WALL PRESSURES, INSULATION, TEMPERATURE AND AIR DISTRIBUTION OF POTATO STORAGES

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Experience is a good teacher, and since this time last year we've had quite a bit of experience with potato storage in the Columbia Basin.

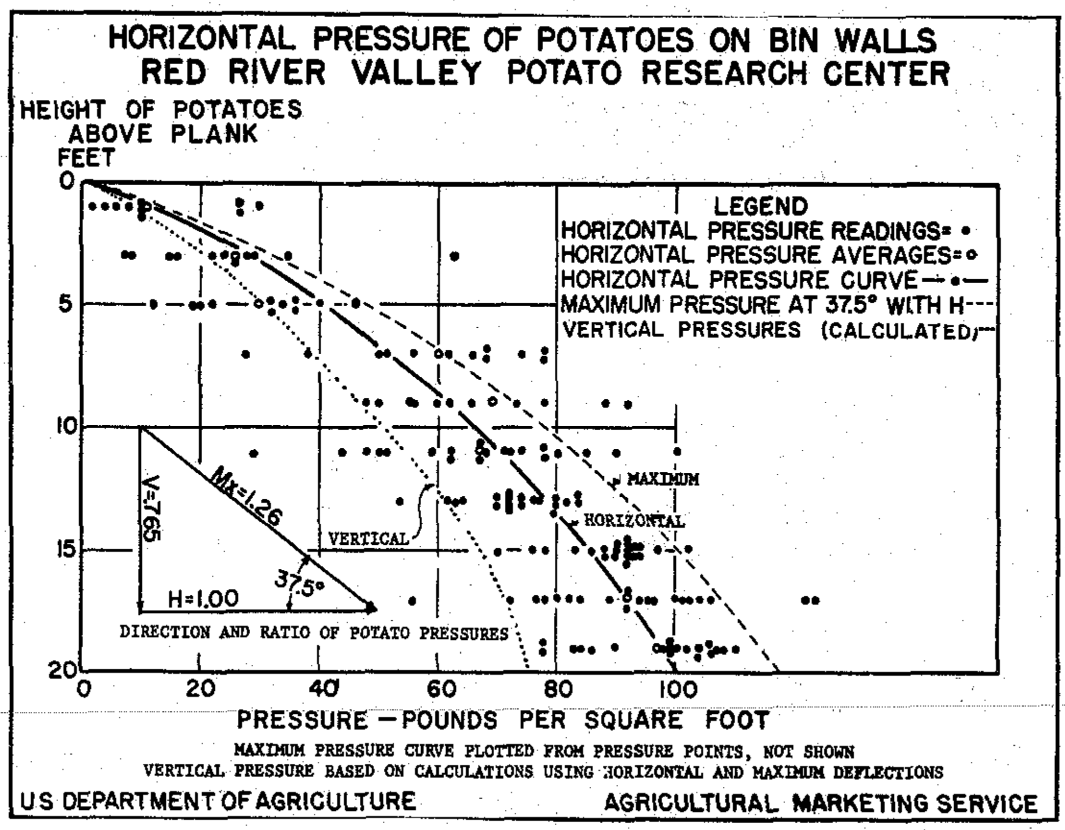
Some of the experience has been good and some not so good. From some of the experiences we can revise our list of recommendations for storing potatoes here in the Columbia Basin.

Some of the items I think we should stress during the coming year:

1. Make better use of known potato pressures on walls.
2. Be sure all potato storages are well insulated.
3. Install adequate ventilation.
4. Operate the ventilation system continually from the start of putting spuds in storage until storage temperature has been reached.

WALL PRESSURES

First let's consider the horizontal pressures that potatoes exert on walls. One major change is that the walls of recently constructed storages are higher than those constructed a few years ago. Also, more of the storages are entirely above ground so that framework must resist the pressures formerly held by earth excavations.



The horizontal pressures of potatoes on bin walls were measured at the Red River Valley Potato Research Center a few years ago. In this respect, potatoes in the Red River Valley are pretty much the same as potatoes in Maine or Idaho or the Columbia Basin. They all exert a lot of horizontal pressure on bin walls.

Figure 1 shows the results of the Red River Valley Tests. Note that potatoes 15 feet deep exert about 85 pounds of pressure per square foot on walls. Note that this is an average of many readings. Some measurements were higher and some lower. For example, one reading at 15 ft. depth is over 100 pounds per square foot. At 10 feet of depth the horizontal pressure is 65 pounds per square foot. If you will consider every square foot of a potato bin wall you will see that there is tremendous pressure exerted against it.

Table 1 summarizes these pressures for various depths of potatoes and indicates what our structures must be designed to withstand.

Table 1
REACTION FORCES AT SILL AND PLATE, AND BENDING MOMENT FOR VARIOUS DEPTHS OF POTATOES AND WALL HEIGHTS FOR EACH FOOT OF WALL LENGTH

Depth of potatoes	Height of wall (H)	Height of centroid of 1/ horizontal potato pressure (h)	Horizontal pressure of potatoes at centroid (P)	Reaction force 2/ At sill (R_s)	Reaction force 2/ At plate (R_p)	Bending moment at centroid of horizontal pressure 3/ (M_x)
Feet	Feet	Feet	Pounds	Pounds	Pounds	Inch-Pounds
8	10	2.82	252	181	71	3,030
10	12	3.56	375	264	111	5,650
12	14	4.3	516	358	158	9,330
14	16	5.1	673	458	215	14,000
16	18	5.83	844	571	273	20,000
18	20	6.6	1,028	689	339	27,600
20	22	7.38	1,223	813	410	36,000

1/ Centroid is a point where all forces on a member are in balance. With vertical forces it is called center of gravity. Note it is not at center of height. All forces multiplied by their distance on one side from centroid just equal all forces on other side multiplied by by their distance from centroid.

2/ Reaction at sill and plate are determined in this manner:

$$R_s + R_p = P \quad R_p = Ph/H$$

where R_s = Reaction force at sill in pounds
R_p = Reaction force at plate in pounds
h = Height of centroid of horizontal pressure in inches
H = Height of wall in inches
P = Horizontal pressure of potatoes at centroid

3/ Bending moment at center of horizontal potato pressure (according to horizontal pressure graph) $M_x = R_s h/2$ where R_s = reaction at sill in pounds and h = height of centroid horizontal potato pressure in inches.

A building designer needs to know especially the reactions at sill (R_s) and plate (R_p) as well as the bending moment (M_x) at the centroid.

Figure 2 illustrates these pressures and how the structure must react to withstand them. For example, a 20-ft. high wall with potatoes 18 feet deep must have adequate strength at the top plate to withstand a pressure (R_p) of 27,600 pounds per foot of wall. Thus, if cables or trusses 4 feet apart are tying the building together, each one must withstand 4 x 27,600 = 110,400 pounds in addition to the forces placed on it by carrying the roof load, snow and wind.

The bending moment (M_x) indicates to the designer the strength needed in studding or other vertical members.

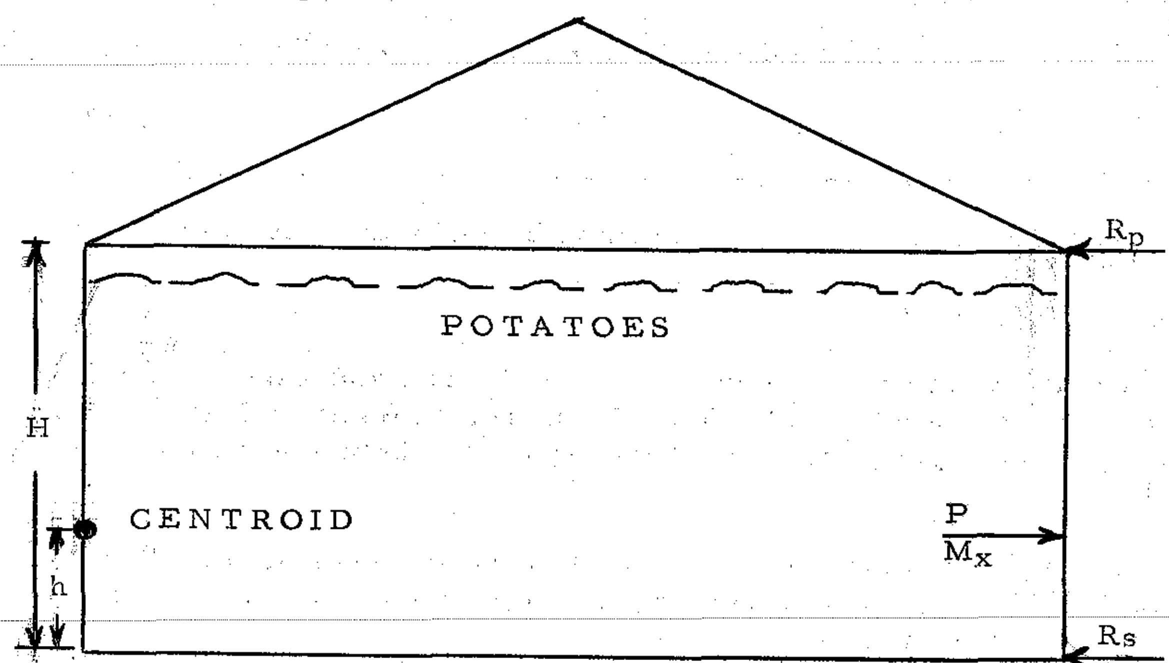


Figure 2

Wall pressures are so great, and the value of the stored product is so high that an engineer should be employed to design potato storages. The cost will be very small compared either to the total cost of the structure or to the value of the stored product.

Table 2 gives the sizes of studdings required for walls of several heights. This information is for guidance in designing potato storages. However, a design by an engineer would include considerably more information, for example, methods and types of fastenings at top and bottom of the studdings. Simple nailing is inadequate.

Table 2
SIZES OF STUDDING REQUIRED WHEN SPACED VARIOUS DISTANCES TO SUPPORT CERTAIN DEPTHS OF POTATOES WITH SELECTED WALL HEIGHTS

Depth of potatoes	Height of potatoes	Sizes of studding required when spaced 1/			
		1.33 feet	2 feet	3 feet	4 feet
Feet	Feet	Inches	Inches	Inches	Inches
8	10	2 x 4	2 x 6	2 x 6	2 x 6r
10	12	2 x 6	2 x 6r	2 x 8	2 x 8r
12	14	2 x 6r	2 x 8r	2 x 10	2 x 10r
14	16	2 x 8r	2 x 10	2 x 12	2 x 12r
16	18	2 x 10	2 x 12	4 x 10	4 x 12
18	20	2 x 10r	2 x 12r	4 x 12	4 x 12r
20	22	2 x 12r	4 x 12	4 x 12r	6 x 12

1/ Nominal sizes listed but strength is based on dressed dimensions.

(r) means rough size only

The information presented in Figures 1 and 2 and Tables 1 and 2 is taken from Bulletin AMS-401, "Pressures on Walls of Potato Storage Bins" published by the Agricultural Marketing Service of the USDA.

Although the information is directed toward wood frame construction, it can also be applied to steel, concrete, plywood or any materials used in potato storage construction.

INSULATION

Insulation is becomg more and more important in potato storage construction as more of the structures are built above ground and as better quality potatoes are required for processing and table use.

A number of insulations in several forms are on the market. Table 3 gives the resistance value (r) of the more common ones.

Table 3
INSULATION VALUES OF MATERIALS (r)

Insulating Material			(r) per inch
Blankets or batts			
Cotton fiber			3.85
Mineral wool, rock, slag or glass			3.70
Wood fiber			4.00
Board and Slab			
Corkboard			3.84
Glass fiber			4.00
Expanded polystyrene			4.00
Urethane			7.14
Loose fill			
Macerated paper			3.57
Mineral wool			3.70
Sawdust or shavings			2.22
Vermiculite			2.18
Building Materials			
Concrete		per inch	.08
Brick		per inch	.20
Wood - fir, pine		per inch	1.25
Concrete Block			
Sand and gravel	8"		1.11
Sand and gravel	12"		1.28
Light weight aggregate	8"		2.00
Light weight aggregate	12"		2.27
Roofing			Usual thickness
Asphalt roll			.15
Asphalt shingles			.44
Built-up roofing			.33
Wood shingles			.94
Sheet metal			.00

from ASHRAE Guide and Data Book 1965 and 1966

Nearly all insulations will reduce heat loss satisfactorily when applied properly in adequate amounts and if kept dry.

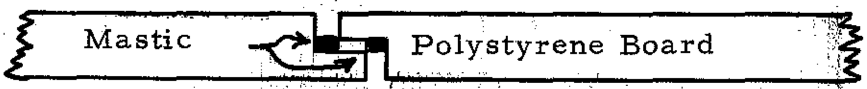
A vapor barrier is essential to keeping the insulation dry. Water vapor in the air will penetrate most building materials and insulations. In winter the temperature of the outside surface of a wall or roof is normally colder than the inside surface. The temperature of material within the wall will vary between the inside and outside surface temperatures. Much of the time the temperature at some point within an insulated wall will be low enough to condense moisture from the moist inside air. When this condensation occurs, free water becomes available in the insulation, making it wet. Wet insulation loses its insulation value and will cause decay of organic materials.

Thus it is necessary that the moisture vapor be kept out of the insulation. This is done with a vapor barrier. Such materials as sheet metal, metal foil, polyethelene film and some asphalt-impregnated papers are vapor barriers. Also, some insulations such as expanded polystyrene will not permit water vapor to penetrate.

It is very important that a perfect vapor barrier be installed on the inside surface of a potato storage wall or roof, or that the insulation itself be impervious to water vapor.

Bat or blanket insulation has a vapor barrier on one side. This must be placed on the inside surface of the insulation. Any holes, tears or gaps in the vapor barrier must be repaired and sealed. Even a pinhole will permit a large amount of water vapor to seep through over a period of time.

Boards of polystyrene or other insulation impervious to water vapor must be joined with a vapor proof mastic. Shiplap joints with mastic on the inside corner are considered good.

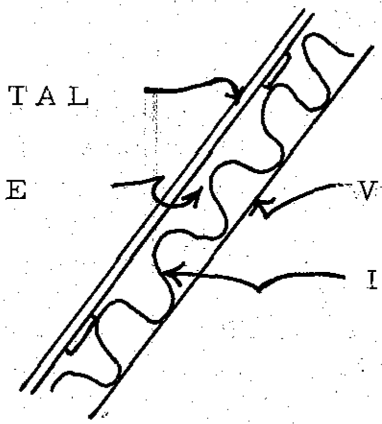


The amount or thickness of insulation is important to the proper storage of potatoes. Actually there are two functions of insulation in a potato storage. First is the usual function of maintaining proper temperature and second is to prevent condensation on the inside surface from dripping onto the potatoes.

This second function, preventing condensation, is apt to require more insulation than the first. In the Columbia Basin, proper temperature may be maintained with 2" or 3" of ordinary insulation such as mineral wool or fiberglass. However, to maintain condensation-free interiors 5" or more are necessary.

Table 4 gives the insulation values (R) of a typical roof with different thicknesses of insulation.

Table 4
THE INSULATION RESISTANCE (R) VALUES OF SHEET METAL ROOFS WITH VARYING AMOUNTS OF INSULATION



	Thickness of Insulation				
	2"	3"	4"	5"	6"
Mineral Wool Bats*	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.

It is recommended that walls and roofs for potato storages have an insulation resistance of 20 or higher. Note in Table 4 that 5" or more of most insulations are required for an R of 20 or more. It should also be pointed out that the values in Table 4 are for the sections of the roof with the best insulation. Sections including rafters or other framing members will usually have a lower insulation value. This fact reinforces recommendations made previously that "a potato storage needs 6 inches of insulation."

Table 5 shows how low the outside temperature can drop before condensation begins to form on the inside surface of roofs with varying amounts of insulation.

Table 5
OUTSIDE TEMPERATURE AT WHICH CONDENSATION WILL APPEAR ON CEILINGS WITH VARYING INSULATION
(Based on storage temperature of 49° F.)

Insulation Value R	Outside Temperature At Which Condensation Starts
9	21.6°F
12	15.4°F
16	7.2°F
20	- 1.0°F
24	- 9.2°F
30	-21.5°F

Comparing the information in Table 5 with the information in Table 4, it can be seen that a roof with 5 inches of polystyrene will prevent condensation at outside temperatures down to about 4° below zero, whereas a roof with only 2 inches will begin condensation on the inside surface at about 21° F.

Since condensation drip on potatoes hastens decay and the spread of disease, it is obvious that 5 inches or more of most insulations are necessary for adequate potato storage.

TEMPERATURE AND VENTILATION

Maintaining the proper temperature during the entire in-storage period is very important both for potatoes to be processed and for table stock.

When first placed in storage, potatoes need a temperature of 50° to 60° and a relative humidity of 90% or more to heal the wounds caused by harvesting and handling. After maintaining this temperature for 10 days to two weeks the potatoes should be further cooled to the storage temperature.

If sprout inhibitors have been used, the storage temperature may be as high as 45°F. with 90% or higher relative humidity. Without sprout inhibitors a temperature of 40°F is necessary to prevent sprouting.

One of the most critical periods is the first two or three days after the potatoes are put in storage. If soil and outside temperatures are high, the tubers not only have a high temperature but also produce an excessive amount of heat (heat of respiration).

Figure 3 shows the heat of respiration at various storage temperatures. Note that it increases very rapidly at storage temperatures above 50°F. In addition, during the first few days after harvest, heat produced can be expected to be twice that shown in the graph, due to suberization or wound healing.

Thus, it is very important to start the ventilation as soon as you begin to place potatoes in a storage, especially if outside temperatures are high during harvest.

The ventilation system should be started the first night after a few loads of potatoes are put in the storage. Air ducts should be blocked off to force the air through the potatoes.

The ventilation system should then run continuously, day and night, while the storage is being filled and until the suberization period is over and the potatoes have been cooled to storage temperature.

At any time when the outside temperature is higher than the inside temperature, no outside air should be admitted to the fan intake. However, the fan should be kept in operation and inside air recirculated.

In this way the pile can be cooled with night air and by recirculating inside air during the daytime, "hot spots" can be prevented and the surface of the spuds on the top of the pile will remain dry even though high humidity air is being recirculated.

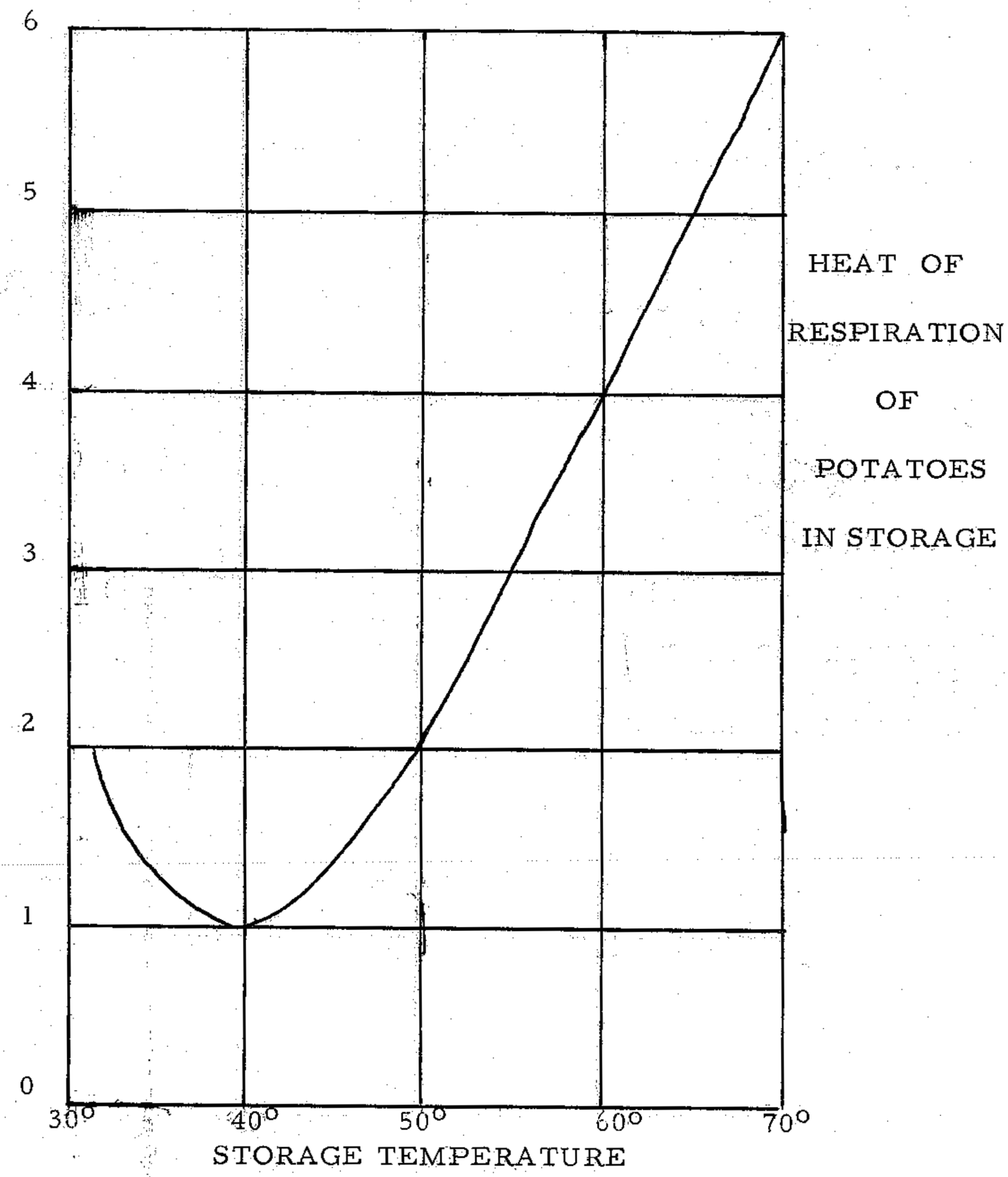


Figure 3

If the fans are shot off during the daytime, heat will build up in the pile, the hot air carrying high humidity will rise to the top of the pile and condense on the surface potatoes that have been cooled by convection currents above the pile. See Figure 4.

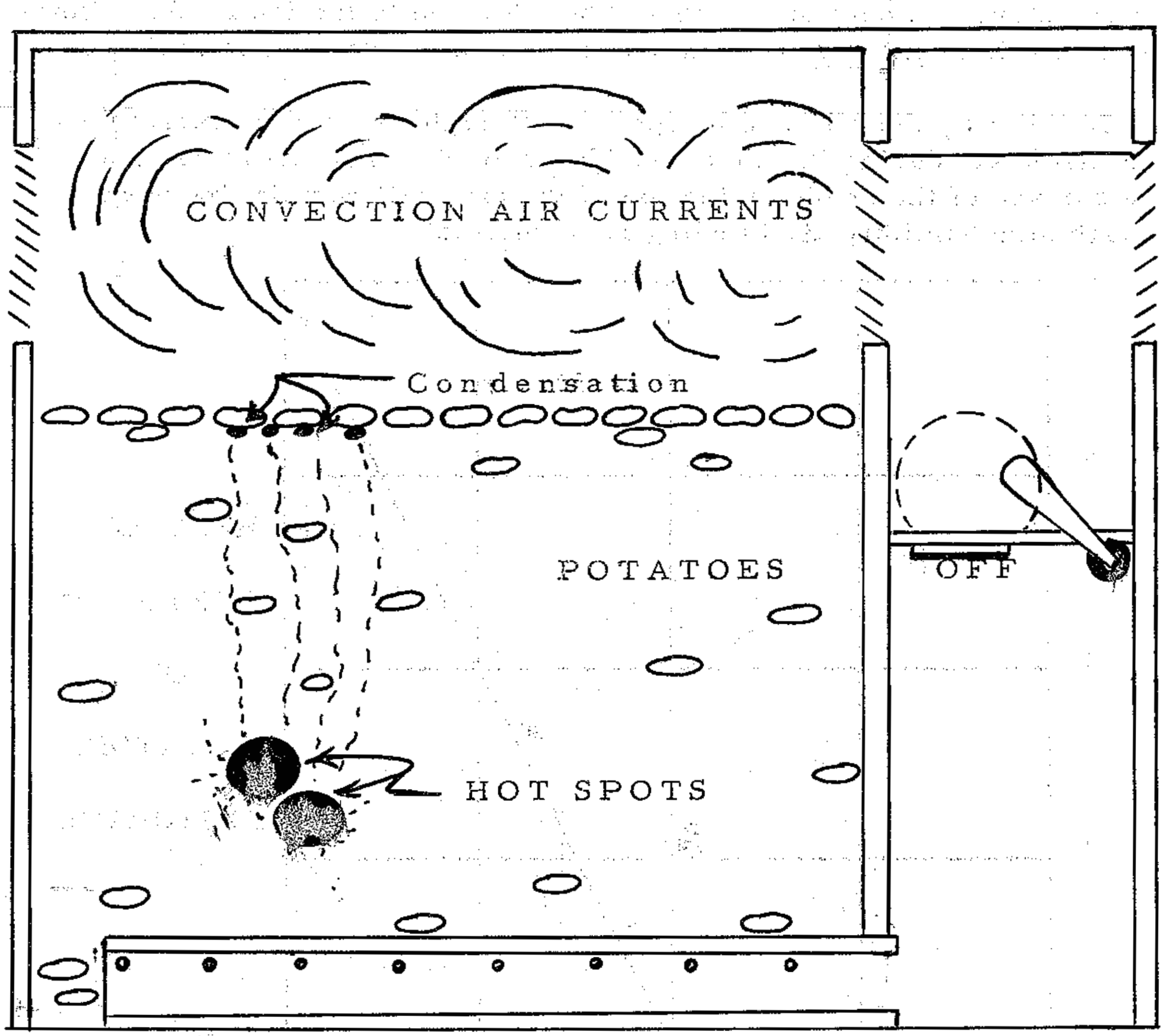


Figure 4

Cooling potatoes each night and recirculating inside air during the day time makes the best use of what cool air is available. By cooling small piles first, as they are built, it is much easier to cool a storage than if air is not started until the storage is filled. Much of the time during the harvest season temperatures do not drop low enough for long enough periods of time to adequately cool the storages unless every advantaage is taken of what cool air does occur.

Fig. 4. The fan should run continually, recirculating inside air when outside air is too warm, to prevent hot spots from occurring and condensation from forming on the surface of the potatoes at the top of the pile.

SUMMARY OF OTHELLO DAILY TEMPERATURES

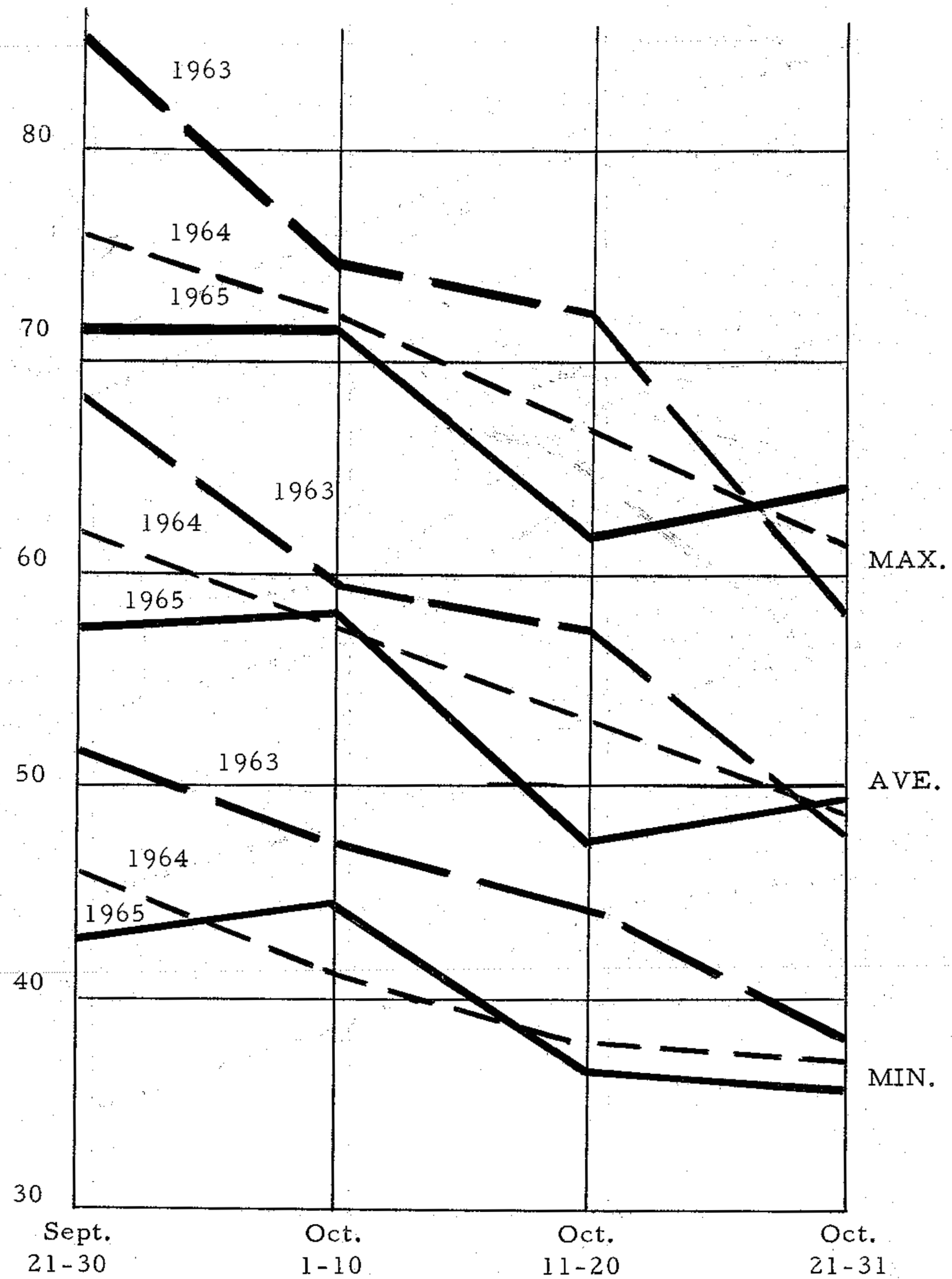


Figure 5

Figure 5 shows 10-day average temperatures for Othello over the last three harvest season.

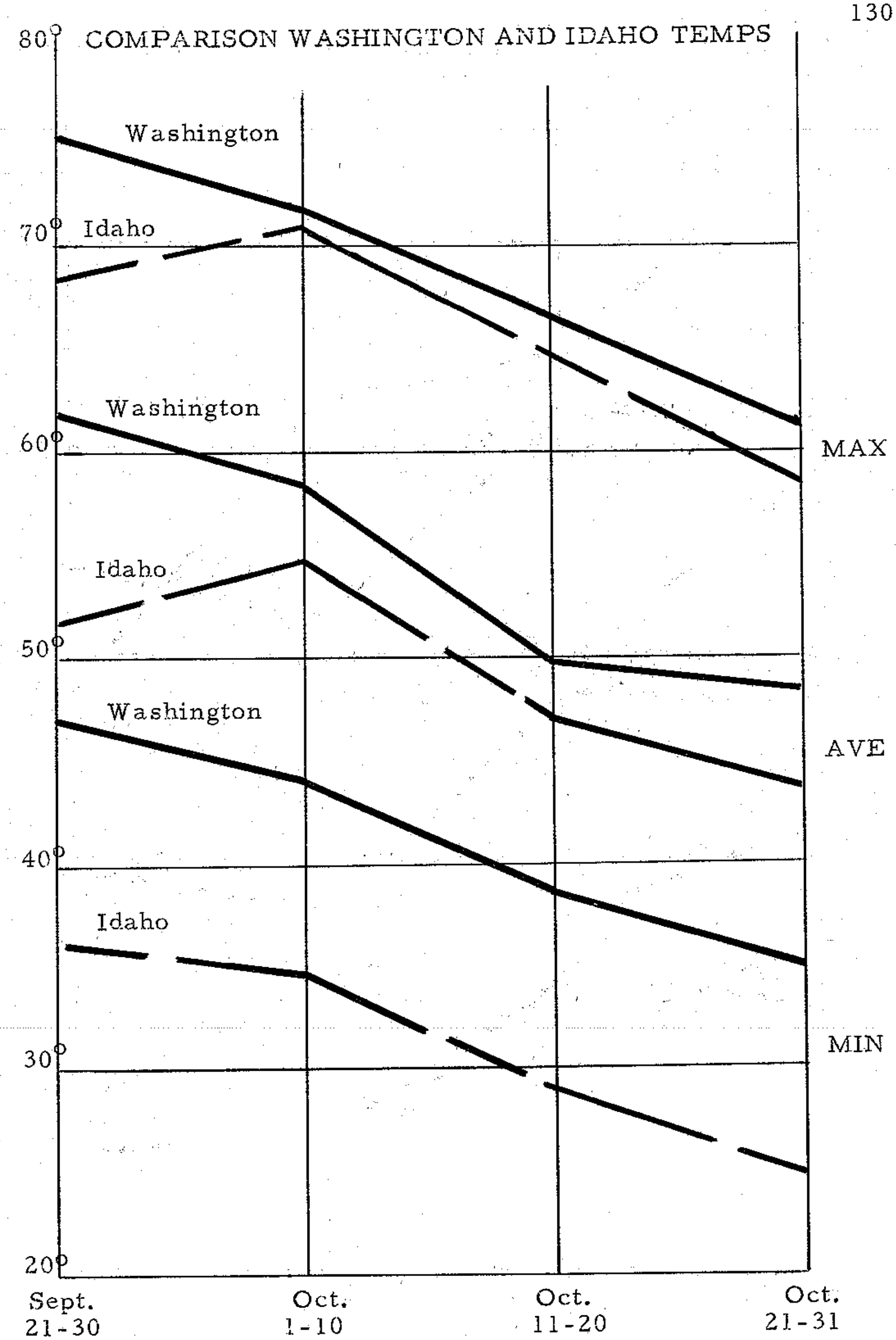


Figure 6 compares these temperatures with Aberdeen, Idaho for the last three harvest seasons.

Note that all average temperatures in the Columbia Basin are above the average temperatures in Idaho's potato producing area. However, most significant is the fact that night temperatures (MIN) are much lower in Idaho than in Washington.

This points up several differences in our ventilation systems as compared to Idaho's. First with less cool air available, we need greater fan capacity during the initial suberization and cooling periods. Second, we need to wait until later in the fall to harvest potatoes for storage. Third, if early harvested potatoes are to be put in storage, we may need refrigeration.

AIR DISTRIBUTION SYSTEMS

Last year we used Idaho's recommendation of 10 cubic feet of air per minute per ton of potatoes. When we ran into trouble during the first part of the harvest season we began looking for explanations. With the temperatures we experienced in the Columbia Basin it appears that we should have more air available during the initial storage period.

Table 6 gives air volume rates for the Red River Valley Area. It appears that we should adapt these figures for the Columbia Basin. At least for the first few weeks of the season we may need as much as 17 cfm per ton.

Table 6
POTATOES PLACED IN STORAGE (MSR 579)

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

A system of air ducts, 10 feet apart, under the potatoes forcing air up through the pile of potatoes seems adequate. The information in WSU Bulletin EM 2523, "Potato Storage Structures and Ventilation", can be used to determine duct sizes and layouts. However, for higher air volumes such as the 17 cfm per ton mentioned above, the cross-sectioned area of the duct will need to be proportionately larger.

SUMMARY

1. Design bin walls strong enough to withstand the high horizontal pressures indicated by tests (page 120).

2. Install 5 or more inches of most insulations, a resistance value (r) of 20 or more.

3. Start ventilation system as soon as a few loads of potatoes are in storage and run it continuously, day and night until entire storage is cooled to storage temperature

4. Provide about 17 cfm per ton of storage, at least for the first few weeks.