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

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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)

$$R_t = R_0\left\{1+\alpha\left[t-\delta\left(\frac{t}{100}\right)\left(\frac{t}{100}-1\right)-\beta\left(\frac{t}{100}-1\right)\left(\frac{t}{100}\right)^3\right]\right\} \qquad (1)$$

where: Rt = resistance at temperature t (ohms)

R0 = resistance at 0°C

t = temperature, °C

α, δ, and β are calibration constants

For temperatures above 0°C, $\beta = 0$, and equation (1) becomes

$$R_t = R_0\left\{1+\alpha\left[t-\delta\left(\frac{t}{100}\right)\left(\frac{t}{100}-1\right)\right]\right\} \qquad (2)$$

and this equation is known as the **Callendar Equation.**

When t_1 = 100°C then, from equation (2)

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

where α is the temperature coefficient over the range 0°C to 100°C.

Knowing the value of α, δ can be calculated from a third calibration point, t_2 as follows:

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

Finally, knowing the value of α and δ, β can be calculated from a fourth calibration point, t_2, (below 0°C) as follows:

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

For efficient computation, however, a method that relates α, β, and δ 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

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

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

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

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

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

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°C, another is a high temperature > 250°C, and a third temperature ≅ 100°C. The constants A, B, and C may be computed by solution of the simultaneous equations:

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

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

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

The solution set is as follows:

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

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

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

<u>Solving for Temperature</u>

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°C, another method must be used. The first derivative of equation (12) is used to successively approximate t. This equation is

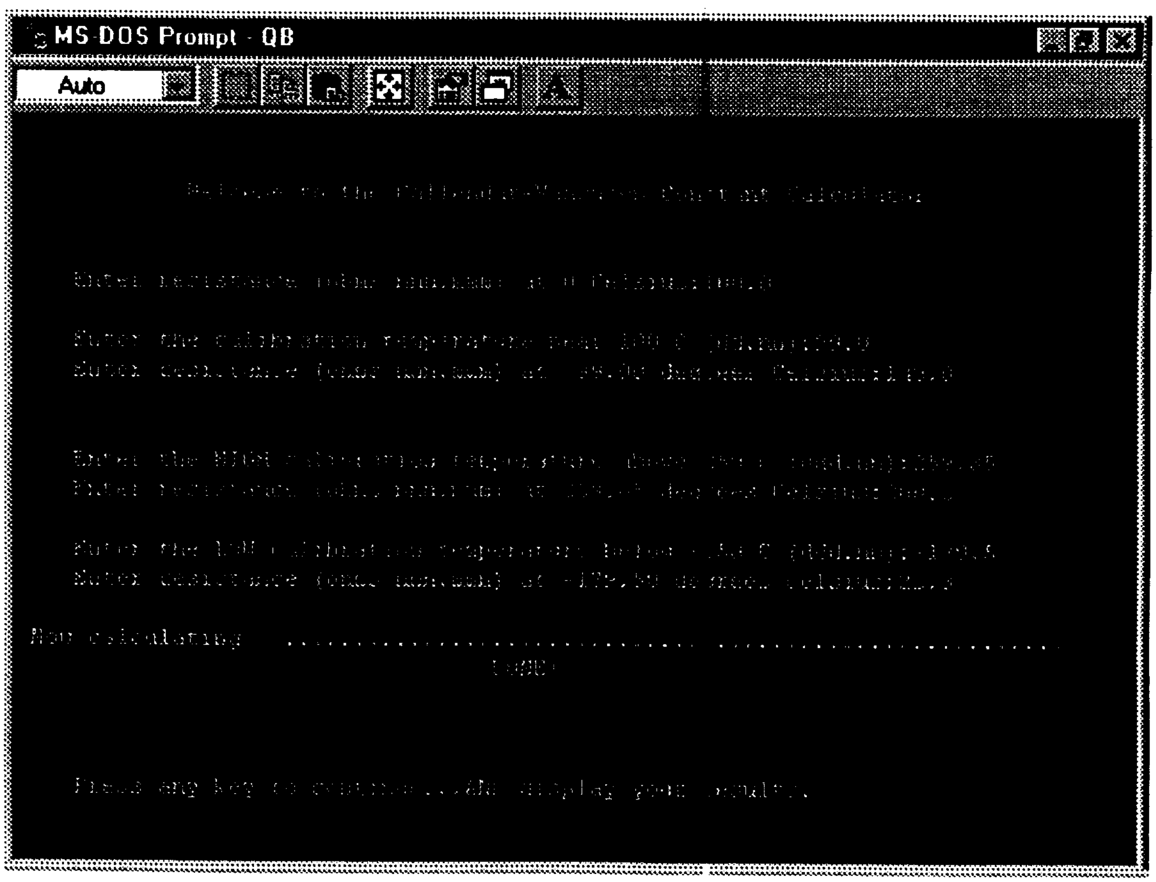
$$\frac{dW}{dt} = A + 2Bt + 4Ct^{2}(t - 75) \qquad (20)$$

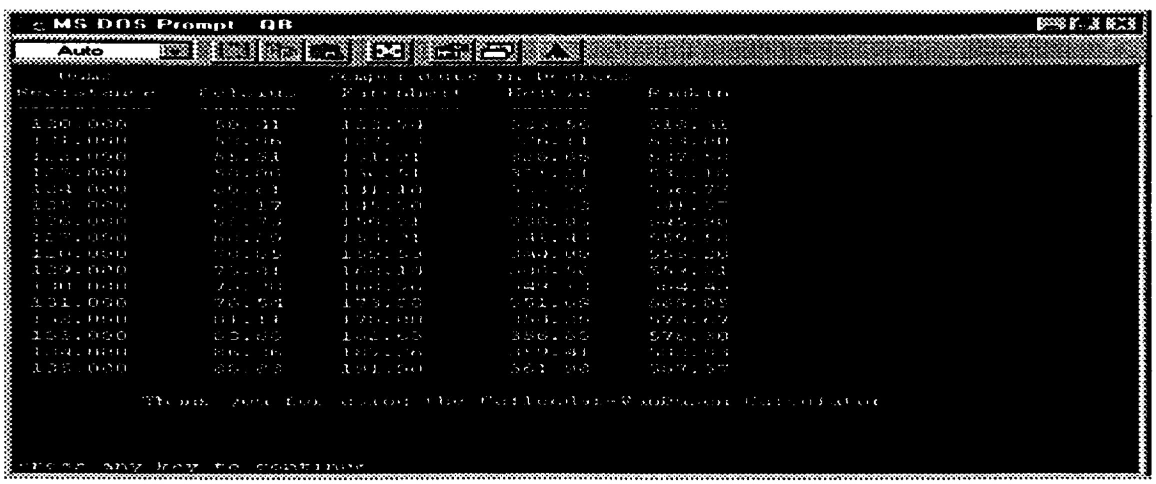
where C = 0 for t > 0°C

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





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References

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