DT6500 CONTROLLER

for the

AQUARIUS™ DEIONIZED WATER HEATING SYSTEM

ICD/Heateflex
405 E. Santa Clara St.
Arcadia, CA 91006-7218
TEL: (626)599-8566; FAX: (626)599-9567

Rev. 23, 01/16/03, (DT6500)

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Table of Contents

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The Model **DT6500** is a microprocessor based controller for the ICD/Heateflex® Aquarius™ **DeI**onized (**DI**) Water Heating System. It monitors and controls all functions of the Aquarius™ System. Although its primary function is to accurately control the temperature of the discharged DI water, it also provides monitoring for input temperature, output temperature, flow rate (in both gallons/minute and liters/minute), input voltage, input amperage, input pressure, and (optional) output water resistivity.

The **DT6500** receives data from many sensors in the Aquarius™ System. Temperature inputs are direct thermocouple connections. Separate thermocouples are used for input temperature of the ambient DI water, output temperature of the heated DI water, and a thermocouple is used on each heating element in the Aquarius™ System serving as independent over-temperature safety interlocks (**HIGH LIMIT**). A liquid level sensor checks for proper liquid level at the top of the final heating module. A sensor checks flow rate at the input to the first heating module (all modules are in series). Pressure sensing is done with a pressure transducer at the ambient DI water input. Input line voltage monitoring is done with a step-down transformer at the power line. If the resistivity option is present a resistivity sensor output is also connected to the **DT6500**.

All independent over-temperature safety interlocks (**HIGH LIMIT**) are controlled by a separate circuit panel. It is powered by an isolation transformer that draws power from the primary side of the master relay. The sensors are type J thermocouples. This circuit shuts off the internal master relay should an over-temperature condition occur on any of the heater **HIGH LIMIT** thermocouples. The controller receives **HIGH LIMIT** thermo-couple inputs from each heating module in the Aquarius™ unit.

Twenty-six discreet LEDs are utilized to indicate system and display status and various alarm conditions. A twelve key, membrane switch, keyboard is incorporated in the faceplate to allow for user setup and adjustment of the system.

Two different numeric displays, **Data 1** and **Data 2**, each with four digits, are used to view system parameters. Identifier LEDs to the right of each display indicate which parameter is currently displayed. Four different parameters may be viewed by successive depression of the **Data 1** keyboard switch. A different set of four parameters are displayed with the **Data 2** keyboard switch. Additionally, each of the displays has multiple diagnostic and setup functions that may be activated by the keyboard or by the microprocessor during various setup and alarm conditions. **DATA 1** and **DATA 2** are collectively referred to as the **Data Display**.

The **DT6500** contains four printed circuit boards. The control board contains two transformers and provides the isolated DC supplies (+5 and +12 volts) necessary to run the system. In addition, it contains the A/D converter, multiplexer, RAM, PROM and microprocessor. The display board contains all of the numeric and LED displays as well as the audio transducer and display drivers. The I/O board contains the analog input conditioning circuitry, the high limit circuitry, the multiplexer and a number of calibration potentiometers. An auxiliary board is provided on the I/O board that contains the resistivity monitoring hardware.

A standard RS232 communications interface port is provided. This port allows direct connection to an on site customer computer for automated control. This port may also be used to temporarily connect to the factory computer at ICD/Heateflex® Corporation, via modem/telecommunication link, for remote evaluation and troubleshooting by an ICD/Heateflex® factory engineer.

MODE LEDs:

The six primary status modes are indicated by LEDs on the faceplate and are marked **STANDBY, ACTIVE, HEAT, PURGE, PROGRAM, and ALARM.**

MODE LED	DESCRIPTION
STANDBY:	When the system is first turned on it goes into **STANDBY** mode. In this mode, all of the keyboard operational features are active, but the safety relay is inactive (disabling all power to the heaters). The system is "standing by" and is ready to go into **ACTIVE MODE**.
ACTIVE:	This is the normal operating mode for the system. In this mode, if there are no alarms and a flow greater than 0.3 GPM is detected, the control system will meter power to the heaters to raise the output DI water temperature to the **Process Setpoint (PS)** parameter.
HEAT:	This mode indicates that the heaters are turned on. The LED will cycle as required by the system parameters.
PURGE:	This mode provides for an automatic flushing of the system. It may be activated either manually by the **PURGE** key or automatically by a counter if so programmed (see **SETUP** for details).
PROGRAM:	This mode allows **SETUP** parameters to be entered or checked. When in **PROGRAM MODE** the **PROG** key causes the controller to step through a series of parameters (see **SETUP** for details).
ALARM:	Various **ALARM** conditions are activated by many sources and are annunciated by both the displays and audio tone. The **ALARM MODE** LED shows that an **ALARM** has occurred and that the system is still performing under the special conditions required by that **ALARM**. **ALARM**s are classified as either automatic reset or manual reset type. If the **ALARM** is an automatic reset, this mode will be cleared when the **ALARM** condition is no longer present. If the **ALARM** is a manual reset type, the **ALARM** may remain active even after the condition has been cleared. The **RESET** key switch is utilized to clear the manual reset alarms.

ALARM LEDs:

The various alarms in the system are indicated by LEDs on the faceplate and are marked **SYSTEM, SENSOR, HIGH LIMIT, LOW LEVEL, RESISTIVITY, HEATER, HIGH TEMP, LOW TEMP, HIGH FLOW, LOW FLOW, HIGH PRES,** and **LOW PRES**.

ALARM LED	DESCRIPTION

SYSTEM: This is a catch-all indicator for the miscellaneous diagnostics. An example would be a malfunction of the EEPROM save routine. It would simply indicate to the user that something has gone wrong and he should either repeat the command or reset the unit. The **Data Display** will alternately flash "**SYS**".

Note: The **SYSTEM** LED is also illuminated when the (optional) **GFCI** (**G**round **F**ault **C**ircuit **I**nterrupt) alarm is active.

SENSOR: This alarm indicates that there is a defective **SENSOR** (thermocouple). The **SENSOR** is either open or not connected. Special circuitry has been incorporated to monitor the **SENSOR**s for an open circuit. The microprocessor continually monitors these circuits and if it detects an open **SENSOR**, it disables the heater and activates the **SENSOR** alarm.
The **Data Display** will alternately flash "**SENX OPEN**", where the "**X**" indicates the thermocouple that is open. It will be **I**=Input, **O**=Output, **1-9** indicates the corresponding **HIGH LIMIT** thermocouple.

Note: The alarm condition must be present continuously for 3 seconds to trigger this alarm.

HIGH LIMIT: This LED is wired directly to the **HIGH LIMIT** circuitry and lights when ever a **HIGH LIMIT**, over-temperature, condition is detected in any of the heater modules. This **HIGH LIMIT** condition turns off the master relay, disables the heaters, and turns off the **DT6500** controller. Since the **HIGH LIMIT** circuit is powered by a separate power supply, the **HIGH LIMIT** LED remains on even if the master relay has been de-energized and the controller is turned off. (Note: The **HIGH LIMIT** LED will turn off when the alarming thermocouple cools.)

LOW LEVEL: This is the **LOW LIQUID LEVEL** alarm. It is activated any time the fluid falls below the liquid level sensor. The heaters are disabled and the code "**LO**" is alternately flashed in the **Data Display**.

Note: The **LOW LIQUID LEVEL** condition must be present continuously for 3 seconds to trigger this alarm. This is to prevent nuisance tripping due to air bubbles.

RESISTIVITY: Resistivity sensing is an optional feature. Whenever the value of the DI water **RESISTIVITY** falls below the programmed limit this alarm will activate. "**RES LO**" will alternately flash in the **Data Display**.

HEATER: This alarm LED is not used.

HIGH TEMP: This is the **HIGH TEMPERATURE** alarm. It is activated any time the discharge DI water temperature exceeds the **HIGH TEMP** programmed limit. When activated, the **Data Display** alternately flashes the code "**HI**". The heaters are disabled.

LOW TEMP: This is the **LOW TEMPERATURE** alarm. It is activated any time the discharge DI water temperature falls below the **LOW TEMP** programmed limit. This alarm is only functional in **ACTIVE MODE**. The code "**LO**" is alternately flashed in the **Data Display**.

HIGH FLOW: The system monitors the DI water flow. If the flow rate exceeds the **HI FLOW** programmed limit this alarm will activate. The code "**HI FLO**" will alternately flash in the **Data Display**. There is no other effect on the operation of the system. This is strictly an enunciator.

LOW FLOW: The system monitors the DI water flow. If the flow rate falls below the **LOW FLOW** programmed limit this alarm will activate. The code "**LO FLO**" will alternately flash in the **Data Display**. The heaters are disabled.

HIGH PRES: This is the **HIGH PRESSURE** alarm. The system pressure is continually monitored and if the pressure exceeds the **HIGH PRES** programmed limit, this alarm is activated. The code "**HI PRES**" will alternately flash in the **Data Display** and the heaters are disabled.

LOW PRES: This is the **LOW PRESSURE** alarm. The system pressure is continually monitored. If the system pressure drops below the **LOW PRES** programmed limit, this alarm is activated. The code "**LO PRES**" will alternately flash in the **Data Display**. There is no other effect on the operation of the system. This is strictly an enunciator.

EPO: This alarm activates when the (optional) **GFCI** (**G**round **F**ault **C**ircuit **I**nterrupt) has detected a ground fault current. The code "**EPO**" will alternately flash in the **Data Display**. The heaters are disabled and the unit is placed in **STANDBY MODE**.

All the alarms activate an audio tone in addition to illuminating an LED. The audio tone and the LEDs alternate between ON and OFF to draw attention to the alarm condition. Also, as previously noted, many of the alarms have messages flashed in the **Data Display** to further define and draw attention.

The alarm **SILENCE** key switch eliminates the audio alarm and also stops alarm messages from being flashed in the **Data Display**. This essentially allows the unit to be returned to a functional condition where setpoints can be examined and reset without the interference of the special alarm messages. However, the alarm LED will continue to flash to indicate the alarm condition. If the alarm condition has disabled the heaters, they remain disabled to protect the equipment from any potential damage.

A safety relay is provided as an additional mechanical interlock for a number of alarms. This safety relay is wired in series with the master relay and controls the system master contactor. A number of alarms are manual reset type and if activated, drop out the safety relay. The relay may only be reset by a manual depression of the **RESET** key switch, after the alarm condition has been cleared. The **LOW FLOW, HIGH TEMPERATURE, HIGH PRESSURE,** and **LOW LEVEL** alarms fall into this category.

KEYBOARD:

The 12 key switch keyboard is used to program and control the Aquarius™ System. The switches are labeled ⮝ (UP), ⮟ (DOWN), **SAVE/SILENCE, DATA1, DATA2, ON, OFF, PURGE, RESET, RETURN, SET,** and **PROG** (PROGRAM).

KEY SWITCH	DESCRIPTION
ON: **OFF:**	These are the master power switches for the controller. They activate and deactivate an electronic latch which in turn switches the master power relay inside the unit **ON** or **OFF**.
	Note: The **RESET** key switch must be pressed to initially activate the system after power up. See **"RESET".**
PROG:	This is the **PROGRAM MODE** key switch. It has two functions. Pressing this key switch will place the **DT6500** into **PROGRAM MODE**. However, if the **DT6500** already is in **PROGRAM MODE**, pressing this key will step to the next parameter code and setting (see **SETUP**).
SET:	**SET** refers to Process **SET**point. Press and hold this key switch to display the Process **SET**point (Discharge Temperature Setpoint).
⮝ (UP)**:**	This key switch is only active during **PROGRAM MODE**. It is used to advance the parameter setting display. Pressing the key once will advance the display one unit, which allows the accurate setting of the least significant digit of the entered parameter. Holding the key switch down will sequentially advance the display until the key switch is released, or until the display reaches the upper limit of the range for that parameter setting.
⮟ (DOWN)**:**	This key switch is only active during **PROGRAM MODE**. It is used to decrement the parameter setting display. Pressing the key once will decrement the display one unit, which allows the accurate setting of the least significant digit of the entered parameter. Holding the key switch down will sequentially decrement the display until the key switch is released, or until the display reaches the lower limit of the range for that parameter setting.

SAVE / SILENCE: This key switch has two functions.

If the unit has an active alarm, it will serve as a **SILENCE** Key. It is used to **SILENCE** the audio alarm. If the alarm has a special alpha code flashing in the **Data Display**, this is also canceled.

If the unit is in **PROGRAM MODE** and does not have an active alarm, it will serve as a **SAVE** key.

This **SAVE** feature is only active during **PROGRAM MODE**. Press the key switch to write the current program parameters into the EEPROM memory. This is a permanent (ten year minimum life) memory that does not require battery backup. The **SAVE** routine takes about one second to complete and is indicated by a series of dashes through the **Data Display**. This feature provides the OEM with the ability to program initial parameters prior to shipment. The end user may also modify these parameters and permanently save their changes in EEPROM memory, all from the **DT6500** keyboard.

RETURN: This key switch is used to exit **PROGRAM MODE**.

RESET: The **RESET** key switch has two functions:

When the system is first powered on, it comes up in **STANDBY MODE**. The **RESET** key switch must be pressed to initially activate the system.

When a manual alarm occurs, the **RESET** key switch must be pressed, after the alarm condition has been cleared, to re-activate the system.

DATA1: Selects one of four possible parameters for the **Data 1** Display. It sequences between: **°C IN, °C OUT, GPM,** and **LPM**.

DATA2: Selects one of four possible parameters for the **DATA 2** Display. It sequences between: **Volts, Amps, PSIG** and **M OHMS** (MEG OHMS).

PURGE: This key switch manually activates and deactivates the **PURGE** cycle (if the **PURGE** option is installed).

PROGRAMMING:

In **PROGRAM MODE** a number of parameters may be set. The key switches labeled **PROG** (PROGRAM), ⮝ (UP), ⮟ (DOWN), **SAVE**, and **RETURN** are utilized to enter **PROGRAM MODE**, view parameters, set parameters, **SAVE** parameters, and exit **PROGRAM MODE**. (See the description of these modes and key switches earlier in this manual.)

All of the parameters may be viewed except the **ACCESS CODE** which will display as "**----**" if access code protection (described later) has been selected.

The parameter alpha code will appear in one data display (as a prompt) and the parameter value in the other data display. The following is a listing of the parameter codes, parameter names, and parameter setting ranges:

CODE	PARAMETER NAME	SETTING RANGE
PS	**Process Setpoint**	**0.0 to 95.0°C**
HI	**High Temp. Setpoint**	**0.0 to 99.0°C**
LO	**Low Temp. Setpoint**	**0.0 to 95.0°C**
HF	**High Flow Setpoint**	**0.0 to 13.0 GPM, 0.0 to 60.0 LPM**
LF	**Low Flow Setpoint**	**0.0 to 13.0 GPM, 0.0 to 60.0 LPM**
HP	**High Pressure Setpoint**	**0.0 to 100.0 PSIG**
LP	**Low Pressure Setpoint**	**0.0 to 100.0 PSIG**
HA	**Heater Amperage**	**0.0 to 400.0 Amps**
RES	**Resistivity Setpoint**	**0.0 to 20.0 Meg Ohms**
AC	**Access Code**	**0 to 9999**
CR	**Cycle Rate**	**0.0 to 19.9 seconds**
CA	**Calibration**	**-9.9 to +9.9°C**
AP	**Auto Purge Period**	**0.0 to 10.0 Hours**
AD	**Auto Purge Duration**	**0.0 to 99.0 Minutes**
PR	**Power Reset**	**0 to 600 Seconds**
DB	**Dead Band**	**0 to 9.9°C**
PA	**Power Adjust**	**Minus 99 to Plus 99 Counts**
AR	**Auto Reset**	**0 = No, 1 = Yes**
SN	**Flow Sensor**	**0 = SPX-3/4, 1 = 3-2530**

ACCESS CODE:

In some cases it may be desirable to restrict access to the setting of the program parameters. Thus an **ACCESS CODE** system is incorporated to limit access to **PROGRAM MODE**.

The **ACCESS CODE** may be any number from **0001** to **9999** as programmed into the system by the user's authorized personnel. If the **ACCESS CODE** is set to **0000** there is no restriction to **PROGRAM MODE**, and the system operates as previously described. If the **ACCESS CODE** is set to any value between **0001** and **9999**, access to **PROGRAM MODE** is restricted to those who know the **ACCESS CODE**.

Once an **ACCESS CODE** (**0001**-**9999**) is entered into the EEPROM, any attempt to enter **PROGRAM MODE** will cause "**CODE**" to appear in the **Data Display**. The ⮝ (UP) and ⮟ (DOWN) key switches are then used to select the previously programmed **ACCESS CODE** number. The **PROG** key switch is then pressed a second time to gain access to **PROGRAM MODE**. Any other entry, the wrong code number, or no action for 30 seconds will return the unit to its previous mode.

OPERATION:

The basic function of the **DT6500** controller is to provide hot DI water on demand. The unit continually monitors the flow sensor and once flow is detected the heaters are turned on to a proportional power level that is calculated by the following formula:

$$KW = \frac{GPM \times \Delta T°C}{3.79}$$

This formula utilizes the input thermocouple temperature and process setpoint temperature to calculate _T°C. The GPM is taken from the flow meter reading and the KW is adjusted by time proportioning the on time of the heaters ratioed to the time base set in the **Cycle Rate (CR)** parameter.

This value becomes the maximum KW that the system may utilize. The actual percentage of power that is utilized is additionally determined by the temperature control section utilizing the output thermocouple.

The temperature control section operates as an adjusting mechanism to the power requirement. It monitors the discharge temperature and compares it against the required setpoint. Based on the **Power Reset (PR)** parameter, it will adjust the power that is applied to the unit to bring the discharge temperature into complete compliance with the requirements. The **Dead Band (DB)** setting is utilized to establish a range above and below the setpoint in which the temperature control section will take no further action. This means that the **PR** parameter will adjust the power on a periodic basis and examine the temperature output to determine whether the temperature is within the customer specified control band. If the temperature is within this **Dead Band**, it will leave the power alone. If the temperature is outside this **Dead Band**, it will continue to adjust the power until the temperature is within the **Dead Band**.

The **DT6500** has a large number of inputs and outputs. The main output is the solid state relay drive to the heaters. This is a 12 VDC output signal that is active high. It has sufficient capacity to drive 10 solid state relays. The alarm output is an open collector transistor that may be interfaced with an external alarm. The purge valve output is a form C relay. It will close either on automatic or manual purge.

When the system is first turned on, it will come up in **STANDBY MODE**. In this mode, all of the keyboard operational features are active, but the safety relay is inactive. This

allows **SETUP** of the system program parameters without the heaters being active. Under all other normal operating conditions, the heater outputs are triggered by flow. In this special start up condition, flow does not trigger the heaters until the **RESET** key switch is pressed to initially put the unit into **ACTIVE MODE**. An exception to this exists when the **Automatic Reset (AR)** parameter is set to 1. When this selection is made, the system will not wait for the **RESET** key switch to be pressed to go from **STANDBY MODE** to **ACTIVE MODE**. It will automatically go from **STANDBY MODE** to **ACTIVE MODE** when there are no alarms and there is a flow above 0.3 GPM. For this feature to be effective, the **Low Flow** alarm must be eliminated. This is done by setting the **LF** parameter to 0.0.

The **DT6500** has two internal relays that are wired in series with the Master System Contactor. The first is the Master Relay which is controlled by the **ON** and **OFF** switches on the front panel and the **HIGH LIMIT** circuits. If the unit is turned off, either manually by the **OFF** switch, or automatically by an over-temperature condition on one of the **HIGH LIMIT** thermocouples, the power to the system master contactor is interrupted and the heaters are disabled. The control of this relay is not linked to the microprocessor section. Its function is controlled by an independent power supply and analog circuitry. It thus serves as a redundant backup to the intelligent portion of the controller.

The safety relay is interlocked with a number of intelligent alarms. The more critical alarms in the system are designated as manual reset alarms. When any of these alarms are triggered, the unit will not return to normal operation until the alarm has been cleared and the system has been manually **RESET** by pressing the **RESET** key switch. Each of these alarms has the capability of disabling the safety relay. Thus, when the alarms are triggered, they not only shut down the intelligent drive to the solid state relay, but also mechanically turn off the system master contactor to provide an additional element of protection by mechanically eliminating the power to the heaters.

As previously mentioned, when the system is first powered up, the safety relay is utilized to disable the heaters until the **RESET** key switch is pressed. When program parameters do not have to be changed, this feature acts as an extra step required before power is enabled to the heaters, to insure that the operator specifically wants to activate **HEAT MODE**.

The **DT6500** has an additional safety interlock feature that is transparent to its normal operation. If for some reason, the discharge temperature reaches 5°C higher than the setpoint, the heaters are disabled. This is not announced as an alarm unless this temperature exceeds one of the alarm settings. However, it is provided to insure that the setpoint has overriding control over all of the automatic calculations. This provides

additional first line protection against erroneous heater output due to conditions such as bad voltage or current sensors.

The Aquarius™ System has an optional Auto **PURGE** feature that flushes or purges the unit after a programmable period of time where there is no demand for DI water. Auto **PURGE** monitors the amount of time elapsed since leaving **ACTIVE MODE** (i.e.: "No Flow Time"). If this amount of time exceeds the programmed **Auto Purge Period (AP)** parameter, the system is purged for the amount of time programmed in the **Auto Purge Duration (AD)** parameter. The system will continue to purge even if a flow is detected while the unit is in **AUTO RESET** mode or **MANUAL** mode. Once the **Auto Purge Period** has elapsed, the unit will return to **AUTO REST** mode. The **PURGE** cycle may be terminated prematurely by pressing the **PURGE** key. (The **DT6500** also supports a remote **PURGE** switch, which would be connected to the "Purge T" input on the back of the controller). Note that the heaters are disabled during **Auto Purge Duration** time.

A Resistivity Option is offered for the Aquarius**™** System. The Resistivity section utilizes a standard Resistivity Sensor with a cell constant of 0.05. It excites the sensor with an AC signal to prevent any interference due to electrolysis or secondary reactions with the electrode material. The standard cell has an extremely non-linear characteristic with respect to temperature. The controller has an extensive compensation algorithm to handle the standard 3D curve. It should be noted, that while the cell has an internal temperature sensor, this sensor is not utilized in the system. The output thermocouple temperature is utilized in the temperature compensation algorithm.

The Aquarius™ System has a large red emergency power off switch; an optional remote emergency power off switch is also supported. Each of these switches produce the same effect. When the switch is pressed, the normally closed contacts open, interrupting power to the Master Contactor holding coil, disabling the heaters. Also the Controller is powered off.

SETUP:

The values that are entered into the various program parameters determine the actual operation of the system. While many of the parameters will be specifically dictated by user requirements, the purpose of this section is to give a general indication of the meaning and affect of the control parameters.

The **Process Setpoint (PS)** is the primary control parameter for the system. This is the desired discharged temperature. It serves as the target around which all of the other control parameters function.

The Power to Flow® computations are based on the readings taken from the Flow Sensor, the Input Thermocouple and the Line Voltage. These inputs are used in conjunction with the **Heater Amperage (HA)** setting to compute the heater "on" time. The **HA** parameter should be set to the nominal heater amperage at rated line voltage. This setting will allow the unit to compute the nominal available KW. Variations in the line voltage will allow the adjustment of this figure, should other than expected line voltages exist.

To further compensate for potential thermocouple errors, the **CAlibration (CA)** parameter is provided. This parameter allows the user to adjust the reading from the discharge thermocouple. This can compensate for errors due to the Teflon® encapsulation of the thermocouple, as well as the tolerance of the thermocouple.

The Power-To-Flow® section automatically computes the first approximation of the KW required to establish the desired discharge temperature. The **Power Reset (PR)** parameter is utilized in conjunction with the **Dead Band (DB)** parameter to adjust further computations to compensate for any error that might exist. The **DB** setting should be made to establish a satisfaction band for the system. If, for example, it is desirable to maintain the discharge temperatures to within + or - 0.5 degrees, then the **DB** should be set to 0.5. This will inhibit any further adjustment when the temperature is within this tolerance band. Initially, it would appear that the tighter this band, the better the control. However, it should be noted that depending on system operations, if the band becomes too small, the system will simply oscillate, rather than becoming stable.

The **Power Reset PR** parameter is the primary temperature compensation for the system. It functions much like the Reset parameter in a standard three mode control algorithm. However, in this algorithm, the Reset parameter actually adjusts the output power of the system to compensate for errors in discharge temperature. The **PR** setting is adjusted in seconds and roughly indicates the period at which power

adjustments will be made in an attempt to compensate for errors in the discharge

temperature. As an example, if the parameter is set to 30 seconds, the system will make an adjustment in the system power once every 30 seconds in a positive or negative direction depending on whether the discharge temperature is below or above the process temperature.

The control loop is capable of adjusting the power to the nearest half cycle. Therefore, at 60 Hz., this amounts to 120 half cycle adjustments every second. If the **Cycle Rate (CR)** parameter is set to one second, there are 120 power adjustments that can be made. This is approximately a 1 percent resolution. If the **cycle rate** is set to 2 seconds, there are 240 adjustment points corresponding to approximately 0.4 percent resolution.

The **PR** parameter will make an adjustment of 1 resolution point after each time-out. Therefore, in a system with a **Cycle Rate** of 1 second and a **PR** of 30 seconds, the system will adjust out at the rate of approximately 1 percent per 30 seconds. If the **Cycle Rate** is increased to 2 seconds, this means that every 30 seconds the power is adjusted by approximately 0.4 percent (1/240).

In setting the **PR** parameter, it is desirable to examine the throughput for the system. The initial setting for this parameter should be such that the effect of the power change can be seen by the output sensor, prior to its making another change. In essence, this dictates the time that is approximately equal to the throughput time for a given system.

To compensate for this, the unit automatically adjusts the **PR** parameter in an inverse ratio to the flow. The **PR** setting should be made initially with the flow of 1 GPM. The system will then take this value and adjust it in accordance with varying flows. For example, when the flow is 2 GPM, the **PR** parameter will be cut in half.

The net effect of the **PR** parameter is that it will compute a necessary addition or subtraction to the required KW to match the discharge temperature to the **Process Setpoint**. The **Power Adjust (PA)** parameter is provided as a manual reset function for the system. The **PA** setting allows the user to directly input the offset to the power formula, if desirable. This setting is normally not necessary, but may be utilized, if it is found that for some reason, the system has either a fixed over-temperature or under temperature initialization. The **PR** parameter will eventually adjust this error out, but if it is desirable to decrease the settling time, the **PA** parameter may be set. The net effect will be that the Power-to-Flow® computation will be completed and the **PA** parameter will be added to this computation as a percentage power, just as the **PR** parameter previously described. However, the **PA** parameter will not vary and will serve as a fixed constant in this computation. The **PR** parameter will continue to adjust and fine tune, if necessary, regardless of the setting of the **PA** parameter.

TROUBLESHOOTING PARAMETERS:

Two additional parameters have been included in the initial programming stack. They are intended for debugging purposes and will allow a view of the control computations. In the stack, the parameters will appear as **On Count (OC)** and **Power Offset (PO)**.

The internal computations for the output power are accurate to within 1/120th of a second. This allows for the maximum control possible over half wave zero cross power output. Therefore, if the **Cycle Rate** is set for 1.0 seconds, the maximum number for **On Count** is 120. The internal mathematics will compute the number of counts that the power should be on to provide the proper percentage of output KW. Thus, if the computations indicate that 40% power is required, the **On Count (OC)** will be 48 (48/120=40%).

The **OC** parameter may be viewed in the stack. The parameter is not intended to be set, but will automatically change to allow the viewing of the results of the internal computations. This parameter may be helpful in troubleshooting and/or understanding the way the system functions.

The **Power Offset (PO)** parameter allows the viewing of the results of the **Power Reset** computations. The **Power Reset** computations work as a digital integrator adjusting the power as the function of the temperature error. These results may be either + or - and are expressed in counts, similar to the **OC** counts. These counts are then added or subtracted to the computations that have been done by the power section. The **PO** parameter allows the user to view the on running results of the **PR** function. This may aid in the initial setting of the parameter because it will show how rapidly the power is being adjusted in the system.

It should be noted that the **OC** parameter, as viewed, is a compilation of the actual **On Count** that is actually computed by the power section and the **Power Offset** as displayed in the **PO** parameter. For example, if the power section has computed that 40 counts are necessary to provide the output power and the reset section has determined that 3 additional counts are necessary to offset a discharge error, the **OC** parameter will display 43, which is the actual number of counts that are used.

COMMUNICATION INTERFACE:

An RS232 interface allows the user to have remote computer access to the DT6500 Controller. Through this serial link all of the standard functions of the Controller may be activated, tested, and adjusted.

Since this unit is a Controller, it does not handle a great deal of data. Therefore, the link has been optimized to allow the user, through very simple instructions, to control and interrogate the unit.

Ten key commands allow the user to instruct the Controller to perform all of its normal operations. However, only 3 or 4 of these are actually required for computer operation. The remainder are provided, but are not often used, since these keys are utilized in programming. The serial link has direct access to the programming stack through the **READ** and **WRITE** commands. Utilizing these commands, the serial link can interrogate or overwrite any of the items in the program stack.

The current thermocouple temperatures and time are accessed by the **READ** command.

All of the internal status conditions for the Controller are accessed through 3 bytes of data. These bytes may be read out at any time using the **STATUS** command.

The Controller may be hooked to any standard terminal or computer system via the DB25 connector on the back panel. The link is internally fixed at 9600 baud, 8 bit, 1 stop and 1 start bit, no parity. The baud is internally selected via a bit switch, but does require that the unit be taken apart. The link only requires 3 leads to function. As viewed from the Controller, Pin 7 is the Signal Ground, Pin 3 is Receive Data, and Pin 2 is Transmit Data.

The Protocol for the serial link consists of 5 basic commands:

R - READ
W - WRITE
K - KEY
S - STATUS
X - CANCEL

All commands will be prefixed by one of the above five letters. The data format is standard ASCII and all data, with the exception of the Status Bytes are BCD values. The Status Bytes are transmitted in ASCII as hexadecimal, since they contain bit information.

There are no group commands, since there is so little data in the Controller and most functions require direct access to specific locations.

The following is a breakdown of each of the commands and the way they are accessed. It should be noted that the format allows for the unit to be hooked directly to a dumb computer terminal. This can be very useful in checkout. The unit will echo all characters that are typed to it. When used with a terminal, this will provide the appropriate display. When used with a computer system, this will provide direct feedback of the fact that unit has accepted the command.

All commands are completed with a carriage return from the computer. With the exception on the **CANCEL** command **(X)**, all commands will be acknowledged by a carriage return line feed ($0A,$0D).

KEY COMMAND:

The **KEY** command allows the user to instruct the Controller just as would be done by depressing the Face Panel keys. The exact operation and sequence for these keys is covered in the Controller manual. This description will simply indicate how the link may be used to send these key functions. The command is entered as a letter followed by 2 numbers, followed by a carriage return:

K01(Return)

The **K** indicates that this is to be a **KEY** command. The **01** indicates the **KEY** number and the **Return** activates the command.

The following is a listing of the key numbers:

KEY NUMBER	KEY
01	**DOWN**
02	**SAVE/SILENCE**
03	**DATA 1**
04	**UP**
05	**SET**
06	**RETURN**
07	**RESET**
08	**PROGRAM**
09	**DATA 2**
10	**PURGE**

When a **KEY** command is set, the Controller will echo each of the characters and acknowledge with a carriage return line feed, once the command is entered. If an invalid command is detected, it will simply be ignored, although it will acknowledge the fact that the command has been received.

READ COMMAND:

The **READ** command is utilized to read from the Controller any of the program data or current time and temperature readings. The format for the command is essentially the same as the **KEY** command.

R07(Return)

The **R** indicates to the Controller that the command is to be a **READ** command. The next two digits indicate the data location to be read. The carriage return indicates that the command is to be activated. The following is a listing of the data locations that may be read:

DATA LOCATION	DESCRIPTION	DATA LOCATION	DESCRIPTION
01	PS	18	AP
02	HI	19	AD
03	LO	20	PR
04	HF	21	DB
05	LF	22	OC
06	HP	23	PO
07	LP	24	PA
08	HA	25	UNUSED
09	RES	26	UNUSED
10	SEN	27	TEMPERATURE IN
11	UNUSED	28	TEMPERATURE OUT
12	AC	29	FLOW-GPM
13	CR	30	FLOW-LPM
14	AR	31	VOLTAGE
15	UNUSED	32	AMPERAGE
16	UNUSED	33	PRESSURE
17	CA	34	RESISTIVITY

All data is returned in ASCII format with 4 BCD characters. When the Controller displays information, such as the **Proportional Band** in tenths of degrees C, the data that is returned will be in tenths of degrees. For example, 10.0 degrees C. will be transmitted as 0100. Reference the **PROGRAMMING** section to determine the exact meaning of each of the readings.

STATUS COMMAND:

The **STATUS** command is utilized to access 4 bytes of information that are utilized by the Controller to indicate its operating status. The format for the **STATUS** command is similar to the **KEY** and **READ** commands.

S01(Return)

The **S** indicates the activation of a **STATUS** command. The number indicates the status byte that is to be read out. The carriage return activates the command. The following is a listing of the available bytes:

NUMBER	DESCRIPTION
01	ALARM 1, ALARM CONDITIONS
02	ALARM 2, ALARM CONDITIONS
03	MODBYT, SYSTEM MODE

Each of these bytes contains bits that are set internally by the control algorithms and indicate all the operating information for this system. The **ALARM** and **MODE** bytes (MODBYT) are displayed on the Controller via the **ALARM** and **MODE** LEDs. The following is a description of the appropriate bits that may be utilized to monitor the system functions:

ALARM 1	ALARM 2	MODBYT
7----	7-UNUSED	7-UNUSED
6-SSR	6-EPO	6-CODE
5-HEATER	5-LOW PRESSURE	5-ALARM
4-RESISTIVITY	4-HIGH PRESSURE	4-UNUSED
3-LL	3-LOW FLOW	3-PROGRAM
2-UNUSED	2-HIGH FLOW	2-ACTIVE
1-SENSOR	1-LOW TEMP	1-PURGE
0-SYSTEM	0-HIGH TEMP	0-STAND-BY

These bytes require data transmission in a hexadecimal format. The actual data is sent as an ASCII character, but its meaning is translated in hexadecimal to determine the appropriate bit pattern. For example, the ASCII transmission of $31,$30 would translate to a hex reading of 10, which would indicate for the **ALARM 2 BYTE** that a high pressure condition existed.

BITS	7654	3210	
ALARM 2	0001	0000	Binary
	1	0	

After the carriage return, the Controller will acknowledge with a carriage return and a line feed and then send the two ASCII characters that indicate the hex representation for the appropriate bit pattern requested.

WRITE COMMAND:

The **WRITE** command allows the user to overwrite almost all the information in the programming stack. The single exception is the calibration value which is not accessible. It should be noted that while this information may be over written, it will not be permanently saved in the controller without first accessing the **PROGRAM** mode and then activating the **SAVE** command via the keys. If the values written are to be permanently saved in the controller's EEPROM memory, after all changes have been made, a **K08** (**PROG**) followed by a **K02** (**SAVE**) must be transmitted. A **K06 (RETURN)** should be sent after the **SAVE** has been transmitted to take the Controller out of the **PROGRAM** mode. There must be a two second delay between the **SAVE** and **RETURN** commands to allow time for the Controller to complete the **SAVE** operation.

If it is not desirable to have these values permanently saved, the user may simply go in and overwrite the current information for temporary use. When the system is repowered, the information that is currently stored in its EEPROM will be reinserted into the Program stack. The following is the format for a **WRITE** command:

W010750

The command essentially follows the same format as all the previous commands. The **W** indicates that it is a **WRITE** command. The next two characters indicate the location that is to be written to and the last four characters indicate the data value that is to be entered. Again, the data is in BCD and transmitted in an ASCII format. The example **WRITE** command would put 75.0 degrees C. in the **Process Setpoint**.
The data locations are the same as those covered in the **READ** command section. However, locations above 24 are **READ** only and may not be written. These are the locations that indicate the current temperature and operating conditions of the system. It should be noted that locations 24 will allow negative numbers to be written to them. The following is the format for writing negative numbers:

W24-010

This entry would write negative 10 into the **Power Adjust (PA)** parameter.

CANCEL COMMAND:

The **CANCEL** command is simply a way to reestablish proper control, should an error occur or an incorrect command be transmitted. For the most part, an incorrect command will simply be ignored and the controller will prepare for an additional command. However, a command may be canceled midstream by transmitting an 'X' (ASCII). This command does not require a carriage return, nor will it acknowledge with a carriage return. However, it will echo an 'X' to indicate that the **CANCEL** command has been received.

PROGRAMMING AND SAVING PARAMETERS THROUGH THE RS232

Programming the parameters through the communication port of the ICD **DT6500** controller is covered in the communication section of the manual. Not covered in detail in the procedure used to save the parameters to non-volatile memory. By saving the parameters, they will become the default parameter values when the control is turned on.

PROGRAMMING:

The Write and Read command are used to write new values and read back the written values for verification. Not mentioned in the manual is that the Write command takes about 4 mS to execute. (The actual time delay varies depending on the value and location written.) During this time, any incoming commands are not processed or stored. This delay can be implemented as a time delay in software or by sending "**X**" Reset Communication command characters. At 9600 baud, each character takes about 1 mS to send (0.96 mS) so by sending five "**X**" commands there will be sufficient delay in the communications channel to allow the next command to be executed. The sequence would be:

W010250<CR>
XXXXX
nnnnnnn

Where "**nnnnnnn**" is the next command, **Rxx**, **Wxxdddd**, **Kxx**, etc.

The character <**CR**> is the ASCII carriage return character. This is used to terminate all commands.

After writing a new parameter value, the same location may be read to verify a correct write. This is optional as the controller echoes all received characters. This echo can be used as a communication port check.

Saving:

The current operating parameters can be saved to non-volatile memory by using the keypad **SAVE** key or by sending the Key **K02** command. Like the **SAVE** key, this command through the communications port is active only in the program mode. The control must be in the program mode to do the save function.

The control can be set to the program mode through the communications port. This is done by sending the control a Program **K08** command. This will place the control in

program mode if the access code is zero. Then the Save **K02** command can be sent, followed by a Return **K06** command.

The save operation will also take time to execute, just as does the Write command. However, the save will take up to 1.5 seconds. Again, a delay can be implemented in software or "**X**" commands can be used to time the save operation. For this operation a software delay is recommended.

If the access code parameter (**AC**) is not zero, then and extra step is required to change the control into program mode. Two techniques are possible. Changing to program mode can be done by temporarily changing the access code to zero, entering the program mode, rewriting the access code and then performing the save. This is shown below:

R12<CR>
W120000<CR>
K08<CR>
W12cccc<CR>
K02<CR>
K06<CR>

Delays are not shown but should be included as indicated in the text. The Read command will return a four digit string that is the current access code. This should be saved by the host computer software and used in the Write command to restore the access code before the save.

A second technique is to read the access code and, using the Up key **K04** command, duplicate the sequence used to access the program mode from the keypad. To do this a Read command is used to get the access code. The Program key command is then sent. This is followed by a sequence of Up key **K04** commands. The number of Up key **K04** commands sent is equal to the access code read from the control. The Program command is sent a second time, followed by the Save **K02** and Return **K06** commands. This is shown below:

R12<CR>
K08<CR>
K04<CR>
repeat K04 as required
K08<CR>
K02<CR>
K06<CR>

Again, delays are not shown but should be included. Either of these techniques will allow a save with a non-zero access code. If the access code is zero, then the simple sequence of Program, Save, and Return commands can be sent.

MANUAL REVISIONS

Revision	Eng. #	Description
Rev 12	DT6500S9	
Rev 13	DT6500T1	* Add Flow Sensor Selection * Limit High/Low Flow to 13.0 gpm
Rev 14	DT6500T1	* Revision to Manual
Rev 15	DT6500T1	* Revision to Manual
Rev 16	DT6500T1	* Write Command Correction
Rev 17	DT6500T2	* RS232 Range Settings
Rev 18	DT6500T3	* Negative Value Tests
Rev 19	DT6500T4	* H2O Leak Alarm
Rev 20	DT6500T5	* Cancel of Auto Purge by demand, when in Auto Reset, Removed
Rev 21	DT6500T6	* Increase 'HA' Parameter to 400.0max.
Rev 22	DT6500T7	* Add Standby Input Function
Rev 23	DT6500T7	* Misc. Manual Changes

SPECIFICATIONS:

DT6500 CONTROLLER
FOR THE
AQUARIUS™ DEIONIZED WATER HEATING SYSTEM

RANGE:	Temperature: 0.0 to 95.0°C Flow: 0.0 to 13.0 GPM 0.0 to 60.0 LPM Pressure: 0.0 to 100.0 PSIG Resistivity: 0.0 to 20.0 Meg. Ohms
RESOLUTION:	Temperature: 0.1°C Flow: 0.1 GPM/LPM Pressure: 0.1 PSIG Resistivity: 0.1 Meg. Ohm
NOISE REJECTION:	NMR - 60 db @ 60 HZ CMR - 120 db @ 60 HZ
MEASURING TIME:	4 Conversions/Sec
A/D RESOLUTION:	12 Bit, 4000 Count
MICROPROCESSOR:	Motorola, 6809, 1 MHZ
DISPLAYS:	Eight, 0.56 Inch High, 7 Segment, LED Uniplanar numerals. Twenty Six Discrete LEDs, (Red, Green, Amber).
COMMUNICATION:	Serial Link, RS232C, 9600 Baud, 8 Bit, 1 Stop, 1 Start, No Parity.
ALARMS:	High & Low Temperature, High & Low Flow, High & Low

Pressure, Low Resistivity, and Low Liquid Level.
High Limit: Independent, Discrete with Manual Setpoint, 3, 6 or 9, Type J Thermocouple.

ANNUNCIATOR:	Audio Tone, ~ 2500 HZ
PROGRAM MEMORY:	EEPROM, All Parameters
PROGRAM MEMORY RETENTION:	10 Years without power
SENSORS:	Temperature - Standard Type J Thermocouple Pressure - 1-5 VDC = 0-100 PSI, +12 VDC Powered Flow - TTL input, +5 VDC Powered Liquid Level - TTL, Low = Low Level, +5 VDC Powered Resistivity - .05 Standard Cell Voltage - 0 to 12 VAC = 0 to 480 VAC
CONTROL:	Power-To-Flow® Custom Algorithm with Power Reset Offset
ADJUSTMENT:	Cycle Rate: 0.1 to 19.9 Seconds Power Reset: 0 to 600 Seconds Dead Band: 0.0 to 9.9°C Calibration Offset: ±0.0 to ±9.9°C
OPERATING RANGE:	0 to 50°C
STORAGE RANGE:	-40 to 60°C
CONSTRUCTION:	Enclosure - Kydex, Face - Lexan, Back Printed
SIZE:	8 x 12 x 5 inches, 203 x 304 x 127 mm (HxWxD)
WEIGHT:	< 7 LBS. (3.1 kg)
CONNECTION:	Rear, Screw-Type, 3/8 Inch Center Communications - DB25 Connector
OUTPUTS:	Heater - Optically Isolated, Open Collector Transistor Relays - 5 amp, 24 VAC
POWER:	20 VA, 24 VAC ±10%, 50/60 HZ