UNIVERSITY OF IDAHO
College of Agriculture

Idaho Potato Storages— Construction and Management

By

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Harvesting and Handling as Related to Storage

Successful storage begins by preventing, or eliminating bruised and injured tubers. An especially important factor is that potatoes should go into storage with the least possible injury. Unblemished, or unbruised, tubers will store well with little loss. Injured tubers require special care. In a storage period of eight months, the moisture loss from sound tubers may be as low as 4%. Serious bruises may often result in rot and storage losses of 50% or more. In several tests conducted at the University of Idaho Aberdeen Branch Experiment Station, sound tubers did not rot even under unfavorable conditions, but tubers that were badly injured, rotted under the best possible storage conditions[1]. Rot-causing fungi and bacteria can enter bruised and injured tubers easily but seldom enter through the unbroken skin of uninjured tubers. The more injuries present, the more need for special care to prevent loss during storage.

With the advent of the digger-picker and bulker-combines, bruising caused by the human element has become less and the machine element has become all important. Therefore before harvesting and storing potatoes all equipment should be examined, and all points where injury might occur should be eliminated or rubberized. Precautions that all machine operators should follow include:

1. **rubberize all chains**
2. **reduce the speed of transfer, elevator, and piler chains to 70 feet per minute**
3. **never drop tubers more than 6 inches**
4. **pad the sacking platform, truck bed, and piler hopper**
5. **DO NOT THROW tubers into piler hopper—pour steadily**
6. **use small boards in the bottom of bulk trucks, so only a few potatoes can be released at a time**
7. **do not walk on piled tubers**
8. **if possible allow the potato temperature to increase to 45°F. before removing from storage.**

Whether the potatoes are put into the storage through the ceiling, or whether they are unloaded into a piler on the floor and elevated to the top of the pile makes little difference **provided equal care and caution are taken to eliminate injuries and bruises.**

A well-supervised harvest and handling program can make more money for a farmer than a complete complement of ventilating equipment. All the storage equipment obtainable cannot make sound tubers from bruised and injured ones. **Uninjured tubers store well with little loss. Injured tubers require special care and loss is usually high.**

[1]Sparks, Walter C., *Effects of Mechanical Injury Upon the Storage Losses of Russet Burbank Potatoes.* Univ. of Idaho Agr. Expt. Sta. Bul. 220. 1954.

Idaho Potato Storages

Construction and Management

By

Walter C. Sparks, Galen McMaster, J. E. Dixon, D. W. Works, Eric B. Wilson[2]

The necessity of maintaining high-quality, sprout-free potatoes over an extended storage period for the fresh market and the processing industry, has resulted in an increased emphasis on the proper construction and management of potato storage facilities. In years past, a hole dug in the ground, covered with straw and soil, usually kept tubers in a marketable condition until spring. Now, with increased emphasis on maintaining high quality and appearance over a longer storage period, improved temperature and humidity control are necessary. Well designed track-side and farm storages, with automatic air ventilation and temperature control systems, are becoming a necessity and are replacing the older types.

PURPOSES OF STORAGE

Potatoes are stored (1) to maintain the tubers in the most edible and salable condition during the winter, spring, and early summer months, (2) to provide a uniform supply to the fresh market and processing industry, (3) to keep seed potatoes in good condition, and (4) to maintain high processing qualities throughout the entire storage season.

A potato storage properly constructed and managed prevents the development of rot, retards growth of sprouts, reduces dehydration and excessive moisture loss, and reduces the number of pressure bruises and black spot.

TYPES OF STORAGE

Many types and sizes of structures are used to store potatoes. Each has its advantages and disadvantages. Choice of the type depends upon cost, available material, convenience, space requirements inside the cellar, and local conditions such as water table, rock and soil structure, and sub-soil winter temperatures.

Most structures used for storing potatoes in Idaho can be classified into two types: The partially below-ground, pole-type structure; and the above-ground, wood or steel frame building.

Many requirements are standard for a good storage structure, regardless of size or type. These are:

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1. The building must be structurally sound. Properly designed footings and structural members must be used so the storage building will stand rigidly under its dead weight load (rafters, insulation, roofing material) and all expected live weight loads (snow, wind, and rain). The roof load may be as high as 100 pounds per square foot of roof area.
2. The building must be economical.
3. The building must be easily accessible. Since the cellar may be filled or emptied under poor weather conditions, access to good roads is important and adequate filling and emptying facilities are necessary.
4. The building must be constructed to withstand adverse weather conditions.
5. The building must be suitable for maintaining a favorable inside atmosphere.

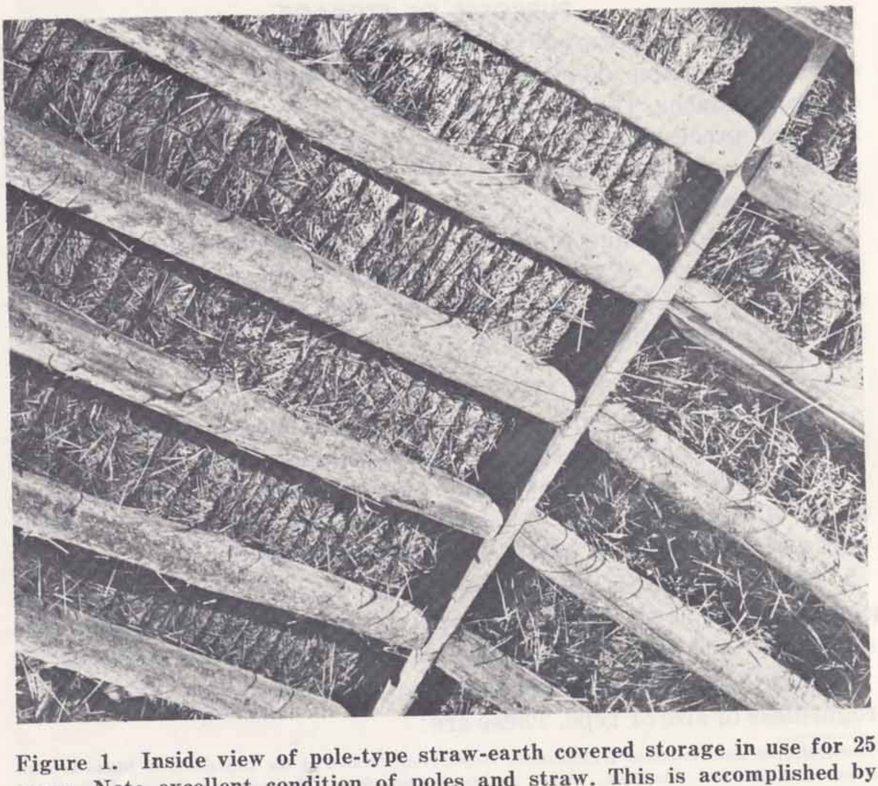

Figure 1. Inside view of pole-type straw-earth covered storage in use for 25 years. Note excellent condition of poles and straw. This is accomplished by use of sufficient insulating material at time of construction.

Pole-Type, Partially Below Ground

The pole-type cellar is the most common type in Idaho. This type may have either a soil or metal roof. Materials are inexpensive and the type of construction can utilize unskilled labor. The structure is popular because it does a good job and is inexpensive.

The soil roof type is usually built with timbers for rafters and three covering layers: A first layer of small branches, rough lumber or woven wire; a second layer of bales of straw; and a third layer of several inches of soil to keep out the moisture. Both the soil and straw act as insulation. A minimum depth of one bale of straw (16-18 inches of compressed straw) should be used. Loose straw is stuffed in the cracks among the bales before cutting the bale ties. After cutting the bale ties, an additional 3 or 4 inches of loose straw is spread on top of the baled straw. Soil is spread on top of the straw to a depth of 4 to 6 inches, if a medium to heavy top soil is used. An 8-inch depth is recommended if subsoil is used or if severe erosion is expected. Only in areas of the state where the rainfall is less than 15 inches can the soil roof type structure be used effectively without danger of damage from moisture. Some of these storages with pole, wire, straw and earth roofs have lasted more than 25 years and are still in excellent condition (figure 1). Remember, however, that wood in very humid air or in contact with the earth, is subject to accelerated decay. Thus, a preservative

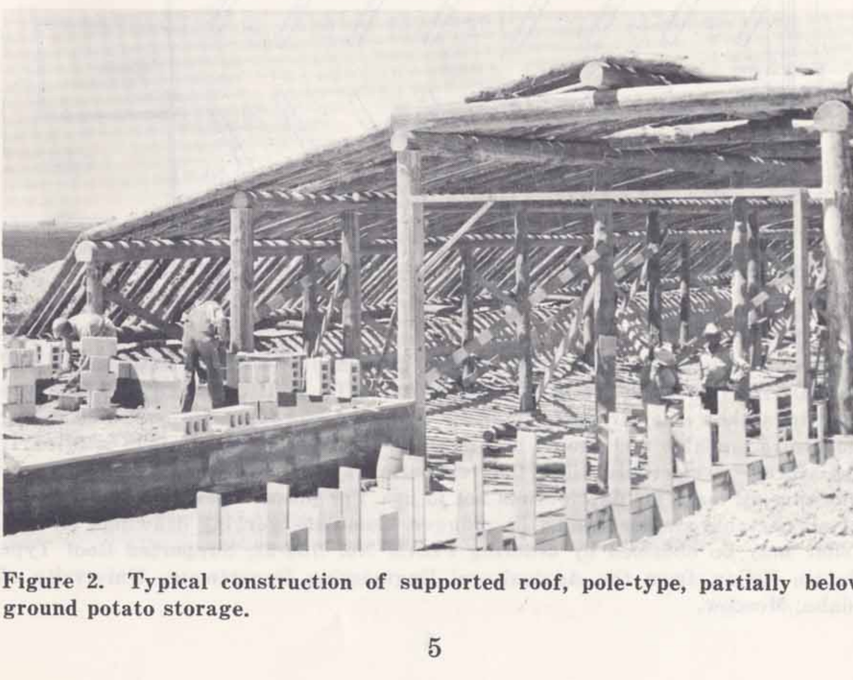

Figure 2. Typical construction of supported roof, pole-type, partially below ground potato storage.

treatment of posts and poles prolongs the life and reduces the maintenance of the structure.

Footings should be carefully designed for this straw and soil-covered cellar. The normal roof load of this type of structure is high. In addition, a certain amount of moisture will be absorbed in the straw and soil thus adding to the roof load. Pole columns, beams, and footings will be required to support a load as high as 100 pounds per square foot of roof area.

Most farm and commercial cellars of the partially below ground type are included in two groups according to structural principles. These are buildings with supported roofs; i.e., roof beams and rafters held up by columns, and clear span (self-supported) roofs.

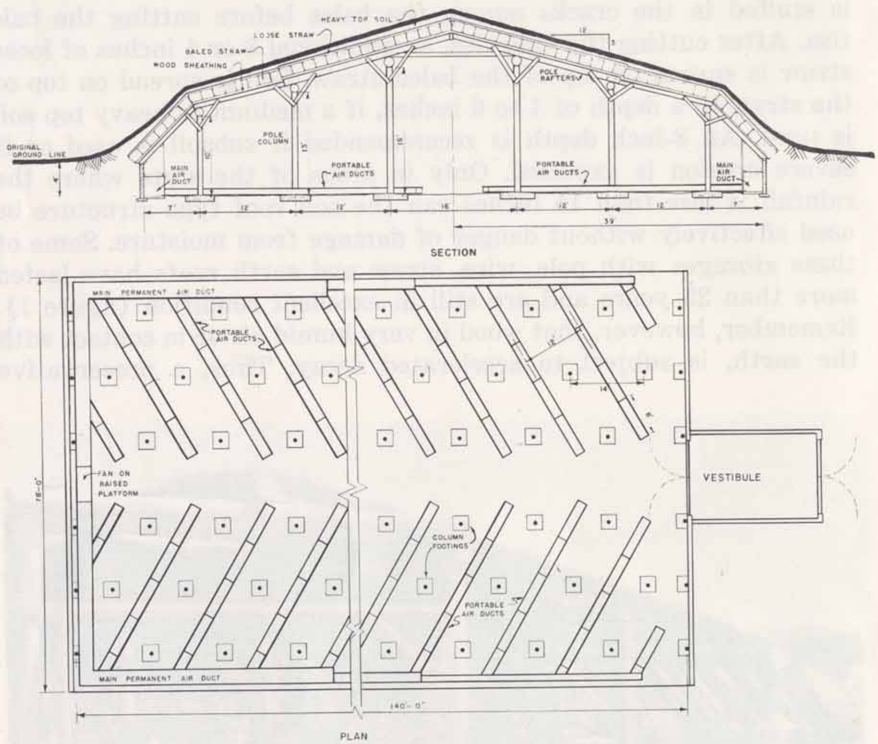

Figure 3. Floor plan and cross section drawings of a PARTIALLY BELOW GROUND, SUPPORTED ROOF TYPE POTATO STORAGE CELLAR. These drawings show the air ducts in place as if the storage were full. The center ducts are portable and should be placed on the floor as the storage is filled. If the storage is partially filled, the ventilating system can be made effective by blocking all main air duct outlets not in use. For proper operation the free end of all portable air ducts must be plugged. Complete working drawings for this cellar may be obtained by ordering PLAN No. .734-22, Supported Roof Type Potato Cellar, from the Agricultural Engineering Department, University of Idaho, Moscow.

Supported Roofs

Cellars with supported roofs can be wide without excessive ceiling height. The roof, however, should have sufficient slope so that surface drainage takes place. A slope of about 3 in 12 is desirable for soil-covered supported roof cellars. The soil surface should be smooth and free from depressions. Typical construction details for a supported roof cellar are given in figures 2 and 3.

Clear Span (Self-Supported) Roof

Structural principles of the clear span cellar are considerably different from those of the supported roof. A clear span of the entire cellar width, usually 40 to 45 feet for a pole rafter cellar, is accomplished by using a simply constructed pole truss. This truss is commonly in the form of an A-frame. Since the footings supporting an A-frame truss must bear both a large outward force and the downward weight of the roof, careful designing is necessary. Concrete footings must be of sufficient size to reduce the load to the safe bearing capacity of the soil. (See figure 4).

The two factors that govern the slope of a clear span A-frame roof truss are footing load and soil erosion. To keep the outward force on the footings to a minimum, the rafters should be as steep as possible. But, if the roof is to be covered with soil, the slope of the roof must not be so steep that the soil will slip or erode. Experience has shown that a medium-textured top soil will remain in place satisfactorily on an A-frame type roof with a slope of 8 in 12 (approximately 34 degrees from horizontal). Typical construction details for an A-frame cellar are given in figures 5 and 6.

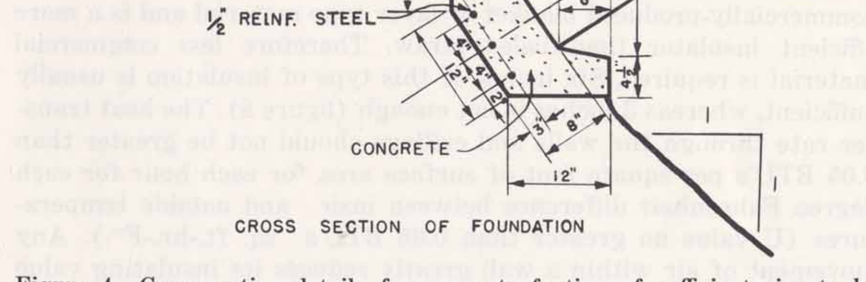

Figure 4. Cross-section detail of a concrete footing of sufficient size to be within the bearing capacity of a soft clay soil.

Figure 5. Typical construction of a self-supported A-frame type potato storage.

Above-Ground Potato Storage

Above-ground potato storage buildings are usually designed and sold by commercial manufacturers. The basic structural members are steel, wood (laminated, poles, timbers), concrete, or cinder blocks. Any building adequately constructed to the proper dimensions, properly insulated and ventilated, will serve satisfactorily. An example of one type of such a building is seen in figure 7.

The insulation used for above-ground storages is usually a commercially-produced blanket or layer type material and is a more efficient insulator than baled straw. Therefore less commercial material is required. Six inches of this type of insulation is usually sufficient, whereas 3 inches is not enough (figure 8). The heat transfer rate through the walls and ceilings should not be greater than 0.05 BTU's per square foot of surface area for each hour for each degree Fahrenheit difference between inside and outside temperatures (U value no greater than 0.05 BTUs/ sq. ft.-hr.-F°.). Any movement of air within a wall greatly reduces its insulating value (thermal resistance). To eliminate such air movement, the blanket

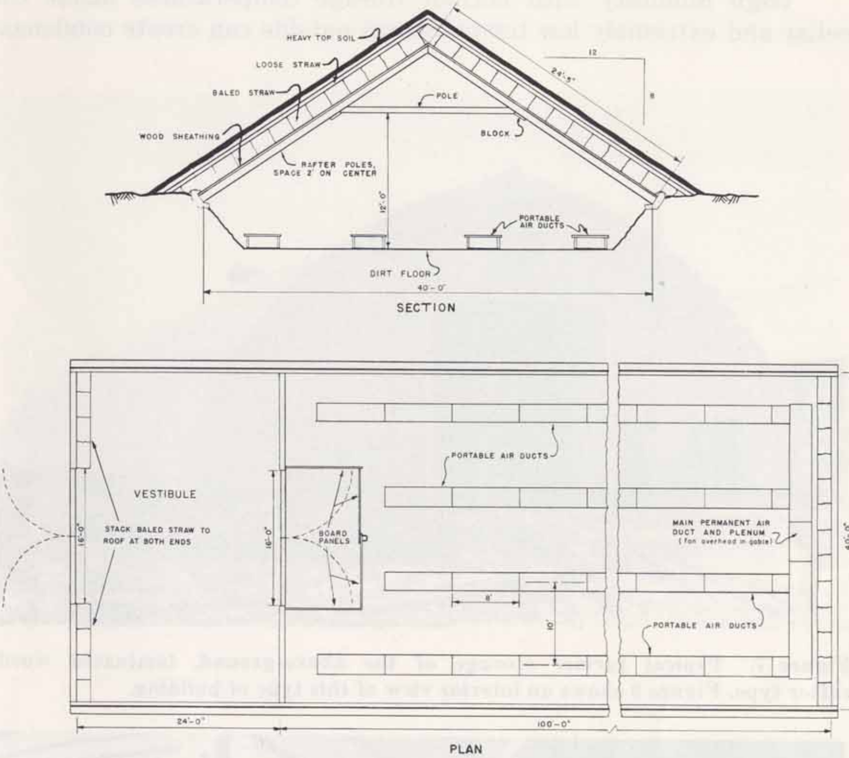

Figure 6. Floor plan and cross section drawings of a PARTIALLY BELOW GROUND, A-FRAME TYPE POTATO STORAGE CELLAR. These drawings show the air ducts in place as if the storage were full. The center ducts are portable and should be placed on the floor as the storage is filled. For proper operation the free end of all portable air ducts must be plugged. This is true for a partially filled storage as well as a filled storage. Complete working drawings for this cellar may be obtained by ordering PLAN No. .734-21, A-frame Type Potato Cellar, from the Agricultural Engineering Department, University of Idaho, Moscow.

insulation should be flanged and thoroughly tacked to the rafter or stud so no air can flow around the edges of the insulating material.

Since potatoes should be stored at a high relative humidity (90% or higher), provisions should be made to protect the building and insulating materials from condensation. **The most effective way to prevent condensation on the inside surface of the storage is to provide enough insulation so the inside air and the inside surfaces are nearly the same temperature.** When they are nearly the same temperature, no moisture will condense and drip down onto the potatoes.

High humidity with normal storage temperatures inside the cellar and extremely low temperatures outside can create condensa-

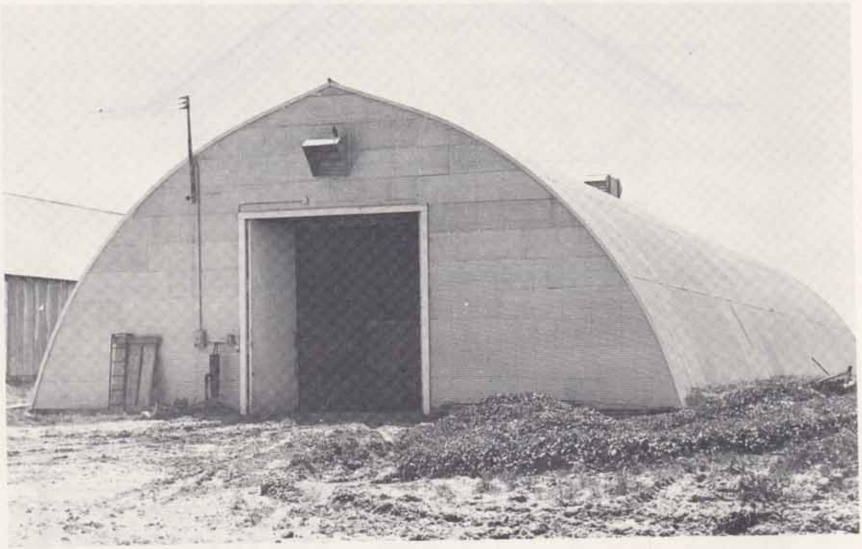

Figure 7. Typical farmer storage of the above-ground, laminated wood, rafter type. Figure 9 shows an interior view of this type of building.

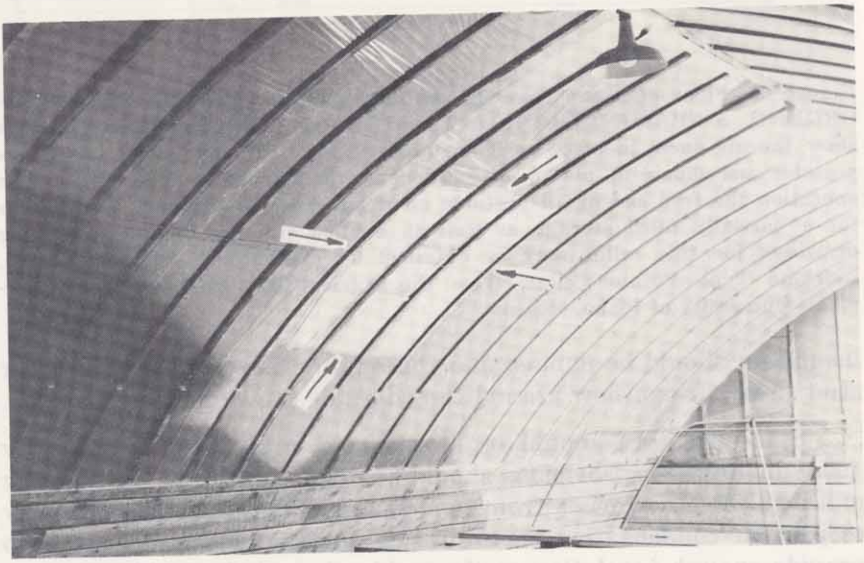

Figure 8. This figure shows condensation of moisture on a test section in the Aberdeen Branch Experiment Station potato storage research building where only 3 inches of insulation were used. The areas around the test section with 5½ inches of effective insulation had no condensation.

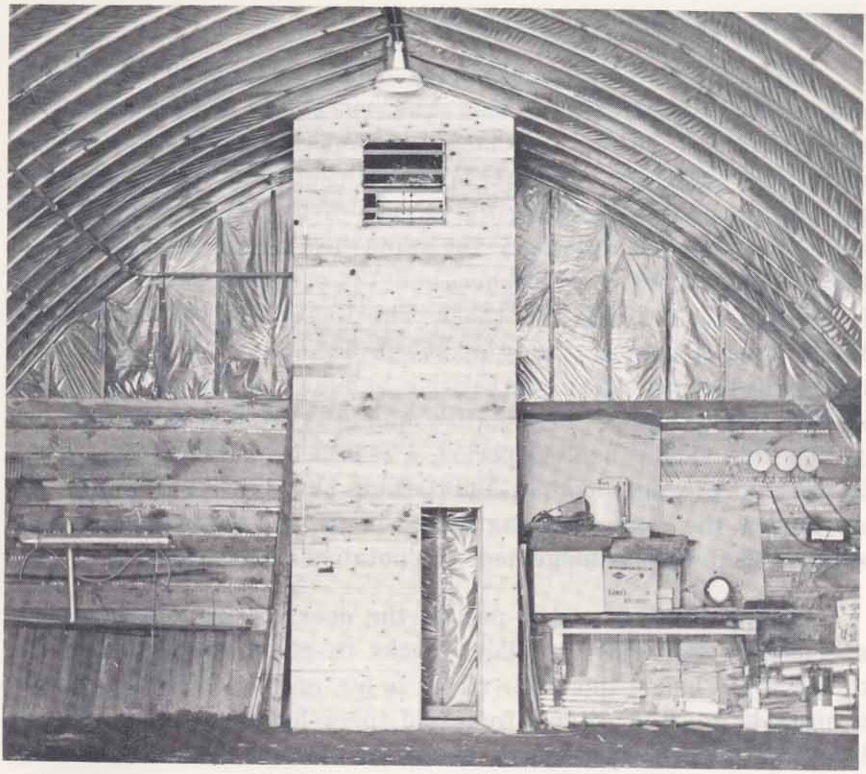

Figure 9. Vapor barrier of polyethylene film lining inside of potato storage.

tion within the wall and ceiling. To prevent this, all moisture must be excluded from the wall and ceiling. The most economical way to do this is to place a vapor barrier on the **inside** of the walls and ceiling, (the point of highest vapor pressure). This can be accomplished by lining the inside of the storage with polyethylene plastic (4 mil. or thicker), tar, sealed aluminum foil, or other suitable vapor barrier material (see figure 9). Since the humidity in a potato storage is very high, the vapor barriers often used for homes have too great a permeability for potato storage use.

STORAGE MANAGEMENT

Proper management of a potato storage includes control of temperature, humidity, and air circulation, so that stored tubers retain maximum appearance and food value with a minimum loss from rot, shrinkage, and sprouting.

Storage management can be divided into three definite periods: (1) the wound healing and curing period, (2) the storage or holding period, and (3) the removal or grading and sacking period. Each period has a particular function and should be carefully managed.

The Wound Healing and Curing Period

The wound healing and curing period is that period immediately following harvest. During this period the bruises and other wounds caused during the harvesting operation heal over, i.e., a wound periderm or suberized layer forms preventing entrance of rot organisms and reducing the danger of rot. Two conditions are usually considered necessary for rapid healing of wounds: (1) A temperature of 45°F. or higher, and (2) a high relative humidity in the air surrounding the tuber. The Russet Burbank variety in Idaho heals about as readily at 45° to 50°F. as it does at warmer temperatures, providing the relative humidity of the storage cellar is 90% or higher. If the relative humidity of the storage is low during this wound healing period, a starch layer may form over a bruise and prevent healing. **Maintaining sufficient humidity in the air during the wound healing period is one of the most important steps in the proper management of a potato storage cellar.**

During the harvesting period, the doors of the storage cellar are usually left open to allow trucks to go in and out, and the temperature inside the cellar raises to 50° or even 60°F. Therefore, to provide good conditions for rapid tuber healing, proper relative humidity must be maintained inside the storage cellar. First, thoroughly wet down (soak) the cellar during the late summer months so that **at the time of storage, the floor of the storage is moist but not muddy.** Different methods of maintaining a high humidity are:

1. wetting down the alleyway or vestibule
2. keeping wet burlap sacks in or by an air stream
3. blowing air across a free water surface
4. spraying a fine mist of water into an air stream.

If water rot or field frost is present, a great deal of harm can be done by keeping the temperature higher than 50°F. immediately after harvest. A much safer practice is to reduce the temperature of the storage cellar as rapidly as possible to 40°F. Healing is slower at 40°F. but will take place if the humidity is kept high (above 90% r.h.). Practically no water rot infection occurs at this temperature.

The rate of weight loss during the wound healing and curing period is greater than at any other period (figure 10). This is the

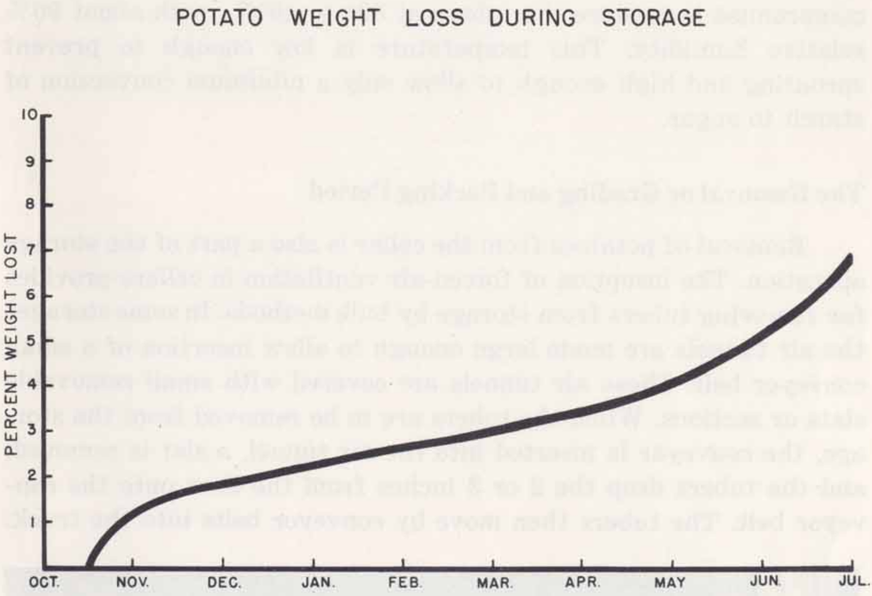

Figure 10. Potato weight loss during storage.

time when the respiration rate is high and the amount of water lost through injuries is also high. Careful handling of tubers and proper management of equipment and the storage cellar during harvest and filling the storage will reduce weight loss during the entire storage period.

The Holding or Storage Period

The second phase of storage management is the holding or storage period. In general the higher the storage temperature above 40°F., the shorter the storage period will be without sprouting and excessive shrinkage. Tubers can be kept for only 12 to 15 weeks at a temperature of 50°F. before they begin to sprout, but they can be kept 40 weeks or more without sprouting at 40°F. even if no chemical sprout inhibitors are used. Thus, if potatoes are to be stored until late May, June, or July without excessive dehydration or sprouting, they must be kept at or slightly below 40°F., and the relative humidity must be maintained at 90% or above. If chemical sprout inhibitors are used, the temperature may be slightly higher.

The lower the temperature below 38°F. the greater is the conversion of starch to sugar. Sprouting increases as temperature increases above 40°F. Therefore for long-term storage, the best compromise is to store the tubers at 39° to 40°F., with about 90% relative humidity. This temperature is low enough to prevent sprouting and high enough to allow only a minimum conversion of starch to sugar.

The Removal or Grading and Packing Period

Removal of potatoes from the cellar is also a part of the storage operation. The inception of forced-air ventilation in cellars provides for removing tubers from storage by bulk methods. In some storages the air tunnels are made large enough to allow insertion of a small conveyor belt. These air tunnels are covered with small removable slats or sections. When the tubers are to be removed from the storage, the conveyor is inserted into the air tunnel, a slat is removed, and the tubers drop the 2 or 3 inches from the floor onto the conveyor belt. The tubers then move by conveyor belts into the truck.

Figure 11. The mechanical scoop conveys the bulk potatoes from the storage cellar to a bulk truck.

In most of the larger storages today, tubers are removed by means of a self-propelled mechanical scoop. The scoop is forced into the pile of potatoes (figure 11). As the tubers roll down the face of the pile, they are caught on a conveyor belt and carried into the truck.

Some storages are built adjacent to the processing or grading plant, and the tubers are removed by means of water flumes. The

Figure 12. A water flume is used here to move potatoes out of storage.

water is piped to the back of the bins and flows under the bin of potatoes in the same ducts used for air distribution. Boards cover the air-water duct and are removed to allow the tubers to roll down into the water for transporting to the grader or processing plant (figure 12).

Care must be exercised in removing tubers from storage regardless of the method used.

Cold brittle potatoes are easily injured. Research at the University of Idaho Aberdeen Branch Station found that over 2 per cent cullage could be prevented by warming the tubers from 35° to 40° before they were handled.[3] Therefore, warm tubers to a temperature of 40° to 45°F. or more before removing them from the storage. Closing the air vents to prevent cold air from entering the storage is an easy way to raise the temperature. Heat from the respiring tubers will be enough to raise the temperature several degrees in a few days. In large storages, where potatoes are taken out of storage over a period of several months, a warm-up period may have to be omitted to prevent sprouting of those tubers remaining in the storage cellar. In all cases, **careful handling must be practiced to reduce injury.**

VENTILATION OF STORAGES

The main reason for ventilating potato storage cellars is to maintain the desired temperature and humidity within the pile of potatoes. Ventilation can be done by manually opening and closing the doors, or by using automatically controlled air circulating systems. The oldest method of ventilation and temperature control is manual operation of the doors. Constant attention and supervision are required so that doors are open enough to provide cooling, but not enough to allow freezing. Various automatic temperature control units are available that will reduce the number of man hours required to keep storages at the proper temperatures.

A completely automatic temperature control system requires refrigeration. In Idaho, potatoes are not usually stored into late summer. Since refrigeration equipment is expensive, the completely automatic temperature controlled system is not discussed here. If such a system is desired, an engineer should be consulted.

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[3] Sparks, Walter C., "*Mechanical Injury to Potatoes from Harvester to Consumer*," Univ. of Idaho Agr. Expt. Sta. Bul. 280, 1957.

Ventilating Systems

Two ventilating systems will be discussed here. Both are partially automatic and require a minimum of attention. Remember, however, that mechanical devices are involved, and none of them is without its limitations. In large storages, a system is used which is a semi-automatic or air mixing, proportioning damper type system. In this system, the proper amount of cold outside air is mixed with inside air by use of dampers and a mixing chamber to provide the proper air temperature for cooling the pile of tubers. The desired temperature is maintained by thermostats which control dampers and fans to mix and circulate the air.

The other system to be described is the exhaust fan system. This system is useful in smaller storages and does not involve all of the equipment needed in the semi-automatic system.

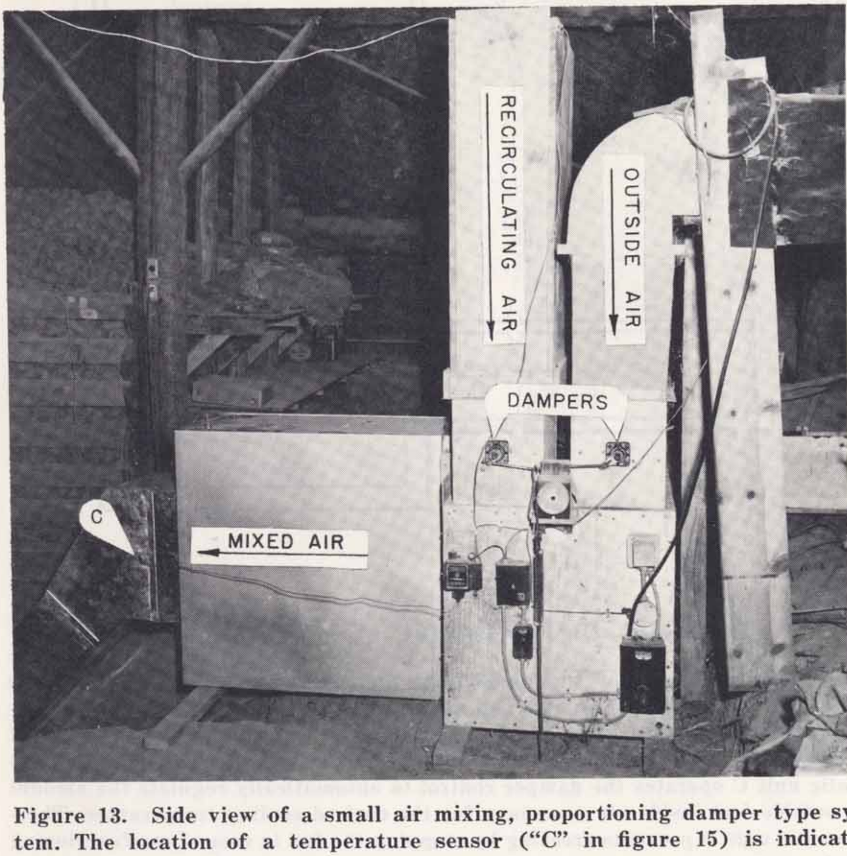
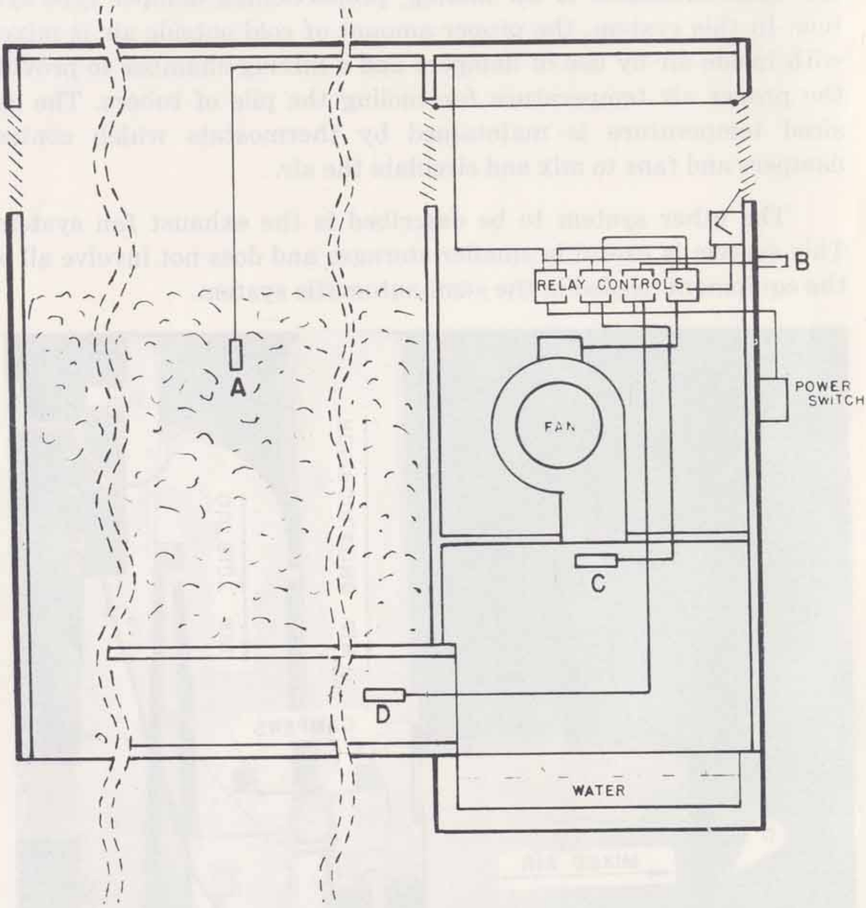


Figure 13. Side view of a small air mixing, proportioning damper type system. The location of a temperature sensor ("C" in figure 15) is indicated above by "C."

Semi-Automatic System

This temperature control system involves at least three temperature sensors that relay responses to mechanical devices. The sensors must be located in regions of critical temperature requirements, usually at some distance from the switching portion of the thermostat. Figures 13, 14 and 15 illustrate this setup. The sensing



WITHOUT DIFFERENTIAL CONTROL

Figure 14. Diagram of the air-mixing, proportioning damper type system WITHOUT differential control. The sensing element A in the potato pile activates the controls that turn the fan on to cool the potatoes. Thermostatic unit B stops the fan when the outside air temperaure is too warm. The thermostatic unit C operates the damper control to automatically regulate the amount of outside and inside air necessary for the desired cooling temperature. Thermostatic unit D prevents freezing by stopping the fan in case of malfunctioning equipment.

element (A in Figures 14 and 15) of one thermostat is located in the pile of potatoes. This sensor activates a control that turns on a fan when the potatoes reach a temperature above 40°F., and that turns the fan off when the potato temperature drops below 38°F. The second thermostat is installed with its sensing element (B in figure 14) in or near the incoming air stream. This thermostat

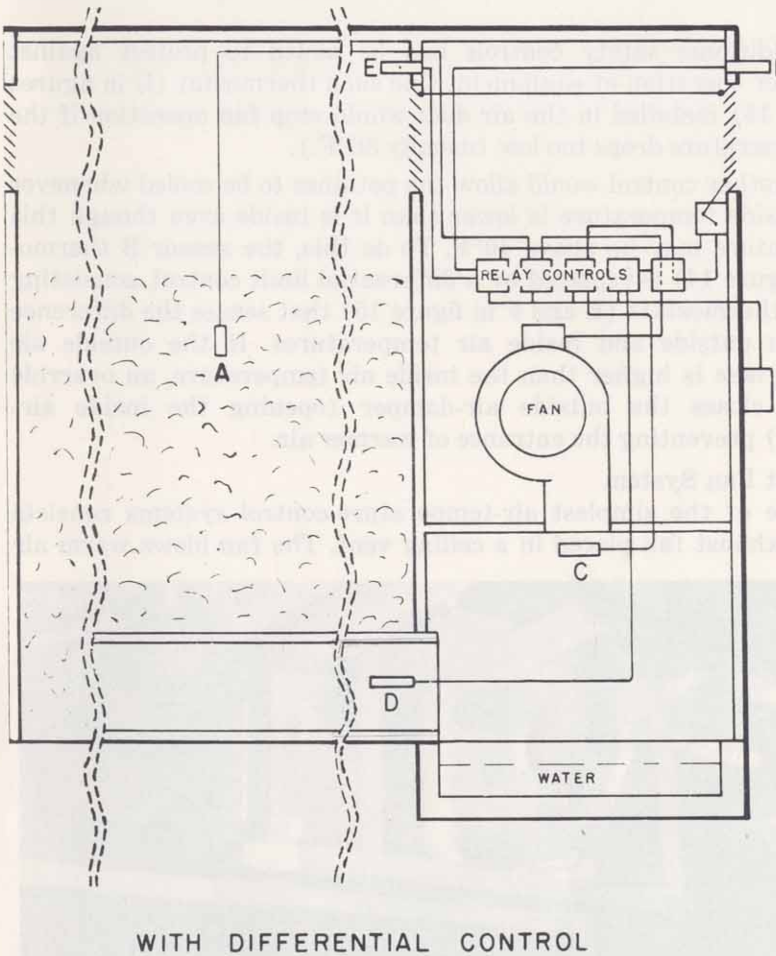


Figure 15. This diagram INCLUDES the differential control as a protective device in an air-mixing, proportioning damper type system. The sensing element, A, in the potato pile activates the controls which turn the fan on to cool the potatoes. The thermostatic unit C operates the damper control to automatically regulate the mount of outside and inside air necessary for the desired cooling temperature. Thermostatic units E and F close the outside air inlet damper whenever the air is warmer outside than it is inside. Thermostatic unit D prevents freezing by stopping the fan in case of malfunctioning equipment.

protects the potatoes from being warmed by preventing air-flow when outside temperatures are above 40°F. A third thermostat (C in figures 13, 14 and 15) operates the damper control and is activated by a sensor placed in the main air tunnel, or mixing chamber. This automatically regulates the amount of outside and inside air necessary to provide the proper cooling temperature (usually 38°F.).

Additional safety controls can be added to protect against improper operation of equipment. One such thermostat (D in figures 14 and 15) installed in the air duct would stop fan operation if the air temperature drops too low (usually 36°F.).

Another control would allow the potatoes to be cooled whenever the outside temperature is lower than it is inside even though this temperature may be above 40°F. To do this, the sensor B thermostat (figure 14) is replaced by a differential limit control, consisting of two thermostats (E and F in figure 15) that senses the difference between outside and inside air temperatures. If the outside air temperature is higher than the inside air temperature, an override control closes the outside air-damper (opening the inside air-damper) preventing the entrance of warmer air.

Exhaust Fan System

One of the simplest air-temperature-control systems consists of an exhaust fan placed in a ceiling vent. The fan blows warm air

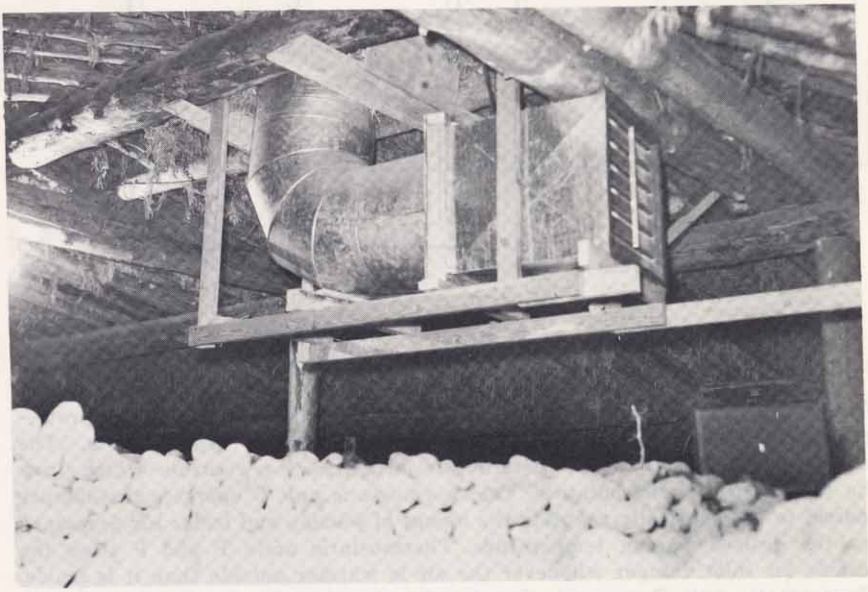


Figure 16. Exhaust fan unit placed in an air vent in the ceiling to blow warm air out.

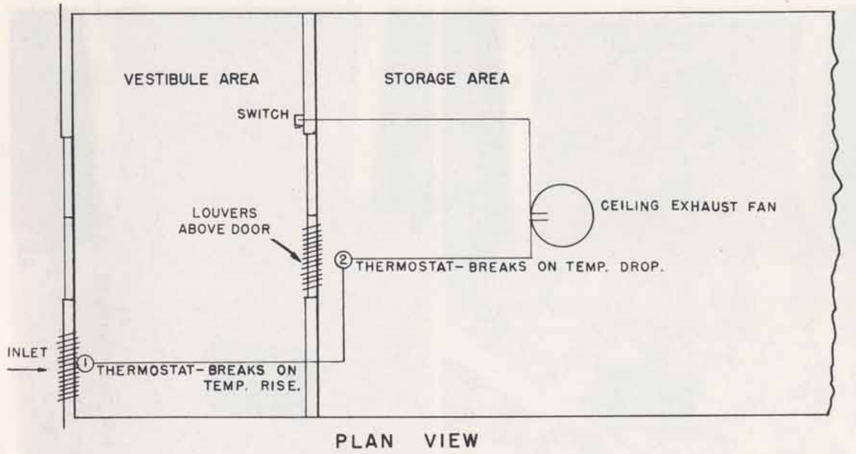


Figure 17. Diagrammatic sketch of exhaust fan air temperature control system.

out (figure 16). This creates a reduced pressure and cold air is drawn first into a mixing chamber and then into the storage. The intake is usually in one end of the cellar.

Most cellars have a vestibule or equipment storage space that can serve as a mixing chamber. The vestibule provides space where the cold outside air is mixed with the inside air, and will be warm enough to prevent freezing or chilling of the tubers. Some systems of this type are manually operated. All that is necessary to convert a manually operated exhaust fan system into a partially automatic air temperature control system is to provide two thermostats connected in series with the exhaust fan motor. (See figure 17). A thermostat that breaks contact when the temperature falls is placed in louvers above the door between the vestibule and the potato storage area. This thermostat acts as a protective device against freezing the potatoes. The temperature setting can be adjusted to the desires of the individual operator but is usually set from 36° to 38°F. to prevent chilling. The second thermostat is placed on the outside of the building or in the intake air duct. The purpose of this thermostat is to prevent drawing warm air into the cellar when the outside air is warmer than that being maintained inside. When the air temperature outside rises higher than the temperature of the potatoes inside (usually 40°F.), this thermostat automatically turns off the exhaust fan.

In this type of air-temperature-control system, the humidity should be checked frequently, because the warm air being exhausted carries a large amount of moisture from the cellar. Therefore, some provision should be made to add moisture to the incoming air.

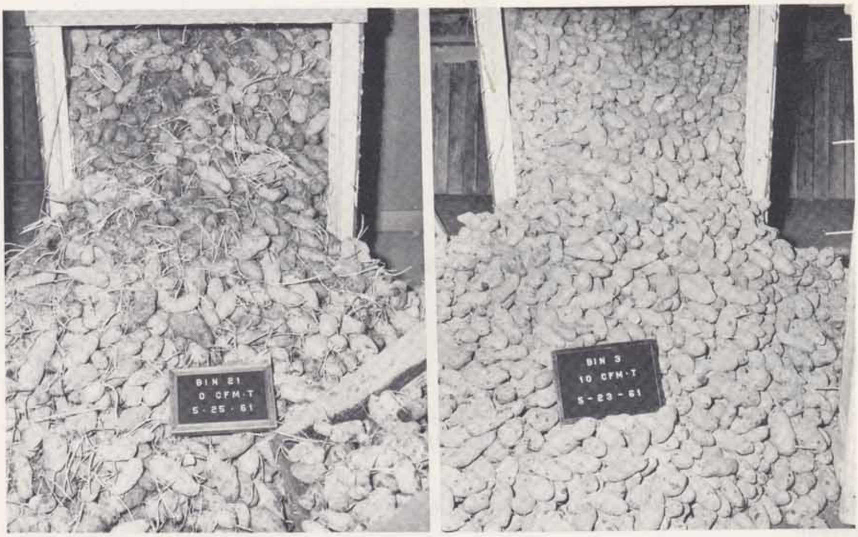


Figure 18. Potato tubers receiving no air (0 cfm/T) and those receiving 10 cfm/T. Note the absence of sprouts on the tubers receiving 10 cfm/T. The fan operation was on an intermittent basis.

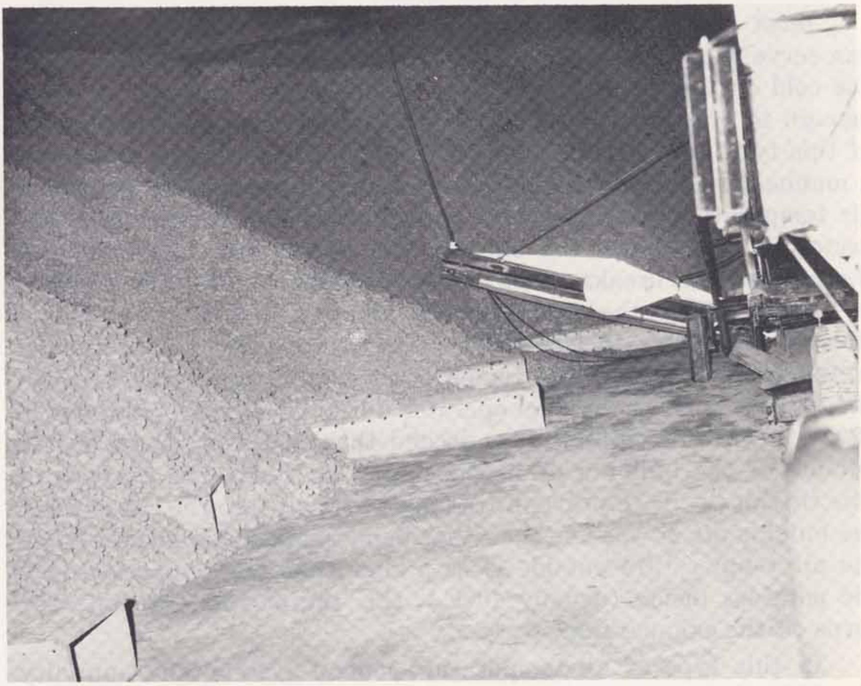


Figure 19. A large commercial storage showing air ducts placed every 10 feet that provide excellent air distribution throughout the pile. The ducts may be portable (above) or stationary.

Amount of Air

Only enough air needs to be supplied to the tubers to provide the desired uniform temperature throughout the pile. Research carried on by the University of Idaho Aberdeen Branch Experiment Station indicates that 10 cubic feet of air per minute per ton (cfm/T) of potatoes supplied on an intermittent basis will maintain

Figure 20. The temperature sensing unit should be placed directly in the pile of tubers, usually from 1 to 1½ feet from the top of the pile.

a uniform temperature throughout a pile of potatoes 20 feet deep[1]. This air-flow will keep potatoes in a firm, sprout-free condition into late May, without the aid of refrigeration (figure 18). Figure 19 shows a large commercial potato storage cellar with air ducts placed every 10 feet. This method has proved to be very satisfactory. Other designs are acceptable providing air movement and temperature are maintained at desirable levels. The temperature sensing unit (A in figures 14 and 15) should be placed directly in the pile of potatoes at the warmest spot, usually from 1 to 1½ feet from the top of the pile (figure 20). The fan needs to run only when the temperature of the potatoes in the pile is higher than the desired storage temperature. This sensor will also turn the fan off when the potatoes are cooled to a given temperature (usually 38° or 39°F.). The 10 cfm/T is provided to cool the potatoes as rapidly as possible, whenever the outside temperature is low enough.

For potatoes stored no later than March or early April, 5 cfm/T has given good results. However, if tubers are to be stored until late May, the 5 cfm/T airflow is inadequate to keep the tubers cool and to prevent sprouting (figure 21 compared to figure 18).

Duct Design and Fan Selection

Many factors affect duct design, such as air quantity, velocity, pressures, temperatures, altitude, duct shape, and materials of construction. An engineer considers all relevant factors and determines the most economical design consistent with proper functioning of the ventilating system. The following information makes possible the approximation of duct and fan sizes.

It is assumed that duct systems similar to those indicated in figures 3 and 6 will be used in the majority of Idaho potato storages. Air is delivered to the stored potatoes through a series of 1" diameter holes in each side of the portable air duct. Table 1 gives the recommended hole spacing for various depths of potatoes. Air should be allowed to leave the ducts only through the holes drilled for that purpose.

TABLE 1. Hole spacing in both sides of portable air ducts for various depths of potatoes with air ducts 10 feet apart.

Depth of Potatoes	6 ft.	8 ft.	10 ft.	12 ft.	16 ft.	20 ft.
Holes Spacing	20 in.	15 in.	12 in.	10 in.	7½ in.	6 in.

All of the information included here is based on the recommended spacing of 10 feet between centers of portable air ducts and an air pressure of 0.5" of water within the delivery ducts. If a wider spacing is contemplated, the additional potatoes ventilated per delivery duct must be considered. Adequate air distribution

[1]Sparks, Walter C., "Potato Storage Air Volume Research Results Reported," *Univ. of Idaho Agr. Sci.* Vol. 47 No. 2, 1962.

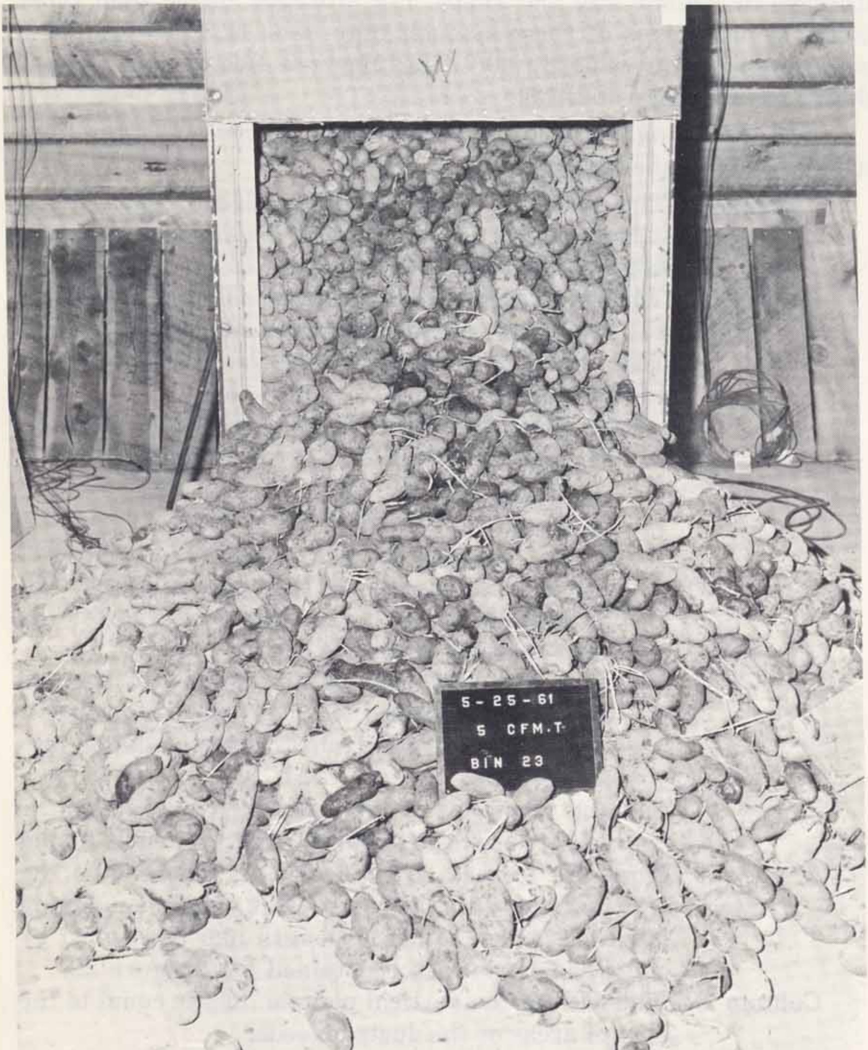


Figure 21. Potato tubers receiving 5 cubic feet of air per minute per ton on an intermittent basis.

cannot be expected with spacing over 12 feet. If an air pressure lower than 0.5" of water is desired in the ducts, the holes must be closer together, however, a loss in uniformity of air distribution will result.

Table 2 gives duct sizes and fan requirements for a number of typical-size potato storages. These may be used directly for storages of similar size and shape. For storages longer than those listed, combinations of these systems may be used. For example, a potato storage 40' wide by 300' long may use two of the systems shown for a storage 40'x150'.

The following information and explanations are offered in connection with the data in Table 2.

Column 3 The quantity of air to be supplied by each fan is calculated at 10 cfm per ton. Tonnage is based on potatoes weighing 42 lbs. per cu. ft.

Column 4 This column gives the static pressure against which the fan must deliver the indicated quantity of air. This static pressure was calculated according to the formula $SP = K_e (P_1 + h_e + h_f)$

where: SP is the static pressure in inches of water,

K_e is a correction factor for altitude and temperature (K_e for 4000 ft. and 40°F = 1.18 K_e for sea level and 70°F = 1.00)

P_1 is the static pressure required at the first 1-inch hole in the last portable air duct. (P_1 is assumed to be 0.5" of water and is for the duct farthest from the fan.)

h_e is the head loss of air entry into the fan chamber (assumed to be 0.08" of water).

h_f is the head loss from friction of ducts, tees and elbows.

Tee and elbow losses are calculated by finding the equivalent length of straight duct for each fitting from the formula $L = 6.67 \times w$, where w is the width of the duct in inches. This equivalent fitting length is added to actual length and multiplied by the Head Loss Factor obtained from figure 22.

Column 5 The area of the vertical plenum duct is equal to the sum of areas of the ducts it feeds.

Column 6 Horizontal main ducts may be tapered as the air is discharged along their length. The cross-sectional area at any point may be calculated by the formula $A = Q/V$, where Q is the air being carried in cfm and V is the permissible velocity in feet per minute. (For these calculations 1000 ft/min has been used as permissible velocity). Square ducts have less resistance to air flow than rectangular ducts of the same cross-sectional areas and are the only shape suitable for use with figure 22.

TABLE 2. Fan Selection and Duct Sizes for Typical Idaho Potato Storages.

Size of Storage	FAN SELECTION			DUCT SIZES			
	No. of Fans	Fan Capacity	Static Pressure	Vertical Plenum or Main	Large End Horizontal Main	Small End Horizontal Main	Delivery or Portable Air Duct
(1)	(2)	(3)*	(4)*	(5)*	(6)*	(7)*	(8)*
Feet		CFM	In. of Water	inches	inches	inches	inches
W x L x D				w x d	w x h	w x h	w x h
40 x 100 x 10	1	8,400	1"	24 x 52	24 x 26	24 x 26	30 x 12
40 x 150 x 12	1	15,120	1"	33 x 66	33 x 33	33 x 33	40 x 15
40 x 200 x 12	1	20,160	1"	38 x 76	38 x 38	38 x 38	45 x 18
60 x 100 x 10	1	12,600	1¼"	30 x 62	30 x 31	12 x 31	15 x 7
60 x 150 x 12	1	22,700	1¼"	40 x 82	40 x 41	12 x 41	15 x 8
60 x 200 x 12	2	15,120	1⅛"	46 x 48	46 x 48	12 x 48	15 x 8
80 x 100 x 10	1	16,800	1¼"	35 x 70	35 x 35	12 x 35	17 x 8
80 x 150 x 12	2	15,120	1⅛"	46 x 48	46 x 48	12 x 48	18 x 10
80 x 200 x 12	2	20,160	1⅛"	54 x 54	54 x 54	12 x 54	18 x 10
80 x 200 x 16	2	26,880	1⅛"	62 x 63	62 x 63	12 x 63	24 x 10

*Column numbers referred to in the text.

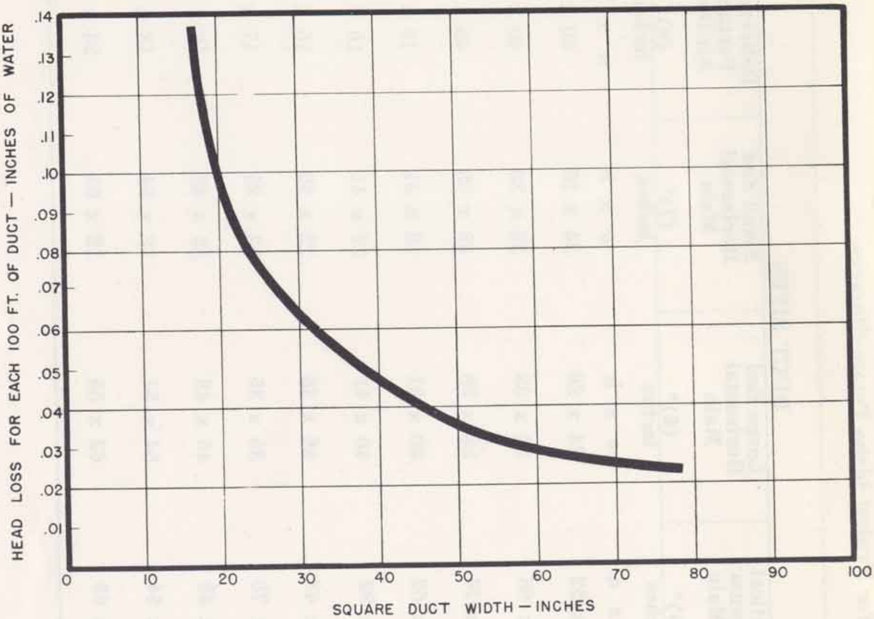


Figure 22. A graph for determining head loss in an air duct with: Air velocity=1000 fpm, square duct, and very rough inside surface.

Column 7 The small end of the horizontal main duct is calculated in the same manner as the large end. However, since it may not be practical to taper both dimensions the height is usually kept constant and the width only is tapered. Also, since narrow ducts will increase the resistance appreciably the width of these ducts should not be less than 12 inches.

Column 8 Portable air duct cross-sectional areas may be obtained by the same formula $A = Q/V$. However, for stability reasons it is usually desirable to construct them wider than they are high. If they are constructed with the width not more than 2½ times the height, a 10% increase in cross-sectional area will compensate for the loss due to shape. Portable air ducts in Table 2 are figured on this basis. The portable air ducts may be tapered. However, the height should not be greater than the width. It is practical to taper from the calculated dimensions at the large end down to a square cross-section at the small end with a side equal to the height at the large end.

All ducts may be constructed straight using the large end dimensions, instead of tapering from large end to small end. This will not diminish the air carrying capacity or uniformity of distribution but will require more building material and will reduce potato storage space.

HUMIDITY

The relative humidity of the air inside the storage cellar should be maintained as high as possible without causing condensation on the tubers or ceiling. The preferred relative humidity is 90% or higher. The relative humidity should not be allowed to drop below 85%.

Moisture is supplied to the air stream by various methods. Some sytems have spray or fog nozzles directly in the air stream; others simply blow the air across a free water surface. This can take place either in the mixing chamber, or in the air distribution tunnels or ducts (figures 14 and 15). Many farmers have found that wetting down the driveway, or alleyway, every few days provides enough humidity to prevent dehydration of the potatoes.

ELECTRICAL WIRING

The electrical wiring for a potato storage should be designed to provide adequate power for the necessary lighting, conveyor and loading equipment, ventilating-fan motor, and controls. For more information on wiring, refer to PNW Bulletin 52, "Planning Farm Wiring." This bulletin is available at your County Extension Agent's Office or from the Mailing Room, College of Agriculture, University of Idaho.

TABLE 3. Typical full-load current for electric motors.

Horsepower	Single Phase 120 volts	Single Phase 240 volts	Three Phase 220 volts	Three Phase 440 volts
	amps.	amps.	amps.	amps.
½	9.8	4.9	2.0	1.0
1	16	8	3.5	1.8
2		12	6.5	3.3
3		17	9	4.5
5		28	15	7.5
7½		40	22	11
10		50	27	14
15			40	20

The following are wiring applications in potato cellars requiring special attention:

Lighting: Allow one 150 watt lamp per 15 feet of alleyway length. Projector lamps with built-in reflectors direct the light

TABLE 4. **Wire sizes required for loads up to 100 amperes for 120 and 240 volts (Based on 1 percent voltage drop)**

Load in Amperes	Length of run in feet for 240 volts							
	60	80	100	150	200	250	300	400
	Length of run in feet for 120 volts							
	30	40	50	75	100	125	150	200
15	10	8	8	6	4	4	2	2
20	8	8	6	4	4	2	2	1
25	8	6	6	4	2	2	1	0
30	6	6	4	4	2	1	0	00
40	6	4	4	2	1	0	00	000
50	4	4	2	1	0	00		
70	4	2	2	0	00			
100	1	1	0	000				

TABLE 5. **Wire sizes required for loads up to 100 amperes for 120 and 240 volts (Based on 3 percent voltage drop)**

Load in Amperes	Length of run in feet for 240 volts							
	60	80	100	150	200	250	300	400
	Length of run in feet for 120 volts							
	30	40	50	75	100	125	150	200
15	12	12	12	10	10	8	8	6
20	12	12	12	10	8	8	6	6
25	10	10	10	8	8	6	6	4
30	10	10	10	8	6	6	4	4
40	8	8	8	6	6	4	4	2
50	6	6	6	6	4	4	2	2
70	4	4	4	4	2	2	2	0
100	1	1	1	1	1	1	0	00

downward for more effective use. Standard porcelain lampholders are acceptable, but the use of weather-proof or vapor-tight fixtures is recommended. Light elsewhere in the storage area must be restricted to prevent the potatoes from turning green. Not more than twelve 150 watt lamps may be connected to a 20-amp circuit.

Convenience outlets: Duplex outlets should be provided at each end of the alleyway and in the vestibule for portable tools and other small motor operated equipment. Outlets should be provided approximately every 50 feet. All outlets should be 2-wire grounding type.

Conveyor and loading equipment: Heavy-duty outlets should be conveniently located to supply power for loading and unloading equipment. Wire size to these outlets should be based on 125 percent of the full load current for all motors that start at the same time and 100 percent of the full load current for drive motors on equipment that operate intermittently. See Table 3 for approximate full load current for electric motors.

Ventilating-fan motor: Allow 125 percent of the full load current for the fan motor.

Service entrance: Total all lighting and motor equipment, allowing 125 percent of the full load current for the largest motor and 100 percent of the full load current for all other motors. The fan motor will likely be the largest motor. (Watts divided by the voltage will give current in amperes).

Wire sizes are determined by the connected load and the necessary wire length. The wire size can be determined by referring to Tables 4 and 5. These tables are based on 1 percent and 3 percent voltage drop. To determine the wire size for motor circuits use the table based on 3 percent. The wire size for lighting circuits and service entrance should be determined from the tables based on 1 percent voltage drop.

Potato cellars are considered damp locations. Type N.M.C. (Barn Wire), type U.F. non-metallic cable, electrical metallic tubing (EMT), and galvanized rigid conduit may be used. All cables must include a grounding conductor and be protected by conduit or EMT when brought down a post to a receptacle or other equipment. NOTE: All receptacles must be of the grounding type and must be grounded. Also, all metal raceways, switch enclosures, and electrical equipment (fixed and portable) within reach from the ground must be grounded.[5]

Flexible cords, non-metallic cable, and open wiring on insulators requires a separate grounding conductor to ground all electrical equipment. Metal raceways may be used as the grounding conductor. Grounding must be provided for all portable equipment. Without grounding, a person handling electrical equipment is in danger of receiving a severe shock.

The wiring system has been designed for the potato storage plans illustrated in figures 3 and 6. Complete plans are available from the Extension Agricultural Engineer, University of Idaho. The design includes the wiring for lighting, loading equipment, and the ventilating system.

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[5]Bulletin No. 6A, Potato Cellars, Idaho State Electrical Board, Boise, 1960.