

Specifications on Building a Cold Stress Simulator
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Objective:

Construct and test a low-cost cold stress simulation chamber for use in plant cold hardiness testing.

Rationale:

Instruments such as the Tenney Junior (Tenney Environmental, Thermal Product Solutions, Williamsport, PA) can be used successfully to test the cold hardiness of plant tissues. Though effective, this equipment is often expensive and has limited internal space which limits the number of treatments and the amount of plant tissue tested. Beard et al. (1980) provide limited instructions on constructing a low-cost cold stress simulation chamber, but their method requires the use of dated technologies and procedures that void manufacturer warranties. Therefore, because of the need for a low-cost programmable freezer for our research we were able to develop a more current construction procedure. This article provides a method for the construction of a low-cost cold stress simulation chamber for use in plant cold hardiness testing.

Items needed to construct cold stress simulation chamber:

- Programmable controller - Watlow 981 (981C-10EA-AARG)
- Output: Turn off and on freezer through contactor
- Input: Type T thermocouple
- Chest freezer (19.7 ft³, 0.55 m³) (Frigidaire model # 179791)
- At least 2 fans to circulate air (ac computer case cooling fans)
- Thermocouple and extension
- 120 V ~ (ac) IEC contactor (Allen-Bradley 100-C09*10)
- Electrical, control box, and flooring supplies

Estimated Costs:

Item	Unit Price (\$)	Quantity	Cost (\$)
Freezer (19.7 ft ³ , 0.55 m ³)	366	1	366
Controller - Watlow 981	470	1	470
Controller box supplies	21	1	21
Flooring supplies	30	1	30
Type T thermocouple	34	1	34
Thermocouple extension	16	1	16
IEC Contactor	63	1	63
AC computer case fans	22	6	132
Electrical supplies	57	1	57
Total			\$ 1,189

Electrical, control box and flooring supplies:

- Shelf/flooring (\$30)
- Three 8 ft. replacement cords (\$18)
- Wire nuts (\$4)
- Electrical tape (\$2)
- Wood for control box (\$10)
- Hinges and lock (\$5)
- Wiring for fans (\$7)
- Surge protector (\$9)
- Inline fuses and holder (\$7)
- Wire ties (\$2)
- Wire cutter/stripper (\$8)
- Concrete screws/hangers (\$3)
- Holder for Handheld therm. (\$3)

Construction:

Step 1. Construct shelf/flooring using wood and vinyl closet shelf. The material chosen for this step was not specific and could be modified to fit user preferences (Figure 1).



Figure 1. Vinyl shelving was used to construct flooring for the base of the freezer and computer case fans were attached with Velcro and used to circulate air within the chamber.

Step 2. Attach fans to the shelf/flooring and sides to help circulate air and provide uniform temperature within the chamber (Figure 1). The method provided by Beard et al. (1980) required drilling holes into the freezer body and installing fans so that the motor would be located outside the chamber and thus would not add heat to the system. We chose instead to use 120VAC computer case fans because they were capable of circulating air and could be operated without adding little heat to the chamber and without modifying the chamber and voiding the manufacturer warranty.

Step 3. The controller box is possibly the crudest element of this construction (Figure 2). We chose a simple wooden box construction because of the low cost, but a more standard electrical fuse box could also be used.

Step 4. Wiring. We chose to wire the controller output, controller, and contactor each with their own power source, but they could all be wired in circuit. A detailed wiring diagram is available in Figure 4. The design of this programmable freezer requires the freezer (controller output) to be turned off and on in order to achieve the desired temperature. Because of the “in rush” of power a 120 V ~ (ac) IEC Contactor was wired into the system to help provide a “slow start” to the freezer compressor which will greatly extend its life span (Figures 3 and 4). We wired the contactor to an outlet so that the freezer could be plugged into the system without modifying the freezer power supply and voiding the warranty. Inline fuses (0.5 and 5.0 amp) were also wired into the system to prevent damaging the controller.

Step 5. The controller was programmed (Figure 5 and Table 1) to hold the chamber temperature at $-3\text{ }^{\circ}\text{C}$ overnight and then to reduce the temperature linearly by $1\text{ }^{\circ}\text{C h}^{-1}$ similar to Anderson et al. (1993). The controller was also auto-tuned prior to testing to help calibrate the controller. After programming and auto-tuning the programmable chamber was tested to see how accurately the output mimicked the desired program (Figure 6). Additional changes were made to the controller settings after auto-tuning to best mimic the desired program (Table 2).

Step 6. A pilot test was conducted to determine the effectiveness of the programmable chamber for use in plant cold hardiness testing.

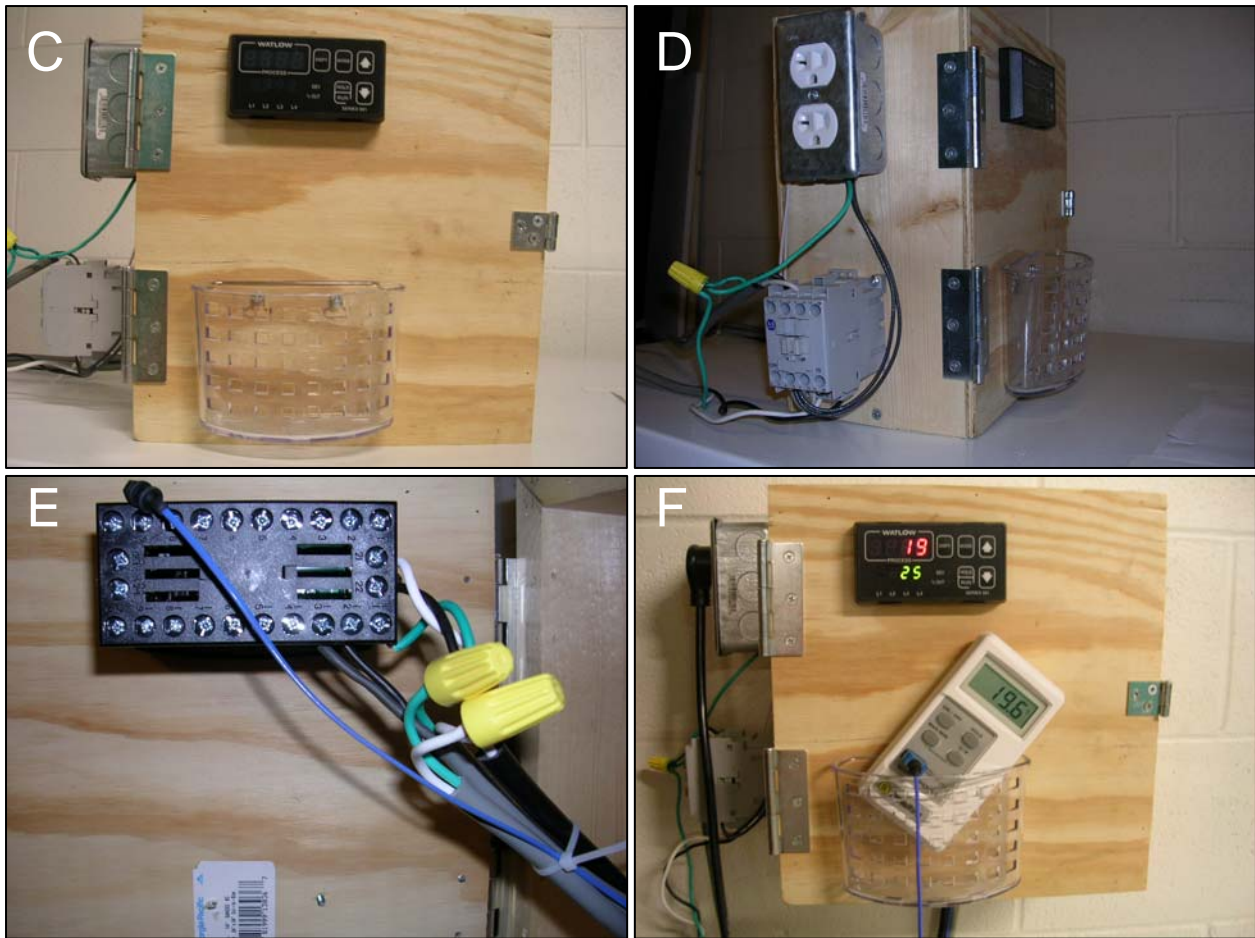


Figure 2. Controller box with IEC contactor and watlow controller (C and D). Inside of box showing controller body and wiring (E). Controller in operation (top value is temperature, bottom value is set point) also with Type-T thermocouple handheld meter (F).

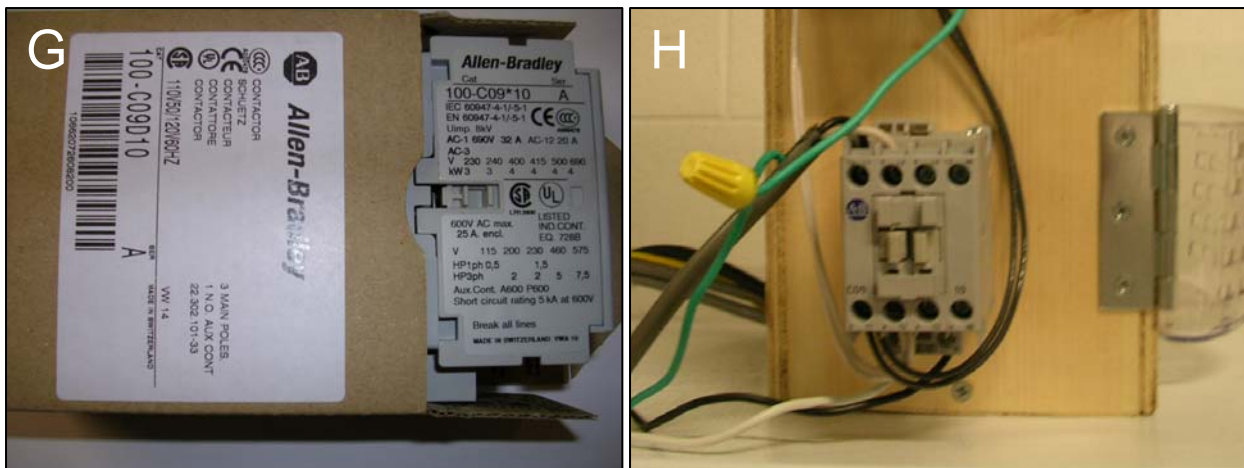


Figure 3. An IEC Contactor (G and H) was used to reduce "in rush" to the freezer compressor.

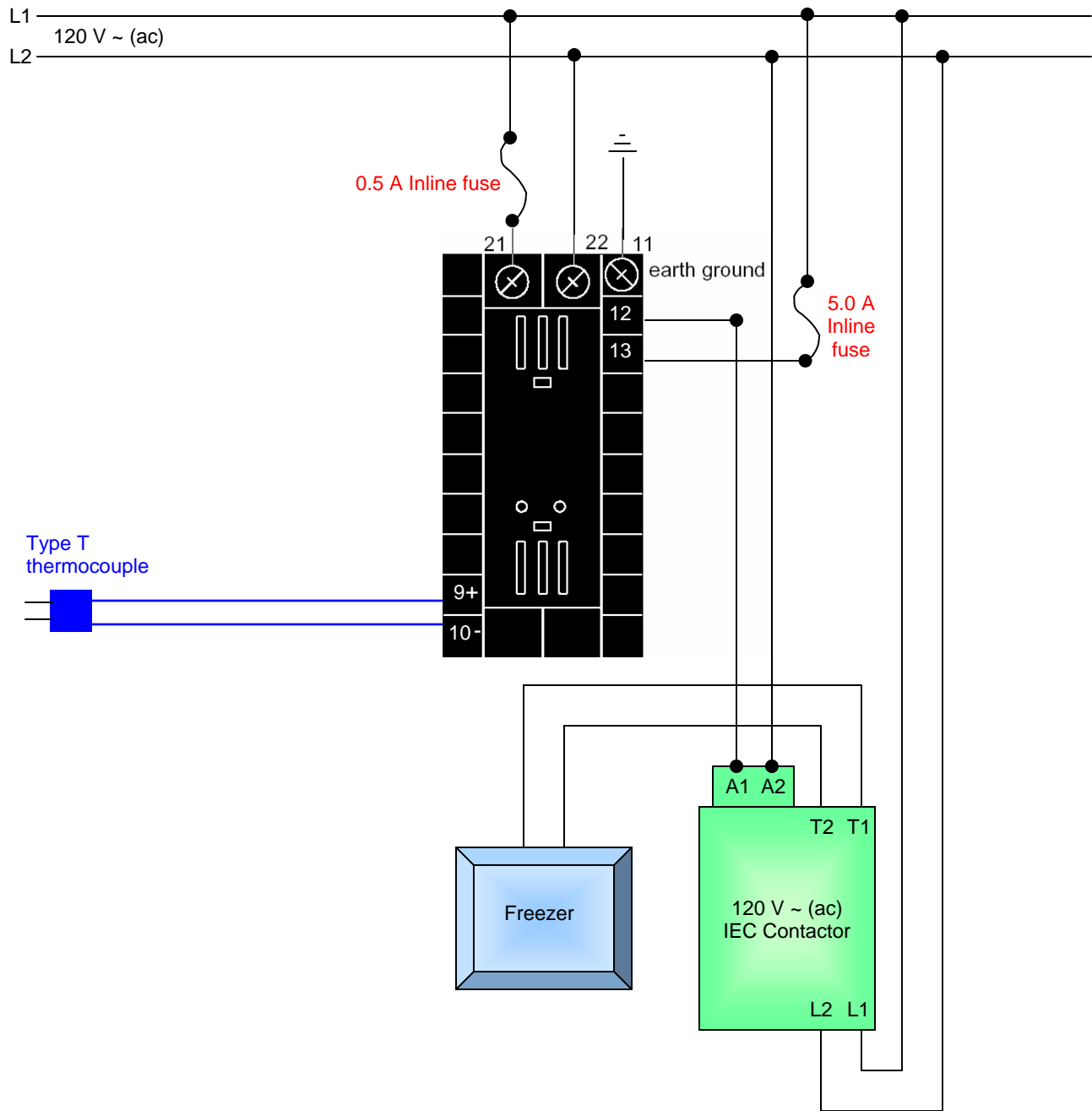


Figure 4. Wiring diagram for programmable freezer. L1 constitutes the hot (black) wire while L2 constitutes the neutral (white) wire. All components were grounded although the diagram only shows a ground on the controller.

Program:

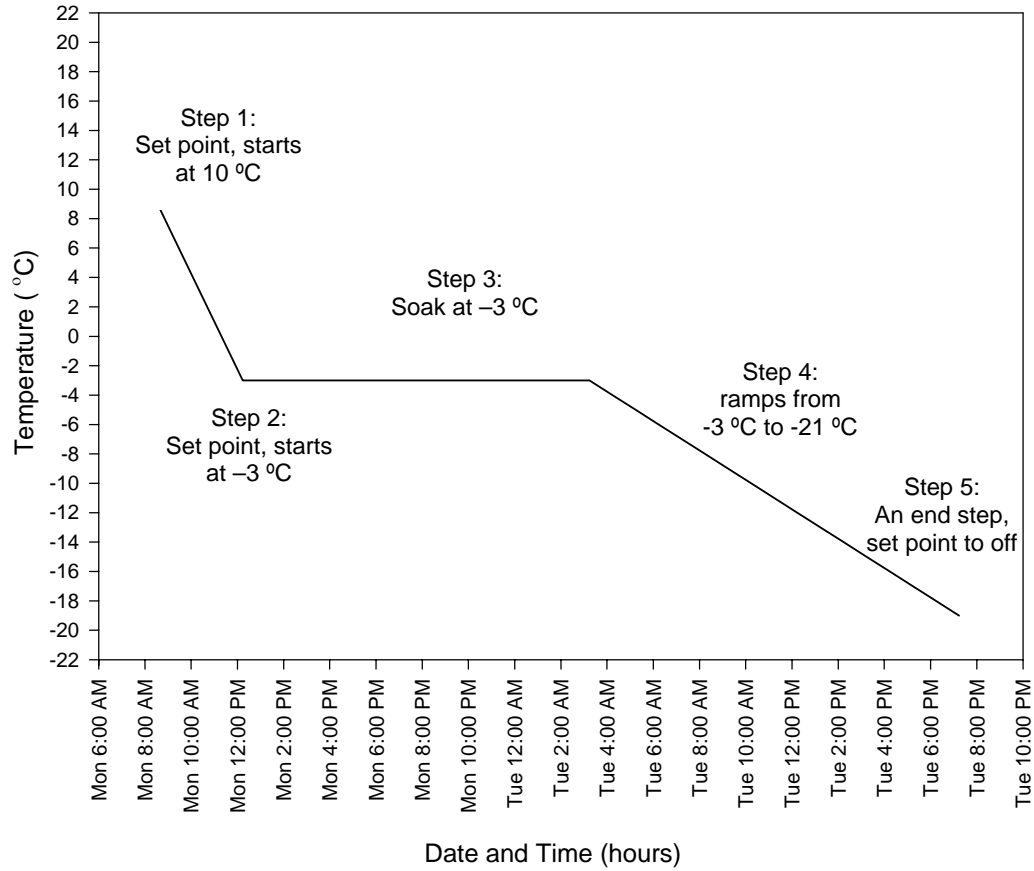


Figure 5. Controller program with set points, soak step and end step.

Table 1. A file was created and stored in the programmable controller with the following options in order to produce the desired temperature hold and ramps.

Step #	StyP	Set Point	Hour	Min	Sec	End
1	StPt	10 C	0	0	0	--
2	StPt	-3 C	4	0	0	--
3	SoAH	-3 C	15	0	0	--
4	StPt	-21 C	18	0	0	--
5	End	--	--	--	--	End

Note: The soak (SoAH) step will not begin until the temperature reaches -3 °C. Therefore, soak will start sometime 4h after the program is initiated.

Chamber Test:

Many tests were conducted to see how closely the cold stress simulator soil temperatures followed the program (Figure 6). Adjustments were made to provide more accuracy each time a test was run (Table 2).

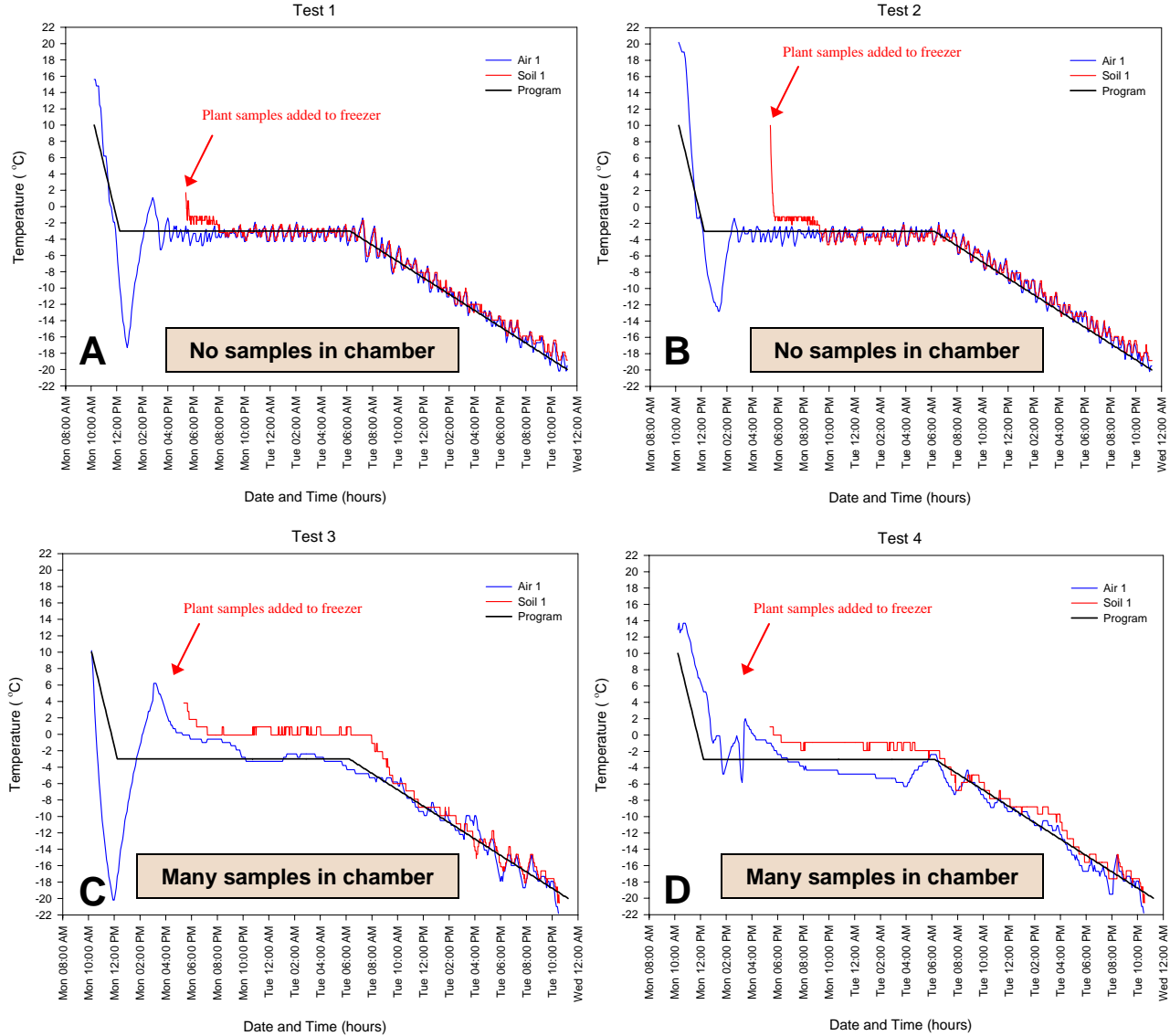


Figure 6. Temperature readings from the four tests.

Table 2. Controller settings used during chamber tests.

Figure 6	Proportional band (Pb1)	Integral band (rE1)	Derivative band (rA1)	Cycle time (Ct1)
A	4.0	0.02	1.0	30 sec
B	8.0	0.02	1.0	30 sec
C	8.0	0.02	1.0	30 sec
D	8.0	0.02	1.0	30 sec

NOTE: Additional test were performed at different settings with the settings of 8.0 (proportional band), 0.02 (integral band), 1.0 (derivative band), and 30 s (cycle time) ultimately used for all our cold stress simulation.

Conclusions:

Things to consider when constructing and using a cold stress simulator.

- The fewer the samples in the freezer (cold stress simulator) the more uniform the air distribution and the more closely the simulator will follow the program (compare Fig. 6A and B with 6C and D). Additionally, samples take longer to freeze when the mass is greater inside the chamber (compare Fig. 6A and B with 6C and D).
- Despite circulation fans there still will be vertical differences in air/soil temperatures, so we recommend using only one level of plant samples.
- Fan motors add very little heat, and we feel that most any kind of fan could be used to help circulate air in the chamber. Horizontal air temperatures are usually uniform with little or no circulation, but vertical air temperatures (top to bottom) are different and fans should be placed to favor mixing of the air vertically.
- Construction was relatively simple once the design was finalized (through troubleshooting).
- This chamber should provide a low cost option for researchers wishing to test the freeze tolerance of plant material.

This chamber was successfully tested and used for research testing the freeze tolerance of zoysiagrass cultivars.

References:

1. Anderson, J.A., C.M. Taliaferro, D.L. Martin. 1993. Evaluating freeze tolerance of bermudagrass in a controlled environment. *HortScience*. 28:955.
2. Beard, J.B., J.M. DiPaola and S.M. Batten. 1980. Development of a cold stress simulator to be used in screening for cold hardiness. *Texas Turfgrass Research - 1978-1979*. Texas Agric. Exp. Sta. PR-3675. pp. 35-40.