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for Agriculture and Beyond

Supplemental Heating FAQ

Using Supplemental Heat to Manage Grain in the Bin

Rain, snow and cool temperatures at harvest time mean producers must manage grain in the bin as carefully as they manage it in the field. Adding supplemental heat to natural air drying (NAD) can be an efficient and effective way to dry stored grain if done correctly. Here are the answers to some frequently asked questions about supplemental heat.

NOTE: The recommendations below apply to all varieties of crops.

Q: What does supplemental heat mean? How is it different from other drying systems?

A: Supplemental heating means adding heat to a fan used for natural air drying. Adding heat increases the capacity of air to hold moisture and, therefore, its capacity to dry grain. A comparison of systems, including pros and cons, is shown here:

	Description	Pros	Cons
Heated air drying	▪ Usually a small batch process ▪ Uses hot air (45-80° C) to dry grain ▪ Uses very high air flow rates (approx. 20 cfm/bu)	▪ Success does not depend on ambient conditions ▪ Dries grain quickly (hours) ▪ Suitable for any ambient condition	▪ Can result in seed damage ▪ Requires cooling cycle ▪ High capital and energy costs
Natural air drying (NAD)	▪ Turns the grain bin into a "dryer" ▪ Blows ambient air (5-25° C) through grain ▪ Uses moderate air flow rates (approx. 1 cfm/bu)	▪ Energy savings ▪ Smaller investment ▪ Reduced risk of heat damage ▪ Most suitable when ambient > 15ºC	▪ Slow (can take weeks) ▪ Requires management ▪ Success dependent on ambient conditions
NAD with heat	▪ Adding a heater to a NAD fan to increase the temperature of the air going into the bin	▪ Turns a "poor" drying day into a "good" drying day ▪ Minimal capital investment ▪ Most suitable when ambient > 0ºC ▪ Reduces drying time to days	▪ Requires management (and grain turning) ▪ Few options for temperature control ▪ Energy cost

NOTE: cfm/bu = cubic feet per minute per bushel

Photo by: Amy Hogemann

Q: How much does adding heat affect the capacity of air to dry grain?

A: For every 10° C increase in the temperature of the air going into the bin, the relative humidity (RH) of the air is cut in half.

With added heat, a cold, drizzly fall day can be turned into a beautiful drying day. For example, the equilibrium moisture content (EMC) chart for wheat is shown below.

On a day when ambient air conditions are 5°C and 70% RH, the air will have no capacity to dry since the EMC for wheat is 16.1% (and target moisture content is 14.4%). But, by increasing the air temperature to 15° C using some heat, the resulting RH will be cut in half, to about 35%, and the air will have capacity to dry since its EMC for wheat will be 10.3%.

EMC chart for wheat

Temp ºC	Relative humidity (%)										
	35	40	45	50	55	60	65	70	75	80	85
-2	11.5	12.2	13.0	13.7	14.5	15.3	16.0	16.9	17.7	18.7	19.8
2	11.1	11.9	12.6	13.4	14.1	14.9	15.6	16.4	17.3	18.2	19.3
5	10.9	11.7	12.4	13.1	13.8	14.6	15.3	16.1	17.0	17.9	19.0
8	10.7	11.5	12.2	12.9	13.6	14.3	15.1	15.8	16.7	17.6	18.7
10	10.6	11.3	12.0	12.7	13.4	14.2	14.9	15.7	16.5	17.4	18.5
13	10.4	11.1	11.8	12.5	13.2	13.9	14.6	15.4	16.2	17.1	18.2
15	10.3	11.0	11.7	12.4	13.1	13.8	14.5	15.2	16.1	17.0	18.0
18	10.1	10.8	11.5	12.2	12.9	13.6	14.3	15.0	15.8	16.7	17.7
22	9.9	10.6	11.3	11.9	12.6	13.3	14.0	14.7	15.5	16.4	17.4
26	9.7	10.4	11.1	11.7	12.4	13.0	13.7	14.4	15.2	16.1	17.1
28	9.6	10.3	11.0	11.6	12.3	12.9	13.6	14.3	15.1	15.9	16.9

Photo by: Danielle Bergen

Q: Should I turn the heater off when it is raining?

A: Unless the rain affects the safe operation of the heater and fan, you do not have to turn off the heater. Air with an RH of 100% can be turned into air with an RH of approximately 50% by increasing the temperature of the air by 10° C.

Q: Should I avoid propane or direct-fired heating systems because they add water to the air?

A: Not necessarily. Combustion of fuels like propane or natural gas does generate water, but the amount of water added to air is negligible compared to the amount of water being removed from the bin. For example, the amount of water added to the air using a propane heater (assuming 10° C increase for 5,000 cfm) is approximately 7 lb/hr. The amount of water being removed from the bin is approximately 120-200 lb/hr.

An indirect heating system like a heat exchanger or hydronic heating system will be slightly more efficient because it will not be adding any water to the air, but if a propane or natural gas heater is available or more convenient, they are very effective.

Q: What temperature increase should I target?

A: The target temperature increase will depend on ambient conditions. Plan for a target air plenum temperature of 15-25° C (possibly 30° C with sufficient air flow). Any increase in air temperature will increase the capacity of air to dry, but the optimal temperature is 15-25° C.

Be cautious with using higher temperatures when it is very cold outside. First, it will require a large heater, and resulting higher fuel costs, to achieve temperatures in the 15 to 25° C range. Second, there is an increased chance of condensation and freezing grain at the edge of the bin when it is very cold outside. Limit the temperature and reduce the drying rate of NAD and supplemental heat when it is cold outside.

Q: If warm air is good, hot air is better, right? Should I crank up the temperature as high as I can?

A: No. The air temperature is what pulls the moisture out of the grain kernel itself, but it is the air flow (measured in cubic feet per minute – cfm) from the fan that pulls the moisture out of the grain mass and out the top of the bin. The relatively low air flow from aeration or NAD fans cannot keep up with high water removal rates. The temperature needs to be matched with the fan capacity.

A minimum of 0.75 cfm/bu air flow rate is recommended for any NAD with supplemental heat. With that air flow rate, you should be able to use plenum temperatures of 15-20° C. Higher temperatures will require higher air flow rates.

Q: How do I determine how large of a heater I need? Or, I have an existing heater that is 100,000 btu/hr – how much grain will it dry?

A: The size of heater you need depends on two things:

1. the air flow rate (cfm) from your fan, and
2. your desired temperature increase.

Heater capacity (btu/hr) = temperature increase (degrees C) x air flow rate (cfm) x 2.05

Example: to raise the air temperature by 10° C for a bin/fan that is pushing 5000 cfm, the required heater capacity is 10 x 5000 x 2.05 = 102,500 btu/hr

Example: if you have a 100,000 btu/hr heater and you attach it to a bin/fan that is pushing 7500 cfm, the expected temperature increase will be 100,000/7500/2.05 = 6.5° C.

Keep in mind these equations assume a highly efficient heat transfer setup meaning all of the heat generated by the heater ends up in the air. The overall efficiency of some systems may be as low as 50%, so estimate the required size of your heater accordingly.

Q: Which fuel type is most cost effective?

A: The total fuel cost theoretically depends on its cost ($/L) AND its energy density. The cost will fluctuate from month to month and region to region, but the energy density is constant.

Fuel	Fuel cost *(variable)*	DIVIDED BY	Energy density *(fixed)*	EQUALS	Fuel cost *(variable)*	X 1056	Fuel cost *(variable)*
Diesel	**$1.00/L**		**38.6 MJ/L**		**$0.026/MJ**		**$27.45 per million btu**
Natural gas	**$0.1387/$m^3$**		**37.0 MJ/m^3**		**$0.0037/MJ**		**$3.90 per million btu**
Propane	**$0.49/L**		**25.3 MJ/L**		**$0.019/MJ**		**$20.45 per million btu**

If a carbon tax is applied, that will increase the cost per million btu. The amount of that increase depends on the fuel since each fuel emits a different amount of carbon per L burned.

Also note that propane and natural gas are considered "clean burning" fuels, so they can be used to directly heat the air entering the fan or bin. Diesel should only be used as an indirect source of heat.

Q: How do I best manage a NAD system with supplemental heat?

A: Some general management practices include:

1. Only use a CSA certified heater that is designed for use with grain storage fans for safety and grain quality reasons. Follow manufacturer's instructions for installation and operation.
2. Ensure adequate air flow rate (minimum 0.75 cfm/bu) or there is a risk of overheating the grain.
    - Low air flow rates may not have enough energy to fully remove moisture from the bin.
    - Refer to pami.ca/storage for information on measuring air flow rate.
3. Limit air temperature increase to 15°C or less.
    - Higher temperature increases result in high fuel costs, reduced heat transfer efficiency, increased chance of over drying, and increased chance of freezing/sticking at edge of bin.
    - For every temperature increase of 10°C, the RH of the air is cut in half.
4. Do not exceed an inlet (after heater) temperature of 30°C.
    - Even though higher temp = more drying capacity, you do not want to overheat the grain.
    - Air flow rates of 0.75 to 1 cfm/bu can "keep up" with moderate drying rates, but not with high drying rates associated with high temperatures (>30°C).
5. As much as possible, maintain a CONSISTENT air temperature going into the bin.
    - Thermostatic controllers are becoming more common and will help achieve a consistent temperature going into the bin. This will help minimize day-to-night variations in temperature.
6. Ensure adequate ventilation in the headspace since condensation on a cold bin roof can cause moisture problems in the stored grain.
    - A minimum of one square foot of vent space for every 1000 cfm of air flow is required.
    - Consider the use of "active" ventilation in the headspace which helps to expel moist air more effectively.
7. Consider turning the grain partway through drying to distribute over-dry grain at the bottom.
8. Grain MUST BE turned and cooled to less than 15°C after drying
    - Cooling will also remove some moisture, so drying may be complete when moisture is within 1% of target.
9. Monitor grain conditions with in-bin cables and/or samples during drying.