



## **The WA Guide to High Moisture Harvest Management, Grain Storage and Handling**



In partnership with

SOUTH EAST PREMIUM WHEAT GROWERS ASSOCIATION



### **About this publication**

A partnership between the CBH Group and the South East Premium Wheat Growers Association (SEPWA) has produced this publication to help grain growers evaluate the potential to start harvest earlier and use high moisture grain management to maximise financial returns by controlling grain quality.

The CBH Group sees this as an important part of helping growers streamline their harvest programs and limit the efficiency losses in their handling system during damp conditions. While the relevance of high grain moisture management to each grower will vary across the state and between seasons, most are likely to encounter grain moisture related issues at some stage.

While all care has been taken in preparing this publication, early harvesting may not always be appropriate for each grower in each year. Growers should always consider all relevant information and circumstances when deciding to harvest their grain. What works well for one grower may not produce the same benefits for another grower due to differing circumstances and if a grower has any doubts regarding the timing of harvesting they should obtain further advice.

### **Measurements**

This publication discusses equipment manufactured in the northern hemisphere, including references to both metric and imperial measurements. To assist, a conversion table can be found at the back of the publication.

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### **Cost references**

While care has been taken preparing the financial information used in this publication, seek further advice before making any decisions based on financial aspects of high grain moisture handling.

### **Foreword**

Most Western Australian grain growers have experienced harvest disruptions caused by high grain moisture levels. This publication aims to help growers adopt high moisture handling methods to avoid delay and frustration caused by high grain moisture levels at harvest. Although this information is presented in reference to cereal grains, some application can also be made to pulses and oil seed crops.

Delayed harvest is a key reason for quality downgrading and yield loss. Earlier harvesting on a more consistent basis, not dictated by traditional moisture levels, can speed up harvest programs for greater efficiency. In coastal areas with daily high moisture levels, there is potential to improve the capital efficiency of header investment and extend daily harvest hours.

The ability to harvest at higher moisture levels can also allow harvest programs to start earlier. This helps limit the per day losses for each day the crop remains in the paddock and can translate to thousands of dollars income difference by reducing the amount of crop downgraded by weather damage late in the harvest program.



**Grains Research &  
Development Corporation**



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# 1. High moisture in cereal grains

Traditionally, cereal grain has a maximum moisture content (MC) of 12.5 per cent at receipt and this has been set to comply with the international shipping standard of 12%MC. Most grain growers have, at some stage, used blending to push slightly beyond 12.5%MC to extend their harvesting hours. Consistently dealing with tonnages higher than 12.5–13%MC calls for alternative management approaches to ensure the grain is properly stored and prepared for the market.



The traditional focus on grain moisture content alone comes from a grain marketing perspective. When considering the maintenance of grain quality in storage, temperature plays an equally important role.

*Note: High moisture grain, as discussed in this publication, refers to grain above 12.5%MC.*

## 2. Grain moisture and the harvest program

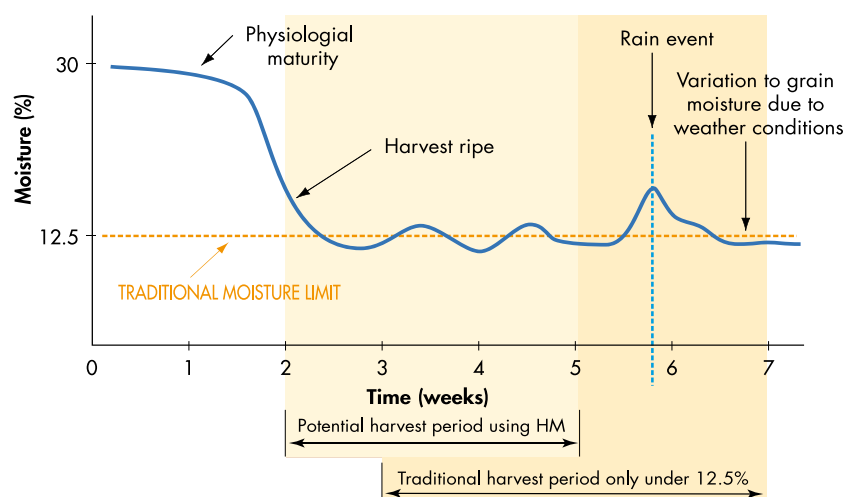
**An earlier start to the harvest program and more consistent equipment operation helps secure potential crop yield and quality.**

Ideally, harvest begins as soon as the crop is mature or ripe. A cereal crop can be harvested any time after it reaches physiological maturity and dries down from about 20%MC. But in most situations, harvest does not begin as soon as the crop is ready. The actual start of harvest is usually dictated by the options each grain grower has available to deal with high moisture grain. For example, a grower with access to a heated air dryer could harvest at 18%MC, a grower with aerated storage could harvest at about 15%MC, while a grower without high moisture management techniques would have to wait until the moisture was below 12.5%.

Figure 2.1 highlights how harvesting at higher moisture levels can allow an earlier start to harvest, reduce exposure to weather events and result in a shorter total harvest period. The potential harvest period at higher moisture levels spans three weeks (week two to week five) but traditional harvesting, at 12.5%MC, spans four weeks (week three to week seven).

Apart from being a week longer in overall duration, the week later start at traditional moisture harvesting levels results in two extra weeks of the crop being exposed to potential loss of quality. A significant rainfall event in week five might cause substantial quality loss and hence a significant reduction in the crop's value.

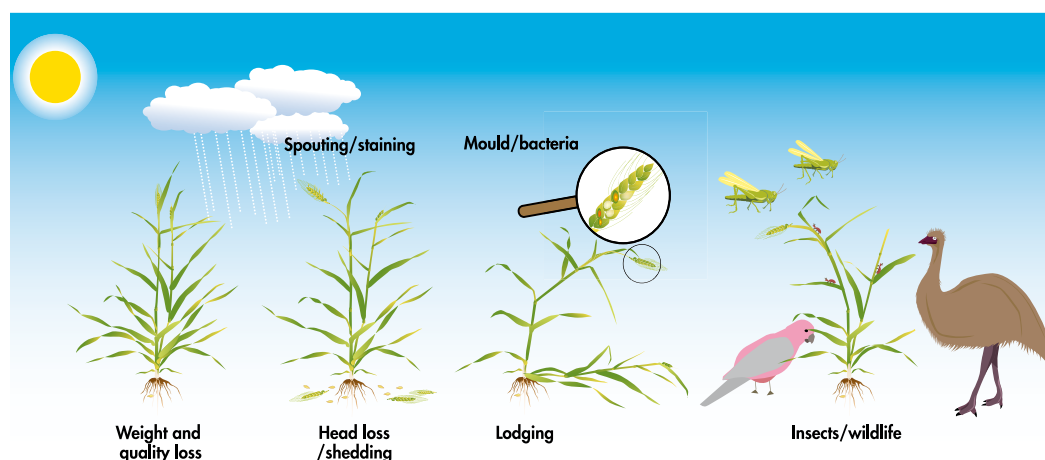
**Figure 2.1 – Grain moisture and harvest period**





### 3. Risks to delaying harvest

Figure 3.1 – What are the risks to your crop?



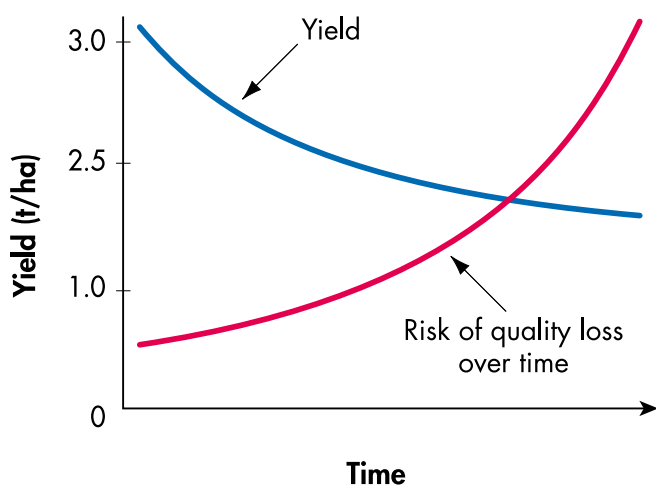
#### Delaying harvest

Every day a crop stands in the paddock it is exposed to ongoing yield loss and quality degradation (see Figure 3.1). Yield is reduced by shedding, head loss and general exposure to the elements. This is measured as a loss of yield each day in dry matter (DM). Research on this topic in the 1980s at Esperance by M Bolland and J Richardson Organisation, revealed daily DM losses for wheat of 0.18–0.53%DM and for barley losses were 0.25–0.75%DM (depending on the season and distance from the ocean).

Most growers have also experienced some form of grain quality losses due to delayed harvest. Barley becomes darker in colour reducing its acceptance for malting grade, wheat sprouts reducing its flour quality characteristics and fungi growth reduces the end use possibilities. These factors can combine to result in heavy discounts from a crop's net return. Time increases these risks and ongoing exposure to moisture will eventually cause yield loss and one or more of these quality defects to develop (see Figure 3.2).

**With an average daily weight loss of 0.5%DM, a one day delay to starting a 5000t cereal program equates to 25t of lost yield.**

Figure 3.2 – Yield and risk of quality loss over time



## Harvest start date

As previously mentioned, harvest can theoretically start as soon as the grain moisture falls below about 20%MC. Late tillers in cereal crops, particularly those on spray tracks, are often a source of green sappy grains in early harvested grain samples.



There is a lack of specific research and information

*There is allowance of some green grains within sample guidelines.*

about what happens to green grains during storage or drying and how they impact the end use of the overall grain sample. Grain quality guidelines do allow for some green grains within the sample and with this in mind, growers can still consider the option of starting harvest three to five days earlier by adopting methods to manage high moisture grain.

## The effect of rain

When a crop is exposed to rain after physiological maturity, the process of quality loss occurs more quickly. Mould and fungi development increase, colour darkens and the exposure of the grain to moisture starts to stimulate germination, commonly referred to as sprouting. The sprouting process consumes part of the grain's starch energy stores, which reduces bulk density, overall weight and hence yield.



*Sprouting of grain before harvest can reduce wheat yields between 10 and 50% in wheat.*

Results from field trials in Esperance during 2003–04 indicate that the combined reduction in yield over seven weeks can range from 10–20% depending on the severity of sprouting. Yield losses of 10–50% have been recorded in years with exceptional sprouting events. (Biddulph 2005)

## 4. Impact of moisture on-farming businesses

Handling high moisture grain with storage, drying or blending techniques involves a financial investment. The level of investment will vary from year to year and from grower to grower. The factor most likely to influence the level of investment made by a WA grain grower will depend on the distance of their property from the ocean.

Coastal locations have more moisture cycling in the local environment via sea breezes and overnight dew, while inland locations are inherently drier. By considering previous seasons' experiences, growers can estimate how their harvest programs are affected by high moisture and determine their investment accordingly. Delivery statistics combined with historical weather data can be a starting point to assess this risk.

Growers may also consider what proportion of their income comes from grain production. A reliance on grain production with no livestock enterprise means a high level of exposure to risk. Adopting high moisture handling approaches in the harvest program is one avenue to manage the risk of preharvest quality and yield loss.

Starting a harvest program earlier and continuing to harvest through cooler damp conditions means the program can be completed sooner. Traditionally growers have used larger headers, or multiple machines to try to complete harvest more quickly but if grain moisture levels are the reason for a slow harvest then this form of investment is ineffective.



*If grain moisture is the reason for stopped harvest, then additional headers can be an ineffectual investment.*

## Assessing financial factors

Conscious of the effect of a delayed harvest on grain yield and quality, the South East Premium Wheat Growers Association (SEPWA) developed an economic model to examine the daily yield losses over time and the financial impacts on an overall cropping program's profitability. Known as the 'Harvest Loss Model', the model works on the theory that by harvesting for longer periods each day under high moisture conditions a crop can be harvested sooner, yield losses limited and the exposure to quality loss reduced.

### The Harvest Loss Model

The model compares two or more grain growers who have exactly the same harvest situations. Consider the following example:

- Each grower has a 4000t cereal crop to harvest, with the same average net value of \$165/t.
- The average cost to deliver to the CBH Group High Moisture services is \$7.07 (actual average from the 2005 Esperance wheat trial).
- Each has a harvesting capacity of 30t/hr, which costs \$330/hr to run.
- During harvest, two people are employed at \$22/hr and paid for at least eight hours per day.
- There is a freight cost of \$9/t from the paddock to the CBH Group.
- There is a loss of 0.5%DM on the crop which remains in the paddock at the end of each day for each grower.

In this scenario the two growers take alternative approaches to harvesting their crops.



*Growers need to remember every day their crop stands in the paddock it is at risk of losing quality and value.*

### **Grower A – Wait**

This grower takes the conventional approach to harvesting and harvests grain at 12.5%MC and below. This grower has eight hours per day available to harvest and produces 240t/day. Grower A starts harvesting on December 4.

### **Grower B – High moisture approach**

This grower is prepared to harvest with grain moisture levels of up to 13.5% and will pay an average additional cost of \$7.07/t to deliver grain into a high moisture service offered by the CBH Group. Grower B has the conventional eight hours of harvesting available each day, but also an additional two hours each morning and two hours every evening. With 12 hours available to harvest each day, this grower produces 360t/day.

The higher moisture limit allows Grower B to start harvest on December 1, three days sooner than Grower A. During the first three days, Grower B harvests for eight hours per day due to the cooler and generally damper conditions in the early harvest period. All tonnes harvested in this period incur a high moisture management charge.

**Table 4.1 – Comparison of grower returns**

	Grower A – Wait	Grower B – High moisture approach
Tonnes harvested per day	240	360
Date of harvest completion	December 19	December 12
Actual tonnes harvested	3777	3866
Gross value at \$165/t (estimated wheat 2005–06 value)	<b>\$623,252</b>	<b>\$637,846</b>
Less –		
• Harvest, cartage and labour costs	\$81,180	\$83,124
• High moisture management charge \$7.07/t	\$0	\$12,726
<b>Net return to grower</b>	<b>\$542,072</b>	<b>\$541,996</b>
Difference in value		+ \$76

**The additional costs incurred by Grower B for high moisture deliveries are paid for by the yield benefit of earlier harvest. Grower B also finishes harvest seven days sooner than Grower A.**



## Quality downgrades

Grain quality loss from weather damage has long been an issue for grain producers in WA. Incorporating a downgrading event into the Harvest Loss Model simulations highlights how much value early harvest can have in protecting net crop returns.

In reality the extent and timing of quality downgrading will vary from season to season. Coastal locations generally will be at a higher risk than inland locations.

As a generic downgrading situation consider the following:

- \$6/t downgrading for crop harvested after December 10.
- An additional \$10/t downgrading in value for crop harvested after December 15.

If we apply this downgrading scenario to the previous simulation of Grower A and B there are significant changes in the net crop returns between the growers as highlighted in Table 4.2.

**Table 4.2 – Comparison of grower returns with quality downgrades**

	Grower A – Wait	Grower B – High moisture approach
Tonnes harvested per day	240	360
Date of harvest completion	December 19	December 12
Actual tonnes harvested	3777	3866
Gross value at \$165/t (estimated wheat 2005–06 value)	<b>\$623,252</b>	<b>\$637,846</b>
Less –		
• Harvest, cartage and labour costs	\$81,180	\$83,124
• High moisture management charge \$7.07/t	\$0	\$12,726
<b>Less downgrading</b>		
\$6/t post December 10	\$12,582	\$3,756
\$10/t post December 15	\$10,764	
<b>Net return to grower</b>	<b>\$518,726</b>	<b>\$538,240</b>
Difference in value		+ \$19,514

**Analysing the impact when grain quality is downgraded as the season progresses, it becomes clear that potential financial returns can be increased (or losses avoided) by harvesting at high moisture levels.**

Some growers may experience a higher exposure to downgrading risk than this simulation and hence would be exposed to even further economic loss.

Examining past delivery tonnages and payment grades can help to build a profile of individual grower risk exposure to financial loss through downgrading.



*Grain quality loss from weather damage and subsequent downgrading can cost growers thousands of dollars.*

**What you harvest at high moisture today is an investment towards securing your whole harvest program's income.**

## High moisture management costs

Money invested in high moisture management, on a per tonne basis for drying or delivery, or on a capital item like a grain dryer, needs to be considered in the context of the whole harvest program. Considering costs on a per tonne basis alone can be misleading.

The evaluation of a high moisture management cost on a per hectare basis a more realistic method.

**Table 4.3: Cost /ha with an average net cost of \$10.00 / tonne**

Cost /ha with an average per tonne cost of \$10.00	10% deliveries into HM service		20% deliveries into HM service	
	Crop yield 2t/ha	Crop yield 3t/ha	Crop yield 2t/ha	Crop yield 3t/ha
	<b>\$2.00/ha</b>	<b>\$3.00/ha</b>	<b>\$4.00/ha</b>	<b>\$6.00/ha</b>

On a per hectare basis these charges are extremely competitive with other input costs of your crop production.

For example, feed barley may be the first ripe crop of the harvest program. Being a lower value grain a high moisture charge may be seen as too expensive. On the other hand, by starting the harvest program several days earlier, a greater proportion of the total grain production may be protected from a downgrading weather event later in the season. Hence the cost of delivering the feed barley at a higher moisture level is an investment towards limiting the risk of a \$20–30/t downgrading of milling wheat later in the harvest program.

## 5. Approaches to dealing with high moisture grain

### Blending

- Higher moisture grain is combined with lower moisture grain to result in a sample with a required overall average moisture content.
- A cost-effective way to deal with grain that has moisture levels only slightly higher than the required 12.5%MC.
- Able to handle grain up to about 13.5%MC.

### Swathing

- Commonly used in barley crops to prevent head loss, eliminate green grains and promote slightly faster drying down of the crop.
- Ideal for removing a small margin of moisture (0.5%).

### Aeration

- Enables safe storage of high moisture grain by passing small volumes of air through the grain.
- The stored grain will still require blending or drying before delivery or export.
- Requires moderate capital expenditure and often depends on existing storage facilities.
- Able to handle grain up to 15%MC, depending on aeration system design.

### Drying

- Large volumes of heated air are used to remove moisture from grain.
- Generally requires the greatest level of capital investment.
- Often interlinked with blending, swathing and aeration to increase dryer capacity.
- Able to handle grain with up to 18%MC depending on the dryer.

## Blending

Blending involves mixing several parcels of grain with different moisture contents, to result in one mass of grain with suitable moisture content for delivery. This technique of moisture management requires on-farm storage for quantities of grain, which may need to be held for a period of time. Blending offers the greatest opportunity when a succession of hot days is experienced and a large stockpile of dry grain can be accumulated. This can then be blended with grain harvested in cooler weather. Alternatively, with a confident forecast of hot weather, high moisture grain can be temporarily stockpiled and blended with drier grain harvested during the following days.

Blending to manage moisture content largely depends on the storage capacity available. It is a cost-effective way of dealing with small moisture margins and can also help accommodate other grain quality characteristics. Blending does involve significant double handling of grain and this is a factor which needs to be remembered when making cost calculations and comparisons. Rain events and ongoing damp conditions quickly limit the use of blending and it does not offer much scope for harvest to start earlier.

### A potential blending scenario

A grower harvests with a capacity of about 30t/hr. The average grain moisture is less than 12.5% for eight hours per day, which produces 240t of dry grain. The grower has noticed the grain harvested between 12pm and 4pm is below 11%MC. The 120t of drier grain harvested during these four hours can be stored and used to blend with grain harvested later that evening or early the following morning when the moisture level may be higher.

A potential truck-blending ratio may be 40% of high moisture grain (about 13.5%MC) and 60% of the dry grain (about 11%MC) to give a weighted truck average of 12%MC. To build some safety margin into the blend the grower decides to use one-third high moisture grain to two-thirds dry grain. At this ratio, the 120t of dry grain can be blended with about 60t of higher moisture grain. The grower might then be able to complete two extra hours of harvesting later in the evening or the following morning when moisture conditions are higher. In this scenario, blending would result in a 25% increase in harvesting time for the day.

### Blending a load

– Legitimately mixing grain parcels with different specifications to achieve a final grain mass with specific characteristics, either by homogeneous mixing or truck/trailer separation.

### Layering a load

– Deliberately loading a truck to deceive the sampling processes and hence falsely represent the load's true grain characteristics.



*Using a stockpile of grain to blend can increase harvester operation hours and provide options to manage other quality issues.*

### Like to know more?

Additional information on the technical aspects of swathing and ways to limit contamination can be found in the CBH Group's publication 'Swathing – A harvest management tool for Western Australia' available through the CBH Group offices.

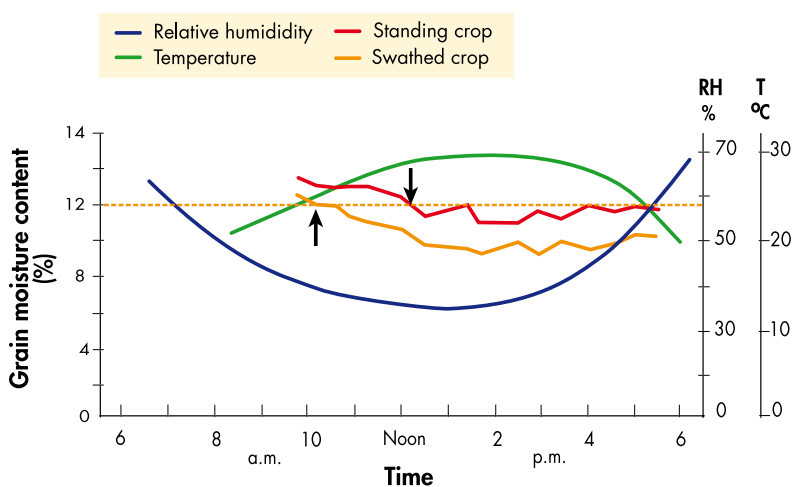
## Swathing

Swathing can be a useful tool to manage small margins of moisture at harvest. In south coastal areas of WA swathing is often used to accelerate crop maturity and help moisture management. Laying the crop down in rows allows it to heat more quickly, resulting in quicker drying and moisture reduction. Research in the Esperance region during the early 1980s demonstrated the impact of swathing on grain moisture and temperature (see Figure 5.1). The swathed crop falls below 12.5%MC about two hours earlier in the day than the standing crop and the swathed crop is slower to absorb moisture later in the afternoon.



Swathing cereals has been common practice for moisture management across the south coast.

**Figure 5.1 – Swathed versus standing crops, grain moisture movement in relation to temperature and relative humidity**



(Source: Bolland and Ricardson)

By lying the crop down, swathing increases the risk of soil, rock and animal dropping contamination during the harvesting process, particularly if heavy rain has fallen on the swathed rows. Wider crop row



Swathing allows slightly earlier harvest start times.

spacing combined with stricter export market specifications for soil and rocks in recent years has reduced the suitability of swathing for harvest moisture management. Swathing remains valuable in helping to partly secure a crop when a header may not yet be available to complete harvest. This is particularly the case in barley varieties which are prone to head loss.

## Aeration

Aeration involves passing relatively small volumes of air through grain while it is in storage. The air is generally distributed by a ducting system so it enters the storage area and has to pass through the grain before being able to exit the storage area. Aeration is primarily aimed at temperature control to prevent grain spoilage, allowing high moisture grain to be held safely until it can be blended, dried or processed when convenient – even after the peak of harvest. In aeration designs with higher flow rates grain moisture will be redistributed and in some cases removed. But aeration is not necessarily a reliable way to remove moisture from grain. When used in conjunction with blending and drying; aeration offers the opportunity to begin harvest at earlier dates; continue in cool damp conditions; and protect grain quality. Aeration can be a cost-effective option for high moisture management, especially when retrofitting existing grain storages.

Depending on the design and airflow of a system, aeration can have three main uses, or categories (see Figure 5.2):

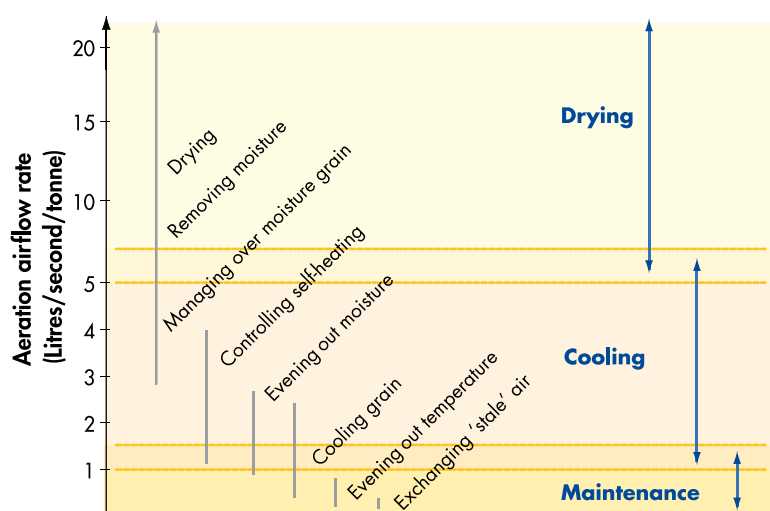
**Aeration maintenance** – Using aeration to protect grain quality and prevent temperature increases.

**Aeration cooling** – Using aeration to rapidly cool grain to protect the quality and limit insect activity.

**Aeration drying** – Using aeration to remove moisture from the grain.

The precise line between the three functions is not distinct but the key factor in an aeration system is the rate of airflow. As a rule of thumb, higher rates of airflow and more uniform air distribution enable an aeration system to manage higher moisture levels, but these factors also increase the capital and operation cost of the system.

**Figure 5.2 – Typical airflow rates for different aeration functions**



## Drying

Grain drying involves using large quantities of air to remove moisture from the grain. This is generally the most expensive technique to manage high moisture grain, but it offers the greatest degree of flexibility and capacity to harvest in high moisture conditions. Most growers who use drying tend to incorporate the three earlier mentioned approaches of blending, swathage and aeration as this increases the dryer's capacity and efficiency.

### Like to know more?

Additional information on the technical aspects of Aeration and Aeration Drying is available in other sections of this handbook. Aeration – see page 16. Aeration Drying – see page 26.

### Like to know more?

Additional information on the technical aspects of heated air drying can be found in the Heated Air Grain Drying section of this handbook – see page 41.



## 6. Harvester operation

Growers sometimes comment that harvesters do not operate in cool or damp conditions. When compared with usual operation in warm, easy threshing conditions the damper environment of higher moisture harvesting can mean the machinery does not operate at its peak design capacity. But, a loss in capacity does not mean harvesters cannot operate. It is worth remembering that harvesters sold in Australia are manufactured in the northern hemisphere and are capable of harvesting grain at most temperatures and moisture levels. Understanding several components of harvester design and operation can help manage their function in cool or damp conditions.

### General operation in cool or damp conditions



*Harvesting in cool damp conditions generally reduces harvester capacity, however with adjustment all machines can operate.*

Crop material is heavier, more pliable in cool or damp conditions and will not break up as easily during the threshing process. This means the crop will generally need to be threshed slightly harder and the machine's grain cleaning sieves may come under more load. Hence capacity is generally reduced and fuel consumption can increase.

The precise effect varies from machine to machine and some harvester designs have no capacity loss, when harvesting grain up to about 15%MC. Eventually all machines start to reduce in capacity as the effects of the crop moisture make it more difficult to thresh the crop and separate the chaff from the grain.

Moisture in the crop residue will also make the straw difficult to cut at the header front. Green or damp straw puts additional load on header knives and leaf matter can build up under the knife fingers. Slowing the ground speed or lowering the cutter height, can generally help this issue.

### Stripper fronts

Stripper fronts are often a better alternative in consistent damp conditions. Stripper fronts are purpose-built header fronts that strip the crop head from the stalk rather than cutting it.

The front is essentially a hydraulically driven rotating reel with protruding fingers running in reverse to the direction of travel. The crop is laid over by the front and then the heads are stripped from the plant.



*Stripper fronts strip the heads from the crop rather than cutting and have virtually no high moisture limitations.*

With the reel spinning at about 600rpm these fronts have almost no limit on the crop moisture levels they can operate in. They also have the added advantage of increasing header capacity by as much as double because only the crop heads are taken into the machine for threshing and separation. Although suitable for header performance in high moisture conditions, the aggressive nature of the rotating reel can cause losses via shedding in hot dry conditions.

## Common harvester adjustments

The most common harvester adjustment in high moisture conditions is the reduction of ground speed and hence throughput capacity. This allows the crop to receive more threshing attention and the grain cleaning sieves are not placed under as much load.

The need to thresh harder in moist conditions has been noted by growers who have increased rotor/drum speeds by 10% and/or closed up the concave gaps by 10–20%. Increases in threshing speeds are more associated with rotary machines aimed at maintaining rotor momentum in the tougher conditions. Under tough conditions it is not uncommon to run single rotor machines at full speed for this reason. In conventional thresh machines, operators often prefer to close concave gaps before increasing threshing speed in an effort to minimise grain damage via cracking and skinning.

In barley crops, the sample can become whiskery with more awns being left on the kernels. Closing the bottom sieve can improve this situation, but care needs to be taken not to skin the grain. Most machines can be fitted with 'de-awning plates' on the underside of the concave which can greatly assist this issue.

The discharge of crop residue material from the rear of the machine can also become less effective when it contains more moisture. Using straw choppers requires more horsepower and straw spreaders often don't spread the residue as far. Poorly distributed residue can result in a mat that may later cause issues for sowing equipment.

## Machine threshing design

*Note: The following information is neither an endorsement nor condemnation of any machine – it is included to share grower feedback and anecdotal observations.*

European design hybrid rotary and conventional thresh machines traditionally perform more consistently in damp conditions. When grain moisture is lower than about 9%MC, cracking can be a serious issue for these machines, particularly the conventional threshing design.

**It is important to remember to reverse adjustments in warmer conditions as the drier conditions combined with harder threshing can cause grain damage via skinning or cracking.**

Cool dry grain is even more prone to cracking, making care necessary when a hot day is followed by a cool evening.

Older single rotary machines have excellent capacities in hot weather but are quickly affected as moisture comes into the straw. Newer machines seem to have overcome this by using a more direct drive mechanism on the rotor and higher engine horsepower.

One of the key factors affecting machine performance is the evenness of crop feed into the harvester. Uneven feed leads to uneven threshing and can result in machine blockage. Draper belt fronts feed more evenly than the older style spiral metal fronts.

## **Common conditions affecting harvester operation**

### **Dry straw and damp grain**

Dry straw and damp grain is common on mornings after heavy dew, or overnight sea breezes. The moist conditions created by the dew or sea breeze, raise the grain moisture level above 12.5%MC but the morning sun dries out the straw so it can be quite easily threshed. Stored soil moisture can have a similar effect. Dry straw and damp grain conditions are common in areas close to the coast, due to sea breezes, and at the start of the harvest season, when dews and moist conditions are common. Under these conditions harvesting can start with minimal capacity loss as the straw breaks up fairly easily on threshing. The limiting factor in this situation is the options available to manage the high moisture grain.

The fact that there is little to no capacity loss when harvesting under these conditions means harvest efficiency can be greatly improved by having the ability to deal with high moisture grain. The frustration of having to wait for the moisture to drop can be overcome.

### **Damp straw and dry grain**

As the temperature of the air drops, it has less ability to hold moisture. This is common in the late afternoon or evening, as sea breezes bring moisture from the ocean. It also occurs when there is a cool change in the weather. The crop plant material absorbs moisture first, while grain has a slower absorption rate and can remain dry for some time. These conditions are often termed 'getting tough' and are characterised by a grinding sound during threshing and uneven feeding of the crop into the machine.

The machine capacity can start to be affected in these conditions and unthreshed heads may pass through the machine. Slowing capacity via ground speed and threshing harder are generally required in response to this. Care needs to be taken when threshing harder in these conditions, as the grain is essentially still fairly dry, but the conditions are cooler. Cold, dry grain is prone to cracking and damage and this should be monitored. Swathed crops will be affected by these conditions less than standing crops.

### **Damp straw and damp grain**

When both the straw and the grain are damp, harvester capacity is significantly reduced. These conditions are common after rain or when targeting early harvesting. Harvesting in these conditions can result in tough threshing and heavy crop residue on the grain cleaning sieves. Grain moisture levels are often between 15–18% and harvesting at these moisture levels requires designated drying or aeration facilities. Grain stored at this moisture content, without aeration, will quickly self-heat and spoil.

## 7. High moisture storage and handling – the use of air

The solution to handling and storing high moisture grain is to either remove the excess moisture, or cool the grain mass. This can be achieved by passing air through the grain mass. The ability to dry grain or simply control temperature depends on three main factors:

- The rate of airflow passing through the grain.
- The distribution effectiveness of air delivery.
- The thermodynamic properties of the air passing through the grain.

At one end of the spectrum there is maintenance aeration, which uses low airflow rates and offers limited distribution of cool (unheated) air, aimed at grain temperature control for safe storage. At the other end of the spectrum is drying, which uses high airflow rates, and offers even distribution of heated air for rapid removal of grain moisture. Ranges of engineering solutions exist between these two extremes and these are explained in other sections of this handbook.

### Rate of airflow

The rate of airflow is determined by the fan's output (the volume of air) in relation to the quantity of grain the air has to pass through. Fan motor size is measured in kilowatts (kW) or horsepower (hp) and the air volume output is measured in litres per second (L/s), cubic meters per hour (m<sup>3</sup>/hr), or cubic feet per minute (cfm). The air volume output is generally directly proportional to the fan motor size. The measurement of fan output in relation to the quantity of grain it has to pass through, is measured in litres per second per tonne (L/s/t) or cubic feet per minute per bushel (cfm/bushel). It is important to note the airflow rating is not simply the total output volume divided by the grain tonnage. The resistance of the air passing through the grain must also be considered. For this reason, fans are often rated at a particular static pressure, measured in kilopascals (kPa), pounds per square inch (psi) or inches water gauge (in H<sub>2</sub>O).





### The distribution effectiveness of air delivery

The effectiveness of air distribution is determined by how evenly the air is delivered and then passes through the total quantity of grain. Aeration tends to be distributed over large quantities of grain with a deeper bed depth. Drying systems are designed to evenly distribute air across smaller quantities of grain in storages with a shallow bed depth so that moisture can be quickly carried out of the grain mass. The effectiveness of air delivery is an extremely important factor in the design of aeration and drying systems.

### The thermodynamic properties of air

Air has two properties, which are particularly important for drying and aeration. They are temperature and RH. Cool air reduces insect activity and mould growth and allows safe storage of grain for an extended period. Dry air, (with a low RH) is ideal for removing moisture from the grain. Despite having a low RH, if air is both cool and dry, it is not effective at removing moisture from a grain mass. For this reason, warm or heated air is necessary to remove moisture from grain quickly and efficiently. Heating air makes moisture more mobile and easily released into the airflow. Heating also allows more water to be carried in the same volume of air because the RH of the air has been reduced.

**Table 7.1 – Summary of common system basic specifications**

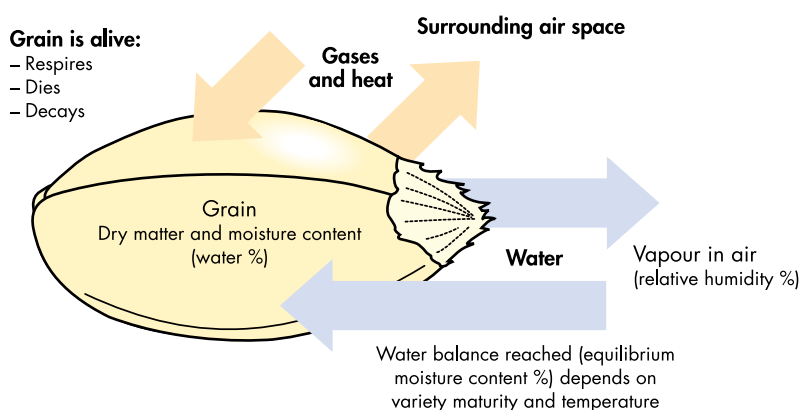
	Description	Holding capacity (wheat)	Fan motor size	Depth of grain	Distribution	Airflow delivered	Thermodynamic air properties	Effect on grain
 Basic silo aeration	Basic silo aeration	75t	0.37 kW	5m	Single perforated duct	1 to 3 L/s/t	Ambient (cool)	Cooling grain only
 Aerated storage silo	Aerated storage silo	500t	4 kW	8m	Partial floor ducted in flat floor silo	3 to 5 L/s/t	Ambient (cool)	Cool, and even out moisture
 Drying Silo	Drying silo	200t	2X 7.5kW	4.5m	Full floor perforation /distribution in silo floor	15 to 20 L/s/t	Ambient (dry)	Gradual drying of grain depending on weather conditions
 Cross Flow Dryer	Cross flow dryer	6.5t	11kW	0.4m	Fully perforated walls	450 L/s/t	Heated (hot and dry)	Rapidly remove moisture
 Mixed Flow Dryer	Mixed flow dryer	15t	22kW	0.2m	Series of inverted ducts at 300mm spacing	750 L/s/t	Heated (hot and dry)	Rapidly remove moisture

*Note: It is important to thoroughly assess the specifications of any aeration or drying installation to determine its likely realistic performance.*

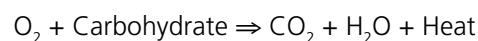
## 8. Aeration

When looking at the management opportunities offered by aeration it is important to understand the physical characteristics of grain and how it behaves while in storage.

**Figure 8.1 – Grain is a living mass**



Kernels of grain are living organisms that 'respire' using the same biological process as all other living things. They take in oxygen and combined with carbohydrates, undergoes the respiration reaction to produce carbon dioxide, water and heat.



This living process is ongoing in grain and the surrounding environment including insect and bacteria activity. At lower temperatures and moisture the biological processes of the grain

and the surrounding environment are slower and more dormant.

Limiting the level of biological activity in stored grain has two significant benefits:

- It helps maintain the grain kernels in a dormant but living state ready for germination or milling.
- It minimises bacterial and insect growth so the grain kernels are not attacked from the outside.



The following conditions support low levels of biological activity in stored grain:

- **Low moisture content**  
*Not having enough moisture available in the environment to support any significant biological activity. For cereal grains this is below about 12%MC.*
- **Lower temperature**  
*Cooler conditions slow down the biological processes of all the living organisms: grain; bacteria; and insects alike.*
- **Both low moisture and temperature combine for optimal long-term storage.**

## Self-heating

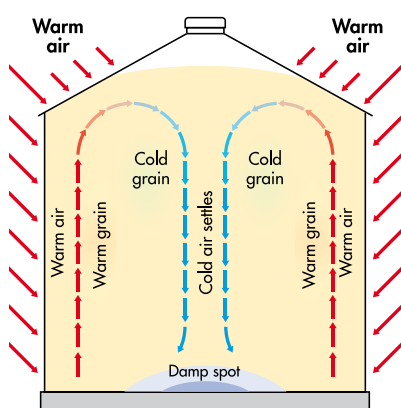
A higher temperature and moisture content in stored grain causes a higher level of biological activity (grain, bacteria and insect). As shown in the respiration equation (see Figure 8.1) this process of biological activity produces water and heat which then further stimulates the biological activity of the grain storage. For this reason grain can self-heat and rapidly deteriorate in quality if moisture and temperature are not managed.

## Moisture migration – heat and cooling over time

Stored grain moisture levels are also influenced by the temperature of the external environment. Warm or cold conditions outside the storage cause convection currents inside the grain storage and this causes overall moisture migration within the grain mass.

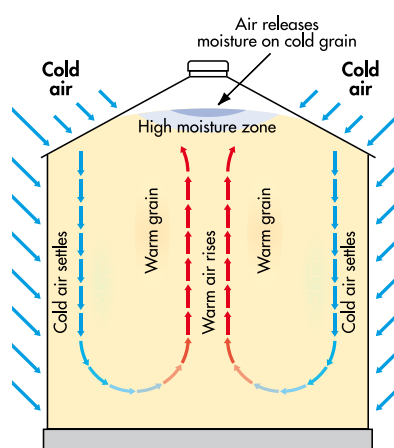
In cool weather conditions the outer of the storage will have a downward convection current. The middle of the storage will remain warm and when reaching the lower part of the storage the current will then rise with the warmth. The end result is that there can be moisture migration to accumulate under the surface near the peak of the storage.

**Figure 8.3 – Moisture migration – cold grain**



*Moisture migration with cold grain and warm air temperatures.*

**Figure 8.2 – Moisture migration – warm grain**



*Moisture migration with warm grain and cold air temperatures.*

**Aeration prevents moisture migration by breaking up the convection current and evening out temperature.**

Alternatively if grain is much cooler while in storage than its external environment the reverse moisture migration will occur. In this circumstance there will be rising currents along the outside of the storage and falling currents in the centre with moisture accumulation at the base of the storage. This direction of moisture migration is not common under Australian conditions.

## Grain and air – their relationship

Grain is constantly interacting with its surrounding air space. The internal moisture content of the grain kernel moves to be at equilibrium with the moisture level in the surrounding air. As a result grain moisture levels will correspond to air of certain relative humidity (RH). This moisture level is known as the equilibrium moisture content (EMC).

Table 8.1 shows that different types of grain have a different EMC for the same RH.

*Note: This table is **only a guide** for grain moisture between 20–30°C as precise EMC varies with individual sample characteristics.*

**Table 8.1 – Comparison of EMC for different grains**

Relative humidity	Corresponding Equilibrium Moisture Content (EMC) at 25°C					
	Wheat	Barley	Oats	Canola	Lupin	Peas
30%	8.6	8.4	8.0	4.5	7.8	8.6
40%	9.4	9.3	9.1	5.2	9.1	10.3
50%	10.5	10.7	10.1	6.0	10.5	11.9
60%	11.8	12.1	11.8	6.9	11.7	13.5
70%	13.6	14.0	13.6	8.0	13.4	15.0
80%	17.7	18.8	15.1	9.3	16.7	17.1
90%	19.0	19.5	18.5	12.1	20.4	22.0

*(Source: The Drying and Storage of Grain and Herbage Seeds, FAR, 1999.)*

As air temperature increases the rate of transfer of water between grain kernels and the surrounding air increases. The result is that for increases in air temperature corresponding EMC decreases for the same RH. Table 8.2 shows EMC values for wheat at varying temperatures.

**Table 8.2 – Approximate EMC of wheat at various temperatures**

Air temperature	Relative humidity (RH)				
	30% RH	40% RH	50% RH	60% RH	70% RH
15 °C	9.8%	11.0%	12.1%	13.4%	15.0%
25 °C	9.0%	10.3%	11.4%	12.8%	14.0%
35 °C	8.5%	9.7%	10.7%	12.0%	13.5%

*(Source: QDPI)*

### **The cooling ability of air**

The temperature of air is not the only factor which enables it to cool a grain mass. Air with a low enough RH can cause an evaporative cooling effect in the grain mass as the air has the ability to take on moisture from the grain and this enhances the aeration process. For this reason cool, relatively dry air has the best aeration cooling potential.

Table 8.3 helps show how the moisture content of the grain mass can influence the evaporative cooling effect of the aeration process. Grain with higher moisture content is able to cool more as it has more moisture to release (evaporate) into the air passing through the mass.

**Table 8.3 – Comparison of cooling aeration at varied grain moisture content**

Inlet air conditions		Approximate resulting temperatures in wheat at varied moisture contents			
Temperature	Relative humidity	10%	12%	14%	16%
10 °C	30%	10.2 °C	8.5 °C	7.7 °C	5.6 °C
10 °C	60%	14.0 °C	11.6 °C	10.0 °C	8.7 °C
20 °C	30%	18.7 °C	16.1 °C	14.2 °C	13.0 °C
20 °C	60%	24.1 °C	21.0 °C	18.8 °C	17.5 °C

(Source: QDPI)

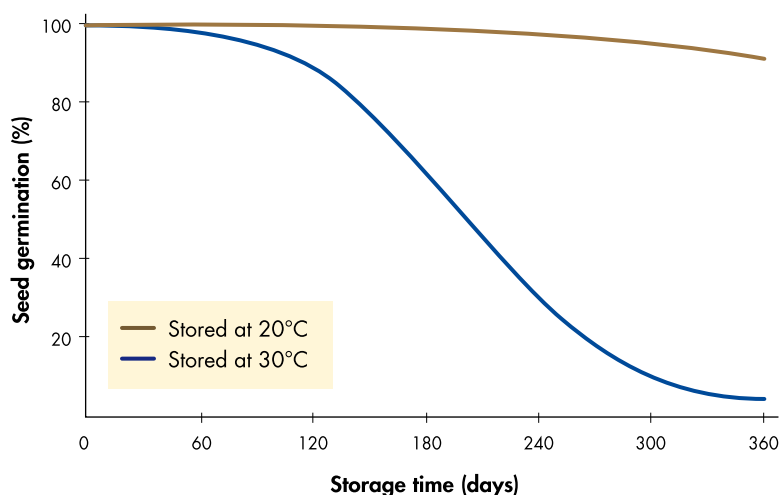
### **Aeration for seed quality**

Safely storing grain at cooler temperatures is one way to maximise the germination rate of seed. Aeration can be used to control the temperature of stored grain and hence limit loss of germination and seedling vigour. Seed merchants often aerate grain, despite it being well under 12.5%MC. Figure 8.1 shows that over time, grain stored at a higher temperature deteriorates in germination more rapidly than grain stored at a lower temperature.



*Aerated storage helps preserve germination and is often used by seed merchants.*

**Figure 8.1 – Influence of stored wheat temperature on germination**



(Source: CSIRO)

Be wary of information giving guidelines of how long you can store grain of certain moistures and temperatures. This information is often based on northern hemisphere research with significant climatic differences to WA and different insect pressures.

## Storage without aeration

In the past, growers have often stored high moisture grain without aeration and then blended it. The long-term storage of grain above 13%MC, with out aeration, can result in quality loss and possible insect problems.

Unfortunately there is no simple answer to the question of how long grain can be stored without aeration, but there are several factors to consider:

- **The type of storage facility**

A grain shed or bunker where the grain has a large area exposed to the atmosphere will store much better than being confined in a silo where it has greater thermal gain from the sun on the metal wall.

- **Overall moisture of the grain**

Spearing the stored grain allows the moisture content and any wet spots to be monitored.

*Note: The average moisture content throughout the grain does not determine how long cereal grains can be stored. Spoilage may occur at isolated locations in the storage where grain moisture is high.*

- **The temperature**

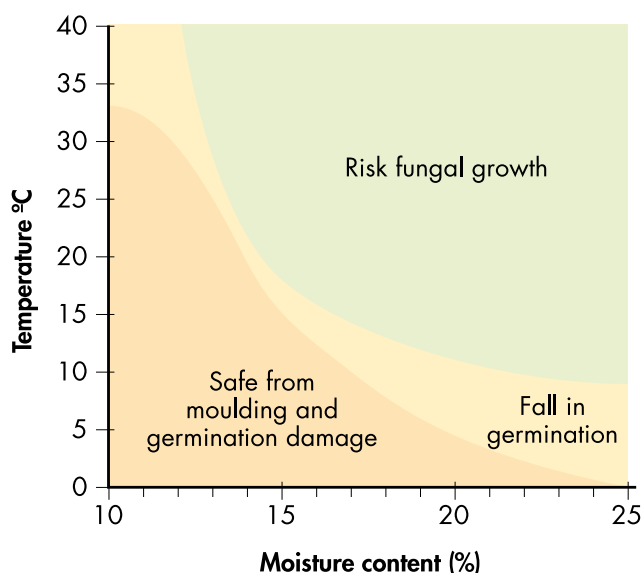
Temperature should be monitored to identify rising trends or hot spots which are early signs of quality deterioration. Rising trends with grain temperatures above 30°C are cause for concern. Simply moving the grain from one storage to another, or one side of the shed to another can be an effective tool to disperse hot spots.



Storage of grain at either high temperature or moisture can lead to quality loss.

Being aware of these factors allows the risk of deterioration to be assessed. Figure 8.2 indicates the relative risks of grain at specific temperatures and moisture contents for short-term storage.

**Figure 8.2 – Temperature and moisture effect in grain storage**



(Source: CSIRO Entomology)

*Note the relationship between temperature and moisture on the risk to grain quality loss. High moisture grain can be stored safely if it is kept cool enough. Alternatively very dry grain, if hot enough, can reduce germination. Aeration enables grain quality to be protected when storing at high moisture levels.*

## Aeration maintenance

Aeration maintenance uses very low airflow rates (between 0.5–1L/s/t) to avoid hot spot development and control grain temperature over time. This type of system can be used to maintain seed viability, preserve other grain quality characteristics and manage insect activity. Systems designed at these low airflow rates are not suitable for long-term storage of wet grain and will have limited ability to cool grain, limit moisture movement and prevent self-heating. But these lower airflow rates still help control grain temperature and maintain grain quality by changing void air.

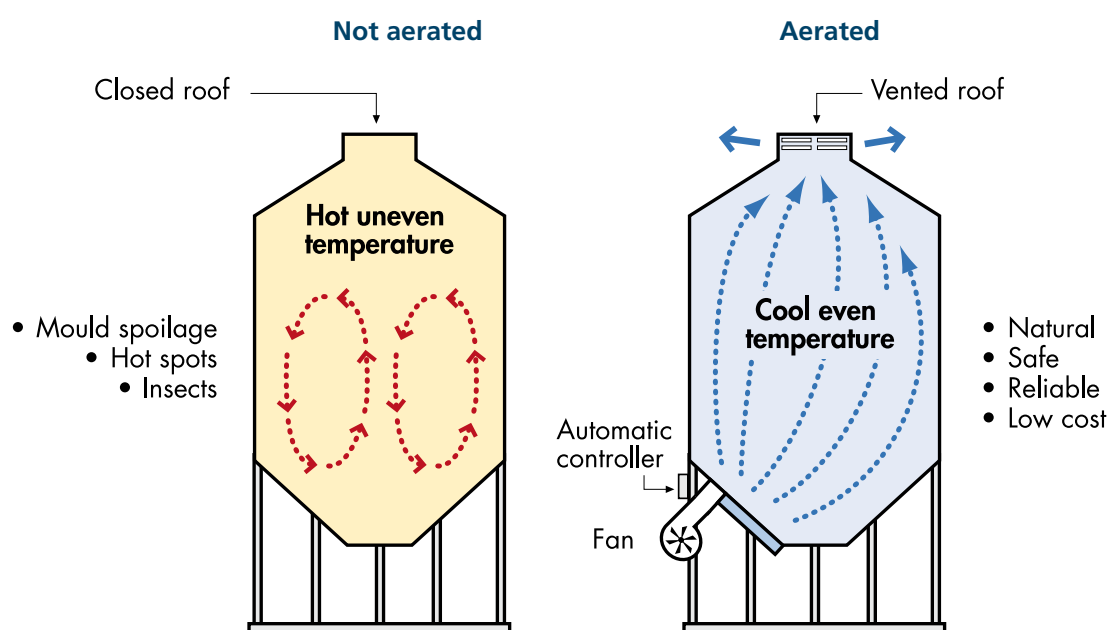
The air conditions during the periods the fans operate in an aeration maintenance situation are critical to the system's success. The aim of the system is to cool the grain, so it is important that fans run at times when the air offers the maximum cooling potential for the grain mass.

## Aeration cooling

Aeration cooling involves airflow rates between 1–5L/s/t. This system of aeration also makes use of cooler air for fan run times with the aim of cooling the grain mass. The slightly higher flow rate than maintenance aeration enables cooling aeration to lower grain temperature relatively quickly, which means higher moisture grain can be stored for longer periods without spoiling. Like maintenance aeration, cooling aeration can also be used to protect seed viability and assist insect control.

With time, aeration cooling flow rates will redistribute moisture relatively evenly throughout the grain mass. This is useful before drying to ensure grain with even moisture is delivered to the dryer for optimal drying performance.

Figure 8.4 – Aeration maintenance and cooling



*Aeration cooling is useful for protecting grain quality by maintaining a cool and even temperature through the grain mass.*

### Aeration Maintenance

**0.5 to 1 L/s/t airflow**

Capable of:

- Exchanging stale air and
- Evening out temperature

### Aeration Cooling

**1 to 5 L/s/t airflow**

Capable of:

- Cooling grain
- Evening out moisture
- Controlling self heating
- Managing over moisture grain



### Like to know more?

For further information refer to the section on aeration management and design on page 31.



Two aeration kits have been fitted to this silo for more rapid aeration cooling.

Aeration cooling is also useful after drying to allow thorough cooling and to 'breathe off' any additional moisture mobilised in the drying process. Over several weeks aeration cooling can remove marginal amounts of moisture from a grain mass if the weather conditions are appropriate, the aeration system is well designed and the process is thoroughly managed.

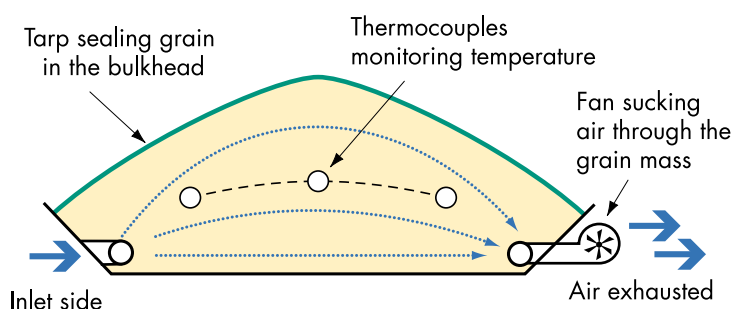
Although moisture can be equalised and sometimes removed from grain, aeration does not offer a rapid method to dry grain.

## Examples of maintenance and cooling aeration

Aeration systems vary greatly but their performance is directly related to airflow. Greater airflow will affect temperature quicker, allow higher moisture grain to be stored for longer and offer more moisture movement potential.

### The CBH Group bulkhead aeration

Figure 8.5 – Bulkhead aeration



The CBH Group bulkhead system is a relatively new aeration design. As the bulkhead grain storage is under tarpaulins and sealed for fumigation it is not possible to use a positive pressure system for aeration. The CBH Group bulkhead system involves the use of negative pressure centrifugal fans which draw air from one side of the bulkhead to the other. A set of inlet ducting on one side allows air into the grain mass while ducting on the other side is attached to suction fans which draw the air through the grain.

These systems deliver between 0.8–1 L/s/t of airflow. The use of the fans under suction results in slightly less airflow in these systems, but the negative pressure inlet has the advantage of revealing exactly how much air is passing through the grain mass. Thermocouples are placed across the grain mass to track the cooling front's progress from one side to the other.

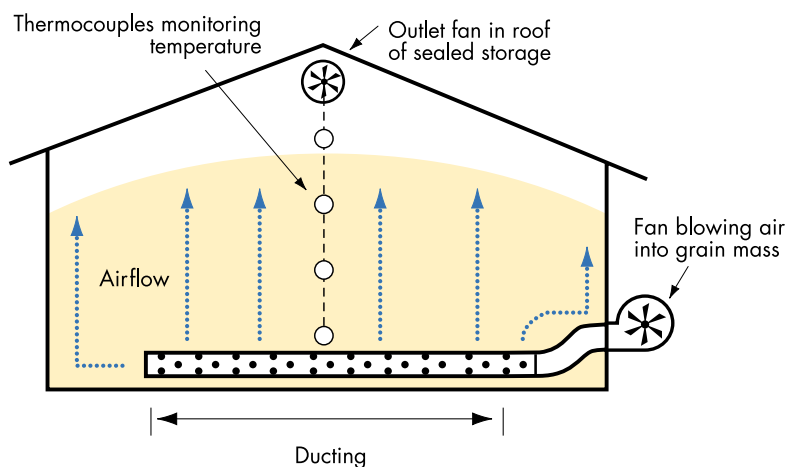
This aeration design relies strongly on adequate sealing of the storage and may not be practical in most on-farm storage facilities. Poor sealing results in air leaking into the system outside the designed ducting and does not allow correct airflow distribution.



CBH bulkhead aeration system during filling. Note the ducting down either side of the storage.

## The CBH Group sealed storage aeration

Figure 8.6 – Sealed storage aeration



The sealed storage systems that the CBH Group uses for aeration generally have better airflow than the bulkhead storage systems. The enclosed shed or cell structure allows a positive pressure system to be used. Air is blown in through the bottom of the grain, along the floor, in perforated ducts which are evenly located throughout the storage system. There are also suction fans installed in the roof of this system to assist in exhausting aeration air. Thermocouples extend down through the grain to track the cooling front's progress and gain temperature. This traditional aeration design has been used throughout the world for several decades. Most systems of this kind in WA run between 1–1.5L/s/t.



A CBH sealed storage during filling.

## Screw-in aerators

A simple yet effective way to aerate a grain mass temporarily is via portable screw-in aerators. These are usually about two metres long and a perforated spear is used to screw into the grain before a fan is connected to the top. The fan is then run via an extension lead.

This simple design allows multiple screw-in aerators to be placed into the grain and moved between various locations.

This can supply a minimal amount of airflow to the grain to help prevent spoilage while waiting for access to a grain dryer. This concept is also useful to supplement aeration where a hot spot could be developing and may not be effective at containing it. An English variation in design of a similar concept is to have large diameter ducting standing vertical on the floor of the storage with vertical tubes attached. After the storage has been filled around the standing ducts or tubes, fans are connected to the tube openings at the top of the grain mass.



The simple, portable screw-in aerator.

## Basic silo aeration



*A basic silo aeration kit for fitting to cone bottom silos on display.*

Several manufacturers offer after market fan kits for both flat and cone bottom silos, giving growers the opportunity to install aeration to existing silos. Precise airflows in this situation will vary significantly as the type of grain, silo size and fan specifications vary in each situation. A common example might be to fit a single 0.37 kW (0.5hp) fan to a 90m<sup>3</sup> (2500 bushel) silo. This would give airflow of 1.3–1.5L/s/t depending on the type of grain. This enables safe storage of slightly higher moisture grain and/or to protect seed germination. This airflow will give little to no moisture removal and is only for cooling and maintenance.

### Warning:

– Opening silo lids while fans are running can be extremely dangerous due to the pressure build-up created by the fans.

## Aeration and sealed silos

Most elevated silos currently manufactured are sealed to allow phosphine fumigation for insect control. Fitting aeration to a sealed silo does not mean foregoing its sealable status. Many aeration fans come with intake covers which enable sealing for fumigation as well as modified lids to ensure ventilation during aeration and sealing during fumigation.

It is also important to provide adequate exhaust ventilation to a silo during aeration. Simply leaving a lid unclipped but still in place often restricts airflow and so reduces the aeration effectiveness. If purpose built vents are not fitted to the silo it may be best simply to leave the silo lids open during aeration. Some growers have opted to fit aeration to older silos first as they generally are not sealed and the aeration then provides a cooling option to assist in insect control.



*An aeration fan with intake cover for sealing during grain fumigation.*

## Purpose-built flat bottom aeration silos



*An aerated flat bottom silo, note the fan and exhaust vent in the roof.*

Flat bottom silos with aeration are relatively common throughout WA. When building from scratch, flat bottom silos offer one of the most cost-effective aeration storage options. These silos are available in a variety of diameters and heights, both factors influence storage capacity and airflow resistance.

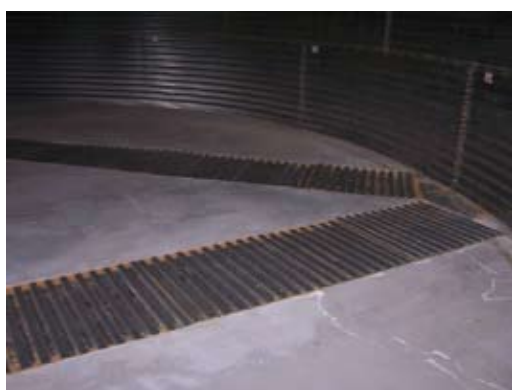
It is important to obtain detailed design specifications before buying an aeration storage system so the expected performance level can be accurately established. Keep in mind that by half filling a silo and aerating it, the airflow per tonne can be at least doubled.

### Points to consider when choosing a flat bottom aeration silo:

- There are several concrete pad constructions with different airflow void/trench designs. This will often result in varying difficulty to set up and pour.
- The aeration ducting will need to be lifted and cleaned under before each season.
- Shorter fatter silos have less air resistance for aeration than taller designs.
- Hygiene and sealing around the base of silos are important factors to guard against insect infestation and water intrusion.



*Silo sealing onto the pad needs to be completely waterproof.*



*The 'V trench' system and central square area are alternative ducting designs for flat bottom silo aeration.*

### Bunker or shed aeration systems

Retrofitting an existing shed with aeration is often one of the most cost-effective means for growers to move into aerated storage. A shed also has multiple uses for a farming operation and can be a more attractive investment than silos. Shed grain storage also offers the advantage over silos for temperature control as the grain has a large surface area to breathe as well as not having the thermal gain characteristics of a silo.

When retrofitting a shed with aeration, above floor tube ducting is usually the only suitable option. This ducting can be planned and positioned to allow the required outlets for grain removal. Minor ducting damage is generally inevitable, especially for the first out-loading of a system, but the ducts can be repaired and are not the most expensive component of the aeration system. While below floor ducting may seem a better option, often it isn't. Below floor ducting can be damaged, fill with grain or water, and present problems if the shed is used for storing other products such as fertiliser.



*A shed storage retrofitted with aeration.*

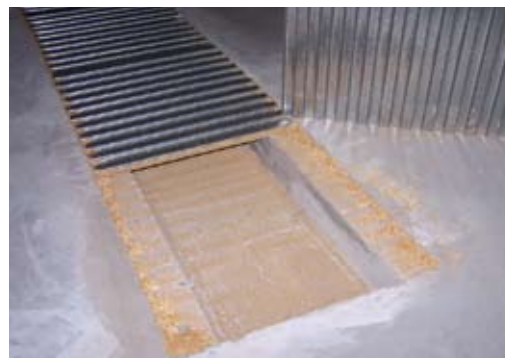


*Wall transition and initial ducting of a shed aeration system.*





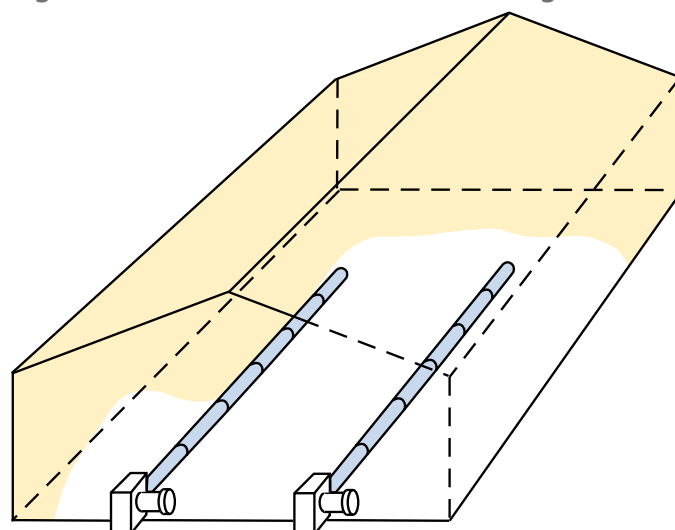
*Ducting tubes come in a variety of diameters depending on design, and are hand assembled during filling.*



*Below-floor ducting, although attractive for ease of out loading can present problems if storing other products in the shed.*

The exact airflows of a shed aeration system will depend on its design and fan size. Most shed aeration systems are custom designed to ensure airflow requirements are met as well as accommodating the out-loading system. Common airflow rates are between 1–5L/s/t, with higher flow rates corresponding to larger fan sizes, cost increases and greater moisture management potential.

**Figure 8.7 – Shed aeration retrofit design**



*An example layout of aeration ducting in a shed retrofit design. Side-entry and other layouts are also used.*

### **Aeration Drying**

**5 to 30 L/s/t airflow**

Drying of grain over a period of time, given appropriate air conditions and fan run times.

## **9. Aeration drying**

Aeration drying involves airflows from 5–30L/s/t. The increase in airflow and generally better distribution allows the process to pick up moisture from the grain mass and dry it over time. The selection of suitable air for fan run times in these systems is based on lower RH rather than lower temperatures. Aeration drying is sometimes called fixed bed drying and often involves a fully perforated floor in either a silo or storage shed. Lower airflow rates (5–10 L/s/t) can only lift smaller amounts of moisture from the grain mass, while higher flow rates (15–30L/s/t) can lift up to 0.5% moisture a day given ideal drying conditions.

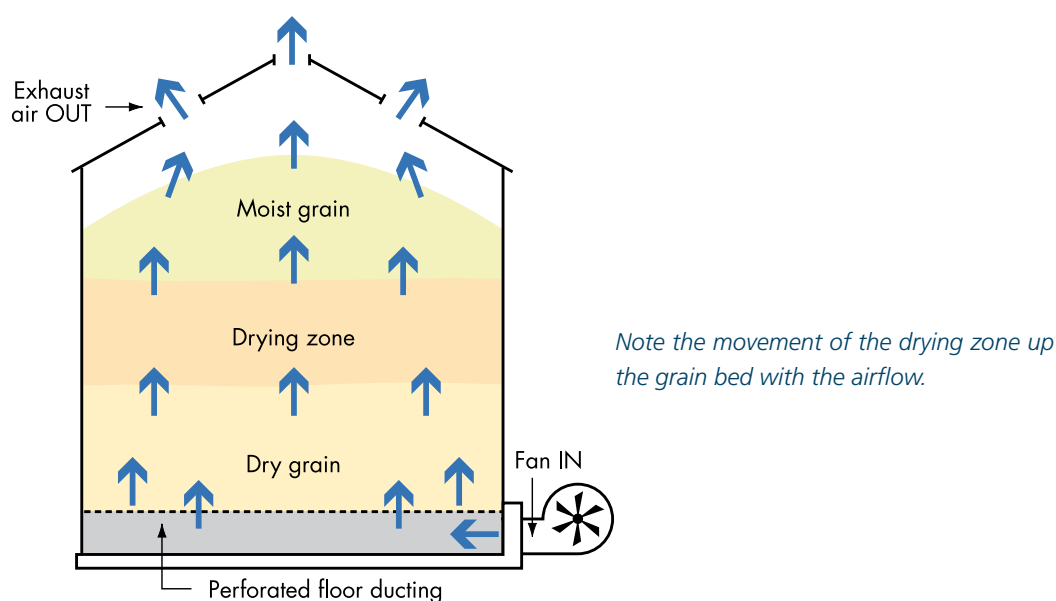
Aeration drying can be a useful tool for relatively low-cost drying, provided it is well understood and managed. A key concept for successful aeration drying is equilibrium moisture content (EMC) (see page 18). By considering air temperature and RH, the grain EMC can then be estimated. If the EMC is of a desired moisture level then air is considered capable of ‘drying’ and the fans can be run.



Most aeration drying involves air being pushed in from the bottom of the storage facility and up through the grain bed. As it passes through the grain it picks up moisture and drying fronts form in the grain. Grain at the bottom dries first, while grain at the top of the storage is relatively unaffected. There may even be a slight increase in moisture content at the top as the moisture from further down in the grain bed moves up to the surface.

Drying in this way is a relatively slow process, taking days and in some cases weeks, depending on fan run times and air conditions. It is also important that the top of the storage is adequately vented to allow the moist air to escape before condensation occurs.

**Figure 9.1 – Aeration drying concept in a flat bottom silo**



### Stalling drying fronts

As air passes through the grain it picks up moisture and forms a drying front (see Figure 9.1) which increases in moisture as it rises and makes its way out of the grain mass. If the aeration fans are stopped, the drying front will stall and if left for too long this high moisture area of grain can heat up and deteriorate the grain quality.

An example of this may be when using ambient air for drying on a hot day and then moist conditions prompt the fans to be stopped. In this situation the fans may need to be left running, despite the change to unsuitable air conditions, so the progress of the drying front is not stalled in the grain mass.

As a rule of thumb, fans should be run continuously until the drying zone moves to the top of the grain.

### Too slow drying

Aeration drying is generally only suitable for grain with moisture contents up to 15% as higher amounts of moisture can take too long to remove from the grain and lead to quality deterioration. The warm, moist conditions, particularly in the drying front region, can lead to potential quality loss via heating and mould growth. To prevent this it may be necessary to also use aeration cooling techniques until appropriate air is available.

## Is aeration drying an option?

A key to aeration drying success is having suitable consistent ambient air available for drying. This means having average air conditions of relative humidity (RH) that equate to a grain EMC less than that of the grain being dried. A starting point of assessment is to examine local historic weather data for temperature and RH levels at 9am and 3pm from November through till March.

This information can be obtained by contacting the Department of Agriculture and Food Western Australia (DAFWA). It is also possible to install a weather station to assess the specific local climate for drying potential, but this would only be necessary for coastal locations. It is fairly common to have air with the ability to dry grain down to about 13%MC but the last 1% of moisture requires more select air of about 50–60%RH.

## Supplementary heating

Supplementary heating can be used to overcome variable weather conditions.

Adding heat to air lowers the RH and enhances the air's ability to carry moisture. Increases in temperature also increase the transfer rate of moisture between the grain kernels and air, enhancing the potential of the air to lift moisture from the grain. Aeration drying generally uses ambient air, but supplementary heating can be applied via gas, diesel or electricity. Supplementary heating is usually used where the local weather conditions are frequently unreliable in providing suitable air for drying grain.

Supplementary heating in aeration drying does not hasten the drying process in the sense of a heated air dryer, it instead aims to increase the potential run time for fans each day. It is important the air is not excessively heated in an attempt to speed up the drying process. Excessive heating of air (above 35°C) risks the grain immediately adjacent to the inlet ducting becoming heat damaged and over dry.

**Table 9.1 – Guide to supplementary heating in aeration drying systems.**

Ambient conditions temperature/ RH%	Corresponding EMC	RH with air heated +4° C	Corresponding EMC	RH with air heated +6° C	Corresponding EMC
25 °C / 70%	14.0%	56%	11.8%	49%	11.0%
25 °C / 90%	>16%	71%	14.1%	64%	12.7%

(Source: QDPI)

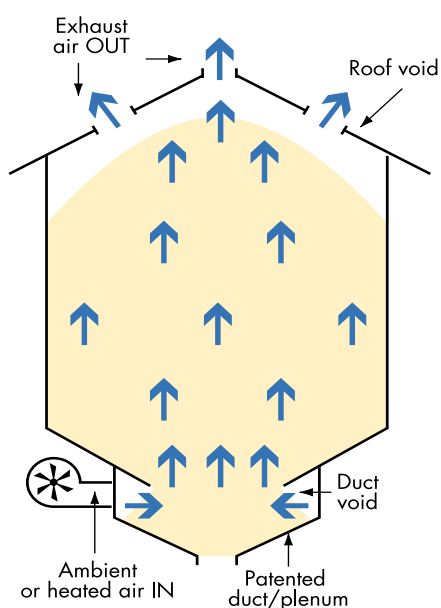
## Examples of aeration drying

### Purpose designed aeration drying silos

#### *Elevated cone bottom drying silos*

The Kotzur drying silo is a cone bottom drying silo option manufactured in Australia. This silo has a patented ducting design with a false secondary cone where the fan is mounted pushing air into the silo. Depending on the silo size and the fans selected, airflow for these silos varies between 15–20L/s/t. These silos offer the opportunity for genuine production drying of 100–200 tonne batches.

**Figure 9.2 – Kotzur drying silo**



*The concept of the Kotzur drying silo with patented plenum.*



*A 154m<sup>3</sup> elevated cone bottom drying silo.*

#### *Full floor drying silos*

There are several northern hemisphere and Australian full floor drying silos available in WA.

These silos range in size from several hundred tonne to greater than 1000t capacity, but they are often designed to only be half filled when drying grain. In addition to the drying option, these silos can double as sizable grain storage during harvest.

Currently only the Australian manufactured silos are gas tight and offer a phosphine fumigation option.



*A full floor drying silo with multiple fans. This model features 1200t of storage capacity but is only half filled when used for drying.*

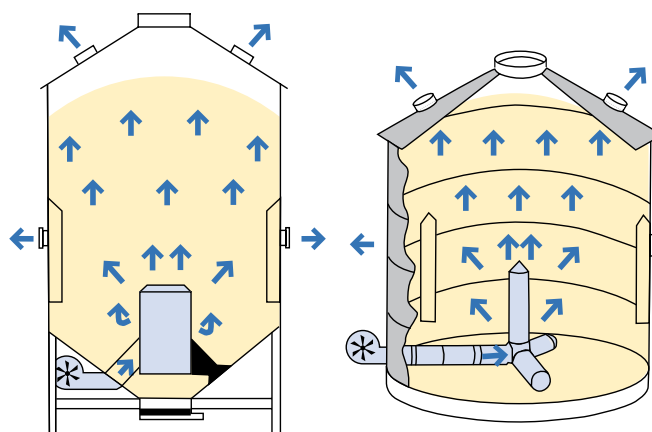
### ***Rocket aeration drying***

Aeration drying in silos with a central vertical duct resembling a rocket is common in North America. The tall ducting system vertically up the silo aims to give this system less static pressure resistance than floor-based aeration, and the option of being retrofitted to existing silos. On larger silos with diameters greater than 7m, side venting is used to reduce the distance of the drying fronts and speed up potential drying times.

**Figure 9.3 – Rocket aeration designs**



*Rocket aeration ducting design for a flat floor silo or shed application.*



*The rocket aeration drying concept common in North America.*

### ***Stirrers***

Stirring augers can be fitted to aeration drying to assist in evenness of drying and avoid grain compaction caused during filling. Stirrers are a set of vertical augers which pull grain up from the bottom as they move around the storage.

They are claimed to reduce drying time by up to 30% and have the ability to break up developing hot spots. Stirrers are also useful when the available electricity supply can limit the fan size and cause less than desired airflow rates for aeration drying.

### ***Retrofitted silo drying systems***

It is possible to fit aeration drying systems to existing silos. Retrofit systems generally come as a basic kit and include a fan, ducting and connection hoses. There is also the option of a temperature or humidity controller, which the fans and power supply can plug directly into, eliminating the need for electrician services.

The system's ducting is an inverted triangle running across the inside of the silo cone and it is generally fitted to 60–90m<sup>3</sup> capacity silos. The drying capacity of these systems may vary, depending on the actual silo size and the performance of the supplied fan and ducting system.

## 10. Aeration management and design

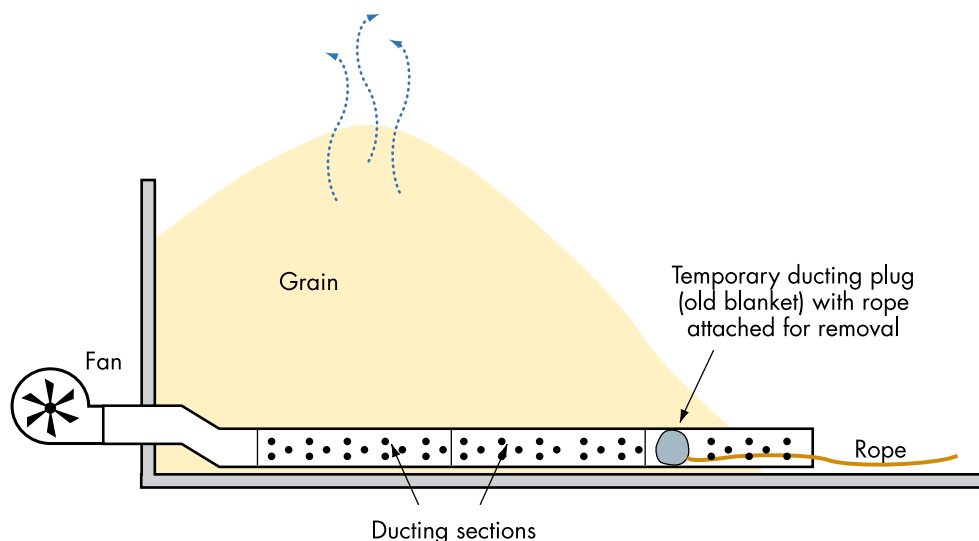
The concept of aeration is relatively simple and employs low maintenance mechanical components. The design of these systems, on the other hand, has many subtle factors that need to be understood for it to be successfully managed and operated.

### Aeration system management

It is important to operate the fans as soon as possible after filling the storage with grain and it is generally recommended the fans be run continuously for at least the first 48 to 72 hours. If possible run fans as soon as the ducting has been properly covered.

If a shed or bunker system has longitudinal ducts (end entry) it may be necessary to make temporary plugs for the partially constructed ducting. These can be as simple as a rope attached to an old blanket which is pushed into the ducts to allow the fans to be run. The rope is then used to remove the blanket plugs before filling the remainder of the storage.

**Figure 10.1 – Temporary plugging of ducts**



*Temporary plugging of ducts may be necessary to run fans while filling a storage.*

The precise time to run the fans after filling depends on the depth of the grain bed and characteristics of the grain being stored. This first aeration is to push an initial cooling front through the grain and remove field temperature. The passage of this initial cooling front can usually be tracked by the smell of the air exiting the grain mass. When the air changes from a warm moist smell to a grainy or nutty smell, the cooling front has passed.

The cooling front may carry moisture out of the grain mass depending on:

- Input air conditions (low RH will lift more moisture than high RH).
- The rate of airflow (higher airflow aeration is more likely to move moisture).
- The grains input temperature (hot grain will allow a greater evaporative cooling effect).
- The type of moisture held in the grain (internal or surface moisture).

After the initial cooling front has passed, the system can be switched to maintenance run times aimed at long-term temperature control.



**As a rule of thumb, aeration systems should not be run in humid, foggy or rainy conditions unless absolutely necessary.**

Intermittent run times are required to maintain and further lower the grain temperature. For about seven days after the initial cooling, a more aggressive cooling approach should be maintained so that the fans run for between 80–100 hours per week. For automatic time proportioning controllers this is the 'rapid' setting.

After this period, long-term maintenance aeration management requires fan run times of 20–30 hours per week. On time proportioning controllers this is the 'normal' setting.



*Time proportioning aeration control systems have designated manual, rapid and normal settings for aeration management.*

### **Aeration is not a set and forget process.**

It is important to check the system regularly to ensure it is working. Points to check:

- Are fans working – can you feel suction during operation?
- Are vents and lids open to allow air to exhaust from the storage?
- Are fans running appropriately? Check the hour meters.

## **Temperature sensors**

Some grain storages may be fitted with sensors to track temperature changes in the grain mass and monitor for hot spots. This is a more precise way to monitor the passage of cooling fronts and overall storage safety. Sensors also offer a reliable method to monitor grain quality while in storage. These can be particularly useful in larger storages where there is greater potential for hot spot development or in canola which is prone to self-heating.

## **Positive and negative pressure designs**

### ***Positive pressure***

Positive (or over) pressure systems involve compressing air and using the fan to blow it through the grain mass. This is the most common design and it has the advantage of slightly heating the air before it enters the grain which enhances its ability to pick up moisture. If the air temperature is increased by 2 to 3°C, its ability to carry moisture is enhanced without risking an increase in grain moisture.

With this system design the warmest layer of grain is at the top of the storage where it can be manually monitored for temperature and smell. Generally a more uniform airflow can be obtained by pushing air up through the grain mass.

### Fan intakes

Fan intakes must be well sheltered from rain. Blowing water droplets into the aeration system or water entering ducting may cause serious problems.

### Exhaust venting

In a positive pressure system, exhaust venting is important to prevent moisture in the air condensing on the roof of the storage. Water droplets forming on the roof tend to gather on metal beams, or run down walls to cause pockets of spoilage. Improper exhaust venting also creates additional resistance for fans and reduces overall airflow and system performance. This is particularly important when aerating sealable silos.



*Adequate roof venting is important in positive pressure aeration systems to let exhaust air vent out.*

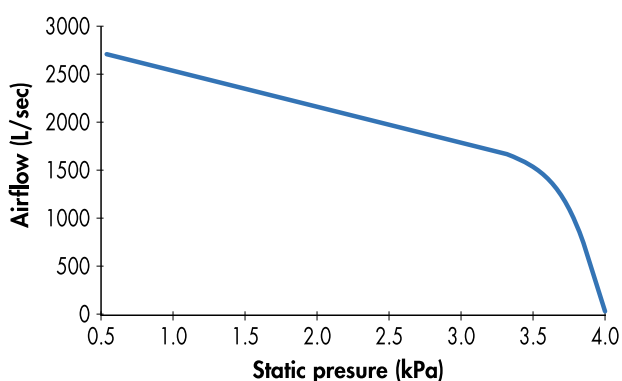
### Negative pressure

Negative (or under) pressure systems use the fan to create a vacuum, which sucks air through the grain (such as the CBH Group bulkhead system). This design has the advantage of ensuring all moisture is exhausted through the fan system and hence condensation cannot occur inside the storage. Storages with this style of aeration must have well-maintained sealing throughout for the system to work correctly. Negative pressure fans can be used to assist exhaust venting in positive pressure systems and are common in cold regions where roof condensation is a problem.

### Fans and airflow through grain

Aeration fans are measured by airflow delivery in litres per second (L/s) and their kilowatt (kW) drive motor rating is generally in proportion with the airflow. This performance of air delivery is rated against various levels of resistance known as static pressure. Static pressure is measured in kilopascals (kPa) but other pressure units such as millimetres or inches water gauge are common. Figure 10.1 shows a power curve for a 7.5kW centrifugal fan at various static pressures. The fan's efficiency gradually decreases under increasing static pressure to about 3kPa. From 3 to 4kPa the fan's delivery drops sharply and hence application under these pressures would not be effective.

**Figure 10.1 – 7.5kW fan airflow delivery with increasing static pressure**



Often there is a temptation to find relatively cheap second-hand fans and retrofit them to systems. A fan without a power curve cannot be rated and hence it is not possible to determine if its performance can match the planned application.

### Static pressure

Static pressure is a measurement of the resistance to airflow through a grain mass. It is determined by a combination of factors, including:

- **Depth of grain**  
The deeper the grain bed the more difficult it is to push the air. For example, 3m of grain will have roughly half the resistance of 6m of grain.
- **Airflow rate**  
Increasing airflow rate causes greater competition for the available space between the grains by the air, this increases the resistance and hence static pressure. Doubling the airflow generally results in triple the resistance of static pressure.
- **The type of grain**  
Canola has roughly twice the resistance of cereal grains due to the smaller grain size, and pulses have roughly half the resistance of cereals.
- **Sample purity**  
Chaff and other material will clog the space between grains and compaction will cause greater resistance.
- **Air delivery and exhaust venting**  
Air distribution ducting must have sufficient open area (for example, perforation) to prevent unacceptable static pressure build up. Exhaust vents must typically allow 0.2m<sup>2</sup> of open area for every 1000L/sec of airflow.

**Table 10.1 – Resistance to airflow**

Table 10.1 demonstrates the resistance to airflow through a depth of 1m of grain.

Resistance to airflow in kPa			
Air velocity	0.10 m/sec	0.20 m/sec	0.30 m/sec
Wheat	0.29	0.76	1.37
Barley	0.28	0.72	1.33
Oats	0.32	0.81	1.47
Canola	0.66	1.55	2.70
Peas	0.11	0.28	0.55
Beans	0.08	0.27	0.54

(Source: *The Drying and Storage of Grain and Herbage Seeds*, FAR, 1999.)

### More fans – more flow?

Fitting more fans to a storage facility generally increases the flow rate of air per tonne, giving more opportunity for moisture management through the aeration. But as previously mentioned increases in flow rates dramatically increase static pressure of airflow resistance. Hence multiple fans in some situations will not give the desired results. They essentially will compete against each other's static pressures generated by the faster flow rates of air through the grain.

## Fan selection

There are three common styles of fan used for aeration and drying: the in-line axial flow fan; the centrifugal fan; and the in-line centrifugal fan.



*An in-line axial flow fan fitted to grain dryer. Note the visible blades similar to that of an aeroplane.*



*Centrifugal fans, with the fan motor on the outside. These fans have yet to be fitted to the storage.*



*An in-line centrifugal fan fitted to a cone bottom silo.*

- In-line axial flow fans feature fan blades and an electric motor contained within the tubular fan body. They are characterised by the large visible blades, similar to those of an aeroplane, and are often quite noisy. These fans are effective at supplying larger volumes of air at lower static pressures but are the least efficient of the fan types.
- Centrifugal fans are the most commonly used fans in Australia with the traditional air inlet on the side coming into a centrifugal drum. The air is forced through an outlet around outside. The fan motor is situated outside the airflow area. This type of fan has the greatest efficiency and will offer the best performance of energy input per static pressure of resistance. Centrifugal fans are also far less noisy.
- In-line centrifugal fans are a hybrid between the axial flow and the centrifugal fan concepts and are similar in appearance to an axial flow fan. The fan consists of a centrifugal drum and motor contained within the tubular fan body. Air is sucked in from one end of the tube, forced to the outside via the centrifugal drum and then via air straightening vanes, is forced down the tube past the motor. This type of fan is more efficient than the axial flow design but will not handle as high a static pressure standard as the centrifugal fans. In-line centrifugal fans are popular on Canadian imported equipment and have the advantage of the motor being protected from the weather.

## On-site electricity supply

Electricity supply is a costly and often limiting factor to aeration design. When considering an aeration system, be sure to enquire about the system's power draw and what the power delivery requirements will be. Many locations throughout WA do not have sufficient grid supplied electricity to run high flow aeration systems.



*On-site electricity supply is a costly and often limiting factor to system design.*

### Air distribution and flow through grain

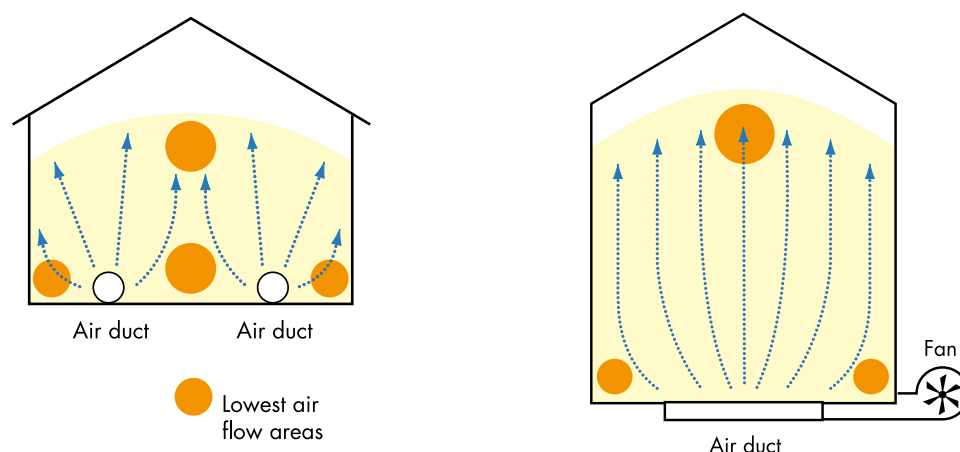
As air is forced through the grain it will take the shortest path or the path of least resistance to exit. This is a key factor in determining appropriate air distribution and its success for aeration or drying. Airflow through the grain is often mapped in flow paths, from the ducting entry to the nearest exit point of the grain mass. Optimally all air paths should be roughly equal in length and generally the longest flow path should not be more than 1.5 times the length of the shortest flow path. Even distribution is ideal but often this has to be compromised due to cost and ducting logistics. This design consideration is generally helped by the storage being taller and is the reason why many bunker systems with low wall height can be difficult to retrofit with aeration.

*For optimal airflow, as rule of thumb, the longest airflow path (A) should be no more than 1.5 times the length of the shortest airflow path.*

### Dead zones

More often than not, aeration systems will have dead zones where airflow will be at the minimum for the storage. These zones form in the longest path of airflow, as they have greatest resistance and most of the air goes via the shorter paths. It is important to note these zones of a system so they can be monitored for grain spoilage.

**Figure 10.3 – Dead zones in aeration systems**

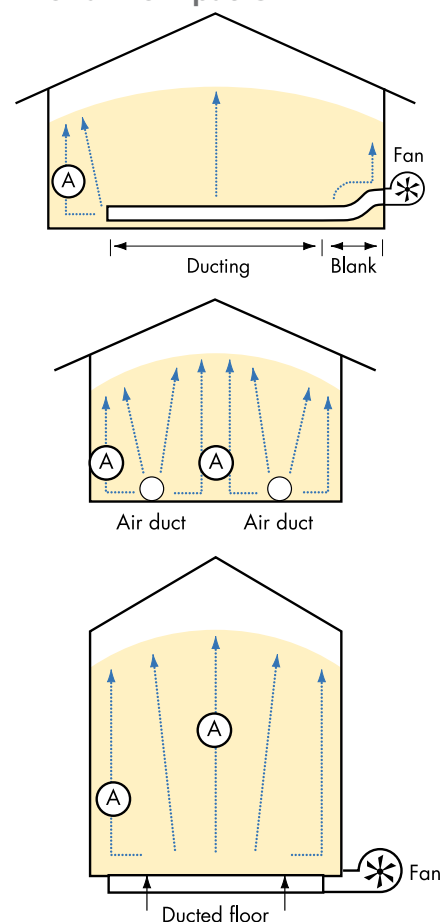


*Dead zones in an aeration system will be where airflow rates are at the minimum for the storage.*

### Ducting design

Air delivery via ducting is important to ensure minimal pressure loss. Sharp bends and excessive air speeds can cause friction loss and will reduce the aeration system's efficiency.

**Figure 10.2 – Length of airflow paths**





## Aeration control

Aeration can be managed manually by simply switching the fans on and off as required but electronic controllers are more common. Some control units are supplied as fully assembled cabinets with all hardware included and this significantly reduces on-site electrical costs. It is also possible to have a single controller which operates multiple fans on different storage areas.

## Manual control

In an attempt to cut costs some aeration systems are controlled by manually switching the fans on and off. This form of aeration management can be aided by wet and dry bulb temperature thermometers to help determine the appropriate times of the day to run the fans. Inevitably the fans will at some stage be forgotten. For this reason, fans are not run at the most appropriate times, may not be run enough or are left running using power when not necessary. Although it can be successful, manual control is the least preferred method of aeration control.

## Time clock switches

Consistent cool mornings and in some cases the cooling effect of afternoon sea breezes, provide ambient air conditions which may be suitable for aeration cooling. These consistent cooler periods each day mean aeration may be controlled by a simple 24-hour timer clock system available at most hardware stores. Although low cost and simple, timers can result in fans running when air conditions may be unsuitable. If the fans do operate in unsuitable conditions, the grain can be re-wet or re-warmed, resulting in large variations in the storage temperature and moisture. Time switches offer an improvement on manual control but they are still far from optimal and may deliver erratic results.



*Time clock switches, although an improvement on manual control, may still run fans when air conditions are unsuitable.*

## Temperature sensors only

Aeration by temperature alone has been reasonably successfully used in Australia for many years. This method of control allows for cool air only to be selected with relatively regular run times. A drawback of this method is the lack of a RH sensor on the controller which may mean damp conditions are inadvertently selected for an aeration run time. The number of temperature alone controllers used in Australia is decreasing as they tend to be replaced with time proportioning controllers.

## Temperature and relative humidity presets



*The simple temperature and RH preset controller; only runs fans when air conditions are below manually selected settings. It does not take into account run time frequency.*

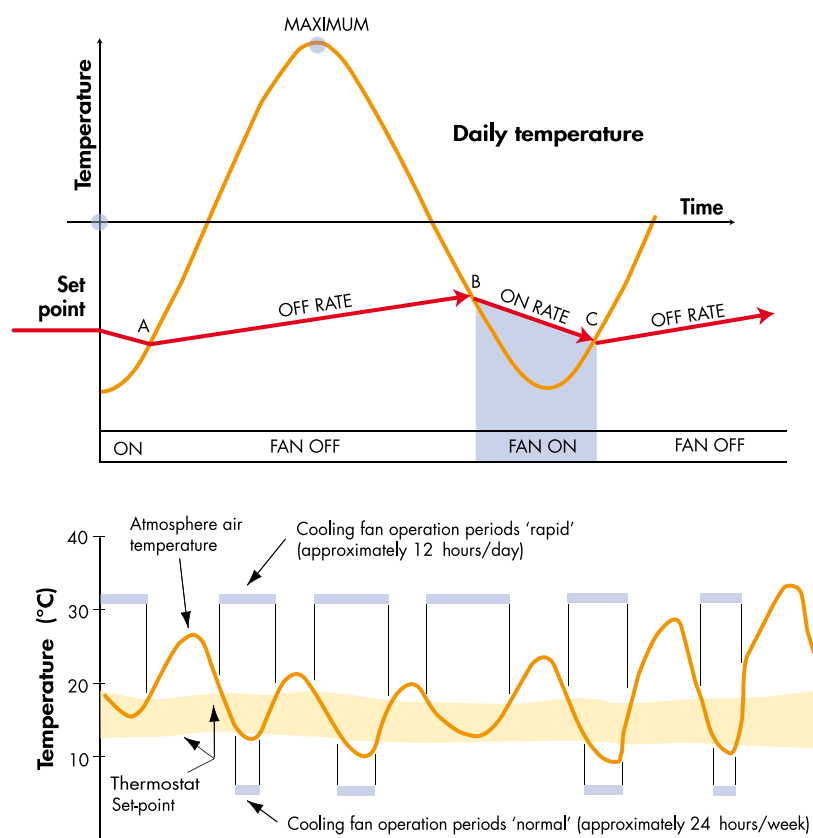
There are simple control systems which allow limit points to be set for air temperature and RH. This enables points to be set for either cooling aeration or aeration drying management approaches. Aeration cooling set points are generally for temperatures less than 25°C and RH maximums of about 80–90%. This would result in early morning or evening run times.

Alternatively the system could be set with low RH levels (a maximum of 65%RH) and higher temperature limits of 35°C aimed at drying grain over time. This method of control is limited by the fact it does not take into account the run time frequency. If conditions do not match the set points for a period of time then the system will not run and grain spoilage could occur.

## Time proportioning controller (with RH sensor)

A time proportioning controller allows fans to be run for a selected proportion of hours each week. This type of controller is completely automatic and selects the best available cooling air for aeration. This is achieved by the controller making constant adjustments in relation to weather conditions to ensure optimal run times of regular frequency.

**Figure 10.2 – Time proportioning adjustment of fan run times**



*The time proportioning controller is constantly adjusting its set points of fan run times to capture air of the maximum cooling potential while ensuring frequent aeration.*

A RH sensor enables the controller to consider both temperature and humidity when selecting fan run times. It also prevents the system running in damp conditions. Time proportioning controllers are effective at aeration for long-term grain cooling.

The controller includes a 'rapid' mode, for faster evening-out of moisture and temperature levels when the grain is initially loaded into storage. The time proportioning controller has been designed to work most effectively on systems with typical rates of 1 to 4L/s/t airflow.

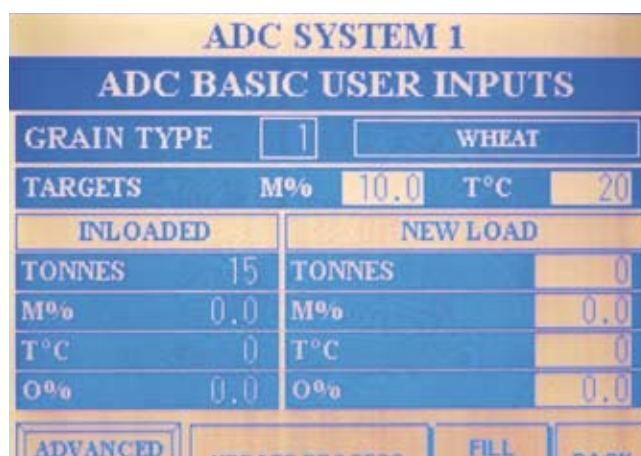


*Time proportioning controllers may be hooked to multiple storages to automate aeration fan run times.*

## Adaptive discount control

The adaptive discount controller (ADC) was developed by CSIRO. Relatively new to the marketplace, it uses more sophisticated programming and a greater range of input to help in its decision-making. Its programming is designed to take into consideration the grain type, in-loading moisture, type of storage, airflow, and if there is supplementary heating in the system. It can be used simply as an aeration control, but it is aimed at achieving set temperature and moisture points in the grain over the period of storage.

The ADC controller uses ambient air sensing to determine average air characteristics and airflows through the grain bulk to ensure drying fronts are not stalled and grain quality is protected. The success of this controller relies on the accuracy of information which is input through a touch-screen and used to automate the fan run times. It is the only dual purpose controller offering automated aeration and moisture removal potential and it is the most expensive control option.



*The touch screen of the ADC controller from which input information about grain is entered and then aeration run times determined.*

## 11. Aeration and heated air drying – complimentary systems

At minimum aeration post drying is recommended to protect grain quality and help manage moisture rebound.

### Aeration pre-drying

Aeration helps safely store high moisture grain until a dryer is available. It also has the benefit preconditioning grain by evening out the moisture. The consistent moisture and temperature of grain entering the dryer means a constant throughput can be set for operation. Some drier operators have noted significant efficiency improvements when drying with preconditioned grain.

### Aeration post-drying

The drying process mobilises moisture from the grain into space between the grains. Although the cooling phase used in some dryers removes the majority of this moisture, there is still residual heat and moisture left in the grain mass. By aerating post-drying this residual heat can be removed from the grain mass along with any additional mobile moisture. Some growers have found aeration overnight at 3–5L/s/t provides additional cooling. More importantly this aeration can remove around half a per cent of moisture along with the residual heat.

### Moisture rebound

Grain can often test dry immediately after drying but if put back into storage, the grain can reabsorb moisture from the intergranular space. This is known as moisture rebound. Aeration post-drying is an extremely effective way to manage moisture rebound. At minimum aeration post-drying is recommended to protect grain quality and help manage moisture rebound.

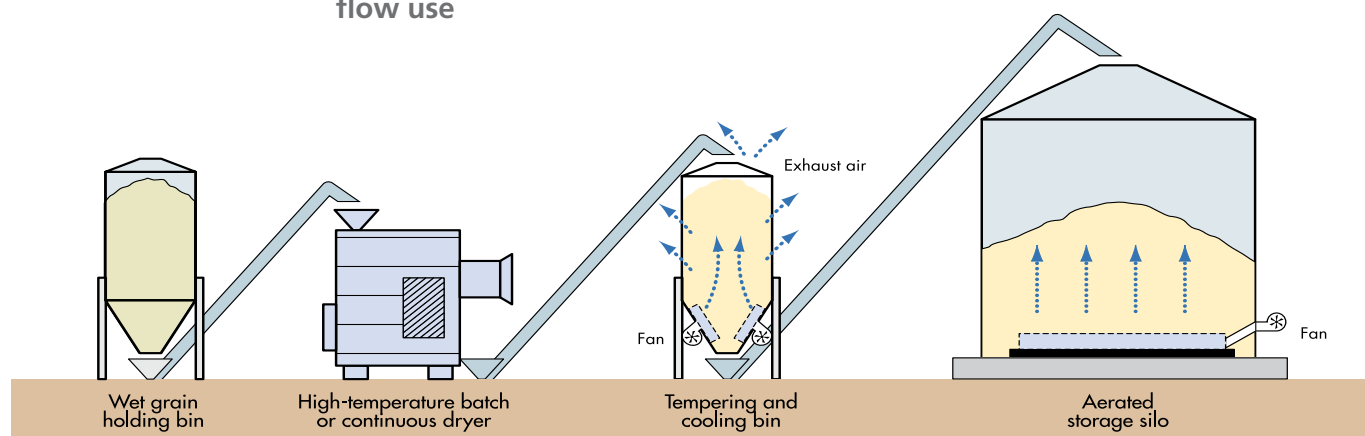
### Dryeration

Dryeration refers to the aeration of grain with relatively high airflow rates (10–30L/s/t) after the heating component of drying to act as a cooling and final moisture removal. Provided the grain is immediately aerated this option can be gentler on grain and results in less stress cracking than rapid cooling. It also has the benefit of maximising heating fuel efficiency as the grain is more thoroughly cooled and the maximum moisture is drawn off during the dryeration process. The airflow rates in dryeration storages are significantly lower (20L/s/t compared to the dryer of 500L/s/t) and hence will not remove moisture as quickly should the grain have been cooled in the grain drier. It is important to note the dryeration process mobilises significant amounts of water and hence silo roofs need to be extremely well vented.



An old silo batch dryer converted to act as a cooling bin in a dryeration system.

Figure 11.1 – A typical dryeration system for either batch or continuous flow use



## 12. Heated air grain drying

Grain drying commonly refers to the rapid drying of grain with heated air in batches or under continuous grain flow. Three key characteristics distinguish grain dryers from aeration or aeration drying:

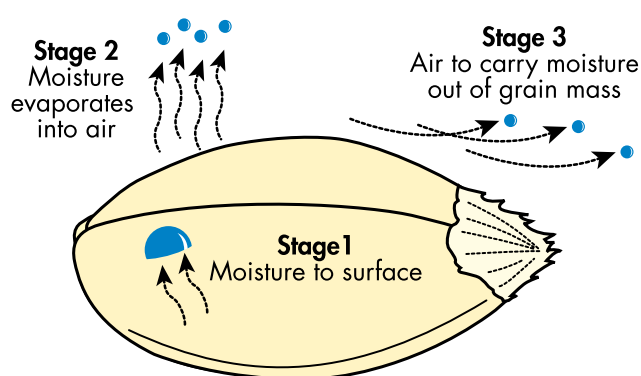
- They quickly and reliably remove moisture from the grain at most ambient air conditions.
- There is extremely high airflow well distributed over a relatively small grain mass.
- The air used is significantly heated which reduces RH levels considerably and the higher temperatures promote faster moisture transfer from the grain to the surrounding air.

**Stage 1:** Grain drying has three stages. Firstly the moisture must move to the surface of the grain. The greater the moisture level in the grain the more freely the moisture will move to the surface hence drying from 18–16%MC will be easier than from 12–10%MC. The moisture movement to the grain surface is generally the slowest part of the drying process.

**Stage 2:** After the moisture is on the grain surface, it must be evaporated into the surrounding air and this is significantly improved at higher temperatures as moisture becomes more mobile in hotter conditions.

**Stage 3:** Finally the airflow must be sufficient to carry the moisture out of the grain mass.

Figure 12.1 – The stages of drying grain



**It is important to note grain heating occurs in a dryer relatively quickly, much faster than the moisture can diffuse out from the kernel.**

### Basic mechanics of a dryer

Dryers generally force air into a central area where it then passes out through the grain. The central hollow void is referred to as the 'plenum' and the burner heats the air adjacent to the fan before entering the plenum.

### Ways to dry grain

#### Batch drying

Batch drying involves heating and then cooling a parcel of grain. The same fan is usually used for both the heating and cooling phases, only with the burner switched off.

Many older style dryers were for batch drying, with manual controls for the heating and cooling time allocations.

Some machines also use augers to circulate the grain in each batch to provide more even heating.



Batch drying with an older style silo dryer.





*The more modern field bin batch dryer with improved portability and throughput.*

After grain has reached a target temperature the burner is then switched off and the fan is left running to cool the grain.

During cooling, moisture continues to be removed from the grain. This method of drying can have exceptional heating efficiency if the grain is completely cooled before the batch is finished and out loaded. A disadvantage of batch drying is that grain immediately adjacent to the plenum may be prone to overheating and damage.

### **Continuous flow drying**

When the grain is moved through a heating phase followed by a cooling phase in an ongoing flow, a dryer is termed continuous flow. This is usually controlled by electric in-loading and out-loading augers, either on sensors or continually running.

Overall dryer efficiency in continuous flow dryers is enhanced by longer uninterrupted operation where the heat build-up in the machine can be maintained instead of stopping and starting. The movement of grain through the system also allows for some mixing of the grain and can limit overheating damage.

The more complex mechanics and controls make this type of dryer installation more expensive.

### **Mobile or fixed plant drying**

The advantage of having a fixed plant dryer is that larger more convenient storage infrastructures can be developed adjacent to the dryer to take advantage of storage, aeration and blending opportunities.

The disadvantage of this is that grain needs to be transported back to the central point for it to be dried and growers who have multiple property locations may find this unrealistic and a mobile machine more suitable.

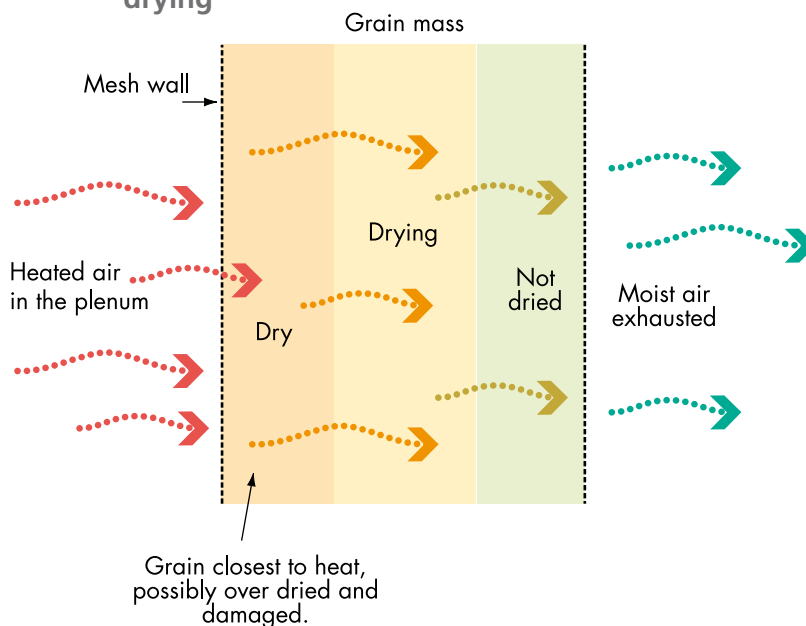
## Airflow in drying

### Cross flow drying

Cross flow dryers force heated air through a layer of grain, from one side across to the other. The holding area of the dryer is normally made of a perforated material which allows air to pass through. Cross flow drying can be used in batch drying situations and continuous flow systems.

One of the key drawbacks of cross flow drying is the grain on heat side, tends to get over dried, while the grain on the opposite side dries much less. Grain immediately adjacent to the plenum can also easily overheat and be damaged so plenum temperatures for this type of dryer need to be closely monitored. It is also important to test grain temperature next to the plenum to assess the maximum temperature.

Figure 12.2 – Airflow in cross flow drying



*Grain adjacent to the plenum can be prone to overheating and damage in cross flow drying.*

### Mixed flow drying

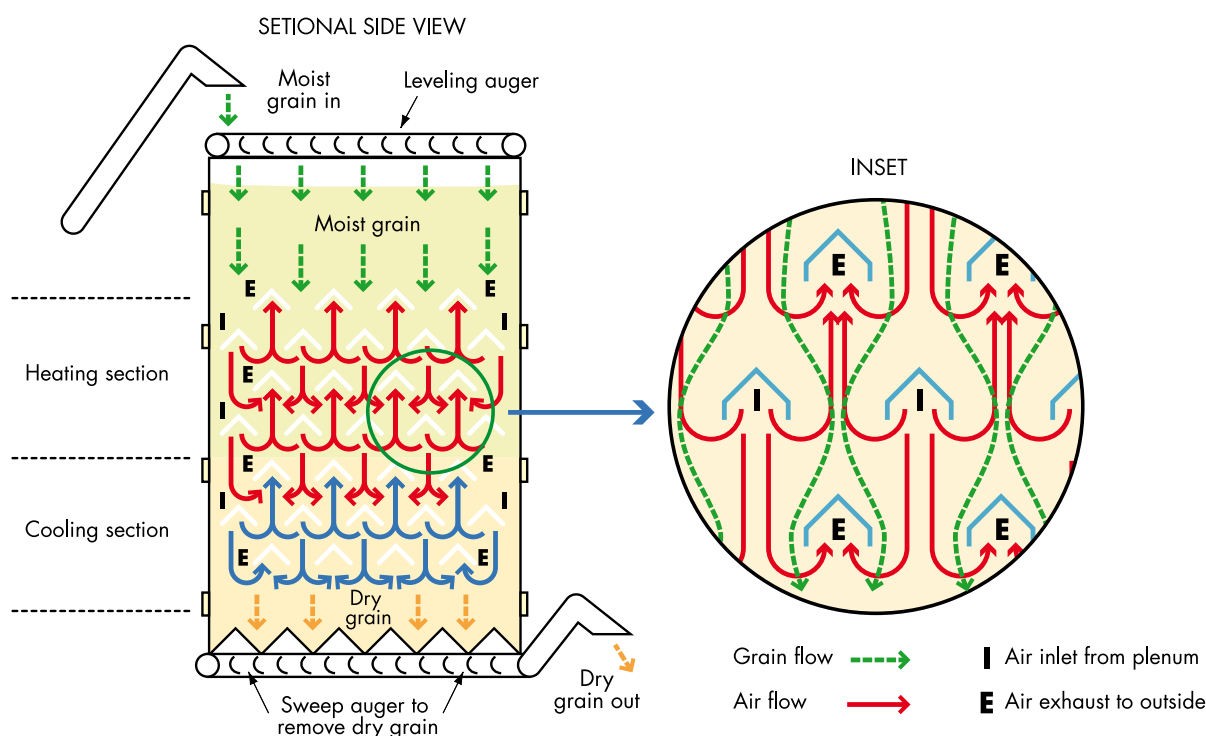
Mixed flow machines force airflows in several directions as the grain passes through the machine in a continuous flow. This type of dryer is easily identified by the inverted triangle design of intake and exhaust ducts.

Mixed flow dryers can be mobile or fixed but transport height restrictions limit the design of mobile dryers and they often do not have the same cooling ability as the taller stationary designs. The mobile machines can have trouble cooling grain properly in warmer conditions. This may be addressed by fitting aeration fans to the output silos to provide additional cooling after drying. Some models have also been manufactured above legal height, compromising the transport possibilities of the machine but maximising its drying and cooling design capabilities.

### Mixed flow dryers can be easily identified by their triangle ducting design



**Figure 12.3 – Grain and air movement in mixed flow drying**



*Mixed flow drying has air moving in several directions as grain continuously flows down through the machine.*

As the air is blown from the plenum into the intake ducts, it passes both upwards and downwards to the adjacent exhaust ducts. As the grain passes through the machine it is subject to changing airflows and each triangular duct level mixes it slightly, resulting in a truly mixed flow of grain and air.

During its passage through the machine, grain will pass an intake duct where it will be have direct hot air, heating and drying it rapidly. Then as it moves down past an exhaust duct, it has time to rest and further moisture can migrate out from the internal of the kernel. Because this process is repeated many times as grain flows down through the machine, this type of drying is gentler on grain kernels, and the system can use higher operating temperatures than cross flow dryers.

It is important to note that if a mixed flow dryer is set only to batch dry, the mixing of airflow directions and grain will not occur. In batch dry mode it may be necessary to reduce the burner settings.



*On-farm drying generally requires an on-site three phase power generator.*

### Electricity supply and dryers

Heated air dryers normally have electrically driven fans and grain conveying. The electricity supply required for this is often beyond what is available from the grid electricity supply in regional WA.

## Continuous flow grain dryers used in Western Australia

Figure 12.4 – A continuous cross flow dryer in silo design

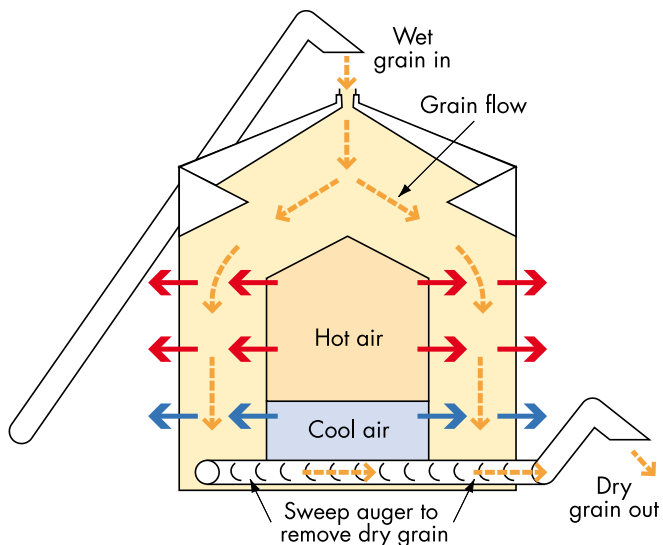


Figure 12.5 – The cascade dryer design, also a continuous cross flow design

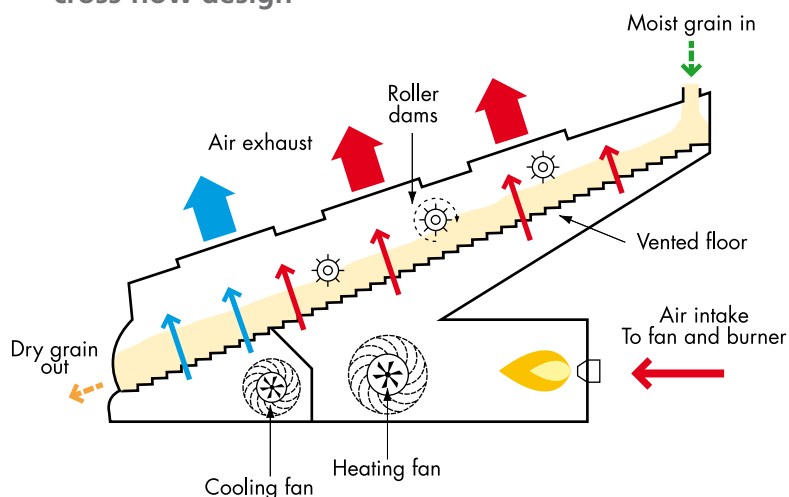
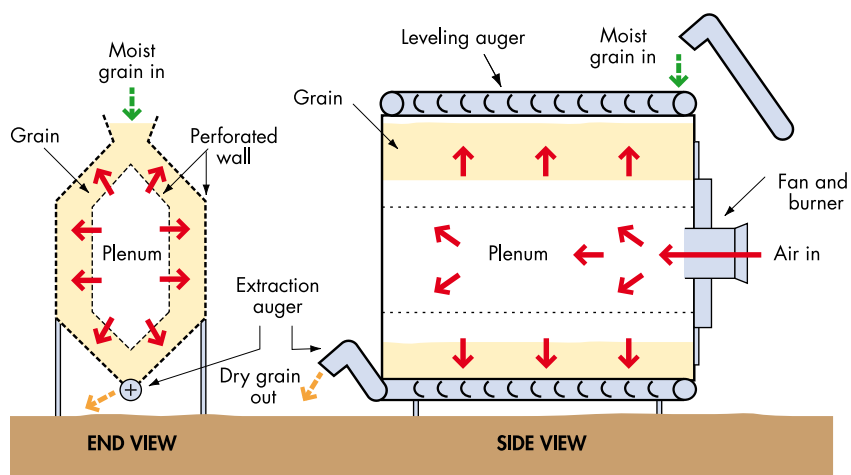


Figure 12.6 – A cross flow dryer with separate cooling bin, allowing continuous operation as a dryeration system





A fixed plant mixed flow machine, note the taller height than the mobile design



A mobile mixed flow machine ready for transport



Paddock operation of a mobile mixed flow machine



## 13. Dryer operation and performance

### Overheating – drying too fast – thermo stress cracking of grain

As hot air is pushed past the grain it draws moisture away from the kernel. This drying process causes the surface of the kernel to shrink slightly. With excessive temperatures or prolonged exposure, the heating causes the internal core of the kernel to expand. Expanding and shrinking results in grain kernels forming stress cracks during the drying process.

This stress cracking affects grain milling and germination characteristics. It also provides possible points on the kernel surface for mould, fungi or insect attack. The risk of this is increased with higher drying temperatures and rapid cooling rates.



To prevent thermo stress cracking of grain it is important to monitor grain temperatures and maintain them within the recommended guidelines in the dryer operation manual. It is important to remember grain is a living mass.

## Dry grain is prone to cracking

The lower the moisture content of a grain kernel the more susceptible it is to cracking and damage. After drying, grain is more prone to damage during moving than when it had higher moisture content before drying. Rapidly cooled grain also tends to be more brittle and prone to damage.

## Operation temperatures and grain temperatures

To prevent grain damage from overheating, dryer operators need to be conscious of the actual grain temperature. Most dryers are equipped with thermometers or thermostats to monitor the dryer's operation temperature. The location of these thermometers varies on different machines and so does the information they provide to the operator.

There are several common places to measure temperature in a dryer.

- **Plenum temperature**

The temperature of the air after it has passed the burner but is still inside the machine is known as the plenum temperature. Plenum temperature is used to monitor the heating of the air and burner operation.



*Plenum temperature is used to monitor burner operation.*

- **Grain and air temperature**

The grain mass temperature can be measured with the hot air passing through it. This is often done with simple probe thermometers in the side of the machine to give an indication of grain temperature and the cooling effectiveness of the drier. This type of measurement does not provide the exact grain temperature as the thermometers are affected by the air temperature as it passes through the dryer.



*Grain and air temperature is measured by simple probe thermometers in the side of the dryer.*

**Table 13.1 – Plenum temperature operation guide for different dryers**

Type of dryer	Malting/seed grain	Milling grains	Feed grains
Cross flow – static grain	55°C	60°C	75°C
Cross flow – moving grain	60°C	65°C	75°C
Mixed flow dryer	65°C	70°C	80°C

Notes:

- Refer to the dryer operation manual for more specific temperatures.
- There can be up to 20°C drop from plenum temperature to grain temperature.
- In mixed flow dryers faster throughput can allow higher temperature operation and slower throughputs require lower temperatures.

## Actual grain temperature



*The only way to measure actual grain temperature is to isolate the grain from the dryer's airflow.*

The only way to test the true grain temperature is to isolate it from the dryer's airflow. This is done by removing grain from the dryer and placing it in a container. The temperature can be taken after the sample is allowed to stabilise for several minutes. This method allows the true temperature of the grain alone to be assessed.

It is important the grain sample to be measured is taken from the hottest point in the dryer. In continuous flow dryers this will be at the end of the heating section as the grain flows down through the machine. On cross flow machines the grain closest to the plenum will be the hottest and should be sampled.

Table 13.2 provides a guide to the optimal and maximum temperature of grain during the drying process.

**Table 13.2 – Guide to actual grain temperature during drying**

*Note: These figures are only a guide to optimal and maximum grain temperature during the drying process.*

Grain type	Optimal	Maximum
Malting/seed barley	40°C	43°C
Milling wheat	50°C	55°C
Seed wheat	40°C	43°C
Feed grains	60°C	65°C
Canola	40°C	43°C
Grain legumes	40°C	43°C

*(Source: The Drying and Storage of Grain and Herbage Seeds, FAR, 1999.)*

*Dryers usually have instruction manuals which indicate operation temperatures. These temperatures are higher than aeration drying temperatures due to the heat exposure being for a limited amount of time followed by a cooling phase.*

## Throughput performance

One of the most important assessment of a dryer is its tonne per hour throughput. When sold, dryers are rated at a percentage moisture reduction, t/hr capacity at certain atmospheric conditions (for example, dropping 2% moisture content, 27t/hr in wheat with atmospheric conditions of 20°C and 75%RH).

The throughput of a dryer is an extremely elastic and variable figure affected by temperature, RH, and specific grain moisture conditions. Figures should only be used as a guide. It is both unrealistic and uneconomic for a dryer to match header capacity. Storage and blending are integral parts to any drying operation and are an important part of determining dryer capacity.

## Factors affecting dryer throughput

### **Temperature**

Cold ambient temperatures require more fuel to heat the air before drying. Often dryer operators notice an increase in fuel consumption at sunset or on cold days. If a burner reaches its capacity, it will simply not heat the air adequately to dry the grain. In batch dryers this will mean longer cycle times and in continuous flow machines throughput will need to be slowed.

### **Relative humidity**

Relative humidity (RH) is an expression of the amount of water in the air in relation to temperature. Higher amounts of water means the gradient for water diffusion will not be as steep, hence drying will occur at a slower rate.

### **Type of grain moisture**

Generally there are two types of moisture grain can hold, surface moisture and kernel moisture.

Surface moisture is moisture the grain has recently absorbed from its surrounding environment, for example, a small rain event, a sea breeze or morning dew. This moisture is associated with the surface of the grain and is fairly easy to remove in the drying process.

Kernel moisture is carried more throughout the grain and is significantly harder to dry out. This type of moisture is present in the initial dry down of the grain as it matures, or after a significant rain fall event in which the grain has absorbed moisture to the extent of swelling.



*Hand held temperature and RH sensors can help manage dryer throughput or batch times.*

### **Type of crop**

Different crop types with individual kernel sizes, shapes and physical characteristics alter their ability to lose moisture to the surrounding air. Legumes generally are slower, cereals moderate and canola the fastest drying of the WA crop types.

## Burners, heating fuels and efficiencies

The heating component of a dryer is referred to as the burner. Burner size and performance are metrically rated in megajoules (MJ), but British thermal units (BTU) are commonly referred to. To fire burners there are three fuels commonly used diesel, liquid propane gas (LPG) and natural gas (NG). Traditionally diesel has been associated with higher burner maintenance and a less clean fuel.

More recently, technology and regular maintenance have both contributed to diesel firing being an equally viable option to gas. Gas firing dryers have strict safety requirements for plumbing and electrical set up. When installed, gas firing dryers are simple, lower maintenance systems.

Traditionally fuel choice has been based on logistics for the individual dryer operation, but as fuel costs increase, the choice may be more based on the fuels' heat energy release.

Measured in megajoules (MJ) per unit of measure this indicates how much heat a particular fuel will produce.

**Table 13.3 – Comparison of fuels**

Calorific heating value of fuels				
Fuel	Heat energy per unit	Approximate cost	Cost per MJ (cents)	Characteristics
Diesel	38.4 MJ/L	\$1.20/L	3.13	Requires a well maintained burner. Simple to store and transport.
LPG (Liquid Propane Gas)	50.4 MJ/Kg bottled	\$100/45kg bottle	4.41	Low maintenance burning. More costly set up and storage.
	25.6MJ/L bulk delivery	\$0.80/L	3.13	
NG (Natural Gas)	3.6 MJ/unit	\$0.08/unit	2.22	Clean burning. No storage required. Normally only available via pipeline delivery.

Gas and diesel burners are not necessarily interchangeable. The way the fuel is combusted is affected by the pressure delivery of the drying fan. Diesel burners traditionally have worked at relatively low pressure while gas can fire in full blast of the drying fan. For this reason there may need to plenum and airflow modifications if a dryer is converted from gas to diesel.



*As drying fuel costs increase, fuels should be considered in their calorific heating values for relative efficiency.*

## Removing water – removing weight

Drying removes part of the moisture content of a grain mass therefore the weight is reduced.

For example, one tonne of wheat at 15% moisture contains 150kg or 150L of water.

To reduce this down to 12% moisture, about 30kg or 30L of water will need to be removed from that tonne of grain. For this reason there is always a weight loss of grain when drying. The following table gives provides information on corresponding weight differences in grain of varying moistures.

**Table 13.4 – Weight loss in kg/t from drying grain**

Weight loss in kg/tonne when drying																			
DryGrain %	Wet Grain moisture content %																		
	12.0	12.2	12.4	12.6	12.8	13.0	13.2	13.4	13.6	13.8	14.0	14.2	14.4	14.6	14.8	15.0	16.0	18.0	20.0
9.0	33.0	35.2	37.4	39.6	41.8	44.0	46.2	48.4	50.5	52.7	54.9	57.1	59.3	61.5	63.7	65.9	76.9	98.9	120.0
9.2	30.8	33.0	35.2	37.4	39.6	41.9	44.1	46.3	48.5	50.7	52.9	55.1	57.3	59.5	61.7	63.9	74.9	96.9	118.0
9.4	28.7	30.9	33.1	35.3	37.5	39.7	41.9	44.2	46.4	48.6	50.8	53.0	55.2	57.4	59.6	61.8	72.8	94.9	117.0
9.6	26.5	28.8	31.0	33.2	35.4	37.6	39.8	42.0	44.2	46.5	48.7	50.9	53.1	55.3	57.5	59.7	70.8	92.9	115.0
9.8	24.4	26.6	28.8	31.0	33.3	35.5	37.7	39.9	42.1	44.3	46.6	48.8	51.0	53.2	55.4	57.6	68.7	90.9	113.0
10.0	22.2	24.4	26.7	28.9	31.1	33.3	35.6	37.8	40.0	42.2	44.4	46.7	48.9	51.1	53.3	55.6	66.7	88.9	111.0
10.2	20.0	22.3	24.5	26.7	29.0	31.2	33.4	35.6	37.9	40.1	42.3	44.5	46.8	49.0	51.2	53.5	64.6	86.9	109.0
10.4	17.9	20.1	22.3	24.6	26.8	29.0	31.3	33.5	35.7	37.9	40.2	42.4	44.6	46.9	49.1	51.3	62.5	84.8	107.0
10.6	15.7	17.9	20.1	22.4	24.6	26.8	29.1	31.3	33.6	35.8	38.0	40.3	42.5	44.7	47.0	49.2	60.4	82.8	105.0
10.8	13.5	15.7	17.9	20.2	22.4	24.7	26.9	29.1	31.4	33.6	35.9	38.1	40.4	42.6	44.8	47.1	58.3	80.7	103.0
11.0	11.2	13.5	15.7	18.0	20.2	22.5	24.7	27.0	29.2	31.5	33.7	36.0	38.2	40.4	42.7	44.9	56.2	78.7	101.0
11.2	9.0	11.3	13.5	15.8	18.0	20.3	22.5	24.8	27.0	29.3	31.5	33.8	36.0	38.3	40.5	42.8	54.1	76.6	99.0
11.4	6.8	9.0	11.3	13.5	15.8	18.1	20.3	22.6	24.8	27.1	29.3	31.6	33.9	36.1	38.4	40.6	51.9	74.5	97.0
11.6	4.5	6.8	9.0	11.3	13.6	15.8	18.1	20.4	22.6	24.9	27.1	29.4	31.7	33.9	36.2	38.5	49.8	72.4	95.0
11.8	2.3	4.5	6.8	9.1	11.3	13.6	15.9	18.1	20.4	22.7	24.9	27.2	29.5	31.7	34.0	36.3	47.6	70.3	93.0
12.0	0.0	2.3	4.5	6.8	9.1	11.4	13.6	15.9	18.2	20.5	22.7	25.0	27.3	29.5	31.8	34.1	45.5	68.2	90.0
12.2		0.0	2.3	4.6	6.8	9.1	11.4	13.7	15.9	18.2	20.5	22.8	25.1	27.3	29.6	31.9	43.3	66.1	88.0
12.4			0.0	2.3	4.6	6.8	9.1	11.4	13.7	16.0	18.3	20.5	22.8	25.1	27.4	29.7	41.1	63.9	86.0
12.6				0.0	2.3	4.6	6.9	9.2	11.4	13.7	16.0	18.3	20.6	22.9	25.2	27.5	38.9	61.8	84.0
12.8					0.0	2.3	4.6	6.9	9.2	11.5	13.8	16.1	18.3	20.6	22.9	25.2	36.7	59.6	82.0
13.0						0.0	2.3	4.6	6.9	9.2	11.5	13.8	16.1	18.4	20.7	23.0	34.5	57.5	80.0
13.2							0.0	2.3	4.6	6.9	9.2	11.5	13.8	16.1	18.4	20.7	32.3	55.3	78.0
13.4								0.0	2.3	4.6	6.9	9.2	11.5	13.9	16.2	18.5	30.0	53.1	76.0
13.6									0.0	2.3	4.6	6.9	9.3	11.6	13.9	16.2	27.8	50.9	74.0
13.8										0.0	2.3	4.6	7.0	9.3	11.6	13.9	25.5	48.7	71.0
14.0											0.0	2.3	4.7	7.0	9.3	11.6	23.3	46.5	69.0

(Source: Agridry RIMIC)



## 14. Drying and malting barley



*Barley germination is vital in the malting process and can be easily damaged during drying.*

Malting barley is germinated under controlled conditions during processing. Grain with less than 98% germination is unsuitable for malting. Overheating the grain during grain drying and inappropriate grain storage can decrease the germination viability of malting barley resulting in the production of poor quality malt.

Grain drying malting barley offers an opportunity to harvest crops before quality deterioration in the paddock, but care must be taken in drying and storage to protect the barley's germination rate and malting quality.

While the grain drying process itself is quite simple, there is scope for significant problems to develop and barley quality to decline if grain drying is not carried out correctly.

### Key points for protecting malting barley:

- **Cool in storage**

Aeration preserves seed viability and vigour by keeping an even and cool temperature and also offers the option to store at higher moisture.

- **Do not overheat**

Grain temperatures above 45°C reduce the ability of barley to germinate and can denature enzymes in the grain which are needed in the malting and brewing process.

- **Do not over dry and blend back**

Over dried barley is susceptible to germination loss and mechanical damage during handling.

- **Properly cool grain after drying**

Post aeration drying protects grain quality and also offers maximum moisture removal for heating dollar spent.

## 15. Farmer case studies

During the 2005–06 harvest, research examined the on-farm adoption of high moisture management strategies. Information from this research is presented in case studies to highlight several management approaches currently used across the southern region of WA to harvest during periods of high moisture.

Costs mentioned in the case studies are indicative only and are only relevant to the years and scenarios being explained. Further research should be undertaken before applying these concepts to individual farming systems.

**Farmer:**

**Rodd King**

**Location:**

**River Plains,  
Cascade, 45km from  
the coast**

## Case study 1 – Simple storage and blending

### Outline

Building an on-farm storage shed enabled the Kings to extend their harvest hours by capitalising on blending opportunities. The shed complex holds about 3000t, with a concrete dividing wall between the three main areas.

### Advantages

- Storage and blending can be extremely cost-effective.
- Blending can be advantageous for other grain quality characteristics not just grain moisture.
- The shed has multiple uses for the farming operation.

### Disadvantages

- There is significant double handling, which is often a hidden cost.
- The system is limited to handle only minor increments in moisture.
- The system does not offer safe longer term storage of grain of higher moisture.

### How the concept is applied

The shed is used to accumulate a stockpile of either dry or over moisture grain that then forms blending buffer storage at a latter date. Generally grain is carted back to the shed, unload and then pushed up with a loader. Although fairly cost-effective the convenience of higher moisture receival limits at the CBH Group is preferred to the double handling.

This blending system works well with minor moisture issues during harvest, but ongoing damp conditions soon limit this approach. Swathing is also used in barley crop to manage moisture.



*Stockpiling grain allows for other quality factors as well as grain moisture to be managed by blending.*



*Grain is trucked back to the shed and then pushed up to maximise storage capacity.*

### Cost (2002)

Shed construction

\$250,000

**Farmer:**

**Rod Ebert**

**Location:**

**West River, 40km  
from the coast**

## Case study 2 – Aeration storage with blending

### Outline

Two aerated flat bottom silos of 280t capacity each, provide the Eberts with safe storage of over moisture grain to blend with dry grain on out-loading. The silos aeration fans run times are automated via a time proportioning controller. In addition to the silos, there is a concrete storage shed capable of holding 800t of wheat beside the silos.

### Advantages

- The aerated silos allow high moisture grain to be safely stored without any fears of quality degradation.
- The aeration system is automated, requiring limited attention during the peak periods of harvest.
- The shed and silos are centrally located to allow for easy blending during outloading.
- There are two smaller silos rather than one larger to allow for segregations.

### Disadvantages

- There is double handling of grain.

### How the concept is applied

The high moisture grain storage allows the Eberts to start harvest each morning and cart back to the aerated silos. The grain moisture is tracked throughout the day and when it falls below 12.5%, the grain is carted and dumped into the storage shed adjacent. Recording tonnages and moisture levels is an integral part of successfully blending trucks so that they are not rejected. The use of the CBH Group aeration services also allows for a greater blending margin. Contract trucking arrives at the shed and silo area where it is loaded in accordance with wet and dry grain. With this approach 10 hours per day harvesting can be consistently achieved where previously only test samples would be taken. The use of aerated storage means the fear of what to do with wet grain is removed and they can get on and harvest. If prolonged damp conditions are experienced then contract drying can be sought for the high moisture grain stored under aeration.



*Two aerated 280 tonne silos allow for grain segregation and safe storage of high moisture grain.*

### Cost (1999)

2 x 280 tonne aerated twister silos, including fans and automatic controller	\$53,000
50ft fill auger	\$10,000
Electricity connection for aeration system	\$6000
Total	\$69,000

**Farmer:****Andrew Fowler****Location:****Condingup, 15km  
from the coast**

## Case study 3 – On-farm aeration storage with contract drying

### Outline

Managing labour during the peak of harvest prompted the Fowlers to sell their on-farm grain dryer and start using contract drying. An integral part of this approach is to store grain under aeration and have large consistent parcels dried by a contract dryer. The Fowlers now have 500t of aerated shed storage with two 500t aerated flat bottom silos designated as high moisture storage. Aeration fan run times are automated by time proportioning controllers. Aeration is vital to the concept in that it protects grain quality during the storage period while waiting to be dried.

### Advantages

- Less labour required at harvest than having own dryer.
- On-farm storage allows for blending for other quality characteristics.
- Larger consistent parcels of grain are more attractive for contract dryers than individual truck deliveries.

### Disadvantages

- There is double handling of grain on-farm.

### How the concept is applied

The Fowlers start harvest as early as possible aiming to maximise grain quality. Often there will still be green sappy grains in the sample and under aeration they mature and are not a sampling issue. This better quality grain then becomes a blending buffer for any quality issues that may occur later in the season. As harvest progresses the warmer weather allows accumulation of dry grain in a 1000t non-aerated storage. This dry grain is then used to blend with the wet grain held under aeration. If possible dry grain is also blended direct from the paddock rather than the dry stockpile. Located so close to the ocean, blending is limited and there is still a reliance on the contract dryer. A large proportion of the grain dried by the contract dryer is carried out post harvest, after the rush period, for a discounted rate.



*The two 500 flat bottom aerated silos.*

### Cost

Retrofit aeration to concrete shed (2001)	\$12,000
2 x 500t silos @ \$45,000 each (2004) (Includes concrete and electricity)	\$90,000
Total	\$102,000

**Farmer:**

Glen Calvert

**Location:**

Gairdner River,  
26km from the coast

## Case study 4 – Aeration drying silos

### Outline

A combined need for on-farm storage and moisture management resulted in the Calverts investing in two 154m<sup>3</sup> (120 wheat tonnes) Kotzur drying silos. The silos are primarily aimed at safe storage of wet grain, but the higher airflow gives the management option to remove moisture should ambient air conditions allow.

### Advantages

- Safe storage of wet grain.
- Ability to dry grain over time with appropriate weather conditions.

### Disadvantages

- Will only dry the grain over a period of several days **if** weather conditions permit.
- There is no automated system to optimise fan run hours.

### How the concept is applied

The silos are primarily used as harvest storage to blend grain for moisture and other quality aspects. The aeration of the silos removes any concerns of what to do with wet grain and gives the Calverts the confidence to harvest when they otherwise might not. The silos offer aeration drying flow rates of 13L/s/t, and when appropriate conditions are experienced the fans can be left running to remove moisture. Average weather conditions experienced at Gairdner River are 25°C and 65%RH which means drying grain to 13.5%MC is relatively easy but to achieve lower moisture levels there needs to be more precise air selection. An electronic controller could be fitted to the fans to manage this. It takes about 30 fan run hours to push a drying front through the grain column.

The silos had to be installed with a generator, as insufficient power was available from the grid network.



*The patented design aeration cone of the Kotzur drying silos.*



*The aerated drying silos serve as significant storage and blending options as well as being able to remove moisture over time.*

### Cost (2002)

2 Kotzur drying silos @ \$21,000 each (120t)	\$42,000
Generator	\$10,000
Electrics and wiring (fans and loading augers)	\$18,000
Total	\$70,000



**Farmer:**

Paul Barret

**Location:**

Jerramungup–  
Gairdner River,  
50km from the coast

## Case study 5 – Mobile in paddock batch drying

### Outline

Several years ago the Barrets decided buffer storage was not sufficient to keep their header working throughout harvest and they needed a grain dryer. Farming in multiple locations also meant the need for portability. The advantages of additional paddock storage led the Barrets to choose the Agridry mobile field bin dryer.

### Advantages

- A mobile, simple dryer which is easy to operate by a chaser bin driver.
- Additional paddock storage.

### Disadvantages

- Dryer is batch cross flow design making overheating and grain damage possible.

### How the concept is applied

Often the first one or two truckloads of the day's harvest are dried completely or dried and partly blended with previous the day's dry grain. The machine is filled either direct from the chaser or header. When an overnight dew effect increases surface moisture in the grain, the dryer is operated on 40 minutes of heating followed by 20 minutes for cooling, (removing only 1–2% moisture in barley). During the heating cycle the burner uses about 40L of diesel equating to about 2L/t. Longer batch times are required for higher moisture removal and use greater amounts of fuel.

It has been noted the dryer works best with the rear facing into the wind to assist in the removal of exhausted moist air. The dryer holds just over 22t of wheat and comfortably can dry six batches in a day. The chaser bin driver who has a clock timer to track the heating and cooling times of each batch operates the dryer. When the dryer is not required the rapid unloading auger and ease of filling means the dryer can double as additional paddock storage. A dedicated tractor powers the dryer. The Barrets also have 140t of aerated storage, which they use to hold wet grain before to drying.



*The dryer has a PTO driven fan and is self contained with its own diesel tank and electricity alternator.*



*The mobile field bin dryer is well suited to paddock operation and is easily portable.*

### Cost (2003)

Agridry FB 2000 dryer

\$110,000

**Farmer:****Kevin Fox-Slater****Location:****Munglinup, 15km  
from the coast****Case study 6 – Mobile continuous, mixed flow dryer****Outline**

Located only 15km from the ocean, it is common for the Fox-Slaters to dry almost half of their cereal crop. The Fox-Slaters purchased their own mobile Parker dryer in 2002 and have dried grain every year since. The machine is diesel fired and is all electrically operated from an on-site generator. Despite being a mobile machine the Fox-Slaters have opted make the dryer stationary where they have developed additional storage for both wet and dry grain holding. The dryer is capable of up to 30t/hr removing 1–2% moisture, but normal capacity is about 20t/hr removing between 2–3% moisture. Removing 4–5% moisture reduces the dryer's capacity to 10t/hr.

**Advantages**

- On-farm drying offers flexibility for blending and an optimal approach to managing high moisture conditions.

**Disadvantages**

- There is significant capital investment.
- The system requires full time supervision.

**How the concept is applied**

*Being a mobile machine means that out of season it can be stored under cover.*

It is common to harvest grain of 14%MC and this is taken directly from the header to the dryer. This grain is dried down to about 11.6% moisture and then used as super dry grain to blend back with grain of about 13.5%, harvested in the warmer part of the day. With this method, the capacity to handle over moisture grain is roughly double the dryer alone at 20t/hr. Removing this amount of moisture the dryer burns 5.5L of diesel per tonne and electricity generation uses an additional 1L/t. The dryer is supervised full time by a dedicated person to monitor output grain temperatures and moisture levels. An Infratec is hired each season from the CBH Group to measure grain moisture to ensure optimal dryer throughput and operation. The use of blending to increase the dryer capacity has resulted in further development of storage either side to maximise this potential.



*Although being a mobile machine, development of storage either side of the dryer for blending potential means it is used as a fixed plant machine.*

**Cost (2002)**

Parker mobile dryer	\$120,000
Generator	\$16,000
Fuel tanker	\$6000
Total	\$142,000
Additional storage and handling facilities (2003–04)	
3 x 38t field silos	\$24,000
3 x 75t wet storage silos	\$30,000
Conveyor and fill auger	\$30,000
Concrete work	\$25,000
Electrics wire up and sample hut	\$14,000
Total	\$123,000

**Farmer:****Chris Ross****Location:****Gairdner River, 25km  
from the coast**

*The 6.5t holding capacity dryer heats the grain before then going to the cooling silo in a dryeration style system.*

## Case study 7 – Small scale fixed plant drying installation

### Outline

After dedicating the whole farming operation to grain production, but being close to the coast, the Ross family decided a grain dryer was essential to maximise harvest operations and ensure a high grain quality standard was achieved. The Ross family purchased the smaller model cross flow gas fired Canadian manufactured Energy Miser – Superb grain dryer. This machine holds 6.5t of wheat and is used as a continuous flow machine with an old silo dryer converted to act as an auxiliary cooling tank. The drying facility is centrally located adjacent to the sheds and house, where it can be easily monitored at night. The Ross family found the investment had paid for itself within two years.

### Advantages

- A relatively simple system.
- A lower capital input than larger dryer installations.
- Gas firing ensures a low maintenance burner.
- Automated safety shutdown procedures ensure safe working operations and prevent grain damage.

### Disadvantages

- Cross flow dryer design.
- Small loss of grain when drying canola due to the perforation design.

### How the concept is applied

The dryer has enabled the Ross family to start harvest about one week earlier than they traditionally had. After the header starts for the season the dryer is operated making harvesting and drying a continuous process. The dryer is low maintenance and is operated 24 hours per day allowing heat to build up in the machine to maintain fuel efficiency.

Drying down from 15% to 12%MC the Ross achieve a throughput of about 15t/hr. There is a grain temperature sensor on the output grain ensuring it is heated to the set temperature and act as a control for the dryer throughput. Cooler conditions, such as during the night, and lower grain temperatures do slow the dryer throughput. The automation on the controller requires adjustment when there is a variance of more than 3%MC. The dryer is connected to a bank of eight gas bottles and uses one 45kg bottle for about every 22.5t dried. A 45kVA generator powers the installation. When dry grain is harvested it is delivered direct to the CBH Group.

### Cost (2001)

Energy Miser dryer 230 Bushel model	\$70,000
Old silo dryer cooling tank	\$7500
Augers	\$4000
Generator	\$7000
Wiring, gas connection and certification	\$15,000
Total	\$103,500



*From left to right; Wet grain input silo, cross flow dryer (heating only); cooling silo and dry grain output silo. The system is continuous flow.*



*The dryer is gas fired and powered by and on-site generator.*

**Farmer:****Simon Tiller****Location:****Beaumont, 40km  
from the coast**

## Case study 8 – Larger scale fixed plant drying installation

### Outline

After moving to Beaumont, the Tillers were quickly confronted with the frustration of high grain moisture slowing their harvest program. During 2004 they decided on-farm drying was the way to safeguard their wheat quality. They constructed a 48m x 24m shed with a 10m roof height and 3m concrete walls, capable of holding 2500t. In the corner of this storage area they fitted a continuous mixed flow LPG fired Agridry AR-1614 dryer. Rated at 27 t/hr capacity (drying wheat from 15% to 12% in 20oC at 70% RH) the dryer is powered by a 200kVA generator and has bulk delivery gas tankers adjacent.

### Advantages

- The shed has multiple uses for the farm operation.
- There is significant storage allowing capitalising on blending opportunities.
- The facility has potential to manage large volumes of high moisture grain.

### Disadvantages

- There is a large capital investment involved.
- All in bulk shed means there is no grain segregation opportunity.
- The system is quite labour intensive.



*A front-end loader is used to load grain into the dryer, to push up dry grain as well as out loading via a hopper and conveyor.*



*The dryer is housed inside a shed holding some 2500t of grain, allowing blending opportunities to be capitalised on.*

### How the concept is applied

The Tillers start harvesting barley when traditionally many growers are swathing. This enables them to start their harvest program 7–10 days sooner and avoid contamination issues associated with swathing. Green sappy grains in the harvested sample disappear after several days in storage and are not an issue when sampled at the CBH Group. The Tiller's have found it is only necessary to dry grain with 14–15% moisture. Grain of 13% moisture can be managed via blending either from the paddock or via the shed storage.

Wet grain is bought to the shed, dumped and pushed up with a loader. The wet grain is shifted into the dryer through a giant hopper which is fed by the loader. The hopper holds between 12–15t. With the dryer removing 3.5% moisture it operates at 25t/hr, so the hopper needs to be topped up every 30 minutes. Output grain from the dryer is augered back onto the shed floor. There is an additional giant hopper and auger used for out-loading into trucks. The grain movement and hopper filling, makes the dryer supervision a full time job for one person. The running costs of the operation are \$7/t for diesel and gas with about \$1/t for labour.

### Cost (2004)

Shed – steel and cladding	\$100,000
Concrete floor and walls	\$120,000
Agridry AR 27 dryer	\$110,000
200 kVA generator	\$15,000
Electrical and gas connections	\$20,000
Grain fill and output augers	\$10,000
Total	\$375,000

## 16. Terms and definitions

**Aeration** – Passing low volumes of air (1–6 L/s/t) through a grain mass while in storage to cool it and evenly distribute moisture.

**Aeration drying** – Passing moderate volumes of air (5–20L/s/t) through a grain mass with the aim to reduce moisture over time. This may or may not use artificial heating

**Ambient air conditions** – The air temperature and humidity levels in the atmosphere.

**Batch drying** – Holding the grain static in the dryer to heat for a time then run without the burner for a cooling time.

**Bed depth** – The depth of grain from bottom to top through which air must pass during the aeration or drying process.

**Biological activity** – The level or rate at which grain, insects, moulds and fungi are respiring at certain temperature and moisture conditions while in storage.

**Blending grain** – Mixing grain together to achieve a specific sample parameter, either by homogeneous mixing or truck trailer separation.

**Continuous flow dryer** – A dryer which has a moving passage of grain through it during operation.

**Cooling front** – The passage of air through a grain mass reducing its temperature.

**Denaturing of enzymes** – The breaking down of proteins within grain, often due to excessive heating during drying.

**Dew point** – When air cools to a temperature when it no longer can support all of its moisture content and water droplets form.

**Dryeration** – The heating of grain in a grain dryer and then using high flow aeration in a separate storage of to cool the grain and remove moisture in either a batch or continuous flow system format.

**Drying front** – The passage of air through a grain mass removing moisture.

**Dry matter loss** – The loss of grain yield over time, often expressed as a percentage of total weight per day.

**Evaporative cooling effect** – When moisture is evaporated it removes heat energy from the immediate proximity, hence having a cooling effect.

**Equilibrium moisture content (EMC)** – The relative moisture content of grain in correspondence to the surrounding air at specific RH and temperatures.

**Heated air drying** – The use of artificially heated air at extremely high flow rates (300–500 L/s/t) to rapidly remove moisture from grain.

**High moisture grain** – Grain with moisture content greater than normal receival limits. In the case of cereal grains this is above 12.5% moisture. Sometimes referred to as 'over moisture grain'.



**Layering grain** – The purposeful loading of a truck to deceive the sampling process and hence falsely represent the trucks true grain characteristics.

**Moisture content (MC)** – The amount of water present in a grain kernel expressed in percentage terms.

**Pre-conditioned** – The aeration of grain to even out moisture and temperature before drying.

**Relative humidity (RH)** – The amount of water or moisture present in the air relative to the temperature.

**Respiration** – The process of all living organisms where carbohydrates and oxygen are combined to produce energy (heat), water and carbon dioxide.

**Retrofitting aeration** – The installation of aeration equipment after construction of the initial storage, often where the initial construction did not have provision for aeration designs.

**Sprouting** – The germination of a grain kernel caused by three days of the grain having a moisture content of greater than 45%MC. It involves mobilisation of enzymes within the kernel to break down starch, hence reducing the bulk density (weight) and altering the grains end use characteristics.

**Swathing** – (or windrowing) is a simple mechanical means of cutting a crop and bringing it together into a row for latter pickup and threshing by the harvester.

**Self-heat** – the ability for respiration in a grain mass to produce heat and moisture, further stimulating biological activity buildup, heat and causing spoilage while in storage.

**Static pressure** – The amount of pressure a fan builds up with air force under certain conditions of resistance to airflow.

**Thermodynamic properties of air** – The interaction of air characteristics in relation to moisture levels (measured in RH) at given temperatures.

**Thermal gain** – The gain of heat of grain while in storage from the outside environment.

**Thermocouples** – Electronic sensors to monitor grain temperature while in storage.

**Thermo stress cracking** – The physical damage of grain due to excessive heating or to rapid cooling post heating during the drying process.

## 17. Imperial – Metric conversions

All northern hemisphere equipment will be rated in imperial measurements

### Airflow

1 litre/second	= 2.1 cfm (cubic feet per minute)
1 m <sup>3</sup> /hr	= 0.59 cfm

### Volume

1 m <sup>3</sup>	= 1000 litres
	= 27.5 Bushels
1 bushel (bu)	= 36.4 L
	= 8 UK Gallons
1 UK Gallon	= 4.55 litres

### Pressure

1 kilopascal (kPa)	= 0.145 psi
1 lb/in <sup>2</sup> (psi)	= 6.9 kPa
1 inch water (inH <sub>2</sub> O)	= 0.249 kPa
703 mm water gauge (mmH <sub>2</sub> O)	= 6.9 kPa
1 psi	= 27.7 inH <sub>2</sub> O

### Power

1 kilowatt (kW)	= 1.34 hp
1 Horsepower (hp)	= 0.75 kW

### Temperature

Celsius (°C)	= 0.56 x (°F – 32)
Fahrenheit (°F)	= (1.8 x °C) + 32

### Bulk densities of grains (kg per cubic m)

Guide only – Moisture, variety and quality will affect exact values

Barley	630
Canola	690
Chickpeas	740
Lupins	770
Oats	470
Triticale	700
Wheat	780

## 18. Industry contacts

The following contact details are for company head offices – some eastern states companies may have representatives in Western Australia.

### ***Agridry– RFM, Toowoomba, Queensland***

[www.agridry.com.au](http://www.agridry.com.au)

Phone: (07) 4631 4300

Manufacture and supply of grain dryers, aeration equipment and controllers.

### ***Concord Equipment***

Phone: (08) 9041 2211

Australian distributors of Canadian built dryers.

### ***Customvac Australia, Toowoomba Queensland***

[www.customvac.com.au](http://www.customvac.com.au)

Phone: 1800 242 699

Supply aeration equipment and controllers. Specialise in aeration design and pneumatic grain handling.

### ***Geronimo Farm Equipment, Cowra NSW.***

[www.geronimo.com.au](http://www.geronimo.com.au)

Phone: 1800 242 432

Supply Canadian manufactured storage, aeration, handling and monitoring equipment.

### ***Industrial Automation, Perth WA***

Phone: (08) 9300 1844

Install industrial control systems for aeration and drying plant.

### ***Parker Silos and Sheet metal, Esperance WA***

[www.parkersilos.com.au](http://www.parkersilos.com.au)

Phone: (08) 9071 5440

Manufacture grain silos and grain dryers.

### ***Modern Engineering and Construction, Walla Walla NSW***

[www.kotzur.com](http://www.kotzur.com)

Phone: (02) 6029 4700

Manufacture and supply aeration drying silos. Distribute automatic control systems.



