86
61.1	0.83	60	0.83	1.88
66.5	0.85	65	0.84	1.90
71.7	0.86	70	0.85	1.93
77.0	0.87	75	0.86	1.95
82.2	0.88	80	0.87	1.98
87.5	0.90	85	0.89	2.00
92.9	0.89	90	0.90	2.03
98.3	0.92	95	0.91	2.06
103.6	0.94	100	0.92	2.09
108.9	0.94	105	0.94	2.11
114.1	0.96	110	0.95	2.14
119.2	0.98	115	0.96	2.18
124.5	0.99	120	0.98	2.21
129.8	1.00	125	0.99	2.24
135.1	1.02	130	1.00	2.27
140.4	1.04	135	1.02	2.30
145.5	1.05	140	1.03	2.34
150.8	1.04	145	1.05	2.37
156.2	1.06	150	1.06	2.39
161.6	1.04	155	1.05	2.38
167.0	1.06	160	1.05	2.37
172.4	1.05	165	1.05	2.37
177.8	1.02	170	1.04	2.36
183.2	1.04	175	1.04	2.35
188.5	1.03	180	1.04	2.35
193.9	1.03	185	1.04	2.34
199.3	1.03	190	1.03	2.34
204.6	1.03	195	1.03	2.33
210.0	1.03	200	1.03	2.33
215.3	1.04	205	1.03	2.32
220.6	1.03	210	1.03	2.32
226.0	1.00	215	1.02	2.32
231.3	1.04	220	1.02	2.31
236.6	1.00	225	1.02	2.31
242.0	1.01	230	1.02	2.31
247.3	1.01	235	1.02	2.30
252.6	1.03	240	1.02	2.30
257.9	1.02	245	1.02	2.30
263.2	1.02	250	1.02	2.30
268.5	1.01	255	1.02	2.30
273.7	1.02	260	1.02	2.30
279.0	1.02	265	1.02	2.30
284.2	1.02	270	1.02	2.30
289.4	1.02	275	1.02	2.30
294.6	1.02	280	1.02	2.30
299.8	1.03	285	1.02	2.30
		290	1.02	2.30
		295	1.02	2.31
		300	1.02	2.31

Data Summary

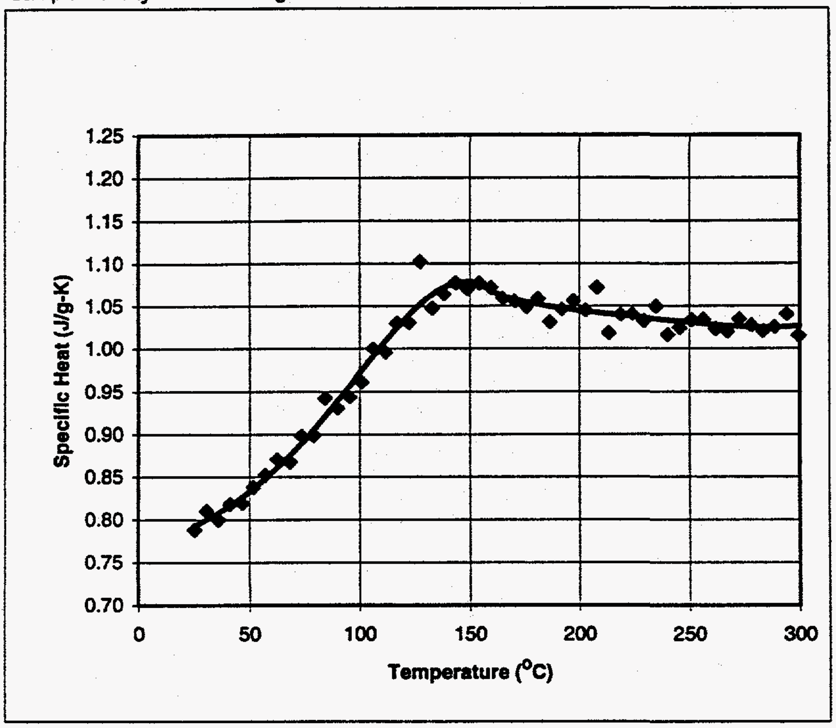
Sample ID	NRG-5-864.0-SNL-C
Borehole	USW-NRG-5
Depth (ft)	864.0
Lithology	Welded Devitrified
T/M Unit	TSw2

Test Conditions

Saturation State	Air Dry

Sample Data

Initial Mass	234.67 g		
Final Mass	233.46 g		
Sample Size	49.68 mm OD	10.52 mm ID	58.75 mm Len
Sample Volume	108.78 cc		
Sample Density	2.16 g/cc		



Original Data		Curve-fit Data		
Temp	C_p	Temp	Cp	ρC_p
25.3	0.79	25	0.79	1.71
30.6	0.81	30	0.80	1.73
36.0	0.80	35	0.81	1.74
41.3	0.82	40	0.81	1.76
46.6	0.82	45	0.82	1.78
51.9	0.84	50	0.83	1.80
57.3	0.85	55	0.84	1.82
62.8	0.87	60	0.85	1.85
68.3	0.87	65	0.87	1.87
73.7	0.90	70	0.88	1.90
79.1	0.90	75	0.89	1.93
84.4	0.94	80	0.91	1.96
89.9	0.93	85	0.92	1.99
95.5	0.94	90	0.94	2.03
101.0	0.96	95	0.95	2.06
106.4	1.00	100	0.97	2.10
111.8	1.00	105	0.99	2.13
117.1	1.03	110	1.00	2.17
122.3	1.03	115	1.02	2.20
127.5	1.10	120	1.03	2.23
132.8	1.05	125	1.05	2.26
138.2	1.06	130	1.06	2.28
143.5	1.08	135	1.07	2.31
148.9	1.07	140	1.07	2.32
154.3	1.08	145	1.08	2.33
159.7	1.07	150	1.08	2.33
165.1	1.06	155	1.08	2.32
170.5	1.06	160	1.07	2.31
175.9	1.05	165	1.06	2.29
181.3	1.06	170	1.06	2.29
186.7	1.03	175	1.06	2.28
192.1	1.05	180	1.05	2.27
197.5	1.06	185	1.05	2.27
202.9	1.05	190	1.05	2.26
208.2	1.07	195	1.05	2.26
213.5	1.02	200	1.04	2.26
218.9	1.04	205	1.04	2.25
224.3	1.04	210	1.04	2.25
229.6	1.03	215	1.04	2.25
235.0	1.05	220	1.04	2.24
240.4	1.02	225	1.04	2.24
245.8	1.02	230	1.04	2.24
251.2	1.03	235	1.03	2.24
256.6	1.03	240	1.03	2.23
261.9	1.02	245	1.03	2.23
267.3	1.02	250	1.03	2.23
272.7	1.03	255	1.03	2.22
278.1	1.03	260	1.03	2.22
283.4	1.02	265	1.03	2.22
288.8	1.03	270	1.03	2.22
294.2	1.04	275	1.03	2.22
299.5	1.02	280	1.03	2.21
		285	1.02	2.21
		290	1.03	2.21
		295	1.03	2.22
		300	1.03	2.22

Temperature Interval and Regression Equations

25 to 164 $Cp = -2.0496E\text{-}09xT^4 + 4.9835E\text{-}07xT^3 - 2.7488E\text{-}05xT^2 + 2.0083E\text{-}03xT + 0.75178$

$r^2 = 0.98$

165 to 300 $Cp = 3.9433E\text{-}10xT^4 - 3.6415E\text{-}07xT^3 + 1.2619E\text{-}04xT^2 - 1.9717E\text{-}02xT + 2.2227$

$r^2 = 0.47$

Data Summary

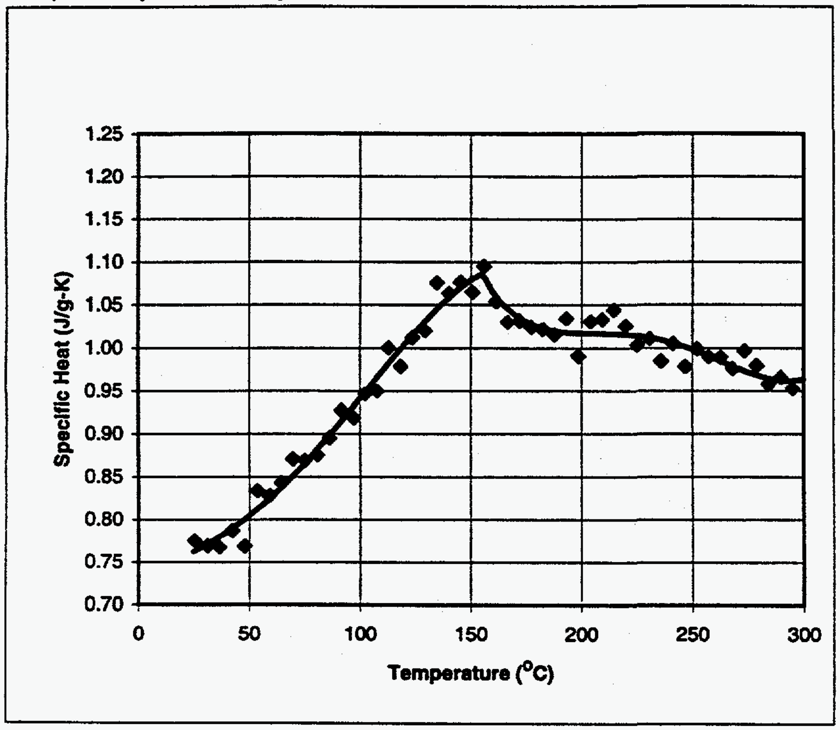
Sample ID	NRG-5-866.7-SNL-C
Borehole	USW-NRG-5
Depth (ft)	866.7
Lithology	Welded Devitrified
T/M Unit	TSw2

Test Conditions

Saturation State	Air Dry

Sample Data

Initial Mass	228.33 g		
Final Mass	227.03 g		
Sample Size	49.63 mm OD	10.57 mm ID	58.50 mm Len
Sample Volume	108.04 cc		
Sample Density	2.11 g/cc		



Original Data		Curve-fit Data		
Temp	C_p	Temp	Cp	ρC_p
25.5	0.77	25	0.76	1.61
31.0	0.77	30	0.77	1.62
36.7	0.77	35	0.78	1.64
42.3	0.79	40	0.79	1.66
48.0	0.77	45	0.79	1.68
53.5	0.83	50	0.80	1.70
58.9	0.83	55	0.82	1.72
64.2	0.84	60	0.83	1.75
69.5	0.87	65	0.84	1.77
75.0	0.87	70	0.85	1.80
80.6	0.88	75	0.87	1.83
86.1	0.90	80	0.88	1.86
91.6	0.93	85	0.90	1.89
97.1	0.92	90	0.91	1.92
102.4	0.95	95	0.93	1.95
107.7	0.95	100	0.94	1.99
113.0	1.00	105	0.96	2.02
118.4	0.98	110	0.97	2.05
123.9	1.01	115	0.99	2.09
129.4	1.02	120	1.00	2.12
134.8	1.08	125	1.02	2.15
140.1	1.06	130	1.03	2.18
145.4	1.08	135	1.05	2.21
150.7	1.06	140	1.06	2.23
156.0	1.09	145	1.07	2.25
161.3	1.05	150	1.08	2.28
166.6	1.03	155	1.09	2.29
172.0	1.03	160	1.06	2.24
177.3	1.02	165	1.05	2.21
182.7	1.02	170	1.04	2.19
188.1	1.02	175	1.03	2.17
193.4	1.03	180	1.03	2.16
198.7	0.99	185	1.02	2.16
204.1	1.03	190	1.02	2.15
209.4	1.03	195	1.02	2.15
214.7	1.04	200	1.02	2.15
220.0	1.03	205	1.02	2.15
225.3	1.00	210	1.02	2.15
230.6	1.01	215	1.02	2.14
236.0	0.98	220	1.02	2.14
241.4	1.00	225	1.01	2.14
246.8	0.98	230	1.01	2.14
252.2	1.00	235	1.01	2.13
257.5	0.99	240	1.01	2.12
262.9	0.99	245	1.00	2.12
268.2	0.98	250	1.00	2.11
273.6	1.00	255	0.99	2.10
279.0	0.98	260	0.99	2.08
284.4	0.96	265	0.98	2.07
289.8	0.97	270	0.98	2.06
295.3	0.95	275	0.97	2.05
		280	0.97	2.04
		285	0.96	2.03
		290	0.96	2.03
		295	0.96	2.03
		300	0.96	2.03

Temperature Interval and Regression Equations

25 to 159 $Cp = -6.7313E-10xT^4 + 1.0697E-07xT^3 + 9.9887E-06xT^2 + 6.2786E-04xT + 0.7391$

$r^2 = 0.98$

160 to 300 $Cp = 2.7912E-09xT^4 - 2.6240E-06xT^3 + 9.1122E-04xT^2 - 1.3901E-01xT + 8.8964$

$r^2 = 0.75$

Appendix G
Lithostratigraphic Unit Assignments for
All Test Specimens

This page intentionally left blank

The U.S. Geological Survey (USGS) has recently developed a lithostratigraphic nomenclature that is described by Geslin et al. (1995) and summarized in Tables G-1 and G-2. This nomenclature is applied to boreholes NRG-4, NRG-5, and NRG-6 in Geslin et al. (1995), and is applied to NRG-7/7A in Geslin and Moyer (1995). The test specimens included in this report are given in terms of the USGS nomenclature in Tables G-3, G-4, and G-5 for thermal conductivity, thermal expansion, and heat capacity, respectively.

Table G-1. Lithostratigraphic Nomenclature[d] of the Paintbrush Group

at Yucca Mountain, Nevada (USGS)

Lithostratigraphic Unit	Abbreviated Nomenclature
Paintbrush Group	
Tuff Unit "X"	Tpki
Pre-Tuff Unit "X" Bedded Tuff	Tpbt5
Tiva Canyon Tuff	Tpc
crystal-rich member (quartz latite)	Tpcr
vitric zone	Tpcrv
non-to partially welded subzone	Tpcrv3
moderately welded subzone	Tpcrv2
vitrophyre subzone	Tpcrv1
nonlithophysal zone	Tpcrn
subvitrophyre transition subzone	Tpcrn4
pumice-poor subzone	Tpcrn3
mixed pumice subzone	Tpcrn2
crystal transition subzone	Tpcrn1
lithophysal zone	Tpcrl
crystal transition subzone	Tocrl1
crystal-poor member (high-silica rhyolite)	Tpcp
upper lithophysal zone	Tpcpul
spherulite-rich subzone	Tpcpul1
middle nonlithophysal zone	Tpcpmn
upper subzone	Tpcpmn3
lithophysae-bearing subzone	Tpcpmn2
lower subzone	Tpcpmn1
lower lithophysal zone	Tpcpll
lower nonlithophysal zone	Tpcpln
hackly subzone	Tpcplnh

[d] From Brechtel et al., 1995

Lithostratigraphic Unit	Abbreviated Nomenclature
spherulitic pumice interval	Tpcplnc3
argillic pumice interval	Tpcplnc2
vitric pumice interval	Tpcplnc1
vitric zone	Tpcpv
vitrophyre subzone	Tpcpv3
moderately welded subzone	Tpcpv2
non- to partially welded subzone	Tpcpv1
Pre-Tiva Canyon Tuff Bedded Tuff	Tpbt4
Yucca Mountain Tuff	Tpy
Pre-Yucca Mountain Tuff Bedded Tuff	Tpbt3
Pah Canyon Tuff	Tpp
Pre-Pah Canyon Tuff Bedded Tuff	Tpbt2
Topopah Spring Tuff	Tpt
crystal-rich member (quartz latite)	Tptr
vitric zone	Tptrv
non- to partially welded subzone	Tptrv3
moderately welded subzone	Tptrv2
vitrophyre subzone	Tptrv1
nonlithophysal zone	Tptrn
lithophysal zone	Tptrl
crystal-rich lithophysal subzone	Tptrl2
crystal transition subzone	Tptrl1
crystal-poor member (high-silica rhyolite)	Tptp
upper lithophysal zone	Tptpul
cavernous lithophysae subzone	Tptpul2
small lithophysae subzone	Tptpul1
middle nonlithophysal zone	Tptpmn
upper subzone	Tptpmn3
lithophysae-bearing subzone	Tptpmn2
lower subzone	Tptpmn1
lower lithophysal zone	Tptpll

Lithostratigraphic Unit	Abbreviated Nomenclature
lower nonlithophysal zone	Tptpln
vitric zone	Tptpv
vitrophyre subzone	Tptpv3
moderately welded subzone	Tptpv2
non- to partially welded subzone	Tptpv1
Pre-Topopah Spring Bedded Tuff	Tpbt1

Table G-2. Definitions of Characters used in Abbreviated Nomenclature

Character Sequence	Nomenclature Abbreviations
1	T = Tertiary
2	p = Paintbrush
3	c = Tiva Canyon Tuff
	bt4 = Pre-Tiva Canyon Tuff Bedded Tuff
	y = Yucca Mountain Tuff
	bt3 = Pre-Yucca Mountain Tuff Bedded Tuff
	p = Pah Canyon Tuff
	bt2 = Pre-Pah Canyon Tuff Bedded Tuff
	t = Topopah Spring Tuff Formation
	bt1 = Pre-Topopah Spring Tuff Bedded Tuff
4	r = crystal rich
	p = crystal poor
5	l = lithophysal
	n = nonlithophysal
	v = vitric
	ul = upper lithophysal
	ll = lower lithophysal
	mn = middle nonlithophysal
	ln = lower nonlithophysal
6	c = columnar
	h = hackly
7	1 = subzone
	2 = subzone
	3 = subzone

Table G-3 Thermal/Mechanical Unit and USGS Lithostratigraphic Nomenclature for All Thermal Conductivity Specimens

Specimen ID	T/M Unit	USGS Lithostratigraphic Nomenclature
NRG-4-431.3-SNL-B	PTn	Tpp
NRG-4-450.6-SNL-B	PTn	Tpp
NRG-4-470.0-SNL-A	PTn	Tptrv2
NRG-4-470.0-SNL-B	PTn	Tptrv2
NRG-4-529.0-SNL-A	TSw1	Tptrn
NRG-4-529.0-SNL-B	TSw1	Tptrn
NRG-4-545.0-SNL-G	TSw1	Tptrn
NRG-4-586.2-SNL-A	TSw1	Tptrn
NRG-4-586.2-SNL-B	TSw1	Tptrn
NRG-4-590.0-SNL-B	TSw1	Tptrn
NRG-4-610.5-SNL-B	TSw1	Tptrn
NRG-4-619.9-SNL-B	TSw1	Tptrn
NRG-4-654.0-SNL-A	TSw1	Tptrn
NRG-4-654.0-SNL-B	TSw1	Tptrn
NRG-5-781.8-SNL-A	TSw1	Tptpul
NRG-5-791.3-SNL-A	TSw1	Tptpul
NRG-5-791.6-SNL-A	TSw1	Tptpul
NRG-5-834.8-SNL-A	TSw2	Tptpmn3
NRG-5-834.8-SNL-B	TSw2	Tptpmn3
NRG-5-843.5-SNL-A	TSw2	Tptpmn3
NRG-5-848.0-SNL-B	TSw2	Tptpmn2
NRG-5-852.5-SNL-B	TSw2	Tptpmn2
NRG-5-853.8-SNL-A	TSw2	Tptpmn2
NRG-5-874.3-SNL-B	TSw2	Tptpmn1
NRG-5-874.9-SNL-B	TSw2	Tptpmn1
NRG-5-879.6-SNL-A	TSw2	Tptpmn1
NRG-5-886.5-SNL-B	TSw2	Tptpmn1
NRG-5-893.3-SNL-B	TSw2	Tptpmn1
NRG-5-899.8-SNL-B	TSw2	Tptpmn1
NRG-6-28.8-SNL-B	TCw	Tpcpll
NRG-6-28.8-SNL-C	TCw	Tpcpll
NRG-6-98.1-SNL-H	TCw	Tpcplnc
NRG-6-98.1-SNL-I	TCw	Tpcplnc
NRG-6-111.0-SNL-H	TCw	Tpcplnc
NRG-6-111.0-SNL-I	TCw	Tpcplnc
NRG-6-152.9-SNL-D	PTn	Tpcpv1
NRG-6-152.9-SNL-E	PTn	Tpcpv1
NRG-6-187.0-SNL-E	PTn	Tpp
NRG-6-187.0-SNL-F	PTn	Tpp

Specimen ID	T/M Unit	USGS Lithostratigraphic Nomenclature
NRG-6-241.5-SNL-D	PTn	Tpbt2
NRG-6-241.5-SNL-E	PTn	Tpbt2
NRG-6-277.5-SNL-D	TSw1	Tptrn
NRG-6-277.5-SNL-E	TSw1	Tptrn
NRG-6-321.1-SNL-D	TSw1	Tptrn
NRG-6-321.1-SNL-E	TSw1	Tptrn
NRG-6-354.9-SNL-B	TSw1	Tptrn
NRG-6-354.9-SNL-C	TSw1	Tptrn
NRG-6-392.1-SNL-C	TSw1	Tptrn
NRG-6-392.1-SNL-D	TSw1	Tptrn
NRG-6-416.0-SNL-J	TSw1	Tptrn
NRG-6-416.0-SNL-K	TSw1	Tptrn
NRG-6-421.8-SNL-C	TSw1	Tptrn
NRG-6-421.8-SNL-D	TSw1	Tptrn
NRG-6-425.3-SNL-A	TSw1	Tptrn
NRG-6-425.3-SNL-B	TSw1	Tptrn
NRG-6-451.2-SNL-A	TSw1	Tptrl
NRG-6-451.2-SNL-B	TSw1	Tptrl
NRG-6-556.1-SNL-A	TSw1	Tptpul1
NRG-6-556.1-SNL-B	TSw1	Tptpul1
NRG-6-693.1-SNL-C	TSw1	Tptpul1
NRG-6-757.0-SNL-A	TSw2	Tptpmn3
NRG-6-757.0-SNL-B	TSw2	Tptpmn3
NRG-6-778.1-SNL-A	TSw2	Tptpmn2
NRG-6-778.1-SNL-B	TSw2	Tptpmn2
NRG-6-787.5-SNL-A	TSw2	Tptpmn1
NRG-6-787.5-SNL-B	TSw2	Tptpmn1
NRG-6-802.7-SNL-C	TSw2	Tptpmn1
NRG-6-802.7-SNL-D	TSw2	Tptpmn1
NRG-6-809.4-SNL-A	TSw2	Tptpmn1
NRG-6-809.4-SNL-B	TSw2	Tptpmn1
NRG-6-900.4-SNL-C	TSw2	Tptpll
NRG-6-900.4-SNL-D	TSw2	Tptpll
NRG-6-926.3-SNL-D	TSw2	Tptpll
NRG-6-926.3-SNL-E	TSw2	Tptpll
NRG-6-987.0-SNL-A	TSw2	Tptpll
NRG-6-987.0-SNL-B	TSw2	Tptpll
NRG-7-18.6-SNL-C	TCw	Tpcpln
NRG-7-18.6-SNL-D	TCw	Tpcpln
NRG-7-27.0-SNL-A	TCw	Tpcpln
NRG-7-27.0-SNL-B	TCw	Tpcpln
NRG-7-56.8-SNL-C	TCw	Tpcpln
NRG-7-56.8-SNL-D	TCw	Tpcpln

Specimen ID	T/M Unit	USGS Lithostratigraphic Nomenclature
NRG-7-75.0-SNL-C	PTn	Tpcpv
NRG-7-75.0-SNL-D	PTn	Tpcpv
NRG-7-91.6-SNL-C	PTn	Tpcpv
NRG-7-91.6-SNL-D	PTn	Tpcpv
NRG-7-104.1-SNL-B	PTn	Tpbt4
NRG-7-104.1-SNL-C	PTn	Tpbt4
NRG-7-113.1-SNL-C	PTn	Tpy
NRG-7-113.1-SNL-B	PTn	Tpy
NRG-7-248.5-SNL-C	PTn	Tpp
NRG-7-248.5-SNL-D	PTn	Tpp
NRG-7-293.3-SNL-C	PTn	Tptrv2
NRG-7-312.8-SNL-C	TSw1	Tptrn
NRG-7-312.8-SNL-D	TSw1	Tptrn

Table G-4 Thermal/Mechanical Unit and USGS Lithostratigraphic Nomenclature for All Thermal Expansion Specimens

Specimen ID	T/M Unit	USGS Lithostratigraphic Nomenclature
NRG-4-450.6-SNL-D	PTn	Tpp
NRG-4-506.0-SNL-D	TSw1	Tptrn
NRG-4-529.0-SNL-C	TSw1	Tptrn
NRG-4-586.2-SNL-D	TSw1	Tptrn
NRG-4-610.5-SNL-D	TSw1	Tptrn
NRG-4-654.5-SNL-A	TSw1	Tptrn
NRG-4-690.6-SNL-A	TSw1	Tptrl1
NRG-5-779.8-SNL-A	TSw1	Tptpul
NRG-5-829.0-SNL-A	TSw2	Tptpmn3
NRG-5-831.8-SNL-A	TSw2	Tptpmn3
NRG-5-848.0-SNL-A	TSw2	Tptpmn2
NRG-5-852.5-SNL-A	TSw2	Tptpmn2
NRG-5-874.9-SNL-A	TSw2	Tptpmn1
NRG-5-879.6-SNL-D	TSw2	Tptpmn1
NRG-5-886.5-SNL-A	TSw2	Tptpmn1
NRG-5-892.8-SNL-A	TSw2	Tptpmn1
NRG-5-893.3-SNL-A	TSw2	Tptpmn1
NRG-5-899.5-SNL-A	TSw2	Tptpmn1
NRG-5-899.8-SNL-A	TSw2	Tptpmn1
NRG-6-28.8-SNL-D	TCw	Tpcpll
NRG-6-28.8-SNL-F	TCw	Tpcpll
NRG-6-28.8-SNL-G	TCw	Tpcpll
NRG-6-98.1-SNL-F	TCw	Tpcplnc
NRG-6-98.1-SNL-G	TCw	Tpcplnc
NRG-6-111.0-SNL-F	TCw	Tpcplnc
NRG-6-111.0-SNL-G	TCw	Tpcplnc
NRG-6-148.4-SNL-A	TCw	Tpcpv2
NRG-6-148.4-SNL-A	TCw	Tpcpv2
NRG-6-152.9-SNL-B	PTn	Tpcpv1
NRG-6-152.9-SNL-C	PTn	Tpcpv1
NRG-6-187.0-SNL-D	PTn	Tpp
NRG-6-277.5-SNL-B	TSw1	Tptrn
NRG-6-277.5-SNL-C	TSw1	Tptrn
NRG-6-321.1-SNL-B	TSw1	Tptrn
NRG-6-321.1-SNL-C	TSw1	Tptrn
NRG-6-354.9-SNL-E	TSw1	Tptrn
NRG-6-354.9-SNL-D	TSw1	Tptrn
NRG-6-392.1-SNL-E	TSw1	Tptrn
NRG-6-392.1-SNL-F	TSw1	Tptrn

Specimen ID	T/M Unit	USGS Lithostratigraphic Nomenclature
NRG-6-416.0-SNL-L	TSw1	Tptrn
NRG-6-416.0-SNL-M	TSw1	Tptrn
NRG-6-421.8-SNL-A	TSw1	Tptrn
NRG-6-421.8-SNL-B	TSw1	Tptrn
NRG-6-458.7-SNL-A	TSw1	Tptrl1
NRG-6-458.7-SNL-B	TSw1	Tptrl1
NRG-6-528.4-SNL-A	TSw1	Tptpul1
NRG-6-528.4-SNL-B	TSw1	Tptpul1
NRG-6-648.6-SNL-A	TSw1	Tptpul1
NRG-6-648.6-SNL-B	TSw1	Tptpul1
NRG-6-693.1-SNL-A	TSw1	Tptpul1
NRG-6-693.1-SNL-B	TSw1	Tptpul1
NRG-6-729.2-SNL-A	TSw2	Tptpmn3
NRG-6-729.2-SNL-B	TSw2	Tptpmn3
NRG-6-729.2-SNL-C	TSw2	Tptpmn3
NRG-6-732.6-SNL-A	TSw2	Tptpmn3
NRG-6-732.6-SNL-B	TSw2	Tptpmn3
NRG-6-732.6-SNL-C	TSw2	Tptpmn3
NRG-6-777.8-SNL-A	TSw2	Tptpmn2
NRG-6-777.8-SNL-B	TSw2	Tptpmn2
NRG-6-788.3-SNL-A	TSw2	Tptpmn1
NRG-6-788.3-SNL-B	TSw2	Tptpmn1
NRG-6-789.4-SNL-A	TSw2	Tptpmn1
NRG-6-802.7-SNL-A	TSw2	Tptpmn1
NRG-6-802.7-SNL-B	TSw2	Tptpmn1
NRG-6-806.0-SNL-A	TSw2	Tptpmn1
NRG-6-806.0-SNL-B	TSw2	Tptpmn1
NRG-6-806.0-SNL-C	TSw2	Tptpmn1
NRG-6-849.9-SNL-A	TSw2	Tptpll
NRG-6-849.9-SNL-B	TSw2	Tptpll
NRG-6-886.5-SNL-A	TSw2	Tptpll
NRG-6-886.5-SNL-B	TSw2	Tptpll
NRG-6-900.4-SNL-A	TSw2	Tptpll
NRG-6-900.4-SNL-B	TSw2	Tptpll
NRG-6-911.2-SNL-A	TSw2	Tptpll
NRG-6-911.2-SNL-B	TSw2	Tptpll
NRG-6-911.2-SNL-C	TSw2	Tptpll
NRG-6-926.3-SNL-A	TSw2	Tptpll
NRG-6-926.3-SNL-B	TSw2	Tptpll
NRG-6-926.3-SNL-C	TSw2	Tptpll
NRG-6-952.2-SNL-A	TSw2	Tptpll
NRG-6-952.2-SNL-B	TSw2	Tptpll
NRG-6-987.6-SNL-A	TSw2	Tptpll

Specimen ID	T/M Unit	USGS Lithostratigraphic Nomenclature
NRG-6-987.6-SNL-B	TSw2	Tptpll
NRG-6-1016.6-SNL-A	TSw2	Tptpll
NRG-6-1016.6-SNL-B	TSw2	Tptpll
NRG-6-1017.2-SNL-A	TSw2	Tptpll
NRG-6-1081.0-SNL-A	TSw2	Tptpll
NRG-6-1081.5-SNL-A	TSw2	Tptpll
NRG-6-1081.5-SNL-B	TSw2	Tptpll
NRG-7-18.6-SNL-A	TCw	Tpcplnh
NRG-7-27.3-SNL-A	TCw	Tpcplnh
NRG-7-56.8-SNL-A	TCw	Tpcplnc
NRG-7-75.0-SNL-B	PTn	Tpcpv2
NRG-7-91.6-SNL-A	PTn	Tpcpv1
NRG-7-104.1-SNL-A	PTn	Tpbt4
NRG-7-113.1-SNL-A	PTn	Tpy
NRG-7-120.9-SNL-A	PTn	Tpy
NRG-7-181.7-SNL-A	PTn	Tpp
NRG-7-248.5-SNL-A	PTn	Tpp
NRG-7-293.3-SNL-A	PTn	Tptrv2
NRG-7-329.2-SNL-A	TSw1	Tptrn
NRG-7-359.1-SNL-A	TSw1	Tptrn
NRG-7-378.9-SNL-A	TSw1	Tptrn
NRG-7-496.3-SNL-A	TSw1	Tptrl1
NRG-7-550.9-SNL-A	TSw1	Tptpul
NRG-7-606.4-SNL-A	TSw1	Tptpul
NRG-7-608.1-SNL-A	TSw1	Tptpul
NRG-7-625.7-SNL-A	TSw1	Tptpul
NRG-7-641.0-SNL-A	TSw1	Tptpul
NRG-7-699.0-SNL-A	TSw1	Tptpul
NRG-7-856.5-SNL-A	TSw2	Tptpmn1
NRG-7-867.8-SNL-A	TSw2	Tptpmn1
NRG-7-956.6-SNL-A	TSw2	Tptpll
NRG-7-979.2-SNL-A	TSw2	Tptpll
NRG-7-1187.4-SNL-A	TSw2	Tptpll
NRG-7-1261.8-SNL-A	TSw2	Tptpln
NRG-7-1269.9-SNL-A	TSw2	Tptpln
NRG-7-1305.7-SNL-A	TSw2	Tptpln
NRG-7-1364.6-SNL-A	TSw2	Tptpln
NRG-7-1407.4-SNL-A	TSw2	Tptpln

Table G-5 Thermal/Mechanical Unit and USGS Lithostratigraphic Nomenclature for All Heat Capacity Specimens

Specimen ID	T/M Unit	USGS Lithostratigraphic Nomenclature
NRG-4-545.0-SNL-B	TSw1	Tptrn
NRG-4-619.9-SNL-C	TSw1	Tptrn
NRG-4-619.9-SNL-D	TSw1	Tptrn
NRG-5-808.5-SNL-C	TSw2	Tptpmn3
NRG-5-828.2-SNL-C	TSw2	Tptpmn3
NRG-5-834.8-SNL-E	TSw2	Tptpmn3
NRG-5-843.5-SNL-D	TSw2	Tptpmn3
NRG-5-844.0-SNL-C	TSw2	Tptpmn3
NRG5-864.0-SNL-C	TSw2	Tptpmn2
NRG-5-866.7-SNL-C	TSw2	Tptpmn2

APPENDIX H

Thermal Properties Data Sorted by Lithostratigraphic Unit

This page intentionally left blank

Table H-1. Rock Thermal Conductivities at T<100°C: Data Sorted by Lithostratigraphic Units

Strati-graphic Unit	Thermal Conductivity (W/mK)											
	Saturated			Partially Saturated			Air Dry			Dry		
	Sample Mean	Sample Std. Dev.	Sample Count	Sample Mean	Sample Std. Dev.	Sample Count	Sample Mean	Sample Std. Dev.	Sample Count	Sample Mean	Sample Std. Dev.	Sample Count
TMG*	No data available.											
Tpki	No data available.											
Tpbt5	No data available.											
Tpcrv	No data available.											
Tpcrn	No data available.											
Tpcpul	No data available.											
Tpcpmn	No data available.											
Tpcpll	1.92	3.00	3	2.08	0.03	3	1.72	0.02	3	1.64	0.14	3
Tpcpln	1.88	0.12	15	1.25	0.51	15	1.51	0.15	6	1.07	0.30	15
Tpcpv	0.98	0.13	13	0.64	0.16	13	0.47	0.04	6	0.49	0.08	13
Tpbt4	0.50	0.05	5	0.50	0.05	5	N/A	N/A	N/A	0.35	0.01	5
Tpy	0.97	0.06	5	0.54	0.04	5	N/A	N/A	N/A	0.40	0.02	5
Tpbt3	No data available.											
Tpp	0.82	0.09	8	0.49	0.04	5	0.18	0.03	3	0.33	0.06	18
Tpbt2	0.67	0.06	3	N/A	N/A	N/A	0.28	0.01	3	0.18	0.02	3
Tptrv	1.00	0.07	8	0.57	0.04	5	N/A	N/A	N/A	0.37	0.01	5
Tptrn	1.62	0.12	33	1.23	0.46	11	1.23	0.09	21	0.95	0.28	47
Tptrl	1.68	0.03	3	N/A	N/A	N/A	1.12	0.02	3	1.22	0.02	3
Tptpul	1.97	0.11	12	N/A	N/A	N/A	1.20	0.21	6	1.07	0.12	9
Tptpmn	2.33	0.45	42	N/A	N/A	N/A	1.68	0.12	15	1.51	0.49	39
Tptpll	2.13	0.13	9	N/A	N/A	N/A	1.65	0.08	9	1.45	0.03	9
Tptpln	No data available.											
Tptpv	No data available.											
Tpbt1	No data available.											
Tac	No data available.											

* Timber Mountain Group: Bedded Tuffs (no abbreviation available)

Table H-2. Rock Thermal Conductivities at T>100°C: Data Sorted by Lithostratigraphic Units

Stratigraphic Unit	Thermal Conductivity (W/mK)		
	Dry		
	Sample Mean	Sample Standard Deviation	Sample Count
TMG*	No data available.		
Tpki	No data available.		
Tpbt5	No data available.		
Tpcrv	No data available.		
Tpcrn	No data available.		
Tpcpul	No data available.		
Tpcpmn	No data available.		
Tpcpll	1.73	0.08	10
Tpcpln	1.49	0.15	47
Tpcpv	0.58	0.16	28
Tpbt4	0.34	0.02	9
Tpy	0.47	0.02	9
Tpbt3	No data available.		
Tpp	0.36	0.03	37
Tpbt2	0.27	0.02	10
Tptrv	0.37	0.01	9
Tptrn	1.17	0.12	136
Tptrl	1.31	0.03	5
Tptpul	1.06	0.22	32
Tptpmn	1.60	0.11	101
Tptpll	1.54	0.04	19
Tptpln	No data available.		
Tptpv	No data available.		
Tpbt1	No data available.		
Tac	No data available.		

* Timber Mountain Group: Bedded Tuffs (no abbreviation available)

Table H-3. Mean Coefficient of Thermal Expansion during Heating: Data Sorted by Lithostratigraphic Units

Strati-graphic Unit	Saturation State	Statistics	Mean CTE on Heat-up ($10^{-6}/{}^{0}C$)										
			25–50°C	50–75°C	75–100°C	100–125°C	125–150°C	150–175°C	175–200°C	200–225°C	225–250°C	250–275°C	275–300°C
TMG*	No data available.												
Tpki	No data available.												
Tpbt5	No data available.												
Tpcrv	No data available.												
Tpcrn	No data available.												
Tpcpul	No data available.												
Tpcpmn	No data available.												
Tpcpll	Saturated	Mean	7.45	7.61	8.11	10.97	12.11	13.87	15.80	18.10	22.35	29.66	86.02
		Std. Dev.	0.18	0.26	0.50	0.87	0.24	0.46	0.60	N/A	N/A	N/A	N/A
		Count	2	2	2	2	2	2	2	1	1	1	1
	Dry	Mean	5.66	8.02	9.78	12.39	12.88	15.03	17.75	25.02	50.58	52.01	79.25
		Std. Dev.	2.59	1.94	1.58	0.65	1.40	1.93	3.16	10.45	40.46	30.20	59.60
		Count	3	3	3	2	2	2	2	2	2	2	2
Tpcpln	Saturated	Mean	6.74	7.63	8.05	9.70	14.23	16.54	18.17	19.43	20.90	26.30	21.47
		Std. Dev.	0.05	0.01	0.71	2.13	0.07	0.27	0.10	0.81	1.27	0.13	3.57
		Count	2	2	2	2	2	2	2	2	2	2	2
	Dry	Mean	7.00	8.41	9.55	9.78	12.61	14.85	16.74	18.95	21.26	30.28	37.11
		Std. Dev.	0.68	0.42	0.92	1.14	1.75	2.12	2.27	1.87	1.29	5.92	15.37
		Count	7	7	7	5	5	5	5	5	5	5	5
Tpcpv	Saturated	Mean	4.65	5.08	0.12	-37.77	5.63	4.91	1.23	-1.79	-4.24	-5.60	-3.84
		Std. Dev.	0.01	0.25	2.23	19.16	0.53	0.30	0.02	N/A	N/A	N/A	N/A
		Count	3	3	3	3	2	2	2	1	1	1	1
	Dry	Mean	4.99	5.11	4.01	-10.37	6.87	5.82	3.67	1.66	-0.75	-2.59	-3.29
		Std. Dev.	1.14	1.42	2.17	20.28	1.45	1.75	2.00	4.19	6.28	6.69	5.47
		Count	4	4	4	3	3	3	3	3	3	3	3
Tpbt4	Saturated	Mean	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
		Std. Dev.											
		Count											
	Dry	Mean	3.95	2.66	-0.01	-6.66	5.57	4.85	5.37	6.20	6.57	6.07	4.26
		Std. Dev.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		Count	1	1	1	1	1	1	1	1	1	1	1
Tpy	Saturated	Mean	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
		Std. Dev.											
		Count											
	Dry	Mean	4.28	4.89	5.11	3.27	6.35	6.28	4.90	2.62	-0.08	-0.82	-1.63
		Std. Dev.	0.23	0.22	0.24	3.05	0.34	0.15	1.94	4.99	8.38	7.39	5.00
		Count	2	2	2	2	2	2	2	2	2	2	2
Tpbt3	No data available.												
Tpp	Saturated	Mean	3.89	1.87	-6.16	-8.35	5.35	3.59	-0.54	-7.51	-15.34	-21.32	-22.08
		Std. Dev.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		Count	1	1	1	1	1	1	1	1	1	1	1
	Dry	Mean	4.26	3.00	1.86	-6.07	5.96	4.60	1.11	-4.49	-10.14	-14.67	-14.68
		Std. Dev.	0.22	0.75	1.84	1.93	0.40	0.37	2.65	7.70	12.70	16.36	14.23
		Count	4	4	4	3	3	3	3	3	3	3	3
Tpbt2	No data available.												
Tptrv	Saturated	Mean	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
		Std. Dev.											
		Count											
	Dry	Mean	5.09	5.98	6.63	1.66	7.82	8.26	6.62	2.65	-3.55	-10.75	-19.54
		Std. Dev.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		Count	1	1	1	1	1	1	1	1	1	1	1
Tptrn	Saturated	Mean	5.96	7.32	6.33	5.40	10.67	14.81	23.03	43.55	46.92	42.03	37.73
		Std. Dev.	1.14	0.59	1.85	3.12	2.33	4.19	8.53	23.63	20.70	16.19	14.03
		Count	6	6	6	6	6	5	5	5	5	5	5
	Dry	Mean	5.66	7.10	8.05	8.43	9.88	15.89	24.15	34.75	33.31	33.51	34.02
		Std. Dev.	1.10	0.97	0.94	1.35	1.28	5.19	12.53	24.62	16.31	12.19	10.07
		Count	20	20	20	15	15	15	15	15	15	15	15
Tptrl	Saturated	Mean	7.02	8.28	6.61	6.12	10.91	15.61	23.50	ND	ND	ND	ND
		Std. Dev.	N/A	N/A	N/A	N/A	N/A	N/A	N/A				
		Count	1	1	1	1	1	1	1				
	Dry	Mean	6.80	8.21	8.97	9.77	11.22	19.58	32.73	43.15	41.33	39.32	38.83
		Std. Dev.	0.92	0.93	0.86	0.94	1.34	2.88	8.17	12.42	8.64	6.88	5.43
		Count	3	3	3	3	3	3	3	3	3	3	3

Table H-3. Mean Coefficient of Thermal Expansion during Heating: Data Sorted by Lithostratigraphic Units

Strati-graphic Unit	Saturation State	Statistics	Mean CTE on Heat-up ($10^{-6}/^{0}C$)										
			25–50°C	50–75°C	75–100°C	100–125°C	125–150°C	150–175°C	175–200°C	200–225°C	225–250°C	250–275°C	275–300°C
Tptpul	Saturated	Mean	7.59	7.00	7.91	10.22	10.76	12.95	16.73	25.60	32.83	43.98	53.94
		Std. Dev.	0.01	0.33	0.65	0.69	0.32	1.76	3.19	7.08	3.35	8.99	3.49
		Count	3	3	3	3	3	3	3	3	3	3	3
	Dry	Mean	7.41	8.43	8.89	9.52	10.86	13.51	19.38	29.34	32.35	40.16	48.83
		Std. Dev.	0.42	0.36	0.39	0.52	1.34	2.57	6.89	10.73	8.56	17.22	18.41
		Count	10	10	10	10	10	9	8	7	7	7	7
Tptpmn	Saturated	Mean	7.20	7.78	7.93	8.73	10.11	11.74	12.96	15.53	20.60	31.23	50.39
		Std. Dev.	0.84	1.90	0.94	2.04	0.87	0.47	0.70	1.02	2.04	3.75	7.55
		Count	9	9	9	9	9	9	9	7	7	7	7
	Dry	Mean	6.89	8.45	8.95	9.50	10.12	10.95	12.09	14.57	19.45	27.24	41.56
		Std. Dev.	1.45	0.30	0.24	0.27	0.36	0.52	1.01	2.04	3.47	6.23	7.92
		Count	20	20	20	20	20	20	20	17	17	17	17
Tptpll	Saturated	Mean	7.09	7.20	7.03	9.37	9.87	11.73	13.20	15.42	17.80	20.65	26.93
		Std. Dev.	0.45	1.09	1.31	2.78	0.69	1.76	1.85	2.22	3.29	4.80	8.26
		Count	10	10	10	10	10	10	10	9	9	9	9
	Dry	Mean	6.41	8.15	8.77	9.12	9.87	10.75	12.55	15.14	25.19	26.15	33.40
		Std. Dev.	0.75	0.47	0.54	0.57	0.68	1.01	1.80	3.26	27.61	13.65	17.99
		Count	15	15	15	15	15	13	13	13	13	13	13
Tptpln	Saturated	Mean	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
		Std. Dev.											
		Count											
	Dry	Mean	6.55	8.24	8.79	9.58	10.65	11.56	11.90	12.78	13.87	15.28	17.78
		Std. Dev.	1.29	0.57	0.47	1.07	2.17	2.75	2.35	1.53	1.11	1.94	4.38
		Count	5	5	5	5	5	5	5	5	5	5	5
Tptpv	No data available.												
Tpbt1	No data available.												
Tac	No data available.												

* Timber Mountain Group: Bedded Tuffs (abbreviation not available)

Table H-4. Mean Coefficient of Thermal Expansion during Cooling: Data Sorted by Lithostratigraphic Units

Strati-graphic Unit	Saturation State	Statistics	Mean CTE on Cool-down ($10^{-6}/^{0}C$)										
			300–275°C	275–250°C	250–225°C	225–200°C	200–175°C	175–150°C	150–125°C	125–100°C	100–75°C	75–50°C	50–35°C
TMG*	No data available.												
Tpki	No data available.												
Tpbt5	No data available.												
Tpcrv	No data available.												
Tpcrn	No data available.												
Tpcpul	No data available.												
Tpcpmn	No data available.												
Tpcpll	Saturated	Mean	18.78	29.72	52.48	67.23	26.55	18.60	15.69	13.61	12.49	11.38	12.47
		Std. Dev.	N/A	N/A	N/A	N/A	16.41	5.61	3.40	2.55	2.07	1.95	0.58
		Count	1	1	1	1	2	2	2	2	2	2	2
	Dry	Mean	17.79	26.29	46.21	52.24	23.03	16.05	10.78	8.74	8.29	8.14	6.61
		Std. Dev.	3.12	6.50	8.87	10.33	2.57	2.20	0.56	0.06	0.64	1.10	2.33
		Count	2	2	2	2	2	2	2	2	3	3	3
Tpcpln	Saturated	Mean	12.69	18.10	24.05	21.90	21.06	18.36	15.75	13.42	11.69	10.18	9.22
		Std. Dev.	1.90	1.52	1.45	0.67	1.05	0.50	0.18	0.14	0.02	0.56	0.82
		Count	2	2	2	2	2	2	2	2	2	2	2
	Dry	Mean	17.32	26.36	33.24	26.31	22.79	18.19	15.13	12.98	11.17	9.95	6.58
		Std. Dev.	4.24	7.77	10.89	6.00	3.65	1.77	1.31	0.98	0.64	0.57	2.36
		Count	5	5	5	5	5	5	5	5	6	6	6
Tpcpv	Saturated	Mean	16.31	9.72	7.41	6.51	7.53	6.58	6.12	5.41	5.09	4.11	1.27
		Std. Dev.	N/A	N/A	N/A	N/A	1.68	0.85	0.47	0.43	0.42	0.87	3.19
		Count	1	1	1	1	2	2	2	3	3	3	3
	Dry	Mean	10.95	7.54	6.40	6.11	6.28	6.50	6.26	5.96	5.90	5.23	2.95
		Std. Dev.	1.47	0.79	1.20	1.45	1.74	2.09	2.24	2.12	1.25	1.01	0.77
		Count	3	3	3	3	3	3	3	3	4	4	4
Tpbt4	Saturated	Mean	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
		Std. Dev.											
		Count											
	Dry	Mean	8.31	7.37	7.10	6.91	6.53	6.22	5.52	5.27	4.63	3.77	1.07
		Std. Dev.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		Count	1	1	1	1	1	1	1	1	1	1	1
Tpy	Saturated	Mean	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
		Std. Dev.											
		Count											
	Dry	Mean	13.59	8.87	7.16	6.56	6.27	6.33	5.91	5.75	5.30	4.94	2.90
		Std. Dev.	3.78	1.15	0.49	0.06	0.17	0.20	0.12	0.22	0.25	0.40	0.02
		Count	2	2	2	2	2	2	2	2	2	2	2
Tpbt3	No data available.												
Tpp	Saturated	Mean	14.84	8.52	6.99	6.27	5.90	5.70	5.55	5.21	5.20	4.99	3.98
		Std. Dev.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		Count	1	1	1	1	1	1	1	1	1	1	1
	Dry	Mean	9.95	7.36	6.44	6.11	6.06	5.94	5.62	5.37	5.19	4.33	1.76
		Std. Dev.	1.28	0.71	0.43	0.32	0.31	0.12	0.08	0.16	0.51	0.40	0.46
		Count	3	3	3	3	3	3	3	3	4	4	4
Tpbt2	No data available.												
Tptrv	Saturated	Mean	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
		Std. Dev.											
		Count											
	Dry	Mean	14.00	9.32	7.90	7.84	8.65	9.04	8.08	7.24	6.64	5.97	3.23
		Std. Dev.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		Count	1	1	1	1	1	1	1	1	1	1	1
Tptrn	Saturated	Mean	12.19	14.71	17.59	21.77	24.56	30.06	35.72	24.07	11.45	9.59	9.27
		Std. Dev.	2.69	4.08	5.00	5.17	7.33	11.96	20.31	7.95	2.60	1.86	1.30
		Count	5	5	5	5	5	5	6	6	6	6	6
	Dry	Mean	14.48	16.80	19.51	19.32	22.37	24.89	30.46	20.41	10.07	8.78	6.78
		Std. Dev.	2.61	3.27	4.09	3.89	5.58	9.19	17.54	10.32	2.36	1.61	2.93
		Count	15	15	15	15	15	15	15	15	20	20	20
Tptrl	Saturated	Mean	ND	ND	ND	ND	19.45	18.84	16.17	12.67	10.18	9.12	8.36
		Std. Dev.					N/A	N/A	N/A	N/A	N/A	N/A	N/A
		Count					1	1	1	1	1	1	1
	Dry	Mean	16.32	20.35	23.96	27.10	38.99	36.83	30.76	19.18	12.61	10.56	8.08
		Std. Dev.	2.07	2.34	1.67	0.87	4.64	8.53	12.49	7.80	2.84	1.79	1.15
		Count	3	3	3	3	3	3	3	3	3	3	3

Table H-4. Mean Coefficient of Thermal Expansion during Cooling: Data Sorted by Lithostratigraphic Units

Strati-graphic Unit	Saturation State	Statistics	Mean CTE on Cool-down ($10^{-6}/{}^{0}C$)										
			300–275°C	275–250°C	250–225°C	225–200°C	200–175°C	175–150°C	150–125°C	125–100°C	100–75°C	75–50°C	50–35°C
Tptpul	Saturated	Mean	19.87	28.46	34.81	33.46	35.28	23.61	17.14	13.93	11.91	10.84	9.84
		Std. Dev.	2.44	1.92	3.38	2.90	5.21	5.79	2.61	1.30	0.41	0.26	0.01
		Count	3	3	3	3	3	3	3	3	3	3	3
	Dry	Mean	21.56	29.24	34.20	30.06	30.33	22.27	16.63	13.40	10.82	9.68	6.95
		Std. Dev.	3.32	9.61	15.44	8.76	11.03	7.57	4.29	2.41	0.91	0.81	1.80
		Count	7	7	7	7	8	9	10	10	10	10	10
Tptpmn	Saturated	Mean	27.79	38.28	36.20	25.84	17.93	14.51	12.75	11.48	10.65	9.83	9.14
		Std. Dev.	1.45	2.14	5.05	4.41	3.02	1.32	0.84	0.63	0.47	0.40	0.52
		Count	7	7	7	7	9	9	9	9	9	9	9
	Dry	Mean	24.82	30.08	28.39	22.55	17.20	13.72	11.88	10.73	9.93	9.34	8.38
		Std. Dev.	2.25	5.33	6.30	4.27	5.10	3.42	2.78	1.86	1.07	0.45	1.25
		Count	17	17	17	17	20	20	20	20	20	20	20
Tptpll	Saturated	Mean	17.30	19.71	19.05	17.91	16.75	13.66	12.26	11.56	9.92	9.16	8.50
		Std. Dev.	3.93	5.31	4.90	3.92	3.16	1.38	1.65	2.77	0.54	0.64	0.57
		Count	9	9	9	9	10	10	10	10	10	10	10
	Dry	Mean	17.15	20.16	22.11	21.69	22.06	15.80	11.47	10.10	8.88	8.12	7.03
		Std. Dev.	2.71	4.78	8.25	8.17	14.24	5.54	3.63	2.87	2.50	2.33	2.39
		Count	13	13	13	13	13	13	15	15	15	15	15
Tptpln	Saturated	Mean	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
		Std. Dev.											
		Count											
	Dry	Mean	15.02	15.52	15.38	15.07	14.08	13.03	11.98	10.85	9.95	9.20	5.24
		Std. Dev.	2.70	2.89	2.28	1.63	2.06	2.61	2.56	1.87	1.09	0.63	0.23
		Count	5	5	5	5	5	5	5	5	5	5	5
Tptpv	No data available.												
Tpbt1	No data available.												
Tac	No data available.												

* Timber Mountain Group: Bedded Tuffs (abbreviation not available)

Table H-5. Thermal Capacitance (ρCp): Data Sorted by Lithostratigraphic Units

Tptrn				Tptpmn			
Temperature (°C)	Mean ρCp (J/cm^3K)	Standard Deviation (J/cm3K)	No. of Tests	Temperature (°C)	Mean ρCp (J/cm3K)	Standard Deviation (J/cm3K)	No. of Tests
25	1.58	0.04	3	25	1.79	0.11	7
50	1.68	0.05	3	50	1.88	0.11	7
75	1.80	0.05	3	75	2.00	0.11	7
100	1.91	0.05	3	100	2.16	0.11	7
125	2.03	0.06	3	125	2.32	0.11	7
150	2.14	0.11	3	150	2.45	0.13	7
175	2.13	0.10	3	175	2.43	0.18	7
200	2.09	0.07	3	200	2.40	0.16	7
225	2.07	0.06	3	225	2.39	0.17	7
250	2.05	0.05	3	250	2.39	0.19	7
275	2.03	0.05	3	275	2.39	0.22	7
300	2.03	0.06	3	300	2.43	0.26	7

Note: Thermal capacitance data for other stratigraphic units not available.

YUCCA MOUNTAIN SITE CHARACTERIZATION PROJECT
SAND95-1955 - DISTRIBUTION LIST

1 D. A. Dreyfus (RW-1)
Director
OCRWM
US Department of Energy
1000 Independence Avenue SW
Washington, DC 20585

1 L. H. Barrett (RW-2)
Acting Deputy Director
OCRWM
US Department of Energy
1000 Independence Avenue SW
Washington, DC 20585

1 S. Rousso (RW-40)
Office of Storage and Transportation
OCRWM
US Department of Energy
1000 Independence Avenue SW
Washington, DC 20585

1 R. A. Milner (RW-30)
Office of Program Management
and Integration
OCRWM
US Department of Energy
1000 Independence Avenue SW
Washington, DC 20585

1 D. R. Elle, Director
Environmental Protection Division
DOE Nevada Field Office
US Department of Energy
P.O. Box 98518
Las Vegas, NV 89193-8518

1 T. Wood (RW-14)
Contract Management Division
OCRWM
US Department of Energy
1000 Independence Avenue SW
Washington, DC 20585

4 Victoria F. Reich, Librarian
Nuclear Waste Technical Review Board
1100 Wilson Blvd., Suite 910
Arlington, VA 22209

1 Wesley Barnes, Project Manager
Yucca Mountain Site Characterization
Office
US Department of Energy
P. O. Box 30307 MS 523
North Las Vegas, NV 89036-0307

1 Director, Public Affairs Office
c/o Technical Information Resource Center
DOE Nevada Operations Office
US Department of Energy
P.O. Box 98518
Las Vegas, NV 89193-8518

8 Technical Information Officer
DOE Nevada Operations Office
US Department of Energy
P.O. Box 98518
Las Vegas, NV 89193-8518

1 J. R. Dyer, Deputy Project Manager
Yucca Mountain Site Characterization Office
US Department of Energy
P. O. Box 30307 MS 523
North Las Vegas, NV 89036-0307

1 S. A. Orrell
Laboratory Lead for YMP
M&O/Sandia National Laboratories
1180 Town Center Drive
Las Vegas, NV 89134

1 J. A. Canepa
Laboratory Lead for YMP
EES-13, Mail Stop J521
M&O/Los Alamos National Laboratory
P.O. Box 1663
Los Alamos, NM 87545

1 Repository Licensing & Quality
Assurance
Project Directorate
Division of Waste Management, MS T7J-9
US NRC
Washington, DC 20555

1 Senior Project Manager for Yucca
Mountain
Repository Project Branch
Division of Waste Management, MS T7J-9
US NRC
Washington, DC 20555

1 NRC Document Control Desk
Division of Waste Management, MS T7J-9
US NRC
Washington, DC 20555

1 Chad Glenn
NRC Site Representative
301 E Stewart Avenue, Room 203
Las Vegas, NV 89101

1 Center for Nuclear Waste
Regulatory Analyses
Southwest Research Institute
6220 Culebra Road
Drawer 28510
San Antonio, TX 78284

2 W. L. Clarke
Laboratory Lead for YMP
M&O/ Lawrence Livermore Nat'l Lab
P.O. Box 808 (L-51)
Livermore, CA 94550

1 Robert W. Craig
Acting Technical Project Officer
US Geological Survey
1180 Town Center Dr.
Las Vegas, NV 89134

1 J. S. Stuckless, Chief
Senior Science Advisor
MS 425
Yucca Mountain Project Branch
US Geological Survey
P.O. Box 25046
Denver, CO 80225

1 L. D. Foust
Asst. General Mgr., Nevada Site
TRW Environmental Safety Systems
1180 Town Center Drive
Las Vegas, NV 89134

1 A. L. Flint
U. S. Geological Survey
1180 Town Center Drive
Las Vegas, NV 89134

1 Robert L. Strickler
Vice President & General Manager
TRW Environmental Safety Systems, Inc.
2650 Park Tower Dr.
Vienna, VA 22180

1 Jim Krulik, Geology Manager
US Bureau of Reclamation
Code D-8322
P.O. Box 25007
Denver, CO 80225-0007

1 B. T. Brady
Records Specialist
US Geological Survey
MS 421
P.O. Box 25046
Denver, CO 80225

1 M. D. Voegele
Deputy of Technical Operations
M&O/SAIC
1180 Town Center Drive
Las Vegas, NV 89134

2 A. T. Tamura
Science and Technology Division
OSTI
US Department of Energy
P.O. Box 62
Oak Ridge, TN 37831

1 P. J. Weeden, Acting Director
Nuclear Radiation Assessment Div.
US EPA
Environmental Monitoring Sys. Lab
P.O. Box 93478
Las Vegas, NV 89193-3478

1 John Fordham, Deputy Director
Water Resources Center
Desert Research Institute
P.O. Box 60220
Reno, NV 89506

1 The Honorable Jim Regan
Chairman
Churchill County Board of
Commissioners
10 W. Williams Avenue
Fallon, NV 89406

1 R. R. Loux
Executive Director
Agency for Nuclear Projects
State of Nevada
Evergreen Center, Suite 252
1802 N. Carson Street
Carson City, NV 89710

1 Brad R. Mettam
County Yucca Mountain
Repository Assessment Office
P. O. Drawer L
Independence, CA 93526

1 Vernon E. Poe
Office of Nuclear Projects
Mineral County
P.O. Box 1600
Hawthorne, NV 89415

1 Les W. Bradshaw
Program Manager
Nye County Nuclear Waste Repository
Project Office
P.O. Box 1767
Tonopah, NV 89049

1 Florindo Mariani
White Pine County Coordinator
P. O. Box 135
Ely, NV 89301

1 Tammy Manzini
Lander County Yucca Mountain
Information Officer
P.O. Box 10
Austin, NV 89310

1 Jason Pitts
Lincoln County Nuclear Waste
Program Manager
P. O. Box 158
Pioche, NV 89043

1 Dennis Bechtel, Coordinator
Nuclear Waste Division
Clark County Dept. of Comprehensive
Planning
P.O. Box 55171
Las Vegas, NV 89155-1751

1 Juanita D. Hoffman
Nuclear Waste Repository
Oversight Program
Esmeralda County
P.O. Box 490
Goldfield, NV 89013

1 Sandy Green
Yucca Mountain Information Office
Eureka County
P.O. Box 714
Eureka, NV 89316

1 Economic Development Dept.
City of Las Vegas
400 E. Stewart Avenue
Las Vegas, NV 89101

1 Community Planning & Development
City of North Las Vegas
P.O. Box 4086
North Las Vegas, NV 89030

2 Librarian
YMP Research & Study Center
1180 Town Center Drive
Las Vegas, NV 89134

1 Library Acquisitions
Argonne National Laboratory
Building 203, Room CE-111
9700 S. Cass Avenue
Argonne, IL 60439

1 Glenn Van Roekel
Manager, City of Caliente
P.O. Box 158
Caliente, NV 89008

1 Gudmundur S. Bodvarsson
Head, Nuclear Waste Department
Lawrence Berkeley National Laboratory
1 Cyclotron Road, MS 50E
Berkeley, CA 94720

1 Yvonne Tsang
Lawrence Berkeley National Laboratory
1 Cyclotron Road, MS 50E
Berkeley, CA 94720

1 Steve Hanauer (RW-2)
OCRWM
U. S. Department of Energy
1000 Independence Ave.
Washington, DC 20585

1 Randolph J. Martin III
New England Research
76 Olcott Drive
White River, VT 05001

1 Robert W. Clayton
M&O/WCFS
1180 Town Center Dr. / MS 423
Las Vegas, NV 89134

1 Richard C. Quitmeyer
M&O/WCFS
1180 Town Center Drive/ MS 423
Las Vegas, NV 89134

1 Mark C. Tynan
DOE/YMPSCO
1180 Town Center Drive / MS 423
Las Vegas, NV 89134

2 Paul Ricci
Holometrix, Inc.
25 Wiggins Avenue
Bedford, MA 01730-2323

5 James R. Connolly
Dept. of Earth and Planetary Sciences
Northrop Hall
Albuquerque, NM 87131-11126

	MS	
1	1325	R. H. Price, 6811
10	0751	N. S. Brodsky, 6117
1	0751	L. S. Costin, 6117
1	1399	J. Danneels, 6853
1	1326	N. Francis, 6851
5	1399	D. S. Kessel, 6850
2	1399	Mike Riggins, 6850
1	1324	C. Rautman, 6115
2	1330	K. Hart 6811
	100/1232711/SAND95-1955/QA	
20	1330	WMT Library, 6752
1	9018	Central Technical Files, 8940-2
5	0899	Technical Library, 4414
2	0619	Review and Approval Desk, 12690, For DOE/OSTI