A COLD HARDINESS CABINET*

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The vaporization of liquid nitrogen has been used as a cooling medium for many purposes, including winter-hardiness testing of fruit trees (1) and in extensive medical and industrial applications. Its use for temperature control in plant growth chambers is limited because an atmosphere of nitrogen gas does not support normal active plant growth processes (2). The purpose of this report is to describe a cabinet that uses liquid nitrogen to obtain controlled low temperatures for cold hardiness testing of plant material, and to discuss its operating economy. Plant material within the cabinet is insulated from direct contact with the nitrogen gas by sealing in polyethylene bags.

The cabinet (Fig. 1) is made of 10 cm thick rigid urethane, covered with fiberglas and lined with stainless steel. It has a working volume of 0.6 × 0.6 × 0.6 m. Removable perforated metal shelves support the plant material.

Liquid nitrogen is admitted to the cabinet via a solenoid valve (A, Fig. 2) by a spray boom (C) which has eleven 1.02 mm diameter holes drilled on alternate sides at 30° to the horizontal. The cold nitrogen gas thus creates a stirring action within the cabinet. A fan (D) at the rear of the cabinet provides additional stirring. The gas escapes from the cabinet via a 3 cm diameter hole in the side of the cabinet.

Temperature in the cabinet is controlled by an electronic unit (B, Fig. 2) and a thermistor probe (F). The controller is a modified commercial unit similar to one previously described (3, 4) except that the temperature is selected manually by ten turn dial.

Spatial and temporal variations were recorded by 22 thermocouples evenly distributed over 2 shelves placed 23 and 46 cm from the bottom of the cabinet. At temperatures ranging from +10° to —40°C the maximum temperature difference between the two levels was 2.5°C and the maximum temporal variation at any single point recorded was ±0.7°C. Maximum spatial variation between points on any one level was ±0.7°C. During pull-down to any temperature these limits were exceeded until the chamber temperature stabilized. Pull-down from ambient temperature to a stable state at 0°C took 25-30 min, thereafter a 5.0°C reduction required 4-5 min before stable conditions were

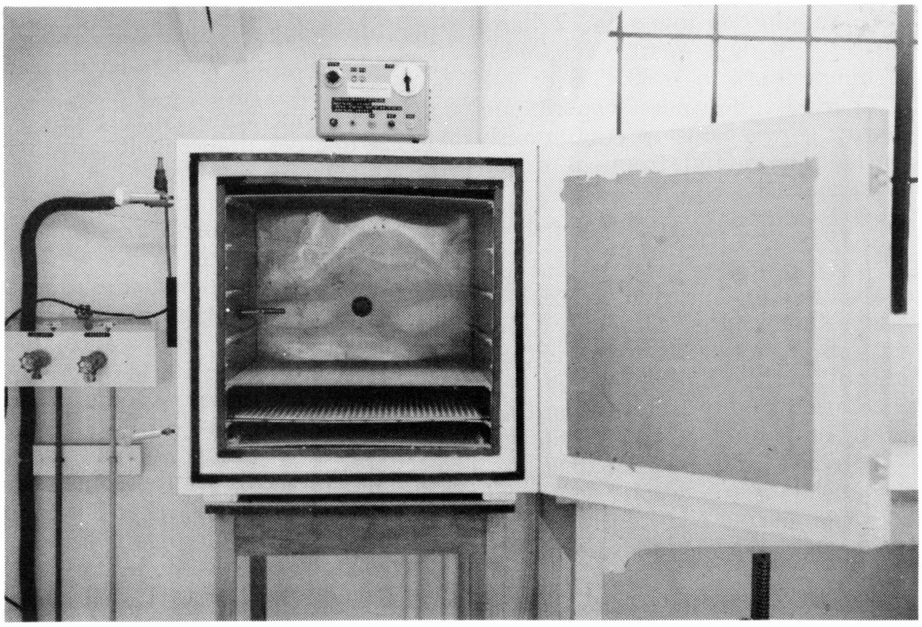

Figure 1. The cabinet for testing plant cold-hardiness

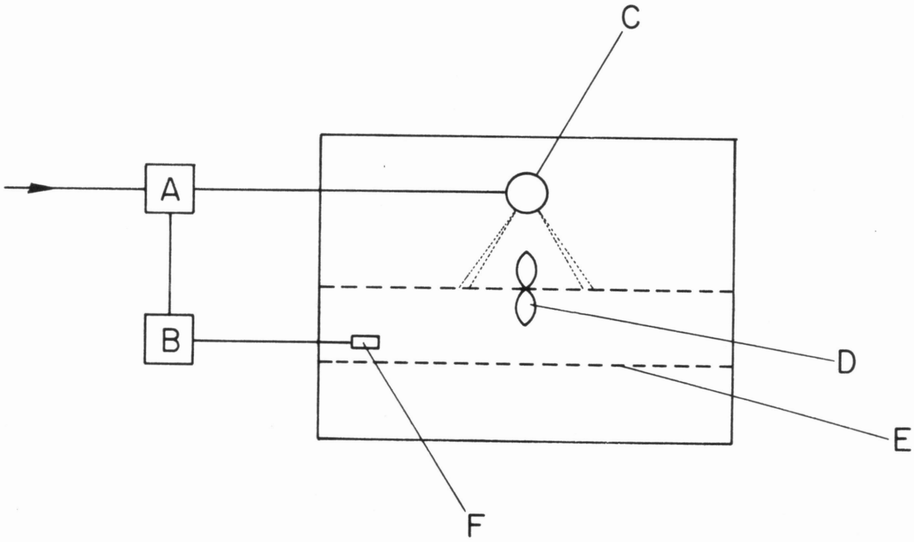

Figure 2. Diagram of liquid nitrogen system. A. solenoid valve; B. temperature control; C. liquid nitrogen spray boom; D. fan; E. perforated metal shelf; F. temperature probe.

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established. During the tests, the dial of the temperature controller was calibrated and it was found that the cabinet could operate at temperatures from +10° to —85°C.

Consumption of liquid nitrogen ranged from 2.7 Kg/hr at 10°C to 5.4 Kg/hr at —85°C. In a typical experimental run where the temperature was reduced in increments from +2° to —85°C over an 8 hr period, total liquid nitrogen consumption was 36 Kg. The cost of liquid nitrogen purchased in small quantities (110L bottle) is $0.53/Kg, thus the cost of an experiment is approximately $19.00. In routine practice one 110L bottle supplies nitrogen for 2 hardiness tests 10 days apart, each reducing temperature to —80°C over a 10 hr. period. Between experiments, nitrogen slowly boils off continuously. For long term and frequent experiments the cost of nitrogen can be reduced by purchasing bulk quantities.

The cost of components and materials used to construct the cabinet was less than $180. This low capital cost and the moderate operating cost indicate that the liquid nitrogen is an economical facility for cold-hardiness testing of plant material. If the cost of purchase and maintenance of a mechanical refrigeration system for the same purpose is considered the liquid nitrogen system compares favorably. The apparatus described offers the advantages of simplicity of design and operating reliability.

While the effect of an atmosphere of nitrogen on plant material is not fully understood it was concluded that by sealing the specimen in plastic bags deleterious effects were minimized. This conclusion was supported by the fact that viable plant material cooled to temperatures that previous experience indicated did not cause damage were not affected by testing in the cabinet.

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CALORIMETRIC DETERMINATION

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mean value is 0.448. The standard deviation is 0.028. The average temperature range is 30.2 to 127.8 degrees Centigrade. Two other reported values of specific heat (3) are 0.47 for the temperature range of 75.2 to 129.2 degrees Fahrenheit and 0.49 for the temperature range of 73.4 to 190.3 degrees Fahrenheit. Both of these were based on respiration data and not on a calorimetric determination. This could account for some of the difference between the value determined in this study and those values found in the 1964 Agricultural Engineers' Handbook. Another reason for the difference lay in the moisture content at which each was determined. As the moisture content increased, the specific heat increased (Table II). This increase is to be expected since the specific heat of water is twice as great as that of the bean.

ASSUMPTIONS OF THIS PAPER

1. The two hour heating period has no effect on the specific heat of the soybeans.
2. The heat left in the Stanolax and soybeans at the time of the first plateau in the temperature rise was compensated for in the value of the water equivalent.
3. The moisture content determination of a sample of the soybeans before a test was an indication of the soybeans even after the heating.
4. The radiation loss curve gave accurate values independent of the absolute ambient temperature. Because all tests were run at approximately the same absolute temperature, the variations on this value between different tests was felt to be negligible.
5. The millivolt output of a copper-constantan thermocouple is linear in the range of 110 to 140 degrees Centigrade.
6. The water that was sucked into the can due to the contraction of the Stanolax on cooling had no effect on the value of the specific heat.
7. The distance between the two tin plate terminals on the can lid was so small that the temperature gradients over that distance would not induce any further thermal voltages.

SUMMARY

It was necessary to know the specific heat of soybeans in order to determine the temperature to which they are being raised in a microwave oven. The specific heat was determined using a modified calorimetric method for the approximate temperature range required in the microwave oven and for the moisture content at which soybeans are stored. The problems involved in the modification of the Parr bomb calorimeter have been discussed with particular emphasis on the temperature measurement of the heated can, the calorimeter water, and ambient air. The calibration of the calorimeter has been described, as have the results of the specific heat determinations. The average specific heat was found to be 0.45 calories per gram per degree Centigrade at a moisture content of 7.4 per cent (w.b.) and a temperature range of 30.2 to 127.8 degrees Centigrade.

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