Potential for Semi-Underground Storage of Farmers Stock Peanuts

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ABSTRACT

A small semi-underground warehouse was constructed by waterproofing and placing a 7.6 cm thick precast concrete tank 304.8 cm long by 152.4 cm wide by 152.4 cm deep in the ground with the top of the tank at ground level. Two courses of 20.3-cm concrete blocks were installed above the walls and the warehouse was covered with a sheet-metal gable roof having a 45-degree slope. The warehouse had a peanut storage capacity of approximately 10.2 m^3. A fan located in the south gable changed the headspace air once every two minutes. Thermocouples and relative humidity sensors placed at various locations throughout the warehouse indicated temperatures and relative humidities at these locations. Free fatty acid and total carbonyl analyses indicated acceptable quality maintenance in the underground storage and compared well with peanuts in conventional storages. Temperatures were more uniform in the underground warehouse than in the conventional warehouse.

Key Words: *Arachis hypogaea* L., storage, underground, in-shell

The popular flat-type warehouses for storing farmers stock peanuts offer the potential for maintaining quality of peanuts in storage; however, problems (8) that sometime occur dictate the need for continued research to identify potentially better storage methods. Throughout history reasonable success has been achieved in storing various foods underground (6). Research on storing barley in underground pits has been conducted (4). The modern trench silo is an example of a semi-underground storage for livestock feed. Underground or semi-underground storage structures may offer a practical alternative to present farmers stock storage facilities.

Soil temperature a meter or more below the surface varies slowly over a relatively narrow range in most of the peanut producing areas in the United States during the normal storage period for farmers stock peanuts. Ambient soil temperatures of 12-22 C, could provide acceptable temperature conditions for maintaining peanut quality during the normal farmers stock storage period (9). As in conventional storage facilities, an acceptable kernel moisture content must be maintained, and this condition could be met with proper ventilation and/or aeration.

The objectives of this research were to evaluate the concept of semi-underground storage of farmers stock peanuts by developing a small semi-underground warehouse, examining temperature and relative humidity parameters throughout storage and comparing the quality of peanuts stored therein to conventionally stored peanuts.

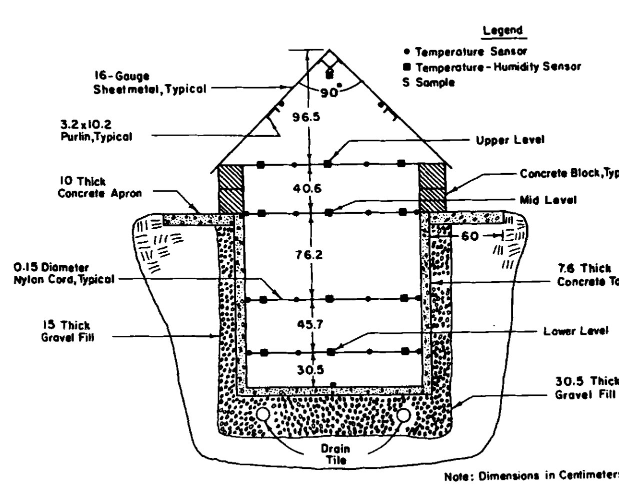
Methods and Materials

A standard, precast, open-top septic tank was produced by a local manufacturer without the normal inlet and outlet openings. The tank was cast using 7.6 cm thick concrete and had inside dimensions of 304.8 cm by 152.4 cm by 152.4 cm. Two coats of a polyurethane sealer were applied to all surfaces (inside and out) of the finished tank to prevent moisture penetration. A final coat of an asphalt base sealer was applied to the exterior surfaces.

A hole was excavated at least 30 cm greater than the tank in all directions. Coarse crushed stone aggregate was poured over the bottom of the hole to a depth of approximately 10 cm. Two 10.2-cm diameter PVC drain tiles were placed on the aggregate approximately 1.2 m apart beneath the tank and an additional 20 cm of aggregate was added. The drain tiles were connected to a 10.2-cm diameter PVC pipe which was extended approximately 12 m with a 2% fall to where it surfaced and drained the excavation. The tank was positioned in the hole in a north-south orientation and backfilled with a 15-cm thick buffer of coarse stone against the surface of the tank. A 10-cm thick by 60-cm wide concrete apron was poured flush with the top of the tank and sloped sufficiently to drain water away. Two courses of 20.3-cm high concrete blocks were laid flush with the inside tank wall, increasing the tank depth by 40.6 cm. Both sides of the block wall received two coats of polyurethane sealer while the exterior side also received two coats of water-proof swimming pool paint.

The tank top was framed with 3.2-cm by 10.2-cm channel iron 0.23 cm thick and 5.1-cm by 5.1-cm angle iron 0.32 cm thick to produce a gable roof with a slope of 45 degrees, which corresponds to the roof slope of many peanut warehouses (Fig. 1). The roof and the gable ends were covered with 16-gauge sheet metal. Both roof and gables were painted with two coats of reflective white paint to minimize solar heat gains. The metal roof covering was gasketed with plastic foam tape at contact points and secured by sheet metal screws to prevent air entry except through the gable inlet. A squirrel-cage, shaded-pole blower rated at 1.4 m^3/min at 75 Pa static pressure was mounted near the ridge in the south gable to exhaust the air in the overspace. Air entered through a 10-cm by 30-cm opening in the north gable near the ridge. The opening was covered with fly screen hardware cloth. A small view-port was also located in the north gable of the warehouse.

Fig. 1. Cross-Sectioned view of semi-underground storage model.



The inside of the semi-underground warehouse was 304.8 cm long by 152.4 cm wide by 193 cm high at the eaves and 289.5 cm high at the ridge (Figs. 1 and 2). The storage capacity with runner type farmers stock peanuts was approximately 10.2 m^3 or 3.3t (323.5 kg/m^3). The completed facility was instrumented to monitor temperature and re-

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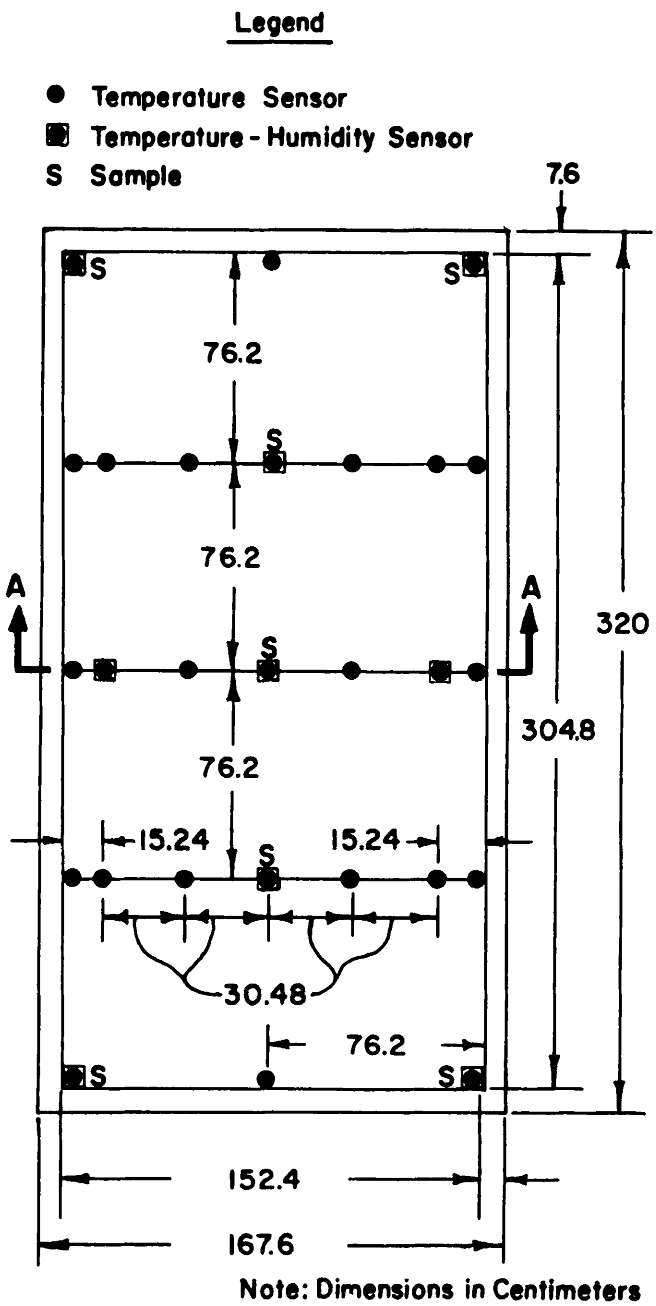
lative humidity throughout the storage. Three vertical cross sections with four levels on each were selected for sensor locations (Figs. 1 and 2). Sensors were also located at the ends, corners, overspace and roof.

Fig. 2. Plan view of semi-underground storage model.



The sensors were securely attached to a nylon cord anchored to the walls on each level of each cross section. ANSI type T thermocouples and Phys-Chemical Research Corp. PCRC-11 relative humidity sensors were used to determine temperature and relative humidity changes during storage. A Monitor Labs data logger interfaced with a Phys-Chemical Research Corp. signal conditioner and a Techtran magnetic tape recorder collected temperature and relative humidity data at two-hour intervals.

Thermocouples were installed in a cross section of the peanut mass in the conventional warehouse beginning 12.2 m from the north end and 30 cm from the west wall at 2.6 m intervals. They were placed at 6 levels beginning at floor level and proceeding to top level which was ca. 30 cm beneath the top of the peanut mass with interior levels at 61, 305, 610 and 915 cm. All interior level thermocouples were attached to 0.6 cm diameter nylon ropes stretched across the warehouse at the noted levels. Thermocouples at floor level were taped in position while those at the top level were positioned by hand ca. 30 cm beneath the surface at the desired locations.

Sixteen samples from the same lot, each containing 2.7 kg of farmers stock peanuts in mesh bags, were placed in the semi-underground warehouse at locations as indicated in Figs. 1 and 2 as it was filled. A 16-kg sample of peanuts from the same lot was placed 60 cm below the surface in the center of the peanut mass in a mechanically ventilated, conventional warehouse during filling. Six additional samples, randomly selected from the same lot, were shelled and sized according to various commercial categories. Analyses of total carbonyls and free fatty acids (1,3) were performed in duplicate on each size category in each sample. Similar analyses were performed on the stored samples from each warehouse when it was unloaded. All samples were analyzed for aflatoxin by the mini-column method of Holaday and Lansden (5).

The semi-underground warehouse was filled on September 2, 1984, with Florunner cultivar peanuts having a moisture content of approximately 8.5% w.b. at a temperature of approximately 29 C. Filling was accomplished by removing one side of the roof and using a portable flat-belt inclined conveyor to discharge the peanuts along the center of the longitudinal axis of the warehouse. When the peanuts reached from end to end at the top of the walls at natural angle of repose, filling was considered complete. The semi-underground warehouse was emptied May 21, 1985 (241 days), and the samples were removed for analysis. The conventional warehouse was filled between September 13 and October 1, 1984, with the same cultivar peanuts having approximately the same moisture content and temperature as those in the semi-underground warehouse. The peanut sample was placed in the conventional warehouse on September 28, 1984. This sample remained in storage until April 17, 1985 (207 days), at which time it was removed and analyzed.

Results and Discussion

Figures 3 and 4 are plots of temperature and relative humidity, respectively, (7-day means) for three levels in the middle section of the semi-underground warehouse with outside ambient air temperature and relative humidity for 241 days of storage beginning September 2, 1984. Means were computed from data collected at 2-hour intervals for each 7-day period except for the last period which was 4 days. Temperature and relative humidity patterns were similar at other sensor locations. During the first half of the storage season temperatures outside the warehouse were generally lower than temperatures inside although both were decreasing (Fig. 3). This was in part due to the moderating effect of the soil. Approximately midway through the storage season, temperatures began to rise but unlike the first half of the storage season inside temperatures were generally lower than outside temperatures. Of the three levels in the warehouse, temperature was consistently lower at the lowest level during the second half of the storage season.

No excessive moisture buildup was indicated by the relative humidity sensors during storage in the semi-underground warehouse. Initially, relative humidity was at the upper limit considered for good storage (9). Measurements in the lower level indicated a more rapid decrease in relative humidity than occurred in the mid and upper levels. Relative humidity at all three levels generally increased in the second half of the storage season as the length of storage time increased. Relative humidity gradients for September 28 - October 4 (Fig. 5, period 2) and January 25-31 (Fig. 6, period 19) show how the moisture migrated from the lower portion of the semi-underground warehouse to the upper portion

Fig. 3. Mean temperature changes occurring at weekly intervals (last interval was 4 days) during 241 days of storage in semi-underground warehouse at lower mid and upper levels of peanut mass beginning September 2, 1984.

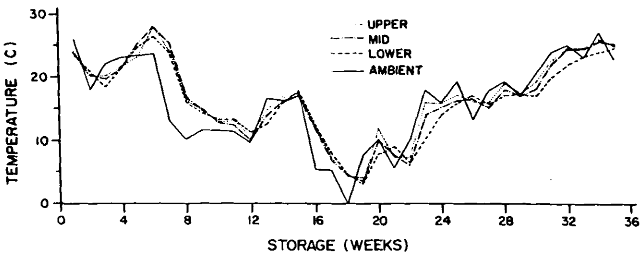


Fig. 4. Mean relative humidity changes occurring at weekly intervals (last interval was 4 days) during 241 days of storage in semi-underground warehouse at lower, mid and upper levels of peanut mass beginning September 2, 1984.

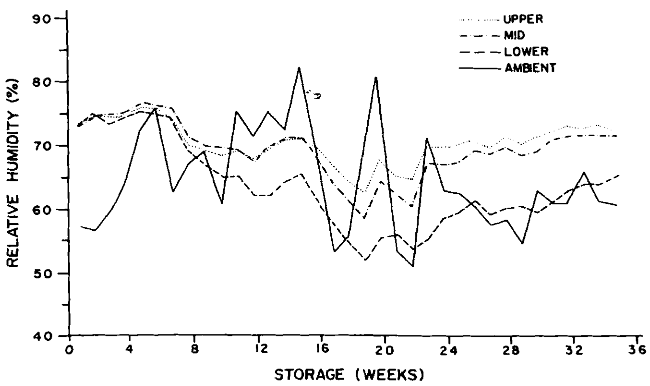
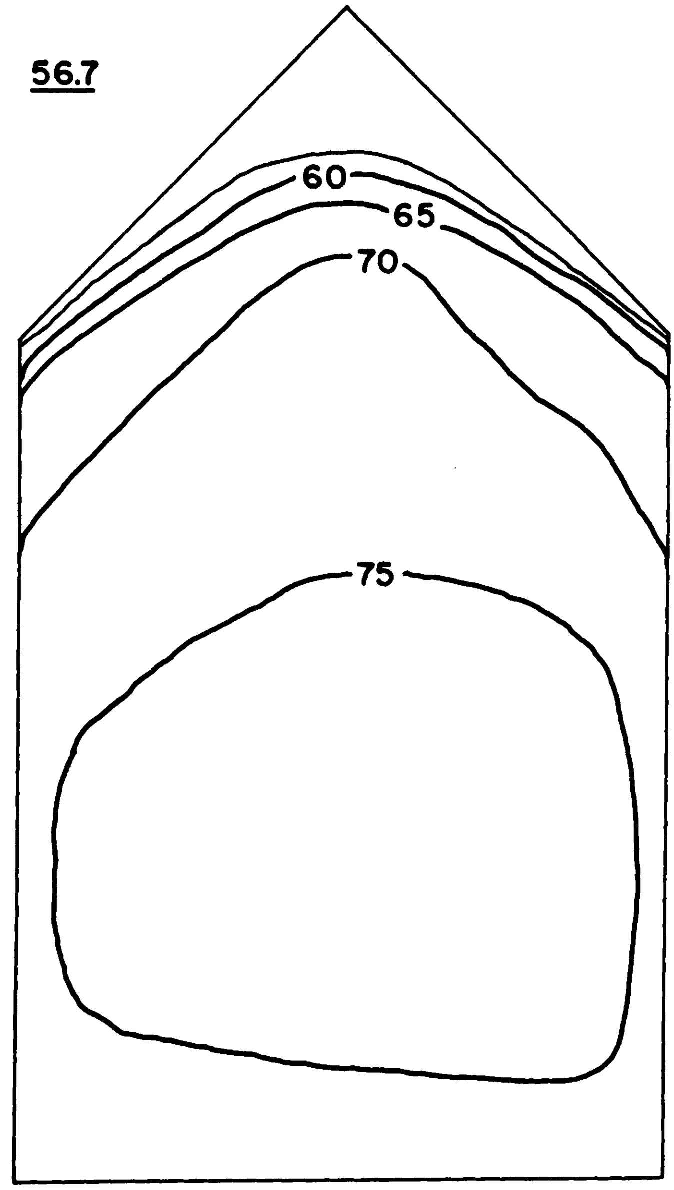


Fig. 5. Semi-underground relative humidity gradients with mean outside relative humidity (%), Sep. 28 - Oct. 4, 1984.



by mid-winter. Although moisture migration is evident, it is well within the limits for good storage.

There was no evidence that any free water had been present during storage when the warehouse was unloaded. However, condensation was observed in November and December on the underside of the roof and adjacent structural metal. No drip lines were found during unloading to indicate that the condensation had dripped from the roof to the stored peanuts. During the period of observed condensation, a slight amount of mold, genus *Eurotium*, was detected on top of the peanuts near the ridge. Although undesirable, this mold was not considered a serious threat to quality.

Isotherms were constructed from temperature data for various time periods throughout storage for the semi-underground and conventional warehouses. Figures 7 and 8 are isotherm plots for cross sections of both warehouses averaged over a seven-day period in late September and early October. The below grade walls of the semi-underground warehouse were warmer than the exposed part of the walls and the center of the peanut mass (Fig. 7). During the same period the walls of the conventional warehouse were also cooler than the center portion (Fig. 8). The center portion of the conventional warehouse was 10 degrees warmer than desired for seed storage. Isotherm plots for the storages from January 25-31 are shown in Figs. 9 and 10. The earlier observations (Figs. 7 and 8) are still apparent except for lower overall temperatures. Considering the entire cross sectional area of both warehouses, temperatures are more uniform in the semi-underground warehouse. However, this may result from the cross sectional area of the conventional warehouse being ca. 75 times that of the semi-underground warehouse.

Aflatoxin was not detected in any of the seed size categories from the 26 samples before or after storage. Data for free fatty acids and total carbonyls for similar sized samples from the semi-underground warehouse were statistically analyzed (Duncan's new multiple-range test, 5% level of significance) for differences due to depth and front to back location in the warehouse. No differences due to location were found and therefore the mean of all data for a given size category are presented. The free fatty acid content of the various categories before and after storage are shown in Table 1. Although some changes occurred, they were small and final values were similar to those in the sample from the conventional warehouse. Table 2 lists the carbonyl content before and after storage for the two warehouses and again the results obtained from each warehouse are similar. Although the relatively large standard devia-

Fig. 6. Semi-underground relative humidity gradients with mean outside relative humidity (%), Jan. 25-31, 1985.

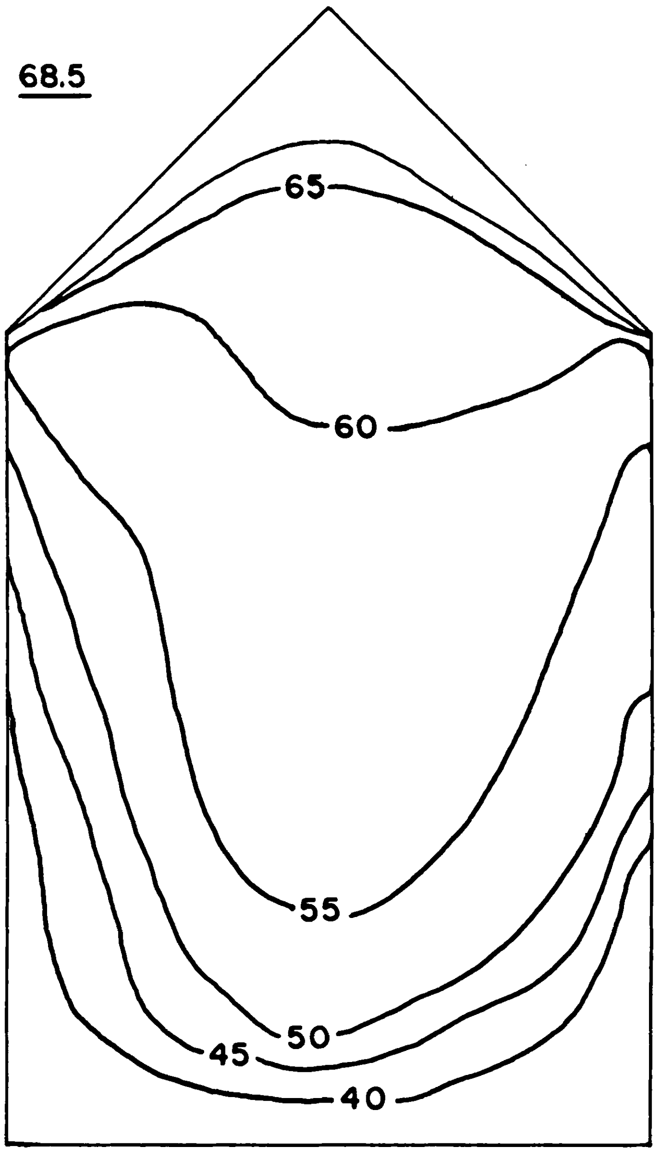
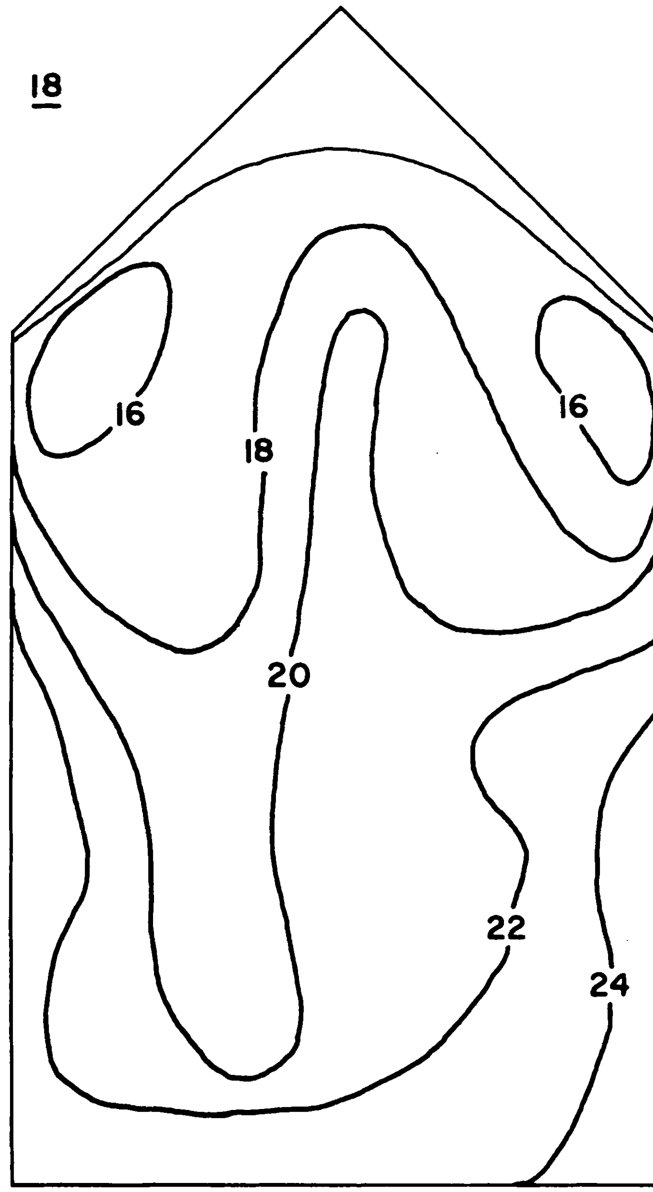


Fig. 7. Semi-underground warehouse isotherms with mean outside temperature (C), Sep. 28-Oct. 4, 1984.



tions (Tables 1 and 2) indicate a difference between samples, there was no set pattern for given sample locations since relative changes between seed size categories within a location varied considerably. Several studies (2,7,8) have demonstrated that free fatty acids and carbonyls increase with storage time and increased temperature and that overall quality decreases. Peanuts in the semi-underground warehouse remained in storage 241 days, therefore, it can be reasonably assumed that the semi-underground warehouse was adequate for maintaining peanut quality during storage.

Maintaining relatively low temperatures and low moisture contents during storage maintains acceptable quality of stored peanuts considerably longer than when they are stored at high temperatures and high moisture contents. The semi-underground concept offers a more stable temperature environment than the conventional, above ground type warehouse since the exterior walls are not exposed to large changes in ambient temperature and radiation.

Table 1. Percent free fatty acids and standard deviations (S.D.) in various seed size categories of farmers stock peanuts going into and coming out of semi-underground and conventional type warehouses.

Seed Size Category	Free Fatty Acids Initial (0 Days)		Semi-Underground (241 Days)		Conventional (207 Days)
	---% as oleic acid---				
		(S.D.)		(S.D.)	
Jumbo	0.10	(.00)	0.15	(.03)	0.15
Medium	0.10	(.00)	0.19	(.08)	0.15
No. 1	0.11	(.02)	0.23	(.07)	0.25
Other Edibles	0.10	(.00)	0.27	(.07)	0.25

Fig. 8. Conventional warehouse isotherms with mean outside temperature (C), Sep. 28-Oct. 4, 1984.

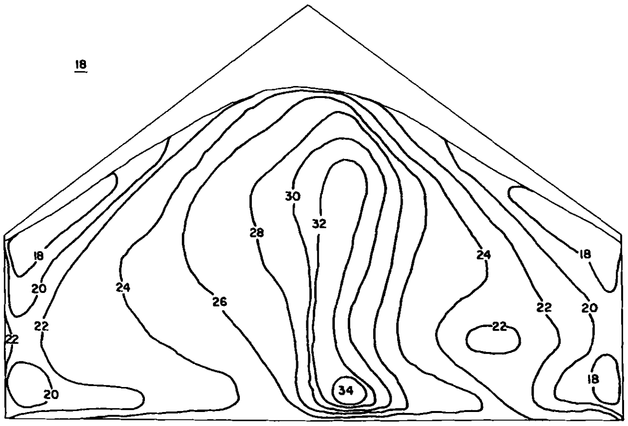


Fig. 9. Semi-underground warehouse isotherms with mean outside temperature (C), Jan. 25-31, 1985.

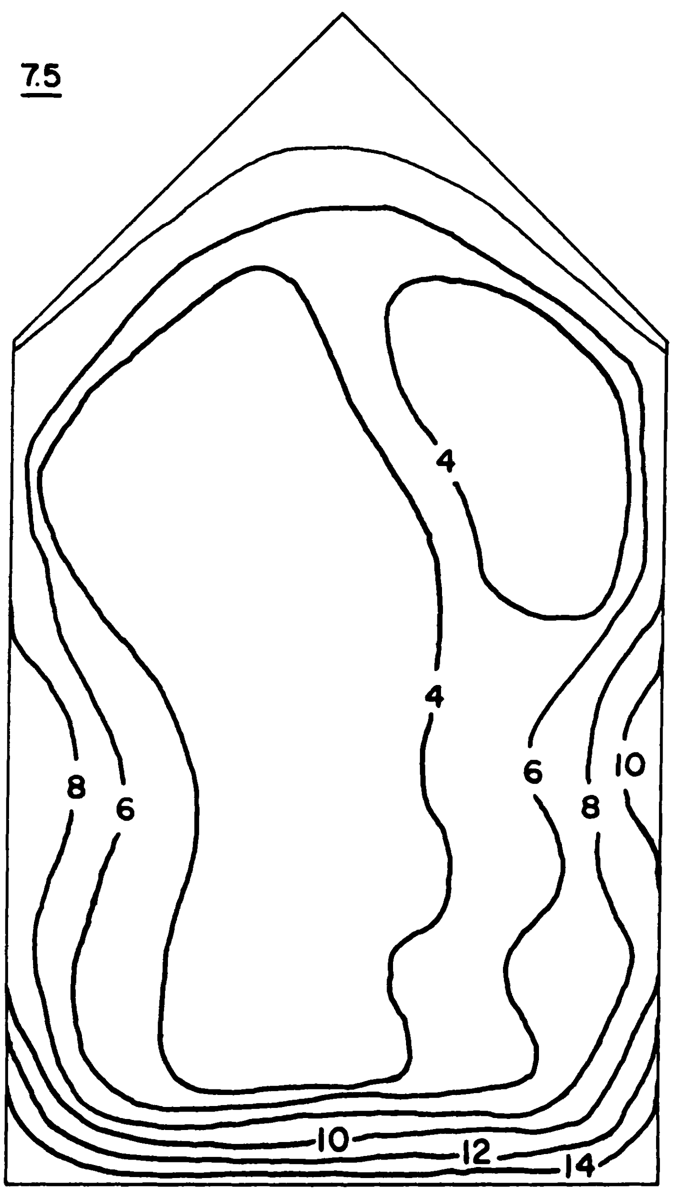


Fig. 10. Conventional warehouse isotherms with mean outside temperature (C), Jan. 25-31, 1985.

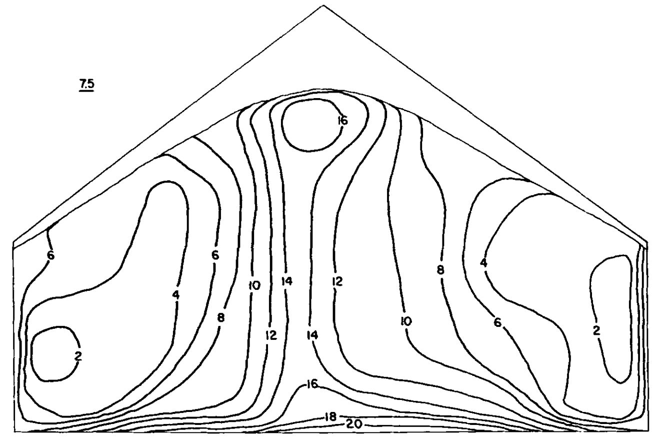


Table 2. Total carbonyls and standard deviations (S.D.) in various seed size categories of farmers stock peanuts going into and coming out of semi-underground and conventional type warehouses.

	Carbonyls (m moles/kg oil)				
Seed Size Category	Initial (0 Days)	(S.D.)	Semi-underground (241 Days)	(S.D.)	Conventional (207 Days)
Jumbo	0.88	(.17)	1.98	(.40)	1.79
Medium	0.84	(.04)	1.99	(.39)	1.95
No. 1	1.12	(.05)	2.43	(.58)	2.39
Other Edibles	1.25	(.06)	2.77	(.46)	2.70

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