AIR AND MOISTURE DISTRIBUTION IN POTATO STORAGES

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The importance of high relative humidity (90 percent or greater) in potato storages has been generally quite well established (2, 3) 1/.

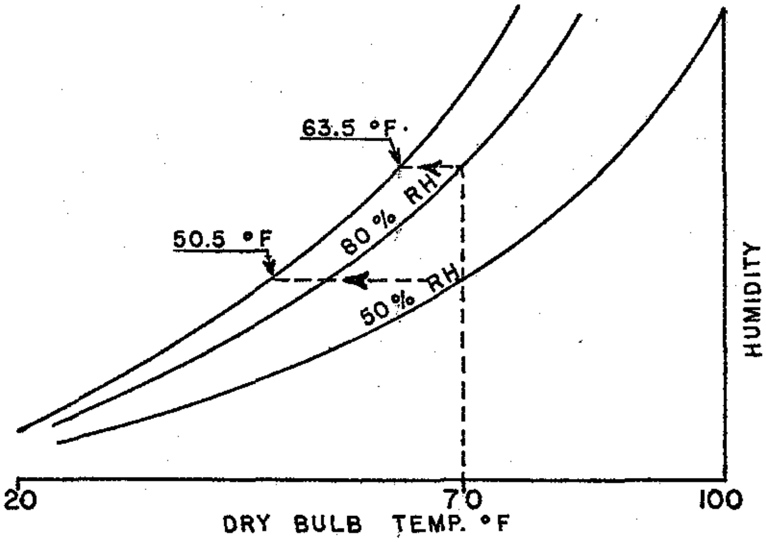
High relative humidity is particularly important during the suberization period and during the first two months of the storage period when tuber weight loss rates are the highest.

Most storages constructed in the last year or two have much better humidification systems than those of previous years. The advent of better humidification systems and therefore higher relative humidity levels has intensified the problem of moisture condensation on the walls and ceiling of the storage buildings. Excessive amounts of condensation can cause wet spots to develop on the top of the potato pile. These wet spots may result in tuber deterioration and should be avoided if possible. The remainder of this paper discusses the causes of condensation and suggests some design and management practices which may be helpful in keeping the problem under control.

Causes of Condensation

Condensation will occur on a surface when the surface temperature reaches the dew point temperature of the air in contact with it. Dew point temperature can be defined as the temperature at which the air is saturated with moisture; that is, the air can not retain any additional water vapor. As the air is cooled further, the water vapor will begin to condense and form water droplets.

Figure 1. Determining the dew point temperature of air by use of a psychrometric chart.



1/ Number in parenthesis refer to appended references.

The dew point temperature of air can be determined by the use of a phychrometric chart. The use of the psychrometric chart for determining water requirements in potato storages was discussed previously (2). You may remember that the base plot of the psychrometric chart is dry bulb temperature versus absolute humidity. The dew point is reached by cooling the air. On the psychrometric chart, cooling is depicted by a horizontal process line. Therefore, one can read the dew point temperature by going horizontally on the chart from the state point of the air until the saturation line (100 percent relative humidity) is reached. Figure 1 shows two examples of dew point temperatures of air. The influence of relative humidity on dew point can be readily seen from these examples. Air at 70°F dry bulb and 50 percent relative humidity has a dew point temperature of 50.5°F. If the relative humidity is increased to 80 percent, the dew point temperature now becomes 63.5°F. This means that as relative humidity levels are increased, condensation will form on surfaces at higher and higher temperatures. Table 1 shows some typical dew point temperatures for conditions which might be encountered in a potato storage.

Table 1. Dew point temperatures for some typical storage conditions

Dry Bulb °F	Wet Bulb °F	RH %	Dew Point °F
40	37.0	75	33
40	38.0	83	35
40	39.5	96	39
42	39.0	77	35
42	40.0	85	38
42	41.5	96	41
45	42.0	78	38
45	43.0	86	41
45	44.5	96	44

Insulation and Condensation

It has been shown that the formation of condensation is related not only to the conditions of the air in the building, but also to the temperatures of the interior building surfaces. The interior surface temperatures are a function of the outside environmental conditions and the thermal insulation properties of the construction material used in the building.

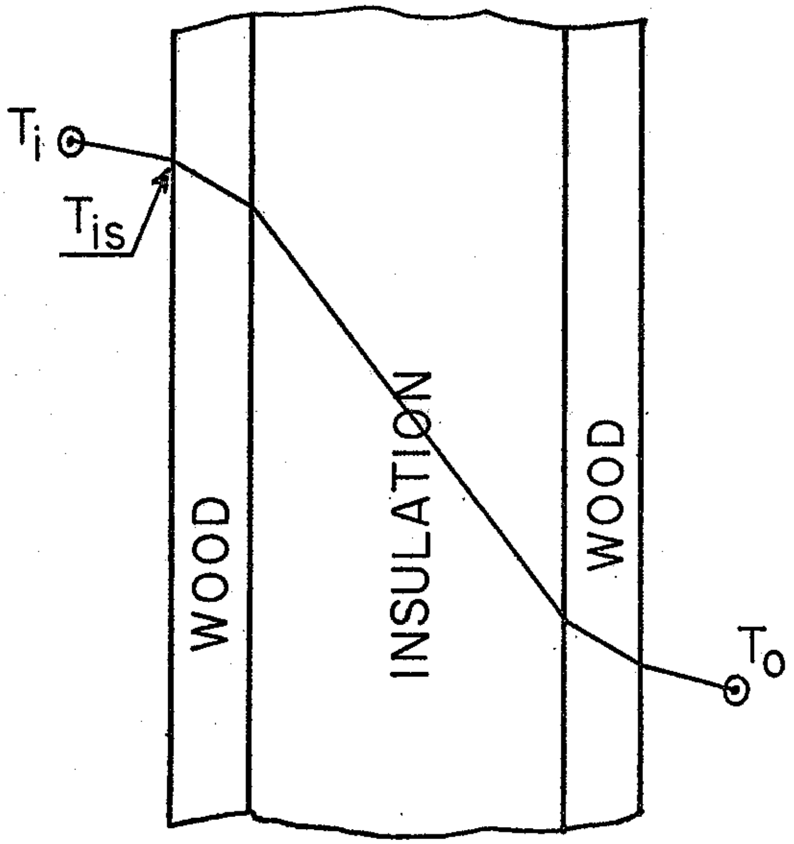
Insulation is generally thought of as important in limiting the loss of heat from or the entry of heat into a building. In a potato storage, the insulation serves another equally important function; namely, maintaining the desired inside surface temperatures in order to minimize condensation.

The temperature gradient through a wall or ceiling depends upon the thermal resistance. In addition to the thermal resistances of the insulation and the materials of construction, there are thin films of relatively stagnant air next to each surface which provide a thermal resistance. The resistance of these surface air films depends upon the air velocity and the orientation of the surface. The air film resistance, during winter conditions, next to a ceiling is larger than that next to a wall. Higher air velocities next to a surface reduce the resistance of the air film. This phenomena is part of the reason that the heat loss from a building is greater when the wind velocities increase.

Figure 2 shows a diagram of the temperature gradient through a wall section. This example represents a section between framing members and is composed of insulation material with a wood sheathing material on each side. The temperature gradient through the insulation is much steeper than that through the wood since it has a larger resistance to heat flow. The temperature gradient through each surface air film is also depicted. The selection of the proper amount of insulation to prevent condensation is based on keeping the inside surface temperature (T_{is}) above the dew point temperature of the air inside the storage building. The inside surface temperature can be estimated using the following relationship:

$$T_{is} = T_i - \frac{R_i}{R_i + R_o + R_w} (T_i - T_o) \quad (1)$$

Figure 2. Temperature gradient through a section of a wall for winter conditions.



R_i is the thermal resistance of the inside air film. For estimation purposes, this can be taken as 0.6. R_w is the thermal resistance of wall and is the sum of the resistances of the structural material and the insulation. The resistance of the outside air film (R_o) is approximately 0.2. This value is based on a 15 mile per hour wind velocity. Substituting these values into Equation 1,

$$T_{is} = T_i - \frac{0.6}{R_w + 0.8} (T_i - T_o). \quad (2)$$

If the thermal resistance of the building material is known, Equation 2 can be used to estimate the inside surface temperature for various combinations of inside and outside temperatures. The thermal resistances of some common building materials are given in Table 2. Additional thermal resistance information can be found in the ASHRAE Handbook of Fundamentals (1). Table 3 shows some typical surface temperatures which might be encountered in a storage building. Remember, if the surface temperature is lower than the dew point temperature of the air in the building, condensation will occur.

Table 2. Thermal resistance of selected building materials and insulations. Values are given per inch of thickness.

Material	Thermal Resistance (R)
Soft wood	1.25
Plywood	1.25
Polystyrene (Extruded)	4.00
Polystyrene (Molded Beads)	3.57
Urethane	7.14
Glass Fiber	3.70
Mineral Fiber	3.70
Concrete	0.08
Sheet Metal[1/]	----

[1/] Sheet metal siding has negligible thermal resistance in common thicknesses.

Table 3. Inside surface temperatures for selected conditions

Insulation[1/]	Temperature (°F)		Surface Temperature (°F)
	Outside	Inside	
Urethane 2"	20	45	44.0
	0	45	43.2
	-15	45	42.6
Urethane 3"	20	45	44.3
	0	45	43.8
	-15	45	43.4
Urethane 6"	20	45	44.7
	0	45	44.4
	-15	45	44.2

[1/] This example considers a sheet metal building

Management Suggestions

It can readily be seen from Table 3 that, with cold outside temperatures and high relative humidity in the storage, condensation will occur even with a relatively large amount of insulation in the storage. Condensation will be more severe on the ceiling than on the side walls. What can be done to minimize the problem? Under some conditions, it may become necessary to reduce the relative humidity in the storage for a period of time. This should be done by shutting off some of the humidifiers in systems where multiple humidifiers are in use. It is not generally a good practice to shut off all the humidifiers as some additional water will still be required. In order to maintain a uniform distribution of moisture in the building, the fans should be operated at least part of the time even though no outside air is being drawn in. In fact, it may be better to increase the hours of operation of intermittently operated fans during these periods. However, care must be taken to insure that large quantities of very cold outside air are not drawn into the building during this time. If extremely severe condensation problems are encountered, portable fans can be placed on top of the pile and directed to move additional air along the ceiling surface. This tends to raise the ceiling surface temperature as well as provide better moisture distribution above the potato pile.

The air distribution system should be designed to provide a uniform distribution of air through the potato pile. This is important not only to insure constant temperature within the pile, but also a uniform distribution of moisture. If possible, the air return and exhaust systems should be placed so that the air flows along the ceiling. This will help to minimize condensation problems.

Literature Cited

1. ASHRAE Handbook of Fundamentals. 1972.
2. Pettibone, C. A., and W. M. Iritani. 1973. Humidity Requirements during the Early Storage Period. 12th Annual Washington State Potato Conference.
3. Sparks, Walter C., and Larry V. Summers. 1974. Potato Weight Losses, Quality Changes and Cost Relationships During Storage. Idaho Agricultural Experiment Station Bulletin 535.