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by

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TEMPERATURE MEASUREMENTS IN THE PRECAMBRIAN SECTION
OF GEOTHERMAL TEST HOLE NO. 2

by

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ABSTRACT

Temperature measurements have been made throughout most of the Precambrian section of Geothermal Test Hole No. 2 (GT-2), the second deep exploratory test hole in the Los Alamos Scientific Laboratory's Dry Hot Rock Geothermal Energy Project. Successful bottomhole temperature measurements were made at nine successive depths during interruptions in drilling. A thermistor probe was used to measure temperature under conditions in which the bottom 10 m of the borehole was filled with either air, water, mud, or water-saturated silt. Several techniques were developed to insure that the thermistor sonde was positioned directly on bottom and isolated from the convecting borehole fluids. These techniques proved successful. Equilibrium rock temperatures calculated from relaxation data using a new method show geothermal gradients of from 50 to 60°C/km in the intervals measured, the gradient generally increasing with depth. The equilibrium rock temperature is 195.8°C at a depth of 2900 m (28 m above the present bottom of the borehole) based on 30 h of continuous bottomhole temperature measurements. The extrapolated equilibrium rock temperature at the GT-2 terminal depth of 2928 m is 197°C.

INTRODUCTION

A 2928-m-deep (9607-ft) 244-mm-diam (9-5/8-in.) borehole recently has been drilled as part of the Los Alamos Scientific Laboratory's Dry Hot Rock Geothermal Energy Project. This borehole, designated Geothermal Test Hole No. 2, or simply GT-2, is located on the western flank of the Valles Caldera in north-central New Mexico. An effort was initiated to develop methods for measurement and data reduction which would allow determination of rock temperatures during economically acceptable interruptions in drilling operations. This goal has been realized.

Past attempts at inferring rock temperatures have been concentrated on the analysis of relaxation temperatures measured in a fluid-filled borehole sufficiently distant from the bottom so that end effects could be ignored and data could be reduced using cylindrical heat-flow theory.¹⁻³ However, in GT-2 the time necessary for temperature relaxation to approach theoretical behavior (neglecting convective disturbances) was prohibitively long for these methods to be of practical use during drilling.

Rapid determination of the equilibrium rock temperature is possible, however, if bottomhole measurements are used. Since the rock at the bottom of a borehole is the least disturbed by the drilling process, the temperature range observed there during relaxation is substantially greater than that observed elsewhere in the borehole. This gives the desirable result of reducing both the precision and amount of data needed for accurate equilibrium rock-temperature determinations. Furthermore, at the bottom of a borehole, temperature sensors easily can be isolated from the cooling effects of convecting borehole fluids.

White et al.,⁴ Grisafi et al.,⁵ and Summers⁶ approximate equilibrium rock temperatures by measuring the bottomhole temperature with a maximum-reading thermometer. However, the use of maximum-reading thermometers in high-temperature, low-permeability rocks--an environment not encountered by these investigators--is likely to introduce significant error. In the hot and essentially impermeable basement rocks encountered in GT-2, the measured bottomhole

temperatures increasingly diverge, with depth, from the equilibrium rock temperatures. This is because the cooling effect of the drilling process is more pronounced at higher rock temperatures, and cannot be as quickly reduced by fluid exchange between the borehole and the surrounding rocks as it can be in low-temperature permeable rocks.

This report summarizes a new method by which equilibrium rock temperatures are inferred with high precision from an analysis of the thermal recovery of the bottomhole temperature measured continuously during a time interval of less than 24 h. The gradient in GT-2 is the first gradient to be so determined.

BOREHOLE PREPARATION FOR TEMPERATURE MEASUREMENTS

Considerable effort was expended in finding suitable ways to position a temperature sonde on successive bottoms of GT-2 and to isolate the sonde from the effect of convecting fluids. At depths in excess of 1.3 km (4265 ft), temperature measurements were made in a borehole in which the bottom 10 m (33 ft) was filled with either water, a viscous mud, or water-saturated silt. The remainder of the borehole was water filled. After cessation of drilling, drilling fluid circulation was maintained for a specified period of time, usually on the order of an hour, to insure that the borehole was as clear as possible of silt and larger rock fragments. With the drill string removed, bottomhole temperature measurements with a thermistor sonde could be taken if complete removal of silt was anticipated. If not, an open-ended drill string was set 2 m (6.6 ft) off bottom, a sonde then lowered through the drill string and a volume of high viscosity drilling mud pumped to bottom. Mud inhibited the settling of silt and allowed the probe to be positioned on bottom and easily retrieved. The use of viscous mud had the added advantage of damping convective instabilities arising from the high temperature gradient.

At depths greater than 2 km, excessive silt and dehydration of the bentonitic mud necessitated adoption of a scheme in which the drill string, terminated in a phenolic adapter, was washed to bottom by fluid circulation supplied by the rig pump (Fig. 1). On cessation of pump circulation, the phenolic end was set on bottom and the temperature sonde lowered through the drill string and inserted into the

Fig. 1. Phenolic extension to the drill string used for bottomhole temperature measurements.

adapter. The eventual settling of silt between the drill pipe and borehole wall prevented all but pore fluid movement in this annulus. The adapter-sonde seal mating entrapped a small amount of water at the bottom of the borehole and essentially isolated the thermistor from the effects of convective water currents in and surrounding the drill pipe.

DATA REDUCTION

Assume for an arbitrary time interval, short in comparison with the time required for temperature relaxation to be complete, that the rate of temperature relaxation depends only on the difference between the bottomhole temperature and the equilibrium, or undisturbed, rock temperature. Allowing the constant in this proportionality to vary from interval to interval, and following the change in the proportionality with time, enables the determination of equilibrium rock temperature. It will be shown that relaxation temperatures observed at any depth in a borehole can be treated in the same manner to give equilibrium rock temperature. However, sufficient data can be collected in hours rather than months or years, if only bottomhole temperatures are measured.

Fig. 2. Calculation of $c^i \theta_\infty^i$ interval parameters. Typically the range of θ_∞^i is less than 12°C.

Muskat,⁷ in an analysis of oil-well production, makes the above assumption for pressure relaxation, but requires that the same proportionality hold throughout the entire period of relaxation. Following Muskat's theoretical development expressed in terms of temperature, we have for the i th time interval beginning at t_0 :

$$\theta^i(t) - \theta_\infty^i = (\theta_0^i - \theta_\infty^i) e^{-c^i(t - t_0^i)},$$

where c^i is a constant for the i th interval, and θ_0^i , $\theta^i(t)$, and θ_∞^i are temperatures at times t_0^i , t , and t_∞ , respectively. Knowing the temperature at three specified times, two equations can be written and solved simultaneously for the unknown interval parameters c^i and θ_∞^i . Repeating this process n times, new choices are made of t_0^i and new values for c^i and θ_∞^i are calculated. Figure 2 shows two such calculations, one at early time and another at later time. For temperature relaxation, a unique value of θ_∞^i cannot be found which reproduces all of the observed temperature data if c^i is held constant throughout the entire relaxation interval (Muskat's method). In our case, since c^i varies during relaxation, only temperature behavior during intervals short in comparison to complete recovery can be modeled by any

Fig. 3. Reduction of temperature recovery data¹ for a depth of 181 m (595 ft) in the South Barrow Well No. 3.

particular calculated θ_∞^i . With successive calculations of θ_∞^i , both the curve fit and the extrapolation to the undisturbed rock temperature improve.

The choice of the time interval, $t_2^i - t_0^i$, for successive calculations of c^i and θ_∞^i is made to maximize the range of θ_∞^i available from the observed temperature data within limitations imposed by the precision of the temperature measurements. A plot of c^i versus θ_∞^i enables the determination of equilibrium rock temperature θ_∞^i since, as $c^i \rightarrow 0$, $\theta_\infty^i \rightarrow \theta_\infty$. Regression analysis of the linear portion of each $c^i \theta_\infty^i$ curve is used to obtain the most likely value of θ_∞ .

Theoretical and Experimental Verification of the LASL Method

That the dependence of c^i on θ_∞^i is not a transient phenomenon is demonstrated by the analysis of data reported by Lachenbruch and Brewer.¹ Figure 3 shows a $c^i \theta_\infty^i$ plot calculated from temperature measurements made at a depth of 181 m (595 ft) during a

6-yr period after the drilling of a 610-m (2000-ft) well near Barrow, Alaska.* As can be seen, c^i closely approaches zero as θ_∞^i approaches θ_∞ . The equilibrium temperature predicted at $c^i = 0$ corresponds closely to Lachenbruch's value of -6.735°C predicted from theory.**

Analysis of thermal recovery data for a laboratory model, reported by Cooper and Jones,² provides experimental verification of the relationship between the interval parameters c^i and θ_∞^i . In their experiment, a cubic meter of sandstone was allowed to come to equilibrium with room temperature. A 4-cm-diam (1.5-in.), 0.6-m-deep (24-in.) borehole was then drilled into the center of the block and filled with a chilled slurry. The temperature in the borehole 8 diameters off bottom was measured intermittently during thermal recovery. Figure 4 shows a c^i/θ_∞^i plot for the recorded temperature data. Both the c^i/θ_∞^i extrapolation and the Cooper and Jones theoretical prediction approximate, within measurement error, the equilibrium rock temperature which in this case is known.

Equilibrium and Virgin Rock Temperatures

The term "equilibrium" rock temperature is here used in its usual context: the steady-state temperature which would exist when thermal relaxation was complete. However, the equilibrium rock temperature at a specified depth need not be equivalent to the temperature at that depth prior to drilling. The latter temperature is commonly called the virgin rock temperature. The difference arises from permanent changes in the physical and chemical properties of the surrounding rock, and from the presence of the borehole. Neither the magnitude nor the significance of this difference can be evaluated; however, it is presumed to be small.

Errors in Temperature Measurement

The accuracy of each temperature determination is estimated to be $\pm 0.2^\circ\text{C}$. Precision in measurement is limited by the rate of change of thermistor resistance and by the minimum measureable resistance with temperature.

*Probable errors in Fig. 3 have been calculated assuming an 0.008°C precision-of-measurement over the entire range of observed temperature, rather than the 0.01°C estimated by Lachenbruch.

**The application of a theoretical model presented by Lachenbruch and Brewer¹ to the bottomhole temperature relaxation observed in GT-2 is discussed in Appendix A.

Fig. 4. Reduction of temperature recovery data² for laboratory experimental model.

The precision of measurement is generally better than 0.01°C for temperatures less than 200°C .

Errors in c^i/θ_∞^i Plots

Systematic errors have negligible effect on c^i but substantially affect θ_∞^i . For instance, a 1% systematic measurement error in the thermistor resistance results in 0.3°C error in θ_∞^i . Random measurement errors cause uncertainties in both c^i and θ_∞^i , skewed principally in the direction of higher θ_∞^i and lower c^i . Both of these latter errors increase with decreasing c^i . Uncertainties at small c^i can be reduced by choice of a greater time interval in computing c^i and θ_∞^i , but such a choice has the undesirable consequence of reducing the range of θ_∞^i available for extrapolation.

EQUILIBRIUM ROCK TEMPERATURES IN GT-2

Estimates of θ_∞ Between 1387 and 2040 m

Figure 5 shows c^i/θ_∞^i determinations of equilibrium rock temperature at specified depths between 1387 m (4550 ft) and 2040 m (6692 ft) in GT-2.

Relaxation data are compiled in Appendix B. Table I gives regression coefficients and statistics for the

Fig. 5. Equilibrium rock determinations for various depths ($t^{i+1} - t^i \leq \frac{1}{2}h$; $t_2^i - t_0^i = 6h$).

TABLE I
LINEAR REGRESSION PARAMETERS USED IN ESTIMATING θ_{∞}

Depth (m)	Equilibrium Rock Temp θ_{∞} (°C)	$-\frac{\Delta\theta_{\infty}^i}{\Delta c^i} \times 10^4$ (°C-sec)	Coefficient of Determination	Standard Error in θ_{∞} (°C)	Standard Error in $\frac{\Delta\theta_{\infty}^i}{\Delta c^i} \times 10^3$ (°C-sec)
1387	113.58	13.35	0.99	0.06	2.3
1475	117.78	6.50	0.99	0.04	1.2
1595	125.66	7.15	0.99	0.02	0.6
1670	128.35	7.29	0.99	0.01	0.5
1825	135.63	9.34	0.99	0.03	1.5
1877	138.57	9.29	0.99	0.04	0.5
1998	142.50	24.47	0.99	0.10	5.4
2040	146.20	16.06	0.99	0.01	0.5
2900	195.84	3.35	0.98	0.22	7.7

TABLE II
BOREHOLE CONDITIONS AND MEASUREMENT PARAMETERS

Depth (m)	Borehole Condition	Time Lapse ^a (h)	Total Measurement ^b Time (h)
1387	water	12	21
1475	water	6	30
1595	water	6	48
1670	water	10	32
1825	water	19	36
1877	mud	10	48
1998 ^c	mud	15	17
2040	mud	2	20
2900	in adapter	2	30

^aTime lapse between cessation of circulation and first temperature measurement.

^bHours of continuous measurement.

^cOff bottom short distance.

linear portion of each curve. The standard error in the determination of θ_{∞} in each case is less than 0.1°C. Curvature in the $c^i\theta_{\infty}^i$ plots at early time probably indicates adjustments in the borehole attenuated by the thermal inertia of the temperature-measuring system. Absence of strong curvature occurring in estimates at 1387 and 1825 m is primarily the result of a long lapse between the time circulation was stopped and the time the first temperature measurements were taken (Table II). Changes in the

slope of the linear portions of the $c^i\theta_{\infty}^i$ curves occur but are not systematically related to depth.

Borehole convective instabilities are identified on $c^i\theta_{\infty}^i$ curves as reversals of direction of time-sequential $c^i\theta_{\infty}^i$ points. The result of borehole convection is to reset the time reference for conductive heat flow (ahead for a convectively driven increase in the rate of temperature change and behind for a decrease). Hence, extrapolated rock temperatures should not be affected, the $c^i\theta_{\infty}^i$ plots being essentially retraced.

Final Temperature Determination at 2900 m

The $c^i\theta_{\infty}^i$ plot for the data at 2900 m (9514 ft), Fig. 6a, shows a nonlinear branch. Consequently, a determination of equilibrium rock temperature cannot be made directly from the raw data with confidence. Nonlinearity and scatter in this plot resulted from a discontinuous and decreasing resistance to ground in the thermistor resistance-measuring circuit. The thermistor resistance data were corrected for this condition and the data again reduced. Figure 6b shows the resulting $c^i\theta_{\infty}^i$ plot. The remaining scatter probably results from interpolation errors in the resistance-to-ground measurements. Application of regression analysis to data within limits of probable error (33 of 42 data points) gives a 0.98 goodness-of-fit and a bottomhole temperature determination of 195.8°C.

Geothermal Gradient--Lower Precambrian Section

The geothermal gradient in the lower Precambrian section, 1387 to 2900 m (4550 to 9514 ft) is shown

Fig. 6. Reduction of raw data from 2900 m (9514 ft) (top). Equilibrium rock determination using corrected relaxation data. Only circular data points were used in regression analysis (bottom).

in Fig. 7. The accuracy of each temperature determination is estimated to be $\pm 0.2^\circ\text{C}$, with a corresponding precision of better than 0.1°C (except for the 2900-m, 9514-ft, point). The average gradient throughout the entire section is 54°C/km , increasing from 50°C/km in the 1.2- to 2.1-km (3940- to 6890-ft) interval to 60°C/km in the 2.1- to 2.9-km (6890- to 9514-ft) interval. Temperature logging subsequent to the completion of drilling indicates that the 50°C/km gradient may extend to 2530 m (8300 ft), requiring a gradient greater than 60°C/km from that depth to 2900 m (9514 ft).

Fig. 7. Geothermal gradient in the lower Precambrian section of GT-2 (1387-2900 m, 4550-9514 ft).

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APPENDIX A

APPLICATION OF LINE SOURCE THEORY

Lachenbruch and Brewer have shown that the cooling of a well, in which the drilling operation approximates a constant linear heat source persisting throughout the time of drilling, is adequately described by an equation of the form

$$\theta = \theta_{\infty} - \frac{q}{4\pi K} f(t, s) ,$$

where $f = \ln \frac{t}{t-s}$;

and θ , relaxation temperature;

θ_{∞} , equilibrium temperature;

t , time elapsed since the drill bit reached the depth in question;

q , cooling per unit time per unit depth;

K , thermal conductivity of the rocks penetrated by the borehole;

s , time elapsed since the drill bit first reached the depth in question until the drilling operation ceased.

If only radial components of heat flow into a borehole are allowed, an expression identical to Eq. (2) describes bottomhole temperature relaxation. In this case s is the cooling associated with drilling and post-drilling intervals (convection and forced fluid circulation). Because convection continued for an indefinite time in GT-2 subsequent to the cessation of drilling, s is not known.

Likely estimates of s , and hence θ_{∞} and $q/2\pi$, however can be derived through iterative calculations of the regression of s on f and its derivative f' . Regressions applied to selected bottomhole temperature data from GT-2 give 0.99 coefficients of determination and θ_{∞} estimates within error of the LASL method. The model expressed by Eq. (2) is incomplete because it does not account for the axial component of the heat flow into the bottom of the borehole, and thus cannot be used to verify the LASL method. Our calculations, however, do not preclude the possibility that axial effects may in fact be small.

APPENDIX-B

TEMPERATURE RELAXATION DATA IN GT-2

TEMPERATURE MEASUREMENTS AT 1387M

TIME (SEC)	TEMP. (°C)	TIME (SEC)	TEMP. (°C)
0	104.056	27600	107.156
1200	104.629	28800	107.270
2400	104.428	30000	107.330
3600	104.604	31200	107.424
4800	104.781	32400	107.505
6000	104.947	33600	107.586
7200	105.108	34800	107.667
8400	105.263	36000	107.742
9600	105.413	37200	107.816
10800	105.558	38400	107.891
12000	105.696	39600	107.960
13200	105.829	40800	108.028
14400	105.963	42000	108.104
15600	106.085	43200	108.166
16800	106.213	44400	108.235
18000	106.330	45600	108.290
19200	106.446	46800	108.353
20400	106.557	48000	108.415
21600	106.661	49200	108.464
22800	106.766	50400	108.527
24000	106.871	51600	108.583
25200	106.964	52800	108.639
26400	107.063	54000	108.695

TEMPERATURE MEASUREMENTS AT 1475M

TIME (SEC)	TEMP. (°C)	TIME (SEC)	TEMP. (°C)
0	9.94442E1	40800	113.185
1200	9.96218E1	42000	113.275
2400	1.02236E2	43200	113.366
3600	1.03783E2	44400	113.457
4800	1.04824E2	45600	113.540
6000	1.05665E2	46800	113.614
7200	1.06394E2	48000	113.689
8400	1.07010E2	49200	113.773
9600	1.07572E2	50400	113.840
10800	1.08097E2	51600	113.916
12000	1.08548E2	52800	113.991
13200	1.08949E2	54000	114.067
14400	1.09313E2	55200	114.126
15600	1.09645E2	56400	114.186
16800	1.09944E2	57600	114.237
18000	1.10209E2	58800	114.288
19200	1.10470E2	60000	114.339
20400	1.10702E2	61200	114.399
21600	1.10914E2	62400	114.450
22800	1.11112E2	63600	114.493
24000	1.11311E2	64800	114.544
25200	1.11496E2	66000	114.587
26400	1.11667E2	67200	114.630
27600	1.11831E2	68400	114.673
28800	1.11988E2	69600	114.725
30000	1.12138E2	70800	114.751
31200	1.12273E2	72000	114.794
32400	1.12408E2	73200	114.829
33600	1.12536E2	74400	114.872
34800	1.12657E2	75600	114.846
36000	1.12778E2	76800	114.933
37200	1.12883E2	78000	114.968
38400	1.12989E2	79200	115.003
39600	1.13087E2	0	0.000

TEMPERATURE MEASUREMENTS AT 1595M

TIME (SEC)	TEMP. (°C)	TIME (SEC)	TEMP. (°C)
0	112.489	70200	122.650
1800	114.036	72000	122.705
3600	115.804	73800	122.785
5400	116.427	75600	122.807
7200	116.952	77400	122.856
9000	117.411	79200	122.905
10800	117.817	81000	122.950
12600	118.180	82800	122.999
14400	118.514	84600	123.039
16200	118.813	86400	123.084
18000	119.088	88200	123.115
19800	119.347	90000	123.156
21600	119.580	91800	123.192
23400	119.803	93600	123.228
25200	120.003	95400	123.264
27000	120.193	97200	123.309
28800	120.372	99000	123.328
30600	120.535	100800	123.360
32400	120.692	102600	123.387
34200	120.845	104400	123.419
36000	120.982	106200	123.451
37800	121.112	108000	123.469
39600	121.238	109800	123.520
41400	121.365	111600	123.528
43200	121.470	113400	123.555
45000	121.576	115200	123.574
46800	121.674	117000	123.597
48600	121.772	118800	123.619
50400	121.862	120600	123.642
52200	121.953	122400	123.656
54000	122.031	124200	123.684
55800	122.113	126000	123.707
57600	122.187	127800	123.716
59400	122.261	129600	123.739
61200	122.335	131400	123.762
63000	122.401	133200	123.780
64800	122.467	135000	123.799
66600	122.533	136800	123.817
68400	122.590	0	0.000

TEMPERATURE MEASUREMENTS AT 1670M

TIME (SEC)	TEMP. (°C)	TIME (SEC)	TEMP. (°C)
0	115.598	45000	124.314
1800	117.473	46800	124.413
3600	118.556	48600	124.503
5400	119.300	50400	124.597
7200	119.871	52200	124.678
9000	120.339	54000	124.763
10800	120.746	55800	124.840
12600	121.095	57600	124.916
14400	121.415	59400	124.983
16200	121.696	61200	125.051
18000	121.958	63000	125.118
19800	122.196	64800	125.181
21600	122.419	66600	125.244
23400	122.621	68400	125.302
25200	122.812	70200	125.356
27000	122.990	72000	125.409
28800	123.156	73800	125.458
30600	123.319	75600	125.507
32400	123.469	77400	125.551
34200	123.610	79200	125.595
36000	123.743	81000	125.639
37800	123.868	82800	125.683
39600	123.993	84600	125.723
41400	124.104	86400	125.762
43200	124.211	0	0.000

TEMPERATURE MEASUREMENTS AT 1825M

TIME (SEC)	TEMP. (°C)	TIME (SEC)	TEMP. (°C)
0	129.329	39600	131.834
1800	129.519	41400	131.901
3600	129.694	43200	131.968
5400	129.864	45000	132.029
7200	130.018	46800	132.090
9000	130.173	48600	132.151
10800	130.311	50400	132.207
12600	130.444	52200	132.256
14400	130.572	54000	132.312
16200	130.689	55800	132.361
18000	130.800	57600	132.405
19800	130.906	59400	132.448
21600	131.012	61200	132.492
23400	131.113	63000	132.535
25200	131.208	64800	132.579
27000	131.291	66600	132.616
28800	131.381	68400	132.660
30600	131.465	70200	132.704
32400	131.543	72000	132.741
34200	131.621	73800	132.779
36000	131.694	75600	132.817
37800	131.767	0	0.000

TEMPERATURE MEASUREMENTS AT 1877M

TIME (SEC)	TEMP. (°C)	TIME (SEC)	TEMP. (°C)
Z			
0	115.594	44880	133.107
1800	121.704	46680	133.241
3600	124.062	48480	133.382
5400	125.404	50280	133.504
7200	126.360	52080	133.626
9000	127.121	53880	133.743
10800	127.759	55680	133.847
12600	128.303	57480	133.957
14400	128.781	59280	134.049
16200	129.223	61080	134.154
18000	129.620	62880	134.240
19800	129.984	64680	134.332
21600	130.328	66480	134.418
23400	130.630	68280	134.491
25200	130.923	70080	134.578
27000	131.190	71880	134.645
28800	131.435	73680	134.719
30600	131.670	75480	134.793
32400	131.888	77280	134.860
34200	132.102	79080	134.921
35880	132.280	80880	134.981
37680	132.466	82680	135.035
39480	132.641	84480	135.096
41280	132.804	86280	135.158
43080	132.955	88080	135.205

TEMPERATURE MEASUREMENTS AT 1998M

TIME (SEC)	TEMP. (°C)	TIME (SEC)	TEMP. (°C)
Z			
0	130.479	25200	133.717
1200	130.929	26400	133.814
2400	131.220	27600	133.905
3600	131.447	28800	133.997
4800	131.646	30000	134.082
6000	131.815	31200	134.167
7200	131.974	32400	134.240
8400	132.127	33600	134.326
9600	132.269	34800	134.405
10800	132.405	36000	134.485
12000	132.529	37200	135.233
13200	132.654	38400	134.632
14400	132.773	39600	134.712
15600	132.892	40800	134.786
16800	133.006	42000	134.853
18000	133.114	43200	134.927
19200	133.222	44400	134.995
20400	133.330	45600	135.063
21600	133.427	46800	135.131
22800	133.529	48000	135.199
24000	133.620	49200	135.260

TEMPERATURE MEASUREMENTS AT 2896M

TIME (SEC)	TEMP. (°C)	TIME (SEC)	TEMP. (°C)
Z			
0	158.479	52200	180.279
1800	160.260	54000	180.605
3600	161.789	55800	180.895
5400	163.263	57600	181.183
7200	164.623	59400	181.414
9000	165.804	61200	181.645
10800	166.979	63000	181.844
12600	168.010	64800	182.124
14400	169.012	66600	182.469
16200	169.836	68400	182.717
18000	171.024	70200	182.933
19800	171.663	72000	183.077
21600	172.340	73800	183.352
23400	173.031	75600	183.571
25200	173.660	77400	183.761
27000	174.266	79200	183.894
28800	174.862	81000	184.093
30600	175.420	82800	184.277
32400	175.941	84600	184.426
34200	176.440	86400	184.512
36000	176.916	88200	184.683
37800	177.356	90000	184.845
39600	177.813	91800	184.964
41400	178.244	93600	185.017
43200	178.670	95400	185.068
45000	179.035	97200	185.060
46800	179.363	99000	185.075
48600	179.331	100800	185.074
50400	179.956	0	0.000