394109

358268

1997

# NASA/ASEE SUMMER FACULTY FELLOWSHIP PROGRAM

# MARSHALL SPACE FLIGHT CENTER THE UNIVERSITY OF ALABAMA IN HUNTSVILLE

## SOFTWARE PRODUCTS FOR TEMPERATURE DATA REDUCTION OF PLATINUM RESISTANCE THERMOMETERS (PRT)

Prepared By:	Jerry K. Sherrod, Ph.D.
Institution and Department:	Pellissippi State Technical Community College Business and Computer Technology
NASA/MSFC:	Instrumentation Branch Astrionics Laboratory
MSFC Colleague:	William B. White

\_ \_\_\_\_\_

### **Introduction**

The main objective of this project is to create user-friendly personal computer (PC) software for reduction/analysis of platinum resistance thermometer (PRT) data.

#### The Callendar-Van Dusen Equation

The Callendar-Van Dusen equation is the accepted method (International Temperature Scale - 1927, ITS-27, and International Practical Temperature Scale - 1948, IPTS-48) for calculating resistance, R, given a temperature, t, for PRTs.

The general expression for the Callendar-Van Dusen equation is: (Rosemount Report 68023F)

$$R_{t} = R_{0} \left\{ 1 + \alpha \left[ t - \delta \left( \frac{t}{100} \right) \left( \frac{t}{100} - 1 \right) - \beta \left( \frac{t}{100} - 1 \right) \left( \frac{t}{100} \right)^{3} \right] \right\}$$
(1)

where:Rt = resistance at temperature t (ohms)

R0 = resistance at 0°C

t = temperature, °C

 $\alpha$ ,  $\delta$ , and  $\beta$  are calibration constants

For temperatures above  $0^{\circ}$ C,  $\beta = 0$ , and equation (1) becomes

$$R_{t} = R_{0} \left\{ 1 + \alpha \left[ t - \delta \left( \frac{t}{100} \right) \left( \frac{t}{100} - 1 \right) \right] \right\}$$
(2)

and this equation is known as the Callendar Equation.

When  $t_1 = 100^{\circ}$ C then, from equation (2)

$$\alpha = \frac{R_{100} - R_0}{100R_0}$$
(3)

where  $\alpha$  is the temperature coefficient over the range 0°C to 100°C.

Knowing the value of  $\alpha$ ,  $\delta$  can be calculated from a third calibration point, t<sub>2</sub> as follows:

$$\delta = \frac{t_2 - \left(\frac{R_{t_2}}{R_0} - 1\right) / \alpha}{\left(\frac{t_2 - 100}{t_2} \right) \left(\frac{t_2}{100} - 1\right)}$$
(4)

Finally, knowing the value of  $\alpha$  and  $\delta$ ,  $\beta$  can be calculated from a fourth calibration point,  $t_2$ , (below 0°C) as follows:

$$\beta = \frac{R_0 \left(1 + \alpha t_3\right) - R_{t_3}}{R_0 \alpha \left(t_3 / 100 - 1\right) \left(t_3 / 100\right)^3} - \frac{\delta}{\left(t_3 / 100\right)^2}$$
(5)

For efficient computation, however, a method that relates  $\alpha$ ,  $\beta$ , and  $\delta$  is desirable. For this reason, constants A, B, and C can be computed as follows:

$$A = \alpha (1 + \delta/100) \tag{6}$$

$$B = -\alpha \delta / 10^4 \tag{7}$$

$$C = -\alpha\beta/10^8 \tag{8}$$

or

$$\alpha = A + 100B \tag{9}$$

$$\delta = -10^4 \text{B}/(\text{A} + 100\text{B}) = 10^4 \text{B}/\alpha \tag{10}$$

$$\beta = -10^{8} C/(A + 100B) = -10^{8} C/\alpha$$
(11)

With these constants, equation (1) may be computed with

$$W = 1 + At + Bt^{2} + Ct^{3}(t-100)$$
(12)

where W is the resistance ratio  $R_t/R_0$  and C = 0 when t > 0°C

This approach allows the calibration to use three temperature points in addition to 0°C. One is a low temperature <  $150^{\circ}$ C, another is a high temperature >  $250^{\circ}$ C, and a third temperature  $\approx 100^{\circ}$ C. The constants A, B, and C may be computed by solution of the simultaneous equations:

$$W_1 = 1 + At_1 + Bt_1^2$$
 for  $(T_1 > 0^{\circ}C)$  (13)

$$W_2 = 1 + At_2 + Bt_2^2$$
 for  $(T_2 > 0^{\circ}C)$  (14)

$$W_3 = 1 + At_3 + Bt_3^2 + Ct_3^3(t_3 - 100) \text{ for } (t_3 < 0^{\circ}C)$$
(15)

The solution set is as follows:

$$A = \frac{\left(\frac{W_2 - 1}{t_1} \right) t_1 / t_2 - \left(\frac{W_1 - 1}{t_2} \right) t_2 / t_1}{t_1 - t_2}$$
(16)

$$B = \frac{\left(W_2 - 1\right) / t_2 - \left(W_1 - 1\right) / t_1}{t_2 - t_1}$$
(17)

$$C = \frac{W_3 - 1 - At_3 - Bt_3^2}{t_3^3 (t_3 - 100)}$$
(18)

## Solving for Temperature

Equation (12) must be solved for temperature, t, to easily compute the temperature represented by a measured resistance. For temperatures above 0°C only, the solution is as follows:

$$t = \frac{\sqrt{A^2 - 4B(1 - W)}}{2B} - A \tag{19}$$

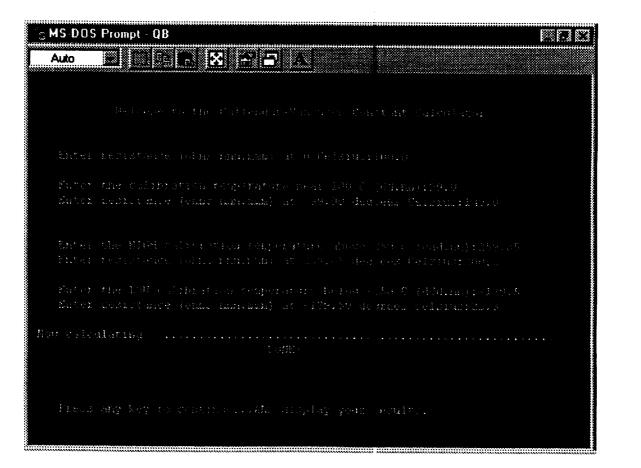
For temperatures <  $0^{\circ}$ C, another method must be used. The first derivative of equation (12) is used to successively approximate *t*. This equation is

$$\frac{dW}{dt} = A + 2Bt + 4Ct^{2}(t - 75)$$
(20)
where C = 0 for t > 0°C

### Software Products for Using these Methods

Software products were designed and created to help users of PRT data with the tasks of using the Callendar-Van Dusen method. Sample runs are illustrated in this report. The products are available from Mr. Bill White, Bldg. 4487, EB-22, Marshall Space Flight Center, Alabama 35812.; telephone (205) 544-6417; email: William.B.White@msfc.nasa.gov.

Sample Output



		******	**********************************			
SMS-DOS P	rompt - QB					
Auto			B A			
ė	1.52 01.505-007	26/235434448248				
		NIVZ16620091D				
C .	ist-8.82820	16.027003874B				
AL	DHA 1.21 0.	0000000				
(5)と)	Ts hat to b					
126	LTA 100 L.	555875557				
	Take. Ples			r Yoar choace t		
	TERFERAT	TUPE SCALE I	ISPLAY MEN	ĩ,		
	C F	Cela Para	a della Febrera di			
		E 6172				
	E	Rank				
	A 65. (EB	FFE E Joilap	twy all rb	e share (DEFAU	.T.)	
12 M						
Euter Y	oun choire:	: Á				
			2	al constant of the state of		
io you want	机体的工作机械机会	a tite of t		data? (∀∠8)		
io you want	机体的工作机械机会			data? (Y70)		
o you want	机体的工作机械机会	a tite of t		dusar (778)		
o yeu want resa C to	to create Date create	a tite of t		dusias (V/B)		
o you waat Loos S tu c MS DOS P	to create Oast the pr Yompt <b>AB</b>	a file of t Cogram boo? )	31	dustas (V/B)		ESS FAX 6
6 Yea waat 12833 (2 10 2 MS DOS P Auto (8	to create Oast the pr Yompt <b>AB</b>	a ille of t ograa boo? -NMPCM-Fis				B≈91°318
6 You Weat 1200 (C to 2 MS DOS P Auto B Come Come	to create Oust the pr Compt OB	a ille of t ograa boo? -> <b>DE</b> Service For doct				<b></b>
e yea Waat raas e ta 2 MS DOS P Auto B Usaa Chatala e 120 Joop	to create part the pr fompt DB fortate fortate to take	a ille of t ograa boo? ) 	H	e Fock to State A		5-99 <b>5-9</b> 3 K
6 YOR WEAT 1200 C to 2 MS DOS P Auto 8 00460 C 12 C 1040	to create Oust the pr Yompt OB Compt OB	a file of t ograa boo? -> DC (fil Super Core Fire Core file S	B Dir te struc Dir te struc Dir te struc Dir te struct	a Factor Alta A StateO		<u></u>
e yea Waat rees e to 2 MS DOS P Auto 8 Uulle collecter e 120.0-25 t 0.0000	to create part the pr fompt DB fortate fortate to take	a line of t ogram boo? ) ev DC (right Super conce Far there the super the super the super the super	B D A CONTRACT D A CONTRACT	2 Fords on States State		E-ST-JA R
e yeu Vant raas 8 to 2 MS DOS P Auto 8 Usias colastan e 120 005 13 006 13 006 13 006 13 006 13 006 13 006 13 006 13 006 13 006	EQUINARS QUIT CHE pr Fompt OB ECTOARS 509-21 Starts 509-21 Starts	A LILE OF C Ogram book 	B Districtions Descriptions	* Fach th 51.5.41 51.5.41 51.7.57 51.7.57 51.7.57 51.7.57		52 F. 3 B
6 Y04 Waat raas 8 tu 2 MS DOS P Auto 8 Usaa Usaa 120 008 121 008 122 008 123 008 123 008 123 009	to create part the pr fompt <b>DB</b> fortate to to atta to to atta	a file of t ogram boo? ( c) PC Prim Startbert Fartbert fartbert	H	2 <b>Ford</b> to <b>SASA W</b> <b>SASA W</b> <b>SASA W</b> <b>SASA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>SA</b> <b>S</b>		₽~3 F . 3 K
<ul> <li>year Want</li> <li>reast 2 to</li> <li>c MS DOS P</li> <li>Auto 2</li> <li>Contact</li> <li>Contact<td>KO CINAKO QUIT CHE pr Prompt QB COMPT QB CONTACT CONTA</td><td>A LILE OF C Ogram book </td><td>B Districtions Descriptions</td><td>* Fach th 51.5.41 51.5.41 51.7.57 51.7.57 51.7.57 51.7.57</td><td></td><td>E</td></li></ul>	KO CINAKO QUIT CHE pr Prompt QB COMPT QB CONTACT CONTA	A LILE OF C Ogram book 	B Districtions Descriptions	* Fach th 51.5.41 51.5.41 51.7.57 51.7.57 51.7.57 51.7.57		E
6 YOU WART 1200 C to 2 MS DOS P 0000 0000 120,000 120,000	to create Out the pr compt GB following following following following following following following following following following	a line of t ogram bee?	<ul> <li>Image: A second s</li></ul>			<u></u>
<ul> <li>Yed Ward rapid (2 to)</li> <li>MS DOS P</li> <li>Auto (2 to)</li> <li>Outation</li> <li>Outation</li></ul>	EQUINANCE QUIT CHE pr Prompt OB ECTORNE 509-11 Not-in Not-	a file of t ogran boo?	H	2 5 5 5 5 5 5 5 5 5 5 5 5 5		52 F . 3 F
<ul> <li>9 you Mant 1 2003 (2 10)</li> <li>2 MS DOS P</li> <li>Ave</li> <li>1 20 200</li> </ul>	to create part the pr fompt fit forest fit forest f	a 1110 of t organic 10002 ( cogram 100000 ( cogram 100000 ( cogram 100000 ( cogra	H			E3 E
<ul> <li>9 Yea Want</li> <li>1 2003 \$ 10</li> <li>2 MS DOS P</li> <li>4 20</li> <l< td=""><td>EQUINANCE QUIT CHE pr Prompt OB ECTORNE 509-11 Not-in Not-</td><td>a file of t ogran boo?</td><td>H</td><td>2 5 5 5 5 5 5 5 5 5 5 5 5 5</td><td></td><td>B-37-3 B</td></l<></ul>	EQUINANCE QUIT CHE pr Prompt OB ECTORNE 509-11 Not-in Not-	a file of t ogran boo?	H	2 5 5 5 5 5 5 5 5 5 5 5 5 5		B-37-3 B
<ul> <li>6 Yeq Mant rank S to</li> <li>2 MS DOS P</li> <li>2 MS DOS P</li> <li>4 MS DO</li></ul>	to create part the pr format fit format fit format fit format for	a 1110 of t organistic of t organistic of t source of the second source	H	2 2 2 3 3 3 3 3 3 3 3 3 3 3 3 3		<u></u>
6 Y00 Vant rass 8 to 2 MS DOS P Auto 8 Usias rectistance 120,055 130,055 130,055 130,050 150,050 150,050 150,050 150,050 150,050 150,050 150,050 150,050 150,050 150,050 151,050	E0         C1+GEC           QGFE         Crown pr           Prompt         QB           Pr	<ul> <li>a 1110 of Cogram book?</li> <li>b 110 of Cogram book?</li> <li>c 20 gram book?</li> <lic 20="" book?<="" gram="" li=""></lic></ul>	H	$\frac{2}{2} = \frac{2}{2} + \frac{2}$		5-92 F
<ul> <li>90 Yea Vanti trazas \$ 10</li> <li>2 MS DOS P</li> <li>2 MS DOS P</li> <li>4 MS DOS P</li> </ul>	EC CIVAE QUITE CHE pr Prompt OB ECTOARTS 500.31 5	<ul> <li>4 1110 0f C</li> <li>6 0f 24a 10002 (</li> <li>7 0f 26a 10002 (</li> <l< td=""><td>1 314 (Wethous Herry 14 518, 56 519, 51 519, 55 519, 51 519, 55 519, 55 519, 55 540, 65 544, 44 544, 55 554, 55 356, 55 357, 55 357, 55 357, 55 356, 55 357, 55 357, 55 356, 55 357, 557, 557, 557, 557, 557, 557, 557,</td><td>2 5 5 5 5 5 5 5 5 5 5 5 5 5</td><td></td><td>5-92 F3 H</td></l<></ul>	1 314 (Wethous Herry 14 518, 56 519, 51 519, 55 519, 51 519, 55 519, 55 519, 55 540, 65 544, 44 544, 55 554, 55 356, 55 357, 55 357, 55 357, 55 356, 55 357, 55 357, 55 356, 55 357, 557, 557, 557, 557, 557, 557, 557,	2 5 5 5 5 5 5 5 5 5 5 5 5 5		5-92 F3 H
6 Yeu Vant rass 2 to 2 MS DOS P Auto 8 Usas voist and e 120,035 121,050 123,050 125,050 120,050 120,050 120,050 120,050 120,050 121,050 131,050 131,050 133,050	EC CIVAE QUITE CHE pr Prompt OB ECTOARTS 500.31 5	<ul> <li>4 1110 0f C</li> <li>6 0f 24a 10002 (</li> <li>7 0f 26a 10002 (</li> <l< td=""><td>1 314 (Wethous Herry 14 518, 56 519, 51 519, 55 519, 51 519, 55 519, 55 519, 55 540, 65 544, 44 544, 55 554, 55 356, 55 357, 55 357, 55 357, 55 356, 55 357, 55 357, 55 356, 55 357, 557, 557, 557, 557, 557, 557, 557,</td><td><math display="block">\frac{2}{2} = \frac{2}{2} + \frac{2}</math></td><td>-1-1-1</td><td>52 F . 3 F</td></l<></ul>	1 314 (Wethous Herry 14 518, 56 519, 51 519, 55 519, 51 519, 55 519, 55 519, 55 540, 65 544, 44 544, 55 554, 55 356, 55 357, 55 357, 55 357, 55 356, 55 357, 55 357, 55 356, 55 357, 557, 557, 557, 557, 557, 557, 557,	$\frac{2}{2} = \frac{2}{2} + \frac{2}$	-1-1-1	52 F . 3 F
<ul> <li>9 Yed Ward r 200 (2 to)</li> <li>2 MS DOS P</li> <li>3 MS</li></ul>	EC CIVAE QUITE CHE pr Prompt OB ECTOARTS 500.31 5	<ul> <li>4 1110 0f C</li> <li>6 0f 24a 10002 (</li> <li>7 0f 26a 10002 (</li> <l< td=""><td>1 314 (Wethous Herry 14 518, 56 519, 51 519, 55 519, 51 519, 55 519, 55 519, 55 540, 65 544, 44 544, 55 554, 55 356, 55 357, 55 357, 55 357, 55 356, 55 357, 55 357, 55 356, 55 357, 557, 557, 557, 557, 557, 557, 557,</td><td>2 5 5 5 5 5 5 5 5 5 5 5 5 5</td><td>ωίας</td><td>E3 E</td></l<></ul>	1 314 (Wethous Herry 14 518, 56 519, 51 519, 55 519, 51 519, 55 519, 55 519, 55 540, 65 544, 44 544, 55 554, 55 356, 55 357, 55 357, 55 357, 55 356, 55 357, 55 357, 55 356, 55 357, 557, 557, 557, 557, 557, 557, 557,	2 5 5 5 5 5 5 5 5 5 5 5 5 5	ωίας	E3 E
6 YOU WARD ABOR 6 10 2 MS DOS P AUG 8 0 JUNE 10 JUNE	EC CIVAE QUITE CHE pr Prompt OB ECTOARTS 500.31 5	<ul> <li>a 1110 of Cogram book?</li> <li>b 200 an book?</li> <li>c 200 an book?</li> </ul>	1 314 (Wethous Herry 14 518, 56 519, 51 519, 55 519, 51 519, 55 519, 55 519, 55 540, 65 544, 44 544, 55 554, 55 356, 55 357, 55 357, 55 357, 55 356, 55 357, 55 357, 55 356, 55 357, 557, 557, 557, 557, 557, 557, 557,	2 5 5 5 5 5 5 5 5 5 5 5 5 5		<u>5-97-33</u> K

### <u>Acknowledgments</u>

The author would like to acknowledge the assistance and guidance of NASA colleague William B. (Willie) White in this research. In addition, the entire team members of EB-22 (B Wing), especially Bobby Money, James Currie, Clint Patrick, and Branch Chief Joe Zimmerman helped acquaint me with the facilities and procedures of the laboratory and branch.

## **References**

Temperature Calibration andInterpolation Methods for PlatinumResistance Thermometers, Rosemount Report 68023F, Rosemount Inc.

.

÷