

# Modbus Networking

## M.1 Description

Modbus is a standard interface used throughout the controls industry to network devices. It originated with Gould Modicon and has been implemented by a multitude of vendors. Tecogen has added the capability to communicate via this protocol to all its products. It is not the intention of this section to provide the information necessary to implement a Modbus master (the device used to control the bus), but rather to detail the controllers' responses to specific commands. Information on the modbus implementation can be found at Modicon's web site, [www.modicon.com](http://www.modicon.com).

Modbus communications can be utilized for three separate purposes on the INV-100. These are as follows:

1. External Communications - The INV-100 can interface with a building energy management system that is Modbus compatible.
2. Master/Slave Control of Multiple INV-100 Modules - The INV-100's control system can utilize Modbus for its own internal dispatching of networked units. This scheme can be implemented to control the building power consumption, as well as to prevent a reverse power situation at the PCC. For this, a watt input is required from a building wattmeter or utility grade relay (i.e Beckwith) to the "Master" unit. Alternatively, "Master/Slave" control can also be implemented based on the Hot Water load. In this case, no external input is required.
3. RMCS - Modbus communications can be used for the RMCS if only one phoneline is desired. (A telephone switchbox is another alternative when there is only one phoneline.)

### **NOTE**

*Features #1 and #3 can not be used concurrently.*

## M.2 External Communications Network

The **TecoNet™** controller's interface is set up as either a two-wire (and ground) RS-232 or RS-485 serial interface running at 9600 baud.

Table M.1 details the DIP switches which must be set to implement the network. These switches are on bank S4 on the Interface Board (see Figure 3.13). Switch S4-1 must be turned on to enable the network. S4-2 is used

to set either the ASCII or RTU protocol. Each unit connected to the network must have a unique, non-zero address. This address is determined by switches S4-4 to S4-8, allowing addresses of 0 to 31. The address is simply the sum of all of these switches set. For example if S4-4, S4-7, and S4-8 are set, the associated values are 1, 8, and 16 and the address is  $1 + 8 + 16 = 25$ .

The network can be set up as either single-drop, two-wire (and ground) RS-232 or multi-drop, two-wire RS-485. It is best to use the RS-485 wiring scheme since this is the most noise-immune, allows greater separation between units, and provides for connection of many units on the same set of wires. In either case, Tecogen can supply a cable, part #78158, which connects to P2 on the Processor Board (see Figures 3.12 and M.1) and terminates in a male DB-25 connector. When using the RS-232 mode, the pinout becomes a simple DCE with no flow control suitable for direct connection to a PC or other DTE device. When setting up the port for RS-485 use, DIP switch SW4-3 must be on, and the jumpers in JP5 and JP6 must be moved to their right-hand positions (see Figure 2.11). In this case, pin 16 on the DB-25 is negative and pin 17 is positive. All controllers on the network should have these two pins connected in a daisy-chain fashion. If the customer-supplied network controller does not have a two-wire RS-485, commercial converters are available.

The controller will only process a modbus message at most once every 320 milliseconds. It may therefore be necessary to relax the normal timing of the modbus controller, particularly with the RTU protocol. In addition, the RS-485 protocol is half-duplex, so it may be necessary to transmit a command more than once to ensure that the controller has received it. It is also best to wait at least 15 milliseconds after receipt of the last message before beginning a new one.

## Implementation

Each readable controller variable is mapped to one or more of the standard Modbus I/O points or internal variables. Modbus commands will then allow the polling device to read and or change these variables.

One significant deviation from the standard implementation is that, to protect the machine, there are very few variables which can be forced. The only output coils which can be forced are numbers 23, 24, and 25, the Start Flag, Network Start Flag, and Alarm Reset Flag. In general, the Start Flag should only be forced under manual control. If the network controller needs to start or stop the unit as part of normal sequencing, it should use the Network Start Flag and DIP switch 2-6 (Network Start) should be turned on.



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Using only this flag will show any personnel near the equipment that is enabled and ready to start. In addition, if they wish to stop the unit, they can do so by pressing the **STOP** button. The Start Flag should be used with great care since it overrides the **START / STOP** buttons on the keypad display. Setting the Alarm Reset flag is equivalent to pressing the **RESET** button on the display. The only registers which can be forced are the holding registers in Table M.4. These values can be used to adjust the clock and the power and temperature setpoints. Only single value forcing can be done, the controller does not support forcing of multiple coils or holding registers.

Table M.2 shows the Modbus commands to which the **TecoNet™** will respond as well as the limits of the range argument. Tables M.3 through M.6 show the different memory range variables which can be addressed.

## M.3 Master / Slave Control

**TECOGEN®** Cogeneration Modules equipped with the **TecoNet™** controller can be networked to control overall building electrical consumption or the building hot water load.

### Building Power Control Mode

This is accomplished by allowing one unit, the master or lead unit, to read the building power at the utility interconnect. Through a communications channel to the other slave units, the master starts the proper number of units and controls their power to maintain imported power at a minimum.

### Installation

As shown in Figure M.2, the contractor should supply a building wattmeter with a 4-20 mA output signal. Using a single twisted pair, this signal is wired to the master **TecoNet™** on J-9 V3 (S, -) along with a 501-Ohm precision resistor. If required by the local utility, the master can monitor each of the 3 phases of incoming power separately and act on the lowest of these phases. A Beckwith Relay also can be equipped with a wattage output. If this is utilized, this wattage information will be communicated to the master unit via Modbus.

The master is connected to up to 30 slaves via a second, daisy-chained twisted pair (shielded). This wire connects to the Interface Board J18 +, J18 -, and the shield to ground (see Figure M.2)

Once the wiring is complete, Jumpers JP5 and JP6 on the processor board should be moved to their right-hand positions. In addition, the DIP switches should be set as indicated in Tables M.7 and M.8.

Any unit may be designated as the master. The master does not operate any differently than the other units, it is merely the unit designated to make the decisions about which units should run and at what power level. Any unit designated as the master will make this decision in the same way as any other unit.

### Operation

The master unit watches the power signal from the wattmeter(s) or Beckwith Relay. When the power rises above the minimum power at which a single **TECOGEN®** will operate, the unit with the least number of run hours will be started. The master will then control this unit's power to maintain the power imported to the building at a minimum. As power increases beyond the point where the first unit can maintain the minimum imported power, the master controller will start another slave and reduce the power on both running units to again maintain the imported power at a minimum.

As building power decreases, the master controller will reverse the sequence. In case the power drops quickly, the master will have a fast shutdown command available, allowing it to immediately disconnect the running units from the grid, preventing power export.

The master also keeps track of which units are ready to run. If any are manually shut off or are in an alarm condition, the master will use others to meet the building demand. In this manner, the plant will run with the fewest number of **TECOGEN®** units possible and thus at peak efficiency. In addition, by keeping the run hours on the units matched, they will require routine service at the same times. Finally, this is all accomplished within the **TecoNet™** controller, requiring only a simple wattmeter and interconnecting wire to function properly.

### Building Hot Water Control Mode

The networked group of units can be set to control water temperature rather than building load.

Hot Water Mode stages and cycles the units based upon the building hot water load. If the load is dropping off, resulting in a leaving water temperature (on any of the cogeneration units) that is too hot, the Lead will start shutting units down and/or reduce their power output. Alternatively, if this temperature becomes too cold, the Lead will turn units on and/or increase their power output. Connections to the units are identical to that used for building power control except that the wattage input is not required. Also, DIP switch S3-3 should be "Off".

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## M.3 RMCS Networking

Modbus networking can be used to implement the RMCS on multiple units when only one phoneline is available. However, this feature can not be used concurrently for external Modbus communications.

For networking the RMCS, connect the phoneline to the modem of one unit. Then daisy chain the P2 connection on the other units together. Follow the DIP switch setting for a Network as described in Section M2.

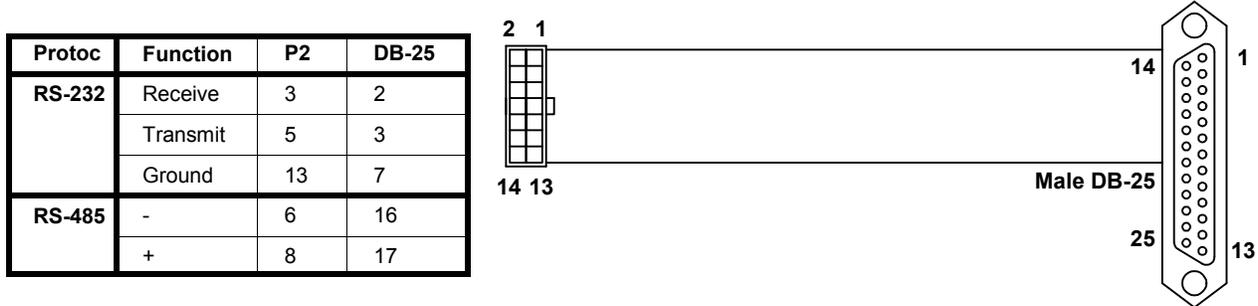


Figure M.1 P2 Connection Diagram

Table M.1 Network DIP Switches– Bank 4

No.	Off	On
S4-1	No network	Network installed
S4-2	ASCII protocol	RTU protocol
S4-3	RS-232	RS-485
S4-4	Add 0 to address	Add 1 to address
S4-5	Add 0 to address	Add 2 to address
S4-6	Add 0 to address	Add 4 to address
S4-7	Add 0 to address	Add 8 to address
S4-8	Add 0 to address	Add 16 to address

Table M.2 Supported Commands

Function	Name	Minimum	Maximum	Excluded
1	Read Output Coil Status	0	25	
2	Read Input Coil Status	0	103	
3	Read Holding Registers	0	44	
4	Read Input Registers	0	112	
5	Force Output Coil	23	25	
6	Preset Single Register	0	44	
7	Read Exception Status			
8	Diagnostic	0	20	9-15
11	Read Comm Event Counter			
12	Read Comm Event Log			
17	Report Slave ID			



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**Table M.3 Output Coils**

No.	Use
0	Fuel valve step command
1	Fuel valve open command
2	O2 sensor 1 heater
3	O2 sensor 2 heater
4	Gas / Ignition relay
5	Engine starter relay
6	Pump relay
7	Contactory relay
8	Alarm relay
9	Radiator fan output
10	Inverter wakeup
11	Hourmeter
12	EFLH meter
13	Unit started
14	Load shed
15	Customer output
16	Ready LED
17	Startup LED
18	Run LED
19	Shutdown LED
20	Alarm LED
21	Start LED
22	Stop LED
23	Start flag
24	Network start flag
25	Alarm reset flag

**Table M.4 Input Coils**

No.	Use
0	High water pressure switch
1	Low water pressure switch
2	Low oil pressure switch
3	Low oil level switch
4	Ignition power verify
5	Emergency stop verify
6	Protective relay input
7	Customer run switch
8	Standby run input
9	Temperature control mode
10	Unused
11	Unused
12	Counter 1
13	Counter 2
14	Counter 3
15	Counter 4
16 - 79	Dip switch settings S1-1 to S8-8
	<b>Inverter Status Bits</b>
80	Unused
81	PCS overload
82	Unused
83	Unused
84	Unused
85	Unused
86	PCS PLL OK
87	PCS AC line OK
88	PCS MG mode
89	PCS GT mode
90	Unused
91	Unused
92	Unused
93	Unused
94	PCS receive error
95	PCS system fault
96	MG feeder mode
97	MG e voltage OK
98	MG e frequency OK
99	MG PLL enable
100	MG PLL OK
101	MG PLL fault
102	MG voltage low
103	MG contactor fault



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**Table M.5 Holding Registers**

0	Day of week (0 - 7, Sunday = 0)
1	Year (0 - 99)
2	Month (1 - 12)
3	Date (1 - 31)
4	Hour (0 - 23)
5	Minute (0 - 59)
6	Second (0 - 59)
7	Hundredth of second (0 - 99)
8	Permanent power setpoint (kW X 10)
9	Permanent Temperature setpoint (°F X 10)
10	Inverter Operation Command
11	Inverter Control Mode Command
12	Inverter Readback Command
13	Inverter Current Set
14	Microgrid Operating Mode Command
15	Microgrid Voltage Command (0.1V/Bit)
16	Microgrid Output Power Command (0.1kW/Bit)
17	Microgrid Feeder Power Command (0.1kW/Bit)
18	Microgrid Q Vs E Droop Command (0.01V/kVA/Bit)
19	Microgrid Q Max Command (0.1kVA/Bit)
20	Microgrid P Vs Frequency Droop Command (0.00001V/Hz/Bit)
21	Microgrid Max Power Command (0.1kW/bit)
22	Microgrid Min Power Command (0.1kW/bit)
23	Microgrid Feeder Power Vs Frequency Drop Command (0.00001V/Hz/Bit)
24	Microgrid Frequency Command (0.01Hz/Bit)
25	Inverter Readback Command
26	Setting For Overfrequency 1 (Hz X 10)
27	Setting For Underfrequency (Hz X 10)
28	Delay For Overfrequency 1 (cycles)
29	Delay For Underfrequency 1 (cycles)
30	Setting For Overfrequency 2 (Hz X 10)
31	Setting For Underfrequency (Hz X 10)
32	Delay For Overfrequency 2 (cycles)
33	Delay For Underfrequency 2 (cycles)
34	Setting For Overvoltage 1 (V)
35	Setting For Undervoltage 1 (V)
36	Delay For Overvoltage 1 (cycles)
37	Delay For Undervoltage 1 (cycles)
38	Setting For Overvoltage 2 (V)
39	Setting For Undervoltage 2 (V)
40	Delay For Overvoltage 2 (cycles)
41	Delay For Undervoltage 2 (cycles)
42	Grid-Tie Reconnect Delay (msec)
43	Sensitivity For Anti-Islanding
44	GT Settings Readback Command





**Table M.6 Input Registers**

No.	Use	No.	Use	No.	Use
0	Day of week (0 - 7, Sunday = 0)	38	Oil temperature (°F X 10)	76	Micogrid Faults
1	Year (0 - 99)	39	Enclosure temperature (°F X 10)	77	Micogrid VLoop
2	Month (1 - 12)	40	Exhaust temperature (°F X 10)	78	Inverter DC Voltage
3	Date (1 - 31)	41	Customer 1 temperature (°F X 10)	79	Inverter Voltage Phase A
4	Hour (0 - 23)	42	Customer 2 temperature (°F X 10)	80	Inverter Current Phase A
5	Minute (0 - 59)	43	Customer 3 temperature (°F X 10)	81	Inverter kW Phase A X 10
6	Second (0 - 59)	44	Customer 4 temperature (°F X 10)	82	Inverter kVA Phase A X 10
7	Hundredth of second (0 - 99)	45	Customer 5 temperature (°F X 10)	83	Inverter Voltage Phase B
8	Operating mode	46	Customer 6 temperature (°F X 10)	84	Inverter Current Phase B
9	Active alarm number	47	Customer 7 temperature (°F X 10)	85	Inverter kW Phase B X 10
10	Active prealarm number	48	SKiiP temperature (°F X 10)	86	Inverter kVA Phase B X 10
11	Active runback number	49	Catalyst outlet temperature (°F)	87	Inverter Voltage Phase C
12	Present power setpoint (kW X 10)	50	Catalyst inlet temperature (°F)	88	Inverter Current Phase C
13	Permanent Temperature setpoint (°F X 10)	51	TecoNET output coils as word	89	Inverter kW Phase C X 10
14	Logic voltage (mV)	52	TecoNET input coils as word	90	Inverter kVA Phase C X 10
15	Analog voltage (mV)	53	O2 sensor (mV)	91	Inverter Skiip Temperature
16	Battery voltage (mV)	54	Long-term block learn	92	Inverter Debug 1
17	RPM	55	Short-term block learn	93	Inverter Debug 2
18	Total starts	56	Fuel valve position (%)	94	Inverter Debug 3
19	Total hourmeter (hours)	57	Manifold absolute pressure ("Hg X 10)	95	Line Voltage Phase A
20	V1 voltage (V)	58	Barometric absolute pressure ("Hg X 10)	96	Line Voltage Phase B
21	V2 voltage (V)	59	Customer voltage input 1	97	Line Voltage Phase C
22	V3 voltage (V)	60	Customer voltage input 2	98	Inverter Power X 10
23	Average voltage (V)	61	Customer voltage input 3	99	Inverter Power Percent X 10
24	C1 current (A)	62	Customer voltage input 4	100	Inverter Current Sum Of Mean
25	C2 current (A)	63	Customer voltage input 5	101	Micogrid Current D (0.1A/Bit)
26	C3 current (A)	64	Customer voltage input 6	102	Micogrid Current Q (0.1A/Bit)
27	Average current (A)	65	Counter 1	103	Micogrid Voltage D (0.1V/Bit)
28	Power Leg 1 (X 10)	66	Counter 2	104	Micogrid Voltage Q (0.1V/Bit)
29	Power Leg 2 (X 10)	67	Counter 3	105	Micogrid P (0.1kW/Bit)
30	Power Leg 3 (X 10)	68	Counter 4	106	Micogrid Q (0.1kVA/Bit)
31	Average Power (X 10)	69	Total energy (MW-hr)	107	Micogrid F (0.1kW/Bit)
32	Frequency (Hz X 10)	70	Total heat (MMBTU)	108	Micogrid E0 (0.1V/Bit)
33	Generator inlet temperature (°F X 10)	71	Inverter State	109	Micogrid Feeder Current D (0.1A/Bit)
34	Generator outlet temperature (°F X 10)	72	Inverter Status	110	Micogrid Feeder Current Q (0.1A/Bit)
35	Water inlet temperature (°F X 10)	73	Inverter Faults	111	Micogrid E Out (0.1V.bit)
36	Water outlet temperature (°F X 10)	74	Micogrid State		Micogrid Frequency (0.01Hz/bit)
37	Coolant temperature (°F X 10)	75	Micogrid Status		

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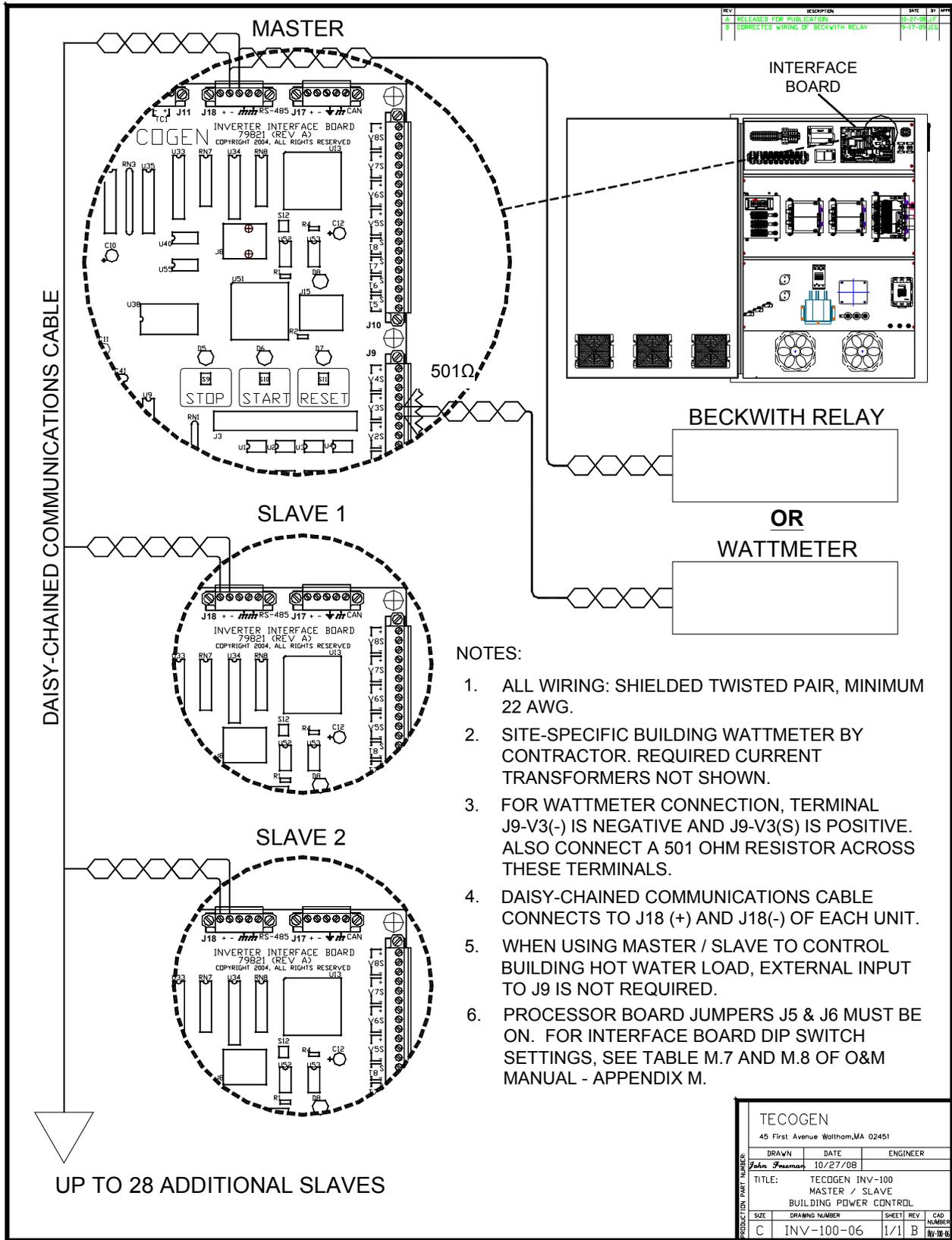


Figure M.2 Master / Slave Wiring



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**Table M.7 Building Power Control Settings**

DIP Switch	Building Power Control Setting	Building Hot Water Control Setting
S3-1	Master—ON, Slave— OFF (See Table M.7)	Master—ON, Slave— OFF (See Table M.7)
S3-2	Master—OFF, Slave— ON (See Table M.7)	Master—OFF, Slave— ON (See Table M.7)
S3-3	On	
S3-7	On *	OFF
S4-1	ON	ON
S4-2	ON	ON
S4-3	Master/Slave (See Table M.7)	Master/Slave (See Table M.7)
S4-4	Master/Slave (See Table M.7)	Master/Slave (See Table M.7)
S4-5	Master/Slave (See Table M.7)	Master/Slave (See Table M.7)
S4-6	Master/Slave (See Table M.7)	Master/Slave (See Table M.7)
S4-7	Master/Slave (See Table M.7)	Master/Slave (See Table M.7)
S4-8	Master/Slave (See Table M.7)	Master/Slave (See Table M.7)

*\* If Beckwith Relay is used*



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**Table M.8 Master/Slave Address Settings**

Unit Designation	DIP Switch Settings						
	S3-1	S3-2	S4-4	S4-5	S4-6	S4-7	S4-8
Master	On	Off	On	Off	Off	Off	Off
Slave 1	Off	On	Off	On	Off	Off	Off
Slave 2	Off	On	On	On	Off	Off	Off
Slave 3	Off	On	Off	Off	On	Off	Off
Slave 4	Off	On	On	Off	On	Off	Off
Slave 5	Off	On	Off	On	On	Off	Off
Slave 6	Off	On	On	On	On	Off	Off
Slave 7	Off	On	Off	Off	Off	On	Off
Slave 8	Off	On	On	Off	Off	On	Off
Slave 9	Off	On	Off	On	Off	On	Off
Slave 10	Off	On	On	On	Off	On	Off
Slave 11	Off	On	Off	Off	On	On	Off
Slave 12	Off	On	On	Off	On	On	Off
Slave 13	Off	On	Off	On	On	On	Off
Slave 14	Off	On	On	On	On	On	Off
Slave 15	Off	On	Off	Off	Off	Off	On
Slave 16	Off	On	On	Off	Off	Off	On
Slave 17	Off	On	Off	On	Off	Off	On
Slave 18	Off	On	On	On	Off	Off	On
Slave 19	Off	On	Off	Off	On	Off	On
Slave 20	Off	On	On	Off	On	Off	On
Slave 21	Off	On	Off	On	On	Off	On
Slave 22	Off	On	On	On	On	Off	On
Slave 23	Off	On	Off	Off	Off	On	On
Slave 24	Off	On	On	Off	Off	On	On
Slave 25	Off	On	Off	On	Off	On	On
Slave 26	Off	On	On	On	Off	On	On
Slave 27	Off	On	Off	Off	On	On	On
Slave 28	Off	On	On	Off	On	On	On
Slave 29	Off	On	Off	On	On	On	On
Slave 30	Off	On	On	On	On	On	On

