May 2005

by James Darby

Adaptive Discounting Control for grain aeration

Part 3. *User Inputs, User Feedback* and how to operate ADC

A Technical Report prepared by CSIRO Entomology
Adaptive Discounting Control
for grain aeration

Part 3.

*User Inputs, User feedback* and how to operate ADC

by

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Adaptive Discounting Control for grain aeration

The Adaptive Discounting Control method is documented with five separate reports. Each report was written for a different audience. This manuscript is the third part in the series written for a User to set up and operate the ADC method effectively.

Part 1. Overview and features

Part 2. Technical description (*commercial-in-confidence*)

Part 3. *User Inputs, User feedback* and how to operate ADC

Part 4. *Installer Inputs* and how to obtain them

Part 5. Software details (*commercial-in-confidence*)
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Preface

Aeration is a common and flexible grain storage tool which is experiencing increased demand in Australia at present. Aeration systems pump air through a grain bulk using an arrangement of ducts, exhaust vents and fans. The aeration air is selected from the local ambient air with an automatic controller for reliable results. It can be used for drying, cooling or ensuring safe long-term storage and applied to all grain types.

The Stored Grain Research Laboratory (SGRL), a joint venture of the Commonwealth Scientific and Industrial Research Organisation (CSIRO), AWB Ltd and the Australian Bulk Handling Companies, together with the Grains Research and Development Corporation (GRDC), has developed this novel aeration control method designed to improve the drying and cooling of agricultural commodities.

This new method is called "adaptive discounting" and will implement all modes of aeration; drying, cooling and maintenance. The method offers the capacity to target out-turned grain moisture and/or temperature conditions, high efficiency, a “user friendly” interface, and a simple but sound technical basis. This method has been successfully tested with field trials across Australia.

A key innovation of the Adaptive Discounting control method is the novel link between the air condition selection process and induced changes in the grain temperature and moisture conditions. This is achieved by predicting "on the run" the time period required for fronts to propagate through the grain and adapting set points accordingly. As a result, the method propagates fronts through the grain bulk being aerated until the target grain moisture or temperature is obtained.

The Adaptive Discounting Control (ADC) method refers to software and supporting documentation that is contained in a package of several components as listed here.

- the ADC software module in the software language C
- documentation of the software
- documentation of the control method itself
- reports for various users of ADC
- reports describing field trials conducted to date

This document describes the User interface of the Adaptive Discounting Control method (ADC). It is aimed at holders of the ADC commercial license. Most of the information of this document applies in general, although different Input and Feedback options may be invoked by licensees. Overall, this document describes details of the interface that a User would need to know to operate the ADC method effectively. ADC licensees can carry out their interface design and develop installer notes or brochures from this document.
1. ADC software module and the *User* interface

The Adaptive Discounting Control method (ADC) is software. It is a collection of C-code text files intended for compilation and linking with Licensee software. This collection of files is called the ADC software module. It relies on the Licensee software to interface with operators and the aeration system hardware. It is written in ANSI C to allow it to run on many different hardware platforms. The ADC software module is not an executable or library. ADC is not hardware and does not involve specific operating systems.

The ADC module accepts inputs specifying the following information which are provided by different operators, licensee software or aeration equipment.
- Grain store parameters
- Aeration equipment parameters
- Current grain condition
- Target grain condition
- Time and date
- Ambient weather
- Feedback from aeration equipment

The ADC module provides the following information to the licensee software.
- Recommended fan, heater and cooler on/off settings
- Predictions of grain condition; moisture or temperature
- Predictions of times until aeration targets are satisfied
- Various calculated aeration progress parameters

These sources of information are received from the licensee software and provided by the ADC module at the ADC software interface which is illustrated on Figure 1. *User Inputs* are one set of information that is passed at the interface as illustrated on Figure 1.

The adaptive discounting control (ADC) method was designed as a multipurpose high performance controller that can be operated without specialist aeration knowledge. A key feature of the ADC control method is the “user friendly” interface that was practical and as realistic as technically possible. This required that each input needed to be readily understood and available to typical users. Users are not required to possess specific aeration skills such as understanding relative humidity or temperature limits, wet bulb temperatures, aeration time fractions, etc.

User inputs describe the grain conditions wanted from the controlled aeration process and those at the start of aeration. Typically, they are entered into the controller at the start of the aeration process, but can be altered at any time during aeration (with the exception of grain type). These inputs are known and easily obtained by aeration system Users.

A further feature was an approximate "set and forget" interaction with the controller, to match the way grain stores are usually operated. This required interaction with the controller at convenient times, typically when operating the store during inloading, outloading, fumigation, etc and further interaction with the controller would not be required. Most importantly, *Users* are not required to interact with the controller at specific or critical times in order to make the method effective.
2. What are User Inputs

The ADC User inputs are as follows.

1. Grain type
2. Grain oil content (for oilseeds only)
3. Inloaded grain moisture content
4. Inloaded grain temperature (dry bulb)
5. Target grain moisture content
6. Target grain temperature
7. Inloaded tonnes (or Fill Percent, see section Appendix 7.2)

There are several more User Inputs that are optionally compiled for the advanced version of the ADC method. The advanced term refers to specialist applications of aeration such as over-drying prevention or supplemental heating. These inputs are not required by ADC to operate effectively and remain “silent” unless compiled by the licensee.

8. Minimum moisture
9. Minimum temperature
10. Use supplemental heating
3. **User Inputs** and how each is estimated.

Each *User Input* is described here along with an explanation of how these inputs are obtained or estimated.

3.1. Association of *User Inputs*

Grain type, target moisture and target temperature are treated as separate individual inputs. Each can be entered on separate occasions and does not affect other *User Inputs*. Whereas the inputs tonnes (or Fill percent see section 3.8), inloaded grain moisture, inloaded grain temperature, and oil content (where applicable) are treated as a group of related values. All of these inputs are received simultaneously by ADC (providing a full description of the grain being added to the aeration system).

3.2. **User Input 1:** Grain Type

Grain type is the most readily known parameter. The ADC method currently caters for 20 different grain types. Particular varieties or grades of a grain type are all addressed by the same grain type. E.g. prime hard, ASW and biscuit wheat are all catered for by the wheat grain type. Grain type cannot be changed during an aeration process. When the ADC system is initialised or started, the grain type selected at that time is used. The only way to revise the grain type is to start a new aeration process.

1. Wheat
2. Barley
3. Oats
4. Sorghum
5. Maize (corn)
6. Triticale
7. Paddy Rice
8. Lupins
9. Field peas
10. Chick peas
11. Faba beans
12. Mung beans
13. Navy beans
14. Canola
15. Cottonseed
16. Linseed
17. Peanuts (unshelled)
18. Safflower
19. Soybeans
20. Sunflower
3.3. **User Input 2; Grain oil content**

An oil content input applies for the 7 oilseeds of the above list of grain types. The oil content is selected as a percentage as typically used in the trade (on a total weight basis).

1. Canola
2. Cottonseed
3. Linseed
4. Peanuts
5. Safflowerseed
6. Soybeans
7. Sunflowerseed

The oil content value should be the average of the seed in the store (a weighted average with respect to mass in store). In practice, variations of oil content throughout a grain mass can be significant, for example canola can range from 33 to 46% w/w. An average value approximates this reality, but is fine for ADC.

Where possible, the average value can be estimated as a weighted average with respect to mass in store. For example, if a 100 tonne store is composed of 20 tonnes at 40% oil content, 40 tonnes at 30% oil, and 40 tonnes of 20% oil, the mass weighted average oil content will be determined as follows.

\[
O_{\text{average}} = \frac{20\text{tonnes}}{100\text{tonnes}} \times 40\% + \frac{40\text{tonnes}}{100\text{tonnes}} \times 30\% + \frac{40\text{tonnes}}{100\text{tonnes}} \times 20\%
\]

\[
= 8 + 12 + 8
\]

\[
= 28\%
\]

Calculating the average in this manner is appropriate whether an aerated grain mass is composed of 20 truck loads each with a differing oil content, or a 3/4 full transportable silo being topped up with last years low oil content grain. The more accurate the estimate of the average is, the more accurate ADC User Feedback.

In practice, determining the oil content on the farm can be difficult as instruments are not common. Inloaded oil contents can be estimated from experience, although this will provide a less accurate input but will be OK for ADC operation. Where available, there are different methods to measure oil content. The type of method is not critical to the performance of ADC.

The estimate of the average oil content of the grain in the store should aim to be within 3% of the “true” average value. E.g. for a “true” value of 42% oil, estimates of 39% and 45% would be equally representative.

3.4. **User Input 3; Inloaded grain moisture content**

The inloaded moisture content input applies for all grain types. Moisture contents are expressed as percentages (on a total weight basis) as used in trade. The input value should be the best estimate of the grain tonnes being inloaded into the store. In practice, variations of moisture content throughout a grain mass can be significant. As described
in section 3.3, average values approximate the true range of grain moistures, but is fine for ADC.

The average value is determined as a weighted average with respect to mass in store (as per oil content averages of section 3.3). For example, if a 100 tonne store is composed of 20 tonnes at 14% moisture, 40 tonnes at 16% moisture and 40 tonnes of 17% moisture, the mass weighted average moisture will be determined as follows.

\[
M_{\text{average}} = \frac{20\text{tonnes}}{100\text{tonnes}} \times 14\% + \frac{40\text{tonnes}}{100\text{tonnes}} \times 16\% + \frac{40\text{tonnes}}{100\text{tonnes}} \times 17\%
\]

\[
= 2.8 + 6.4 + 6.8
\]

\[
= 16\%
\]

The estimate of the average moisture content of the grain being inloaded should aim to be within 1% of the “true” average value. E.g. for a “true” value of 15% moisture, estimates of 14% or 16% would be equally representative.

In practice and where measurements allow, inloaded moisture content estimates should be more accurate the closer they are to the target moisture content, especially if they are below the target moisture content. E.g. for a “true” value of 15% moisture with a target of 12%, estimates of 14% and 16% would allow good ADC operation. Whereas, for a “true” value of 11% moisture with a target of 12%, estimates of 9 or 12% would result in significant differences in ADC operation. Estimates of 10.2% and 10.7% would allow ADC to perform optimally.

A range of methods can be used to measure moisture content. The type of method is not critical to the performance of ADC, although accuracies better than ± 0.5% of the true sample value will provide accuracies in proportion with the uncertainties described above.

3.5. **User Input 4; Inloaded grain temperature**

The inloaded grain temperature input applies for all grain types. It is required to be expressed in degrees Celsius. The input value should be the best estimate of the average temperature of the grain tonnes being inloaded into the store. In practice, variations of grain temperature up to 10°C through out a truck load are common. However, an average value is fine for ADC (as per inloaded oil content and moisture).

The estimate of the average temperature of the grain being inloaded should aim to be within 3°C of the “true” average value. E.g. for a “true” value of 33°C, estimates of 36°C and 30°C would be equally representative.

In a similar manner to inloaded grain moisture content, inloaded grain temperature estimates should be more accurate the closer they are to the target temperature, especially if they are below the target temperature. E.g. for a “true” temperature of 33°C with a target of 15°C, estimates of 29°C to 37°C would allow good ADC operation. Whereas, for a “true” value of 20°C temperature with a target of 15°C, estimates of 18°C and 22°C would allow ADC to perform optimally. In practice, determining grain temperatures accurately can be difficult, so the best estimate possible is fine.
Grain temperature is not a currently measured parameter in the grain industry of Australia in 2002. As a result, standard methods and equipment for grain temperature measurement are not well known, although temperature measurement instruments in general are readily available. A simple method is explained in Appendix 7.1.

Inloaded grain temperatures can also be roughly estimated from experience, although this will provide a less accurate input and less accurate control action accordingly.

3.6. **User Input 5: Target grain moisture content**

The target grain moisture content is the maximum moisture wanted by the User. That is, the final moisture content of the aeration process can be at or below the target value. The target grain moisture is required as a percentage on a total mass basis (11.5% w/w). As this parameter is chosen, not measured, any realistic value is acceptable. Typically, target values are related to trade standards or long term storage requirements. For example, a target of 11.8% moisture for wheat meets Australia’s trade standards.

ADC operation is very responsive to chosen target values including the precision of the moisture wanted, for example 11.5%. Selecting values at a precision of 0.1% is significant to the control action performance, allowing useful set point adjustments in marginal weather conditions. However, this does NOT imply that the final moisture content of the grain mass will be aerated to within a 0.1% range.

3.7. **User Input 6: Target grain temperature**

The target grain temperature is the maximum temperature wanted by the User. That is, the final grain temperature of the aeration process can be at or below the target value. The target grain temperature is required as a value in degrees Celsius (18°C). This input is the conventional temperature (dry bulb) as used with weather forecasts. As this parameter is chosen, not measured, any realistic value is acceptable.

Typically, target values are related to insect control conditions, specific grain quality parameters or long term storage requirements. For example, 15°C could be chosen to suppress insect growth, or 20°C to ensure malt grade is maintained for long periods.

As described in section 3.6, ADC operation is responsive to chosen target values, so selecting a value to a precision of 1°C is significant. However, this does NOT imply that the final temperature of the grain mass will be aerated to within a 1°C range.

3.8. **User Input 7: Inloaded tonnes (or Fill Percent %)**

ADC has been designed to allow two different ways of inputting the amount of grain that is to be aerated. The default approach is based on inputs of the tonnes of grain inloaded into the store; in-loaded tonnes. This is referred to as the “load history” approach. As the name implies, this input is required in metric tonnes, for example 153 tonnes. The use of the term “load” in the ADC inputs does not refer to truck, header or rail loads.

The inloaded tonnes input value should be the best estimate of the tonnes of grain put into the aeration system when this value is input into the controller. The ADC method does not make any assumptions about the mass of grain that will be put into a store in any given time. A single entry representing the grain tonnage for the whole bin, or the
tonnes across a single day or each individual truck load can be entered. ADC tallies all the grain tonnes being aerated as the User enters these values into the controller.

As described in section 3.1, the value of inloaded tonnes is associated with the moisture and temperature of the grain tonnes being inloaded. The moisture and temperature of this grain tonnage is also passed to ADC when the tonnage input is entered (see sections 3.4 and 3.5).

An alternative option for describing the mass of grain to be aerated is given in Appendix 7.2.

4. When should User Inputs be entered

ADC responds to each User Input at the time that the input is entered into the controller. Typically, initial values (or possibly the only values) would be entered when the aeration control process is started or initialised. This often coincides with inloading, but does not mean the store has to be filled to start the ADC process. ADC commences a new aeration process according to all the entered inputs once reinitialised.

The ADC method has a dynamic User interface. This means that all of the inputs apart from Grain Type, can be changed at any time during the operation of the ADC control process and the controller will respond appropriately. This enables varying inputs such as Inloaded Tonnes, Inloaded Grain Moisture, Target Grain Moisture or Target Grain Temperature, etc, with the latest or improved estimates during the operation of the control method.

Throughout an aeration process, changes to Inloaded grain moisture or temperature has less impact on the control process as the process continues. For example, changing the Inloaded grain moisture at the end of an aeration drying process will not cause significant variation in the control action.

5. ADC User Feedback

There are many feedback parameters available from ADC, each providing aeration performance or status information. These have been categorised into several groups as follows.

1. Common User feedback
2. Predictions or Calculated Parameters
3. Load History

Commercial ADC controllers have used a selection of these parameters and tended to display each group on different screens, although this depends on the design preferences of the licensee. The available parameters and a description of what information is provided with each are provided in the following sections. Explanations of the values are provided where their meaning was not obvious.

5.1. Common User Feedback parameters

Control mode or current operating state. The current aeration control mode or operating state; Dry, Cool, Maintain, Never-Started, Terminated, Weather Station Fail.
Local air. The current temperature and relative humidity values passed to ADC; temperature °C and relative humidity %.

Aeration start. The time and date when the current aeration process was commenced by the User by entering the initialise or start command; 09:30am, 1 April 2004.

Fan last ran. The time and date when the aeration fan(s) were last operated by the ADC controller; 09:30am, 1 April 2004.

Inloaded tonnes. The total accumulated tonnes of grain in the aeration system as entered by the User; 230 tonnes.

Discounting action. A signal that indicates if the “discounting” action of the ADC method is currently being used.

Rain out. A signal that indicates if the “rain-out” action of the ADC method is currently being used.

Batch drying. A signal to indicate that the drying situation is a batch drying operation.

Fan requested. A signal that the ADC method has requested that the aeration fan(s) be operated.

Another user feedback parameter that is optionally compiled for the advanced versions of the ADC control method is as follows. The advanced term refers to specialist applications of aeration such as over-drying prevention or supplemental heating.

Burner last ran. The time and date when the burners were last operated by the ADC controller; 09:30am, 1 April 2004.

Further to these ADC specific feedback items are general controller operating inputs such as power on, ADC activity status, etc. These items are not specific to the ADC method.

Aeration system. Identification of the aeration system for which the feedback items are currently being displayed.

Controller status. A signal indicating if the controller has been activated.

Fan operating. A signal indicating that the fan is currently running. Note; this is distinct from the ADC fan request signal as it is independently confirmed by an electrical feedback connection from the fan.

Fill Percent. The total amount of grain in the aeration system as entered by the User expressed as a percentage of the total capacity of the aeration system; 65%. (This parameter is the alternative to the Inloaded Tonnes parameter, see Appendix 7.2)
5.2. ADC predictions or calculated parameters

Average fan hours per day. An estimate of the number of hours that the fan has been running per day on average across the current aeration process; E.g. 5.6 hours.

Days to completion. An estimate of the number of days required to complete the current aeration process (days to reach target moisture for drying, or temperature for cooling). This feedback item is returned as a range; E.g. 43-65 days.

The prediction is based on the amount of aeration time calculated to achieve the target condition and the proportion of the day that the fan has been operating. The range of values indicates the uncertainty present in the estimate at early stages of the aeration process. In practice, this estimate can vary considerably depending on the weather conditions experienced. Generally, the range of days will slowly decrease towards zero once the aeration process has been measured as progressing to the target. However, if the weather is poor for aeration, the prediction can actually increase slightly reflecting the low proportion of the day the fan has been operating.

Grain moisture being achieved. An estimate of the grain moisture content that the current aeration process is achieving. This is the moisture content of the grain where the aeration front has passed. It is not the average moisture content of the grain across the store. This feedback item is returned as a range. E.g. 12-13%.

The prediction is based on the inlet air that has been used by the aeration system in the current aeration process. The ADC method logs the air conditions experienced and allows for the fan heat to make this prediction. The range of values indicates the type of uncertainty present across an aeration process. In practice, this estimate is dependent on the relative humidity temperature sensor being positioned correctly and its calibration kept up (at least every 2 years).

Grain temperature being achieved. An estimate of the grain temperature that the current aeration process is achieving. This is the temperature of the grain where the aeration front has passed. It is not the average temperature of the grain across the store. This feedback item is returned as a range. E.g. 20-25°C. This prediction is estimated in like manner to the grain moisture being achieved prediction.

Front progress. An estimate of the percentage of the aeration process that has been completed. This feedback item is returned as a range, for example 50–65%.

This prediction is based on the amount of aeration time calculated to achieve the target condition and the proportion of this time that has been completed. The range of values indicates the type of uncertainty present in the estimate at early stages of the aeration process. The estimate is dependent on the weather conditions experienced. The range of progress will have a wide range where-ever progress to the target is uncertain, but steadily narrows and increases towards 100% once the aeration process has been determined to be achieving the target. If the weather is poor for aeration or that the target selected is unrealistic, progress will appear to stop with the range not changing in value.

Remaining moisture. An estimate of the moisture content of the grain that has not been changed by the current aeration-drying front. This feedback item is returned as a range, for example 12-13%.
Remaining temperature. An estimate of the temperature (dry bulb) of the grain that has not been changed by the current aeration-cooling front. This feedback item is returned as a range, for example 20-25°C. This prediction is estimated in like manner to the "remaining temperature" prediction.

Active set points. Values of ADC set points currently being used; "equilibrium grain moisture content" and "wet bulb temperature". Wet bulb temperature set points are not used when the aeration mode is in drying mode.

Inlet air. Values of the "equilibrium grain moisture content" and "wet bulb temperature" of the inlet air calculated by the ADC method that includes the temperature rise caused by fan heat (and burner heat if applicable).

5.3. Load History

The load history parameters provide a summary of the grain tonnes, moisture, temperature and oil content (for oilseeds only) that has been entered into the controller by the User. This display acts like a cumulative summary of the grain that is to be aerated.

Grain type. The type of grain entered into the controller, for example wheat.

Load. Provides a line summary of the time, date, tonnes, moisture, temperature and oil content (for oilseeds only) of a mass of grain as entered by the User. For example; Load 12:45 Jan 01, Tonnes 25, M% 19.0, T°C 15, O% 00.

Inloaded. Provides a line summary of the cumulative tonnes, average moisture, average temperature and average oil content (where applicable) of the accumulated mass of grain as entered into the controller by the User. For example; Tonnes 25, M% 19.0, T°C 15, O% 00.

3.6. Using ADC

What does adaptive refer to? The term adaptive discounting portrays the major characteristics of the ADC method. The term adaptive refers to set points being adapted or changed during the control process by the control action. (Adaptive is a term common in control engineering.)

What does discounting refer to? The term adaptive discounting portrays the major characteristics of the ADC method. Discounting refers to the discounting of aeration control set points which is an innovation of this control method. During some weather conditions, an aeration process can dry or cool grain more than required. This grain has experienced "extra" drying or cooling. ADC determines when this occurs and adjusts its set points to use up the extra drying or cooling, enabling faster aeration and less over-drying. In this way, air that would normally have been rejected will be put to good use.

Which control mode is used? Do I have to select it? The ADC method determines the appropriate control mode "automatically" from the User Inputs; Inloaded moisture and temperature and target moisture and temperature. The User is not required to choose a control mode, although this can be "forced" by choosing appropriate target conditions.
The ADC method follows a predetermined "default" sequence of control modes; dry then cool then maintenance.

**How does ADC determine the control mode?** The need for drying and/or cooling is determined "automatically" from the User Inputs. Firstly, if grain is wetter than the target conditions (Inloaded moisture > Target moisture), then the controller will implement drying action. If the grain is dry (Inloaded moisture <= Target moisture) then the need for cooling is tested. If grain is warmer than the target conditions (Inloaded temperature > Target temperature), then the controller will implement cooling action. If the grain is both dry and cool (Inloaded moisture <= Target moisture and Inloaded temperature <= Target temperature), then maintenance action is implemented. If ADC started in Dry mode, it will automatically select the next control mode based on the grain conditions achieved during aeration-drying.

**ADC uses a default sequence of control actions; Dry then Cool then Maintenance. Why is this?** This sequence of control actions ensures the risks to grain are addressed according to need, while carrying out the various aeration actions efficiently. Of the risks to grain during storage, wet grain experiences the greater risk from mould spoilage and self heating which can occur in days to weeks. Warm grain incurs risks with insects and quality losses (malt grade loss, rancidity, etc) which occur over months. Dry cool grain can incur moisture migration and crusting over many months and years. If the default control sequence involved cooling before drying, energy involved in cooling is made redundant by the subsequent drying action where the grain can be reheated during drying.

**What is maintenance action? What does maintenance do?** Maintenance aims to maintain the grain in a good state at the target grain moisture and temperature conditions, while minimising the running of the fans to reduce energy consumption. It also aerates to address potential omissions and inadequacies in the grain store or aeration system. Maintaining grain in a good state involves aerating the grain with small quantities of carefully selected air on a regular basis to prevent cumulative storage spoilage processes that occur due to localised moisture build, headspace condensation problems, addressing incompletely dried or cooled "edges" and localised minor ingresses of moisture from nails holes, inadequate seals, etc. The aim of the air changes is to disperse such localised problems.

**How can I cool wet grain without the controller drying it?** The need for drying and/or cooling is determined "automatically" from the User Inputs. Firstly, if grain is wetter than the target conditions (Inloaded moisture > Target moisture), then the controller will implement drying action. So entering a target moisture greater or equal to the Inloaded moisture will prevent the default drying action being implemented (E.g. Target moisture = 18% = Inloaded moisture = 18%). The ADC method then checks if cooling is required. If the inloaded grain is warmer than the target conditions (Inloaded temperature = 30°C > Target temperature = 20°C), then the controller will implement cooling action. The target grain moisture and temperature conditions can be used to implement any control action in this manner.

**What will happen when I start the aeration controller?** The ADC method is designed to aerate the grain to the target (wanted) grain moisture and temperature. When the initialise input is entered, a fresh aeration process commences according to the User inputs selected at that time. All aeration decisions are automatically made from these inputs. The user feedback and prediction displays will be updated to reflect the current
status and indicate the expected operation of the ADC process. These displays can be consulted to check if your intentions are likely to be achieved.

I typically fill the store in stages. How does ADC cater for this? ADC enables Users to enter the tonnes to be aerated in stages (or as a completely filled store) to match User needs using the New Load User Input. As the aeration system is filled, the User can enter the grain tonnage for each stage without stopping the controller and ADC will respond adjust its action appropriately “on the run”. The New Load User inputs of tonnage, moisture and temperature can be entered throughout the whole aeration process, from minutes to weeks apart. The idea is to make additions or changes when it is convenient for you, while providing ADC with details of the grain it is aeration.

I don't know how many tonnes are in the aeration system? I don't know how many tonnes are held at the moment, can I fix this later? ADC will operate satisfactorily with non-accurate inputs about the grain to be aerated. If approximate values of the tonnes of grain are all that is known, these values should be entered. They can be improved in future (this afternoon, tomorrow, or later in the week). When entering rough estimates of tonnes until a better value is established, use over-estimates. This ensures the grain is over-aerated and not under aerated.

I don't wish to dry or cool the grain necessarily. I just want to hold the grain safely for a week or two until processing. What is the best way to do this? This can be handled in two separate ways. Aerating the grain so that regular air exchange occurs will keep grain safe, with more air required the wetter the grain. Maintenance action automatically adjusts the amount of air exchanged in response to the risk involved. So setting the target grain moisture and temperature equal to the inloaded grain moisture and temperature respectively invokes the appropriate maintenance action. Alternatively, instigating cooling by setting a low target grain temperature could be used.

I understand that good cooling air occurs at high relative humidities. How does ADC prevent rewetting during cooling? Aerating grain with cool but wet air will steadily rewet the grain near the aeration air inlet, although usually this is not excessive. ADC cooling action prevents aeration when the inlet air will rewet the grain above the target grain moisture. If the grain is drier than the target moisture, a limited amount of aeration with high moisture air during cooling action is allowed until the grain is estimated to have been rewetted to the target moisture. Furthermore, if a small amount of rewetting is tolerable (say allow wheat near aeration ducts to rewet up to 14%), the target grain moisture content should be set to the tolerable level (14%), and ADC will maximise cooling against the rewetting allowed.

Should I turn the controller off when the feedback displays maintenance mode for several weeks? No. ADC maintenance mode is designed to keep the grain at the target conditions while preventing longer term spoilage processes and replenishing the inter-granular air. It does this by making a predetermined minimum number of air changes depending on the target grain conditions. So allowing aeration-maintenance action to continue will look after your grain with low energy consumption.

I initially entered the wrong target values. Do I need to initialise or restart ADC? No. New target values can be entered at any time during the ADC control process. ADC then controls the fans to achieve the new target values, from the grain conditions that have been achieved till that time.
When I change User Inputs such as the Target Moisture, ADC can take up to 10 minutes to respond to this change. Why doesn’t ADC respond instantly? ADC computations are carried out on a regular interval of approximately 10 minutes. This enables ADC to supervise a series of aeration systems simultaneously, that may be significant distances from the controller hardware, with relatively small memory requirements. So if your input change happened to occur just after the latest ADC computation, just under another 10 minutes will elapse before your latest change is responded to.

How does ADC work out the grain moisture or temperature achieved? A characteristic of aeration is that the grain comes into an equilibrium state with the average inlet air condition under certain constraints. Aeration processes can be described mathematically using relatively compact approaches. ADC monitors the inlet air used during the aeration process and determines the progress of the aeration process mathematically. If the constraints are met, ADC predicts the final moisture or temperature from the inlet air and mathematical representation of aeration. In practice, good prediction accuracies are obtained.

How does ADC work out the time periods for drying or cooling? From an engineering perspective, aerating grain is a fairly well defined process. It is dependent on the mass (tonnes) and type of grain, initial grain conditions (moisture and temperature), the inlet air conditions (relative humidity and temperature), and characteristics of the aeration system (fan size, store dimensions, duct layout). All of these parameters are either entered into the controller (e.g. User inputs of inloaded moisture and inloaded temperature) or measured during the control process (e.g the inlet air used is measured with the weather station). The aeration system characteristics are input into the controller by your supplier. From these inputs, estimates of the range of time periods for drying or cooling can be determined at any stage during the aeration process (energy and mass balances). The inlet air conditions for an aeration process are not known at the start, so estimates are made based on typical values for aeration in Australia. However, this does result in more uncertainty which is conveyed via larger differences in the maximum and minimum values for the range provided by ADC. As the aeration process continues, actual values of air used are accumulated, and the predictions of drying or cooling periods are improved accordingly.

Why do the cooling time period predictions fluctuate so dramatically on occasions? The cooling time predictions require an estimate of the average inlet air condition (temperature and relative humidity) throughout the aeration-cooling process. For aeration cooling, the aeration process can be quite intermittent as air suitable for cooling often only occurs for small proportions of a day (during summer), and in some scenarios, weeks may pass without any suitable air being available. Many cooling scenarios in Australia are dependent on the progress of low pressure cells (synoptic weather fluctuation) across the country that occur every 3-8 days, creating large variations in the availability of cooling air. This causes large variations in the predictions of cooling times accordingly. When long periods of no aeration occur, the predictions can "jump" to higher values as ADC anticipates that an extra cooling front may be required to achieve the target temperature. If low values of target grain temperatures are selected by a User, they may not be achievable during warmer months, and cooling time predictions will increase as the aeration process progresses, an apparently contradictory result.

How does ADC respond to fog or rain conditions? The ADC method has a specific feature to prevent grain rewetting caused by aeration during prolonged rain, fog or
extended periods of high relative humidities. It does this while catering for the inadequacies of relative humidity sensors to measure such conditions reliably. The controller logs the amount of time that an excessive relative humidity condition has occurred and "locks out" for a couple of hours until such conditions have ceased. This is carried out automatically so users do not have to intervene.

Why does ADC indicate batch drying? How is batch drying different to aeration drying? ADC estimates when the drying situation being encountered will not satisfy the assumptions used for calculating the time period for an aeration-drying front to propagate through the grain bulk. These assumptions are not met with high air flow rates relative to the mass of grain being aerated. In these cases, the grain dries as a batch and not via the progression of a front (a characteristic of aeration processes). Hence the term batch drying is used. In practice, these situations occur with large aeration fan capacities, relatively shallow filled grain stores, or both. When these situations occur, ADC still controls the drying process, but does not provide predictions of drying times or final moisture values.

How often should I check the relative humidity sensor? The ADC method is dependent on good relative humidity sensor accuracy for good performance. The accuracy of ADC to achieve the target grain moisture or temperature is better the truer the sensor calibration. A relative humidity sensor should be checked for calibration every 2 years at least and recalibrated if necessary, or replaced if very bad (if in doubt, contact supplier). If final moisture or temperature results are very critical, a yearly check should be implemented.

What happens if a power failure occurs? Do I need to restart the controller after a power failure? No. ADC software is not affected by power failures. The method detects such events and continues once the power is reconnected. A user does not have to change inputs or re-initialise the controller. If the power has been off for a long period (several weeks) during maintenance mode, users may notice the ADC method change to cooling mode in order to re-establish the target grain conditions.

What happens if the aeration fan(s) trip out and were not operated for some time. Do I need to restart the controller after the fan(s) have been re-instated? No. ADC software is not affected by fan failures. The method detects such events and continues once the fan is re-instated. A user does not have to change inputs or re-initialise the controller. If the fan(s) has been off for a long period (several weeks) during maintenance mode, users may notice the ADC method change to cooling mode in order to re-establish the target grain conditions.

If I choose not to have the "feedback link" option with my ADC, how can this affect ADC performance? The feedback link from the aeration system is designed to confirm to ADC that its control decisions were implemented. For example, when the fan was requested by ADC to be turned on, the feedback link "proves" that this occurred. This addresses many issues, a common one being that the power to the fan was interrupted or manually over-ridden. Confirmation of ADC control commands is not essential in many scenarios, and your supplier will assist in establishing if your scenario benefits by inclusion of this option. If the feedback option was not included with your ADC, this will affect how accurately ADC achieves target grain conditions and the associated predictions (final moisture or temperature, drying or cooling days, etc). ADC tunes the air selection process and makes predictions of the final moisture or temperature achieved based on the measured inlet air used during a drying or cooling process respectively. If a fan was
turned off for significant periods of the drying or cooling process and ADC was not aware of this (feedback was not invoked), then ADC does not have meaningful data on the inlet air used. Therefore, the tracking of the air conditions used to condition grain to the target and make predictions will be less accurate. The greater the discrepancy between ADC’s requested fan operation schedule and that actually used, the greater the inaccuracy of ADC.

How does the minimum moisture limit option work? This issue is only relevant to the advanced ADC option. The ADC method provides for minimum moisture limits to be set during drying mode where the controller will prevent the grain being dried below this limit. This feature is desirable for breakage sensitive grains such as maize, rice, and pulses. The ADC method monitors the drying action and when the grain is predicted to be drying below this limit, over-drying, a low equilibrium moisture set point is introduced. This prevents further drying below this limit. This low set point is only introduced when over-drying is occurring.

What happens when weather station failure is indicated? The weather station fail indicator is caused by a sensor/hardware failure being detected by ADC. When this occurs, the operation of the aeration system is stopped by ADC until appropriate weather station data is passed to ADC. Typical problems are a bad connection that results in both the relative humidity and temperature reading zeroes and the relative humidity sensor becoming "super saturated" and continually reading above 100%.

7. Appendix.

7.1. Measuring grain temperatures

Grain temperatures can be easily measured by obtaining a sample of grain of 500 grams or greater, placing it in a non-metal container (ice cream container, six pack esky, or similar), and putting a temperature device into the grain. The key issues with measuring grain temperatures are ensuring that equilibrium is established between the measuring device and the grain, and the measuring device does not have a large mass relative to the grain. For example, common mercury in glass thermometers (less than 50 grams) pushed into a 4 Litre ice cream container of grain will take up to 8-12 minutes to stabilise at the temperature of the grain. Fine wire thermocouples will take up to 3-5 minutes. When the temperature reading has stabilised, a good estimate of the grain temperature has been made.

7.2. Optional User Input 7: Fill Percent

ADC provides an alternative method to enter the mass of grain being aerated referred to as the Fill Percent approach. This option is invoked by entering a value for the Standardised Tonnes Installer Input (see Adaptive Discounting Control for grain aeration, Part 4., Installer Inputs and how to obtain them.)

This option describes the mass of grain in the aeration system as a percentage of the totally full system. This Fill Percent value is expressed as a percentage, for example 15%. This input is treated differently to inloaded tonnes described in section 3.8. The Fill Percent value represents the amount of grain in the aeration system when the input is entered. That is, it indicates the accumulative filling extent when the User enters the value. Which method is implemented is at the discretion of the licensee.