M&M Systems, Inc.

Refrigeration Split Package Controller

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Revision History

Revision	Date	Approval	Description of Change	Comments
-	5/10/06		Preliminary Release	

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1. Equipment summary

The M&M Systems Spit Package Control System (SPCS) uses distributed methodology to control Heating, Ventilation, Air Conditioning, and Refrigeration (HVAC/R) equipment in the facility. Control panels may be located close to the controlled equipment to reduce wiring costs. An RS-422 multi-drop serial communications network is used to connect multiple control panels to a Master control panel for alarm reporting, data logging and interface to the PC-based monitoring system.

The design of the SPCS has been ruggedized for use in indoor or outdoor applications. Typical Split Package refrigeration systems consist of two primary components, the Condensing Unit and the Evaporator. The SPCS control panel may be mounted in any convenient location; such as the rooftop by the condensing unit, within the refrigerated space next to the evaporator, or in a machinery room or hallway.

The application of the SPCS into various manufacturers' equipment will determine what features and functions will be available for use by the plant personnel. This document specifies all available functions and how they can be used. Additional contactors, sensors, or wiring may be required in order to make full use of the capabilities of the SPCS.

1.1. Control System Components

The SPCS consists of the following components and sub-systems:

1. Control panel
   - Microprocessor-based controller board
   - Memory (RAM, EPROM, EEPROM)
   - Analog Input and Output Signal Conditioning
   - Discrete Input/Output Signal Conditioning
   - Communications ports
   - Power Supply
   - Enclosure
2. Sensors and actuators
   - Analog sensors for temperature, pressure, etc.
   - Form-C relay outputs.
   - Discrete contact inputs
3. Operator Interface
   - Remote access via PC
   - *Optional* remote access via modem
   - *Optional* remote monitoring via Modbus RTU protocol
   - *Optional* two-line display with keypad

1.2. Environmental Specifications

The SPCS will be designed to survive in an outdoor or indoor industrial environment under the following conditions:

Ambient Temperature:	-20 : 50 DEGC (Operating) -20 : 50 DEGC (Non-Operating)
Water Resistance:	NEMA 4
Power Input:	110/220 VAC 50/60 Hz
Agency Approvals:	UL 508A Listed Industrial Control Panel UL File Number NITW.E232237 cUL File Number NITW7.E232237

1.3. Control Software

The Control Software executes from non-volatile memory which requires no operator intervention in the event of a power failure. The software is designed to provide control and monitoring functions to maintain the proper room temperature and to notify plant personnel that there is a problem with the system. Also included are various optional safety controls and monitoring points to improve system performance. For a detailed description of the Control Software see the *Detailed System Description* section below.

An optional local display and keypad is available to allow local monitoring and setpoint modification. For a detailed description of the Operator Interface, see the *Operator Interface* section below.

An interface is also provided for a PC, Laptop, or other hand-held device to allow qualified maintenance personnel access to more advanced system functions. System configuration, historical log viewing, graphing, and report printing may all be performed through the PC interface. The PC Monitor software is described in a separate document titled *PC Monitor User's Manual*.

1.4. Remote Monitoring

Several options are available for remote monitoring of real-time data from the SPCS. A PC may be permanently or temporarily connected to the one or more controllers through an RS-422 communications network. In addition, the PC may dial-into the system if a modem and telephone line are provided. In either case, all the functionality available with a local PC is available from the remote location.

If an open protocol is desired, the Modbus RTU protocol is supported on an RS-422/RS-485 interface. All real-time analog, discrete, and state data are available; as well as access to a limited number of control and monitoring setpoints.

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2. Detailed System Description

2.1. Evaporator Control

Controlling the room temperature is the primary function of the SPCS and controlling the evaporator liquid valve is the minimum required control operation. Compressors, condensers, and fans may or may not be controllable, depending on how much additional wiring or contactors are added to the equipment. The following paragraphs discuss controlling the liquid valve, fans, and defrost.

One or two coils can be controlled and each can have its own fan, as long as they share the same liquid valve. If the fans are not controllable, then features such as fan cycling and fan sampling will not be available.

If defrost is required, two methods are provided. Air defrost simply stops refrigeration for a period of time to allow ice to melt from the coils. Electric defrost also energizes electric heating elements to reduce the amount of time required to defrost the coils. In practice, other types of defrost may be supported, as long as they can be initiated with a relay contact closure.

Defrost termination is also supported. When used, one or more discrete inputs or temperature sensors are used to signify that the timed defrost cycle may be terminated early.

2.1.1. Zone Control

Zone Temperature Control is the manipulation of the evaporator Liquid valve and fans to maintain the temperature of a refrigerated space. This includes evaporator setpoint scheduling and zone defrost control. The zone temperature is continuously monitored and controls are adjusted to maintain the current temperature setpoint. The operator can change evaporator operating modes, adjust fan cycling, schedule control setpoints, and adjust defrost parameters to match the individual needs of each refrigerated space.

Each Evaporator zone can operate in one of several different states including Cooling, Stop, Max Cool, Defrost, Stop Defrost, Shutdown, Satisfied, Standby, and Power Fail. The function for each state in the evaporator zone is documented below.

1. Cooling

In the Cooling state, the liquid valve is opened and closed in response to temperature changes. On the evaporator zone setpoint screen, the operator can set the cooling setpoint and a deadband for each of four control setpoint groups. The cooling temperature is the value the controller will try to maintain for that particular zone. When the temperature is above the cooling setpoint by half the deadband the liquid valve will open, and when the temperature is below the cooling setpoint by half the deadband the liquid valve will close. For example, if the cooling temperature is set to 45 DEGF with a deadband of 2 DEGF the liquid valve will open at 46 DEGF and close at 44 DEGF.

The operator may select one of three fan cycling options for fan control while a zone is operating. If No Fan Cycling (NONE) is selected, the zone fans will remain running even when the zone is Satisfied. If Temperature Fan Cycling (TEMP) is selected, the zone fans will stop when the zone is Satisfied. If Fan Sampling (SAMP) is selected, the fans will stop when the zone is Satisfied but will restart periodically for a short period of time to mix the air in the room.

Fan On and Fan Off delays are also provided to allow fan staging when multiple fans are instrumented for an individual zone.

2. Stop

The Stop state is an operator-selected state and is used to cancel all automatic control of an evaporator zone and shuts it down. The fans turn off and the liquid valve closes. An evaporator in the Stop state will still defrost based on the defrost schedule or by manual initiation of defrost via the manual override command. Any defrost in progress when the operator selects the Stop state will run to completion.

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3. Max Cool

The Max Cool state cancels automatic control of an evaporator zone and leaves it running. The fans turn on and the liquid solenoid opens. An evaporator in the Max Cool state will still defrost based on the defrost schedule, liquid feed runtime, or by manual initiation of defrost via the manual override command.

4. Satisfied

The Satisfied state is when an evaporator zone is within its setpoints; not cooling or heating. The Fans may or may not be running, depending on the Fan Cycling status.

5. Defrost

The Defrost state indicates that a zone is undergoing a defrost cycle. The type of defrost to be performed is a function how the zone is instrumented. Electric, Water, and Air defrost methods are supported. A defrost cycle can be initiated manually, through a time schedule, or through liquid feed runtime. Zones are defrosted on a first-come, first-served basis by entering the zone in a defrost queue. A zone can be identified as a priority defrost zone which allows it to be entered at the top of the queue.

6. Shutdown

The Shutdown state is entered when the Shutdown/Standby input is active and Shutdown operation has been programmed by the operator. Shutdown is typically used when dangerous conditions are detected such as a refrigerant leak or mechanical failure. Shutdown cancels automatic control of an evaporator zone and shuts it down. The fans turn off and the liquid solenoid closes. Any defrost in progress will be canceled. An evaporator in the Shutdown state will not defrost based on the defrost schedule, liquid feed runtime, or by manual initiation of defrost via the manual override command. When the condition that caused the shutdown is no longer active, the control state will be restored to the previous state. Defrosts which are cancelled by a Shutdown will not be re-queued.

7. Standby

The Standby state is entered when the Shutdown/Standby input is active and Standby operation has been programmed by the operator. Standby is typically used when a zone needs to be stopped for washdown or cleanup operations. Standby may also be used for Load Shedding by external control functions. Standby cancels automatic control of an evaporator zone and shuts it down. The fans turn off and the liquid valve closes. An evaporator in the Standby state will still defrost based on the defrost schedule or by manual initiation of defrost via the manual override command. Any defrost in progress will run to completion. Zone high temperature alarms will be inhibited in the Standby state and for a user-programmable time delay after the zone restarts.

8. Power Fail

The Power Fail state is used to reduce the demand power requirements for restarting evaporators after a power failure. When power is restored to the system, the operator has the option of allowing the zone to restart immediately, or to be restarted one at a time based on time and temperature.

The Master controller uses a user-programmable power fail stage delay timer to restart zones after a power failure. The zone whose temperature differential is highest from setpoint will be restarted until all zones have been restarted.

2.1.2. Zones With Heat

A zone with Heat uses a second zone control setpoint for use when the room temperature is too low. Electric heat is typically used when a zone is instrumented for heating but any heating method can be used as long as it is controllable with a single output. When a zone with heat is in the Satisfied state, the setpoint will reflect whether the zone is in heating or cooling mode.

2.1.3. Evaporator Setpoint Scheduling

Each zone has four temperature setpoint groups which may be scheduled for use by the operator. Each schedule consists of a weekly schedule and three daily schedules. The operator can enter up to eight times into any one of the daily schedules. The user also assigns the desired temperature setpoint group and fan cycling control to each time entered.

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Temperature setpoint groups are referred to by group number (G1 - G4). Setpoint groups consist of a setpoint, deadband, and high and low alarms. If heating is provided, a heating setpoint is also provided. Daily schedule times can be entered in any order and the SPCS will automatically reorder them in chronological order when the screen is saved. The operator then assigns a daily schedule to each day of the week using the selectable field on the weekly schedule screen. Each daily schedule is referred to by its schedule number (SCH1 - SCH3). A new day starts and schedules change at midnight.

The operator may also override the current schedule setpoint or disable scheduling all together. The evaporator setpoint screen allows the operator to override the current control group and the current active daily schedule. In addition, scheduling may be disabled by the operator by selecting disable on the evaporator setpoint screen.

2.1.4. Defrost Control

A number of different defrost techniques are supported by the controller; including Electric, Hot Gas, Water or Air. The following table shows the valve configuration for each Defrost state. Each state also includes a user-programmable time which may be set to zero to bypass the state. For example, if the Pre-Defrost valve is not used, the Pre-Defrost timer can be set to zero.

DEFROST STATE	LIQUID SOL	SUCTION SOL	PRE-DEFROST	DEFROST	POST-DEFROST	FANS
NO DEFROST	**OPEN**	**OPEN**	CLOSED	CLOSED	CLOSED	**ON**
PUMP OUT	CLOSED	**OPEN**	CLOSED	CLOSED	CLOSED	**ON**
PRE-DEFROST	CLOSED	CLOSED	**OPEN**	**OPEN**	CLOSED	OFF
DEFROST	CLOSED	CLOSED	CLOSED	**OPEN**	CLOSED	OFF
POST-DEFROST	CLOSED	CLOSED	CLOSED	CLOSED	**OPEN**	OFF
COOL COIL	**OPEN**	**OPEN**	CLOSED	CLOSED	CLOSED	OFF
ALARM DELAY	**OPEN**	**OPEN**	CLOSED	CLOSED	CLOSED	**ON**

The following list documents the detailed operation for each defrost state.

1. Pump Out. The Pump Out cycle is used to evaporate any remaining refrigerant liquid from the coils. The Liquid Valve is closed, the Suction Valve (if provided) is open, and the Fans are on. If compressor monitoring is enabled, the Pump Out cycle will terminate early once the compressor stops.
2. Pre-Defrost (Pre-Heat). The Pre-Defrost cycle may be used to open a Pre-Hot Gas valve prior to Hot Gas Defrost. For systems with Electric Defrost, the Pre-Defrost cycle may be used as a delay to allow the coil to warm-up prior to energizing the Electric Defrost output. The Pre-Defrost timer may be set to zero to skip the Pre-Defrost cycle.
3. Defrost. For systems with Electric Defrost, the Defrost output is used to turn on the Defrost Heaters; for systems with Hot Gas Defrost, the Hot Gas valve is opened; and for systems with Water Defrost, the Defrost Water valve is opened. The Defrost cycle may be set to run for a user-programmable, time period, or until the early termination input is satisfied.
4. Post-Defrost (Bleed). The Post-Defrost cycle may be used to open a Bleed (equalization) valve after a Hot Gas defrost cycle. For systems with Electric Defrost or Water Defrost, the Post-Defrost cycle may be used as a delay to allow the coil to drip dry and to allow pressures to equalize prior to entering the Cool Coil state. The Post-Defrost timer may be set to zero to skip the Post-Defrost cycle.
5. Cool Coil. The Cool Coil cycle is used to re-freeze any remaining water on the coils and drip pan to prevent excess water from blowing into the room. The Liquid valve is opened and the fans remain off for the duration of the Cool Coil cycle.
6. Alarm Delay. After the Cool Coil cycle, normal refrigeration may resume. The Alarm Delay cycle is used to inhibit zone temperature high alarms for a period of time after a defrost cycle in order to allow time for the room temperature to recover.

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2.1.5. Defrost Termination

Early termination of a defrost cycle is provided as a user-selectable option. A temperature sensor or discrete contact closure may be used for each fan coil. When termination on temperature is enabled, the defrost cycle will be terminated when the coil temperature sensor rises above a user-programmable setpoint. When a discrete contact termination input is used, the defrost cycle will be terminated when the termination contact closes.

When defrost termination is enabled, an optional alarm may be generated if the defrost cycle is terminated on time instead of temperature. The operator may enable or disable this feature.

2.1.6. Defrost Scheduling

A defrost cycle may be initiated in a number of different ways including Time of Day scheduling, Liquid Feed Runtime, Demand Defrost, or by operator input. For Time of Day scheduling, eight defrost cycles per day are supported. Three different daily schedules may be assigned to each day of the week.

For Liquid Feed Runtime scheduling, a defrost cycle will be performed when the Liquid valve has been open for a user-programmable cumulative period of time.

The Demand Defrost input is provided to allow external devices to initiate a defrost cycle. When the Defrost Initiate input contact is closed, the zone will begin a defrost cycle.

2.1.7. Defrost Queue

When multiple zone controllers are configured in a network, one controller is specified as a Master. The Master controller handles the management of the Defrost Queue which ensures that only a specified number of zones are allowed to defrost at any given time. When a zone requires defrosting, a Defrost Request is entered into the Defrost Queue. If the current number of zones defrosting is less than the maximum specified, the zone is allowed to defrost. If the maximum number of zones is already defrosting, the zones will be defrosted on a first-come, first-served basis.

Each zone can be designated as a Priority Defrost zone. When the Defrost Queue is full, zones with Priority Defrost will be entered at the top of the queue.

2.2. Compressor Monitoring

Compressor monitoring is an optional way to keep track of the operation and health of the compressor. The Compressor Running input is used to monitor the state of the compressor to ensure that it is running when required. An alarm will be generated if the compressor does not start within a user-programmable time after the liquid valve opens.

The Compressor Running input may also be used to provide early termination of the Pump Out defrost state. When this feature is enabled, the Pump-Out defrost cycle will be terminated when the compressor stops.

Three safety inputs have been provided; High Pressure Cut Out, Low Pressure Cut Out, and Oil Pressure Cut Out. These inputs are typically wired to pressure switches mounted in the equipment which will shutdown the compressor when a problem occurs. The controller monitors these inputs and will change the evaporator state to Shutdown when active.

2.3. Shutdown/Standby Input

The Shutdown/Standby input is provided to allow external equipment to stop the evaporator. The operator may select Shutdown or Standby operation for this input. In either case, the zone will be shutdown in an orderly fashion. The primary difference between Shutdown and Standby operation is that a failure will be reported and zone high temperature alarms will remain enabled in the Shutdown state.

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3. Operator Interface

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Appendix A.Alarm and Failure Conditions

The following table lists the system alarm and failure conditions. Alarms are information only and will not cause the unit to shutdown. Failures indicate that a particular piece of equipment has failed or a critical parameter has exceeded its failure setpoint. Failures are categorized as fatal or non-fatal to the operation of the unit. Only failures will cause the unit or sub-system to be shutdown. Fatal failures for the unit are indicated in the following table by the letter “F” and non-fatal failures use the letter “N”

Parameter Name	Low Alarm	High Alarm	High Fail	Other Alarm	Other Fail	Inhibit conditions

Alarm and Failure inhibit Conditions

1.

Appendix B.Hardware Requirements

Hardware Version	STARS
Memory M0	256K EPROM
Memory M1	512K RAM (Fixed)
Memory M2	8K EEPROM (Fixed)

Display Sub Assembly	Option
Modem	Option
Analog Output Board	Option

Analog Inputs:

ANALOG INPUTS						
TYPE	OFFSET	CHAN	NAME	RANGE	UNITS	SENSOR TYPE
3-Wire RTD	0	1	ZONE TEMP	-58 : 302	DEGF	RTD
RTD/Temptran	1	2	AU1 DEFR TERM TEMP	-58 : 122	DEGF	4-20 mA
RTD/Temptran	2	3	AU2 DEFR TERM TEMP	-58 : 122	DEGF	4-20 mA
	3	4				
	4	5				
	5	6				
	6	7				
	7	8				

Discrete I/O:

DISCRETE I/O						
TYPE	OFFST	CHAN	DESCRIPTION	OFF STATE	ON STATE	NOTES
OUTPUT	0	1	LIQUID SOL	CLOSED	OPEN	1
OUTPUT	1	2	SUCTION SOL	CLOSED	OPEN	1
OUTPUT	2	3	PRE-DEFROST	CLOSED	OPEN	1
OUTPUT	3	4	DEFROST/HEAT	CLOSED	OPEN	1
OUTPUT	4	5	POST-DEFROST	CLOSED	OPEN	1
OUTPUT	5	6	AU1 FAN	OFF	ON	1
OUTPUT	6	7	AU2 FAN	OFF	ON	1
OUTPUT	7	8	ALARM/FAILURE	NORMAL	ALARM	1
INPUT	8	9	COMPRESSOR RUNNING	NO	YES	2
INPUT	9	10	HIGH PRESS CUT-OUT	ALARM	NORMAL	2,4
INPUT	10	11	LOW PRESS CUT-OUT	ALARM	NORMAL	2,4
INPUT	11	12	OIL PRESS CUT-OUT	ALARM	NORMAL	2,4
INPUT	12	13	AU1 DEFROST TERM SW	OPEN	CLOSED	2
INPUT	13	14	AU2 DEFROST TERM SW	OPEN	CLOSED	2
INPUT	14	15	SHUTDOWN/STANDBY	OPEN	CLOSED	2
INPUT	15	16	DEFROST INITIATE	OPEN	CLOSED	2

Notes

1. 120 VAC, 5 Amp, Form-C mechanical relay
2. 120 VAC, Solid-State Input Module
3. 120 VAC, Solid-State Output Module
4. Normally energized

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Appendix C.Modbus Communications

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