Quality Assurance of Paddy & Rice by Grain Cooling/Grain Chilling

FrigorTec LP
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GRANIFRIGOR™ Grain Cooling

- Suctioned ambient air will be cooled down and de-hydrated.
- HYGOTHERM™ heats up the cold and wet air a little again, so the relative humidity decreases.
- Conditioned air is pressed through the grain in storage.
- Cold air takes energy (moisture and temperature) from the Grain and moves it to the Exhaust.

**Temperature**

- Ambient air: 100 °F / 80 % r.H.
- Ambient air: 75 °F / 50 % r.H.
- Chilled Air: 45 °F / 100 % r.H.
- Reheated air 52 °F / 65 % r.H.
Storage time for grain (days)

Grain temp. (°F)
- 90
- 84
- 80
- 75
- 70
- 64
- 60
- 55
- 50
- 44
- 40

Grain moisture (%)
- 1
- 2
- 4
- 8
- 16
- 32
- 64
- 128
- 256
- 512
- 1024
- 13
- 14
- 15
- 16
- 17
- 18
- 19
- 20
- 21
- 22
- 23

Approx. 3 weeks

Guidelines for grain cooling!

The storage time and treatment measures depend on the results of continuous controls.
Losses through respiration

The grain respiration – total formula of the chemical process:

\[ \text{C}_{12}\text{H}_{22}\text{O}_{11} + 12 \text{ O}_2 \rightarrow 12 \text{ CO}_2 + 11 \text{ H}_2\text{O} + 1.567 \times 10^{-3} \text{ kWh} \]

carbohydrates + oxygen → carbon dioxide + water + heat

Grain lives, it breathes and produces heat!

➢ **Dependent on product moisture content and -temperature**
Heat generation of Rice (acc. to Jouin)

Heat generation [M\text{J}/\text{t}, \text{day}]

Grain’s moisture content [%]

- 30
- 26
- 22
- 20
- 18
- 17
- 16
- 15
- 14
- 13

Grain temperature [°F]

41 56 77 95 133

14.5%
Calculation of respiration / Substance losses

<table>
<thead>
<tr>
<th>Data</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Grain type</td>
<td>Rice</td>
<td>Weight = 49 bu/t</td>
</tr>
<tr>
<td>Grain moisture</td>
<td>14,5%</td>
<td></td>
</tr>
<tr>
<td>Grain temperature</td>
<td>25 °C / 77 °F</td>
<td></td>
</tr>
<tr>
<td>Grain price</td>
<td>320 US$/t</td>
<td>(US$6.5/Bu)</td>
</tr>
<tr>
<td>Storage time</td>
<td>120 days</td>
<td></td>
</tr>
<tr>
<td>Storage quantity</td>
<td>10.000 t</td>
<td>490,000 Bu</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Formula</th>
<th></th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Result</th>
<th>Grain losses [t]</th>
<th>Losses [US$]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grain stored at 25°C / 77°F</td>
<td>60,0 (2.940 Bu)</td>
<td>19,200</td>
</tr>
<tr>
<td>Grain stored at 20°C / 68°F</td>
<td>37,0 (1.813 Bu)</td>
<td>11,840</td>
</tr>
<tr>
<td>Grain stored at 12°C / 55°F</td>
<td>negligible (&lt; 1)</td>
<td>-</td>
</tr>
</tbody>
</table>
GRANIFRIGOR™ Grain Cooling

Slowly reheating of cold stored grain, Paddy and rice because of:

- Only point contact of grain
  - Low convection of air between the grain
  - Slow reheating as result of reduced respiration

Advantages:

- Grain stays cool for 4 - 6 months
- Also in tropical area
- One cooling cycle required
- Considering energy savings to ventilation
GRANIFRIGOR™ Grain Cooling

Insects

Lesser grain borer
*Tribolium castaneum*

Maize weevil
*Sitophilus zeamais*

Granary weevil
*Sitophilus granarius*

Rice weevil
*Sitophilus oryzae*
Development of damaging insects

- **Grain weevil**
- **Rice weevil**
- **Lesser grain borer**
- **Flour moth**
- **Rice flour beetle**

°F

- **Optimum development**
- **No development**
Development of rice weevil

Number of grain weevils

- Juni
- Juli
- August
- September
Development of various mould fungi

- Fusarium culmorum
- Penicillium rugulosum
- Penicillium cyclopium
- Aspergillus versicolor
- Aspergillus glaucus
- Absidia rhizopus arrhizus
- Streptomyces altus
- Aspergillus candidus
- Penicillium capsulatum
- Talaromyces thermophilus

Fusarium culmorum
Aspergillus glaucus

400 x
Sorption isotherm of grains at ≈ 70 °F

- Barley 25°C
- Wheat 25°C
- Corn 20°C
- Oats 25°C
- Rape 20°C
- Rice 20°C
**GRANIFRIGOR™ Grain Cooling**

**Ventilation with Ambient Air**

Starting with Grain temperature of 75 °F

First night ventilation with 65 °F

High risk of condensation and spoiling after stopping the aeration fans

Never blow warm or humid air to the Grain to prevent spoiling

**GRAIN COOLING**

After starting the GRANIFRIGOR the Grain Cooler handle the humidity and temperature and is running 24/7 until the Silo is completely cooled.

No risk of condensation inside the Silo!
## Drying Effect

<table>
<thead>
<tr>
<th>Grain moisture</th>
<th>Drying effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 17 %</td>
<td>&gt; 1,5 %</td>
</tr>
<tr>
<td>14% – 17%</td>
<td>~ 0,5% - 1,5 %</td>
</tr>
</tbody>
</table>
GRANIFRIGOR™ Grain Cooling

Combination drying - cooling

- 1st drying step: 86 °F
- 2nd drying step: 95 °F (tempering)
- 3rd drying step: 95 °F
- Cooling: 59 °F (storage for milling or 2nd cooling)

Cooling time depends on cooling capacity and storage capacity.

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Combination drying - cooling

- 1st drying step: 95 °F for 5 days
- 1st cooling: 59 °F for 20 days
- 2nd drying step: 95 °F for 5 days
- 2nd cooling: 59 °F
- storage

Cooling time depends on cooling capacity and storage capacity.

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Combination drying - cooling

conventional System

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Husk</td>
<td>20%</td>
</tr>
<tr>
<td>Bran</td>
<td>10%</td>
</tr>
<tr>
<td>Broken Rice</td>
<td>5%</td>
</tr>
<tr>
<td>Head Rice</td>
<td>65%</td>
</tr>
</tbody>
</table>

combination drying - cooling

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<tr>
<td>Husk</td>
<td>20%</td>
</tr>
<tr>
<td>Bran</td>
<td>10%</td>
</tr>
<tr>
<td>Broken Rice</td>
<td>2%</td>
</tr>
<tr>
<td>Head Rice</td>
<td>68%</td>
</tr>
</tbody>
</table>

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Economical Feasibility (Flexibility)

Barley, Canadian no.1 Western Barley, spot price, US$ per metric ton

Apr 2009 - Mar 2010: 36,02 (32.44 %)

Source: International Monetary Fund
Energy consumption during cooling

depending on:

- Ambient air humidity and temperature
- Grain moisture and temperature
- Adjusted cold-air humidity and temperature

Practical values:
8.0 – 10.0 kWh/t per ton Rice (tropical zones)
0.1 – 0.2 kWh/Bu per Bushel Rice (tropical zones)

4.0 – 6.0 kWh/t per ton Rice (moderate zones)
0.08 – 0.12 kWh/Bu per Bushel Rice (moderate zones)
### GRANIFRIGOR™ Grain Cooling

<table>
<thead>
<tr>
<th>Date:</th>
<th></th>
<th>City:</th>
<th>Belize</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Customer:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project:</td>
<td></td>
<td>Country:</td>
<td>Belize</td>
<td></td>
</tr>
<tr>
<td>Basic data of stored grain:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Storage time (days):</td>
<td>120</td>
<td>Temperature (°F):</td>
<td>65.0</td>
<td></td>
</tr>
<tr>
<td>Storage quantity (t):</td>
<td>7,000</td>
<td>Moisture content (%):</td>
<td>14.5</td>
<td></td>
</tr>
<tr>
<td>Storage quantity (bushels):</td>
<td>318,182</td>
<td>Grain self-heating factor:</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>Sales price (tonne):</td>
<td>$320.00</td>
<td>Loss to dust (Multiplier):</td>
<td>0.60</td>
<td></td>
</tr>
<tr>
<td>Total value of grain:</td>
<td>$2,240,000</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Energy cost:

| Electrical power (kW) | $0.190 | Oil ($/l) or Gas (m³) | $1.00 |

### GRANIFRIGOR™ Recommendation:

<table>
<thead>
<tr>
<th>Unit</th>
<th>KK310 Tropic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooling capacity/unit (Tropical climate)</td>
<td>(1)</td>
</tr>
</tbody>
</table>

#### Calculated number of units

<table>
<thead>
<tr>
<th>KK310 Tropic</th>
<th>(calculated)</th>
</tr>
</thead>
</table>

#### Practical number of units

<table>
<thead>
<tr>
<th>KK310 Tropic</th>
<th>(practical)</th>
</tr>
</thead>
</table>

#### Costs / year

|   | $28,548.45 |

### Flexibility in storage time (%)

|   | 0.1% |

### Keeping the freshness and quality of rice (%)

|   | 0.3% |

### No losses through insect pests (%)

|   | 0.1% |

### No losses through mould fungi (%)

|   | 0.1% |

### No moving of the grain:

- No abrasion (%)
- No labour & storage costs (%)

### No losses of dry substance (Jouin) (tonne)

|   | 50 | $16,000.00 |

### Savings (all) by minimizing the drying (1 %) ( Stored)

|   | $6,363.64 |

### No chemical treatment necessary* (€/t)

|   |   |

### No breakage (%)

|   | 1.5% |

### No decoloring (%)

|   | 0.2% |

### No oxidation (%)

|   |   |

### Number of aeration ventilators:

- Dissolved hours/day (during storage time) [h/day]
- Electrical power/unit of existing or new units [kW]
- Service & spare parts of existing or new units [%]
- Investment of new units [€]

### Savings / year

|   | $73,883.64 |

### GRANIFRIGOR™ investment:

| 1 units | $70,000.00 |

### Amortisation (ROI): 1.5 Years

* Fixed costs and fixed tax will become payable expenses.

** Remark:** All data are approximate practical values, based on the assumptions made and are therefore non-binding.

- Individual economic feasibility calculation
- Fast ROI
GRANIFRIGOR™ Grain Cooling

Advantages of grain conservation by cooling (Part 1)

• Risk-free long-term storage without quality loss

• Conservation of harvest freshness for outstanding taste of rice / grain

• Minimizing respiration losses

• Protection from insects and their damage

• Avoiding expensive and unecological chemical treatment

• Protection of organic grain, paddy and rice

• Protection from fungi and their mycotoxins

• Reduction from drying costs and energy consumption

• No yellow discoloration of rice because of over drying and low storage quality

• Higher head rice recovery because of less fissures and cracks
Advantages of grain conservation by cooling (Part 2)

• Higher milling performance and efficiency
• No aggressive rice polishing
• Faster parboiling with brighter whiteness of rice (moisture content)
• Simplification of storage management
• No breakage of Rice by circulation
• Conservation of germinating quality for fast grow and high yield
• Independent operation of weather conditions
• Increase of revenue and improving of market position
• Short amortization period
GRANIFRIGOR™ Grain Cooling in Silos

GRANIFRIGOR™ KK 145 TY
Grain cooling with flexible air hose

GRANIFRIGOR™ KK 220
GRANIFRIGOR™ Grain Cooling

Application

In general: all kind of grains and (oil) seeds

- (Buck)wheat
- (Malting) barley
- Maize
- Millet
- Oats
- Rye
- Sorghum
- Rice, paddy
- Rapeseed / Oil seeds
- Sunflower seed

- Hops
- Soybeans
- Peanuts
- Peas
- Grass seeds
- Potatoes
- Nuts
- Pellets
- Coffee
- Cacao beans
Thank you for your attention!

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