AERATION OF STORED WHEAT IN THE CANADIAN PRAIRIES

J. F. Metzger1 and W. E. Muir2

1Agricultural Engineering Branch, British Columbia Ministry of Agriculture and Food, 33832 South Fraser Way, Abbotsford, B.C. V2S 2C5; and 2Agricultural Engineering Department, University of Manitoba, Winnipeg, Man. R3T 2N2.

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Aeration airflow rates and fan control methods for maintaining quality of stored wheat were evaluated with a verified computer simulation model. The model predicts grain conditions in two dimensions of a cylindrical granary, with and without aeration. Historical weather data for 15 or more harvest years from four Canadian Prairie locations ranging from Fort St. John, British Columbia, to Winnipeg, Manitoba were used. The effects of climate, initial moisture content, harvest date, and initial grain temperature on the condition of stored wheat were determined from results of the model. All aeration airflow rates and fan control methods reduced the rate of grain deterioration. An airflow rate of 1.0 (L/sec)/m3 was best for continuous aeration. The optimum methods for controlling the fan were humidistat with settings between 50 and 70%, 6-h time-clock operation at night, and differential thermostat with settings between -10 and -15°C. The choice of control method was independent of climate within the range of climates studied.

INTRODUCTION

The objective of ventilating (aerating) stored grain with low flows of near-ambient temperature air is to maintain grain quality. Aeration limits biological activity by cooling the grain, and prevents moisture migration by maintaining a relatively uniform temperature throughout the grain mass (Brooker et al. 1974; Burrell 1974). As well, aeration can be used to remove grain storage odors and to distribute fumigants throughout the grain mass (Brooker et al. 1974).

Uncertainty in production and marketing can often result in lengthy storage periods. The "dry" moisture contents specified by the Canadian Grain Commission for marketing may not necessarily be "safe" moisture contents for storage. Moisture migration, or high initial grain temperatures in large storages can result in serious deterioration, even when the grain is "dry." Variable weather and field conditions during harvest may produce "tough" or "damp" grain which has an even greater tendency to deteriorate than "dry" grain.

Although grain aeration is not new, it was not until the early 1950s that it came into general use (Burrell 1974). Much interest in aeration during this time resulted from a need to maintain quality in large commercial storages (Kelly 1941; Johnson 1957; Holman 1960). It was suggested, as an alternative to the management practice of turning grain, to reduce maximum temperatures. Although turning succeeds in producing a more uniform temperature throughout the storage, its ability to cool grain is limited to reducing peak temperatures to near the average of the bulk (Watters 1963). Recent trends toward large on-farm grain storages in Canada (Muir 1980) as well as towards drying of grain with near-ambient temperature air has carried interest in aeration systems to the farm level.

The objectives of this study were to determine effective airflow rates and fan control methods for intermittently operated aeration systems used for on-farm storage in Canadian Prairie regions. The method of investigation was a computer simulation model developed and verified by Metzger (1980) and fully described by Metzger and Muir (1983). This model can be used to predict temperatures, moisture contents and deterioration of wheat stored in a circular steel granary with and without ventilation. Predicted results are based on initial grain conditions, airflow rate, weather conditions, and a variety of fan control parameters. The model sufficiently represents the real processes that useful trends can be observed. This reduces the need for more expensive and time-consuming field studies. The study provides information on wheat aeration in the Canadian Prairies from which guidelines for system designs can be developed.

SIMULATION PARAMETERS

Canadian Prairie Climatic Regions

There are four general climatic regions which encompass most of the grain-producing areas of the Canadian Prairies (Putnam and Putnam 1970). These are the semi-arid or dry-belt, the sub-humid prairie, the sub-boreal, and the humid prairie (Fig. 1). Local climatic differences do not make these subdivisions exact. The Edmonton area, for instance, has a higher summer rainfall than the Peace River area (Putnam and Putnam 1970).

Historical hourly weather data on tape were obtained for use as input data for the computer simulation model. The locations and years to be analyzed were chosen considering (1) the climatic data available at the University of Manitoba, and (2) the climatic regions of the Canadian Prairies. The following four locations were studied (1) Winnipeg, Manitoba — Humid Prairie (1961-1978); (2) Swift Current, Saskatchewan — Semi-arid. (1961-1976); (3) Edmonton, Alberta — Sub-humid to Sub-boreal (1961-1976); (4) Fort St. John, British Columbia — Sub-boreal, Peace River Region (1961-1978).

Initial Grain Temperatures

Prasad et al. (1978) established that the initial temperature of grain in storage can be related to the average air temperature during harvest. They found that the temperature of harvested wheat was 8°C above the ambient air temperature on sunny days.

To establish initial grain temperatures for the computer simulations, 3-wk running means of the hourly temperatures were calculated for each possible harvest date during the normal harvest period at the four climatic areas (Fig. 2). Initial grain temperature in storage was established by adding 8°C to the 3-wk running mean temperature on the harvest date. The initial temperature of stored grain can be much higher due to peak daytime temperatures and yearly variations of the 3-wk mean.
Storage Bin and Aeration System

Based on trends in the size of on-farm granaries in Canada, a storage of 133 m³ capacity (100 tonne of wheat at 14.5% moisture content) and 5.97 m diameter was chosen (Muir 1980). A fully perforated floor was assumed with air blown upward through the floor and grain by a direct-drive, axial-flow fan.

SIMULATION RESULTS AND DISCUSSION

Grain Deterioration in Unventilated Storage

To establish the worst storage conditions, predictions of grain condition were made for wheat stored for 1 yr with no ventilation. The effects of harvest date, initial moisture content, and initial temperature at the four climatic locations were examined.

The model developed by Fraser and Muir (1980) to predict the allowable safe storage time for wheat was used to assess grain deterioration with and without ventilation. For each time interval the temperature and moisture content of each spatial element are used to calculate the allowable storage time. The proportion of allowable storage time elapsed during the time interval is calculated by dividing the length of time interval by the calculated allowable storage time. This value is added to the proportion of allowable storage time which has already elapsed to obtain an estimate of the total deterioration since harvest. The proportion of allowable storage-time elapsed is expressed as a decimal fraction. A value of 1.0 indicates that the allowable storage time has expired. The model is based on the criterion that spoilage has occurred when seed germination decreases about 5%.

Spoilage occurred within 1 yr for wheat stored at an initial moisture content of 15% at most harvest dates (Fig. 3). This first occurrence of spoilage was always predicted at the bin center, approximately...
1.5 m below the top grain surface. The later the harvest date, the longer the safe storage period. This was due largely to the lower grain temperatures at harvest. Fort St. John was the only location where safe storage periods of over 1 yr were predicted.

The effect of initial moisture content on the average number of days of storage to first occurrence of spoilage was evaluated for wheat harvested on 1 Sept. (Fig. 4). Initial grain temperatures were again based on harvest temperatures. Deterioration was predicted to occur earlier as moisture content increased. The Canadian Grain Commission has established that 14.5% moisture content is “dry” for wheat. At this moisture content, spoilage occurred at an average of 100 days in Winnipeg, 130 days in Swift Current, 355 days in Edmonton, and over 1 yr in Fort St. John. Since the deterioration model has not been adequately verified, it is difficult to know how realistic these predictions are. A decrease in germination (as used in the deterioration model) may not result in a drop in grade; however, given the relatively high initial grain temperatures at Winnipeg and Swift Current, the size of the grain bin, and the low thermal diffusivity of wheat, these results may not be unrealistic. In addition, moisture migration, which was not included, may further increase the rate of deterioration.

To assess the effect of initial grain temperature on these results, the initial temperature for all locations was set at 23.6°C, the initial grain temperature for Winnipeg on 1 Sept. (Fig. 5). Within the limits of the Canadian Prairies, climate during storage had little effect on the predicted number of days to the first occurrence of spoilage. Hence, air temperature at harvest can have an extremely large effect on spoilage (Figs. 4, 5).

The previous comparisons were made on the basis of the first occurrence of spoilage. Another method of analysis was to compare deterioration throughout the bin based on the average proportion of allowable storage time elapsed for all grain volume elements (Fig. 6). Initial grain temperature had a significant effect on the rate of deterioration, especially immediately following harvest in the fall. The effect of climate on grain deterioration near the wall resulted in differences among the geographical locations even with the same conditions.
Initial conditions and aeration periods.

The initial grain temperature of 23.6°C results in a fall cool-down period that lasts longer than 0.5% of the grain volume.

The airflow rates investigated were 0.5 to 3.0 (L/sec)/m³ for the continuous ventilation. The airflow rate was varied from 0.5 to 3.0 (L/sec)/m³, and the resulting changes in moisture content, temperature, and rate of deterioration were recorded for the following conditions:

- Fall cool-down period: After harvest, the stored grain is to be cooled as quickly as possible to between -10°C and 0°C.
- Winter holding period: Intermittent fan operation during the winter when the outside temperature is near the grain temperature to maintain uniform grain temperatures.
- Spring warm-up and summer holding period: Intermittent fan operation to warm grain to 10-15°C by the middle of June, and to maintain uniform grain temperatures.

Airflow Rates for Fall Aeration at Winnipeg

The effect of continuous ventilation on grain moisture content, temperature, and rate of deterioration were evaluated for airflow rates from 0 to 3 (L/sec)/m³ during the fall cool-down period (1 Sept. to 31 Oct.) at Winnipeg. The points plotted represent mean values for the 17 yr of weather data analyzed. The vertical bars indicate standard deviations of the mean. Airflow rates of 0.5-3.0 (L/sec)/m³ resulted in moisture content reductions of 0.5-0.7 percentage points. The higher standard deviations at higher airflow rates reflect the greater response to yearly variations in ambient air temperature on the final days of the aeration period. This can be an advantage to the operator as consistent results can be expected from year to year if continuous ventilation is practiced.

Average grain temperatures drop sharply with as little airflow as 0.5 (L/sec)/m³ and level off at 4.5-5.0°C at higher rates. Average proportion of allowable storage time elapsed drops quickly from 0.58 with no ventilation, to 0.24 with 0.5 (L/sec)/m³ and levels off at about 0.20 at higher airflow rates.

Energy use increases rapidly with increasing airflow rate; however, in all cases, energy use is low. For example, at an electricity cost of $0.01/MJ, and wheat priced at $200/tonne, the 3.0 (L/sec)/m³ airflow rate costs about $0.28/tonne for continuous ventilation over 60 days, or less than 0.2% of the grain value.
aeration of 15% wheat at Winnipeg, and consistent with past recommendations (Friesen and Harms 1980; Cloud and Morey 1979; Holman 1960; Johnson 1957; Shove 1962).

Based on this airflow rate analysis, 1.0 \((L/sec)/m^3\) was selected for investigating the various fan control methods. Grain temperatures and average allowable storage times are not reduced significantly by airflow rates greater than 1.0 \((L/sec)/m^3\). At higher airflow rates, moisture content can be reduced excessively below the economical minimum of 14.5%. The increase in energy use at airflow rates greater than 1.0 \((L/sec)/m^3\) does not appear to be justified for continuous operation. If higher airflow rates are used with intermittent operation during the fall cool-down period, energy use may be comparable because of the shorter fan operating times required to cool the grain. This, however, would require more intensive management by the operator, or a suitable fan controller to eliminate the possibility of overdrying the grain and unnecessary energy use. The higher capital cost of larger fans can be more significant than the energy costs.

A 100-tonne mass of wheat \((133 m^3\) volume) stored in a 5.97-m-diameter bin results in a grain depth of 4.67 m. To provide an airflow rate of 1.0 \((L/sec)/m^3\), a 0.16-kW fan operating at a total efficiency of 0.2 is required (Metzger et al. 1981). This results in a temperature rise across the fan of 0.9°C. These values were used in all aeration simulations requiring an airflow rate of 1.0 \((L/sec)/m^3\).

Control Methods for Fan Operation During the Fall Cool-Down Period at Winnipeg

Humidistat control

The uncertainty over which is the best type of fan control method is due, in part, to differing opinions about the effect that each method may have on the grain condition. This is further complicated by variations in climate and by the complexity of the heat and moisture transfer relationships which exist during grain ventilation under constantly changing air conditions. Five methods of controlling fan operation during the fall cool-down period were evaluated for Winnipeg.

Humidistat control permits fan operation only at ambient-air relative humidities less than the maximum set on the humidistat. Humidistat control was evaluated for relative humidity settings from 0% or no ventilation to 100% or continuous ventilation (Fig. 8).

As the humidistat setting was increased from 0 to 100%, the average grain moisture content after 60 days of storage during the fall cool-down period was reduced. Increases in average moisture contents due to rewetting at higher relative humidities were expected with humidistat settings greater than 70%. The fact that predicted grain moisture content continued to decrease with increased humidistat settings can be partly explained by the addition of fan heat to the air. For example, if the temperature of saturated air at 10°C is raised by 0.9°C, the relative humidity of that air reduces to about 93%. This air would have a slightly reduced potential for rewetting the grain than would saturated air. To test this hypothesis, 70% and

![Figure 8.](image)

**Figure 8.** Grain condition and energy consumption after the fall cool-down period with humidistat controlled aeration at Winnipeg. (Simulation parameters: 6-m-diameter bin; fully perforated floor; 1.0 \((L/sec)/m^3\) airflow rate; 100-tonne wheat; 1 Sept. harvest date; 15% initial moisture content; 23.6°C initial temperature; mean and standard deviations for 1961–1977 weather data).
100% relative humidity simulations were carried out using a temperature rise across the fan of only 0.1°C (Fig. 8). Average moisture contents were slightly higher than for the 0.9°C simulations by 0.02 percentage points at a humidistat setting of 70%, and 0.10 percentage points at a humidistat setting of 100% relative humidity. Due to yearly climatic variations there was no statistical difference between the mean grain moisture contents at the 70 and 100% humidistat settings, at the 1% level of significance. The fact that the average moisture content was still not greater at 100% relative humidity than at 70% relative humidity may be further explained by the relatively low temperature associated with high humidities during the fall. Lower temperatures during the fall offer a reduced potential for rewetting and if this air warms as it passes through the grain bulk, its relative humidity is reduced to offer little or no potential for rewetting, and may even contribute to moisture removal.

Average grain temperature decreased from 12.5°C to about 3.6°C as humidistat setting was increased to 70%. As humidistat setting was further increased, the average temperature increased slightly to about 4.3°C at continuous operation, however, due to yearly climatic variations, at humidistat settings of 60% or greater no statistical difference exists between the mean temperatures at the 1% level of significance.

Thermostat control

A major objective of aeration is to cool the grain. Thermostatic control permits fan operation only at ambient air temperatures less than the maximum set on the thermostat. Average moisture content of the grain reached a minimum with a 10-20°C thermostat setting (Fig. 9). As thermostat settings were increased to 25°C or greater (i.e., continuous fan operation), the resultant average moisture contents were higher. This may be due to the greater rewetting potential of warm air which can carry more moisture than cold air. Warm air blown into the bin during the day could deposit considerable moisture in the layers of grain cooled by nighttime air.

Higher thermostat settings resulted in nearly continuous ventilation. There were no statistical differences in mean grain temperatures for thermostat settings of 0°C and greater, at the 1% level of significance. Average proportion of allowable storage time elapsed decreased with increases in thermostat setting. The cooling air reached the warm grain sooner with the higher thermostat settings resulting in reduced storage time elapsed. There were no statistical differences in mean allowable storage time elapsed at thermostat settings of 15°C and greater, at the 1% level of significance.

Energy consumption at thermostat settings of 15°C and over was 80–100% of the energy consumption during continuous operation. Overdrying at 15°C was 0.4 percentage points. As the thermostat setting was increased, overdrying was reduced and energy consumption increased. The thermostat did not provide an effec-
Time-clock control

A time-clock controls fan operation by time of day only. Because nighttime air temperatures are usually lower than daytime temperatures, and control or reduction of grain temperatures is the prime objective of aeration, two control strategies, using 6-h and 12-h nighttime operation of the fan, were simulated (Table I). (Due to the method the simulation model uses to control fan operating times, the fan operation time periods are slightly greater than 6 and 12 h, the energy use values are not direct multiples of each other, as would be expected.)

Although the 12-h schedule with fan operation from 1800 h to 0600 h resulted in a slightly lower average proportion of allowable storage time elapsed than the 6-h schedule from 0000 h to 0600 h, there is no significant difference between these values at the 1% level of significance. The 6-h schedule resulted in about one-half the energy consumption of the 12-h schedule.

Differential thermostat control

The differential thermostat measures the temperature difference between two sensors. One is located in the grain approximately 0.5 m below the top surface, the other measures the dry bulb temperature of the ambient air. Fan operation is permitted only when the temperature of the ambient air is less than the temperature of the top grain layer plus the differential thermostat setting. For example, a \(-5\)°C differential thermostat setting would result in fan operation only when the ambient air temperature is at least \(5\)°C below the average temperature of the top layer of grain.

The differential thermostat is more complicated to physically install in an aeration system than the other controllers previously discussed. It does, however, sim-
ulate the optimum level of manual control, since it is the only method modelled which relates ambient air conditions to grain conditions. A conscientious operator would attempt to manage an aeration system by carefully monitoring grain temperatures and weather changes, and controlling fan operation in a manner similar to the differential thermostat. Cloud and Morey (1979) suggested that the fan be operated when average air temperatures are at least 6°C below the temperature of the top layer of grain. This would correspond to a differential thermostat setting of −6°C.

Predicted average grain moisture contents were reduced below 14.5% by about 1.0 percentage points using a differential thermostat range of 4 to −6°C (Fig. 10). Assuming $200/tonne to be the value of wheat at 14.5% moisture content, the average overdrying cost at a thermostat setting of 0°C is $1.53/tonne, or more than 20 times the energy cost for continuous fan operation. Fan operating time and energy costs were reduced significantly at thermostat settings of −10°C and less; however, the average proportion of allowable storage time elapsed began to increase more rapidly at this point. The relatively steep slopes of the moisture content, and proportion of allowable storage time elapsed relationships at a setting of −10°C, indicate that the resulting grain condition (except final grain temperature) is sensitive to small changes in differential thermostat setting. There was no difference in final mean grain temperature at the 1% level of significance for differential thermostat settings between 5 and −15°C.

**Control method comparison**

All aeration methods significantly reduced grain deterioration as compared with no ventilation. If fan control methods are evaluated on the basis of minimizing the average proportion of allowable storage time elapsed and minimizing overdrying and energy consumption the following comparisons become evident: (1) Continuous operation provided effective quality control without excessive overdrying; however, energy use was maximum at 8.1 MJ/tonne. (2) Humidistat operation provided effective quality control in the 50% and over relative humidity range, with no overdrying up to the 90% setting. Energy use decreased with decreasing relative humidity setting, such that at a setting of 60%, energy consumption was 2.3 MJ/tonne. This is a reduction of 72% from energy use for continuous operation. (3) Thermostat operation provided effective quality control at settings of 15°C and greater. Overdrying, with moisture reductions from the initial moisture content of 0.8 percentage points or more, occurs in the 10 to 20°C range. At thermostat settings of 15°C and greater, energy consumption was more than 2.8 times greater than that for the humidistat control setting of 60%. (4) Both time-clock operations provided effective quality control with no overdrying. Average energy use was 2.2 MJ/t with the 6-h schedule, and 4.2 MJ/tonne with the 12-h schedule. (5) Differential thermostat operation provided good quality control at settings of +10°C (continuous operation) to −10°C, but considerable overdrying occurred in the +5 to −5°C range. Energy use decreased from 6.2 MJ/t at 0°C to 1.4 MJ/tonne at...

![Figure 11](image-url)
Aeration During the Fall Cool-Down Period: Comparison of Prairie Climates

Humidistat control

Predictions of grain condition with humidistat controlled aeration at the three other climatic areas of Western Canada yielded similar results to those obtained for Winnipeg (Fig. 11). Differences reflect variations in climate during the 60-day fall cool-down period. The semi-arid climate of Swift Current caused the most drying and in turn reduced grain deterioration. The colder temperatures of the sub-boreal climate at Edmonton and Fort St. John resulted in the lowest final grain temperatures and the lowest grain deterioration.

Average moisture content, grain temperature, proportion of storage time elapsed, and energy use trends are all similar in shape. Based on these results, maximum relative humidity settings between 50 and 70% result in the following: maximum reduction in proportion of allowable storage time elapsed; energy use ranging from 16 to 57% of continuous operation; and average reductions from initial moisture content of 0.2 to 0.5 percentage points. Humidistat settings greater than 70% would result in further moisture content reductions and increased energy use, with little reduction in proportion of allowable storage time elapsed. These humidistat settings should be used only if greater moisture content reductions are required.

Time-clock control

The 6-h and 12-h-per-day time-clock control ventilation schedules were simulated for the three other Prairie climates (Tables II, III, and IV). As with Winnipeg, maximum benefit was achieved with the 6-h schedule. Swift Current was the only location where a significant reduction in the average proportion of allowable storage time elapsed was achieved by using the 12-h rather than the 6-h schedule; however, energy use was nearly doubled by the 12-h schedule of fan operation. As with the simulation of Winnipeg, operating time periods are simulated for slightly longer than 6 and 12 h. Therefore, the energy-use values shown are not direct multiples of each other.

Differential thermostat control

Predictions of grain conditions using differential thermostat control at Swift Current, Edmonton, and Fort St. John yielded similar trends to those obtained for Winnipeg (Fig. 12). Overdrying is a problem which provided adequate quality control, this method results in the lowest energy use. Based on minimizing both overdrying and proportion of allowable storage time elapsed, most suitable differential temperature settings are near −10°C for Edmonton and Fort St. John.

TABLE II. GRAIN CONDITION AND ENERGY CONSUMPTION AFTER THE FALL COOL-DOWN PERIOD WITH TIME-CLOCK-CONTROLLED AERATION AT SWIFT CURRENT. (SIMULATION PARAMETERS: 6-m-DIAMETER BIN; FULLY PERFORATED FLOOR; 1.0 (L/sec)/m³ AIRFLOW RATE; 100-TONNE WHEAT; 1 SEPT. HARVEST DATE; 15% INITIAL MOISTURE CONTENT; 22.4°C INITIAL TEMPERATURE; MEAN AND STANDARD DEVIATIONS FOR 1961-1977 WEATHER DATA)

<table>
<thead>
<tr>
<th>Fan operation</th>
<th>Moisture content (%)</th>
<th>Grain temperature (°C)</th>
<th>Proportion of allowable storage time elapsed</th>
<th>Energy use (MJ/tonne)</th>
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</thead>
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<tr>
<td>6 h/day (0000-0600 h)</td>
<td>14.5±0.1</td>
<td>3.7±2.3</td>
<td>0.23±0.04</td>
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<tr>
<td>12 h/day (1800-0600 h)</td>
<td>14.5±0.1</td>
<td>3.8±3.6</td>
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<td>24 h/day (continuous)</td>
<td>14.2±0.2</td>
<td>3.6±3.9</td>
<td>0.16±0.03</td>
<td>8.1</td>
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</tbody>
</table>

TABLE III. GRAIN CONDITION AND ENERGY CONSUMPTION AFTER THE FALL COOL-DOWN PERIOD WITH TIME-CLOCK-CONTROLLED AERATION AT EDMONTON. (SIMULATION PARAMETERS: 6-m-DIAMETER BIN; FULLY PERFORATED FLOOR; 1.0 (L/sec)/m³ AIRFLOW RATE; 100-TONNE WHEAT; 1 SEPT. HARVEST DATE; 15% INITIAL MOISTURE CONTENT; 19.7°C INITIAL TEMPERATURE; MEAN AND STANDARD DEVIATIONS FOR 1961-1975 WEATHER DATA)

<table>
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<th>Fan operation</th>
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<th>Grain temperature (°C)</th>
<th>Proportion of allowable storage time elapsed</th>
<th>Energy use (MJ/tonne)</th>
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<tbody>
<tr>
<td>6 h/day (0000-0600 h)</td>
<td>14.6±0.1</td>
<td>2.6±2.2</td>
<td>0.18±0.03</td>
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<tr>
<td>12 h/day (1800-0600 h)</td>
<td>14.5±0.1</td>
<td>2.3±2.6</td>
<td>0.16±0.02</td>
<td>4.3</td>
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<tr>
<td>24 h/day (continuous)</td>
<td>14.5±0.2</td>
<td>2.3±2.7</td>
<td>0.15±0.02</td>
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TABLE IV. GRAIN CONDITION AND ENERGY CONSUMPTION AFTER THE FALL COOL-DOWN PERIOD WITH TIME-CLOCK-CONTROLLED AERATION AT FORT ST. JOHN. (SIMULATION PARAMETERS: 6-m-DIAMETER BIN; FULLY PERFORATED FLOOR; 1.0 (L/sec)/m³ AIRFLOW RATE; 100-TONNE WHEAT; 1 SEPT. HARVEST DATE; 15% INITIAL MOISTURE CONTENT; 18.5°C INITIAL TEMPERATURE; MEAN AND STANDARD DEVIATIONS FOR 1961-1977 WEATHER DATA)

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<tr>
<th>Fan operation</th>
<th>Moisture content (%)</th>
<th>Grain temperature (°C)</th>
<th>Proportion of allowable storage time elapsed</th>
<th>Energy use (MJ/tonne)</th>
</tr>
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<tbody>
<tr>
<td>6 h/day (0000-0600 h)</td>
<td>14.7±0.1</td>
<td>2.2±2.1</td>
<td>0.17±0.02</td>
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<tr>
<td>12 h/day (1800-0600 h)</td>
<td>14.6±0.1</td>
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<td>0.15±0.02</td>
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<td>24 h/day (continuous)</td>
<td>14.5±0.1</td>
<td>2.4±2.8</td>
<td>0.14±0.02</td>
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</tr>
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</table>
Intermittent Aeration During the Winter and Summer Periods

Following the fall cool-down period, an intermittent ventilation regime consisting of 96 h of fan operation every 8 wk (airflow rate 1.0 (L/sec)/m³) was established. Operation was limited to ambient air temperatures between -10 and +10°C. The resulting average grain bin temperatures on 1 Apr. were -4.5°C at Swift Current, -4.9°C at Fort St. John, -5.5°C at Edmonton, and -6.8°C at Winnipeg. In all aeration cases, the model predicted that the largest deterioration in grain quality would occur during the 5-mo summer period (Fig. 13).

Summer ventilation is recommended as a preventive measure against moisture migration in the summer. Unfortunately, the model cannot simulate moisture migration; however, deterioration was simulated with no ventilation during the summer (Fig. 13). The low grain temperatures achieved by intermittent winter ventilation resulted in reductions in the proportion of allowable storage time elapsed, compared with intermittent summer ventilation which warms the grain. If moisture migration during the summer does occur then summer ventilation may be effective in preventing serious grain deterioration; however, if moisture migration is not a problem, summer ventilation increases the deterioration of the stored grain.

CONCLUSIONS

1. All continuous aeration airflow rates between 0.5 and 3.0 (L/sec)/m³ greatly decreased the rate of grain deterioration during the fall cool-down period at Winnipeg. An airflow rate of 1.0 (L/sec)/m³, operated continuously for 60 days, was judged preferable in terms of minimizing overdrying, grain temperature, and energy use for wheat harvested at 15% moisture content on 1 Sept. As well, the low airflow rates resulted in less variability of the final moisture content from year to year.

2. Ventilating with any of the fan control methods considered resulted in decreased grain deterioration as compared with no ventilation.

3. The choice of fan control method is independent of climate within the range of climates studied. It may be, however, that fan control method selection should be affected by harvest date and initial moisture content. These two parameters were not studied here.

4. Humidistat control with settings of 50–70% relative humidity resulted in effective control of grain quality deterioration; energy use ranging from 16 to 57% of that for continuous operation; and moisture content reductions of 0.2–0.5 percentage points.

5. Humidistat settings greater than 70% resulted in greater moisture content reductions and energy use than lower settings.

6. Thermostat control did not provide an effective means of reducing the rate of grain quality deterioration, energy use or overdrying.

7. A 6-h time-clock control between
0000 h and 0600 h provided effective grain quality control, reduced energy use, and minimized moisture content reductions for all climates. Swift Current was the only location at which the 12-h schedule of fan operation between 1800 h and 0600 h provided effective grain quality control, reduced energy use, and the average proportion of allowable storage time elapsed.

8. Differential thermostat settings of −10 to −15°C provided effective control of grain quality deterioration, with energy use ranging from 10 to 26% of that for continuous fan operation, and moisture content reductions of 0.3–0.6 percentage points.

9. Intermittent summer ventilation predicted increased grain quality deterioration when compared with no summer ventilation. However, because the effects of moisture migration in the summer were not included in the unventilated simulation, the need for intermittent summer ventilation cannot be determined with these data. If moisture migration in the summer is not a major cause of deterioration, summer ventilation may be a liability.

10. Regardless of fan control method, stored wheat showed lower rates of deterioration in the sub-boreal and sub-humid prairie climates than in the semi-arid and humid prairie climates.

11. Initial grain temperature affects the rate of deterioration more significantly in unventilated than in ventilated storages. Weather conditions after harvest date affect the rate of deterioration less in unventilated than in ventilated storages.

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