AGI FRAME

Maintaining grain quality in stored grains through good management & well designed aeration systems

29TH ANNUAL
IAOM
MIDEAST & AFRICA
CONFERENCE & EXPO
22-25 October 2018, Nairobi-Kenya

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INTERNATIONAL ASSOCIATION OF OPERATIVE MILLERS

TOPICS

- Introduction to food safety and challenges on stored product protection - *The state of the art*
- Grain losses overview
- Aeration system design for steel bins
- Aeration system management
- Future visions

INTRODUCTION

- **1/3** of grains produced is lost or wasted each year before consumed:
  - Temperate climates: **1-2%** loss during storage
  - Warm climates : **10%** loss during storage
- population growth increase food (and then grains) demand
- climate changes are affecting agricultral productity all around the world
- lack of knowledge on aeration operations

INTRODUCTION

FRAME FLAT BOTTOM silo mod.FP 23/20

D=21 m

H=23 m

V=7000 m^3

C=5500 MT (Wheat basis)

Which is the real value?

Storage building cost

≈ 150.000 € ÷ 200.000 €

- Including foundation and assembly cost
- Once for building lifetime (20÷30 years)

TOTAL VALUE STORED

≈ 1 M€

- Yearly turnover

GRAIN QUALITY & GRAIN LOSSES

Grain quality factors:

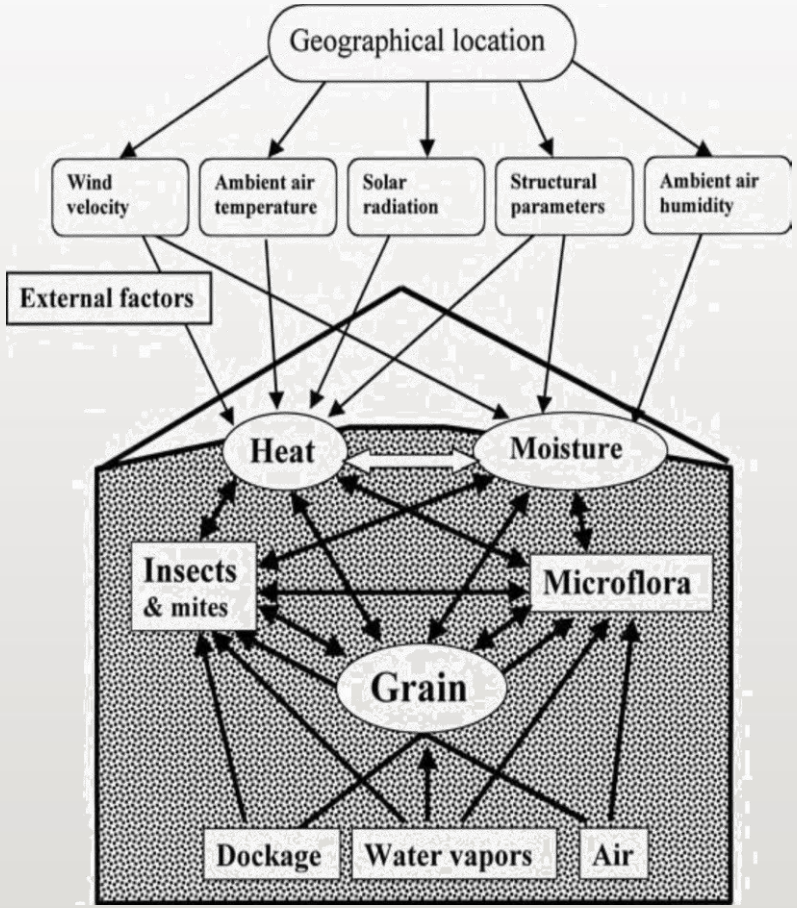
- moisture content
- specific weight (bulk density)
- foreign material contamination
- protein and oil content
- color (percentage of discolored kernels)
- percentage of broken/damaged kernels
- insects and molds presence

GRAIN LOSSES

GRAIN QUALITY & GRAIN LOSSES

- Grain losses due to insects and molds presence:
  - Quantitative
  - Qualitative
- How do they behave?
  - Insects life influenced by temperature
  - Molds activity influenced by moisture content

Stored grain ecosystem



STORAGE & GRAIN LOSSES

Storage = longest time where the grain stays throughout the cycle of its processing.

Aeration= practice of moving air through stored grain to control the ecosystem

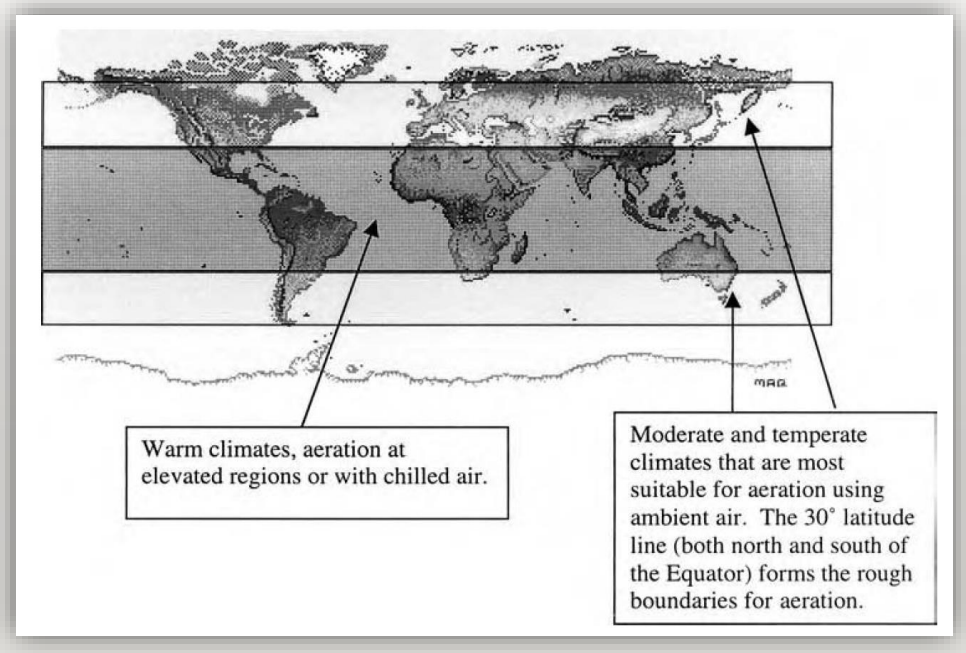
Design

AERATION SYSTEM
TO REDUCE GRAIN LOSSES

Management

AERATION SYSTEM PURPOSES

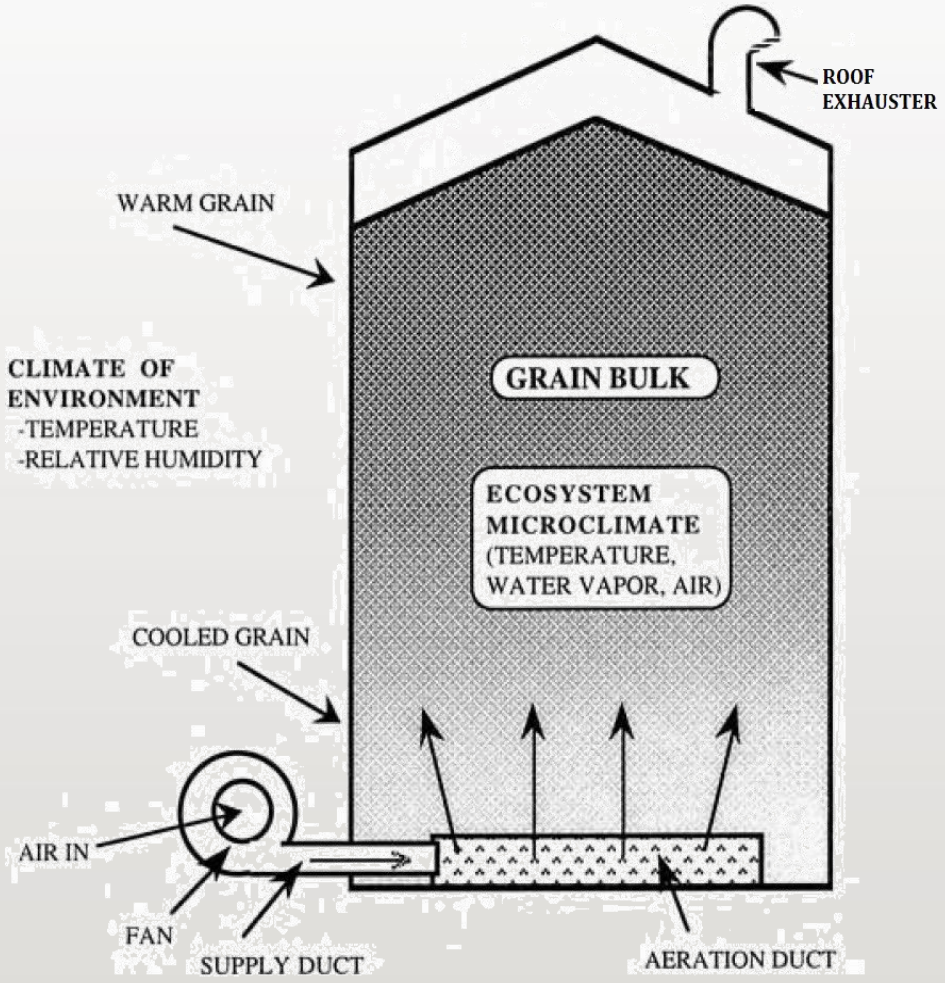
- Ventilation
  - **6 ÷ 8** **m^3/h/Ton** for temperate climates
  - **10 ÷ 15** **m^3/h/Ton** for warm regions (limited cooling time)
- Drying
  - Almost **10 times** the above values
- Chilling
- *Fumigation*



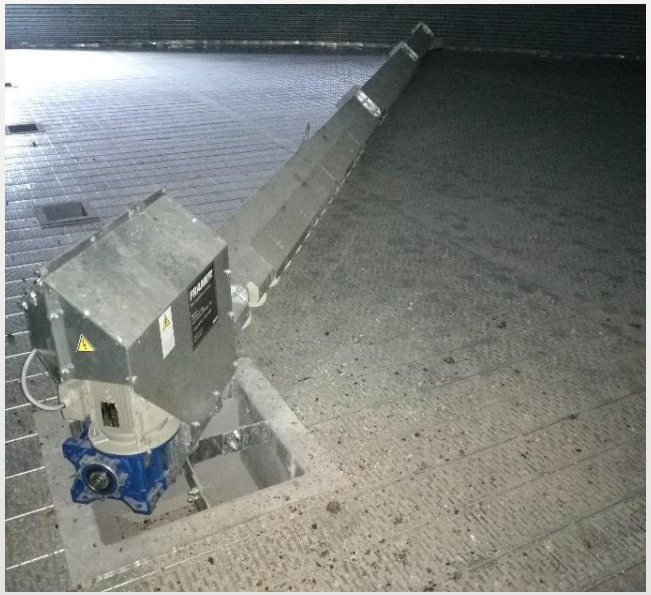
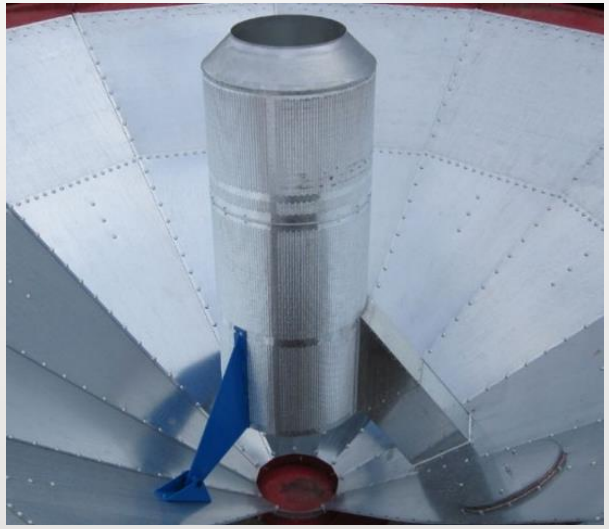
AERATION SYSTEM DESIGN

Asses the fan power requirement:

- Aeration flooring system
- Transition ducts
- Grain bulk depth
- Roof exhauster
- Fan power requirement

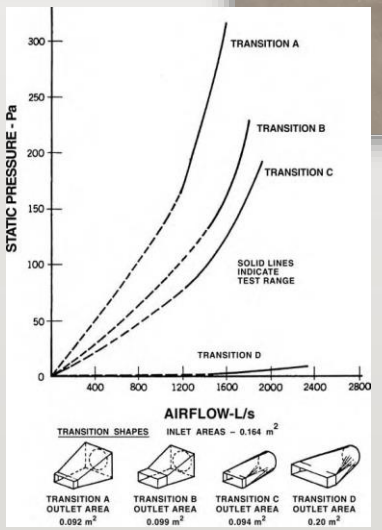


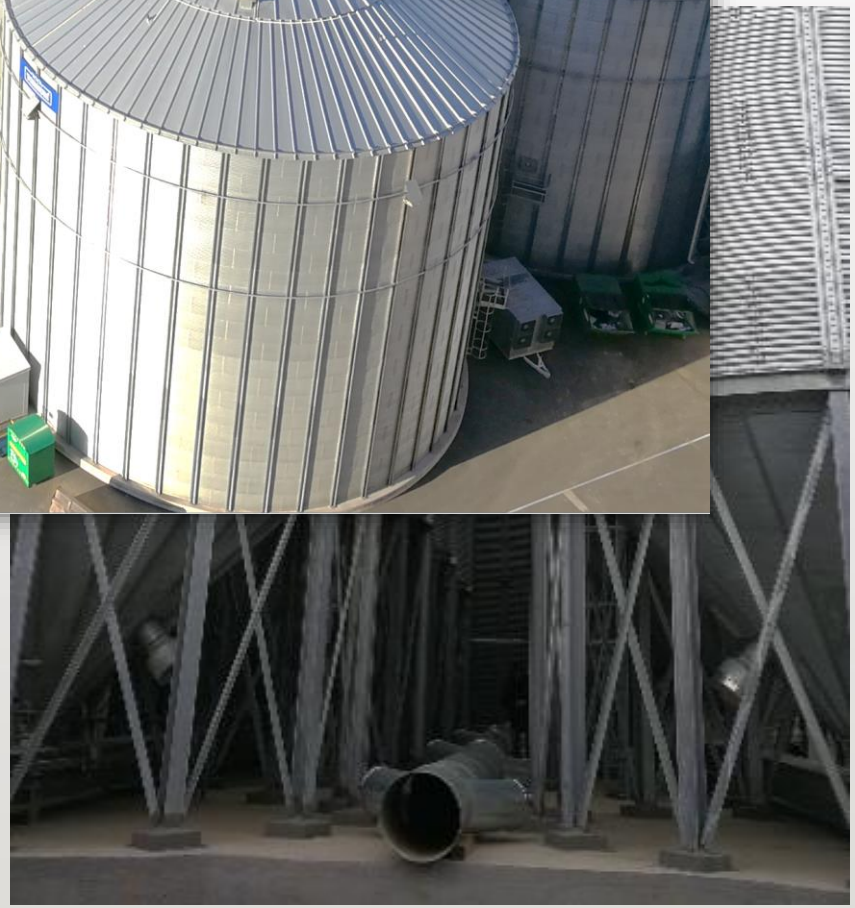
AERATION FLOORING SYSTEM

Flat bottom silos		Hopper bottom silos	
Partially perforated floors	**Fully perforated floors**	**Rocket system**	**Aeration pipes**
			
• Perforated surface ≥15% total floor surface (including dead surface) • Simplified rules to calculate airflow resistance	• Uniform airflow throughout the grain bulk • Negligible resistance to airflow if openings area >20% total floor surface	• Suitable for small size bins • Improved airflow in the grain bulk core	• Suitable for huge size bins • Suitable for high air flow rates

TRANSITION DUCTS

- Air velocity **≤ 10 m/s**
- No sudden changes in cross-sections
- Elbows R> 1.5-2D duct
- Unloading tunnel as a supply ducts
- Manifold supply duct for individual hopper bins

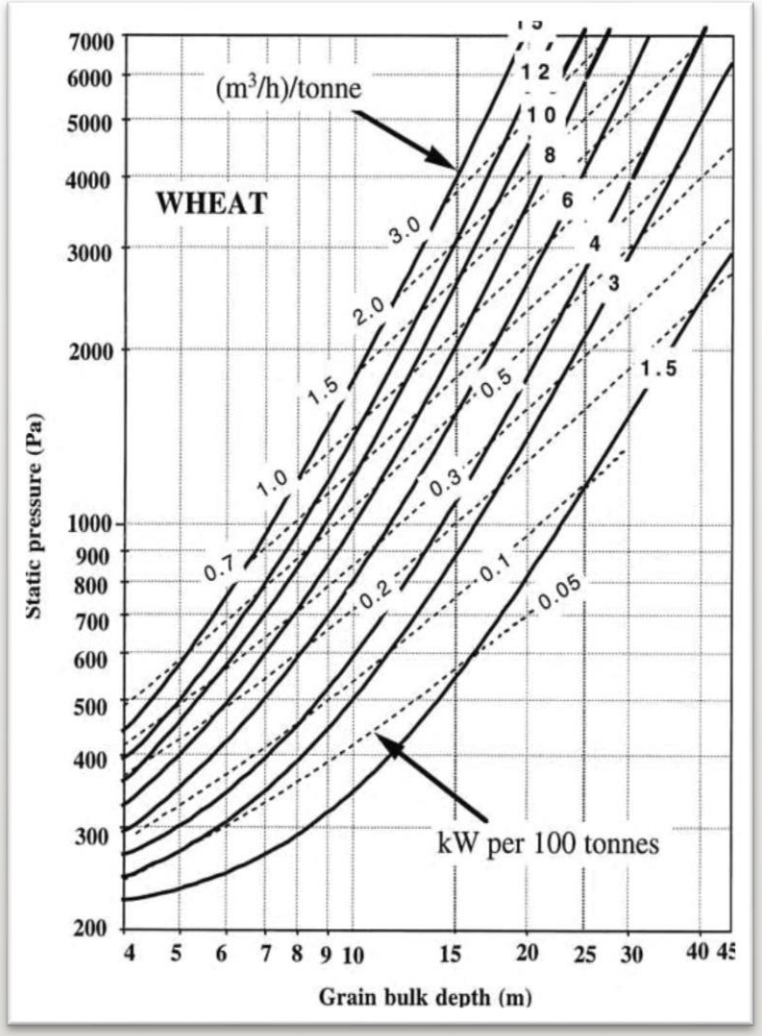




GRAIN BULK DEPTH

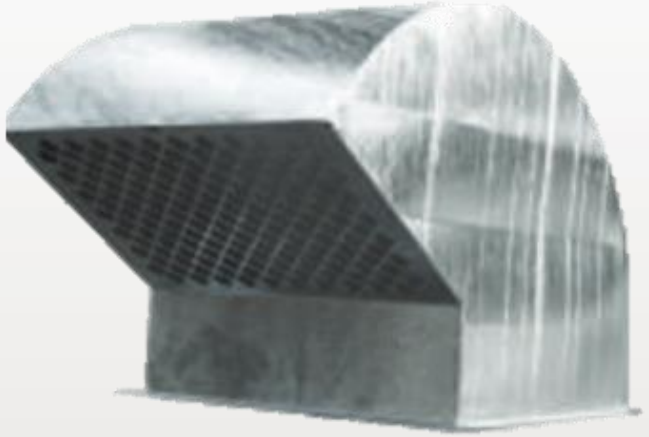
- Resistance to airflow through the grain is the most significant design factor
- Moisture content, airflow rate & direction through the grain and filling method influence the resistance to airflow

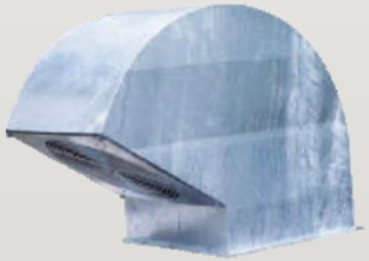
$$\frac{\Delta P}{L} = \frac{\alpha V^2}{\ln(1 + bV)}$$



ROOF VENTS/EXHAUSTER

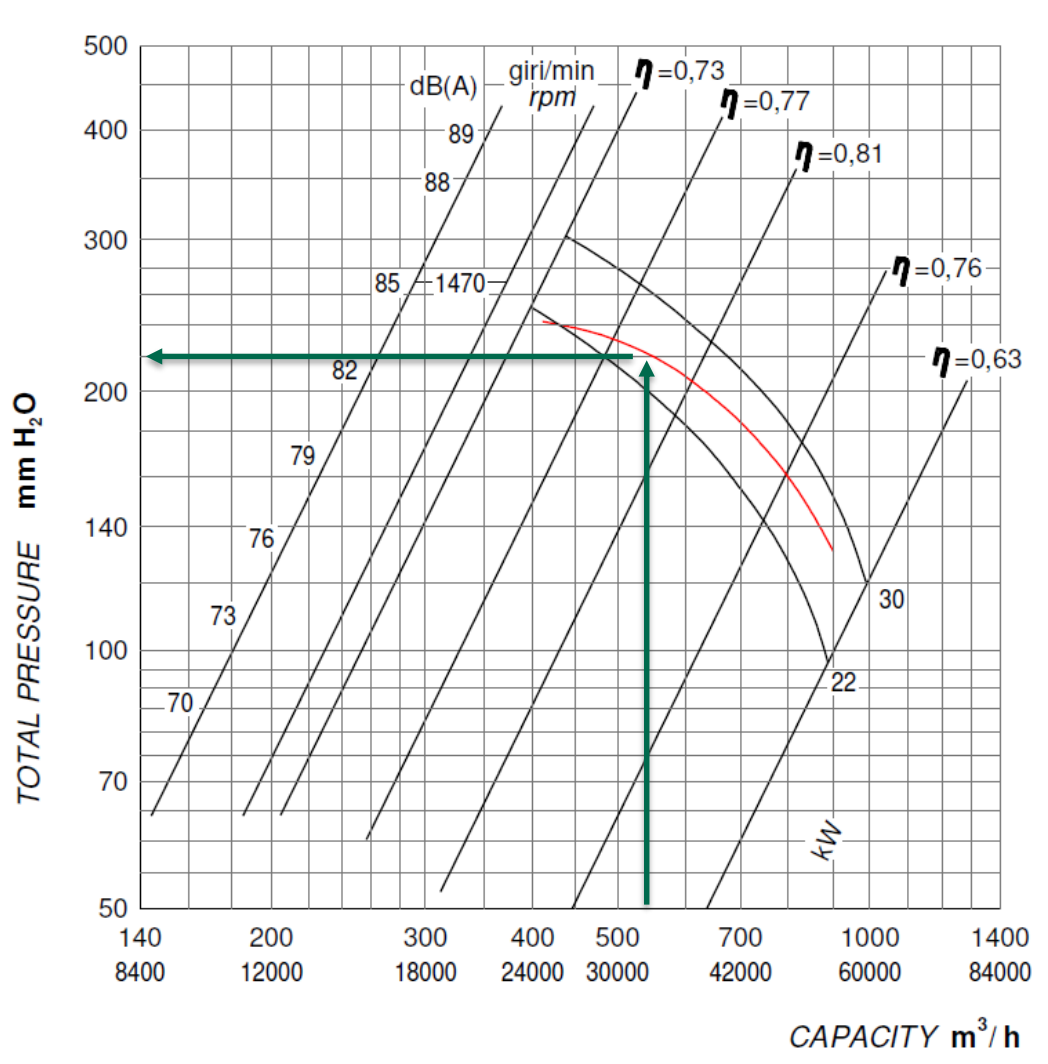
- Air velocity **≤ 7.5 m/s**;
- «Gooseneck» weather shielding;
- screened to prevents birds entrance;
- equally spaced;
- **1/3** height from eave;





FAN POWER SELECTION

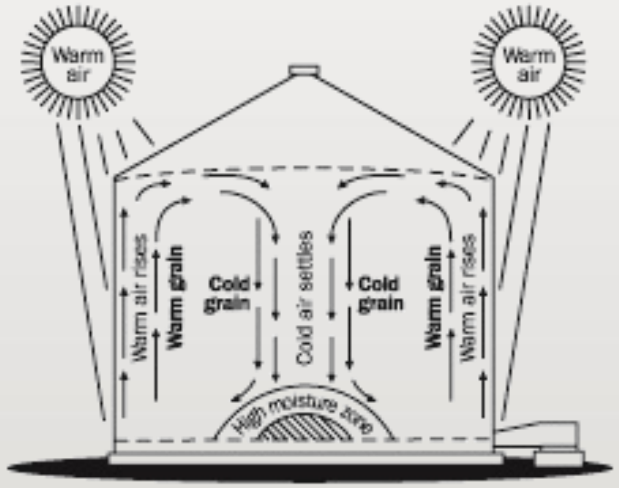
- V_{target}=6 m^3/h/Ton
- C=5500 Ton
- F=33000 m^3/h
- H_{eq}=19 m
- SP=225 mmH_20
- **P=30 kW**
- **η=79%**



AERATION MANAGEMENT

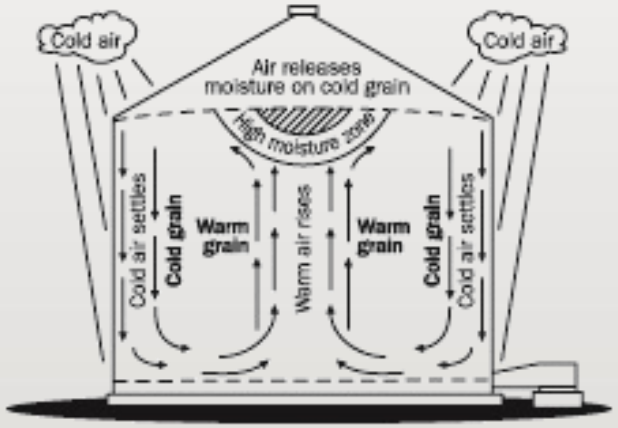
Hygroscopic nature of grains

take up/release moisture from/to the atmosphere in which they are placed.



Why AERATION is it needed?

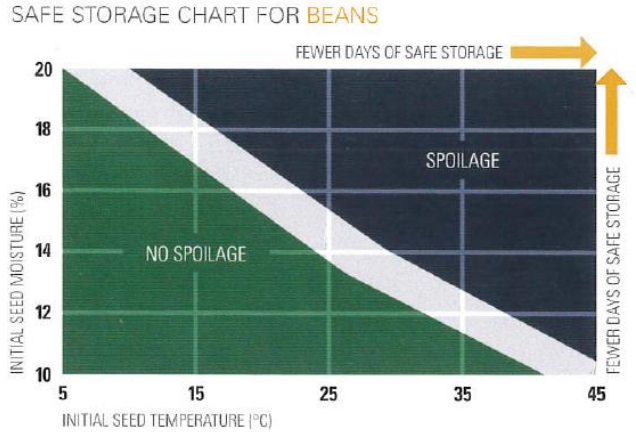
- Avoid temperature gradients
- Control grain temperature
- Control grain moisture migration



SAFE STORAGE PERIOD (DAYS)

Safe Storage Chart for Cereals (Wheat and Rice)

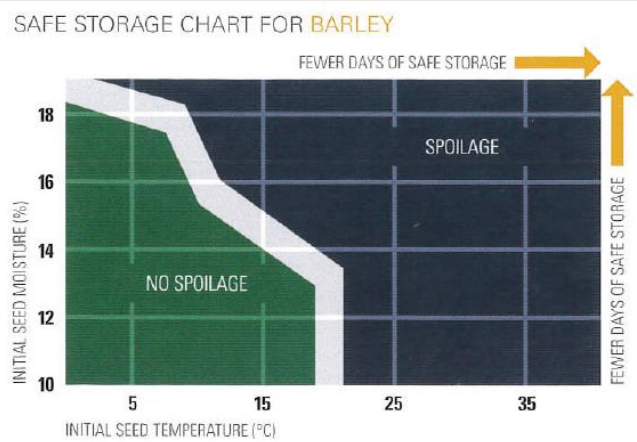
Grain Temperature		Grain Moisture (%)										
*C	*F	14	15	16	17	18	19	20	21	22	23	24
30	86	40-120	20-30	8-15	5-8	3-5						
27	81	120-160	40-60	10-30	10-15	5-8	5-8	3-5				
25	77	160-240	40-120	20-60	20-30	10-15	5-15	5-8	5-8	3-5		
20	68	<270	80-160	40-120	40-60	20-30	10-20	10-15	10-15	5-10	5-8	5-8
15	59	>270	160-240	80-150	60-120	40-60	20-30	20-30	10-30	10-15	10-15	5-8
10	50	>270		160-240	90-160	80-120	50-80	40-60	20-30	15-30	10-20	10-15
5	41	>270			<270	120-240	80-120	50-90	40-60	30-50	20-30	10-20



Beans: spoilage occurs when initial temperature ranges from 5°C to 42°C with respective moisture from 20% to 10% moisture content.

Safe Storage Chart for Canola

Grain Temperature		Grain Moisture (%)											
*C	*F	6	7	8	9	10	11	12	13	14	15	16	17
30	86	150-210	90-130	40-80	30-70	8-15	5-8	5-8	3-5				
27	81	<300	130-210	70-150	50-90	20-50	8-15	8-15	5-8	3-5			
25	77	>300	150-240	100-180	70-105	30-70	20-40	15-30	8-15	5-8	3-5		
20	68	>300	<300	<300	100-150	70-120	40-60	30-60	20-40	8-15	5-8	3-5	
15	59	>300			<300	130-200	100-180	60-100	40-80	20-70	10-30	5-8	5-8
10	50	>300				<300	130-210	130-200	100-200	60-90	10-40	10-30	5-15
5	41	>300					<300	150-250	100-240	80-105	20-50	10-30	8-15



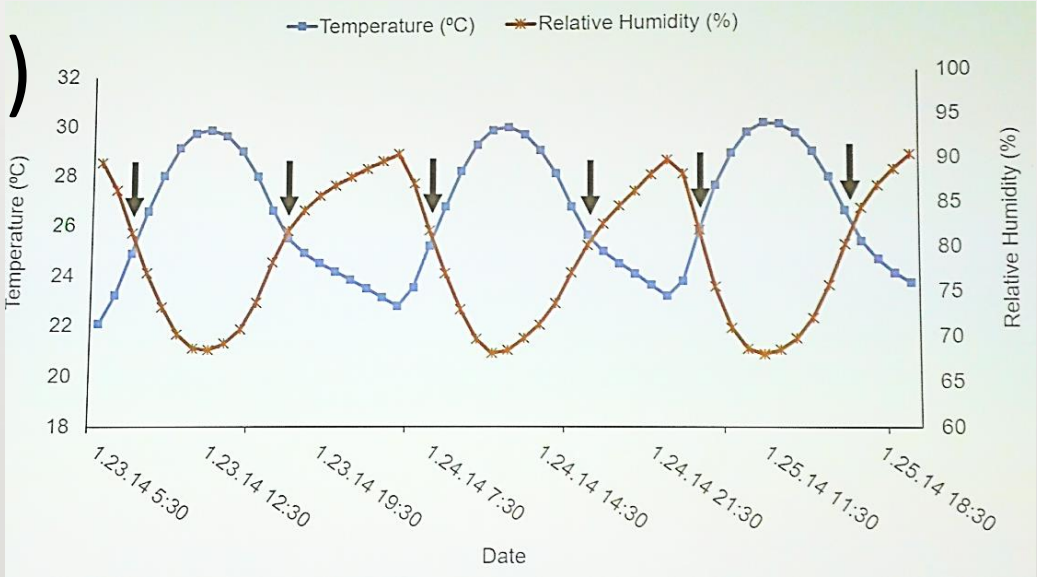
Barley: spoilage occurs when initial temperature ranges from 5°C to 20°C with respective moisture from 18% to 10% moisture content.

AERATION MANAGEMENT

When to aerate?

1) When ambient temperature < 10 °C grain temperature

2)

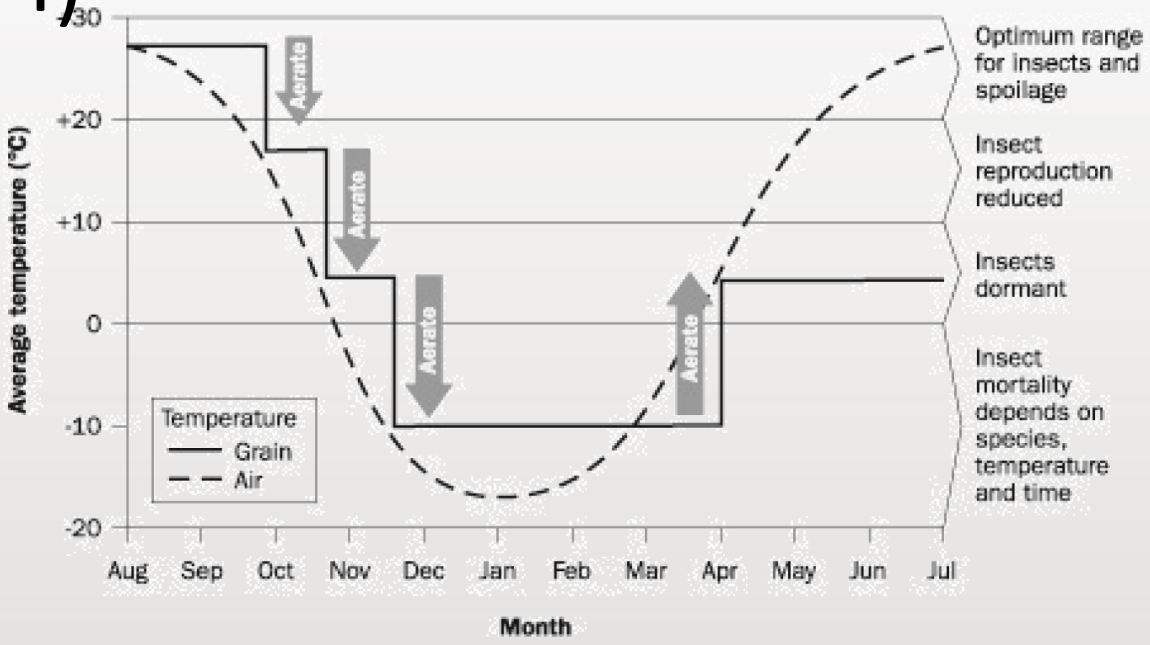


3)

WHEAT DURUM EQUILIBRIUM MOISTURE CONTENT															
		Relative Humidity (%)													
		25	30	35	40	45	50	55	60	65	70	75	80	85	90
Temperature (C°)	2	8,3	8,9	9,6	10,2	10,9	11,5	12,2	13,0	13,8	14,7	15,8	17,1	18,8	21,3
	4	8,2	8,8	9,5	10,1	10,7	11,4	12,1	12,8	13,7	14,6	15,7	17,0	18,7	21,1
	7	8,1	8,8	9,4	10,0	10,6	11,3	12,0	12,7	13,5	14,4	15,5	16,8	18,5	20,9
	10	8,0	8,7	9,3	9,9	10,5	11,2	11,9	12,6	13,4	14,3	15,4	16,6	18,3	20,7
	13	7,9	8,6	9,2	9,8	10,4	11,1	11,7	12,5	13,3	14,2	15,2	16,5	18,1	20,5
	16	7,8	8,5	9,1	9,7	10,3	10,9	11,6	12,3	13,1	14,0	15,1	16,3	18,0	20,4
	18	7,8	8,4	9,0	9,6	10,2	10,8	11,5	12,2	13,0	13,9	14,9	16,2	17,8	20,2
	21	7,7	8,3	8,9	9,5	10,1	10,7	11,4	12,1	12,8	13,7	14,7	16,0	17,6	20,0
	24	7,6	8,2	8,8	9,4	10,0	10,6	11,2	11,9	12,7	13,6	14,6	15,8	17,4	19,8
	27	7,5	8,1	8,7	9,3	9,9	10,5	11,1	11,8	12,6	13,4	14,4	15,7	17,3	19,6
	29	7,4	8,0	8,6	9,2	9,8	10,4	11,0	11,7	12,4	13,3	14,3	15,5	17,1	19,4
	32	7,3	7,9	8,5	9,1	9,6	10,2	10,9	11,5	12,3	13,1	14,1	15,3	16,9	19,2
	35	7,2	7,8	8,4	9,0	9,5	10,1	10,7	11,4	12,2	13,0	14,0	15,2	16,7	19,0
	38	7,2	7,7	8,3	8,8	9,4	10,0	10,6	11,3	12,0	12,8	13,8	15,0	16,5	18,8

AERATION MANAGEMENT

4)



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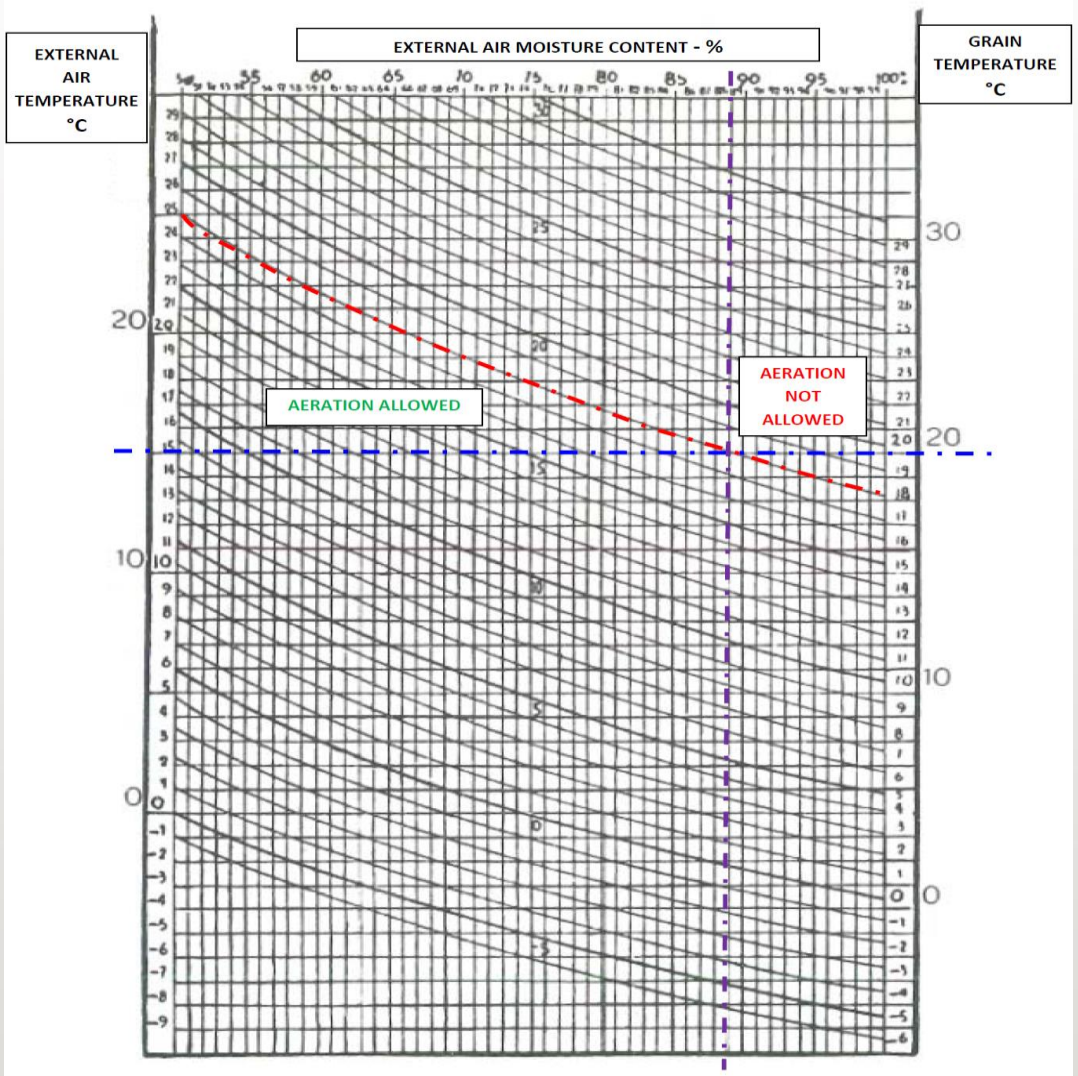
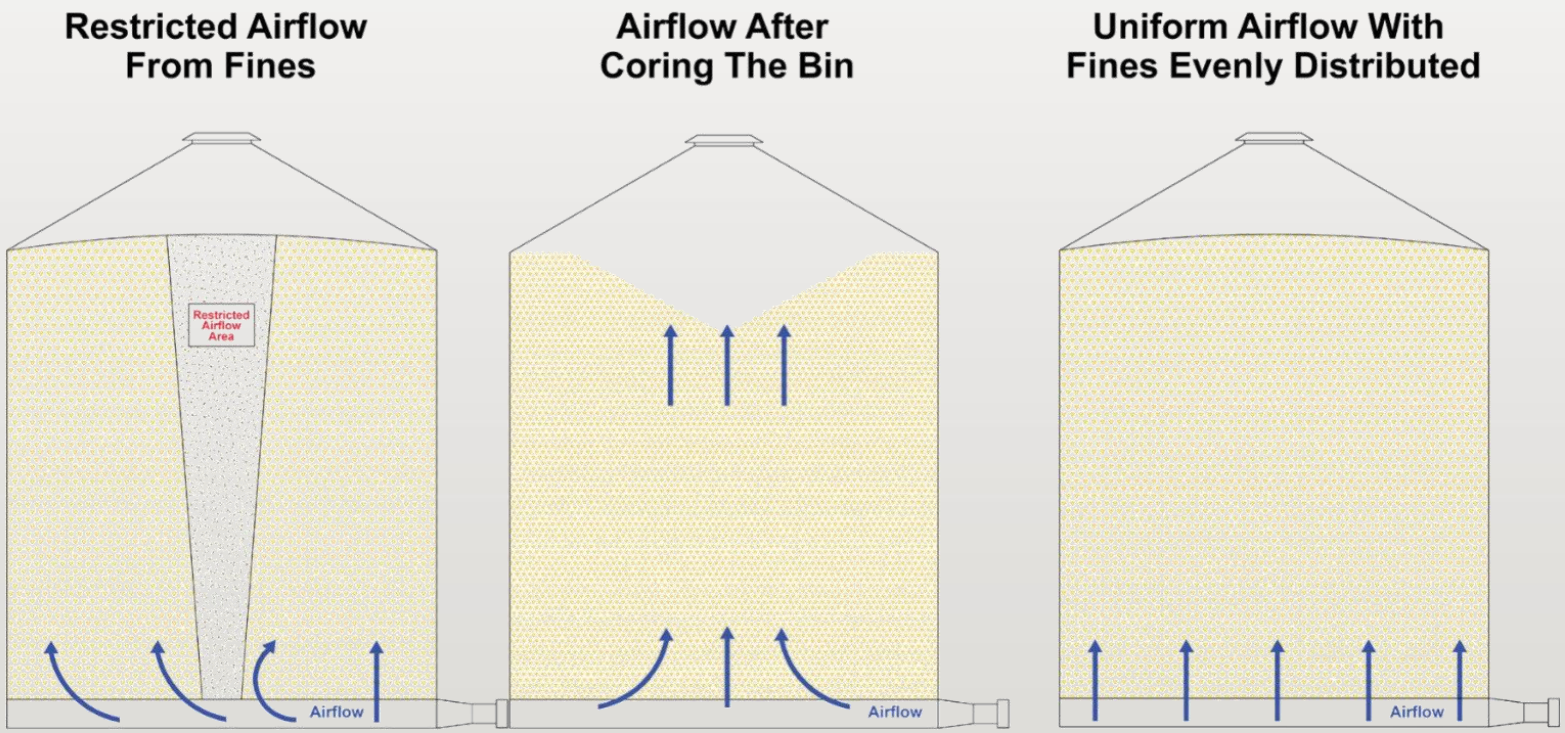


GOOD PRACTICES TO IMPROVE AIRFLOW

- Inspect & clean aeration trenches & panels
- Use of grain spreaders/ladders
- Stirring machines
- Bin coring
- Circulating



FUTURE VISIONS

Large scale use of grain chillers

Fully sealed bins

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