⚠ ***This product is intended for use ONLY in direct-current (DC) powered systems. Acceptable nominal operating voltage ranges from 6VDC to 24VDC.***

⚠ ***DO NOT USE in alternating-current (AC) powered systems; this will void your warranty and may create a safety hazard.***

⚠ ***This product MAY NOT BE PROTECTED against long-term reverse polarity connection. If this product is not configured with a polarized power connector, make sure that the RED wire is connected to POSITIVE (+). The BLACK wire must be connected to NEGATIVE (-).***

⚠ ***DO NOT, UNDER ANY CIRCUMSTANCES, REMOVE THE HEATER FROM THIS PRODUCT AND ATTEMPT TO OPERATE IT WITHOUT A CONTROL. This will void your warranty and may create a personal safety hazard.***

Thank you for purchasing Engenity's patent-pending ThermEvolve® product. This paper describes the basic functionality of, and the options available with, both IntelliThaw® heating jackets and IntelliHose® heated hoses. Please bear in mind that the product you have received may not be configured with any of the available options. To determine which options have been configured on your ThermEvolve product refer to the "Configuration Details" sheet that came with your product. Please take time to write down the serial number of the product so that you can register it at http://engenity.com/thermevolve/warranty-registration. The warranty period is two (2) years from the date of installation.

Do not attempt to modify your ThermEvolve product in any way. Your product was configured collaboratively by the engineers at Engenity and the manufacturer of your equipment to perform safely and reliably under the most extreme conditions. If you suspect your product is not functioning correctly, please contact Technical Support via the method listed on the "Configuration Details" sheet.

OPERATION

ThermEvolve products were developed to provide safe and reliable heating of hoses and fluid handling components in DC-powered systems over a temperature range from as low as -50˚C and upwards. This is accomplished through a combination of: 1) the application of adequate heating power to meet the performance goals at the minimum temperature, and; 2) dual-channel heater control to ensure safe and efficient operation at higher temperatures.

Please refer to ***FIGURE 1*** for the following operational description.

Definitions

HEATED OBJECT - A hose in the case of IntelliHose or just about anything else (e.g., fuel filter, filter canister, fuel injector, pneumatic valve, etc.) in the case of IntelliThaw.

HEATER - An electric resistive heater of either the constant resistance or positive temperature coefficient (PTC) types, and designated as **R1** in *FIGURE 1*.

HEATER SURFACE TEMPERATURE SENSOR - The sensor, shown as a thermocouple and designated as **T1** in Figure 1.

AVERAGE TEMPERATURE SENSOR - The sensor, shown as an RTD (Resistance Temperature Detector) and designated as **R2** in Figure 1. The placement of the AVERAGE TEMPERATURE SENSOR has been carefully determined so as to accurately measure the average temperature of the HEATED OBJECT.

INSULATING JACKET - Closed cell insulation. Typically EPDM extruded tubing in the case of IntelliHose, or molded nylon in the case of IntelliThaw. In the case of IntelliThaw heating jackets, the insulating jacket acts as the carrier for the system components while ensuring good thermal coupling between the HEATED OBJECT and the HEATER.

THERMEVOLVE TEMPERATURE CONTROL - A dual-channel, dual-function, microcontroller-based temperature control. Channel 1 receives its input from T1, which is sensing the surface temperature of the heater, and is configured to provide a high-limit function that governs the maximum surface temperature of the heater. Channel 2 receives its input from R2, which is sensing the average temperature of the heated object, and is configured to provide on-off control to achieve the desired average system temperature. The two channels' upper and lower setpoints are typically configured independently of each other—*e.g.*, in an IntelliHose DEF hose application Channel 1's upper setpoint (the temperature at which the heater must be shut off) is programmed to 100˚C and its lower setpoint (the temperature at which the heater may be switched on) is programmed to 50˚C, while Channel 2's upper setpoint is programmed to 0˚C and its lower setpoint (the temperature at which the heater must be switched on) is programmed to -5˚C. Power to the HEATER is modulated via a solid state switch, designated as **S1** in Figure 1, as determined by an algorithm that compares the average temperature of the HEATED OBJECT and the surface temperature of the HEATER.

SYSTEM - The INSULATING JACKET and everything within it.

All system components listed above form the basis of every ThermEvolve product. The items below are optional and may or may not be present in your ThermEvolve product.

SYSTEM BYPASS - this is an input signal line that is used to put the ThermEvolve product into an ultra-low-power consumption state (typically consuming less than 1mA). Applying 0V (ground in a negative ground system) will completely shut off the system. Applying any voltage greater than 0.5V (up to and including your system's supply voltage) will activate the system. This is typically used in applications where it would not be desirable to have the ThermEvolve product continuously consuming battery power.

TEST MODE/ALTERNATE SETPOINT - this is an input signal line that is used to change at least one of the setpoints of the ThermEvolve control. This may be desirable for system testing (TEST MODE), or to, for example, enable the system to deliver increased power at exceptionally low temperatures (ALTERNATE SETPOINT). Applying 0V (ground in a negative ground system) will change the setpoints until a voltage greater than 1.5V is applied to the input. The standard configuration for TEST MODE is to set the average system temperature to 100˚F and the heater's high-limit temperature to 110˚F. In utilizing the TEST MODE function, installers can verify that all internal components of the ThermEvolve product are functioning as intended even when ambient temperatures are warm enough that the heater(s) would not normally become energized.

SYSTEM READY - this is an output signal line that may be configured as either a TTL compatible level (for communication with an ECU or other control components) or to drive an LED. Once the desired average system temperature has been achieved, this line will go high.

SYSTEM ERROR - this is an output signal line that may be configured as either a TTL compatible level (for communication with an ECU or other control components) or to drive an LED. If an unrecoverable system fault occurs (see the section below, System Health Self-Monitoring) this line will go high.

CROWBAR CIRCUIT - this function will be present in your ThermEvolve product only if it is also equipped with a fuse, F1. The crowbar circuit is represented by X1, a silicon controlled rectifier. In the event that a system fault occurs, the ThermEvolve Temperature Control will trigger X1, thereby effectively putting a short circuit across the power supply, which, in turn, will blow (open) the fuse, F1. This option is recommended for ThermEvolve systems that will be operating autonomously (not communicating with an ECU or other control components) or that are not utilizing LED indicators.

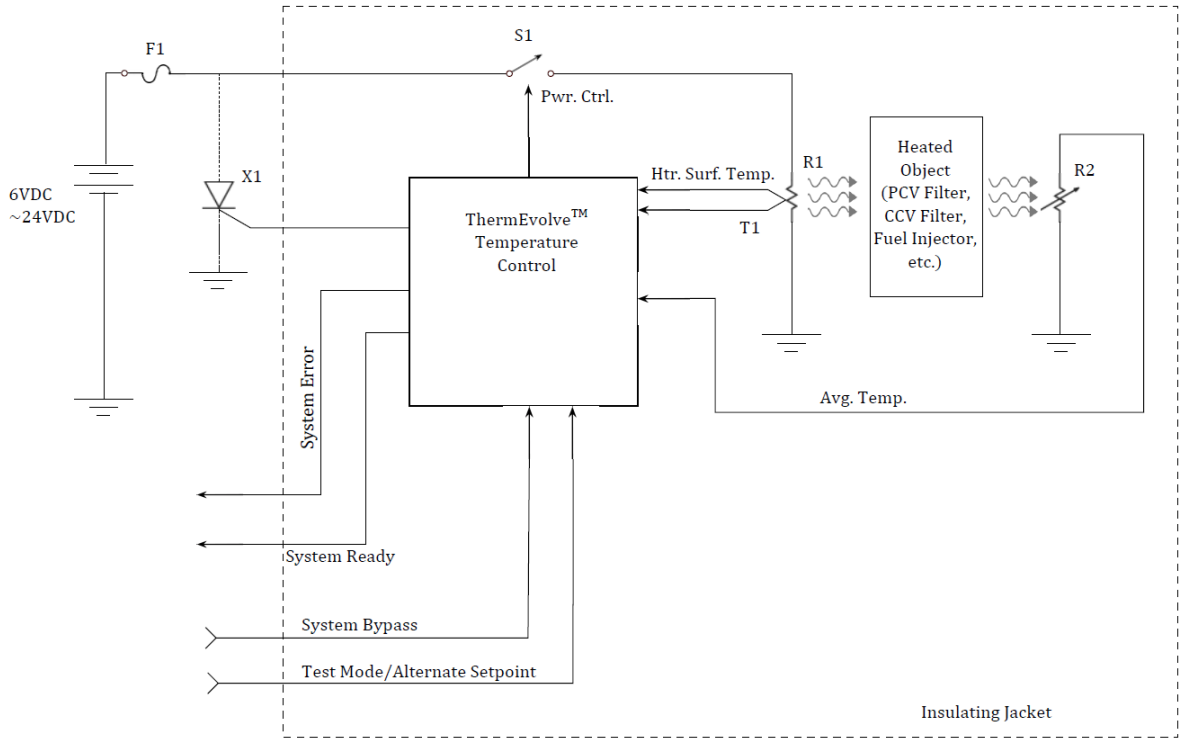

FIGURE 1

Temperature Control

As previously discussed, the ThermEvolve temperature control is effectively a two-channel (a.k.a. dual-loop) temperature control with one channel limiting the maximum surface temperature of the heating element and the other channel controlling the average system temperature.

Referring to *FIGURE 2*, this is a graphical representation of temperatures within a ThermEvolve system from the time a system is switched on to the time that the desired system temperature is achieved. T_H, the heater's surface temperature, is determined by factory programmed values for T_{HL}, the high-limit (maximum) temperature the heater is allowed to obtain, and T_{DB}, the deadband temperature, which is the difference between T_H and the lower high-limit temperature. There are many factors that are considered when determining these values. Among them are, to name just a few: maximum allowable operating temperature of the heated object; allowable degree of overshoot of the system temperature, T_{PV}, relative to the desired average system temperature, T_{SET}; and, electrical noise considerations. T_H will never be greater than 140˚C in an IntelliHose heated hose, or 180˚C in an IntelliThaw heating jacket. In *FIGURE 2* the high-limit's lower setpoint temperature is represented as being less than the lower setpoint temperature for the system, but this will not always be the case.

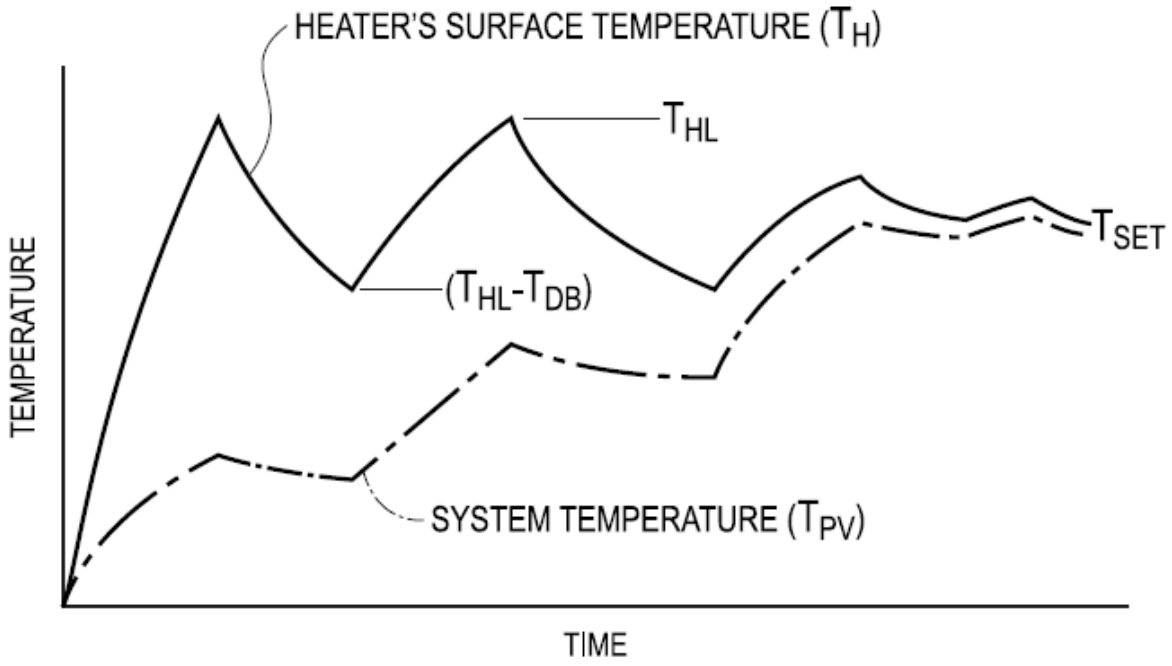

FIGURE 2

System Health Self-Monitoring

The ThermEvolve temperature control is based on an 8-bit microcontroller. As such, it allows for a great deal of internal monitoring ensuring that the system is functioning properly. To summarize, there are two general categories of internal testing that occur in the control's program:

- Watchdog Timer — this is a timer circuit that is separate from and independent of the microcontroller. Every time the program gets back to its starting point, the microcontroller resets the watchdog. If the microcontroller fails to perform this function internal logic circuitry assumes that a failure has occurred and the system is shut down. (Depending on the options that are built into your ThermEvolve product, the System Error output will go high or the Crowbar Circuit will be triggered.)
- Logical Testing — this consists of the program making tests to ensure that the system is functioning properly. If the result of any of the tests is negative, internal logic circuitry assumes that a failure has occurred and the system is shut down. (Depending on the options that are built into your ThermEvolve product, the System Error output will go high or the Crowbar Circuit will be triggered.) The tests, stated as questions are:
    - S1 should be switched on, is voltage actually being applied to the heater?
    - S1 should be switched on, are T_H and T_{SET} both increasing?
    - S1 should be switched off, is voltage actually disconnected from the heater?
    - S1 should be switched off, are T_H and T_{SET} either decreasing or remaining steady?