The importance and process of optimising grain aeration systems

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Key words

silo aeration systems, grain aeration, aeration controllers, optimising grain storage, aeration fans

Take home messages

- Increasing the number of grain aeration fans doesn't always increase airflow in grain storage facilities
- Grain storage aeration systems should be set up to achieve airflow rates of 2 to 4 litres of air, per second, per tonne of grain (L/s/t) for cooling or 15 to 25 L/s/t for drying
- Grain temperatures under 23°C during summer storage and less than 15°C during winter are best to maintain grain quality and manage insect and pathogen incursion.
- Grain type, grain bed depth and moisture content are key considerations when aerating stored grain
- There are four key hardware components to optimise aeration performance in grain storage facilities: these include fans, vents, ducting and an aeration controller
- Its best to perform monthly checks to ensure aeration systems are operating effectively.

Control Unlimited is a company that manufactures automatic aeration controllers for fans used in grain storage facilities. Our company regularly undertakes research to characterise storage facility aeration systems. The aim of this research is to better understand how to optimise the process of cooling or drying grain. Recent research has identified that adding more fans to a silo can decrease the total airflow if fan performance limits are reached. The findings prompted the need to review aeration systems to ensuring all components are matched appropriately to the task.

Fundamental targets

Appropriate airflow rates

Airflow rates measured in grain storage are most typically referred to in litres of airflow, per second, per ton of grain (L/s/t). Targeting the correct airflow rate is extremely important as without sufficient airflow the grain becomes increasingly susceptible to mould development and insect infestation. Measuring aeration fan airflow is not difficult and can be undertaken using the GRDC Grain Storage Fact Sheet 'Performance testing aeration systems.' The optimal airflow rates for both long-term grain maintenance (e.g. cooling airflow rates) and ambient air grain drying (e.g. drying airflow rates) are as follows:

- Cooling airflow rate: 2 - 4 L/s/t
- Drying airflow rate: 15 - 25 L/s/t

Safe temperatures

Regular monitoring of grain temperatures is integral to ensuring seed stored for planting purposes maintains acceptable seed viability. Cool storage conditions also minimise the risk of mould and insect damage. This is most easily monitored using a grain temperature probe and should be checked monthly when checking for insect pests in stored grain. Grain storage aeration systems should target temperatures of:

- Summer: 18-23°C
- Winter: less than 15°C

Key considerations

With the fundamental targets of air flow rate and target temperature in mind, there are a number of additional factors that need to be considered when evaluating an aeration system and how it is intended to be used:

Grain type

The type of grain being stored can cause variation in airflow rates. Larger grains such as chickpeas and mung beans enable higher airflow rates due to the large air spaces between grain. However, small grains such as canola provide far greater resistance to air movement which results in higher back pressures being applied to fans and results in lower airflow rates though grain. Grain type needs to be considered when purchasing or setting up grain storage facilities.

Grain bed depth

The height to which a silo is loaded also has a profound impact on the performance of aeration systems. A fully loaded silo 10 metres tall will require considerably more airflow to counter the extra back pressure on fans when compared to loading it half-full to a bed depth of 5 metres.

Moisture content of grain

Operation of aeration equipment requires a different approach depending on the moisture content of the grain stored. For example, the temporary storage of high moisture grain has a greater susceptibility to self-heat, so requires effective air distribution and longer fan run times each day than grain stored at receivable moisture (e.g. 12.5%).

Hardware for optimised aeration systems

In order to achieve the optimal airflows and grain temperatures there are four major hardware components that allow this to be attained. They are aeration fans, ducting, silo vents and an automatic aeration controller.

Aeration fans

The size and number of fans on a silo is integral to achieving a desired airflow and must be done with the silo size and fan performance curves in mind. This should be achieved in consultation with a silo manufacturer or grain aeration specialist if required. When considering if additional fans should be added to a storage it is important to note that this will increase the static backpressure, so each extra fan will contribute less to total airflow. When configured correctly, added fans will still supply as much additional airflow as possible (Figure 1). However, if backpressure created by additional airflow exceeds the performance of the fans, the total airflow through the grain is undesirably reduced (Figure 2). Fitting extra fans without checking air flow and back pressure can be a waste of both equipment and electricity. Seeking professional advice is critical to ensure the number of fans and their design performance are matched with the storage and aeration system.

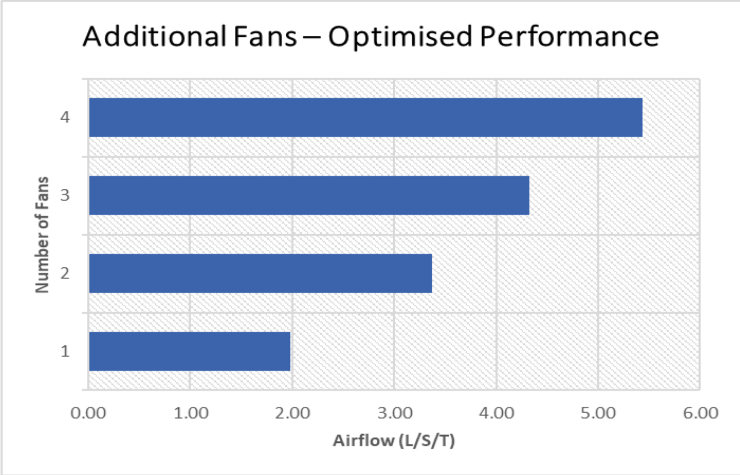

Figure 1. An optimised aeration fan configuration

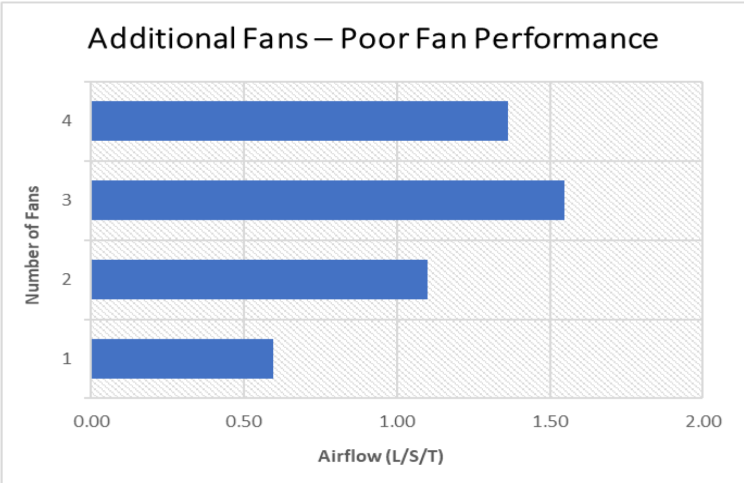

Figure 2. Poorly sized aeration fan configuration

Ducting

Ducting comes in various shapes and configurations; however, this is typically not as important as their length and placement in the silo. Ducting should be as long as possible and evenly placed between the wall and tip of the cone. Sufficient distance should be observed so that air can't easily escape up the wall (approximately 300 mm from wall) and far enough away from the bottom slide that the ducting doesn't interfere with silo unloading.

Silo vents

Vents are the best way to ensure maximised performance of the fans by releasing any excess pressure in a silo. This simply ensures that air is not trapped and pressurising the headspace of the silo. To avoid pressurising the headspace the typical rule of thumb is for every 500 L/s of airflow, a 0.9 m^2 vent area is required. The best way to test this is by measuring airflow with all vents open, and then perform another test with both vents, roof manhole and silo top fill hole open to see if any additional airflow is achieved. If the airflow rate increases after this second test it, indicates that the storage requires additional ventilation. For any smaller storages under approximately 100 tonnes, opening the top fill hole, or using a tin hat with mesh sides on the fill hole is generally sufficient ventilation.

Automated aeration controller

An important component of an aeration system is an automated aeration controller. This piece of equipment will accurately and reliably select the best air to introduce into the storage to keep grain temperatures as low as possible for maintenance of long term grain quality. However, not all aeration controllers are the same, there are several different theories of operation to be aware of:

- Set-point: The temperature and humidity set points are manually selected for when the fan will run.
- Automatic
    - Time proportioning controller (TPC): Fans are controlled in accordance with an algorithm that targets the best air available for the aeration mode that is selected.
    - Adaptive discounting controller (ADC): Controls fans based on a modelled cooling process given an array of information including grain condition, stack size and aeration system, manually entered by the operator.

The most common form of aeration controller is TPC so the focus of this paper will be directed towards this controller type. These systems vary between manufacturers, but controllers can typically manage up to 24 silos with the one system and have functions to automatically start and stop generators when they are required at remote sites. They work using a three stage cooling process. This is further represented in Figure 3.

- **Continuous**: runs the fans constantly unless the humidity setpoint is reached (typically 85% RH), to ensure that fans are not running through rain events or heavy dew mornings. This function should be used for the first 5 days (120 hours total) after grain has been placed in a silo to provide maximum fan run time to remove harvest heat from the grain and even out the moisture content throughout the storage.

- **Purge or rapid:** This function is used for the next 7 days of the storage period. Fans run approximately 12 hrs each day (84 hours total). The fans will typically be run during the night when the temperature is at its coolest to continue bringing down the grain temperature. It still incorporates a humidity override function (i.e. will not run if the humidity setpoint is reached).

- **Protect or maintenance:** Used for long-term grain maintenance where fans run for approximately 100 hours per month. This mode endeavours to select the coolest air available to introduce into the silo to keep the storage temperature as cool as possible. Most TPC controllers have an algorithm that allows them to adapt to local conditions, meaning that if a heat wave passes through, the fan will not run during this warmer period until more normal temperature conditions return (refer to figure 3 from 14/12/20 – 23/12/20).

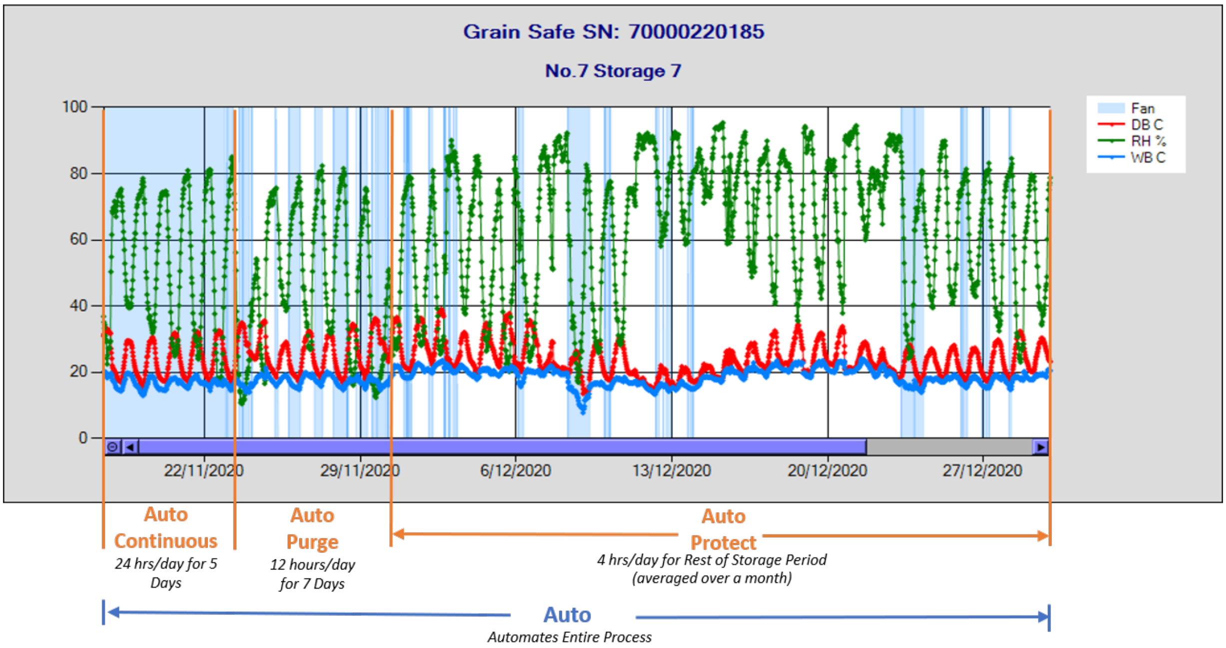

Figure 3. Aeration controller modes

Economics

The investment in aeration systems scales better as the volume of grain being stored increases. For an example, 8 elevated silos with a capacity of 180 tonnes each, storing grain valued at $270/t equates to $388,800 worth of grain.

Using this example, aeration fans will cost 0.2% of the value of grain over a 10-year period. A further 0.1% will be required for all ducting, 0.17% to cover vents, 0.12% for an automated aeration controller and another 0.2% for an aeration control cabinet. The cost of all the equipment to optimise a new aeration system for this example would be less than 1% of the value of grain it protects, over 10 years. The running costs of the fan then depend on variables such as the system, time in storage and energy costs. Estimated running costs per tonne include 35 cents for the first month then 15 cents per month of storage thereafter.

Monitoring

Grain in storage requires regular and consistent monitoring, just as a crop does throughout the growing season. This allows any problems or equipment faults to be detected early before any significant damage can occur to the grain. A monitoring schedule performed monthly should involve:

- Fan testing: a well-equipped aeration controller will typically provide a 'test' function that allows the operator to temporarily test each aeration fan for any faults
- Temperature testing to ensure the grain mass is within the target range for the time of year
- Monitor grain moisture to ensure it is remaining consistent
- Check for pests in traps and sieve grain.

The industry is also moving toward remote grain monitoring where live temperature and moisture readings can be viewed on a smart phone or computer. This technology is still adapting into a format suitable for Australian conditions and is something to keep in mind to improve monitoring efficiency and become aware of any issues as soon as they develop.

Conclusion

In summary, aeration systems should be targeting airflows of 2 to 4 L/s/t for cooling and 15 to 25 L/s/t for drying. Grain temperatures in summer should aim for between 18 and 23 degrees Celsius, and below 15 degrees in winter. The influence of grain type, grain bed depth and moisture content need to be understood and managed. Ensure the four major components of an aeration system: fans, ducting, venting and an aeration controller, are set up correctly in consultation with a silo manufacturer or aeration specialist. The investment in quality on-farm storage with aeration can be maximised by regular monitoring of the system over its lifespan.

Declaration

The author work for Control Unlimited which manufactures automatic aeration controls for grain storage facilities.

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