agridry

Grain Dryers   Grain Aeration Systems   Food Processing Dryers

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Introduction

The benefits of using dryers were established long ago, but it is only over the past 25 years that there has been a large increase in the use of dryers for grain drying. Dryers have a place both on farms, in central bulk receival facilities operated by traders and consolidators, and for contract harvester operators.

For traders of grain the benefit of being able to receive grain having moisture contents above specification gives them a market edge in purchasing an early and sometimes cheaper product. For farmers, having a drying facility gives them the ability to effectively manage an early harvest which otherwise would be impossible.

In the early days of grain drying on Australian farms there were dryers based on designs from the UK or the Continental countries. These were brought to Australia and expected to work in completely different weather and farm management situations.

These early dryers were slow, expensive to run and labour intensive, and many of these older designs proved to be inappropriate for Australian conditions and climates. Ambient conditions drastically affect the way a dryer works and they must be designed for the weather conditions expected in the locality of use.

Very early dryers were primarily designed for use when grain was bagged in the paddock and transported and sold in the bags. These dryers were typically just a warm air supply comprising a fan and heater. The operator was left to arrange the product to be dried in some container or stack, as in the case of bagged products.

When bulk handling began it was natural that attempts were made at using these types of "dryers" for drying bulk grains. This approach met with little success leading to the general opinion that grain drying was costly, time consuming and more nuisance than it was worth. Even at the best of times, it was hard to predict the time taken to dry the crop with these early machines. Some were so bad that at certain times during bad weather they would not dry at all!

What use is a dryer that only functions in good weather? Even today we often are asked, "Will a dryer dry grain when the weather is bad or when it is raining?"

With the advent of bulk grain handling and ever-increasing harvesting speeds, these early machines proved to be a frustration when applied to drying grain in bulk. They were generally rejected, with good reason, as being ineffective in helping with harvesting management.

Today, dryers, like most other machinery and equipment, have changed in style and efficiency compared to machines available 25 years ago. Most modern dryers now work effectively and meet the needs of today's farming practices of bulk truck transport and on-farm storage. With the advent of aeration in silos, even more effective use of dryers is possible.

These days dryers are designed as a machine comprising a complete matched set of components including heaters, fan, control system and the bin or vessel to hold the grain whilst it is drying. They assist in harvest management by allowing freedom in harvesting hours independent of grain moisture content. Dryers can be used "on the run" by drying as you harvest or they can be used as a part of a storage and handling system operating independently from the field harvest.

Like all purchase decisions, selecting and buying a dryer to suit your needs will require careful consideration because of the many and varied styles now available. It is best to seek expert advice before making purchase decisions.

Many commonly asked questions arise when drying grain is discussed and some of these are addressed in the articles below.

Contents

Drying process

The drying process is one in which the equilibrium between the grain moisture and the moisture in the surrounding air is changed so that moisture moves from the grain to the surrounding air.

Heated air

In a heated air dryer the drying air is heated to reduce its RH and is then passed through the product being dried where it picks up the moisture from the product. The drying air RH must be below the EMC (see below) for the material and furthermore the difference between the drying air RH and the EMC must be substantial if a practical drying rate is to be achieved.

For drying to occur a condition has to exist so that the material being dried is in a state where it can give up water, and the air around it is capable of taking up that water.

Dehumidifiers

In air dryers this is most commonly achieved in one of two ways. Most commonly by adjusting the air temperature with heat or alternatively by reducing the air moisture content which is a process known as dehumidification.

Air dryers that use heated air are by far the most common and are used for most applications where the material being dried is not affected by the operating temperatures involved. By heating the ambient air its ability to carry more water vapour is increased. No moisture is removed from the air. In dehumidification dryers, which operate by cooling the drying air to a temperature below its "dew point", a portion of the moisture in the air is physically removed as liquid water. This effect can be seen in a domestic refrigerator in which the cooling coils inside can be seen to collect water in the form of ice. This water comes from the environment within the refrigerator. There is less need to heat the air in this type of dryer. Therefore dehumidification dryers are used where temperature limits are such that the product being produced would be affected by the temperature of a heated air dryer.

Another type of dehumidification dryer uses a desiccant to remove water vapour from the air before it is used to dry the material.

In general both these latter types of dryers are more expensive to build than heated air dryers.

Benefits of having a dryer

Early harvest
Better quality and quantity
Reduced losses
Better prices
More harvest hours per day
Smaller header/combine or more from existing header/combine
Shorter harvest period
Early finish to harvest

Makes effective harvest management possible
Scheduling delivery / storage / marketing
Quality control

Dryers are simple machines and therefore cost little to maintain over a long lifetime. They also last a long time.

Using dryers can dramatically increase the capacity of your present header simply by allowing it to work more hours of the day.

"Grain drying puts you in control of your harvest"

The earlier a mature crop leaves the paddock, the lower the risk of weather damage and quality loss. Grain dryers are an essential link in many harvesting operations on Australian farms. They deliver the flexibility to manage every harvest for maximum profit and minimum risk.
Most purchasers in recent years use dryers as a vital part of their harvesting strategy. The days of using dryers for wet seasons and emergencies only are gone.

Grain growers and contractors with dryers enjoy many advantages over those who depend solely on the weather to dry their grain. They use their dryers to:-

- Avoid weather damage and harvest losses
- Increase the harvest hours available each day
- Improve grain and seed quality
- Gain premium prices for grain
- Open more opportunities for double cropping
- Maximise marketable weight

Without a dryer there is no option but to delay your harvest until the moisture has reached a saleable or safe storage level. In our climates, this means: -

- Delaying harvest for several weeks after maturity
- Starting late in the morning when night moisture has dried off the crop
- Finishing when the evening moisture increases the crop moisture level. The usual result of delayed harvesting is inefficient use of machinery, lower quality grain and reduced dollar returns from your investment.

Objectives at harvest time or harvestability vs saleability

In managing a harvest it is best to consider the three distinct operations.

1. Getting the crop off the field.

2. Preparing the grain for sale - Cleaning / Drying / Blending / Storage

3. Delivery for Sale.

The object of the field operation is to get the crop off the field at the earliest practical time consistent with ground conditions and crop maturity and thrashability, whereas the object of the drying / cleaning / storage operation is to: -

- Make the crop saleable (moisture content, impurities etc.) and

- Allow for scheduling delivery to the buyer.

Usually these two broad objects can conflict if the field operation and the subsequent operations are carried out together or are dependent on one another.

Without a dryer it is mandatory to time the harvest to coincide with the saleable moisture content for the crop.

Losses which occur in the field

A physiologically mature crop in the field is subject to many dangers, some of these are :-	
Weathering	• degradation of visual quality • degradation of material quality (proteins & lipids) • reduction in mass quantity • splitting, cracking • over drying • loss of germination • sprouting in the head
Shedding	• loss of seed from the head
Lodging	• whole plant loss
Wild life	• eating the plant and/or seeds • damaging plant and/or seeds
Insects	• eating the plant and/or seeds • damaging plant and/or seeds
Moulds	• damaging plant and/or seeds • residual toxins
Bacteria	• attack and disease • residual toxins

No doubt you have heard of the ultimate case where a complete crop is lost after having reached maturity.
The point to note here is that from the point of physiological maturity, which is around 30% moisture content, both the quality and quantity can only decrease. Ideally we would harvest the day after the crop matures and then dry it down to a storable or saleable moisture content, thus achieving the best quality and quantity of seed from our crop.

Having a dryer should allow you to sell the crop to gain the maximum $ yield by selling at the highest moisture content acceptable at the earliest time.

"To sell a crop at say 9% moisture content, when it could be sold at 12%, is giving away 3% of your income!"

When to harvest when you do not have a dryer

A lot of farmers would say the answer is, "when it's RIPE". Usually they mean that the crop is thrashable or easy to harvest and it is dry in the sense that it is dry enough to sell. That is about 12% for most crops.

Without a dryer there is no option. The time to start is simply when the moisture has reached the saleable moisture.

Do not confuse this definition of RIPE with MATURE (See Frequently Asked Questions for a definition). They usually mean quite different things and it's important to differentiate between them when discussing harvesting and drying.

In our climates, waiting until the average moisture is satisfactory for sale means: -

- Waiting until the crop average moisture has fallen to saleable moisture (this can be 3 or 4 weeks after maturity)
- Waiting until late in the morning for the prior evening's moisture to naturally dry off the crop.
- knocking off as soon as the evening's moisture begins to increase the crop moisture level

The result is inefficient utilisation of machinery, poor quality and reduced returns.

When to harvest when you have a dryer

The decision of "WHEN TO HARVEST?" is a critical decision when a dryer is available and quite different from the decision when no dryer is available. The general answer would be, "as soon as practical after crop MATURITY". Doing this will give all the benefits of being able to harvest early and deliver quality crop. However, there are many practical considerations which need to be considered like: -

- Paddock conditions
- Thrashability
- Cost and time to dry

  The time to start should be as soon as practicable after maturity considering these factors. Ideally it would be a time when the moisture in the crop just begins to allow clean thrashing and you can: -
- Get into the paddock

- Thrash a satisfactory sample
- Afford to aerate/dry economically
- Finish harvest before losses become significant

There has been work carried out by others (G.Y. Abawi) in Australia, which concludes there are indeed some easily definable criteria which will indicate an economic and practical level of optimal moisture content at harvest time.

Grain moisture content at harvest

Experience shows that harvestability and cost of drying indicate that harvesting is best carried out as indicated in the table below: -

Grain	Harvestable Moisture %
Wheat	16 -14
Maize	25 -20
Sorghum	20 -16
Barley	20 -16
Navy Beans	20 -17
Sunflower	14 -12

This is only a general guide and if you need more specific information please seek further advice.

Aeration cooling - how it works with wet grain so as to buy time!

Aeration is the process of passing cool air through grain to reduce its temperature to a level where insect development, mould growth and moisture migration are dramatically inhibited. Cool air that is naturally available is blown through the grain to provide the cooling. Low airflow rates are used so the capital and running costs of aeration are very low.

The benefits of aeration are many and very important to everyone who stores grain. The main benefits are: -

1. Insect and mould activity is dramatically suppressed, reducing spoilage and weight loss of grain.

2. Temperature and moisture variations within the grain are prevented, thus avoiding hot spots and condensation due to moisture movement.

3. Cooling helps maintain grain quality - especially important for grain kept for seed.

4. Insecticides maintain their effectiveness for far longer when grain is cooled by aeration.

5. Aeration is a low energy process - running costs are low. Aeration can dramatically improve the storage life of dry grain. This practice has met with a wide acceptance in the past few years with farmers installing many of these units for improving the storage conditions in their silos.

It is not generally known that aeration can also be a very effective means of relieving the pressure on a drying system by allowing the wet grain to be safely stored for longer periods of time than would be possible without it.

When considering the purchase of a dryer you will naturally want to buy the appropriate size. This will depend on the availability of storage and whether or not it is aerated. Having aerated storage can mean buying a smaller capacity dryer, and saving money.

Using aeration to hold wet grain allows more time to dry. As harvest time is usually busy and all too short, this benefit is very useful in managing a harvest.

For example, 16% sorghum has been successfully kept in Queensland on-farm for periods from 2 to 4 weeks under aeration cooling with no detectable deterioration. This buys a lot of extra time in which your header can keep on harvesting and the dryer can "catch up".

How to manage wet grain prior to drying - use two silos

Most existing silos on-farm have conical bases with slopes of about 30 degrees and although these can be used to store dry grain satisfactorily, they can present problems if used with wet grain. The problem with 30 degree base slopes is that wet grain will not completely empty, necessitating cleaning out by hand before it is refilled - a time-consuming nuisance! If it is left in the silo, then of course it will eventually mould and go off. Wet grain needs slopes of around 45 degrees to flow and special bases are constructed to cope with these needs. Aeration ducting is also specially designed for these steep coned wet silos.

Another important point to note is that these wet-holding silos need to be completely emptied before they are refilled. They should not be topped up.

Silos empty by the grain flowing through the outlet in a funnel-like manner from the top surface of the grain pile. If a partly empty silo is topped up, the next time it is emptied, the fresh top-up grain is the grain which will be unloaded, leaving some of the original grain still in the silo.

It is necessary, therefore, to ensure complete emptying before refilling. In systems requiring a constant supply of wet grain to a dryer it is necessary to have at least two wet silos which can be alternatively used after completely emptying.

The use of two wet silos also allows more time for the wet grain to remain under aeration and this can also be an advantage. Whilst the wet grain remains under aeration it not only keeps better, it also evens out in its moisture content. Grain coming off a paddock is more than likely uneven in moisture content.

There is a major trap for those operators who think aeration cooling can be used for drying in all conditions. It may work in a drought, but don't try it when you really need a dryer in bad weather conditions. With the use of modern controllers and increased air flow rates, aeration drying is achievable but only with good management and the right weather conditions.

Points to consider in selecting a dryer

1. The quantity of grain to be dried. A good rule of thumb here is to estimate the best possible crop you would expect and then assume that you will need to dry at least half of it.

This will give a machine size, which will, in a normal year, dry at an acceptable rate, and in a bad year, dry the whole crop in a reasonable time.
NOTE: It is usual to think that it is necessary to get a dryer that will dry at the same rate as the harvesting rate. This approach is usually completely unrealistic and leads to buying a dryer far too large. Good for the salesman, but severe on your pocket!

2. Think of harvesting and drying as independent jobs. Keeping the header going is of paramount importance and a dryer should not prevent the harvest from progressing.

3. A silo/silos for interim storage of wet grain is/are usually a good purchase decision in that it will allow the harvest to proceed and at the same time allow a dryer to catch up with the harvest rate.

4. Dryers can be worked day and night, 24 hours per day if needed, but a header is usually limited by paddock conditions to something less than 24 hours per day.

5. Also remember, if you want to take advantage of all the benefits of early harvesting, no matter how big and efficient the header, it cannot be used unless a dryer of some kind is available.

"Remember - no matter how many or how big the header, you cannot harvest early without a dryer!"

6. A smaller header combined with a dryer can give better harvest management than a large header (or multiple headers) in that the smaller header can be operated both earlier and for more hours thus achieving a better result.

"Keep in mind that silos are cheaper than dryers and dryers are cheaper than headers."

Types of equipment

Equipment to manage over moisture grain can be divided into 5 general types. These are :-

Type	Description	Performance	Drying Times (typical)
1	Continuous flow dryers	Predictable all weather performance Low labour input	1 hour
2	Batch dryers	Many types versatile and predictable all weather performance	3 hours
3	In storage dryer (added heat)	Lower capital cost Variable performance High level of operator expertise required	Several days
4	Aeration dryer (no added heat)	Depends on ambient conditions	Days or weeks
5	Aeration cooling	Optimises coolness in stored grain Any drying or wetting effects incidental	Not intended as dryer

Type 1 and 2

Figure 1

Continuous machines (Figure 1) work by drying wet grain whilst it is flowing through in a continuous manner, whereas a batch machine dries a fixed quantity at a time.

In most currently available machines the drying "process" within these two types of dryers is exactly the same. They use a drying process where warm "conditioned air" is passed through the grain while it is held in, or is passing through the machine.

Provided they come from reliable and well known suppliers, either type can be efficient and dry grain well. As far as drying the grain is concerned, both types are perfectly satisfactory when used in the right situation. One type or the other should be selected on a number of operational considerations and not on "type" alone.

Inherently, batch machines can be made more fuel efficient. However, that is not to say that, when properly applied, continuous machines are not fuel efficient enough to justify their use.

There are several important differences in the installation, use and operation of the two types that affect the situation in which they are best used.

If, for example, an easily portable unit is required, the portable batch machine, which requires little setting up, may be best. If a fixed location and large quantity of the same type of grain is to be dried, a continuous machine may well be the better choice. In other words, it is the situation in which they are to be used which should lead to the selection decision, not merely the type.

In the final analysis, the type of dryer to be used will depend on your individual situation. Seek expert advice and consider the points mentioned above.

Portable vs stationary (fixed) dryers

Having explained why dryers are popular and how to decide which type (continuous/batch) may best suit your situation, it is necessary to now consider whether your selected type (continuous/batch) should be a portable or stationary machine.

Like most machinery, there is an ideal place for each variation of type, but in most cases a compromise must be reached in trying to select the best type for your installation.

Both batch and continuous flow dryers can be purchased in a stationary or mobile (portable) form. The question is - which type would best suit your needs.

Why use portable dryers?

Owning portable farm equipment of any type has many advantages - mainly its versatility and ease of resale. On the other hand, there is always the temporary element in portable equipment, and repairs and maintenance can be high. However, the versatility of these machines usually far outweighs any extra maintenance costs. Portable stand-alone machines are ideal where a farmer has several properties or little or no storage or handling facilities. Contractors also put these machines to good use.

Portability means being able to dry grain anywhere with little or no setting-up procedure needed. Many portable dryers are used solely in the paddock with the only other machinery being the header and truck used at harvest-time. A well-designed, portable dryer can be added to your equipment as a single purchase item, and be used immediately with no additional equipment.

Why use stationary dryers?

Stationary dryers are best utilised as a component of a well established and well designed grain storage and handling complex of silos and conveyors. In this situation, they can be fully or semi-automated and provide a very satisfactory grain management system. However, this does mean that all the grain to be dried must be carted to the dryer site, and in some cases this may be an unjustifiable extra cost burden.

By their very nature, stationary dryers must be associated with "wet" holding silos (which must be aerated), and a handling system which services the dryer's needs without interfering with normal harvest in-loading and out-loading requirements. Simply, this means that it is best to set them up with their own silo and handling system. This applies particularly to continuous flow dryers where it is mandatory to set up a completely separate wet and dry handling loop to maintain a flow of grain to and from the dryer.

Stationary batch dryers only require the handling system at periodic intervals and can sometimes be set up satisfactorily using one grain storage and handling system serving the dryer, and the normal harvest-time storage handling requirements.

Figure 2- a portable batch dryer

A typical continuous flow dryer

In most modern cascade mixed flow dryers, grain is introduced into the top of the dryer from where it moves in a zig zag fashion to the bottom of the dryer. This occurs in columns into which warm air is introduced through ducts by a fan and a heater. The warm air is allowed to pass through the grain as it is moving down the columns. The air picks up moisture on its journey and then is exhausted to the outside of the machine.

The amount of moisture removed is relative to the amount of time the grain remains in the influence of the warm drying air. The speed of a set of valves, or control gates at the bottom of the grain columns, controls the amount of time the grain remains in the dryer. Increasing the speed of these controls reduces the amount of drying and vice versa. Usually this speed control is carried out automatically using a controller. The desired amount of time for the grain to remain in the dryer is by adjusting the speed of these devices.

Below the warm air section there is usually a cooling section that can be separated from the warm air section. This section is supplied with unheated air that passes through the grain in the same manner as the warm air, but it cools the grain before it passes out of the dryer.

Dryer capacity can be increased if no cooling is carried out in the dryer and the "cooling section " is used as an "extension" of the warm air section. Dried grain must always be cooled prior to storage, so in this case, cooling would need to be carried out in a silo or external cooler.

Drying air volume can be adjusted using air intake slides fitted to the sides of the fan. Air temperatures are set using the heater controls.

A typical static batch dryer

A static batch dryer is a very basic dryer in which a quantity of grain is housed on a bin (or special container) and arranged so that drying air is able to be blown through the grain mass. Machines with drying capacities from a few tonne to 60 tonne per batch are available. They are cheap and simple dryers that are reliable and long lasting in their usefulness.

A typical recirculating batch dryer

Recirculating batch dryers are small 10 to 15 tonne machines built for on farm use to carry out high speed drying. They are convenient for portable use because of their size and operate by stirring or turning the grain whilst it is being dried in a batch.

A typical in-storage dryer with added heat

An in-storage dryer with added heat is a grain silo designed for the storage of grains, rather than for the drying of grains. It is fitted with air delivery fans and some sort of air distribution system. Because of the slow drying rates in these types of dryers, it is usually necessary to ensure that an intelligent controller is fitted to manage the fan running times. To be successful in using this type of dryer, it is important to understand the principles involved in the in-store drying process.

There have been many attempts over the last 30 years to dry grain in storage silos in Australia. Typically these attempts have been in the form of a small air fan and heater being used to blow air into the grain mass within the silo.

This approach is based on the general principle that grain will dry if air of lower relative humidity than the equilibrium moisture content (EMC) (refer EMC definition) of the grain is passed through the grain. If the relative humidity is too high the addition of heat will lower the humidity, so that drying can take place. Provided the required drying takes place in a time short enough to prevent grain spoilage, this process can be used effectively. However, in most practical cases where it is necessary to reduce the moisture content in time to sell the grain or ensure it is safe to store, the drying times are too long or too unpredictable to be of any managerial use.

Grain drying should be manageable and predictable so that a predetermined result can be achieved. A system which will only dry when conditions are favourable, is limited in its usefulness. It would be best applied in locations where weather conditions are predictable and conducive to drying and where management does not require a predictable time to dry.

Having grains of higher than normal moisture content usually arises when the weather conditions are unfavourable for in field drying to occur. The air will be above the EMC of the required dry grain. It is unlikely that this same air will be able to be used to successfully dry grain in a silo. Increasing the temperature of this air by heating it will reduce its relative humidity and give it more ability to pick up moisture from the grain. The more it is heated, the more it will dry. However, this action will result in the grain being heated. If grain heating occurs for a few minutes, or maybe a few hours, and it is cooled again, no damage would occur. But if the grain temperatures are kept above the recommended "safe" temperatures of 15 Degrees Celsius, deterioration in quality will occur. The longer the grain is kept heated, the more it will be damaged.

The addition of extra heat in these circumstances can often cause increased moisture content differences in the silo. This is a result of moisture being removed from the layers of grain closest to the air inlet and redeposited at the drying front. Water recondenses in the grain and very wet layers are produced within the grain mass.

These systems also suffer practical management problems in establishing how much the "average" drying has progressed. The larger the grain mass, the more difficult it is to sample and measure the drying conditions.

Aeration drying with no added heat

For in silo grain moisture management there is far safer and satisfactory drying to be had by adopting the new methods available using intelligent control of aeration drying. This method provides for keeping the grain as cool as possible, whilst selecting natural air conditions which will aid drying.

Aeration drying with no added heat relies on the fact that ambient air, which is lower in relative humidity than the equilibrium relative humidity of the grain being dried, is available and is passed through the grain to pick up moisture from it.
If air which is wetter than this is used, the grain will become wetter, not drier. This means that control of this operation is vitally important. It cannot be carried out without controls. It also means that there are some places in Australia where this method of treating grain is not possible. This method may not work because it is weather dependent. Nevertheless, it is a very low cost and effective method of reducing grain moisture contents when the correct conditions exist. The key to success is to have favourable conditions for sufficient time to be able to dry the grain before it has a chance to spoil.

It is important to note that this process usually takes days, not hours. Therefore, the grain is subjected to the conditions in the storage for this amount of time.
(further notes, see drying options below)

Aeration & Drying Options to Manage Over-moisture Grain

- Plan early for managing over-moisture grain at harvest.
- Managing large volumes of over-moisture grain during a wet harvest needs high capacity purpose-designed drying and aeration equipment.

- Controlled aeration drying systems (natural and heated air designs) suit smaller batches of grain at marginal over-moisture levels. Drying rates and risk of spoilage vary widely depending on weather conditions.
- Starting the harvest early, then aerating and drying over-moisture grain, is a sound risk management strategy in any season.
- Automatic controllers improve the reliability of aeration-cooling and aeration-drying.

Grain growers regularly lose profits by using unsuitable systems to handle over-moisture grain at harvest. Minimizing the risk of losses at harvest depends on having access to purpose-designed aeration and drying equipment and an understanding of how to operate it correctly.

Managing a wet harvest successfully means handling large volumes of wet grain quickly without quality loss. High capacity drying and aeration equipment is essential.

Harvesting early at marginal moisture levels, and then aerating and possibly drying the grain is a risk management strategy available to growers every season. Benefits include reduced risk of field losses and improved quality of harvested grains.

Over-moisture Grain Management Options

Early-Harvest: Grain growers who start their harvest early at higher moistures have a large degree of control over grain losses. Many growers adopt this approach every season to broaden the harvest window and reduce the risk of field loss. Most operators harvest part of the crop at higher moistures and then use purpose-designed aeration systems to manage it. Others use grain dryers and aerated storage to allow management of much higher moisture contents. The combined aeration/dryer approach to early harvesting delivers a higher level of risk management.

In a wet harvest the weather takes control of most decisions. Well-planned aeration and drying systems allow much greater flexibility during wet seasons than harvest systems that depend on field drying alone.

Harvest moisture management systems may include one or more of the following types of equipment:

1. Continuous Flow Dryers
2. Batch Dryers (Stationary & Portable)
3. In-storage Heated Air Dryers
4. In-storage Aeration Drying (no added heat)
5. In-storage Aeration Cooling and Moisture Management

Removing moisture using purpose-built continuous dryers and batch dryers is both predictable and measurable. They typically use high airflows and heat inputs (combined with controlled temperatures and direct grain sampling) to deliver medium to high throughputs of grain, even under adverse weather conditions.

Drying with in-storage and aeration-drying methods is a much less predictable system. Care is needed to avoid quality loss caused by holding grain for extended periods at high temperatures and moistures. The danger of grain damage under adverse weather conditions is much higher than in higher performance continuous dryers and batch dryers.

Continuous Flow Dryers

These dryers deliver predictable performance and dry all grain types (in all weather conditions) from any moisture content. Efficient handling equipment, before and after the dryer, is necessary in order to gain greatest benefit. Continuous flow dryers need minimal supervision and produce an evenly dried result. Economies of scale mean that they are best suited to high throughput applications.

Batch Dryers

Batch dryers dry a single batch of grain completely, before unloading and starting a new batch. They may be fixed or portable and generally need more supervision than continuous flow machines. Some in-field models need no extra handling or storage equipment for operation …they are filled directly from a header and have their own high capacity out-loading conveyor. Batch machines are well suited to handling smaller quantities of harvested grain, especially where segregation is needed.

In-storage Heated Air Dryers

Most in-storage heated air dryers use high flow aeration fans and small heaters fitted to standard storage silos. Heating the air allows it to remove moisture from grain faster than if it were unheated.

In-storage drying uses much lower airflows (10 to 20 litres per second per tonne) than higher speed dryers. Performance varies widely depending on location and seasonal conditions.

In-store drying must be used with caution in regions where weather conditions are unpredictable. If drying ‘stalls’ during wet weather, the hot, moist grain may spoil rapidly. Unsuitable equipment and operating methods result in major losses each year in Australia.

Aeration-Drying Systems (no added heat)

Aeration drying (for removing moisture) needs much higher airflow than aeration cooling (for protecting grain quality). Moisture removal rates are slow (days to weeks) and depend on availability of suitable drying air for extended periods. Aeration drying is most reliable when managing small batches of marginal-moisture grain as part of an early-harvest strategy.
The performance of aeration drying is unpredictable in a wet harvest and must be monitored carefully to avoid grain damage.

Controlled Aeration-Cooling

Aeration-cooling systems reduce the grain bulk to a lower temperature than average air temperature. The primary purpose is not the drying of the grain mass out, but to create cool, even conditions throughout the mass.
Automatic controllers optimise the cooling effect and ensure high level protection against grain quality loss caused by moulds, insects and heat. Aeration cooling controllers must not be confused with aeration drying controllers … Each is specially designed to deliver different benefits.
Aerated storage allows over-moisture grain to be held safely for longer periods before drying. Hot, over-moisture grain can be delivered from a high speed dryer to high airflow aerated storages for final cooling and moisture removal. This increases dryer throughput.
Controlled aeration cooling may result in a drop in measured moisture levels in stored grain, over an extended period of time, but the result is difficult to predict. Controllers with in-built relative humidity (RH) limit control may enhance this limited drying effect available under aeration cooling.

Planning your Strategy:

Planning and implementing a strategy to manage over-moisture grain at harvest is a multi-step process. A typical plan is:

- Review your previous harvests to identify areas where profits were lost.
- Source information on ways to avoid these losses in future and then prepare a strategy that suits your operation. Your decisions will depend in part on the level of losses you are willing to risk.
- Identify the storage, handling, aeration and drying equipment needed to carry out your plan and install it well before harvest. Talk with companies that have broad-based Australian experience. Strategies and equipment from other countries may not suit Australian conditions.
- Once harvest starts, monitor weather conditions regularly. Change your aeration and drying methods as needed to suit the conditions. In

some cases this may mean switching from drying to short-term aeration cooling of high-moisture grain.

Summary

Plan early for managing over-moisture grain at harvest.
Managing large volumes of over-moisture grain during a wet harvest needs high capacity purpose-designed drying and aeration equipment.
Controlled aeration drying systems (natural and heated air designs) suit smaller batches of grain at marginal over-moisture levels. Drying rates and risk of spoilage vary widely depending on weather conditions.
Starting the harvest early and then aerating and drying over-moisture grain is a sound risk management strategy in any season.
Automatic controllers improve the reliability of aeration cooling and aeration-drying.

………………………………..

Comparison Table of Management Equipment for Over-moisture Grain

Specifications and costs are TYPICAL ONLY. Individual applications may vary from the examples given.

Type	Equipment	Typical Grain Depth (mm)	Typical Air Flow (l/s/t)[1]	Typical Fan Power kW (hp)	Typical Throughput (Initial grain moisture & weather affect drying rates)	Typical Upper Moisture Limit	Typical Capital Cost (AUD$)	Typical Running Cost ($/tonne)[2]	Comments
1	Continuous Flow Dryer (High Air flows & Heat Input)	150 – 200 (shallow bed)	750	22 kW+ (30 hp +)	Rapid & Predictable (15 - 20 t/hr; 300 - 500 t/day typical)	20%+	$70,000	$5.00 per tonne	Allows flexible scheduling of harvest deliveries. Allows wet harvests to continue. Predictable Performance.
2	Batch Dryer	400 (shallow bed)	450	11 kW + (15 hp +)	Fast & Predictable (3 - 4 t/hr; 40 to 60 t/day typical)	20%+	$30,000	$5.00 per tonne	Similar benefits to Continuous Flow Dryers but slower throughput. Predictable Performance.
3	In-storage Dryer (with added heat)	4000 (deep bed)	15	7.5 kW (10.0 hp)	Slow (days) Relatively unpredictable (10 - 20 t/day typical)	15%	$20,000 for 75 tonne (including silo)	$2.00 per tonne	Lower cost slower and higher risk than Type 1 /2 Performance difficult to predict.

									High operator expertise.
4	Aeration Drying System (without added heat)	6000 (deep bed)	15	1.5 kW (2.0 hp)	Slow (weeks) Highly unpredictable (10 to 20 t/day typical)	14%	$3,000 for 75 tonne inc. Controller	Less than $1.00 per tonne	Low capital cost. May remove marginal moisture from small batches over long periods. Performance varies widely and depends heavily on weather & operator experience.
5	Aeration Cooling System (with Controller)	6000 (deep bed)	2	0.4 kW (0.5 hp)	Designed for protecting grain quality, not drying. Possible removal of marginal moisture over extended storage period.	14%	$2000 for 100 t	Less than $0.50 per tonne	Extends safe storage time of over-moisture grain. Protects grain quality during long-term storage.

[1] litres per second per tonne of grain
[2] Costs are approximate only and will vary depending on your buying price for different fuels

Operating a Dryer

Times/rates

Drying rate depends on many things some of which are:-
Drying air temperature
Amount of grain
Amount of moisture to be removed
Ambient conditions
Air flow available
Quality of grain
Condition of grain
Type of grain

In general, the drier the air being used the faster the drying proceeds for any given system.
In dryers the drying times vary from minutes to a few hours.
For aeration drying systems, the times are typically days and weeks, not hours.
High speed fluidised bed dryers can remove moisture in a few seconds, but they cost more and they are usually only used to take off the initial end high moisture from grains.

Drying rate in seeds and grains depends on a number of factors associated with the seed - seed type, its moisture content at the time of drying, the growth history of the seed, previous drying and wetting cycles and also factors related to the dryer (such as the air flow, temperature and humidity of the drying air).

Most seeds will dry at some constant rate when relatively wet and then dry at a continually diminishing or falling rate until equilibrium is reached with the drying air.
These factors are controlled by the nature of the seed, not the dryer performance.

Effect of weather

Ambient weather has a marked affect on the drying rate because drying occurs as a result of the difference in the air moisture and the grain moisture at any one time. For a given dryer, drying speeds can vary due to ambient weather conditions. It is not unusual for some dryers to dry three times faster in good conditions than what they would in poor conditions.

Drying in the rain

All modern dryers will dry in all weather conditions. In wet weather they will dry slower than what they would in dry weather.
Aeration drying, on the other hand, needs to be accurately controlled and probably needs to be turned off during adverse weather conditions. Automatic controllers should be used.

Drying in hot weather

In hot weather, some dryers could possibly dry three times faster than what they would in adverse conditions, other factors being equal.
Aeration drying in storages may cause overheating, leading to grain damage.

Why is the grain wetter after drying in a batch dryer?

In static batch dryers, in which the grain is stationary whilst drying, the grain may end up wetter. This is because the drying front moves from the inside of the dryer to the outside, pushing in front of the moisture from the dried grain. Sampling the grain from the outer part of the dryer will at times indicate a spot moisture content higher than the initial moisture content. With batch drying, as with all drying, the dry average is what is important.

Grain Quality maintenance

Grains and seeds are living biological materials and many conditions can affect their quality. Some of these conditions are: growing conditions, timing and system of harvest and post harvest treatment (including drying, storage conditions, transportation practices).

Some properties affecting grain and seed quality are:-

Moisture content*
Test weight*
Foreign material
Discoloured, broken, heat damaged or shrunken grains*
Susceptibility to breakage*
Milling characteristics*
Oil content*
Protein content*
Nutritive value*

Viability*
Vigour*
Mould count*
Carcinogen content
Insect damage
(*Quality factors which can be affected by heated air drying).

Buyers' interests differ as to the importance of these characteristics. For example, a grower would be interested in seed viability whilst a feed miller may only be interested in the protein content of a particular grain.

It is often forgotten, when discussing storage transport and drying of seeds and grains, that they are usually living seeds. These seeds respire, resulting in the release of gases, heat and moisture, whilst consuming some of the dry matter they comprise. This important factor cannot be overlooked when considering the design, operation and management of dryers. Conditions within a grain mass are not static and can change rapidly given certain conditions.

In storage, and in dryers, seeds and grains typically occupy about 60% of the available space and the remaining 40% is the space around each grain or seed. This space is usually occupied by air. In a dryer, the air is being continually replaced by the drying air. By replacing this air with air below the EMC humidity, an exchange of moisture from the grain to the air occurs.

Temperatures

One of the greatest benefits of using a dryer is to produce a high quality product and this must be kept in mind when answering questions about temperature.

A drying temperature is selected to not only maximise the effectiveness of the dryer, but to also produce the best quality for the market into which the grain is to be sold. The selected temperature is a compromise between a high temperature (which will give the highest drying capacity for the machine) and a lower temperature (which will give the highest quality).

To produce a quality product does not necessarily mean that the lowest temperature possible should be used. If the drying proceeds at a very low speed the grain being dried may spoil before it has a chance to dry. This can and does often happen when drying over long periods of time with in-storage bin drying.

Always check with the dryer manufacturer for a recommendation.

Batch dryers
Some guide lines for static batch dryers are:-

Grain use or type	Maximum drying air temperature degrees C
Feed	65
Food for human consumption	55
Seeds for planting	43

Continuous mixed flow dryers
Dryers which move the grain whilst drying is proceeding can use much higher temperatures. Some guide lines are given below for modern ducted mixed flow dryers like our AR series.

Note: In reading the information in the table below, the temperature given for the drying air temperature is that of the air which is entering the grain. The grain temperature limit is the temperature that the grain will reach. The grain temperature limit is difficult to measure. The nearest practical measurement is to measure either the temperature of air leaving the grain (exhaust air) or the temperature just inside the grain mass (at the exhaust side at the bottom/hottest part of the dryer).

NB: Always check with the dryer manufacturer for a recommendation before proceeding to set your operating temperatures.

Continuous mixed flow dryers:

Crop	Maximum drying air temperature degrees C	Grain temperature limit degrees C
Feed grains -generally Maize - corn	110	60
Sorghum Oil seeds Rape - canola Sunflower Linseed Safflower Beans	85	50
Food grains - generally	70	45
Seeds for planting Malting	65	45

Costs

Costs can be divided into two parts. Firstly the running cost which comprises the fuel or energy cost plus labour and maintenance costs. And secondly the cost of owning the dryer. For convenience this is usually expressed as a cost per tonne. Because fuel prices are constantly changing, it is impossible to give accurate costings. You can utilize the following methods, by using your own expences, to arrive at a reliable drying cost.

Method A:-

For example: For drying 20 tonnes per hour of good quality wheat from 15% to 12% in average conditions-
Fuel cost for heating:
1. Fuel used by heater (3000 MJ/h (25.4MJ/l)) LPG is 118 litres @ $x.xx/l
2. Divide this result by the number of tonnes (in this case 20) to give the cost per tonne. ie. $x.xx/20 = $y.yy/t
3. Fuel used by fan drives: Here you need to know the cost of electricity per kWh. Assuming you are drying 20 t per hour (3% moisture reduction) the cost per tonne is 22kWh @ $x.xx/20 = $y.yy/t

Labour one man for supervision ¼ time (This person will generally be carrying out other tasks around the grain handling/storage complex at the time the dryer is running).

Capital cost of dryer. (The cost of purchase and installation).
Maintenance - taken at 2% x capital cost.

By applying similar calculations to other dryer operations a cost can be estimated.

Method B

Another very quick and rough method is to estimate the fuel used on the basis of an average of 150MJ/tonne dried from 15% to 12%. For LPG, having a fuel heating value of about 25MJ/l, the fuel used would be estimated at 150/25 or 6 litres per tonne dried. For diesel, having a heating value of about 38MJ/l, the fuel used would be 150/38 or 3.9 litres.

Fuels comparative prices

Fuel prices vary from time to time and place to place. Therefore, it is necessary to make a comparison before making a decision. Prices should be compared on a cost per unit thermal energy basis (Cents per MJ), not a cost per litre. Refer to Table below.

Heating Value of Fuels					
Fuel	**MJ/kWh**	**MJ/l**	**MJ/m^3**	**MJ/kg**	Characteristics
Diesel		38.4			liquid at no pressure - easy to store and transport
LPG Liquid propane gas		25.4			liquid under pressure - more difficult to store
NG Natural gas			38.8		Usually pipeline delivery
Ethanol		21.2			High cost, poor supply
Fuel oil		40			Good supply, least cost
Coal				20 to 30	Poor supply, limited combustion plant
Wood				16 to 20	Poor supply, limited combustion plant
Electricity	3.6				limited supplies - usually highest cost per unit

Equivalent Fuel Prices

	Equivalent price						**Equivalent price**	
Diesel price cents/l	**LPG price cents/l**	**NG price cents/m^3**	**Elect cents /kWh**		**LPG price cents/l**	**Diesel price cents/l**	**NG price cents/m^3**	**Elect cents/kWh**
50	33	51	4.69		50	76	76	7.09
100	66	101	9.38		100	1.52	1.52	14.18

	Fuel equivalent		
Heat	Diesel	LPG	Elect'y
MJ/h	l/h	l/h	kWh
50	1.3	2.0	14
100	2.6	3.9	28
250	6.5	9.8	69
500	13.0	19.7	139
1,000	26.0	39.4	278
2,000	52.1	78.7	556

Fuel type comparison

There is no ‘best fuel’ because all sources of energy may be used in dryers and they can all be as equally effective in the drying process. However, availability, cost, and maintenance are the usual determinants a final selection of fuel type.

In general, liquid fuels (like diesel) or heating oils are readily available and are therefore cheaper to install, but they do have higher maintenance requirements than gases.

Gases, such as LPG, have a higher cost of installation. This is because of the need for a special pressure vessel (tank) and on site protection, as well as more stringent safety requirements. However, gas burning heaters have a much lower maintenance requirement over time. The increasing availability of Natural piped gases (NG) will make the use of NG much more attractive in the future, because it has no need for costly on site storage vessels.

Both LPG and NG are now used extensively in grain drying in Australia.

With good maintenance, both fuels can be made to combust well and both have been used for many years in direct fired grain dryers. In recent times, purchasers of grain destined for human consumption in Europe have asked for gas to be used in direct fired dryers in preference to diesel or heating oils.

Both gas and oils of any kind are hydrocarbons and they form similar products of combustion when burnt. Oils are more difficult than gas to burn cleanly. Therefore, they require the combustion system to be well maintained at all times, whereas gas burners are relatively easy to maintain.

The future will probably demand that all drying for human consumption products be done by indirect fired equipment. With indirect fired heating, no products of combustion enter the grain regardless of the fuel type. Indirect firing will add an extra 15 to 20 % to running costs because of the losses incurred in the heat exchangers.

Agridry dryers can be fitted with any type of heater system, including indirectly fired heaters.

Microwaves

A question often asked is - “Can microwave energy be used for drying?”

There are two fundamental requirements for drying to take place (see FAQ How does drying occur?). One is energy to replace the energy absorbed by moisture evaporation and the other is air movement. Microwave generators (magnetrons) can be used to supply the evaporative energy needed. They are very good in penetrating into grains and seeds, thereby increasing their internal temperature. This allows the moisture to be more easily transported to the drying surface where it can be removed by the drying air. Microwaves can be and are used in this way. However, for grain drying on the scale needed for farm and commercial dryers, the magnetron sizes needed are not available. Even if they were there would be a major limitation in their adoption in locations where electrical supply is limited. Even a farm sized dryer would need about a (1 GJ/h) 300 kW supply whilst a commercial unit may require over (5 GJ/h) 1500 kW. This size of electrical supply is large by most standards. Furthermore, the cost of both the installation (wiring) and operation may be prohibitive.

Corn

Cracking of corn kernels is a problem when buyers are wanting to use the corn for “gritting”. Buyers of corn are usually very particular in specifying that corn should not be cracked.

Cracking is a result of the kernel coming under temperature stress. Stress occurs when temperatures change rapidly, either up or down. It is the change in temperature in a short space of time that causes the major problems. In dryers it is, therefore, most important to control, as far as is possible, the changes in temperature. A change in temperature occurs when the grain first meets the warm drying air, and again when the grain passes into the cooling section where the warm grain meets much colder air.

There are some methods of reducing the rapidity of temperature changes. One is to use a pre heat layer in the top of the dryer which allows a small amount of initial heating to take place. Another is to use either a small amount of cooling in the dryer (or none at all), in which case the cooling is carried out in an aerated silo.

In general, a cascade type dryer, where a lot of gentle mixing takes place during drying, is the best type to use. Dryers which handle the corn in a physically rough manner, particularly during the drying process should be avoided.

Corn in batch dryers

When using batching dryers, it is best to follow the same basic rules of heating and cooling the corn slowly. This may mean manually controlling the air temperature so that it is progressively increased over a period of time. When cooling is required, it may be best to use a separate aerated cooling bin which will take a longer time to cool the corn and lower the temperature gently. Merely turning off the heater and allowing the fan to continue to run to cool the grain can be very stressful on the corn when the ambient air is cold. If an aerated cooling bin is not available, when the ambient air is cold, it would be best to either run the fan at a much reduced speed (in the case of a PTO driven machine) or to run the fan for a short time and then turn it off. This will allow the corn to “equilibrate” before again turning the fan on, and so on, once again allowing a longer, gentler cooling to take place.

Sunflower

Sunflowers dry easily compared to many other grains and they can be dried safely if a few precautions are taken.

Drying air temperature must be kept below 60 C at all times because at 60 C or about 65 C sunflowers give off a gas which can spontaneously catch fire. If they do catch fire, sunflowers burn rapidly because they are full of oil and air passes through them easily.

Keep the grain dryer clean and free of all trash and ensure that the combustion system is in good condition. Never leave the dryer unattended.

Extra caution is required when drying sunflowers, but they are easy to dry and can be successfully dried. (Always refer to the dryer manufacturers instructions and advice).

Malting Barley

Malting Barley should be treated as if it were a seed for planting since it needs to germinate prior to malting.

Seeds for planting should always be dried for maximum quality because seeds harvested as early as possible after physiological maturity have the best chance of maintaining a high germination. Almost all seed companies in the world harvest early and dry to storage moisture for the purpose of maintaining a high quality germinable seed. To dry seeds for planting, moisture extraction rates and the time-temperature combinations must be kept within strict limits.

Ensure you seek the advice of the dryer manufacturer on the dryer settings for seeds and malting barley. In general, it is no more difficult to dry Malting Barley than it is to dry any other grain when the germination factor is considered.

Fear of drying

There is a conception that grain dryers damage grain. The argument goes, “Dryers have heaters and heat damages grains and seeds, ruins germination and ends up “cooking” the grain-therefore, don’t use a dryer if you want quality grain and seed”. This leads to a “fear of drying”! Why dry if you can avoid it, as drying will damage the grain and the process is expensive and risky? Studies have shown (Abawi QDPI) that early harvesting of grain crops prevents field losses and allows the grain to be harvested in better condition, thus giving higher quality. Grain drying is now practiced in many sections of the grain industry, lead by the seed companies (many of whom now harvest early and dry all of their seed crops). Seed companies make money from high quality germinable seed sales. Of all the properties sensitive to damage in grains and seeds, germination is the first to be effected. Farmers, now conscious of the need to produce both quantity and quality grains for the market, are adopting the use of dryers to enable them to deliver grain of the highest quality and reduce field losses by early harvest.
Correctly managed, modern dryers allow seeds and grain to be dried with no damage to the seed and grain quality. In fact, there are many situations which occur during harvest when adverse conditions make using a dryer mandatory, if quality grain and seeds are to be produced.

Drying risks are minimised in modern dryers.
Loss risks in the field usually far-out weigh drying risks.

Fear of moisture

In harvesting, storing, and trading in grain, there is a fear of moisture. This fear is based on the idea that high moisture leads to grain spoilage and eventual loss. Little or no consideration is given to the grain temperature, which is just as important as moisture content. Upper limits have been established by traders in the hope that they will receive grain which can be stored safely. In fact, grains of commercially “dry” condition typically have large amounts of moisture in them. For example, grain with 12% moisture would have 12,000 litres of water within a 100 tonne bulk!
Safe grain storage depends on moisture, as well as temperature.

When can grain be harvested?

As soon as it can be harvested!

How wet can the grain be dried?

If it can be harvested, it can be dried.

When is grain ripe?

Most growers start harvesting when the crop is 'ripe'. By 'ripe' they mean that the crop is thrashable and it is dry enough to sell or store. This is typically around 12 - 13% moisture for most grain crops. Ripe is a vague term which is often used in a misleading fashion. Grain maturity, thrashable, storeable and saleable are better terms to use in describing the condition of grains.

Is the grain mature?

Most grain crops reach full maturity when the grain moisture is still high - typically around 30%. At this stage the grain has reached its maximum weight and has developed to its full potential. It cannot improve and can only deteriorate from this point in its life cycle.

The difference between this stage and that at which it can be sold or stored safely, is the amount of moisture in each kernel. Unfortunately, when seeds are allowed to dry in the field they lose quality as well as water and, the longer they remain in the paddock, the higher the risk of losses from weathering, shedding, lodging and disease.

Air moisture - psychometrics

The atmosphere around us is a mixture of gases and water vapour. The amount of water vapour it contains varies enormously from time to time and is influenced by temperature and the “weather” conditions at the time. The amount of water in the atmosphere at any time is usually expressed as a percentage (%) of the maximum possible for that condition. The maximum amount possible depends on the temperature and pressure of the air at the time. Typically, 1 cubic metre of air at 25 degrees Celsius can hold a maximum of about 17 g of water at sea level pressure (101.325 kPa). If air had this amount of water it would be said to be saturated and would have a relative humidity of 100%. The water contained at any time varies and for any given condition it is compared with the maximum amount at saturation and is expressed as a percentage. An average day may be around 40 to 60% Relative Humidity (RH) and a “Humid” day, 60 to 80%. Prior to rain the relative humidity reaches 80% to 90% and then 100% when it is raining.

Fire control

Fires can and do occur in dryers, the main cause being fine trash which is allowed to become very dry by letting it lie in the hot air plenums of the dryer. This fine, very dry material easily catches on fire as it is tinder-like. Any small spark or burning fuel which contacts it will ignite a fire.

PREVENTION OF FIRES IN DIRECT FIRED DRYERS -

- Make sure the fan intake is clear of all trash, straw, dry grass, etc.
- The fan intake should face the prevailing wind direction.
- Don't carry out cleaning or grading where trash can enter the fan intake.
- Bulk fuel tanks should be well clear of the dryer (Refer local regulations).
- Never leave your machine unattended.

CEREAL GRAINS

1. Be aware that fires in the dryer can occur.
2. When a fire occurs there will be a lot of smoke.
3. Don't panic!
4. Turn off the fan and the heater.
5. Smoke quantity will immediately decrease.
6. Wait for approximately 15 minutes and then restart the fan momentarily. See whether smoke is still being produced. If there is no smoke,

continue with the drying. If there is smoke, immediately stop the fan and try to ascertain where the seat of the fire is within the dryer.

7. Initially, small fires usually start in dry trash which accumulates within the air plenums. Depending upon the style of dryer, open up the access to the plenum and see if you can establish where the fire is. If it is a small smouldering fire it can be simply doused with a small amount of water, and then drying can be resumed.

8. If the fire is well established and burning into the actual grain being dried (which may be the case if the dryer has been unattended for some time before the fire was noticed), there is usually only one course of action – immediately unload the grain from the bin as shown below.

9. Unload the bin as fast as possible into a heap on the ground.
10. Do not put it into another bin or silo.
11. Do not get into the bin while attempting to put out the fire.
12. Deal with the burning portion when it comes out of the dryer. It will usually only be a small amount.

OIL SEEDS

1. Sunflower makes a good fuel. It burns easily.

2. Keep a close watch on the dryer all the time.

3. Never use temperatures in excess of 60^{o}C (140^{o}F).

4. In hot dry conditions oilseeds can catch fire spontaneously. No spark is necessary.

5. If a fire occurs, turn the fan and the heater off.

6. Usually it is necessary to unload the dryer as fast as possible into a heap on the ground. For a small fire, action as per instruction 6 above, may be successful. But note that fires in oilseeds proceed at a much, much higher rate than fires in cereal grains. Therefore, the time for an uncontrollable fire to establish in oilseeds is much less than what it would be in cereal grains.

7. Be careful when emptying a dryer which has been on fire. The fire sometimes flares up as soon as the top of the plenum chamber is uncovered.

Records

There are many factors which will affect the drying rate as drying proceeds. Therefore, records are essential to managing a dryer.
Understand that ambient conditions affect performance. Keep a constant check on ambient RH and temperature to ascertain drying rates.
Use accurate moisture measurement equipment.

Keep records. A suggested dryer operational record sheet is shown below.

Date	Time	Ambient condition	Drying air temp	Initial Grain condition % mc	Final Grain condition % mc	Comments

Conditions at the start of the process should be recorded and then records should be made progressively throughout the drying process.

Maintenance

The first most important task is to keep the machine clean of trash and grain build - up in all warm air plenum spaces. This should be a daily task and should not be neglected at any time. A clean dryer is safer and dries more efficiently than a machine that is full of fines and built - up trash.

The heater system should be kept in top order because with oil and gas burning systems good maintenance provides reliability, safety and efficiency. Poor combustion is not only a hazard. It costs more money to run an inefficient burner. With direct fired dryers, poor combustion can also lead to grain contamination.

It should be noted that for gas and oil burners, it is usually best to employ experts to service and maintain the equipment. This is because of the serious safety and costly consequences of getting it wrong!

Storing the dryer ready for the next season

There are some important things to do before leaving your dryer idle for any length of time.

1. Clean it! Make sure the dryer is cleaned of all grain and seeds as well as all the trash and fine build - up which occurs inside and outside the dryer.
Using a jet of water is OK for most cleaning jobs and in most dryers. The water will drain away from the machine and dry out satisfactorily. When using water, be careful not to force water into the electrical components or into the holes of the gas burner. Make sure the water has not accumulated somewhere instead of draining away. Dry off by using compressed air and then allow the dryer to remain open to the air until completely dried.

Cleaning the dryer achieves two important things. It keeps corrosion to a minimum and it keeps insects, mice and rats from being attracted to the machine. It is much better to keep the dryer clean than to use large amounts of insecticide in the hope of keeping insects away.
Open any clean - out doors and slides and leave them open. It is best to allow a free flow of air throughout the whole machine.
Close any openings likely to attract birds. Leave lids and covers in place to protect the dryer from the weather.

2. Check mechanicals
Dryers are usually fairly simple mechanically and only require bearings and belt/chain drives to be maintained. Grease the bearings and chains, and adjust all belts and chain drives.

3. Check and clean electrics
Open and clean out all control boxes. Make sure there are no water leaks into these boxes and ensure that any mouse access holes are effectively plugged. Close up all electrical boxes after making sure they are dry inside.

4. Clean Gas and burner equipment
Clean all areas around the burner (some packaged type burners can be easily removed from the dryer for safe storage away from weather and rodents). Brush off all build - up from electrodes and fuel holes in the burner. If burner holes look corroded or blocked, remove burner and clean out the burner holes and inside pipes.
Check the condition of all gas train valves, gas hoses, and fittings and controls. Check for leaks and noises, check electrical cables and safety shut down equipment.

It is recommended that a suitably qualified person carries out this work.

5. Clean and check all instruments (thermometers, air pressure switches, etc).
Major damage is caused each year by rodents and insects getting into electrical wiring and combustion system controls.

6 Check electrical mains and gas supply.

Instruments

To Measure Atmospheric RH

Wet and Dry bulb thermometer – This is the simplest instrument for measuring RH of the atmosphere.
NOTE: Humidity sensors and humidistats used in controlled atmosphere application (such as cool storages and air conditioning) are usually not recommended for grain storage/drying aeration measurements and control. These perform badly in atmospheres containing grain dust.

To Measure Grain Moisture

Grain moisture meter – There are several available of generally two types: Ground sample and Whole grain sample.

To Measure Temperatures

Thermometers – There are many types available-
Mercury in glass, alcohol in glass, bimetallic, capillary, and electronic.

To Measure Air Pressures

Water gauge manometers can be made up from plastic tubing.
Dial Gauges (bourden tube).
Electronic gauges (piezoelectric).

To Obtain Grain Sample

Sampling Spears - Manual and automatic.
Special Devices fitted to storages.
Grain Conveyors, both manual and automatic.

To Measure Insect Numbers

Insect Traps.

To Measure Protein and Moisture Content

There are a number of Near Infra Red (NIR) protein analysers, a few of which are priced for the farm market. These will change repeatedly as new instruments are being released regularly.

Sampling

Grain sampling is fraught with difficulties because of its non homogeneous nature. The variation in most grain bulks is great, particularly in freshly harvested grains. This makes finding a typical representative sample a challenge..

Dryer supervision

Fully automatic dryers are available. It is suggested that they never be left unattended, as there is always a possibility that a dryer may catch fire.

Products of combustion

In warm air dryers, there are many ways to heat drying air. The simplest is to use a heater which uses a fuel like oil or gas. The fuel burns it and allows the heat and products of combustion to mix with the drying air and the grain being dried. This is described as a direct fired system.
Indirect fired systems use heat exchangers whereby the products of combustion are kept separate from the air mixing with the grain. Indirect systems use more fuel, typically 15% to 20% more, and of course cost more to build as they are more complex.

Swathing

Swathing is carried out usually to accelerate the field drying process to allow an earlier harvest. Cutting the crop early and leaving it lying in the field in Australia can lead to losses. Weathering and shattering losses cannot be prevented if poor weather conditions persist. Preservation of quality requires: early removal of the grain from the field, drying as necessary, and then aerated storage.

Aeration

Aeration cooling - definition

Aeration involves passing selected cool ambient air through a grain mass so as to reduce and maintain a reduced even - bulk temperature.

Aeration maintenance - definition

Aeration maintenance requires passing selected ambient air through a grain mass so as to maintain an even - bulk temperature and moisture content.

Aeration drying - definition

Aeration drying is the passing of selected drying ambient air through a grain mass so as to reduce and even - out its average moisture content.

Aeration drying

When aeration drying is used in storages, a drying front is established in the grain mass. This front is an emerging line at which drying is occurring because the air being supplied by the controller has a Relative Humidity (RH) less than the Equilibrium Relative Humidity (ERH). As this air picks up the grain moisture (drying is occurring) it becomes wetter or has a high RH beyond the drying front. If the RH in this area is greater than ERH, grain wetting will occur.

Typically, this air will become saturated and “free” water is available to condense on any surfaces at the same or lower temperature. This effect will be easily seen in the head space of a silo (if airflow from bottom to top is used) as water will condense on the roof surfaces.

This condition should be carefully monitored to make sure it does not continue to the point where grain is damaged.

If suitable air conditions exist, the drying front will progressively pass through the grain mass to finally emerge at the surface.

Suitable conditions for Aeration drying

When there is sufficient difference between the ambient RH and the ERH, drying of the whole grain mass will occur in a short enough time to ensure that space that spoilage does not occur. If there is too small a difference, drying will occur too slowly.

Control of aeration drying

As with all modes of aeration, for aeration drying to be successful, there needs to be careful control.

Any controller needs to make sure that the drying air being forced into the grain is of a suitable condition. There are two ways this can be done:-

1. Manually - Check the grain moisture and the temperature; look up the ERH at that temperature; measure the RH and the temperature; and make a decision whether or not to run the dryer.

2. Use an auto aeration drying controller to carry out 1 above.

Option 1 is the extreme opposite of option 2 in that 1 is completely "manual" and 2 is "fully" automatic.

3. Manually check the grain moisture content and the temperature; look up the ERH at that temperature and set RH temperature controller to operate the fans at some level below the ERH.

- (Automatic controllers aeration only, are available from Agridry - see suppliers list)

What problems can occur with aeration drying?

1. If drying does not proceed quickly enough, spoilage occurs.

2 Poor control allows the grain to dry and rewet causing temperature increases and uneven temperatures in the grain. This results in spoilage of the grain.

3. Grain over - dries and financial loss occurs due to reduced weight.

4. Grain dries too fast causing cracking and splitting. This is rare but can occur in crops like Peanuts when there are severely dry ambient conditions.

5. Grain moisture increases due to poor control causing grain swelling and catastrophic silo failures.

6. Aeration drying cannot accurately estimate current moisture content of the grain in storage. Therefore, it cannot make an RH control point decision.

7. Aeration drying cannot accurately estimate the progress of the drying process.

Measuring grain moisture

From a scientific point of view there is probably only one way to measure moisture content and that is to carry out a controlled oven - drying type test. This is an industry standard for the commodity.

In practice, a moisture meter of some kind is usually used and there are many of these in use. One that suits the operator the buyer and the seller of the product is the most practical instrument to choose.

Convenience of use and agreement between all parties are the most important considerations when choosing an instrument.

Types of instruments currently available

Model	Type	Supplier
Protimeter	Ground grain resistive	Agridry
HE50	Ground grain resistive	Agridry
Dickey John	Capacitive whole grain	Agridry
Kett	Ground grain resistive	
Sinar	Whole grain	Agridry

Measuring air moisture

Air moisture is most easily accurately measured by using a wet and dry thermometer. On – the - wall type weather instruments that use mechanical elements which stretch and shrink, depending on air moisture, are usually useless for this purpose as they are too inaccurate.

Rebound

Rebound is when freshly dried grain seems to increase in moisture content after being left to equilibrate in a bin. This is really a measuring inaccuracy caused by the grain being in a warm drying state and of uneven moisture content throughout the grain. In estimating the final moisture content of grain coming from a dryer, this effect should be taken into account.

Weight loss due to drying

During drying weight is lost. This is a loss of water, not of dry matter (grain), and can be calculated. You can estimate this water loss by using the table below.

	Wet %														
Dry %	12.0	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
9.0	33.0	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
9.2	30.8	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
9.4	28.7	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
9.6	26.5	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
9.8	24.4	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
10.0	22.2	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
10.2	20.0	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
10.4	17.9	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
10.6	15.7	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
10.8	13.5	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
11.0	11.2	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
11.2	9.0	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
11.4	6.8	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
11.6	4.5	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
11.8	2.3	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
12.0	0.0	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
12.2		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
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
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
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
13.0					0.0	2.3	4.6	6.9	9.2	11.5	13.8	16.1	18.4	20.7	23.0
13.2						0.0	2.3	4.6	6.9	9.2	11.5	13.8	16.1	18.4	20.7
13.4							0.0	2.3	4.6	6.9	9.2	11.5	13.9	16.2	18.5
13.6								0.0	2.3	4.6	6.9	9.3	11.6	13.9	16.2
13.8									0.0	2.3	4.6	7.0	9.3	11.6	13.9
14.0										0.0	2.3	4.7	7.0	9.3	11.6

Using this table

To find the weight loss due to drying 1 tonne of grain from 15% to 12%:

find 15 at the top of the Wet % column and 12% down the side row. Find the intersection of the column and the row to find an estimated water loss of 34.1%.

1 tonne of grain dried from 15% to 12% will lose 34.1 kg through loss of water.

Equilibrium Moisture Content Typical

Table and charts of ERH are available for most seeds, grains and pluses. Some typical figures are shown below.

Equilibrium Moisture Content

Generalised Table (25-30 degrees C)*

Relative Humidity %	Wheat	Barley	Maize	Sorghum	Sunflower	Soyabeans
90	20	23	21	19	18	20
80	16	17	16.5	16	11	15
70	14	15	15	14	9	12
60	13	13	13	12	7	9
50	12	11.5	12	11	6.5	8
40	11	10	11	10	5.5	7

These figures are only approximates since the equilibrium moisture contents of a given kind of seed varies because of variety and location, and especially with whether the grains or seeds are absorbing or losing moisture to attain the equilibrium.

What these figures mean
If air of 80%RH is continuously passed through a mass of wheat, the wheat will stabilise at a moisture content of 16%. Similarly, if air of 70%RH is continuously passed through a mass of sunflower seed, the sunflower seed will stabilise at a moisture content of 9%.

To be able to understand the aeration drying process and ensure that any potential damage during the process is minimized, a thorough understanding of the ERH for the particular grain is necessary.

Generally, the higher the grain moisture the higher the ERH. The consequence of this fact is that, when drying high moisture grain, air of a high RH will dry the seed. Conversely, it follows that it is necessary to use a low RH drying air in order to dry to a lower moisture content.

Therefore, in a typical drying process, air of a higher RH can be successfully used to dry grain at the beginning of the drying process more so than at the end of the process.

Another factor to note is that the drying <u>rate</u> will be related to the difference between the drying air RH and the ERH at any time. It is this difference that is the “pressure” driving the drying rate. For a large difference the drying occurs faster and vice versa.

As with all drying processes, there is an optimal rate which is not too slow (allowing the grain to deteriorate during the process) and not too fast (so as to split, crack or kill the grain).

Definitions

Equilibrium Moisture Content EMC - Definition

Equilibrium Moisture content EMC is defined as the moisture content of the material after it has been exposed to a particular environment for a long period of time. Alternatively, the EMC may be described as the moisture content at which the internal product vapour pressure is equal to the vapour pressure of the product environment.

The EMC, therefore, depends on the humidity and temperature conditions of the environment.

Equilibrium relative humidity ERH - Definition

Equilibrium relative humidity for a given temperature, is the air RH in balance with the seed moisture content so that the seed neither takes up or looses moisture.

Relative humidity RH - Definition

Relative Humidity RH is a percentage expression comparing the amount of moisture the air holds with the maximum amount it could hold for a given temperature.

Wet basis moisture content %

Wet basis moisture content percentage is the usual measurement in commercial trading of grains and is an expression of the amount of water in a material compared with its total (wet) weight.

Dry Basis Moisture Content %

Dry basis moisture content percentage is used by scientists and engineers. It is an expression of the amount of water in a material compared with the dry matter in that material. This is usually not used in the grain trading industry.

Drying rate

Drying rate measures how fast the moisture is extracted from the seed. This rate can greatly effect the end quality of the seed so it must be appropriate to the end use.

Amount dried

Whereas the drying rate is a function of the type of dryer and its operating conditions, the amount dried is simply the total amount of grain dried in a given time. This is important from a planning and management point of view. The amount dried will be the main determinant in sizing the dryer, whilst the drying rate is an operational decision related to the type of crop and its end use.

Dryer capacity

Manufacturers usually talk about drying capacity as the amount of grain dried over a period of time under specific conditions.

When making comparisons of dryer performance, it is essential to understand that the amount of dried grain a dryer can produce depends on many factors. For example:

- The type of grain /seed
- The amount of moisture removal
- The ambient weather conditions
- The drying air temperature
- The grain/seed condition (trash, broken, weeds etc)
- Cooled or uncooled grain

Usually dryers are rated for comparative purpose only as if they were drying Wheat from 15 to 12 % moisture content at an ambient condition of 20 degrees C and a relative humidity of 50% using drying temperatures of 70 Degrees air temperature.

As an example of these differences, for any given machine the capacity for drying corn will be around half that for wheat and small seeds (like millets). Wheat and small seeds pack tightly, form a greater resistance to the air flow and dry more slowly.

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Some useful tables:

Bulk density and angle of repose of grain and seed

The bulk density (kg/cubic metre or tones/cubic metre) and repose angle of grain varies with type, variety, moisture content, quality and contamination level.

Estimate bulk density by weighing 1 litre of grain. Its weight in kilograms is the bulk density in tonnes/cubic metre. Multiply by 100 if you want kg/hL or by 1000 if you want kg/m^3.

Commodity	t/m^3	Kg/m^3	Commodity	t/m^3	Kg/m^3
Barley grain	0.62	620	Canary seed	0.70	700
Canola	0.69	690	Chickpea	0.74	740
Cotton Seed	0.40	400	Cowpea	0.75	750
Flax Seed	0.70	700	Linseed	0.73	730
Lucerne pellets	0.67	670	Lucerne seed	0.77	770
Lupins	0.77	770	Maize – grain	0.72	720
Millet	0.63	630	Mung bean	0.75	750
Navy beans	0.76	760	Oats whole	0.48	480
Peanut in shell	0.30	300	Peanut – shelled	0.64	640
Rye – grain	0.70	700	Safflower	0.53	530
Sorghum (milo)	0.73	730	Soybean – whole	0.75	750
Sesame seed	0.59	590	Sunflower – seed	0.42	420
Triticale	0.70	700	Wheat – grain	0.77	770

Angle of repose for common grains

Grain	Angle	Grain	Angle
Barley	28°	Linseed	22°
Safflower	25°	Sorghum	30°
Sunflower	30°	Wheat	27°

(Actual value depends on moisture content, variety, quality and contamination level.)

Storage capacity of circular silos

Take care whenever silo sizes are quoted in tonnes of grain, especially when shopping for a new silo. The amount of grain in tonnes varies widely depending on the type and condition of the grain, but the volume in cubic metres doesn't change.

For example, the bulk density of wheat samples could vary from 750 to 850 kg/$m^{3.}$ Therefore, a 100 cubic metre capacity silo could hold between 75 and 85 tonnes of wheat – a big difference if you don't know which bulk density figure was used!

Tonnes of grain = cubic metres of grain x grain bulk density in tonnes/ m^3.

Partially filled silos

You can estimate the amount of grain in your partially-filled silos using the information in the following tables.

The calculations assume peaked grain surface angle of 25 degrees. Grain typically sits between 23 and 27 degrees when dropped in a pile. Some (for example Linseed) may sit at shallower angles, so the tables will over-estimate volumes for those grains.

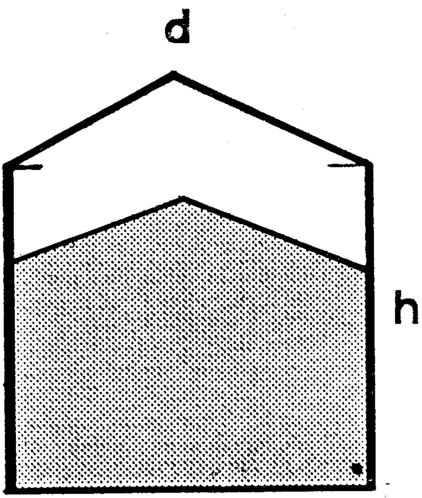
Volume of grain (cubic metres) in partially – filled flat-bottomed circular silos

PEAKED Surface	**$(0.8h + 0.06d) \times d^2$**
LEVEL Surface	**$(0.8h \times d^2$**
D = diameter of silo in metres	
H = wall height of grain in silo (m)	

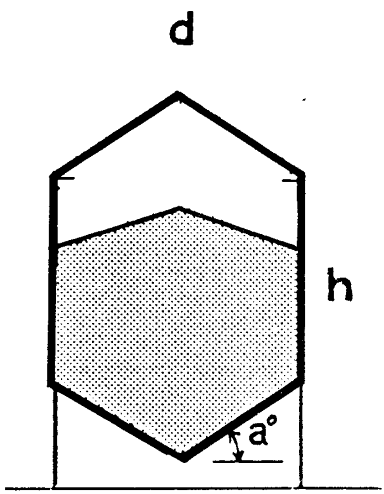
Volume of grain (cubic metres) in partially-filled elevated circular silos

Angle of silo base cone	Grain volume (cubic metres) (PEAKED surface)	(LEVEL surface)
30 degrees	$(0.14d + 0.8h) \times d^2$	$(0.08d + 0.8h) \times d^2$
35 degrees	$(0.15d + 0.8h) \times d^2$	$(0.09d + 0.8h) \times d^2$
40 degrees	$(0.17d + 0.8h) \times d^2$	$(0.11d + 0.8h) \times d^2$
45 degrees	$(0.19d + 0.8h) \times d^2$	$(0.13d + 0.8h) \times d^2$
50 degrees	$(0.22d + 0.8h) \times d^2$	$(0.16d + 0.8h) \times d^2$
55 degrees	$(0.25d + 0.8h) \times d^2$	$(0.19d + 0.8h) \times d^2$
60 degrees	$(0.29d + 0.8h) \times d^2$	$(0.23d + 0.8h) \times d^2$

d = diameter of silo in metres
h = wall height of grain in silo (m)



Dimensions used for flat-bottomed silos



Dimensions used for elevated silos