

# Basic Stuff

## (A Frank Talk About Supply Air and Potato Storage Management)

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Potato storage supply air recommendations today vary considerably among potato-growing regions around the world. This presentation is a frank talk about how significantly different supply airflow recommendations can affect potatoes in storage. A typical recommendation in the United States is 20 CFM per ton of potatoes. A significantly higher airflow of 100 cubic meters per hour per cubic meter of potatoes (83.3 CFM/Ton), for example, is recommended by some folks in Europe.

When it comes right down to it, whether potato harvest is in American Falls or Amsterdam, Boise or Britain, Pasco or Prague, Twin Falls or Tasmania, the requirements for optimum storage management of healthy potatoes are based on Two Primary Categories:

1. The physiological properties of the potatoes to be stored; and,
2. The basic physical and mechanical properties of air and air movement through the pile.



The **Basic Stuff** necessary for optimum storage management applies . . . anywhere in the world. General worldwide agreement exists for storage management regarding most of the physiological properties and general condition of potatoes to be stored. And, let's agree that there is almost always more than one way to get the job done. However, whether air is blown UP through the pile, or sucked DOWN through the pile, **Basic Stuff** still needs to be appreciated, and tended-to. Air is the lifeblood for successful storage. The question before us here: Is there any logic for significantly different supply air recommendations for potatoes in the same physiological condition in one corner of the world than any other location?

While we're "agreeing", let's agree that the **Basic Stuff** for optimum storage management must also include exceptionally uniform air distribution; appropriate supply air humidity to minimize weight loss; along with tight temperature control to minimize quality losses.

Consider this article a very close, but narrow look at one of the least appreciated and least understood aspects of optimum storage management: the **Basic Stuff** associated with the physical and mechanical properties of air and air movement through the pile at harvest. The primary reason this aspect of storage management is one of the least appreciated storage management issues has to do with a lack of understanding of the psychrometric chart, and the subject of psychrometrics in potato storage. Psychrometrics deals with the relationship between *water vapor* and *dry air*, in the supply airflow, as a function of temperature.

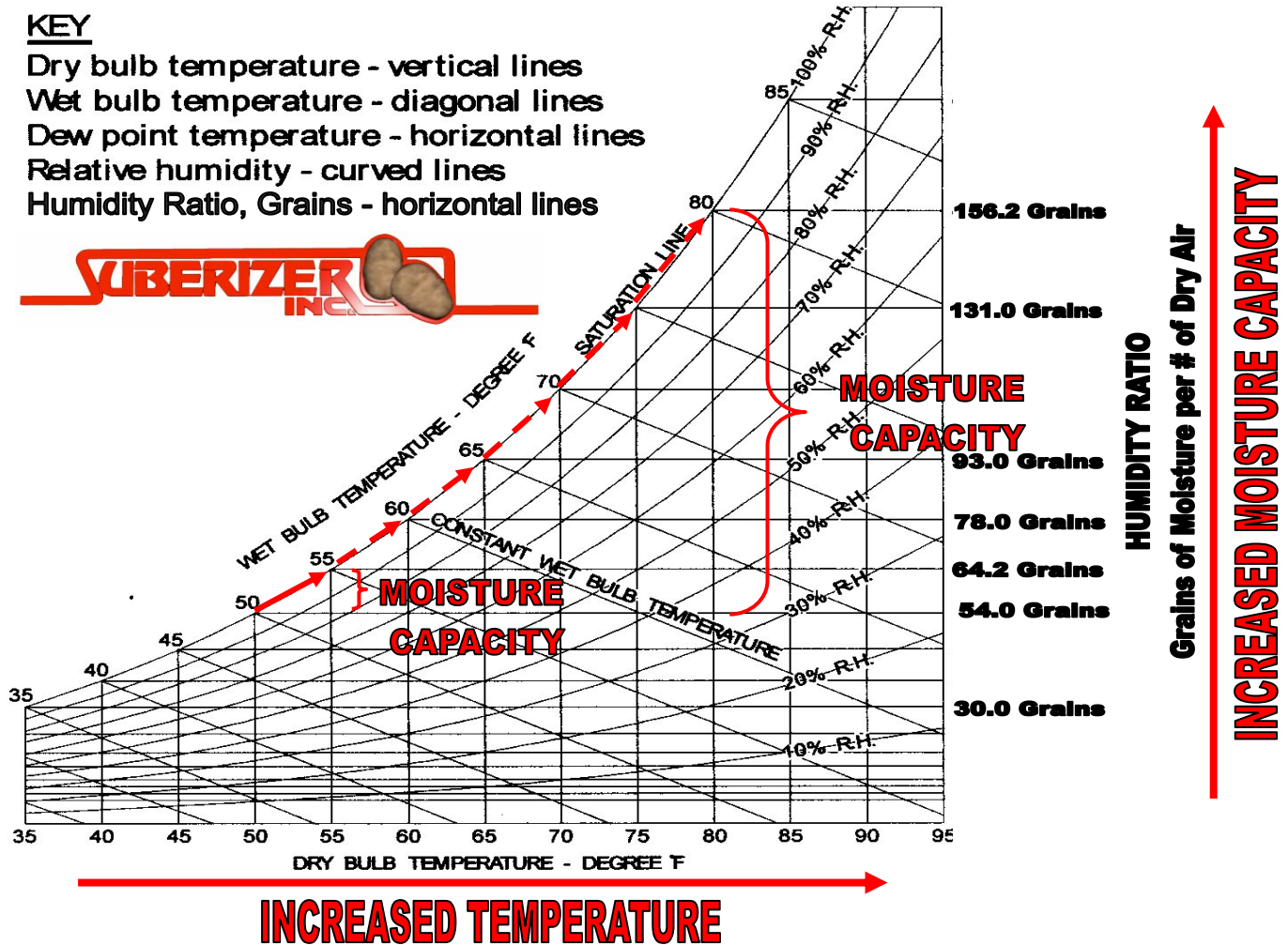
## The Psychrometric Chart

At first glance the Psych Chart does look confusing. But, if you stay with me, the mystery will be removed, and it will be worth your time, because an understanding of the psychrometric conditions in potato storage provides valuable insight to storage management.

At the end of this presentation you will agree that a complete appreciation of supply air at harvest is one of the most important aspects of the *Basic Stuff* required for optimum storage management. Furthermore, you may agree that no logic exists for significantly different supply air recommendations for potatoes in the same physiological condition in one corner of the world than any other location.

A complete psych chart, with all normally-presented information, does look confusing. Here is a simplified chart, which presents the information important for our study:

## THE PSYCHROMETRIC CHART



## THE PSYCH CHART LET'S US SEE :

- HOW MUCH COOLING IS AVAILABLE FROM OUTSIDE AIR
- WHAT HAPPENS WHEN SATURATED SUPPLY AIR IS WARMED BY THE PILE
- HOW MUCH MOISTURE SUPPLY AIR CAN ABSORB WHEN IT IS WARMED
- WHAT HAPPENS WHEN WARMER AIR IS SUPPLIED TO COOLER POTATOES.

### Supply Air Properties:

We will use this chart to determine the effect two different supply airflow rates have when saturated supply air (100% RH) is warmed as it flows through the pile. In different parts of the world airflow is discussed in different units. So, just to get numbers on common ground for the various ways of discussing airflow let's begin by establishing some equivalent units. For example: cubic feet per minute per hundred weight (or per ton) of potatoes is common in the United States; and, Europe often discusses airflow in cubic meters per hour per cubic meter of potatoes, as suggested in the opening paragraph. In order to correlate different units we need to assume a specific weight for potatoes. Specific weight does vary with variety and potato size, but, for the sake of simplicity, let's base our calculations for this discussion using 40 pounds per cubic foot of potatoes (640 Kg per cubic meter of potatoes), which is the same as 50 cubic feet per ton (1.41584 M<sup>3</sup>/Ton); and, say a ton is 2,000 pounds (907.18 Kg). Then, the following table presents equivalent numbers:

SPECIFIC WEIGHT	≡	SPECIFIC VOLUME
40 #/Ft <sup>3</sup> = 640 Kg/M <sup>3</sup>	≡	50 Ft <sup>3</sup> /Ton = .00156 M <sup>3</sup> /Kg = 1.41584 M <sup>3</sup> /Ton

With different values for Specific Weight or Specific Volume, converted to equivalent units, the resulting message would be the same.

So, now, let's compare what happens when 50°F (10°C) supply air at saturation is supplied in the two above-mentioned airflow units.

A look at the Psych Chart shows that as supply air warms, the relative humidity stays at 100% if moisture is available, and the air properties follow the Saturation Line. The moisture capacity for air at any air temperature can be determined by following a horizontal line from the air temperature at the saturation line to the vertical axis on the right. The amount of moisture air can hold is presented as a Humidity Ratio: "Grains of H<sub>2</sub>O per # of Dry Air", for any air temperature on the Saturation Line. The change in moisture content the supply air can absorb is directly related to the difference in the Humidity Ratio from one air temperature to another.

Recognizing that 7,000 Grains = one Pound of water, here's what the Psych Chart suggests 50°F/10°C supply air has the capacity to absorb (from the potatoes, or the air surrounding the potatoes), as it warms, without addressing the total airflow rate:

Supply Air Temperature °F/°C	Pulp Temperature °F/°C (assumed air temperature)	Supply Air Temperature Change (ΔT) °F/°C	Grains H <sub>2</sub> O per # Dry Air Absorbed In Pile	Pounds H <sub>2</sub> O per # Dry Air Absorbed In Pile	Pounds H <sub>2</sub> O Absorbed per Day per CFM/Ton of Potatoes	Pounds H <sub>2</sub> O Absorbed per Day per M <sup>3</sup> /H/Meter <sup>3</sup> of Potatoes
50°F/10°C	55°F/12.8°C	5°F/2.8°C	10.2	0.00146	0.15768	0.092806944
50°F/10°C	60°F/15.5°C	10°F/5.5°C	24.0	0.00343	0.37044	0.218032752
50°F/10°C	65°F/18.3°C	15°F/8.3°C	39.0	0.00557	0.60156	0.354064849
50°F/10°C	70°F/21.1°C	20°F/11.1°C	57.0	0.00814	0.87912	0.517430497
50°F/10°C	75°F/23.9°C	25°F/13.9°C	77.0	0.01100	1.18800	0.699230401
50°F/10°C	80°F/26.7°C	30°F/16.7°C	102.2	0.01460	1.57680	0.928069441

Next, let's get the two airflow rates in the same units using the above equivalent weights for potatoes:

$$100\text{M}^3/\text{Hr}/\text{M}^3 \text{ of Spuds} = (100\text{M}^3/\text{Hr}/\text{M}^3 \text{ of Spuds})(1 \text{ Ft}^3/.0283168 \text{ M}^3)(1.41585 \text{ M}^3/\text{Ton})(1\text{Hr}/60 \text{ min}) \\ = 83.33 \text{ CFM}/\text{Ton of Potatoes}$$

$$20 \text{ CFM}/\text{Ton of Spuds} = (20\text{ft}^3/\text{Min}/\text{Ton of Spuds})(1 \text{ M}^3/35.314667 \text{ Ft}^3)(60 \text{ Min}/\text{Hr})(1 \text{ Ton}/1.41584 \text{ M}^3) \\ = 24.0 \text{ M}^3/\text{Hr}/\text{M}^3 \text{ of Potatoes}$$

Now, when the respective supply airflow rates are introduced, the following table presents the amount of moisture saturated supply air can absorb as the air heats-up in the pile for various storage sizes:

**SUPPLY AIR: @ 20 CFM per Ton of Potatoes (24.0 M<sup>3</sup>/Hour per M<sup>3</sup> of Potatoes)**

Supply Air Temperature °F/°C	Return Air Temperature (due to pulp) °F/°C	Supply Air Temperature Change (ΔT) °F/°C	Pounds H <sub>2</sub> O Absorbed by Supply Air Per Day			
			1,000 Ton Storage	2,000 Ton Storage	5,000 Ton Storage	10,000 Ton Storage
50°F/10°C	55°F/12.8°C	5°F/2.8°C	3,153.6	6,307.2	15,768.0	31,536.0
50°F/10°C	60°F/15.5°C	10°F/5.5°C	7,408.8	14,817.6	37,044.0	74,088.0
50°F/10°C	65°F/18.3°C	15°F/8.3°C	12,031.2	24,062.4	60,156.0	120,312.0
50°F/10°C	70°F/21.1°C	20°F/11.1°C	17,582.4	35,164.8	87,912.0	175,824.0
50°F/10°C	75°F/23.9°C	25°F/13.9°C	23,760.0	47,520.0	118,800.0	237,600.0
50°F/10°C	80°F/26.7°C	30°F/16.7°C	31,536.0	63,072.0	157,680.0	315,360.0

**SUPPLY AIR: @ 100 M<sup>3</sup>/Hour per M<sup>3</sup> of Potatoes (83.33 CFM/Ton Potatoes)**

Supply Air Temperature °F/°C	Return Air Temperature (due to pulp) °F/°C	Supply Air Temperature Change (ΔT) °F/°C	Pounds H <sub>2</sub> O Absorbed by Supply Air Per Day			
			1,000 Ton Storage	2,000 Ton Storage	5,000 Ton Storage	10,000 Ton Storage
50°F/10°C	55°F/12.8°C	5°F/2.8°C	13,139.9	26,279.8	65,699.5	131,399.0
50°F/10°C	60°F/15.5°C	10°F/5.5°C	30,869.8	61,739.6	154,349.0	308,698.0
50°F/10°C	65°F/18.3°C	15°F/8.3°C	50,129.6	100,259.2	250,648.0	501,296.0
50°F/10°C	70°F/21.1°C	20°F/11.1°C	73,259.4	146,518.8	366,297.0	732,594.0
50°F/10°C	75°F/23.9°C	25°F/13.9°C	98,999.2	197,998.4	494,996.0	989,992.0
50°F/10°C	80°F/26.7°C	30°F/16.7°C	131,399.0	262,798.0	656,995.0	1,313,990.0

These tables clearly demonstrate the amount of water lost per ton of potatoes when saturated (100% RH) supply air is warmed as it flows through the pile. The amount of water lost from the pile is a combined effect of temperature, supply air flow rate, and the percent saturation.

More complete information about the Psychrometric Chart is available at the following websites:

- [http://highered.mcgraw-hill.com/sites/0072383321/student\\_view0/chapter13/chapter\\_glossary.html](http://highered.mcgraw-hill.com/sites/0072383321/student_view0/chapter13/chapter_glossary.html)
- <http://architecture.arizona.edu/Templates/bcdc/chart/index.html>

**PHYSIOLOGICAL POTATO PROPERTIES:**

Physiological properties of the potato, along with the conditions at harvest that affect potato physiology, are reasonably easy to appreciate, and generally acknowledged by storage managers. Although supply air to the pile in storage is unquestionably regarded as the life-blood necessary to maintain a healthy pile, details associated with supply air properties, and the relation between supply air properties and tuber physiology seem to be one of the least truly-appreciated requirements necessary to achieve optimum storage performance.

**WEATHER CONDITIONS:**

Weather conditions at harvest vary dramatically between potato growing regions around the world. And, weather conditions can vary dramatically for each region, from year-to-year, and even during each harvest. Since the weather, soil, and actual condition of potatoes at harvest all contribute to the picture for appropriate storage management, these issues are clearly part of the picture.

An important point is that often, weather conditions at harvest can assist with storage management: Warm, dry weather conditions at harvest allow significant cooling with appropriate humidification. For example, 85°F outside air at 20% RH can be reduced to 60°F supply air if brought to saturation. 70°F outside air at 20% RH can be reduced to 50°F supply air if brought to saturation.

**WINDING IT UP:**

For the sake of wound-healing and suberization, ideal pulp temperature at harvest is between 10°C (50°F) and 20.5°C (69°F). Tuber temperature below 10°C (50°F) adversely affects suberization. In fact, suberization comes to a screeching halt as pulp temperature drops below 10°C (50°F). However, research suggests that the pulp temperature for an optimum suberin deposit is in the high 70-80°F range. Since the normal, or usual, temperature in many potato-growing regions includes very warm weather, this presentation is directed especially at healthy potatoes harvested into storage with pulp temperatures warmer than the desired steady-state long-term storage temperature:

The above calculations show that a supply air temperature much lower than the coolest pulp in storage will result in significant weight loss. The following table summarizes the capacity of saturated supply air to absorb moisture, and presents the moisture which saturated (100% RH) supply air has the capacity to absorb in tons of water per day.

**COMPARE MOISTURE ABSORPTION CAPACITY FOR THE TWO SUPPLY AIR RATES:**

SUPPLY AIR TEMP INCREASE, °F	CAPACITY OF SUPPLY AIR TO ABSORB MOISTURE							
	Tons of H <sub>2</sub> O per Day							
	1,000-Ton Storage		2,000 Ton Storage		5,000 Ton Storage		10,000 Ton Storage	
	20 CFM Per Ton	100 M <sup>3</sup> /H Per M <sup>3</sup>	20 CFM Per Ton	100 M <sup>3</sup> /H Per M <sup>3</sup>	20 CFM Per Ton	100 M <sup>3</sup> /H Per M <sup>3</sup>	20 CFM Per Ton	100 M <sup>3</sup> /H Per M <sup>3</sup>
Tons/Day	Tons/Day	Tons/Day	Tons/Day	Tons/Day	Tons/Day	Tons/Day	Tons/Day	
50°F to 55°F	1.6	6.6	3.2	13.1	7.9	32.8	15.8	65.7
50°F to 60°F	3.7	15.4	7.4	30.9	18.5	77.2	37.0	154.3
50°F to 65°F	6.0	25.1	12.0	50.1	30.1	125.3	60.2	250.6
50°F to 70°F	8.8	36.6	17.6	73.3	44.0	183.1	87.9	366.3
50°F to 75°F	11.9	49.5	23.8	99.0	59.4	247.5	118.8	495.0
50°F to 80°F	15.8	65.7	31.5	131.4	78.8	328.5	157.7	657.0

A quick calculation suggests that tens of thousands of dollars can be lost per day, in weight loss alone, for a large storage with high supply airflow rates, especially when significantly cooler supply air is warmed by the pile. Furthermore, as supply air velocities increase in the storage air distribution arrangement, uniform air distribution falls apart. In addition, higher supply air velocities reduce the ability of the system to supply saturated air to the pile without “hosing-down” the potatoes.

The message is clear: Attention to the detail management of supply air during early storage is a crucial element for optimum storage management. A basically healthy pile of potatoes arriving at storage in the 55°F to 80°F range can easily absorb surface moisture with saturated air supplied at 20 CFM per Ton, at an appropriate supply air temperature.

How can the weight loss, and associated quality losses, be considered acceptable, when even saturated air is supplied at excessively high airflow rates to potatoes warm-enough to significantly raise supply air temperature as it flows through the pile?! Optimum storage management requires complete knowledge of the coolest pulp in storage during harvest, and setting the supply air temperature only 2-3°F cooler than the coolest pulp in storage.

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