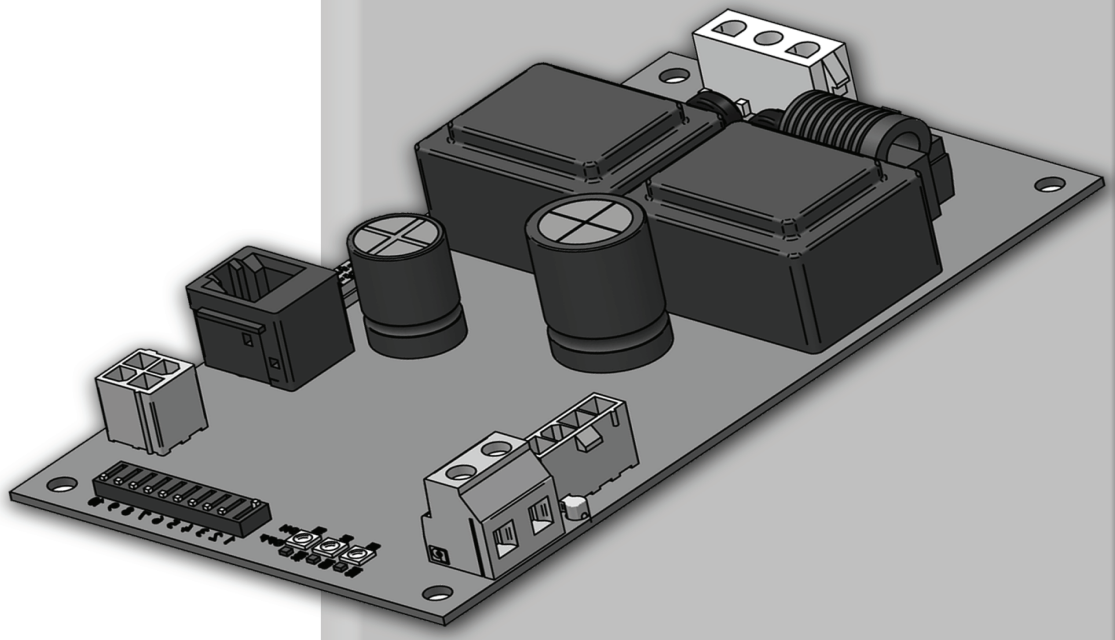
MODBUS AND BACNET COMMUNICATION INSTRUCTIONS

Models:
KEB 0015 - 0150



⚠ WARNING

This manual must only be used by a qualified heating installer / service technician. Read all instructions, including this manual, the Installation and Operation Manual, and the Service Manual, before installing. Perform steps in the order given. Failure to comply could result in severe personal injury, death, or substantial property damage.

Save this manual for future reference.

Lochinvar®
HIGH EFFICIENCY BOILERS & WATER HEATERS

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1 Introduction

The information contained in this manual provides general guidelines for the implementation of ModBus and BACnet communication with the Lochinvar Lectrus boiler (KEB0015 - 0150).

All ModBus networks are implemented utilizing a master-slave arrangement where all boilers/water heaters are slaves and the master is a building automation system capable of communicating over a RS-485 half duplex serial connection. BACnet networks are implemented using a token passing process where multiple masters and slaves share a common RS-485 bus. The Lochinvar BACnet interface is a master only.

Definitions

Abbreviation or Acronym	Meaning
ASCII	American Standard Code for Information Interchange
BACnet	A data communication protocol for Building Automation and Control Networks
BAS	Building Automation System
Baud (Baud Rate)	Number of data bits transmitted per second (bps)
EMS	Energy Management System
FDX	Full-Duplex
HDX	Half-Duplex
Hex	Hexadecimal Number (0 - 9, A - F)
I/O Box	Input/Output (I/O)
LSB	Least Significant Byte
ModBus	A serial, half-duplex data transmission protocol developed by AEG Modicon
MSB	Most Significant Byte
RS232	A standard for serial, full-duplex (FDX) transmission of data based on the RS232 Standard
RS485	A standard for serial transmission of data based on the RS-485 Standard
RTU	Remote Terminal Unit

Minimum System Requirements

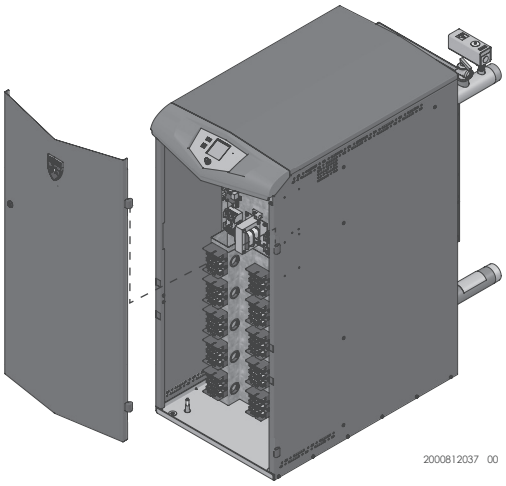
- BAS system or computer with a serial or USB port with a converter to RS-485 half duplex.
- Unit equipped with communication board.
- Shielded twisted pair communication cable.

2 Installation

To gain access to the interior of the appliance:

1. Turn OFF the main electrical power to the appliance and disconnect all electrical circuits.
2. With a flat head screwdriver open the door. You may remove the door from its hinges for convenience (Figure 1).

Figure 2-1 *Remove front door*



To install the modbus:

1. Place spacers on screws as shown in Figure 2.
2. Set the address, baud rate, and parity switches on the ModBus board to the desired settings. Refer to the kit-provided ModBus manual for an explanation of these settings.
3. Mount and secure the Modbus/BAcnet Board as shown in Figures 2 and 3.
4. Connect control and Power Harnesses as show in Figure 4.
5. Close all panels.
6. Turn on all water and power to the appliance.
7. If there are any concerns with the installation, please call Technical Services at 1-800-722-2101.

Figure 2-2 *Mount Modbus/BAcnet board*

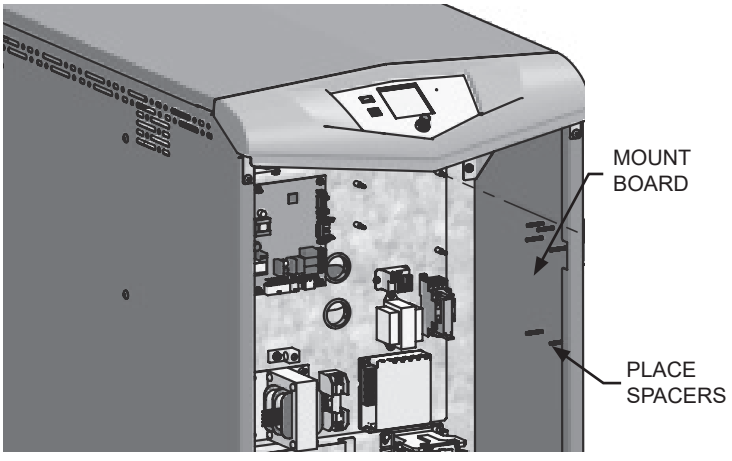
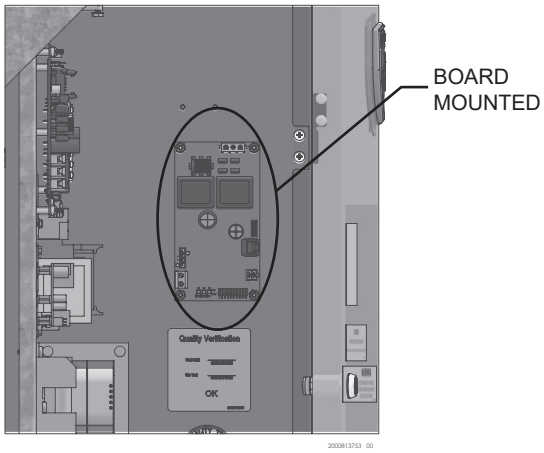


Figure 2-3 *Modbus/BAcnet board*



⚠WARNING For an appliance already installed, you must turn off power, switch off the electrical supply, and allow appliance to cool before proceeding. Components may be HOT! Failure to comply could result in severe personal injury, death, or substantial property damage.

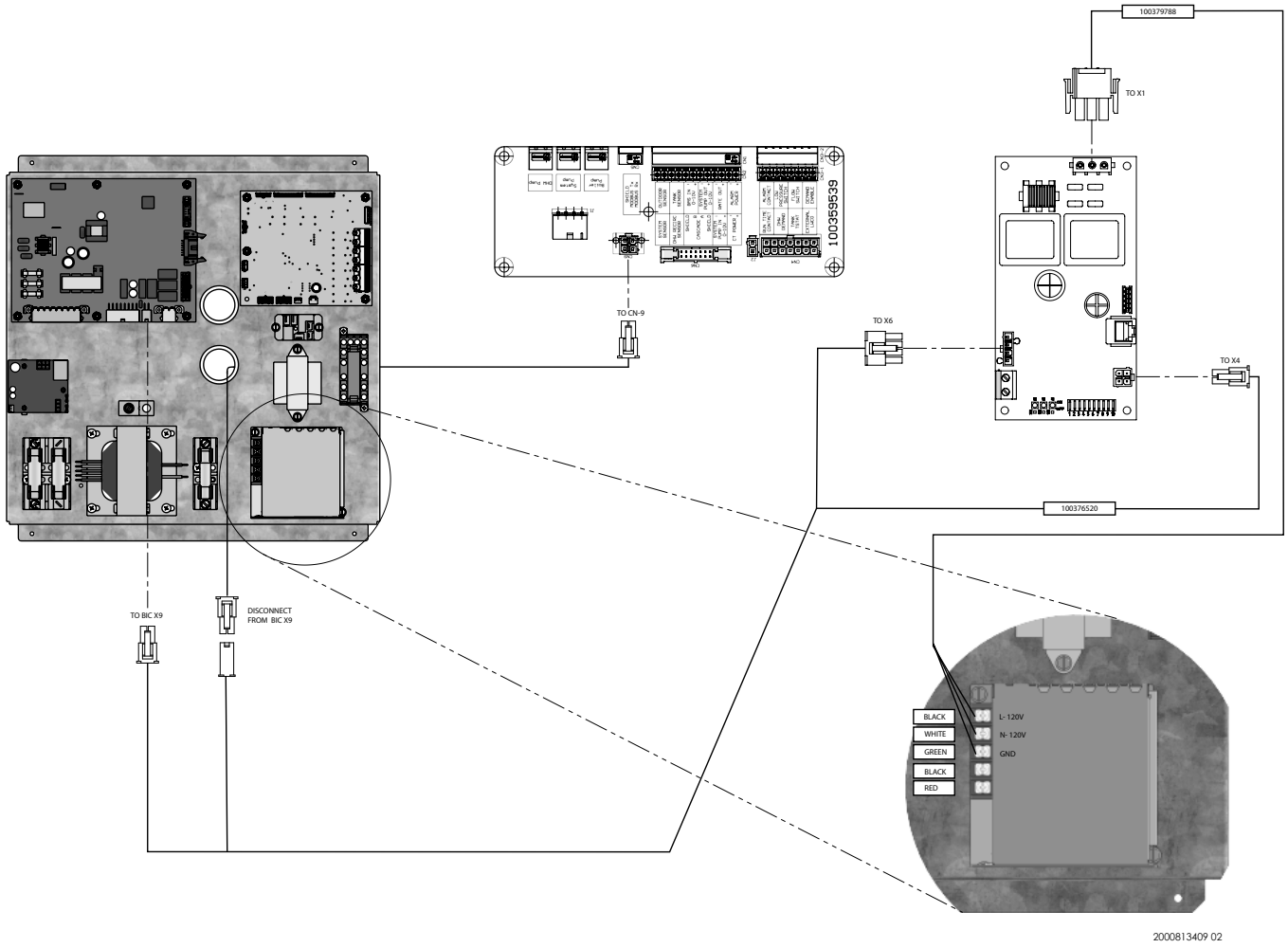
⚠WARNING Power to the unit must always be off while working with internal components, wiring, etc. Failure to comply could result in severe personal injury, death, or substantial property damage.

⚠WARNING Risk of electrical shock. The appliance may be connected to more than one electrical circuit. Disconnect all electrical circuits before servicing.

⚠WARNING Installation and service must be done by a qualified installer or service agency.

2 Installation

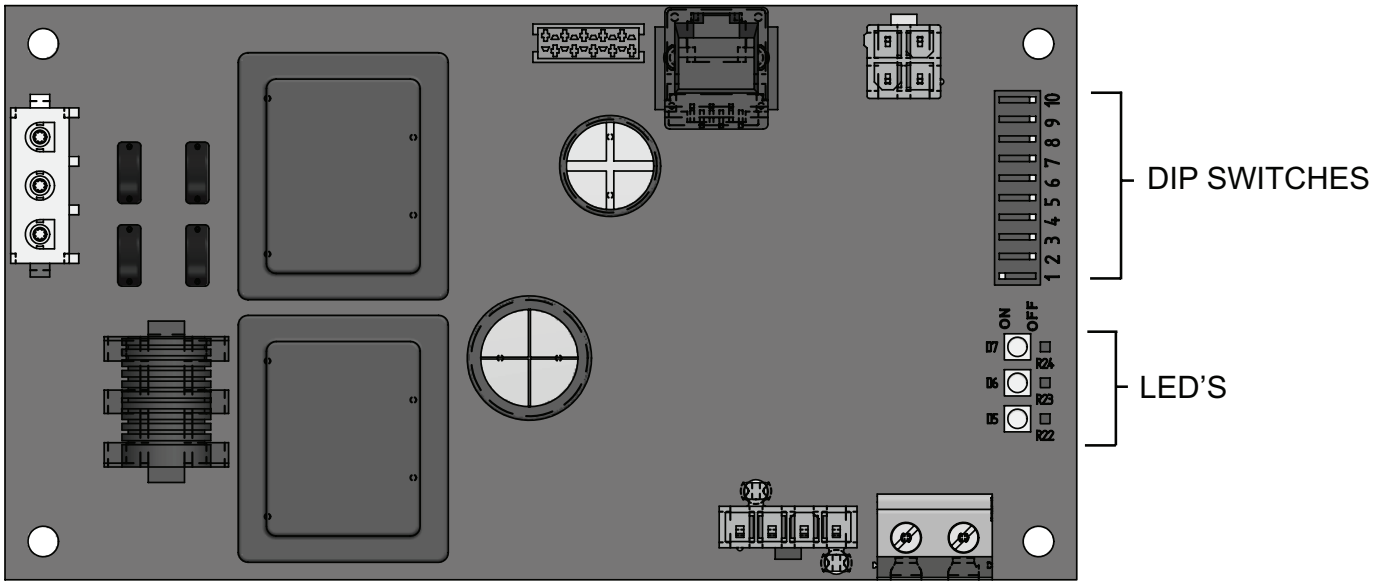
Figure 2-4 *Make connections*



3 ModBus Configuration

The ModBus communication board is equipped with a set of ten dip switches that are used to set the board configuration (address, baud rate, and parity settings). The first eight are used to set the address of each board. The ninth is baud rate. The tenth is parity.

Figure 3-1_ModBus Communication Board



Addressing

The ModBus addressing space is comprised of 256 different addresses.

- Maximum address of 127.

To set the ModBus address the dip switches can be set in either the 0 position or the 1 position. For switches set to the 1 position their value will be added together to determine the address.

Each switch set to the 1 position has the following value:

Dip switch 1 = 1
Dip switch 2 = 2
Dip switch 3 = 4
Dip switch 4 = 8
Dip switch 5 = 16
Dip switch 6 = 32
Dip switch 7 = 64

Any dip switch set to 0 has a value equal to 0.

Accomplish the different selections with Dip switch #8 on the board. The OFF position displays Celsius while the ON position is Fahrenheit.

Example:

To set the address of the ModBus board to 50, dip switches 2, 5, and 6 have to be set to the 1 position. The address is determined by adding the values of all the dip switches together.

Address = Value of Dip switch 1 + Value of Dip switch 2 + Value of Dip switch 3 + Value of Dip switch 4 + Value of Dip switch 5 + Value of Dip switch 6 + Value of Dip switch 7 + Value of Dip switch 8

In this example:

Address = 0 + 2 + 0 + 0 + 16 + 32 + 0 + 0 = 50

3 ModBus Configuration *(continued)*

Timing Specifications

The baud rate for the ModBus board is selectable with Dip switch #9.

1 = 19200 bps
0 = 9600 bps

Each message is started by at least 3.5 character times of silence. The maximum delay between frames is 1.5 character times.

When the system temperature, tank temperature, and/or 0-10V BMS voltage is provided by the BAS to the boiler, it is critical that the values be updated every few seconds. If the boiler does not receive updated values within a timeout period (installer adjustable), the control will revert to using its own readings (if connected). The timeout is programmable as follows:

NOTICE Please note that the brackets ([]) denote screen status.

1. Press and hold the LEFT SELECT [MENU] key for 5 seconds.
2. Enter installer code - 5309.
3. Scroll down and select [CONTROL MODES].
4. Scroll down and select [MODBUS T/O].
5. Scroll to desired time. Press the RIGHT SELECT [SAVE] key.

The timeout is adjustable between 5 and 120 seconds. The default timeout is 10 seconds.

When the BAS is not providing any of these values, but is still controlling the boiler (such as providing an enable command), the BAS must refresh these commands at least every 4 minutes. If the commands are not refreshed, the boiler will revert to operating based on its own inputs.

Parity

Parity is set by the position of Dip switch #10.

0 = No Parity
1 = Even Parity

If No Parity is selected there will be two stop bits, otherwise there will be one.

Data Transmission Mode

Many ModBus bus master devices can be configured to transmit data in either ModBus RTU or ModBus ASCII modes. Since RTU messages can be formatted to use fewer data bits and are therefore more efficient, RTU has been chosen to be used with all Lochinvar ModBus communication. Please ensure that the master device is transmitting ModBus RTU.

ModBus Board Diagnostics

The ModBus board is equipped with three LED's for visual diagnostics: Two yellow LED's and one green. One yellow LED (D5) is used to indicate transmission of data. The other yellow LED (D6) is used to indicate reception of data. The green LED (D7) is used to show internal faults.

Internal Faults:

Normal Operation = 1 second bright, 1 second dim
Controller Fault = Continuously on
No Burner Control Communication = 0.5 seconds on, 1.5 seconds off
No ModBus Communication = 1.5 seconds on, 0.5 seconds off

ModBus Communication

The ModBus communication commands and exception codes that are supported by the ModBus communication board can be found in this manual.

3 ModBus Configuration

ModBus Function Set

Function		Sub Function	HEX	Description
Dec	HEX	Dec		
1	01			Read Coil Status
2	02			Read Input Status
3	03			Read Holding Registers
4	04			Read Input Registers
5	05			Force Single Coil
6	06			Preset Single Register
7	07			Read Exception Status
8	08	0	00	Diagnostic - Return Query Data
		1	01	Diagnostic - Restart Communication
		2	02	Diagnostic - Return Diagnostic Register
		4	04	Diagnostic - Force Listen Mode
		10	0A	Diagnostic - Clear Counters and Diagnostic Registers
		11	0B	Diagnostic - Return Bus Message Count
		12	0C	Diagnostic - Bus Communication Error Count
		13	0D	Diagnostic - Bus Exception Error Count
		14	0E	Diagnostic - Return Slave Message Count
		15	0F	Diagnostic - Return Communication Error Count
		16	10	Diagnostic - Return Slave NAK Count
		17	11	Diagnostic - Return Slave Busy Count
		18	12	Diagnostic - Return Bus Character Overrun Count
		20	14	Diagnostic - Clear Overrun Counter and Flag
11	0B			Get Communication Event Counter
12	0C			Get Communication Event Log
15	0F			Write Multiple Coils
16	10			Write Multiple Registers
17	11			Report Slave ID
23	17			Read / Write Multiple Registers

3 ModBus Configuration *(continued)*

ModBus Exception Codes

MODBUS Exception Codes		
Code	**Name**	**Meaning**
01	ILLEGAL FUNCTION	The function code received in the query is not an allowable action for the server (or slave). This may be because the function code is only applicable to newer devices, and was not implemented in the unit selected. It could also indicate that the server (or slave) is in the wrong state to process a request of this type, for example because it is unconfigured and is being asked to return register values.
02	ILLEGAL DATA ADDRESS	The data address received in the query is not an allowable address for the server (or slave). More specifically, the combination of reference number and transfer length is invalid. For a controller with 100 registers, the PDU addresses the first register as 0, and the last one as 99. If a request is submitted with a starting register address of 96 and a quantity of registers of 4, then this request will successfully operate (address-wise at least) on registers 96, 97, 98, 99. If a request is submitted with a starting register address of 96 and a quantity of registers of 5, then this request will fail with Exception Code 0x02 “Illegal Data Address” since it attempts to operate on registers 96, 97, 98, 99 and 100, and there is no register with address 100.
03	ILLEGAL DATA VALUE	A value contained in the query data field is not an allowable value for server (or slave). This indicates a fault in the structure of the remainder of a complex request, such as that the implied length is incorrect. It specifically does NOT mean that a data item submitted for storage in a register has a value outside the expectation of the application program, since the MODBUS protocol is unaware of the significance of any particular value of any particular register.
04	SLAVE DEVICE FAILURE	An unrecoverable error occurred while the server (or slave) was attempting to perform the requested action.
05	ACKNOWLEDGE	Specialized use in conjunction with programming commands. The server (or slave) has accepted the request and is processing it, but a long duration of time will be required to do so. This response is returned to prevent a timeout error from occurring in the client (or master). The client (or master) can next issue a Poll Program Complete message to determine if processing is completed.
06	SLAVE DEVICE BUSY	Specialized use in conjunction with programming commands. The server (or slave) is engaged in processing a long -- duration program command. The client (or master) should re-transmit the message later when the server (or slave) is free.
08	MEMORY PARITY ERROR	Specialized use in conjunction with function codes 20 and 21 and reference type 6, to indicate that the extended file area failed to pass a consistency check. The server (or slave) attempted to read record file, but detected a parity error in the memory. The client (or master) can retry the request, but service may be required on the server (or slave) device.
0A	GATEWAY PATH UNAVAILABLE	Specialized use in conjunction with gateways, indicates that the gateway was unable to allocate an internal communication path from the input port to the output port for processing as the request. Usually means that the gateway is misconfigured or overloaded.
0B	GATEWAY TARGET DEVICE FAILED TO RESPOND	Specialized use in conjunction with gateways, indicates that no response was obtained from the target device. Usually means that the device is not present on the network.

4 ModBus Memory Map

Primary Data Tables

Table	Data Type	Read / Write
Discrete Inputs	Single Bit	Read Only
Coils	Single Bit	Read / Write
Input Registers	16-Bit Word	Read Only
Holding Registers	16 Bit Word	Read / Write

Memory Map

Coils						
Address	**Description**	**Default**	**Unit**	**Min.**	**Max.**	**Resolution**
00001	Boiler Enable	0	None	0	1	1
00005	DHW Enable	0	None	0	1	1
Discrete Inputs						
10002	Flow Switch	0	1=ON / 0=OFF	0	1	1
10003	Low Pressure Switch	0	1=ON / 0=OFF	0	1	1
10004	External Low Water Cut Off	0	1=ON / 0=OFF	0	1	1
10005	Low Water Cut Off/ Manual Reset High Limit	0	1=ON / 0=OFF	0	1	1
10007	Auto Reset High Limit	0	1=ON / 0=OFF	0	1	1
10009	SH Enable	0	1=ON / 0=OFF	0	1	1
10010	DWH Enable	0	1=ON / 0=OFF	0	1	1
10033	Run-time Contacts	0	1=ON / 0=OFF	0	1	1
10034	Alarm Contacts	0	1=ON / 0=OFF	0	1	1
10035	Boiler Pump	0	1=ON / 0=OFF	0	1	1
10036	DHW Pump	0	1=ON / 0=OFF	0	1	1
10037	Low Water Cut Off Enable	0	1=ON / 0=OFF	0	1	1
10038	Safety Monitor Relay	0	1=ON / 0=OFF	0	1	1
10039	System Pump	0	1=ON / 0=OFF	0	1	1
Input Registers						
30001	Discrete Inputs 1 - 15	0	N/A	0	65535	1
30002	Discrete Inputs 16 - 31	0	N/A	0	65535	1
30003	Discrete Inputs 32 - 47	0	N/A	0	65535	1
30004	System / Cascade Setpoint	0	Degrees Celsius Degrees Fahrenheit	0 32	130 266	0.5 1.5
30005	System Pump Speed	0	%	0	100	1
30006	Cascade Total Power	0	%	100	800	1
30007	Cascade Current Power	0	%	0	800	1
30008	Outlet Setpoint	0	Degrees Celsius Degrees Fahrenheit	0 32	110 230	0.5 1.0
30009	Outlet Temperature	0	Degrees Celsius	0	130	0.1
30010	Inlet Temperature	0	Degrees Celsius	-20	130	0.1
30012	Modulation Rate	0	%	0	100	1
30013	Boiler Pump Speed	0	%	0	100	1
30014	Boiler Status Code	0	N/A	0	65535	1
30015	Boiler Blocking Code	0	N/A	0	65535	1
30016	Boiler Lockout Code	0	N/A	0	65535	1

4 ModBus Memory Map *(continued)*

Memory Map

Holding Registers						
Address	**Description**	**Default**	**Unit**	**Min.**	**Max.**	**Resolution**
40001	Configuration	0	NA	0	65535	1
40002	BV 0-4	0	NA	0	65535	1
40003	0-10 BMS	0	%	0	100	1
40004	Tank Setpoint	0	Degrees Celsius Degrees Fahrenheit	20 68	88 190	0.5 1.0
40005	Tank Temperature	0	Degrees Celsius	0	130	0.1
40006	Outdoor Temperature	0	Degrees Celsius	-40	60	0.1
40007	System Supply Temperature	0	Degrees Celsius	-20	130	0.1
40008	DHW Recirculation Temperature	0	Degrees Celsius	-20	130	0.1

Configuration Bits

Address 40001 contains configuration bits sent from the BAS to the appliance. These bits tell the boiler/water heater to use its own internal inputs, or inputs from the BAS. When a bit is set to 1, the boiler/water heater will ignore the corresponding value contained internally, and expect the BAS to write that value into the Holding Registers. The configuration bits are as follows:

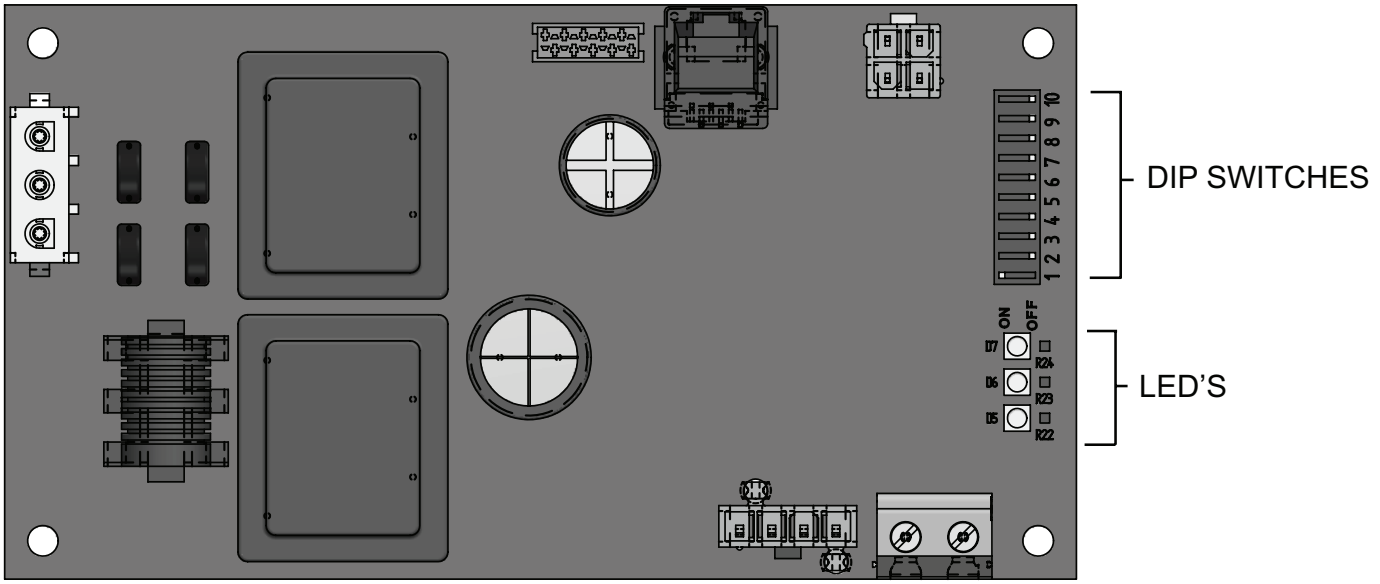
Bit 0 (LSB): Boiler Enable
Bit 1: DHW Enable
Bit 2: 0-10V BMS Input
Bit 3: Tank Setpoint
Bit 4: System Supply Temperature
Bit 5: Outdoor Temperature
Bit 6: Tank Temperature
Bit 7: Not Used (Default = 0)
Bit 8 - 15: Not Used (Default = 0)

NOTICE The installer must input a value that respects the Min and Max indicated in the above Memory Map.

5 BACNET Configuration

The BACnet communication board is equipped with a set of ten dip switches that are used to set the board configuration (address and baud rate). The first eight are used to set the address of each board. The ninth and tenth are baud rate.

Figure 5-1_Communication Board



Addressing

The BACnet local addressing space is comprised of 256 different addresses.

- 255 is reserved for broadcast messages from a master device.
- 128 - 254 are free to use for slave devices only.
- 0 - 127 are free to use for master or slave devices.

Since the BACnet communication board is a BACnet master, address 127 is the highest address that can be used.

To set the BACnet local address, the dip switches can be set in either the 0 position or the 1 position. For switches set to the 1 position their value will be added together to determine the address.

Each switch set to the 1 position has the following value:

Dip switch 1 = 1
Dip switch 2 = 2
Dip switch 3 = 4
Dip switch 4 = 8
Dip switch 5 = 16
Dip switch 6 = 32
Dip switch 7 = 64
Dip switch 8 = 128

Any dip switch set to 0 has a value equal to 0.

Example:

To set the address of the BACnet board to 50, dip switches 2, 5, and 6 have to be set to the 1 position. The address is determined by adding the values of all the dip switches together.

Address = Value of Dip switch 1 + Value of Dip switch 2 + Value of Dip switch 3 + Value of Dip switch 4 + Value of Dip switch 5 + Value of Dip switch 6 + Value of Dip switch 7 + Value of Dip switch 8

In this example:

Address = 0 + 2 + 0 + 0 + 16 + 32 + 0 + 0 = 50

The BACnet Device Instance is calculated by adding the BACnet local address to 600000. Using the above example, the Device Instance will be:

Device Instance = 600000 + 50 = 600050

The base address (600000 in this example) is model dependant and can be changed by the integrator. It can be set to any value between 0 and 4194048. The resulting device instance will be this value + the local address, as before. Once the base address is changed, it can be reset back to the default base address (600000 in this example) using the following procedure:

1. Turn OFF power to the interface board.
2. Set Dip switches 1 - 8 to the 1 position.
3. Turn ON power to the interface board.
4. After a few seconds, turn OFF power to the interface board.
5. Set Dip switches 1 - 7 to the desired local address. Set Dip switch 8 to the 0 position.
6. Turn ON power to the interface board.

Device Name

The default device name is "MTR-01 BACnet." This can be changed by the integrator as desired.

5 BACnet Configuration *(continued)*

Timing Specifications

The baud rate for the BACnet board is selectable with Dip switches #9 and #10.

Switch #9	Switch#10	Baud Rate
OFF	OFF	9600
ON	OFF	19200
OFF	ON	38400
ON	ON	76800

When the system temperature, tank temperature, and/or 0-10V BMS voltage is provided by the BAS to the boiler, it is critical that the values be updated every few seconds. If the boiler does not receive updated values within a timeout period (installer adjustable), the control will revert to using its own readings (if connected). The timeout is programmable as follows:

NOTICE Please note that the brackets ([]) denote screen status.

1. Press and hold the LEFT SELECT [MENU] key for 5 seconds.
2. Enter installer code - 5309.
3. Scroll down and select [CONTROL MODES].
4. Scroll down and select [MODBUS T/O].
5. Scroll to desired time. Press the RIGHT SELECT [SAVE] key.

The timeout is adjustable between 5 and 120 seconds. The default timeout is 10 seconds.

When the BAS is not providing any of these values, but is still controlling the boiler (such as providing an enable command), the BAS must refresh these commands at least every 4 minutes. If the commands are not refreshed, the boiler will revert to operating based on its own inputs.

Communication Board Diagnostics

The Communication board is equipped with three LED's for visual diagnostics: Two yellow LED's and one green. One yellow LED (D5) is used to indicate transmission of data. The other yellow LED (D6) is used to indicate reception of data. The green LED (D7) is used to show internal faults.

Internal Faults:

Normal Operation = 1 second bright, 1 second dim
Controller Fault = Continuously on
No Burner Control Communication = 0.5 seconds on, 1.5 seconds off
No BACnet Communication = 1.5 seconds on, 0.5 seconds off.

6 BACnet MSTP Memory Map

Primary Data Tables

Object Type	Data Type	Read / Write
Binary Input (BI)	Single Bit	Read Only
Binary Value (BV)	Single Bit	Read / Write
Analog Input (AI)	16-Bit Word	Read Only
Analog Value (AV)	16 Bit Word	Read / Write

Memory Map

Gas Object Name	Electric Object Name	Object Type	Address	Unit	Min	Max	Resolution
Binary Values							
SH Enable 1	Boiler Enable	BV	0	none	0	1	1
SH Enable 2	Not Used	BV	1	none	0	1	1
SH Enable 3	Not Used	BV	2	none	0	1	1
Tank Thermostat	DHW Enable	BV	4	none	0	1	1
Binary Inputs							
Flow Switch	Flow Switch	BI	1	none	0	1	1
Gas Pressure Switch	Low Pressure Switch	BI	2	none	0	1	1
Louver Proving Switch	External Low Water Cut Off	BI	3	none	0	1	1
APS/ Flap Valve	LWCO/ MRHL	BI	4	none	0	1	1
Blocked Drain Switch	Not Used	BI	5	none	0	1	1
Auto Reset High Limit	Auto Reset High Limit	BI	6	none	0	1	1
SH Enable	SH Enable	BI	8	none	0	1	1
Tank Thermostat	DHW Enable	BI	9	none	0	1	1
Run Time Contacts	Run-time Contacts	BI	32	none	0	1	1
Alarm Contacts	Alarm Contacts	BI	33	none	0	1	1
Boiler Pump	Boiler Pump	BI	34	none	0	1	1
DHW Pump 1	DHW Pump	BI	35	none	0	1	1
	Low Water Cut Off Enable	BI	36	none	0	1	1
Gas Valve	Safety Monitor Relay	BI	37	none	0	1	1
System Pump	System Pump	BI	38	none	0	1	1
DHW Pump 2	Not Used	BI	43	none	0	1	1
Inputs							
BI Inputs 0 - 15	Discrete Inputs 0 - 15	AI	0	none	0	65535	1
BI Inputs 16 - 31	Discrete Inputs 16 - 31	AI	1	none	0	65535	1
BI Inputs 32 - 47	Discrete Inputs 32 - 47	AI	2	none	0	65535	1
System / Cascade Setpoint	System / Cascade Setpoint	AI	3	Deg C Deg F	0 32	130 266	0.5 1.0
System Pump Speed	System Pump Speed	AI	4	%	0	100	1
Cascade Total Power	Cascade Total Power	AI	5	%	100	800	1
Cascade Current Power	Cascade Current Power	AI	6	%	0	800	1
Outlet Setpoint	Outlet Setpoint	AI	7	Deg C Deg F	0 32	110 230	0.5 1.0
Outlet Temperature	Outlet Temperature	AI	8	Deg C	0	130	0.1
Inlet Temperature	Inlet Temperature	AI	9	Deg C	-20	130	0.1

6 BACnet Memory Map *(continued)*

Memory Map *(continued)*

Gas Object Name	Electric Object Name	Object Type	Address	Unit	Min	Max	Resolution
Firing Rate	Modulation Rate	AI	11	%	0	100	1
Boiler Pump Speed	Boiler Pump Speed	AI	12	%	0	100	1
Boiler Status Code	Boiler Status Code	AI	13	none	0	65535	1
Boiler Blocking Code	Boiler Blocking Code	AI	14	none	0	65535	1
Boiler Lockout Code	Boiler Lockout Code	AI	15	none	0	65535	1
Analog Values							
Configuration	Configuration	AV	0	none	0	65535	1
BV 0-4	BV 0-4	AV	1	none	0	65535	1
0-10V BMS Input	0-10V BMS Input	AV	2	%	0	100	1
Tank Setpoint	Tank Setpoint	AV	3	Deg C Deg F	20 68	88 190	0.5 1.0
Tank Temperature	Tank Temperature	AV	4	Deg C	0	130	0.1
Outdoor Temperature	Outdoor Temperature	AV	5	Deg C	-40	60	0.1
System Supply Temperature	System Supply Temperature	AV	6	Deg C	-20	130	0.1
	DHW Recirc Temperature	AV	7	Deg C	-20	130	0.1

Configuration Bits

BACNET object AV0 contains configuration bits sent from the BAS to the appliance. These bits tell the boiler/water heater to use its own internal inputs, or inputs from the BAS. When a bit is set to 1, the boiler/water heater will ignore the corresponding value contained internally, and expect the BAS to write that value into the Holding Registers. The configuration bits are as follows:

Bit 0 (LSB): Boiler Enable
Bit 1: DHW Enable
Bit 2: 0-10V BMS Input
Bit 3: Tank Setpoint
Bit 4: System Supply Temperature
Bit 5: Outdoor Temperature
Bit 6: Tank Temperature
Bit 7: Not Used (Default = 0)
Bit 8 - 15: Not Used (Default = 0)

NOTICE The installer must input a value that respects the Min and Max indicated in the above Memory Map.

7 Wiring Requirements

Note that when the System Supply Temperature and/or the Tank Temperature are provided by the BAS, they need to be refreshed every few seconds. This is required in order to prevent unwanted fluctuations in these temperatures. If these values are not provided every few seconds (timeout is programmable), the boiler will revert to its own internal control. If neither of these temperatures is provided by the BAS, but any of the other control signals are being provided, the BAS will still need to refresh these inputs at least every 4 minutes.

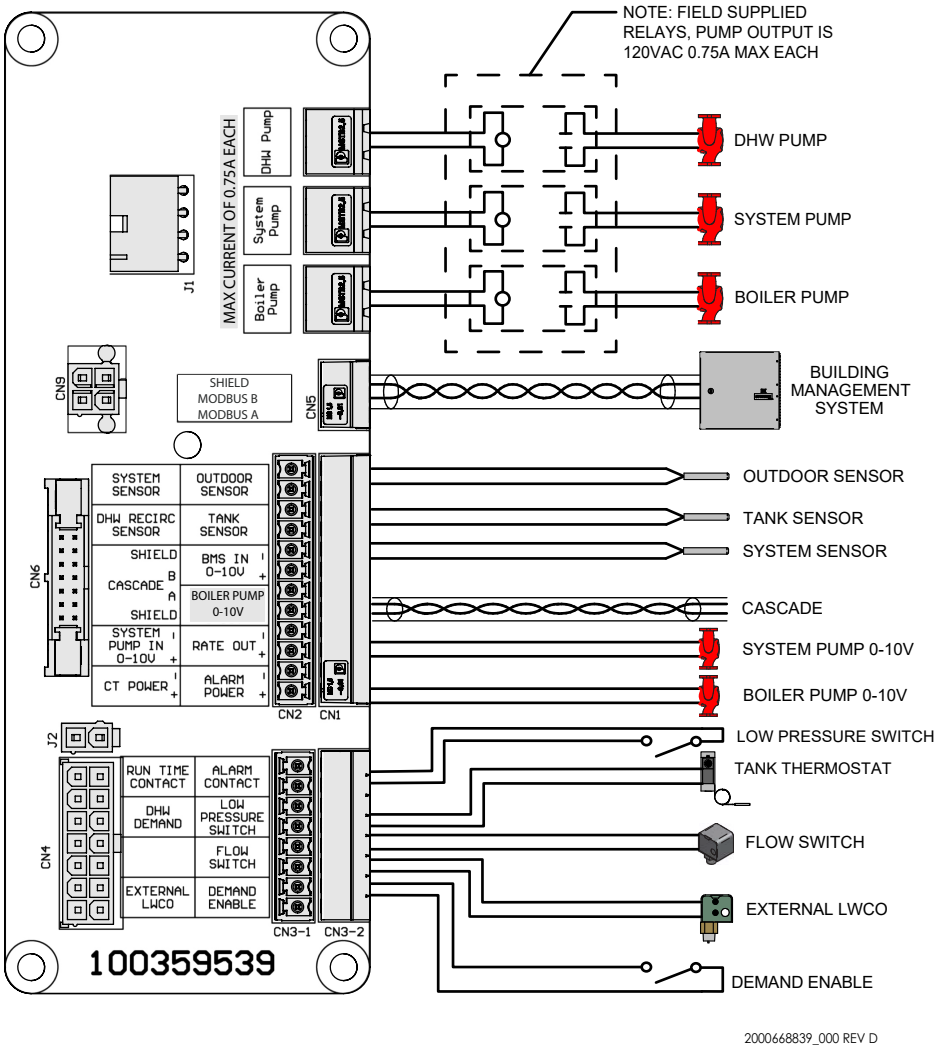
Physical Wiring

RS-485 Communication Bus

- Maximum Length = 4000 feet
- Cable Specification = 24 AWG / A,B (twisted pair) and GND Shielded, with characteristic Impedance = 120 ohm
- Maximum Load = 32 units (32 nodes)

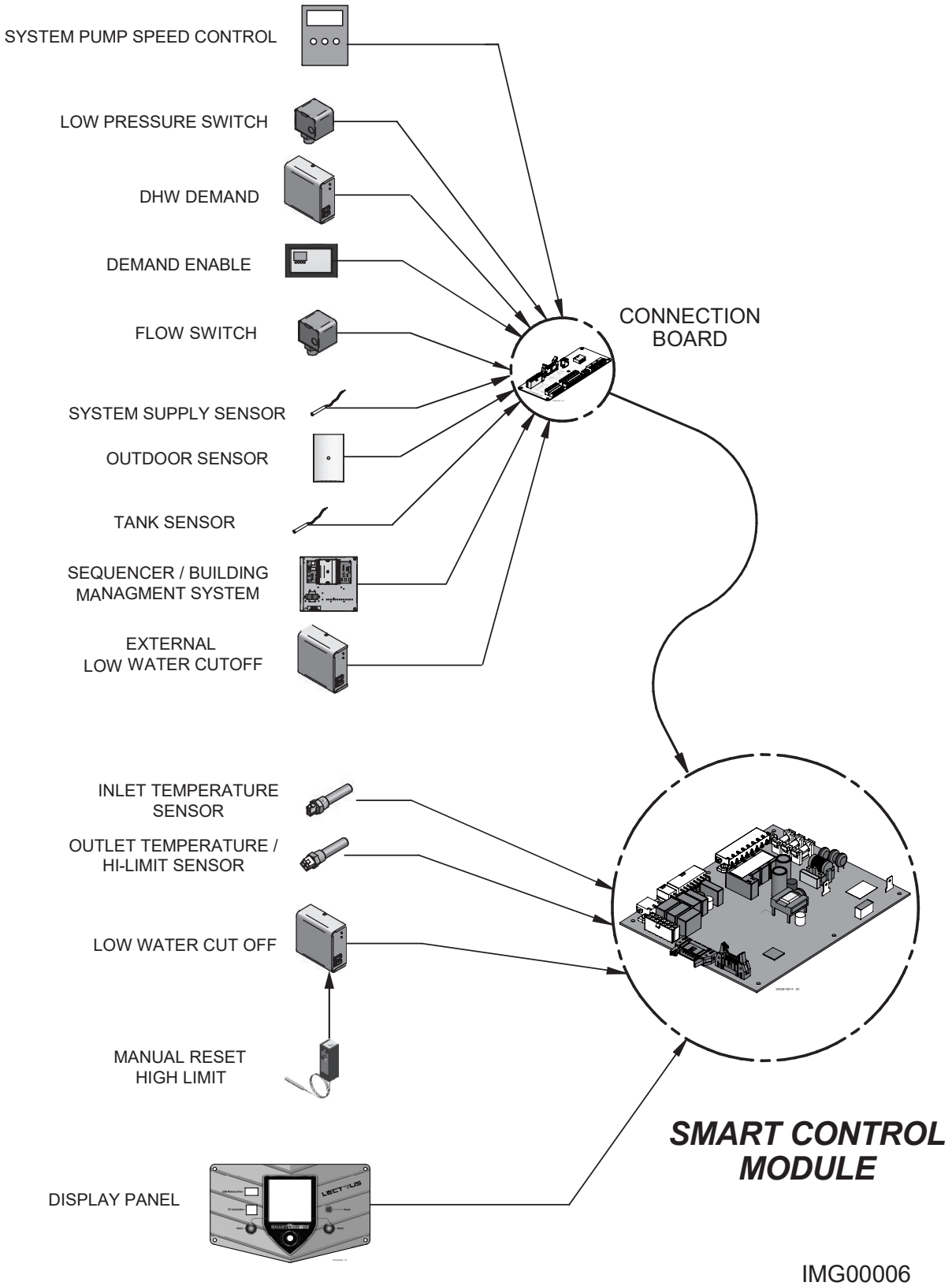
NOTE: Cable must be terminated with 120 ohm impedance matching resistor on each end.
A + (positive)
B - (negative)

Figure 7-1_Terminal Strip Connections



7 Wiring Requirements *(continued)*

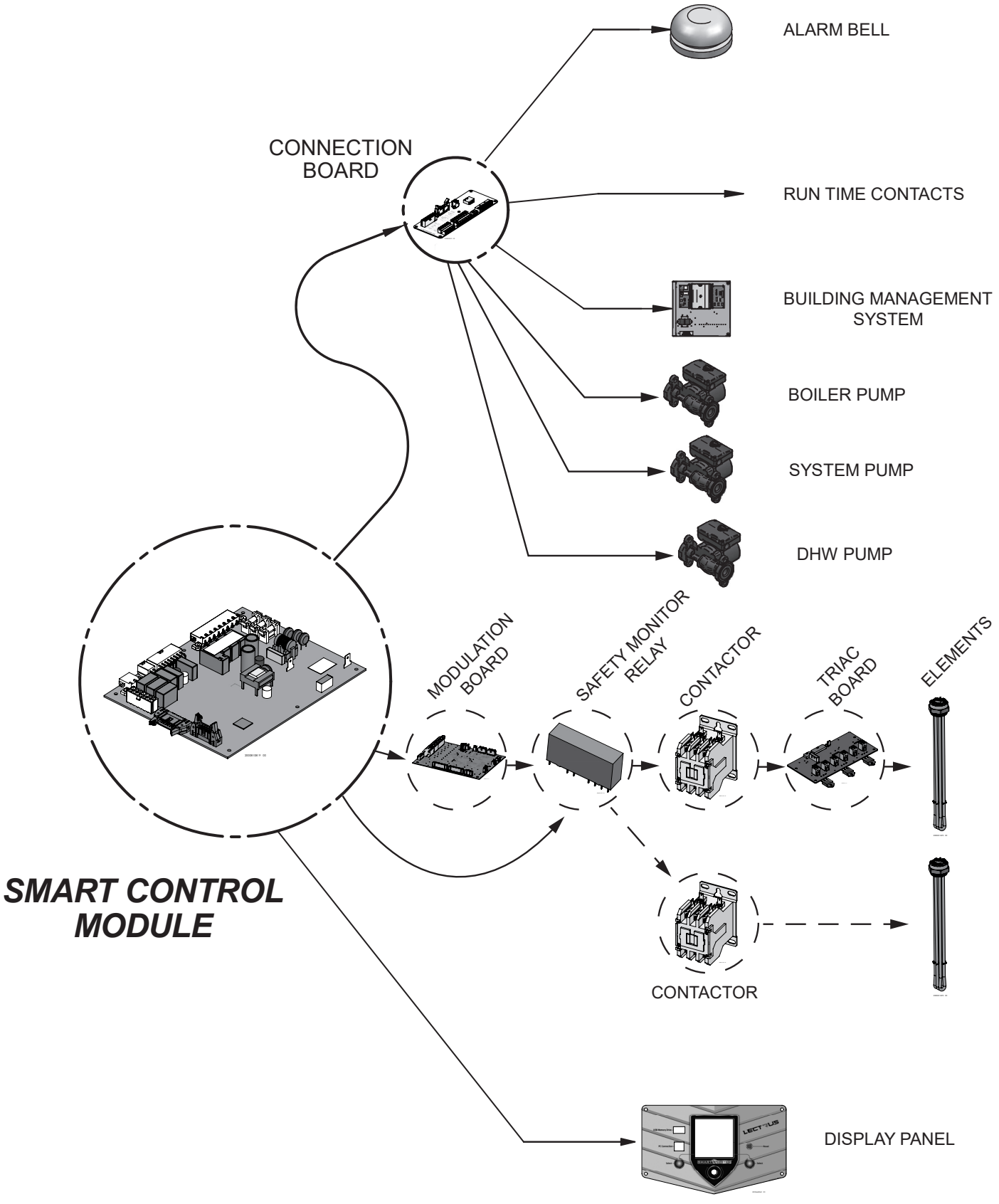
Figure 7-2_Control Inputs



7 Wiring Requirements

Figure 7-3_Control Outputs

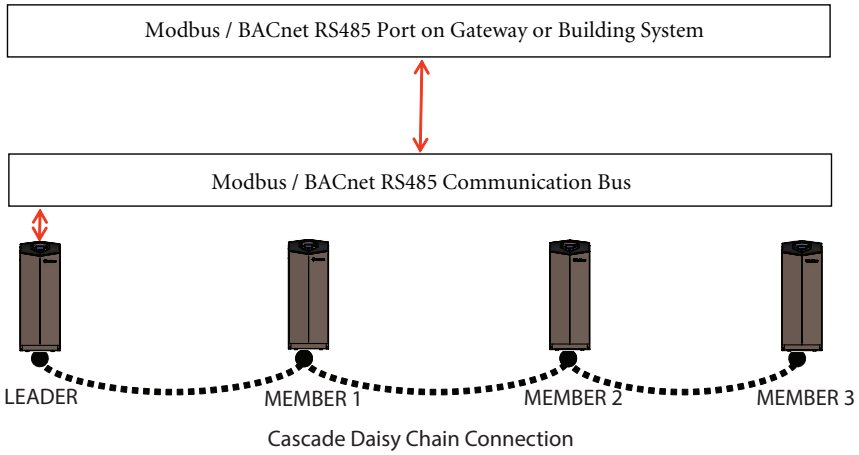
Control outputs



7 Wiring Requirements *(continued)*

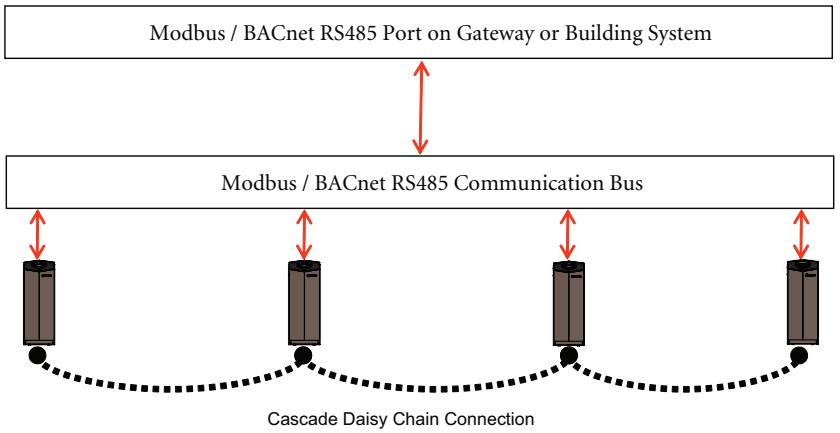
Typical Boiler/Water Heater System Wiring

Physical Configuration: Cascade without Individual Monitoring



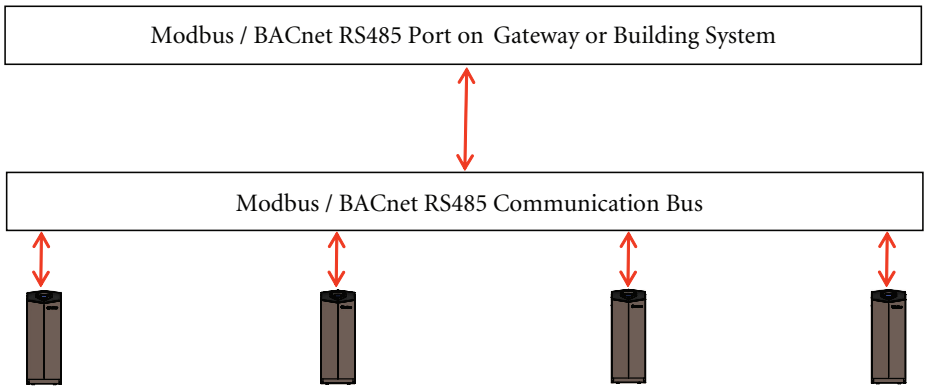
NOTICE You will need a Modbus or BACnet board only for the Leader.

Physical Configuration: Cascade with individual Monitoring



NOTICE You will need a Modbus or BACnet board for all appliances.

Physical Configuration: Direct Control



NOTICE You will need a Modbus or BACnet board for all appliances.

8 Unit Operation

Unit Operation with ModBus or BACnet Communications

To control a boiler/water heater through a Building Management System communicating through ModBus or BACnet, the boiler/water heater control mode must be properly configured. These configurations allow different control points for a variety of applications. There are five (5) configuration parameters that need to be set.

General Set-up

NOTICE Please note that the brackets ([]) denote screen status.

1. Press and hold LEFT SELECT [MENU] key.
2. Enter installer code - 5309.
3. Scroll down and select [CONTROL MODES].
4. Select ModBus or BACnet by pressing the NAVIGATION dial.
5. Scroll to ACTIVE.
6. Press the RIGHT SELECT [SAVE] key.
7. Exit one level.
8. Choose the appropriate Control Mode and continue set-up to complete.

Figure 8-1_Control Modes (Default)

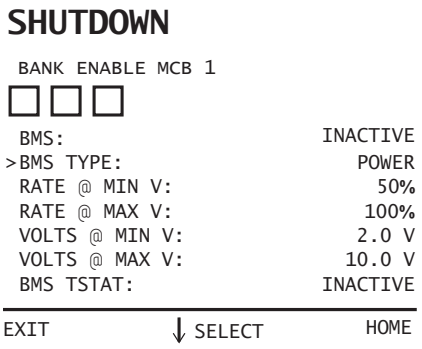
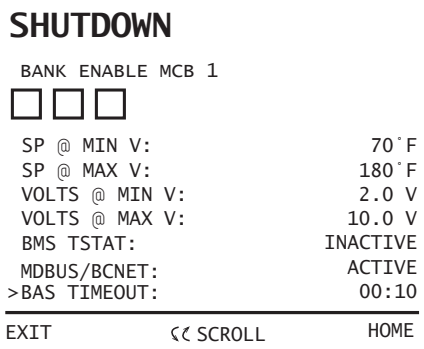


Figure 8-2_Control Modes - ModBus Active



The boiler/water heater is equipped with a ModBus communication timer. This timer is programmable from 0 - 120 seconds. The timer can be programmed in the ModBus T/O Menu, reference Section 3 - Timing Specifications of this manual. The purpose of the timer is to ensure proper temperature data is communicated to the boiler/water heater in a timely manner. Additionally, it will provide for fail safe operation should BMS communication be lost. This timer will cause the unit to revert back to internal unit controls should the BMS communication be interrupted longer than the ModBus timer. The timer is reset every time a write command is received with updated temperatures or commands. It is the recommendation of Lochinvar that this timer be set to the shortest value possible.

When operating off the BMS communication bus and with remote sensors connected to the Building Automation System (BAS), it is very important to ensure that the correct configuration bits are sent to holding register 40001 (ModBus) or AVO(BACnet), and that the correct data and enable signals are sent to holding registers 40002 - 40008 (ModBus) or AVO(BACnet), per the control mode.

Control Mode 1

In this configuration the unit is controlled by setting the set points locally on the boiler/water heater and providing an enable signal through BMS communications.

All sensors and limiting devices should be hardwired to the terminal strip on the back of the unit excluding the thermostat enable and tank thermostat enable signal. These signals will be sent to the unit via ModBus or BACnet.

Control Mode 1 - Set-up (Configuration Parameters)

BMS Type default (FIG. 8-3) remains.

Object	Holding Registers	Definition	Bit Value (HEX)	Action
AV0	**40001**	Configuration	00 01	Set Configuration to read 40002
AV1	**40002**	Coils / BV	00 01	Enables unit *(00 00 disables unit)*

NOTE: To ensure proper operation re-send the configuration bits to holding register 40001 or object AV**0** prior to issuing a command.

8 Unit Operation *(continued)*

Control Mode 2

In this configuration the unit is controlled by setting the set points locally on the boiler/water heater and providing an enable signal and a rate command through ModBus or BACnet communications.

The BMS Type will be 0 - 100% of modulation or a temperature set point.

Control Mode 2 - Set-up (Configuration Parameters)

To Set BMS Type:

1. While still in Installer Menu Set, scroll down and select [BMS] by pressing the NAVIGATION dial.
2. In the BMS Menu, select [BMS TYPE], scroll to [POWER] or [SETPOINT] and press the RIGHT SELECT [SAVE] key.

Reference FIG.'s 8-3 and 8-4 to set BMS Type to the appropriate operation.

Figure 8-3_BMS Type - Set Point (Default)

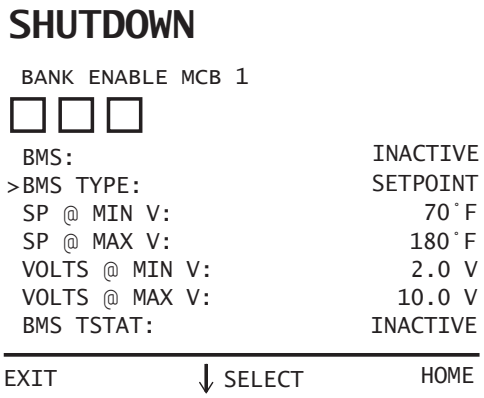
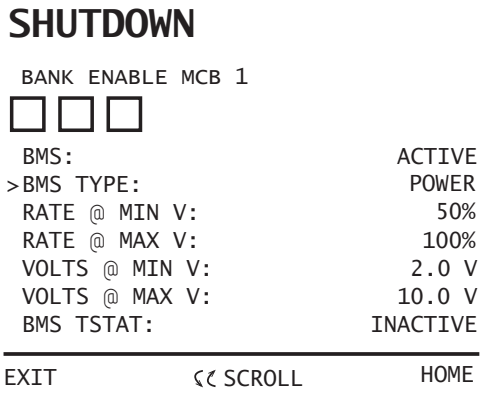


Figure 8-4_BMS Type - Power



All sensors and limiting devices should be hardwired to the terminal strip on the back of the unit excluding the thermostat enable and tank thermostat enable signal. These signals will be sent to the unit via ModBus.

Control Mode 2 - Set-up (Command Parameters)

1. While in the Control's Installer Main Menu, select [CONTROL MODES].
2. In Control Modes Menu select [BMS] and set to [ACTIVE].
3. Press the RIGHT SELECT [SAVE] key.

Figure 8-5A_Control's Installer Main Menu

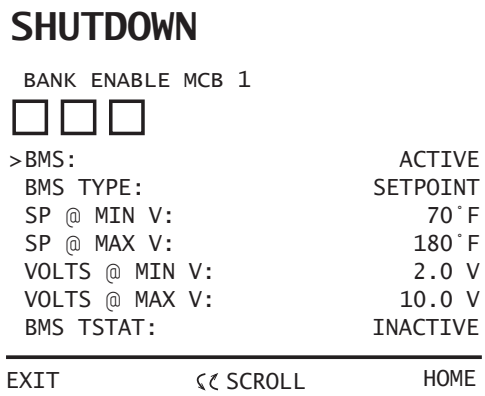
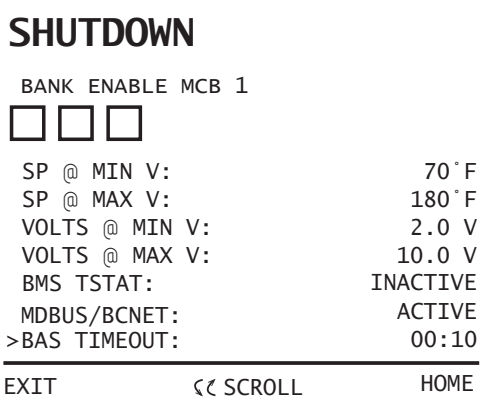


Figure 8-5B_Control's Installer Main Menu



8 Unit Operation

Control Mode 2 - Set-up (Command Parameters) *(continued)*

The holding registers/objects will need to be set as follows:

Object	Holding Registers	Definition	Bit Value (HEX)	Action
AV0	**40001**	Configuration	00 05	Set Configuration to read 40002 & 3
AV1	**40002**	Coils / BV	00 01	Enables unit *(00 00 disables unit)*
AV2	**40003**	Rate Command	00 ##	Sets Modulation % or Setpoint

NOTE: To ensure proper operation re-send the configuration bits to holding register 40001 or Object AV**0** prior to issuing a command.

For proper hexadecimal conversion of rate percentage or temperature conversion, please refer to the Rate and Temperature Conversions section of this manual.

Control Mode 3

In this configuration the unit is controlled by setting the modulation set point from 0 - 100%. The modulation set point will provide the enable function as well.

The BMS Type will be 0 - 100% of modulation.

Control Mode 3 - Set-up (Configuration Parameters)

Reference FIG.'s 8-3 and 8-4 to set BMS Type to [POWER].

All sensors and limiting devices should be hardwired to the terminal strip on the back of the unit excluding the thermostat enable and tank thermostat enable signal. These signals will be sent to the unit via ModBus.

Control Mode 3 - Set-up (Command Parameters)

1. Enter the installer code - 5309.
2. While in the Control's Installer Main Menu, scroll to and select [CONTROL MODES].
3. In Control Modes Menu select [BMS] and set to [ACTIVE] (see FIG. 6-5).
3. Press the RIGHT SELECT [SAVE] key.

The holding registers/objects will need to be set as follows:

Object	Holding Registers	Definition	Bit Value (HEX)	Action
AV0	**40001**	Configuration	00 04	Set Configuration to read 40003
AV2	**40003**	Rate Command	00 00	Sets Modulation %

NOTE: To ensure proper operation re-send the configuration bits to holding register 40001 or Object AV**0** prior to issuing a command.

For proper hexadecimal conversion of rate percentage, please refer to the Rate and Temperature Conversions section of this manual.

8 Unit Operation

Control Mode 4 (DHW)

Domestic Hot Water Generation (DHW) can be accomplished with one of two methods when a boiler/water heater is connected to a BAS system, DHW with direct control, and DHW with remote control.

DHW with direct control:

This is a typical installation with a hot water generator in close proximity to the boiler/water heater with the tank thermostat or the tank temperature sensor wired to the terminal strip of the unit.

DHW with remote control:

This installation may have the hot water generator in close proximity to the boiler/water heater. Its sensors or thermostat values are only available through the ModBus / BACnet communication bus.

Control Mode 4 - Set-up

1. Enter the installer code - 5309.
2. While in the Control's Installer Main Menu, scroll to and select [CONTROL MODES].
3. In Control Modes Menu select [BMS TSTAT] and set to [ACTIVE] (see FIG. 8-6).
4. Perform Step 2 to set BMS TSTAT, and BMS reference FIG. 8-6.
5. Press the RIGHT SELECT [SAVE] key (see FIG. 8-6) to save all of the above parameter settings.

Figure 8-6A_Control Modes Menu - Control Mode 4 - Set-up

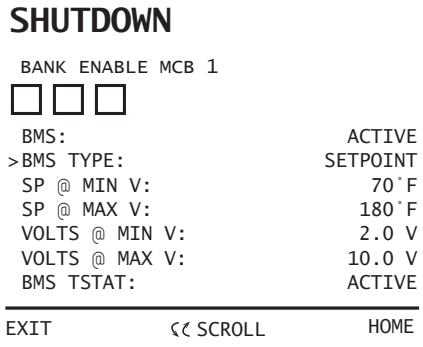
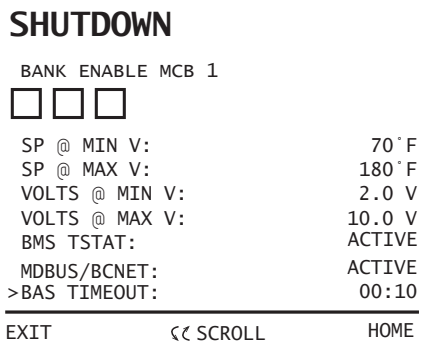


Figure 8-6B_Control Modes Menu - Control Mode 4 - Set-up



To ensure that the boiler/water heater can properly respond to a call for hot water generation the following holding registers must be set in addition to other commands:

Object	Holding Registers	Definition	Bit Value (HEX)	Action
AV0	**40001**	Configuration	00 4A	Set Configuration to read 40002, 4 & 5
AV1	**40002**	Coils / BV	00 08	Enables Tank Tstat *(00 00 disables unit)*
AV3	**40004**	Tank Set Point	0# ##	Sets Set Point
AV4	**40005**	Tank Temperature	0# ##	Passes tank temp from remote sensor

NOTE: To ensure proper operation re-send the configuration bits to holding register 40001 or Object AV**Ø** prior to issuing a command.

For proper hexadecimal conversion of rate percentage, please refer to the Rate and Temperature Conversions section of this manual.

8 Unit Operation

Cascade

In order to operate the boiler/water heater in Cascade with ModBus or BACnet communications, configure the Leader unit per the control modes in this manual. Connect the remaining boilers/water heaters in the Cascade through the normal daisy chain Cascade communications wiring. Cascade control can then be accomplished automatically through the Leader boiler.

Please note that with ModBus or BACnet communication connected to only the Leader unit, only total Cascade information can be seen through the communications link. If you wish to see all the individual temperatures of each unit in the Cascade, each unit will have to have a ModBus / BACnet communication board. However, each unit can be monitored without the need to control each one individually.

Monitoring Only

Any boiler/water heater can be equipped with the communication board and then set up to operate with its own internal controls. By default settings, the communication board is a ready monitoring device for the read only variables by polling the board.

Rate and Temperature Conversions:

Rate

When issuing a rate command the rate can be communicated as percent modulation or a desired set point, depending on the setting of the BMS Type in the BMS Setup Menu.

The proper data format for the modulation percentage is the direct conversion to hexadecimal. This conversion can be accomplished through online number based converters or some scientific calculators.

For Example:

Rate %	HEX
0	00
20	14
45	2D
60	3C
80	50
95	5F
100	64

To send a desired setpoint, the hexadecimal value must be determined through linear interpolation of programmable parameters on the BMS Setup Menu:

- BMS temperature set point at low analog input
- BMS temperature set point at high analog input

These variables set the temperature values corresponding to the minimum and maximum voltage settings of the 0-10 volt signal. The defaults are as follows:

PARAMETER	DEFAULT VALUES		DEFAULT
	Deg C	Deg F	Voltages
BMS temperature set point at low analog input	21	70	2
BMS temperature set point at high analog input	82	180	10

For Example:

Send a set point of 110°F.

The formula to use for the interpolation is:

Rate Command =

$$\frac{\text{(Desired Set point – BMS Temp at Low Analog Input) (High Voltage-Low Voltage) + Low Voltage}}{\text{(BMS Temp at High Analog Input – BMS Temp at Low Analog Input)}}$$

From the default values:

Desired Setpoint = 110
BMS Temp at Low Analog Input =68
BMS Temp at High Analog=158
High Voltage =10
Low Voltage = 2

[(110-69)(10-2)/(158-68)] + 2 = 5.73 Volts

5.73 Volts = 57.3% Modulation

57% = 39 Hexadecimal

A value of [00][39] in hexadecimal would be written to Holding register 40003 to issue a command for a 110°F setpoint.

Temperature

The boiler/water heater passes temperature data in degrees Celsius. Also, to accommodate decimal places the decimal value must be divided by 10.

Here are the conversions to and from Celsius:

$T_c = (5/9) * (T_f-32)$ $T_f = (9/5) * T_c+32$

Example:
Outdoor temperature from remote sensor on BAS System = 80°F

80°F = 26.7°C
Data that needs to be transmitted is 26.7 * 10 = 267

Decimal	Binary	HEX
267	100001011	10B

Outlet temperature from unit sensor = 155°F

155°F = 68.3°C
Data transmitted from unit in HEX = 2AB = 683
683 ÷ 10 = 68.3 (°C)

Decimal	Binary	HEX
683	1010101011	2AB

8 Unit Operation

Unit Operation with ModBus / BACnet Communications

To control an appliance through a Building Management System communicating through ModBus or BACnet, the Demand Configuration must be set to one of three options. These configurations allow different control points for a variety of applications. The configuration can be set by selecting Main Menu>>Setup>>BMS.

The appliance is equipped with a ModBus communication timer. This timer is programmable from 0 - 120 seconds. The timer can be programmed from the ModBus Setup Menu by selecting Main Menu>>Setup>>ModBus. The purpose of the timer is to ensure proper temperature data is communicated to the boiler in a timely manner. Additionally, it will provide for fail safe operation should ModBus communication be lost. This timer will cause the unit to revert back to internal unit controls should the ModBus communication be interrupted longer than the ModBus timer. The timer is reset every time a ModBus write command is received with updated temperatures or commands. It is the recommendation of Lochinvar that this timer be set to the shortest value possible.

When controlling an appliance through a Building Automation System (BAS), it is very important to ensure that the correct configuration bits are sent to holding register 40001 or Object AV0, and that the correct data and enable signals are sent to holding registers 40002 - 40007 or Objects AV1 - AV6, per the demand configuration.

Demand Configuration: ENABLE = ACTIVE; BMS = INACTIVE

In this configuration the unit is controlled by setting the setpoints locally on the appliance and providing an enable signal through ModBus or BACnet communications.

All sensors and limiting devices should be hardwired to the terminal strip on the back of the unit excluding the enable signal. This signal will be sent to the unit via ModBus.

The holding registers will need to be set as follows:

Object	Holding Registers	Definition	Bit Value (HEX)	Action
AV0	**40001**	Configuration	00 01	Set Configuration to read 40002
AV1	**40002**	Coils	00 01	Enables unit (00 00 disables unit)

NOTE: To ensure proper operation re-send the configuration bits to holding register 40001 or Object AV0 prior to issuing a command.

8 Unit Operation

Demand Configuration: ENABLE = ACTIVE; BMS = ACTIVE

In this configuration the unit is controlled by providing an enable signal. The setpoint command will be determined by the parameters in the control and a rate command through ModBus or BACnet communications.

The rate command will be 0 - 100% of modulation.

All sensors and limiting devices should be hardwired to the terminal strip on the back of the unit excluding the enable and 0-10V BMS signal. These signals will be sent to the unit via ModBus or BACnet.

The holding registers will need to be set as follows:

Object	Holding Registers	Definition	Bit Value (HEX)	Action
AV0	**40001**	Configuration	00 05	Set Configuration to read 40002 & 3
AV1	**40002**	Coils	00 01	Enables unit (00 00 disables unit)
AV2	**40003**	Rate Command	00 ##	Sets Modulation % or Setpoint

NOTE: To ensure proper operation re-send the configuration bits to holding register 40001 or Object AV0 prior to issuing a command.

For proper hexadecimal conversion of rate percentage, please refer to the Rate and Temperature Conversion section of this manual.

Demand Configuration: ENABLE = INACTIVE; BMS = ACTIVE

In this configuration the unit is controlled by setting the modulation setpoint from 0 - 100%, or the setpoint. The setpoint command will be determined by the parameters in the control.

Rate command will be 0 - 100% of the modulation range.

All sensors and limiting devices should be hardwired to the terminal strip on the back of the unit excluding the 0 - 10Vdc signal. This signal will be sent to the unit via ModBus or BACnet.

The holding registers will need to be set as follows:

Object	Holding Registers	Definition	Bit Value (HEX)	Action
AV0	**40001**	Configuration	00 04	Set Configuration to read 40003
AV1	**40003**	Rate Command	00 00	Sets Modulation % or Setpoint

NOTE: To ensure proper operation re-send the configuration bits to holding register 40001 or Object AV0 prior to issuing a command.

For proper hexadecimal conversion of rate percentage, please refer to the Rate and Temperature Conversion section of this manual.

Hot Water Generation

Hot water generation can be accomplished with one of two methods when an AWH or KBX appliance is connected to a BAS system, DHW with direct control, and DHW with remote control.

DHW with direct control:

This is the typical installation with a hot water generator in close proximity to the boiler with the tank thermostat, or tank temperature sensor, wired to the terminal strip of the unit.

8 Unit Operation

DHW with remote control:

This installation may or may not have the hot water generator in close proximity to the appliance. Its sensors and thermostat values are only available through the ModBus or BACnet communication bus.

To ensure that the appliance can properly respond to a call for hot water generation the following holding registers must be set in addition to other commands:

Object	Holding Registers	Definition	Bit Value (HEX)	Action
AV0	**40001**	Configuration	00 4A	Set Configuration to read 40002, 4 & 5
AV1	**40002**	Coils	00 08	Enables Tank Tstat (00 00 disables unit)
AV3	**40004**	Tank Setpoint	0# ##	Sets Setpoint
AV4	**40005**	Tank Temperature	0# ##	Passes tank temp from remote sensor

NOTE: To ensure proper operation re-send the configuration bits to holding register 40001 or Object AV0 prior to issuing a command.

For proper hexadecimal conversion of rate percentage, please refer to the Rate and Temperature Conversion section of this manual.

Cascade

In order to operate the appliance in Cascade with ModBus / BACnet communications, configure the leader appliance per the demand configurations in this manual. Connect the remaining appliances in the cascade through the normal cascade communications wiring. Cascade control can then be accomplished automatically through the leader appliance.

Please note that with ModBus / BACnet communication connected to only the leader appliance, total Cascade information can be seen through the communications link. If you wish to see all the individual temperatures of each unit in the Cascade, each unit will have to have a communication board. However, each unit can be monitored without the need to control each one individually.

Monitoring Only

All appliances are equipped with the communication board and can be set up to operate with its own internal controls. If necessary, ModBus / BACnet can be configured as a monitoring device by polling the communication board for the read only variables.

8 Unit Operation

Rate and Temperature Conversions:

Rate

When issuing a rate command the rate can be communicated as percent modulation or a desired setpoint, depending on the setting of the BMS Type in the BMS Setup Menu.

The proper data format for the modulation percentage is the direct conversion to hexadecimal. This conversion can be accomplished through online number based converters or some scientific calculators.

For Example:

Rate %	HEX
0	00
20	14
45	2D
60	3C
80	50
95	5F
100	64

To send a desired setpoint, the hexadecimal value must be determined through linear interpolation of programmable parameters on the BMS Setup Menu:

- BMS temperature set-point at low analog input
- BMS temperature set-point at high analog input

These variables set the temperature values corresponding to the minimum and maximum voltage settings of the 0-10 volt signal. The defaults are as follows:

PARAMETER	DEFAULT VALUES		DEFAULT
	Deg C	Deg F	Voltages
BMS temperature setpoint at low analog input	21	69.8	2
BMS temperature setpoint at high analog input	82	179.6	10

For Example:

Send a setpoint of 110°F.

The formula to use for the interpolation is:

Rate Command =

(Desired Setpoint – BMS Temp at Low Analog Input) (High Voltage-Low Voltage) + Low Voltage

(BMS Temp at High Analog Input – BMS Temp at Low Analog Input)

From the default values:

Desired Setpoint = 110
BMS Temp at Low Analog Input =68
BMS Temp at High Analog=158
High Voltage =10
Low Voltage = 2

[(110-69.8)(10-2)/(179.6-69.8)] + 2 = 4.92 Volts

(4.92/10) x 100 = 49.2

49 = 31 Hexadecimal

A value of [00][31] in hexadecimal would be written to Holding register 40003 to issue a command for a 110°F setpoint.

Temperature

The appliance passes temperature data in degrees Celsius. Also, to accommodate decimal places the decimal value must be divided by 10.

Here are the conversions to and from Celsius:

$T_c = (5/9) * (T_f-32)$ $T_f = (9/5) * T_c+32$

Example:
Outdoor temperature from remote sensor on BAS System = 80°F

80°F = 26.7°C
Data that needs to be transmitted is 26.7 * 10 = 267

Decimal	Binary	HEX
267	100001011	10B

Outlet temperature from unit sensor = 155°F

155°F = 68.3°C
Data transmitted from unit in HEX = 2AB = 683
683 ÷ 10 = 68.3 (°C)

Decimal	Binary	HEX
683	1010101011	2AB

9 Troubleshooting

Should you encounter problems communicating over ModBus, the following items should be checked in this order:

1. Physical Layer
2. Communications Configuration and Port Settings
3. ModBus Error Codes
4. Unit Status / Blocking / Lockout Codes

Physical Layer

1. Check that all components have power (Boiler, Gateway, BAS Master)
2. Check all wire lengths. Are any drops too long?
3. Check proper shield grounding
4. Check A, B terminal connections
5. Check for Terminating Resistors (120 ohms)
6. Check for broken wires

Communications

1. Check Dip Switch Configuration of Communication Board
2. Check Baud Rate (9600, 19200, etc.)
3. Check Parity (ModBus only)
4. Check Slave ID
5. Check Port Setting on Master, Gateway, and Computers

ModBus Error Codes

1. Check ModBus communication for error codes (see page 12 for ModBus Exception Codes)
2. Check ModBus PDU
3. Check Slave ID
4. Check ModBus Command
5. Check Configuration bits for Holding Register 40001
6. Check Commands and data for Holding Registers 40002 - 40007

Unit Status Codes

See Codes in this section.

Boiler Status

The boiler/water heater status code indicates what the unit is actually doing. This status code should be compared to the command issued and what is expected. If the boiler/water heater status code does not agree with the command issued, check communication and configuration.

Status Codes (Input Register 30014 or Analog Input AI13)

2 = Heat Demand blocked due to high absolute outlet temperature
4 = Heat Demand blocked due to high absolute Delta T (Outlet - Inlet)
8 = Heat Demand blocked due to Low 24 VDC
10 = Block due to switch OFF boiler (ON/OFF of Display)
16 = Service function
19 = DHW function Storage Tank
21 = Heat demand from Input Sensor
22 = Heat demand from Boiler Management System
23 = Heat demand from Cascade
30 = Heat demand activated by Freeze Protection
32 = DHW Pump Delay
33 = Boiler Pump Delay
34 = No heat function (after pump delay)
40 = Lockout
32767 = Code not present

Blocking Codes (Input Register 30015 or AI14)

2 = Blocking Due to Low 24 VDC Supply
5 = Blocking due to Switched OFF boiler (Display ENTER switch)
7 = Blocking due to High Delta
9 = Blocking due to High Outlet Temperature
13 = Blocking anti-cycling time
18 = Power limitation due to high Delta T

9 Troubleshooting

Lockout Codes (Input Register 30016 or AI15)

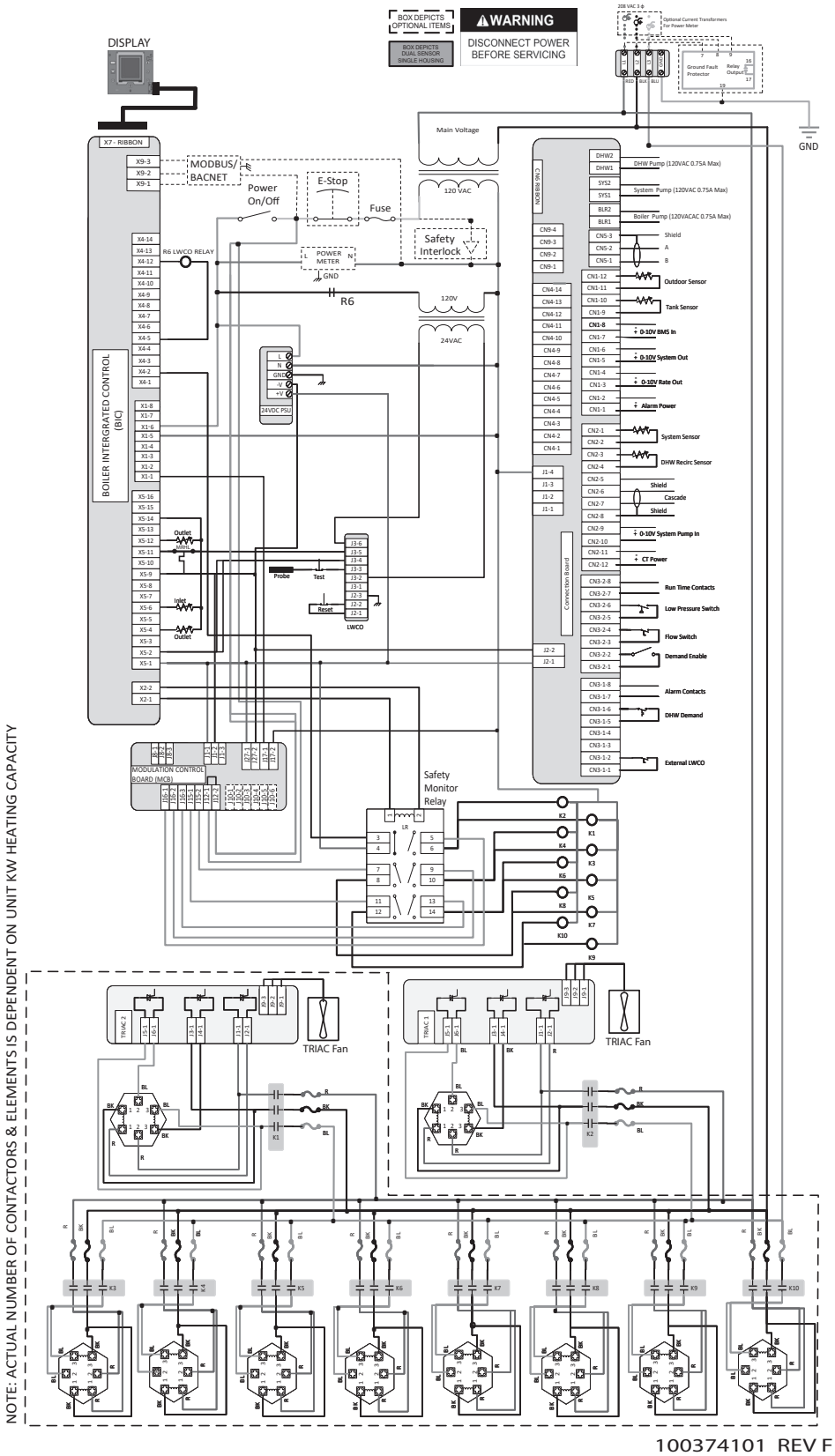
NOTICE

The lockout code is constantly changing during operation and should not be used for lockout notification until the status code (Input Register 30014 or AI13) indicates a code of 40.

166 = EEPROM code Auto Reset High Limit
167 = EEPROM code Auxiliary Alarm Contact
168 = EEPROM code Flow Switch Open
169 = EEPROM code Water Pressure
170 = EEPROM code External Low Water Cut Off
179 = Sensor 2 fault (Inlet Sensor)
180 = Sensor 2 missing (Inlet Sensor)
192 = Sensor 1 fault (Outlet Sensor)
193 = Sensor 1 error (Outlet Sensor)
230 = EEPROM code Main Control Board error
235 = EEPROM code LWCO/MRHL
237 = EEPROM code Monitor Relay is not functioning properly
241 = Low water cut off recycling
242 = Auxiliary alarm contact recycling
243 = Flow switch recycling
244 = Water pressure recycling

10 Diagrams

Figure 10-1 *Ladder Diagram - 208V, 3 Phase*

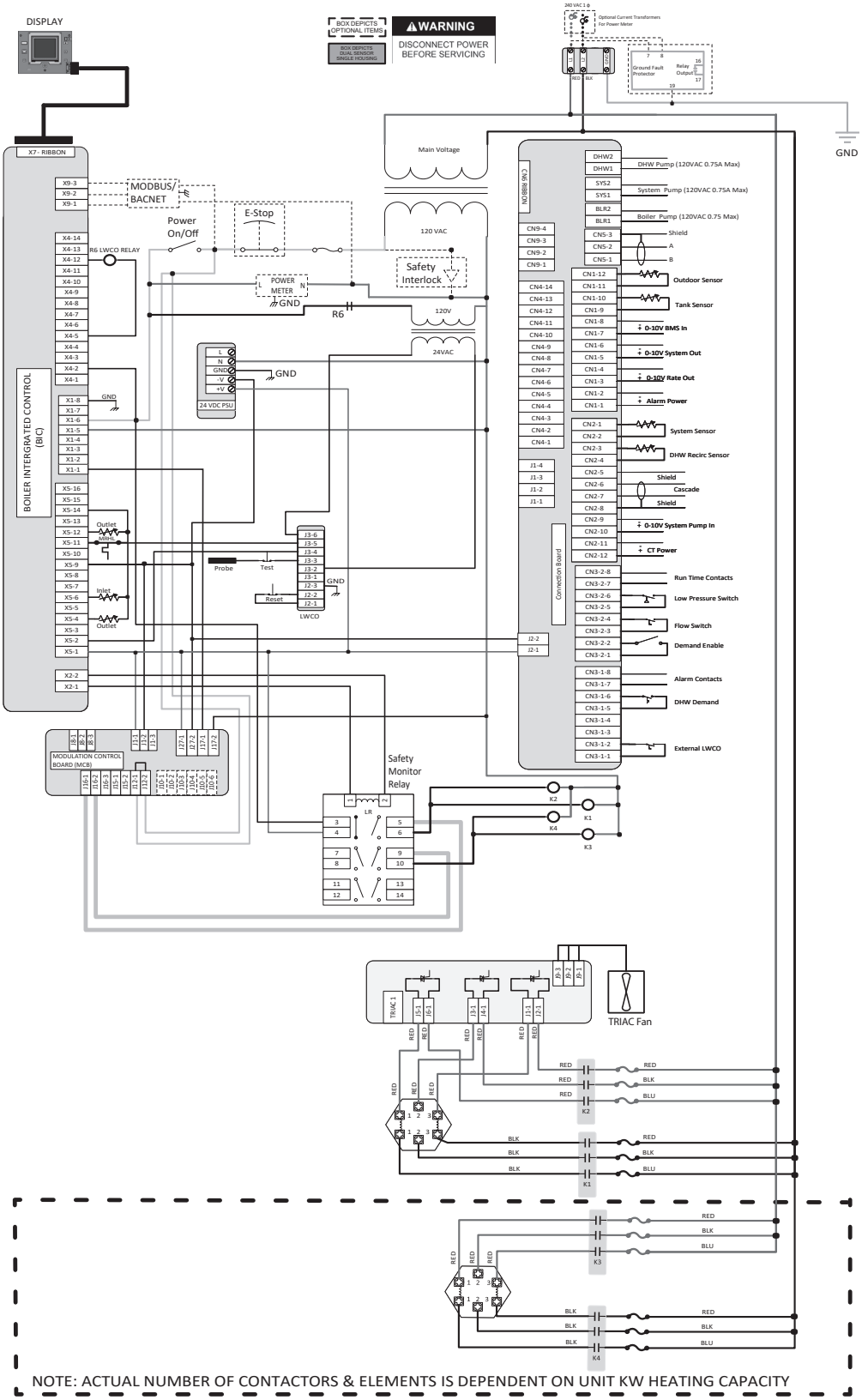


Notes:

1. Where possible, switches are shown without utilities (water or electricity) connected to the unit. As such, actual switch states may vary from those shown on diagrams depending upon whether utilities are connected, or a fault condition is present.
2. See wiring diagram for additional notes.

10 Diagrams

Figure 10-2 *Ladder Diagram - 240V, 1 Phase*

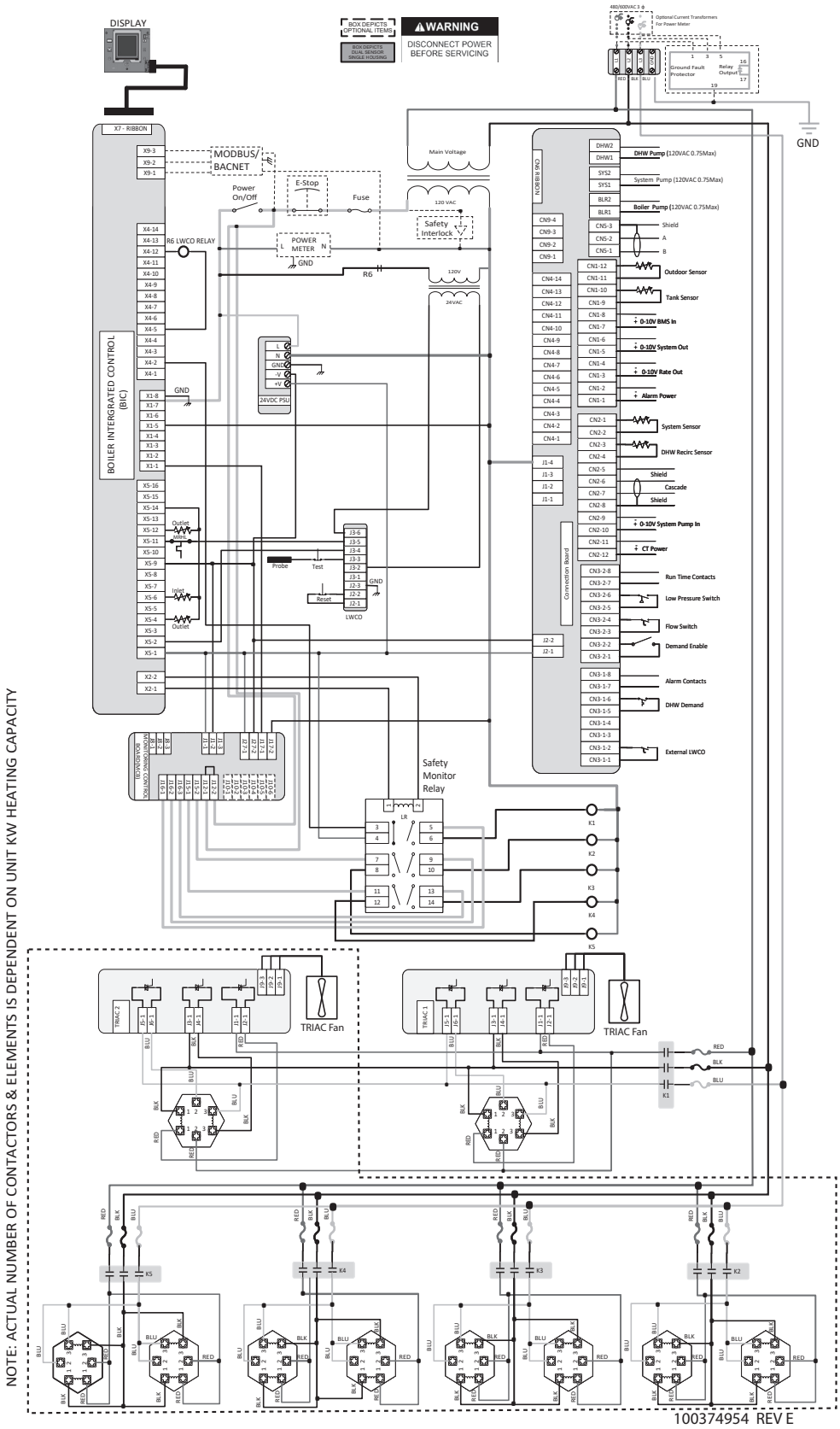


Notes:

1. Where possible, switches are shown without utilities (water or electricity) connected to the unit. As such, actual switch states may vary from those shown on diagrams depending upon whether utilities are connected, or a fault condition is present.
2. See wiring diagram for additional notes.

10 Diagrams *(continued)*

Figure 10-3 *Ladder Diagram - 400-600V, 3 Phase*



Notes:

1. Where possible, switches are shown without utilities (water or electricity) connected to the unit. As such, actual switch states may vary from those shown on diagrams depending upon whether utilities are connected, or a fault condition is present.
2. See wiring diagram for additional notes.

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