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Potato Storage Design and Operation

Michigan State University

Cooperative Extension Service

Farm Science Series

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POTATO STORAGE Design and Operation

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CONTENTS

	Page
Building and Size of Layout	1
Capacity	1
Pallet Box Storage	2
Structure	2
Foundation	2
Wall Construction	2
Insulation	4
Doors	5
Vapor Barrier	6
Roofs	6
Moving Potatoes In and Out	6
Conveying Into The Storage	6
Conveying Out of Storage	6
Fluming	7
Pallets	9
Temperature and Humidity Controls	9
Recirculating Fan	10
Exhaust Fan	10
Ducts	10
Furnace	10
Controls	10
Management and Operating Procedures	12
When the Storage is Empty	12
Appendix	

POTATO STORAGE DESIGN AND OPERATION

BY J. S. BOYD, A. L. RIPPEN, F. H. BUELOW

Authors are respectively: Professor of Agricultural Engineering; Associate Professor of Food Science; and former Professor of Agricultural Engineering.

A modern, effective and efficient potato storage building should meet seven requirements:

1. Potatoes should be easily placed in storage.
2. Potatoes should be cooled to storage temperature.
3. A constant temperature should be maintained.
4. Adequate ventilation should hold the relative humidity in the storage between 85 and 90 percent.
5. Potatoes should be easily removed from the storage.
6. The building should be easily kept in a clean and sanitary condition.
7. The cost of construction and operation should be reasonable.

Many different designs, procedures and equipment can be used to meet these requirements. The suggestions given in this bulletin have been found effective and practical in Michigan. Since individual requirements and desires may differ, alternatives and their advantages and disadvantages are discussed.

BUILDING SIZE AND LAYOUT

CAPACITY

Most new storages are designed for storing potatoes in bulk. The size of the building will be determined in part by anticipated future storage needs as well as present requirements. Space necessary for a bulk storage can be estimated by the following formula:

$$\frac{L \times W \times D}{1.44} = \text{Capacity in bushels}$$

Where: L = length of storage area in feet.

W = width of storage area in feet.

D = depth of pile in feet.

This formula assumes that a bushel (weight 60 lb.) occupies 1.44 cubic feet. Stated another way, 1 cubic foot of potatoes weighs 42 lb. A hundredweight occupies 2.4 cubic feet. Allowances should be made for space required by air ducts, passageways, or associated equipment.

A pile depth of 16 feet or less will minimize pressure bruising and achieve good air movement. In calculating the building dimensions, a 14-foot depth of potatoes is suggested. A 4-foot head space above the potatoes will permit (1) easy movement of an elevator when filling the storage and (2) good air circulation.

A separate adjacent room for grading and bagging is recommended for several reasons: (1) controlling temperature and humidity in the storage is easier, (2) people operating grading and bagging equipment usually prefer a warmer temperature than normally exists in the storage, (3) washing potatoes at the time of grading, adds unwanted moisture to the storage atmosphere, (4) removal of wash water collected in the air ducts can be troublesome if provisions have not been made for water drainage, (5) washing, sorting, drying, and packaging equipment can be permanently installed in one location, (6) larger capacity grading lines may be set up.

The following construction tips may be helpful: (1) doors or openings between the grading room and storage area should be no larger than absolutely necessary and when the grading operation is shut down, the openings should be closed, (2) self-closing doors or flexible curtains should be used to minimize air movement between the storage and grading room during grading operations.

A new storage and grading facility plan should have provisions for future expansion. The grading room plan should consider shape, size, convenience to packaging supplies, potato and truck traffic patterns.

The grading room should be sufficiently large to store at least one day's grading volume. Equipping the load-out door with a truck seal cushion helps to maintain proper temperature and humidity, both in the grading room and in the truck during loading.

Bags and other supplies should be kept clean and dry. Therefore, grading room housekeeping is important. A sloping reinforced concrete floor in the grading room permits easy scrubbing and flusking. A slope of $\frac{1}{8}$ inch per lineal foot is satisfactory. The floor should pitch away from the storage area.

A grading room should be equipped with a space heater which is entirely independent from the heater in the main storage. Automatic thermostatic control for this heater is desirable.

PALLET BOX STORAGE

Storage designed for storing potatoes in pallet boxes must be larger than a bulk storage, since space must be left for aisles. Pallet boxes also vary in size and capacity, which may influence the dimensions of a building.

Stacks four or five boxes high are the most common in this type of storage. The main air duct may be designed and constructed to permit placing boxes on top of it. This is optional, as some may prefer a narrower but higher air duct which is not built of heavy materials. The floor area of a pallet box storage is about 15 percent greater than a bulk type storage of comparable capacity.

A pallet box storage offers the following advantages:

1. Many varieties of potatoes can be kept separated by tagging each pallet with information describing its contents.
2. Each section of the building is accessible at any time by merely moving boxes with a fork lift.
3. Because various lots are separated, the storage may be used for seed as well as table stock potatoes.
4. Only a flat concrete floor is needed because the space between the stringers of the pallet boxes serve as an air duct.
5. Walls do not have to be built to withstand the pressure of potatoes.

Some disadvantages of the pallet box storage are:

1. Maintenance of pallet boxes is almost a continual job. Box replacement is also costly.
2. With mechanical harvesters, potatoes are usually delivered to the storage in bulk trucks which requires pallet box filling equipment.
3. Pallet boxes require the same amount of storage space whether they are filled or empty. The building is always full of boxes unless they are stored elsewhere when empty. Out of doors storage of empty boxes is not recommended.
4. A larger building is required than for bulk storage.

STRUCTURE

FOUNDATION

The foundation to be used in a potato storage will depend to a large extent on the type of construction. If pole type construction is used, the foundation consists of concrete pads placed under the poles to prevent

the pole from settling. Around the edge of the floor a foundation 18 to 20 inches deep is poured integral with the floor and against the splash boards to keep the edge of the floor from cracking away.

The foundation under tilt-up concrete walls requires special reinforcing, depending on the size of the panels, so an engineered plan should be obtained and used.

The floor for most storages will be on ground level and 6 inches of sand fill should be provided. When several feet of sand fill must be added, it should be done far enough in advance of construction so that it is well settled. When the concrete is poured directly on compacted ground, the floor is made 4 inches thick and reinforcing bars are not necessary. However, it is difficult to make a large concrete floor that will not crack. Because of this, and in order to prevent cracks from opening up, 6 inch x 6 inch x 9 gauge wire mesh should be placed in the floor. Then, if the floor does crack, sections of it will not settle and become rough. Sections over which large heavy trucks move should be reinforced with ½ inch rods spaced 12 inches on center, and have 6 inches of concrete.

WALL CONSTRUCTION

Although it was once common practice to build potato storages partly below ground, most modern storages are built completely above ground. With modern methods of construction and newer materials, it is easier to build a structure above ground and still control the conditions in the building.

Pole construction has developed very rapidly and is used for almost all types of farm buildings. In this type of construction, the poles are set from 4 to 15 feet apart and these support the weight of the roof. Then, by using a simple light weight roof truss made of wood, the interior of the storage will be free of posts. When potatoes are stored in bulk, there is considerable horizontal pressure on the walls, which makes it necessary to place the poles 4 feet on center as shown in Figure 1b. When pallet storage is used, these poles could be spaced twice as far apart, since there will be no horizontal load on the wall. The posts can be either round or square, but should be tied in to the concrete floor as shown on the plan. All interior partitions should also be constructed strong enough to withstand horizontal pressure. Potatoes might be stored on either side of the wall when the other side is empty and the wall must be designed accordingly.

Tilt-up concrete walls have been adapted to large storages of various kinds and produce a durable, low maintenance structure. Here the panels are poured

flat on the concrete floor and, after they have cured, are raised into place with a crane or other lifting device (Fig. 2). Then the concrete columns are poured between the panels to anchor them to the foundation and to hold them in place. It is very convenient with this construction to make a sandwich panel, where the insulation is in the center of the wall, and a concrete face is on the outside and on the inside.

Metal buildings can also be used for storages. However, insulating these buildings is more difficult than either concrete or wood pole construction. If a metal building is to be used, it should be ordered for the specific purpose of a storage. Normally, buildings are not designed to withstand great horizontal pressure caused by a wall of potatoes, so that if the building is to be used for bulk storage, it must be redesigned and reinforced to hold this additional load.

Connections between the wall and the floor are very important to keep the side walls from coming loose at the floor line.

Concrete masonry walls are not recommended for bulk storages. It is difficult to reinforce a concrete block wall. If properly done, this will probably be much more expensive than other types of construction. Where pallets are used, however, so that no load other than the roof itself is placed on the wall, concrete masonry can be used.

The interior bin walls could have a horizontal load from either side of the wall. This requires that the connection between the wall and the floor be made very strong. Probably the easiest way of constructing such a wall would be to imbed poles in the ground and pour the concrete floor around them. Pole tops should be tied to wall poles.

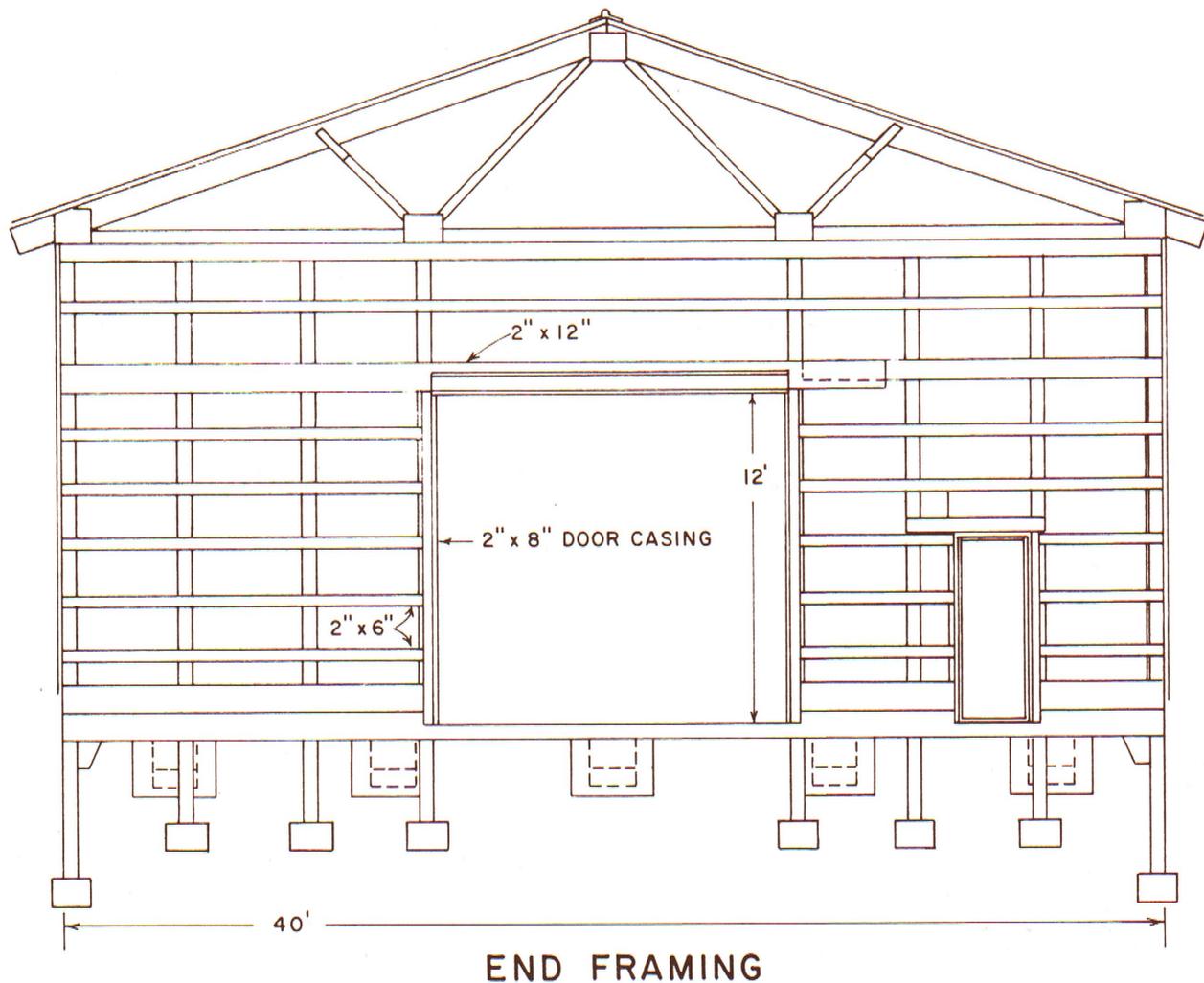
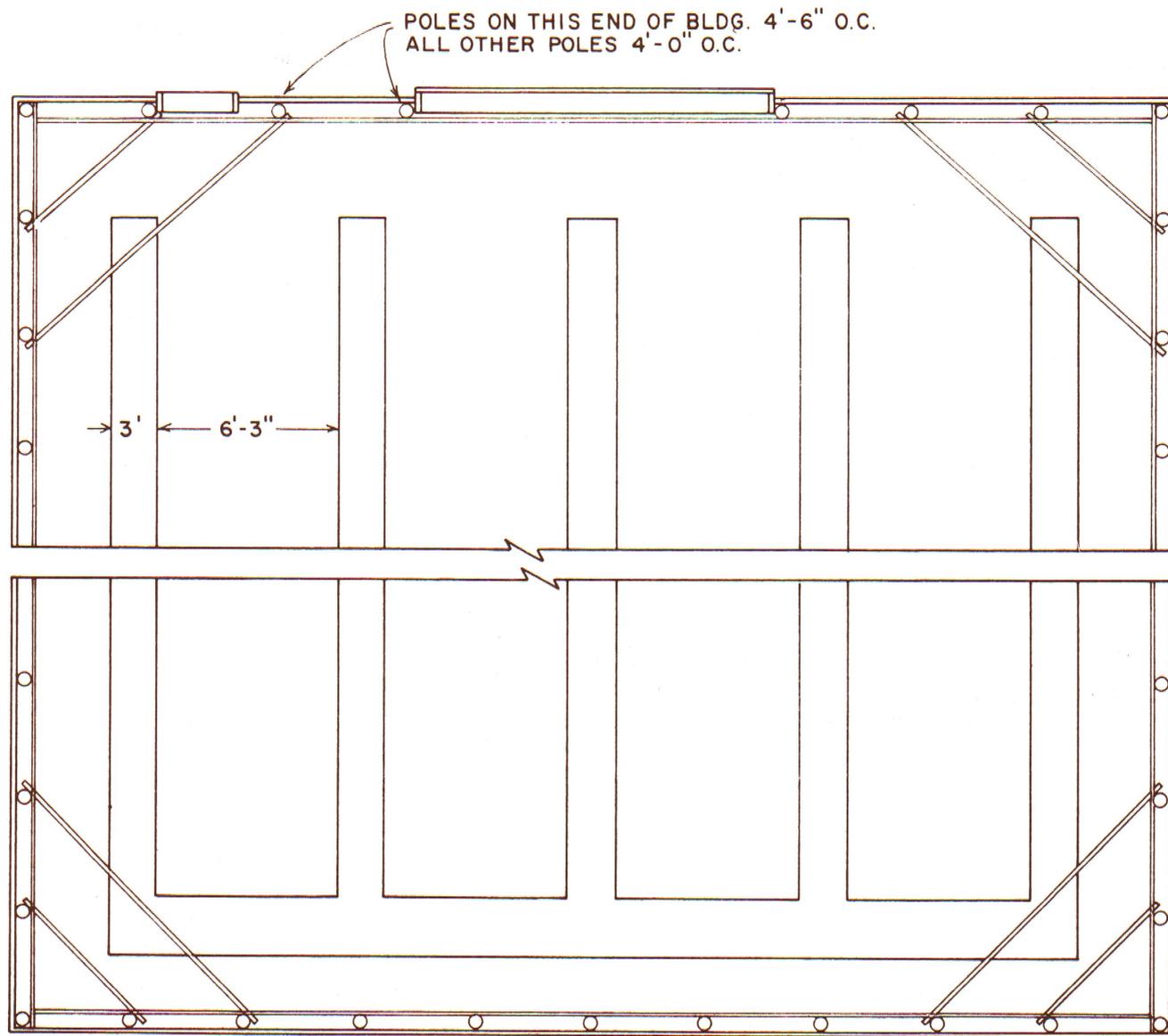


Figure 1A. The structural detail of a pole frame bulk potato storage.



FLOOR PLAN

Figure 1B. The structural detail of a pole frame bulk potato storage.

INSULATION

The selection and application of insulation in the walls and ceiling is probably one of the most important factors in the control of conditions in the storage. Either too much or too little insulation could upset the operation of the storage. In southern Michigan, the walls and ceiling should have an R value of 6 to 8, (about 2 inches of commercial insulation in the wall and three inches in the ceiling), while in northern Michigan, the R value should be about 10 (three inches of insulation in the wall and four inches in the ceiling). With these amounts of insulation in the

structure, some of the field heat which is in the potatoes when the storage is loaded can pass through the walls. During the cold parts of the year, there is sufficient insulation to keep the walls from condensing moisture. The selection of insulation will depend on the type of construction used. Remember, however, that the proper *application* of insulation is probably as important as the thickness of insulation.

In pole construction, the easiest insulation to use is the 4-foot wide bat or blanket of insulation which can be placed between the vertical poles spaced four

feet apart (Fig. 3). When a blanket type of insulation is used, the side of the blanket containing the heavy paper should go on the inside of the wall.

In tilt-up concrete, a sandwich panel using rigid board insulation is probably the most convenient. The panels are poured on the floor. First, two or three inches of concrete are poured. Then, with the concrete still plastic, a 2-inch core of a plastic board type of insulation is placed on the wet concrete, and a second layer of concrete poured on top of the insulation.

The edge of the concrete floor should be insulated as shown in Fig 4, to prevent the outside edge of the floor from getting cold. A good method of installing insulation in a steel building is to fasten furring strips on the inside surface and then install the insulation between these furring strips. Then the inside surface can be applied. There is no insulation that can be applied successfully directly to the metal, especially where the humidity in the building is high. In installing insulation, remember that the insulation layers should be continuous over the whole wall. Wherever small openings occur, the heat escapes and the damp moist air from the storage leaks through the hole and condenses on the outside surface. There is no substitute for good workmanship in installing insulation.

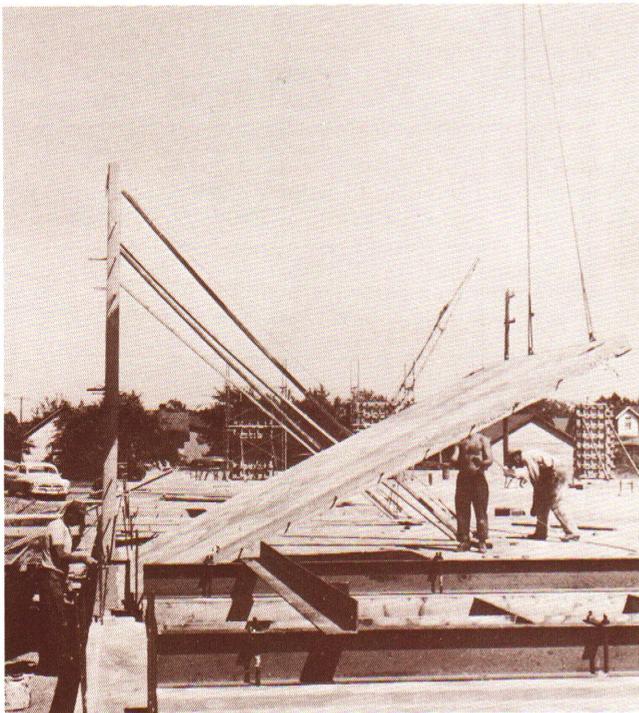


Figure 2. Reinforced concrete tilt-up panels for the side walls of a storage. For some panels containing doors and/or windows, steel channel iron strong-backs are used for lifting.

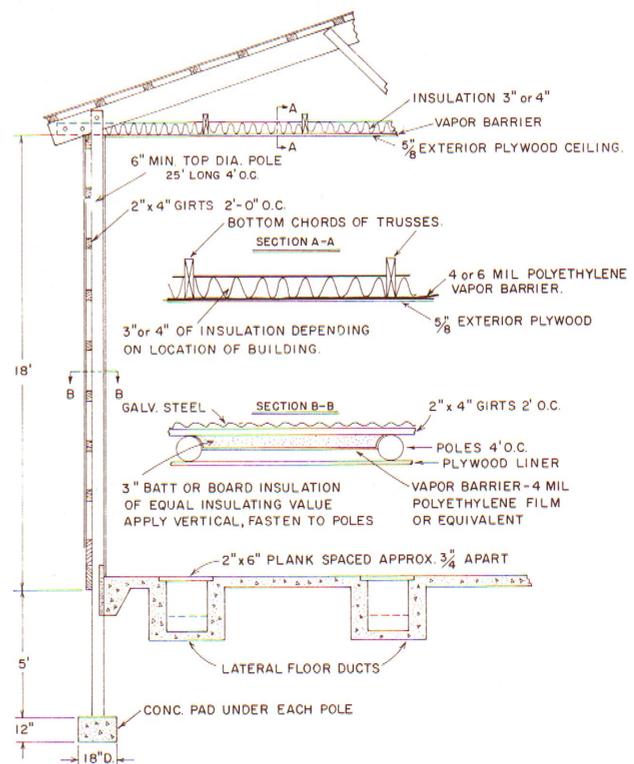


Figure 3. A cross section of a pole frame storage.

DOORS

Insulating doors occasionally presents problems. Doors are large, representing a large part of the storage wall, and must be insulated the same as the wall. Usually the most convenient would be a core of 2 inches of rigid plastic insulation covered with plywood on both sides. If the door is made 8 inches wider than the opening on each side and on the top, a gasket can be placed between the door and the wall; large hooks may be fixed to the door casing so the door can be pulled up tight. Be sure to install the track high enough above the opening so the top can be made tight.

Large swinging doors may not be practical, since hinges are not heavy enough to support the weight of the insulated door. The swinging door can be made of a 2 inch x 4 inch frame with rigid insulation cores, with 1/2 inch or 5/8 inch plywood glued to each side and glued to the 2 x 4 inch frame. A 2 x 6 or 2 x 8 on the hinge side of the door makes better anchorage for the hinge screws. Good gaskets should be supplied so the infiltration of cold air around the door can be reduced to an absolute minimum.

Overhead doors are probably the most difficult to insulate, as they are hinged in several places so they can be raised. When overhead doors are used, each panel should be insulated, leaving clearances at the

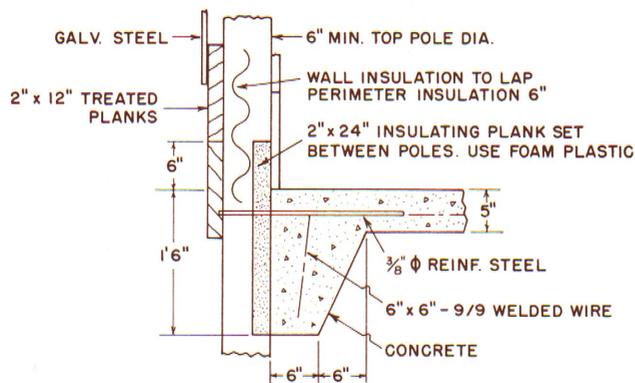


Figure 4. Pole anchoring and insulation detail.

crack. Strips should be provided which can be manually placed over the cracks during cold weather.

For door openings which are used only for loading the storage, and not for removing the potatoes, an insulated panel can be made. After the potatoes are in, the panel can be securely fastened in the opening. This eliminates the necessity for a heavy door which must be used all year, and solves the problem of sealing the cracks against infiltration.

In the upper peninsula and the north half of the lower peninsula, three inches of insulation should be used in doors rather than two inches.

VAPOR BARRIER

In potato storages, high humidity is maintained in order to preserve the quality of the potatoes. This high humidity must be kept away from cold surfaces, so that it does not condense and form water. Whenever a wall or roof surface becomes cool, it acts as a condenser. In order to protect the insulation from becoming wet, due to condensation on the cold outside wall, a vapor barrier should be installed on the inside surface of the insulation. This vapor barrier must be free from holes and all seams should be well sealed, either by some type of mastic or by adequate nailing strips. The vapor barrier should be four- to six-mil polyethylene, heavy kraft paper, or aluminum foil. The lining used on the inside will depend on the material available. The following materials can be used:

1. One-inch matched boards.
2. Exterior grade fir plywood, three-quarters inch thick on the lower nine feet of the wall, and one-half inch thick above that.
3. Corrugated galvanized metal placed horizontally across the poles.

ROOFS

The most economical roof construction for normal size storages would probably be a lightweight roof truss. These can be fabricated using glue and plywood gusset plates, or ring and bolt construction, or a type of metal plate. These trusses can be made on the ground and lifted into place with a crane.

Plans and bulletins on truss construction are available from your county agent.

MOVING POTATOES IN AND OUT OF STORAGE

The type of potato harvesting, grading, and removal systems to be used will determine to a large extent the type of handling system used in the storage. Assuming a bulk handling method is used, either conveyors or flumes may be practical. However, if a separate grading room is not planned, a flume system should not be considered.

CONVEYING INTO THE STORAGE

Conveyors provide a very practical means for filling a bulk storage. Care should be exercised in the use of conveyors however, to avoid tuber bruising. Padded hoppers or conveyors should be used. The most common method is to enter the storage with the truck directly from the harvester and unload into the elevating conveyor equipment. This system reduces the length of conveyors required. The second system involves conveyors which may be used in conjunction with a truck unloading hopper fixed in a permanent location. More feet of conveyor are necessary with this system. However, this disadvantage is sometimes off-set because it is an efficient truck unloading method, especially if powered conveyor bulk potato truck bodies are not used. The truck box can be emptied by hoisting the front of the truck. The conveyors must be portable and some may be of the telescoping type.

Careful handling with the elevating conveyor is especially important for several reasons.

1. The potatoes should not drop more than 2 or 3 feet onto the pile to minimize bruising.
2. The finished pile should be reasonably level on top for uniform air flow.

CONVEYING OUT OF STORAGE

A portable bin unloader conveyor designed to fit into the air duct beneath the pile facilitates conveying to grading equipment. This conveyor reduces labor requirements significantly. Potatoes are allowed to roll onto the conveyor belt by removing air duct planks at the edge of the pile. By using a flexible system of powered belt conveyors, the grading equipment

may be located in a permanent position while being fed from the portable bin unloader. To accommodate the bin unloader, an air duct width of 24 inches is usually recommended; however, some equipment will operate in duct widths of only 20 inches. An angle iron mounted on each side wall of the duct 18 inches below the floor surface is satisfactory for supporting the conveyor.

If a small portable grader is used inside the storage, it may be short-coupled to the bin unloader and moved intermittently with the unloader as the pile recedes.

In general, conveyor speeds should be no faster than necessary to keep the grader uniformly supplied. Uniform feeding of potatoes on grader supply conveyors results in a more desirable operation.

Conveyors which are not designed for potatoes are not recommended. Bruising, scuffing, or puncturing of the tubers is more likely to occur with improperly designed machinery.

Equipment is available which will feed a conveyor from a bulk pile directly off a flat floor. A flat scoop

or blade about 24 inches wide is forced under the pile and a powered chain equipped with metal "fingers" sweeps the potatoes along the edge of the blade to an elevating rod conveyor. This is a compact portable unit with considerable capacity. It is especially useful in large bulk storages for loading bulk trucks or feeding a conveyor system to relatively high speed grading and bagging equipment. Processors sometimes find this "pick-up" conveyor feeder very adaptable for their operation.

FLUMING

Fluming or sluicing in a trough of flowing water is becoming more popular for moving potatoes from storage to a fixed position grader. The main reason for this is that fluming is a more economical method of handling, particularly in storages of 35,000 bushels and larger. Rather high initial investment costs makes a fluming system somewhat expensive for a small storage of 10,000 to 15,000 bushels capacity. Fluming achieves significant labor savings in many installations.

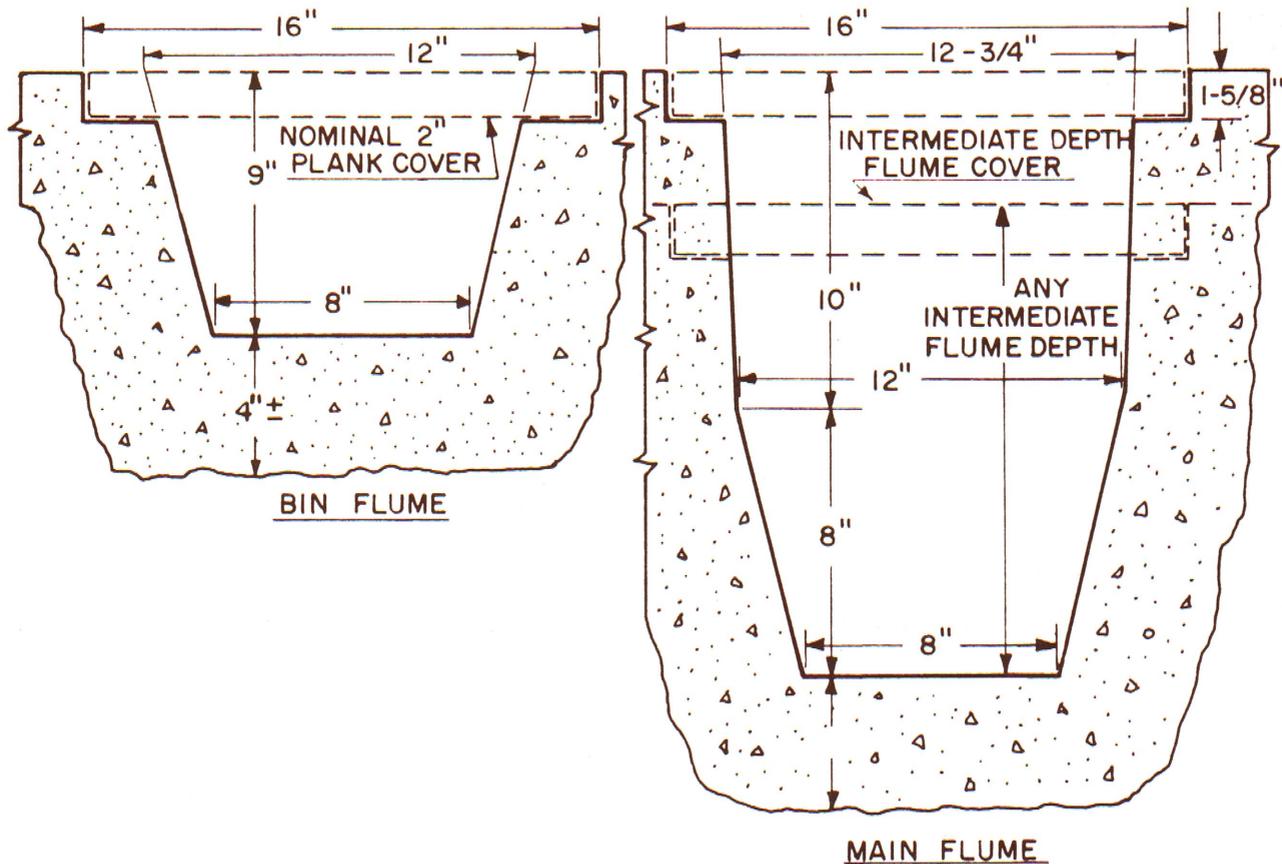


Figure 5. Cross section of the flumes for removing potatoes from storage.

Other advantages of a flume system are:

1. Potatoes receive a presoak before reaching the washer.
2. Tubers are handled with little damage.
3. The system is simple to operate and reasonably trouble free.
4. There is no conveyor or bulky equipment to store and maintain.

Flumes are designed so the maximum water velocity is 120 feet per minute and potatoes should move no faster than 60 feet per minute to minimize injury. In normal operation, potatoes usually move about 20 to 35 feet per minute in the flume. Flumes are made of concrete in the floor and maintain a uniform slope of 1 inch per 15 feet. The size and shape of flumes are illustrated in Figure 5. Forms should be made carefully to get uniformity in the finished flumes. At the upper ends of flumes (farthest from pit), a depth of 9 inches is satisfactory. If the floor is made to slope 1 inch per 15 lineal feet, the flume depth remains uniform. If a level floor is desired, the flume becomes deeper as it approaches the pit. Main flumes which connect the laterals should be about 2 inches

deeper than the laterals. This increases the velocity at the turn, reducing blockage of potatoes.

The water volume required is usually 300 to 400 GPM. A trash-type pump is a must because of debris which accumulates in the recirculated water. The common centrifugal type of water pump will not perform satisfactorily. Irrigation pipe may be used between the pump and the discharge into the flumes. A pipe size of 5 inches is recommended. Running the main pipe line through the main air duct with a tee at each flume is very satisfactory. To reduce initial cost, a cap may be placed on the supply line to each flume instead of a valve.

A storage 50 feet wide or more may have flumes across the storage rather than lengthwise. Fluming across a storage permits removal of potatoes from any section of the building any time, which could be useful if only a portion of the potatoes are to be removed.

The pit for the system should be sufficiently large to fill the longest flume and piping without causing the pump to suck air, or dropping the water level below that desired for operating. The pit must not overflow when the pump is stopped. A pit should

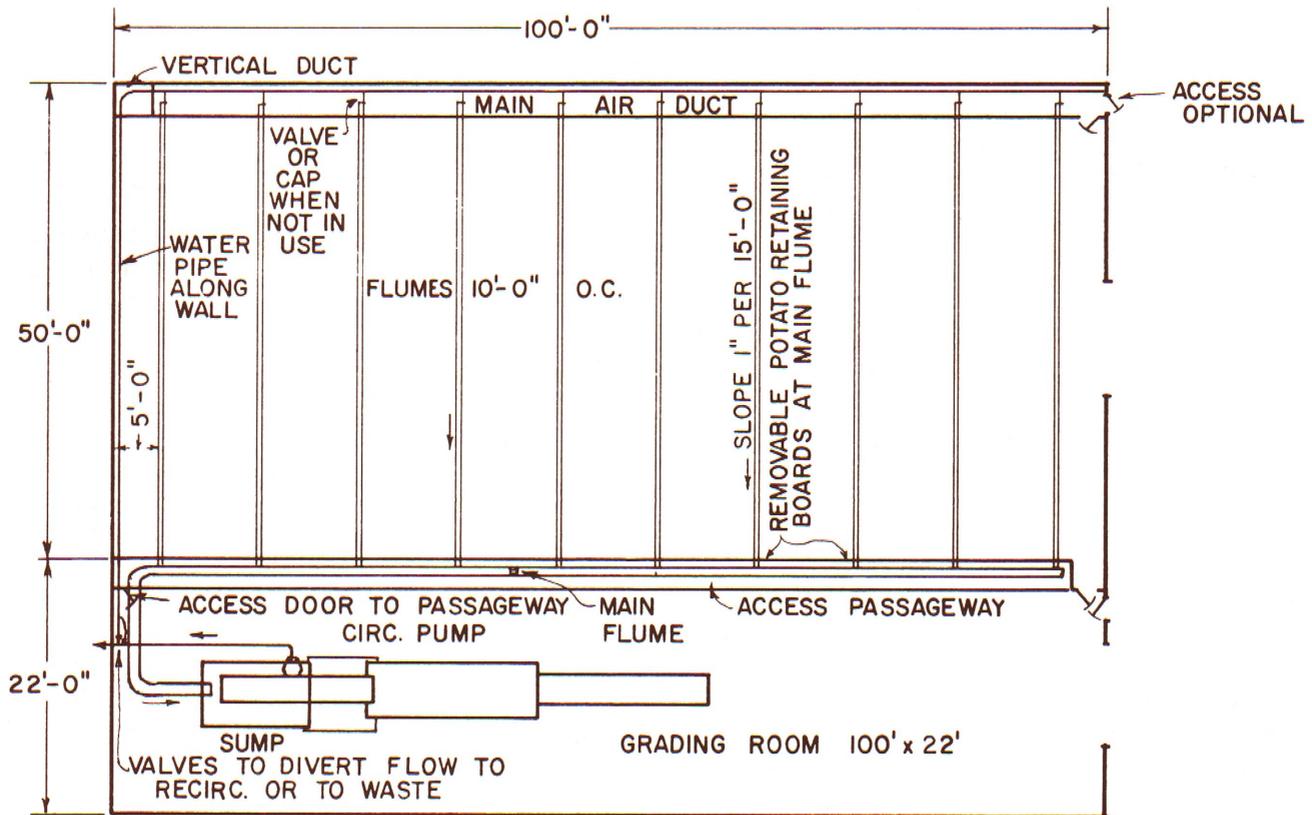


Figure 6A. Schematic flume layout for storage 50'-0" or more feet wide.

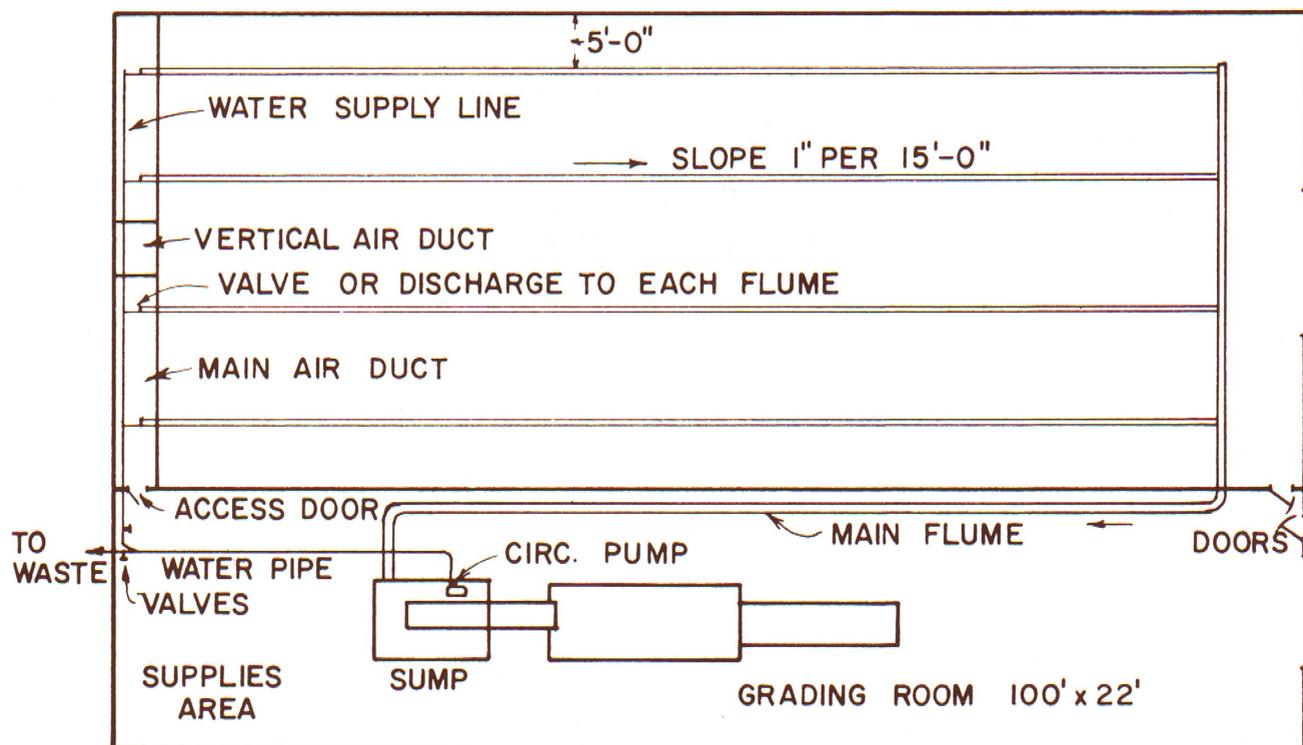


Figure 6B. Schematic flume layout for storage 40'-0" wide.

hold at least one cubic foot of water for each foot of flume. An overflow pipe should be installed in the pit at approximately the maximum operating level. Installing a coarse screen or rods around the pump intake will retain larger particles in the pit. A diaphragm type sewage pump equipped with 2- or 3-inch hoses is very useful in cleaning the pit. A tee with valves in the discharge line from the recirculating pump permits directing the flow to a discard line from the building.

The recirculated water should be chlorinated. Approximately 100 ppm active chlorine will aid in disease control and increase the shelf life of potatoes. A typical layout of a flume system is illustrated in Fig 6.

PALLETS

Pallet boxes should be handled carefully, to prevent bruising the potatoes when filling or emptying. A box tipper for position control is very helpful. Foamed rubber is useful padding material at points where potatoes may strike hard surfaces. Good quality sturdy pallet boxes are recommended. Poorly constructed boxes result in high repair costs.

Pallet boxes should be arranged in storage to give the desired air flow with the necessary allowance for aisles. Normally, the aisle will be along the wall opposite the air duct.

Carbon monoxide poisoning is a major hazard when operating gasoline engines in a building. Battery-powered fork lift trucks are most desirable in storages. LP gas engines are slightly less hazardous than the gasoline type.

TEMPERATURE AND HUMIDITY CONTROL

The control of temperature and humidity in a potato storage is best accomplished with an integrated system of ducts, fans, furnace, and controls. If all of these components are chosen to fit the particular storage, the air surrounding each potato can be kept at the desired temperature and humidity during the entire storage season.

Potatoes in storage produce both heat and moisture. However, they do not produce enough heat during the winter months to control temperature and humidity, so extra heat must be added with a furnace. The moisture they give off will increase the humidity of the air until the moisture condenses on cold surfaces such as the walls and ceiling. Some of the high moisture air must be removed with an exhaust fan to prevent this condensation. By keeping the humidity between 85 and 90 percent, the potatoes will shrink very little. Air should be recirculated through the potatoes to keep conditions uniform throughout the storage.

RECIRCULATING FAN

The recirculating fan should move about 4 cubic feet of air per minute for each ten bushels of potatoes. The static pressure rating for the fan should be about $\frac{3}{8}$ inch of water. Approximately one HP is required for each 4,000 cfm. A 50,000-bushel storage would require a 20,000-cfm fan with a 5-HP motor.

EXHAUST FAN

The exhaust fan for a storage should have 1 cfm capacity for each 12 bushels of potatoes. The static pressure rating for the fan should be about $\frac{1}{4}$ inch of water. Approximately 1 HP is required for each 5,000 to 8,000 cfm. A 50,000-bushel storage would require a 4,000-cfm fan. The motor size for the fan would probably be $\frac{3}{4}$ HP.

DUCTS

The ducts should be arranged so that the recirculating fan will draw air from the space above the potatoes and blow it into the bottom of the pile. The ducts under the pile should be about 10 feet apart and within 5 feet of each wall. They may be built into the floor or set on it. Their shape may be determined by the method used for removing potatoes from storage. Check the section in this bulletin on moving for information.

The ducts should have at least 1 square foot of cross sectional area for each 1,000 cfm of air. A duct for 20,000 cfm would have an area of 20 square feet. Typically, the cross section might be 4 feet by 5 feet or $3\frac{1}{2}$ feet by 6 feet.

A common arrangement is to have a vertical main duct at one end of the storage with the recirculating fan in it. It should have a door that opens to the outside so that outdoor air can be drawn into the fan and blown through the potatoes during the fall curing period. Another door should be used to close the inside inlet during this curing period. This main vertical duct usually connects to a horizontal duct across the end of the building. The ducts under the potato pile connect to the horizontal duct. Portions of the ducts not under potatoes should be blocked off to force air through the pile.

If the potatoes are to be stored in pallet boxes, the main air duct is built along a wall of the storage. A four-inch wide slit along the side of the duct at the floor is provided to allow air to move between stringers of the bottom pallet. The pallet deckboards are spaced to allow air to pass up between them and through the potatoes. All the openings between the stringers of the pallets next to the aisle should be covered to prevent air from escaping there. It is also desirable to provide covers for the slit in the duct so

that floor sections which are not covered with pallets can be closed off from the duct. The duct along the side of the building could be built 4 feet wide so that pallets can be stacked on top of it. A slit for air passage should be provided along the top of the duct to allow air movement up through these pallets. The slit should be about $\frac{1}{2}$ inch wide.

FURNACE

The size of furnace required depends on the size of the building and the insulation in the walls and ceiling. If the recommendations on construction in this bulletin are followed, the following furnace sizes should be adequate:

STORAGE SIZE	FURNACE SIZE
10,000 bushel	50,000 btu/hr
20,000 bushel	75,000 btu/hr
40,000 bushel	120,000 btu/hr
60,000 bushel	175,000 btu/hr
100,000 bushel	275,000 btu/hr

The furnace should be near the outside air inlet for the storage. The warm air discharge into the storage should be toward the top center of the storage, but not blow directly at the thermostat or humidistat above the potatoes.

CONTROLS

The control system for a potato storage must operate the recirculation fan, the exhaust fan, and the furnace. When operating properly, it should expose all potatoes to a constant temperature and relative humidity. A system which will accomplish this is shown in Figure 7. Switches are included to provide manual control.

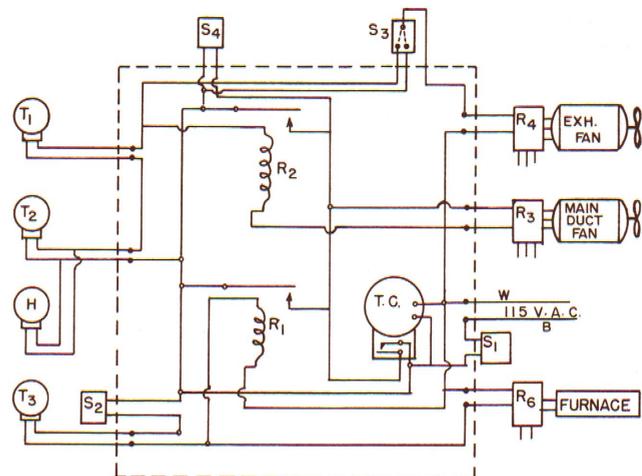


Figure 7. Wiring diagram of automatic controls for environmental conditions in the storage.

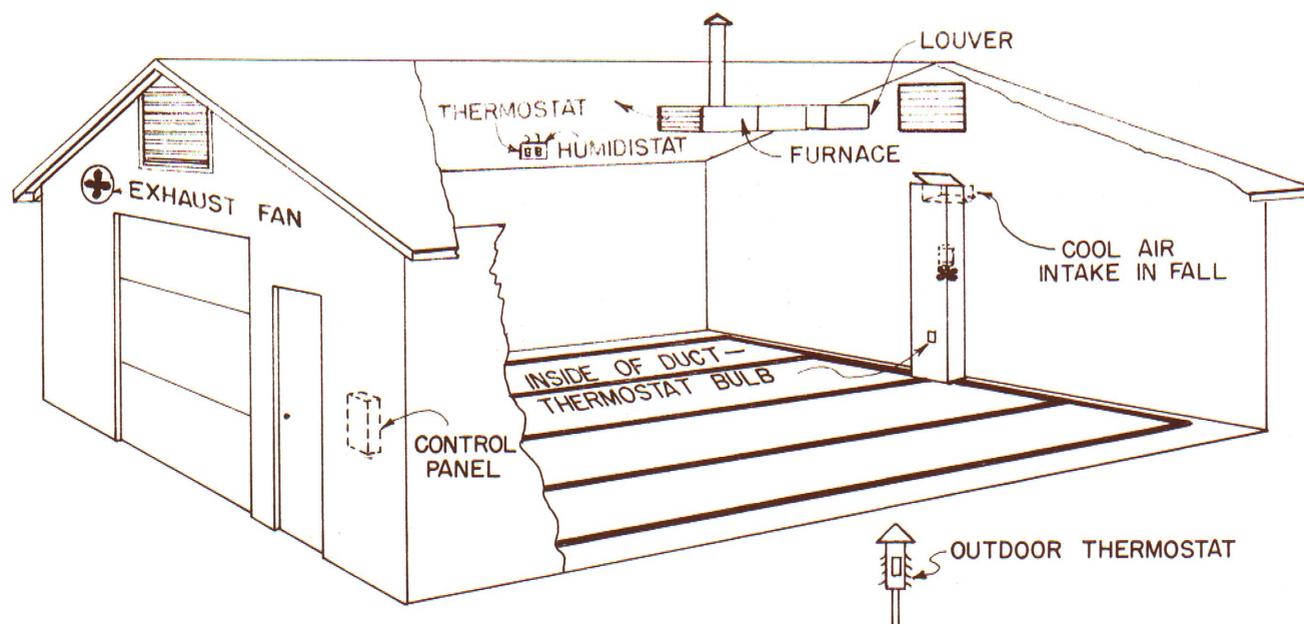


Figure 8. The essential features of a potato storage with environmental control.

The components shown in Figure 7 are as follows:

- T₁ — Outdoor thermostat, turns off when temperature is above desired level.
- T₂ — Thermostat in storage, turns on when temperature is above desired level.
- T₃ — Thermostat in main air duct, turns off when temperature is above desired level.
- H — Humidistat in storage, turns on when humidity is above desired level.
- S₁ — Master switch for the control system.
- S₂ — Switch for furnace operation, may be set for "off" or "thermostatic control".
- S₃ — Manual control switch for exhaust fan, may be set for "on" or "automatic control".
- S₄ — Manual control for main duct fan, may be set for "on" or "automatic control".
- R₁, R₂ — 115 volt a.c. SPST, n.o. relays.
- R₃ — Magnetic relay for main duct fan.
- R₄ — Magnetic relay for exhaust fan motor (may not be necessary for small exhaust fan operating from 115 volts a.c.).
- R₆ — Magnetic relay for furnace (may not be necessary if furnace can be controlled with 115 volts a.c.).
- T.C. — Recycling timer, 15 minutes on, 45 minutes off. 115 volt a.c. clock motor.

All of the components shown within the dashed area and the switches may be assembled into a single control panel. Then, two-wire cables can be extended to the thermostats, humidistats, motors, and furnaces.

The control panel should be installed at some readily accessible point.

The outdoor thermostat (T₁) may be placed on a post or wall outside, or if it is a type with separate bulb, only the bulb need be outside. Care should be taken that the bulb is always shaded from the sun and sky.

The storage thermostat (T₂) and humidistat (H) should be installed above the potatoes, but at least one foot below the ceiling.

The main air duct thermostat (T₃) should be a type with separate bulb. The bulb should be placed in the main air duct at least 20 feet downstream from the main duct fan.

A complete system installation is shown in Fig 8. A kit consisting of a completely preassembled control panel, the three thermostats, and the humidistat as described above is available commercially. At the time of this writing, the two sources for these kits are:

John M. Perry Co.
 2339 Oakwood Drive, S.E.
 Grand Rapids, Michigan 49506

Emtrol Company
 1262 Loop Road
 Lancaster, Pennsylvania 17604

The control system, when set for automatic operation, will operate the fans and furnaces as follows:

The furnace will be on whenever the temperature in the storage is below the desired level (as measured by T_3).

The exhaust fan will be on whenever the temperature in the storage is above the desired level (as measured by T_2) or the humidity is above the desired level (as measured by H). It will not operate when outdoor temperature is over the temperature set on T_1 , regardless of the temperature and humidity in the storage.

The recirculating fan will operate whenever the furnace is on, or the exhaust fan is on, or when called for by the timer (5 to 15 minutes of every hour).

MANAGEMENT AND OPERATING PROCEDURES

Most important in the construction and operation of a potato storage is to FINISH ALL CONSTRUCTION, WIRING, AND EQUIPMENT INSTALLATIONS before potatoes are put into the storage. A partially finished storage is like a new automobile with one wheel missing. Not only will it fail to do the job properly, but damage to the building or potatoes may occur if operation is attempted. The cost of installing everything at the beginning is usually less than adding parts gradually, so there is little justification for a partially finished storage.

When potatoes are placed into the storage in the fall, they can best be cooled by setting the dampers so the recirculation fan will draw outside air. The recirculation fan may be run continuously with the furnace switch turned off.

After the curing period, or when the outside air temperature drops below 32° , the control system should be set for automatic operation. All switches should be on automatic operation position. The door allowing outside air into the recirculating fan should be closed and the door at the top of the main duct opened. Doors should be sealed to prevent heat loss and frost accumulation.

If the temperature is to be kept at 40° and the relative humidity at 85 percent, the following control settings are recommended:

- T_1 — Outdoor thermostat, 40°
- T_2 — Storage thermostat, 43°
- T_3 — Duct thermostat, 38°
- H — Humidistat, 88 percent

For a 55° storage temperature, the settings would be as follows:

- T_1 — 55°
- T_2 — 58°
- T_3 — 52°
- H — 88 percent

It is strongly recommended that the storage operator check temperature and humidity in the storage regularly with a sling psychrometer. This instrument will show whether the thermostat T_3 and humidistat H require adjustment to bring storage conditions to desired values.

WHEN THE STORAGE IS EMPTY

Good housekeeping in the grading room and storage is important at all times. Plant diseases such as ring rot, and Fusarium and Verticillium wilts can be harbored in unclean storages.

The storage should be cleaned promptly after the potatoes are removed. Since cleaning will raise some dust, the instruments of the control system should be tightly covered with plastic or similar dust-proof material. The humidistat is particularly sensitive to dust and should always be protected except during the months when actually used.

The first step in cleaning is the sweeping out of dust and dirt. All equipment must be included in the cleaning program. During the summer months, the upper vents should be opened for airing the building. Screening the opening will keep birds out if they become a problem.

About one week before harvest, the interior surfaces should be cleaned with detergent solution followed by a sanitizing solution to help control diseases. Applying the cleaning and sanitizing solutions with a high pressure sprayer saves time and has been found very satisfactory. In smaller storages simple garden hose sprayers are suitable. These same procedures apply to preparing pallet boxes before filling.

One has a choice of chemicals normally used for sanitizing; they are: hypochlorites, quarternary ammonium compounds, and soluble copper sulfate. Hypochlorites react quickly in bacterial destruction and the solution strength should be about 1000 ppm active chlorine. Soluble copper sulfate is suitable for sanitizing when used at a rate of 10 to 15 pounds per 100 gallons of water. Quarternary ammonium compounds should be used according to manufacturer's recommendations.

Certain safety precautions are to be observed when handling chemicals. They are:

1. Avoid contact with the skin and prolonged inhalation.
2. Protect eyes with goggles when spraying.
3. Use a respirator when spraying.

4. Wear rubber gloves and protective clothing.
5. To reduce the hazard from short circuits, turn the power off in the area being sprayed.

Keep in mind that we are handling a food product deserving good sanitation practices. These practices also help to reduce spoilage losses, control diseases, and achieve consumer satisfaction.

APPENDIX

CONVERSIONS*

	Bushels	Cwt	Ton	Lbs.	Cu. ft.
1 bushel =	1	0.6	.03	60	1.44
1 cwt. =	1.67	1	0.05	100	2.4
1 ton =	33.3	20	1	2000	48
1 lb. =	0.0167	0.01	0.0005	1	0.024
1 cu. ft. =	0.695	0.417	0.0208	41.7	1

*Although the definition of a bushel is 1.25 cubic feet, more realistic storage design will result if it is assumed that 60 pounds of potatoes requires a space of 1.44 cubic feet. This table is set up on this basis.

RULES FOR QUICK DESIGN

(See Text for more limitations)

Floor Area

At 14½ feet depth, 10 bushels will take about one square foot.

Insulation

Lower peninsula: 2 inch walls, 3 inch in ceiling
 Upper peninsula: 3 inch walls, 4 inch in ceiling

Recirculating Fan

- 1 cfm for 150 pounds of potatoes
- 1 ton requires 13 cfm
- 10 bushels requires 4 cfm
- Static pressure = ⅜ inch
- 1 HP for each 4,000 cfm

Exhaust Fan

- 1 ton requires 2.5 cfm
- 1 cfm for about 12 bushels
- Static pressure = ¼ inch
- 1 HP for each 5,000 to 8,000 cfm

Furnace Sizes for Various Storage Sizes

BUSHEL CAPACITY	FURNACE SIZE
10,000 bushels	50,000 btu/hr
20,000 bushels	75,000 btu/hr
40,000 bushels	120,000 btu/hr
60,000 bushels	175,000 btu/hr
100,000 bushels	275,000 btu/hr



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