THE LATEST DEVELOPMENTS IN POTATO STORAGE VENTILATION

by

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The purpose of storage is to protect potatoes from adverse effects of light, water, and temperature. Any reasonable structure will protect them from light, but it takes a well insulated and ventilated building to protect them from water and temperature.

INSULATION

Insulation goes a long way in helping to control both water and temperature. However to do a good job, insulation must go hand in hand with ventilation. The principle purpose of insulation, in addition to maintaining constant temperature, is to prevent condensation on the inside surfaces of a roof and walls.

We know that potatoes keep better and have much less deterioration from bruising or shrinkage if a high relative humidity is maintained within the storage. With high humidity inside, however, it means that the inside surfaces of the wall and roof or ceiling must be at relatively high temperatures to prevent condensation. Naturally when it is cold outside and warm inside, the inside surfaces of the walls are going to be cooler than the air within the structure.

Table 1 shows the dew point of 45° air at various relative humidities. Note that at 96 percent relative humidity the dew point is 44°F., or just 1° under the air temperature. The dew point is the temperature at which moisture will begin to condense out. At 89 percent relative humidity, the wall surfaces can be only 3° colder than the inside air before condensation begins.

Table 1. Dew Points for Various Relative Humidities at 45°F.

Relative Humidity	Air Temperature	Dew Point
96%	45°	44° F.
93%	45°	43° F.
89%	45°	42° F.
86%	45°	41° F.
82%	45°	40° F.
79%	45°	39° F.
71%	45°	36° F.
61%	45°	32° F.
52%	45°	29° F.
39%	45°	22° F.
29%	45°	17° F.

Since it is desirable to maintain a relative humidity of approximately 90 percent in potato storage, we need enough insulation to maintain the inside surface of the walls and ceilings at 42° or higher in order to prevent condensation.

Table 2 indicates the outside temperatures at which condensation will appear on ceilings with varying amount of insulation. These figures are based on a storage temperature of 45° and a relative humidity of 89 percent. With an insulation value R of 9, the temperature outside can do down to only 22.9° before condensation begins. With an insulation value of 16, it can go down to 5.6°. With an insulation value of 20, it can go down to a -4°.

Table 2. Outside Temperatures at which Condensation will Appear on Ceilings with Varying Insulation (Based on Storage Temperature of 45° and R.H. of 89%

Insulation Value R	Outside Temperature at which Condensation Starts
9	22.9°F.
12	15.5°F.
16	5.6°F.
20	-4.2°F.
24	-14.0°F.
30	-28.8°F.

Since outside temperature in this area does occasionally go down around the zero mark, we have selected an insulation value of 20 as our goal, or requirement for insulation.

The three main types of insulation that are being used in modern potato storages are mineral wool, which includes fiberglass; polystyrene board; and urethane. Up to a year or so ago it was my observation that polystyrene board was perhaps the most popular. This made an excellent insulation, providing the joints between boards and between the board and structural members, was sealed adequately. Some fiberglass insulation was used and it made an excellent insulation, provided it was well protected with a vapor barrier and wall sheathing to prevent mechanical harm.

This last year it looked as though urethane, which is blown on, became quite popular. This also is an excellent insulation and requires less thickness than do the other insulations.

Table 3 indicates the resistance values obtained with metal roofs and varying amounts of insulation. For example; with the mineral wool base 2 inches thick, you get an insulation value of 9.09. This is only enough insulation to prevent condensation down to about 22° outside temperature. In order to get the recommended resistance of 20, you need 5 inches of this type insulation.

Table 3. The Insulation Resistance (R) Values of Sheet Metal Roofs with Varying Amounts of Insulation

	Thickness of Insulation				
	2"	3"	4"	5"	6"
Mineral Wool Base+	9.09	12.79	16.49	20.19	23.89
Polystyrene Board	9.69	13.69	17.69	21.69	25.69
Urethane	15.97	23.11	30.25		

+Includes rock wool, slag, or fiberglass.

Polystyrene board is a little better, but still you need between 4 and 5 inches to get the desired R = 20. With urethane, about 2-1/2 inches will produce the desired insulation resistance of 20 on a metal roof.

VENTILATION

The purpose of ventilation is very similar to that of insulation--to control water and temperature.

A. Water Content

Since we want a high relative humidity, we generally have to add water to the ventilation air. As far as temperature is concerned, we usually use ventilation to reduce temperature.

High humidity and high temperatures together are conducive to the growth of rot and disease organisms, but we want the high humidity so the potatoes do not lose water and thus shrink in weight.

Figure 1 shows the relationship between water loss and relative humidity. Notice that there is water loss to potatoes even though the relative humidity of the ventilation air is maintained at 100 percent. The loss is much larger, however, with lesser relative humidities.

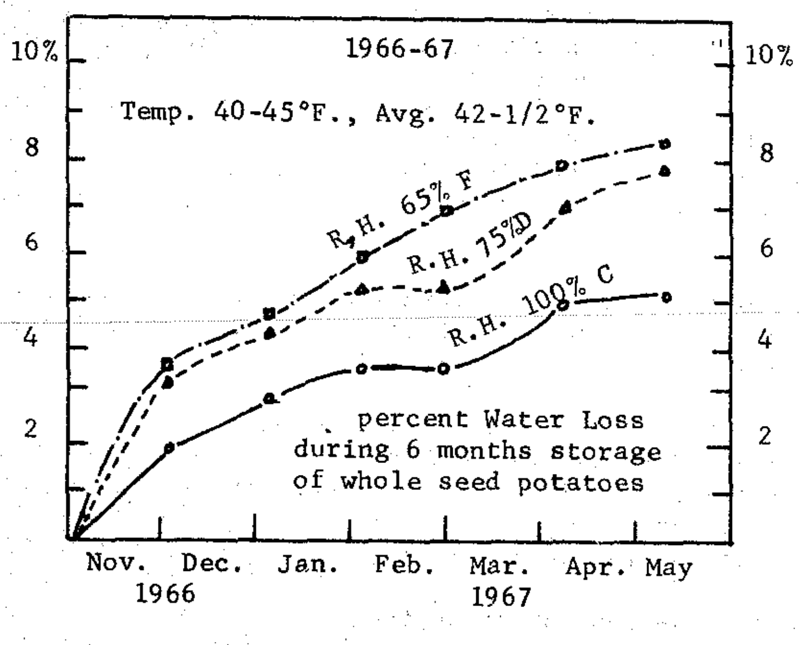

Figure 1. Potato Storage Tulelake Field Station

B. Temperature

At temperatures below about 50°F., the potato starch turns to sugar which in processing causes dark chips, fries, etc. Above 50° F., in fact above about 35°F., we get more sprouting, more decay, and more growth of disease organism. The storage temperature of 45° F. is therefore a compromise.

C. Through Circulation

Most potato storages in this area utilize through circulation, that is the air is forced through the pile to maintain temperature and prevent hot spots.

The latest development in "through circulation" in this area is the underground duct system. With this system we generally see a mechanical room which houses the fan and louvers on the side of the storage and in the middle of the building lengthwise. This location permits the smallest possible ducts. There is a large underground main plenum in the center, and the distribution ducts take off in both directions. If the main plenum was at one end, the distribution ducts would have to be approximately twice as large as they are this way.

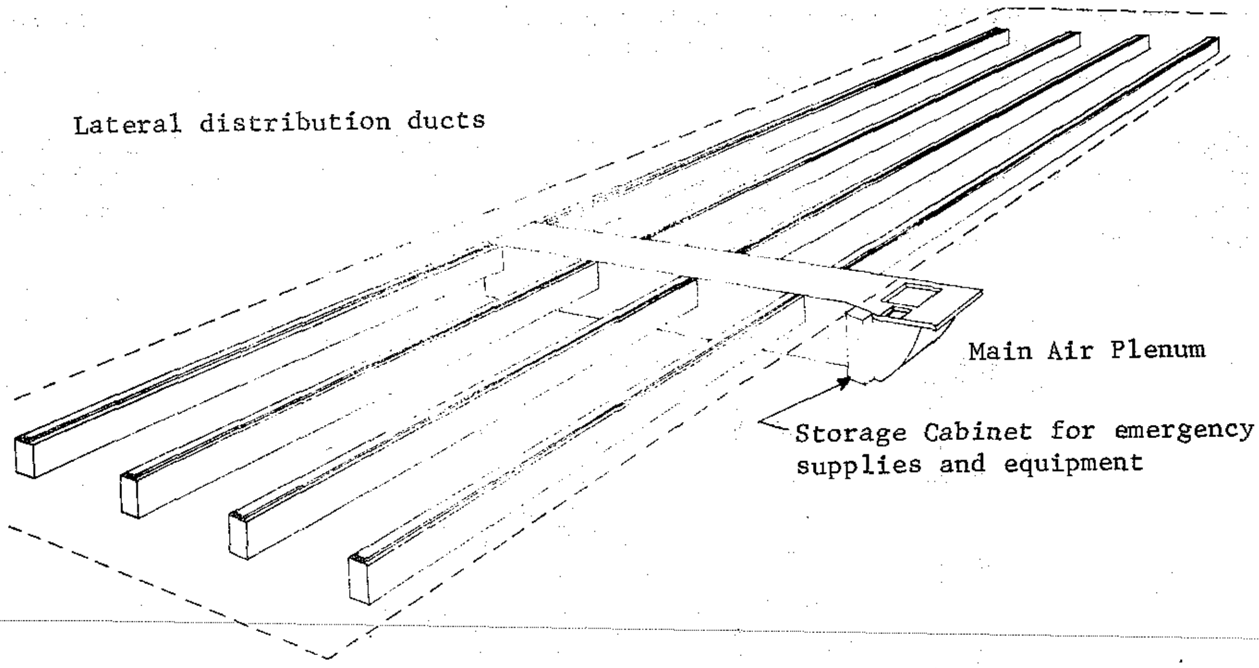

Figure 2. Concrete Underfloor Air Duct System

Figure 2 indicates the underground duct system of a good sized storage. Notice the main plenum in the center and the distribution ducts going out in each direction from it. A large fan forces air into the main plenum and out through the distribution ducts. Notice that this plenum is large enough for a man to get into. In fact, there is generally a trap door along side the fan so that the operator can get down there to make inspections and adjustments.

(1) Fallout Shelter

Being underground as well as within the confines of the storage structure makes it an excellent fallout shelter for a pretty good number of people. Generally these plenum chambers are at least 6 feet deep, 6 feet wide, and 50 feet long. Such a chamber would, using National Civil Defense criteria, hold about 30 people. All that would be needed to use it as a fallout shelter would be to shut down the fan and crawl in. At that time the necessary supplies could be taken in through the trap door also. That would be food, blankets, radio, and so forth. The temperature would be cool, but tolerable. There would be plenty of air so no ventilation would be needed for the people. If necessary, the potatoes could furnish both food and water for the duration.

Most of these underground ducts are made of concrete or concrete block. The walls of the distribution ducts can be poured flat on the ground and then tilted up into position to save the cost of forming, which is considerable.

Different methods have been used to get the air out of the ducts into the pile of potatoes. Drilled holes in the cover boards have given way to the more simpler 3/4 inch slots between the cover boards. These are covered with a 2 inch plank supported above the slots. The plank will let the air out without letting dirt or potatoes in. See Figure 3.

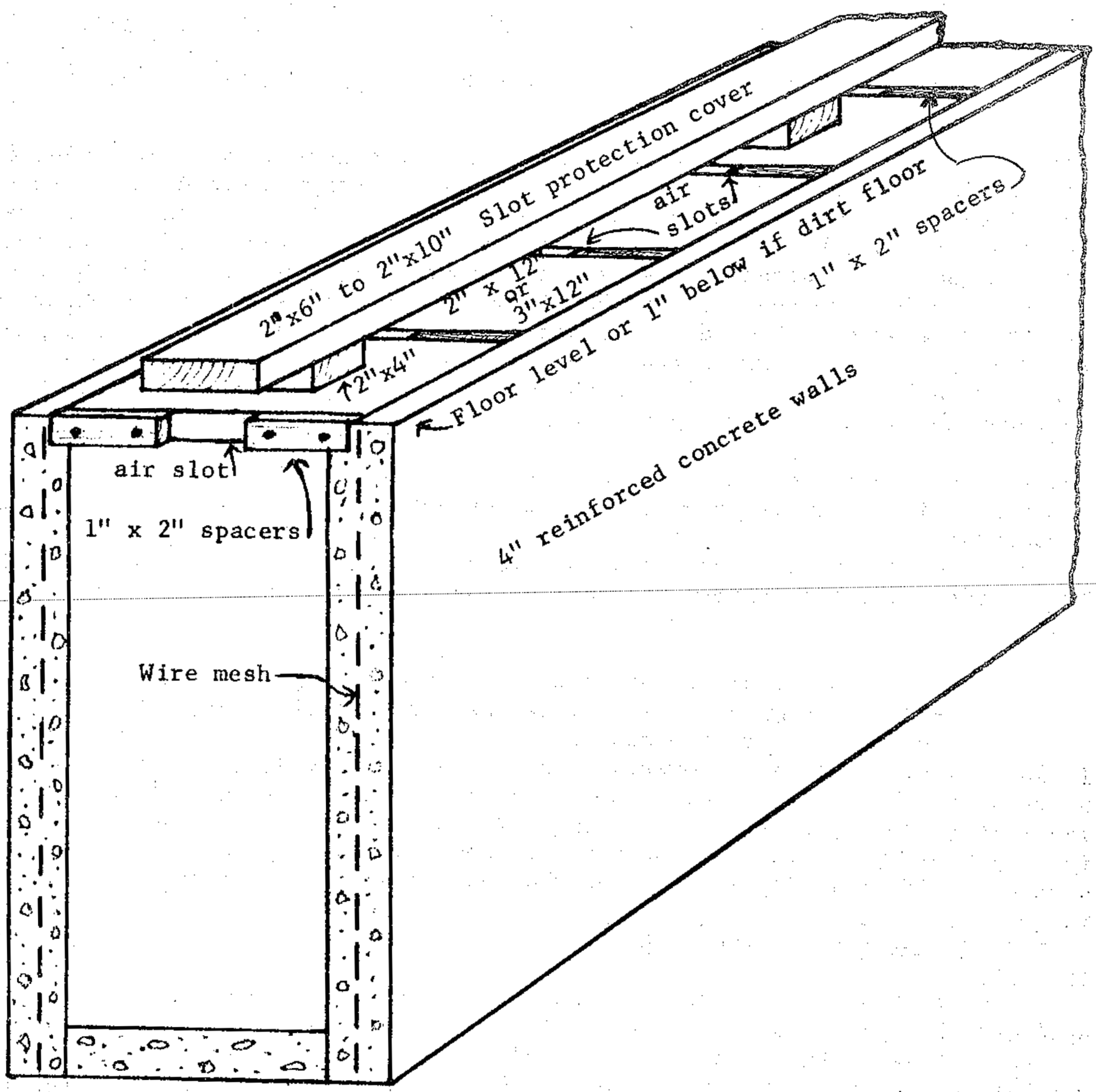

Figure 3. Section of Air Distribution Duct

The slots are made by nailing pieces of 3/4 inch board at each end of one side of the cover planks. The length of the slot is determined by the amount of air that needs to go through it, which in turn is determined by the distance between the distribution ducts and the depth of the potatoes.

Table 4 indicates the length of 3/4 inch slot to provide 17 cubic feet per minute of air per ton of potatoes from ducts ten feet apart. If ducts extend toward but not to a wall, extra slot width should be allowed for the distance not covered by the ducts. For example; if duct ends three feet from the wall, the last slot area should be three times the others.

Table 4. Length of 3/4" slot to provide 17 cfm of air per ton from ducts 10 feet apart

Depth of Potatoes	8'	10'	12'	14'	16'	18'	20'
Length of 3/4" slot	2-3/4"	3-1/2"	4-1/8"	4-5/8"	5-1/2"	6-1/4"	6-7/8"

In some potato storages circular ducts have been used instead of rectangular ducts. These are fine and in some cases less costly than rectangular concrete ducts. Ordinary circular corrugated culvert has been used successfully, both for the main plenum and the distribution duct. Also another idea is being tried to get the air out of the ducts at distant intervals rather than every foot or so through slots or holes. The idea behind this is that if ducts ten feet apart are adequate and the potatoes between the two ducts do not suffer, then by the same token it must be satisfactory if discharge-holes from the duct are ten feet apart. Thus, ventilation systems have been installed with ducts spaced eight or nine feet apart and discharge-holes spaced every eight or nine feet along the duct.

Actually, the diagonal of the distance between holes should not be greater than ten feet if this system is to give the same or better distribution than the ducts with continuous outlets. If discharge holes are placed on a square pattern, the ducts should be seven feet apart and the discharge holes seven feet apart on the ducts in order that the maximum diagonal distance between holes will not be more than ten feet.

This system has one difficulty. Since the air is discharged for a considerable amount of potatoes through one hole, there must be a considerable amount of air discharged. Therefore, the hole has to be quite large. In fact, it must be so large that if not adequately covered potatoes, as well as dirt or debris, can fall into the duct. Thus, a good cover system must be used to let the air out of the duct and keep the potatoes from entering. If the cover protrudes above the floor, it is difficult to remove the potatoes from above and around it without either damaging the cover or taking if off so that potatoes can fall into the duct.

D. Operating the Ventilation System

Ventilation air should be started as soon as any potatoes are placed in the storage. Quite likely the first potatoes placed will be highest in temperature. Continuous air movement through the potatoes will tend to prevent hot spots. When hot spots form within the pile, there is apt to be wet spots on top of the pile caused by condensation on the potatoes which have had a chance to cool because they are on the top of the pile.

Potatoes respire and when they do, they give off considerable heat. During the first ten days or two weeks that they are in storage they will give off several times as much heat as they will later on.

Figure 4 shows the amount of heat given off by respiration at various storage temperatures. This graph, however, is not true during the first ten days while the bruises are healing. At this period it is likely to be two or three times the values indicated on the graph. Thus, it is very important that air circulation be started and maintained continuously day and night while the storage is being filled.

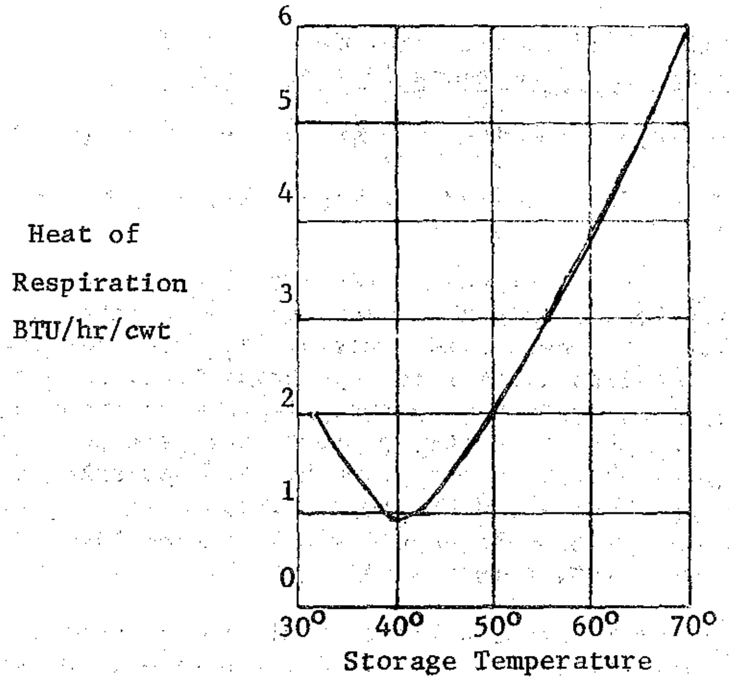

Figure 4. Heat of Respiration of Potatoes in Storage

E. Ventilating Air Requirements

The greatest air requirements are during and immediately after placing the potatoes in storage. Not only is the heat of respiration high at this time, but the potatoes themselves hold considerable field heat and unless this is late in the fall, the outside air is apt to be rather warm.

Table 5 is research data indicating the amount of ventilating air necessary with different outdoor and potato temperatures. Note that with an average outdoor air temperature of 60° and a potato temperature of 70° an air flow of 17 cfm/ton is needed. These conditions are frequently met or exceeded in the Columbia Basin, hence, our recommendation of 17 cfm/ton or more.

Table 5. Air Requirements for Potatoes in Storage

Outside Temp.	Potato Temp.	Air Flow Required
40°	50°	10 cfm
50°	60°	13 cfm
60°	70°	17 cfm

In Idaho where they recommend 10 cfm/ton, their nights are much cooler. During the harvest period our nights are something like 10° or 12° warmer than Idaho's.

F. Other Ventilating Systems

In the Columbia Basin and Yakima Valley we use, or recommend for use, a system which circulates air through the potatoes. When refrigeration is added it is generally added to this through-the-pile circulation. Figure 5.

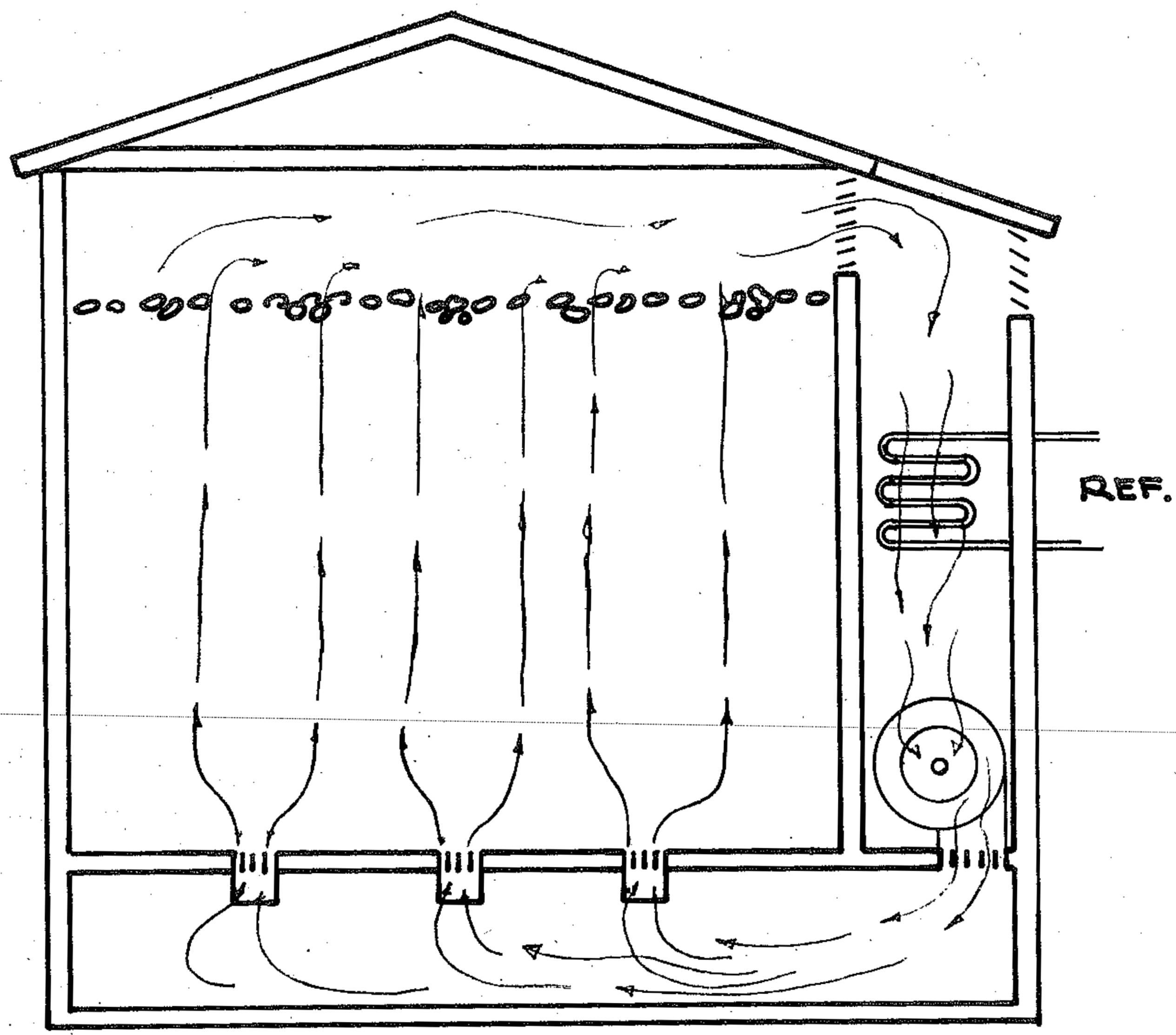

Figure 5. Through Circulation

The duct system is somewhat expensive to install and/or expensive to maintain.

Other systems have been tried with varying degrees of success. Figure 6 shows the Envelope System of removing heat from potatoes. Here the ventilating air does not go through the potatoes, but around them. Heat is carried away from the potatoes through the walls of this system. Its main advantage is that the air is not exchanged with the air in the potato pile, therefore, it maintains humidity without adding moisture, thus reducing the possibility of excess shrinkage. Whenever outside air is introduced into the pile of potatoes, the relative humidity of the air drops unless moisture is added to the air.

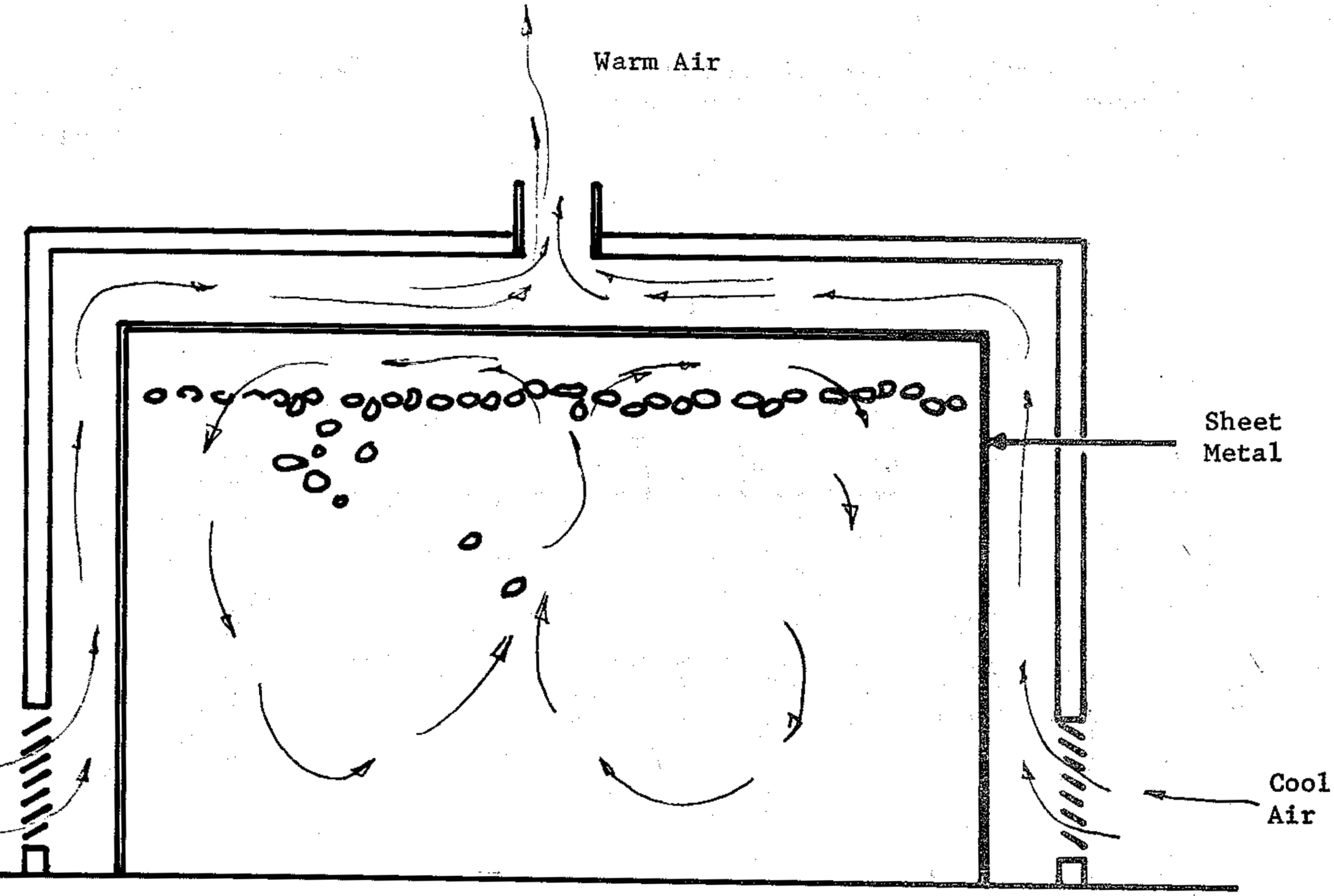

Figure 6. Envelope System

Table 6 shows the relationship between temperature and relative humidity. With a normal November temperature of 40° F. and normal relative humidity of 76% this same air when heated to 45°, as it will be in the potato storage, will have a relative humidity of only 65 per cent. Likewise, a normal January temperature of 26° with a normal relative humidity of 82%, when the air is heated to 45°, will drop the relative humidity to only 39%. Thus, if no outside air is introduced into the pile of potatoes, they will maintain their own high relative humidity. However, when outside air is introduced it almost always lowers the relative humidity.

Table 6. Temperature - Relative Humidity Relationships

	Nov.	Jan.
Normal Temperature	40°	26°
Normal R H	76%	82%
Same Air at	45°	45°
R.H.	65%	39%

The envelope system has not been used by itself satisfactorily. However, after the temperature has been reduced to storage temperature, the envelope system has been adequate in removing heat.

Another system similar to the envelope system is the Shell Ventilation system. Figure 7 shows how, in the shell system, air passes around the side of the pile then over it, but as it goes over the pile is permitted to mix with the air naturally circulating within the potato pile.

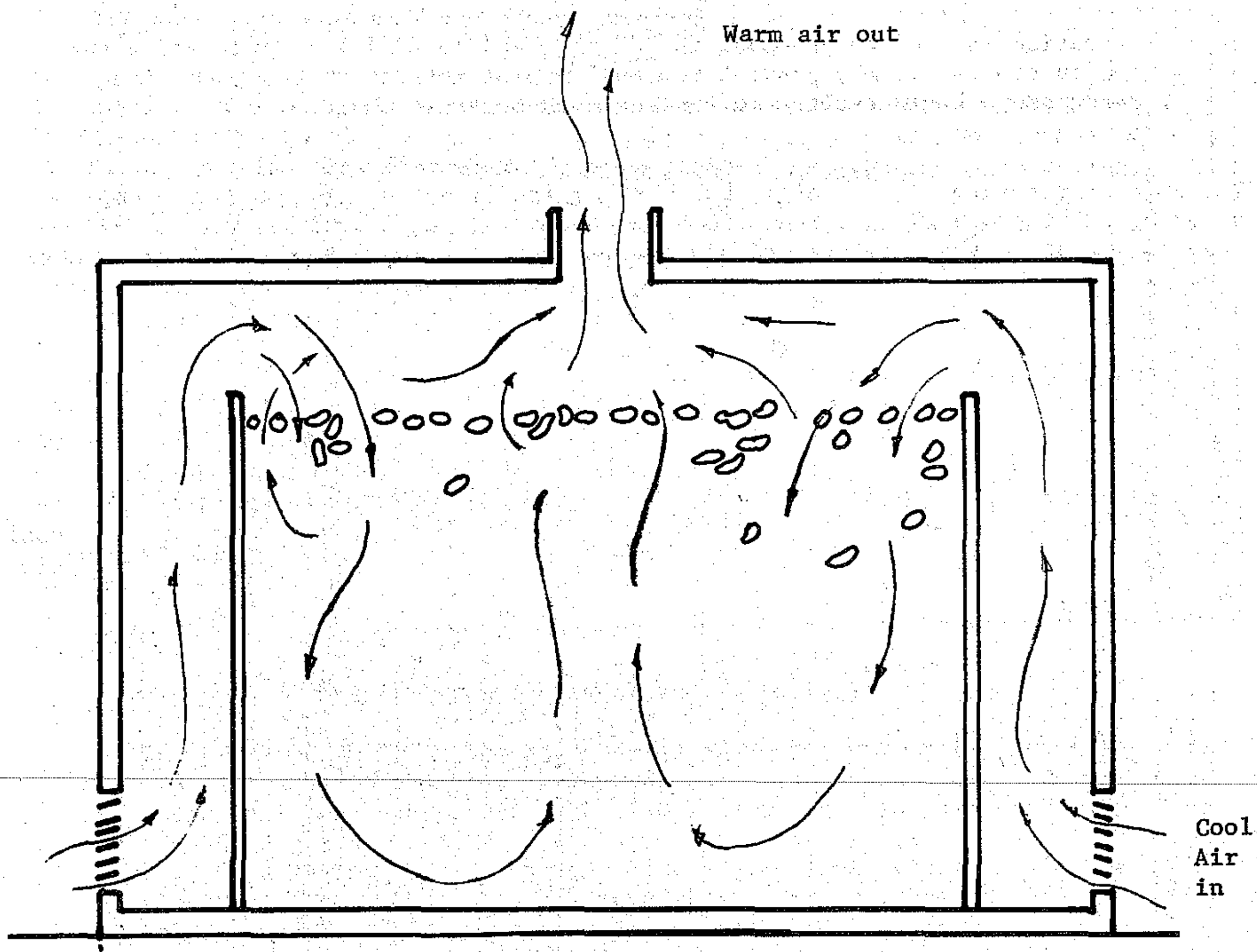

Figure 7. Shell Ventilation

A combination of shell ventilation and envelope ventilation, with the envelope being used after temperatures have been brought down, have been successful.

Neither of these systems uses under-the-pile ducts. However, either one of them could be used in combination with under-pile ducts. When this is done, however, the saving of the cost of ducts is not realized.

Another system that is sometimes used and with some degree of success, especially for short time storage is just to circulate air over the top of the pile of potatoes. Actually the air within the pile circulates by gravity, the warm air comes to the top and is removed or mixed in with the air above the pile. If this system were combined with refrigeration, it is possible that the potatoes could be maintained over a long storage period without either air ducts or shell ventilation.

Refrigeration

Refrigeration can be used in combination with any of the above mentioned systems. Its purpose is merely to cool the air, regardless of outside temperature, before it is forced through or around the potato pile.

If refrigeration is used to pre-cool the storage and to cool the potatoes as they are placed in storage it may prevent the build-up of rot and disease organisms. Also harvest could begin earlier in the fall and potatoes could be stored later in the spring or summer.

The cost of refrigeration is high, but not completely out of reason. In fact, by using refrigeration, cost reductions can be made in duct work, possibly to such an extent that a refrigerated storage may not cost more than a well ventilated storage.