Peanut Science (1983) 10:88-93

# Changes in the Temperature Profile of Farmers Stock Peanuts During Storage

J. S. Smith, Jr.,* J. I. Davidson, Jr., T. H. Sanders, J. A. Lansden, and R. J. Cole[1]

## ABSTRACT

Thermocouples were positioned at similar locations in the peanut mass in two typical flat-type-metal building peanut warehouses, one mechanically ventilated and the other naturally ventilated. Temperatures were recorded 12 times daily for each location during a 9-month storage period. Temperature profiles were constructed for selected times throughout storage. Generally, the isotherms composing the profiles were similarly shaped for like periods. The mechanically ventilated warehouse maintained a mean temperature of 1 to 4 C less than the naturally ventilated warehouse throughout most of the storage period.

Key Words: peanuts, storage, warehouse, temperature, ventilation, isotherms

[1]Agricultural Engineer, Mechanical Engineer, Plant Physiologist, Chemist and Research Microbiologist, respectively, USDA, ARS, National Peanut Research Laboratory, Dawson, GA 31742.

Mention of firm name or trade products does not imply that they are endorsed or recommended by the U.S. Department of Agriculture over other firms or similar products not mentioned.

Temperature is one of the most important factors affecting the quality of farmers stock peanuts during storage. Aflatoxin production in unshelled peanuts depends upon temperature being within the range from 12 to 41 C with relative humidity in excess of 80% (1). High temperature during storage increases both free fatty acid and carbonyl contents which results in rancidity and flavor deterioration (4). Poor milling quality results when shelling peanuts at kernel temperatures below 7 C (2). Insect control is greatly improved when storage temperatures are at 10 C or less since most insects become dormant and their eggs do not hatch at these temperatures (3). Smith and Davidson (5) showed graphically on a psychrometric chart the conditions which cause the above stated undesirable and desirable effects encountered during peanut storage.

The desired warehouse temperature for maintaining quality in farmers stock peanuts should be 10 C or less. Southeastern peanuts are usually harvested from late August until mid-October depending upon the particular season and the cultural practices. During this period peanuts normally leave the dryer at approximately 32 C and are moved directly into the warehouse where the temperature often exceeds 32 C during the day. Ventilation by moving large quantities of air through the overspace and sometimes aeration by forcing small quantities of air through the mass are required to lower peanut temperatures and moisture contents to safe storage ranges, and then to maintain these ranges. Temperatures below 10 C usually do not occur in the Southeastern U.S. until after mid-November. Later in the harvest season the daytime temperatures are usually much less than those occurring at first of harvest with nightime temperatures dropping as low as 5 C.

The objective of this study was to determine and compare the temperature profiles within the peanuts in flat-type storages with natural and mechanical ventilation for various periods during the storage season.

## Materials and Methods

Two adjacent warehouses designed for storing farmers stock peanuts were selected for this study. Both warehouses were steel frame buildings covered with galvanized sheet metal. One had sheet metal on both sides of the 0.15-m-wide "Z-bar" girts forming the walls. This warehouse (Warehouse A) had a mechanical ventilating system and a 37° roof slope. Air entered through louvers in the north gable and exited through two 0.91-m-dia fans in the south gable. Each fan was rated at 400 $m^3$ per minute at 31 Pa. The other warehouse (Warehouse B) had sheet metal on the outside of the girts and had a 45° roof slope. Warehouse B had a natural air flow ventilation system with air intakes just below the rain gutter at the eaves and a ridge exhaust vent extending the length of the ridge except for the first 4.5 m on the elevator end of the warehouse. Both warehouses were 7.3 m high at the eaves and were erected on 0.15-m-thick concrete pads that were 24.4 m by 42.7 m with a north-south orientation. Warehouse A and Warehouse B had theoretical capacities of 3450 and 3680 t, respectively.

Loading was by a bucket elevator operating in a dump pit at the south end of each warehouse. A cyclone separator installed at the top of the elevator removed a portion of light trash, hulls, and dirt as the peanuts flowed into Warehouse A. A foreign material extractor removed a small quantity of foreign material consisting of peanut leaves, sand, dirt, and small pieces of other substances from the peanuts as they flowed from the elevator into Warehouse B.

Figure 1 is a schematic layout of the temperature sensor locations for both warehouses. The test section of each warehouse was located approximately 12.2 m from the north end and had temperature sensors distributed as shown in Fig. 1. At these locations a 6.4-mm-dia nylon cord was stretched across the warehouse between structural columns at approximately 3- and 6-m heights. Thermocouples, ANSI Type T, were attached to the cords at 2.6-m intervals beginning at 0.3 m from the wall. Thus, 10 thermocouples were equally spaced across the peanut pile at each level. A second set of thermocouples was attached to the lower cord and allowed to hang at approximately 0.6 m above the floor.

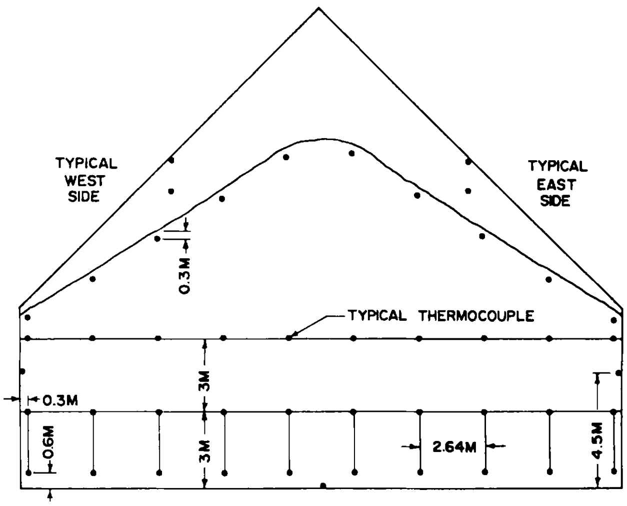


**Fig. 1. Schematic diagram of thermocouple locations in warehouses.**

A thermocouple was located on the floor at the center of the cross section and on each interior wall 4.5 m above the floor. A thermocouple was placed approximately 0.3 m beneath the pile surface directly above each thermocouple located on the cords. Overspace temperature was obtained by suspending a thermocouple midway each side of the roof halfway between the roof and the pile. Roof temperatures were sensed by a thermocouple attached to the roof underside midway on each side. Outside temperature was sensed by a thermocouple located 1.5 m above ground.

Thermocouples were attached to two 24-point temperature recorders at each warehouse. Recorders were programmed to record the temperatures at 2-h intervals on the even numbered hours throughout the storage period.

Warehouse loading began on September 7, 1979, and was completed by October 15, 1979. Crop maturity rate, size of crop, and weather conditions during harvest determine the time required to load a warehouse. Peanuts were loaded into the warehouses at similar rates ranging up to 35 t/h. During loading, peanuts were alternately diverted to either side of the horizontal conveyor forming a conical pile on each side about 3 m to the right and left of the center of the warehouse. A final topping off filled in all the valleys, leaving a smooth sloping pile across the entire warehouse.

Isotherms at intervals of 2 C were constructed for various storage periods by drawing lines between points of equal temperature on a cross section of the peanut mass. These points were determined by straightline interpolation between the average recorded temperatures for adjacent thermocouple locations during the storage period represented. Surface temperatures for the peanuts were not recorded but overspace, sidewall and center of floor temperatures were recorded. Peripheral thermocouples within the peanut mass were located within 0.3 m of the sidewalls and overspace and within 0.6 m of the floor (Fig. 1). Location of isotherms between the peripheral thermocouples and the mass surface were constructed using floor, sidewall, overspace, outside ambient, and peripheral thermocouple temperatures. Since most of the masss is located inside the peripheral thermocouples, the isotherms give a good representation of the temperatures existing within the major portion of the stored peanuts. Data were collected from each sensor as soon as it was covered with peanuts or was placed in sensing position when not located in peanuts. These data were analyzed in weekly periods from September 14 (time all sensors were covered at the 3-m level) through November 1 and at half-month intervals thereafter except for the April 1 to 9 period.

## Results and Discussion

Table 1 contains mean, maximum, and minimum

**Table 1. Mechanically ventilated Warehouse (A) and naturally ventilated Warehouse (B) - Mean peanut, outside air, and overspace temperatures for 1979-1980 storage season.**

| Period | Peanut temperature, C | | | | | | Outside air temperature, C | | | Overspace temperature, C | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | | | B | | | | | | A | | | B | | |
| | Mean | Max. | Min. | Mean | Max. | Min. | Mean | Max. | Min. | Mean | Max. | Min. | Mean | Max. | Min. |
| Sept. 14-20 | 28.6 | 36 | 23 | 28.9 | 35 | 24 | 23.5 | 29 | 17 | | | | | | |
| Sept. 21-27 | 28.7 | 37 | 21 | 27.1 | 29 | 22 | 21.4 | 28 | 16 | | | | | | |
| Sept. 28- Oct. 4 | 28.9 | 37 | 21 | 26.5 | 29 | 22 | 22.1 | 32 | 12 | | | | | | |
| Oct. 5-11 | 26.6 | 35 | 16 | 26.1 | 30 | 17 | 17.5 | 28 | 7 | | | | | | |
| Oct. 12-18 | 23.8 | 33 | 12 | 24.0 | 30 | 11 | 18.1 | 28 | 7 | | | | | | |
| Oct. 16-31 | 21.8 | 31 | 12 | 22.1 | 30 | 17 | 18.6 | 30 | 4 | 20.7 | 36 | 6 | 19.7 | 32 | 8 |
| Oct. 19-25 | 22.1 | 30 | 13 | 22.7 | 30 | 17 | 18.9 | 29 | 4 | 20.6 | 36 | 6 | 20.1 | 32 | 9 |
| Oct 26- Nov. 1 | 19.2 | 24 | 12 | 20.7 | 28 | 11 | 18.2 | 30 | 5 | 21.5 | 31 | 14 | 19.0 | 28 | 8 |
| Nov. 1-15 | 19.1 | 24 | 12 | 18.8 | 27 | 9 | 15.2 | 28 | 1 | 15.0 | 31 | 1 | 16.9 | 29 | 5 |
| Nov. 16-30 | 15.6 | 20 | 11 | 16.5 | 26 | 7 | 13.8 | 27 | -3 | 10.5 | 30 | 0* | 15.4 | 27 | 0 |
| Dec. 1-15 | 12.1 | 19 | 0 | 13.2 | 23 | 1 | 9.8 | 24 | -4 | 10.6 | 29 | 0* | 11.5 | 25 | 0 |
| Dec. 16-31 | 9.5 | 18 | 1 | 11.1 | 20 | 2 | 9.2 | 20 | -3 | 9.1 | 26 | 0* | 10.2 | 28 | 1 |
| Jan. 1-15 | 8.3 | 15 | 3 | 9.9 | 26 | 4 | 9.1 | 24 | -3 | 9.0 | 27 | 0* | 9.4 | 21 | 0 |
| Jan. 16-31 | 8.4 | 13 | 5 | 10.1 | 19 | 6 | 11.4 | 26 | -2 | 11.4 | 30 | 0* | 12.3 | 24 | 2 |
| Feb. 1-14 | 7.5 | 14 | -1 | 9.7 | 17 | -2 | 3.8 | 13 | -6 | 4.4 | 23 | -4 | 4.8 | 14 | -3 |
| Feb. 15-29 | 7.0 | 14 | 1 | 9.6 | 18 | 2 | 13.3 | 26 | -2 | 12.6 | 29 | -4 | 14.6 | 29 | 1 |
| Mar. 1-15 | 6.5 | 11 | 2 | 9.5 | 18 | -1 | 12.1 | 27 | -8 | 11.2 | 27 | -9 | 12.8 | 27 | -4 |
| Mar. 16-31 | 6.3 | 11 | 3 | 10.2 | 16 | 6 | 16.1 | 24 | 6 | 15.4 | 34 | 3 | 16.6 | 31 | 8 |
| Apr. 1-9 | 6.8 | 11 | 4 | 10.9 | 16 | 8 | 18.1 | 27 | 7 | 18.0 | 36 | 4 | 19.0 | 31 | 9 |
| Apr. 1-15 | 7.0 | 13 | 4 | 11.1 | 16 | 8 | 17.9 | 27 | 7 | 17.6 | 36 | 4 | 18.7 | 31 | 9 |
| Apr. 16-30 | 7.8 | 10 | 5 | 12.1 | 17 | 9 | 19.4 | 33 | 7 | 19.4 | 37 | 4 | 20.8 | 36 | 9 |
| May 1-15 | 9.4 | 16 | 6 | 13.3 | 17 | 10 | 21.9 | 33 | 11 | 22.3 | 37 | 10 | 23.4 | 42 | 13 |
| May 16-31 | 15.0 | 32 | 7 | 15.3 | 21 | 12 | 24.7 | 33 | 17 | 24.4 | 37 | 17 | 26.2 | 38 | 19 |
| Jun. 1-15 | | | | 18.1 | 28 | 12 | 26.7 | 36 | 16 | | | | 29.1 | 41 | 19 |

*This value could be less than zero. Lower limit on recorder used during this period was zero.

temperatures within the peanut mass and for outside and overspace air at various periods throughout the storage season. The mean temperature of the peanut mass for any period consists of a "weighted" mean of the thermocouple values for that period. The peripherial 1.5-m layer (up the sides and across the top) of the mass with included thermocouples was omitted in calculating the mean temperature of the mass. Each thermocouple within the resulting mass was "weighted" depending on the portion of the mass it represented.

The warehouses had similar temperature profiles for the 7-day period, September 14-20, after the thermocouples had been covered at the 3-m level. Random loading of each warehouse with peanuts at temperatures between 28 and 30 C accounts for these similarities. After 3 weeks of loading, all thermocouples were covered at the 6-m level. The temperature increased considerably near the center of Warehouse A. Temperatures along the sides of the masses in both warehouse were similar in magnitude for similar locations.

The warehouses each have a large door approximately 4 x 5 m located about 10 m from the elevator end and these doors were left open until the mass approached them during loading. Although the exhaust fans in the south end of Warehouse A were running, the air was drawn in through the open door and exhausted without passing over and through the peanut mass thereby accounting for the heat buildup. A stagnant air condition existed over much of Warehouse A until the door was closed on October 4 and air was drawn across the peanut mass. In warehouse B air entered through the numerous inlet louvers along the eaves as well as through the open door and exhausted through the louvers along the length of the roof ridge.

Both warehouses were filled by October 16 with all temperature sensors in place. Figs. 2 and 3 are the isotherms for the first 2 weeks after filling (October 16-31). These isotherms show a marked thermal gradient

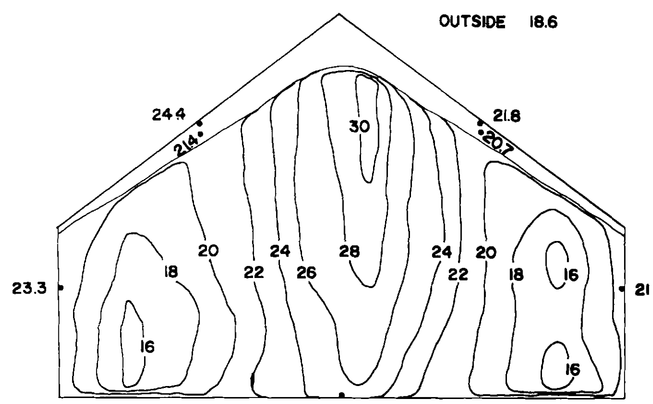


**Fig. 2. Warehouse A (mechanical ventilation) isotherms, October 16-31, after all thermocouples were in place.**

from the center of the warehouses outward. During this period the mean outside temperature was 18.6 C, but areas along the sides of the masses cooled to less than this mean temperature. At this time Warehouse A was lightly warmer than Warehouse B.

Isotherms for the early winter storage period (month of December) are shown in Figs. 4 and 5. With a mean

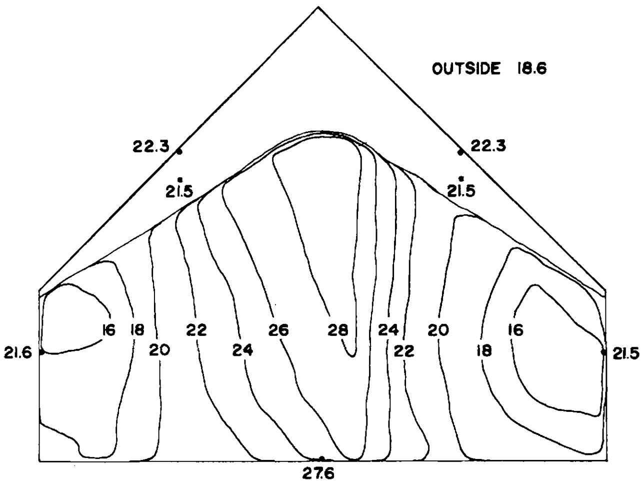


Fig. 3. Warehouse B (natural ventilation) isotherms, October 16-31, after all thermocouples were in place.

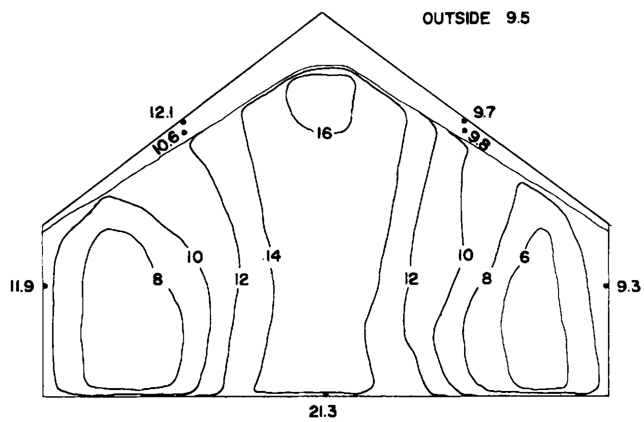


Fig. 4. Warehouse A (mechanical ventilation) isotherms for the month of December.

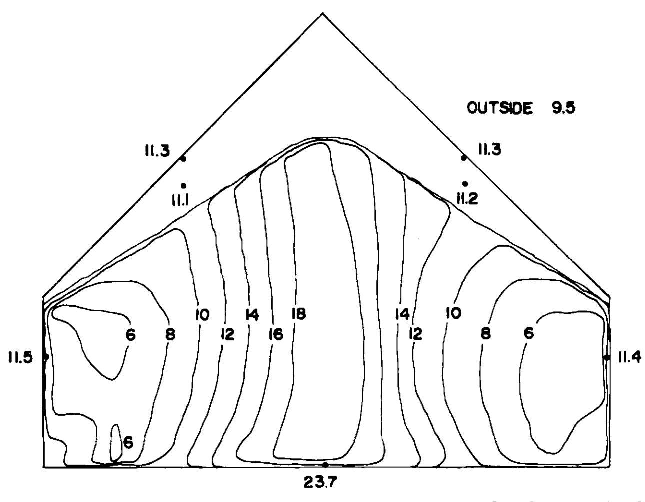


Fig. 5. Warehouse B (natural ventilation) isotherms for the month of December.

outside air temperature of 9.5 C for December, Warehouse A reached a lower mean temperature in the peanut mass than did Warehouse B. Warehouse B depended on temperature differential and the resulting chimney effect for air changes while Warehouse A had a constant air flow through the overspace regardless of the inside or outside temperature. During late December the mean interior temperatures of the outer quarters of the peanut mass in both warehouses were lower than the mean outside air temperature.

Midwinter (February) isotherms for the warehouses are shown in Figs. 6 and 7. The central portion of Warehouse A was considerably cooler than Warehouse

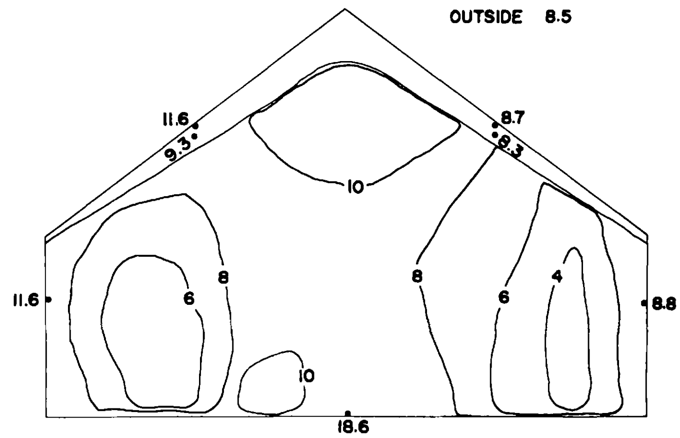


Fig. 6. Warehouse A (mechanical ventilation) isotherms for the month of February.

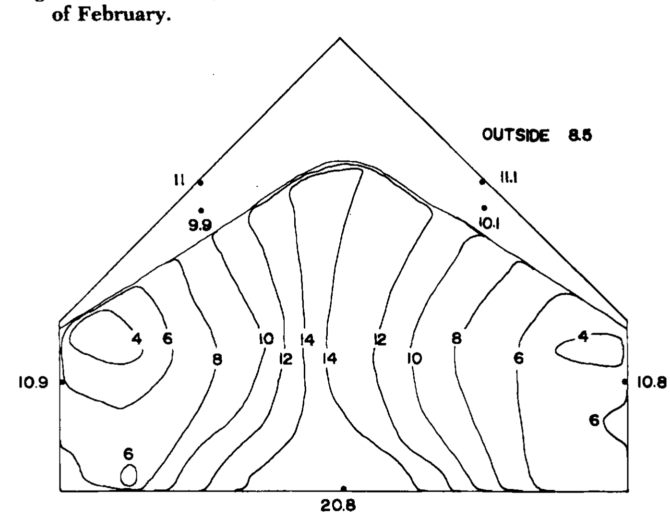


Fig. 7. Warehouse B (natural ventilation) isotherms for the month of February.

B. The isotherms in both warehouses tended to show less lateral temperature gradient than during the early winter period. After the initial heat load had been removed and the peanuts had been in storage for several months, changes in the mean temperatures at specific locations within the mass for various periods slowed considerably and were not affected greatly by increases in mean outside temperatures. The approximate ranges for the isotherms were 4 to 10 in Warehouse A and 4 to 14 in Warehouse B. Isotherms in Figs. 6 and 7 indicated that the center of the mass in Warehouse A was between 8 and 10 C while the approximately comparable center of the mass in Warehouse B was between 10 and 14 C.

Figures 8 and 9 show the isotherms during late season storage, April 1 through 9. The temperature profiles show little horizontal gradient except for very near the sides of the warehouses. The mean outside temperature for this period was 18.1 C or approximately 10 C above the midwinter period. With this increase in the mean outside temperature, the mean temperatures of the

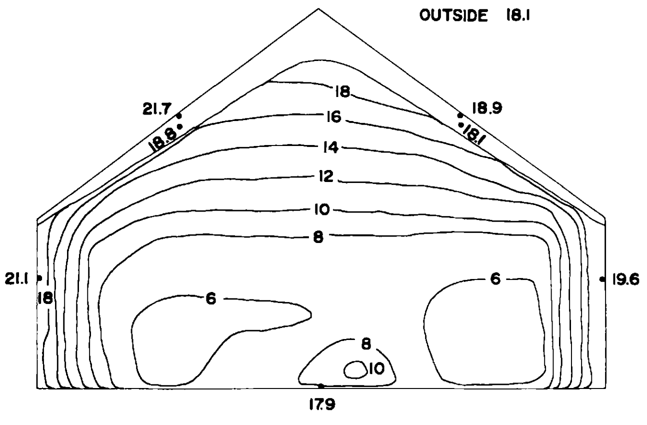


**Fig. 8. Warehouse A (mechanical ventilation) isotherms for April 1-9.**

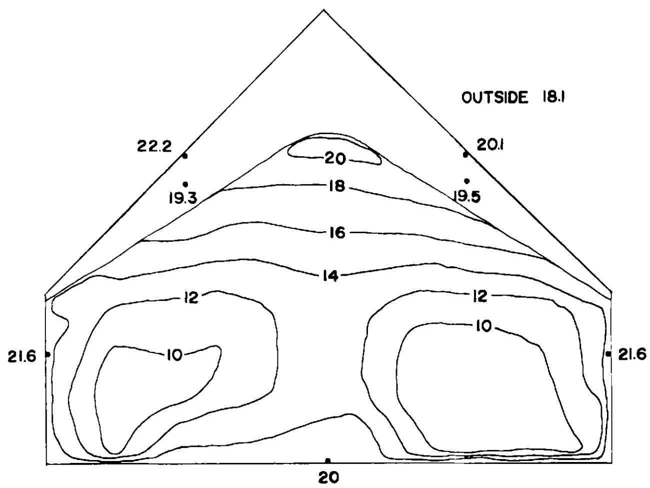


**Fig. 9. Warehouse B (natural ventilation isotherms for April 1-9.**

peanut masses increased only slightly (see Fig. 10). This supports the research results obtained by Suter et al. (9) reporting low thermal conductivity for spanish peanuts. The temperature profiles depicted by the closely spaced isotherms near the sides of Warehouse A indicated that the mass was slowly warming up. Since the peanuts were cooler than the outside ambient air, the cool air surrounding them was not being replaced by lighter warm air.

The mean floor temperatures of the warehouses

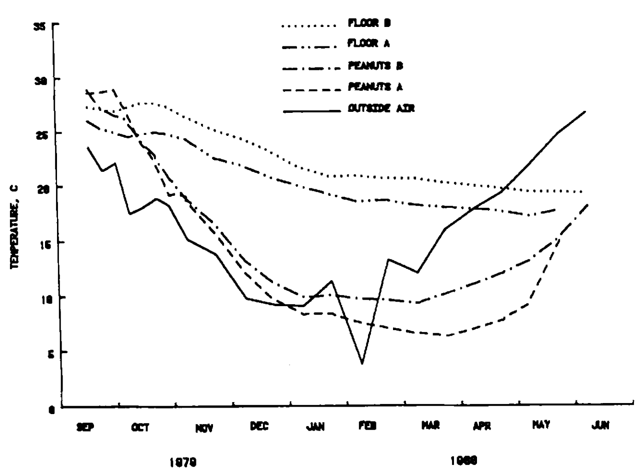


**Fig. 10. Graph of mean outside air temperatures, mean peanut pile temperatures, and mean floor temperatures for Warehouses A and B during the 1979-80 storage season.**

throughout the storage season are shown in Fig. 10. The higher initial temperature of the floor in Warehouse B was probably due to absorption of solar energy during July and August prior to the erection of the warehouse. This difference was maintained throughout storage ranging from approximately 1.5 to 3.2 C. There was a slight increase in the floor temperature of both warehouses in mid-October from the newly warehoused peanuts. After mid-October and until the end of the storage period the floor temperature slowly decreased although mean outside temperatures increased rather rapidly after mid-February. This decrease can be attributed to the insulating effects of the farmers stock peanuts and the settling of the cooler air in the mass.

Mean overspace temperatures approximated mean outside air temperatures throughout the storage season for corresponding periods with Warehouse A never exceeding the mean outside air temperature by more than 3.3 C and with Warehouse B never exceeding it by more than 2.4 C. Warehouse B never had a lower mean overspace temperature than the mean outside air temperature for the corresponding period. However, this was not true for Warehouse A. The maximum overspace temperature reached in Warehouse A was 37 C while that in Warehouse B was 42 C on one occasion. Roof temperatures reached a maximum of 63 C in each warehouse during the latter part of storage and they were as high as 50 C in January. The sidewall temperature reached a maximum of 56 C in Warehouse B compared to 52 C in Warehouse A. The double layered wall with 0.15-m air space in Warehouse A probably accounts for the difference. Sidewalls reached temperatures as high as 40 C in January. Differences in excess of 25 C were observed between maximum and minimum temperature of the sidewalls over a 24-h period. Peanuts in close proximity to and touching the metal walls approximate the wall temperature. Quality in these peanuts is likely to be lowered during the normal storage period and when mixed with the other peanuts during unloading could contribute to an overall lowering of quality during storage.

A graphical comparison of the mean outside and peanut temperature throughout the storage period is shown in Fig. 10. The storage period extended from September 13 until unloading began to uncover the thermocouples located at the 6-m level. During loading and through mid-December, the slope of the temperature curves for mean outside, Warehouse A and Warehouse B temperatures were similar. Warehouse temperatures were higher and less variable than the outside temperature. Warehouse B dissipated the heat better when partially filled as compared to Warehouse A but approximately a month after filling Warehouse A was cooler than Warehouse B and remained this way throughout storage. The mean outside temperature began an upward trend in early January except for a cold period in early February. Warehouse A decreased in temperature slightly from mid-December through late March, whereas, Warehouse B maintained essentially the same temperature during the period. The mean temperature in Warehouse B increased slightly in late March and continued on approximately the same slope until unloaded. Warehouse A did not show a temperature increase until late March when it continued at approximately the same slope until early May when a sharp increase in the slope of the temperature curve was noted. This sharp increase occurred when the warehouse doors were opened and the air to the fan short-circuited. It is worthy to note this in conjunction with the increase in temperature during loading before the door was closed.

## Conclusions

Statistical analyses of data from the two types of warehouses show that temperature differences existed between warehouses.

The temperature profiles for naturally and mechanically ventilated warehouses are basically similar. During loading and the early part of storage, the naturally ventilated warehouse tended to remove the trapped heat better than the mechanically ventilated warehouse. However, after loading was completed and with an adequate air change rate, the mechanically ventilated warehouse was equal to the naturally ventilated warehouse in removing heat. Warehouse A cooled to equal the temperature in Warehouse B after a month of storage and then gradually cooled to as much as 4.3 C less than Warehouse B by late storage (Fig. 10). The temperature profiles and the mean temperatures of the mass indicate the importance of assuring that the air supply is adequate and not short-circuited in mechanically ventilated warehouses.

## Literature Cited

1. Diener, U. L. and N. D. Davis. 1977. Aflatoxin formation in peanuts by *Aspergillus flavus*. Auburn Univ. Agric. Exp. Sta. Bull. 493. 49 pp.
2. McIntosh, F. P. and J. I. Davidson, Jr. 1971. Effect of temperature on shelling runner- and Spanish-type peanuts. U. S. Dept. Agr. ARS-52-65. 4 pp.
3. Refrigeration Research Foundation. 1980. Commodity Storage Manual: Insect Inactivation and Destruction by Cold Temperatures. Washington, D. C. 2pp.
4. Sanders, T. H., J. S. Smith, Jr., J. A. Lansden, and J. I. Davidson, Jr. 1981. Peanut quality changes associated with deficient warehouse storage. Peanut Sci. 8(2):121-124.
5. Smith, J. S., Jr., and J. I. Davidson, Jr. 1982. Psychrometrics and kernel moisture content as related to peanut storage. Trans. Amer. Soc. Agr. Eng. 25(1):231-236.
6. Suter, D. A., K. K. Agrawal, and B. L. Clary. 1975. Thermal properties of peanut pods, hulls, and kernels. Trans. Amer. Soc. Agr. Eng. 18(2):370-375.

Accepted November 2, 1983