COLORADO FLOWER GROWERS ASSOCIATION, INC.

IN COOPERATION WITH COLORADO STATE UNIVERSITY
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Accuracy of Common Thermometers

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With increased fuel costs, thermometer accuracy is more important. English literature has indicated that a difference of one degree can mean 3000 gallons of oil per acre over a year's time. A one-degree error can result in an additional 54,844 BTU/hr. loss from one acre of ridge-and-furrow, fiberglass covered greenhouse. One degree can make considerable difference in crop timing and quality. The results of this study show that common alcohol thermometers — less than $10.00 — use one-degree scale divisions and can be expected to vary more than 3°F from the true temperature.

Methods

Fig. 1 shows the types of thermometers examined. Ten thermometers of one-degree scale division and 10 with two-degree scale division were taken directly from stock and calibrated simultaneously. Fourteen common alcohol thermometers were obtained from 10 greenhouses and calibrated. All thermometers were of the "total immersion" type, alcohol, and cost less than $10.00.

The thermometers were totally immersed in an agitated water bath, with the temperature controllable from below freezing to near boiling. A digital thermocouple thermometer, readable to within 0.1°F and guaranteed accurate to within 0.3°F, was used as the primary standard. This instrument was in turn calibrated to 32.0°F with a triple-point cell which reproduces the triple point of water (0.0100°C) to within 0.0005°C. A precision, expanded scale, mercury thermometer was utilized as a check. This had scale divisions of 0.2°F. Calibration began near 32°F and continued in approximate 10-degree steps to 100°F, allowing an equilibration period between each step.

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The response time of representative alcohol thermometers, direct from stock, was measured in still air. The thermometers were cooled to near freezing and allowed to warm to a room temperature of about 72°F.

Results

Fig. 2 shows calibration curves for new thermometers taken directly from the stock shelf. Both one-degree and two-degree scale division thermometers showed a range of two to three degrees from actual. The standard deviation was 1.5°F. This is considered

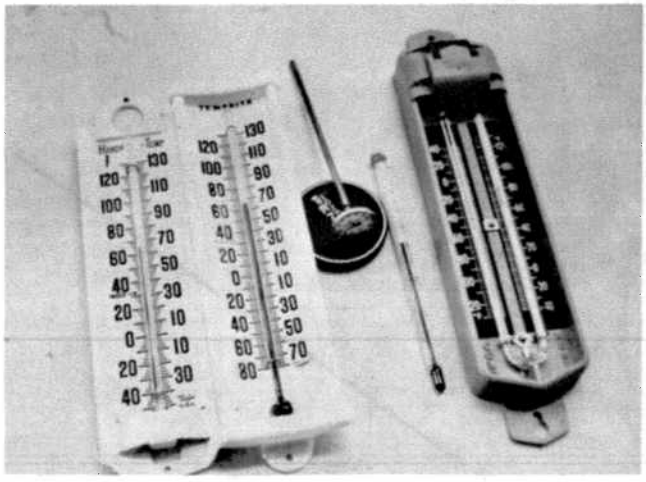

Fig. 1. Types of thermometers examined for accuracy in this study. From left to right: alcohol thermometer with one-degree scale divisions; alcohol thermometer with two-degree scale divisions; bimetallic, circular dial with one-degree scale divisions, adjustable; glass, alcohol thermometer with two-degree scale divisions; and a mercury, maximum-minimum thermometer with two-degree scale divisions.

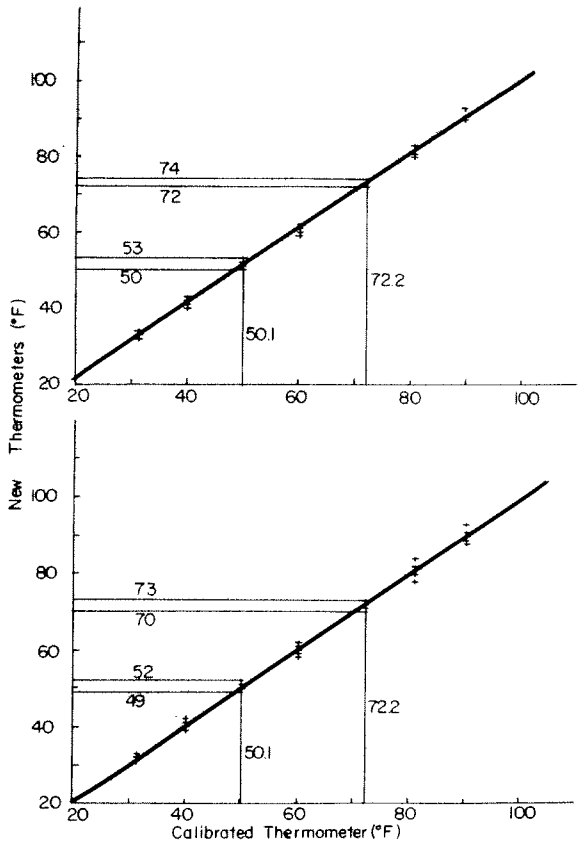

Fig. 2. Calibration curves for alcohol thermometers taken directly from the stock shelf. Upper: one-degree scale divisions; lower: two-degree scale divisions.

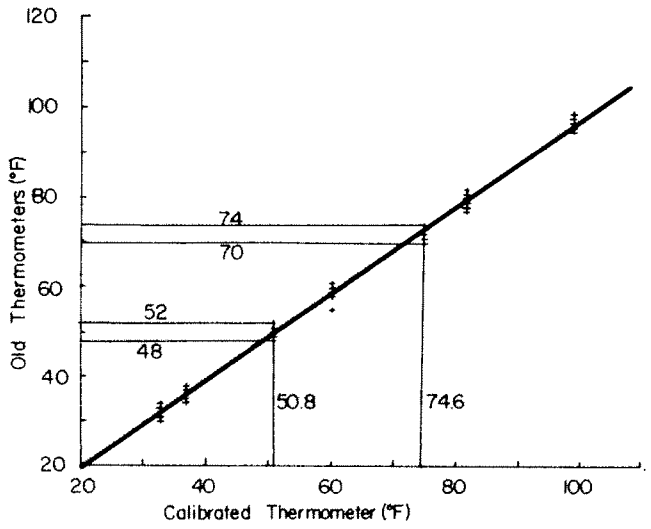

Fig. 3. Calibration curve for various types of alcohol thermometers taken from different greenhouses.

acceptable for these types of thermometers but indicates that, for example, while a grower may think he is controlling at 53°F, the actual temperature could be 50 or 56°F, or double the standard deviation.

Thermometers in various states of repair, taken directly from greenhouses, showed a wider range of four degrees from actual with a calculated standard deviation of 3.8°F. Thus, a grower's thermometer could be a maximum of 7.6 degrees in error, although none of the tested thermometers were actually this much off. Where the grower had made some attempt to calibrate his thermometer, the readings were usually within one degree of actual.

Response time of the tested thermometers was found to be extremely slow in still air. With timing started at 35°F, none of the thermometers had reached within 15 degrees of the air temperature after 6 minutes. The results indicate that, even in high velocity air, these thermometers may be several degrees in error if the air temperature is changing rapidly. They can only be expected to show true air temperature if they have been allowed to equilibrate for several minutes (10 or more) under static or very slowly changing conditions. Aspiration reduces the equilibration time by more than one-half.

Thermometer Characteristics

The thermometers commonly found in Colorado greenhouses are alcohol, total immersion types. For the prices paid, accuracy to within less than 1.5°F cannot be expected. Since they are total immersion types, the alcohol column must be totally immersed in the medium whose temperature is being determined. Furthermore, even in water, at least 2 to 3 minutes must be allowed for equilibration before a reading is taken. In air, they are valid only if the air's temperature is changing very slowly or not at all. Temperature on one-degree scale division thermometers may be estimated to within one-half degree, on two-degree scale division instruments to within one degree. However, if particular care is not taken, errors from "parallax" may result in errors of one to three degrees for both types. The scale behind the alcohol column must be viewed in a line of sight that is perpendicular to the scale and horizontal to the top of the alcohol column. As there is no provision to prevent parallax problems with these thermometers, attempting to estimate temperatures to within tenths of one degree is meaningless.

Precision thermometers can be purchased. If they are expanded scale, they are usually guaranteed to within plus or minus one scale division (e.g. 0.2°, 1/5°, etc.). However, their bulk is much greater and response times are correspondingly slower. Prices range from $40.00 to more than $50.00.

Growers can calibrate their thermometers at 32.0°F and assume that a one-degree change on the ther-

mometer is actually a one-degree change in real temperature anywhere else on the thermometer scale. To calibrate, a thermos jug is filled with a mixture of pure water and crushed ice. The column must be totally immersed, but it is not necessary to immerse the entire thermometer. The crushed ice must extend to the bottom of the thermos. A period of 3 to 4 minutes is allowed for equilibration. The ice water mixture will be at 32°F, and either the thermometer may be marked as so many degrees high or low, or the glass tube may be adjusted so the column reads 32°F.

CSU has calibration facilities with standards traceable to the National Bureau of Standards. If growers desire a calibration over the entire range, they may send a good thermometer to us which we can check and provide them with a calibration curve for that thermometer. The fee is $10.00.

When using thermometers to test air temperature, it should be emphasized that they be protected against any radiation such as direct sunlight. They should be isolated from the possibility of heat being conducted through their mounting — for example, sunlight on the backs of thermometer shelters. They should be aspirated in a totally enclosed shelter.