

Saving Lives in Grain

Research and Strategies for Grain Entrapment Prevention



College of Agricultural,
Consumer &
Environmental Sciences

UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

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GRAIN & FEED
ASSOCIATION
of Illinois

John Lee



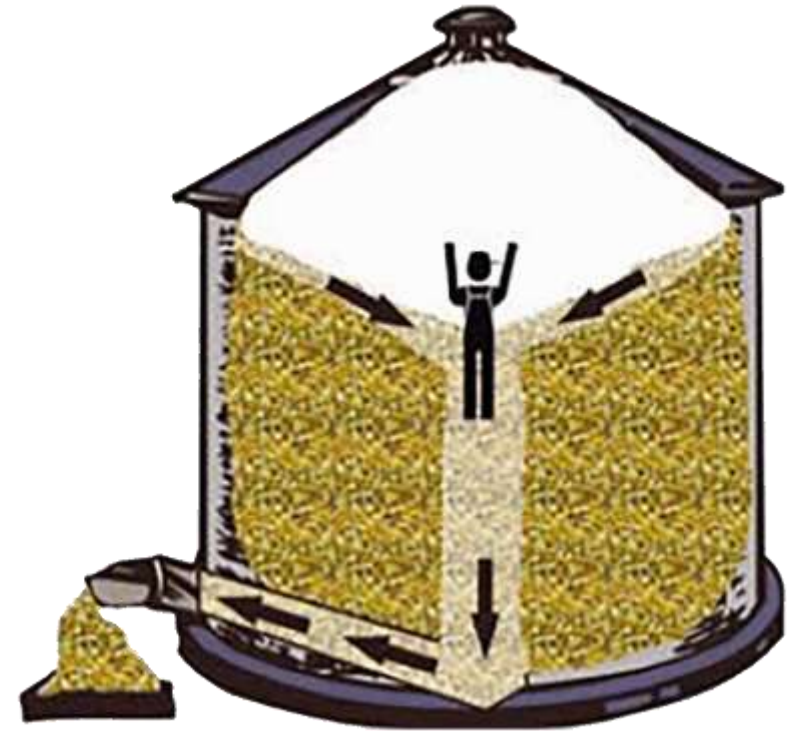
Objectives

- Understand the different types of grain entrapments
- Differentiate between youth and adult entrapments
- Recognize the significant pressure exerted by grain and its implications for injuries and fatalities
- Explore effective strategies to minimize the necessity of entering grain bins

Key Definitions:

Engulfment

Any case in which a person is buried in grain to the point that their airways are under the grain mass.

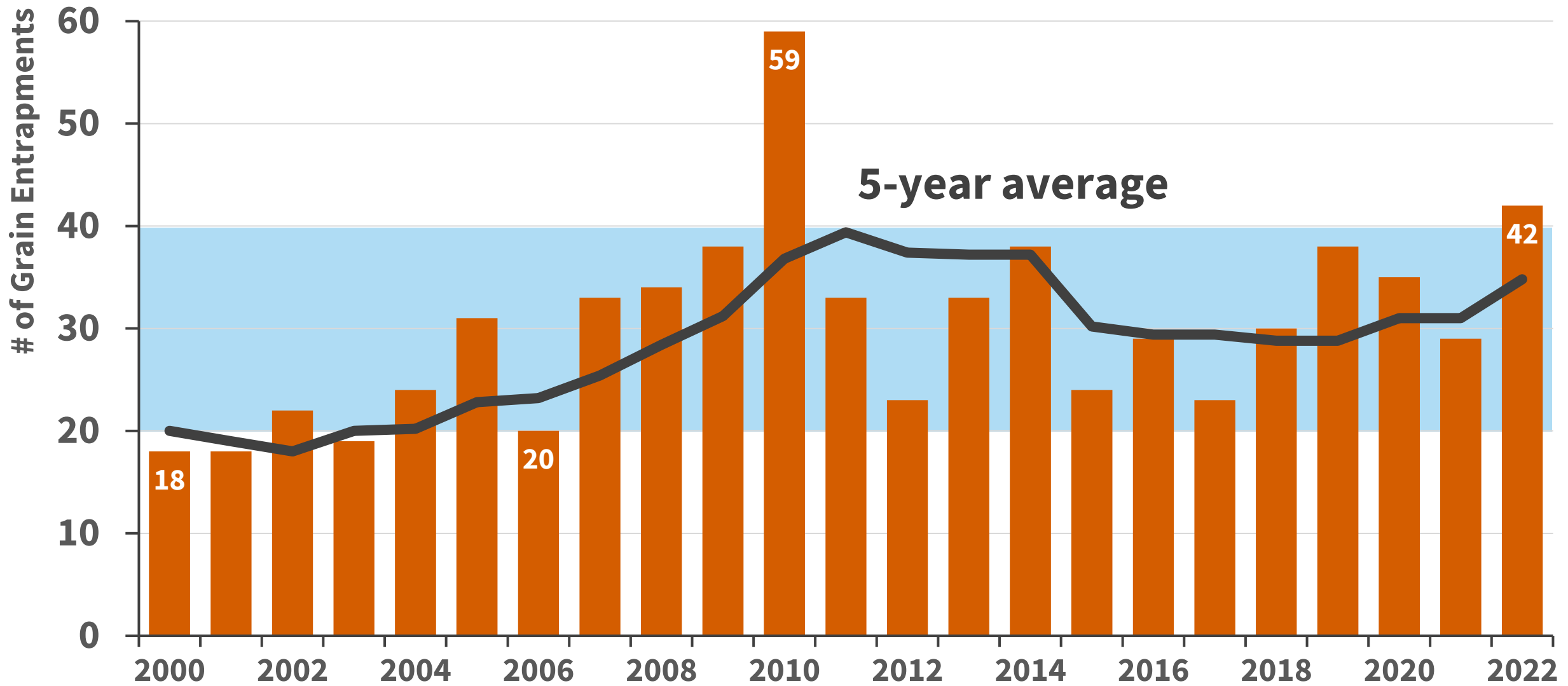


Grain Entrapment

Any case in which a person is stuck in a grain mass.

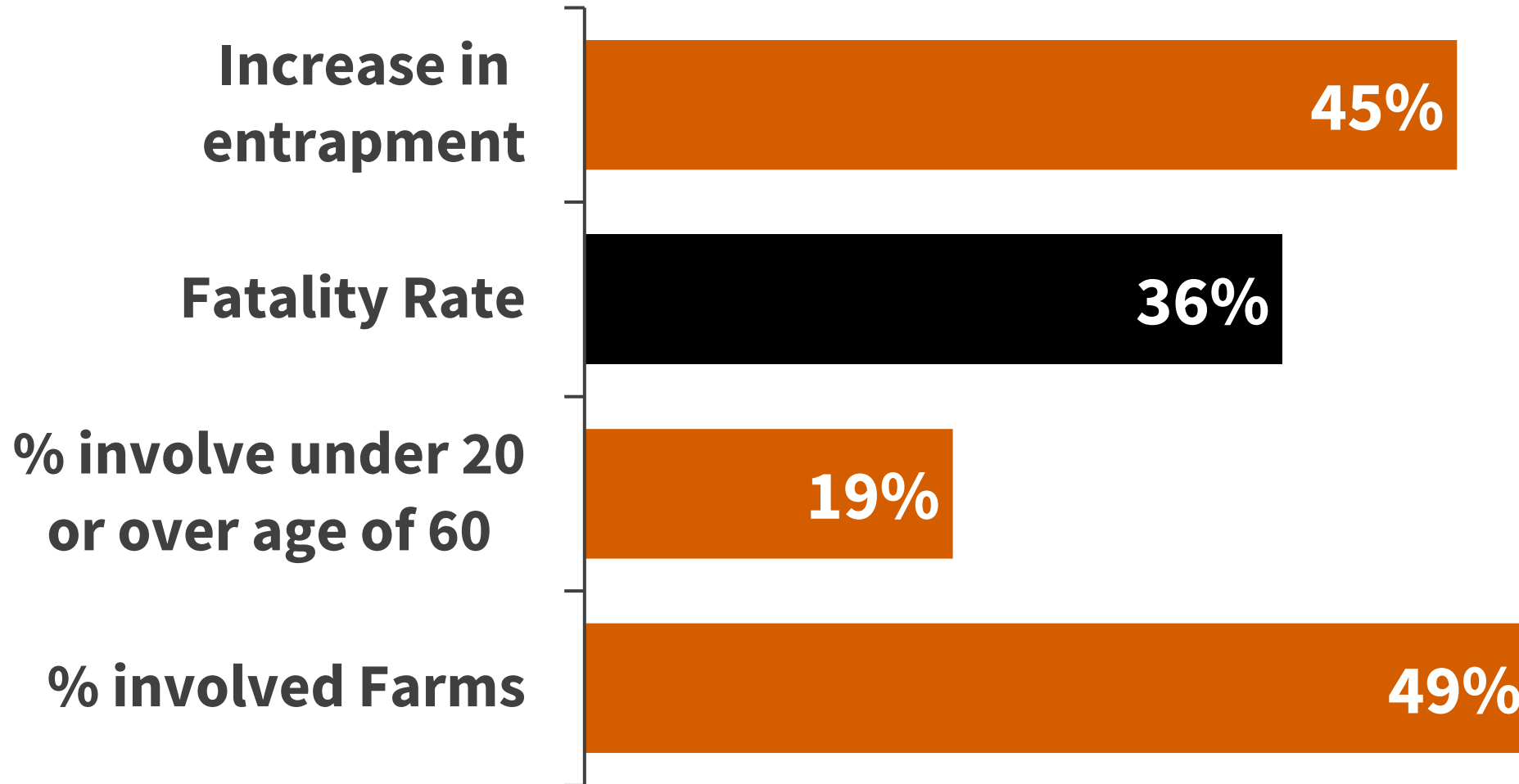
If contrasting with engulfment, then entrapment is limited to cases in which the persons airways is not under the grain mass.

Number of Cases...



▲ Data from Purdue University PACSID Database.

2022 Entrapment/Engulfment



Purdue University. 2022 Summary of Confined Spaces in US
https://extension.entm.purdue.edu/grainsafety/pdf/2020_Confined_Space_Summary.pdf

Type of Grain Entrapments

- Free Flowing Column of Grain
- Collapse of Vertically crusted grain (Avalanche)
- Collapse of Crusted Surface (Bridging)
- Free-Standing Pile
- Structural Failure
- Grain Vacuum
- Covered by Grain

Poor Grain = Potential Hazards

- **Bad Grain Condition**
- Hot temperature
- High moisture content
- Minimal Sinking
- Bad Smell
- Striations, Towers, etc.



Slide courtesy of Grain Handling Safety Council:
Grain Bin Entry

Why Bin Entry Fails

- Farmer entered bin with PVC pipe to rod/unplug bin
- Unload system was running
- Farmer would not have entered if grain was not out of condition

Grain bin entry safety starts with Grain Quality Management



Rodding grain to unplug a sump
with unload equipment running is
#1 cause of grain engulfment





Flowing Grain Entrapment

Occurs when an individual is trapped into a flowing column of grain. **NEVER “walk down” grain!**



Image courtesy of Grain Handling Safety Council: Grain Bin Entry
Agricultural and Biological Engineering

Video courtesy of Grain Handling Safety Council

Grain Bin Entry



Avalanche Entrapment

Occurs when an individual tries to break down a column of grain that ends up collapsing on top of them.

Historically

9% of all entrapments

~61% are fatal

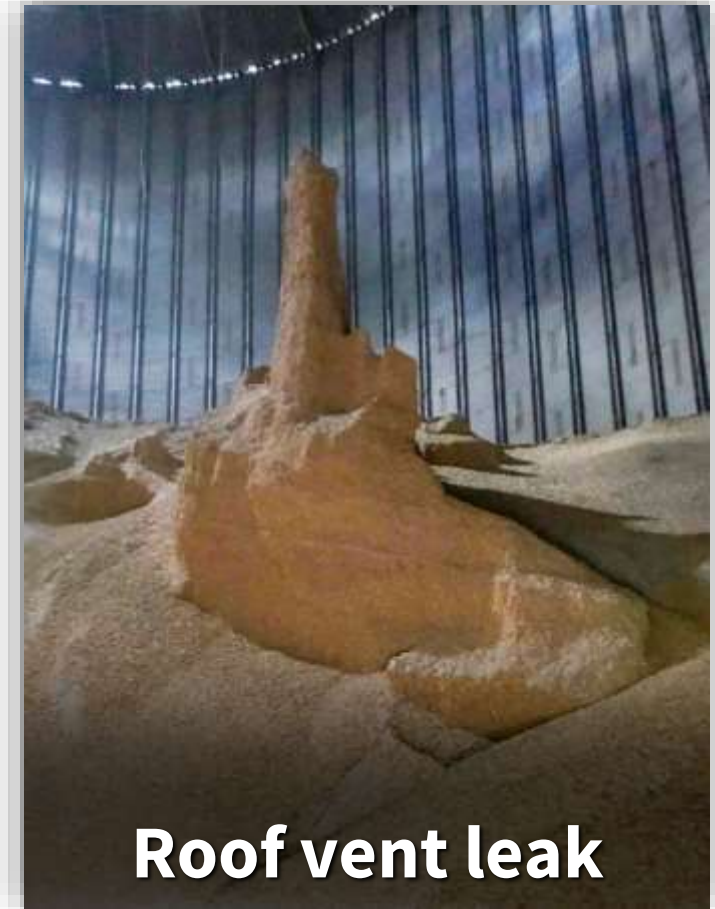
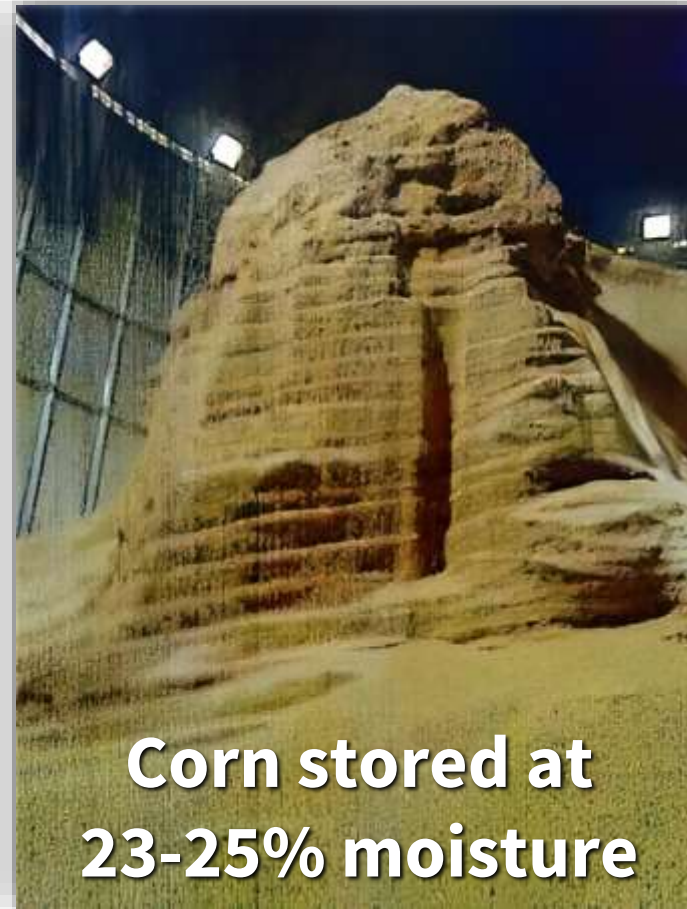


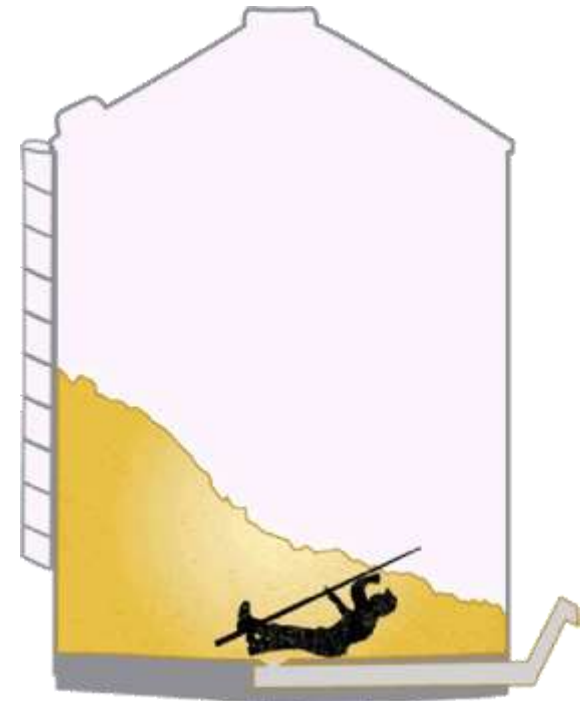
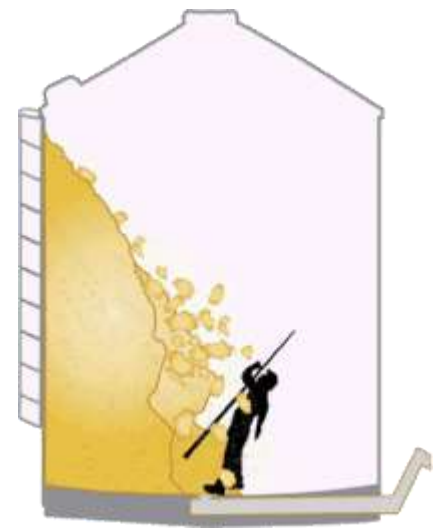
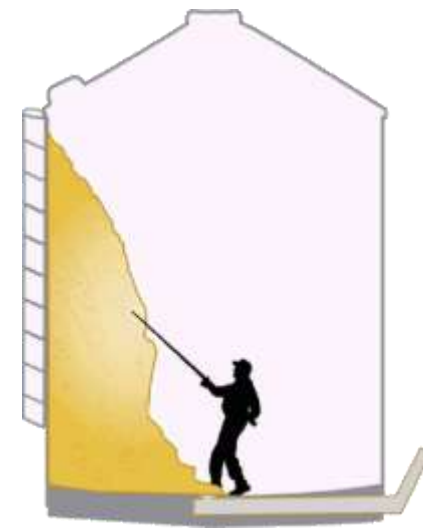
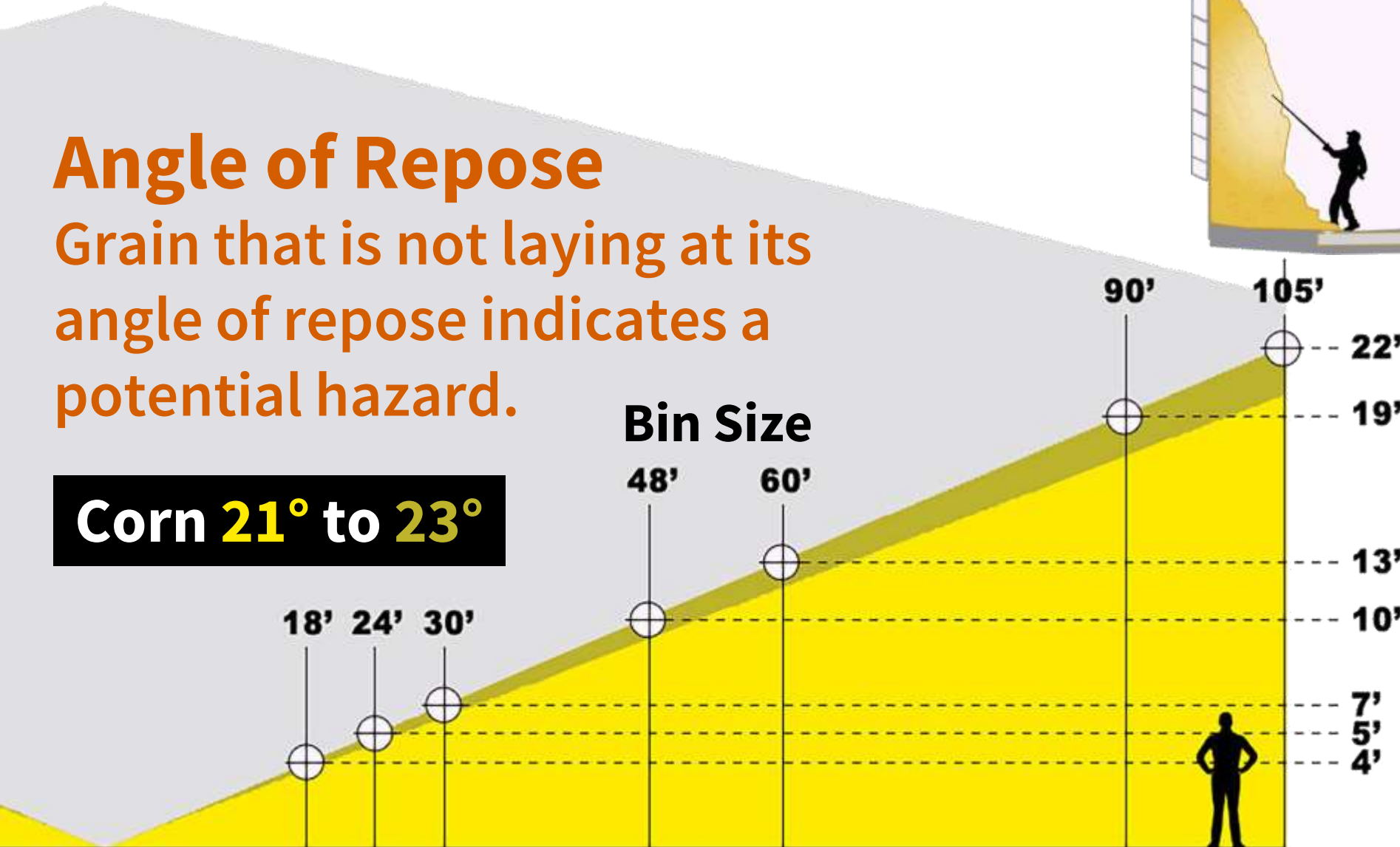
Image courtesy of Grain Handling Safety Council
Grain Bin Entry

Avalanche Entrapment

Angle of Repose

Grain that is not laying at its angle of repose indicates a potential hazard.

Corn **21° to 23°**





Bridging Entrapment



**Crust forms on top
Void created when
bin is emptied**



**Collapse when
walked on**



**Traps and
buries worker**

Image courtesy of Grain Handling Safety Council: Grain Bin Entry

TikTok
@lastcallexpress



Structural Failure Entrapment

Entrapped when grain or feed is unexpectedly released from an access point or due to structural failure of grain.

- 4% of all cases
- 90% fatality rate



Image courtesy of Purdue University
Against the Grain: Unit 3

Grain Vacuum Entrapment

Occurs when grain vacuum is used close to feet causing grain to fluidize.

- 3% of entrapments
- 85% fatality rate

Image courtesy of Purdue University
Against the Grain
Unit 3



Youth Entrapment Cases

Incidents with documented ages occurred to:

- 28% youth under the age of 21
- 20% adults over 60 years of age

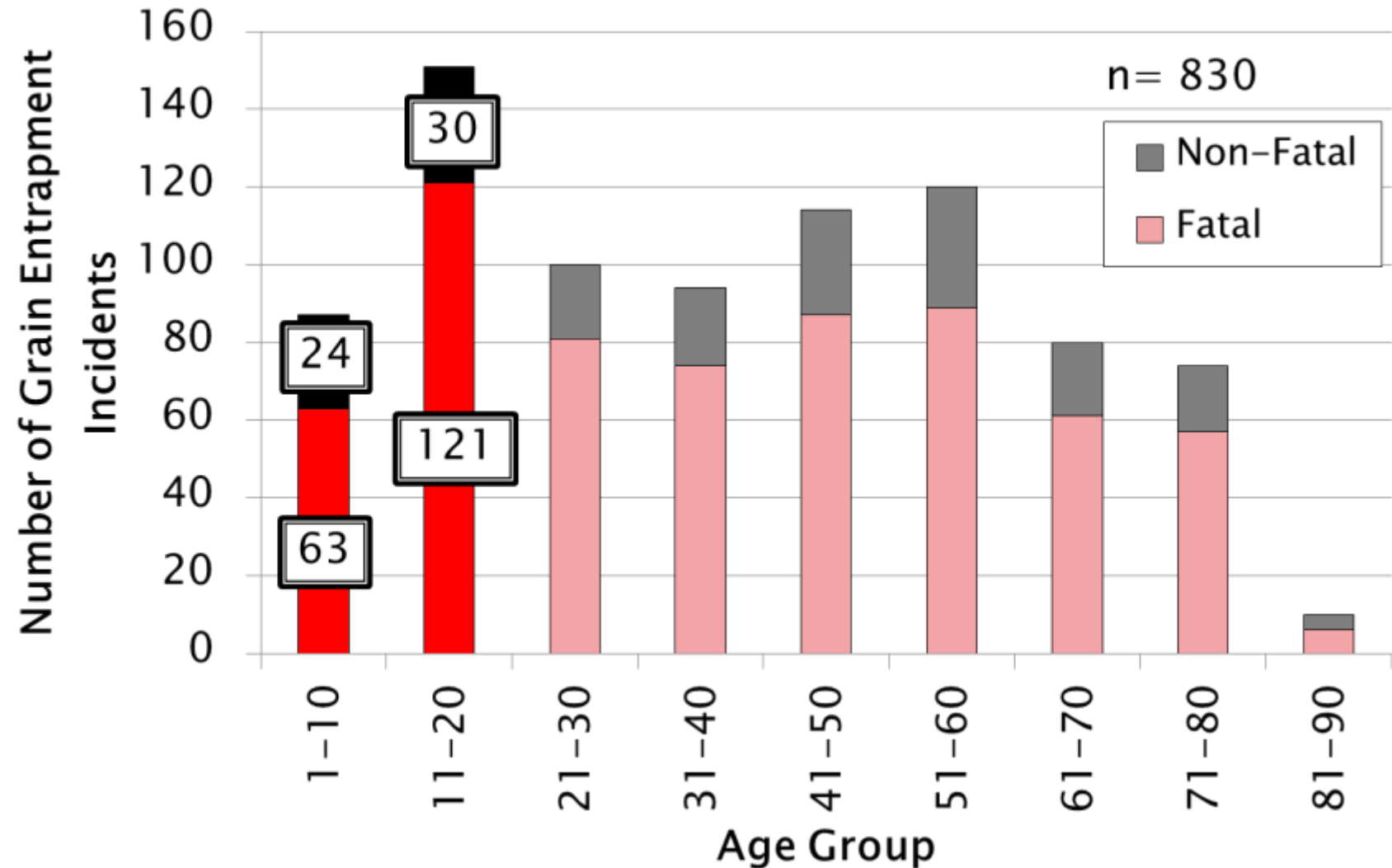


Image courtesy of Purdue University: Against the Grain: Unit 3

Youth Entrapment Cases

Grain Entrapments Incidents by Month for Ages 1-20

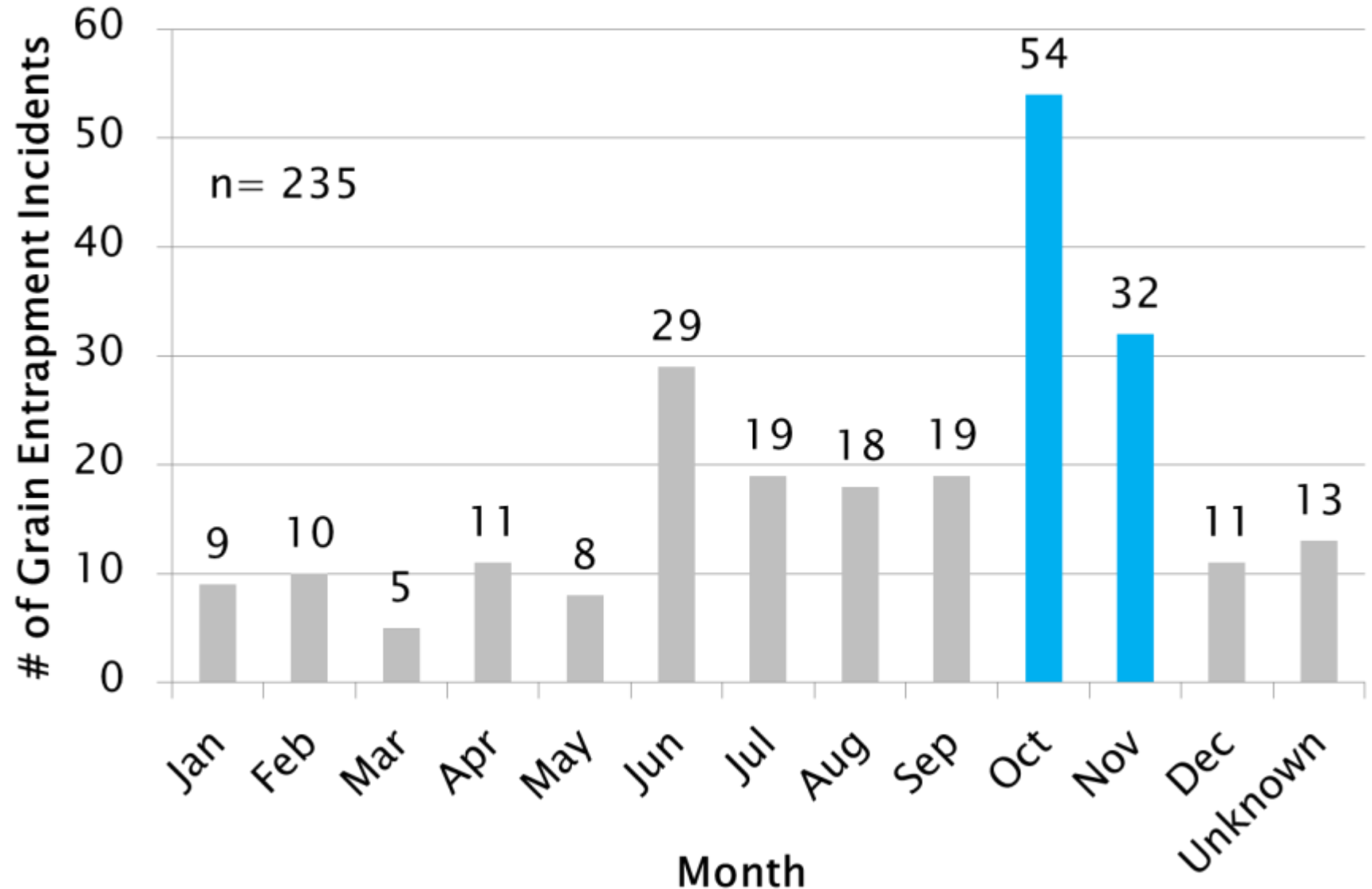


Image courtesy of
Purdue University:
Against the Grain: Unit 3

Other Important Facts

Approximately 1,400 grain entrapment cases in the US since 1960's.

- 75% of all cases are in the Midwest**
- Type of entrapment is known in about 70% of the cases**

Corn has been documented as the grain in about 50% of the cases

Soybean , wheat, rice, pinto beans, cotton seeds, and processed feed were other sources of entrapment

Other Important Facts

- Overall fatality rate is 67%;
last five years is 42% [as of 2016]
 - Engulfments – 570 cases (88 % fatality)
 - Entrapment – 210 cases (7% fatality)
- Cause of death (33 cases)
 - Asphyxiation – 64%
 - Crushing – 12%
 - Lack of oxygen or ability to breath – 9%
 - Other – 15%


Research Needs



Unique Cases

Medical Report (Bachlmann)

- Old man entrapped to chest
- Entrapped in 0°C grain
- Had heart issues
- Complained of chest pain
- Rescuers tried to extract
- Pain gone only when fully removed from grain



The sign features a red header with a white exclamation mark in a triangle and the word "DANGER" in white. Below this are four icons: a person falling from a roof, a person in a harness, a red prohibition sign over a grain bin with a loader, and a person climbing a ladder into a grain bin. The text "GRAIN BIN PROCEDURE" is followed by a list of safety instructions.

GRAIN BIN PROCEDURE

- Do not enter bin when equipment is operating.
- Lock-out and Tag-out all equipment before unloading.
- Body harness, safety line and respirator must be worn when entering the bin.
- Avoid the center of the bin.
- Do not stand on bridged or flowing grain.
- Station an observer outside of the bin when an employee is entering.
- Failure to follow can result in serious injury or death.

Unique Cases

Next Case: Texas

- Wore Harness, safety line and tied to an SRL and anchor point
- Pulled into grain and **engulfed!**



Unique Cases

- Middle aged man entrapped to chest in wheat
- Struggled to breathe
- Pulled out of grain
- Caused injury to spine and legs
- Experiences panic attacks in confined spaces

Research Needs

Grain Pressure

- Pressure on chest when entrapped in grain
- Force needed to extract an individual

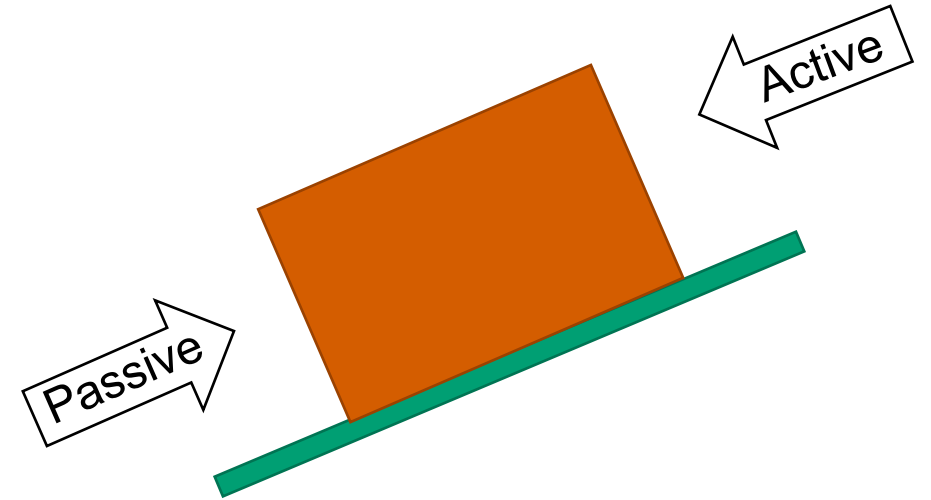
Physiological and Psychological Impacts

- Tensile Forces that a spine can handle
- Blood flow rate during entrapment
- Grain Temperature impact on body
- Does Psychology play a role?

Grain Pressure

Chest Pressure

- Passive vs Active
- Load cells measure active
- Ribcage experiences passive



Previous Research

- Moore and Jones (2016) @ 24 cm depth = 2.82 kPa
- Hydrostatic (corn) @ 30 cm = 2.5 kPa
- **Hydrostatic (water) @ 30 cm = 2.9 kPa**
- Thompson (1997) @ 2 m - Passive = 2.7 x Active

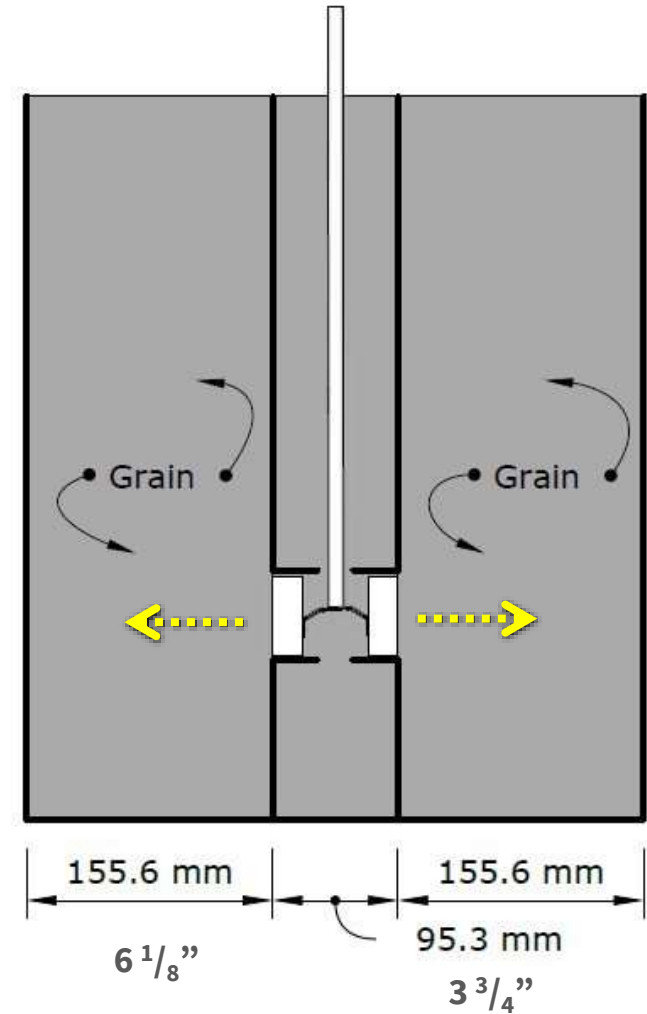
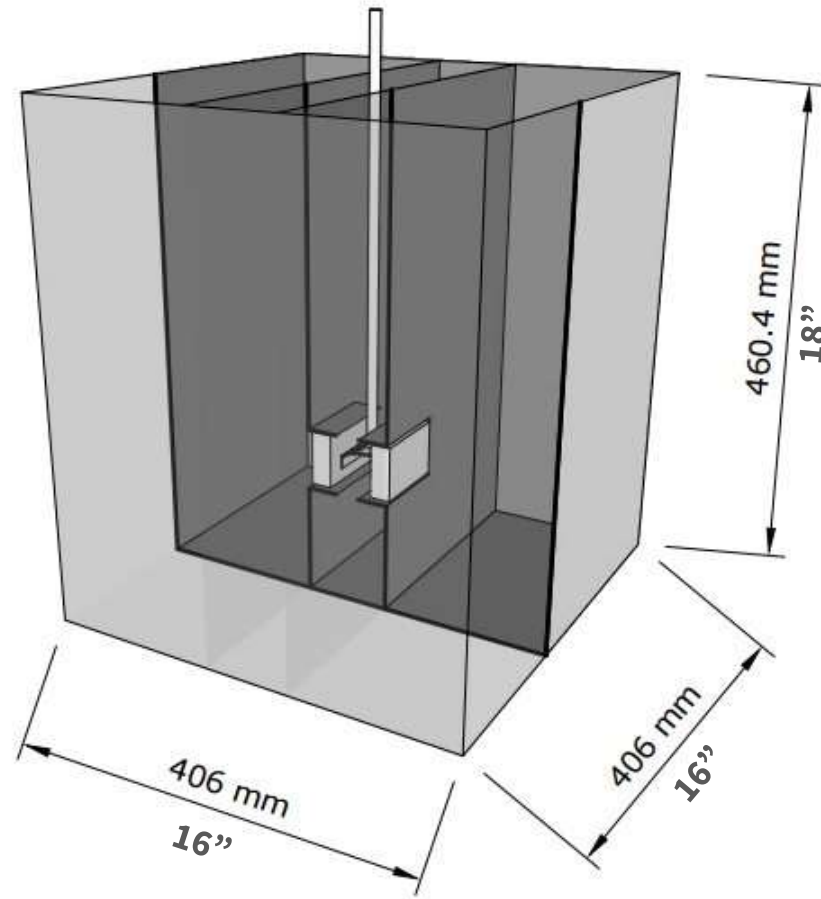
Grain Pressure Methods

Measured passive pressure by measuring force needed to push grain

Corn

At 10 to 30 cm (4 to 12 inches) depth

Pushed grain about 2 cm (0.8 inches)

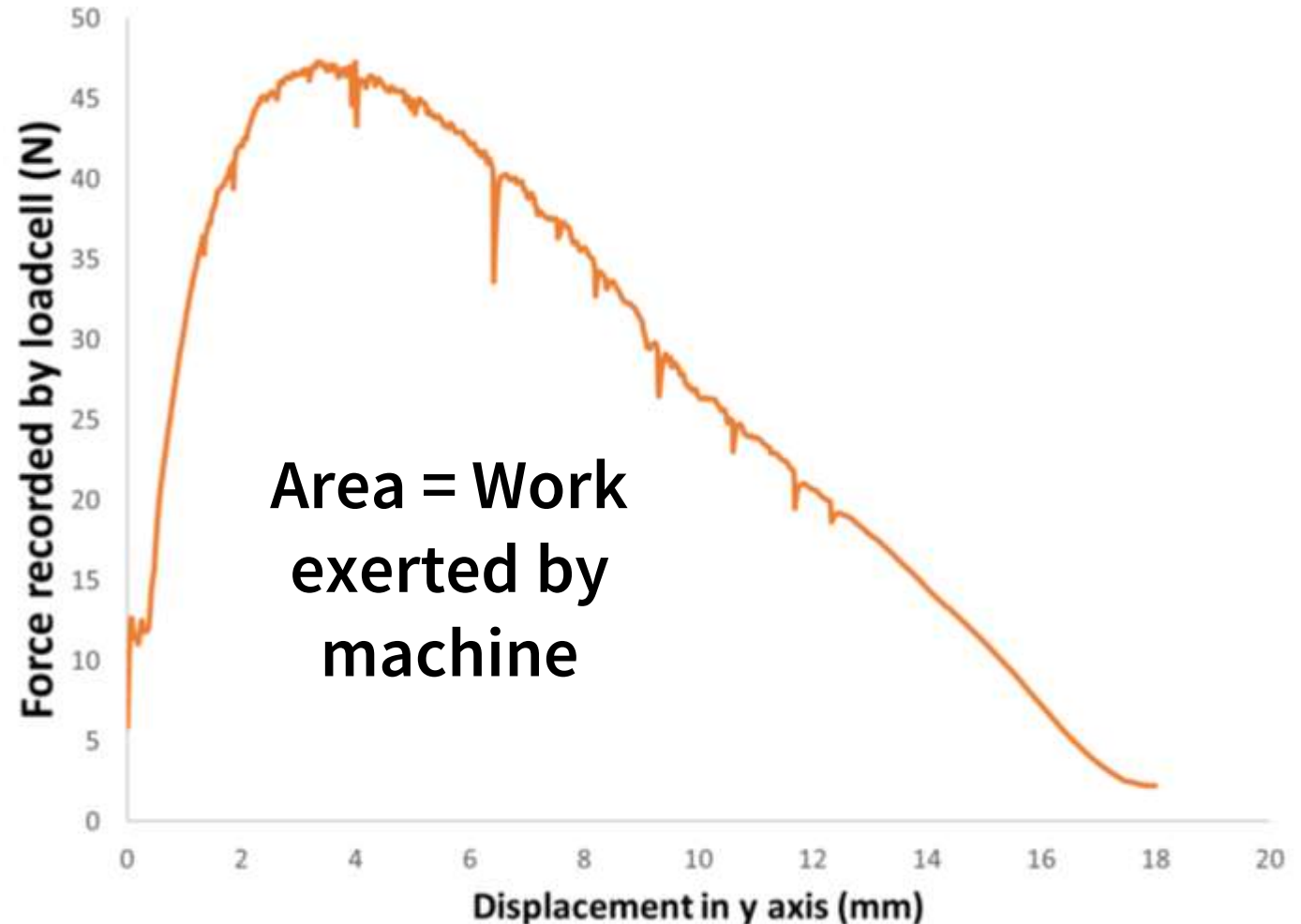


Grain Pressure Results

Passive pressure

- 10 cm = 6.0 kPa
4 inches = 0.87 psi
- 20 cm = 7.3 kPa
8 inches = 1.06 psi
- 30 cm = 8.8 kPa
12 inches = 1.28 psi

**Passive pressure
2-3 than active**



Force required to extricate mannequin

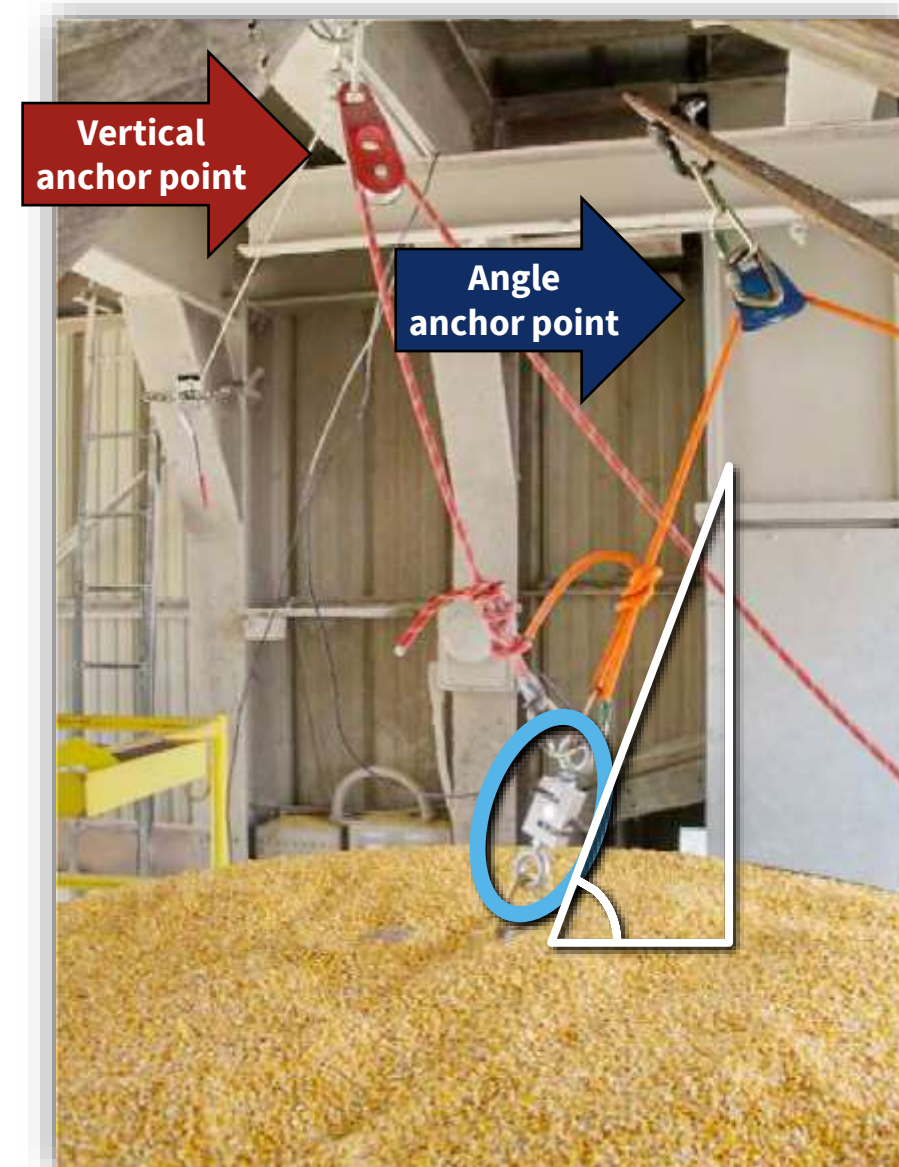


Previous Research

- Schwab et al. (1985)
2700 N @ Shoulder depth
- Load cells measure active
- Ribcage experiences passive

Methods

- 1.8x2.4m (6x8 ft) bin
- 82 kg (180 lb) Mannequin
- Grain: Corn and Soybean
- Angle: 15°, 30°, 45°, 60°, 75° and 90°
- Depth: Top of Head



Force Experiment Results

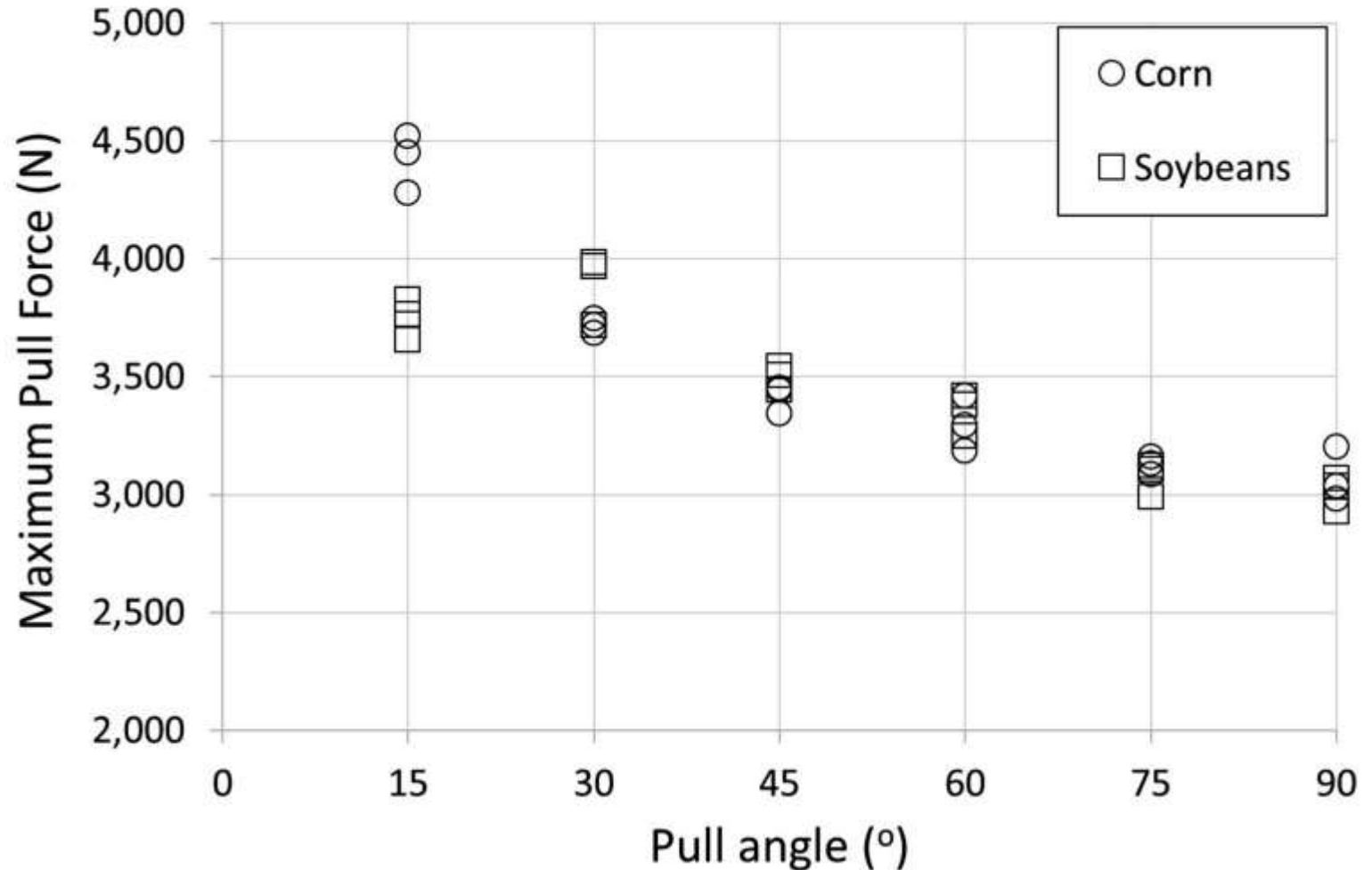
- Shallow angles do not significantly increase force

- Sharp angles increase force significantly for **corn**

Max force: 4,400 N

989 pound-force (corn)

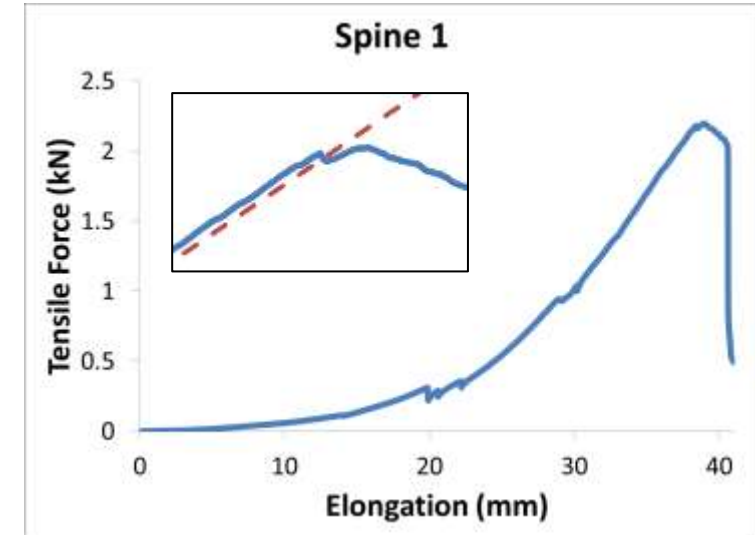
- Corn and Soybean results are not significantly different.



Spine Tensile Strength Experiment

Pulled lamb spines

- Intervertebral discs + ligaments behaved like brittle material.
- Maximum tensile force required ranged from 1700 N to 2500 N.
- Average of 2100 N (St. Dev. = 300 N)



Other Physiological factors

Grain temperature

- Grain can remain significantly cooler ($>10^{\circ}\text{C}$ or $>50^{\circ}\text{F}$) than the outside temperature.
- A person can survive about 30-90 minutes at 4°C (39.2°F) in water.
- Water 25x more conductive than air; Grain is only 7-8x



Other Physiological factors

Blood flow and Heart rate

- Harness Suspension
- Boa Constrictors

Psychological

- Fear of burial
- Stress cardiomyopathy
 - Triggered by emotional stress due to loss or fear
 - Causes chest pains and shortness of breath



Recommendation

Do not get entrapped

- 94% of all grain entrapments are preventable.
- Lock out tag out is critical for safety.

But now what ?



The sign features a red header with a white exclamation mark in a triangle and the word "DANGER" in white. Below this, there are four icons: a person falling from a grain pile, a person wearing a harness and safety line, a person entering a grain bin with a red prohibition sign over it, and a person climbing a ladder into a grain bin.

GRAIN BIN PROCEDURE

- Do not enter bin when equipment is operating.
- Lock-out and Tag-out all equipment before unloading.
- Body harness, safety line and respirator must be worn when entering the bin.
- Avoid the center of the bin.
- Do not stand on bridged or flowing grain.
- Station an observer outside of the bin when an employee is entering.
- Failure to follow can result in serious injury or death.

Strategies to handling out-of-condition grain

What to do when grain stops coming out?



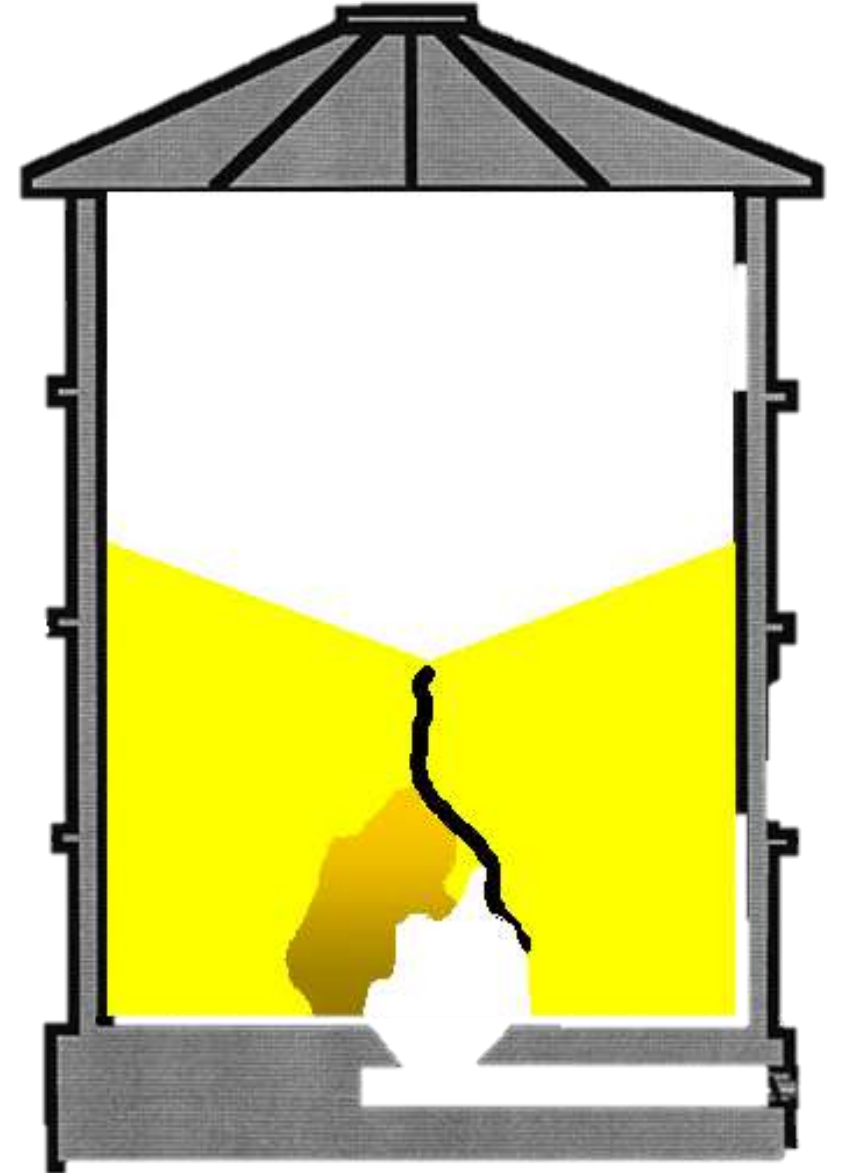
A worker wearing a blue hard hat and a high-visibility yellow-green vest is using a long wooden rod to clear a tunnel in a grain storage facility. The worker is positioned on the right side of the frame, looking into a dark opening in a metal structure. The rod is held with both hands and extends into the tunnel. The background shows the interior of the facility with various metal components and pipes.

Rodding Grain from Tunnel

Rodding Bridged Grain Hazard

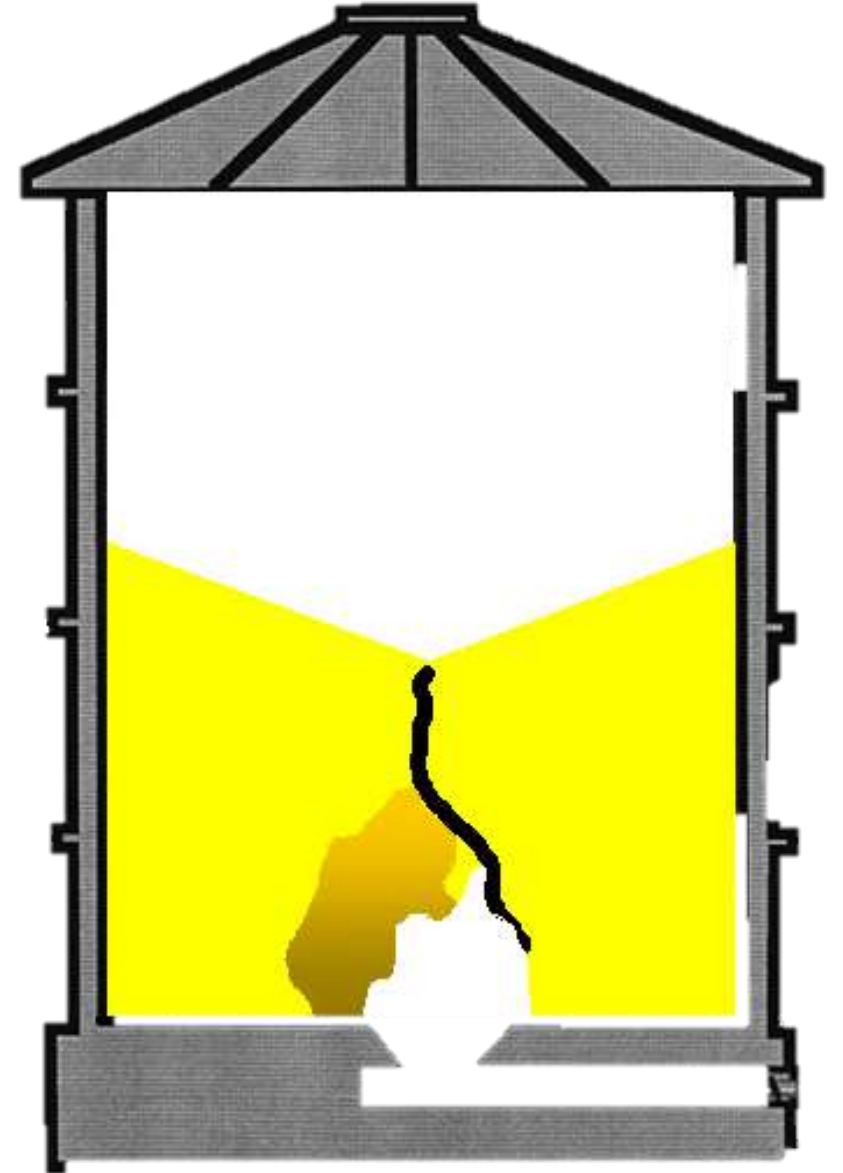
Suspect a cavity if there is little resistance to rodding.

WARNING! Hidden danger



Rodding Grain – No tunnel

What is wrong?



Rodding Grain – No tunnel

▲ Lockout/tagout (LOTO)

▲ Body Harness

▲ Lifeline

▲ Observer

▲ Permits

▲ Atmospheric





**Brock
“Well Guard”**



**Mighty Mini
Sump Saver**



Built-in Rodding Pins

Slide gate
with rods





Using a long pole from outside the bin



Avoiding Entry Using Grain Vac

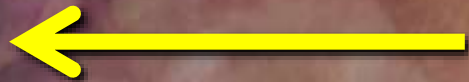


Safe Grain Vac Use

⚠ Assess grain condition

⚠ Communicate to person operating

⚠ Use PPE



Do not vacuum from under person's feet!

Compressed Air

Use high pressured air to break up clumps and knock down towers.

- Cheap
- Can be inserted in auger flighting
- Will break up clumps located near sump.



Compressed Air Concerns

- Dust clouds
 - Air quality
 - Dust explosions
 - Fires
- Sound level
- Projectiles (grain)
- Heat



Compressed Air Hardware



Control end



**Threaded end
for extension**



**Connection
end**

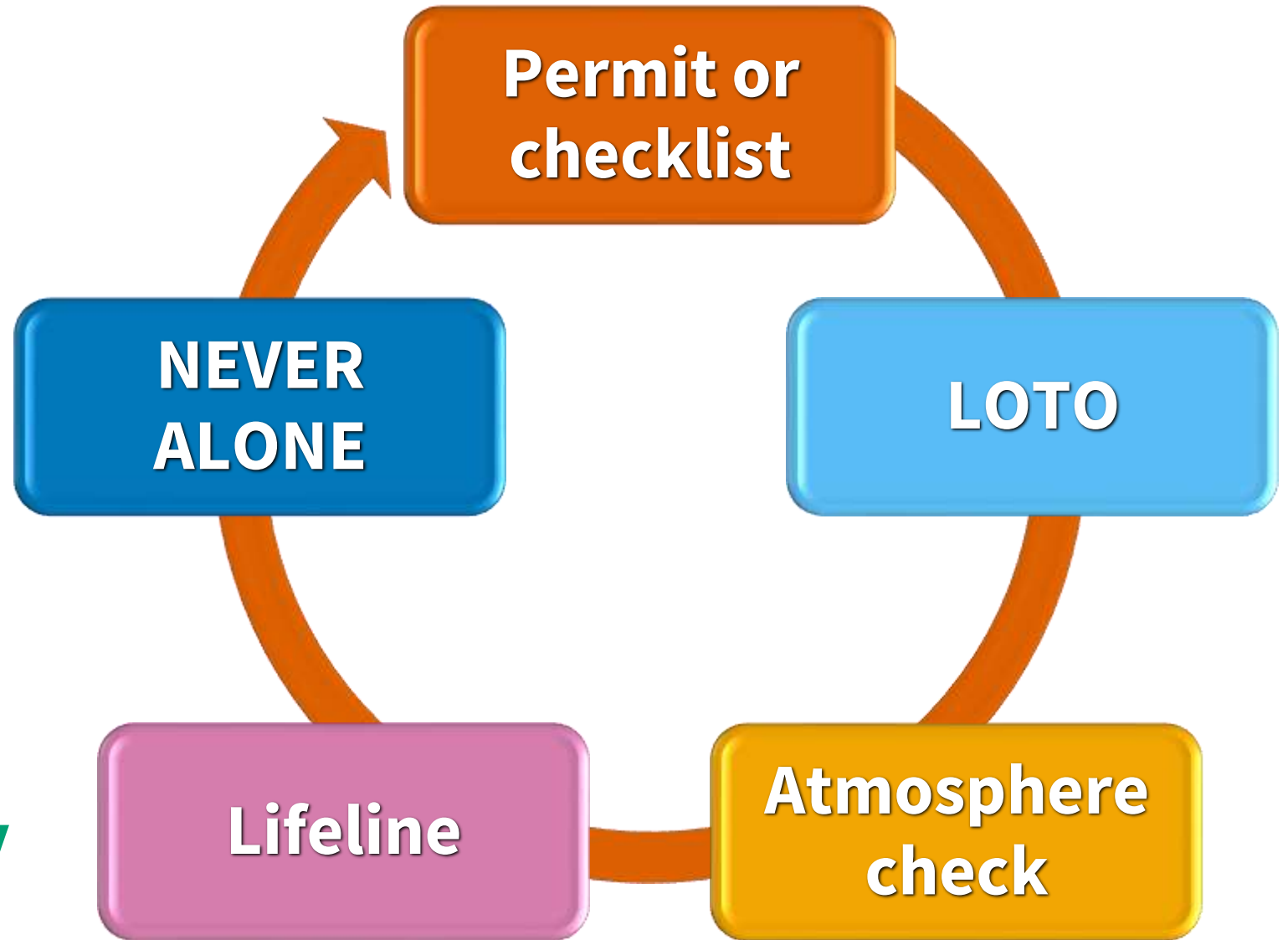
Commercial Bin Cleaning Services



Grain Weevil Robot



5 Critical Steps for Safe Entry



How to respond to a grain entrapment?

BOZEMAN DAILY CHRONICLE NEWS OPINIONS SPORTS BUSINESS OUTDOORS RUGGIES DRILLIAMS CONTESTS MAGAZINES PLACE AD

Man rescued after being trapped in grain bin

MIKE SUNNICKS Bozeman News 11 hrs ago



Firefighters and emergency crews from across the area responded to a grain bin fatality incident near Manhattan Monday evening. CVD/Bozeman Fire/Bozeman Fire

**March 12,
2024**

**Near
Manhattan,
Montana**

NOWCAST KMBC 9 News at 5PM Sunday Watch on Demand

KMBC NEWS 9 abc

Fire Chief: Teen rescued after being buried up to his chest in grain bin in Clinton, Missouri



**January 29,
2024**

Firefighters in Clinton have special equipment on their rescue trucks that allows them to cut an access hole into the roof of a bin when needed.

"This piece of equipment is called The Great Wall of Rescue," Clinton Fire Chief Mark Manuel said. "What it is – is it's panels, wall panels on several sections, and when our rescue crew gets to the victim, they will surround the victim with these panels. What this does is create a safe place for that victim to be if any more corn or any more grain falls down that keeps that grain from covering the victim."

Don't Let This Happen Where You Work!



Acknowledgements

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Next farmdoc webinar

Thursday, April 4, 2024 from 11 am to noon CT

Managing Risks with Cover Crops

A Case Study of the Most Profitable Illinois Farms Using Cover Crops
Register at go.illinois.edu/PCM2024

Cover crops remain the best conservation practice in the organic rich soils of the Midwest where nutrient loss, soil health, and climate change are concerns. Many farmers have also seen agronomic benefits related to weed control, water infiltration, and protection during crop-loss weather events. Still, there are challenges for farm-level profitability and risks. Using Precision Conservation Management (PCM) data and farmer interviews, we present the current best practices to manage risks and protect profitability for Midwest farmers.

April 16, 2024, is next

Cultivating Caution

A Monthly Guide to Farm Safety & Health

go.illinois.edu/SafeAg2024

Farmworker Safety and Health

Farm work presents many hazards that can lead to injury, illness, and even death. This webinar focuses on the unique risks faced by agricultural workers, including migrant and hired laborers, and ways to protect their safety and health. We will discuss common issues like pesticide exposure, musculoskeletal disorders, transportation incidents, and lack of adequate housing. You'll learn practical tips for creating a culture of safety, training workers (including seasonal, migrant, and hired laborers), and implementing best practices to protect all workers in your agricultural operation.

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