SUPPLY AIR, POTATOES, and WATER at HARVEST

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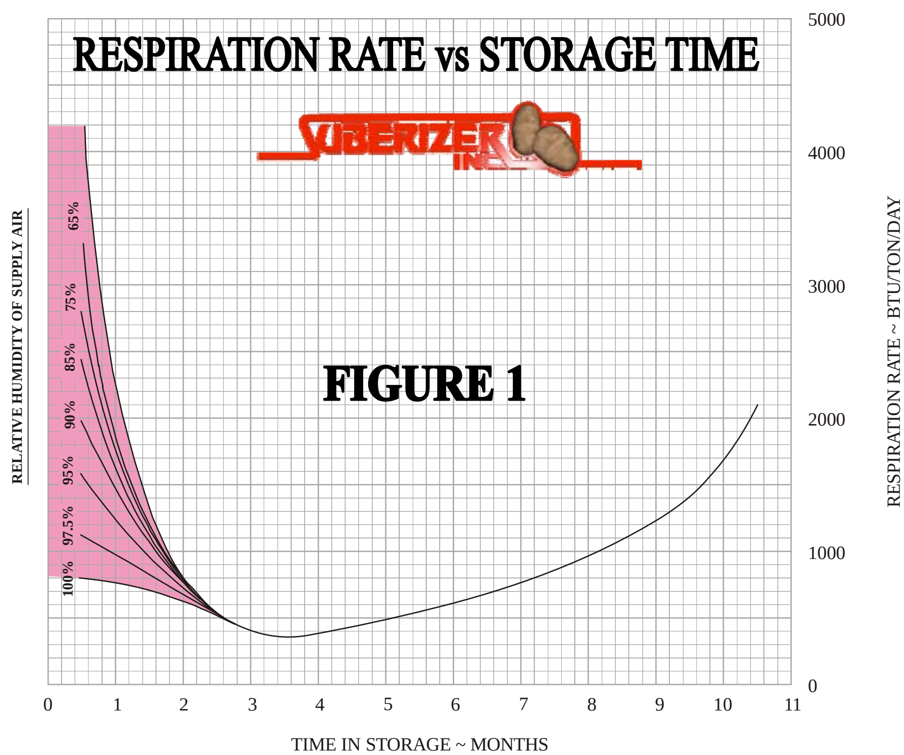
The subject of storage management during harvest, and storage management the first weeks following harvest, requires special attention to the subject of Supply Air. The Basic Task of storage is to preserve both the **quantity** and **quality** of the raw product placed in storage at harvest. Preservation of the *quantity* and *quality* simply means minimizing losses: weight loss, quality losses, and loss due to spoilage. Research has shown that for every percent of weight loss during storage there is an additional percent of quality loss. Since Supply Air is easily considered the lifeblood for maintaining a healthy pile, the condition, or properties of the Supply Air during harvest must be important. And, Supply Air properties must be based on a complete appreciation of potato condition coming into storage.

Wound healing and suberization take place during the first few weeks spuds are in storage. Suberization includes the deposit of suberin, a waxy, fatty substance, into tuber cells adjacent a wound, along with transforming the surface of the damaged area and skin into corklike tissue. This process sets the stage for successful storage. Proper suberization is simply the key to minimum losses in storage. Weight loss will be dramatically minimized, and quality losses can be even more significantly minimized if the suberization process is optimum. In addition, good suberization has a direct positive effect on the disease resistance of potatoes in storage. Supply Air properties are one of the most easily overlooked details that affect good suberization.

Before we wade into a discussion of Supply Air properties, though, let's take a look at the spuds. It simply makes good sense that the more thoroughly we understand what's going on in storage, the more successful storage will be. Since a potato is a living, breathing organism throughout storage, let's begin by taking a look at the **Respiration Rate** during storage. Webster's dictionary defines respiration as "the sum total of the physical and chemical processes in an organism by which oxygen is conveyed to tissues and cells, and the oxidation products: heat, carbon dioxide and water, are given off."



Respiration is actually a combustion process. Living, breathing organisms need oxygen. The oxygen that potatoes need in storage supports this combustion process, and the products of combustion are heat, CO_2 and water. Note that the right ordinate in **FIGURE 1** presents the heat associated with the respiration process in BTUs per ton of potatoes per day. This heat and CO_2 associated with respiration must be exhausted to control temperature and provide a proper environment for wound healing and maturation of the potatoes. How well the storage manages this heat has everything to do with successful storage.

Right off the bat, when spuds are placed in storage, the plot suggests that the respiration rate can vary from an extremely high rate to a relatively low rate. Several things actually determine the respiration rate during early storage. We do know that healthy, disease-free spuds have a lower respiration rate. Furthermore, respiration rate is a function of temperature. The respiration rate is higher in a warmer pile. The left ordinate suggests that the respiration rate during the first few weeks potatoes are in storage might be a function of supply air relative humidity: that a low respiration rate is associated with high relative humidity supply air. This correlation is based on weight loss studies with various supply air relative humidities.

FIGURE 2, on the following page presents weight loss as a function of time for various supply air relative humidities. For example, with a supply air relative humidity of 95% and a storage period of 7 months, note that you should expect a total weight loss of about 4%. Actual weight loss in storage for a seven month storage period is often much greater. Note that after the first month and a half, or so, in storage, the slope of the 75% RH weight loss curve is not that different from the 95% RH curve. But, look at the difference between the slopes of the same two curves in the first month of storage!

After the first month or so in storage, weight loss potential is not so drastically affected by supply air relative humidity. Sure, the 75% RH curve is somewhat steeper after two months of storage than the 95% curve. But, during the first month and a half of storage the rate of weight loss is highly dependent on supply air relative humidity. The stage is clearly set during suberization for weight loss that will take place. Both tuber temperature and supply air relative humidity affect the process of suberization; and supply air temperature relative to tuber temperature has a huge impact on supply air relative humidity in the pile.

FIGURE 3 demonstrates an interesting thing that happens when we superimpose the two previous figures. The period of "initial high respiration rate" coincides directly with the period of time that sets the stage for the initial "rate of weight loss". Since research has shown that a portion of the cause for a high initial respiration rate is low supply air relative humidity, it's not surprising that the first month in storage is critical for weight loss.

During the first month, weight loss for 100% Rh supply air is 0.4%, for 65% RH supply air: weight loss is 3.0% !

A complete appreciation of the Basic Task in potato storage must focus on temperature. The relation between supply air temperature, tuber temperature, and relative humidity has everything to do with the Basic Task. Control of virtually every storage concern, problem, and factor is related to a complete understanding of temperatures in storage and the relation between temperature and humidity. This brings us close to our primary focus on **Supply Air, Potatoes, and Water at Harvest**.

However, first, recognize that excellent storage management at harvest requires taking enough action to <u>know what you've got coming into storage</u>. A very simple six-step procedure is worth considering:

<u>STEP ONE</u>:
KNOW PULP TEMPERATURES IN THE FIELD

<u>STEP TWO</u>:
PLAN YOUR HARVEST

<u>STEP THREE</u>:
RECORD PULP TEMPERATURES INTO STORAGE

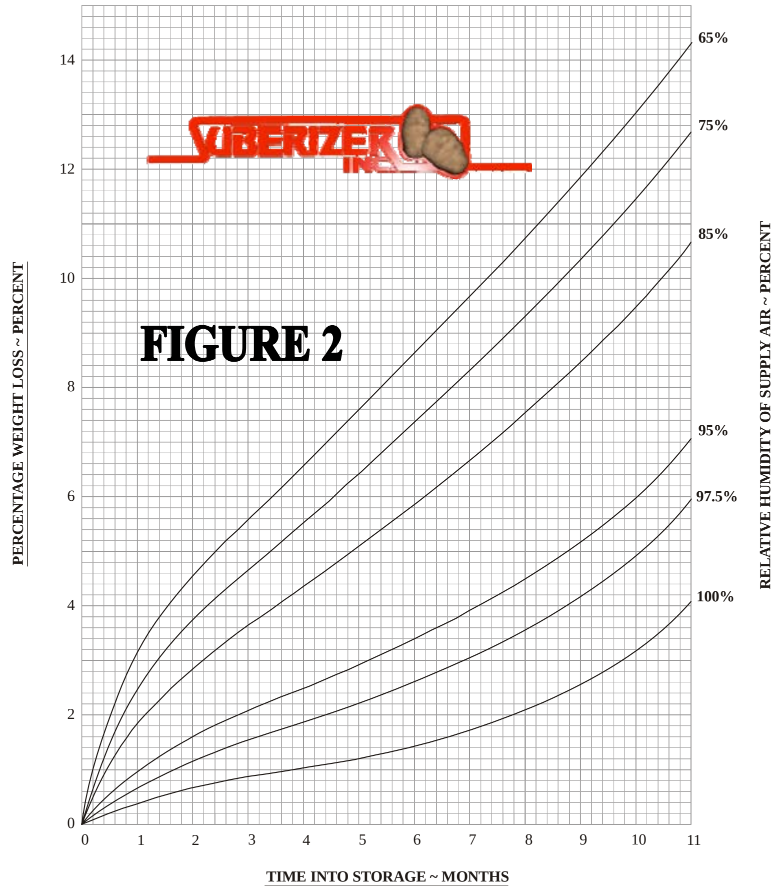
<u>STEP FOUR</u>:
ESTABLISH AN INITIAL SUPPLY AIR SETPOINT

<u>STEP FIVE</u>:
CHECK TOP OF PILE PULP TEMPERATURE EACH MORNING

<u>STEP SIX</u>:
SUBERIZE, SUBERIZE, SUBERIZE

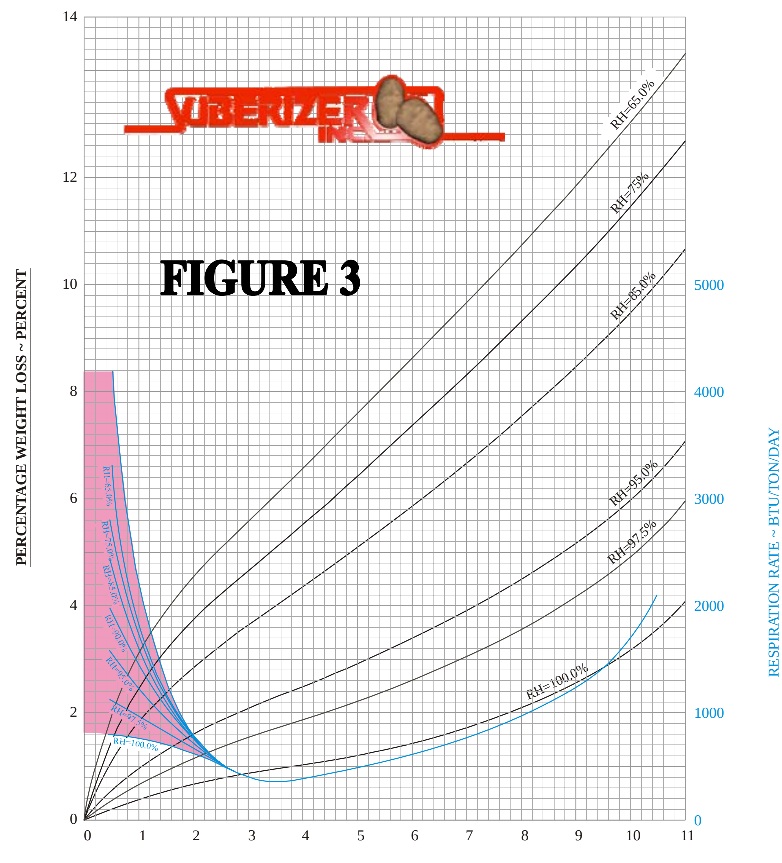
Let's briefly consider each step on the next page.

PERCENTAGE WEIGHT LOSS vs STORAGE TIME



PERCENTAGE WEIGHT LOSS vs STORAGE TIME

RESPIRATION RATE vs STORAGE TIME



STEP ONE: KNOW PULP TEMPERATURES IN THE FIELD
Take a little booklet, or a simple spiral notebook you can carry in your pocket, along with an accurate pulp thermometer, and start a daily log of pulp temperatures in the field for a couple weeks before harvest begins.

STEP TWO: PLAN YOUR HARVEST
Make a conscious effort to plan your harvest so that you bring spuds into storage with a manageable pulp temperature range. An ideal pulp temperature range for all spuds into storage would be maybe between 55°F and 70°F.

STEP THREE: RECORD PULP TEMPERATURES INTO STORAGE
When harvest begins, the piler operator is the perfect person to continue the task of logging pulp temperatures from each load of spuds coming into storage. He should record two or three sample temperatures from each truckload during each day of harvest in the logbook you started in the field. Date the top of each page.
This pulp temperature information is the basis for establishing an initial setpoint for system supply air temperature, and is the basis for lowering setpoint as harvest continues.

STEP FOUR: ESTABLISH AN INITIAL SUPPLY AIR SETPOINT
Use an initial setpoint for saturated supply air that is cooler than the coolest pulp in storage. Pulp temperatures on the first day of harvest are often quite warm. Let's assume the pulp temperature range for the first day into storage is 61.7°F (16.5°C) in the morning to a high logged temperature of 69.8°F (21°C). By the end of the first day of harvest the spuds associated with the coolest temperatures in your logbook have probably warmed a few degrees. For this example consider using an initial setpoint of 61°F or 62°F (16.1 or 16.7°C) for the first night.

STEP FIVE: CHECK TOP OF PILE PULP TEMPERATURE EACH MORNING
Now, with spuds in storage, please start a STORAGE RECORD booklet. Most field men and storage managers feel that this STEP is most important! The key here is to make certain that the pulp temperature on top of the pile does not increase during harvest. In this Storage Record Booklet record pulp temperatures on the top of the pile each morning during harvest.

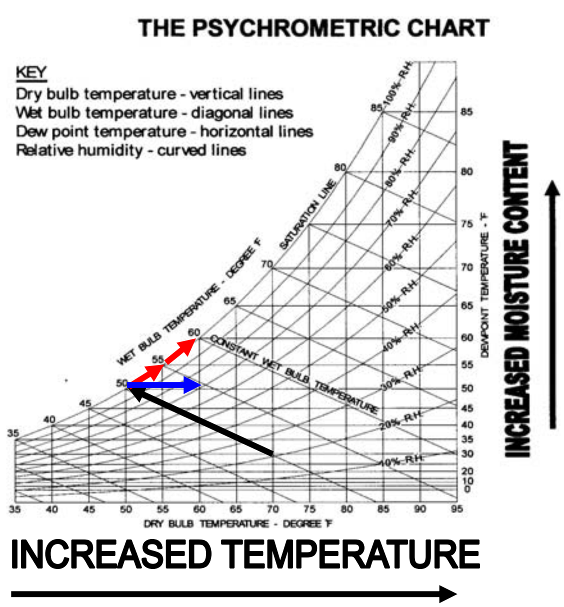
STEP SIX: SUBERIZE, SUBERIZE, SUBERIZE
Suberization is Mother Nature's process of depositing the waxy-fatty substance suberin in the skin cells and turning the skin cork-like. When the suberization process is complete, since the skin is less permeable, weight loss is minimized, quality losses are minimized, rot is minimized, and disease resistance is maximized. Suberization begins about the third day after harvest, and suberization is complete about two weeks after harvest. Since the suberization process is completed faster at temperatures in the sixties, the first spuds into storage are usually suberized by the time the storage is full and the doors are closed.

With potato temperature information available, let's turn to the business of **Air, Potatoes and Water at Harvest.** An appreciation of information the Psychrometric Chart can provide is fundamental.

The PSYCHROMETRIC CHART

The subject of psychrometrics in potato storage is the relationship between *water vapor* and *dry air*. An understanding of the psychrometric conditions in potato storage provides valuable insight to storage management that will provide a more complete picture of humidification, condensation, and the all-important effect **Supply Air properties** have on potatoes in storage. In fact, **Supply Air** psychrometrics is fundamental to the effective storage of potatoes.

The simplified **psychrometric chart** presented below shows the following properties of moist air: 1. **Dry Bulb Temperature** (Vertical Lines); 2. **Wet Bulb Temperature** (Diagonal Lines); 3. **Dew Point Temperature** (Horizontal Lines); and 4. **Relative Humidity** (Curved Lines). If any two of these properties are known, the other two properties can be determined from the psych chart.



There are several reasons the psych chart is helpful. **First**, the chart allows us to see just how much cooling is available when using outside air. Let's assume outside air temperature is 70°F, and the relative humidity is 20% RH. A well-designed humidification system with a blow-through air washer will bring the air to saturation. Find the intersection of 70°F on the abscissa (dry bulb temperature) and the 20% RH line. As outside air passes through the humidification system water vapor is added to the the air, and the air follows a constant wet bulb (diagonal) line to saturation (100% RH). Supply air in the plenum will be at about 50°F. That's a 20°F reduction in temperature!
The **Second** benefit from the psych chart shows us what happens during early storage when saturated supply air enters a warmer pile during harvest. Often during harvest pulp temperature can be in the 60's… 70°F is not uncommon. And suppose you decide to use a 50°F supply air setpoint. As the 50°F saturated air is warmed by 60°F pulp the supply air, following the saturation line, has the capacity to hold additional moisture.

This new "ability" for warmer supply air to hold additional moisture is important to understand. The amount of moisture the air can hold (at any temperature) is referred to as the vapor pressure deficit. Moisture to satisfy the new vapor pressure deficit can come from surface moisture, if the potatoes are wet, or moist. Otherwise, since potatoes are 80-odd percent water, as air travels through the pile, the potatoes will quickly bring the supply air to saturation.

Another way to consider what happens when 50°F saturated air is warmed: Note that following a flat horizontal line from 50°F on the saturation line to 60°F shows that the relative humidity drops to 70%! Warm air can hold more moisture, so the relative humidity drops.

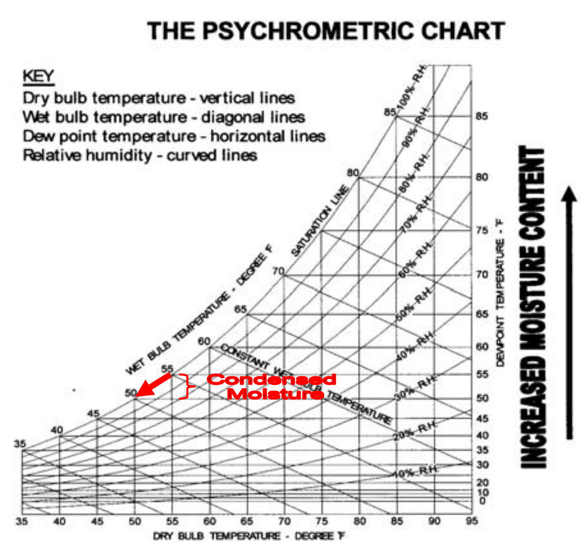
And, that presents a very interesting point: Regardless of the supply air condition (the relative humidity of the supply air), air leaving the pile will be virtually saturated due to moisture present in the pile. The real message here is that if we're not careful during early storage, if the spuds are quite warm relative to the supply air temperature, we will actually be subjecting the pile to relatively low humidity air, even if the supply air in the plenum is close to saturation!

In fact, at least five factors actually hinder getting saturated supply air to the pile. Let's take a quick look at each factor:

1. Relative humidity of the outside air must be brought to saturation by the system. When outside air is very dry it takes a surprising amount of water to get the air to saturation. When the fresh air dampers are fully open, a high-performance humidification system is necessary to actually achieve saturation.
2. Mechanical heat from the fans and other equipment is a significant portion of the total heat load. Air moving across the fans will warm the air about 1°F. This 1°F increase in temperature results in a loss of about 5% RH. Therefore, it is most important that the humidification system is downstream from the fans.
3. Impingement of the air on its way to the pile. Air in a plenum and in the ducts is turbulent. As air is redirected by structure, and by corrugations in the airpipe, the impingement during this re-direction causes a change in state of moisture in the air. Air does not want to stay saturated, anyway, and this impingement simply wrings moisture out of the supply air. To help make up the vapor pressure deficit caused by this impingement it is important for the air supply to carry along some micron-sized droplets.
4. Heat of product is the heat associated with warm harvested spuds. Our example of cooler air going into a warmer pile presents this very important issue.
5. Respiration adds additional heat. The respiration rate is significant during suberization, especially if the spuds have been bruised or damaged during harvest. This combustion process is a big contributor to pile heat, and consequently respiration lowers relative humidity. Furthermore, another look at the weight loss curve presented earlier suggests that supplying saturated air can even reduce the respiration rate. So attention to temperature and supply air relative humidity, especially during suberization is a must.

But, what happens when the weather turns cold, and potatoes are brought into a warmer storage? A **third** benefit from the psych chart shows us what happens <u>when saturated supply air in the storage is blown on colder spuds coming into storage</u> during harvest. Suppose the storage setpoint during harvest is 55°F, and all of a sudden a cold snap drops the pulp in the field to 50°F: Condensation will form on the cooler pulp if the 55°F storage environment is more moist than ≈82% RH, so just count on those cooler spuds getting wet, unless you take some action. What can you do (if you don't have another storage to go in to with this cooler pulp)? The best bet is to close the duct gates to the warmer potatoes, turn off the humidification, keep the same 55°F setpoint, and warm those cooler spuds. It's not perfect, because the supply air returning from the pile will be moist. In order to provide warmer supply air effectively, air drier than the return must be "made" available, possible by heating drier outside air.

Refer to the complete Psych Chart on the following page. Note that following a horizontal line from 55°F on the saturation line to the right, suggests that saturated 55°F air has a Humidity Ratio of 65 grains of water per pound of dry air. And, following a horizontal line from 50°F on the saturation line to the right, suggests that saturated 50°F air has a Humidity Ratio of 54 grains of water per pound of dry air, a difference of 11 grains of water per pound of dry air. (7,000 grains = 1 pound)



Making the calculation, at an air flow rate of 20 CFM/Ton of spuds: (11 grains)(.075#/ft^3)(20 CFM/Ton of Spuds)= 16.5 # of water will form in the pile each minute, for each Ton of spuds. The primary message is do everything possible to plan harvest so that you always need to cool potatoes at harvest.

Think about this for a moment: the average spud at harvest is only about halfway to the table: It is up to the storage and the storage manager to maintain both the ***quantity*** and the ***quality*** of the potatoes placed in storage for as long as necessary.