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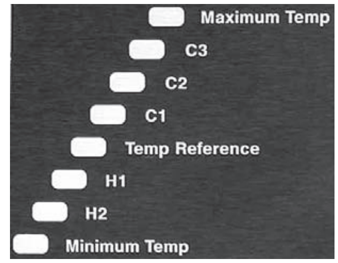
Tstat 23
Operator's Manual
92-01710-2

1. Performance

The Tstat23 will automatically coordinate all heating and cooling equipment to maintain temperatures which are choosen by grower. Electricians may view the Tstat 23 as an electonic 6-stage thermostat with high and low alarm output. The relation amongst 2 heating stages, the circulation (Temp Reference) and 3 cooling stages are shown to the right in Figure 1. As the temperature rises, the heating stages (H2 & H1) shut off and the cooling stages (C1, C2 and C3) turn on. An output labeled CIR may be used to activate the HAF fans until C1 turns on.

When the Tstat23 automatically controls heating and cooling equipment, then growers report precise and tighter temperature control. Also, both the first stage of heating and the first stage of cooling will never accidentally run at the same time.

Figure 1. As the temperature rises, the heating stages (H2 & H1) shut off and the cooling stages (C1, C2 and C3) turn on.



2. Installation

A) Mount Tstat23 in dry area at eye level so that switches may be set easily.

B) Connect 120VAC to transformer of the Tstat23 using standard electrical practices. This transformer powers the digital circuitry and powers the relays/contactors which control the heating and cooling equipment. Apply power to the Tstat23. The 24VAC LED should light and the digital display should show about 26˚F as its minimum reading and the LED above the Temperature Reference switches should begin to blink once per second. If not, then check the fuse in the Tstat23 and that you have properly wired power to the Tstat23. Figure 2 is the schematic of the Tstat23.

C) Connect the temperature sensor to the Tstat23 using 22-14 gage stranded wire. It is best to use shielded wire. Sensor wires should be run separate from other wires which may be electrically noisy. The sensor may be located 300 feet from the Tstat23. The temperature sensor must be mounted in the air flow and in the shade so that it is NOT heated by the sun. If necessary build shade over the sensor. A piece of plywood (not metal) with a hole in the center may be mounted horizontally in the greenhouse about 1/3 to 1/2 the way down the greenhouse and near the plant height, but out of the spray of any misting systems.

Make the wiring connections using the 3M connectors supplied with the sensor. These connectors are filled with silicone to prevent moisture from causing corrosion. Figure 3a shows the 2 wires inserted into the 3M connector, one wire from the temperature sensor and another wire from the Tstat23. Figure 3b shows pliers ready to squeeze the connector to make the electrical connection. It is best to have the blue side of the connector down so that the wires may be seen through the top of the connector at the end of the passage ways inside the connector.

Figure 4 shows the terminals for connecting the temperature sensor.

D) FANS, vents and heaters must be connected to the Tstat23 by relays and contactors. The relays and contactors must be selected by the electrician. These installation instructions are accompanied by worksheets and a list of relays and contactors which are compatible with the Tstat23. For greenhouses with equipment which is mostly 120VAC or lower, Relay Box #1 may be ordered. It is designed specifically to connect between Tstat23 and heating and cooling equipment.

Figure 4 shows the terminals for connecting the relays and contactors to the Tstat23. These terminals are also shown in the wiring schematic in Figure 2.

E) Lightning damage is a consideration in some areas of the country. Twelve year of field experience indicates that the Tstat23 will survive well. Generally, the lightning strike must be powerful enough that it either damages your phone system or destroys the power company's transformer on the mainline leading to your property. Of course, then the Tstat23 will be the least of your problems.

There is much protection on the circuit board of the Tstat23. But there is one protective step that can be taken. A ground connection may be made to the right terminal of the 24VAC input on the Tstat23. By grounding this terminal, any voltage surges that travel on the power lines to the transformer of the Tstat23 will have a path to ground. This ground path will be preferred by the surges over paths inside the Tstat23. This ground connection will be like a heavy anchor which the surge must lift before it can do damage to the electronic components of the Tstat23.

Installation Completed

Figure 2. Wiring schematic of 120VAC and 24VAC circuits.

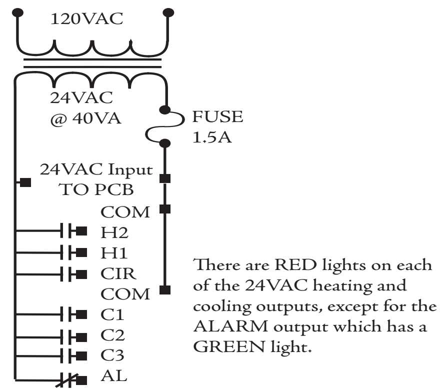


Figure 3a. Temperature sensor, silicone-filled connectors and wires to the Tstat23.

Figure 3b. Pliers are ready to squeeze the connector to complete electrical circuit between temperature sensor and the Tstat23.

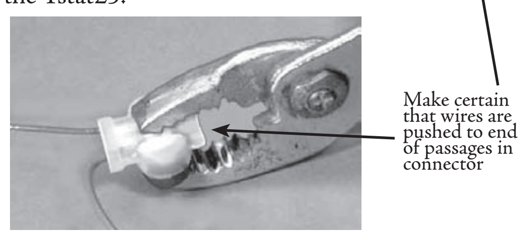
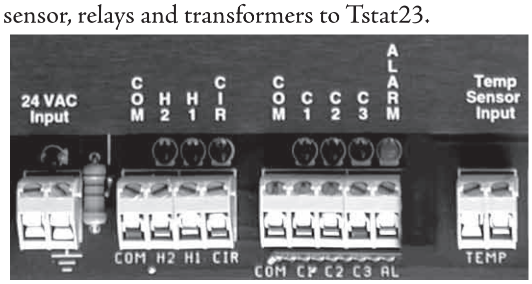


Figure 4: Terminal connections of temperature sensor, relays and transformers to Tstat23.



3. Operating Procedure and programming

A) Use the Manual ON switches to activate and test each stage of heating and cooling. Figure 5 shows that C3 through H2 are pushed to the Auto position. To test each stage, push-ON each stage and verify that the RED light is activated at the terminal strip of the Tstat23 and that the proper piece of heating/cooling equipment is also activated.

B) Time-Delay controls the rate at which the Tstat23 changes from one heating/cooling stage to another. Typical Time-Delay is 2 to 3 minutes. A maximum Time-Delay of 7 minutes (4+2+1) is possible. For the following tests, push-OFF all time-delay switches. Then the Tstat23 will change stages once every 15 seconds, if needed. After the following steps, then return to set the Time-Delay.

C) The Temperature Reference is the main control setting of the Tstat23. The Temperature Reference is NOT the operating temperature of the greenhouse; the Temperature Reference is the temperature around which the Tstat23 makes decisions. During cold nights, the operating temperature of the greenhouse will be near the heating stages. During hot days, the operating temperature of the greenhouse will be near the cooling stages.

To choose the Temperature Reference, first pick the maximum and minimum temperatures that your plants will enjoy. Write these temperatures in pencil in Figure 6 and on the Tstat23. To set the Temperature Reference, choose a temperature half way between these maximum and minimum temperatures, and set this number in the switches in Figure 7. NOTE that the digital display changes as these switches are changed. The digital display is adding the switches which you push-ON to confirm your setting for the Temperature Reference. This is an easy way to check this setting a future time. Figure 7 shows a Temperature Reference of 69˚F (=64+4+1).

D) The next step in programming the Tstat23 is choosing the first temperature step for H1 and C1, which are the first stage of heating and the first stage of cooling. This decision will have a great impact on the cost of energy. A small temperature step will cause the Tstat23 to use lots of energy to maintain tight control of the temperature of the greenhouse. Use a setting of 10˚F for a total separation of 20˚F between C1 and H1, if plants can grow well with such temperature variations. Figure 8 shows a setting of 10˚F. Over this 20˚F spread, only the low operating cost HAF fans will be active. With 69˚F as the Temperature Reference, then C1 will activate at 79˚F and H1 will activate at 59˚F.

E) The final programming steps are choosing the temperature steps to the second stage of heating (H2) and cooling stages C2 and C3. Figure 9 shows steps of +3˚F to both C2 and C3, and a step of -4˚F to heating stage H2. With these steps based on the previous settings, then C2 will activate at 82˚F and C3 will activate at 85˚F. Heating stage H2 will activate 55˚F.

F) The Alarm output will shut-off when the temperature rises 10˚F above the last cooling stage or falls 10˚F below the last heating stage.

Programming Completed

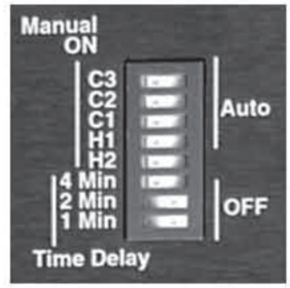


Figure 5: All switches for heating and cooling stages are pushed to the AUTO position. Time-Delay is set to 3 minutes. The 2 Min and 1 Min switches are pushed-ON.

Figure 6: This diagram will serve as a worksheet in picking setting for the Tstat23.

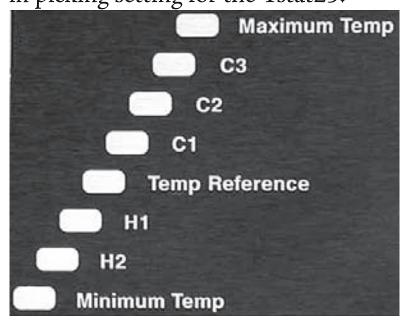


Figure 7: Temperature Reference with RED light which blinks once per second.

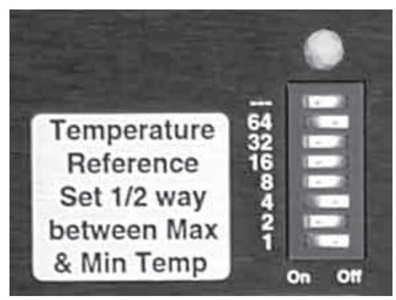


Figure 8: Temperature step from Reference to first stage of heating (H1) and first stage of cooling (C1).

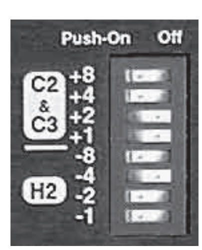


Figure 9: Temperature steps to cooling stages C2 and C3, and to heating stage H2.

4. Specifications

Electrical Input: 120VAC, 50/60HZ
Electrical Output: 24VAC @ 40VA
Weight: 8 lbs.
Dimensions: 10.5"x8.6"x4.2" (HxWxD)
Temperature mesaurements: 26˚F to 105˚F
Temperature accuracy: + or - 1˚F.
Gel-filled connectors are 3M#314

5. Trouble-shooting

A) If the displays and lights of the Tstat23 are blank, then check the fuse between the transformer and the circuit board.

B) If the display of the temperature is wrong and shows "26"˚F, then the wiring to the temperature sensor is probably broken.

C) If the display of the temperature is wrong and shows "05"˚F, then the wiring to the temperature is probably shorted.

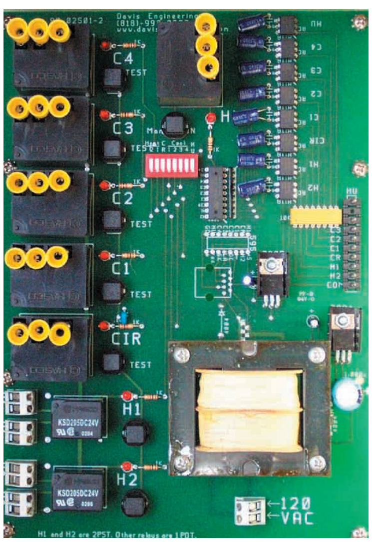
D) If the display of the temperature bounces several degrees each second, then there is probably electrical noise on the wires. Review installation instruction 2C.

E) Resistance measurements of the temperature sensor wires may be made when the wires are disconnected from the Tstat23. The following chart gives resistance readings at typical temperatures. The resistance of a 1,000 feet of 18 gage wire is only 1 ohm. So, the wiring runs are not significant.

Temperature	Resistance (1K ohms = 1,000ohms)
30˚F	34K
40˚F	26K
50˚F	19K
60˚F	15K
70˚F	12K
80˚F	9.3K
90˚F	7.4K
100˚F	5.6K

If the above resistances are NOT read, then check the connections for corrosion. Also, the temperature sensor may be chilled by mist system or heated by the sun. Review installation instruction 2C.

6. Relay Box #1



This photo shows the circuit board inside Relay Box #1. The left side of relay board shows 7 relays with power connections on top of relays. All relays are rated at 30 amps on both NC and NO contacts. Next to relays are "Push-to-Test" switches and LED indicators. In center of relay board is part of 2-foot, color-coded cable for easy connection to Tstats and DIFtrollers.

Relay Box #1 is the first of several relay boxes which are designed to complete the wiring between the 24VAC outputs of the Tstat23 and the 120VAC power of fans and other equipment in the greenhouse.

Where the power in each heating and cooling stage is under 30 amps @ 120VAC, then the Relay Box #1 can handle all the power switching. The 30 amps limit is equivalent to 1HP @ 120VAC. A 2-foot, color-coded cable comes with each relay box for quick and easy connection to the Tstat23.

If an occasional circuit has greater than 30 amps or has higher voltage, then an extra contactor may be added easily in the field to augment the Relay Box #1. See next section of this manual.

The following equipment may be controlled easily with the Relay Box #1: shutters, 2-speed fans, HAF, inflatable walls, multiple heaters and water walls. Also, Wadsworth vent controllers may be controlled.

7. Selecting Relays and Contactors

Make a chart which lists the equipment on each stage that you want the Tstat23 to activate. Group the 120VAC equipment together on each stage. Compute the current required for each group and use that information to pick contactors from the list below.

A small distinction may be made between the words relay and contactor. Relays are small contactors which are usually enclosed and may be in sockets, or mounted on circuit boards. Relays usually carry 10 amps or less.

For Control Logic and small motors (110VAC @ 1 HP, 220VAC @ 2HP): Omron relay #G7L2A-BUB-J-CB-AC24

For large motors, there are 3 types of contactors: Definite Purpose, IEC and NEMA.

1) Definite Purpose contactors are the least expensive. But, they have more exposed contacts which will more easily allow careless fingers to touch high-voltage. Also, these contactors do NOT provide protection to the motor during over-load conditions. They may not meet local electrical codes for motors. However, when operated within the AMPERE rating of the contacts, contact life is rated about 250,000 cycles. If fans are cycling 6 times per hour for 10 hours per day for every day of the year, then over 10 years of useful life may be expected from Definite Purpose contactors. Most greenhouses can expect longer life because the load of the fans will be below the AMPERE rating.

2) IEC Motor-Starters are contactors with Over-Load relays. IEC contactors have protected contacts to reduce accidental touching of high-voltage. They have over-load relays to protect motors from locked-rotor conditions. They have contacts with life-time ratings that are 10 times higher than Definite Purpose contactors. IEC contactors will meet electrical codes. With the Over-load relays, IEC contactors are about 2-3 times more expensive than Definite Purpose contactors.

3) NEMA rated contactors are even more rugged than IEC contactors. The lists do not include NEMA devices. NEMA motor-starters and relays will work even better. They are well-suited for starting and stopping the heaviest loads like conveyor belts.

Definite Purpose Contactors with 24VAC coils for DIFtrollers and Tstat.

Amps	Poles	GE	Square D	Furnas
20	1	CR353CA3AH1	DP11V14	45CG10AJD8A
20	2	CR353CA2AH1	DP12V14Y240	45CG20AJ
25	1	CR353CB3AH1	DP21V14	45DG10AJD8A
25	2	CR353CB2AH1	DP22V14Y240	45DG20AJ
25	3	CR353AB3AH1	DPA23V14	42BE35AJ478
30	2	CR353AC2AH1	DP32V14Y240	45EG20AJ
30	3	CR353AC3AH1	DPA33V14	45BE35AJ106
40	2	CR353AD2BH1	DPA42V14	42CE15AJ106
40	3	CR353AD3BH1	DPA43V14	42CE35AJ106
50	2	CR353FE2BH1	8910-M0-2	42DE15AJ106
50	3	CR353FE3BH1	8910-M0-3	42DE35AJ106

IEC Motor-Starters = Contactor+OverLoad Relay with 24VAC coils

The contactors in this chart have coils which are compatible with the controller. When ordering, ask your electrical supplier to assist you in selecting the proper Over-load Relays to handle the amperage of the motors. For artifical lighting, IEC contactors may be used without over-load relays.

	HORSE-POWER RATING				
Amps	115V	230V	GE	Square D	Allen Bradley
9	0.3	1	CR7-CAH	PD2.10EV01	100A09NJ3
12.5	0.5	2	CR7-CBH	PD3.10EV01	100A12NJ3
17.5	1	3	CR7-CCH	PE4.10EV01	100A18NJ3
25.3	1.5	3	CR7-CEH	PE5.10EV01	100A24NJ3
30	2	5	CR7-CFH	PF1.11V01	100A30NJ3
37	3	5	CR7-CGH	PG1.11V01	100A38NJ3
45	3	7.5	CR7-CHH	PF3.11V01	100A45NJ3
56	5	10	CR7-CJH	PG3.11V01	100A60NJ3
73	5	15	CR7-CKH	PG3.11V01	100A75NJ3

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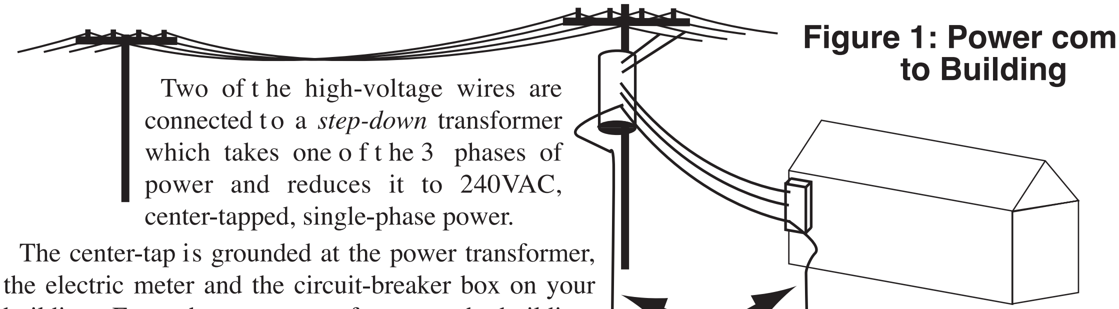
Explanation of Electrical Power Systems

AN 94-01083-0

Electrical power travels on 3 or 4 wire systems driven by 4,000 and 20,000 volts of 3-phase power.

Figure 1: Power coming to Building



Two of the high-voltage wires are connected to a *step-down* transformer which takes one of the 3 phases of power and reduces it to 240VAC, center-tapped, single-phase power.

The center-tap is grounded at the power transformer, the electric meter and the circuit-breaker box on your building. From the power transformer to the building, the center-tap is often the metal cable that carries the weight of the wires running to the building.

2 electrical grounding rods, easily seen on power poles and breaker boxes

Figure 2: Schematic of Transformer

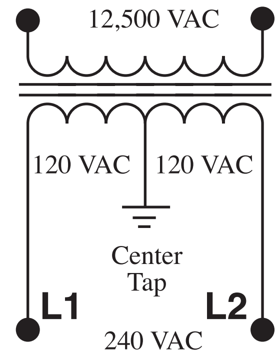


Figure 3: Wiring schematic for circuits inside building.

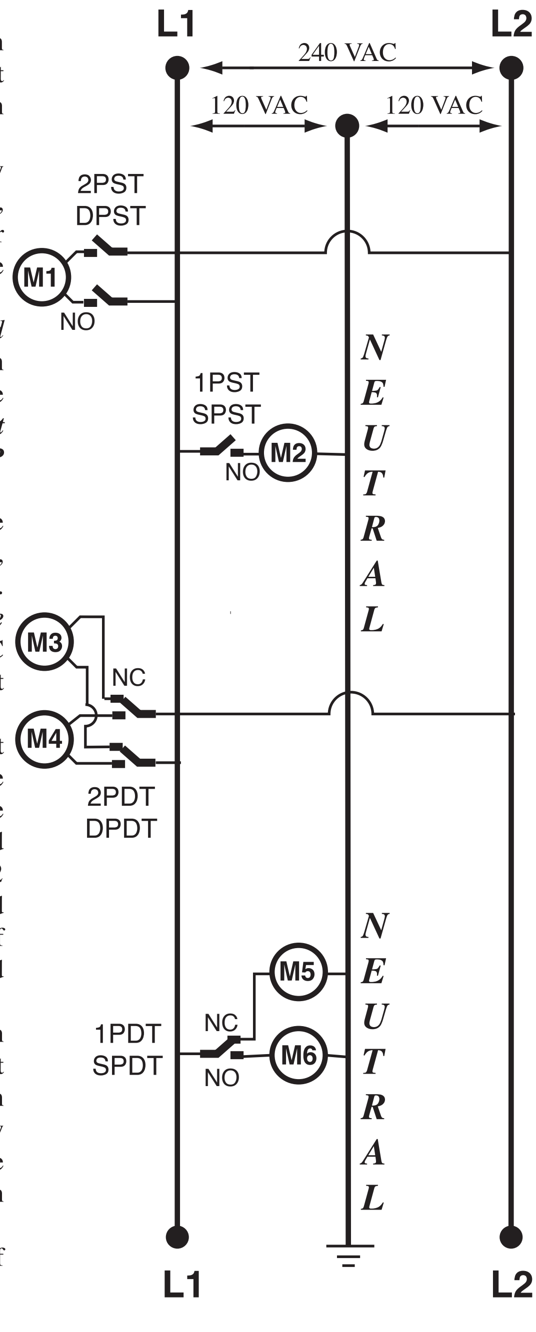


Figure 2 shows the single-phase 240VAC power that is delivered by the power companies to most properties. Many electricians refer to the center-tap as "neutral". It is relatively safe because it is grounded but still carries hazardous current. If standard electrical practices are followed, it is the white wire that runs through the conduit in your house and business.

Commonly, the 240VAC/120VAC uses black wire for power (hot) wiring. However, in buildings with many circuits, electricians will use orange, blue and other colors (except green) to help them trace different 120VAC lighting and wall sockets in the building. Green is reserved for grounding connections which carry no current and are safe to touch.

Figure 3 is a wiring schematic for 240VAC/120VAC single-phase power inside many buildings. It illustrates how to wire 240VAC and 120VAC equipment. In a residence, 240VAC equipment may be an electric clothes drier or an air-conditioner. Most other residential electrical equipment requires 120VAC. In businesses, many motors require 240VAC. Big contactors or small relays are used to switch power to motors in Figure 3.

For equipment which is powered by 240VAC, ***both*** *electrical wires must be switched* because both electrical wires are "hot" or powered as shown in Figure 3 for M1. Then, when the equipment is shut-off, no part of the equipment is connected to the "hot" wiring in the building. For safely controlling 240VAC, circuit-breakers ***must*** have 2 poles; switches ***must*** have 2 poles; and contactors ***must*** have 2 poles. Contactors with 2 poles are classified as ***2P*** (2-pole) or ***DP*** (double-pole) as shown in Figure 3.

For equipment which is powered by 120VAC (M2), only one of the wires must be switched, but *it must be the "hot" wire which is switched* as shown in Figure 3 for M2. Then, when the equipment is shut-off, it will still be connected to the neutral grounding wiring. Since only one wire is switched, circuit-breakers, switches and contactors may have a ***single pole*** and are identified by either ***1P*** or ***SP*** markings. Figure 3 shows all the 120VAC electrical loads placed on leg L1. However, 120VAC equipment is usually distributed so that the same amount of electricity is drawn through both legs (L1, L2) of the transformer.

After the number of "***poles***" of a contactor, circuit-breaker or switch, the next characteristic of such devices to be explained is the number of "***throws***". In Figure 3, the contactors which control M1 and M2 can "*throw*" *electricity in* ***only one direction;*** either the electricity is thrown to the motor or is shut-off. The contactors which control M3/M4 and M5/M6 can "*throw*" *electricity in* ***two directions***. Contactors which can throw electricity in 2 directions are called "***double-throw***" ***(DT) contactors***. They have contacts which are called "normally-open" (NO) and "normally-closed" (NC). The de-energized, relaxed positions of the contactors send electricity to the "normally-closed" (NC) contacts and energizes M3 and M5. When the contactors are energized, then the other motors are energized, M4 and M6.

This double-throw action can be *useful in controlling HAF/circulation fans* in greenhouses. In cold climates, when the vents open on cooling stage #1, the HAF must continue to run to distribute and mix the cold air through greenhouse. But, when the main fans begin to run on C2 and C3, the HAF fans should shut-off. Otherwise, the smooth flow which C2 and C3 are trying to create from one side of the greenhouse to other will be destroyed by the turbulent mixing and the HAF fans. The vent motors will take the position of M3 or M5 depending on the voltage of the vents.

These "normally-closed" contacts of DT relays are also used with the alarm outputs of Tstat23 and DIFtrollers to signal power outages and hazardous temperatures.