BROOKFIELD PROGRAMMABLE TEMPERATURE CONTROLLER
MODEL 106

Operating Instructions

Manual No. M/02-207

This manual intended for use with newer controllers sold after August 2002. Please check your serial number. If the number after the dash is lower than 4000, you will require a different manual. Please contact Customer Sales & Service to obtain the correct manual.

BROOKFIELD

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I. INTRODUCTION

The Programmable Temperature Controller is used with the Brookfield Thermosel for measuring viscosity at high temperatures. The unit includes a solid state proportioning temperature controller, a means for entering the desired temperature/time data and appropriate status indicators.

The Programmable Temperature Controller can maintain a constant temperature in the Thermosel or be programmed to effect temperature changes. The program indicates each desired temperature and the period of time that the Thermosel should be maintained at that temperature. In this manual, a time/temperature combination is termed an "entry" or "step". A program can have up to 10 entries. The Programmable Temperature Controller can automatically stop maintaining the temperature of the Thermosel Container at the termination of the program. Alternatively, the Programmable Temperature Controller can be programmed to maintain the final preset temperature at the termination of the program.

The front panel is used to display and edit temperature/time programs. The front panel also presents the status of the system (e.g. the current temperature of the Thermosel and error messages).

An RS-232C communication channel is provided to establish control and/or observe operating parameters via a remote device (e.g. a personal computer or a remote terminal). Rheocalc, an optional software package available from BROOKFIELD, can be used, in conjunction with the BROOKFIELD Model DV-III+ Rheometer, to provide temperature/time inputs to the Programmable Temperature Controller via a personal computer. (Optional Cable HT-106 is required to interface the Programmable Temperature Controller to the PC.)

An analog output port is available to send temperature data to a strip chart recorder. Optional Recorder Output Cable (Part No. HT-88Y) is available from Brookfield.

A list of the parts shipped with the Programmable Temperature Controller is provided below. If any parts are missing or damaged, please contact BROOKFIELD or your local authorized representative immediately.

Systems Contents

Description	Part Number	Quantity
Programmable Temperature Controller	HT-110	1
RTD Temperature Probe	DVP-94Y	1
Operating Instructions Manual	M/94-202	1

TABLE 1

If you intend to use this Programmable Temperature Controller with a Brookfield DV-III+ Rheometer, *optional cables are required*:

- For direct temperature control (via DV-III+), *you will require optional cable DVP-141*
- For temperature control using Rheocalc software (via computer), *you will require optional cable HT-106*

Please contact Brookfield or your local authorized representative with your Thermosel Controller Serial Number to obtain these cables.

II. SPECIFICATIONS

Utilities

Voltage Specifications	
Input Voltage:	85 to 265 VAC
Input Frequency:	50/60 Hz
Replaceable Fuses:	Two fuses, 2A, 250V, 5 x 20mm, Fast Acting
Load:	TRIAC (250 watts max)
	(check the label beneath the Programmable Temperature Controller for the voltage requirements of your unit)

TABLE 2

Controller

Measurement/Control Specifications	
Range	15°C above ambient to 300°C 27°F above ambient to 572°F
Resolution	0.1 °C or °F
Reading Accuracy	± 0.5°C (between ambient and +100°C) ± 1.0°C (between +101°C and +200°C) ±2.0°C (between +201°C and +300°C)
Setpoint Accuracy	The temperature will be maintained within 0.3°C of the setpoint
Recorder Output Voltage	0 to 4 Volts 1 volt = 0°C/32°F; 4 Volts = 300°C/572°F

TABLE 3

NOTE: The temperature accuracies stated above are a result of the combined accuracies of the Programmable Temperature Controller, the temperature probe, and the Thermo container.

Thermo Container

Thermo Container Specifications	
Range	15°C above ambient to 300°C
Accuracy	±0.5% of the controller setpoint

TABLE 4

Conforms to CE Standards:

BSEN 50081-1:	Emission Standard - Light Industrial
BSEN 50082-1:	Immunity Standard - Light Industrial
BSEN 61010-1:	Safety requirements for electrical equipment, for measurement, control and laboratory use.

III. SAFETY SYMBOLS AND PRECAUTIONS

Safety Symbols

The following explains safety symbols which may be found in this operating manual.

Refer to the manual for specific warning or caution information to avoid personal injury or damage to the instrument.

Precautions

This instrument is not intended for use in a potentially hazardous environment.

If this instrument is not used in a manner specified by the manufacturer, the protection provided by the instrument may be insufficient.

IV. INSTALLATION

Plug the temperature sensor into the Probe receptacle, the Thermo Container into the Thermosel receptacle, the strip chart recorder (if used) into the Recorder jack and a remote RS-232C device (again, if used) into the Comm Ports 25-pin plug. The rear panel will appear as follows in Figure 1.

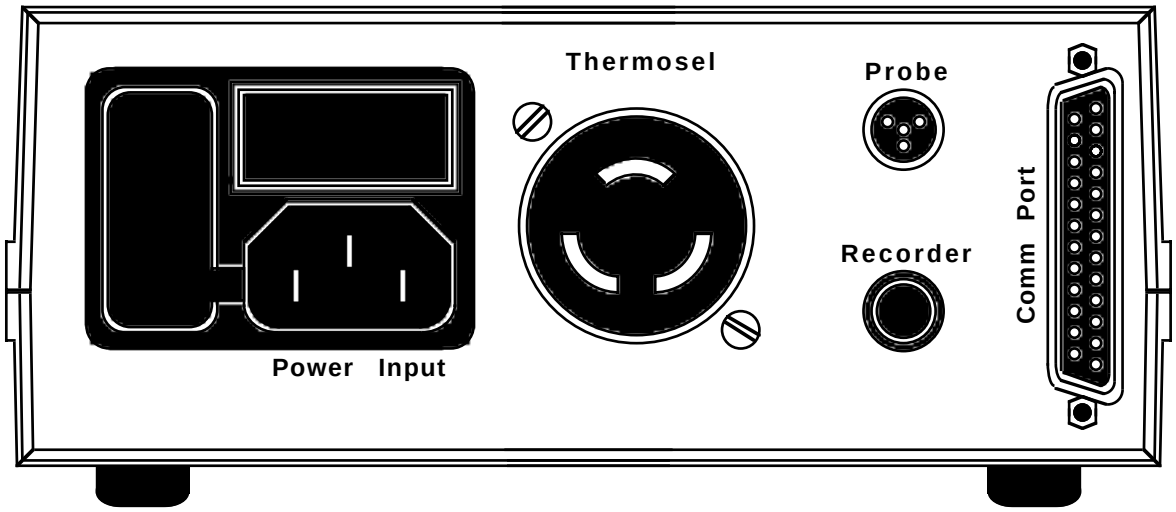


Figure 1

IV.1 Probe

The probe is a 100 ohm precision platinum RTD (resistance temperature detector) probe (Brookfield Part Number DVP-94Y) which is plugged into the Probe port on the rear panel.

Note: The RTD Probe *must* be plugged into the Programmable Temperature Controller and the RTD Probe end must be inserted into the Thermo Container before power is turned on. The Controller will beep on/off. An error message (0.RTD) will be displayed if the Programmable Temperature Controller is turned on and the RTD Probe is not installed.

IV.2 Recorder

The Recorder jack provides a signal to a recording device (the optional HT-88Y cable is provided for this service) such as a strip chart recorder. The full scale recorder output signal range is from 0 to 4 V for the Thermosel systems. The temperature can be obtained from the output potential (in mV) as follows:

The 0 to 4 volt output corresponds to a temperature range of -100°C (-148°F) to 300°C (572°F). Realistically, temperatures in Thermosel systems will typically be above ambient. Therefore, output voltages will generally range from slightly less than 2 volts (<100°C) to the full 4 volts (300°C). The temperature corresponding to any intermediate output voltage can be obtained from the following:

(0.1 * mV) -100 = °C(Centigrade Temperatures)
(0.18 * mV) -148 = °F(Fahrenheit Temperatures)

For example, the temperature corresponding to a reading of 2.5 V (2500 mV) would be calculated as follows:

(0.1 x 2500) - 100 = 150°C or (0.18 x 2500) - 148 = 302°F

The recorder jack is a standard 1/4" phono jack. An optional analog output cable (Brookfield Part No. HT-88Y) is available from Brookfield.

IV.3 Comm Port

The **COMMUNICATION PORT** provides an **RS-232C** data link to an external device such as a computer or remote terminal. The **RS-232C** pin assignments are:

RS-232C Pin Connections	
Pin Number	**Function**
2	Data Out (Tx)
3	Data In(Rx)
7	Ground(Gnd)
13 and 25	Remote Mode

TABLE 5

NOTE: Pin number 13 should be connected to pin 25 on the connector being inserted into the **Comm Port** in order to place the Programmable Temperature Controller in the Remote mode (indicated by the lit **REMOTE** LED on the instrument front panel).

RS-232C Protocol	
Baud Rate	9600
Data Bits	8
Stop Bits	1
Parity	None

TABLE 6

IV.4 AC, Power Switch and Power Fuse

The primary power requirement for the Programmable Temperature Controller can range from 85 to 265 VAC; 50/60 Hz and must be connected through the power cord. The voltage for which the unit has been configured will be indicated on the bottom of the Programmable Temperature Controller. The power consumption at 120 VAC is 400 ma plus the Thermo Container load power.

The power fuse must be a 2A/250V Littlefuse, fast acting type, GMA series or equivalent. This fuse protects the controller electronics only.

IV.5 Load

The Thermosel connector is provided to supply power to the Thermo Container. The connector is

specially keyed so that other loads cannot be readily substituted. The power limit supplied by this connector is 300 watts.

Note: The current provided to the Thermosel connector is potentially dangerous. Do not insert or remove the Load plug while power is applied to the Programmable Temperature Controller.

V. CONTROL KEYS AND DISPLAY PANEL

The front panel of the unit, which includes all user controls and status indicators, is shown in Figure 2:

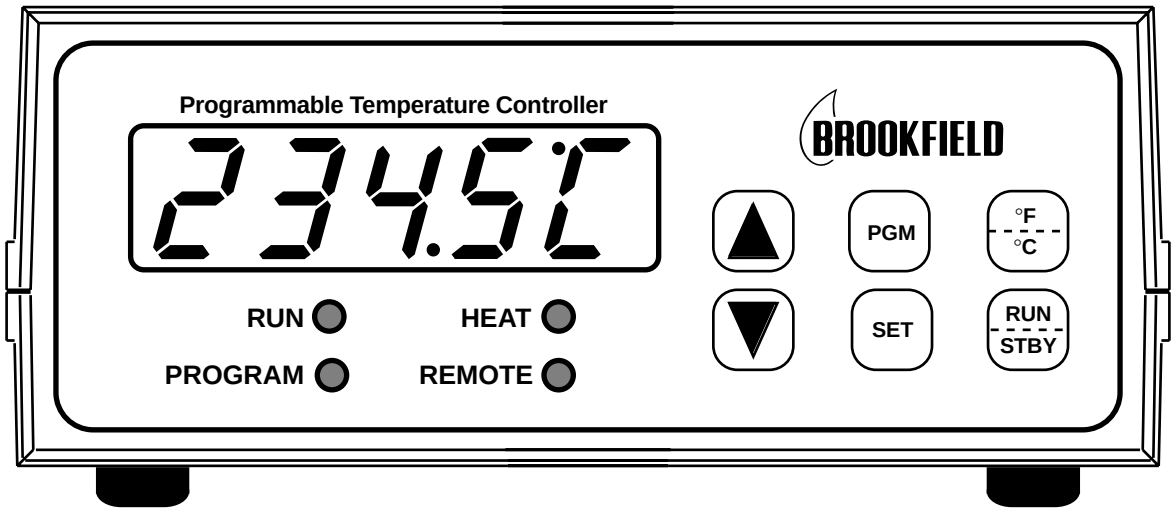


Figure 2

The digital display is used to display system status, to set up temperature/time programs, to review temperature/time programs and to present certain messages to the user.

The allowable range for temperature entries is:

0.0°C to 300.0°C (32.0°F to 572.0°F), with a minimum increment of 0.1° (either scale). The allowable range for time entries is from 1 to 900 minutes with a minimum increment of 1 minute.

If a proposed temperature value is above the maximum input for that unit, or if a proposed temperature value is below the minimum input for that unit, an audible sound (beep) will be heard and the current maximum (or minimum) value will be displayed.

The various buttons and light emitting diodes (LED's) have the following functions or meanings:

V.1 °F/°C The °F/°C Key

This key is used to toggle the units in which temperatures are displayed and entered. The right most digit in the main display indicates the units currently being used (F = Fahrenheit; C = Centigrade).

V.2 RUN/STBY The Run/Stby Key

The **RUN/STBY** key initiates or stops operation of the Programmable Temperature Controller. To initiate a temperature program or single setpoint operation, press **RUN/STBY**. The LED labeled *RUN* will light up to indicate the present status of the controller. When the Temperature Controller is operating, pressing the **RUN/STBY** key will place the unit in a standby mode and cease control of the Thermo Container.

V.3 SET The Set Key

The **SET** key is pressed when the operator wants to view or edit temperature and time data. In single setpoint (non-program) mode, the **SET** key accesses the temperature setpoint. In programmed mode, the **SET** key is used to cycle through the time/temperature program and to accept various options when the user is "building" a temperature/time program.

V.4 PGM The Program Key

The **PGM** key is pressed when the operator wants to establish, review or use a temperature/time program. The LED labeled PROGRAM is illuminated when the Programmable Temperature Controller is in the program mode.

V.5 The Arrow (direction) Keys

The **ARROW** keys are used to increment (or decrement) temperature values and to scroll through sub-program options where required. When used to input temperatures, a single press of either of these keys will result in a single digit increment in the displayed temperature value. When large temperature steps are required, the user will find it simpler to press and hold these keys. At first, this will result in a slow increment (or decrement) of the display temperature. However, after a couple of seconds, the display will rapidly increment (or decrement) and the user must be careful not to overshoot (or undershoot) the desired input value.

These keys will not work when the Programmable Temperature Controller is in the run mode.

V.6 HEAT ○ The Heat LED

The **HEAT** LED is illuminated when the controller is providing power to the Thermo Container. The LED will flash at a rapid rate when the temperature of the Thermo Container is being maintained at a programmed temperature.

V.7 REMOTE ◯ The Remote LED

The REMOTE LED is illuminated when an **RS-232C** cable (Brookfield Part No. HT-106 for connecting the Model 106 to a computer) is plugged into the Programmable Temperature Controller.

V.8 RUN ◯ The Run LED

The **RUN** LED is illuminated when the temperature of the Thermo Container is being controlled by the Programmable Temperature Controller.

V.9 PROGRAM ◯ The Program LED

The **PROGRAM** LED is illuminated when a temperature program is being established, viewed or run.

V.10 Piezo Buzzer

The unit includes a buzzer which will provide an audible tone (beep) in the following situations:

- During the Programmable Temperature Controller startup sequence.
- When a temperature/time program has been completed.
- If an illegal data entry has been made (e.g. attempting to set a temperature above or below the allowable inputs).
- If the temperature probe is removed.

VI. PROGRAMMABLE TEMPERATURE CONTROLLER OPERATION

VI.1 Powering Up the Temperature Controller

The Programmable Temperature Controller is turned on by placing the rear panel mounted ON/OFF switch in the ON position. The buzzer will beep and, after a few seconds, the digital display will indicate the present temperature of the Thermo container. When the unit is initialized, all of the indicator LED's are off. The **REMOTE** LED will be illuminated if the Programmable Temperature Controller is connected to an external device through an **RS-232C** cable.

VI.2 Control Modes

The user can select one of three control modes.

In the MANUAL or SINGLE SETPOINT MODE, the Programmable Temperature Controller functions as a single setpoint controller. The user sets a desired temperature, presses the **RUN/STBY** key and the unit will control the Thermo Container at this temperature indefinitely until the unit is shut off, or a new setpoint is entered and run or the Programmable Temperature Controller is placed in the standby mode.

In the PROGRAM MODE, the Programmable Temperature Controller functions as a multiple setpoint temperature controller. The user may define up to ten different setpoints in the controller's memory. The user must also define the time interval which will be used for each temperature setpoint (up to 15 hours 00 minutes per setpoint). The user may then run this pre-set program and the Programmable Temperature Controller will automatically execute the program. The Thermo Container will be con-

trolled to a specified setpoint temperature for the specified time interval and then the setpoint will be automatically changed to the next programmed temperature. The programmed setpoints may be of a "RAMP UP" type, "RAMP DOWN" type or a mixture of the two. At the last step of the program, the user can have the Programmable Temperature Controller stop controlling temperature after the last setpoint has been held at the last prescribed time interval, or continue controlling at the last setpoint temperature indefinitely.

In the REMOTE MODE the Programmable Temperature Controller accepts and executes commands from an external control device via an **RS-232** cable. You may not use the REMOTE MODE to run the program resident in the Programmable Temperature Controller memory.

The sections that follow explain these options in greater detail. The Programmable Temperature Controller may only be used in one of these modes at a time.

VI.3 Single SetPoint Operation - Non Program Mode

In the single setpoint mode of operation, the system is operated at a constant temperature. To establish the desired temperature, use the following procedure:

1) Press the SET key.

> **NOTE:** The Temperature Controller will display the last set point temperature value upon entering the temperature setpoint screen.

If you do not press either of the ▲ or ▼ keys or the SET key within approximately 4-5 seconds, the Temperature Controller will "beep" and revert to its non setpoint mode (the temperature will again be displaying tenth degree values). Simply press the SET key again to re-enter the temperature setpoint mode.

2) A press of either the ▲ or ▼ keys will cause the tenths degree digit to stop flashing and the tenths degree value to begin incrementing (or decrementing) at a one-to-two character per second rate. When the scrolled tenths value exceeds ten-tenths of a degree (i.e. one degree) in either direction, the scroll speed will then accelerate, and the ones digit will then be incremented (or decremented) as required. If the ▲ or ▼ keys are held in for an extended time, the scroll speed will again increase to its maximum rate.

3) If the user lets up on an ▲ or ▼ key for more than the 4-5 second timeout period, the display will revert to that of the current Thermo Container temperature with no change in the setpoint temperature taking place. At this point, a press of the SET key will display the last valid setpoint temperature that existed before the user began to change the setpoint temperature.

4) If the user lets up on the ▲ or ▼ key for less than the 4-5 second timeout period, and then re-presses an ▲ or ▼ key, the display will return to the tenths degree digit set mode and again begin the temperature set mode as described above.

5) If the user scrolls to some new setpoint temperature lets up on the ▲ or ▼ keys and presses the SET key, the Temperature Controller will accept the scrolled-to temperature as the new setpoint temperature. If the user had pressed the RUN STBY instead of the SET key, the temperature controller would have begun controlling the Thermo Container at the new scrolled-to setpoint temperature. In this case, the **RUN** ◯ LED would illuminate and the **HEAT** ◯ LED may or may not be lit depending on the temperature in the Thermo Container.

In any case, the Temperature Controller action will be to regulate to the new setpoint temperature. The current temperature of the Thermo Container will be displayed on the front panel digital display with the **RUN** ◯ LED illuminated. Power will be provided to the Thermo Container if the new setpoint temperature is higher; the Thermo Container **HEAT** ◯ LED will be illuminated. The Temperature Controller will provide power to reach the indicated set point and maintain it at that level indefinitely.

NOTE: The last scrolled-to-temperature (the last setpoint temperature) will be *retained in non-volatile* memory and will become the default setpoint temperature the next time the Temperature Controller is powered up.

6) Temperature control of the Thermo Container will be maintained for as long as the Temperature Controller is powered up, or until the RUN STBY key is pressed to stop the control action.

VI.4 Program Mode

There are two options available to the user in the PROGRAM MODE:

1) Run a program and terminate temperature control at the end of the program cycle.
2) Run a program and maintain temperature control at the last program setpoint temperature.

The fundamental approach to programmed operation is to create a table that includes the desired temperatures and the hold time period that is required for each temperature. A sample temperature/time program is shown in **Table 7**. Entry number 6 in the table is the last desired temperature step. Please note that the remaining program slots 7, 8 and 9 may have temperatures in them.

SAMPLE TEMPERATURE/TIME PROGRAM

TEMPERATURE (°C)	HOLD TIME (Minutes)	ENTRY NUMBER
100.0	5	0
140.0	15	1
160.0	10	2
205.0	8	3
240.0	4	4
265.0	5	5
290.0	2	6

TABLE 7

The time required to reach a temperature set point is dependent on a variety of factors such as the ambient temperature and the difference between the desired temperature and the previous temperature. The temperature/time program indicates how long the Thermo Container should be maintained at the selected temperature before the temperature is changed to the next temperature. The Programmable Temperature Controller allows individual "hold" times for each temperature.

VI.5 Entering A Temperature/Time Program

In this section you will learn how to enter a temperature/time program. Essentially the steps are:

- Enter the program temperature/time steps one at a time sequentially until your program is defined or until you reach reach the ten (10) step limit whichever comes first.
- Choose to either maintain the last programmed (not necessarily the tenth program step) temperature at its setpoint value or, choose to stop maintaining temperature control when the last program step time has expired.
- Select the start and end steps which will define your program. If you have entered ten (10) program steps, you could execute all ten (10) steps or you could elect to only execute a contiguous sub-set of the ten steps.

  Temperature/Time programs remain in memory when the Programmable Temperature Controller is turned off. It is not necessary to re-enter these programs when the unit is turned on again.

1) Use the **°F/°C** key to select whether temperatures will be entered in the Fahrenheit or Centigrade format. Since **Table 7** indicates temperatures in °C, we press the **°F/°C** key until a **C** is shown in the rightmost display position.

2) Press the **PROGRAM** key. The PROGRAM LED will illuminate and the last temperature programmed in program slot zero will be displayed as follows:

   where 40 is the previously set temperature for the first temperature entry and could be any value. If the program in Table 7 was being reviewed, 40 would be 100.

   0 indicates program step 1. Note that the ten (10) available programs are numbered from 0 to 9.

3) For this example, we will assume that we are entering a program to control a Thermo Container. The program we will enter is depicted in Table 7. We now enter the desired temperature for the first program temperature step using the **ARROW** keys.

4) The display now reads:

We have now altered the current program step to correspond to the first entry for Table 7.

5) Press the SET key to accept this value. The "hold" time is now displayed for this step. Use the arrow keys to change the displayed time to 5 minutes as listed in Table 7.

6) Press the **SET** key to accept this value and move to the next program step.

7) 45 is the previously set temperature for the second entry.

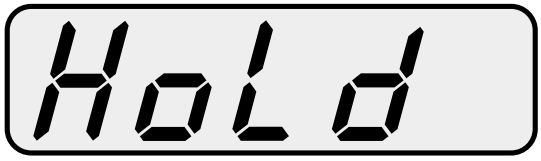
1 indicates the second program entry.

Enter the desired temperature for the second entry (140) and press the SET key when the correct value has been entered. Enter the desired time for the second step and press the SET key to accept it and move to the next step.

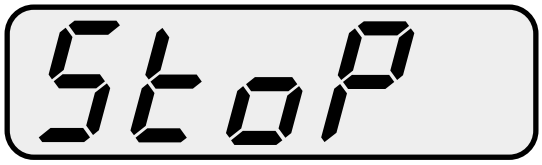
8) Continue to enter additional steps for the temperature/time program. The Programmable Temperature Controller can accept up to 10 entries. The tenth entry is indicated by the integer 9.

> **NOTE:** No matter how many steps you have in a program you will always have to press the **SET** key to cycle through all ten (10) temperature time steps. This also holds if you simply want to review a program.

9) Press the **SET** key once to accept the last (i.e. tenth step) hold time interval and to advance to the *HoLd/StoP* decision screen:

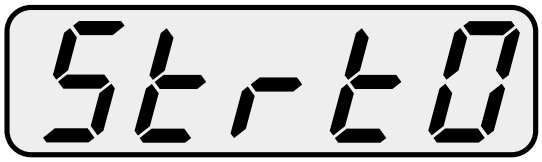


This could just as easily have been displaying the word **StoP** if that were the last selected **HoLd/StoP** decision. It will always on first entry display the last option selected. Here, you are being asked if you want the Programmable Temperature Controller to maintain or terminate the last programmed temperature (290 in our example) when the last program step time interval (2 minutes) expires. In the terminate temperature case, the last screen would have displayed:



At this point you may select either option by using the **ARROW** keys to display the method of your choice. If **StoP** is displayed, pressing the **DOWN ARROW** key will cause **HoLd** to be displayed. You can return to **StoP** by pressing the **UP ARROW** key. Make your choice and then press the **SET** key to accept it.

10) You will now see the following screen asking for your input for the start step number for your program:



Use the **ARROW** keys to scroll through the numbers 0 to 9 and select your starting step. Press the **SET** key to accept your selection and then see the following screen:

Again use the **ARROW** keys to scroll through the numbers 0 to 9 and select your program end step. You cannot select an end step that is less than your selected start step. Any attempt to do so will result in an audible alert from the Programmable Temperature Controller. The start and end step selections allow you a great deal of flexibility in running your program input. You could elect to start with step 0 and end with step 7, or you could start with step 3 and end with step 4 to run a sub-set of your program.

At this point your program input is complete. One more press of the **SET** key will return you to the display of step 2 above. If you want to run your program at this time, press the **RUN/STBY** key and note that both the **PROGRAM** and **RUN** LED's will be lit. However, if you don't want to run your program at this time, press **PROG** key to exit program mode. This is indicated by the PROGRAM LED being extinguished.

VI.6 Reviewing and Editing An Existing Program

To review an existing program, press the **PROG** key. The *PROGRAM* LED will be illuminated. Simply press the **SET** key to "scroll" through all the various steps of your program. When you are done, press the **PROG** key once more to exit program review. If you find a program step that is in error (or simply needs to be changed), advance to that step using the **SET** key and then use the **ARROW** keys to change the step to the correct (or new) temperature value or mode if you are altering the HoLd/StoP option.

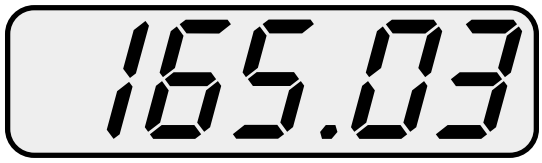
VI.7 Running A Temperature/Time Program

To run a program, press the **PROG** key (if the PROGRAM LED is already illuminated, you do not have to press the **PROG** key), and then press the **RUN/STBY** key. The *PROGRAM* LED and the *RUN* LED will now both be illuminated.

When the **RUN/STBY** key is pressed, Programmable Temperature Controller will begin ramping to that temperature. The *HEAT* LED will be illuminated when the Programmable Temperature Controller is providing power to the Thermo Container. When the temperature has reached the set point for that step (+/- 1°F or +/- 0.5°C), the Programmable Temperature Controller will maintain that temperature for the programmed time period.

While the Programmable Temperature Controller is in the hold time interval for a given setpoint, you can press the **SET** key twice to obtain the following information:

1) The first press of the **SET** key will display the current setpoint temperature and the current step number:



As shown here, we are holding in step 3 with a setpoint temperature of 165°C (or °F if that had been selected as the temperature display units).

2) The second press of the SET key will display the hold time remaining in step 3 before the Programmable Temperature Controller goes to the temperature programmed in step 4. The time remaining display would appear as follows:

The display shows that there are between 8 and 9 minutes left in the hold time period for this step. It is important to remember that the Programmable Temperature Controller starts all program steps at 0, and that all hold times are decremented to 0. This means, for instance, that if 15 minutes were entered as a hold time, you would see 14 displayed as the time remaining if you were to look at the hold time immediately after its start, and 0 if the hold time were in its last minute.

While the Programmable Temperature Controller is ramping up (or down), you can also determine the temperature setpoint for the next step by pressing the **SET** key twice: once to view the next setpoint temperature and once to see the programmed HoLd time interval.

VI.8 Stopping A Program

To stop a program that is presently running, simply press the **RUN/STBY**key. The *PROGRAM* LED will be extinguished and the current temperature of the Thermosel Container will be displayed. The Programmable Temperature Controller will display the setpoint temperature and step number for the program step it was executing at the time the **RUN/STBY** key was pressed.

VI.9 Remote Operation

The Programmable Temperature Controller can be interfaced to an external device such as a personal computer via the RS-232C protocol. The RS-232C cable (Brookfield Part Number HT-106) is used to interface the two devices.

Appendix A contains a sample program written in the BASIC language to demonstrate the use of the external control of the Programmable Temperature Controller. This program executes a temperature program from 100° C to 200° C in 25° C increments. At each setpoint, the temperature is maintained for a period of 10 minutes. The program can be readily adapted to include additional temperature setpoints and different time periods.

NOTES: 1) Only setpoint temperatures may be sent to the Programmable Temperature Controller in the external mode. It is up to the PC program to keep track of any desired hold times.

2) All previously stated temperature limits also apply to the external mode. However, the only limits on a step hold time or on the number of steps to be executed are any that may exist in the external device being used to program the Programmable Temperature Controller.

3) All Programmable Temperature Controller front panel keys are disabled when the unit is used in the external mode.

4) Every command sent to the Programmable Temperature Controller will be echoed back as part of the controller's response to the command received.

5) In the examples that follow do not enter the brackets ({}). CR indicates a carriage return (on a keyboard the Return or Enter key will produce a carriage return), and should be used after each command. When the Programmable Temperature Controller sends a command to the computer, it will be terminated by a carriage return. A carriage return may cause a line feed on some terminals.

6) All sensed and setpoint temperatures sent to or received from the Programmable Temperature Controller are formatted as a four digit integer number. Setpoint temperatures being sent should first be multiplied by a factor of ten and expanded to four digits with leading zeros if necessary. All temperatures (sensed or setpoint) being read from the Programmable Temperature Controller should be divided by a factor of ten to obtain the actual temperature.

The operator/user can develop a variety of programs for controlling the Programmable Temperature Controller via the RS-232C protocol to meet specific needs of the laboratory. The following communication protocol can be used in any desired combination:

1) To read the current temperature, enter T **{CR}** at the external device.
The response from the **Programmable Temperature Controller** to the external device will be:

T{tttt}{u}{s_t}{CR}

where:

tttt	indicates the current temperature multiplied by a factor of ten;
u	indicates the temperature scale (°F or °C);
s_t	indicates the present *state* of the **Programmable Temperature Controller** (as described in **Table 8** at the end of this section).

A typical response might be **T2345F1**, which means that the temperature is 234.5°F, and the controller is presently in the run mode (1).

2) To read the current temperature setpoint, enter **S{CR}** at the external device. The response from the **Programmable Temperature Controller** to the computer will be:

S{$s_p s_p s_p s_p$}{u}{s_t}{CR}

where**:**

$s_p s_p s_p s_p$	indicates the current setpoint multiplied by a factor of ten;
u	indicates the temperature scale (°F or °C);
s_t	indicates the present state of the controller.

A typical response might be **S1004C2**, which means that the current setpoint is 100.4 °C, and the controller is in the wait or standby mode (i.e. the Programmable Temperature Controller is not controlling the Thermo Container).

3) To adjust the temperature setpoint, enter **RS{$s_p s_p s_p s_p$}{u}{CR}** at the external device where **$s_p s_p s_p s_p$** is the setpoint temperature multiplied by ten and **u** indicates the temperature scale in either °**F** or °**C**.

A typical command sent to the controller might be **RS1004C{CR}**, which indicates the new setpoint should be 100.4 °C. The generic form of the response from the **Programmable Temperature Controller** to the computer will be in the form:

RS{$s_p s_p s_p s_p$}{u}{s_t}{CR}

The actual response to the above command will be **RS1004F2{CR}**. The last digit indicates that the system is in stand-by mode (see Table 8).

4) To change the operating mode, enter **RA{s_t}{CR}** at the external device where s_t indicates the desired state of the controller (as described in **Table 8**) and must be either a 1 or a 2.

s_t Codes Defining the State of the Programmable Temperature Controller	
Code	**Definition**
1	RUN mode; control to the setpoint temperature
2	STANDBY mode; do not control; wait for further input
3	Probe error 1 (probe disconnected from controller)
4	Overheat of the Thermo Container. This occurs after approximately 3 minutes of constant heat output with no sensed temperature rise in the Thermo Container.
5	Probe error 2 (temperature reading is above allowable limit)

TABLE 8

NOTE: Only codes **1** and **2** will be accepted by the Programmable Temperature Controller. Codes **3, 4** and **5** are indications only. All five codes may be returned by the Programmable Temperature Controller to the connected device (i.e. PC or terminal).

Any command other than those listed above sent to the Programmable Temperature Controller will cause the controller to respond with a question mark **(?{CR})**.

NOTE: Temperature/Time programs entered in stand-alone mode (i.e. from the **Programmable Temperature Controller** front panel) cannot be executed in the external mode via the **RS-232C** port. The commands explained above are the only means with which to control the **Programmable Temperature Controller**.

VII. REMOTE OPERATION USING RHEOCALC©

RHEOCALC©, a software program available from Brookfield Engineering Laboratories that controls the operation of the Brookfield DV-III+ Rheometer, can also be used concurrently to control the Programmable Temperature Controller in its external mode.

VIII. ERROR MESSAGES AND FAILSAFES

If the display shows an error message or there is a continuous “beeping” from the piezo buzzer, you are in one of the following error conditions:

1) The probe has become disconnected from the Programmable Temperature Controller. Plug the probe back in to the Programmable Temperature Controller to correct the error.

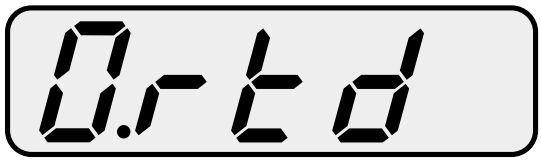
2) The controller is providing power to the Thermo Container, but the temperature sensor is not reporting an increase in temperature. The power to the Thermo Container will be interrupted. It will be necessary to power down the Programmable Temperature Controller and determine the cause of the fault before continuing operation.

3) The Programmable Temperature Controller sensed a temperature higher or lower than its built-in limits.

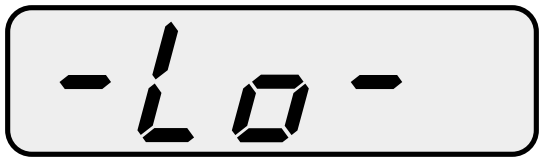
The following paragraphs provide further detail.

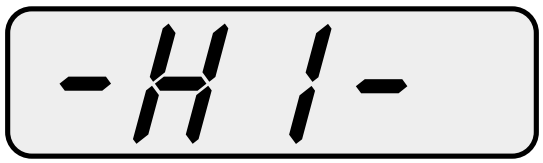
VIII.1 Open Sensor Error

If the sensor fails or an open circuit condition occurs (infinite resistance), the unit will cause a probe error as follows:



Note: The controller will intermittently beep. This error message could be momentarily preceded by either of the following displays:





The Programmable Temperature Controller will stop control and will stay in this state until the problem is corrected. This is usually due to the temperature probe not being plugged into the Programmable Temperature Controller. Once corrected, the unit will return to viewing the controlled temperature.

VIII.2 Thermosel Overheat Error

If the sensor becomes dislodged from the Thermo Container, or if the sensor is left out of the Thermo Container due to an operator error, or the Thermo Container coils become open, and the Programmable Temperature Controller is not sensing a temperature rise while dispensing power to the Thermo Container. It will display the following message after approximately a 3-minute delay:

The Programmable Temperature Controller will stop control and will stay in this state until the problem is corrected. The only way to correct this error is to power-down (turn off) the Programmable Temperature Controller and then turn it back on.

VIII.3 High/Low Temperature Limit Error

If a temperature outside of the **Programmable Temperature Controllers** high or low temperature limits is detected, either of the two messages -Lo- or -HI- shown directly above will be displayed. The Programmable Temperature Controller will stop control and will stay in this state until the problem is corrected. Once corrected, the unit will return to viewing the controlled temperature.

IX. TROUBLESHOOTING

In the event that the Programmable Temperature Controller does not appear to be working, check the power fuses (located in a removable section of the power input block) to determine whether they are still functional.

Note: Disconnect the **Programmable Temperature Controller** from the power source (mains) before checking the fuses.

The power fuse protects the controller electronics. This fuse (Brookfield Engineering Laboratories part number DVP-30) is a 2A/250V fast blow Littlefuse, fast acting type, GMA series or equivalent.

The Programmable Temperature Controller is designed to require a minimum amount of user maintenance. There are no user serviceable parts inside the unit. In the event of difficulties with the product, contact Brookfield Engineering Laboratories or its authorized representative. When calling Brookfield Engineering Laboratories, please have the serial number of the unit available (the serial number is indicated on a label on the bottom of the controller).

```
1000 ‘
1010 ‘ Programmable Temperature Controller External Mode Command
1020 ‘ Protocol Demonstration Copyright 1991, Brookfield Engineering
1030 ‘ Labs....Written by Greg Krysko
1040 ‘
1050 ‘
1060 CLS
1070 PRINT SPC(26); “Brookfield Engineering Labs”
1080 PRINT SPC(16); “External Mode Demonstration Program”
1090 PRINT SPC(32); “Copyright 1991”
1100 PRINT
1110 PRINT “This program is intended to demonstrate the use of the RS-232”
1120 PRINT “command set employed by the Brookfield Engineering Labs Model”
1130 PRINT “Programmable Temperature Controllers in their External mode.”
1140 PRINT “This program and/or any of the commands used within may be freely”
1150 PRINT “used in your own applications.”
1160 PRINT
1170 PRINT “Press any key to continue...”
1180 GOSUB 1670                                    ‘ Wait for a keypress
1190 GOSUB 1760                                    ‘ Initialize variables
1200 OPEN “COM1:9600,N,8,1,CS,DS,CD” FOR RANDOM AS #1 ‘ Open com port #1
1210 CLS
1220 PRINT “The Controller will run a temperature ramp from 100°C to 200°C”
1230 PRINT “in 25°C increments.  When the current temperature is within”
1240 PRINT “one half a degree of the setpoint, there will be a 10 minute”
1250 PRINT “delay before ramping to the next temperature to allow the”
1260 PRINT “temperature to settle.  When the ramp is complete, the”
1270 PRINT “controller will be placed in the Standby mode and allow the”
1280 PRINT “Thermosel to return to ambient temperature.”
1290 PRINT
1300 PRINT “Press any key to continue...”
1310 GOSUB 1670                                    ‘ Wait for a keypress
1320 CLS
1330 PRINT “Beginning temperature ramp...”
1340 PRINT
1350 WHILE SETPOINT <= 200                         ‘ Repeat until temp = 200
1360 LOCATE CURSY, 1
1370 PRINT “Temperature Setpoint #”;
1380 PRINT USING “#”; POINTNUM;
1390 PRINT “ = “;
1400 PRINT USING “###.#”; SETPOINT;                ‘ Print Setpoint Temperature
1410 PRINT SPC(3);
1420 HTCMD$ = “RS” + RIGHT$(STR$(FIX(SETPOINT * 10)), 4) + “C” ‘ Form command
1430 GOSUB 1890                                    ‘ Send command to Controller
1440 GOSUB 1970                                    ‘ Wait for Controller to reply
1450 GOSUB 2090                                    ‘ Parse response
1460 ‘ Send a run mode command if not already in run mode
1470 IF INRUN = 0 THEN INRUN = 1:HTCMD$ = “RA1”:GOSUB 1890:GOSUB 1970
1480 WHILE ((SETPOINT - .5) > TEMPERATURE) OR ((SETPOINT + .5) < TEMPERATURE)
1490 GOSUB 2480
1500 WEND
1510 GOSUB 2290
1520 SETPOINT = SETPOINT + 25                      ‘ Increment setpoint by 25
1530 CURSY = CURSY + 2
1540 POINTNUM = POINTNUM + 1
1550 WEND                                          ‘ End WHILE from line 1245
1560 HTCMD$ = “RA2”                                ‘ Set Controller to Stby mode
1570 GOSUB 1890                                    ‘ Send command to HT-104
```

```
1580 PRINT
1590 PRINT SPC(25); “Temperature ramp complete!”
1600 PRINT SPC(25); “Returning the Controller to its Standby state.”
1610  GOSUB  2240                                    ‘  Close  Communications  channel
1620  END
1630  ‘
1640  ‘
1650  ‘  Routine  that  waits  for  a  keystroke
1660  ‘
1670  KEYSTROKE$  =  “”
1680 WHILE KEYSTROKE$ = “”
1690 KEYSTROKE$ = INKEY$
1700 WEND
1710  RETURN
1730  ‘
1740  ‘  Initialize  variables  and  constants
1750  ‘
1760  CR$  =  CHR$(13)
1770  TEMPERATURE  =  0
1780  SETPOINT  =  100
1790  TMPTUNITS$  =  “C”
1800  CURSY  =  3
1810  POINTNUM  =  1
1820  INRUN  =  0
1830  RESP$  =  “”
1840  RETURN
1860  ‘
1870  ‘  Routine  to  send  commands  to  the  Programmable  Temperature  Controller
1880  ‘
1890  GOSUB  2160
1900  HTCMD$  =  HTCMD$  +  CR$
1910  PRINT  #1,  HTCMD$
1920  RETURN
1930  ‘
1940  ‘
1950  ‘  Routine  to  receive  a  response  from  the  Programmable  Temp  Controller
1960  ‘
1970  RESP$  =  “”
1980  WHILE  RIGHT$(RESP$,  1)  <>  CR$              ‘  Wait  for  a  carriage  return
1990  IF  LOC(1)  >  0  THEN  RESP$  =  RESP$  +  INPUT$(LOC(1),  #1)
2000 WEND
2010 ‘DO
2020  ‘LOOP  UNTIL  INKEY$  <>  “”
2030  RETURN
2040 ‘
2050 ‘
2060  ‘  Routine  to  parse  response  to  a  response
2070  ‘
2080  ‘  Extract  temperature  and  status  info  from  the  response
2090  IF  (LEFT$(HTCMD$,  1)  =  “T”)  OR  (LEFT$(HTCMD$,  2)  =  “RS”)  THEN  TMPTRESP$  =
MID$(RESP$,  2,  4):  TMPTUNITS$  =                  MID$(RESP$,  6,  1)
2100  IF  LEFT$(HTCMD$,  1)  =  “T”  THEN  TEMPERATURE  =  VAL(TMPTRESP$)  /  10
2110  RETURN
2120  ‘
2130  ‘
2140  ‘  Routine  to  clear  the  com  port  input  buffer
2150  ‘
2160  WHILE  LOC(1)  >  0                            ‘  If  data  in  input  buffer
2170  DUMMY$  =  INPUT$(LOC(1),  #1)                 ‘  Dump  it  out
2180  WEND
2190  RETURN
2200  ‘
```

```
2210 ‘
2220 ‘ Routine to close communications channel
2230 ‘
2240  CLOSE  #1
2250  RETURN
2260  ‘
2270  ‘  Routine  to  countdown  10  minutes
2280  ‘
2290  T1  =  TIMER
2300  T2  =  T1  +  600
2310 WHILE T1 < T2                                    ‘ Loop until 10 mins pass
2320 LOCATE (CURSY + 1), 1
2330 PRINT “Countdown to next temperature increase: “;
2340 PRINT USING “##”; FIX((T2 - T1) / 60);
2350 PRINT “:”;
2360  PRINT  USING  “##”;  (T2  -  T1)  MOD  60
2370  T1  =  TIMER
2380  GOSUB  2480
2390  WEND
2400  LOCATE  (CURSY  +  1),  1
2410  PRINT  SPC(50);
2420  LOCATE  CURSY,  32
2430  PRINT  SPC(35);
2440  RETURN
2450  ‘
2460  ‘  Routine  to  update  and  print  current  temperature
2470  ‘
2480  HTCMD$  =  “T”
2490  GOSUB  1890                                     ‘  Send  get  temp  command
2500  GOSUB  1970                                     ‘  Wait  for  response
2510  GOSUB  2090                                     ‘  Parse  response
2520  LOCATE  CURSY,  35                              ‘  Position  cursor
2530  PRINT  “Current  Temperature  =  “;
2540  PRINT  USING  “###.#”;  TEMPERATURE;            ‘  Print  current  temperature”
2550  PRINT  “◦”  +  TMPTUNITS$;
2560  RETURN
```

Appendix B - Warranty Repair and Service

Warranty

The Brookfield Model 106 Programmable Temperature Controller is guaranteed for one year from date of purchase against defects in materials and workmanship. The Controller must be returned to Brookfield Engineering Laboratories, Inc. or the Brookfield dealer from whom it was purchased for no charge warranty service. Transportation is at the purchaser's expense.

For repair or service in the **United States** return to:

Brookfield Engineering Labs., Inc.
11 Commerce Boulevard
Middleboro, MA 02346 U.S.A.

Telephone: (800) 628-8139 (USA); (508) 946-6200 FAX: (508) 946-6262
email: service@brookfieldengineering.com

For repair or service **outside the United States**, consult Brookfield Engineering Laboratories, Inc. or the dealer from whom you purchased the instrument.

For repair or service in the **United Kingdom**, return to:

Brookfield Viscometers Limited
1 Whitehall Estate
Flex Meadow
Pinnacles West
Harlow, Essex CM19 5TJ, United Kingdom

Telephone: (44) 27/945 1774 FAX: (44) 27/945 1775
email: sales@brookfield.co.uk

For repair or service in **Germany**, return to:

Brookfield Engineering Labs. Vertriebs GmbH
Hauptstrasse 18
D-73547 Lorch, Germany

Telephone: 7172/927100 FAX: 7172/927105
email: info@brookfield-gmbh.de