# THERMAL

THERMAL

308 - - - Q200002080002
Scientific Notebook # 173 (Thermal Effects on Flow KTI)

21
150

R

Melissa Hill MH CNWRA X2012

## The Boorum & Pease® Quality Guarantee



CNWRA
CONTROLLED
COPY 173

5/1/96 JP

Thermal Effects on Flow KTI

Initial entry 5/1/96 by James D. Prikryl JP

This notebook chronicles the laboratory investigations for the Thermal Effects on Flow KTI.

5/1/96 JP

Preparation of crushed rock for thermal conductivity experiments.

Objective - prepare size graded crushed rock for use in thermal conductivity experiments.

Method - crushing using hammer and anvil and size grading by sieving.

Materials and Equipment
- Apache leap tuff
- Steel hammer and anvil
- plastic bags
- plastic containers
- Grieve drying oven Model PL-326
- Rubber bands
- Ro-Tap sieve shaker
- Bronze 8 inch sieves; 5/8", No. 5, and No. 10

Jim Prikryl & Ronald Green are investigators on this project [signature] 6/12/97



Procedure

a) Break up bulk pieces of Apache leap tuff into pieces 4 cm in diameter or smaller using hammer and anvil.

b) Separate ~~the~~ broken pieces into 3 size fractions by sieving.

The sizing of the fractions are as follows:

4 - 1.6 cm
1.6 - 0.4 cm
0.4 - 0.2 cm

c) Place the crushed rock in plastic containers and place in drying oven set at 90°C for at least two days.

d) Remove rock from drying oven and immediately place in double plastic bags. Secure tops of bags with rubber bands so that air cannot enter.

e) Label bags with size fraction of the material.

6/3/96 gf
Construction of thermal conductivity cell

Obj: build apparatus to measure the thermal conductivity of unconsolidated or crushed rock.

Method: measure heat flux and temperature difference over distance

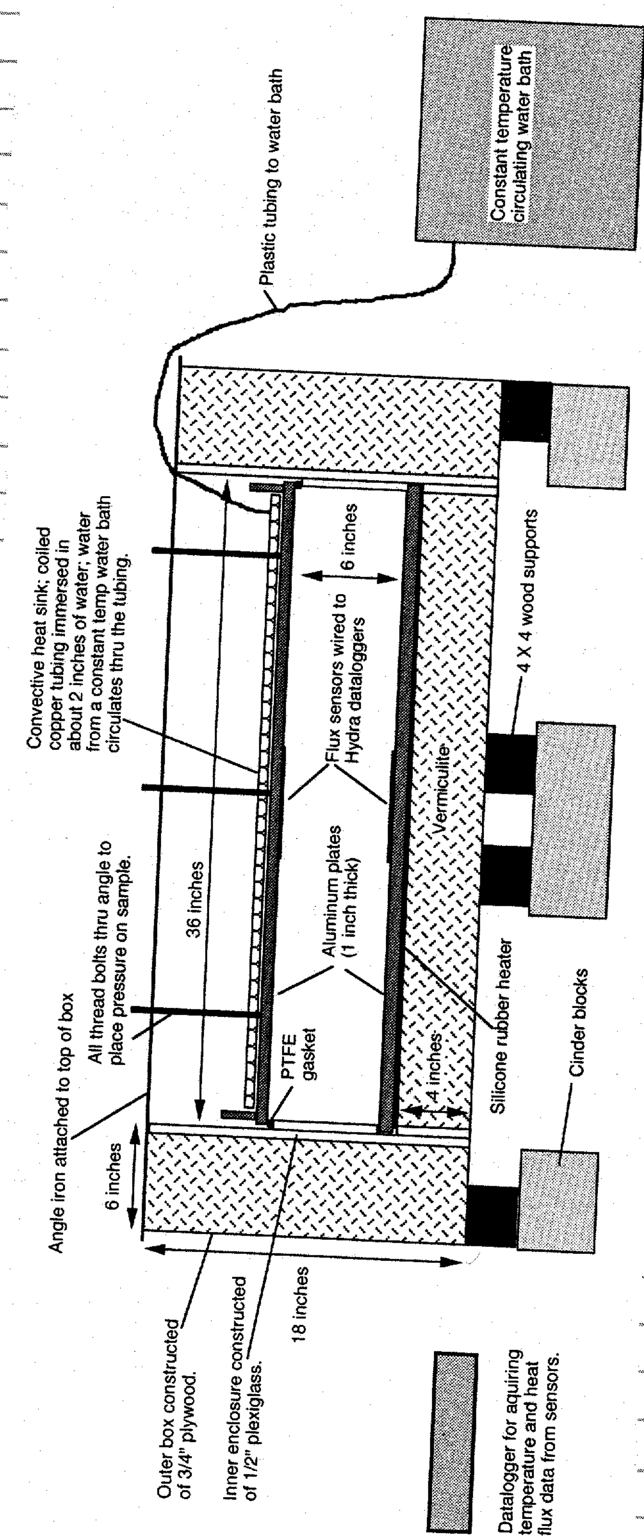
Materials and equipment:

- 1/2 inch plexiglass
- 3/4" plywood
- 2x4 and 4x4 lumber
- 1" steel bolts
- Micro-Foil Heat Flow Sensors - 8 total - 4 each in 6"x6" Al plates x1/8"
  Serial nos. 96041631, 96041632, 96041630, 96041633, 95J0642, 95J0641, 95J0639, 95J0640
- FLUKE Hydra data loggers
  Serial nos 5777650 and 5832651 Calibration not required
- Hydra starter software
- OMEGA Type T copper-constantin thermocouples length 6 inch
- Vermiculite
- 1/2" copper tubing
- 2 36"x36"x1" aluminum plates
- 34"x36" silicone rubber heater
- Statco energy variable transformer
- Angle iron 2"x2"x 1/8"
- C clamps



- bolts, all tread, 8"
- fittings and tubing as necessary
- PTFE joint sealant
- silicone rubber sealant
- excal water bath (ser no. 89BML 93540-11)
- excal temperature controller
- Neslab cooler (ser no 910ML 24800-23)
- Aluminum tape
- 36"x34" silicone rubber heater
- torque wrench
- tygon tubing
- Dayton 1 ton mobil crane Model 3ZC72
- HP 3458A multimeter (s/n 2823A02203)

A schematic diagram of the thermal conductivity system is shown below:






Description & Procedure

① A 4'x4'x18" box made of 3/4" plywood. The box was supported by an inner frame of 2"x2" wood and 4"x4" wood on the outside bottom.

② A 3'x3'x18" enclosure made of 1/2" plexiglass was constructed as shown in the schematic diagram. This consisted of an 18" high outer enclosure and 6" and 4" inside enclosures. These enclosures are placed in the middle of the plywood box.

③ 6 1/8"x6 1/8"x1/8" areas were milled out in the center of the two 1" aluminum plates. The 6"x6"x1/8" flux sensors were mounted in the milled areas with Al tape so that the microfoil meters are approximately flush with the plate surface.

④ A 34"x36" silicone rubber heater was mounted to the surface of one of the Al plates; opposite to the surface with the flux sensor.

(4a) Wiring for heater runs thru a hole drilled in the bottom of the box and then to a variable transformer.

⑤ Vermiculite was placed between the inside plexiglass and outside plywood enclosures and in the bottom of the 4" high inside plexiglass enclosure. Before placing the vermiculite in the inside plexiglass enclosure a layer of 1/8" Kelvar material was placed in the bottom and two type T thermocouples were placed in the wood below the Kelvar to monitor the temperature at the base

of the box. Location of these thermocouples will be shown in following diagrams.

⑥ The bottom Al plate was placed in the box supported by the 4" high plexiglass enclosure as shown in the diagram.

⑦ The bottom Al plate was bolted to the outside 18" high plexiglass enclosure to add support.

⑧ Wiring for the flux sensor on the bottom Al plate was run along a groove milled in the plate, then thru holes drilled in the plexiglass and plywood enclosures, and then to a datalogger. Location of the individual microfoil sensors will be shown in following diagrams.

⑨. A bead of silicone rubber sealant was placed around the outside edge of the bottom Al plate and then the 6" high plexiglass enclosure was placed on the Al plate as shown in the diagram. The silicone will act as a watertight sealant between the plexiglass + Al.

⑩. A 1/8" PTFE gasket was mounted on the top edge of the 6" high plexiglass enclosure as shown in the diagram.

⑪. A ~36" x 36" x 1/16" sheet of Al was placed on top of the bottom Al plate and will act of protect the microfoil sensors

(12a) Wiring for the flux sensors on the top Al plate were run along a groove milled in the plate and then to a datalogger. Location of individual sensors will be shown in following diagrams.



⑫ The top Al plate is placed in the plexiglass enclosure supported by the 6" high plexiglass as shown in the diagram. Note: when a sample is loaded in the system a ~36" x 36" x 1/16" sheet of Al will be placed on top of the sample to protect the microfoil sensors in the top Al plate.

⑬ A 4" lip of Al has been welded to the top of the upper Al plate as shown in the diagram. This was done so that water could be ponded on the top plate to act as a heat sink.

⑭ 1/2" coiled copper tubing was placed on the top Al plate. The tubing was immersed in about 2" of water. Water was circulated thru the copper tubing via a constant temperature circulating water bath.

⑮ Type T thermocouples were mounted on the outside of the top + bottom Al plates to monitor the temperature differences of the systems. Location of these thermocouples will be shown in following diagrams.

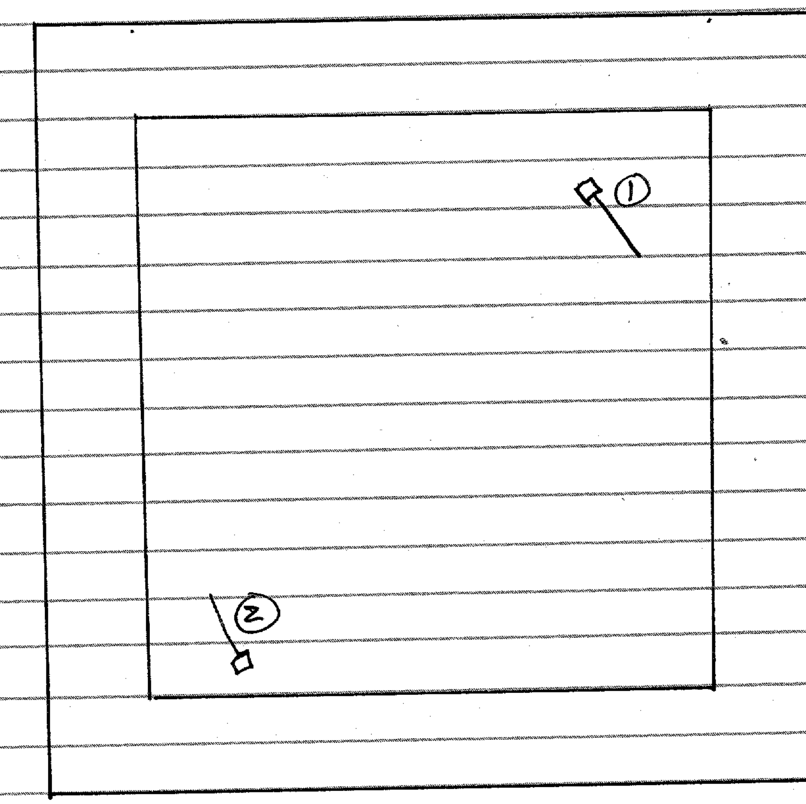
⑯ Three 4' long pieces of 2"x2"x1/8" angle iron were attached to the top of the box with C clamps. Each piece of angle iron has 3 evenly spaced all thread bolts attached as shown in the diagram. The bolts are torqued down on the top Al plate to apply a pressure to the sample.

(17) Sample is loaded in the system by removing the top Al plate using a hand operated crane. Loading the sample on top of the bottom Al plate and then placing the top Al plate on the sample.
Pressure is applied to the sample using the all thread bolts.
Heat is applied to the system via the silicone heater by applying voltage using the variable transformer.
Temperature of top plate is controlled by the circulating water bath.
A thermal conductivity measurement is taken when system reaches equilibrium; i.e. constant temperature at both top and bottom of system as measured by flux + temperature sensors.



Diagrams showing locations of monitoring thermocouples and flux sensors.

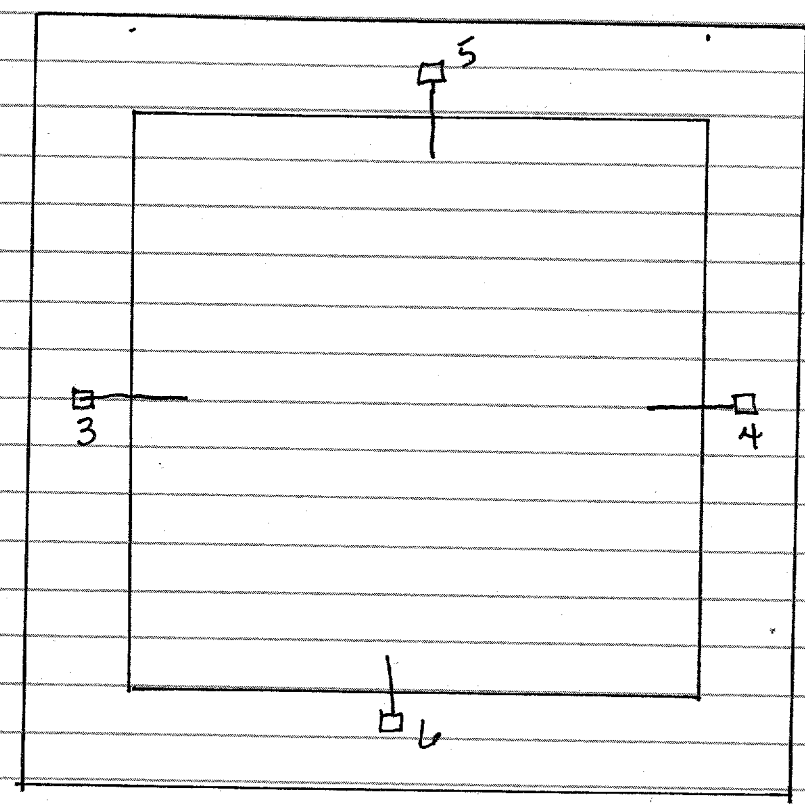
Monitoring thermocouples in bottom of box.




Front of box

* Numbers correspond to channel numbers of datalogger to which these thermocouples are attached.

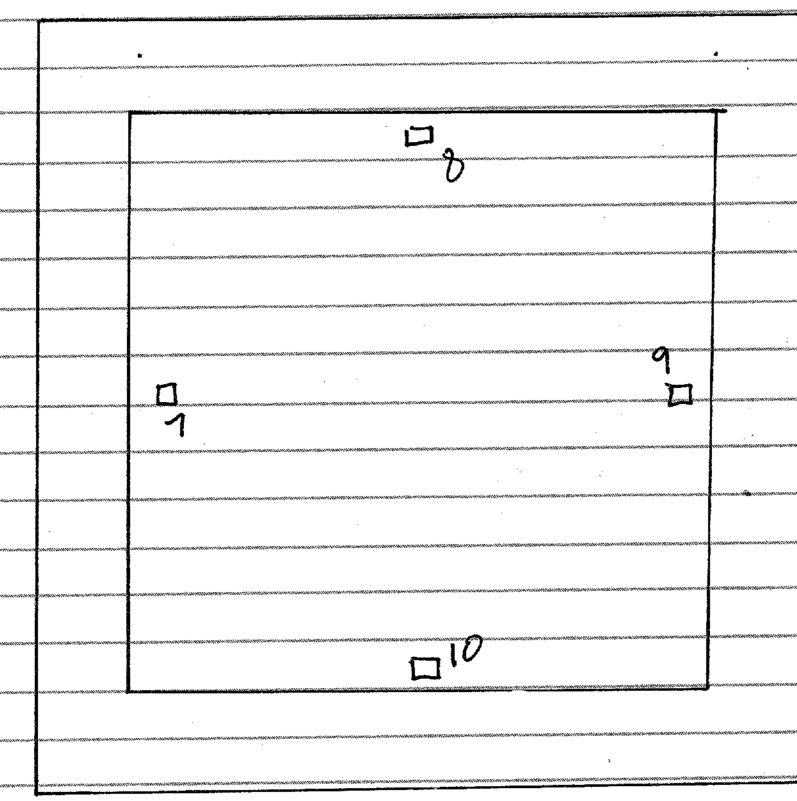
Monitoring thermocouples in bottom Al plate




Front of box

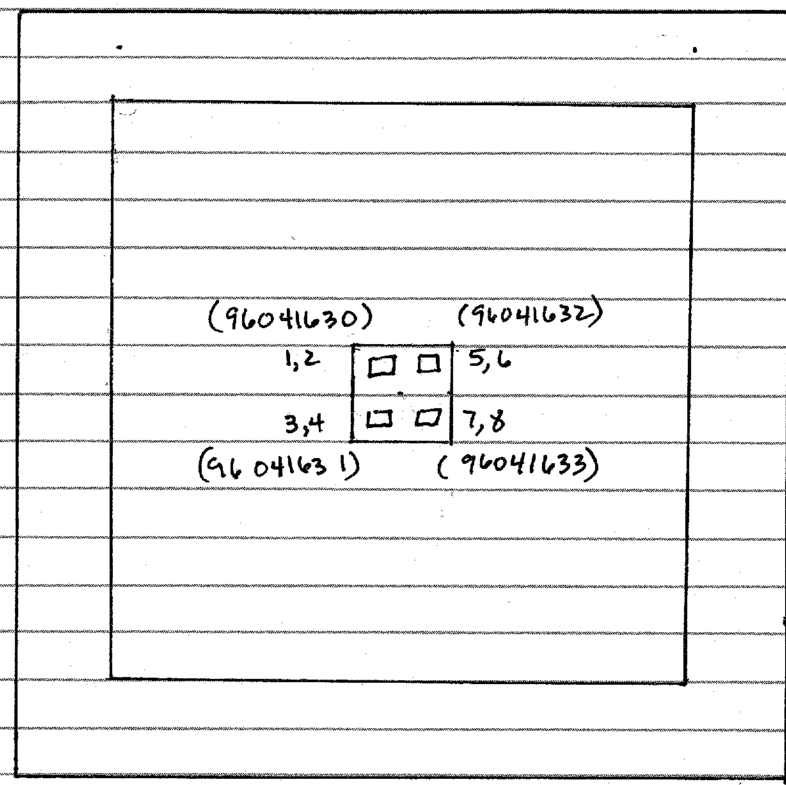


Monitoring thermocouples in top Al plate




Front of box

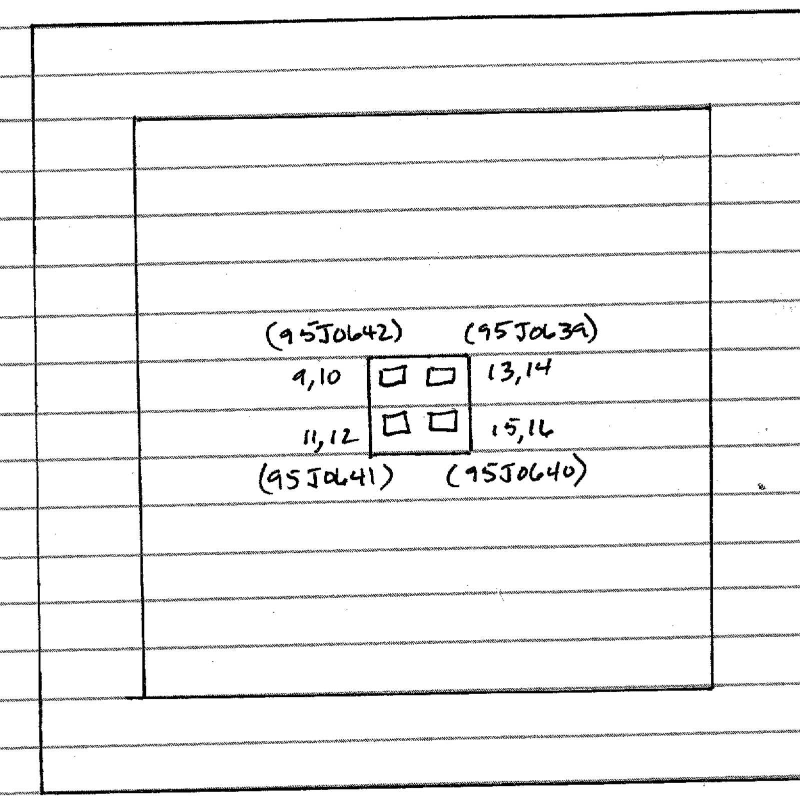
Flux meters on bottom Al plate
Serial nos. of each microfoil sensor are shown in parentheses.




Front of box



Flux meters on top Al plate
(when plate is in place)




Front of box

Following are certificates of calibration for each microfoil sensor

RdF CORPORATION
23 Elm Avenue
Hudson, New Hampshire 03051-0490
Tel: (603) 882-5195 FAX: (603) 882-6925

Q-116-12

ISO 9001 CERTIFIED

MICRO-FOIL™ HEAT FLOW SENSOR

CALIBRATION

RdF PART NO. 27070-1

SERIAL NO. 96041630

HEAT FLOW SENSOR:

Output at 70°F: 3.39 microvolts/Btu-Ft⁻² - Hr⁻¹

Polarity: (For heat flow into surface)
White - Positive (+)
Red - Negative (-)

Temperature Multiplication Factor: See Attached Graph

*Thermal Resistance: 0.01 °F/Btu-Ft⁻² -Hr⁻¹ (Typ)

*Heat Capacity: 0.03 Btu-Ft⁻²/°F (Typ)

Response Time: 0.60 sec. (62% response to step function) (Typ)

THERMOCOUPLE:

| ANSI Type | Material | Polarity | Color |
|---|---|---|---|
| K | Chromel<br>Alumel | Pos. (+)<br>Neg. (-) | Yellow<br>Red |

Output per ANSI MC96.1-1975 and NBS Monograph 125

* Thermal resistance is the temperature difference between the front surface and rear mounting surface of the sensor per unit of heat flow through the sensor. Heat capacity is the amount of heat required to raise the mean temperature of the sensor 1°F. Typical values of these two properties are given primarily to indicate sensor capabilities and are required for heat flow calculations only in very rare instances.

BY: Elaine Tardif DATE: 4-19-96

Specialists in Temperature Measurement



RdF CORPORATION
23 Elm Avenue
Hudson, New Hampshire 03051-0490
Tel: (603) 882-5195 FAX: (603) 882-6925

Q-116-12

ISO 9001 CERTIFIED

MICRO-FOIL™ HEAT FLOW SENSOR

CALIBRATION

RdF PART NO. 27070-1

SERIAL NO. 96041631

HEAT FLOW SENSOR:

Output at 70°F: 3.30 microvolts/Btu-Ft⁻² - Hr⁻¹

Polarity: (For heat flow into surface)
White - Positive (+)
Red - Negative (-)

Temperature Multiplication Factor: See Attached Graph

*Thermal Resistance: 0.01 °F/Btu-Ft⁻² -Hr⁻¹ (Typ)

*Heat Capacity: 0.03 Btu-Ft⁻²/°F (Typ)

Response Time: 0.60 sec. (62% response to step function) (Typ)

THERMOCOUPLE:

| ANSI Type | Material | Polarity | Color |
|---|---|---|---|
| K | Chromel<br>Alumel | Pos. (+)<br>Neg. (-) | Yellow<br>Red |

Output per ANSI MC96.1-1975 and NBS Monograph 125

* Thermal resistance is the temperature difference between the front surface and rear mounting surface of the sensor per unit of heat flow through the sensor. Heat capacity is the amount of heat required to raise the mean temperature of the sensor 1°F. Typical values of these two properties are given primarily to indicate sensor capabilities and are required for heat flow calculations only in very rare instances.

BY: Elaine Tardif DATE: 4-19-96

Specialists in Temperature Measurement

RdF CORPORATION
23 Elm Avenue
Hudson, New Hampshire 03051-0490
Tel: (603) 882-5195 FAX: (603) 882-6925

Q-116-12

ISO 9001 CERTIFIED

MICRO-FOIL™ HEAT FLOW SENSOR

CALIBRATION

RdF PART NO. 27070-1

SERIAL NO. 96041632

HEAT FLOW SENSOR:

Output at 70°F: 3.23 microvolts/Btu-Ft⁻² - Hr⁻¹

Polarity: (For heat flow into surface)
White - Positive (+)
Red - Negative (-)

Temperature Multiplication Factor: See Attached Graph

*Thermal Resistance: 0.01 °F/Btu-Ft⁻² -Hr⁻¹ (Typ)

*Heat Capacity: 0.03 Btu-Ft⁻²/°F (Typ)

Response Time: 0.60 sec. (62% response to step function) (Typ)

THERMOCOUPLE:

| ANSI Type | Material | Polarity | Color |
|---|---|---|---|
| K | Chromel<br>Alumel | Pos. (+)<br>Neg. (-) | Yellow<br>Red |

Output per ANSI MC96.1-1975 and NBS Monograph 125

* Thermal resistance is the temperature difference between the front surface and rear mounting surface of the sensor per unit of heat flow through the sensor. Heat capacity is the amount of heat required to raise the mean temperature of the sensor 1°F. Typical values of these two properties are given primarily to indicate sensor capabilities and are required for heat flow calculations only in very rare instances.

BY: Elaine Tardif DATE: 4-19-96

Specialists in Temperature Measurement



RdF CORPORATION
23 Elm Avenue
Hudson, New Hampshire 03051-0490
Tel: (603) 882-5195 FAX: (603) 882-6925

Q-116-12

ISO 9001 CERTIFIED

MICRO-FOIL™ HEAT FLOW SENSOR

CALIBRATION

RdF PART NO. 27070-1

SERIAL NO. 96041633

HEAT FLOW SENSOR:

Output at 70°F: 3.42 microvolts/Btu-Ft⁻² - Hr⁻¹

Polarity: (For heat flow into surface)
White - Positive (+)
Red - Negative (-)

Temperature Multiplication Factor: See Attached Graph

*Thermal Resistance: 0.01 °F/Btu-Ft⁻² -Hr⁻¹ (Typ)

*Heat Capacity: 0.03 Btu-Ft⁻²/°F (Typ)

Response Time: 0.60 sec. (62% response to step function) (Typ)

THERMOCOUPLE:

| ANSI Type | Material | Polarity | Color |
|---|---|---|---|
| K | Chromel<br>Alumel | Pos. (+)<br>Neg. (-) | Yellow<br>Red |

Output per ANSI MC96.1-1975 and NBS Monograph 125

* Thermal resistance is the temperature difference between the front surface and rear mounting surface of the sensor per unit of heat flow through the sensor. Heat capacity is the amount of heat required to raise the mean temperature of the sensor 1°F. Typical values of these two properties are given primarily to indicate sensor capabilities and are required for heat flow calculations only in very rare instances.

BY: Elaine Tardif DATE: 4-19-96

Specialists in Temperature Measurement

RdF CORPORATION
23 Elm Avenue
Hudson, New Hampshire 03051-0490
Tel: (603) 882-5195 FAX: (603) 882-6925

Q-116-12

ISO 9001 CERTIFIED

MICRO-FOIL™ HEAT FLOW SENSOR

CALIBRATION

RdF PART NO. 27070-1

SERIAL NO. 95J0639

HEAT FLOW SENSOR:

Output at 70°F: 3.28 microvolts/Btu-Ft$^{-2}$ - Hr $^{-1}$

Polarity: (For heat flow into surface)
White - Positive (+)
Red - Negative (-)

Temperature Multiplication Factor: See Attached Graph

*Thermal Resistance: 0.01 °F/Btu-Ft$^{-2}$ -Hr$^{-1}$ (Typ)

*Heat Capacity: 0.03 Btu-Ft$^{-2}$/°F (Typ)

Response Time: 0.60 sec. (62% response to step function) (Typ)

THERMOCOUPLE:

| ANSI Type | Material | Polarity | Color |
|---|---|---|---|
| K | Chromel<br>Alumel | Pos. (+)<br>Neg. (-) | Yellow<br>Red |

Output per ANSI MC96.1-1975 and NBS Monograph 125

* Thermal resistance is the temperature difference between the front surface and rear mounting surface of the sensor per unit of heat flow through the sensor. Heat capacity is the amount of heat required to raise the mean temperature of the sensor 1°F. Typical values of these two properties are given primarily to indicate sensor capabilities and are required for heat flow calculations only in very rare instances.

BY: Elaine Tardif DATE: 9-28-95

Specialists in Temperature Measurement



RdF CORPORATION
23 Elm Avenue
Hudson, New Hampshire 03051-0490
Tel: (603) 882-5195 FAX: (603) 882-6925

Q-116-12

ISO 9001 CERTIFIED

MICRO-FOIL™ HEAT FLOW SENSOR

CALIBRATION

RdF PART NO. 27070-1

SERIAL NO. 95J0640

HEAT FLOW SENSOR:

Output at 70°F: 3.26 microvolts/Btu-Ft$^{-2}$ - Hr $^{-1}$

Polarity: (For heat flow into surface)
White - Positive (+)
Red - Negative (-)

Temperature Multiplication Factor: See Attached Graph

*Thermal Resistance: 0.01 °F/Btu-Ft$^{-2}$ -Hr$^{-1}$ (Typ)

*Heat Capacity: 0.03 Btu-Ft$^{-2}$/°F (Typ)

Response Time: 0.60 sec. (62% response to step function) (Typ)

THERMOCOUPLE:

| ANSI Type | Material | Polarity | Color |
|---|---|---|---|
| K | Chromel<br>Alumel | Pos. (+)<br>Neg. (-) | Yellow<br>Red |

Output per ANSI MC96.1-1975 and NBS Monograph 125

* Thermal resistance is the temperature difference between the front surface and rear mounting surface of the sensor per unit of heat flow through the sensor. Heat capacity is the amount of heat required to raise the mean temperature of the sensor 1°F. Typical values of these two properties are given primarily to indicate sensor capabilities and are required for heat flow calculations only in very rare instances.

BY: Elaine Tardif DATE: 9-28-95

Specialists in Temperature Measurement

RdF CORPORATION
23 Elm Avenue
Hudson, New Hampshire 03051-0490
Tel: (603) 882-5195 FAX: (603) 882-6925

Q-116-12

ISO 9001 CERTIFIED

MICRO-FOIL™ HEAT FLOW SENSOR

CALIBRATION

RdF PART NO. 27070-1

SERIAL NO. 95J0641

HEAT FLOW SENSOR:

Output at 70°F: 3.20 microvolts/Btu-Ft$^{-2}$ - Hr $^{-1}$

Polarity: (For heat flow into surface)
White - Positive (+)
Red - Negative (-)

Temperature Multiplication Factor: See Attached Graph

*Thermal Resistance: 0.01 °F/Btu-Ft$^{-2}$ -Hr$^{-1}$ (Typ)

*Heat Capacity: 0.03 Btu-Ft$^{-2}$/°F (Typ)

Response Time: 0.60 sec. (62% response to step function) (Typ)

THERMOCOUPLE:

| ANSI Type | Material | Polarity | Color |
|---|---|---|---|
| K | Chromel<br>Alumel | Pos. (+)<br>Neg. (-) | Yellow<br>Red |

Output per ANSI MC96.1-1975 and NBS Monograph 125

* Thermal resistance is the temperature difference between the front surface and rear mounting surface of the sensor per unit of heat flow through the sensor. Heat capacity is the amount of heat required to raise the mean temperature of the sensor 1°F. Typical values of these two properties are given primarily to indicate sensor capabilities and are required for heat flow calculations only in very rare instances.

BY: Elaine Tardif DATE: 9-28-95

Specialists in Temperature Measurement



RdF CORPORATION
23 Elm Avenue
Hudson, New Hampshire 03051-0490
Tel: (603) 882-5195 FAX: (603) 882-6925

Q-116-12

ISO 9001 CERTIFIED

MICRO-FOIL™ HEAT FLOW SENSOR

CALIBRATION

RdF PART NO. 27070-1

SERIAL NO. 95J0642

HEAT FLOW SENSOR:

Output at 70°F: 3.43 microvolts/Btu-Ft$^{-2}$ - Hr $^{-1}$

Polarity: (For heat flow into surface)
White - Positive (+)
Red - Negative (-)

Temperature Multiplication Factor: See Attached Graph

*Thermal Resistance: 0.01 °F/Btu-Ft$^{-2}$ -Hr$^{-1}$ (Typ)

*Heat Capacity: 0.03 Btu-Ft$^{-2}$/°F (Typ)

Response Time: 0.60 sec. (62% response to step function) (Typ)

THERMOCOUPLE:

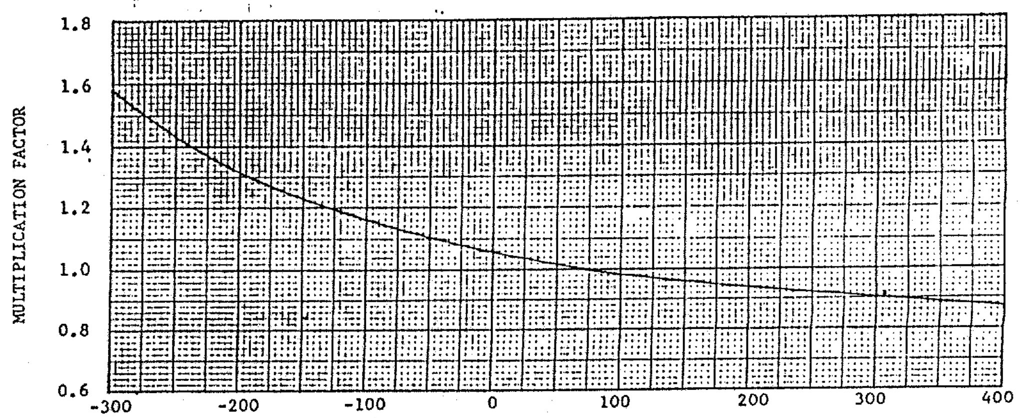
| ANSI Type | Material | Polarity | Color |
|---|---|---|---|
| K | Chromel<br>Alumel | Pos. (+)<br>Neg. (-) | Yellow<br>Red |

Output per ANSI MC96.1-1975 and NBS Monograph 125

* Thermal resistance is the temperature difference between the front surface and rear mounting surface of the sensor per unit of heat flow through the sensor. Heat capacity is the amount of heat required to raise the mean temperature of the sensor 1°F. Typical values of these two properties are given primarily to indicate sensor capabilities and are required for heat flow calculations only in very rare instances.

BY: Elaine Tardif DATE: 9-28-95

Specialists in Temperature Measurement




SURFACE TEMPERATURE, DEGREES FAHRENHEIT
MICRO-FOIL HEAT FLOW SENSOR
OUTPUT MULTIPLICATION FACTOR VS RECEIVING SURFACE TEMPERATURE
(70°F Base)

RdF CORPORATION
Hudson, New Hampshire

Q-116-12



6/4/96 gp

Initial readings of flux sensors before heat was applied to the system. Sample was not loaded at this point

Bottom Al plate

| Serial NO | mV | Temp °C |
|---|---|---|
| 96041630 | 0 | 21.5 |
| 96041631 | 0 | 21.4 |
| 96041632 | 0 | 21.4 |
| 96041633 | 0 | 21.4 |

Top Al plate

| | | |
|---|---|---|
| 95J0642 | 0 | 21.4 |
| 95J0641 | 0 | 21.4 |
| 95J0639 | 0 | 21.5 |
| 95J0640 | 0 | 21.5 |

Monitoring thermocouples are for monitoring heat loss from the sides of the system and these temperatures will not be used in determining the Thermal conductivity of the sample. Therefore, these thermocouples do not require calibration.

6/5/95 gp

Thermal Conductivity Measurements of crushed Apache Leap Tuff

Objective: determine thermal conductivity of crushed Apache Leap tuff at different saturation states (eg., dry, fully saturated, matrix saturated, etc...).

Method: measure using thermal conductivity system (see p 4-10).

Equipment + materials
- thermal conductivity cell
- Apache Leap tuff crushed to 1.6 to 4 cm size (see p 2-3).
- Hewlett Packard 3458 A Multimeter (SN 2823A 02203)



Procedure - Dry rock

0915 ① Remove top Al plate from thermal conductivity cell and load the 1.6 to 4 cm size fraction of Apache Leap tuff evenly into the cell.

1015 ② Replace top Al plate, set up heat sink (ie., copper tubing attached to circulating water bath emmersed in about 2" of water), and attach angle iron with all-thread bolts to top of box. Begin experiment using following parameters.

| | | |
|---|---|---|
| Variable transformer setpoint | - | 40 |
| Waterbath temperature setpoint | - | 23°c |
| Torque or pressure on top Al plate | - | 5 ft-lbs. |
| Scan interval for acquiring temperature + heat flow readings | - | 3 min |

③ Allow system to reach steady state which will be achieved when heat flowing into the box as recorded by microVolt readings from sensors on bottom Al plate equal heat flowing out of box as recorded by mV readings from sensors on top Al plate.

④ Temperature & heat flow (mVDC) readings from the sensors will be downloaded from the datalogger to a computer. This data will be kept in a 3-ring binder entitled "Thermal Conductivity Data".

⑤ Final heat flow + temperature readings for each sample at different saturation states will be recorded and the thermal conductivity will be calculated.

⑥ This experiment was referred to as Run 1



gp 6/10/96
0900hrs.

The thermal conductivity cell with the dry Apache Leap tuff inside appears not to be working properly. Heat flow readings as measured in mV for sensors mounted in the top Al plate are lower than readings from sensors mounted in the lower Al plate.

Apparently some process (eg, air pockets between sensor and sample or inadequate contact between sensor + sample) is causing thermal impedance.

1400hrs. To solve this problem steel wool (a good heat conductor) was placed between the sensor and the top 1/16" Al sheet to form a better contact between sample + sensor. However, heat flow readings from the top sensor were still lower than from the bottom sensor.

6/11/96 JP

1000hrs An Aluminum pad made of sheets of Al foil was placed between the flux sensor and the 1/16" Al top sheet to form a better contact between the sensor + sample. Again heat flow readings remained lower than those on the bottom Al plate.



6/12/96 JP

0900hrs Pieces of Al foil were crumpled and mashed into open voids at the top surface of the rock (Apache Leap tuff) in the cell. This was done to provide a better contact between the sample + sensor. Except for one sensor in the top plate, again readings were lower than for the bottom plate sensors.

1400hrs Additional pieces of Al foil were crumpled and mashed into remaining voids in top surface of sample. A film of vacuum grease was smeared on the surface of the top flux sensor to form a wet contact between the sensor and top 1/16" Al sheet. Heat flow readings from the top Al plate sensors are now very similar to those of the lower Al plate.

6/13/96 gp

0815 hrs Results of thermal conductivity experiment on dry Apache Leap tuff. (Run 1)

Heat flow & temperature readings are recorded below. Heat flow (mV) readings were taken on a Hewlett Packard 3458A Multimeter (S/N 2823A 02203) for better sensitivity.

Bottom Al plate

| Serial No. | mV | Temp °C |
|---|---|---|
| 96041630 | ~~.0685~~ .0728 (gp 6/13/96) | 70.0 |
| 96041631 | .0819 | 70.0 |
| 96041632 | .0786 | 70.0 |
| 96041633 | .0986 | 70.0 |

Top Al plate

| | | |
|---|---|---|
| 95J0642 | .0620 | 22.2 |
| 95J0641 | .0685 | 22.2 |
| 95J0639 | .0815 | 22.3 |
| 95J0640 | .0905 | 22.3 |

Monitoring thermocouples

| Channel No | Temp °C |
|---|---|
| 1 | 35.6 |
| 2 | 35.4 |
| 3 | 69.7 |
| 4 | 69.6 |
| 5 | 69.7 |
| 6 | ~~6~~ gp 6/13/96 |
| 7 | 22.0 |
| 8 | 22.2 |
| 9 | 22.0 |
| 10 | 22.0 |



6/14/96 gp
0900 hrs

The tuff sample inside the thermal conductivity cell was removed and then loaded again to see if repacking of the crushed rock has any effect on thermal conductivity measurements.

Procedure on pp 26-28 was followed. In addition pieces of Al foil were crumpled and placed in voids on top surface of sample.
Also the top 3'x3' sheet of 1/16" Al was not used; instead a 6"x6" piece of 1/16" Al was taped over the top flux sensor with Al tape. Vacuum grease was used to provide an even contact between the sensor and the 6"x6" Al plate.

This experiment had the following parameters

| | |
|---|---|
| Variable transformer setpoint | - 40 |
| Waterbath setpoint | - 23 °C |
| Pressure on top Al plate | - 5 ft-lbs |
| Scan interval | - 10 min |

This experiment will be referred to as <u>Run 2</u>.

6/17/96 gp

0815hrs Results of thermal conductivity experiment on dry Apache Leap Tuff (Run 2)

Bottom Al plate

| Serial No | mV | Temp °C |
|---|---|---|
| 96041630 | .0795 | 69.5 |
| 96041631 | .0856 | 69.4 |
| 96041632 | .0771 | 69.4 |
| 96041633 | .0770 | 69.3 |

Top Al plate

| | | |
|---|---|---|
| 95J0642 | .0724 | 22.4 |
| 95J0641 | .0834 | 22.5 |
| 95J0639 | .1182 | 22.5 |
| 95J0640 | .0810 | 22.4 |

Monitoring thermocouples

| Channel No | Temp °C |
|---|---|
| 1 | 36.2 |
| 2 | ~~22.4~~ 36.0 gp 6/17/96 |
| 3 | 69.1 |
| 4 | 69.1 |
| 5 | 69.1 |
| 7 | 22.4 |
| 8 | 22.3 |
| 9 | 22.4 |
| 10 | 22.3 |



6/17/96 gp

0900hrs
Thermal conductivity experiment on dry Apache Leap Tuff Run 3

In this experiment the tuff sample was left in the cell but the temperature at the top of the cell was changed to 40°C.

Parameters were as follows.

| | |
|---|---|
| Variable transformer setpoint | - 40 |
| Waterbath setpoint | - 40°C |
| Pressure on top Al plate | - 5 ft-lbs |
| Scan interval | -10 min |

6/19/96 JP

1100hr Results of TC experiment Run 3 on dry Apache Leap tuff.

Bottom Al plate

| Serial No | mV | Temp °C |
|---|---|---|
| 96041630 | .0663 | 76.6 |
| 96041631 | .0717 | 76.6 |
| 96041632 | .0654 | 76.6 |
| 96041633 | .0643 | 76.6 |

Top Al plate

| | | |
|---|---|---|
| 95J0642 | .0606 | 39.6 |
| 95J0641 | .0692 | 39.6 |
| 95J0639 | .1001 | 39.5 |
| 95J0640 | .0694 | 39.5 |

Monitoring Thermocouples

| Channel No | Temp °C |
|---|---|
| 1 | 39.2 |
| 2 | 38.0 |
| 3 | 76.2 |
| 4 | 76.2 |
| 5 | 76.2 |
| 7 | 38.8 |
| 8 | 39.0 |
| 9 | 39.0 |
| 10 | 38.8 |



6/19/96 JP

1130hrs

Thermal conductivity experiment Run 4 using dry Apache Leap Tuff.

In this run the Tuff sample was again left in the cell and the temperature at the bottom of the cell was increased to 90°C.

Parameters are as follows:

| | |
|---|---|
| Variable transformer setpoint | - 50 |
| Waterbath setpoint | - 40°c |
| Pressure to top Al plate | - 5 ft-lbs |
| Scan interval | -10 min |

6/20/96 gp

1320 hr Results of TC experiment Run 4 on Dry Apache Leap tuff.

Bottom Al plate

| Serial No | mV | Temp °C |
|---|---|---|
| 96041630 | .0993 | 94.3 |
| 96041631 | .1093 | 94.3 |
| 96041632 | .1000 | 94.4 |
| 96041633 | .0971 | 94.3 |

Top Al plate

| Serial No | mV | Temp °C |
|---|---|---|
| 95J0642 | .0917 | 40.1 |
| 95J0641 | .1042 | 40.0 |
| 95J0639 | .1488 | 40.0 |
| 95J0640 | .1032 | 40.0 |

Monitoring Thermocouples

| Channel No | Temp °C |
|---|---|
| 1 | 44.1 |
| 2 | 42.4 |
| 3 | 93.8 |
| 4 | 93.8 |
| 5 | 93.8 |
| 7 | 39.1 |
| 8 | 39.4 |
| 9 | 39.3 |
| 10 | 39.1 |



6/20/96 gp

1330hr Thermal Conductivity experiment Run 5 using dry Apache Leap tuff

In this run the Tuff sample was again left in the cell and the temperature at the top of the cell was decreased to 20°C

Parameters are as follows

Variable transformer setpoint : 50
Waterbath setpoint - 20°C
Pressure on Top of Al plate - 5 ft-lbs
Scan interval - 10 min

6/21/96 gp

1500hrs gp Results of TC experiment Run 5 on dry Apache Leap tuff

Bottom Al plate

| Serial no | mV | Temp °C |
|---|---|---|
| 96041630 | .1166 | 86.5 |
| 96041631 | .1268 | 86.5 |
| 96041632 | .1169 | 86.6 |
| 96041633 | .1125 | 86.5 |

Top Al plate

| | | |
|---|---|---|
| 95J0642 | .1023 | 20.2 |
| 95J0641 | .1174 | 20.1 |
| 95J0639 | .1647 | 20.2 |
| 95J0640 | .1144 | 20.2 |

Monitoring thermocouples

| Channel no | Temp °C |
|---|---|
| 1 | 41.1 |
| 2 | 40.2 |
| 3 | 86.2 |
| 4 | 86.1 |
| 5 | 86.2 |
| 7 | 20.1 |
| 8 | 20.0 |
| 9 | 20.1 |
| 10 | 20.1 |



6/21/96 gp

1530hrs

Thermal Conductivity experiment Run 6 using dry Apache Leap tuff.

In this run the tuff sample ~~in~~ was left in the cell and the temperature on the bottom Al plate was decreased to about 30°C

Parameters are as follows:

- Variable transformer setpoint -
- Waterbath setpoint - 20°C
- Pressure on top Al plate - 5 ft-lbs
- Scan interval - 10 min

6/27/96 gp

0945hrs Results of TC experiment Run 6

Bottom Al plate

| Serial no | mV | Temp °C |
|---|---|---|
| 96041630 | .0227 | 32.1 |
| 96041631 | .0239 | 32.1 |
| 96041632 | .0211 | 32.2 |
| 96041633 | .0203 | 32.2 |

Top Al plate

| | | |
|---|---|---|
| 95J0642 | .0174 | 18.8 |
| 95J0641 | .0204 | 18.7 |
| 95J0639 | .0287 | 18.8 |
| 95J0640 | .0196 | 18.8 |

Monitoring thermocouples

| Channel no | Temp °C |
|---|---|
| 1 | 26.0 |
| 2 | 25.7 |
| 3 | 32.1 |
| 4 | 32.2 |
| 5 | 32.2 |
| 7 | 19.0 |
| 8 | 18.9 |
| 9 | 19.0 |
| 10 | 18.9 |



6/29/96 gp

1000hrs Thermal Conductivity calculation

The thermal conductivity of the dry Apache heap tuff using data from Run 1 is calculated below using the Fourier equation.

$$Q = K_T \frac{dT}{dL}$$

where

$Q$ = heat transfer per unit area (W/Ft$^2$)
$K_T$ = thermal conductivity (W/m-°K)
$dT$ = temperature difference between bottom and top sensors (°K)
$dL$ = distance between bottom and top sensors (m)

W = watts; K = degrees kelvin

Run 1 sensor readings

| | Serial no | Temp °C | Temp °K = °C + 273.2 | Heat flow µV | Heat flow cal. constant (p16-23) µV/Btu/Ft²-hr |
|---|---|---|---|---|---|
| Bottom | 96041630 | 70 | 343.2 | 72.8 | 3.39 |
| | 96041631 | 70 | 343.2 | 81.9 | 3.3 |
| | 96041632 | 70 | 343.2 | 78.6 | 3.23 |
| | 96041633 | 70 | 343.2 | 98.6 | 3.42 |
| Top | 95J0642 | 22.2 | 295.4 | 62 | 3.43 |
| | 95J0641 | 22.2 | 295.4 | 68.5 | 3.2 |
| | 95J0639 | 22.3 | 295.5 | 81.5 | 3.28 |
| | 95J0640 | 22.3 | 295.5 | 90.5 | 3.26 |

Heat flow (Q) for each sensor is calculated by dividing measured heat flow by the calibration constant.

| Serial no | | Btu/Ft²-Hr | W/Ft² (1 Btu/Hr = 0.293 W) |
|---|---|---|---|
| 96041630 | 72.8/3.39 = | 21.47 | 6.29 |
| 96041631 | 81.9/3.3 = | 24.82 | 7.27 |
| 96041632 | 78.6/3.23 = | 24.33 | 7.13 |
| 96041633 | 98.6/3.42 = | 28.83 | 8.45 |
| | | | |
| 95J0642 | 62/3.43 = | 18.08 | 5.30 |
| 95J0641 | 68.5/3.2 = | 21.41 | 6.27 |
| 95J0639 | 81.5/3.28 = | 24.85 | 7.28 |
| 95J0640 | 90.5/3.26 = | 27.76 | 8.13 |

Heat flow for entire system is determined by averaging values from all the sensors.

$$Q = (6.29 + 7.27 + 7.13 + 8.45 + 5.30 + 6.27 + 7.28 + 8.13)/8 = 7.015 \text{ W/Ft}^2$$

$$\text{convert to W/m}^2 = 7.015/.0929 = 75.51 \text{ W/m}^2$$

$$dT = (343.2 + 343.2 + 343.2 + 343.2)/4 - (295.4 + 295.4 + 295.5 + 295.5)/4$$

$$= 47.75 \text{ K}$$

$$dL = 0.5 \text{ Ft} \quad \text{convert to m} = .5 \times .3048 = .1524 \text{ m}$$

$$K_T = 75.51 \text{ W/m}^2 \left(\frac{.1524 \text{ m}}{47.75 \text{ K}}\right) = .241 \text{ W/m-K}$$



Subsequent thermal conductivity calculation will be done using a Microsoft Excel v. 5.0 spreadsheet.

The spreadsheet calculation for Run 1 is shown below.

**Thermal Conductivity calculation using Fourier equation**

**Sample =** Apache Leap tuff (dry) Run 1

$Q = K_T(dT/dL)$

where
- Q = heat transfer per unit area (W/Ft²)
- $K_T$ = thermal conductivity (W/m-K)
- dT = temperature difference between bottom and top sensors (K)
- dL = distance between bottom and top sensors (m)

**Sensor readings**

| Serial no. | Temp °C | Temp °K | Heat flow µV | Cal. constant | Heat flow | Convert to W/Ft² |
|---|---|---|---|---|---|---|
| | | | | µV/Btu/Ft²-Hr | Btu/Ft²-Hr | 1Btu/Hr = 0.293W |
| Bottom | | | | | | |
| 96041630 | 70 | 343.2 | 72.8 | 3.39 | 21.475 | 6.292 |
| 96041631 | 70 | 343.2 | 81.9 | 3.3 | 24.818 | 7.272 |
| 96041632 | 70 | 343.2 | 78.6 | 3.23 | 24.334 | 7.130 |
| 96041633 | 70 | 343.2 | 98.6 | 3.42 | 28.830 | 8.447 |
| Top | | | | | | |
| 95J0642 | 22.2 | 295.4 | 62 | 3.43 | 18.076 | 5.296 |
| 95J0641 | 22.2 | 295.4 | 68.5 | 3.2 | 21.406 | 6.272 |
| 95J0639 | 22.3 | 295.5 | 81.5 | 3.28 | 24.848 | 7.280 |
| 95J0640 | 22.3 | 295.5 | 90.5 | 3.26 | 27.761 | 8.134 |

| | | |
|---|---|---|
| Q = | 7.015 W/Ft² | 75.516 W/m² |
| dT = | 47.75 K | |
| dL = | 0.5 Ft | 0.1524 m |
| $K_T$ = | **0.241 W/m-K** | |

2/27/96 Thermal conductivity spreadsheet calculation for dry Apache Leap Tuff Runs 2 thru 6 are shown in following pages.
gf

Run 2

**Thermal Conductivity calculation using Fourier equation**

**Sample =** Apache Leap tuff (dry) Run 2

$Q=K_T(dT/dL)$

where
- Q =heat transfer per unit area (W/Ft$^2$)
- $K_T$ = thermal conductivity (W/m-K)
- dT = temperature difference between bottom and top sensors (K)
- dL = distance between bottom and top sensors (m)

**Sensor readings**

| Serial no. | Temp $^0$C | Temp $^0$K | Heat flow µV | Cal. constant µV/Btu/Ft$^2$-Hr | Heat flow Btu/Ft$^2$-Hr | Convert to W/Ft$^2$ 1Btu/Hr = 0.293W |
|---|---|---|---|---|---|---|
| Bottom | | | | | | |
| 96041630 | 69.5 | 342.7 | 79.5 | 3.39 | 23.451 | 6.871 |
| 96041631 | 69.4 | 342.6 | 85.6 | 3.3 | 25.939 | 7.600 |
| 96041632 | 69.4 | 342.6 | 77.1 | 3.23 | 23.870 | 6.994 |
| 96041633 | 69.3 | 342.5 | 77 | 3.42 | 22.515 | 6.597 |
| Top | | | | | | |
| 95J0642 | 22.4 | 295.6 | 72.4 | 3.43 | 21.108 | 6.185 |
| 95J0641 | 22.5 | 295.7 | 83.4 | 3.2 | 26.063 | 7.636 |
| 95J0639 | 22.5 | 295.7 | 118.2 | 3.28 | 36.037 | 10.559 |
| 95J0640 | 22.4 | 295.6 | 81 | 3.26 | 24.847 | 7.280 |

| | | |
|---|---|---|
| Q = | 7.465 W/Ft$^2$ | 80.358 W/m$^2$ |
| dT = | 46.95 K | |
| dL = | 0.5 Ft | 0.1524 m |
| $K_T$ = | **0.261 W/m-K** | |



Run 3

**Thermal Conductivity calculation using Fourier equation**

**Sample =** Apache Leap tuff (dry) Run 3

$Q=K_T(dT/dL)$

where
- Q =heat transfer per unit area (W/Ft$^2$)
- $K_T$ = thermal conductivity (W/m-K)
- dT = temperature difference between bottom and top sensors (K)
- dL = distance between bottom and top sensors (m)

**Sensor readings**

| Serial no. | Temp $^0$C | Temp $^0$K | Heat flow µV | Cal. constant µV/Btu/Ft$^2$-Hr | Heat flow Btu/Ft$^2$-Hr | Convert to W/Ft$^2$ 1Btu/Hr = 0.293W |
|---|---|---|---|---|---|---|
| Bottom | | | | | | |
| 96041630 | 76.6 | 349.8 | 66.3 | 3.39 | 19.558 | 5.730 |
| 96041631 | 76.6 | 349.8 | 71.7 | 3.3 | 21.727 | 6.366 |
| 96041632 | 76.6 | 349.8 | 65.4 | 3.23 | 20.248 | 5.933 |
| 96041633 | 76.6 | 349.8 | 64.3 | 3.42 | 18.801 | 5.509 |
| Top | | | | | | |
| 95J0642 | 39.6 | 312.8 | 60.6 | 3.43 | 17.668 | 5.177 |
| 95J0641 | 39.6 | 312.8 | 69.2 | 3.2 | 21.625 | 6.336 |
| 95J0639 | 39.5 | 312.7 | 100.1 | 3.28 | 30.518 | 8.942 |
| 95J0640 | 39.5 | 312.7 | 69.4 | 3.26 | 21.288 | 6.237 |

| | | |
|---|---|---|
| Q = | 6.279 W/Ft$^2$ | 67.586 W/m$^2$ |
| dT = | 37.05 K | |
| dL = | 0.5 Ft | 0.1524 m |
| $K_T$ = | **0.278 W/m-K** | |

Run 4

**Thermal Conductivity calculation using Fourier equation**

**Sample =** Apache Leap tuff (dry) Run 4

$Q=K_T(dT/dL)$

where
- Q =heat transfer per unit area ($W/Ft^2$)
- $K_T$ = thermal conductivity (W/m-K)
- dT = temperature difference between bottom and top sensors (K)
- dL = distance between bottom and top sensors (m)

**Sensor readings**

| Serial no. | Temp $^0$C | Temp $^0$K | Heat flow µV | Cal. constant µV/Btu/Ft$^2$-Hr | Heat flow Btu/Ft$^2$-Hr | Convert to W/Ft$^2$ 1Btu/Hr = 0.293W |
|---|---|---|---|---|---|---|
| Bottom | | | | | | |
| 96041630 | 94.3 | 367.5 | 99.3 | 3.39 | 29.292 | 8.583 |
| 96041631 | 94.3 | 367.5 | 109.3 | 3.3 | 33.121 | 9.705 |
| 96041632 | 94.4 | 367.6 | 100 | 3.23 | 30.960 | 9.071 |
| 96041633 | 94.3 | 367.5 | 97.1 | 3.42 | 28.392 | 8.319 |
| Top | | | | | | |
| 95J0642 | 40.1 | 313.3 | 91.7 | 3.43 | 26.735 | 7.833 |
| 95J0641 | 40 | 313.2 | 104.2 | 3.2 | 32.563 | 9.541 |
| 95J0639 | 40 | 313.2 | 148.8 | 3.28 | 45.366 | 13.292 |
| 95J0640 | 40 | 313.2 | 103.2 | 3.26 | 31.656 | 9.275 |

Q = 9.452 $W/Ft^2$ 101.747 $W/m^2$

dT = 54.3 K

dL = 0.5 Ft 0.1524 m

**$K_T$ = 0.286 W/m-K**



Run 5

**Thermal Conductivity calculation using Fourier equation**

**Sample =** Apache Leap tuff (dry) Run 5

$Q=K_T(dT/dL)$

where
- Q =heat transfer per unit area ($W/Ft^2$)
- $K_T$ = thermal conductivity (W/m-K)
- dT = temperature difference between bottom and top sensors (K)
- dL = distance between bottom and top sensors (m)

**Sensor readings**

| Serial no. | Temp $^0$C | Temp $^0$K | Heat flow µV | Cal. constant µV/Btu/Ft$^2$-Hr | Heat flow Btu/Ft$^2$-Hr | Convert to W/Ft$^2$ 1Btu/Hr = 0.293W |
|---|---|---|---|---|---|---|
| Bottom | | | | | | |
| 96041630 | 86.5 | 359.7 | 116.6 | 3.39 | 34.395 | 10.078 |
| 96041631 | 86.5 | 359.7 | 126.8 | 3.3 | 38.424 | 11.258 |
| 96041632 | 86.6 | 359.8 | 116.9 | 3.23 | 36.192 | 10.604 |
| 96041633 | 86.5 | 359.7 | 112.5 | 3.42 | 32.895 | 9.638 |
| Top | | | | | | |
| 95J0642 | 20.2 | 293.4 | 102.3 | 3.43 | 29.825 | 8.739 |
| 95J0641 | 20.1 | 293.3 | 117.4 | 3.2 | 36.688 | 10.749 |
| 95J0639 | 20.2 | 293.4 | 164.7 | 3.28 | 50.213 | 14.713 |
| 95J0640 | 20.2 | 293.4 | 114.4 | 3.26 | 35.092 | 10.282 |

Q = 10.758 $W/Ft^2$ 115.798 $W/m^2$

dT = 66.35 K

dL = 0.5 Ft 0.1524 m

**$K_T$ = 0.266 W/m-K**

Run 6

| Thermal Conductivity calculation using Fourier equation | | | | | | |
|---|---|---|---|---|---|---|
| **Sample =** | Apache Leap tuff (dry) Run 6 | | | | | |
| | $Q = K_T(dT/dL)$ | | | | | |
| | where | | $Q$ = heat transfer per unit area ($W/Ft^2$) | | | |
| | | | $K_T$ = thermal conductivity (W/m-K) | | | |
| | | | $dT$ = temperature difference between bottom and top sensors (K) | | | |
| | | | $dL$ = distance between bottom and top sensors (m) | | | |
| **Sensor readings** | | | | | | |
| Serial no. | Temp $^0C$ | Temp $^0K$ | Heat flow µV | Cal. constant µV/Btu/$Ft^2$-Hr | Heat flow Btu/$Ft^2$-Hr | Convert to $W/Ft^2$ 1Btu/Hr = 0.293W |
| Bottom | | | | | | |
| 96041630 | 32.1 | 305.3 | 22.7 | 3.39 | 6.696 | 1.962 |
| 96041631 | 32.1 | 305.3 | 23.9 | 3.3 | 7.242 | 2.122 |
| 96041632 | 32.2 | 305.4 | 21.1 | 3.23 | 6.533 | 1.914 |
| 96041633 | 32.2 | 305.4 | 20.3 | 3.42 | 5.936 | 1.739 |
| Top | | | | | | |
| 95J0642 | 18.8 | 292 | 17.4 | 3.43 | 5.073 | 1.486 |
| 95J0641 | 18.7 | 291.9 | 20.4 | 3.2 | 6.375 | 1.868 |
| 95J0639 | 18.8 | 292 | 28.7 | 3.28 | 8.750 | 2.564 |
| 95J0640 | 18.8 | 292 | 19.6 | 3.26 | 6.012 | 1.762 |
| Q = | 1.927 $W/Ft^2$ | | | 20.744 $W/m^2$ | | |
| dT = | 13.375 K | | | | | |
| dL = | 0.5 Ft | | | 0.1524 m | | |
| $K_T$ = | **0.236 W/m-K** | | | | | |



7/2/96 gp

Shown below is the certificate for calibration for the HP 3458A multimeter. This meter has been used to take mV readings from flux sensors in the thermal conductivity system. The meter was recieved in Tolerance. Therefore, readings taken before calibration will be considered good.

Southwest Research Institute
6220 Culebra Road
San Antonio, TX 78238
Department of Quality Assurance
Calibration Laboratory

# Certificate of Calibration

26 June 1996

**Issued to:** RON GREEN DIV20 B57
**Manufacturer/Model:** HP 3458A
**Description:** DIGITAL MULTIMETER
**Serial Number:** 2823A02203
**Asset Number:** 001436

**Environmental Conditions**

**Temperature:** 73.0 **Humidity:** 40%

**Calibration Information**

Calibration was in accordance with requirements of MIL-STD-45662A and ANSI/NCSL Z540-1-1994. Measurements are traceable to the National Institute of Standards and Technology (NIST). This report may not be reproduced except in full without written approval of the originator. Inspection and test data are on file and available for inspection.

**Calibration Date:** 25 Jun 96 **Calibration Procedure:** MFG

**Interval:** 12 months **Accuracy:** MFGR SPECS

**Next Calibration Due:** 25 Jun 97 **Received:** In Tolerance

**Remarks:** CAL BY ROTHE DEV., SAN ANTONIO, TX
CERT# 43931

**Certificate #** 21799 **Signed:**

LAST PAGE OF REPORT
Total Pages Printed: 1

8/27/96 gp

Modification of Thermal conductivity cell

Obj: prepare thermal conductivity cell for high temperature (>90°C) measurements

Method: replace inner plexiglass enclosure with a fiberglass enclosure

Materials - Fiberglass enclosure constructed by Mac's Custom Fiberglass.

Procedure:

① The inner plexiglass enclosure of the thermal conductivity cell as shown on p 6 was removed.

② An enclosure made of 1/2" fiberglass was placed in thermal conductivity cell so that higher temperature (>90°C) measurements could be taken on samples. All other components of the cell remained the same.



8/29/96 gp

0830 hrs gp

Thermal Conductivity experiment RUN 7 on Dry Apache Leap Tuff

In this run the Tuff sample was loaded in the newly modified thermal conductivity cell.

Parameters are as follows:

| | |
|---|---|
| Variable transformer setpoint | - 80 |
| Waterbath setpoint | - 23°c |
| Pressure on top of Al plate | - 5 ft·lbs |
| Scan interval | - 10 min |

9/3/96 gp

0800hr Results of TC experiment Run 7

Bottom Al plate

| Serial No | BTU/Ft²Hr Heat Flux | Temp °C |
|---|---|---|
| 96041630 | 118.7696 | 174.0 |
| 96041631 | 104.8063 | 174.0 |
| 96041632 | 114.4042 | 174.1 |
| 96041633 | 90.5774 | 174.1 |

Top Al plate

| | | |
|---|---|---|
| 95J0642 | 58.5726 | 24.2 |
| 95J0641 | 84.3077 | 24.5 |
| 95J0639 | 99.6924 | 24.2 |
| 95J0640 | 91.0304 | 24.4 |

Monitor Thermocouples

| Channel No | Temp °C |
|---|---|
| 1 | 67.5 |
| 2 | 66.6 |
| 3 | 172.6 |
| 4 | 173.0 |
| 5 | 173.6 |
| 6 | 173.6 |
| 7 | 23.9 |
| 8 | 24.8 |
| 9 | 24.5 |
| 10 | 23.9 |



9/3/96 gp

0820hr

Thermal Conductivity experiment Run 8 on dry Apache Leap Tuff

Parameters are as follows:

Variable transformer setpoint - 90
Waterbath ~~setpoint~~ - 23 °C
Pressure on top Al plate - 5 ft·lbs
Scan Interval - 10 min

9/5/96 gp

0800hr Results of TC experiment Run 8

Bottom Al plates

| Serial No | Heat flux BTU/ft²-hr | Temp °C |
|---|---|---|
| 96041630 | 136.5523 | 205.2 |
| " 31 | 126.6837 | 205.3 |
| " 32 | 1268.5006 | 205.3 |
| " 33 | ~~79.~~ 112.0310 gp | 205.3 |

Top Al plate

| Serial No | Heat flux | Temp °C |
|---|---|---|
| 95J0642 | 79.7509 | 25.0 |
| " 41 | 110.1680 | 25.5 |
| " 39 | 111.5908 | 25.2 |
| " 40 | 102.7014 | 25.4 |

Monitoring Thermocouples

| Channel No | Temp °C |
|---|---|
| 1 | 79.1 |
| 2 | 78.1 |
| 3 | 204.2 |
| 4 | 204.0 |
| 5 | 205.1 |
| 6 | 205.0 |
| 7 | 24.8 |
| 8 | 25.5 |
| 9 | 25.3 |
| 10 | 24.8 |



9/5/96 gp

0810 hrs

Thermal Conductivity experiment Run 9
on dry Apache Leap tuff

Parameters are as follows:

| | |
|---|---|
| Variable transformer setpoint | - 80 |
| Waterbath setpoint | - 23.0°C |
| Pressure on Top plate | - 5 ft lbs |
| Scan Interval | - 10 min |

9/6/96 gp

## Results of TC experiment <u>Run 9</u>

| Bottom Al plate Serial No | BTU/ft²·hr Heat Flux | Temp °C |
|---|---|---|
| 96041630 | 99.1475 | 174.9 |
| " 31 | 101.8552 | 174.9 |
| " 32 | — | 175.0 |
| " 33 | 87.1884 | 174.9 |
| | | ~~24.~~ gp 9/9/96 |

| Top Al plate | | |
|---|---|---|
| 95J0642 | 63.7063 | 24.4 |
| " 41 | 86.5999 | 24.7 |
| " 39 | 87.5334 | 24.5 |
| " 40 | 81.3310 | 24.7 |

| Monitoring Thermocouples Channel No | Temp °C |
|---|---|
| 1 | 67.6 |
| 2 | 67.1 |
| 3 | 173.8 |
| 4 | 174.0 |
| 5 | 174.7 |
| 6 | 174.5 |
| 7 | 24.3 |
| 8 | 24.9 |
| 9 | 25.0 |
| 10 | 24.3 |



9/9/96 gp

0800 hrs
Thermal Conductivity experiment <u>Run 10</u>
on dry Apache Leap Tuff

Parameters are as follows:

| | |
|---|---|
| Variable transformer setpoint | - 70 |
| Waterbath setpoint | - 23°C |
| Pressure on Top plate | - 5 ft-lb |
| Scan Interval | - 10 min |

9/11/96 gp

0840 hr

Results of TC Experiment Rev 10

| Bottom Al plate Serial No | Heat Flux BTU/Ft²-hr | Temp °C |
|---|---|---|
| 96041630 | 76.0859 | 145.5 |
| " 31 | 77.4744 | 145.5 |
| " 32 | — | 145.6 |
| " 33 | 65.1570 | 145.6 |

| Top Al plate | | |
|---|---|---|
| 95J0642 | 48.7880 | 23.6 |
| " 41 | 67.3827 | 23.9 |
| " 39 | 66.9175 | 23.8 |
| " 40 | 62.3581 | 23.9 |

| Monitoring Thermocouples Channel No | Temp °C |
|---|---|
| 1 | 59.0 |
| 2 | 58.0 |
| 3 | 144.2 |
| 4 | 144.5 |
| 5 | 144.9 |
| 6 | 144.8 |
| 7 | 23.6 |
| 8 | 24.1 |
| 9 | 24.1 |
| 10 | 23.6 |

9/11/96 jp

0845hr
Thermal Conductivity Experiment Run 11
on dry Apache Leap Tuff

Parameters are as follows:

| | | |
|---|---|---|
| Variable transformer setpoint | - | 60 |
| Waterbath setpoint | - | 23°c |
| Pressure on top Al plate | - | 5 ft lb |
| Scan Interval | - | 10 min |



9/16/96 jp

1540hr Results of TC Experiment Run 11

| Bottom Al plate Serial No | Heat flux BTU/ft²-hr | Temp °C |
|---|---|---|
| 96041630 | 57.6125 | 121.9 |
| " 31 | 58.8450 | 122.0 |
| " 32 | — | 122.0 |
| " 33 | 49.4404 | 122.0 |
| **Top Al plate** | | |
| 95J0642 | 38.5830 | 23.4 |
| " 41 | 54.2689 | 23.6 |
| " 39 | 53.5807 | 23.5 |
| " 40 | 49.3327 | 23.7 |

Monitor Thermocouple

| Channel No | Temp °C |
|---|---|
| 1 | 52.3 |
| 2 | 51.5 |
| 3 | 120.7 |
| 4 | 121.0 |
| 5 | 121.4 |
| 6 | 121.3 |
| 7 | 23.6 |
| 8 | 23.9 |
| 9 | 23.9 |
| 10 | 23.5 |

9/14/96 JP

1545
Thermal Conductivity Experiment Run 12
on dry Apache Leap Tuff

Parameters

Variable transformer setpoint - 50
Waterbath setpoint -23°C
Pressure on top Al plate - 5ft lb
Scan Interval - 10 min



9/18/96 JP

0800hr Results of TC Experiment Run 12

| Bottom Al plate Serial No | Heat flux BTU/Ft²-hr | Temp °C |
|---|---|---|
| 96041630 | 41.8428 | 94.9 |
| " 31 | 40.0429 | 95.0 |
| " 32 | — | 95.0 |
| " 33 | 32.7399 | 94.9 |
| Top Al plate | | |
| 95J0642 | 27.0595 | 22.5 |
| " 41 | 37.7668 | 22.7 |
| " 39 | 38.0184 | 22.6 |
| " 40 | 34.5651 | 22.7 |

| Monitoring Thermocouples Channel No | Temp °C |
|---|---|
| 1 | 43.1 |
| 2 | 42.6 |
| 3 | 94.1 |
| 4 | 94.3 |
| 5 | 94.7 |
| 6 | 94.6 |
| 7 | 22.6 |
| 8 | 22.8 |
| 9 | 22.7 |
| 10 | 22.5 |

9/18/96 gp

0800hr
Thermal Conductivity Experiment Run 13
on dry Apache Leap Tuff

Parameters
Variable transformer setpoint - 40
Waterbath setpoint - 23°c
Pressure on top Al plate - 5 ft-lb
Scan Interval - 10 min



9/20/96 gp

0800hr Results of TC experiment Run 13

| Bottom Al plate Serial No | Heat Flux BTU/Ft²-hr | Temp °C |
|---|---|---|
| 96041630 | 28.1665 | 69.9 |
| " 31 | 21.9637 | 69.9 |
| " 32 | — | 69.9 |
| " 33 | 18.0905 | 69.9 |
| **Top Al plate** | | |
| 95J042 | 17.1918 | 21.9 |
| " 41 | 23.9464 | 22.0 |
| " 39 | 24.1767 | 22.0 |
| " 40 | 21.9712 | 22.0 |

| Monitoring Thermocouples Channel No | Temp °C |
|---|---|
| 1 | 36.2 |
| 2 | 35.5 |
| 3 | 69.3 |
| 4 | 69.4 |
| 5 | 69.7 |
| 6 | 69.6 |
| 7 | 22.0 |
| 8 | 22.2 |
| 9 | 22.1 |
| 10 | 21.9 |

9/20/96 gp

0800 hrs
Thermal Conductivity Experiment Run 14
Dry Apache Leap Tuff

Parameters
Variable transformer setpoint - 30
Waterbath setpoint - 23°C
Pressure on top Al plate - 5 ft-lb
Scan Interval - 10 min



9/23/96 gp

0805 hrs
Results of TC Experiment Run ~~13~~ 14 gp 9/23/96

| Bottom Al plate Serial No | Heat Flux BTU/Ft²-hr | Temp °C |
|---|---|---|
| 96041630 | 16.7014 | 49.6 |
| " 31 | 12.3603 | 49.6 |
| " 32 | — | 49.6 |
| " 33 | 9.6621 | 49.7 |

| Top Al plate | | |
|---|---|---|
| 95J042 | 9.7431 | 21.5 |
| " 41 | 13.9539 | 21.6 |
| " 39 | 13.6951 | 21.6 |
| " 40 | 12.6049 | 21.6 |

| Monitoring Thermocouples Channel No | Temp °C |
|---|---|
| 1 | 30.9 |
| 2 | 30.1 |
| 3 | 49.3 |
| 4 | 49.4 |
| 5 | 49.6 |
| 6 | 49.5 |
| 7 | 21.7 |
| 8 | 21.8 |
| 9 | 21.7 |
| 10 | 21.6 |

9/23/96 gp

0810 hrs

Thermal Conductivity Experiment Run 15

Dry Apache Deep Tuff

Parameter

| | | |
|---|---|---|
| Variable transformer setpoint | - | 90 |
| Waterbath setpoint | - | 23°C |
| Pressure on top Al plate | - | 5 ft-lb |
| Scan Interval | - | 15 min |



9/25/96 gp

0800 hrs

Results of TC Experiment Run 15

| Bottom Al plate Serial No | Heat Flux BTU/ft²-hr | Temp °C |
|---|---|---|
| 96041630 | 119.5305 | 202.2 |
| " 31 | 130.7246 | 202.3 |
| " 32 | — | 202.4 |
| " 33 | 108.4493 | 202.4 |

| Top Al plate | | |
|---|---|---|
| 95J042 | 78.3287 | 25.3 |
| " 41 | 111.4095 | 25.7 |
| " 39 | 107.5794 | 25.5 |
| " 40 | 98.8020 | 25.7 |

| Monitory Thermocouple Channel No | Temp °C |
|---|---|
| 1 | 80.4 |
| 2 | 76.1 |
| 3 | 201.1 |
| 4 | 201.1 |
| 5 | 202.2 |
| 6 | 202.0 |
| 7 | 25.2 |
| 8 | 25.8 |
| 9 | 25.4 |
| 10 | 24.8 |

9/25/96 JP Thermal conductivity spreadsheet calculation for dry Apache Leap Tuff Runs 7 thru 15 are shown on the following pages.

**Thermal Conductivity calculation using Fourier equation**

**Sample =** Apache Leap Tuff (Run 7)

$Q = K_T(dT/dL)$

where
- Q =heat transfer per unit area ($W/Ft^2$)
- $K_T$ = thermal conductivity (W/m-K)
- dT = temperature difference between bottom and top sensors (K)
- dL = distance between bottom and top sensors (m)

**Sensor readings**

| Serial no. | Temp $^0C$ | Multi- factor | Correct Temp | Temp $^0K$ | Heat flow $Btu/Ft^2$-Hr | Convert to $W/Ft^2$ 1Btu/Hr = 0.293W |
|---|---|---|---|---|---|---|
| Bottom | | | | | | |
| 96041630 | 174 | 0.95 | 165.3 | 438.5 | 118.769 | 34.799 |
| 96041631 | 174 | 0.95 | 165.3 | 438.5 | 104.806 | 30.708 |
| 96041632 | 174.1 | 0.95 | 165.395 | 438.595 | 114.404 | 33.520 |
| 96041633 | 174.1 | 0.95 | 165.395 | 438.595 | 90.577 | 26.539 |
| Top | | | | | | |
| 95J0642 | 24.2 | 1.04 | 25.168 | 298.368 | 58.573 | 17.162 |
| 95J0641 | 24.5 | 1.04 | 25.48 | 298.68 | 84.308 | 24.702 |
| 95J0639 | 24.2 | 1.04 | 25.168 | 298.368 | 99.692 | 29.210 |
| 95J0640 | 24.4 | 1.04 | 25.376 | 298.576 | 91.030 | 26.672 |
| Q = | 27.914 $W/Ft^2$ | | | | | 300.475 $W/m^2$ |
| dT = | 140.05 K | | | | | |
| dL = | 0.5208 Ft | | | | | 0.15873984 m |
| $K_T$ = | **0.341 ±** | | **0.03536 W/m-K** | | | |



**Thermal Conductivity calculation using Fourier equation**

**Sample =** Apache Leap Tuff (Run 8)

$Q = K_T(dT/dL)$

where
- Q =heat transfer per unit area ($W/Ft^2$)
- $K_T$ = thermal conductivity (W/m-K)
- dT = temperature difference between bottom and top sensors (K)
- dL = distance between bottom and top sensors (m)

**Sensor readings**

| Serial no. | Temp $^0C$ | Multi- factor | Correct Temp | Temp $^0K$ | Heat flow $Btu/Ft^2$-Hr | Convert to $W/Ft^2$ 1Btu/Hr = 0.293W |
|---|---|---|---|---|---|---|
| Bottom | | | | | | |
| 96041630 | 205.2 | 0.94 | 192.888 | 466.088 | 136.552 | 40.010 |
| 96041631 | 205.3 | 0.94 | 192.982 | 466.182 | 126.684 | 37.118 |
| 96041632 | 205.3 | 0.94 | 192.982 | 466.182 | 126.580 | 37.088 |
| 96041633 | 205.3 | 0.94 | 192.982 | 466.182 | 112.031 | 32.825 |
| Top | | | | | | |
| 95J0642 | 25 | 1.04 | 26 | 299.2 | 79.751 | 23.367 |
| 95J0641 | 25.5 | 1.04 | 26.52 | 299.72 | 110.168 | 32.279 |
| 95J0639 | 25.2 | 1.04 | 26.208 | 299.408 | 111.591 | 32.696 |
| 95J0640 | 25.4 | 1.04 | 26.416 | 299.616 | 102.701 | 30.091 |
| Q = | 33.184 $W/Ft^2$ | | | | | 357.205 $W/m^2$ |
| dT = | 166.67 K | | | | | |
| dL = | 0.5208 Ft | | | | | 0.15873984 m |
| $K_T$ = | **0.340 ±** | | **0.03532 W/m-K** | | | |

**Thermal Conductivity calculation using Fourier equation**

**Sample =** Apache Leap Tuff (Run 9)

$Q = K_T(dT/dL)$

where
- Q =heat transfer per unit area ($W/Ft^2$)
- $K_T$ = thermal conductivity (W/m-K)
- dT = temperature difference between bottom and top sensors (K)
- dL = distance between bottom and top sensors (m)

**Sensor readings**

| Serial no. | Temp $^0C$ | Multi- factor | Correct Temp | Temp $^0K$ | Heat flow $Btu/Ft^2$-Hr | Convert to $W/Ft^2$ 1Btu/Hr = 0.293W |
|---|---|---|---|---|---|---|
| Bottom | | | | | | |
| 96041630 | 174.9 | 0.95 | 166.155 | 439.355 | 99.148 | 29.050 |
| 96041631 | 174.9 | 0.95 | 166.155 | 439.355 | 101.855 | 29.844 |
| 96041632 | 175 | 0.95 | 166.25 | 439.45 | 101.000 | 29.593 |
| 96041633 | 174.9 | 0.95 | 166.155 | 439.355 | 87.188 | 25.546 |
| Top | | | | | | |
| 95J0642 | 24.4 | 1.04 | 25.376 | 298.576 | 63.706 | 18.666 |
| 95J0641 | 24.7 | 1.04 | 25.688 | 298.888 | 86.600 | 25.374 |
| 95J0639 | 24.5 | 1.04 | 25.48 | 298.68 | 87.533 | 25.647 |
| 95J0640 | 24.7 | 1.04 | 25.688 | 298.888 | 81.331 | 23.830 |
| Q = | 25.944 $W/Ft^2$ | | | | | 279.265 $W/m^2$ |
| dT = | 140.62 K | | | | | |
| dL = | 0.5208 Ft | | | | | 0.15873984 m |
| $K_T$ = | **0.315 ±** | | **0.03282 W/m-K** | | | |

**Thermal Conductivity calculation using Fourier equation**

**Sample =** Apache Leap Tuff (Run 10)

$Q = K_T(dT/dL)$

where
- Q = heat transfer per unit area ($W/Ft^2$)
- $K_T$ = thermal conductivity (W/m-K)
- dT = temperature difference between bottom and top sensors (K)
- dL = distance between bottom and top sensors (m)

**Sensor readings**

| Serial no. | Temp $^0C$ | Multi-factor | Correct Temp | Temp $^0K$ | Heat flow $Btu/Ft^2$-Hr | Convert to $W/Ft^2$ 1Btu/Hr = 0.293W |
|---|---|---|---|---|---|---|
| Bottom | | | | | | |
| 96041630 | 145.5 | 0.96 | 139.68 | 412.88 | 76.086 | 22.293 |
| 96041631 | 145.5 | 0.96 | 139.68 | 412.88 | 77.474 | 22.700 |
| 96041632 | 145.6 | 0.96 | 139.776 | 412.976 | 0.000 | 0.000 |
| 96041633 | 145.6 | 0.96 | 139.776 | 412.976 | 65.157 | 19.091 |
| Top | | | | | | |
| 95J0642 | 23.6 | 1.04 | 24.544 | 297.744 | 48.788 | 14.295 |
| 95J0641 | 23.9 | 1.04 | 24.856 | 298.056 | 67.383 | 19.743 |
| 95J0639 | 23.8 | 1.04 | 24.752 | 297.952 | 66.918 | 19.607 |
| 95J0640 | 23.9 | 1.04 | 24.856 | 298.056 | 62.358 | 18.271 |

Q = 19.429 $W/Ft^2$ — 209.134 $W/m^2$
dT = 114.98 K
dL = 0.5208 Ft — 0.15873984 m

$K_T$ = **0.289 ± 0.03017 W/m-K**

**Thermal Conductivity calculation using Fourier equation**

**Sample =** Apache Leap Tuff (Run 11)

$Q = K_T(dT/dL)$

where
- Q = heat transfer per unit area ($W/Ft^2$)
- $K_T$ = thermal conductivity (W/m-K)
- dT = temperature difference between bottom and top sensors (K)
- dL = distance between bottom and top sensors (m)

**Sensor readings**

| Serial no. | Temp $^0C$ | Multi-factor | Correct Temp | Temp $^0K$ | Heat flow $Btu/Ft^2$-Hr | Convert to $W/Ft^2$ 1Btu/Hr = 0.293W |
|---|---|---|---|---|---|---|
| Bottom | | | | | | |
| 96041630 | 121.9 | 0.97 | 118.243 | 391.443 | 58.613 | 17.173 |
| 96041631 | 122 | 0.97 | 118.34 | 391.54 | 58.845 | 17.242 |
| 96041632 | 122 | 0.97 | 118.34 | 391.54 | 0.000 | 0.000 |
| 96041633 | 122 | 0.97 | 118.34 | 391.54 | 49.440 | 14.486 |
| Top | | | | | | |
| 95J0642 | 23.4 | 1.04 | 24.336 | 297.536 | 38.583 | 11.305 |
| 95J0641 | 23.6 | 1.04 | 24.544 | 297.744 | 54.269 | 15.901 |
| 95J0639 | 23.5 | 1.04 | 24.44 | 297.64 | 53.581 | 15.699 |
| 95J0640 | 23.7 | 1.04 | 24.648 | 297.848 | 49.333 | 14.454 |

Q = 15.180 $W/Ft^2$ — 163.402 $W/m^2$
dT = 93.824 K
dL = 0.5208 Ft — 0.15873984 m

$K_T$ = **0.276 ± 0.02895 W/m-K**



**Thermal Conductivity calculation using Fourier equation**

**Sample =** Apache Leap Tuff (Run 12)

$Q = K_T(dT/dL)$

where
- Q = heat transfer per unit area ($W/Ft^2$)
- $K_T$ = thermal conductivity (W/m-K)
- dT = temperature difference between bottom and top sensors (K)
- dL = distance between bottom and top sensors (m)

**Sensor readings**

| Serial no. | Temp $^0C$ | Multi-factor | Correct Temp | Temp $^0K$ | Heat flow $Btu/Ft^2$-Hr | Convert to $W/Ft^2$ 1Btu/Hr = 0.293W |
|---|---|---|---|---|---|---|
| Bottom | | | | | | |
| 96041630 | 94.9 | 0.98 | 93.002 | 366.202 | 41.843 | 12.260 |
| 96041631 | 95 | 0.98 | 93.1 | 366.3 | 40.043 | 11.733 |
| 96041632 | 95 | 0.98 | 93.1 | 366.3 | 0.000 | 0.000 |
| 96041633 | 94.9 | 0.98 | 93.002 | 366.202 | 32.740 | 9.593 |
| Top | | | | | | |
| 95J0642 | 22.5 | 1.04 | 23.4 | 296.6 | 27.060 | 7.928 |
| 95J0641 | 22.7 | 1.04 | 23.608 | 296.808 | 37.767 | 11.066 |
| 95J0639 | 22.6 | 1.04 | 23.504 | 296.704 | 38.018 | 11.139 |
| 95J0640 | 22.7 | 1.04 | 23.608 | 296.808 | 34.565 | 10.128 |

Q = 10.549 $W/Ft^2$ — 113.557 $W/m^2$
dT = 69.521 K
dL = 0.5208 Ft — 0.15873984 m

$K_T$ = **0.259 ± 0.02723 W/m-K**

**Thermal Conductivity calculation using Fourier equation**

**Sample =** Apache Leap Tuff (Run 13)

$Q = K_T(dT/dL)$

where
- Q = heat transfer per unit area ($W/Ft^2$)
- $K_T$ = thermal conductivity (W/m-K)
- dT = temperature difference between bottom and top sensors (K)
- dL = distance between bottom and top sensors (m)

**Sensor readings**

| Serial no. | Temp $^0C$ | Multi-factor | Correct Temp | Temp $^0K$ | Heat flow $Btu/Ft^2$-Hr | Convert to $W/Ft^2$ 1Btu/Hr = 0.293W |
|---|---|---|---|---|---|---|
| Bottom | | | | | | |
| 96041630 | 69.9 | 1 | 69.9 | 343.1 | 28.167 | 8.253 |
| 96041631 | 69.9 | 1 | 69.9 | 343.1 | 21.964 | 6.435 |
| 96041632 | 69.9 | 1 | 69.9 | 343.1 | 0.000 | 0.000 |
| 96041633 | 69.9 | 1 | 69.9 | 343.1 | 18.091 | 5.301 |
| Top | | | | | | |
| 95J0642 | 21.9 | 1.04 | 22.776 | 295.976 | 17.192 | 5.037 |
| 95J0641 | 22 | 1.04 | 22.88 | 296.08 | 23.946 | 7.016 |
| 95J0639 | 22 | 1.04 | 22.88 | 296.08 | 24.177 | 7.084 |
| 95J0640 | 22 | 1.04 | 22.88 | 296.08 | 21.971 | 6.438 |

Q = 6.509 $W/Ft^2$ — 70.065 $W/m^2$
dT = 47.046 K
dL = 0.5208 Ft — 0.15873984 m

$K_T$ = **0.236 ± 0.02494 W/m-K**

**Thermal Conductivity calculation using Fourier equation**

**Sample =** Apache Leap Tuff (Run 14)

$Q = K_T(dT/dL)$

where
- Q = heat transfer per unit area (W/Ft²)
- $K_T$ = thermal conductivity (W/m-K)
- dT = temperature difference between bottom and top sensors (K)
- dL = distance between bottom and top sensors (m)

**Sensor readings**

| Serial no. | Temp °C | Multi-factor | Correct Temp | Temp °K | Heat flow Btu/Ft²-Hr | Convert to W/Ft² 1Btu/Hr = 0.293W |
|---|---|---|---|---|---|---|
| Bottom | | | | | | |
| 96041630 | 49.6 | 1.02 | 50.592 | 323.792 | 16.701 | 4.894 |
| 96041631 | 49.6 | 1.02 | 50.592 | 323.792 | 12.360 | 3.622 |
| 96041632 | 49.6 | 1.02 | 50.592 | 323.792 | 0.000 | 0.000 |
| 96041633 | 49.7 | 1.02 | 50.694 | 323.894 | 9.662 | 2.831 |
| Top | | | | | | |
| 95J0642 | 21.5 | 1.04 | 22.36 | 295.56 | 9.743 | 2.855 |
| 95J0641 | 21.6 | 1.04 | 22.464 | 295.664 | 13.954 | 4.088 |
| 95J0639 | 21.6 | 1.04 | 22.464 | 295.664 | 13.695 | 4.013 |
| 95J0640 | 21.6 | 1.04 | 22.464 | 295.664 | 12.605 | 3.693 |

Q = 3.714 W/Ft² 39.974 W/m²
dT = 28.18 K
dL = 0.5208 Ft 0.15873984 m

**$K_T$ = 0.225 ± 0.02382 W/m-K**

**Thermal Conductivity calculation using Fourier equation**

**Sample =** Apache Leap Tuff (Run 15)

$Q = K_T(dT/dL)$

where
- Q = heat transfer per unit area (W/Ft²)
- $K_T$ = thermal conductivity (W/m-K)
- dT = temperature difference between bottom and top sensors (K)
- dL = distance between bottom and top sensors (m)

**Sensor readings**

| Serial no. | Temp °C | Multi-factor | Correct Temp | Temp °K | Heat flow Btu/Ft²-Hr | Convert to W/Ft² 1Btu/Hr = 0.293W |
|---|---|---|---|---|---|---|
| Bottom | | | | | | |
| 96041630 | 202.2 | 0.94 | 190.068 | 463.268 | 119.531 | 35.022 |
| 96041631 | 202.3 | 0.94 | 190.162 | 463.362 | 130.725 | 38.302 |
| 96041632 | 202.4 | 0.94 | 190.256 | 463.456 | 0.000 | 0.000 |
| 96041633 | 202.4 | 0.94 | 190.256 | 463.456 | 108.449 | 31.776 |
| Top | | | | | | |
| 95J0642 | 25.3 | 1.04 | 26.312 | 299.512 | 78.329 | 22.950 |
| 95J0641 | 25.7 | 1.04 | 26.728 | 299.928 | 111.910 | 32.789 |
| 95J0639 | 25.5 | 1.04 | 26.52 | 299.72 | 107.579 | 31.521 |
| 95J0640 | 25.7 | 1.04 | 26.728 | 299.928 | 98.802 | 28.949 |

Q = 31.616 W/Ft² 340.320 W/m²
dT = 163.61 K
dL = 0.5208 Ft 0.15873984 m

**$K_T$ = 0.330 ± 0.03432 W/m-K**

9/25/96 gp

0800hr

Thermal Conductivity Experiment Run 16

Dry Apache Leap tuff

Parameter

| | | |
|---|---|---|
| Variable transformer setpoint | - | 90 |
| Waterbath setpoint | - | 90°c |
| Pressure on top Al plate | - | 55 ft lb |
| Scan Interval | - | 15 min |



9/27/96 gp

0800 hr.

Results of TC experiment Run 16

| Bottom Al plate Serial No | Heat flux BTU/Ft²-hr | Temp °C |
|---|---|---|
| 96041630 | 96.8734 | 217.8 |
| " 31 | 89.2305 | 217.9 |
| " 32 | - | 218.0 |
| " 33 | 121.5890 | 217.9 |
| **Top Al plate** | | |
| 95J042 | 80.8202 | 60.2 |
| " 41 | 114.8026 | 60.1 |
| " 39 | 111.1999 | 60.1 |
| " 40 | 104.2579 | 60.0 |

| Monitor Thermocouple Channel No | Temp °C |
|---|---|
| 1 | 86.6 |
| 2 | 81.5 |
| 3 | 216.7 |
| 4 | 216.5 |
| 5 | 217.8 |
| 6 | 217.5 |
| 7 | 57.7 |
| 8 | 56.8 |
| 9 | 57.4 |
| 10 | 58.4 |

8/27/96 gp

0800
Thermal conductivity experiment Run 17
Dry Apache Leap Tuff

Parameters
- Variable transformer setpoint - 70
- Waterbath setpoint - 30°C
- Pressure on top Al plate - 5 ft lb
- Scan Interval - 15 min



8/30/96 gp

0800 hrs
Results of TC experiment Run 17

| Bottom Al plate Serial No | Heat Flux BTU/Ft²-hr | Temp °C |
|---|---|---|
| 96041630 | 57.2942 | 150.8 |
| " 31 | 54.8957 | 150.9 |
| " 32 | - | 150.9 |
| " 33 | 74.3767 | 150.9 |

| Top Al plate | | |
|---|---|---|
| 95T 042 | 50.8228 | 31.0 |
| " 41 | 70.0422 | 31.3 |
| " 39 | 69.5393 | 31.2 |
| " 40 | 64.4171 | 31.3 |

| Monitor Thermocouple Channel No | Temp °C |
|---|---|
| 1 | 62.2 |
| 2 | 56.2 |
| 3 | 149.5 |
| 4 | 149.7 |
| 5 | 150.3 |
| 6 | 150.3 |
| 7 | 30.5 |
| 8 | 30.4 |
| 9 | 30.9 |
| 10 | 31.0 |

9/30/96 JJ

0800hr

Thermal Conductivity Experiment Run 18
Dry Apache Leap tuff

Parameters
- Variable transformer setpoint - 70
- Waterbath temperature - 95°c
- Pressure on top Al plate - 55 ft lb
- Scan interval - 15 min



10/1/96 JJ

0930hrs

Results of TC Experiment Run 18

| Bottom Al plate Serial No | Heat flux BTU/ft²hr | Temp °C |
|---|---|---|
| 96041630 | 51.2334 | 159.3 |
| " 31 | 46.1556 | 159.4 |
| " 32 | – | 159.4 |
| " 33 | 68.1088 | 159.4 |

| Top Al plate | | |
|---|---|---|
| 955042 | 46.8882 | 56.8 |
| " 41 | 66.4480 | 56.7 |
| " 39 | 63.9321 | 56.7 |
| " 40 | 60.4193 | 56.7 |

| Monitoring Thermocouple Channel No | Temp °C |
|---|---|
| 1 | 66.3 |
| 2 | 60.6 |
| 3 | 158.0 |
| 4 | 158.0 |
| 5 | 158.8 |
| 6 | 158.7 |
| 7 | 54.6 |
| 8 | 54.2 |
| 9 | 54.4 |
| 10 | 55.5 |

10/1/96 gp

0930 hr
Thermal Conductivity Experiment Run 19
Dry Apache Leap Tuff

Parameter
Variable transformer setpoint - 60
Waterbath setpoint - 95 °C
Pressure on top Al plate - 5 ft lb
Scan Interval - 15 min



10/3/96 gp

0800 hr
Results of TC experiment Run 19

| Bottom Al plate Serial No | Heat Flux BTU/Ft²/hr | Temp °C |
|---|---|---|
| 96041630 | 37.1212 | 134.2 |
| " 31 | 37.1564 | 134.2 |
| " 32 | — | 134.2 |
| " 33 | 47.8006 | 134.2 |

| Top Al plate | | |
|---|---|---|
| 95J042 | 34.1604 | 56.2 |
| " 41* | 49.6176 | 56.0 |
| " 36 | 46.9747 | 56.1 |
| " 40 | 45.1120 | 56.0 |

| Monitoring thermocouples Channel No | Temp °C |
|---|---|
| 1 | 58.6 |
| 2 | 53.7 |
| 3 | 132.8 |
| 4 | 132.9 |
| 5 | 133.5 |
| 6 | 133.3 |
| 7 | 54.1 |
| 8 | 53.5 |
| 9 | 53.8 |
| 10 | 54.8 |

10/3/96 gp

0800 hr.

Thermal Conductivity Experiment Run 20

Dry Apache Leap Tuff

Parameter

| | |
|---|---|
| Variable temperature setpoint | -50 |
| Waterbath temp | -95°C |
| Pressure on top Al plate | -5 ft lb |
| Scan interval | -15 min |



10/5/96 gp

0800 hr Results of TC experiment Run 20

| Bottom Al plate Serial No | Heat Flux BTU/Ft²-hr | Temp° C |
|---|---|---|
| 96041630 | 24.5847 | 111.1 |
| " 31 | 24.8986 | 111.1 |
| " 32 | — | 111.1 |
| " 33 | 32.7451 | 111.1 |

| Top Al plate | | |
|---|---|---|
| 95J042 | 24.8190 | 54.0 |
| " 41 | 36.9489 | 53.8 |
| " 39 | 34.0667 | 53.9 |
| " 40 | 33.8169 | 53.8 |

| Monitoring Thermocouples Channel No | Temp C |
|---|---|
| 1 | 51.5 |
| 2 | 47.0 |
| 3 | 109.9 |
| 4 | 110.1 |
| 5 | 110.5 |
| 6 | 110.5 |
| 7 | 51.7 |
| 8 | 51.1 |
| 9 | 52.0 |
| 10 | 52.9 |

10/5/96 gp

0805hr
Thermal Conductivity Experiment Run 21
Dry Apache Leap tuff

Parameters
- Variable transformer setpoint - 40
- Waterbath temp - 9.5°C
- Pressure on top Al plate - 5 ft-lb
- Scan Interval - 25°c



10/7/96 gp

0820hr Results of TC experiment Run 21

| Bottom Al plate Serial No | Heat Flux BTU/Ft²-hr | Temp °C |
|---|---|---|
| 96041630 | 12.4210 | 86.1 |
| " 31 | 13.0401 | 86.1 |
| " 32 | — | 86.1 |
| " 33 | 16.9400 | 86.1 |

| Top Al plate | | |
|---|---|---|
| 95J042 | 13.7815 | 53.1 |
| " 41 | 21.7042 | 52.9 |
| " 35 | 19.1449 | 53.1 |
| " 40 | 19.3879 | 52.9 |

| Monitoring Thermocouples Channel No | Temp °C |
|---|---|
| 1 | 43.5 |
| 2 | 40.1 |
| 3 | 85.4 |
| 4 | 85.5 |
| 5 | 85.9 |
| 6 | 85.7 |
| 7 | 51.1 |
| 8 | 50.3 |
| 9 | 51.2 |
| 10 | 52.1 |

10/7/96 gp

0830 hr

Thermal Conductivity Experiment Run 22

Parameter

| | | |
|---|---|---|
| Variable transformer setpoint | - | 40 |
| Waterbath temperature | - | 40°C |
| Pressure on Top Al plate | - | 5 ft-lb |
| Scan Interval | - | 15 min |



10/9/96 gp

0800 hr

Results of TC experiment Run 22

| Bottom Al plate Serial No | Heat Flux BTU/ft²hr | Temp °C |
|---|---|---|
| 96041630 | 14.4430 | 76.9 |
| " 31 | 15.0579 | 76.9 |
| " 32 | — | 76.9 |
| " 33 | 19.8084 | 76.9 |
| Top Al plate | | |
| 95J042 | 15.0065 | 38.1 |
| " 41 | 21.3092 | 38.0 |
| " 39 | 20.3588 | 38.1 |
| " 40 | 19.3934 | 38.1 |

| Monitor Thermocouple Channel No | Temp °C |
|---|---|
| 1 | 39.0 |
| 2 | 35.4 |
| 3 | 76.2 |
| 4 | 76.3 |
| 5 | 76.6 |
| 6 | 76.6 |
| 7 | 37.7 |
| 8 | 37.1 |
| 9 | 37.4 |
| 10 | 37.6 |

10/9/96 gp

0800 hr
Thermal Conductivity Experiment Run 23
Dry Apache Leap tuff

Parameters:

| | |
|---|---|
| Variable transformer setpoint | - ~~8~~0 gp 10/9/96 |
| Waterbath setpoint | - ~~40°C~~ 95°C |
| Pressure on top Al plate | - 5 ft-lb |
| Scan Interval | - 15 min |



10/10/96 gp

0810 hrs
Results of TC experiment Run 23

| Bottom Al plate Serial No | Heat Flux BTU/Ft²hr | Temp °C |
|---|---|---|
| 96041630 | 64.6628 | 173.6 |
| " 31 | 62.4705 | 173.6 |
| " 32 | — | 173.6 |
| " 33 | 88.2036 | 173.6 |
| Top Al plate | | |
| 95J042 | 54.4511 | 54.7 |
| " 41 | 75.2109 | 54.7 |
| " 39 | 75.6271 | 54.6 |
| " 40 | 69.8402 | 54.6 |

| Monitoring thermocouples Channel No | Temp °C |
|---|---|
| 1 | 70.8 |
| 2 | 64.6 |
| 3 | 172.3 |
| 4 | 172.1 |
| 5 | 173.2 |
| 6 | 173.2 |
| 7 | 52.7 |
| 8 | 51.6 |
| 9 | 52.4 |
| 10 | 53.7 |

10/10/96 jl Thermal conductivity spreadsheet calculation for Runs 16–23 are shown on following pages.

**Thermal Conductivity calculation using Fourier equation**

**Sample =** Apache Leap Tuff (Run 16)

$Q = K_T(dT/dL)$

where
- Q = heat transfer per unit area ($W/Ft^2$)
- $K_T$ = thermal conductivity (W/m-K)
- dT = temperature difference between bottom and top sensors (K)
- dL = distance between bottom and top sensors (m)

**Sensor readings**

| Serial no. | Temp $^0C$ | Multi-factor | Correct Temp | Temp $^0K$ | Heat flow $Btu/Ft^2$-Hr | Convert to $W/Ft^2$ 1Btu/Hr = 0.293W |
|---|---|---|---|---|---|---|
| Bottom | | | | | | |
| 96041630 | 217.8 | 0.935 | 203.643 | 476.843 | 96.873 | 28.384 |
| 96041631 | 217.9 | 0.935 | 203.7365 | 476.937 | 89.231 | 26.145 |
| 96041632 | 218 | 0.935 | 203.83 | 477.03 | 0.000 | 0.000 |
| 96041633 | 217.9 | 0.935 | 203.7365 | 476.937 | 121.589 | 35.626 |
| Top | | | | | | |
| 95J0642 | 60.2 | 1.015 | 61.103 | 334.303 | 80.820 | 23.680 |
| 95J0641 | 60.1 | 1.015 | 61.0015 | 334.202 | 114.803 | 33.637 |
| 95J0639 | 60.1 | 1.015 | 61.0015 | 334.202 | 111.200 | 32.582 |
| 95J0640 | 60 | 1.015 | 60.9 | 334.1 | 104.258 | 30.548 |

Q = 30.086 $W/Ft^2$ — 323.852 $W/m^2$
dT = 142.74 K
dL = 0.5208 Ft — 0.15873984 m

**$K_T$ = 0.360 ± 0.03732 W/m-K**

**Thermal Conductivity calculation using Fourier equation**

**Sample =** Apache Leap Tuff (Run 17)

$Q = K_T(dT/dL)$

where
- Q = heat transfer per unit area ($W/Ft^2$)
- $K_T$ = thermal conductivity (W/m-K)
- dT = temperature difference between bottom and top sensors (K)
- dL = distance between bottom and top sensors (m)

**Sensor readings**

| Serial no. | Temp $^0C$ | Multi-factor | Correct Temp | Temp $^0K$ | Heat flow $Btu/Ft^2$-Hr | Convert to $W/Ft^2$ 1Btu/Hr = 0.293W |
|---|---|---|---|---|---|---|
| Bottom | | | | | | |
| 96041630 | 150.8 | 0.96 | 144.768 | 417.968 | 57.294 | 16.787 |
| 96041631 | 150.9 | 0.96 | 144.864 | 418.064 | 54.896 | 16.084 |
| 96041632 | 150.9 | 0.96 | 144.864 | 418.064 | 0.000 | 0.000 |
| 96041633 | 150.9 | 0.96 | 144.864 | 418.064 | 74.377 | 21.792 |
| Top | | | | | | |
| 95J0642 | 31 | 1.035 | 32.085 | 305.285 | 50.823 | 14.891 |
| 95J0641 | 31.3 | 1.035 | 32.3955 | 305.596 | 70.042 | 20.522 |
| 95J0639 | 31.2 | 1.035 | 32.292 | 305.492 | 69.539 | 20.375 |
| 95J0640 | 31.3 | 1.035 | 32.3955 | 305.596 | 64.417 | 18.874 |

Q = 18.475 $W/Ft^2$ — 198.872 $W/m^2$
dT = 112.55 K
dL = 0.5208 Ft — 0.15873984 m

**$K_T$ = 0.280 ± 0.02935 W/m-K**



**Thermal Conductivity calculation using Fourier equation**

**Sample =** Apache Leap Tuff (Run 18)

$Q = K_T(dT/dL)$

where
- Q = heat transfer per unit area ($W/Ft^2$)
- $K_T$ = thermal conductivity (W/m-K)
- dT = temperature difference between bottom and top sensors (K)
- dL = distance between bottom and top sensors (m)

**Sensor readings**

| Serial no. | Temp $^0C$ | Multi-factor | Correct Temp | Temp $^0K$ | Heat flow $Btu/Ft^2$-Hr | Convert to $W/Ft^2$ 1Btu/Hr = 0.293W |
|---|---|---|---|---|---|---|
| Bottom | | | | | | |
| 96041630 | 159.3 | 0.96 | 152.928 | 426.128 | 51.233 | 15.011 |
| 96041631 | 159.4 | 0.96 | 153.024 | 426.224 | 46.156 | 13.524 |
| 96041632 | 159.4 | 0.96 | 153.024 | 426.224 | 0.000 | 0.000 |
| 96041633 | 159.4 | 0.96 | 153.024 | 426.224 | 68.109 | 19.956 |
| Top | | | | | | |
| 95J0642 | 56.8 | 1.02 | 57.936 | 331.136 | 46.888 | 13.738 |
| 95J0641 | 56.7 | 1.02 | 57.834 | 331.034 | 66.448 | 19.469 |
| 95J0639 | 56.7 | 1.02 | 57.834 | 331.034 | 63.932 | 18.732 |
| 95J0640 | 56.7 | 1.02 | 57.834 | 331.034 | 60.419 | 17.703 |

Q = 16.876 $W/Ft^2$ — 181.660 $W/m^2$
dT = 95.141 K
dL = 0.5208 Ft — 0.15873984 m

**$K_T$ = 0.303 ± 0.03161 W/m-K**

**Thermal Conductivity calculation using Fourier equation**

**Sample =** Apache Leap Tuff (Run 19)

$Q = K_T(dT/dL)$

where
- Q = heat transfer per unit area ($W/Ft^2$)
- $K_T$ = thermal conductivity (W/m-K)
- dT = temperature difference between bottom and top sensors (K)
- dL = distance between bottom and top sensors (m)

**Sensor readings**

| Serial no. | Temp $^0C$ | Multi-factor | Correct Temp | Temp $^0K$ | Heat flow $Btu/Ft^2$-Hr | Convert to $W/Ft^2$ 1Btu/Hr = 0.293W |
|---|---|---|---|---|---|---|
| Bottom | | | | | | |
| 96041630 | 134.2 | 0.97 | 130.174 | 403.374 | 37.121 | 10.877 |
| 96041631 | 134.2 | 0.97 | 130.174 | 403.374 | 37.156 | 10.887 |
| 96041632 | 134.2 | 0.97 | 130.174 | 403.374 | 0.000 | 0.000 |
| 96041633 | 134.2 | 0.97 | 130.174 | 403.374 | 47.801 | 14.006 |
| Top | | | | | | |
| 95J0642 | 56.2 | 1.02 | 57.324 | 330.524 | 34.160 | 10.009 |
| 95J0641 | 56 | 1.02 | 57.12 | 330.32 | 49.618 | 14.538 |
| 95J0639 | 56.1 | 1.02 | 57.222 | 330.422 | 46.975 | 13.764 |
| 95J0640 | 56 | 1.02 | 57.12 | 330.32 | 45.112 | 13.218 |

Q = 12.471 $W/Ft^2$ — 134.242 $W/m^2$
dT = 72.977 K
dL = 0.5208 Ft — 0.15873984 m

**$K_T$ = 0.292 ± 0.03050 W/m-K**

**Thermal Conductivity calculation using Fourier equation**

**Sample =** Apache Leap Tuff (Run 20)

$Q = K_T(dT/dL)$

where $Q$ = heat transfer per unit area ($W/Ft^2$)
$K_T$ = thermal conductivity (W/m-K)
$dT$ = temperature difference between bottom and top sensors (K)
$dL$ = distance between bottom and top sensors (m)

**Sensor readings**

| Serial no. | Temp $^0C$ | Multi-factor | Correct Temp | Temp $^0K$ | Heat flow $Btu/Ft^2$-Hr | Convert to $W/Ft^2$ 1Btu/Hr = 0.293W |
|---|---|---|---|---|---|---|
| Bottom | | | | | | |
| 96041630 | 111.1 | 0.97 | 107.767 | 380.967 | 24.585 | 7.203 |
| 96041631 | 111.1 | 0.97 | 107.767 | 380.967 | 24.899 | 7.295 |
| 96041632 | 111.1 | 0.97 | 107.767 | 380.967 | 0.000 | 0.000 |
| 96041633 | 111.1 | 0.97 | 107.767 | 380.967 | 32.745 | 9.594 |
| Top | | | | | | |
| 95J0642 | 54 | 1.02 | 55.08 | 328.28 | 24.869 | 7.287 |
| 95J0641 | 53.8 | 1.02 | 54.876 | 328.076 | 36.949 | 10.826 |
| 95J0639 | 53.9 | 1.02 | 54.978 | 328.178 | 34.067 | 9.982 |
| 95J0640 | 53.8 | 1.02 | 54.876 | 328.076 | 33.817 | 9.908 |

Q = 8.871 $W/Ft^2$ — 95.487 $W/m^2$
dT = 52.815 K
dL = 0.5208 Ft — 0.15873984 m

**$K_T$ = 0.287 ± 0.03000 W/m-K**

**Thermal Conductivity calculation using Fourier equation**

**Sample =** Apache Leap Tuff (Run 21)

$Q = K_T(dT/dL)$

where $Q$ = heat transfer per unit area ($W/Ft^2$)
$K_T$ = thermal conductivity (W/m-K)
$dT$ = temperature difference between bottom and top sensors (K)
$dL$ = distance between bottom and top sensors (m)

**Sensor readings**

| Serial no. | Temp $^0C$ | Multi-factor | Correct Temp | Temp $^0K$ | Heat flow $Btu/Ft^2$-Hr | Convert to $W/Ft^2$ 1Btu/Hr = 0.293W |
|---|---|---|---|---|---|---|
| Bottom | | | | | | |
| 96041630 | 86.1 | 0.99 | 85.239 | 358.439 | 12.421 | 3.639 |
| 96041631 | 86.1 | 0.99 | 85.239 | 358.439 | 13.040 | 3.821 |
| 96041632 | 86.1 | 0.99 | 85.239 | 358.439 | 0.000 | 0.000 |
| 96041633 | 86.1 | 0.99 | 85.239 | 358.439 | 16.940 | 4.963 |
| Top | | | | | | |
| 95J0642 | 53.1 | 1.02 | 54.162 | 327.362 | 13.782 | 4.038 |
| 95J0641 | 52.9 | 1.02 | 53.958 | 327.158 | 21.704 | 6.359 |
| 95J0639 | 53.1 | 1.02 | 54.162 | 327.362 | 19.145 | 5.609 |
| 95J0640 | 52.9 | 1.02 | 53.958 | 327.158 | 19.388 | 5.681 |

Q = 4.873 $W/Ft^2$ — 52.454 $W/m^2$
dT = 31.179 K
dL = 0.5208 Ft — 0.15873984 m

**$K_T$ = 0.267 ± 0.02801 W/m-K**



**Thermal Conductivity calculation using Fourier equation**

**Sample =** Apache Leap Tuff (Run 22)

$Q = K_T(dT/dL)$

where $Q$ = heat transfer per unit area ($W/Ft^2$)
$K_T$ = thermal conductivity (W/m-K)
$dT$ = temperature difference between bottom and top sensors (K)
$dL$ = distance between bottom and top sensors (m)

**Sensor readings**

| Serial no. | Temp $^0C$ | Multi-factor | Correct Temp | Temp $^0K$ | Heat flow $Btu/Ft^2$-Hr | Convert to $W/Ft^2$ 1Btu/Hr = 0.293W |
|---|---|---|---|---|---|---|
| Bottom | | | | | | |
| 96041630 | 76.9 | 0.99 | 76.131 | 349.331 | 14.443 | 4.232 |
| 96041631 | 76.9 | 0.99 | 76.131 | 349.331 | 15.058 | 4.412 |
| 96041632 | 76.9 | 0.99 | 76.131 | 349.331 | 0.000 | 0.000 |
| 96041633 | 76.9 | 0.99 | 76.131 | 349.331 | 19.808 | 5.804 |
| Top | | | | | | |
| 95J0642 | 38.1 | 1.02 | 38.862 | 312.062 | 15.007 | 4.397 |
| 95J0641 | 38 | 1.02 | 38.76 | 311.96 | 21.309 | 6.244 |
| 95J0639 | 38.1 | 1.02 | 38.862 | 312.062 | 20.399 | 5.977 |
| 95J0640 | 38.1 | 1.02 | 38.862 | 312.062 | 19.393 | 5.682 |

Q = 5.250 $W/Ft^2$ — 56.508 $W/m^2$
dT = 37.295 K
dL = 0.5208 Ft — 0.15873984 m

**$K_T$ = 0.241 ± 0.02535 W/m-K**

**Thermal Conductivity calculation using Fourier equation**

**Sample =** Apache Leap Tuff (Run 23)

$Q = K_T(dT/dL)$

where $Q$ = heat transfer per unit area ($W/Ft^2$)
$K_T$ = thermal conductivity (W/m-K)
$dT$ = temperature difference between bottom and top sensors (K)
$dL$ = distance between bottom and top sensors (m)

**Sensor readings**

| Serial no. | Temp $^0C$ | Multi-factor | Correct Temp | Temp $^0K$ | Heat flow $Btu/Ft^2$-Hr | Convert to $W/Ft^2$ 1Btu/Hr = 0.293W |
|---|---|---|---|---|---|---|
| Bottom | | | | | | |
| 96041630 | 173.6 | 0.95 | 164.92 | 438.12 | 64.663 | 18.946 |
| 96041631 | 173.6 | 0.95 | 164.92 | 438.12 | 62.471 | 18.304 |
| 96041632 | 173.6 | 0.95 | 164.92 | 438.12 | 0.000 | 0.000 |
| 96041633 | 173.6 | 0.95 | 164.92 | 438.12 | 88.204 | 25.844 |
| Top | | | | | | |
| 95J0642 | 54.7 | 1.02 | 55.794 | 328.994 | 54.451 | 15.954 |
| 95J0641 | 54.7 | 1.02 | 55.794 | 328.994 | 75.211 | 22.037 |
| 95J0639 | 54.6 | 1.02 | 55.692 | 328.892 | 75.027 | 21.983 |
| 95J0640 | 54.6 | 1.02 | 55.692 | 328.892 | 69.840 | 20.463 |

Q = 20.504 $W/Ft^2$ — 220.715 $W/m^2$
dT = 109.18 K
dL = 0.5208 Ft — 0.15873984 m

**$K_T$ = 0.321 ± 0.03339 W/m-K**

11/1/96 JP

Apache Leap Tuff Saturation

Obj - saturate Apache Leap tuff with water in order to perform saturated thermal conductivity measurements.

Method - saturate using vacuum suction.

Equipment + materials
- crushed Apache Leap Tuff (1.6-4 cm size)
- vacuum chamber
- vacuum pump
- $CO_2$ (gas)
- deaerated $H_2O$



Procedure
1. Loaded crushed tuff into vacuum chamber and sealed chamber.
2. Pulled a vacuum of about -30 inches of Hg for 15 minutes.
3. Release vacuum and introduce $CO_2$ gas for about 15 min.
4. Repeat steps 2+3 several times.
5. Introduce deaired water into chamber until full.
6. Repeated steps 2+3 several times over about 2 weeks.
7. Removed crushed tuff from chamber and placed in DI water to maintain saturation

12/13/96 JP

Thermal conductivity cell was modified for saturated measurements by sealing with silicon sealant. Before loading the crushed rock sample the cell was filled with water and tested to ensure that no leaks developed.

Saturated thermal conductivity measurements on Apache Leap crushed tuff will be conducted in the same manner as those for the dry Apache Leap tuff.

12/16/96 JP

0930 hrs
Thermal Conductivity Experiment Run 24
Totally saturated Apache Leap Tuff

Parameters:
Variable transformer setpoint - ~~40~~ 100 JP 1/6/97
Waterbath temp - ~~23°C~~ 5°C JP 1/6/97
Pressure on top Al plate - 55 lbs
Scan Interval - 15 min



1/6/97

0800 hrs
Results of TC experiment Run 24

| Bottom Al plate Serial No | Heat Flux BTU/Ft²hr | Temp °C |
|---|---|---|
| 96041630 | 289.8323 | 49 |
| 31 | 352.3846 | 49.2 |
| 32 | — | 49.2 |
| 33 | 379.3643 | 49.6 |

| Top Al plate | | |
|---|---|---|
| 95J04 2 | 198.7233 | 35.4 |
| 41 | 245.8960 | 35.9 |
| 39 | 180.3267 | 35.6 |
| 40 | 176.6103 | 35.6 |

| Monitor Thermocouples Channel No | Temp °C |
|---|---|
| 1 | 89.2 |
| 2 | 35.6 |
| 3 | 48.3 |
| 4 | 47.8 |
| 5 | 47.0 |
| 6 | 52.5 |
| 7 | 38.7 |
| 8 | 36.9 |
| 9 | 37.3 |
| 10 | 38.4 |

1/6/97 JP

0830hr JP

Thermal Conductivity Experiment Run 25
Saturated Apache Leap Tuff

Parameter — JP 1/9/97

- Variable transformer setpoint - ~~[illegible]~~ 8
- Waterbath Temperature - ~~23°C~~ 15°C
- Pressure ~ top Al plate - 5 ft-lbs
- Scan Interval - 15 min



1/9/97 JP

1030hrs
Results of TC experiment Run 25

| Bottom Al plate Serial No | Heat Flux BTU/Ft²-hr | Temp °C |
|---|---|---|
| 96041630 | 109.1316 | 35.4 |
| 31 | 154.1018 | 35.4 |
| 32 | ~~169.5197~~ JP 1/9/96 | 35.3 |
| 33 | 169.5197 | 35.3 |
| **Top Al plate** | | |
| 95J042 | 179.5019 | 29.7 |
| 41 | 209.3699 | 30.0 |
| 39 | 168.3686 | 29.6 |
| 40 | 152.5256 | 29.4 |

| Monitoring Thermocouple Channel No | Temp °C |
|---|---|
| 1 | 55.2 |
| 2 | 25.5 |
| 3 | 34.1 |
| 4 | 33.6 |
| 5 | 34.2 |
| 6 | 36.6 |
| 7 | 28.3 |
| 8 | 28.6 |
| 9 | 28.2 |
| 10 | 23.9 |

I have reviewed this notebook and find it in general compliance with QAP-001. There is adequate information for another qualified person to repeat the activities.

E. C. [illegible]

1/8/97



1/9/97
1030hrs [illegible] Thermal Conductivity Experiment Run 26
Saturated Apache Leap Tuff

Parameters
- Variable transformer setpoint - 100
- Waterbath Temp - 3°C
- Pressure on Top Al plate - 5 ft-lb
- Scan Interval - 15 min

1/13/97
0950hrs Results of TC experiment Run 26

| Bottom Al plate Serial No | Heat Flux BTU/ft²hr | Temp °C |
|---|---|---|
| 96041630 | — | 46.3 |
| 31 | 348.3167 | 46.2 |
| 32 | — | 46.1 |
| 33 | 407.5022 | 46.1 |

| Top Al plate | | |
|---|---|---|
| 95J042 | 341.4901 | 34.9 |
| 41 | 340.5578 | 35.1 |
| 39 | 357.0437 | 35.1 |
| 40 | 295.2863 | 34.7 |

| Monitoring Thermocouple | Temp °C |
|---|---|
| 1 | 35.4 |
| 2 | 31.6 |
| 3 | 44.5 |
| 4 | 44.0 |
| 5 | 45.2 |
| 6 | 49.0 |
| 7 | 34.9 |
| 8 | 35.4 |
| 9 | 34.6 |
| 10 | 35.4 |

1/13/97 1000hr JP Thermal Conductivity experiment Run 27
Saturated Apache Leap Tuff

Parameters
Variable Transformer setpoint 80
Waterbath Temp 3°C
Pressure ~ Top Al plate 5 ft lbs.

1/14/97 JP 0825hr

Results of TC experiment Run 27

| Bottom Al plate Serial No | Heat Flux BTU/FT²hr | Temp °C |
|---|---|---|
| 96041630 | 208.5381 | 37.6 |
| 31 | 265.9650 | 37.4 |
| 32 | — | 37.3 |
| 33 | 317.8670 | 37.5 |
| Top Al plate | | |
| 95J042 | 302.0864 | 28.9 |
| 41 | 295.3244 | 29.2 |
| 39 | 263.8976 | 28.7 |
| 40 | 241.8084 | 28.5 |

| Monitoring Thermocouples | Temp °C |
|---|---|
| 1 | 72.3 |
| 2 | 31.2 |
| 3 | 36.0 |
| 4 | 36.3 |
| 5 | 35.3 |
| 6 | 39.1 |
| 7 | 21.7 |
| 8 | 23.1 |
| 9 | 27.4 |
| 10 | 23.0 |



1/14/97 JP 0830hr Thermal Conductivity Experiment Run 28
Saturated Apache Leap Tuff

Parameters
Variable Transformer setpoint 60
Waterbath Temp setpoint 3°C
Pressure ~ Top Al plate 5 ft lbs

1/15/97 JP 0900hr
Results of TC experiment Run 28

| Bottom Al plate Serial No | Heat Flux BTU/Ft²hr | Temp °C |
|---|---|---|
| 96041630 | 137.6004 | 21.2 |
| 31 | 163.5164 | 21.3 |
| 32 | — | 21.3 |
| 33 | 177.2036 | 21.3 |
| Top Al plate | | |
| 95J042 | 106.5424 | 14.7 |
| 41 | 106.8520 | 14.9 |
| 39 | 95.7082 | 14.8 |
| 40 | 105.8362 | 14.8 |

| Monitoring Thermocouples | Temp °C |
|---|---|
| 1 | 47.0 |
| 2 | 24.7 |
| 3 | 21.6 |
| 4 | 20.9 |
| 5 | 21.7 |
| 6 | 22.7 |
| 7 | 15.2 |
| 8 | 15.5 |
| 9 | 14.9 |
| 10 | 15.2 |

1/15/97 jp 0905hr Thermal Conductivity Experiment Run 29
Saturated Apache Leap Tuff

Parameters
Variable Transformer setpoint 60
Waterbath Temp setpoint 20°C
Pressure on Top Al plate 5 ft lb

1/16/97 jp 1030hr Results of TC experiment Run 29

| Bottom Al plate Serial No | Heat Flux BTU/HR²ft | Temp °C |
|---|---|---|
| 96041630 | 125.4369 | 29.8 |
| 31 | 149.0790 | 29.9 |
| 32 | — | 29.9 |
| 33 | 163.4704 | 29.9 |
| Top Al plate | | |
| 95J042 | 103.9139 | 24.4 |
| 41 | 106.3123 | 24.4 |
| 39 | 118.2999 | 24.5 |
| 40 | 94.8534 | 24.3 |

| Monitoring Thermocouple | Temp °C |
|---|---|
| 1 | 47.7 |
| 2 | 24.9 |
| 3 | 30.0 |
| 4 | 24.5 |
| 5 | 30.0 |
| 6 | 31.3 |
| 7 | 24.8 |
| 8 | 25.0 |
| 9 | 24.8 |
| 10 | 25.1 |



1/16/97 jp 1030hr Thermal Conductivity Experiment Run 30
Saturated Apache Leap Tuff

Parameters
Variable Transformer setpoint 50
Waterbath Temp setpoint 20°C
Pressure on Top Al plate 5 ft lb

1/17/97 jp 0905hr Results of TC Experiment Run 30

| Bottom Al plate Serial No | Heat Flux BTU/ft²·hr | Temp °C |
|---|---|---|
| 96041630 | 80.6433 | 27.3 |
| 31 | 73.8381 | 27.2 |
| 32 | ~~116.1280~~ jp 1/17/97 | 27.2 |
| 33 | 116.1280 | 27.2 |
| Top Al plate | | |
| 95J042 | 98.2664 | 23.1 |
| 41 | 81.2476 | 23.0 |
| 39 | 95.6430 | 23.0 |
| 40 | 81.0470 | 22.9 |

| Monitoring Thermocouple | Temp °C |
|---|---|
| 1 | 42.9 |
| 2 | 25.6 |
| 3 | 27.2 |
| 4 | 27.0 |
| 5 | 27.0 |
| 6 | 28.1 |
| 7 | 23.0 |
| 8 | 23.0 |
| 9 | 23.1 |
| 10 | 23.1 |

1/17/97 gp 0910hr Thermal Conductivity Experiment Run 31
Saturated Apache Leap Tuff

Parameters

| | |
|---|---|
| Variable Transformer Setpoint | 45 |
| Waterbath Temperature Setpoint | 20°C |
| Pressure on Top plate | 5 ft lbs |

1/20/97 gp 0800hr Results of TC experiment Run 31

| Bottom Al plate Serial No | Heat Flux BTU/Ft²-hr | Temp °C |
|---|---|---|
| 96041630 | 77.4291 | 25.8 |
| 31 | 86.8512 | 25.8 |
| 32 | — | 25.8 |
| 33 | 102.1762 | 25.8 |

| Top Al plate | | |
|---|---|---|
| 95J042 | 57.4254 | 22.1 |
| 41 | 57.6572 | 22.1 |
| 39 | 53.6024 | 22.1 |
| 40 | 62.4510 | 22.1 |

| Monitoring Thermocouples | Temp °C |
|---|---|
| 1 | 40.0 |
| 2 | 26.2 |
| 3 | 25.9 |
| 4 | 25.7 |
| 5 | 25.9 |
| 6 | 26.6 |
| 7 | 22.3 |
| 8 | 22.4 |
| 9 | 22.3 |
| 10 | 22.3 |



1/20/97 gp 0800hr Thermal Conductivity Experiment Run 32
Saturated Apache Leap Tuff

Parameters

| | |
|---|---|
| Variable Transformer Setpoint | 40 |
| Waterbath Temp Setpoint | 20°C |
| Pressure on Top Al plate | 5 ft lbs. |

1/21/97 gp 0910hr Results of TC experiment Run 32

| Bottom Al plate Serial No | Heat Flux BTU/Ft²-hr | Temp °C |
|---|---|---|
| 96041630 | 59.4150 | 24.4 |
| 31 | 49.4574 | 24.5 |
| 32 | — | 24.5 |
| 33 | 80.3687 | 24.4 |

| Top Al plate | | |
|---|---|---|
| 95J042 | 36.6106 | 21.3 |
| 41 | 50.8361 | 21.4 |
| 39 | 47.4361 | 21.4 |
| 40 | 51.2005 | 21.3 |

| Monitoring Thermocouples | Temp °C |
|---|---|
| 1 | 36.6 |
| 2 | 25.6 |
| 3 | 24.6 |
| 4 | 24.4 |
| 5 | 24.6 |
| 6 | 25.2 |
| 7 | 21.6 |
| 8 | 21.6 |
| 9 | 21.5 |
| 10 | 21.6 |

1/21/97 gp 0915hr Thermal Conductivity Experiment Run 33
Saturated Apache Leap Tuff

Parameters
Variable transformer setpoint 70
Waterbath temp setpoint 20°C
Pressure on top Al plate 5 ft-lb.

1/23/97 gp 1540hr Results of TC Experiment Run 33

| Bottom Al plate Serial No | Heat Flux BTU/Ft²-hr | Temp °C |
|---|---|---|
| 96041630 | 140.6570 | 35.7 |
| 31 | 252.3840 | 35.7 |
| 32 | — | 35.7 |
| 33 | 194.0759 | 35.6 |

| Top Al plate | | |
|---|---|---|
| 95J042 | 227.4126 | 29.4 |
| 41 | 227.9807 | 29.5 |
| 39 | 210.4418 | 29.4 |
| 40 | 174.5569 | 29.1 |

| Monitoring Thermocouples | Temp °C |
|---|---|
| 1 | 60.0 |
| 2 | 31.0 |
| 3 | 34.6 |
| 4 | 34.2 |
| 5 | 34.7 |
| 6 | 36.8 |
| 7 | 28.6 |
| 8 | 28.8 |
| 9 | 28.5 |
| 10 | 28.9 |



1/23/97 gp 1545hr Thermal Conductivity Experiment Run 34
Saturated Apache Leap Tuff

Parameters
Variable transformer setpoint 90
Waterbath temp setpoint 20°C
Pressure on top Al plate 5 ft-lb

1/24/97 gp 1030hr Results of TC experiment Run 34

| Bottom Al plate Serial No | Heat Flux BTU/Ft²-hr | Temp °C |
|---|---|---|
| 96041630 | 207.5612 | 46.9 |
| 31 | 244.7297 | 47.1 |
| 32 | — | 46.9 |
| 33 | 286.5900 | 47.0 |

| Top Al plate | | |
|---|---|---|
| 95J042 | 321.8171 | 38.2 |
| 41 | 328.2229 | 38.7 |
| 39 | 334.5226 | 38.5 |
| 40 | 294.8330 | 38.2 |

| Monitoring Thermocouples | Temp °C |
|---|---|
| 1 | 80.6 |
| 2 | 36.8 |
| 3 | 44.9 |
| 4 | 44.7 |
| 5 | 45.2 |
| 6 | 49.3 |
| 7 | 37.1 |
| 8 | 37.2 |
| 9 | 37.1 |
| 10 | 38.2 |

1/21/97 1200hr JP

Sample was removed from thermal conductivity cell. Both water & rock was removed. The matrix saturated Apache Leap tuff was immediately reloaded into the cell in preparation of matrix saturated rock measurements. Aluminum foil was placed to top of loaded sample to ~~insure~~ good contact between sample + flux meter.



1/24/97 JP 1245hrs Thermal Conductivity Experiment Run 35
Matrix Saturated Apache Leap Tuff

Parameters

| | |
|---|---|
| Variable transformer setpoint | 15 |
| Waterbath temp setpoint | 20°c |
| Pressure on top Al plate | 5 ft lb |

1/27/97 JP 0800hr Results of TC experiment Run 35

| Bottom Al plate Serial No | Heat Flux BTU/Ft²-hr | Temp °c |
|---|---|---|
| 96041630 | 12.1950 | 33 |
| 31 | 12.9861 | 33 |
| 32 | ~~17.5~~ JP 1/27/97 | 33 |
| 33 | 17.5283 | 33 |

| Top Al plate | | |
|---|---|---|
| 955042 | 14.9338 | 18.7 |
| 41 | 16.2295 | 18.7 |
| 39 | 12.3435 | 18.7 |
| 40 | 18.6482 | 18.7 |

| Monitoring Thermocouple | Temp °c |
|---|---|
| 1 | 27.6 |
| 2 | 25.2 |
| 3 | 33.0 |
| 4 | 33.0 |
| 5 | 33.1 |
| 6 | 33.2 |
| 7 | 18.9 |
| 8 | 18.9 |
| 9 | 18.7 |
| 10 | 18.8 |

1/27/97 gf 0805hr Thermal Conductivity Experiment Run 36
Matrix Saturated Apache Leap Tuff

Parameters
Variable transformer setpoint 25
Waterbath temperature setpoint 20°C
Pressure on top Al plate 5 ft lb

1/28/97 gf 0805hr Results of TC experiment Run 36

| Bottom Al plate Serial No | Heat Flux BTU/Ft²-hr | Temp °C |
|---|---|---|
| 96041630 | 31.7899 | 46.1 |
| 31 | 34.6315 | 46.2 |
| 32 | — | 46.1 |
| 33 | 37.4044 | 46.2 |

| Top Al plate | | |
|---|---|---|
| 95J042 | 23.1975 | 19.9 |
| 41 | 32.9430 | 20.0 |
| 39 | 18.0756 | 19.9 |
| 40 | 37.9512 | 20.0 |

| Monitoring Thermocouples Channel No | Temp °C |
|---|---|
| 1 | 33.3 |
| 2 | 27.9 |
| 3 | 45.8 |
| 4 | 45.7 |
| 5 | 45.6 |
| 6 | 46.4 |
| 7 | 20.1 ~~45.6~~ gf |
| 8 | 20.2 ~~45.7~~ 1/28/97 |
| 9 | 19.8 |
| 10 | 19.9 |



1/28/97 gf 0810hr Thermal Conductivity Experiment Run 37
Matrix Saturated Apache Leap Tuff

Parameters
Variable transformer setpoint 35
Waterbath temperature setpoint 20°C
Pressure – Top Al plate 5 ft lb

1/29/97 gf 0900hr Results of TC experiment Run 37

| Bottom Al plate Serial No | Heat Flux BTU/Ft²-hr | Temp °C |
|---|---|---|
| 96041630 | 63.4800 | 59.7 |
| 31 | 58.8665 | 59.9 |
| 32 | — | 60.0 |
| 33 | 60.1333 | 60.2 |

| Top Al plate | | |
|---|---|---|
| 95J042 | 43.2547 | 23.0 |
| 41 | 86.3885 | 23.2 |
| 39 | 43.6202 | 23.0 |
| 40 | 76.3439 | 23.0 |

| Monitoring Thermocouples Channel No | Temp °C |
|---|---|
| 1 | 42.1 |
| 2 | 32.7 |
| 3 | 59.0 |
| 4 | 60.4 |
| 5 | 58.8 |
| 6 | 60.8 |
| 7 | 23.0 |
| 8 | 23.4 |
| 9 | 21.8 |
| 10 | 22.7 |

1/29/97 JP 0900hr Thermal Conductivity Experiment Run 38
Mostly saturated Apache Leap Tuff

Parameters
Variable Transformer Setpoint 30
Waterbath Temp Setpoint 20°C
Pressure on top Al plate 55 lb

1/30/97 JP 0800hr Results of TC experiment Run 38

| Bottom Al plate Serial No | Heat Flux BTU/Ft²-hr | Temp °C |
|---|---|---|
| 96041630 | 47.0257 | 53.7 |
| 31 | 44.6665 | 53.9 |
| 32 | — | 53.9 |
| 33 | 53.5479 | 54.1 |

| Top Al plate | | |
|---|---|---|
| 95J042 | 27.9730 | 21.2 |
| 41 | 50.3687 | 21.3 |
| 39 | 30.1693 | 21.2 |
| 40 | 48.5736 | 21.2 |

| Monitoring Thermocouples | Temp °C |
|---|---|
| 1 | 38.0 |
| 2 | 31.0 |
| 3 | 53.2 |
| 4 | 54.3 |
| 5 | 53.1 |
| 6 | 54.5 |
| 7 | 21.2 |
| 8 | 21.4 |
| 9 | 20.5 |
| 10 | 21.0 |



1/30/97 JP 0805hr Thermal Conductivity Experiment Run 39
Mostly saturated Apache Leap Tuff

Parameters
Variable Transformer setpoint 40
Waterbath temp setpoint 20°C
Pressure on top Al plate 55 lbs

1/31/97 JP 0805hr Results of TC experiment Run 39

| Bottom Al plate Serial No | Heat Flux BTU/Ft²-hr | Temp °C |
|---|---|---|
| 96041630 | 88.2223 | 65.6 |
| 31 | 76.6760 | 65.7 |
| 32 | — | 65.9 |
| 33 | 82.9456 | 66.2 |

| Top Al plate | | |
|---|---|---|
| 95J042 | 47.7706 | 24.2 |
| 41 | 83.9961 | 24.4 |
| 39 | 57.0656 | 24.2 |
| 40 | 73.1280 | 24.1 |

| Monitoring Thermocouples | Temp °C |
|---|---|
| 1 | 46.6 |
| 2 | 35.2 |
| 3 | 64.6 |
| 4 | 67.2 |
| 5 | 64.9 |
| 6 | 67.1 |
| 7 | 24.2 |
| 8 | 24.9 |
| 9 | 22.8 |
| 10 | 24.0 |

1/31/97 JP 0810hr Thermal Conductivity Experiment Run 40
Matrix Saturated Apache Leap Tuff

Parameters
Variable transformer setpoint 45
Waterbath temperature setpoint 20°C
Pressure on top Al plate 5 ft lb

2/1/97 JP 1200hr Results of TC experiment Run 40

| Bottom Al plate Serial No | Heat Flux BTU/Ft² hr | Temp °C |
|---|---|---|
| 96041630 | 111.5246 | 70.1 |
| 31 | 134.6685 | 70.2 |
| 32 | — | 70.4 |
| 33 | 99.4483 | 70.9 |
| Top Al plate | | |
| 955042 | 59.0969 | 22.9 |
| 41 | 102.6903 | 23.3 |
| 39 | 71.3740 | 23.0 |
| 40 | 86.6941 | 22.9 |

| Monitoring Thermocouples | Temp °C |
|---|---|
| 1 | 50.7 |
| 2 | 31.5 |
| 3 | 69.0 |
| 4 | 72.6 |
| 5 | 69.2 |
| 6 | 72.2 |
| 7 | 23.0 |
| 8 | 24.2 |
| 9 | 24.3 |
| 10 | 22.9 |



2/1/97 JP 1205hr Thermal Conductivity Experiment Run 41
Matrix Saturated Apache Leap Tuff

Parameters
Variable transformer setpoint 50
Waterbath temp setpoint 20°C
Pressure on top Al plate 5 ft lbs

2/2/97 JP 1200hr Results of TC experiment Run 41

| Bottom Al plate Serial No | Heat Flux BTU/Ft² hr | Temp °C |
|---|---|---|
| 96041630 | 141.3503 | 74.5 |
| 31 | 144.4607 | 74.7 |
| 32 | — | 74.9 |
| 33 | 141.3194 | 75.4 |
| Top Al plate | | |
| 955042 | 69.1566 | 24.9 |
| 41 | 146.4549 | 25.6 |
| 39 | 88.9339 | 25.0 |
| 40 | 1209533 | 25.0 |

| Monitoring Thermocouples | Temp °C |
|---|---|
| 1 | 55.6 |
| 2 | 31.7 |
| 3 | 73.3 |
| 4 | 77.9 |
| 5 | 73.5 |
| 6 | 77.3 |
| 7 | 24.8 |
| 8 | 26.4 |
| 9 | 22.7 |
| 10 | 24.7 |

2/2/97 gp 1205hr Thermal Conductivity Experiment Run 42
Matrix Saturated Apache Leap Tuff

Parameter
- Variable transformer setpoint: 60
- Waterbath temp setpoint: 20°C
- Pressure on top Al plate: 5 ft lb

2/3/97 gp 0805hr Results of TC experiment Run 42

| Bottom Al plate Serial No | Heat Flux BTU/Ft²hr | Temp °C | CH |
|---|---|---|---|
| 96041630 | 241.9771 | 80.5 | 1 |
| 31 | 206.9798 | 81.1 | 2 |
| 32 | — | 81.2 | 3 |
| 33 | 171.3626 | 81.9 | 4 |
| Top Al plate | | | |
| 95J042 | 159.6835 | 28.5 | 5 |
| 41 | 354.3392 | 29.8 | 6 |
| 39 | 164.2487 | 28.2 | 7 |
| 40 | 327.0279 | 28.7 | 8 |

| Monitoring Thermocouple | Temp °C |
|---|---|
| 1 | 62.5 |
| 2 | 41.6 |
| 3 | 78.9 |
| 4 | 85.9 |
| 5 | 79.1 |
| 6 | 84.4 |
| 7 | 27.1 |
| 8 | 29.3 |
| 9 | 24.7 |
| 10 | 27.5 |



2/3/97 gp 0915hr Thermal Conductivity Experiment Run 43
Matrix Saturated Apache Leap Tuff

Parameter
- Variable transformer setpoint: 70
- Waterbath temperature setpoint: 5°C
- Pressure on Top Al plate: 5 ft lb.

2/4/97 gp Results of TC experiment Run 43

| Bottom Al plate Serial No | Heat Flux BTU/Ft²/hr | Temp °C |
|---|---|---|
| 96041630 | 380.7802 | 88.7 |
| 31 | 281.9293 | 90.9 |
| 32 | — | 90.8 |
| 33 | 192.6807 | 94.5 |
| Top Al plate | | |
| 95J042 | 142.5125 | 19.9 |
| 41 | 112.6541 | 19.4 |
| 39 | 189.8350 | 19.7 |
| 40 | 104.4709 | 18.2 |

| Monitoring Thermocouple | Temp °C |
|---|---|
| 1 | 73.3 |
| 2 | 46.0 |
| 3 | 84.9 |
| 4 | 102.3 |
| 5 | 84.8 |
| 6 | 104.7 |
| 7 | 21.4 |
| 8 | 21.9 |
| 9 | 15.7 |
| 10 | 16.7 |

2/4/97 jp 0820hr Thermal Conductivity Experiment Run 44
Matrix Saturated Apache Leap Tuff

Parameters

| | |
|---|---|
| Variable transformer setpoint | 10 |
| Waterbath temperature setpoint | 20°C |
| Pressure on Top Al plate | 5 ft-lb |

Results of TC experiment Run 44

| Bottom Al plate Serial No | Heat Flux BTU/Ft²-hr | | Temp °C | Ch |
|---|---|---|---|---|
| 96041630 | 7.3000 | ~~3.8737~~ | 28.6 | 1 |
| 31 | 1.8182 | ~~5.9087~~ | 28.6 | 2 |
| 32 | – | ~~–~~ | 28.6 | 3 |
| 33 | 6.0597 | ~~-9.2859~~ | 28.7 | 4 |

jp 2/10/97

| Top Al plate | | | | |
|---|---|---|---|---|
| 955042 | -9.0060 | ~~-8.7447~~ | 18.4 | 5 |
| 41 | -8.9966 | ~~-9.5192~~ | 18.4 | 6 |
| 39 | -8.0553 | ~~7.3002~~ | 18.4 | 7 |
| 40 | -9.3608 | ~~1.8182~~ | 18.4 | 8 |

jp 2/10/97

| Monitoring Thermocouples | Temp °C |
|---|---|
| 1 | 25.6 |
| 2 | 24.5 |
| 3 | 28.6 |
| 4 | 28.8 |
| 5 | 28.7 |
| 6 | 28.9 |
| 7 | 18.6 |
| 8 | 18.6 |
| 9 | 18.5 |
| 10 | 18.4 |



2/6/97 M.H. 13:40 Thermal Conductivity Experiment Run 45
Matrix Saturated Apache Leap Tuff

Parameters

| | |
|---|---|
| Variable Transformer setpoint | 20 |
| $H_2O$ bath temp setpoint | 20°C |
| Pressure on Top Al plate | 5 ft-lb |

2/10/97 jp 0815 hr Results of TC experiment Run 45

| Bottom Al plate Serial # | Heat flux BTU/Ft²-hr | Temp °C |
|---|---|---|
| 96041630 | 26.6430 | 43.6 |
| 31 | 14.9284 | 43.7 |
| 32 | — | 43.7 |
| 33 | 19.6783 | 43.9 |
| **Top Al plate** | | |
| 955042 | 19.4031 | 19.1 |
| 41 | 20.6916 | 19.1 |
| 39 | 17.8096 | 19.0 |
| 40 | 18.4103 | 19.0 |

| Monitoring Thermocouples | Temp °C |
|---|---|
| 1 | 31.8 |
| 2 | 28.5 |
| 3 | 43.3 |
| 4 | 44.1 |
| 5 | 43.3 |
| 6 | 44.3 |
| 7 | 19.3 |
| 8 | 19.4 |
| 9 | 18.8 |
| 10 | 19.0 |

2/10/97 gp 0820hr Thermal Conductivity Experiment Run 46
Matrix Saturated Apache Leap Tuff

Parameters

| | |
|---|---|
| Variable transformer setpoint | 28 |
| Waterbath ~~temperature setpoint~~ | 20°C |
| Pressure – Top Al plate | 55 ft lb |

2/11/97 gp 1435hr Results of TC experiment Run 46

| Bottom Al plate Serial No | Heat Flux BTU/Ft²-hr | Temp °C |
|---|---|---|
| 96041630 | 52.9236 | 54.3 |
| 31 | 56.5790 | 54.6 |
| 32 | — | 54.6 |
| 33 | 36.0717 | 54.9 |

| Top Al plate | | |
|---|---|---|
| 95J042 | 29.2552 | 19.8 |
| 41 | 30.0272 | 19.8 |
| 39 | 29.6428 | 19.7 |
| 40 | 26.1327 | 19.6 |

| Monitoring Thermocouple | Temp °C |
|---|---|
| 1 | 37.1 |
| 2 | 31.4 |
| 3 | 53.5 |
| 4 | 55.4 |
| 5 | 53.5 |
| 6 | 56.0 |
| 7 | 20.2 |
| 8 | 20.3 |
| 9 | 19.4 |
| 10 | 19.5 |



2/11/97 gp 1435hr Thermal Conductivity Experiment Run 47
Matrix Saturated Apache Leap Tuff

Parameters

| | |
|---|---|
| Variable transformer setpoint | 37 |
| Waterbath ~~temperature setpoint~~ | 20°C |
| Pressure on Top Al plate | 55 ft lb |

2/13/97 gp 0800hr Results of TC experiment Run 47

| Bottom Al plate Serial No | Heat Flux BTU/Ft²-hr | Temp °C |
|---|---|---|
| 96041630 | 103.6047 | 65.8 |
| 31 | 75.1815 | 66.4 |
| 32 | — | 66.5 |
| 33 | 58.3685 | 67.3 |

| Top Al plate | | |
|---|---|---|
| 95J042 | 58.0328 | 21.1 |
| 41 | 44.9997 | 20.9 |
| 39 | 51.1326 | 20.8 |
| 40 | 38.3499 | 20.5 |

| Monitoring Thermocouple | Temp °C |
|---|---|
| 1 | 94.8 |
| 2 | 35.3 |
| 3 | 64.3 |
| 4 | 68.7 |
| 5 | 64.2 |
| 6 | 69.6 |
| 7 | 21.7 |
| 8 | 21.6 |
| 9 | 20.0 |
| 10 | 20.3 |

2/13/97 jp Thermal Conductivity Experiment Run 48
Matrix Saturated Apache Leap Tuff

Parameters
Variable transformer setpoint ~~52~~ 47 jp 2/15/97
Waterbath temperature setpoint 20°C
Pressure on Top Al plate 5 ft-lb

2/15/97 jp 0920hr Results of TC experiment Run 48

| Bottom Al plate Serial No | Heat Flux BTU/Ft²hr | Temp °C |
|---|---|---|
| 96041630 | 162.6415 | 74.8 |
| 31 | 110.5683 | 76.0 |
| 32 | — | 76.0 |
| 33 | 85.1841 | 77.5 |
| Top Al plate | | |
| 95J042 | 97.7888 | 22.5 |
| 41 | 47.0360 | 22.0 |
| 39 | 82.3225 | 22.1 |
| 40 | 51.3370 | 21.5 |

| Monitoring Thermocouples | Temp °C |
|---|---|
| 1 | 53.0 |
| 2 | 38.8 |
| 3 | 72.3 |
| 4 | 80.2 |
| 5 | 72.2 |
| 6 | 81.9 |
| 7 | 23.6 |
| 8 | 23.8 |
| 9 | 20.9 |
| 10 | 21.2 |



2/15/97 jp 0930hr Thermal Conductivity Experiment Run 49
Matrix Saturated Apache Leap Tuff

Parameters
Variable transformer setpoint 57
Waterbath temp setpoint 20°C
Pressure on Top Al plate 5 ft-lb

2/17/95 jp 0800hr Results of TC experiment Run 49

| Bottom Al plate Serial No | Heat Flux BTU-Ft²hr | Temp °C |
|---|---|---|
| 96041630 | 272.4855 | 87.9 |
| 31 | 82.8858 | 91.9 |
| 32 | — | 89.5 |
| 33 | 148.3004 | 93.3 |
| Top Al plate | | |
| 95J042 | 151.4614 | 24.9 |
| 41 | 90.1441 | 23.7 |
| 39 | 166.1160 | 24.4 |
| 40 | 71.6752 | 23.0 |

| Monitoring Thermocouples | Temp °C |
|---|---|
| 1 | 64.0 |
| 2 | 44.6 |
| 3 | 82.7 |
| 4 | 99.6 |
| 5 | 82.4 |
| 6 | 102.8 |
| 7 | 27.3 |
| 8 | 26.1 |
| 9 | 21.9 |
| 10 | 22.3 |

2/17/96 gp Thermal Conductivity spreadsheets calculation for Run 24-27 are shown on following pages

**Thermal Conductivity calculation using Fourier equation**

**Sample =** Apache Leap Tuff (Run 24)

$Q=K_T(dT/dL)$

where
- Q =heat transfer per unit area (W/Ft²)
- $K_T$ = thermal conductivity (W/m-K)
- dT = temperature difference between bottom and top sensors (K)
- dL = distance between bottom and top sensors (m)

**Sensor readings**

| Serial no. | Temp °C | Multi-factor | Correct Temp | Temp °K | Heat flow Btu/Ft²-Hr | Convert to W/Ft² 1Btu/Hr = 0.293W |
|---|---|---|---|---|---|---|
| Bottom | | | | | | |
| 96041630 | 51 | 1.02 | 52.02 | 325.22 | 276.850 | 81.117 |
| 96041631 | 51.2 | 1.02 | 52.224 | 325.424 | 352.010 | 103.139 |
| 96041632 | 51.4 | 1.02 | 52.428 | 325.628 | 0.000 | 0.000 |
| 96041633 | 51.7 | 1.02 | 52.734 | 325.934 | 381.140 | 111.674 |
| Top | | | | | | |
| 95J0642 | 38.3 | 1.027 | 39.3341 | 312.534 | 177.460 | 51.996 |
| 95J0641 | 39.3 | 1.027 | 40.3611 | 313.561 | 241.210 | 70.675 |
| 95J0639 | 38.7 | 1.027 | 39.7449 | 312.945 | 165.280 | 48.427 |
| 95J0640 | 38.7 | 1.027 | 39.7449 | 312.945 | 168.580 | 49.394 |

| | | | |
|---|---|---|---|
| Q = | 73.774 W/Ft² | | 794.128 W/m² |
| dT = | 12.555 K | | |
| dL = | 0.5208 Ft | | 0.15873984 m |
| $K_T$ = | **10.040 ±** | **1.00534 W/m-K** | |

**Thermal Conductivity calculation using Fourier equation**

**Sample =** Apache Leap Tuff (Run 25)

$Q=K_T(dT/dL)$

where
- Q =heat transfer per unit area (W/Ft²)
- $K_T$ = thermal conductivity (W/m-K)
- dT = temperature difference between bottom and top sensors (K)
- dL = distance between bottom and top sensors (m)

**Sensor readings**

| Serial no. | Temp °C | Multi-factor | Correct Temp | Temp °K | Heat flow Btu/Ft²-Hr | Convert to W/Ft² 1Btu/Hr = 0.293W |
|---|---|---|---|---|---|---|
| Bottom | | | | | | |
| 96041630 | 35.4 | 1.035 | 36.639 | 309.839 | 109.132 | 31.976 |
| 96041631 | 35.4 | 1.035 | 36.639 | 309.839 | 154.102 | 45.152 |
| 96041632 | 35.3 | 1.035 | 36.5355 | 309.736 | 0.000 | 0.000 |
| 96041633 | 35.3 | 1.035 | 36.5355 | 309.736 | 169.520 | 49.669 |
| Top | | | | | | |
| 95J0642 | 29.7 | 1.038 | 30.8286 | 304.029 | 179.509 | 52.596 |
| 95J0641 | 30 | 1.038 | 31.14 | 304.34 | 0.000 | 0.000 |
| 95J0639 | 29.6 | 1.038 | 30.7248 | 303.925 | 168.369 | 49.332 |
| 95J0640 | 29.4 | 1.038 | 30.5172 | 303.717 | 152.526 | 44.690 |

| | | | |
|---|---|---|---|
| Q = | 45.569 W/Ft² | | 490.518 W/m² |
| dT = | 5.7846 K | | |
| dL = | 0.5 Ft | | 0.1524 m |
| $K_T$ = | **12.923 ±** | **1.29361 W/m-K** | |



**Thermal Conductivity calculation using Fourier equation**

**Sample =** Apache Leap Tuff (Run 26)

$Q=K_T(dT/dL)$

where
- Q =heat transfer per unit area (W/Ft²)
- $K_T$ = thermal conductivity (W/m-K)
- dT = temperature difference between bottom and top sensors (K)
- dL = distance between bottom and top sensors (m)

**Sensor readings**

| Serial no. | Temp °C | Multi-factor | Correct Temp | Temp °K | Heat flow Btu/Ft²-Hr | Convert to W/Ft² 1Btu/Hr = 0.293W |
|---|---|---|---|---|---|---|
| Bottom | | | | | | |
| 96041630 | 46.3 | 1.02 | 47.226 | 320.426 | 0.000 | 0.000 |
| 96041631 | 46.2 | 1.02 | 47.124 | 320.324 | 348.317 | 102.057 |
| 96041632 | 46.1 | 1.02 | 47.022 | 320.222 | 0.000 | 0.000 |
| 96041633 | 46.1 | 1.02 | 47.022 | 320.222 | 407.502 | 119.398 |
| Top | | | | | | |
| 95J0642 | 34.9 | 1.035 | 36.1215 | 309.322 | 341.490 | 100.057 |
| 95J0641 | 35.1 | 1.035 | 36.3285 | 309.529 | 340.558 | 99.783 |
| 95J0639 | 35.1 | 1.035 | 36.3285 | 309.529 | 357.044 | 104.614 |
| 95J0640 | 34.7 | 1.035 | 35.9145 | 309.115 | 295.286 | 86.519 |

| | | | |
|---|---|---|---|
| Q = | 102.071 W/Ft² | | 1098.722 W/m² |
| dT = | 10.925 K | | |
| dL = | 0.5 Ft | | 0.1524 m |
| $K_T$ = | **15.326 ±** | **1.53394 W/m-K** | |

**Thermal Conductivity calculation using Fourier equation**

**Sample =** Apache Leap Tuff (Run 27)

$Q=K_T(dT/dL)$

where
- Q =heat transfer per unit area (W/Ft²)
- $K_T$ = thermal conductivity (W/m-K)
- dT = temperature difference between bottom and top sensors (K)
- dL = distance between bottom and top sensors (m)

**Sensor readings**

| Serial no. | Temp °C | Multi-factor | Correct Temp | Temp °K | Heat flow Btu/Ft²-Hr | Convert to W/Ft² 1Btu/Hr = 0.293W |
|---|---|---|---|---|---|---|
| Bottom | | | | | | |
| 96041630 | 37.6 | 1.032 | 38.8032 | 312.003 | 208.538 | 61.102 |
| 96041631 | 37.4 | 1.032 | 38.5968 | 311.797 | 265.965 | 77.928 |
| 96041632 | 37.3 | 1.032 | 38.4936 | 311.694 | 0.000 | 0.000 |
| 96041633 | 37.5 | 1.032 | 38.7 | 311.9 | 317.867 | 93.135 |
| Top | | | | | | |
| 95J0642 | 28.9 | 1.038 | 29.9982 | 303.198 | 302.886 | 88.746 |
| 95J0641 | 29.2 | 1.038 | 30.3096 | 303.51 | 295.324 | 86.530 |
| 95J0639 | 28.7 | 1.038 | 29.7906 | 302.991 | 263.898 | 77.322 |
| 95J0640 | 28.5 | 1.038 | 29.583 | 302.783 | 241.808 | 70.850 |

| | | | |
|---|---|---|---|
| Q = | 79.373 W/Ft² | | 854.393 W/m² |
| dT = | 8.7281 K | | |
| dL = | 0.5 Ft | | 0.1524 m |
| $K_T$ = | **14.919 ±** | **1.49315 W/m-K** | |

**Thermal Conductivity calculation using Fourier equation**

**Sample =** Apache Leap Tuff (Run 28)

$Q = K_T(dT/dL)$

where
- Q = heat transfer per unit area (W/Ft$^2$)
- $K_T$ = thermal conductivity (W/m-K)
- dT = temperature difference between bottom and top sensors (K)
- dL = distance between bottom and top sensors (m)

**Sensor readings**

| Serial no. | Temp $^0$C | Multi-factor | Correct Temp | Temp $^0$K | Heat flow Btu/Ft$^2$-Hr | Convert to W/Ft$^2$ 1Btu/Hr = 0.293W |
|---|---|---|---|---|---|---|
| Bottom | | | | | | |
| 96041630 | 21.2 | 1.04 | 22.048 | 295.248 | 137.600 | 40.317 |
| 96041631 | 21.3 | 1.04 | 22.152 | 295.352 | 163.516 | 47.910 |
| 96041632 | 21.3 | 1.04 | 22.152 | 295.352 | 0.000 | 0.000 |
| 96041633 | 21.3 | 1.04 | 22.152 | 295.352 | 177.204 | 51.921 |
| Top | | | | | | |
| 95J0642 | 14.7 | 1.045 | 15.3615 | 288.562 | 106.592 | 31.232 |
| 95J0641 | 14.9 | 1.045 | 15.5705 | 288.771 | 106.852 | 31.308 |
| 95J0639 | 14.8 | 1.045 | 15.466 | 288.666 | 95.708 | 28.043 |
| 95J0640 | 14.8 | 1.045 | 15.466 | 288.666 | 105.836 | 31.010 |

| | | | |
|---|---|---|---|
| Q = | 37.391 W/Ft$^2$ | | 402.491 W/m$^2$ |
| dT = | 6.66 K | | |
| dL = | 0.5 Ft | | 0.1524 m |
| $K_T$ = | 9.210 ± | 0.92231 W/m-K | |

**Thermal Conductivity calculation using Fourier equation**

**Sample =** Apache Leap Tuff (Run 29)

$Q = K_T(dT/dL)$

where
- Q = heat transfer per unit area (W/Ft$^2$)
- $K_T$ = thermal conductivity (W/m-K)
- dT = temperature difference between bottom and top sensors (K)
- dL = distance between bottom and top sensors (m)

**Sensor readings**

| Serial no. | Temp $^0$C | Multi-factor | Correct Temp | Temp $^0$K | Heat flow Btu/Ft$^2$-Hr | Convert to W/Ft$^2$ 1Btu/Hr = 0.293W |
|---|---|---|---|---|---|---|
| Bottom | | | | | | |
| 96041630 | 29.8 | 1.038 | 30.9324 | 304.132 | 125.437 | 36.753 |
| 96041631 | 29.9 | 1.038 | 31.0362 | 304.236 | 149.079 | 43.680 |
| 96041632 | 29.9 | 1.038 | 31.0362 | 304.236 | 0.000 | 0.000 |
| 96041633 | 29.9 | 1.038 | 31.0362 | 304.236 | 163.470 | 47.897 |
| Top | | | | | | |
| 95J0642 | 24.4 | 1.04 | 25.376 | 298.576 | 103.914 | 30.447 |
| 95J0641 | 24.4 | 1.04 | 25.376 | 298.576 | 106.312 | 31.150 |
| 95J0639 | 24.5 | 1.04 | 25.48 | 298.68 | 118.300 | 34.662 |
| 95J0640 | 24.3 | 1.04 | 25.272 | 298.472 | 94.853 | 27.792 |

| | | | |
|---|---|---|---|
| Q = | 36.054 W/Ft$^2$ | | 388.098 W/m$^2$ |
| dT = | 5.6343 K | | |
| dL = | 0.5 Ft | | 0.1524 m |
| $K_T$ = | 10.498 ± | 1.05108 W/m-K | |



**Thermal Conductivity calculation using Fourier equation**

**Sample =** Apache Leap Tuff (Run 30)

$Q = K_T(dT/dL)$

where
- Q = heat transfer per unit area (W/Ft$^2$)
- $K_T$ = thermal conductivity (W/m-K)
- dT = temperature difference between bottom and top sensors (K)
- dL = distance between bottom and top sensors (m)

**Sensor readings**

| Serial no. | Temp $^0$C | Multi-factor | Correct Temp | Temp $^0$K | Heat flow Btu/Ft$^2$-Hr | Convert to W/Ft$^2$ 1Btu/Hr = 0.293W |
|---|---|---|---|---|---|---|
| Bottom | | | | | | |
| 96041630 | 27.3 | 1.038 | 28.3374 | 301.537 | 80.643 | 23.628 |
| 96041631 | 27.2 | 1.038 | 28.2336 | 301.434 | 73.838 | 21.635 |
| 96041632 | 27.2 | 1.038 | 28.2336 | 301.434 | 0.000 | 0.000 |
| 96041633 | 27.2 | 1.038 | 28.2336 | 301.434 | 116.128 | 34.026 |
| Top | | | | | | |
| 95J0642 | 23.1 | 1.04 | 24.024 | 297.224 | 98.266 | 28.792 |
| 95J0641 | 23 | 1.04 | 23.92 | 297.12 | 81.248 | 23.806 |
| 95J0639 | 23 | 1.04 | 23.92 | 297.12 | 95.643 | 28.023 |
| 95J0640 | 22.9 | 1.04 | 23.816 | 297.016 | 81.047 | 23.747 |

| | | | |
|---|---|---|---|
| Q = | 26.237 W/Ft$^2$ | | 282.418 W/m$^2$ |
| dT = | 4.3396 K | | |
| dL = | 0.5 Ft | | 0.1524 m |
| $K_T$ = | 9.918 ± | 0.99312 W/m-K | |

**Thermal Conductivity calculation using Fourier equation**

**Sample =** Apache Leap Tuff (Run 31)

$Q = K_T(dT/dL)$

where
- Q = heat transfer per unit area (W/Ft$^2$)
- $K_T$ = thermal conductivity (W/m-K)
- dT = temperature difference between bottom and top sensors (K)
- dL = distance between bottom and top sensors (m)

**Sensor readings**

| Serial no. | Temp $^0$C | Multi-factor | Correct Temp | Temp $^0$K | Heat flow Btu/Ft$^2$-Hr | Convert to W/Ft$^2$ 1Btu/Hr = 0.293W |
|---|---|---|---|---|---|---|
| Bottom | | | | | | |
| 96041630 | 25.8 | 1.038 | 26.7804 | 299.98 | 77.429 | 22.687 |
| 96041631 | 25.8 | 1.038 | 26.7804 | 299.98 | 86.851 | 25.447 |
| 96041632 | 25.8 | 1.038 | 26.7804 | 299.98 | 0.000 | 0.000 |
| 96041633 | 25.8 | 1.038 | 26.7804 | 299.98 | 102.176 | 29.938 |
| Top | | | | | | |
| 95J0642 | 22.1 | 1.04 | 22.984 | 296.184 | 57.425 | 16.826 |
| 95J0641 | 22.1 | 1.04 | 22.984 | 296.184 | 57.657 | 16.894 |
| 95J0639 | 22.1 | 1.04 | 22.984 | 296.184 | 53.602 | 15.706 |
| 95J0640 | 22.1 | 1.04 | 22.984 | 296.184 | 62.451 | 18.298 |

| | | | |
|---|---|---|---|
| Q = | 20.828 W/Ft$^2$ | | 224.196 W/m$^2$ |
| dT = | 3.7964 K | | |
| dL = | 0.5 Ft | | 0.1524 m |
| $K_T$ = | 9.000 ± | 0.90130 W/m-K | |

**Thermal Conductivity calculation using Fourier equation**

**Sample =** Apache Leap Tuff (Run 32)

$Q = K_T(dT/dL)$

where
Q = heat transfer per unit area ($W/Ft^2$)
$K_T$ = thermal conductivity (W/m-K)
dT = temperature difference between bottom and top sensors (K)
dL = distance between bottom and top sensors (m)

**Sensor readings**

| Serial no. | Temp $^0C$ | Multi-factor | Correct Temp | Temp $^0K$ | Heat flow $Btu/Ft^2$-Hr | Convert to $W/Ft^2$ 1Btu/Hr = 0.293W |
|---|---|---|---|---|---|---|
| Bottom | | | | | | |
| 96041630 | 24.4 | 1.038 | 25.3272 | 298.527 | 59.415 | 17.409 |
| 96041631 | 24.5 | 1.038 | 25.431 | 298.631 | 49.457 | 14.491 |
| 96041632 | 24.5 | 1.038 | 25.431 | 298.631 | 0.000 | 0.000 |
| 96041633 | 24.4 | 1.038 | 25.3272 | 298.527 | 80.369 | 23.548 |
| Top | | | | | | |
| 95J0642 | 21.3 | 1.04 | 22.152 | 295.352 | 36.611 | 10.727 |
| 95J0641 | 21.4 | 1.04 | 22.256 | 295.456 | 50.836 | 14.895 |
| 95J0639 | 21.4 | 1.04 | 22.256 | 295.456 | 47.436 | 13.899 |
| 95J0640 | 21.3 | 1.04 | 22.152 | 295.352 | 51.201 | 15.002 |

| | | | |
|---|---|---|---|
| Q = | 15.710 $W/Ft^2$ | | 169.107 $W/m^2$ |
| dT = | 3.1751 K | | |
| dL = | 0.5 Ft | | 0.1524 m |
| **$K_T$ =** | **8.117** ± | **0.81299 W/m-K** | |

**Thermal Conductivity calculation using Fourier equation**

**Sample =** Apache Leap Tuff (Run 33)

$Q = K_T(dT/dL)$

where
Q = heat transfer per unit area ($W/Ft^2$)
$K_T$ = thermal conductivity (W/m-K)
dT = temperature difference between bottom and top sensors (K)
dL = distance between bottom and top sensors (m)

**Sensor readings**

| Serial no. | Temp $^0C$ | Multi-factor | Correct Temp | Temp $^0K$ | Heat flow $Btu/Ft^2$-Hr | Convert to $W/Ft^2$ 1Btu/Hr = 0.293W |
|---|---|---|---|---|---|---|
| Bottom | | | | | | |
| 96041630 | 35.7 | 1.03 | 36.771 | 309.971 | 140.657 | 41.213 |
| 96041631 | 35.7 | 1.03 | 36.771 | 309.971 | 252.384 | 73.949 |
| 96041632 | 35.7 | 1.03 | 36.771 | 309.971 | 0.000 | 0.000 |
| 96041633 | 35.6 | 1.03 | 36.668 | 309.868 | 194.076 | 56.864 |
| Top | | | | | | |
| 95J0642 | 29.4 | 1.038 | 30.5172 | 303.717 | 227.413 | 66.632 |
| 95J0641 | 29.5 | 1.038 | 30.621 | 303.821 | 227.981 | 66.798 |
| 95J0639 | 29.4 | 1.038 | 30.5172 | 303.717 | 210.442 | 61.659 |
| 95J0640 | 29.1 | 1.038 | 30.2058 | 303.406 | 174.557 | 51.145 |

| | | | |
|---|---|---|---|
| Q = | 59.751 $W/Ft^2$ | | 643.180 $W/m^2$ |
| dT = | 6.2799 K | | |
| dL = | 0.5 Ft | | 0.1524 m |
| **$K_T$ =** | **15.609** ± | **1.56215 W/m-K** | |



**Thermal Conductivity calculation using Fourier equation**

**Sample =** Apache Leap Tuff (Run 34)

$Q = K_T(dT/dL)$

where
Q = heat transfer per unit area ($W/Ft^2$)
$K_T$ = thermal conductivity (W/m-K)
dT = temperature difference between bottom and top sensors (K)
dL = distance between bottom and top sensors (m)

**Sensor readings**

| Serial no. | Temp $^0C$ | Multi-factor | Correct Temp | Temp $^0K$ | Heat flow $Btu/Ft^2$-Hr | Convert to $W/Ft^2$ 1Btu/Hr = 0.293W |
|---|---|---|---|---|---|---|
| Bottom | | | | | | |
| 96041630 | 46.9 | 1.02 | 47.838 | 321.038 | 207.561 | 60.815 |
| 96041631 | 47.1 | 1.02 | 48.042 | 321.242 | 244.730 | 71.706 |
| 96041632 | 46.9 | 1.02 | 47.838 | 321.038 | 0.000 | 0.000 |
| 96041633 | 47 | 1.02 | 47.94 | 321.14 | 286.590 | 83.971 |
| Top | | | | | | |
| 95J0642 | 38.2 | 1.022 | 39.0404 | 312.24 | 321.817 | 94.292 |
| 95J0641 | 38.7 | 1.022 | 39.5514 | 312.751 | 328.223 | 96.169 |
| 95J0639 | 38.5 | 1.022 | 39.347 | 312.547 | 334.523 | 98.015 |
| 95J0640 | 38.2 | 1.022 | 39.0404 | 312.24 | 294.833 | 86.386 |

| | | | |
|---|---|---|---|
| Q = | 84.479 $W/Ft^2$ | | 909.357 $W/m^2$ |
| dT = | 8.6697 K | | |
| dL = | 0.5 Ft | | 0.1524 m |
| **$K_T$ =** | **15.985** ± | **1.59981 W/m-K** | |

**Thermal Conductivity calculation using Fourier equation**

**Sample =** Apache Leap Tuff (Run 35)

$Q = K_T(dT/dL)$

where
Q = heat transfer per unit area ($W/Ft^2$)
$K_T$ = thermal conductivity (W/m-K)
dT = temperature difference between bottom and top sensors (K)
dL = distance between bottom and top sensors (m)

**Sensor readings**

| Serial no. | Temp $^0C$ | Multi-factor | Correct Temp | Temp $^0K$ | Heat flow $Btu/Ft^2$-Hr | Convert to $W/Ft^2$ 1Btu/Hr = 0.293W |
|---|---|---|---|---|---|---|
| Bottom | | | | | | |
| 96041630 | 33 | 1.03 | 33.99 | 307.19 | 12.195 | 3.573 |
| 96041631 | 33 | 1.03 | 33.99 | 307.19 | 12.986 | 3.805 |
| 96041632 | 33 | 1.03 | 33.99 | 307.19 | 0.000 | 0.000 |
| 96041633 | 33 | 1.03 | 33.99 | 307.19 | 17.528 | 5.136 |
| Top | | | | | | |
| 95J0642 | 18.7 | 1.04 | 19.448 | 292.648 | 14.934 | 4.376 |
| 95J0641 | 18.7 | 1.04 | 19.448 | 292.648 | 16.230 | 4.755 |
| 95J0639 | 18.7 | 1.04 | 19.448 | 292.648 | 12.344 | 3.617 |
| 95J0640 | 18.7 | 1.04 | 19.448 | 292.648 | 18.648 | 5.464 |

| | | | |
|---|---|---|---|
| Q = | 4.389 $W/Ft^2$ | | 47.248 $W/m^2$ |
| dT = | 14.542 K | | |
| dL = | 0.5 Ft | | 0.1524 m |
| **$K_T$ =** | **0.495** ± | **0.05082 W/m-K** | |

**Thermal Conductivity calculation using Fourier equation**

**Sample =** Apache Leap Tuff (Run 36)

$Q = K_T(dT/dL)$

where
- Q = heat transfer per unit area (W/Ft$^2$)
- $K_T$ = thermal conductivity (W/m-K)
- dT = temperature difference between bottom and top sensors (K)
- dL = distance between bottom and top sensors (m)

**Sensor readings**

| Serial no. | Temp $^0$C | Multi-factor | Correct Temp | Temp $^0$K | Heat flow Btu/Ft$^2$-Hr | Convert to W/Ft$^2$ 1Btu/Hr = 0.293W |
|---|---|---|---|---|---|---|
| Bottom | | | | | | |
| 96041630 | 46.1 | 1.02 | 47.022 | 320.222 | 31.790 | 9.314 |
| 96041631 | 46.2 | 1.02 | 47.124 | 320.324 | 34.632 | 10.147 |
| 96041632 | 46.1 | 1.02 | 47.022 | 320.222 | 0.000 | 0.000 |
| 96041633 | 46.2 | 1.02 | 47.124 | 320.324 | 37.404 | 10.959 |
| Top | | | | | | |
| 95J0642 | 19.9 | 1.04 | 20.696 | 293.896 | 23.198 | 6.797 |
| 95J0641 | 20 | 1.04 | 20.8 | 294 | 32.943 | 9.652 |
| 95J0639 | 19.9 | 1.04 | 20.696 | 293.896 | 18.076 | 5.296 |
| 95J0640 | 20 | 1.04 | 20.8 | 294 | 37.951 | 11.120 |
| Q = | 9.041 | W/Ft$^2$ | | | | 97.318 W/m$^2$ |
| dT = | 26.325 | K | | | | |
| dL = | 0.5 | Ft | | | | 0.1524 m |
| **$K_T$ =** | **0.563** | ± | **0.05764 W/m-K** | | | |

**Thermal Conductivity calculation using Fourier equation**

**Sample =** Apache Leap Tuff (Run 37)

$Q = K_T(dT/dL)$

where
- Q = heat transfer per unit area (W/Ft$^2$)
- $K_T$ = thermal conductivity (W/m-K)
- dT = temperature difference between bottom and top sensors (K)
- dL = distance between bottom and top sensors (m)

**Sensor readings**

| Serial no. | Temp $^0$C | Multi-factor | Correct Temp | Temp $^0$K | Heat flow Btu/Ft$^2$-Hr | Convert to W/Ft$^2$ 1Btu/Hr = 0.293W |
|---|---|---|---|---|---|---|
| Bottom | | | | | | |
| 96041630 | 59.7 | 1.01 | 60.297 | 333.497 | 63.480 | 18.600 |
| 96041631 | 59.9 | 1.01 | 60.499 | 333.699 | 58.867 | 17.248 |
| 96041632 | 60 | 1.01 | 60.6 | 333.8 | 0.000 | 0.000 |
| 96041633 | 60.2 | 1.01 | 60.802 | 334.002 | 60.133 | 17.619 |
| Top | | | | | | |
| 95J0642 | 23 | 1.04 | 23.92 | 297.12 | 43.255 | 12.674 |
| 95J0641 | 23.2 | 1.04 | 24.128 | 297.328 | 86.389 | 25.312 |
| 95J0639 | 23 | 1.04 | 23.92 | 297.12 | 43.620 | 12.781 |
| 95J0640 | 23 | 1.04 | 23.92 | 297.12 | 76.394 | 22.383 |
| Q = | 18.088 | W/Ft$^2$ | | | | 194.704 W/m$^2$ |
| dT = | 36.577 | K | | | | |
| dL = | 0.5 | Ft | | | | 0.1524 m |
| **$K_T$ =** | **0.811** | ± | **0.08242 W/m-K** | | | |



**Thermal Conductivity calculation using Fourier equation**

**Sample =** Apache Leap Tuff (Run 38)

$Q = K_T(dT/dL)$

where
- Q = heat transfer per unit area (W/Ft$^2$)
- $K_T$ = thermal conductivity (W/m-K)
- dT = temperature difference between bottom and top sensors (K)
- dL = distance between bottom and top sensors (m)

**Sensor readings**

| Serial no. | Temp $^0$C | Multi-factor | Correct Temp | Temp $^0$K | Heat flow Btu/Ft$^2$-Hr | Convert to W/Ft$^2$ 1Btu/Hr = 0.293W |
|---|---|---|---|---|---|---|
| Bottom | | | | | | |
| 96041630 | 53.7 | 1.015 | 54.5055 | 327.706 | 47.026 | 13.779 |
| 96041631 | 53.9 | 1.015 | 54.7085 | 327.909 | 44.667 | 13.087 |
| 96041632 | 53.9 | 1.015 | 54.7085 | 327.909 | 0.000 | 0.000 |
| 96041633 | 54.1 | 1.015 | 54.9115 | 328.112 | 53.548 | 15.690 |
| Top | | | | | | |
| 95J0642 | 21.2 | 1.04 | 22.048 | 295.248 | 27.973 | 8.196 |
| 95J0641 | 21.3 | 1.04 | 22.152 | 295.352 | 50.369 | 14.758 |
| 95J0639 | 21.2 | 1.04 | 22.048 | 295.248 | 30.169 | 8.840 |
| 95J0640 | 21.2 | 1.04 | 22.048 | 295.248 | 48.574 | 14.232 |
| Q = | 12.654 | W/Ft$^2$ | | | | 136.216 W/m$^2$ |
| dT = | 32.635 | K | | | | |
| dL = | 0.5 | Ft | | | | 0.1524 m |
| **$K_T$ =** | **0.636** | ± | **0.06491 W/m-K** | | | |

**Thermal Conductivity calculation using Fourier equation**

**Sample =** Apache Leap Tuff (Run 39)

$Q = K_T(dT/dL)$

where
- Q = heat transfer per unit area (W/Ft$^2$)
- $K_T$ = thermal conductivity (W/m-K)
- dT = temperature difference between bottom and top sensors (K)
- dL = distance between bottom and top sensors (m)

**Sensor readings**

| Serial no. | Temp $^0$C | Multi-factor | Correct Temp | Temp $^0$K | Heat flow Btu/Ft$^2$-Hr | Convert to W/Ft$^2$ 1Btu/Hr = 0.293W |
|---|---|---|---|---|---|---|
| Bottom | | | | | | |
| 96041630 | 65.6 | 1 | 65.6 | 338.8 | 88.222 | 25.849 |
| 96041631 | 65.7 | 1 | 65.7 | 338.9 | 76.676 | 22.466 |
| 96041632 | 65.9 | 1 | 65.9 | 339.1 | 0.000 | 0.000 |
| 96041633 | 66.2 | 1 | 66.2 | 339.4 | 82.946 | 24.303 |
| Top | | | | | | |
| 95J0642 | 24.2 | 1.04 | 25.168 | 298.368 | 47.771 | 13.997 |
| 95J0641 | 24.4 | 1.04 | 25.376 | 298.576 | 83.996 | 24.611 |
| 95J0639 | 24.2 | 1.04 | 25.168 | 298.368 | 57.066 | 16.720 |
| 95J0640 | 24.1 | 1.04 | 25.064 | 298.264 | 73.128 | 21.427 |
| Q = | 21.339 | W/Ft$^2$ | | | | 229.698 W/m$^2$ |
| dT = | 40.656 | K | | | | |
| dL = | 0.5 | Ft | | | | 0.1524 m |
| **$K_T$ =** | **0.861** | ± | **0.08740 W/m-K** | | | |

**Thermal Conductivity calculation using Fourier equation**

**Sample =** Apache Leap Tuff (Run 40)

$Q = K_T(dT/dL)$

where $Q$ = heat transfer per unit area ($W/Ft^2$)
$K_T$ = thermal conductivity (W/m-K)
$dT$ = temperature difference between bottom and top sensors (K)
$dL$ = distance between bottom and top sensors (m)

**Sensor readings**

| Serial no. | Temp $^0C$ | Multi-factor | Correct Temp | Temp $^0K$ | Heat flow $Btu/Ft^2$-Hr | Convert to $W/Ft^2$ 1Btu/Hr = 0.293W |
|---|---|---|---|---|---|---|
| Bottom | | | | | | |
| 96041630 | 70.1 | 1 | 70.1 | 343.3 | 111.525 | 32.677 |
| 96041631 | 70.2 | 1 | 70.2 | 343.4 | 134.669 | 39.458 |
| 96041632 | 70.4 | 1 | 70.4 | 343.6 | 0.000 | 0.000 |
| 96041633 | 70.9 | 1 | 70.9 | 344.1 | 99.448 | 29.138 |
| Top | | | | | | |
| 95J0642 | 22.9 | 1.04 | 23.816 | 297.016 | 59.097 | 17.315 |
| 95J0641 | 23.3 | 1.04 | 24.232 | 297.432 | 102.690 | 30.088 |
| 95J0639 | 23 | 1.04 | 23.92 | 297.12 | 71.374 | 20.913 |
| 95J0640 | 22.9 | 1.04 | 23.816 | 297.016 | 86.694 | 25.401 |
| Q = | 27.856 | $W/Ft^2$ | | | | 299.847 $W/m^2$ |
| dT = | 46.454 | K | | | | |
| dL = | 0.5 | Ft | | | | 0.1524 m |
| $K_T$ = | **0.984** | ± | **0.09967 W/m-K** | | | |

**Thermal Conductivity calculation using Fourier equation**

**Sample =** Apache Leap Tuff (Run 41)

$Q = K_T(dT/dL)$

where $Q$ = heat transfer per unit area ($W/Ft^2$)
$K_T$ = thermal conductivity (W/m-K)
$dT$ = temperature difference between bottom and top sensors (K)
$dL$ = distance between bottom and top sensors (m)

**Sensor readings**

| Serial no. | Temp $^0C$ | Multi-factor | Correct Temp | Temp $^0K$ | Heat flow $Btu/Ft^2$-Hr | Convert to $W/Ft^2$ 1Btu/Hr = 0.293W |
|---|---|---|---|---|---|---|
| Bottom | | | | | | |
| 96041630 | 74.5 | 1 | 74.5 | 347.7 | 141.350 | 41.416 |
| 96041631 | 74.7 | 1 | 74.7 | 347.9 | 144.461 | 42.327 |
| 96041632 | 74.9 | 1 | 74.9 | 348.1 | 0.000 | 0.000 |
| 96041633 | 75.4 | 1 | 75.4 | 348.6 | 141.319 | 41.407 |
| Top | | | | | | |
| 95J0642 | 24.9 | 1.04 | 25.896 | 299.096 | 69.157 | 20.263 |
| 95J0641 | 25.6 | 1.04 | 26.624 | 299.824 | 146.455 | 42.911 |
| 95J0639 | 25 | 1.04 | 26 | 299.2 | 88.934 | 26.058 |
| 95J0640 | 25 | 1.04 | 26 | 299.2 | 120.953 | 35.439 |
| Q = | 35.689 | $W/Ft^2$ | | | | 384.162 $W/m^2$ |
| dT = | 48.745 | K | | | | |
| dL = | 0.5 | Ft | | | | 0.1524 m |
| $K_T$ = | **1.201** | ± | **0.12141 W/m-K** | | | |



**Thermal Conductivity calculation using Fourier equation**

**Sample =** Apache Leap Tuff (Run 42)

$Q = K_T(dT/dL)$

where $Q$ = heat transfer per unit area ($W/Ft^2$)
$K_T$ = thermal conductivity (W/m-K)
$dT$ = temperature difference between bottom and top sensors (K)
$dL$ = distance between bottom and top sensors (m)

**Sensor readings**

| Serial no. | Temp $^0C$ | Multi-factor | Correct Temp | Temp $^0K$ | Heat flow $Btu/Ft^2$-Hr | Convert to $W/Ft^2$ 1Btu/Hr = 0.293W |
|---|---|---|---|---|---|---|
| Bottom | | | | | | |
| 96041630 | 80.5 | 0.99 | 79.695 | 352.895 | 241.977 | 70.899 |
| 96041631 | 81.1 | 0.99 | 80.289 | 353.489 | 206.980 | 60.645 |
| 96041632 | 81.2 | 0.99 | 80.388 | 353.588 | 0.000 | 0.000 |
| 96041633 | 81.9 | 0.99 | 81.081 | 354.281 | 171.363 | 50.209 |
| Top | | | | | | |
| 95J0642 | 28.5 | 1.038 | 29.583 | 302.783 | 159.684 | 46.787 |
| 95J0641 | 29.8 | 1.038 | 30.9324 | 304.132 | 354.339 | 103.821 |
| 95J0639 | 28.1 | 1.038 | 29.1678 | 302.368 | 164.249 | 48.125 |
| 95J0640 | 28.7 | 1.038 | 29.7906 | 302.991 | 327.028 | 95.819 |
| Q = | 68.044 | $W/Ft^2$ | | | | 732.441 $W/m^2$ |
| dT = | 50.495 | K | | | | |
| dL = | 0.5 | Ft | | | | 0.1524 m |
| $K_T$ = | **2.211** | ± | **0.22236 W/m-K** | | | |

**Thermal Conductivity calculation using Fourier equation**

**Sample =** Apache Leap Tuff (Run 43)

$Q = K_T(dT/dL)$

where $Q$ = heat transfer per unit area ($W/Ft^2$)
$K_T$ = thermal conductivity (W/m-K)
$dT$ = temperature difference between bottom and top sensors (K)
$dL$ = distance between bottom and top sensors (m)

**Sensor readings**

| Serial no. | Temp $^0C$ | Multi-factor | Correct Temp | Temp $^0K$ | Heat flow $Btu/Ft^2$-Hr | Convert to $W/Ft^2$ 1Btu/Hr = 0.293W |
|---|---|---|---|---|---|---|
| Bottom | | | | | | |
| 96041630 | 88.7 | 0.995 | 88.2565 | 361.457 | 380.780 | 111.569 |
| 96041631 | 90.9 | 0.995 | 90.4455 | 363.646 | 281.929 | 82.605 |
| 96041632 | 90.8 | 0.995 | 90.346 | 363.546 | 0.000 | 0.000 |
| 96041633 | 94.5 | 0.995 | 94.0275 | 367.228 | 192.681 | 56.455 |
| Top | | | | | | |
| 95J0642 | 19.9 | 1.04 | 20.696 | 293.896 | 142.513 | 41.756 |
| 95J0641 | 19.4 | 1.04 | 20.176 | 293.376 | 112.654 | 33.008 |
| 95J0639 | 19.7 | 1.04 | 20.488 | 293.688 | 189.835 | 55.622 |
| 95J0640 | 18.2 | 1.04 | 18.928 | 292.128 | 104.471 | 30.610 |
| Q = | 58.804 | $W/Ft^2$ | | | | 632.977 $W/m^2$ |
| dT = | 70.697 | K | | | | |
| dL = | 0.5 | Ft | | | | 0.1524 m |
| $K_T$ = | **1.364** | ± | **0.13775 W/m-K** | | | |

**Thermal Conductivity calculation using Fourier equation**

**Sample =** Apache Leap Tuff (Run 44)

$Q = K_T(dT/dL)$

where
- Q = heat transfer per unit area ($W/Ft^2$)
- $K_T$ = thermal conductivity (W/m-K)
- dT = temperature difference between bottom and top sensors (K)
- dL = distance between bottom and top sensors (m)

**Sensor readings**

| Serial no. | Temp $^0C$ | Multi-factor | Correct Temp | Temp $^0K$ | Heat flow $Btu/Ft^2$-Hr | Convert to $W/Ft^2$ 1Btu/Hr = 0.293W |
|---|---|---|---|---|---|---|
| Bottom | | | | | | |
| 96041630 | 28.6 | 1.035 | 29.601 | 302.801 | 7.300 | 2.139 |
| 96041631 | 28.6 | 1.035 | 29.601 | 302.801 | 5.909 | 1.731 |
| 96041632 | 28.6 | 1.035 | 29.601 | 302.801 | 0.000 | 0.000 |
| 96041633 | 28.7 | 1.035 | 29.7045 | 302.905 | 6.060 | 1.775 |
| Top | | | | | | |
| 95J0642 | 18.4 | 1.04 | 19.136 | 292.336 | 9.006 | 2.639 |
| 95J0641 | 18.4 | 1.04 | 19.136 | 292.336 | 8.997 | 2.636 |
| 95J0639 | 18.4 | 1.04 | 19.136 | 292.336 | 8.055 | 2.360 |
| 95J0640 | 18.4 | 1.04 | 19.136 | 292.336 | 9.361 | 2.743 |

Q = 2.289 $W/Ft^2$    24.640 $W/m^2$

dT = 10.491 K

dL = 0.5 Ft    0.1524 m

**$K_T$ = 0.358 ± 0.03709 W/m-K**

**Thermal Conductivity calculation using Fourier equation**

**Sample =** Apache Leap Tuff (Run 45)

$Q = K_T(dT/dL)$

where
- Q = heat transfer per unit area ($W/Ft^2$)
- $K_T$ = thermal conductivity (W/m-K)
- dT = temperature difference between bottom and top sensors (K)
- dL = distance between bottom and top sensors (m)

**Sensor readings**

| Serial no. | Temp $^0C$ | Multi-factor | Correct Temp | Temp $^0K$ | Heat flow $Btu/Ft^2$-Hr | Convert to $W/Ft^2$ 1Btu/Hr = 0.293W |
|---|---|---|---|---|---|---|
| Bottom | | | | | | |
| 96041630 | 43.6 | 1.02 | 44.472 | 317.672 | 26.643 | 7.806 |
| 96041631 | 43.7 | 1.02 | 44.574 | 317.774 | 14.928 | 4.374 |
| 96041632 | 43.7 | 1.02 | 44.574 | 317.774 | 0.000 | 0.000 |
| 96041633 | 43.9 | 1.02 | 44.778 | 317.978 | 19.678 | 5.766 |
| Top | | | | | | |
| 95J0642 | 19.1 | 1.04 | 19.864 | 293.064 | 19.403 | 5.685 |
| 95J0641 | 19.1 | 1.04 | 19.864 | 293.064 | 20.692 | 6.063 |
| 95J0639 | 19 | 1.04 | 19.76 | 292.96 | 17.810 | 5.218 |
| 95J0640 | 19 | 1.04 | 19.76 | 292.96 | 18.410 | 5.394 |

Q = 5.758 $W/Ft^2$    61.981 $W/m^2$

dT = 24.787 K

dL = 0.5 Ft    0.1524 m

**$K_T$ = 0.381 ± 0.03941 W/m-K**



**Thermal Conductivity calculation using Fourier equation**

**Sample =** Apache Leap Tuff (Run 46)

$Q = K_T(dT/dL)$

where
- Q = heat transfer per unit area ($W/Ft^2$)
- $K_T$ = thermal conductivity (W/m-K)
- dT = temperature difference between bottom and top sensors (K)
- dL = distance between bottom and top sensors (m)

**Sensor readings**

| Serial no. | Temp $^0C$ | Multi-factor | Correct Temp | Temp $^0K$ | Heat flow $Btu/Ft^2$-Hr | Convert to $W/Ft^2$ 1Btu/Hr = 0.293W |
|---|---|---|---|---|---|---|
| Bottom | | | | | | |
| 96041630 | 54.3 | 1.02 | 55.386 | 328.586 | 52.924 | 15.507 |
| 96041631 | 54.6 | 1.02 | 55.692 | 328.892 | 56.579 | 16.578 |
| 96041632 | 54.6 | 1.02 | 55.692 | 328.892 | 0.000 | 0.000 |
| 96041633 | 54.9 | 1.02 | 55.998 | 329.198 | 36.072 | 10.569 |
| Top | | | | | | |
| 95J0642 | 19.8 | 1.04 | 20.592 | 293.792 | 29.255 | 8.572 |
| 95J0641 | 19.8 | 1.04 | 20.592 | 293.792 | 30.028 | 8.798 |
| 95J0639 | 19.7 | 1.04 | 20.488 | 293.688 | 29.643 | 8.685 |
| 95J0640 | 19.6 | 1.04 | 20.384 | 293.584 | 26.133 | 7.657 |

Q = 10.909 $W/Ft^2$    117.431 $W/m^2$

dT = 35.178 K

dL = 0.5 Ft    0.1524 m

**$K_T$ = 0.509 ± 0.05217 W/m-K**

**Thermal Conductivity calculation using Fourier equation**

**Sample =** Apache Leap Tuff (Run 47)

$Q = K_T(dT/dL)$

where
- Q = heat transfer per unit area ($W/Ft^2$)
- $K_T$ = thermal conductivity (W/m-K)
- dT = temperature difference between bottom and top sensors (K)
- dL = distance between bottom and top sensors (m)

**Sensor readings**

| Serial no. | Temp $^0C$ | Multi-factor | Correct Temp | Temp $^0K$ | Heat flow $Btu/Ft^2$-Hr | Convert to $W/Ft^2$ 1Btu/Hr = 0.293W |
|---|---|---|---|---|---|---|
| Bottom | | | | | | |
| 96041630 | 65.8 | 1.005 | 66.129 | 339.329 | 103.605 | 30.356 |
| 96041631 | 66.4 | 1.005 | 66.732 | 339.932 | 75.182 | 22.028 |
| 96041632 | 66.5 | 1.005 | 66.8325 | 340.033 | 0.000 | 0.000 |
| 96041633 | 67.3 | 1.005 | 67.6365 | 340.837 | 58.369 | 17.102 |
| Top | | | | | | |
| 95J0642 | 21.1 | 1.04 | 21.944 | 295.144 | 58.033 | 17.004 |
| 95J0641 | 20.9 | 1.04 | 21.736 | 294.936 | 45.000 | 13.185 |
| 95J0639 | 20.8 | 1.04 | 21.632 | 294.832 | 51.133 | 14.982 |
| 95J0640 | 20.5 | 1.04 | 21.32 | 294.52 | 38.350 | 11.237 |

Q = 17.985 $W/Ft^2$    193.593 $W/m^2$

dT = 45.175 K

dL = 0.5 Ft    0.1524 m

**$K_T$ = 0.653 ± 0.06661 W/m-K**

**Thermal Conductivity calculation using Fourier equation**

**Sample =** Apache Leap Tuff (Run 48)

$Q = K_T(dT/dL)$

where
- Q = heat transfer per unit area (W/Ft$^2$)
- $K_T$ = thermal conductivity (W/m-K)
- dT = temperature difference between bottom and top sensors (K)
- dL = distance between bottom and top sensors (m)

**Sensor readings**

| Serial no. | Temp $^0$C | Multi-factor | Correct Temp | Temp $^0$K | Heat flow Btu/Ft$^2$-Hr | Convert to W/Ft$^2$ 1Btu/Hr = 0.293W |
|---|---|---|---|---|---|---|
| Bottom | | | | | | |
| 96041630 | 74.8 | 1 | 74.8 | 348 | 162.642 | 47.654 |
| 96041631 | 76 | 1 | 76 | 349.2 | 110.568 | 32.397 |
| 96041632 | 76 | 1 | 76 | 349.2 | 0.000 | 0.000 |
| 96041633 | 77.5 | 1 | 77.5 | 350.7 | 85.184 | 24.959 |
| Top | | | | | | |
| 95J0642 | 22.5 | 1.04 | 23.4 | 296.6 | 77.789 | 22.792 |
| 95J0641 | 22 | 1.04 | 22.88 | 296.08 | 47.036 | 13.782 |
| 95J0639 | 22.1 | 1.04 | 22.984 | 296.184 | 82.323 | 24.120 |
| 95J0640 | 21.5 | 1.04 | 22.36 | 295.56 | 51.337 | 15.042 |
| Q = | 25.821 W/Ft$^2$ | | | | | 277.941 W/m$^2$ |
| dT = | 53.169 K | | | | | |
| dL = | 0.5 Ft | | | | | 0.1524 m |
| **$K_T$ =** | **0.797 ±** | | **0.08097 W/m-K** | | | |

**Thermal Conductivity calculation using Fourier equation**

**Sample =** Apache Leap Tuff (Run 49)

$Q = K_T(dT/dL)$

where
- Q = heat transfer per unit area (W/Ft$^2$)
- $K_T$ = thermal conductivity (W/m-K)
- dT = temperature difference between bottom and top sensors (K)
- dL = distance between bottom and top sensors (m)

**Sensor readings**

| Serial no. | Temp $^0$C | Multi-factor | Correct Temp | Temp $^0$K | Heat flow Btu/Ft$^2$-Hr | Convert to W/Ft$^2$ 1Btu/Hr = 0.293W |
|---|---|---|---|---|---|---|
| Bottom | | | | | | |
| 96041630 | 87.9 | 0.985 | 86.5815 | 359.782 | 272.486 | 79.838 |
| 96041631 | 91.9 | 0.985 | 90.5215 | 363.722 | 82.886 | 24.286 |
| 96041632 | 89.5 | 0.985 | 88.1575 | 361.358 | 0.000 | 0.000 |
| 96041633 | 93.3 | 0.985 | 91.9005 | 365.101 | 148.300 | 43.452 |
| Top | | | | | | |
| 95J0642 | 24.9 | 1.04 | 25.896 | 299.096 | 151.461 | 44.378 |
| 95J0641 | 23.7 | 1.04 | 24.648 | 297.848 | 90.144 | 26.412 |
| 95J0639 | 24.4 | 1.04 | 25.376 | 298.576 | 166.116 | 48.672 |
| 95J0640 | 23 | 1.04 | 23.92 | 297.12 | 71.675 | 21.001 |
| Q = | 41.148 W/Ft$^2$ | | | | | 442.933 W/m$^2$ |
| dT = | 64.33 K | | | | | |
| dL = | 0.5 Ft | | | | | 0.1524 m |
| **$K_T$ =** | **1.049 ±** | | **0.10623 W/m-K** | | | |



17/2/97 Apache Leap Samples Removed from thermal conductivity apparatus for porosity measurements. Mass measured using the Mettler PM480 Delta range Balance which was calibrated on 5 Feb. '97 SN # N45601

| Sample ID | Mass (g) | |
|---|---|---|
| # 1 | 22.187 | 1-5 visually wet |
| # 2 | 17.039 | |
| # 3 | 23.528 | |
| # 4 | 19.878 | |
| # 5 | 22.962 | |
| # 6 | 26.244 | 6-10 visually dry |
| # 7 | 25.224 | |
| # 8 | 19.513 | |
| # 9 | 20.870 | |
| # 10 | 26.092 | |

Note: Measurements of mass were performed immediately upon removal from the thermal conductivity apparatus. Samples # 1-5 were visually wet upon removal and samples # 6-10 were visually dry upon removal. Samples # 1-10 were then placed in a Blue M oven @ 80°C in order to dessicate the samples for porosity measurements. M. Hill 17/2/97

2/17/96 JP

Apache leap tuff sample was removed from thermal conductivity cell. A series of measurements will now be conducted without a crushed tuff specimen in the cell.



2/17/97 JP Thermal Conductivity Experiment Run 50
Air - no rock sample

Parameters
Variable transformer setpoint 5.0
Waterbath temp setpoint 20°C
Pressure on top Al plate 55 lb.

2/19/97 JP Results of TC experiment Run 50

| Bottom Al plate Serial No. | Heat Flux BTU/Ft²-h | Temp °C |
|---|---|---|
| 96041630 | 2.2833 | 22.3 |
| 31 | 2.1311 | 22.3 |
| 32 | — | 22.3 |
| 33 | 3.3786 | 22.3 |

| Top Al plate | | |
|---|---|---|
| 955042 | 3.2961 | 18.5 |
| 41 | 3.5163 | 18.5 |
| 39 | 3.6940 | 18.5 |
| 40 | 4.0906 | 18.5 |

| Monitoring thermocouples | Temp °C |
|---|---|
| 1 | 23.8 |
| 2 | 23.5 |
| 3 | 22.4 |
| 4 | 22.5 |
| 5 | 22.5 |
| 6 | 22.5 |
| 7 | 18.7 |
| 8 | 18.7 |
| 9 | 18.7 |
| 10 | 18.6 |

2/19/97 gp Thermal Conductivity Experiment Run 51
Air

Parameter

| | |
|---|---|
| Variable transformer setpoint | 15 |
| Waterbath temp setpoint | 20°C |
| Pressure on Top Al plate | 55 lb |

2/20/97 gp 0815hr Results of TC experiment run 51

| Bottom Al plate Serial No | Heat Flux BTU/Ft²hr | Temp °C |
|---|---|---|
| 96041630 | 12.7225 | 32.6 |
| 31 | 13.2397 | 32.6 |
| 32 | — | 32.6 |
| 33 | 15.5448 | 32.7 |
| **Top Al plate** | | |
| 95J042 | 14.8248 | 18.9 |
| 41 | 15.1390 | 18.9 |
| 39 | 13.7819 | 18.9 |
| 40 | 14.7785 | 18.9 |

| Monitoring Thermocouples | Temp °C |
|---|---|
| 1 | 28.2 |
| 2 | 26.1 |
| 3 | 32.7 |
| 4 | 32.8 |
| 5 | 32.7 |
| 6 | 32.8 |
| 7 | 19.1 |
| 8 | 19.1 |
| 9 | 19.0 |
| 10 | 19.0 |



2/20/97 gp 0820hr Thermal Conductivity Experiment Run 52
Air

Parameter

| | |
|---|---|
| Variable transformer setpoint | 25 |
| Waterbath temp. setpoint | 20°C |
| Pressure on top Al plate | 55 lbs |

2/21/97 gp 0800hr Results of TC experiment Run 52

| Bottom Al plate Serial No | Heat Flux BTU/Ft²hr | Temp °C |
|---|---|---|
| 96041630 | 33.7541 | 50.3 |
| 31 | 38.2840 | 50.4 |
| 32 | — | 50.4 |
| 33 | 41.0433 | 50.4 |
| **Top Al plate** | | |
| 95J042 | 39.4913 | 19.6 |
| 41 | 39.6863 | 19.4 |
| 39 | 37.0467 | 19.5 |
| 40 | 37.6551 | 19.6 |

| Monitoring Thermocouple | Temp °C |
|---|---|
| 1 | 35.2 |
| 2 | 30.3 |
| 3 | 50.4 |
| 4 | 50.4 |
| 5 | 50.4 |
| 6 | 56.7 |
| 7 | 19.6 |
| 8 | 19.7 |
| 9 | 19.5 |
| 10 | 19.6 |

2/21/97 0800hr Thermal Conductivity Experiment Run 53
Air

Parameters

| | |
|---|---|
| Variable transformer setpoint | 35 |
| Waterbath temp setpoint | 20°C |
| Pressure on Top Al plate | 55 ft lb |

2/23/97 0900hr Results of TC experiment Run 53

| Bottom Al plate Serial No. | Heat Flux BTU/Ft²-hr | Temp °C |
|---|---|---|
| 96041630 | 72.5711 | ~~75.2~~ 74.7 |
| 31 | 73.6655 | ~~75.3~~ 74.8 |
| 32 | — | ~~75.2~~ 74.7 |
| 33 | 84.7000 | ~~75.3~~ 74.8 |

| Top Al plate | | |
|---|---|---|
| 95J042 | 84.1112 | ~~20.9~~ 20.7 |
| 41 | 75.0551 | ~~21.1~~ 20.8 |
| 39 | 73.4692 | ~~21.0~~ 20.8 |
| 40 | 76.7270 | ~~21.0~~ 20.8 |

| Monitoring Thermocouples | Temp °C |
|---|---|
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| 5 | |
| 6 | |
| 7 | |
| 8 | |
| 9 | |
| 10 | |



21/2/97 On 18/2/97 the volume of the 10 Apache Leap samples removed from the thermal conductivity apparatus on 17/2/97 p 145 of this lab notebook were obtained using Archimedes Principle which states that the volume of an irregularly shaped object is equal to ~~that of~~ 21/2/97 the volume of water it displaces when totally submerged.

| Samples | Volume (cm³) | Volume in cylinder without sample (cm³) | Volume in cylinder with sample (cm³) |
|---|---|---|---|
| 1 | 10 | 70 | 80 |
| 2 | 7 | 50 | 57 |
| 3 | 10 | 70 | 80 |
| 4 | 8 | 81 | 89 |
| 5 | 9.5 | 90 | 99.5 |
| 6 | 11 | 67 | 78 |
| 7 | 10 | ~~60~~ 50 21/2/97 | ~~72~~ 60 |
| 8 | 8 | 52 | 60 |
| 9 | 10 | 50 | 60 |
| 10 | 12 | 60 | 72 |

The volumes for samples # 2 & 7 were measured using Fisherbrand 100 ml graduated cylinder cat. # 08-557D. Samples # 1, 3, 4, 5, 6, 8, 9 & 10 however were too large to fit through the aperture of the Fisherbrand graduated cylinder, therefore measurements for those samples were obtained using the KIMAX 250 ml graduated cylinder cat. # 20024-D. All measurements were performed using deionized $H_2O$ & the graduated cylinders were emptied and refilled prior to each measurement of sample volume. Samples were carefully submerged to prevent the loss of any $H_2O$. Samples # 1-10 were then placed back into a Blue M oven set @ 80°C.

On 21/2/97 the 10 Apache Leap samples were removed from the Blue M oven so that measurements of mass could be performed. The procedures are adopted from Rasmussen et al., (1990) and Green, Rice & Meyer-James, (1995). The procedures are as follows: Samples # 1-10 were removed from the oven and immediately placed in a desiccator filled with drierite and were allowed to reach ambient temperature. The mass was then measured using the Mettler PM4000 electronic balance with a deviation of ±0.005 g.

| Sample ID | Mass (g) |
|---|---|
| 1 | 21.480 |
| 2 | 16.511 |
| 3 | 22.885 |
| 4 | 19.552 |
| 5 | 22.230 |
| 6 | 26.220 |
| 7 | 25.113 (M.H. 21/2/97) |
| 8 | 19.424 |
| 9 | 20.520 |
| 10 | 25.886 |

Samples #1-10 were the placed in a Blue M oven set @ 105°C as described in Green, Rice, & Meyer-James (1995). M. Hill 21/2/97



2/23/97 JJP Thermal Conductivity Experiment Run 54
Air

Parameter

| | |
|---|---|
| Variable temperature setpoint | 45 |
| Waterbath temp setpoint | 20°C |
| Pressure on top Al plate | 55 ft lb |

2/24/97 Results of TC experiment Run 54

| Bottom Al plate Serial No | Heat Flux BTU/Ft² hr | Temp °C |
|---|---|---|
| 96041630 | 148.4404 | 102.0 |
| 31 | 109.0847 | 102.1 |
| 32 | — | 102.5 |
| 33 | 156.8277 | 102.4 |

Top Al plate

| | | |
|---|---|---|
| 955042 | 138.8945 | 22 |
| 41 | 129.0570 | 22.1 |
| 39 | 126.2520 | 22 |
| 40 | 134.6505 | 22 |

| Monitoring Thermocouple | Temp °C |
|---|---|
| 1 | 58.4 |
| 2 | 45.7 |
| 3 | 102.7 |
| 4 | 102.8 |
| 5 | 102.3 |
| 6 | 103.7 |
| 7 | 21.7 |
| 8 | 21.8 |
| 9 | 21.5 |
| 10 | 21.6 |

2/24/97 JP Thermal Conductivity Experiment Run 55
Air

Parameter
Variable transformer setpoint 55
Waterbath temp setpoint 20°C
Pressure on top Al plate 55 ft-lb

2/25/97 JP Results of TC experiment Run 55

| Bottom Al plate Serial No | Heat Flux BTU/Ft²hr | Temp °C |
|---|---|---|
| 96041630 | 160.9347 | 133.4 |
| 31 | 141.8063 | 132.9 |
| 32 | — | 133.7 |
| 33 | 209.1939 | 133.9 |

| Top Al plate | | |
|---|---|---|
| 955J042 | 201.4121 | 23.8 |
| 41 | 178.9639 | 23.9 |
| 39 | 177.5692 | 23.9 |
| 40 | 192.7924 | 23.9 |

| Monitoring Thermocouples | Temp °C |
|---|---|
| 1 | 72.9 |
| 2 | 56.0 |
| 3 | 134.2 |
| 4 | 134.2 |
| 5 | 133.2 |
| 6 | 134.5 |
| 7 | 23.1 |
| 8 | 23.2 |
| 9 | 22.9 |
| 10 | 23.2 |



On 2/24/97 the 10 Apache Leap samples were removed from the Blue M oven so that measurements of mass could be performed. Procedures were the same as those discussed on page 152 of this lab notebook

| Sample ID | Mass (g) |
|---|---|
| 1 | 21.473 |
| 2 | 16.500 |
| 3 | 22.868 |
| 4 | 19.317 |
| 5 | 22.271 |
| 6 | 26.198 |
| 7 | 25.153 |
| 8 | 19.397 |
| 9 | 20.801 |
| 10 | 25.867 |

Samples # 1-10 were then placed back into the Blue M oven set @ 105 °C

M. Hill 2/24/97

On 2/25/97 the 10 Apache Leap samples were removed from the Blue M oven so that measurement of mass could again be performed. Procedures followed were the same as those discussed on p 152 of this lab notebook

| Sample I.D. | Mass (g) |
|---|---|
| 1 | 21.471 |
| 2 | 16.500 |
| 3 | 22.868 |
| 4 | 19.317 |
| 5 | 22.269 |
| 6 | 26.198 |
| 7 | 25.151 |
| 8 | 19.398 |
| 9 | 20.800 |
| 10 | 25.866 |

Samples #1-10 were then placed back into the Blue M oven set @ 105°C.
M. Hill 2/05/97



2/25/97 JJP Thermal Conductivity Experiment Run 56
Air

Parameter
Variable transformer setpoint 65
Waterbath temp setpoint 20°C
Pressure on top Al plate 5.5 lbs.

2/26/97 JJP Results of TC experiment Run 56

| Bottom Al plate Serial No | Heat Flux BTU/Ft²h | Temp °C |
| --- | --- | --- |
| 96041630 | 217.6870 | 166.5 |
| 31 | 199.3888 | 165.5 |
| 32 | — | 167.0 |
| 33 | 308.0383 | 167.1 |

| Top Al plate | | |
| --- | --- | --- |
| 955042 | 275.3286 | 29.7 |
| 41 | 246.4913 | 29.9 |
| 34 | 235.5250 | 29.9 |
| 40 | 268.9242 | 29.9 |

| Monitoring Thermocouple | Temp °C |
| --- | --- |
| 1 | 88.7 |
| 2 | 68.2 |
| 3 | 168.1 |
| 4 | 168.3 |
| 5 | 166.8 |
| 6 | 169.8 |
| 7 | 28.7 |
| 8 | 28.8 |
| 9 | 28.4 |
| 10 | 28.8 |

2/26/97 jp Thermal Conductivity Experiment Run 57
Air

Parameter
Variable transformer setpoint 70
Waterbath temp setpoint 10°C
Pressure on top Al plate 55 ft lb

2/27/97 jp Results of TC Experiment Run ~~58~~ 57 jp 3/18/97

| Bottom Al plate Serial No | Heat Flux BTU/Ft hr | Temp °C |
|---|---|---|
| 96041630 | 344.849 | 183.1 |
| 31 | 270.0653 | 182.0 |
| 32 | — | 183.4 |
| 33 | 273.667 | 183.7 |

| Top Al plate | | |
|---|---|---|
| 95J042 | 320.249 | 32.8 |
| 41 | 389.7161 | 32.9 |
| 39 | 269.7220 | 33.0 |
| 40 | 330.1518 | 33.0 |

| Monitoring Thermocouples | Temp °C |
|---|---|
| 1 | 97.6 |
| 2 | 75.3 |
| 3 | 185.2 |
| 4 | 185.2 |
| 5 | 184.3 |
| 6 | 187.1 |
| 7 | 31.5 |
| 8 | 31.8 |
| 9 | 30.9 |
| 10 | 31.7 |



2/27/96 jp Thermal Conductivity Experiment Run 58
Water

Parameter
Variable transformer setpoint 25
Waterbath temp setpoint 20°C
Pressure on top Al plate 55 ft lb

3/4/97
~~2/28/96~~ jp Results of TC experiment Run 58

| Bottom Al plate Serial No | Heat Flux BTU/Ft²hr | Temp °C |
|---|---|---|
| 96041630 | 20.3985 | 21.7 |
| 31 | 27.1484 | 21.7 |
| 32 | — | 21.7 |
| 33 | — | 21.7 |

| Top Al plate | | |
|---|---|---|
| 95J042 | 25.3725 | 19.9 |
| 41 | 19.2339 | 19.9 |
| 39 | 20.9362 | 20.0 |
| 40 | 25.5265 | ~~19.7~~ 20.0 jp 3/4/97 |

| Monitoring Thermocouples | Temp °C |
|---|---|
| 1 | 26.9 |
| 2 | 22.0 |
| 3 | 21.8 |
| 4 | 21.7 |
| 5 | 21.8 |
| 6 | 22.1 |
| 7 | 20.0 |
| 8 | 20.2 |
| 9 | 20.0 |
| 10 | 20.0 |

2/28/97 JP

Entries for Data collected from the Thermal Effects on Flow KTI are contained in Scientific Notebook #212.

This continues in Notebook # 212 [signature] 6/12/97

Final Entry!
This Notebook Appears to comply w/ QAP-001.
P.C. [signature]
2/8/2000