PROCEEDINGS, Thirty-Sixth Workshop on Geothermal Reservoir Engineering
Stanford University, Stanford, California, January 31 - February 2, 2011
SGP-TR-191

RECOVERY OF THE THERMAL EQUILIBRIUM IN DEEP AND SUPER DEEP WELLS: UTILIZATION OF MEASUREMENTS WHILE DRILLING DATA

I. M. Kutasov[1] and L.V. Eppelbaum[2*]

[1]Pajarito Enterprises, 500 Rodeo Rd., Suite 230, Santa Fe, New Mexico *87505*, USA

[2*]Dept. of Geophysics and Planetary Sciences, Raymond and Beverly Sackler Faculty of Exact Sciences, Tel Aviv University, Ramat Aviv *69978*, Tel Aviv, Israel

*Corresponding author, E-mail: levap@post.tau.ac.il

ABSTRACT

It is shown that in deep and super deep wells the temperature of the drilling fluid (at a given depth) depends on the current vertical depth, on drilling technology (flow rate, well design, fluid properties, penetration rate, etc.), geothermal gradient and thermal properties of the formation. It is demonstrated that minimum field data: records of stabilized outlet mud temperature, several values of bottom-hole mud temperature measured while drilling (MWD) are needed to construct an empirical equation which approximates the downhole temperature profile during drilling. An analytical equation is presented which describes recovery of the thermal equilibrium when the temperature of drilling fluid (at a given depth) is a linear function of time. Calculations of shut-in temperatures for two field examples are also presented**.**

INTRODUCTION

The modelling of primary oil production and design of enhanced oil recovery operations, well log interpretation, well drilling and completion operations, and evaluation of geothermal energy resources require knowledge of the undisturbed reservoir temperature. Temperature measurements in wells are mainly used to determine the temperature of the Earth's interior. The drilling process, however, greatly alters the temperature of the reservoir immediately surrounding the well. The temperature change is affected by the duration of drilling fluid circulation, the temperature difference between the reservoir and the drilling fluid, the well radius, the thermal diffusivity of the formations, and the drilling technology used. Given these factors, the exact determination of reservoir temperature at any depth requires a certain length of time in which the well is not in operation. In theory, this shut-in time is infinitely long. There is, however, a practical limit to the time required for the difference in temperature between the well wall and surrounding reservoir to become a specified small value.

The results of field and analytical investigations have shown that in many cases the effective temperature (T_w) of the circulating fluid (mud) at a given depth can be assumed constant during drilling or production (Lachenbruch and Brewer, 1959; Ramey, 1962; Edwardson et al., 1962; Jaeger, 1961; Kutasov et al., 1966; Raymond, 1969). Here we should to note that even for a continuous mud circulation process the wellbore temperature is dependent on the current well depth and other factors. The term “effective fluid temperature” is used to describe the temperature disturbance of formations while drilling. In their classical work Lachenbruch and Brewer (1959) have shown that the wellbore shut-in temperature mainly depends on the amount of thermal energy transferred to (or from) formations. While drilling deep sections of super deep wells, the penetration rates become small and the time of thermal disturbance increases. Below it will be shown that in deep wells the mud circulation temperature can be approximated as a linear time function. The objective of this paper is twofold: (a) to demonstrate how temperature measurements while drilling (MWD) can be utilized to determine the downhole drilling mud temperature profile, and, (b) how the MWD data can be used in estimation of the transient shut-in temperatures.

EMPIRICAL EQUATION

The temperature surveys in many deep wells have shown that both the outlet drilling fluid temperature and the bottom-hole temperature varies monotonically with the vertical depth (Fig. 1).

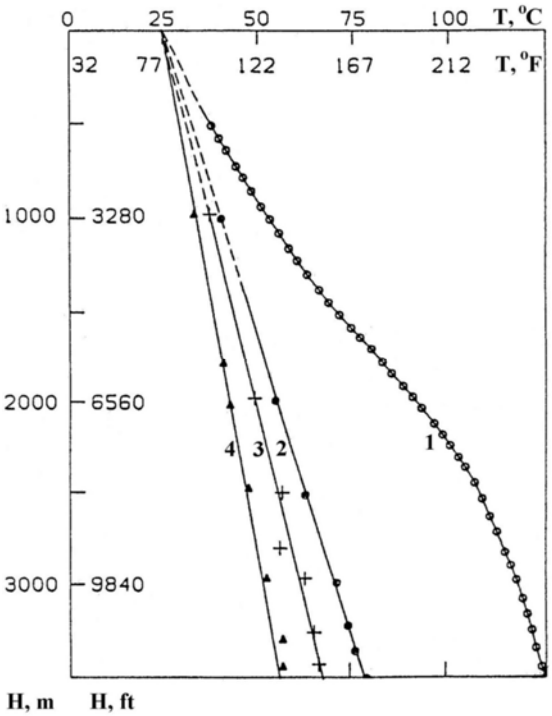

Figure 1: Well 12-PXC, Stavropol district, Russia (Proselkov, 1975). 1 - Geothermal curve, 2 - Circulating bottom-hole temperature, 3 - Outlet drilling mud temperature, 4 - Inlet drilling mud temperature

It was suggested (Kuliev et al., 1968) that the stabilized circulating fluid temperature in the annulus (T_m) at any point can be expressed as

$$T_m = A_o + A_1 h + A_2 H, \qquad h < H, \qquad (1)$$

where the values A_o, A_1, and A_2 are constants for a given area, h is the current vertical depth and H is the total vertical depth of the well (the position of the bottom of the drill pipe at fluid circulation). The values of A_o, A_1, and A_2 are dependent on drilling technology (flow rate, well design, fluid properties, penetration rate, etc.), geothermal gradient and thermal properties of the formation. It is assumed that, for the given area, the above mentioned parameters vary within narrow limits. In order to obtain the values of A_o, A_1, and A_2 the records of the outlet fluid (mud) temperature (at h = 0) and results of downhole temperature surveys are needed. In Formula 1 the value of T_m is the stabilized downhole circulating temperature. The time of the downhole temperature stabilization (t_s) can be estimated from the routinely recorded outlet mud temperature logs (Kutasov et al., 1988; Kutasov, 1999).

Eq. (1) was verified (Kutasov et al., 1988) with more than 10 deep wells, including two offshore wells, and the results were satisfactory ones. Here we are presenting two examples of applying Eq. (1) for prediction downhole circulating temperatures. It will be shown that only a minimum of field data is needed to use this empirical method.

Mississippi well

The results of field temperature surveys and additional data (Table 1) were taken from the paper of Wooley et al. (1984). Three measurements of stabilized bottom-hole circulating temperatures and three values of stabilized outlet mud temperatures were run in a multiple regression analysis computer program and the coefficients of the empirical Formula (1) were obtained

A_o = 32.68°C, A_1 = 0.01685 °C/m,
A_2 = 0.003148 °C/m.

Thus, the equation for the downhole circulating temperature is

$$T_m = 32.68 + 0.01685h + 0.003148H. \qquad (2)$$

Table 1: Measured (T_m) and predicted (T_m) values of wellbore circulating temperature (Kutasov, 1999)*

h, m	H, m	T_m*, °C	T_m, °C	T_m* – T_m, °C
Mississippi well				
4900	4900	129.4	130.7	-1.3
6534	6534	162.8	163.4	-0.6
7214	7214	178.3	177.0	1.3
0	4900	50.0	48.1	1.9
0	6534	51.7	53.2	-1.5
0	7214	55.6	55.4	0.2
Webb County, Texas				
2805	2805	70.6	71.6	-1.0
3048	3048	78.3	77.3	1.0
3449	3449	86.7	86.7	0.0
0	2805	53.3	53.8	-0.5
0	3048	60.0	57.9	2.1
0	3261	60.0	61.6	-1.6

Webb County, Texas

The temperature measurements (Table 1) in this location were obtained from the paper of Venditto and George (1984). It was not known whether these measurements were taken in a single well or in the wells in the same area. But since this empirical method can be applied to an entire area as well as to a single well, the data points were used simultaneously to calculate the coefficients in formula (1). By using the multiple regression analysis computer program was obtained,

A_o = 5.69 °C , A_1 = 0.00636 °C/m ,

A_2 = 0.01714 °C/m.

Thus, the equation for the downhole circulating temperature is

$$T_m = 5.69 + 0.00636\,h + 0.01714\,H. \quad (3)$$

In Table 1 the measured and predicted values of bottom-hole and outlet circulating temperatures are compared and the agreement is seen to be good in both cases. The significant difference in values of A_o, A_1, and A_2 for the Mississippi and the Texas wells indicates that these coefficients are valid only within a given area.

Let us assume that for the well section (H – h) the penetration rate is constant (u).

Then $H = h + ut$ and taking into account Eq. (1):

$$T_m = A_o + A_1 h + A_2 (h + ut)$$

or

$$T_m = B_o + B_1 t,\ B_o = A_o + h(A_1. + A_2),\ B_1 = A_2 u. \quad (4)$$

Introducing the dimensionless circulation time (t_D) we obtain

CUMULATIVE HEAT FLOW

Constant drilling mud temperature

As we mentioned earlier, the wellbore shut-in temperature mainly depends on the amount of thermal energy transferred to (or from) formations (Lachenbruch and Brewer, 1959). It is known that the cumulative heat flow from the wellbore per unit of length is given by:

$$Q = 2\pi\rho c_p r_w^2 (T_w - T_f) Q_D(t_D), \quad (6)$$

where T_w=T_m is thee temperature of the drilling fluid (at a given depth), ρ is the density of formations, c is the specific heat of formations, r_w is the well radius, and Q_D is the dimensionless cumulative heat flow. The time dependent function Q_D can be can be obtained from the integral

$$Q_D = \int_0^{t_D} q_D(t_D)\,dt_D, \quad (7)$$

where q_D is the dimensionless heat flow rate. We found (Kutasov, 1987) that the dimensionless heat flow rate can be approximated by a semi-analytical equation:

$$q_D = \frac{1}{\ln\left(1 + D\sqrt{t_D}\right)}, \quad (8)$$

$$D = d + \frac{1}{\sqrt{t_D} + b},\ d = \frac{\pi}{2};\ b = \frac{2}{2\sqrt{\pi} - \pi};b = 4.9589. \quad (9)$$

The dimensionless flow rate (q_D) can be also determined by using the empirical Eq. (10) (Chiu and Thakur, 1991):

$$q_D = \frac{1}{c_1 \ln\left[1 + c_2\sqrt{t_D}\right]}, c_1 = 0.982, c_2 = 1.81. \quad (10)$$

Commercially available software Maple 7 (Waterloo Maple, 2001) was utilized to compute the integral Q_D, where the function q_D is given by Eq. (10). It was found that

$$\left\{\begin{array}{l} Q_D(t_D) = -2\dfrac{Ei(1,-2.u) - Ei(1,-1.u) - 0.69315}{c_1 c_2^2}, \\ u = \ln(1. + c_2\sqrt{t_D}), \end{array}\right\} \quad (11)$$

where $-Ei(1, -x) = Ei(+x)$ is the exponential integral of a positive argument. In Table 2 the values of Q_D computed by two numerical integration methods are compared. The agreement between values of Q_D calculated by these two methods is seen to be good.

Table 2: Comparison of values of dimensionless cumulative heat flow rate for a well with constant bore-face temperature. Q_D – (Van Everdingen and Hurst, 1949); Q_D – Eq. (11)*

t_D	Q_D*	Q
2	0.2447E+01	0.2448E+01
3	0.3202E+01	0.3204E+01
5	0.4539E+01	0.4540E+01
10	0.7411E+01	0.7411E+01
20	0.1232E+02	0.1233E+02
50	0.2486E+02	0.2485E+02
100	0.4313E+02	0.4302E+02
200	0.7579E+02	0.7555E+02
500	0.1627E+03	0.1606E+03
1000	0.2935E+03	0.2922E+03
2000	0.5341E+03	0.5317E+03
5000	0.1192E+04	0.1187E+04
10000	0.2204E+04	0.2195E+04
20000	0.4096E+04	0.4083E+04
50000	0.9363E+04	0.9342E+04
100000	0.1759E+05	0.1756E+05

DRILLING MUD TEMPERATURE AS LINEAR TIME FUNCTION

When the drilling mud temperature can be approximated by a linear function (Eq. 4) the Duhamel integral can be used

$$Q_{Dt} = \int_0^{t_D} T_{wt}(\lambda)\frac{d}{dt_D}Q_D(t_D-\lambda)d\lambda, \tag{12}$$

where

$$T_{wt} = \frac{T_m}{T_o} = (1+bt_D), \quad T_{wt}(\lambda) = 1+b\lambda,$$

and Q_D is the dimensionless cumulative heat flow rate for a well with constant bore-face temperature. Utilization of Eq. (11) does not allow the integration of Duhamel Integral. For this reason we used the a simple function (Eq. (13))

$$Q_D = At_D^c \tag{13}$$

to approximate the results of a numerical solution (Van Everdingen and Hurst, 1949). A linear regression program was used to compute the coefficients A and c (Table 3).

Table 3: Coefficients c and A

t_D	Number of points	c	A	R, %
5-100	22	0.75361	1.3088	0.68
100-400	15	0.82297	0.97022	0.05
400-1000	25	0.85013	0.82569	0.01
1000-1500	21	0.86236	0.75935	0.00
1500-2000	11	0.86735	0.73392	0.04
2000-3000	21	0.87274	0.70274	0.01
3000-5000	41	0.88213	0.646075	0.01

For t_D > 100 with $R = \Delta Q/Q$ <1.5% the values of coefficients c and a can be approximated by the following expressions:

$$\begin{cases} c = 0.028704\ln t_D + 0.65297, \\ b = -0.148\ln t_D + 1.837. \end{cases} \tag{14}$$

Now the integral (Eq. (12)) can be evaluated

$$Q_{Dt} = At_D^c[1+bt_D - \frac{bt_D}{(c-1)(c+1)}], \; c<1. \tag{15}$$

RADIUS OF THERMAL INFLUENCE

In theory the drilling process affects the temperature field of formations at very long radial distances. There is, however, a practical limit to the distance – the radius of thermal influence (r_{in}), where for a given circulation period ($t = t_c$) the temperature $T(r_{in},\; t_c)$ is practically equal to the geothermal temperature T_f. To avoid uncertainty, however, it is essential that the parameter r_{in} must not to be dependent on the temperature difference $T(r_{in}, t_c) - T_f$. For this reason we used the thermal balance method to calculate the radius of thermal influence.

The results of modeling, experimental works, and field observations have shown the temperature distribution around the wellbore during drilling can be approximated by the following relation (Kutasov, 1968; Kutasov, 1976):

$$\frac{T(r,t)-T_f}{T_w - T_f} = 1 - \frac{\ln r/r_w}{\ln r_{in}/r_w}, \; r_w \le r \le r_{in}. \tag{16}$$

Introducing the dimensionless values of circulation time, radial distance, radius of thermal influence, and temperature

$$t_D = \frac{at_c}{r_w^2},\; r_D = \frac{r}{r_w},\; R_{in} = \frac{r_{in}}{r_w},\; T_D(r_D,t_D) = \frac{T(r,t) - T_f}{T_w - T_f}, \tag{17}$$

we obtain

$$T_D(r_D,t_D) = 1 - \frac{\ln r_D}{\ln R_{in}}, 1 \le r_D \le R_{in}, \tag{18}$$

The dimensionless cumulative heat flow per unit of length is given by:

$$Q_D = \int_o^{t_D} q_D \; dt_D = \int_1^{R_{in}} T_D(r_D,t_D)\, r_D\, dr_D. \tag{19}$$

The last integral is evaluated by using the table for the following integral (Gradshtein and Ryzhik, 1965):

$$\begin{cases} \int x^n \ln x \; dx = \dfrac{x^{n+1}}{n+1}\left(\ln x - \dfrac{1}{n+1}\right), \\ T_m = B_o(1+bt_D),\; t_D = \dfrac{at_c}{r_w^2},\; b = \dfrac{B_1 r_w^2}{B_o a}. \end{cases} \tag{20}$$

From Eqs. (18) – (20) we obtain

$$Q_D = \frac{R_{in}^2 - 1}{4\ln R_{in}} - \frac{1}{2}. \tag{21}$$

By equating values of Q_{Dt} and Q_D (Eqs. (15) and (21)) we obtain a function $R_{in} = f(t_D)$ which can be used to determine the dimensionless radius of thermal influence

$$At_D^c[1+bt_D - \frac{bt_D}{(c-1)(c+1)}] = \frac{1}{4}\frac{R_{in}^2 - 2\ln(R_{in}) - 1}{\ln(R_{in})}. \tag{22}$$

SHUT-IN TEMPERATURE

Thus, for the moment of time $t = t_c$, the temperature distribution in and around the wellbore is

$$\begin{Bmatrix} T_{wt} = T_m = B_o + B_1 t_c, & 0 \le r_D \le 1, \\ T(t_c, r), & 1 \le r_D \le R_{in}, \\ T_f, & r_D > R_{in}. \end{Bmatrix}. \qquad (23)$$

For the temperature distribution (Eq. (23)) we obtained the following formula for the wellbore shut-in temperature T_s (Kutasov, 1999):

$$\frac{T_s(t_s,0) - B_o - B_1 t_c}{T_f - B_o - B_1 t_c} = \frac{Ei[-p(R_{in})^2] - Ei\,(-p)}{2\ln R_{in}}, \quad (24)$$

$$\begin{Bmatrix} p = \dfrac{1}{4nt_D},\ n = \dfrac{t_s}{t_c}, \\ T_f = \dfrac{2(T_s - B_o - B_1 t_c)\ln R_{in}}{Ei[-p(R_{in})^2] - Ei\,(-p)} + B_o + B_1 t_c \end{Bmatrix}. \quad (25)$$

Hence, when the values of B_o and B_1 are known, only one value of shut-in temperature (T_s) is needed to determine the undisturbed formation temperature (T_f). The derivation of Eq. (24) assumes that the difference in thermal properties of drilling mud and formations can be neglected. Although this is a conventional assumption even for interpreting bottom-hole temperature surveys (Timko and Fertl, 1972; Dowdle and Cobb, 1975), when the circulation periods are small, Eq. (24) should be used with caution for very small shut-in times.

FEILD EXAMPLES

Mississippi well (Wooley et al., 1984)

50 days were spent to drill the 6,534 – 7, 214 m section of this well. Thus the average penetration was u = 0.566 m/hr and the values of B_1 and B_o were estimated (see Eq. 4):

$$B_1 = 0.001783\ {}^oC/hr,\ B_o = 163.6\ {}^oC.$$

The undisturbed temperature of formations at h = 6,534 m is T_f = 187.8 ^{o}C, the well radius r_w = 0.0984 m, and the coefficient of thermal diffusivity a = 0.0040 m^2/hr (assumed). The average temperature of the drilling mud at this depth is T_f = 163.6 ^{o}C (Eq. 2). The radius of thermal influence was computed from Eq. (22).

Webb County, Texas. Well #30 (Venditto and George (1984)

The total vertical depth is 10,000 ft. For comparison purposes we will assume that while drilling the 8,000 – 10,000 ft section of the well the average penetration was u = 0.566 m/hr, and r_w = 0.0984m, a = 0.0040 m^2/hr. In this case t_c =1,077 hrs.
The values of B_1 and B_o were estimated (see Eq. (4)):

$$B_1 = 0.009701^oC/Hr,\ B_o = 63.0\ {}^oC.$$

The undisturbed temperature of formations at h = 8, 000 ft m is T_f = 91.6^{o}C. The average temperature of the drilling mud at this depth is T_f = 68.2 ^{o}C (Eq. (3)). The radius of thermal influence was computed from Eq. (22).

In Table 4 we present results of calculations after Eq. (24) values of $\Delta T = T_f - T_s$. We also consider the case when the average temperature of the drilling mud (during the circulation period) is used at calculations of ΔT. For the Well # 30 we present results of calculations when the penetration rate was increased in three times (u = 1.7 m/hr). In this case t_c =359 hrs and B_1 = 0.02971 ^{o}C/hr (Table 4).

From the last Table follows that for large shut-in times the average drilling mud temperature (case when $B_1 = 0$) can be used to estimate the function $\Delta T = f(t_s)$

CONCLUSIONS

It is demonstrated that in deep wells a simple empirical formula approximates the downhole temperature profile during drilling. It is shown that this formula can be combined with an analytical solution and then only one shut-in temperature log is required to estimate the undisturbed (static) formation temperature.

REFERENCES

Chiu, K., Thakur, S.C. (1991), "Modeling of Wellbore Heat Losses in Directional Wells Under Changing Injection Conditions", SPE 22870, *Trans. of the 66th Annual Technical Conference and Exhibition of the Society of Petroleum Engineers*, Dallas, TX, October 6-9, 1991.

Dowdle, W.L., and Cobb, W.M. (1975), "Static Formation Temperatures from Well Logs-an Empirical Method", *J. Petrol. Techn.*, **27**, 1326-1330.

Edwardson, M.L., Girner, H.M., Parkinson, H.R., Williams, C.D., and Matthews, C.S. (1962), “Calculation of Formation Temperature Disturbances Caused by Mud Circulation”, *J. Petrol. Techn*., **14**, 416-426.

Gradshtein, I.S. and Ryzhik, I.M. (1965), “*Table of Integrals, Series and Products*”, Oxford University Press, London, England.

Jaeger, J.C. (1961), “The Effect of the Drilling Fluid on Temperature Measured in Boreholes”, *J. Geophys. Res*., **66**, 563-569.

Kutasov, I.M., Lubimova, E.A., and Firsov, F.V. (1966), “Rate of Recovery of the Temperature Field in Wells on Kola Peninsula”, In: *Problemy glubinnogo teplovogo potoka* (*Problems of the Heat Flux at Depth*), Nauka, Moscow, 74-87.

Kutasov, I.M. (1968), “Determination of Time Required for the Attainment of Temperature Equilibrium and Geothermal Gradient in Deep Boreholes”, *Freiberger Forshungshefte*, **C238**, 55-61.

Kutasov, I.M. (1976), “*Thermal Parameters of Wells Drilled in Permafrost Regions*”, Nedra, Moscow.

Kutasov, I.M. (1987), “Dimensionless Temperature, Cumulative Heat Flow and Heat Flow Rate for a Well with a Constant Bore-face Temperature”, *Geothermics*, **16**, No. 2, 467-472.

Kutasov, I.M., Caruthers, R.M., Targhi, A.K., and Chaaban, H.M. (1988), “Prediction of Downhole Circulating and Shut-in Temperatures”, *Geothermics*, **17**, 607-618.

Kutasov, I.M. (1999), “*Applied Geothermics for Petroleum Engineers*”, Elsevier.

Lachenbruch, A.H., and Brewer M.C. (1959), “Dissipation of the Temperature Effect of Drilling a Well in Arctic Alaska”, *U.S. Geological Survey Bull*., **1083-C**, 74-109.

Proselkov, Yu. M. (1975), “*Heat Transfer in Wells*”, Nedra, Moscow.

Ramey, H. J. Jr. (1962), “*Wellbore Heat Transmission*”, *J. Petrol. Techn*., No. 4, 427-435.

Raymond, L.R. (1969), “Temperature Distribution in a Circulating Drilling Fluid”, *J. Petrol. Techn*., **21**, 333-341.

Timko, D.J. and Fertl, W.H. (1972), “How Downhole Temperatures and Pressures Affect Drilling”, *World Oil*, **175**, 73-78.

.

Venditto, J.J. and George, C.R. (1984), “Better Wellbore Temperature Data Equals Better Cement Jobs”, *World Oil*, February, 47-50.

Van Everdingen, A. F. and Hurst, W. (1949), “The Application of the Laplace Transformation to Flow Problems in Reservoirs”, *Trans., AIME*, 186, 305-324.

Waterloo Maple (2001), “*Maple 7 Learning Guide*”, Waterloo Maple Inc., Waterloo, Canada.

Wooley, G.R., Giussani, A.P., Galate, J.W. and Wederlich, H.F., III (1984), “Cementing Temperatures for Deep-Well Production Liners”, *SPE paper 13046 presented at the 59th Annual Technical Conference and Exhibition*, Houston, Texas, 16-19 September, 1984.

Table 4: Values of $\Delta T = T_f - T_s$ at two depths for two wells

Mississippi well, $t_c = 1200$ hrs, $h = 6{,}534$ m $T_f = 187.8$ ^oC, $u = 0.566$ m/hr			Webb County well, $T_f = 91.60$ ^oC, $h = 2{,}003$ m			
			$t_c = 1077$ hrs, $u = 0.566$m/hr		$t_c = 359$ hrs, $u = 1.70$ m/hr	
t_s, hrs	$R_{in} = 52.6$ $B_o = 163.6$ ^oC $B_1 = 001783$ $^oC/hr$	$R_{in} = 50.34$ $B_o = 164.7$ ^oC, $B_1 = 0$	$R_{in} = 60.09$ $B_o = 63$ ^oC $B_1 = 0.0097$ $^oC/hr$	$R_{in} = 47.91$ $B_o = 68.2^oC$, $B_1 = 0$	$R_{in} = 38.46$ $B_o = 63$ ^oC $B_1 = 0.0291$ $^oC/hr$	$R_{in} = 28.41$ $B_o = 68.2^oC$ $B_1 = 0$
10	15.68	16.36	13.08	16.48	12.46	15.40
20	13.83	14.40	11.61	14.48	10.81	13.08
30	12.72	13.24	10.74	13.28	9.83	11.70
50	11.32	11.76	9.62	11.76	8.58	9.94
70	10.39	10.77	8.88	10.75	7.75	8.78
100	9.40	9.73	8.10	9.68	6.87	7.55
120	8.89	9.20	7.70	9.14	6.42	6.92
150	8.27	8.54	7.21	8.46	5.87	6.16
200	7.47	7.70	6.57	7.60	5.16	5.22
300	6.35	6.51	5.67	6.38	4.18	4.00
500	4.95	5.04	4.55	4.88	3.04	2.73
600	4.47	4.53	4.15	4.38	2.68	2.35
800	3.74	3.78	3.54	3.63	2.16	1.85
1000	3.22	3.24	3.09	3.09	1.81	1.52
1200	2.82	2.84	2.75	2.70	1.56	1.29