AERATION and COOLING of Stored Grain

Mark Casada, Ph.D., P.E.
Agricultural Engineer

USDA – ARS
Grain Marketing & Production Research Center
Manhattan, Kansas

Professional Experience

20+ years: crop storage & handling research and teaching

1981:
B.S. Mechanical Engineering (P.E.)

1980s:
corn, tobacco, peanuts (Ky. & NC)

1990s:
wheat, barley, & potatoes (Idaho)

2000s:
wheat, corn (Kansas)

AERATION and COOLING of Stored Grain

- Introduction... Grain Storage Basics
  - Grain Moisture: affect on storage
- Grain Temperature & Cooling
- Grain Aeration Systems

Grain Storage

The Good News:

Cool, dry, clean grain stores very well:
we expect no quality loss.

Aeration is the tool to keep grain cool:

Always below 60°F,
below 50°F when weather allows.

Grain Storage

The Bad News (grain storage threats):

- Insects
- Fungi (molds)
- Sprouting
- Loss of Germination
- Handling Damage
- Rodents and Birds
- Other (Spoutlines, Moisture Migration, …)

Grain Storage

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Stored Grain Factors

- Temperature
- Grain Moisture Content
- Initial Grain Quality
  - soundness
  - degree of contamination (fungi, insects, …)
  - amount of foreign material
- Time in Storage
- Other (Oxygen Supply, pH, …)

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Dealing with the Threats

The Top Two Threats

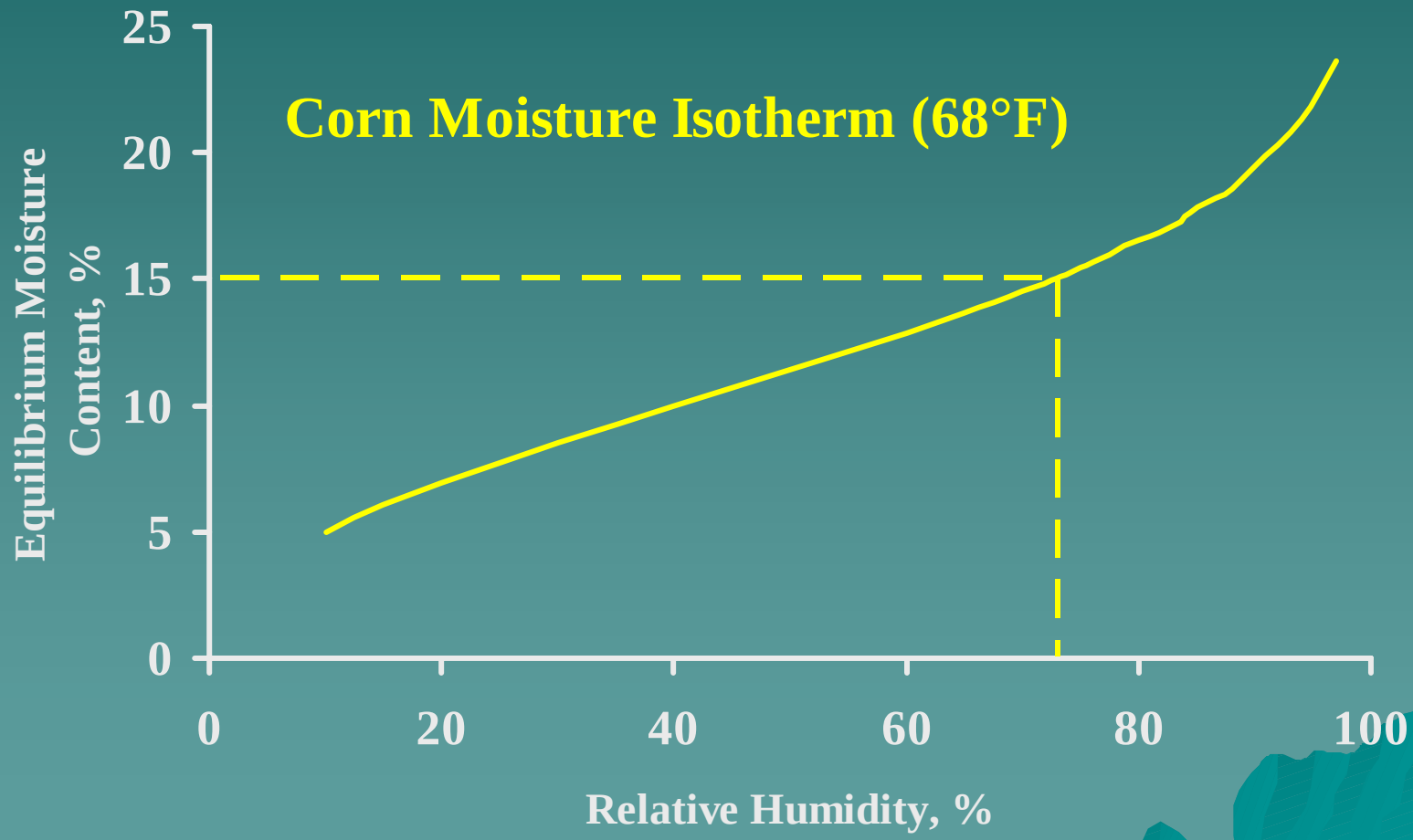
- Insects ← **control w/ temperature**
- Fungi (molds) ← **control w/ moisture**

GRAIN MOISTURE

Dry vs. Wet Grain

- For this lecture:
  - Emphasis on dry grain (or over-dry).
    - Moisture problems usually very limited.
  - Insects usually the bigger issue (temperature).
    - Low moisture content may slow or stop some primary infesting insects.

Grain Moisture Equilibrium

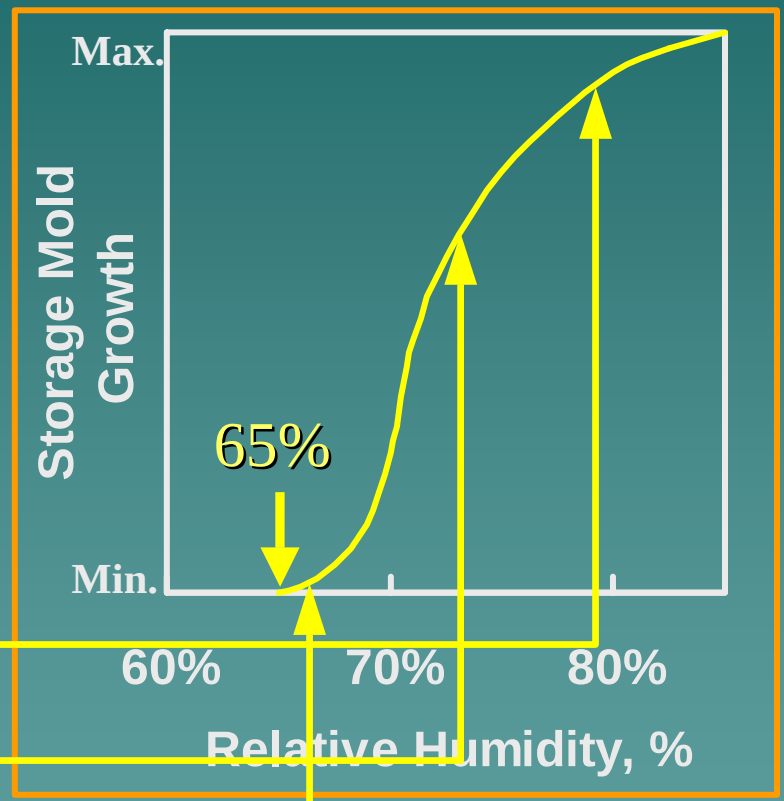


Grain Moisture & Mold Control

- **Moisture Content**

  the key to mold control

Corn at 68°F	
M.C.	ERH
16 %	79 %
15 %	73 %
14 %	66 %



Safe Storage Moisture Content

Grain Stored One Year	South	Central	North
Corn/Milo	13	14	14
Soybeans	12	12	13
Wheat/Barley	11	12	13
Sunflower	9	9	9

Grain Moisture

Average Moisture Content –

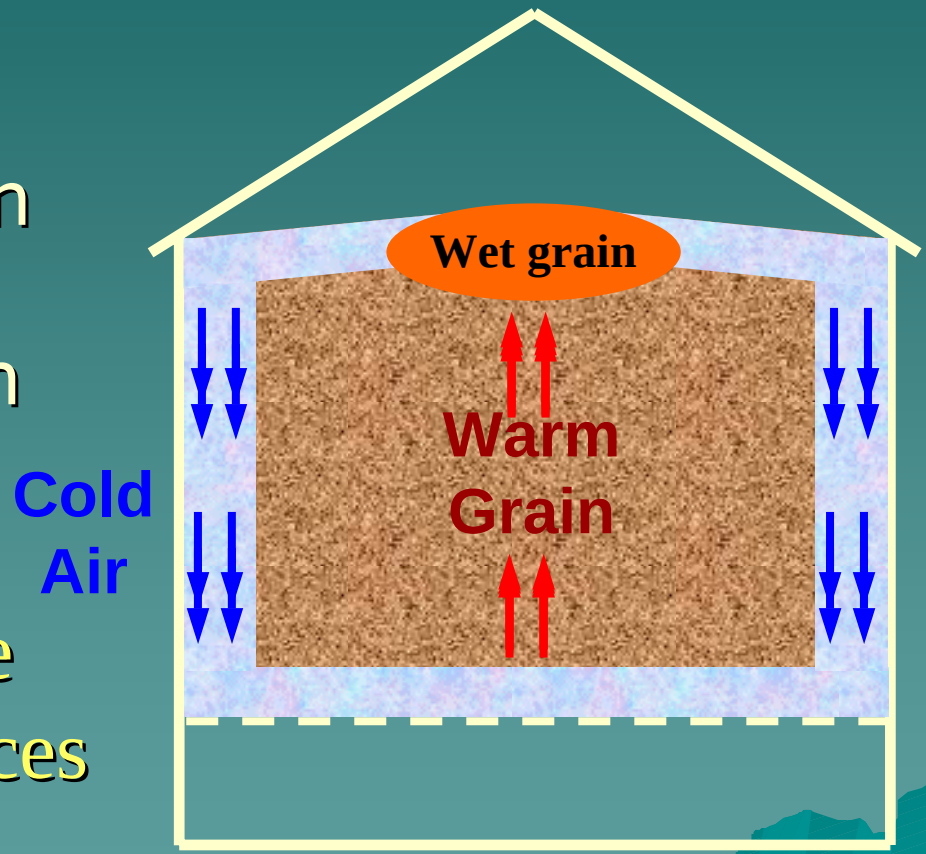
Very little grain is at the "average" moisture content

Must deal with the ***highest*** moisture content in the bin

Grain Moisture

Moisture migration causes additional moisture variation

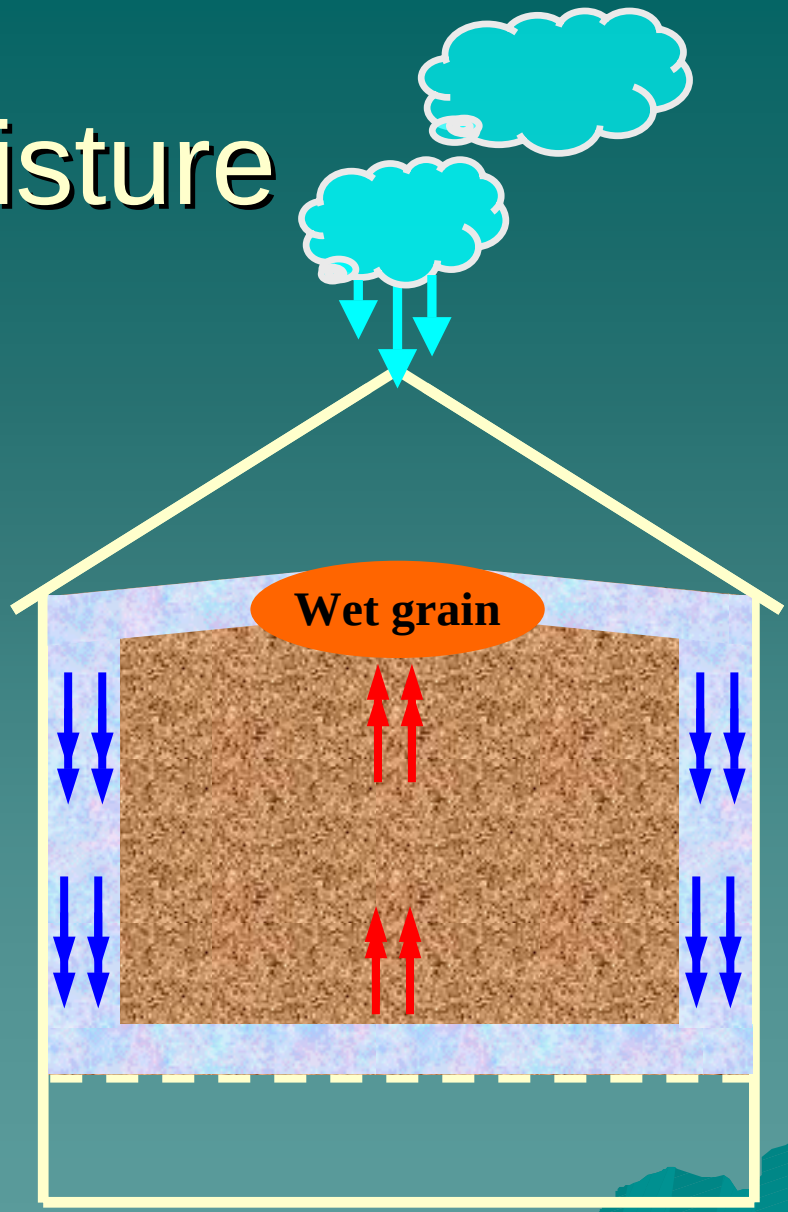
Aerate to eliminate temperature differences



Grain Moisture

Watch for
"simple problems"

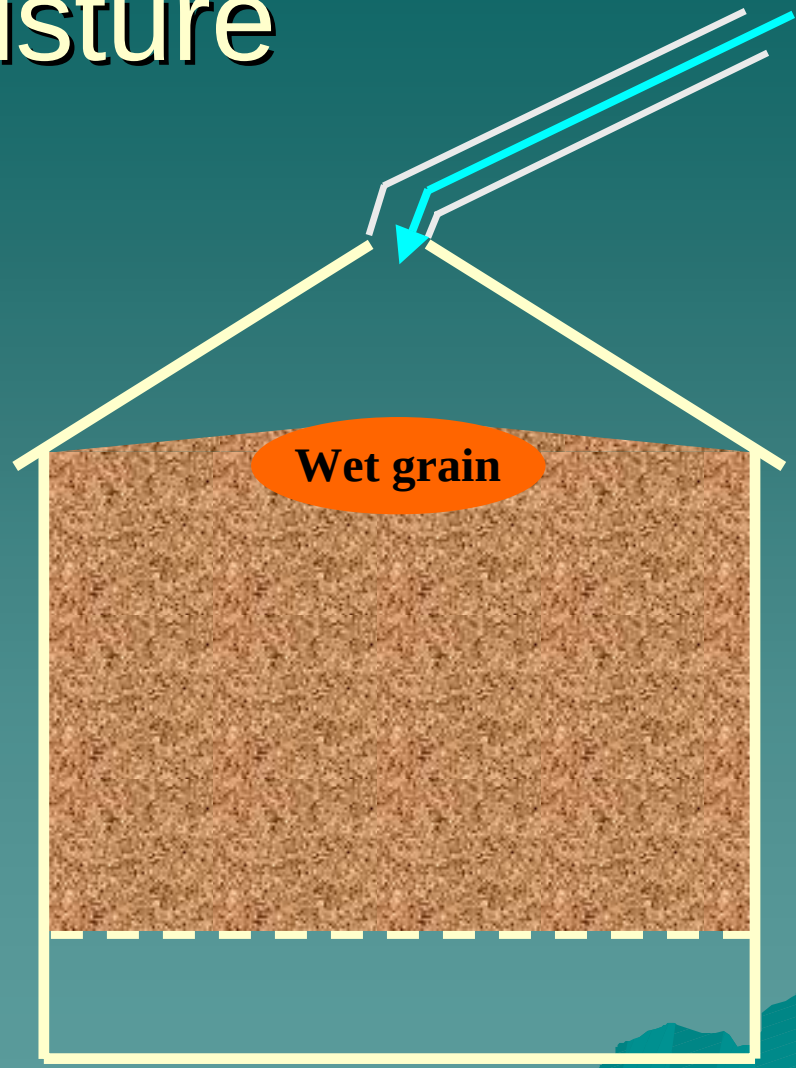
A leak is a leak…



Grain Moisture

Watch for
"simple problems"

Spouting can channel
leaking water…



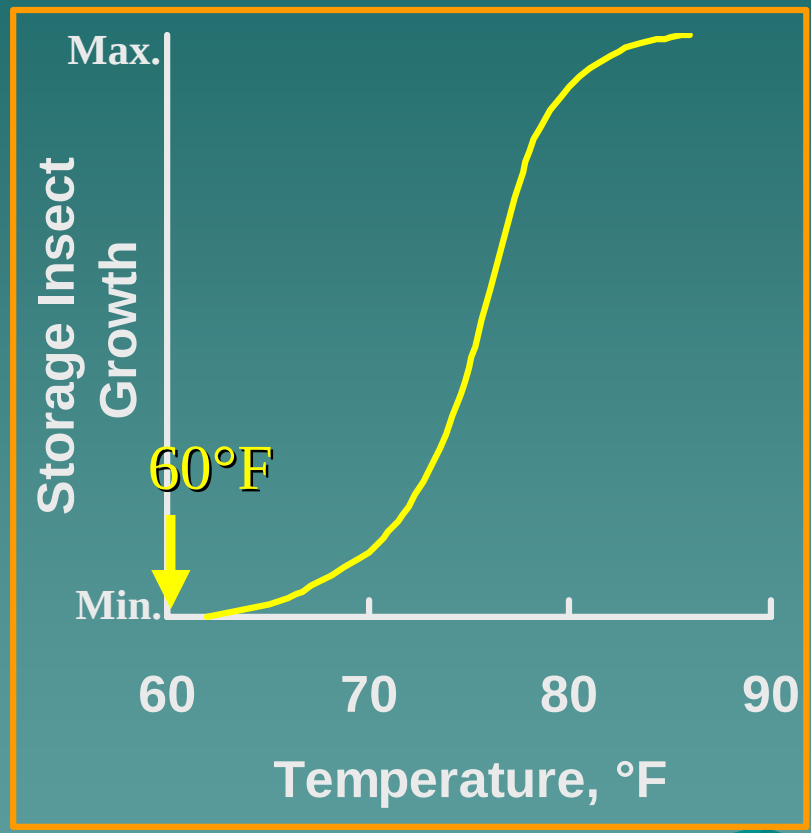
GRAIN TEMPERATURE

Temperature & Insects

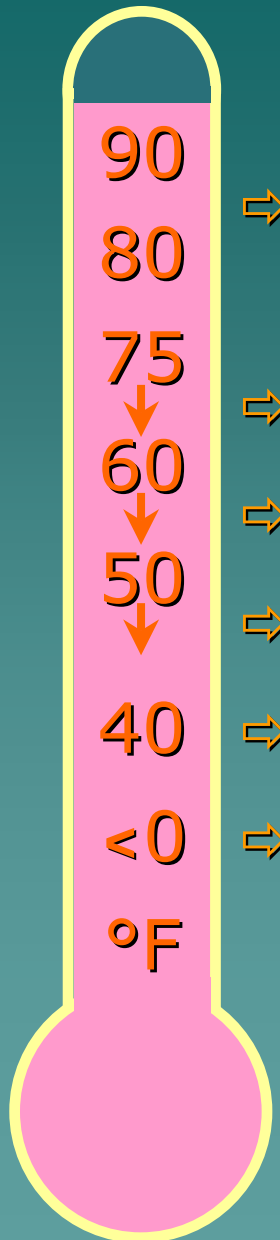
Temperature

is the key
to

insect control



Temperature & Insects



- Optimum for population growth
- Helpful to slow population growth
- Generally stops population growth
- Leads to eventual death of storage insects
- Winter storage (stops moisture migration)
- Only way to achieve quick kill…

Insect Control in Stored Grain

Meet **SAM**:

Sanitation

Aeration

Monitoring

Insect Control in Stored Grain

Sanitation
- eliminate sources of infestation

Aeration
- cool immediately to slow development

Monitoring
- temperature & insect numbers

Controlled Aeration

Using thermostatic controllers to automate the aeration cycles

Objective: keep grain within 10 – 15°F of average ambient temperature

Summer: Cool grain immediately below 75°F

Fall: Cool below 60°F as soon as weather permits

Late Fall: Cool to 40°F for winter storage

Three Cooling Cycles

Controlled Aeration

- Simple aeration controllers are:
  - cheap (pay off ≤ one year)
  - easy to use (thermostat + hour meter)
  - effective and efficient
  - and should be on every grain bin.

Controlled Aeration

Using thermostatic controllers to automate the aeration cycles

Grain Storage Cycle

- Cool grain immediately below 75°F
- Cool to 60°F as soon as feasible (weather)
- Maintain the grain
  - monitor temperatures: ***aerate as needed***
  - monitor insects: ***aerate/fumigate as required***
- Cool to 40°F for winter storage
- Maintain the grain – seal fan opening

Grain Storage Cycle

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Year-Round Grain Storage

Receive Grain All Year

- Insect infested grain mixed with clean grain
- Insects move through the system with grain
- Insect numbers often higher than on-farm

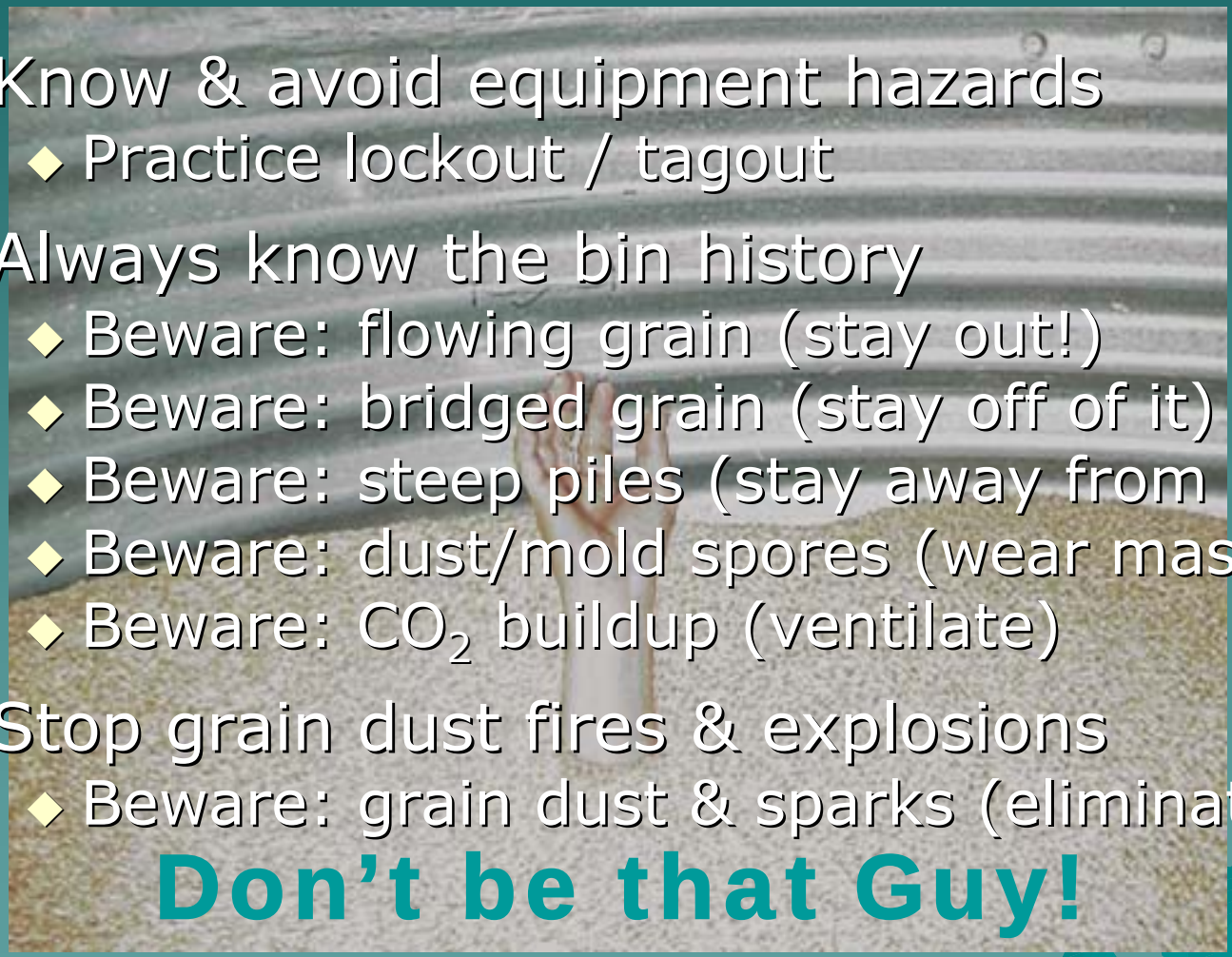
- Segregate by infestation level and treat

Year-Round Grain Storage

Storage Fundamentals

- Sanitation in and around grain bins
- Cooling grain (controlled aeration)
  - lower airflows (cfm/bu) important for cost
  - pressure systems add more heat with deep bins
- Monitoring grain

Grain Storage Safety



- Know & avoid equipment hazards
  - Practice lockout / tagout
- Always know the bin history
  - Beware: flowing grain (stay out!)
  - Beware: bridged grain (stay off of it)
  - Beware: steep piles (stay away from it)
  - Beware: dust/mold spores (wear mask)
  - Beware: CO_2 buildup (ventilate)
- Stop grain dust fires & explosions
  - Beware: grain dust & sparks (eliminate!)

Don't be that Guy!

Grain Storage Safety

Hazards: Grain Dust is the Big One

- Grain dust is an airborne pollutant
  - Long-term effects under investigation
  - Nuisance in surrounding residential areas
- Grain dust is a fire and explosion hazard
  - Powerful and deadly explosions
  - Requires three ingredients

Grain Storage Safety

Stopping Grain Dust Fires/Explosions

- Grain dust suspended in air
  - Design and manage to eliminate dust
- Sparks initiate a flame (at 400°F)
  - Design and maintain to avoid sparks/hotspots
- Confined area permits high pressure/explosion
  - Design to eliminate confined areas

Grain Aeration Systems

Grain Aeration Systems

- Economics of Insect Treatments

lower cost

  - Fumigation w/ turning
  - Fumigation
  - Turning
  - Aeration

Grain Aeration Systems

Recommended Airflow Rates for Dry Grain (Foster & Tuite, 1982):

Storage Type	Recommended rate*, cfm/bu	
	Temperate Climate	**Subtropic Climate**
Horizontal	**0.05 → 0.10**	**0.10 → 0.20**
Vertical	**0.03 → 0.05**	**0.05 → 0.10**

Double these rates for controlled aeration

*Higher rates increase control, flexibility, and cost.

Grain Aeration Systems

Approximate Cooling Cycle Fan Time:

Season	Airflow rate (cfm/bu)		
	0.05	0.10	0.25
Summer	180 hr	90 hr	36 hr
Fall	240 hr	120 hr	48 hr
Winter	300 hr	150 hr	60 hr
Spring	270 hr	135 hr	54 hr

High humidity increases cooling times (evaporative heat)

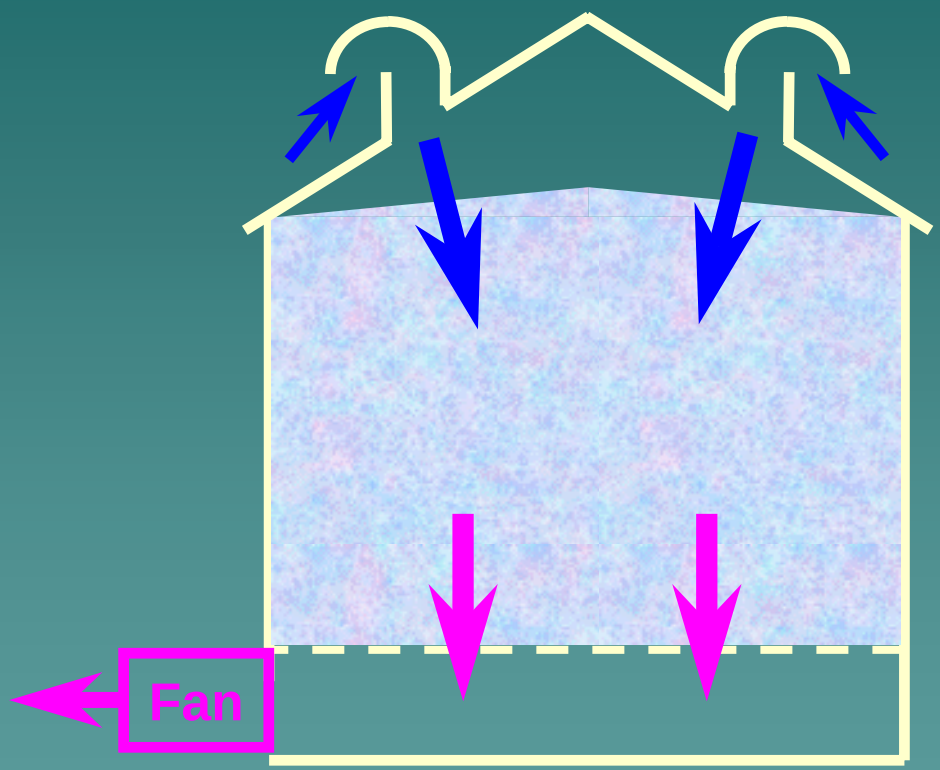
Cooling times a little longer with controlled aeration

Grain Aeration Systems

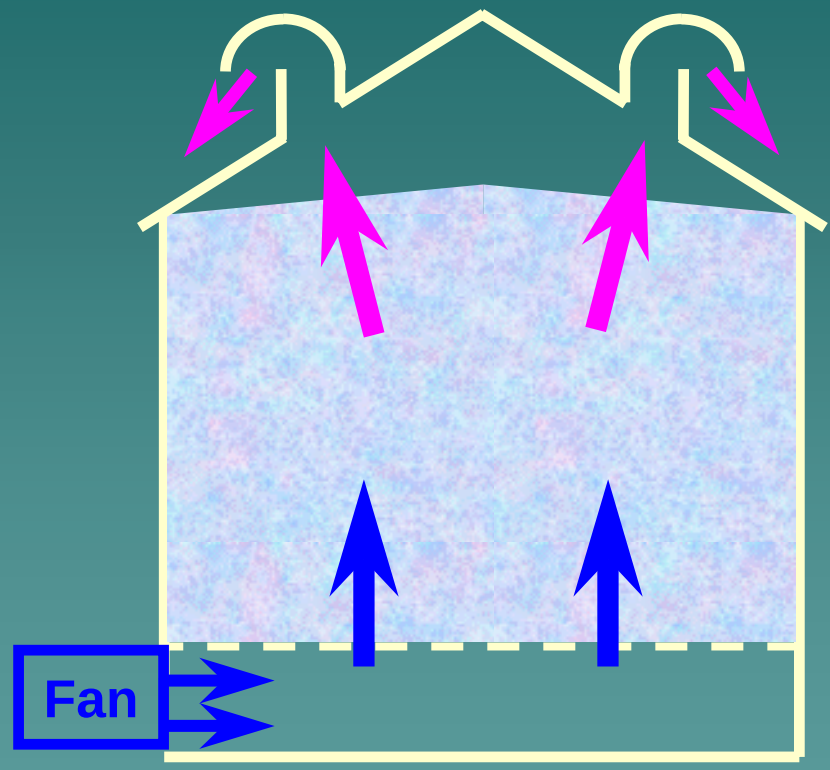
***Fan horsepower per 1000 bu of wheat*:**

	Airflow rate (cfm/bu)		
Depth, ft	**0.05**	**0.10**	**0.25**
100	**0.20 hp**	**0.79 hp**	**6.1 hp**
50	**0.057**	**0.19**	**1.3**
20	**0.020**	**0.050**	**0.20**

Pressure vs. Suction Aeration



Suction (downflow)



Pressure (upflow)

Grain Aeration Systems

Airflow Options:

- Pressure (push) System
- Suction (pull) System
- Push-Pull System
- Crossflow Aeration System

} Tall Silos

Pressure System Advantages

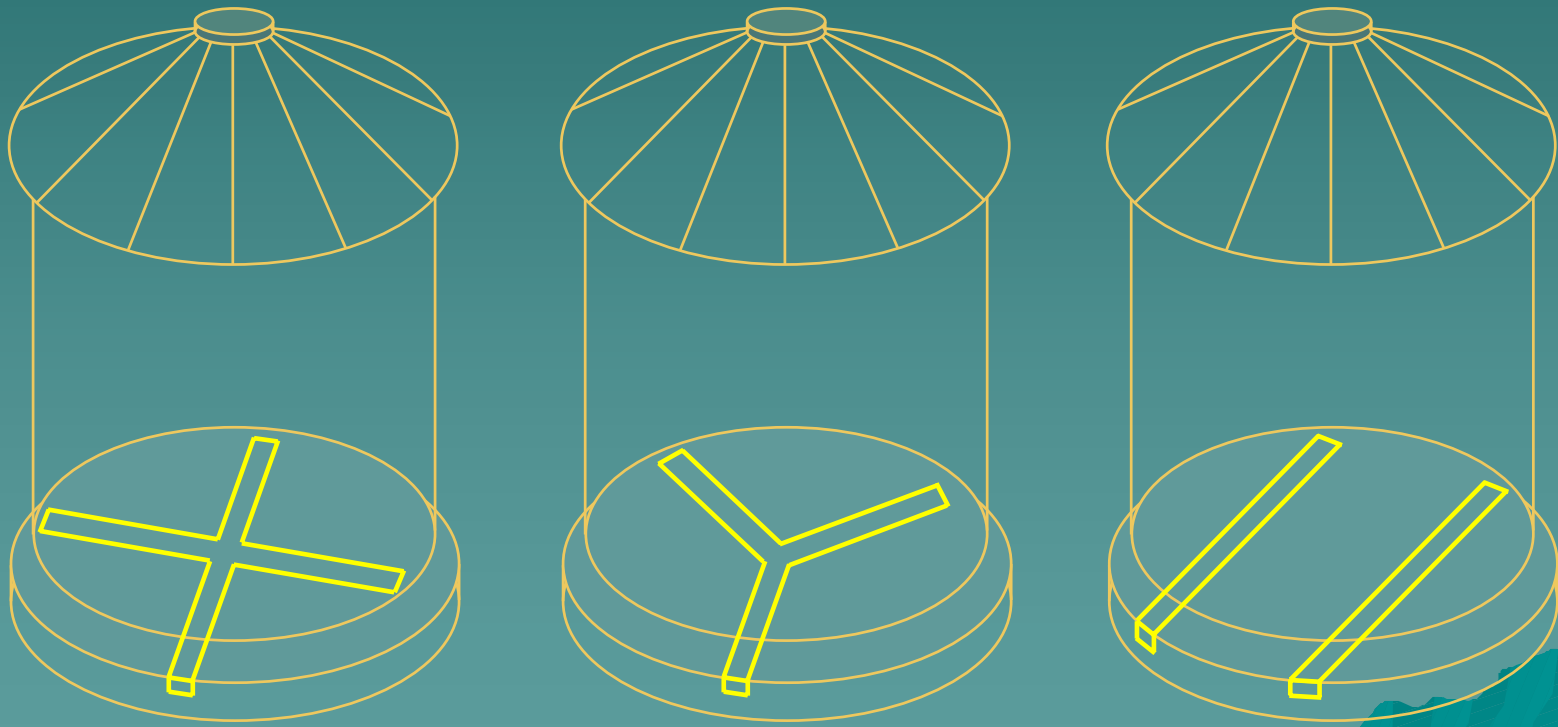
- Required if warm grain placed on top of cool grain
- Last grain to cool is at top: easily monitored
- Natural convection aids aeration in deep bins
- Fan energy compensates for too cool or moist air
- More uniform airflow in flat storages (long ducts)
- No solar heat pulled in from top to over dry grain
- Won’t cause roof collapse if vents freeze

Suction System Advantages

- Excess moisture is easily detected at top
- Allows you to smell the exhaust at ground level
- Condensation ≈ below the grain; limited in duct
- High inlet brings in less dirt and debris
- Eliminates potential to suck in winter snow
- Can aerate spots in flat storages using plastic

Aeration Duct Selection

- Arrangements:



"X" System

"Y" System

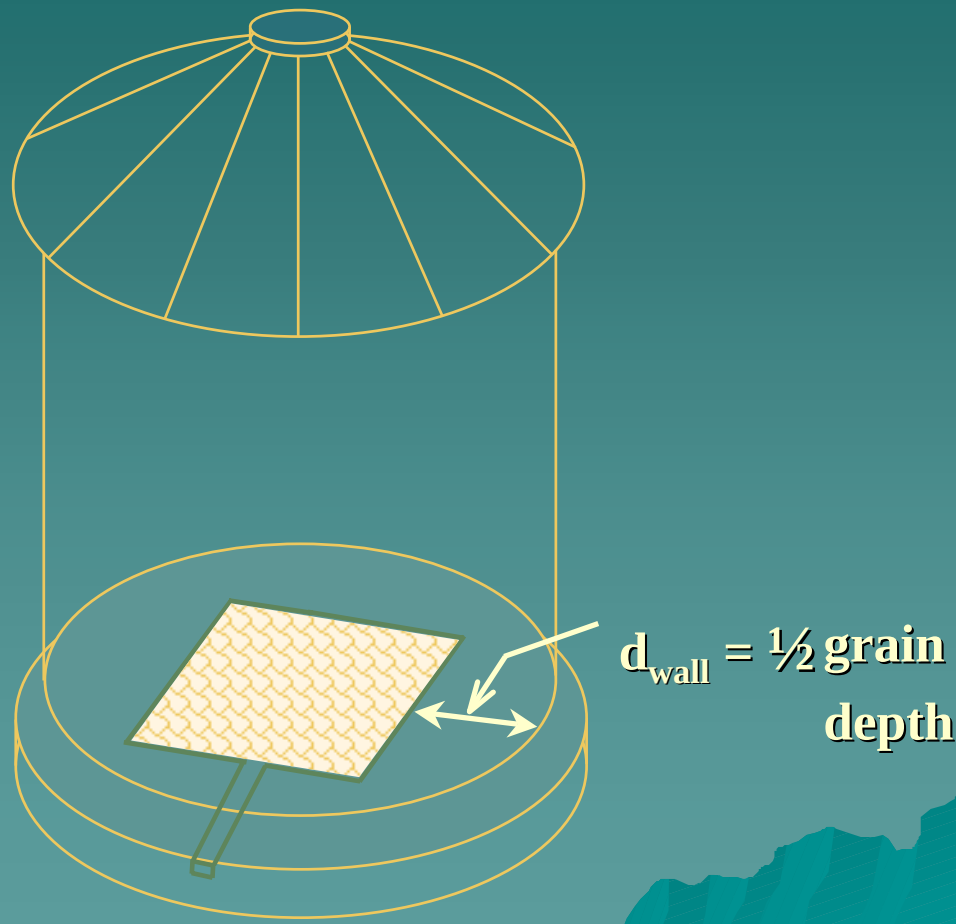
Parallel "I"

Aeration Duct Selection

- Best "duct" arrangement:

  Close to full drying floor effectiveness

  Less expensive than drying floor



Pad System

Aeration Duct Selection

Aeration Fan Selection

...

Grain Storage Summary

- **Moisture Content** to Control Molds
  - ERH < 65 % for long term storage
  - Use the highest moisture in the bin
- **Temperature** to Control Insects
  - T ≤ 40°F in winter (always < 60°F)
  - Watch the highest temperature in the bin
- **Safety** Practices to Control Hazards

Grain Storage Summary

Remember SAM:

Sanitation
- eliminate sources of infestation

Aeration
- cool immediately to slow development

Monitoring
- temperature & insect numbers

Grain Storage on the Web
http://www.gmprc.ksu.edu/

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  - http://pasture.ecn.purdue.edu/~grainlab/
- K-STATE Kansas State University THE WHEAT PAGE
  - http://www.oznet.ksu.edu/wheatpage/
- 
Post-Harvest Handling of Crops
  - http://www.bae.umn.edu/extens/postharvest/
- 
Stored Grain Advisor
  - http://bru.gmprc.ksu.edu/proj/sga/

Aeration Duct Selection

- Three criteria:
  - Duct spacing not "excessive"
    - less than ½ grain depth to duct anywhere on floor
  - Air velocity < 2500 fpm for pressure system
    < 1500 fpm for suction
  - Perforated surface area = 1 ft^2 per 25 cfm

Aeration Duct Selection

- Miscellaneous:
  - Use well-designed fan-to-duct transition
  - Perforated ducts: minimum 10% open
  - Roof vents: 1 ft^2/hp (pressure)
  - In-floor ducts don't interfere with unloading
  - Effective area = 75% for round ducts on floor

Aeration Fan Selection

1. Select lowest airflow (cfm/bu) for cooling rate

2. Airflow: $cfm/ft^2 = (0.8) \times (depth) \times (cfm/bu)$

3. Pressure drop: $\Delta P = (inH_2O/ft) \times (depth) + 0.4$

4. Total airflow: $cfm = (cfm/bu) \times (total\ bushels)$

or: $cfm = (cfm/\ ft^2) \times (floor\ area)$

5. Select fan to deliver flow & pressure (fan data)

Grain Aeration Systems

Double the Recommended Airflows for Controlled Aeration Systems

Storage Type	**Recommended rate*, cfm/bu**	
	Temperate Climate	**Subtropic Climate**
Horizontal	**0.10 → 0.20**	**0.20 → 0.40**
Vertical	**0.05 → 0.10**	**0.10 → 0.20**

*Higher rates increase control, flexibility, and cost.

Grain Aeration Systems

- Closed-Loop Fumigation (CLF)
  - More effective than probing
  - More efficient than probing
    - time
    - fumigant
  - Safer than probing
    - reduces exposure to fumigant
    - reduces dust
    - eliminates enclosed space entry