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A TABULATION OF NEUTRON ENERGIES FROM MONOERGIC PROTONS ON LITHIUM

by

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I. Introduction

The high energy voltage scale in the vicinity of one to three million volts has been calibrated to an accuracy of about 0.1%.[(1)] The ability to control voltages of electrostatic generators in this region is now such that a relative precision of a few hundredths per cent can sometimes be claimed. Hence at times calculation of neutron energy from the $Li^7(p, n) Be^7$ reaction demands calculation to an accuracy exceeding 0.1%, if loss of precision is to be avoided. Such calculations made repeatedly are tedious. The accompanying tables are intended to give neutron energies from the $Li^7(p, n) Be^7$ reaction to about 0.01% or 10 ev, whichever is larger, in terms of the input data considered as numerically exact.

In connection with preparation for calculation of these tables, considerable work has been done to develop a convenient form of relativistic equation. Also a number of sources of shift, spread or error in neutron energies have been studied. The results may be of use in refined measurements or analysis not only of the $Li^7(p, n) Be^7$ reaction, but also of other two-body reactions, whether they yield neutrons or charged particles. The results of these studies are summarized in the following sections.

In case users of these tables discover errors, it will be appreciated if they notify the authors. Send the correction to A. Langsdorf, D203-G113, Argonne National Laboratory, Lemont, Illinois.

II. Theory

The completely relativistic expression for the energy of an outgoing particle in a two-body reaction may be derived in several ways. See, for example, Chapters I and II of Landau and Lifshitz.[(2)] The result may be written

$$T_3 = \frac{4m_3 D - AB \pm 2\sqrt{D\,(B^2 - 2m_3 AB + 4m_3^2 D)}}{A^2 - 4D} \qquad (1)$$

in which

$$A = 2[m_3 + m_4 + T_1 + Q] \qquad (2)$$

$$B = 2T_1\,[m_1 - m_4 - Q] - (2m_4 Q + Q^2) \qquad (3)$$

$$D = T_1 (T_1 + 2m_1) \cos^2 \theta \qquad (4)$$

m_1 is the rest mass of the incident particle (proton)
m_2 is the rest mass of the stationary target atom (lithium -7)
m_3 is the rest mass of outgoing particle of interest (neutron)
m_4 is the rest mass of the other outgoing or recoil atom (beryllium -7)
T_1 is the kinetic energy, in mass units, of the particle of mass m_1 at the moment of collision
T_3 is the kinetic energy in mass units of the particle of mass m_3
θ is the angle between the direction of motion of m_1 and m_3 in the laboratory frame of reference.

$Q = (m_1 + m_2 - m_3 - m_4)$ is the reaction energy in the center of mass system. (5)

When Q is negative, as in the case of interest here, a threshold energy exists below which no reaction can occur. This will be called T_{ft}, or the "forward threshold," because it is the minimum value of T_1 which can give a real value of T_3 from equation (1). We find

$$T_{ft} = -Q\left[1 + \frac{m_1}{m_2} - \frac{Q}{2m_2}\right] \qquad (6)$$

T_{ft} is the threshold which Herb, et al.,[1] measured to be 1.882 Mev and which in the tabulation has been assumed to be 1.88200 exactly.

Another threshold we make use of is the "back-threshold," represented by T_{bt}. This is the value of T_1 above which neutrons are emitted at angles $\theta \geqslant 90°$. We find

$$T_{bt} = -Q\left[1 + \frac{m_1}{m_2 - m_3} - \frac{Q}{2\,(m_2 - m_3)}\right] \qquad (7)$$

The relativistic equation (1) can be made to appear almost like the classical expression as given by Hanson, et al.,[3] if in equations (1) through (4) we substitute according to these defining equations:

$$m_4' = m_4 + Q = m_1 + m_2 - m_3 \qquad (8)$$

$$Q'' = Q\,[1 - (Q/2m_4')] \qquad (9)$$

$$\mu = \cos\theta \qquad (10)$$

$$z = \frac{m_4'\,(m_4' + m_3)}{m_1\, m_3}\left(1 - \frac{m_1}{m_4'} + \frac{Q''}{T_1}\right) \qquad (11)$$

with the result:

$$T_3 = \frac{T_1\, m_1\, m_3\, \beta_1}{(m_3 + m_4')^2}\left[2\mu^2 + z\,\beta_2 \pm 2\mu\sqrt{\mu^2 + z\,\beta_3}\right] \tag{12}$$

where β_1, β_2, and β_3 are correction factors close to unity given by

$$\beta_1 = \frac{1 + (T_1/2m_1)}{1 + \frac{2T_1}{m_1 + m_2}\left(1 - \frac{2m_1 \cos^2\theta}{m_1 + m_2}\right) + \frac{T_1^2\,(1 - \cos^2\theta)}{(m_1 + m_2)^2}} \tag{13}$$

$$\beta_2 = [1 + \{\, T_1/(m_1 + m_2)\}\,]/[1 + (T_1/2m_1)] \tag{14}$$

$$\beta_3 = \frac{1 + \left[T_1/(m_1 + m_2)\right]\left[1 + \frac{m_4'}{2m_3}\left(1 - \frac{m_1}{m_4'} + \frac{Q''}{T_1}\right)\right]}{1 + (T_1/2m_1)} \tag{15}$$

Expression (12), with μ and z given by (10) and (11), becomes just Hanson's expression if one identifies our m_4' and Q'' with his m_4 and Q, respectively, and makes the approximation that $\beta_1 = \beta_2 = \beta_3 = 1$.

It is desirable to eliminate m_4'; then

$$T_3 = T_1\frac{m_1\, m_3\, \beta_1}{(m_1 + m_2)^2}\left[2\mu^2 + z\;\beta_2 \pm 2\mu\sqrt{\mu^2 + z\;\beta_3}\,\right] \tag{16a}$$

which may also be usefully written as

$$T_3 = T_1\frac{m_1\, m_3\, \beta_1}{(m_1 + m_2)^2}\left[\left(\pm\mu + \sqrt{\mu^2 + z\,\beta_3}\right)^2 - \frac{z^2\, m_1\, T_1}{2\left(1 + \frac{T_1}{2m_1}\right)(m_1 + m_2)^2}\right] \tag{16b}$$

From equations (7) and (9) we obtain

$$\frac{Q''}{T_1} = -\frac{T_{bt}}{T_1}\,\frac{m_2 - m_3}{m_1 + m_2 - m_3} \tag{17}$$

by aid of which, from (11) and (15), one obtains

$$z = \frac{(m_1 + m_2)(m_2 - m_3)}{m_1\, m_3}\left(1 - \frac{T_{bt}}{T_1}\right) \tag{18}$$

$$\beta_3 = \frac{1 + \left[T_1/(m_1 + m_2)\right]\left[1 + \frac{m_2 - m_3}{2m_3}\left(1 - \frac{T_{bt}}{T_1}\right)\right]}{1 + (T_1/2m_1)} \tag{19}$$

Expressions (13), (14), (16a), (18), and (19) were the ones actually used in calculation of the tables in this report. The independent parameters in the equations were m_1, m_2, m_3, and T_{ft}. The value of T_{bt} was calculated from equations (6) and (7). It is also at times convenient in such calculation of T_{bt} to use

$$\frac{T_{bt} - T_{ft}}{T_{ft}} = \frac{m_1 m_3}{(m_1 + m_2)(m_2 - m_3)} \frac{1 - (Q/2m_1)}{1 - [Q/2(m_1 + m_2)]} \qquad (20)$$

in which expression only a rough value of Q suffices.

After the actual tables were computed, it was observed that β_3, equation (19), is constant to within 4 parts per million for the Li^7 (p, n) Be^7 reaction up to $T_1 = 10$ Mev. This occurs because m_1 and m_3 are nearly equal; even their slight difference is in a direction to make β_3 more nearly constant. One obtains very closely,

$$\beta_3 \cong 1 - [T_{bt}(m_2 - m_3)/2m_3(m_1 + m_2)] \quad . \qquad (19a)$$

For the masses adopted in the calculation, β_3 is equal to 0.999234. (At $T_1 = 10$ Mev, the exact value of β_3 is 0.99923196.)

A useful approximation for β_1, accurate to a few parts in 10^5 up to 10 Mev proton energy, is the linear expansion

$$\beta_1 = 1 + \frac{T_1}{m_1 + m_2}\left(\frac{m_2 - 3m_1}{2m_1} + \frac{4m_1 \cos^2\theta}{m_1 + m_2}\right) \qquad (13a)$$

III. Investigation of Shift, Spread, or Error in Neutron Energy

A. A preliminary calculation of errors resulting from the classical formulation showed that they might sometimes be of the order of 0.1%. The amount of error in the classical case depends on just what degree of approximation is employed. Rather than to exhaustively analyze the problem to find just when the calculation could be made classically and when it should be made relativistically, it was simpler to make the I.B.M. machine instructions everywhere fit the relativistic equation.

In the following analysis, the classical expression obtained from (16) by setting $\beta_1 = \beta_2 = \beta_3 = 1$ will be employed,* i.e.,

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*We retain equation (18) as the definition of z, classically, since this is most convenient for determination of energies near zero at "back-angles." If, in addition, we retain equation (7) in the calculation of E_{bt}, then E_{ft} is not correctly given by equation (6). However, the difference is only about one part in 10^5, and is not worth further consideration. One may also be consistent if one defines:

$$E_{bt} = -Q(m_1 + m_2 - m_3)/(m_2 - m_3) \text{ and } E_{ft} = -Q(m_1 + m_2)/m_2$$

for purposes of classical calculation.

$$E_3 = \frac{m_1 m_3}{(m_1 + m_2)^2} E_1 \left(2\mu^2 + z \pm 2\mu \sqrt{\mu^2 + z} \right) \tag{21}$$

or

$$E_3 = \frac{m_1 m_3}{(m_1 + m_2)^2} E_1 \left(\pm\mu + \sqrt{\mu^2 + z} \right)^2 \tag{21a}$$

The second form, (21a), is convenient to use, because of the circumstance that the bracket in (21) is a perfect square. The symbol E is used for energy calculated classically or only approximately relativistically, while T is reserved for the fully relativistic kinetic energy. Subscripts have the same meaning as when applied to T. The minus sign of the $\pm \mu$ term only applies in the "double energy" region, that is, with μ positive and z negative. For all z positive cases, μ is taken with the + sign choice so the μ is positive when $\theta < 90°$ and negative when $\theta > 90°$.

B. Doppler Effect - This effect is the largest correction considered and is quite important.

For this case equation (21) is modified by considering the target atom to have a thermal motion energy E_2, with this motion at an angle α to the axis provided by the direction of motion of the incident projectile of mass m_1. We obtain

$$E_3 = \frac{m_1 m_3}{(m_1 + m_2)^2} E_1 \left(\mu_1 + \sqrt{\mu_1^2 + z_1} \right)^2 \tag{22}$$

in which we ignore the lower energy group in the "double energy" region. Here

$$\mu_1 = \cos\theta + \sqrt{\frac{m_2 E_2}{m_1 E_1}} \cos(\theta - \alpha) \tag{23}$$

$$z_1 = z + \frac{m_1 + m_2}{m_3} \left[\frac{(m_1 - m_3) E_2}{m_1 E_1} - 2\sqrt{\frac{m_2 E_2}{m_1 E_1}} \cos\alpha \right] \tag{24}$$

On differentiating (22) with respect to α and setting $(\delta E_3 / \delta \alpha) = 0$ one obtains the angle for which the change in E_3 is greatest. It is given by

$$\tan \alpha_m = \sin\theta \Big/ \left[\cos\theta - \sqrt{\frac{m_1 E_1}{m_3 E_3}} \right] \tag{25}$$

On inserting this value of α_m into (22) one obtains E_{3m}. If then E_{30} is the value of E_3 for $E_2 = 0$, we define $\Delta E_3 = 2 (E_{3m} - E_{30})$ to be the full spread in E_3 for the specified value of E_2, and consider ΔE_3 as a convenient measure of the Doppler effect. (A better measure would be obtained by a suitable integration of ΔE_3 considered as a function of both E_2 and α over all α and over a Maxwellian distribution of E_2.)

The value of ΔE_3 as defined above is found to be given to a close approximation, neglecting some (always small) higher order terms, by

$$\frac{\Delta E_3}{E_3} = \frac{4}{\sqrt{\mu^2 + z}} \sqrt{\frac{m_2 E_2}{m_1 E_1} + \frac{m_2 E_2}{m_3 E_3} - 2\mu \sqrt{\frac{m_2 E_2}{m_1 E_1} \cdot \frac{m_2 E_2}{m_3 E_3}}} \tag{26}$$

It is to be noted that the Doppler spread is considerably less for forward directions than backward. The above expression for the fractional spread, of course, diverges as $E_3 \rightarrow 0$. By aid of (22), equation (26) may be changed to give

$$\Delta E_3 = 4\left(1 + \frac{\mu}{\sqrt{\mu^2 + z}}\right)\sqrt{m_2 E_2 \left\{m_1 E_1 + m_3 E_3 - 2\mu\sqrt{m_1 E_1 \, m_3 E_3}\right\}} \tag{26a}$$

so that as $z \rightarrow 0$ and $E_3 \rightarrow 0$, we find ΔE_3 is given by $\sqrt{m_1 E_1 \, m_2 E_2}$ multiplied by $8/(m_1 + m_2)$ if μ is positive, $4/(m_1 + m_2)$ if μ is zero, and 0 if μ is negative.

Some calculated values of ΔE_3 and $\Delta E_3/E_3$ are given in the table below to show the order of magnitude of the effect. In these calculations $E_2 = 1/40$ ev was used, and $m_1 \cong m_3 \cong 1$, $m_2 \cong 7$.

It may be noted that the Doppler motion makes a slight shift in the mean value of E_3. The shift in the mean is much smaller than the spread, and is generally negligible.

E_1 Mev	E_3	z	θ	$\Delta E_3/E_3$	ΔE_3 ev
1.9217	0	0	90°		290
1.924	90 ev	.056	120°	.36	33
1.931	1120 ev	.228	120°	.073	82
3.58	1.003 Mev	21.94	120°	4.76×10^{-4}	476
2.71	1.005 Mev	13.78	0°	1.7×10^{-4}	170

The Doppler effect also causes the threshold E_{ft} to spread out. Specifically, if the target atoms move toward the projectiles, a reaction can occur below the theoretical threshold for stationary target atoms. Quantitatively, we find, using equations (22) to (24), that for $E_2 = 0.025$ ev, threshold will begin about 190 ev lower than if $E_2 = 0$ for Li^7 (p, n) Be^7. An appreciable part of the low energy "tail" of the nearly linear rise of the neutron counting rate curve just above threshold, as actually observed with a well stabilized electrostatic generator, may be ascribed to this Doppler effect.

C. Mass Uncertainty - As will be discussed below, an appreciable uncertainty exists concerning the proper mass of the target nucleus that should be applied. Most of this uncertainty, within the limitation that the reaction is still described as a two-body type, may be considered to be due to the variability in the number of electrons taking part in the collision and recoil process.

To study the problem analytically, differentiate equation (21a) with respect to m_2 with the result.

$$\frac{1}{E_3}\frac{dE_3}{dm_2} = \frac{-2}{m_1 + m_2} + \frac{1}{(\mu + \sqrt{\mu^2 + z})\sqrt{\mu^2 + z}}\frac{dz}{dm_2} \quad . \qquad (27)$$

Now dz/dm_2 takes on three values, depending on whether one takes E_{bt}, Q, or E_{ft} independent of m_2. The three derivatives are:

$$\left(\frac{\delta z}{\delta m_2}\right)_{E_{bt}} = \left(\frac{1}{m_2 - m_3} + \frac{1}{m_1 + m_2}\right) z \qquad (28)$$

$$\left(\frac{\delta z}{\delta m_2}\right)_{Q} = \left(\frac{\delta z}{\delta m_2}\right)_{E_{bt}} - \frac{(m_1 + m_2)\,[m_1 - (Q/2)]\,Q}{m_1 m_3 (m_2 - m_3)\, E_1} \qquad (29)$$

$$\left(\frac{\delta z}{\delta m_2}\right)_{E_{ft}} = \left(\frac{\delta z}{\delta m_2}\right)_{Q} + \frac{(m_1 + m_2)\,[m_1 - (Q/2)]\,(m_1 + m_2 - m_3 - Q)\,Q}{m_1 m_2 m_3 (m_1 + m_2 - Q)\, E_1} \qquad (30)$$

If we put $m_1 = m_3 = 1$, $m_2 = 7$, $Q = 1.65$ Mev, we find, approximately,

$$\left(\frac{\delta z}{\delta m_2}\right)_{E_{bt}} = 0.29\, z \;;\quad \left(\frac{\delta z}{\delta m_2}\right)_{Q} = 0.29\, z + (2.2/E_1), \text{ and}$$

$$\left(\frac{\delta z}{\delta m_2}\right)_{E_{ft}} = 0.29\, z + (0.55/E_1)$$

where E_1 is given in Mev.

In cases where equation (27) diverges, we may replace it by

$$\frac{dE_3}{dm_2} = \frac{1}{m_1 + m_2}\left\{ -2E_3 + \frac{(dz/dm_2)}{\left(\frac{m_1 + m_2}{m_1 m_3 E_1} - \frac{\mu}{\sqrt{m_1 E_1 m_3 E_3}}\right)}\right\} \qquad (27a)$$

which does not diverge at $E_3 \rightarrow 0$.

The uncertainty in the atomic mass of lithium as given by Li, Whaling, Fowler, and Lauritsen[4] is 0.000026 mass unit. This is so much smaller than an uncertainty of one electron mass, which is 0.00055 mass unit, that we will concentrate attention on effects possibly ascribable to the number of electrons carried by the recoil berylluim.

A complete treatment of the electron problem undoubtedly would remove the reaction from the category of two-body reactions. We will assume the reaction remains a two-body type. This means we insist on retaining equation (5), $Q = m_1 + m_2 - m_3 - m_4$, no matter how the number of electrons carried by recoil particles of mass m_4 may vary. In turn this means that for a recoil of a given ionization, say Be^{+++}, the target atom must be considered always to have one less unit of charge, e.g., Li^{++}, in order that charge and mass be conserved when the recoil occurs with any particular state of ionization.

We assume that the threshold for loss of an electron by a recoil atom of mass m_4, velocity v_4, energy E_4 is at that velocity for which $v_4 = v_e$, if v_e is the velocity of the electron.[6] Then, if E_e is the ionization potential for loss of an electron, we find that an electron will be lost if

$$E_4 > \frac{m_4}{m_e} E_e \quad . \tag{31}$$

Since E_1 and E_3 are given in the tables, it is convenient to define

$$E_{13} = E_1 - E_3 = E_4 - Q$$

In the following tabulation, states of ionization of Be are tabulated together with corresponding ionizations for the Li, and the ranges of E_4 and E_{13} within which these ionization states should apply on the basis of the above assumption:

Be^{+}	Li^{0}	$0 < E_4 < 0.23$	$1.65 < E_{13} < 1.88$
Be^{++}	Li^{+}	$0.23 < E_4 < 1.96$	$1.88 < E_{13} < 3.60$
Be^{+++}	Li^{++}	$1.96 < E_4 < 2.77$	$3.60 < E_{13} < 4.42$
Be^{++++}	Li^{+++}	$2.77 < E_4$	$4.42 < E_{13}$

A survey of the tables will show that the zero degree data (for which only the higher energy group is tabulated in the double-energy region below 1.9217 Mev) should use the mass of neutral lithium, Li^0, the 60° data that for Li^+, and the 120° data that for Li^+ up to 6.5 Mev, then Li^{++} up to 8.75 Mev, and finally Li^{+++} above 8.75 Mev proton energy.*

*The values of m_2 actually used in computation are discussed in Section VI on numerical values and results.

To how much error does a change of one electron mass in the mass m_2 correspond? If the error were made in mis-assigning m_2 in determining threshold, then $(dz/dm_2)_{Eft}$ the derivative in equation (30) should be used because the fixed value E_{ft} applies and Q is a function of m_2. If the error were due to a change in the value of m_2 that should be used from that which applies at threshold calibration, then the derivative $(dz/dm_2)_Q$ should be used from equation (29), because once established, Q is not varied.

The following tabulation presents results of some calculations of ΔE_3 (for Δm_2 = 0.00055 for Li^7 (p, n) Be^7), representative of the magnitude of errors to be expected. Usually they are less than 10 ev or 0.01%. They are considerably less than the Doppler broadening.

It is certain that the above mechanical interpretation of the meaning of a change of number of electrons carried by the recoil is not strictly correct. It is probable however, that the results of this calculation give an order of magnitude estimate of the spreading in neutron energy resulting from sharing of recoil momentum in the reaction by the electrons in the atoms with the recoil nucleus. If this is true, then the results may be interpreted, at least, as meaning that this type of phenomenon is an order of magnitude less important than the Doppler effect.

$\theta = 0°$			$\theta = 60°$			$\theta = 120°$		
E_3	ΔE_{3Q}	ΔE_{3ft}	E_3	ΔE_{3Q}	ΔE_{3ft}	E_3	ΔE_{3Q}	ΔE_{3ft}
121,400 ev	+21 ev	− 7 ev						
135,560	+19	− 8	43,290 ev	+28 ev	+ 4 ev	1,120 ev	+ 5 ev	+ 2 ev
181,900	+16	− 8	82,130	+23	+ 3	12,200	+ 12	+ 4
348,520	+10	−11	218,610	+20	+ 1	81,470	+ 19	+ 8
1,005,020	+ 4	−14	771,820	+21	+ 4	451,040	+ 35	+ 23
2.018 Mev	− 2 ev	−19 ev	1.641 Mev	+20 ev	+11 ev	1.0795 Mev	+ 58 ev	+ 44 ev
4.035	− 2	−19	3.379	+47	+30	2.365	+ 77	+ 64
8.346	− 3	−48	7.103	+68	+55	5.138	+185	+165

In the above tabulation, ΔE_{3Q} represents ΔE_3 calculated by equation (29) for Q constant and ΔE_{3ft} the same for equation (30) where E_{ft} constant.

The above classical calculations agree only approximately with the results of a completely relativistic exact calculation made at T_1 = 10 Mev, where the deviations, on the whole, are the largest. The following tabulation gives the results of this exact calculation made using equations (6), (7), (13), (14), (16a), (18), and (19).

		State of Ionization Determining Mass of Target			
θ		Li^0	Li^+	Li^{++}	Li^{+++}
0°	Li^0	8.346481	8.346501	8.346522	8.346542
	Li^+	8.346475	8.346496	8.346516	8.346536
60°	Li^0	7.103224	7.103153	7.103081	7.103009
	Li^+	7.103218	7.103148	7.103076	7.103004
120°	Li^0	5.137981	5.137798	5.137613	5.137429
	Li^+	5.137977	5.137793	5.137609	5.137425

The first column gives the angle, θ, at which the neutrons are observed. The second column gives the two choices used in determining the effective mass m_2 at threshold by which in turn Q is determined. The next four columns give the neutron energies for the four possible choices of ionization determining m_2 for the reaction at $T_1 = 10$ Mev. It will be seen that the greatest possible change, percentagewise, is for the reaction at 120°, and is just about 0.01%.

It may be of interest to compare values of z, β_1, β_2, and β_3, etc., computed for the four possible values of lithium mass. The values, which were obtained for $T_1 = 10$ Mev, are given in this tabulation.

		Li^0	Li^+	Li^{++}	Li^{+++}
z	Li^0	38.323022	38.316911	38.310799	38.304690
	Li^+	38.322992	38.316881	38.310770	38.304660
β_2		0.99603004	0.99603013	0.99603022	0.99603031
β_3		0.9992319	0.9992320	0.9992320	0.9992320
β_1	0°	1.0033165	1.0033164	1.0033163	1.0033163
β_1	60°, 120°	1.0028122	1.0028120	1.0028119	1.0028117

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D. Angular Resolution - By use of equation (21a) we obtain

$$d E_3 / d\mu = 2 E_3 / \sqrt{\mu^2 + z} \tag{32}$$

It is simple to calculate the stringency of angular resolution demanded for any desired resolution at a given angle and energy. [Values of ΔE_3 for $\Delta\theta = 1°$ are given in the tables for 0°, 60°, and 120°. They were not, in fact, calculated by equation (32) but by calculating E_3 for one degree more and less than the given angle and tabulating one half the difference. The result agrees closely with equation (32).]

E. Target Thickness and Beam Energy Spread - Analytically, these two effects enter in the same way, since they determine the range of values of E_1 at the moment when the neutron producing reaction occurs. Normally the energy spread in the beam may be held in the range of 0.1% to 0.01% by a high resolution beam analyzer and a very stable accelerating machine. Lithium targets may be prepared which are as thin as may be warranted. The thinnest that may justifiably be used, presuming that the neutron flux produced is not the limiting factor, is such a thickness that the spread in neutron energy thereby resulting is about the same as that resulting from the combined effects of Doppler broadening and energy spread in the proton beam itself.

Expressions for $d E_3 / d E_1$ may be written in a number of forms by suitable substitutions after differentiation of equation (21a). Some of these are:

$$\frac{d E_3}{d E_1} = \frac{E_3}{E_1} + \frac{E_3 E_{bt} (m_1 + m_2)(m_2 - m_3)}{E_1^2 (\mu + \sqrt{\mu^2 + z}) \sqrt{\mu^2 + z}} \tag{33a}$$

$$= \frac{E_3}{E_1} + \sqrt{\frac{E_3}{E_1}} \frac{E_{bt}}{E_1} \frac{(m_2 - m_3)}{\sqrt{m_1 m_3} \sqrt{\mu^2 + z}} \tag{33b}$$

$$= \frac{\sqrt{E_3 / E_1}}{\sqrt{\mu^2 + z}} \left\{ \mu \sqrt{E_3 / E_1} + (m_2 - m_3) / \sqrt{m_1 m_3} \right\} \tag{33c}$$

The form (33c) is particularly suited to show that the resolution is in general better at back-angles than forward, and that at low energy in the back direction, better resolution is attainable than a naive view suggests. As $E_3 \rightarrow 0$ at $\mu = -1/2$, for example, one finds $\Delta E_3 / E_3 \rightarrow 12 \Delta E_1 / \sqrt{E_1 E_3}$. If, for example, $\Delta E_1 = 2000$ ev and $E_3 = 300$, one finds $\Delta E_3 / E_3 \cong 1$. Hence one may make measurements almost down to 300 ev neutron energy before the resolution width is as wide as the distance from zero to the energy setting desired for E_3, with a spread in energy E_1 due to target and beam control of only this 2000 ev.

F. Considerations with Respect to Q - If, instead of using $T_{ft} = 1.882$ as the basic input energy, one wishes to use a Q value obtained, for example, by adjustment from other nuclear data, confusion will be avoided if, from this Q value, new values of T_{ft} and T_{bt} are calculated by equations (6) and (7), and these values used in the neutron energy calculation and in the proton energy calibration.

G. Uncertainty in Neutron Energy Resulting from Limited Accuracy of the Threshold Energy; Correction to a New Value of T_{ft}.—In equation (18), the value of z is determined (aside from mass values used) only by the ratio T_{bt}/T_1, and hence the value of z is practically independent of the absolute scale of energy, but experimentally z is limited in accuracy of determination only by the sensitivity and linearity of the voltage measuring system.* In equation (16) the relativity corrections are not very sensitive to small changes in T_1. However, T_3 is linearly related to the value of T_1 which is the leading term on the right side of equation (16). If, then, as is the normal practice, one calibrates the voltage scale for $Li^7(p, n)Be^7$ neutron work against the forward threshold measurements, this value of T_1 is linearly dependent on the value of T_{ft} used.

It is apparent, therefore, that if a new value of T_{ft} is adopted, the present tables can be used by looking up T_3 for a value of T_1, calculated assuming that $T_{ft} = 1.88200$, then multiplying the value of T_3 so found by the ratio of the new T_{ft} to 1.882.

H. Solid Angle Relations Between Intensity of Neutrons in the Laboratory and Center of Mass System - The relativistic relation for this ratio probably is not simply related to the relativistic values of T_1, T_3, etc. However, a simple relation may be found in the classical calculation of this ratio. It is:

$$\frac{I_\ell}{I_{cm}} = \frac{(m_1 + m_2)\,[m_1 m_3 (z + 1) - m_2 m_4]\,E_3}{m_1 m_3 m_4 Q \sqrt{z + 1}\,\sqrt{\mu^2 + z}}$$

which may conveniently be calculated by aid of values of z and E_3 from the tables. The above equation is derived from the relations given by Hanson et al.(3) Here I_ℓ is the intensity per unit solid angle in the laboratory at an angle θ, and I_{cm} is the intensity per unit solid angle in the center of mass system at angle θ_{cm}.

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*Absolute voltage calculations for both electrostatic and magnetic beam energy analyzers may be expected to require relativistic corrections for accuracies approaching 0.01%, since this is a nonlinear correction.

It may be of interest to perform activation experiments at the lowest possible energies. At low enough energies, I_{cm} is probably nearly a constant for Li^7 (p, n) Be^7. If, in addition, one specifies the resolution ΔE_3 desired, one may use equation (32) to find $\Delta E_3 = -2 \sin\theta \cdot \Delta\theta / \sqrt{\mu^2 + z}$, by aid of which we obtain:

$$I_{\ell} \Delta \Omega_{\ell} = \frac{(m_1 + m_2)\,[m_2 m_4 - m_1 m_3 (z + 1)]\, \Delta E_3 \Delta \phi}{2\, m_1 m_3 m_4\, Q \sqrt{z + 1}}$$

Qualitative consideration of this relation will show that if a foil be made in the shape of a ribbon wrapped around the full azimuth angle, the maximum intensity will be obtained at the smallest value of z that can be used, which means θ should be near 90° rather than near 180°. On the other hand, if a simple round foil is preferred, it should be used near 180° so that the flux can be a maximum consistent with the desired ΔE_3. This problem has not been analyzed quantitatively. (See reference (7) for other useful solid angle equations.)

IV. The Excited State in Be^7 and the Second Group of Neutrons from Li^7 (p, n) Be^7.*

Neutron energies from the reaction in which berylluim is left in its excited state were also calculated for 0°, 60°, and 120°, and appear in the tables after the data for the reaction to the ground state. This calculation was set up on the basis of a back-threshold E_{bt} = 2.4234 Mev and assuming the mass of lithium corresponding to Li^+. The corresponding E_{ft} = 2.3733 Mev and Q = 2.0751, which correspond to the excited state in Be^7 being 0.4296 Mev above the ground state. It was intended to choose something a bit higher for E_{ft} and Q, but the above figures correspond to those actually adopted. The results are nevertheless probably accurate to three figures throughout most of the table. The tables are not as complete as the main tables, interpolation figures are not given, and not all data is so spaced that linear interpolation can always be correct. The general method of computation was the same as for the main tables. That is, the fully relativistic equation was employed.

V. Description of the Tables

Table I gives neutron energies for the Li^7 (p, n)Be^7 reaction to the ground state of Be^7. Table II gives similar data for the reaction to the excited state of Be^7 at 430 kev. Both tables also give values of $z\beta_3$ and $z\beta_2$, as well as the neutron energies at θ = 0°, 60°, and 120°.

Column 1. Proton energies, T_p (= T_1 in theory). Between values of T_p lie values of the increment, ΔT_p, as an aid to interpolation.

Column 2. Neutron energies, T_n (0°) (= T_3 in theory). Between values of T_n (0°) lie values of the increment ΔT_n (0°).

Column 3. The decrease in neutron energy on changing from 0° to 1°, ΔT_n (0°, 1°) = T_n (0°) - T_n (1°).

Column 4. The neutron energy T_n (60°) at 60° and the increments.

Column 5. The quantity $\frac{1}{2}$ [T_n (59°) - T_n (61°)] = $\frac{1}{2}\Delta T_n$ (59°, 61°) is the mean differential of neutron energy for a change in angle of one degree at 60°.

Column 6. As columns 2 and 4, but for neutrons at 120°; thus, T_n (120°).

Column 7. Similarly to column 5, this gives $\frac{1}{2}$ [T_n (119°) - T_n (121°)] = $\frac{1}{2}$ ΔT_n (119°, 121°).

Column 8. Values of $z\beta_2$.

Column 9. Values of $z\beta_3$.

In Table II, columns 3, 5, and 7 are omitted. In Table I, the tabular values are so spaced that linear interpolation is accurate throughout. This is not always true for Table II.

For negative values of z, there are two neutron groups (at 0° and at 60° when neutrons appear at 60°). The tables only give the energy of the higher energy group.

The values of $z\beta_2$ and $z\beta_3$ are useful in calculations of T_n for angles not tabulated. Since β_3 is almost constant with the value 0.999233 (± 1 in the last figure between threshold and 10 Mev), z may easily be obtained from the tabulated values of $z\beta_3$, if desired.

The angular increment data in columns 3, 5, and 7 permits simple estimate of the energy resolution of experimental detection methods subtending angles up to a few degrees, and correction of mean energy for a setting deviating slightly from an intended setting of an even value of 60° or 120°.

Details concerning the values of m_2 (corresponding to the lithium target being Li^0, Li^+, Li^{++}, or Li^{+++}) which were actually used for the tabulated values in the tables are given in Section VI below. (See also Section III C above.)

Table I is intended only to be accurate to 0.01% or 10 ev, whichever is larger. Table II is not warranted to be more accurate than about 0.1%. The tables are not, however, rounded off to the number of significant figures the above accuracy implies. The extra figures may be used with caution as a significant indication of the small difference in neutron energy for closely spaced values of T_1, but not otherwise.

Values of T_n (60°) in Table I are not tabulated quite all the way down to the 60° threshold. In Table II, T_n (0°) is not tabulated quite down to threshold which is 2.3733 Mev, nor is T_n (60°) tabulated below the threshold for T_n (120°).

VI. Numerical Values Used in the Computation and Some Numerical Results

Basic input data is:

m_1, proton mass = 1.007594 mass units
m_3, neutron mass = 1.008982
T_{ft}, main group forward threshold = 1.88200
T_{bt}, second group back-threshold = 2.4234
m_e, mass of electron = 0.000548 mass unit
Conversion factor, mass units to Mev = 931.152
m_2, mass of neutral lithium = 7.018223

Some derived quantities* are:

m_2 for Li^+ = 7.017675
m_2 for Li^{++} = 7.017127

	Calculated with m_2 for Li^+	Calculated with m_2 for Li^{++}
Q for main group	1.645529	1.645512
Q′ for second group	2.07505	
T_{bt} for main group	1.9217082	1.9217145
T'_{ft} for second group	2.3733	
β_3 for main group (calc. by equation (19a))	0.9992343	0.9992343

The tabulated values of $z\beta_2$ and $z\beta_3$ were calculated for a threshold m_2 of Li^+ and an m_2 of Li^+ up through T_1 = 6.45 Mev. At 6.5 Mev for T_1 and above, the threshold m_2 seems to be still that of Li^+ and the m_2 for the energy concerned, that of Li^{++}. The value of $z\beta_2$ or $z\beta_3$ above 6.45 Mev and for a mass m_2 of Li^+ may be obtained to the third decimal place by adding 0.006 to the tabulated values.

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*In some cases more figures are given than are significant. This is done to show how slight an effect a change in m_2 has in the computed result.

In the actual I.B.M. calculations all the neutron energies were calculated using the above values of $z\beta_2$ and $z\beta_3$ for m_2 of Li^+ up through 6.45 Mev for T_1, and m_2 of Li^{++} at and above 6.50 Mev. This is not consistent with the theory of Section III C, but will be accurate to the intended 0.01%.

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VIII. Acknowledgements

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Table I

T_p	$T_n(0°)$	$\Delta T_n(0°, 1°)$	$T_n(60°)$	$\frac{1}{2}\Delta T_n(59°, 61°)$	$T_n(120°)$	$\frac{1}{2}\Delta T_n(119°, 121°)$	$z\beta_2$	$z\beta_3$
1.882000	.02992						- 1.00001	- .99999
.000500	.00694							
1.882500	.03686	.00010					- .98715	- .98714
.000500	.00318							
1.883000	.04004	.00007					- .97431	- .97429
.000500	.00254							
1.883500	.04258	.00007					- .96146	- .96145
.000500	.00220							
1.884000	.04478	.00006					- .94863	- .94862
.000500	.00198							
1.884500	.04676	.00005					- .93580	- .93579
.000500	.00183							
1.885000	.04859	.00005					- .92298	- .92297
.000500	.00172							
1.885500	.05031	.00005					- .91017	- .91016
.000500	.00163							
1.886000	.05194	.00005					- .89736	- .89735
.000500	.00155							
1.886500	.05349	.00005					- .88456	- .88455
.000500	.00149							
1.887000	.05498	.00005					- .87177	- .87176
.000500	.00143							
1.887500	.05641	.00005					- .85898	- .85897
.000500	.00139							
1.888000	.05780	.00005					- .84620	- .84619
.000500	.00135							
1.888500	.05915	.00005					- .83343	- .83342
.000500	.00131							
1.889000	.06046	.00004					- .82067	- .82065
.000500	.00128							
1.889500	.06174	.00004					- .80791	- .80790
.000500	.00125							
1.890000	.06299	.00004					- .79515	- .79514
.000500	.00123							
1.890500	.06422	.00004					- .78241	- .78240
.000500	.00120							
1.891000	.06542	.00004					- .76967	- .76966
.000500	.00118							
1.891500	.06660	.00004					- .75694	- .75693
.000500	.00116							
1.892000	.06776	.00004					- .74421	- .74420
.000500	.00114							
1.892500	.06890	.00004					- .73149	- .73148
.000500	.00112							
1.893000	.07002	.00004					- .71878	- .71877
.000500	.00111							
1.893500	.07113	.00004					- .70607	- .70607
.000500	.00109							
1.894000	.07222	.00004					- .69338	- .69337

.000500	.00108					
1.894500	.07330	.00004	-	.68068	-	.68068
.000500	.00106					
1.895000	.07436	.00004	-	.66800	-	.66799
.000500	.00106					
1.895500	.07542	.00004	-	.65532	-	.65531
.000500	.00103					
1.896000	.07645	.00003	-	.64265	-	.64264
.000500	.00103					
1.896500	.07748	.00004	-	.62998	-	.62998
.000500	.00102					
1.897000	.07850	.00004	-	.61732	-	.61732
.000500	.00101					
1.897500	.07951	.00004	-	.60467	-	.60466
.000500	.00100					
1.898000	.08051	.00004	-	.59202	-	.59202
.000500	.00099					
1.898500	.08150	.00004	-	.57939	-	.57938
.000500	.00098					
1.899000	.08248	.00004	-	.56676	-	.56675
.000500	.00097					
1.899500	.08345	.00004	-	.55413	-	.55413
.000500	.00096					
1.900000	.08441	.00004	-	.54151	-	.54151
.000500	.00096					
1.900500	.08537	.00004	-	.52890	-	.52890
.000500	.00095					
1.901000	.08632	.00004	-	.51629	-	.51629
.000500	.00094					
1.901500	.08726	.00004	-	.50370	-	.50369
.000500	.00093					
1.902000	.08819	.00003	-	.49110	-	.49110
.000500	.00093					
1.902500	.08912	.00004	-	.47852	-	.47852
.000500	.00092					
1.903000	.09004	.00003	-	.46594	-	.46594
.000500	.00092					
1.903500	.09096	.00004	-	.45337	-	.45336
.000500	.00091					
1.904000	.09187	.00004	-	.44080	-	.44080
.000500	.00090					
1.904500	.09277	.00003	-	.42824	-	.42824
.000500	.00090					
1.905000	.09367	.00003	-	.41569	-	.41569
.000500	.00090					
1.905500	.09457	.00004	-	.40315	-	.40314
.000500	.00089					
1.906000	.09546	.00004	-	.39060	-	.39060
.000500	.00088					
1.906500	.09634	.00004	-	.37807	-	.37807
.000500	.00088					
1.907000	.09722	.00004	-	.36555	-	.36554
.000500	.00087					
1.907500	.09809	.00004	-	.35303	-	.35303
.000500	.00087					
1.908000	.09896	.00004	-	.34052	-	.34051

Table I (Cont'd)

T_p	$T_n(0°)$	$\Delta T_n(0°, 1°)$	$T_n(60°)$	$½\Delta T_n(59°, 61°)$	$T_n(120°)$	$½\Delta T_n(119°, 121°)$	$z\beta_2$	$z\beta_3$
.000500	.00087							
1.908500	.09983	.00004					- .32801	- .32801
.000500	.00086							
1.909000	.10069	.00004					- .31551	- .31551
.000500	.00085							
1.909500	.10154	.00003					- .30302	- .30301
.000500	.00086							
1.910000	.10240	.00004					- .29053	- .29053
.000500	.00084							
1.910500	.10324	.00003					- .27805	- .27805
.000500	.00085							
1.911000	.10409	.00004					- .26558	- .26558
.000500	.00084							
1.911500	.10493	.00004					- .25311	- .25311
.000500	.00084							
1.912000	.10577	.00004	.01075				- .24065	- .24065
.000500	.00083		.00192					
1.912500	.10660	.00004	.01267	.00270			- .22819	- .22819
.000500	.00083		.00151					
1.913000	.10743	.00003	.01418	.00235			- .21575	- .21575
.000500	.00083		.00132					
1.913500	.10826	.00004	.01550	.00218			- .20330	- .20330
.000500	.00082		.00120					
1.914000	.10908	.00003	.01670	.00208			- .19087	- .19087
.000500	.00082		.00111					
1.914500	.10990	.00003	.01781	.00202			- .17845	- .17844
.000500	.00082		.00106					
1.915000	.11072	.00004	.01887	.00197			- .16602	- .16602
.000500	.00082		.00100					
1.915500	.11154	.00004	.01987	.00194			- .15361	- .15360
.000500	.00081		.00097					
1.916000	.11235	.00004	.02084	.00191			- .14120	- .14120
.000500	.00080		.00093					
1.916500	.11315	.00003	.02177	.00189			- .12880	- .12880
.000500	.00081		.00091					
1.917000	.11396	.00004	.02268	.00188			- .11640	- .11640
.000200	.00032		.00036					
1.917200	.11428	.00004	.02304	.00187			- .11145	- .11145
.000200	.00032		.00035					
1.917400	.11460	.00003	.02339	.00187			- .10649	- .10649
.000200	.00032		.00035					
1.917600	.11492	.00003	.02374	.00187			- .10154	- .10154
.000200	.00032		.00034					
1.917800	.11524	.00003	.02408	.00186			- .09658	- .09658
.000200	.00032		.00035					
1.918000	.11556	.00003	.02443	.00186			- .09163	- .09163
.000200	.00032		.00034					
1.918200	.11588	.00003	.02477	.00186			- .08668	- .08668
.000200	.00032		.00033					
1.918400	.11620	.00004	.02510	.00185			- .08173	- .08173
.000200	.00032		.00034					
1.918600	.11652	.00004	.02544	.00185			- .07678	- .07678
.000200	.00032		.00033					
1.918800	.11684	.00004	.02577	.00185			- .07183	- .07183
.000200	.00032		.00033					
1.919000	.11716	.00004	.02610	.00185			- .06689	- .06689

.000200	.00031		.00032					
1.919200	.11747	.00003	.02642	.00184	-	.06194	-	.06194
.000200	.00032		.00033					
1.919400	.11779	.00004	.02675	.00184	-	.05699	-	.05699
.000200	.00032		.00032					
1.919600	.11811	.00004	.02707	.00184	-	.05205	-	.05205
.000200	.00031		.00032					
1.919800	.11842	.00004	.02739	.00184	-	.04711	-	.04711
.000200	.00032		.00032					
1.920000	.11874	.00004	.02771	.00184	-	.04216	-	.04216
.000200	.00031		.00031					
1.920200	.11905	.00003	.02802	.00184	-	.03722	-	.03722
.000200	.00032		.00032					
1.920400	.11937	.00004	.02834	.00184	-	.03228	-	.03228
.000200	.00031		.00031					
1.920600	.11968	.00004	.02865	.00184	-	.02734	-	.02734
.000200	.00032		.00031					
1.920800	.12000	.00004	.02896	.00184	-	.02240	-	.02240
.000200	.00031		.00031					
1.921000	.12031	.00004	.02927	.00184	-	.01747	-	.01747
.000050	.00008		.00008					
1.921050	.12039	.00004	.02935	.00184	-	.01623	-	.01623
.000050	.00008		.00007					
1.921100	.12047	.00004	.02942	.00184	-	.01500	-	.01500
.000050	.00007		.00008					
1.921150	.12054	.00003	.02950	.00183	-	.01377	-	.01377
.000050	.00008		.00008					
1.921200	.12062	.00003	.02958	.00184	-	.01253	-	.01253
.000050	.00008		.00007					
1.921250	.12070	.00004	.02965	.00184	-	.01130	-	.01130
.000050	.00008		.00008					
1.921300	.12078	.00004	.02973	.00184	-	.01007	-	.01007
.000050	.00008		.00008					
1.921350	.12086	.00004	.02981	.00184	-	.00883	-	.00883
.000050	.00008		.00007					
1.921400	.12094	.00004	.02988	.00184	-	.00760	-	.00760
.000050	.00007		.00008					
1.921450	.12101	.00003	.02996	.00184	-	.00637	-	.00637
.000050	.00008		.00008					
1.921500	.12109	.00004	.03004	.00184	-	.00513	-	.00513
.000010	.00002		.00001					
1.921510	.12111	.00004	.03005	.00183	-	.00488	-	.00488
.000010	.00001		.00002					
1.921520	.12112	.00003	.03007	.00184	-	.00464	-	.00464
.000010	.00002		.00001					
1.921530	.12114	.00004	.03008	.00183	-	.00439	-	.00439
.000010	.00001		.00002					
1.921540	.12115	.00003	.03010	.00184	-	.00414	-	.00414
.000010	.00002		.00001					
1.921550	.12117	.00004	.03011	.00184	-	.00390	-	.00390
.000010	.00002		.00002					
1.921560	.12119	.00004	.03013	.00184	-	.00365	-	.00365
.000010	.00001		.00001					
1.921570	.12120	.00004	.03014	.00184	-	.00340	-	.00340
.000010	.00002		.00002					
1.921580	.12122	.00004	.03016	.00184	-	.00316	-	.00316

Table I (Cont'd)

T_p	$T_n(0°)$	$\Delta T_n(0°, 1°)$	$T_n(60°)$	$½\Delta T_n(59°, 61°)$	$T_n(120°)$	$½\Delta T_n(119°, 121°)$	$z\beta_2$	$z\beta_3$
.000010 1.921590	.00001 .12123	.00004	.00001 .03017	.00184			- .00291	- .00291
.000010 1.921600	.00002 .12125	.00004	.00002 .03019	.00184			- .00266	- .00266
.000010 1.921610	.00001 .12126	.00003	.00001 .03020	.00184			- .00242	- .00242
.000010 1.921620	.00002 .12128	.00004	.00002 .03022	.00184			- .00217	- .00217
.000010 1.921630	.00001 .12129	.00003	.00001 .03023	.00184			- .00192	- .00192
.000010 1.921640	.00002 .12131	.00004	.00002 .03025	.00184			- .00168	- .00168
.000010 1.921650	.00002 .12133	.00004	.00001 .03026	.00184			- .00143	- .00143
.000010 1.921660	.00001 .12134	.00004	.00002 .03028	.00184			- .00119	- .00119
.000010 1.921670	.00002 .12136	.00004	.00001 .03029	.00184			- .00094	- .00094
.000010 1.921680	.00001 .12137	.00003	.00002 .03031	.00184			- .00069	- .00069
.000010 1.921690	.00002 .12139	.00004	.00001 .03032	.00184			- .00045	- .00045
.000010 1.921700	.00001 .12140	.00003	.00002 .03034	.00184			- .00020	- .00020
.000002 1.921702	.00001 .12141	.00004	.00000 .03034	.00184			- .00015	- .00015
.000002 1.921704	.00000 .12141	.00004	.00001 .03035	.00184			- .00010	- .00010
.000002 1.921706	.00000 .12141	.00003	.00000 .03035	.00184			- .00005	- .00005
.000002 1.921708	.00001 .12142	.00004	.00000 .03035	.00183	.00000		.00000	.00000
.000002 1.921710	.00000 .12142	.00004	.00000 .03035	.00184	.00000 .00000	.00000	.00005	.00005
.000002 1.921712	.00000 .12142	.00003	.00001 .03036	.00184	.00000 .00000	.00000	.00010	.00010
.000002 1.921714	.00001 .12143	.00004	.00000 .03036	.00184	.00000 .00000	.00000	.00015	.00015
.000002 1.921716	.00000 .12143	.00004	.00000 .03036	.00184	.00000 .00000	.00000	.00020	.00020
.000002 1.921718	.00000 .12143	.00004	.00001 .03037	.00184	.00000 .00000	.00000	.00025	.00025
.000002 1.921720	.00000 .12143	.00003	.00000 .03037	.00184	.00000 .00000	.00000	.00029	.00029
.000010 1.921730	.00002 .12145	.00004	.00001 .03038	.00184	.00000 .00000	.00000	.00054	.00054
.000010 1.921740	.00002 .12147	.00004	.00002 .03040	.00184	.00000 .00000	.00000	.00079	.00079
.000010 1.921750	.00001 .12148	.00004	.00002 .03042	.00184	.00000 .00000	.00000	.00104	.00104
.000010 1.921760	.00002 .12150	.00004	.00001 .03043	.00184	.00000 .00000	.00000	.00128	.00128
.000010 1.921770	.00001 .12151	.00003	.00002 .03045	.00184	.00000 .00000	.00000	.00153	.00153
.000010 1.921780	.00002 .12153	.00004	.00001 .03046	.00184	.00000 .00000	.00000	.00178	.00178

.000010	1.921790	.00001	.12154	.00003	.00002	.03048	.00184	.00000	.00000	.00000	.00202	.00202
.000010	1.921800	.00002	.12156	.00004	.00001	.03049	.00184	.00000	.00000	.00000	.00227	.00227
.000050	1.921850	.00008	.12164	.00004	.00008	.03057	.00184	.00000	.00000	.00000	.00350	.00350
.000050	1.921900	.00008	.12172	.00004	.00007	.03064	.00184	.00000	.00000	.00000	.00474	.00474
.000050	1.921950	.00007	.12179	.00003	.00008	.03072	.00184	.00000	.00000	.00000	.00597	.00597
.000050	1.922000	.00008	.12187	.00004	.00007	.03079	.00184	.00000	.00000	.00000	.00720	.00720
.001000	1.923000	.00155	.12342	.00003	.00149	.03228	.00184	.00003	.00003	.00000	.03185	.03185
.001000	1.924000	.00155	.12497	.00004	.00145	.03373	.00184	.00006	.00009	.00001	.05646	.05646
.001000	1.925000	.00154	.12651	.00004	.00143	.03516	.00185	.00008	.00017	.00001	.08105	.08105
.001000	1.926000	.00152	.12803	.00003	.00140	.03656	.00185	.00011	.00028	.00002	.10562	.10562
.001000	1.927000	.00152	.12955	.00003	.00138	.03794	.00186	.00013	.00041	.00003	.13016	.13016
.001000	1.928000	.00152	.13107	.00004	.00137	.03931	.00187	.00015	.00056	.00003	.15468	.15468
.001000	1.929000	.00150	.13257	.00004	.00134	.04065	.00188	.00017	.00073	.00004	.17916	.17917
.001000	1.930000	.00150	.13407	.00004	.00133	.04198	.00189	.00019	.00092	.00004	.20363	.20363
.001000	1.931000	.00149	.13556	.00004	.00131	.04329	.00189	.00020	.00112	.00005	.22807	.22807
.001000	1.932000	.00148	.13704	.00003	.00130	.04459	.00190	.00021	.00133	.00006	.25248	.25248
.001000	1.933000	.00148	.13852	.00004	.00129	.04588	.00191	.00023	.00156	.00006	.27687	.27687
.001000	1.934000	.00147	.13999	.00003	.00127	.04715	.00192	.00024	.00180	.00007	.30123	.30123
.001000	1.935000	.00147	.14146	.00004	.00127	.04842	.00193	.00025	.00205	.00008	.32557	.32557
.001000	1.936000	.00146	.14292	.00004	.00125	.04967	.00194	.00025	.00230	.00009	.34988	.34988
.001000	1.937000	.00145	.14437	.00004	.00124	.05091	.00195	.00027	.00257	.00010	.37417	.37417
.001000	1.938000	.00145	.14582	.00004	.00124	.05215	.00196	.00028	.00285	.00011	.39843	.39844
.001000	1.939000	.00144	.14726	.00004	.00122	.05337	.00197	.00029	.00314	.00012	.42267	.42267
.001000	1.940000	.00144	.14870	.00004	.00122	.05459	.00198	.00029	.00343	.00013	.44689	.44689
.001000	1.941000	.00143	.15013	.00004	.00121	.05580	.00199	.00031	.00374	.00013	.47107	.47107
.001000	1.942000	.00143	.15156	.00004	.00120	.05700	.00200	.00031	.00405	.00014	.49523	.49524
.001000	1.943000	.00142	.15298	.00004	.00120	.05820	.00201	.00032	.00437	.00015	.51937	.51938
.001000	1.944000	.00142	.15440	.00004	.00119	.05939	.00202	.00032	.00469	.00016	.54349	.54349

Table I (Cont'd)

T_p	$T_n(0°)$	$\Delta T_n(0°, 1°)$	$T_n(60°)$	$\frac{1}{2}\Delta T_n(59°, 61°)$	$T_n(120°)$	$\frac{1}{2}\Delta T_n(119°, 121°)$	$z\beta_2$	$z\beta_3$
.001000	.00141		.00118		.00033			
1.945000	.15581	.00004	.06057	.00203	.00502	.00017	.56757	.56758
.001000	.00141		.00118		.00034			
1.946000	.15722	.00004	.06175	.00204	.00536	.00018	.59163	.59164
.001000	.00140		.00117		.00034			
1.947000	.15862	.00003	.06292	.00205	.00570	.00019	.61567	.61568
.001000	.00140		.00116		.00034			
1.948000	.16002	.00003	.06408	.00206	.00604	.00019	.63969	.63969
.001000	.00140		.00116		.00036			
1.949000	.16142	.00004	.06524	.00206	.00640	.00020	.66368	.66369
.001000	.00139		.00116		.00036			
1.950000	.16281	.00004	.06640	.00208	.00676	.00021	.68764	.68765
.001000	.00139		.00115		.00036			
1.951000	.16420	.00004	.06755	.00209	.00712	.00022	.71158	.71159
.001000	.00138		.00115		.00037			
1.952000	.16558	.00004	.06870	.00209	.00749	.00023	.73550	.73550
.001000	.00138		.00114		.00037			
1.953000	.16696	.00004	.06984	.00210	.00786	.00024	.75939	.75940
.001000	.00138		.00113		.00037			
1.954000	.16834	.00004	.07097	.00211	.00823	.00025	.78325	.78326
.001000	.00137		.00114		.00038			
1.955000	.16971	.00004	.07211	.00212	.00861	.00025	.80710	.80711
.001000	.00137		.00112		.00039			
1.956000	.17108	.00004	.07323	.00213	.00900	.00027	.83091	.83093
.001000	.00136		.00113		.00039			
1.957000	.17244	.00004	.07436	.00214	.00939	.00027	.85471	.85472
.001000	.00136		.00112		.00039			
1.958000	.17380	.00004	.07548	.00215	.00978	.00028	.87847	.87849
.001000	.00136		.00112		.00039			
1.959000	.17516	.00004	.07660	.00216	.01017	.00029	.90222	.90223
.001000	.00135		.00111		.00040			
1.960000	.17651	.00003	.07771	.00217	.01057	.00030	.92594	.92595
.001000	.00136		.00111		.00041			
1.961000	.17787	.00004	.07882	.00218	.01098	.00031	.94964	.94965
.001000	.00134		.00111		.00040			
1.962000	.17921	.00003	.07993	.00219	.01138	.00031	.97331	.97333
.001000	.00135		.00110		.00041			
1.963000	.18056	.00004	.08103	.00220	.01179	.00032	.99695	.99697
.001000	.00134		.00110		.00041			
1.964000	.18190	.00004	.08213	.00221	.01220	.00033	1.02058	1.02060
.001000	.00134		.00110		.00042			
1.965000	.18324	.00004	.08323	.00221	.01262	.00034	1.04418	1.04420
.001000	.00134		.00110		.00042			
1.966000	.18458	.00004	.08433	.00222	.01304	.00035	1.06776	1.06778
.001000	.00133		.00109		.00042			
1.967000	.18591	.00004	.08542	.00223	.01346	.00036	1.09131	1.09133
.001000	.00133		.00109		.00042			
1.968000	.18724	.00004	.08651	.00224	.01388	.00036	1.11484	1.11486
.001000	.00133		.00108		.00043			
1.969000	.18857	.00004	.08759	.00225	.01431	.00037	1.13834	1.13836
.001000	.00132		.00109		.00043			
1.970000	.18989	.00004	.08868	.00226	.01474	.00038	1.16182	1.16184
.001000	.00132		.00108		.00043			
1.971000	.19121	.00004	.08976	.00227	.01517	.00039	1.18527	1.18530
.001000	.00132		.00108		.00043			
1.972000	.19253	.00004	.09084	.00228	.01560	.00039	1.20871	1.20873

.001000	.00132		.00107		.00044			
1.973000	.19385	.00004	.09191	.00229	.01604	.00040	1.23212	1.23214
.001000	.00131		.00108		.00044			
1.974000	.19516	.00004	.09299	.00229	.01648	.00041	1.25550	1.25553
.001000	.00132		.00107		.00044			
1.975000	.19648	.00004	.09406	.00230	.01692	.00042	1.27886	1.27889
.001000	.00131		.00107		.00044			
1.976000	.19779	.00004	.09513	.00231	.01736	.00042	1.30220	1.30223
.001000	.00130		.00107		.00045			
1.977000	.19909	.00004	.09620	.00232	.01781	.00043	1.32551	1.32554
.001000	.00131		.00106		.00045			
1.978000	.20040	.00004	.09726	.00233	.01826	.00044	1.34880	1.34883
.001000	.00130		.00106		.00045			
1.979000	.20170	.00004	.09832	.00234	.01871	.00045	1.37207	1.37210
.001000	.00130		.00106		.00045			
1.980000	.20300	.00004	.09938	.00235	.01916	.00046	1.39531	1.39535
.001000	.00130		.00106		.00045			
1.981000	.20430	.00004	.10044	.00235	.01961	.00046	1.41853	1.41856
.001000	.00129		.00106		.00046			
1.982000	.20559	.00004	.10150	.00236	.02007	.00047	1.44173	1.44176
.001000	.00129		.00105		.00046			
1.983000	.20688	.00004	.10255	.00237	.02053	.00048	1.46490	1.46494
.001000	.00130		.00106		.00046			
1.984000	.20818	.00004	.10361	.00238	.02099	.00049	1.48805	1.48809
.001000	.00128		.00105		.00046			
1.985000	.20946	.00004	.10466	.00238	.02145	.00049	1.51117	1.51121
.001000	.00129		.00105		.00046			
1.986000	.21075	.00004	.10571	.00239	.02191	.00050	1.53428	1.53432
.001000	.00129		.00105		.00047			
1.987000	.21204	.00005	.10676	.00240	.02238	.00051	1.55736	1.55740
.001000	.00128		.00104		.00046			
1.988000	.21332	.00004	.10780	.00241	.02284	.00051	1.58042	1.58046
.001000	.00128		.00105		.00047			
1.989000	.21460	.00004	.10885	.00242	.02331	.00052	1.60345	1.60349
.001000	.00128		.00104		.00047			
1.990000	.21588	.00004	.10989	.00243	.02378	.00053	1.62646	1.62650
.001000	.00127		.00104		.00047			
1.991000	.21715	.00004	.11093	.00243	.02425	.00053	1.64944	1.64949
.001000	.00128		.00104		.00048			
1.992000	.21843	.00004	.11197	.00244	.02473	.00054	1.67241	1.67245
.001000	.00127		.00104		.00047			
1.993000	.21970	.00004	.11301	.00245	.02520	.00055	1.69535	1.69540
.001000	.00127		.00104		.00048			
1.994000	.22097	.00004	.11405	.00246	.02568	.00056	1.71827	1.71832
.001000	.00127		.00103		.00047			
1.995000	.22224	.00004	.11508	.00247	.02615	.00057	1.74116	1.74121
.001000	.00127		.00103		.00048			
1.996000	.22351	.00004	.11611	.00248	.02663	.00057	1.76403	1.76408
.001000	.00126		.00104		.00049			
1.997000	.22477	.00004	.11715	.00249	.02712	.00058	1.78688	1.78693
.001000	.00127		.00103		.00048			
1.998000	.22604	.00004	.11818	.00249	.02760	.00058	1.80971	1.80976
.001000	.00126		.00103		.00048			
1.999000	.22730	.00004	.11921	.00250	.02808	.00059	1.83251	1.83256
.001000	.00126		.00102		.00049			
2.000000	.22856	.00004	.12023	.00251	.02857	.00060	1.85529	1.85535

Table I (Cont'd)

T_p	$T_n(0°)$	$\Delta T_n(0°, 1°)$	$T_n(60°)$	$½\Delta T_n(59°, 61°)$	$T_n(120°)$	$½\Delta T_n(119°, 121°)$	$z\beta_2$	$z\beta_3$
.005000	.00627		.00512		.00244			
2.005000	.23483	.00004	.12535	.00255	.03101	.00063	1.96885	1.96891
.005000	.00624		.00509		.00248			
2.010000	.24107	.00004	.13044	.00258	.03349	.00067	2.08184	2.08192
.005000	.00620		.00506		.00250			
2.015000	.24727	.00004	.13550	.00262	.03599	.00070	2.19428	2.19436
.005000	.00616		.00504		.00253			
2.020000	.25343	.00004	.14054	.00266	.03852	.00073	2.30615	2.30624
.005000	.00614		.00501		.00255			
2.025000	.25957	.00005	.14555	.00270	.04107	.00076	2.41747	2.41757
.005000	.00609		.00499		.00258			
2.030000	.26566	.00004	.15054	.00273	.04365	.00079	2.52825	2.52836
.005000	.00607		.00496		.00260			
2.035000	.27173	.00004	.15550	.00277	.04625	.00082	2.63847	2.63859
.005000	.00605		.00495		.00262			
2.040000	.27778	.00005	.16045	.00281	.04887	.00085	2.74816	2.74829
.005000	.00601		.00493		.00263			
2.045000	.28379	.00004	.16538	.00284	.05150	.00089	2.85732	2.85746
.005000	.00599		.00491		.00266			
2.050000	.28978	.00004	.17029	.00287	.05416	.00091	2.96593	2.96609
.005000	.00597		.00489		.00267			
2.055000	.29575	.00005	.17518	.00291	.05683	.00094	3.07402	3.07419
.005000	.00594		.00488		.00268			
2.060000	.30169	.00004	.18006	.00294	.05951	.00098	3.18158	3.18176
.005000	.00592		.00486		.00270			
2.065000	.30761	.00004	.18492	.00297	.06221	.00100	3.28863	3.28882
.005000	.00590		.00485		.00272			
2.070000	.31351	.00004	.18977	.00301	.06493	.00103	3.39515	3.39535
.005000	.00588		.00484		.00273			
2.075000	.31939	.00004	.19461	.00304	.06766	.00106	3.50117	3.50138
.005000	.00586		.00482		.00274			
2.080000	.32525	.00004	.19943	.00307	.07040	.00108	3.60667	3.60689
.005000	.00585		.00482		.00275			
2.085000	.33110	.00005	.20425	.00310	.07315	.00111	3.71166	3.71190
.005000	.00582		.00480		.00276			
2.090000	.33692	.00004	.20905	.00313	.07591	.00114	3.81615	3.81641
.005000	.00581		.00478		.00278			
2.095000	.34273	.00005	.21383	.00317	.07869	.00117	3.92014	3.92041
.005000	.00579		.00478		.00278			
2.100000	.34852	.00005	.21861	.00320	.08147	.00119	4.02364	4.02393
.005000	.00578		.00477		.00280			
2.105000	.35430	.00005	.22338	.00323	.08427	.00122	4.12665	4.12695
.005000	.00576		.00476		.00280			
2.110000	.36006	.00005	.22814	.00326	.08707	.00125	4.22916	4.22948
.005000	.00574		.00475		.00282			
2.115000	.36580	.00004	.23289	.00329	.08989	.00127	4.33120	4.33153
.005000	.00574		.00474		.00282			
2.120000	.37154	.00005	.23763	.00332	.09271	.00130	4.43275	4.43310
.005000	.00572		.00474		.00283			
2.125000	.37726	.00005	.24237	.00335	.09554	.00132	4.53382	4.53418
.005000	.00570		.00472		.00284			
2.130000	.38296	.00005	.24709	.00338	.09838	.00135	4.63441	4.63480
.005000	.00569		.00472		.00285			
2.135000	.38865	.00005	.25181	.00341	.10123	.00138	4.73454	4.73494
.005000	.00568		.00471		.00285			
2.140000	.39433	.00005	.25652	.00344	.10408	.00140	4.83419	4.83461

.005000	.00567		.00470		.00286			
2.145000	.40000	.00005	.26122	.00347	.10694	.00142	4.93338	4.93382
.005000	.00566		.00469		.00287			
2.150000	.40566	.00005	.26591	.00350	.10981	.00145	5.03211	5.03257
.005000	.00565		.00469		.00288			
2.155000	.41131	.00005	.27060	.00353	.11269	.00147	5.13038	5.13086
.005000	.00563		.00468		.00288			
2.160000	.41694	.00005	.27528	.00356	.11557	.00149	5.22820	5.22870
.005000	.00563		.00468		.00289			
2.165000	.42257	.00005	.27996	.00359	.11846	.00152	5.32557	5.32608
.005000	.00561		.00467		.00290			
2.170000	.42818	.00005	.28463	.00361	.12136	.00155	5.42248	5.42302
.005000	.00561		.00466		.00290			
2.175000	.43379	.00006	.28929	.00365	.12426	.00157	5.51895	5.51950
.005000	.00559		.00466		.00290			
2.180000	.43938	.00005	.29395	.00367	.12716	.00159	5.61497	5.61555
.005000	.00559		.00465		.00292			
2.185000	.44497	.00005	.29860	.00370	.13008	.00162	5.71056	5.71116
.005000	.00557		.00465		.00291			
2.190000	.45054	.00005	.30325	.00373	.13299	.00164	5.80571	5.80633
.005000	.00557		.00464		.00293			
2.195000	.45611	.00005	.30789	.00375	.13592	.00166	5.90042	5.90106
.005000	.00556		.00463		.00292			
2.200000	.46167	.00005	.31252	.00378	.13884	.00168	5.99470	5.99537
.005000	.00555		.00464		.00294			
2.205000	.46722	.00005	.31716	.00381	.14178	.00171	6.08856	6.08925
.005000	.00555		.00462		.00293			
2.210000	.47277	.00006	.32178	.00384	.14471	.00173	6.18199	6.18270
.005000	.00553		.00462		.00295			
2.215000	.47830	.00005	.32640	.00387	.14766	.00175	6.27500	6.27573
.005000	.00553		.00462		.00294			
2.220000	.48383	.00005	.33102	.00389	.15060	.00177	6.36759	6.36834
.005000	.00552		.00461		.00296			
2.225000	.48935	.00005	.33563	.00392	.15356	.00180	6.45976	6.46054
.005000	.00551		.00461		.00295			
2.230000	.49486	.00005	.34024	.00395	.15651	.00182	6.55151	6.55232
.005000	.00551		.00461		.00296			
2.235000	.50037	.00006	.34485	.00397	.15947	.00184	6.64286	6.64369
.005000	.00550		.00460		.00296			
2.240000	.50587	.00006	.34945	.00400	.16243	.00186	6.73380	6.73465
.005000	.00549		.00459		.00297			
2.245000	.51136	.00006	.35404	.00403	.16540	.00188	6.82433	6.82521
.005000	.00549		.00460		.00297			
2.250000	.51685	.00006	.35864	.00405	.16837	.00191	6.91447	6.91537
.005000	.00548		.00459		.00298			
2.255000	.52233	.00006	.36323	.00408	.17135	.00192	7.00420	7.00513
.005000	.00547		.00458		.00298			
2.260000	.52780	.00006	.36781	.00410	.17433	.00195	7.09353	7.09449
.005000	.00546		.00458		.00298			
2.265000	.53326	.00005	.37239	.00413	.17731	.00197	7.18247	7.18345
.005000	.00547		.00458		.00298			
2.270000	.53873	.00006	.37697	.00416	.18029	.00199	7.27102	7.27203
.005000	.00545		.00458		.00299			
2.275000	.54418	.00006	.38155	.00419	.18328	.00201	7.35917	7.36021
.005000	.00545		.00457		.00300			
2.280000	.54963	.00006	.38612	.00421	.18628	.00203	7.44694	7.44801

Table I (Cont'd)

T_p	$T_n(0°)$	$\Delta T_n(0°, 1°)$	$T_n(60°)$	$½\Delta T_n(59°, 61°)$	$T_n(120°)$	$½\Delta T_n(119°, 121°)$	$z\beta_2$	$z\beta_3$
.005000	.00544		.00456		.00299			
2.285000	.55507	.00006	.39068	.00424	.18927	.00206	7.53433	7.53542
.005000	.00544		.00457		.00300			
2.290000	.56051	.00006	.39525	.00426	.19227	.00208	7.62133	7.62245
.005000	.00543		.00456		.00300			
2.295000	.56594	.00006	.39981	.00429	.19527	.00210	7.70796	7.70910
.005000	.00543		.00456		.00301			
2.300000	.57137	.00006	.40437	.00431	.19828	.00211	7.79420	7.79538
.005000	.00542		.00456		.00301			
2.305000	.57679	.00006	.40893	.00434	.20129	.00213	7.88007	7.88128
.005000	.00542		.00455		.00301			
2.310000	.58221	.00006	.41348	.00436	.20430	.00215	7.96557	7.96681
.005000	.00541		.00455		.00301			
2.315000	.58762	.00006	.41803	.00439	.20731	.00218	8.05070	8.05196
.005000	.00541		.00455		.00302			
2.320000	.59303	.00006	.42258	.00442	.21033	.00220	8.13547	8.13676
.005000	.00540		.00454		.00302			
2.325000	.59843	.00006	.42712	.00444	.21335	.00222	8.21986	8.22118
.005000	.00540		.00454		.00302			
2.330000	.60383	.00006	.43166	.00447	.21637	.00224	8.30390	8.30525
.005000	.00539		.00454		.00302			
2.335000	.60922	.00006	.43620	.00449	.21939	.00226	8.38757	8.38895
.005000	.00539		.00454		.00303			
2.340000	.61461	.00006	.44074	.00451	.22242	.00228	8.47089	8.47230
.005000	.00538		.00454		.00303			
2.345000	.61999	.00006	.44528	.00454	.22545	.00230	8.55385	8.55529
.005000	.00538		.00453		.00303			
2.350000	.62537	.00006	.44981	.00457	.22848	.00232	8.63646	8.63793
.005000	.00538		.00453		.00303			
2.355000	.63075	.00006	.45434	.00459	.23151	.00234	8.71872	8.72022
.005000	.00537		.00452		.00304			
2.360000	.63612	.00006	.45886	.00461	.23455	.00236	8.80062	8.80216
.005000	.00537		.00453		.00304			
2.365000	.64149	.00006	.46339	.00464	.23759	.00238	8.88219	8.88375
.005000	.00536		.00452		.00304			
2.370000	.64685	.00006	.46791	.00466	.24063	.00240	8.96340	8.96500
.005000	.00536		.00452		.00304			
2.375000	.65221	.00006	.47243	.00469	.24367	.00242	9.04428	9.04591
.005000	.00536		.00452		.00305			
2.380000	.65757	.00006	.47695	.00471	.24672	.00244	9.12481	9.12648
.005000	.00535		.00452		.00305			
2.385000	.66292	.00006	.48147	.00474	.24977	.00246	9.20500	9.20670
.005000	.00535		.00451		.00305			
2.390000	.66827	.00006	.48598	.00476	.25282	.00248	9.28487	9.28660
.005000	.00534		.00451		.00305			
2.395000	.67361	.00006	.49049	.00478	.25587	.00250	9.36439	9.36616
.005000	.00535		.00451		.00305			
2.400000	.67896	.00007	.49500	.00481	.25892	.00252	9.44358	9.44538
.005000	.00533		.00451		.00306			
2.405000	.68429	.00006	.49951	.00483	.26198	.00254	9.52245	9.52428
.005000	.00534		.00451		.00305			
2.410000	.68963	.00007	.50402	.00486	.26503	.00255	9.60099	9.60285
.005000	.00533		.00450		.00306			
2.415000	.69496	.00007	.50852	.00488	.26809	.00257	9.67920	9.68110
.005000	.00533		.00451		.00306			
2.420000	.70029	.00007	.51303	.00491	.27115	.00259	9.75708	9.75902

.005000	.00532		.00450		.00307			
2.425000	.70561	.00006	.51753	.00493	.27422	.00261	9.83465	9.83662
.005000	.00532		.00450		.00306			
2.430000	.71093	.00006	.52203	.00495	.27728	.00263	9.91190	9.91391
.005000	.00532		.00449		.00307			
2.435000	.71625	.00007	.52652	.00498	.28035	.00265	9.98882	9.99087
.005000	.00531		.00450		.00307			
2.440000	.72156	.00006	.53102	.00500	.28342	.00267	10.06544	10.06751
.005000	.00532		.00449		.00307			
2.445000	.72688	.00007	.53551	.00502	.28649	.00269	10.14174	10.14386
.005000	.00530		.00449		.00307			
2.450000	.73218	.00006	.54000	.00505	.28956	.00271	10.21773	10.21988
.005000	.00531		.00450		.00307			
2.455000	.73749	.00007	.54450	.00507	.29263	.00273	10.29341	10.29559
.005000	.00530		.00448		.00308			
2.460000	.74279	.00006	.54898	.00509	.29571	.00275	10.36877	10.37100
.005000	.00530		.00449		.00307			
2.465000	.74809	.00006	.55347	.00512	.29878	.00276	10.44384	10.44610
.005000	.00530		.00449		.00308			
2.470000	.75339	.00007	.55796	.00514	.30186	.00278	10.51860	10.52090
.005000	.00529		.00448		.00308			
2.475000	.75868	.00006	.56244	.00517	.30494	.00280	10.59305	10.59539
.005000	.00530		.00448		.00308			
2.480000	.76398	.00007	.56692	.00519	.30802	.00282	10.66721	10.66958
.005000	.00529		.00448		.00308			
2.485000	.76927	.00007	.57140	.00521	.31110	.00284	10.74107	10.74348
.005000	.00528		.00448		.00309			
2.490000	.77455	.00007	.57588	.00524	.31419	.00286	10.81463	10.81708
.005000	.00529		.00448		.00308			
2.495000	.77984	.00007	.58036	.00526	.31727	.00287	10.88789	10.89038
.005000	.00528		.00448		.00309			
2.500000	.78512	.00007	.58484	.00529	.32036	.00289	10.96087	10.96339
.010000	.01055		.00895		.00618			
2.510000	.79567	.00007	.59379	.00533	.32654	.00293	11.10594	11.10854
.010000	.01055		.00894		.00618			
2.520000	.80622	.00007	.60273	.00538	.33272	.00297	11.24986	11.25254
.010000	.01053		.00894		.00619			
2.530000	.81675	.00007	.61167	.00542	.33891	.00301	11.39263	11.39539
.010000	.01053		.00894		.00619			
2.540000	.82728	.00007	.62061	.00547	.34510	.00304	11.53428	11.53712
.010000	.01051		.00892		.00620			
2.550000	.83779	.00007	.62953	.00551	.35130	.00308	11.67482	11.67775
.010000	.01051		.00893		.00620			
2.560000	.84830	.00007	.63846	.00556	.35750	.00311	11.81427	11.81727
.010000	.01050		.00892		.00621			
2.570000	.85880	.00007	.64738	.00561	.36371	.00315	11.95262	11.95571
.010000	.01049		.00891		.00621			
2.580000	.86929	.00007	.65629	.00565	.36992	.00319	12.08990	12.09307
.010000	.01049		.00891		.00622			
2.590000	.87978	.00008	.66520	.00570	.37614	.00322	12.22612	12.22937
.010000	.01047		.00891		.00622			
2.600000	.89025	.00007	.67411	.00574	.38236	.00326	12.36129	12.36463
.010000	.01047		.00890		.00622			
2.610000	.90072	.00007	.68301	.00579	.38858	.00329	12.49542	12.49885
.010000	.01046		.00890		.00623			
2.620000	.91118	.00007	.69191	.00583	.39481	.00333	12.62853	12.63204

Table I (Cont'd)

T_p	$T_n(0°)$	$\Delta T_n(0°, 1°)$	$T_n(60°)$	$½\Delta T_n(59°, 61°)$	$T_n(120°)$	$½\Delta T_n(119°, 121°)$	$z\beta_2$	$z\beta_3$
.010000	.01046		.00889		.00624			
2.630000	.92164	.00008	.70080	.00588	.40105	.00336	12.76062	12.76422
.010000	.01044		.00889		.00623			
2.640000	.93208	.00007	.70969	.00592	.40728	.00340	12.89171	12.89540
.010000	.01044		.00889		.00624			
2.650000	.94252	.00007	.71858	.00597	.41352	.00344	13.02181	13.02559
.010000	.01043		.00888		.00625			
2.660000	.95295	.00007	.72746	.00601	.41977	.00347	13.15093	13.15480
.010000	.01043		.00888		.00625			
2.670000	.96338	.00008	.73634	.00606	.42602	.00350	13.27908	13.28304
.010000	.01042		.00887		.00625			
2.680000	.97380	.00008	.74521	.00610	.43227	.00354	13.40628	13.41033
.010000	.01041		.00888		.00625			
2.690000	.98421	.00007	.75409	.00614	.43852	.00357	13.53252	13.53667
.010000	.01041		.00887		.00626			
2.700000	.99462	.00008	.76296	.00619	.44478	.00361	13.65784	13.66207
.010000	.01040		.00886		.00626			
2.710000	1.00502	.00008	.77182	.00623	.45104	.00364	13.78222	13.78655
.010000	.01040		.00886		.00626			
2.720000	1.01542	.00008	.78068	.00628	.45730	.00368	13.90569	13.91011
.010000	.01039		.00886		.00627			
2.730000	1.02581	.00008	.78954	.00632	.46357	.00371	14.02825	14.03277
.010000	.01039		.00886		.00627			
2.740000	1.03620	.00009	.79840	.00636	.46984	.00375	14.14992	14.15453
.010000	.01037		.00885		.00627			
2.750000	1.04657	.00008	.80725	.00641	.47611	.00378	14.27070	14.27541
.010000	.01038		.00885		.00628			
2.760000	1.05695	.00008	.81610	.00645	.48239	.00381	14.39060	14.39541
.010000	.01037		.00885		.00628			
2.770000	1.06732	.00008	.82495	.00650	.48867	.00385	14.50964	14.51454
.010000	.01036		.00885		.00628			
2.780000	1.07768	.00008	.83380	.00654	.49495	.00388	14.62782	14.63282
.010000	.01036		.00884		.00628			
2.790000	1.08804	.00008	.84264	.00658	.50123	.00392	14.74515	14.75025
.010000	.01035		.00884		.00629			
2.800000	1.09839	.00008	.85148	.00662	.50752	.00395	14.86164	14.86684
.010000	.01035		.00884		.00629			
2.810000	1.10874	.00008	.86032	.00667	.51381	.00398	14.97730	14.98260
.010000	.01035		.00883		.00629			
2.820000	1.11909	.00009	.86915	.00671	.52010	.00402	15.09214	15.09754
.010000	.01034		.00883		.00629			
2.830000	1.12943	.00009	.87798	.00676	.52639	.00405	15.20616	15.21166
.010000	.01034		.00883		.00630			
2.840000	1.13977	.00009	.88681	.00680	.53269	.00408	15.31938	15.32499
.010000	.01033		.00883		.00629			
2.850000	1.15010	.00009	.89564	.00684	.53898	.00412	15.43181	15.43752
.010000	.01032		.00883		.00631			
2.860000	1.16042	.00008	.90447	.00689	.54529	.00415	15.54345	15.54926
.010000	.01033		.00882		.00630			
2.870000	1.17075	.00009	.91329	.00693	.55159	.00418	15.65431	15.66022
.010000	.01032		.00882		.00630			
2.880000	1.18107	.00009	.92211	.00697	.55789	.00422	15.76440	15.77041
.010000	.01031		.00882		.00631			
2.890000	1.19138	.00009	.93093	.00701	.56420	.00425	15.87372	15.87984
.010000	.01031		.00882		.00631			
2.900000	1.20169	.00009	.93975	.00706	.57051	.00428	15.98229	15.98852

.010000	.01031		.00881		.00631			
2.910000	1.21200	.00009	.94856	.00710	.57682	.00431	16.09011	16.09644
.010000	.01030		.00881		.00631			
2.920000	1.22230	.00009	.95737	.00714	.58313	.00435	16.19719	16.20363
.010000	.01030		.00881		.00632			
2.930000	1.23260	.00009	.96618	.00719	.58945	.00438	16.30354	16.31009
.010000	.01030		.00881		.00632			
2.940000	1.24290	.00009	.97499	.00723	.59577	.00442	16.40917	16.41582
.010000	.01029		.00881		.00631			
2.950000	1.25319	.00009	.98380	.00727	.60208	.00445	16.51408	16.52084
.010000	.01029		.00880		.00632			
2.960000	1.26348	.00009	.99260	.00731	.60840	.00448	16.61827	16.62514
.010000	.01029		.00881		.00633			
2.970000	1.27377	.00009	1.00141	.00736	.61473	.00451	16.72177	16.72875
.010000	.01028		.00880		.00632			
2.980000	1.28405	.00009	1.01021	.00740	.62105	.00454	16.82457	16.83166
.010000	.01028		.00880		.00633			
2.990000	1.29433	.00009	1.01901	.00744	.62738	.00458	16.92668	16.93388
.010000	.01028		.00880		.00633			
3.000000	1.30461	.00010	1.02781	.00748	.63371	.00461	17.02811	17.03542
.020000	.02054		.01759		.01266			
3.020000	1.32515	.00010	1.04540	.00757	.64637	.00468	17.22894	17.23648
.020000	.02053		.01758		.01266			
3.040000	1.34568	.00010	1.06298	.00765	.65903	.00474	17.42713	17.43489
.020000	.02052		.01758		.01267			
3.060000	1.36620	.00010	1.08056	.00773	.67170	.00481	17.62272	17.63071
.020000	.02051		.01757		.01268			
3.080000	1.38671	.00010	1.09813	.00782	.68438	.00487	17.81577	17.82399
.020000	.02049		.01757		.01269			
3.100000	1.40720	.00010	1.11570	.00790	.69707	.00493	18.00632	18.01478
.020000	.02049		.01756		.01269			
3.120000	1.42769	.00010	1.13326	.00798	.70976	.00500	18.19443	18.20311
.020000	.02047		.01755		.01269			
3.140000	1.44816	.00010	1.15081	.00807	.72245	.00506	18.38014	18.38905
.020000	.02047		.01755		.01270			
3.160000	1.46863	.00010	1.16836	.00815	.73515	.00512	18.56349	18.57264
.020000	.02046		.01754		.01271			
3.180000	1.48909	.00011	1.18590	.00823	.74786	.00519	18.74452	18.75391
.020000	.02044		.01754		.01271			
3.200000	1.50953	.00010	1.20344	.00832	.76057	.00525	18.92329	18.93292
.020000	.02044		.01754		.01272			
3.220000	1.52997	.00010	1.22098	.00840	.77329	.00532	19.09984	19.10971
.020000	.02043		.01753		.01271			
3.240000	1.55040	.00010	1.23851	.00848	.78600	.00538	19.27419	19.28431
.020000	.02042		.01752		.01273			
3.260000	1.57082	.00010	1.25603	.00856	.79873	.00544	19.44641	19.45678
.020000	.02042		.01752		.01273			
3.280000	1.59124	.00011	1.27355	.00865	.81146	.00551	19.61652	19.62714
.020000	.02040		.01752		.01273			
3.300000	1.61164	.00011	1.29107	.00873	.82419	.00557	19.78457	19.79543
.020000	.02040		.01751		.01274			
3.320000	1.63204	.00011	1.30858	.00881	.83693	.00563	19.95058	19.96170
.020000	.02039		.01751		.01274			
3.340000	1.65243	.00011	1.32609	.00889	.84967	.00570	20.11461	20.12597
.020000	.02038		.01750		.01274			
3.360000	1.67281	.00011	1.34359	.00897	.86241	.00576	20.27667	20.28829

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Table I (Cont'd)

T_p	$T_n(0°)$	$\Delta T_n(0°, 1°)$	$T_n(60°)$	$\frac{1}{2}\Delta T_n(59°, 61°)$	$T_n(120°)$	$\frac{1}{2}\Delta T_n(119°, 121°)$	$z\beta_2$	$z\beta_3$
.020000	.02038		.01751		.01275			
3.380000	1.69319	.00012	1.36110	.00905	.87516	.00582	20.43681	20.44868
.020000	.02036		.01749		.01275			
3.400000	1.71355	.00011	1.37859	.00914	.88791	.00588	20.59507	20.60720
.020000	.02037		.01750		.01275			
3.420000	1.73392	.00012	1.39609	.00922	.90066	.00594	20.75147	20.76386
.020000	.02035		.01749		.01276			
3.440000	1.75427	.00011	1.41358	.00930	.91342	.00600	20.90604	20.91869
.020000	.02035		.01748		.01276			
3.460000	1.77462	.00011	1.43106	.00938	.92618	.00607	21.05883	21.07174
.020000	.02035		.01749		.01276			
3.480000	1.79497	.00012	1.44855	.00946	.93894	.00613	21.20986	21.22302
.020000	.02033		.01748		.01277			
3.500000	1.81530	.00011	1.46603	.00954	.95171	.00619	21.35915	21.37258
.020000	.02034		.01747		.01277			
3.520000	1.83564	.00012	1.48350	.00963	.96448	.00625	21.50675	21.52043
.020000	.02032		.01748		.01277			
3.540000	1.85596	.00012	1.50098	.00970	.97725	.00631	21.65266	21.66662
.020000	.02032		.01747		.01278			
3.560000	1.87628	.00012	1.51845	.00978	.99003	.00638	21.79695	21.81117
.020000	.02032		.01747		.01278			
3.580000	1.89660	.00012	1.53592	.00986	1.00281	.00644	21.93961	21.95410
.020000	.02031		.01746		.01278			
3.600000	1.91691	.00012	1.55338	.00995	1.01559	.00650	22.08068	22.09544
.020000	.02030		.01747		.01278			
3.620000	1.93721	.00012	1.57085	.01003	1.02837	.00656	22.22019	22.23521
.020000	.02030		.01746		.01279			
3.640000	1.95751	.00012	1.58831	.01011	1.04116	.00662	22.35816	22.37346
.020000	.02030		.01746		.01279			
3.660000	1.97781	.00013	1.60577	.01019	1.05395	.00668	22.49462	22.51019
.020000	.02029		.01745		.01279			
3.680000	1.99810	.00013	1.62322	.01027	1.06674	.00675	22.62959	22.64544
.020000	.02029		.01745		.01279			
3.700000	2.01839	.00013	1.64067	.01035	1.07953	.00680	22.76310	22.77923
.020000	.02028		.01746		.01280			
3.720000	2.03867	.00013	1.65813	.01043	1.09233	.00687	22.89517	22.91157
.020000	.02028		.01744		.01279			
3.740000	2.05895	.00013	1.67557	.01051	1.10512	.00693	23.02583	23.04250
.020000	.02027		.01745		.01280			
3.760000	2.07922	.00013	1.69302	.01059	1.11792	.00699	23.15508	23.17204
.020000	.02027		.01744		.01281			
3.780000	2.09949	.00013	1.71046	.01067	1.13073	.00705	23.28297	23.30020
.020000	.02026		.01745		.01280			
3.800000	2.11975	.00013	1.72791	.01075	1.14353	.00711	23.40951	23.42702
.020000	.02026		.01743		.01281			
3.820000	2.14001	.00013	1.74534	.01083	1.15634	.00717	23.53472	23.55251
.020000	.02026		.01744		.01280			
3.840000	2.16027	.00013	1.76278	.01091	1.16914	.00723	23.65862	23.67669
.020000	.02026		.01744		.01281			
3.860000	2.18053	.00014	1.78022	.01099	1.18195	.00729	23.78123	23.79959
.020000	.02025		.01743		.01281			
3.880000	2.20078	.00014	1.79765	.01107	1.19476	.00735	23.90258	23.92122
.020000	.02024		.01743		.01282			
3.900000	2.22102	.00013	1.81508	.01115	1.20758	.00741	24.02267	24.04160
.020000	.02025		.01743		.01281			
3.920000	2.24127	.00014	1.83251	.01123	1.22039	.00747	24.14154	24.16075

.020000	.02024		.01743		.01282			
3.940000	2.26151	.00014	1.84994	.01131	1.23321	.00753	24.25919	24.27869
.020000	.02023		.01743		.01282			
3.960000	2.28174	.00014	1.86737	.01139	1.24603	.00759	24.37566	24.39545
.020000	.02023		.01742		.01282			
3.980000	2.30197	.00013	1.88479	.01147	1.25885	.00765	24.49095	24.51103
.020000	.02023		.01742		.01282			
4.000000	2.32220	.00014	1.90221	.01155	1.27167	.00771	24.60508	24.62545
.020000	.02023		.01742		.01282			
4.020000	2.34243	.00014	1.91963	.01163	1.28449	.00777	24.71808	24.73873
.020000	.02022		.01742		.01283			
4.040000	2.36265	.00014	1.93705	.01171	1.29732	.00783	24.82995	24.85089
.020000	.02023		.01742		.01282			
4.060000	2.38288	.00015	1.95447	.01179	1.31014	.00789	24.94071	24.96195
.020000	.02021		.01742		.01283			
4.080000	2.40309	.00014	1.97189	.01186	1.32297	.00795	25.05039	25.07192
.020000	.02022		.01741		.01283			
4.100000	2.42331	.00015	1.98930	.01194	1.33580	.00801	25.15899	25.18081
.020000	.02021		.01741		.01283			
4.120000	2.44352	.00015	2.00671	.01202	1.34863	.00807	25.26653	25.28865
.020000	.02021		.01741		.01283			
4.140000	2.46373	.00015	2.02412	.01210	1.36146	.00813	25.37303	25.39545
.020000	.02021		.01741		.01284			
4.160000	2.48394	.00015	2.04153	.01218	1.37430	.00819	25.47851	25.50122
.020000	.02020		.01741		.01283			
4.180000	2.50414	.00015	2.05894	.01226	1.38713	.00825	25.58297	25.60597
.020000	.02020		.01741		.01284			
4.200000	2.52434	.00015	2.07635	.01234	1.39997	.00831	25.68643	25.70974
.020000	.02020		.01740		.01283			
4.220000	2.54454	.00015	2.09375	.01242	1.41280	.00837	25.78891	25.81252
.020000	.02020		.01741		.01284			
4.240000	2.56474	.00016	2.11116	.01250	1.42564	.00843	25.89042	25.91432
.020000	.02019		.01740		.01284			
4.260000	2.58493	.00015	2.12856	.01258	1.43848	.00849	25.99096	26.01517
.020000	.02019		.01740		.01284			
4.280000	2.60512	.00015	2.14596	.01266	1.45132	.00855	26.09058	26.11508
.020000	.02019		.01740		.01284			
4.300000	2.62531	.00015	2.16336	.01274	1.46416	.00861	26.18925	26.21406
.020000	.02019		.01740		.01285			
4.320000	2.64550	.00016	2.18076	.01281	1.47701	.00867	26.28701	26.31212
.020000	.02018		.01740		.01284			
4.340000	2.66568	.00015	2.19816	.01289	1.48985	.00873	26.38387	26.40928
.020000	.02018		.01740		.01284			
4.360000	2.68586	.00015	2.21556	.01297	1.50269	.00879	26.47984	26.50555
.020000	.02018		.01739		.01285			
4.380000	2.70604	.00015	2.23295	.01305	1.51554	.00885	26.57492	26.60093
.020000	.02018		.01740		.01285			
4.400000	2.72622	.00016	2.25035	.01313	1.52839	.00891	26.66913	26.69545
.020000	.02018		.01739		.01284			
4.420000	2.74640	.00016	2.26774	.01320	1.54123	.00897	26.76249	26.78912
.020000	.02017		.01739		.01285			
4.440000	2.76657	.00016	2.28513	.01328	1.55408	.00903	26.85501	26.88194
.020000	.02017		.01739		.01285			
4.460000	2.78674	.00016	2.30252	.01336	1.56693	.00908	26.94669	26.97393
.020000	.02017		.01739		.01285			
4.480000	2.80691	.00016	2.31991	.01344	1.57978	.00914	27.03755	27.06510

Table I (Cont'd)

T_p	$T_n(0°)$	$\Delta T_n(0°, 1°)$	$T_n(60°)$	$½\Delta T_n(59°, 61°)$	$T_n(120°)$	$½\Delta T_n(119°, 121°)$	$z\beta_2$	$z\beta_3$
.020000	.02017		.01739		.01286			
4.500000	2.82708	.00016	2.33730	.01352	1.59264	.00920	27.12760	27.15545
.020000	.02017		.01739		.01285			
4.520000	2.84725	.00017	2.35469	.01360	1.60549	.00926	27.21685	27.24502
.020000	.02016		.01739		.01285			
4.540000	2.86741	.00016	2.37208	.01368	1.61834	.00932	27.30531	27.33378
.020000	.02016		.01738		.01286			
4.560000	2.88757	.00016	2.38946	.01375	1.63120	.00938	27.39299	27.42177
.020000	.02017		.01739		.01285			
4.580000	2.90774	.00017	2.40685	.01384	1.64405	.00944	27.47990	27.50899
.020000	.02015		.01738		.01286			
4.600000	2.92789	.00016	2.42423	.01391	1.65691	.00950	27.56606	27.59546
.020000	.02016		.01738		.01286			
4.620000	2.94805	.00017	2.44161	.01399	1.66977	.00956	27.65146	27.68117
.020000	.02016		.01739		.01285			
4.640000	2.96821	.00017	2.45900	.01407	1.68262	.00962	27.73612	27.76615
.020000	.02015		.01738		.01286			
4.660000	2.98836	.00017	2.47638	.01415	1.69548	.00967	27.82006	27.85039
.020000	.02015		.01738		.01286			
4.680000	3.00851	.00017	2.49376	.01423	1.70834	.00973	27.90327	27.93392
.020000	.02015		.01738		.01286			
4.700000	3.02866	.00017	2.51114	.01430	1.72120	.00979	27.98578	28.01674
.020000	.02015		.01737		.01286			
4.720000	3.04881	.00017	2.52851	.01438	1.73406	.00985	28.06757	28.09885
.020000	.02015		.01738		.01287			
4.740000	3.06896	.00017	2.54589	.01446	1.74693	.00991	28.14868	28.18027
.020000	.02014		.01738		.01286			
4.760000	3.08910	.00017	2.56327	.01454	1.75979	.00997	28.22910	28.26100
.020000	.02015		.01737		.01286			
4.780000	3.10925	.00018	2.58064	.01462	1.77265	.01003	28.30884	28.34106
.020000	.02014		.01738		.01286			
4.800000	3.12939	.00017	2.59802	.01470	1.78551	.01009	28.38792	28.42046
.020000	.02014		.01737		.01287			
4.820000	3.14953	.00017	2.61539	.01477	1.79838	.01014	28.46634	28.49919
.020000	.02014		.01737		.01286			
4.840000	3.16967	.00017	2.63276	.01485	1.81124	.01021	28.54411	28.57728
.020000	.02014		.01738		.01287			
4.860000	3.18981	.00018	2.65014	.01493	1.82411	.01026	28.62123	28.65472
.020000	.02014		.01737		.01287			
4.880000	3.20995	.00018	2.66751	.01501	1.83698	.01032	28.69772	28.73152
.020000	.02014		.01737		.01286			
4.900000	3.23009	.00019	2.68488	.01509	1.84984	.01038	28.77358	28.80771
.020000	.02013		.01737		.01287			
4.920000	3.25022	.00018	2.70225	.01517	1.86271	.01044	28.84882	28.88326
.020000	.02013		.01737		.01287			
4.940000	3.27035	.00018	2.71962	.01524	1.87558	.01050	28.92345	28.95821
.020000	.02013		.01737		.01287			
4.960000	3.29048	.00018	2.73699	.01532	1.88845	.01056	28.99748	29.03256
.020000	.02014		.01737		.01287			
4.980000	3.31062	.00019	2.75436	.01540	1.90132	.01062	29.07090	29.10630
.020000	.02012		.01736		.01287			
5.000000	3.33074	.00018	2.77172	.01548	1.91419	.01068	29.14374	29.17946
.050000	.05032		.04342		.03218			
5.050000	3.38106	.00018	2.81514	.01567	1.94637	.01082	29.32329	29.35982
.050000	.05031		.04341		.03218			
5.100000	3.43137	.00019	2.85855	.01587	1.97855	.01097	29.49930	29.53664

.050000	.05031		.04341		.03218			
5.150000	3.48168	.00020	2.90196	.01606	2.01073	.01111	29.67188	29.71002
.050000	.05029		.04340		.03219			
5.200000	3.53197	.00019	2.94536	.01625	2.04292	.01126	29.84113	29.88008
.050000	.05029		.04340		.03219			
5.250000	3.58226	.00019	2.98876	.01645	2.07511	.01141	30.00713	30.04689
.050000	.05029		.04339		.03219			
5.300000	3.63255	.00020	3.03215	.01664	2.10730	.01155	30.16997	30.21056
.050000	.05027		.04339		.03220			
5.350000	3.68282	.00020	3.07554	.01684	2.13950	.01170	30.32976	30.37116
.050000	.05027		.04339		.03219			
5.400000	3.73309	.00020	3.11893	.01703	2.17169	.01184	30.48657	30.52879
.050000	.05027		.04339		.03220			
5.450000	3.78336	.00021	3.16232	.01723	2.20389	.01199	30.64049	30.68354
.050000	.05026		.04338		.03221			
5.500000	3.83362	.00021	3.20570	.01742	2.23610	.01214	30.79159	30.83546
.050000	.05025		.04338		.03220			
5.550000	3.88387	.00020	3.24908	.01762	2.26830	.01228	30.93996	30.98465
.050000	.05025		.04337		.03221			
5.600000	3.93412	.00021	3.29245	.01781	2.30051	.01242	31.08565	31.13118
.050000	.05025		.04338		.03221			
5.650000	3.98437	.00022	3.33583	.01800	2.33272	.01257	31.22875	31.27511
.050000	.05024		.04337		.03221			
5.700000	4.03461	.00022	3.37920	.01820	2.36493	.01271	31.36932	31.41651
.050000	.05023		.04336		.03222			
5.750000	4.08484	.00021	3.42256	.01839	2.39715	.01286	31.50744	31.55546
.050000	.05024		.04337		.03221			
5.800000	4.13508	.00023	3.46593	.01858	2.42936	.01301	31.64315	31.69201
.050000	.05022		.04336		.03222			
5.850000	4.18530	.00022	3.50929	.01878	2.46158	.01315	31.77654	31.82623
.050000	.05022		.04336		.03222			
5.900000	4.23552	.00022	3.55265	.01897	2.49380	.01329	31.90764	31.95818
.050000	.05022		.04336		.03222			
5.950000	4.28574	.00023	3.59601	.01916	2.52602	.01344	32.03652	32.08790
.050000	.05022		.04335		.03222			
6.000000	4.33596	.00023	3.63936	.01936	2.55824	.01359	32.16324	32.21547
.050000	.05021		.04335		.03222			
6.050000	4.38617	.00023	3.68271	.01955	2.59046	.01373	32.28785	32.34092
.050000	.05020		.04335		.03223			
6.100000	4.43637	.00023	3.72606	.01975	2.62269	.01388	32.41040	32.46432
.050000	.05021		.04335		.03222			
6.150000	4.48658	.00024	3.76941	.01994	2.65491	.01402	32.53094	32.58571
.050000	.05020		.04335		.03223			
6.200000	4.53678	.00024	3.81276	.02013	2.68714	.01416	32.64953	32.70514
.050000	.05019		.04334		.03223			
6.250000	4.58697	.00024	3.85610	.02032	2.71937	.01431	32.76620	32.82266
.050000	.05020		.04334		.03223			
6.300000	4.63717	.00025	3.89944	.02052	2.75160	.01445	32.88101	32.93833
.050000	.05019		.04334		.03223			
6.350000	4.68736	.00025	3.94278	.02071	2.78383	.01460	32.99399	33.05216
.050000	.05019		.04334		.03223			
6.400000	4.73755	.00025	3.98612	.02091	2.81606	.01474	33.10519	33.16422
.050000	.05018		.04333		.03223			
6.450000	4.78773	.00025	4.02945	.02110	2.84829	.01488	33.21465	33.27454
.050000	.05020		.04330		.03213			
6.500000	4.83793	.00025	4.07275	.02129	2.88042	.01503	33.31711	33.37783

Table I (Cont'd)

T_p	$T_n(0°)$	$\Delta T_n(0°, 1°)$	$T_n(60°)$	$\frac{1}{2}\Delta T_n(59°, 61°)$	$T_n(120°)$	$\frac{1}{2}\Delta T_n(119°, 121°)$	$z\beta_2$	$z\beta_3$
.050000	.05018		.04333		.03224			
6.550000	4.88811	.00025	4.11608	.02148	2.91266	.01518	33.42320	33.48478
.050000	.05018		.04333		.03223			
6.600000	4.93829	.00026	4.15941	.02168	2.94489	.01532	33.52767	33.59011
.050000	.05017		.04333		.03224			
6.650000	4.98846	.00026	4.20274	.02187	2.97713	.01547	33.63055	33.69385
.050000	.05017		.04333		.03223			
6.700000	5.03863	.00026	4.24607	.02206	3.00936	.01561	33.73188	33.79605
.050000	.05017		.04332		.03224			
6.750000	5.08880	.00027	4.28939	.02226	3.04160	.01575	33.83170	33.89673
.050000	.05016		.04332		.03224			
6.800000	5.13896	.00026	4.33271	.02245	3.07384	.01589	33.93003	33.99593
.050000	.05017		.04333		.03224			
6.850000	5.18913	.00027	4.37604	.02264	3.10608	.01604	34.02692	34.09368
.050000	.05016		.04332		.03224			
6.900000	5.23929	.00027	4.41936	.02284	3.13832	.01618	34.12239	34.19001
.050000	.05016		.04331		.03224			
6.950000	5.28945	.00028	4.46267	.02303	3.17056	.01633	34.21647	34.28496
.050000	.05015		.04332		.03224			
7.000000	5.33960	.00027	4.50599	.02322	3.20280	.01647	34.30920	34.37856
.050000	.05016		.04332		.03224			
7.050000	5.38976	.00028	4.54931	.02341	3.23504	.01662	34.40059	34.47082
.050000	.05015		.04331		.03224			
7.100000	5.43991	.00028	4.59262	.02360	3.26728	.01676	34.49069	34.56178
.050000	.05015		.04331		.03224			
7.150000	5.49006	.00028	4.63593	.02380	3.29952	.01690	34.57951	34.65148
.050000	.05015		.04331		.03224			
7.200000	5.54021	.00028	4.67924	.02399	3.33176	.01705	34.66709	34.73993
.050000	.05015		.04332		.03225			
7.250000	5.59036	.00029	4.72256	.02418	3.36401	.01719	34.75344	34.82715
.050000	.05014		.04330		.03224			
7.300000	5.64050	.00029	4.76586	.02437	3.39625	.01734	34.83860	34.91318
.050000	.05014		.04331		.03225			
7.350000	5.69064	.00029	4.80917	.02457	3.42850	.01748	34.92258	34.99805
.050000	.05015		.04331		.03224			
7.400000	5.74079	.00030	4.85248	.02476	3.46074	.01762	35.00543	35.08176
.050000	.05014		.04330		.03225			
7.450000	5.79093	.00030	4.89578	.02495	3.49299	.01777	35.08714	35.16435
.050000	.05013		.04331		.03224			
7.500000	5.84106	.00029	4.93909	.02515	3.52523	.01791	35.16776	35.24585
.100000	.10027		.08660		.06449			
7.600000	5.94133	.00030	5.02569	.02553	3.58972	.01820	35.32577	35.40561
.100000	.10027		.08660		.06450			
7.700000	6.04160	.00031	5.11229	.02592	3.65422	.01848	35.47962	35.56122
.100000	.10026		.08659		.06449			
7.800000	6.14186	.00031	5.19888	.02630	3.71871	.01877	35.62948	35.71285
.100000	.10025		.08660		.06449			
7.900000	6.24211	.00031	5.28548	.02669	3.78320	.01906	35.77550	35.86063
.100000	.10025		.08658		.06450			
8.000000	6.34236	.00032	5.37206	.02707	3.84770	.01934	35.91782	36.00472
.100000	.10024		.08658		.06450			
8.100000	6.44260	.00032	5.45864	.02746	3.91220	.01963	36.05659	36.14525
.100000	.10024		.08658		.06449			
8.200000	6.54284	.00032	5.54522	.02784	3.97669	.01992	36.19192	36.28236
.100000	.10024		.08658		.06450			
8.300000	6.64308	.00033	5.63180	.02823	4.04119	.02021	36.32395	36.41616

.100000	.10023		.08657		.06450			
8.400000	6.74331	.00034	5.71837	.02861	4.10569	.02049	36.45279	36.54678
.100000	.10022		.08657		.06449			
8.500000	6.84353	.00034	5.80494	.02899	4.17018	.02078	36.57855	36.67432
.100000	.10023		.08656		.06450			
8.600000	6.94376	.00035	5.89150	.02938	4.23468	.02106	36.70135	36.79890
.100000	.10021		.08656		.06450			
8.700000	7.04397	.00035	5.97806	.02976	4.29918	.02135	36.82127	36.92061
.100000	.10022		.08656		.06450			
8.800000	7.14419	.00036	6.06462	.03015	4.36368	.02164	36.93844	37.03956
.100000	.10021		.08655		.06449			
8.900000	7.24440	.00036	6.15117	.03053	4.42817	.02192	37.05292	37.15582
.100000	.10021		.08655		.06450			
9.000000	7.34461	.00037	6.23772	.03092	4.49267	.02221	37.16483	37.26952
.100000	.10020		.08655		.06450			
9.100000	7.44481	.00037	6.32427	.03130	4.55717	.02249	37.27422	37.38071
.100000	.10020		.08655		.06449			
9.200000	7.54501	.00037	6.41082	.03169	4.62166	.02278	37.38120	37.48948
.100000	.10020		.08654		.06450			
9.300000	7.64521	.00038	6.49736	.03207	4.68616	.02307	37.48584	37.59591
.100000	.10020		.08654		.06450			
9.400000	7.74541	.00038	6.58390	.03245	4.75066	.02335	37.58822	37.70008
.100000	.10019		.08654		.06449			
9.500000	7.84560	.00039	6.67044	.03284	4.81515	.02363	37.68840	37.80206
.100000	.10019		.08653		.06449			
9.600000	7.94579	.00039	6.75697	.03322	4.87964	.02392	37.78646	37.90191
.100000	.10019		.08653		.06450			
9.700000	8.04598	.00040	6.84350	.03361	4.94414	.02421	37.88245	37.99970
.100000	.10019		.08653		.06449			
9.800000	8.14617	.00040	6.93003	.03399	5.00863	.02450	37.97644	38.09550
.100000	.10018		.08652		.06449			
9.900000	8.24635	.00040	7.01655	.03438	5.07312	.02478	38.06851	38.18937
.100000	.10018		.08653		.06449			
10.000000	8.34653	.00040	7.10308	.03476	5.13761	.02506	38.15869	38.28135

Table II

T_p	$T_n(0°)$	$\Delta T_n(0°, 1°)$	$T_n(60°)$	$\frac{1}{2}\Delta T_n(59°, 61°)$	$T_n(120°)$	$\frac{1}{2}\Delta T_n(119°, 121°)$	$z\beta_2$	$z\beta_3$
2.378480	.06588						- .89495	- .89493
.000010	.00003							
2.378490	.06591						- .89475	- .89473
.000010	.00003							
2.378500	.06594						- .89454	- .89453
.000100	.00032							
2.378600	.06626						- .89251	- .89250
.000100	.00031							
2.378700	.06657						- .89049	- .89047
.000100	.00031							
2.378800	.06688						- .88846	- .88844
.000100	.00030							
2.378900	.06718						- .88643	- .88641
.000100	.00031							
2.379000	.06749						- .88440	- .88438
.000100	.00030							
2.379100	.06779						- .88237	- .88235
.000100	.00030							
2.379200	.06809						- .88034	- .88033
.000100	.00030							
2.379300	.06839						- .87831	- .87830
.000100	.00029							
2.379400	.06868						- .87628	- .87627
.000100	.00030							
2.379500	.06898						- .87426	- .87424
.000100	.00029							
2.379600	.06927						- .87223	- .87221
.000100	.00029							
2.379700	.06956						- .87020	- .87018
.000100	.00029							
2.379800	.06985						- .86817	- .86816
.000100	.00029							
2.379900	.07014						- .86614	- .86613
.000100	.00029							
2.380000	.07043						- .86412	- .86410
.005000	.01287							
2.385000	.08330						- .76296	- .76295
.005000	.01110							
2.390000	.09440						- .66223	- .66222
.005000	.01010							
2.395000	.10450						- .56191	- .56190
.005000	.00943							
2.400000	.11393						- .46202	- .46201
.005000	.00895							
2.405000	.12288						- .36254	- .36254
.005000	.00858							
2.410000	.13146						- .26348	- .26348
.005000	.00829							
2.415000	.13975						- .16482	- .16482
.005000	.00804							
2.420000	.14779						- .06658	- .06658

.000500	.00079				
2.420500	.14858			- .05677	- .05677
.000500	.00079				
2.421000	.14937			- .04697	- .04697
.000500	.00079				
2.421500	.15016			- .03718	- .03718
.000500	.00079				
2.422000	.15095			- .02739	- .02739
.000500	.00078				
2.422500	.15173			- .01760	- .01760
.000500	.00078				
2.423000	.15251			- .00782	- .00782
.000200	.00032				
2.423200	.15283			- .00391	- .00391
.000200	.00031				
2.423400	.15314	.03828	.00000	.00000	.00000
.000200	.00031	.00030	.00000		
2.423600	.15345	.03858	.00000	.00391	.00391
.000200	.00031	.00030	.00000		
2.423800	.15376	.03888	.00000	.00782	.00782
.000200	.00031	.00030	.00001		
2.424000	.15407	.03918	.00001	.01173	.01173
.001000	.00156	.00149	.00003		
2.425000	.15563	.04067	.00004	.03127	.03127
.005000	.00766	.00708	.00047		
2.430000	.16329	.04775	.00051	.12870	.12870
.005000	.00751	.00669	.00088		
2.435000	.17080	.05444	.00139	.22574	.22574
.005000	.00738	.00642	.00115		
2.440000	.17818	.06086	.00254	.32238	.32238
.005000	.00725	.00620	.00136		
2.445000	.18543	.06706	.00390	.41862	.41863
.005000	.00716	.00604	.00152		
2.450000	.19259	.07310	.00542	.51447	.51448
.005000	.00706	.00590	.00166		
2.455000	.19965	.07900	.00708	.60993	.60994
.005000	.00697	.00580	.00177		
2.460000	.20662	.08480	.00885	.70500	.70501
.005000	.00689	.00570	.00186		
2.465000	.21351	.09050	.01071	.79969	.79970
.005000	.00682	.00562	.00195		
2.470000	.22033	.09612	.01266	.89399	.89401
.005000	.00676	.00555	.00201		
2.475000	.22709	.10167	.01467	.98791	.98793
.005000	.00669	.00549	.00208		
2.480000	.23378	.10716	.01675	1.08145	1.08147
.005000	.00664	.00543	.00213		
2.485000	.24042	.11259	.01888	1.17461	1.17464
.005000	.00658	.00538	.00219		
2.490000	.24700	.11797	.02107	1.26740	1.26744
.005000	.00654	.00533	.00222		
2.495000	.25354	.12330	.02329	1.35982	1.35986
.005000	.00648	.00530	.00227		
2.500000	.26002	.12860	.02556	1.45187	1.45191
.010000	.01285	.01048	.00465		
2.510000	.27287	.13908	.03021	1.63486	1.63492

Table II (Cont'd)

T_p	$T_n(0°)$	$\Delta T_n(0°, 1°)$	$T_n(60°)$	$\frac{1}{2}\Delta T_n(59°, 61°)$	$T_n(120°)$	$\frac{1}{2}\Delta T_n(119°, 121°)$	$z\beta_2$	$z\beta_3$
.010000	.01270		.01035		.00478			
2.520000	.28557		.14943		.03499		1.81640	1.81647
.010000	.01255		.01025		.00488			
2.530000	.29812		.15968		.03987		1.99650	1.99659
.010000	.01243		.01014		.00498			
2.540000	.31055		.16982		.04485		2.17518	2.17528
.010000	.01232		.01006		.00507			
2.550000	.32287		.17988		.04992		2.35246	2.35258
.010000	.01222		.00999		.00514			
2.560000	.33509		.18987		.05506		2.52836	2.52849
.010000	.01212		.00992		.00520			
2.570000	.34721		.19979		.06026		2.70288	2.70304
.010000	.01204		.00986		.00527			
2.580000	.35925		.20965		.06553		2.87605	2.87623
.010000	.01196		.00981		.00533			
2.590000	.37121		.21946		.07086		3.04788	3.04808
.010000	.01188		.00975		.00537			
2.600000	.38309		.22921		.07623		3.21838	3.21861
.010000	.01182		.00971		.00542			
2.610000	.39491		.23892		.08165		3.38758	3.38783
.010000	.01175		.00967		.00546			
2.620000	.40666		.24859		.08711		3.55549	3.55577
.010000	.01169		.00963		.00550			
2.630000	.41835		.25822		.09261		3.72211	3.72242
.010000	.01164		.00959		.00553			
2.640000	.42999		.26781		.09814		3.88748	3.88781
.010000	.01158		.00956		.00557			
2.650000	.44157		.27737		.10371		4.05159	4.05196
.010000	.01154		.00952		.00560			
2.660000	.45311		.28689		.10931		4.21447	4.21487
.010000	.01149		.00950		.00563			
2.670000	.46460		.29639		.11494		4.37613	4.37656
.010000	.01144		.00947		.00566			
2.680000	.47604		.30586		.12060		4.53658	4.53704
.010000	.01140		.00944		.00569			
2.690000	.48744		.31530		.12629		4.69583	4.69633
.010000	.01137		.00942		.00570			
2.700000	.49881		.32472		.13199		4.85391	4.85444
.010000	.01132		.00940		.00573			
2.710000	.51013		.33412		.13772		5.01082	5.01139
.010000	.01129		.00937		.00576			
2.720000	.52142		.34349		.14348		5.16656	5.16717
.010000	.01126		.00936		.00577			
2.730000	.53268		.35285		.14925		5.32117	5.32182
.010000	.01123		.00933		.00579			
2.740000	.54391		.36218		.15504		5.47465	5.47534
.010000	.01119		.00932		.00581			
2.750000	.55510		.37150		.16085		5.62701	5.62774
.010000	.01116		.00930		.00583			
2.760000	.56626		.38080		.16668		5.77827	5.77904
.010000	.01114		.00928		.00585			
2.770000	.57740		.39008		.17253		5.92843	5.92925
.010000	.01111		.00927		.00586			
2.780000	.58851		.39935		.17839		6.07751	6.07838
.010000	.01108		.00925		.00587			
2.790000	.59959		.40860		.18426		6.22552	6.22643

.010000	.01106	.00923	.00589		
2.800000	.61065	.41783	.19015	6.37247	6.37343
.010000	.01104	.00922	.00591		
2.810000	.62169	.42705	.19606	6.51838	6.51938
.010000	.01101	.00921	.00592		
2.820000	.63270	.43626	.20198	6.66325	6.66430
.010000	.01099	.00920	.00593		
2.830000	.64369	.44546	.20791	6.80709	6.80819
.010000	.01097	.00918	.00594		
2.840000	.65466	.45464	.21385	6.94992	6.95107
.010000	.01095	.00918	.00596		
2.850000	.66561	.46382	.21981	7.09175	7.09295
.010000	.01093	.00916	.00596		
2.860000	.67654	.47298	.22577	7.23258	7.23383
.010000	.01091	.00915	.00598		
2.870000	.68745	.48213	.23175	7.37243	7.37374
.010000	.01090	.00914	.00599		
2.880000	.69835	.49127	.23774	7.51131	7.51267
.010000	.01087	.00913	.00599		
2.890000	.70922	.50040	.24373	7.64922	7.65064
.010000	.01086	.00911	.00601		
2.900000	.72008	.50951	.24974	7.78618	7.78766
.010000	.01084	.00912	.00602		
2.910000	.73092	.51863	.25576	7.92220	7.92374
.010000	.01083	.00910	.00602		
2.920000	.74175	.52773	.26178	8.05729	8.05888
.010000	.01081	.00909	.00604		
2.930000	.75256	.53682	.26782	8.19145	8.19310
.010000	.01079	.00908	.00604		
2.940000	.76335	.54590	.27386	8.32470	8.32641
.010000	.01079	.00908	.00605		
2.950000	.77414	.55498	.27991	8.45705	8.45882
.010000	.01076	.00907	.00606		
2.960000	.78490	.56405	.28597	8.58850	8.59033
.010000	.01076	.00906	.00606		
2.970000	.79566	.57311	.29203	8.71906	8.72096
.010000	.01074	.00905	.00608		
2.980000	.80640	.58216	.29811	8.84874	8.85070
.010000	.01073	.00905	.00608		
2.990000	.81713	.59121	.30419	8.97756	8.97958
.010000	.01071	.00903	.00609		
3.000000	.82784	.60024	.31028	9.10552	9.10761
.020000	.02140	.01806	.01219		
3.020000	.84924	.61830	.32247	9.35888	9.36111
.020000	.02135	.01803	.01222		
3.040000	.87059	.63633	.33469	9.60891	9.61127
.020000	.02131	.01801	.01225		
3.060000	.89190	.65434	.34694	9.85567	9.85817
.020000	.02127	.01799	.01226		
3.080000	.91317	.67233	.35920	10.09921	10.10185
.020000	.02122	.01796	.01229		
3.100000	.93439	.69029	.37149	10.33961	10.34240
.020000	.02120	.01794	.01231		
3.120000	.95559	.70823	.38380	10.57692	10.57986
.020000	.02115	.01793	.01233		
3.140000	.97674	.72616	.39613	10.81121	10.81429

Table II (Cont'd)

T_p	$T_n(0°)$	$\Delta T_n(0°, 1°)$	$T_n(60°)$	$\frac{1}{2}\Delta T_n(59°, 61°)$	$T_n(120°)$	$\frac{1}{2}\Delta T_n(119°, 121°)$	$z\beta_2$	$z\beta_3$
.020000	.02113		.01790		.01234			
3.160000	.99787		.74406		.40847		11.04252	11.04576
.020000	.02109		.01789		.01237			
3.180000	1.01896		.76195		.42084		11.27092	11.27431
.020000	.02106		.01787		.01237			
3.200000	1.04002		.77982		.43321		11.49646	11.50001
.020000	.02104		.01786		.01240			
3.220000	1.06106		.79768		.44561		11.71919	11.72291
.020000	.02101		.01784		.01241			
3.240000	1.08207		.81552		.45802		11.93917	11.94305
.020000	.02098		.01783		.01242			
3.260000	1.10305		.83335		.47044		12.15644	12.16049
.020000	.02095		.01781		.01244			
3.280000	1.12400		.85116		.48288		12.37106	12.37528
.020000	.02093		.01780		.01245			
3.300000	1.14493		.86896		.49533		12.58308	12.58747
.020000	.02091		.01779		.01247			
3.320000	1.16584		.88675		.50780		12.79253	12.79710
.020000	.02088		.01777		.01247			
3.340000	1.18672		.90452		.52027		12.99947	13.00422
.020000	.02087		.01776		.01249			
3.360000	1.20759		.92228		.53276		13.20395	13.20887
.020000	.02084		.01776		.01250			
3.380000	1.22843		.94004		.54526		13.40599	13.41110
.020000	.02083		.01774		.01251			
3.400000	1.24926		.95778		.55777		13.60567	13.61096
.020000	.02080		.01773		.01252			
3.420000	1.27006		.97551		.57029		13.80299	13.80847
.020000	.02079		.01772		.01252			
3.440000	1.29085		.99323		.58281		13.99803	14.00369
.020000	.02077		.01771		.01254			
3.460000	1.31162		1.01094		.59535		14.19080	14.19666
.020000	.02075		.01770		.01255			
3.480000	1.33237		1.02864		.60790		14.38135	14.38740
.020000	.02074		.01770		.01256			
3.500000	1.35311		1.04634		.62046		14.56972	14.57596
.020000	.02072		.01768		.01256			
3.520000	1.37383		1.06402		.63302		14.75594	14.76238
.020000	.02070		.01768		.01257			
3.540000	1.39453		1.08170		.64559		14.94005	14.94669
.020000	.02069		.01767		.01258			
3.560000	1.41522		1.09937		.65817		15.12210	15.12894
.020000	.02068		.01766		.01259			
3.580000	1.43590		1.11703		.67076		15.30210	15.30915
.020000	.02066		.01765		.01260			
3.600000	1.45656		1.13468		.68336		15.48010	15.48735
.020000	.02065		.01765		.01260			
3.620000	1.47721		1.15233		.69596		15.65613	15.66359
.020000	.02064		.01764		.01261			
3.640000	1.49785		1.16997		.70857		15.83022	15.83789
.020000	.02062		.01763		.01261			
3.660000	1.51847		1.18760		.72118		16.00240	16.01028
.020000	.02061		.01762		.01262			
3.680000	1.53908		1.20522		.73380		16.17271	16.18080
.020000	.02060		.01762		.01263			
3.700000	1.55968		1.22284		.74643		16.34117	16.34948

.020000	.02059	.01762	.01264		
3.720000	1.58027	1.24046	.75907	16.50782	16.51635
.020000	.02058	.01760	.01264		
3.740000	1.60085	1.25806	.77171	16.67268	16.68142
.020000	.02057	.01761	.01264		
3.760000	1.62142	1.27567	.78435	16.83578	16.84475
.020000	.02055	.01759	.01265		
3.780000	1.64197	1.29326	.79700	16.99716	17.00634
.020000	.02055	.01759	.01266		
3.800000	1.66252	1.31085	.80966	17.15683	17.16624
.020000	.02053	.01759	.01266		
3.820000	1.68305	1.32844	.82232	17.31482	17.32445
.020000	.02053	.01758	.01267		
3.840000	1.70358	1.34602	.83499	17.47117	17.48102
.020000	.02052	.01758	.01267		
3.860000	1.72410	1.36360	.84766	17.62589	17.63597
.020000	.02051	.01757	.01268		
3.880000	1.74461	1.38117	.86034	17.77901	17.78933
.020000	.02050	.01756	.01268		
3.900000	1.76511	1.39873	.87302	17.93056	17.94110
.020000	.02049	.01756	.01268		
3.920000	1.78560	1.41629	.88570	18.08055	18.09133
.020000	.02048	.01756	.01269		
3.940000	1.80608	1.43385	.89839	18.22903	18.24004
.020000	.02048	.01755	.01269		
3.960000	1.82656	1.45140	.91108	18.37599	18.38724
.020000	.02047	.01755	.01270		
3.980000	1.84703	1.46895	.92378	18.52148	18.53296
.020000	.02046	.01755	.01270		
4.000000	1.86749	1.48650	.93648	18.66551	18.67723
.020000	.02045	.01754	.01271		
4.020000	1.88794	1.50404	.94919	18.80810	18.82006
.020000	.02044	.01753	.01271		
4.040000	1.90838	1.52157	.96190	18.94927	18.96147
.020000	.02044	.01753	.01271		
4.060000	1.92882	1.53910	.97461	19.08905	19.10149
.020000	.02043	.01753	.01272		
4.080000	1.94925	1.55663	.98733	19.22746	19.24014
.020000	.02043	.01753	.01272		
4.100000	1.96968	1.57416	1.00005	19.36451	19.37744
.020000	.02042	.01752	.01272		
4.120000	1.99010	1.59168	1.01277	19.50023	19.51341
.020000	.02041	.01752	.01273		
4.140000	2.01051	1.60920	1.02550	19.63464	19.64806
.020000	.02040	.01751	.01273		
4.160000	2.03091	1.62671	1.03823	19.76774	19.78141
.020000	.02040	.01752	.01273		
4.180000	2.05131	1.64423	1.05096	19.89957	19.91349
.020000	.02040	.01750	.01273		
4.200000	2.07171	1.66173	1.06369	20.03014	20.04431
.020000	.02038	.01751	.01274		
4.220000	2.09209	1.67924	1.07643	20.15947	20.17390
.020000	.02039	.01750	.01275		
4.240000	2.11248	1.69674	1.08918	20.28758	20.30225
.020000	.02037	.01750	.01274		
4.260000	2.13285	1.71424	1.10192	20.41448	20.42941

Table II (Cont'd)

T_p	$T_n(0°)$	$\Delta T_n(0°, 1°)$	$T_n(60°)$	$½\Delta T_n(59°, 61°)$	$T_n(120°)$	$½\Delta T_n(119°, 121°)$	$z\beta_2$	$z\beta_3$
.020000	.02037		.01750		.01275			
4.280000	2.15322		1.73174		1.11467		20.54019	20.55537
.020000	.02037		.01749		.01275			
4.300000	2.17359		1.74923		1.12742		20.66472	20.68017
.020000	.02036		.01749		.01275			
4.320000	2.19395		1.76672		1.14017		20.78811	20.80381
.020000	.02036		.01749		.01276			
4.340000	2.21431		1.78421		1.15293		20.91035	20.92631
.020000	.02035		.01749		.01275			
4.360000	2.23466		1.80170		1.16568		21.03146	21.04768
.020000	.02034		.01748		.01276			
4.380000	2.25500		1.81918		1.17844		21.15147	21.16795
.020000	.02034		.01748		.01277			
4.400000	2.27534		1.83666		1.19121		21.27038	21.28712
.020000	.02034		.01748		.01276			
4.420000	2.29568		1.85414		1.20397		21.38821	21.40522
.020000	.02033		.01747		.01277			
4.440000	2.31601		1.87161		1.21674		21.50498	21.52225
.020000	.02033		.01748		.01277			
4.460000	2.33634		1.88909		1.22951		21.62069	21.63823
.020000	.02032		.01747		.01277			
4.480000	2.35666		1.90656		1.24228		21.73537	21.75317
.020000	.02032		.01746		.01277			
4.500000	2.37698		1.92402		1.25505		21.84903	21.86710
.020000	.02032		.01747		.01278			
4.520000	2.39730		1.94149		1.26783		21.96168	21.98002
.020000	.02031		.01746		.01278			
4.540000	2.41761		1.95895		1.28061		22.07333	22.09193
.020000	.02030		.01747		.01278			
4.560000	2.43791		1.97642		1.29339		22.18400	22.20287
.020000	.02031		.01746		.01278			
4.580000	2.45822		1.99388		1.30617		22.29370	22.31285
.020000	.02030		.01745		.01279			
4.600000	2.47852		2.01133		1.31896		22.40244	22.42186
.020000	.02029		.01746		.01278			
4.620000	2.49881		2.02879		1.33174		22.51024	22.52993
.020000	.02029		.01745		.01279			
4.640000	2.51910		2.04624		1.34453		22.61710	22.63707
.020000	.02029		.01745		.01279			
4.660000	2.53939		2.06369		1.35732		22.72305	22.74329
.020000	.02028		.01745		.01279			
4.680000	2.55967		2.08114		1.37011		22.82808	22.84860
.020000	.02029		.01745		.01279			
4.700000	2.57996		2.09859		1.38290		22.93222	22.95301
.020000	.02027		.01745		.01280			
4.720000	2.60023		2.11604		1.39570		23.03547	23.05654
.020000	.02028		.01744		.01279			
4.740000	2.62051		2.13348		1.40849		23.13785	23.15920
.020000	.02027		.01744		.01280			
4.760000	2.64078		2.15092		1.42129		23.23937	23.26099
.020000	.02027		.01745		.01280			
4.780000	2.66105		2.16837		1.43409		23.34003	23.36193
.020000	.02026		.01743		.01280			
4.800000	2.68131		2.18580		1.44689		23.43985	23.46203
.020000	.02026		.01744		.01281			
4.820000	2.70157		2.20324		1.45970		23.53884	23.56130

.020000	.02026	.01744	.01280		
4.840000	2.72183	2.22068	1.47250	23.63701	23.65975
.020000	.02026	.01743	.01281		
4.860000	2.74209	2.23811	1.48531	23.73436	23.75739
.020000	.02025	.01743	.01280		
4.880000	2.76234	2.25554	1.49811	23.83092	23.85423
.020000	.02025	.01744	.01281		
4.900000	2.78259	2.27298	1.51092	23.92668	23.95028
.020000	.02025	.01743	.01281		
4.920000	2.80284	2.29041	1.52373	24.02166	24.04555
.020000	.02024	.01742	.01281		
4.940000	2.82308	2.30783	1.53654	24.11588	24.14004
.020000	.02024	.01743	.01282		
4.960000	2.84332	2.32526	1.54936	24.20933	24.23378
.020000	.02024	.01742	.01281		
4.980000	2.86356	2.34268	1.56217	24.30202	24.32676
.020000	.02024	.01743	.01282		
5.000000	2.88380	2.36011	1.57499	24.39397	24.41900
.050000	.05058	.04355	.03204		
5.050000	2.93438	2.40366	1.60703	24.62064	24.64639
.050000	.05056	.04355	.03205		
5.100000	2.98494	2.44721	1.63908	24.84285	24.86933
.050000	.05055	.04353	.03206		
5.150000	3.03549	2.49074	1.67114	25.06073	25.08794
.050000	.05053	.04353	.03207		
5.200000	3.08602	2.53427	1.70321	25.27440	25.30234
.050000	.05053	.04352	.03207		
5.250000	3.13655	2.57779	1.73528	25.48399	25.51267
.050000	.05050	.04352	.03208		
5.300000	3.18705	2.62131	1.76736	25.68959	25.71902
.050000	.05050	.04350	.03208		
5.350000	3.23755	2.66481	1.79944	25.89134	25.92151
.050000	.05048	.04350	.03209		
5.400000	3.28803	2.70831	1.83153	26.08934	26.12026
.050000	.05048	.04350	.03210		
5.450000	3.33851	2.75181	1.86363	26.28368	26.31536
.050000	.05046	.04349	.03210		
5.500000	3.38897	2.79530	1.89573	26.47448	26.50691
.050000	.05045	.04348	.03211		
5.550000	3.43942	2.83878	1.92784	26.66182	26.69501
.050000	.05044	.04347	.03211		
5.600000	3.48986	2.88225	1.95995	26.84580	26.87975
.050000	.05043	.04347	.03211		
5.650000	3.54029	2.92572	1.99206	27.02650	27.06122
.050000	.05042	.04347	.03212		
5.700000	3.59071	2.96919	2.02418	27.20402	27.23951
.050000	.05041	.04346	.03213		
5.750000	3.64112	3.01265	2.05631	27.37844	27.41470
.050000	.05040	.04346	.03213		
5.800000	3.69152	3.05611	2.08844	27.54983	27.58686
.050000	.05040	.04345	.03213		
5.850000	3.74192	3.09956	2.12057	27.71828	27.75609
.050000	.05038	.04344	.03214		
5.900000	3.79230	3.14300	2.15271	27.88385	27.92244
.050000	.05038	.04344	.03214		
5.950000	3.84268	3.18644	2.18485	28.04663	28.08600

Table II (Cont'd)

T_p	$T_n(0°)$	$\Delta T_n(0°, 1°)$	$T_n(60°)$	$\frac{1}{2}\Delta T_n(59°, 61°)$	$T_n(120°)$	$\frac{1}{2}\Delta T_n(119°, 121°)$	$z\beta_2$	$z\beta_3$
.050000	.05037		.04344		.03214			
6.000000	3.89305		3.22988		2.21699		28.20667	28.24684
.050000	.05037		.04343		.03215			
6.050000	3.94342		3.27331		2.24914		28.36406	28.40501
.050000	.05035		.04343		.03215			
6.100000	3.99377		3.31674		2.28129		28.51885	28.56060
.050000	.05035		.04343		.03215			
6.150000	4.04412		3.36017		2.31344		28.67111	28.71365
.050000	.05034		.04342		.03216			
6.200000	4.09446		3.40359		2.34560		28.82090	28.86423
.050000	.05034		.04341		.03216			
6.250000	4.14480		3.44700		2.37776		28.96827	29.01241
.050000	.05033		.04342		.03216			
6.300000	4.19513		3.49042		2.40992		29.11330	29.15823
.050000	.05032		.04341		.03216			
6.350000	4.24545		3.53383		2.44208		29.25602	29.30176
.050000	.05032		.04340		.03217			
6.400000	4.29577		3.57723		2.47425		29.39650	29.44304
.050000	.05031		.04341		.03217			
6.450000	4.34608		3.62064		2.50642		29.53479	29.58213
.050000	.05033		.04337		.03208			
6.500000	4.39641		3.66401		2.53850		29.66620	29.71435
.050000	.05030		.04339		.03217			
6.550000	4.44671		3.70740		2.57067		29.80023	29.84919
.050000	.05029		.04340		.03218			
6.600000	4.49700		3.75080		2.60285		29.93222	29.98199
.050000	.05029		.04339		.03218			
6.650000	4.54729		3.79419		2.63503		30.06220	30.11279
.050000	.05029		.04338		.03218			
6.700000	4.59758		3.83757		2.66721		30.19024	30.24164
.050000	.05028		.04339		.03218			
6.750000	4.64786		3.88096		2.69939		30.31636	30.36858
.050000	.05027		.04338		.03218			
6.800000	4.69813		3.92434		2.73157		30.44061	30.49364
.050000	.05028		.04338		.03219			
6.850000	4.74841		3.96772		2.76376		30.56304	30.61690
.050000	.05026		.04337		.03218			
6.900000	4.79867		4.01109		2.79594		30.68367	30.73835
.050000	.05027		.04338		.03219			
6.950000	4.84894		4.05447		2.82813		30.80256	30.85807
.050000	.05025		.04337		.03219			
7.000000	4.89919		4.09784		2.86032		30.91974	30.97607
.050000	.05026		.04337		.03220			
7.050000	4.94945		4.14121		2.89252		31.03524	31.09240
.050000	.05025		.04336		.03219			
7.100000	4.99970		4.18457		2.92471		31.14910	31.20709
.050000	.05024		.04337		.03220			
7.150000	5.04994		4.22794		2.95691		31.26136	31.32018
.050000	.05025		.04336		.03219			
7.200000	5.10019		4.27130		2.98910		31.37205	31.43170
.050000	.05024		.04336		.03220			
7.250000	5.15043		4.31466		3.02130		31.48119	31.54167
.050000	.05023		.04336		.03220			
7.300000	5.20066		4.35802		3.05350		31.58883	31.65014
.050000	.05023		.04335		.03220			
7.350000	5.25089		4.40137		3.08570		31.69498	31.75714

.050000	.05023	.04336	.03220		
7.400000	5.30112	4.44473	3.11790	31.79969	31.86269
.050000	.05023	.04335	.03221		
7.450000	5.35135	4.48808	3.15011	31.90299	31.96682
.050000	.05022	.04335	.03220		
7.500000	5.40157	4.53143	3.18231	32.00489	32.06957
.100000	.10044	.08669	.06441		
7.600000	5.50201	4.61812	3.24672	32.20464	32.27100
.100000	.10042	.08668	.06442		
7.700000	5.60243	4.70480	3.31114	32.39915	32.46720
.100000	.10042	.08668	.06442		
7.800000	5.70285	4.79148	3.37556	32.58863	32.65837
.100000	.10040	.08667	.06442		
7.900000	5.80325	4.87815	3.43998	32.77326	32.84470
.100000	.10039	.08667	.06443		
8.000000	5.90364	4.96482	3.50441	32.95323	33.02637
.100000	.10038	.08665	.06443		
8.100000	6.00402	5.05147	3.56884	33.12871	33.20356
.100000	.10038	.08666	.06443		
8.200000	6.10440	5.13813	3.63327	33.29986	33.37642
.100000	.10036	.08664	.06444		
8.300000	6.20476	5.22477	3.69771	33.46685	33.54512
.100000	.10036	.08664	.06443		
8.400000	6.30512	5.31141	3.76214	33.62981	33.70981
.100000	.10035	.08664	.06444		
8.500000	6.40547	5.39805	3.82658	33.78890	33.87061
.100000	.10034	.08663	.06445		
8.600000	6.50581	5.48468	3.89103	33.94424	34.02768
.100000	.10033	.08662	.06444		
8.700000	6.60614	5.57130	3.95547	34.09597	34.18114
.100000	.10033	.08662	.06444		
8.800000	6.70647	5.65792	4.01991	34.24420	34.33111
.100000	.10032	.08661	.06445		
8.900000	6.80679	5.74453	4.08436	34.38907	34.47771
.100000	.10032	.08661	.06445		
9.000000	6.90711	5.83114	4.14881	34.53067	34.62105
.100000	.10030	.08661	.06445		
9.100000	7.00741	5.91775	4.21326	34.66912	34.76124
.100000	.10031	.08660	.06445		
9.200000	7.10772	6.00435	4.27771	34.80452	34.89839
.100000	.10029	.08659	.06445		
9.300000	7.20801	6.09094	4.34216	34.93697	35.03253
.100000	.10030	.08659	.06445		
9.400000	7.30831	6.17753	4.40661	35.06656	35.16392
.100000	.10028	.08659	.06445		
9.500000	7.40859	6.26412	4.47106	35.19338	35.29249
.100000	.10028	.08659	.06445		
9.600000	7.50887	6.35071	4.53551	35.31753	35.41839
.100000	.10028	.08658	.06445		
9.700000	7.60915	6.43729	4.59996	35.43906	35.54168
.100000	.10027	.08657	.06446		
9.800000	7.70942	6.52386	4.66442	35.55810	35.66247
.100000	.10027	.08657	.06445		
9.900000	7.80969	6.61043	4.72887	35.67468	35.78082
.100000	.10027	.08657	.06446		
10.000000	7.90996	6.69700	4.79333	35.78889	35.89679