Concrete Grain Elevators: Their Early Design, Construction, Successes and Failures

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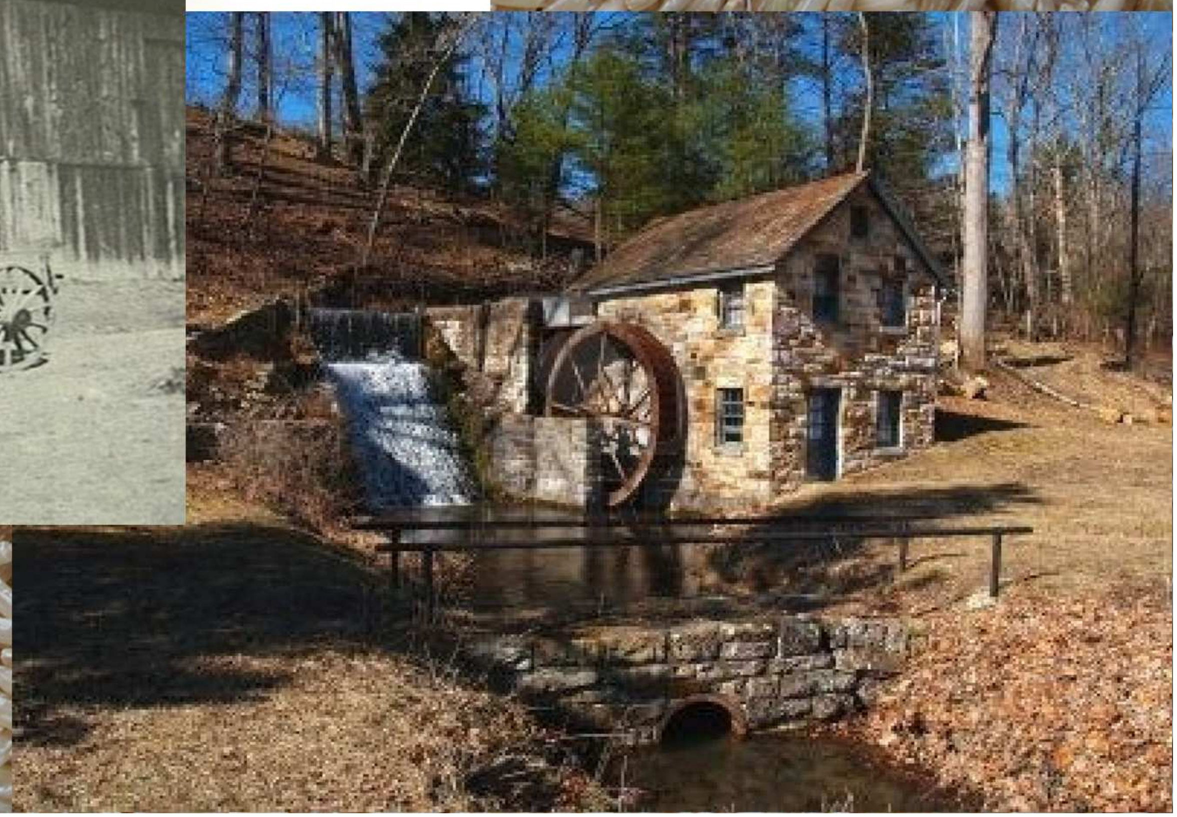
- Wanderer/Gatherer Societies
- Became Agrarian Societies



Needed to store and grind grain

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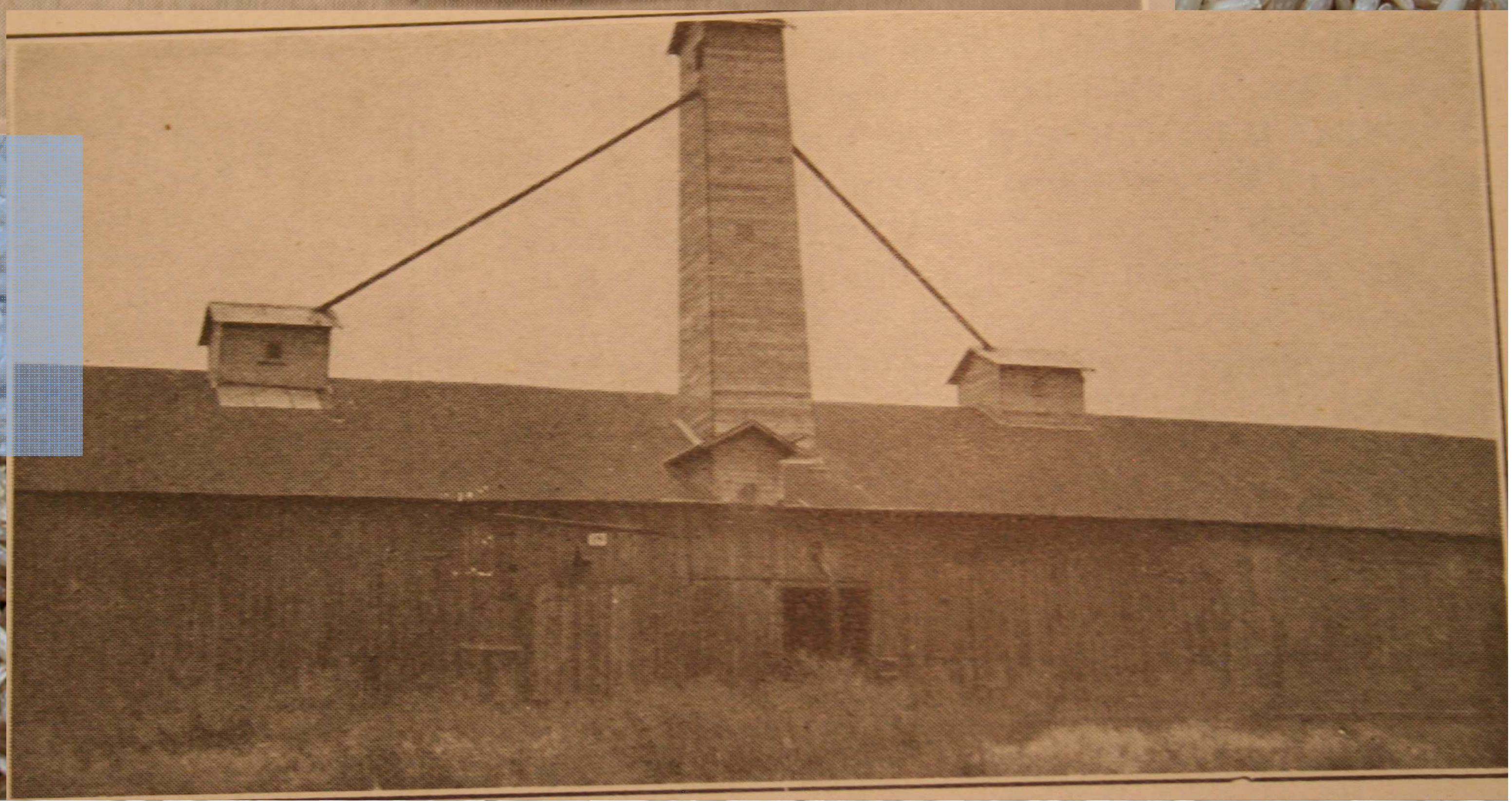

Flat Houses – Early Grain Storage

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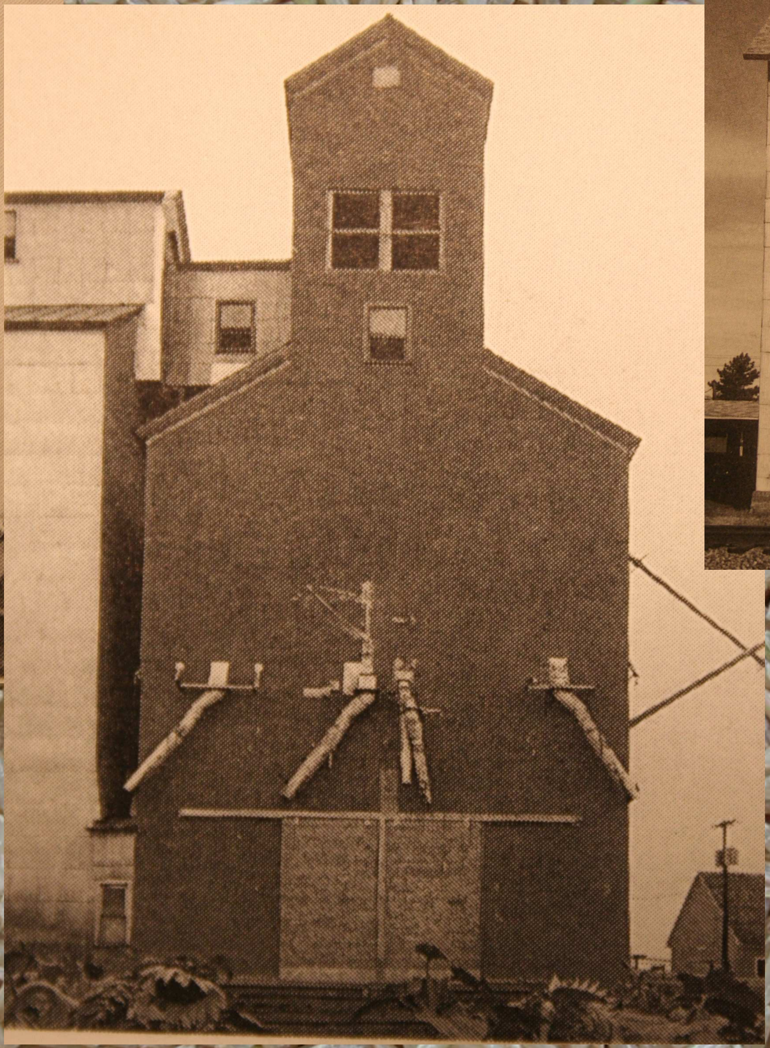
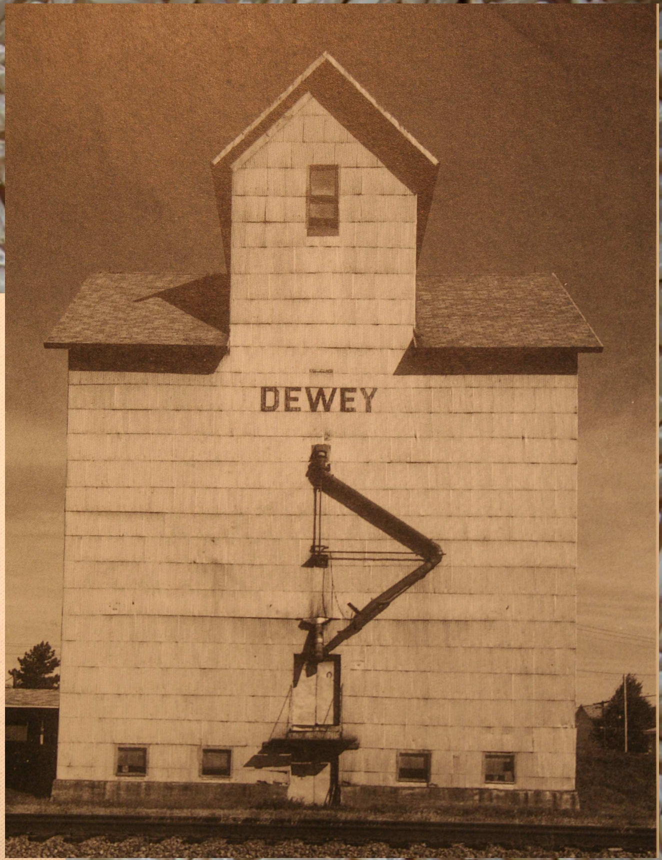
Early Wood Elevators





Early Elevators

- Stored grain between harvest and use
- Provided a transfer point from farm to user

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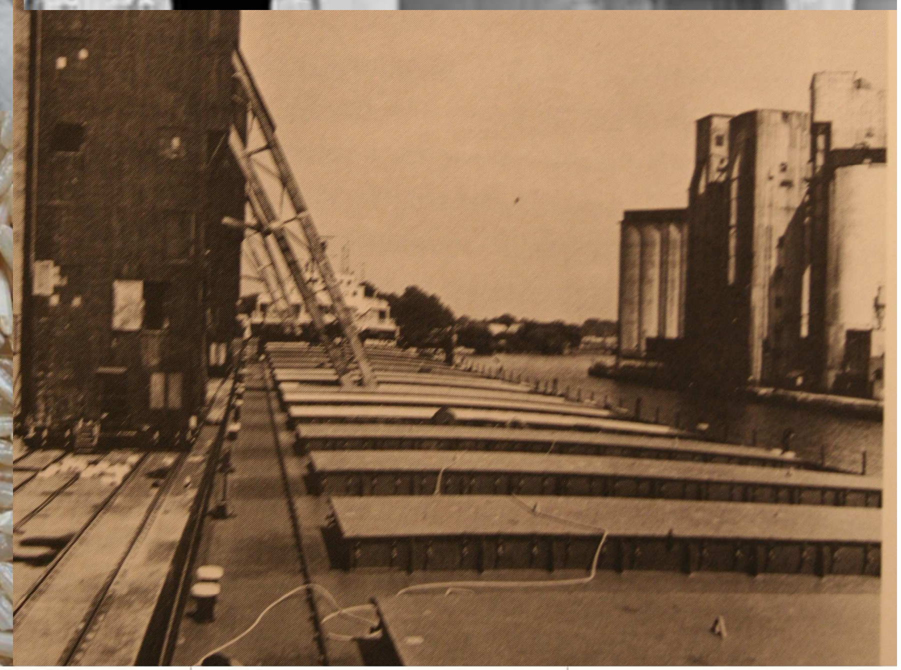
Elevators started on the docks



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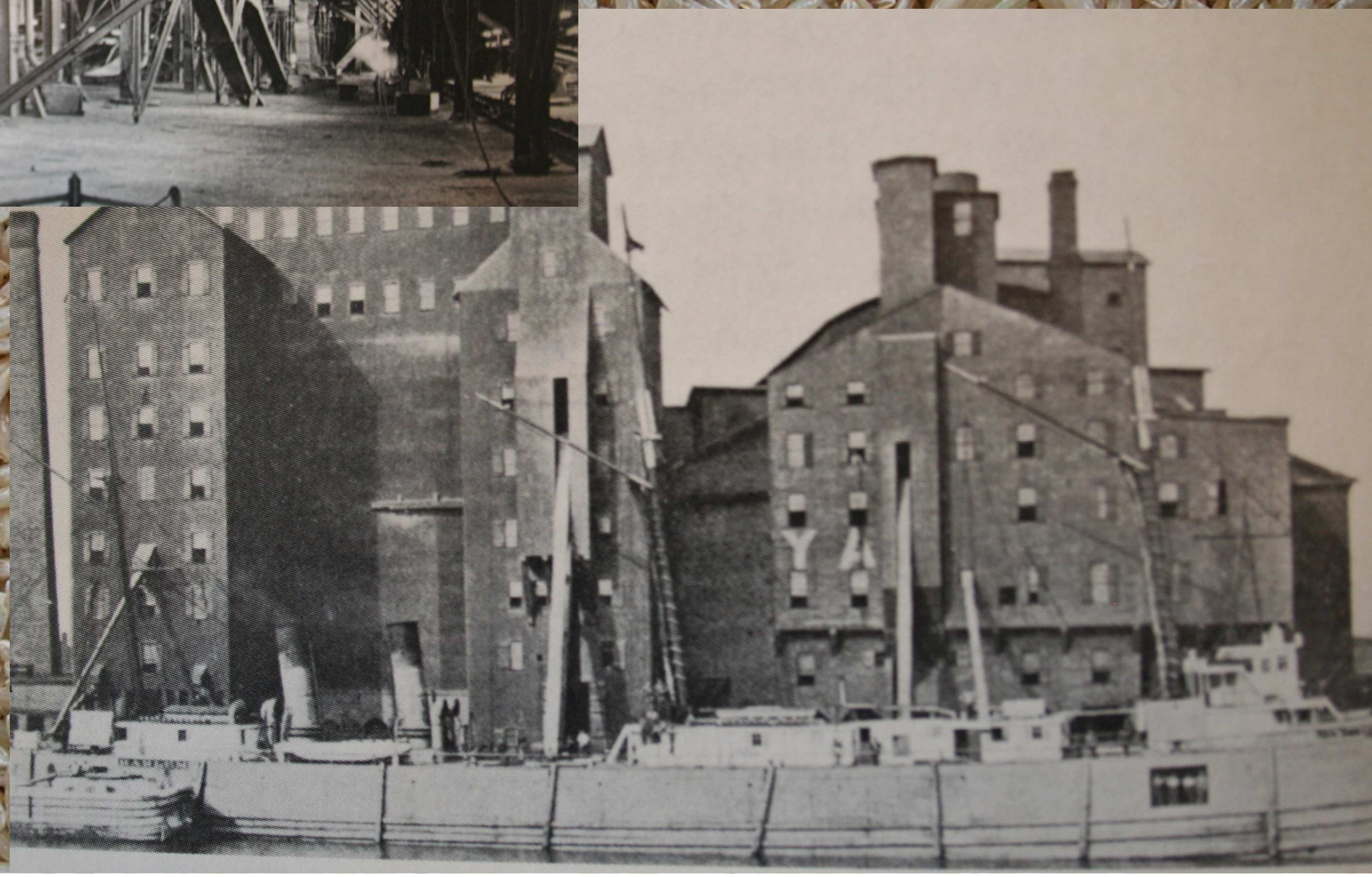
Conveyors moved grain from ships to docks to trains



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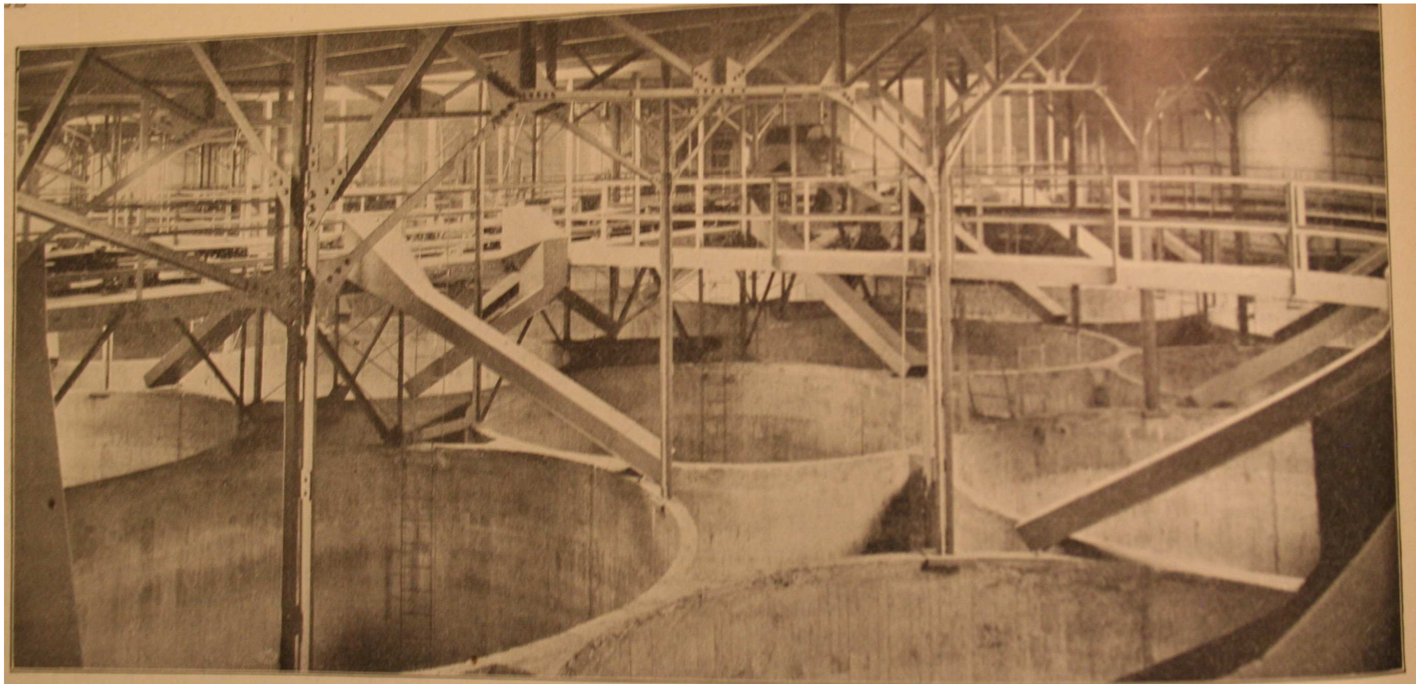
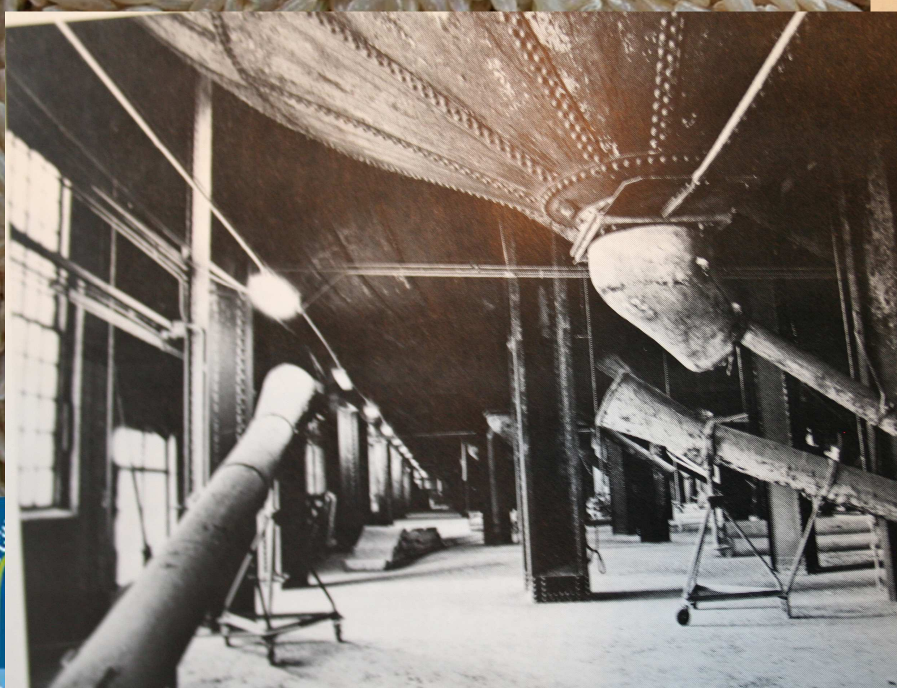
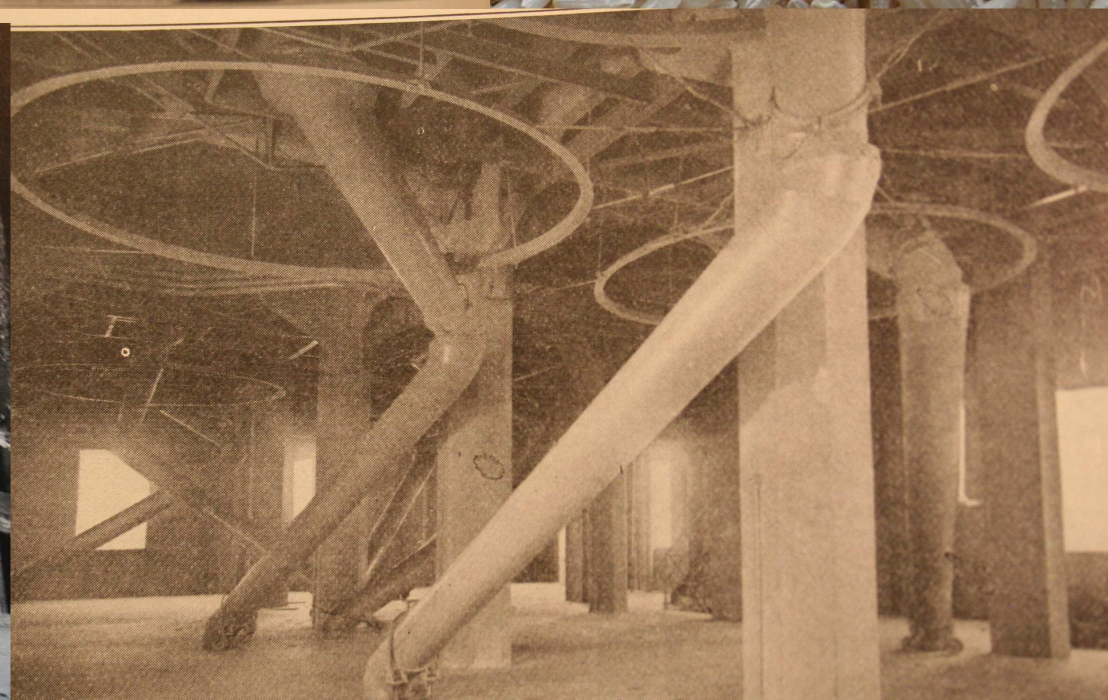


Conveyors moved grain within the elevator





Two Types of Grain Elevators:

Country Elevators
- Smaller (25k-35k bushels)
- Set in rural communities
- Transfer from farm to truck/rail.
- Store grain after harvest

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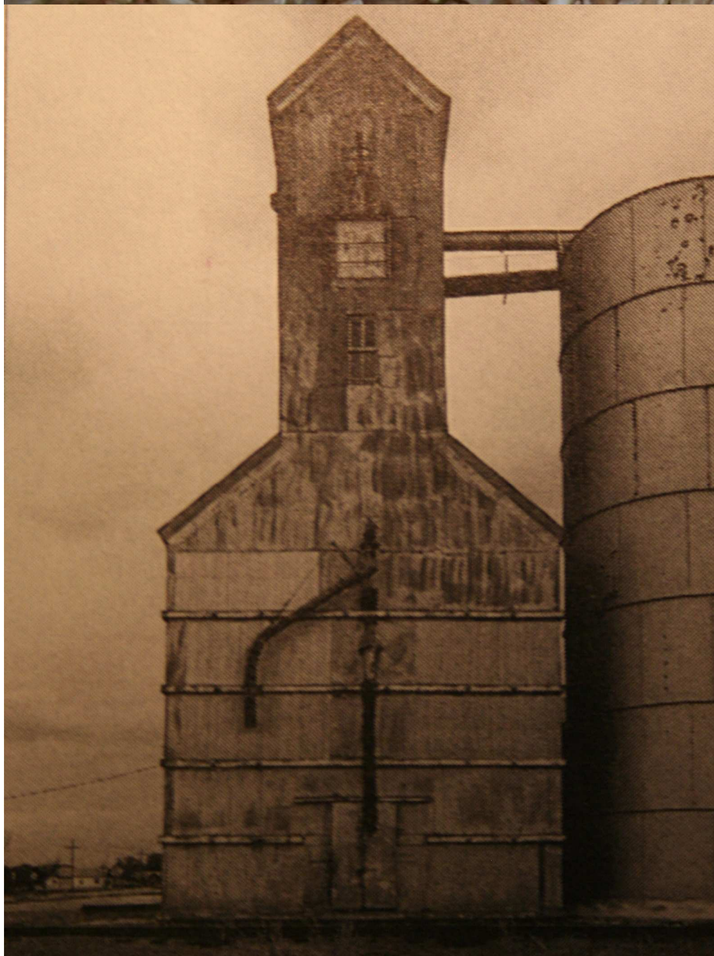
Country Elevators



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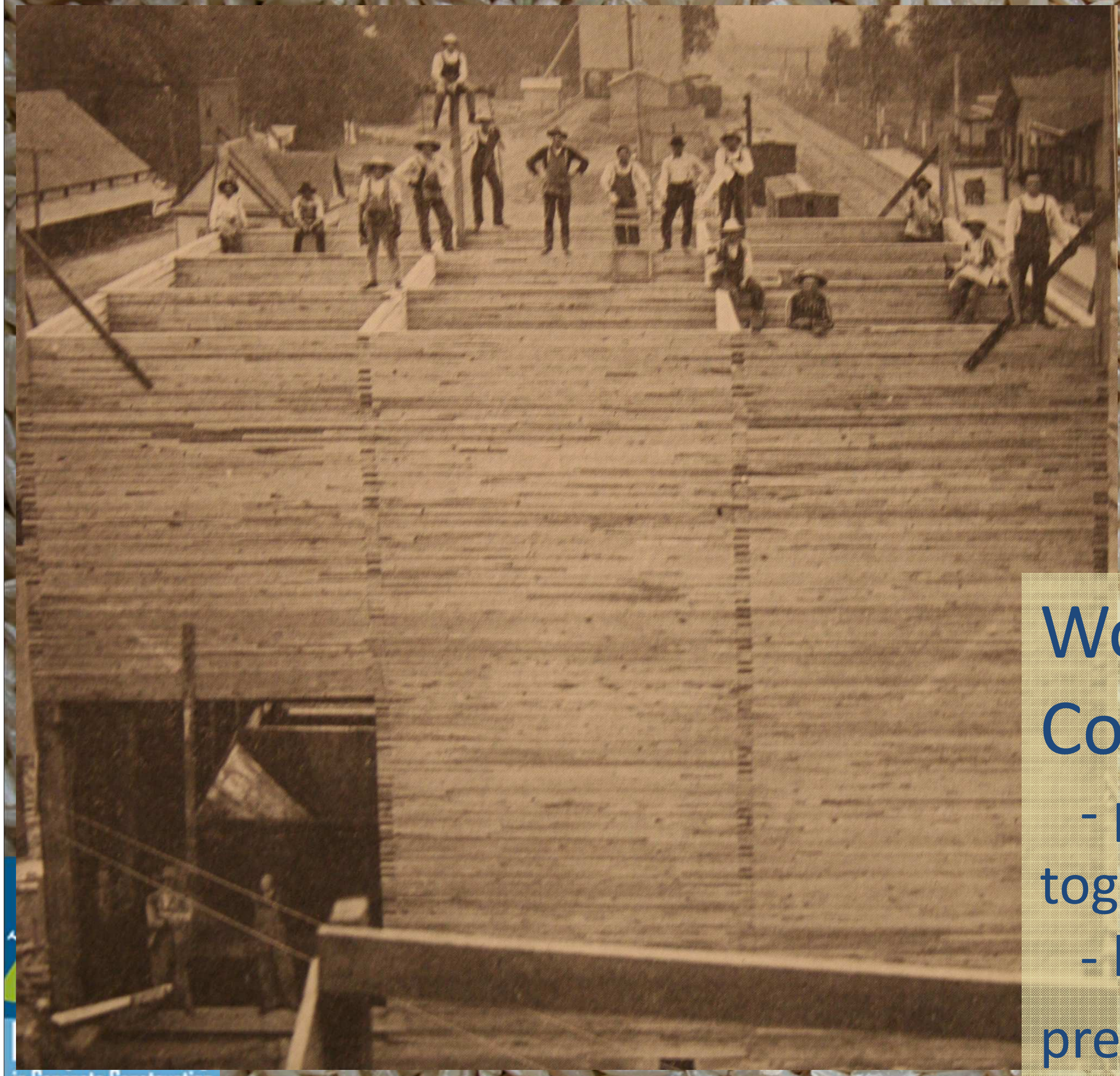
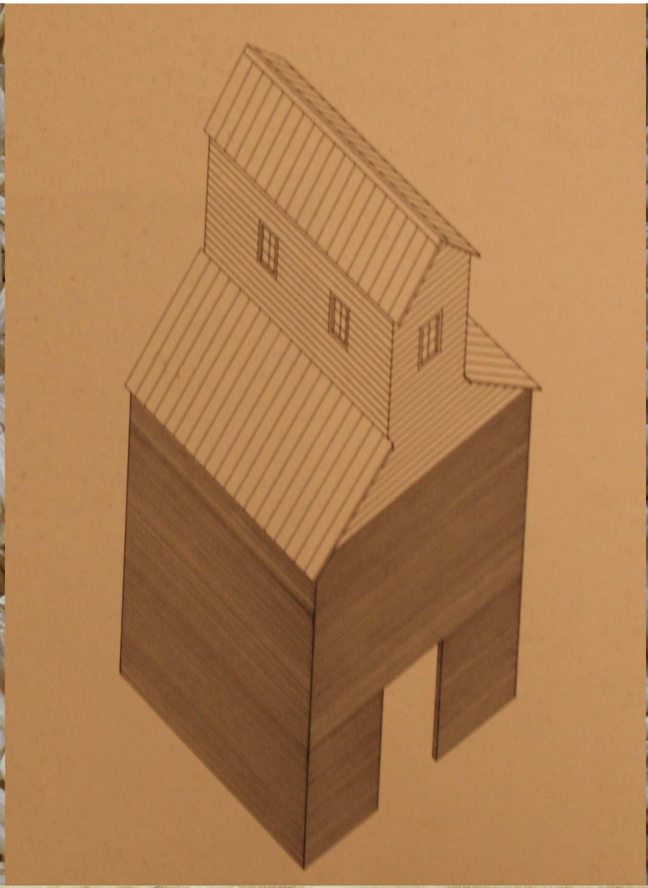
Country Elevators





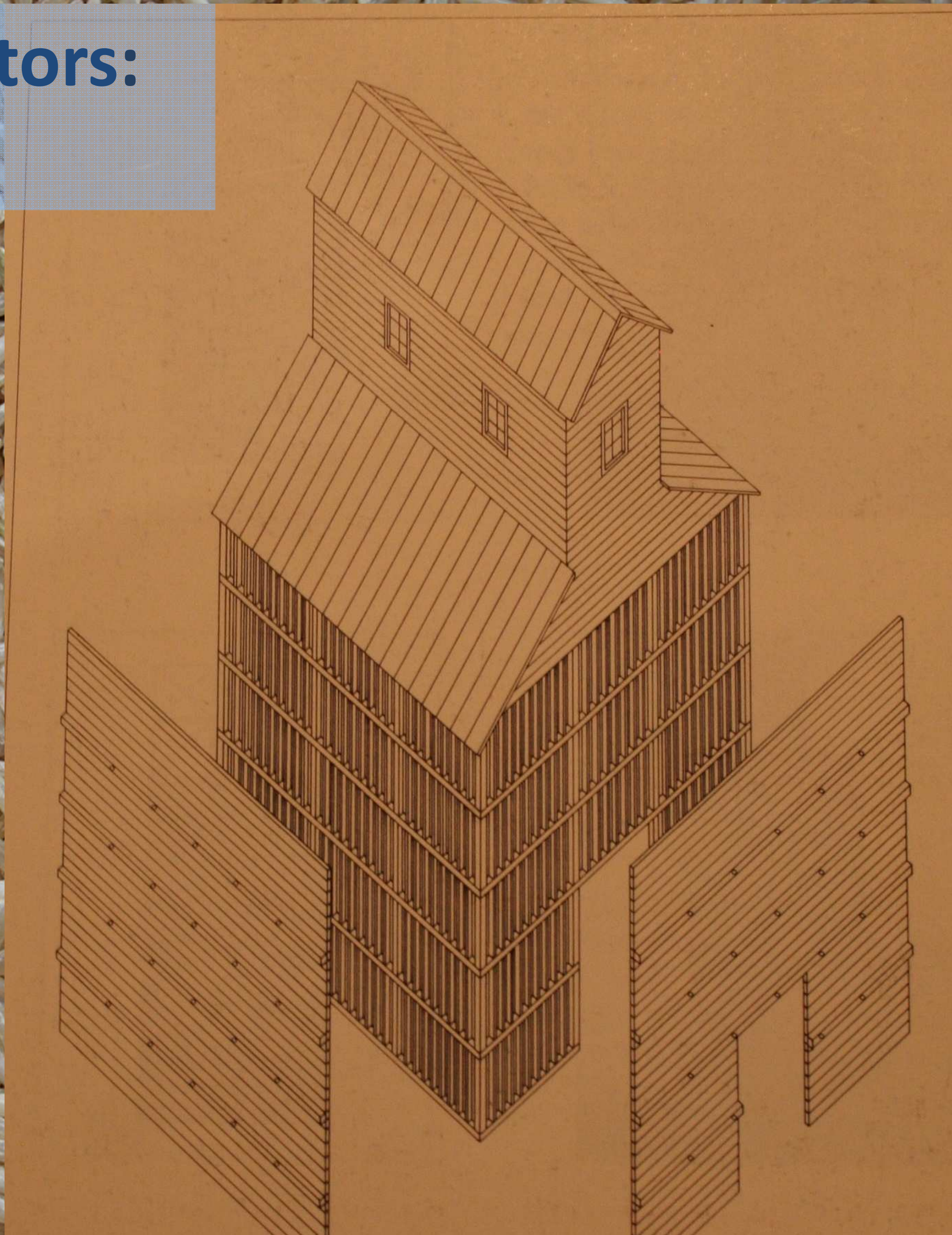
Wood – Cribbed Construction

- planks laid flatwise, spiked together
- high stiffness resists lateral pressure

Two Types of Grain Elevators: Country Elevators

Wood – Studded Construction

- Standard balloon-frame construction



Wood Elevator Problems:

- Prone to fire
- 5-10 year economic life
- Expensive to insure

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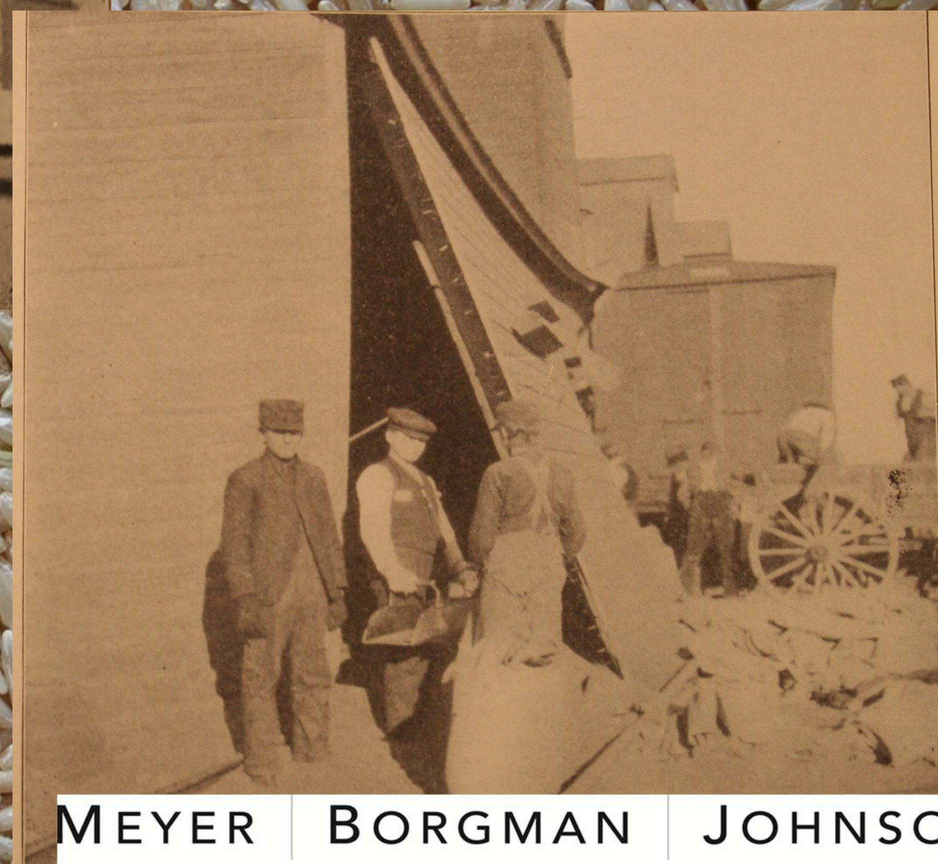
Wood Elevator Problems:

A burst country elevator



19th Century Transportation Advances

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19th Century Transportation Advances

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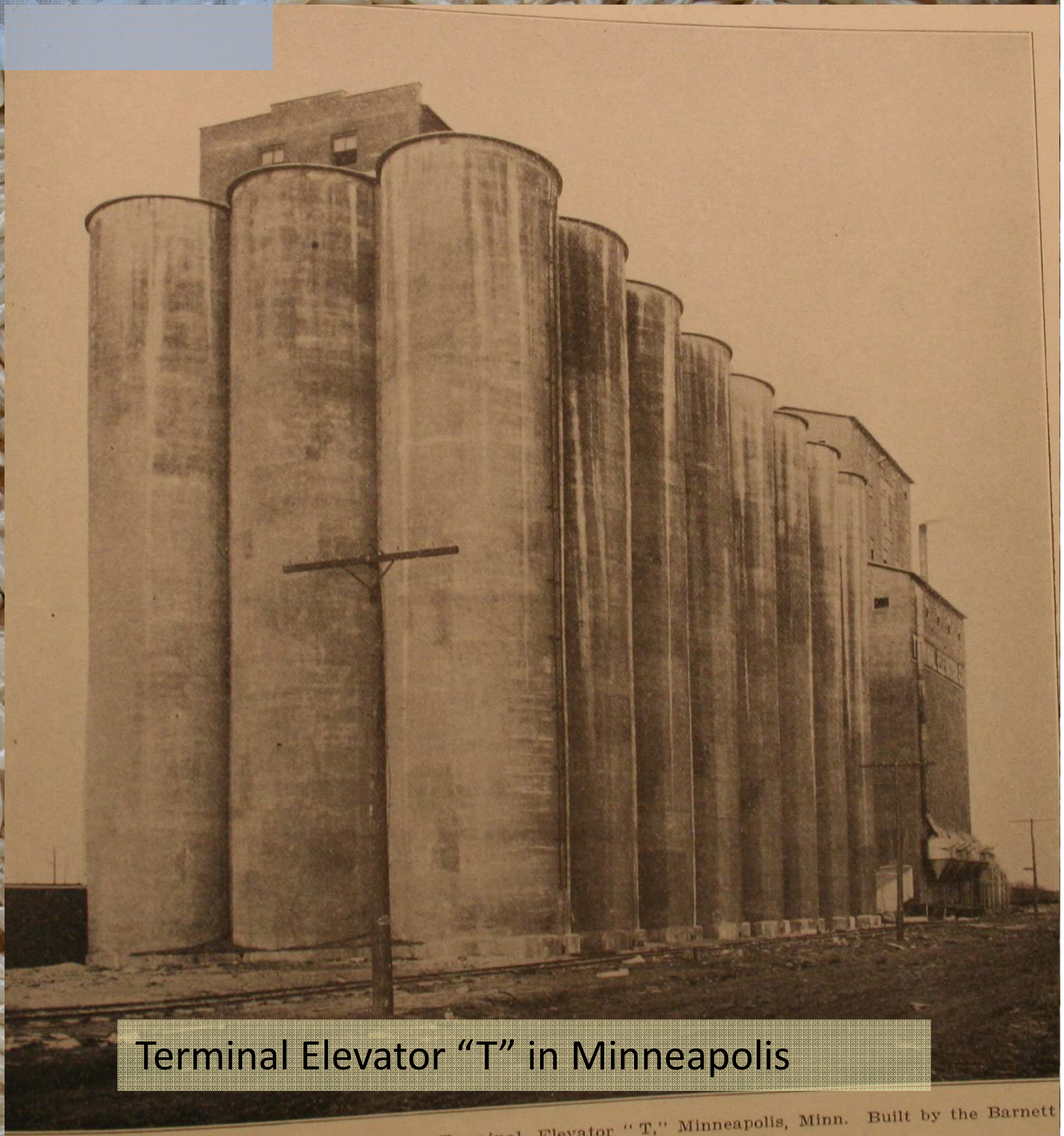
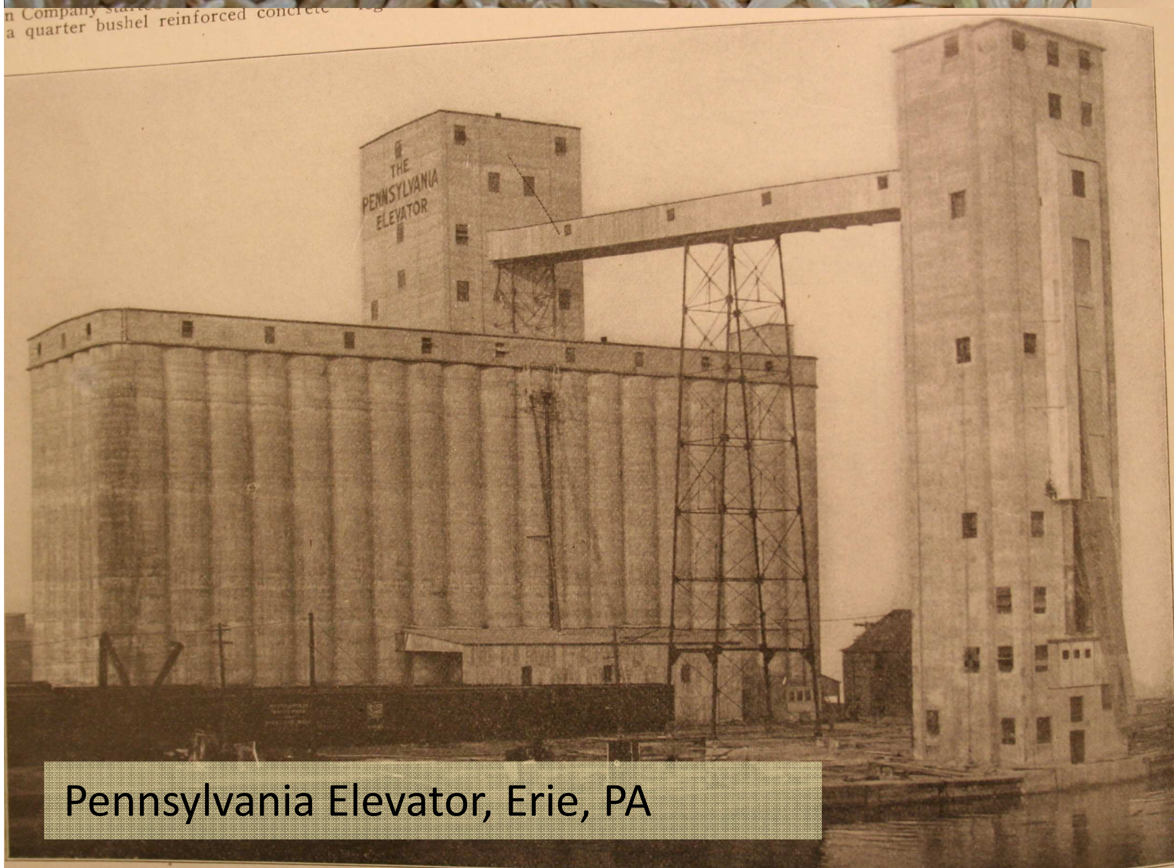
Two Types of Grain Elevators: Terminal Elevators

- Capacity: millions of bushels
- Located in cities, at ports, rail intersections
- In the Midwest, eastern Plains: Minneapolis; Chicago; Buffalo, NY

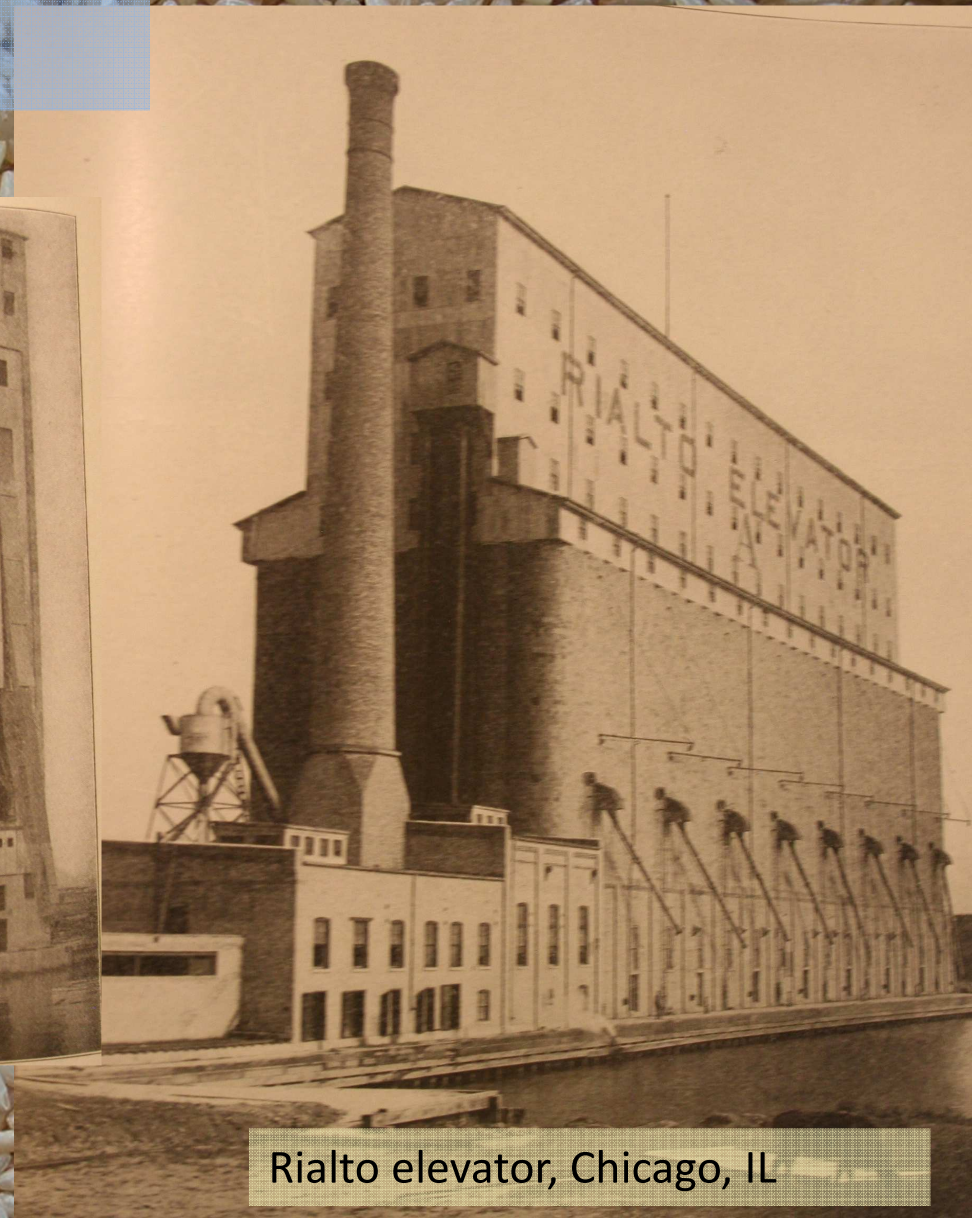


Terminal Elevator "T" in Minneapolis

Two Types of Grain Elevators: Terminal Elevators



Pennsylvania Elevator, Erie, PA



Rialto elevator, Chicago, IL

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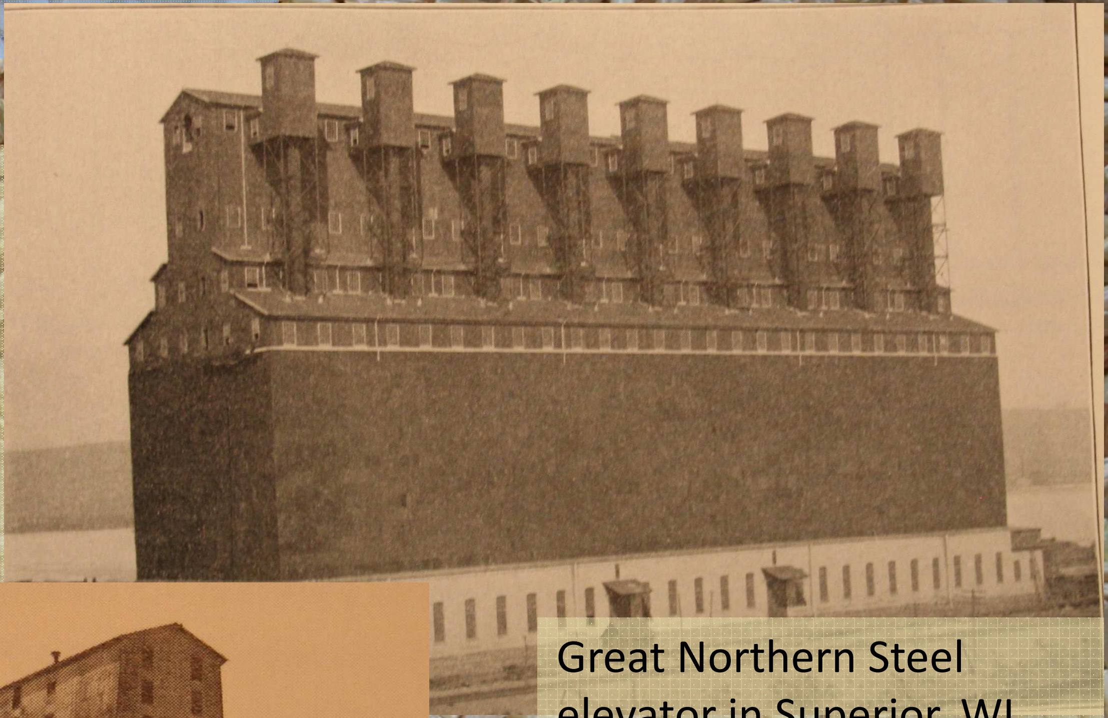
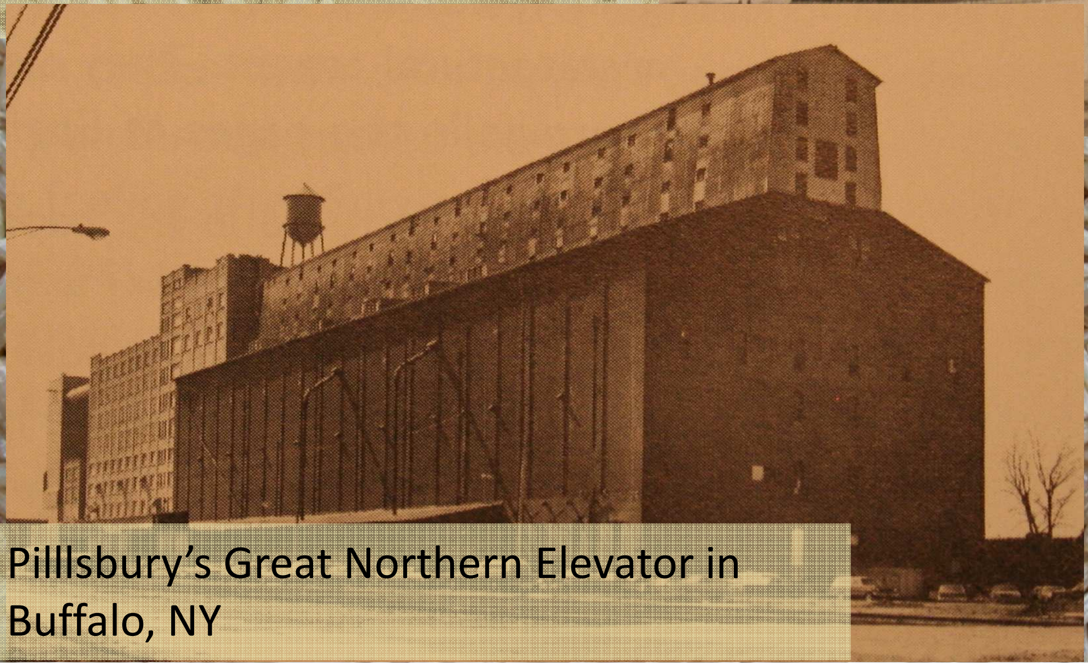
Terminal Elevators: Steel Elevators

- Used pressure vessel technology
- Similar to locomotive boilers, building boilers.



Great Northern Steel elevator in Superior, WI.
- Designed by Max Toltz

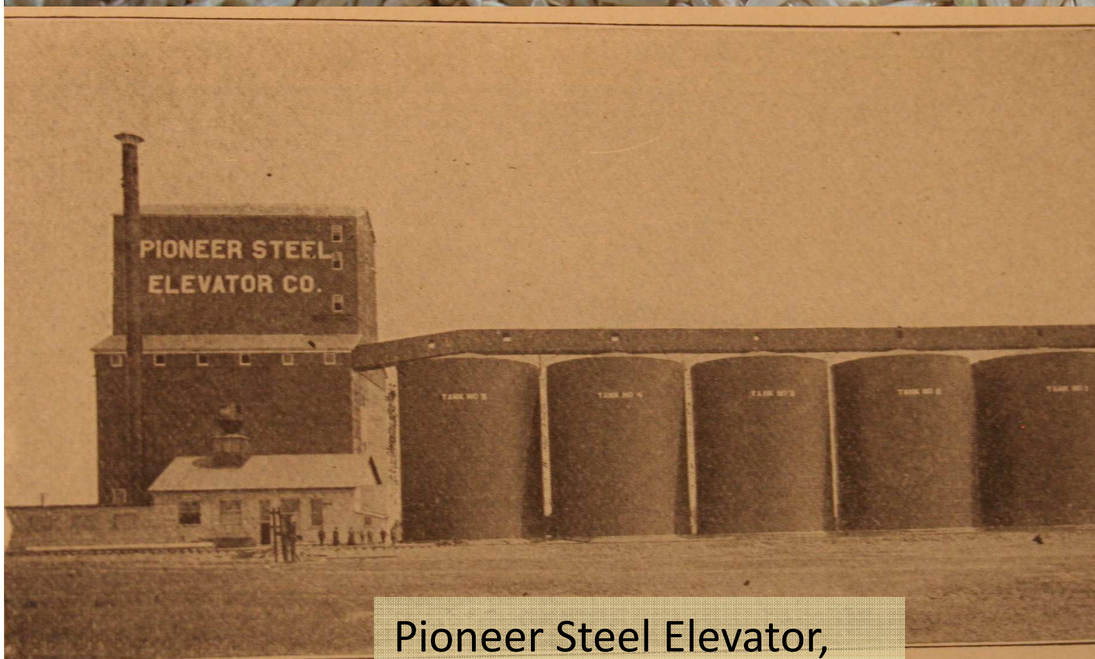


Pillsbury’s Great Northern Elevator in Buffalo, NY

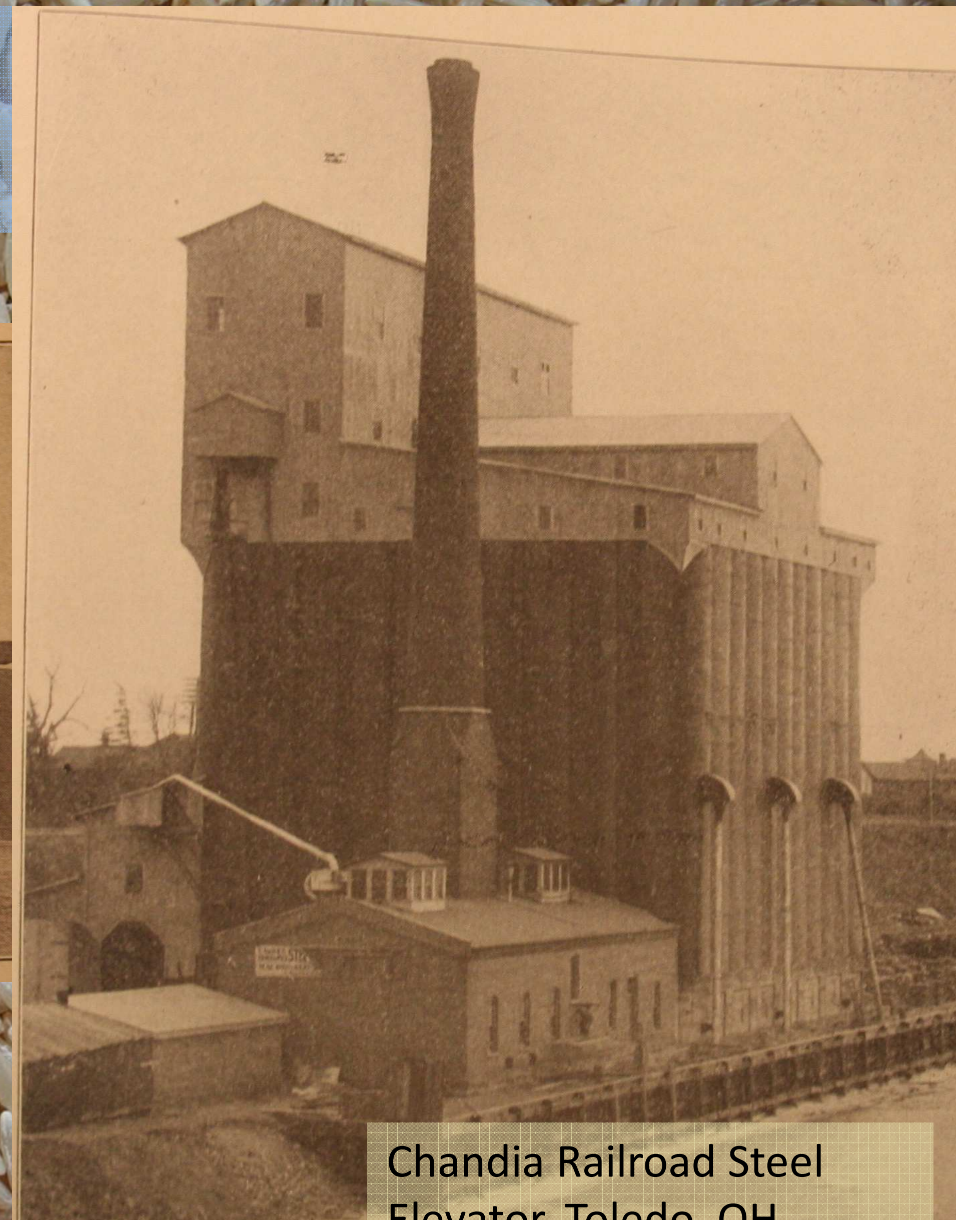
Terminal Elevators: Steel Elevators

Great Northern Steel Elevator, Buffalo, NY

Terminal Elevators: Steel Elevators

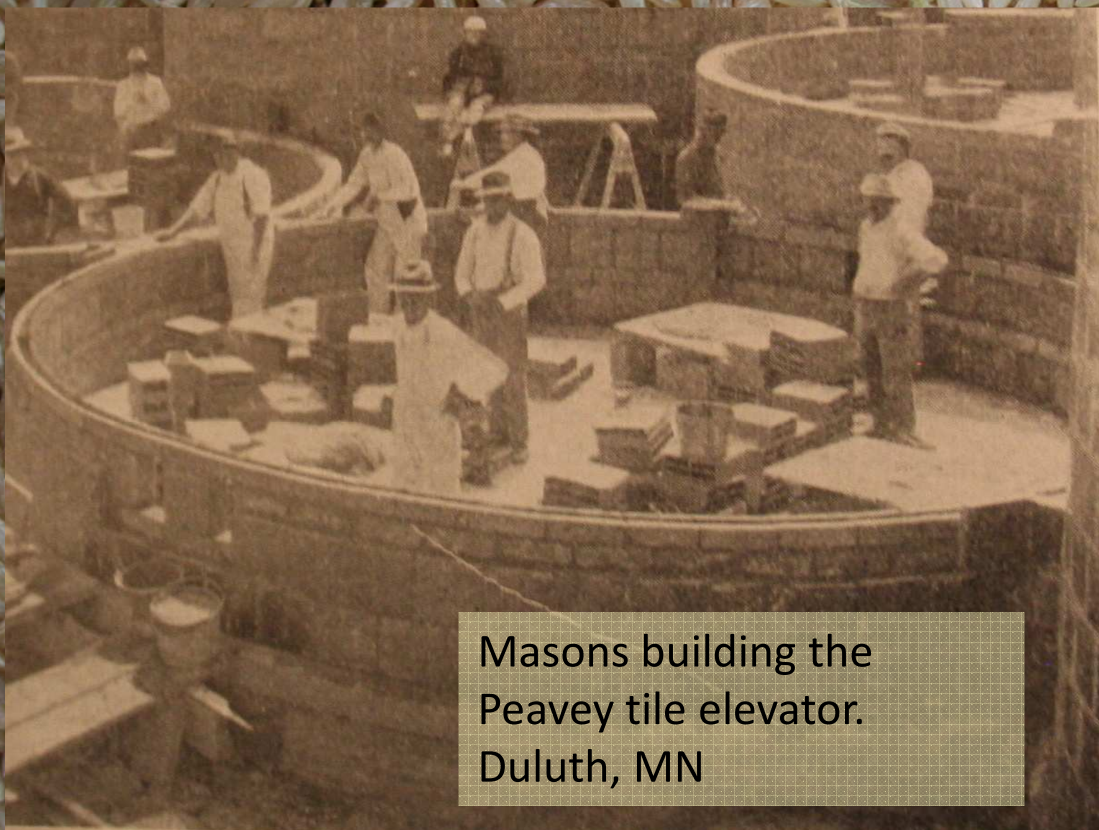


Pioneer Steel Elevator, Minneapolis

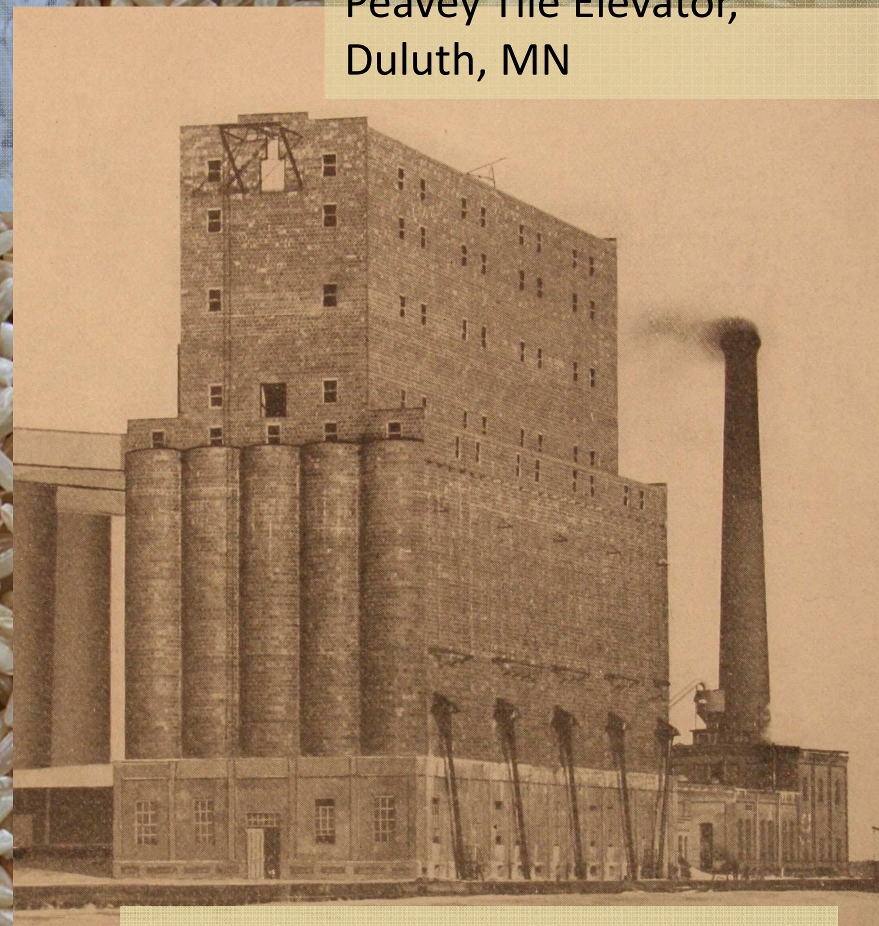


Chandia Railroad Steel Elevator, Toledo, OH

Terminal Elevators: Tile Elevators



Masons building the Peavey tile elevator. Duluth, MN



Peavey Tile Elevator, Duluth, MN

- Provided good thermal insulation
- Expensive to build

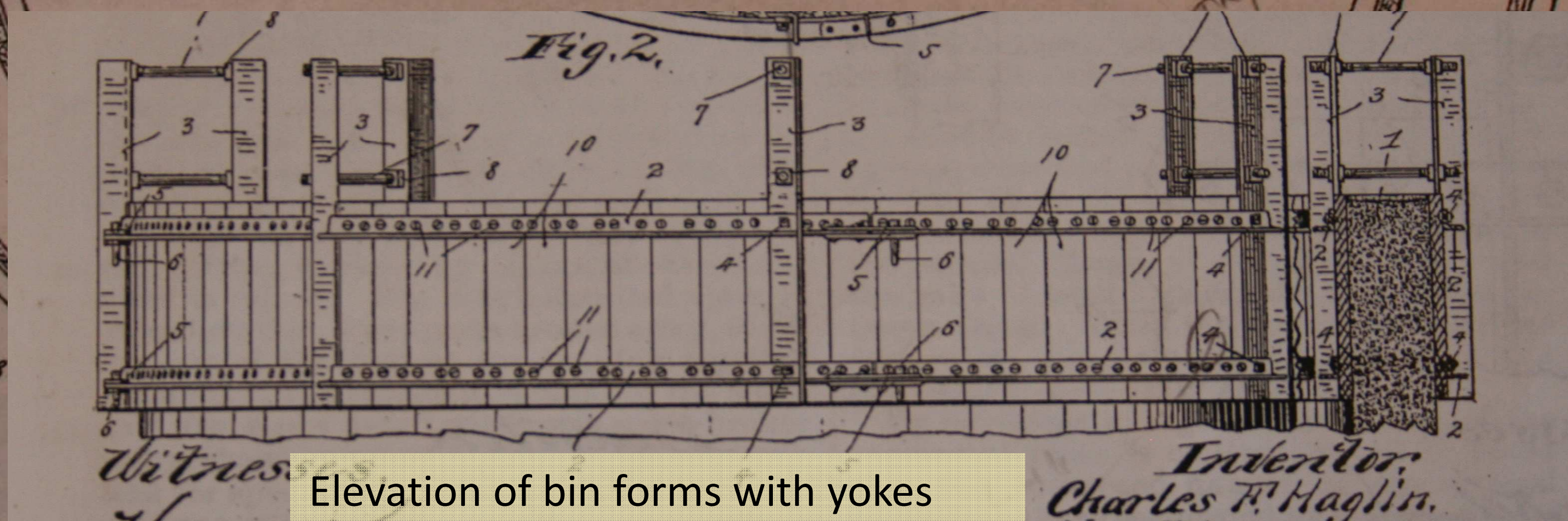
The Beginning of the Concrete Elevator: "Peavey's Folly"

- F.H. Peavey led the largest grain handling company in the world.
- Engaged C.F. Haglin to design a test elevator in St. Louis Park, MN.

Frank Hutchinson Peavey

"Peavey's Folly" - Haglin's Patent.

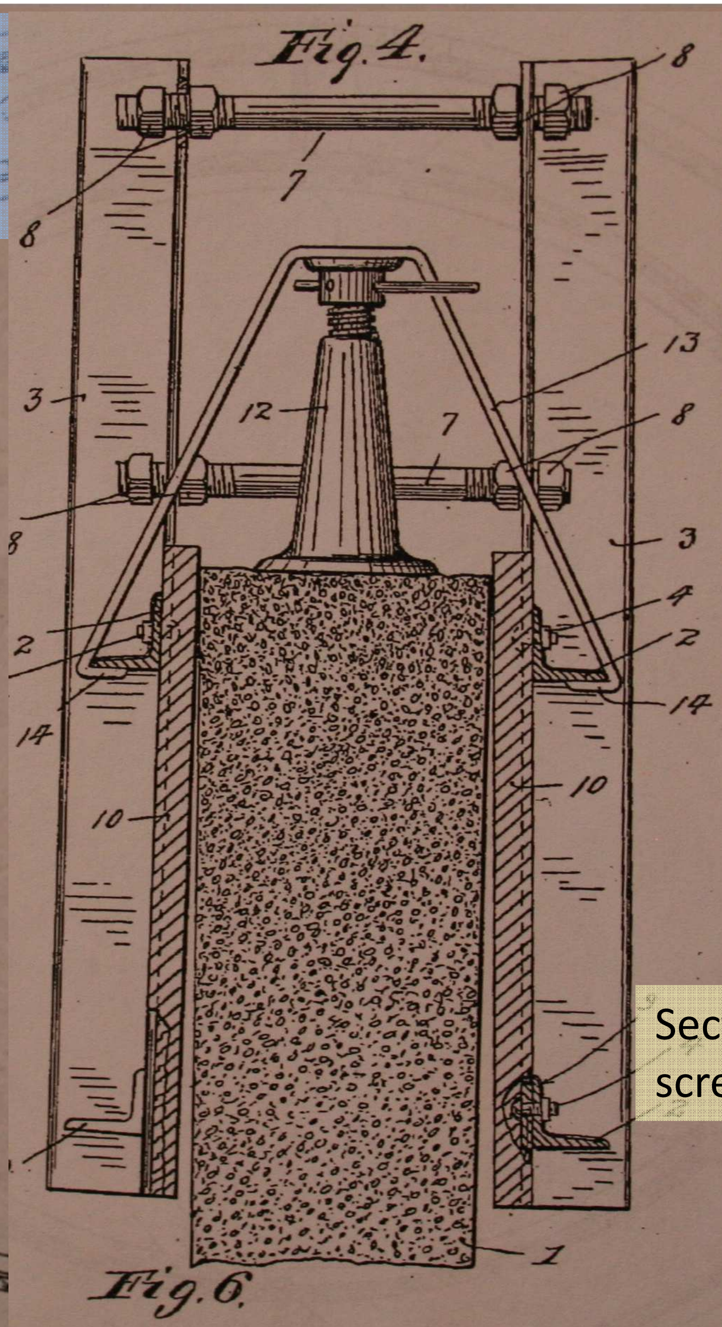
- Charles Haglin's patent # 662,266 drawings, dated Nov 20, 1900.
- Concentric forms
- Wood forms supported by wood frames.



Elevation of bin forms with yokes

“Peavey’s Folly” - Haglin’s Patent.

- Steel yokes connected the inside form to the outside form
- Screw jack lifted forms from top of the day’s pour.



Section of screw jack

The Beginning of the Concrete Elevator: "Peavey's Folly"

- Grain was stored for 6 months in a Minnesota winter
- The resulting grain was dry and unspoiled

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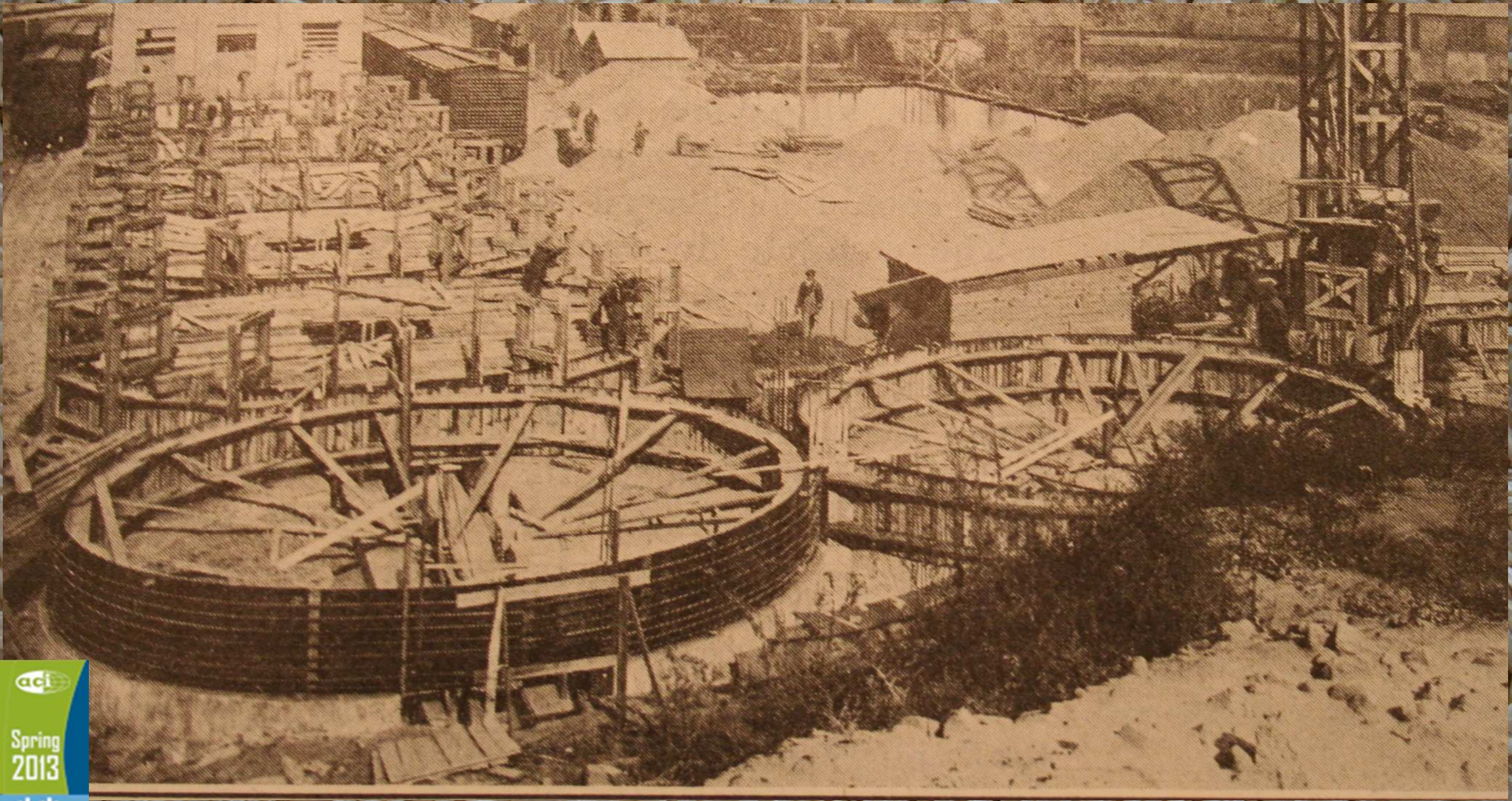
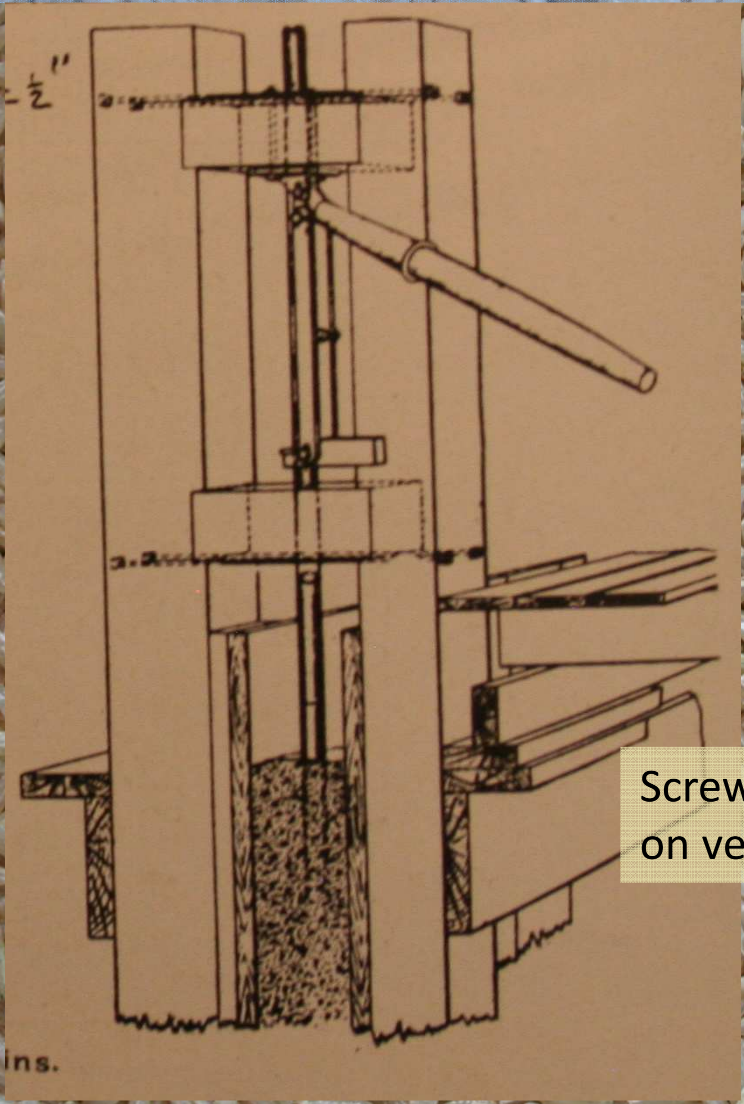
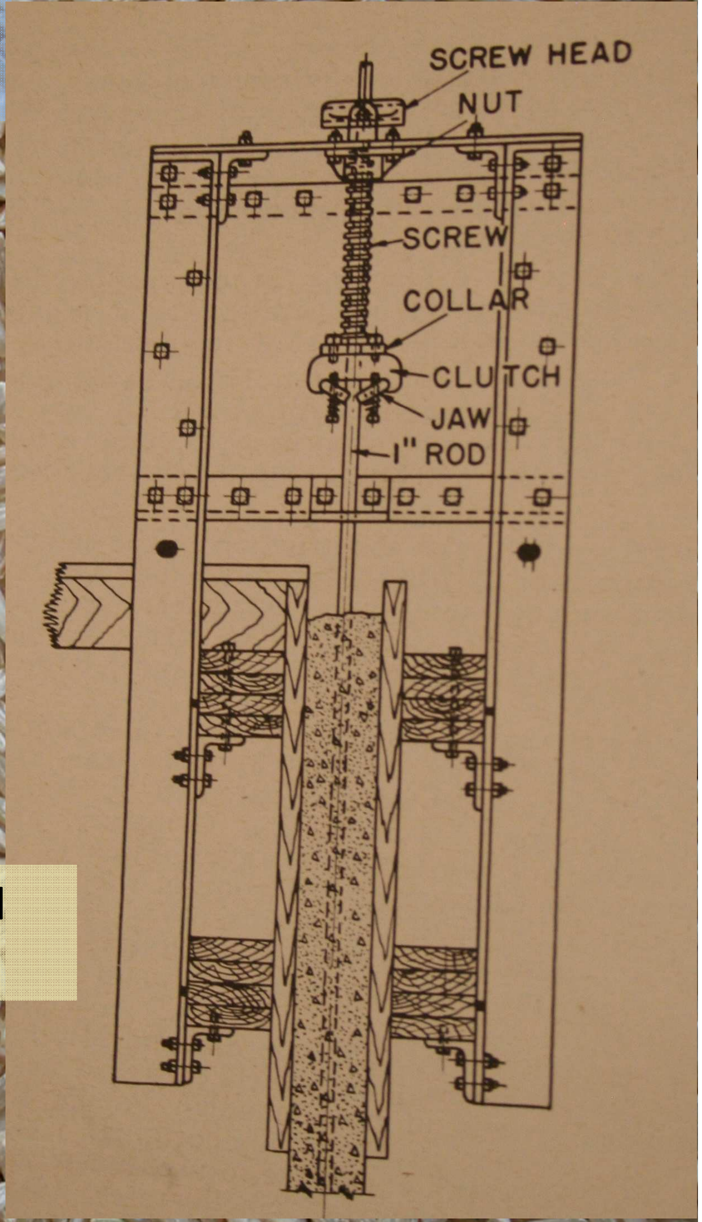
The Concrete Elevator: Improvements on Haglin's Design



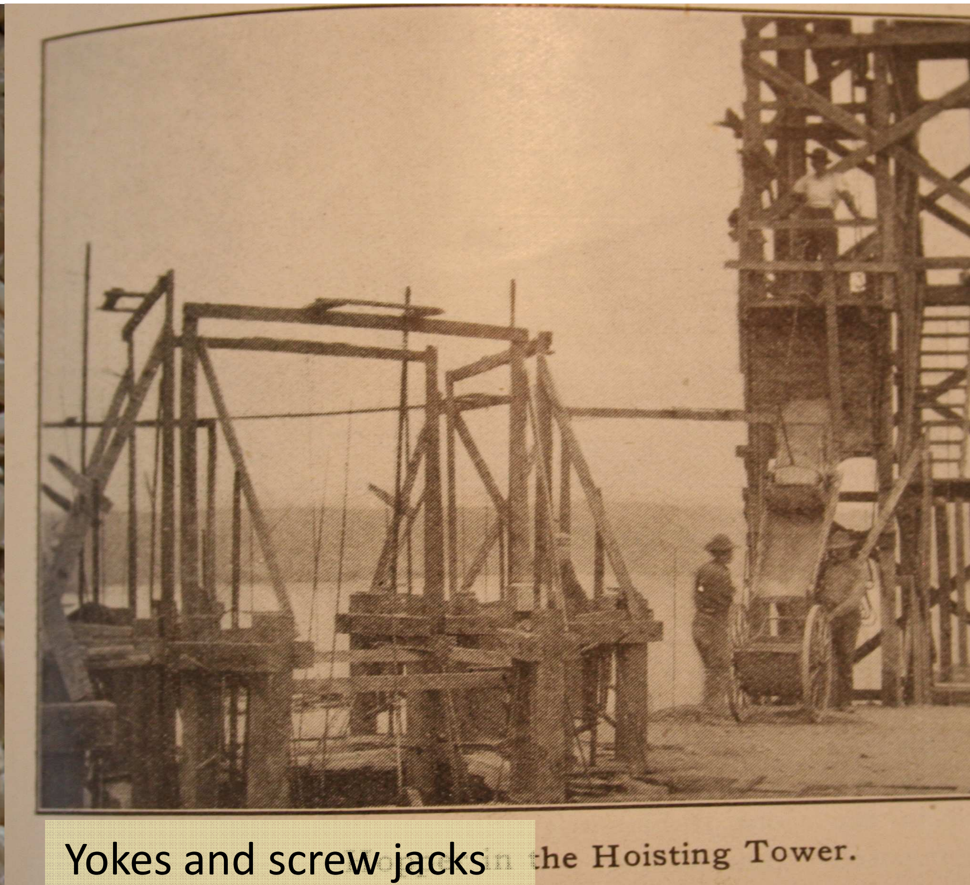
The Concrete Elevator: Improvements on Haglin's Design



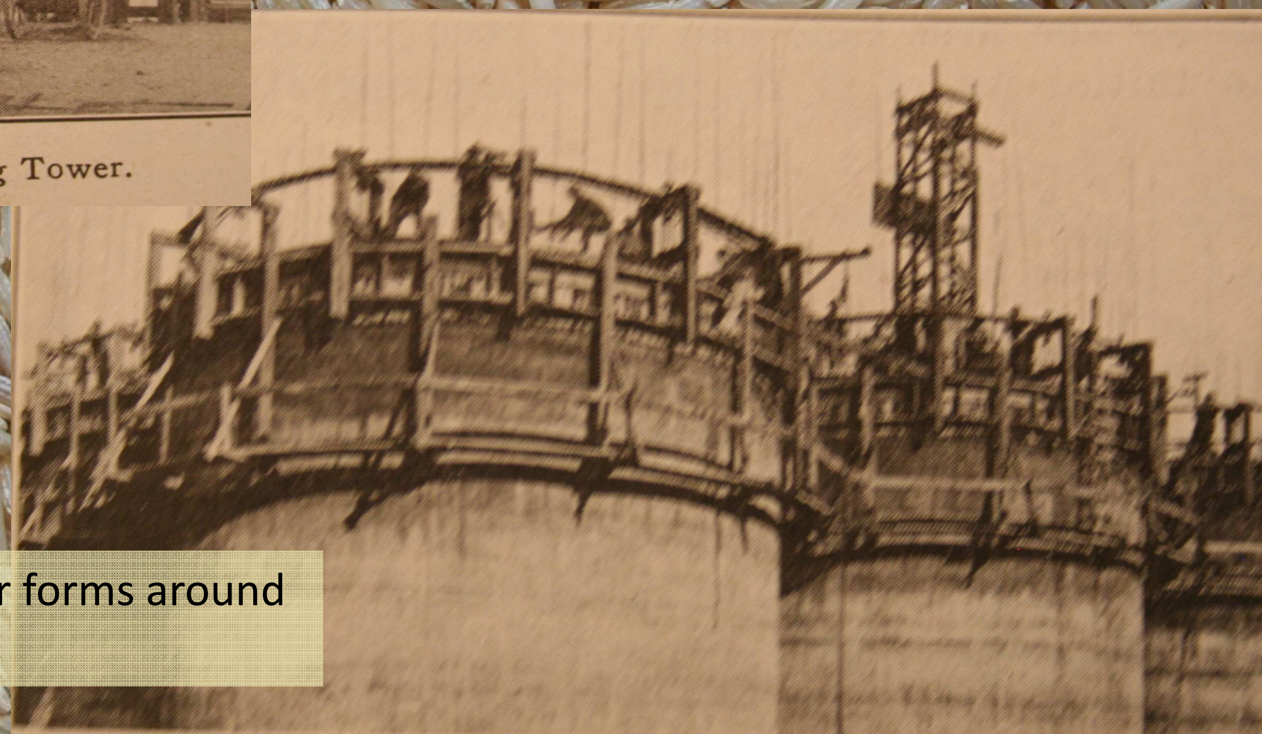
Screw jack supported on vertical rod



The Concrete Elevator: Improvements on Haglin's Design



Yokes and screw jacks atop a bin



Elevator forms around a bin

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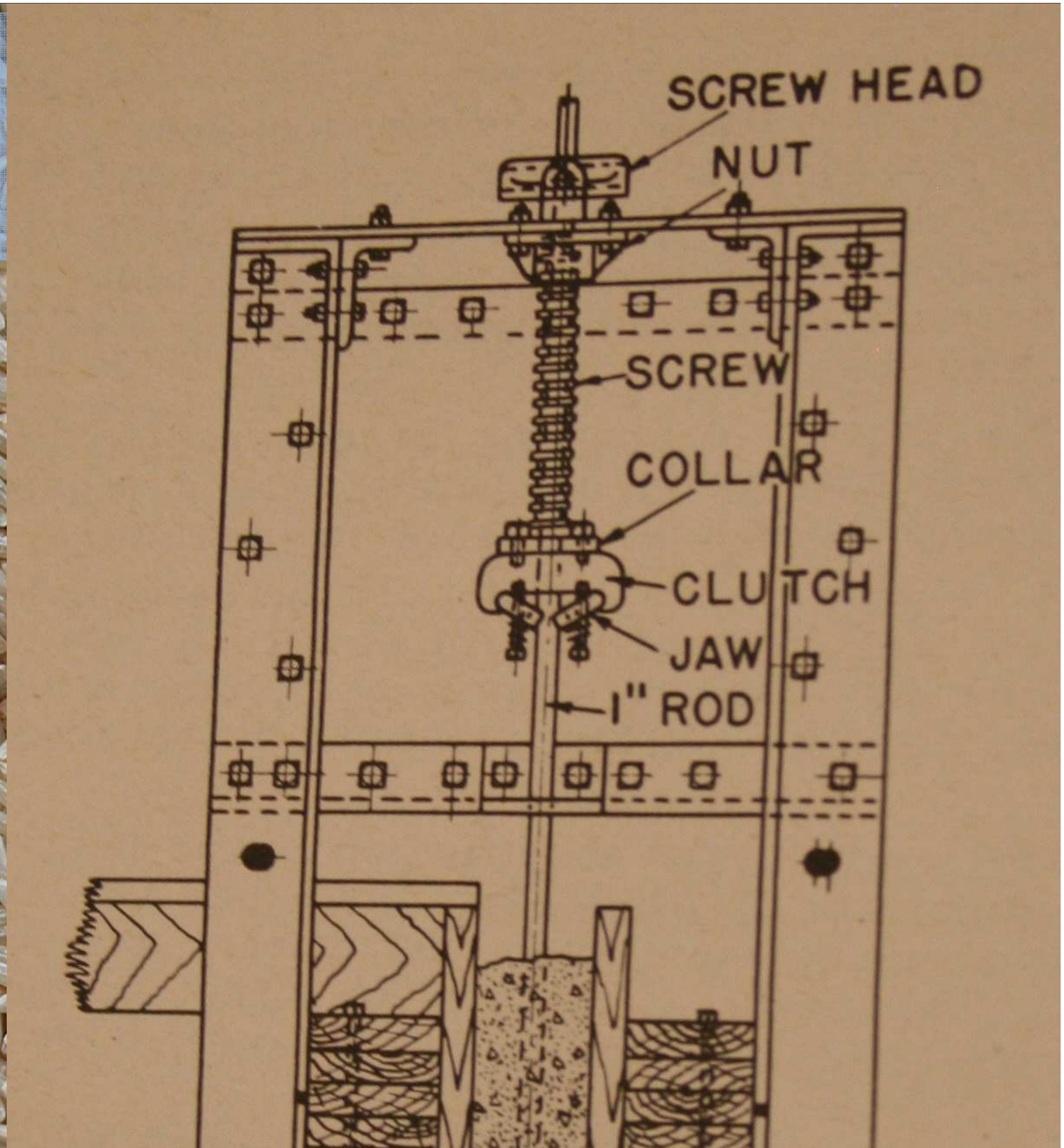
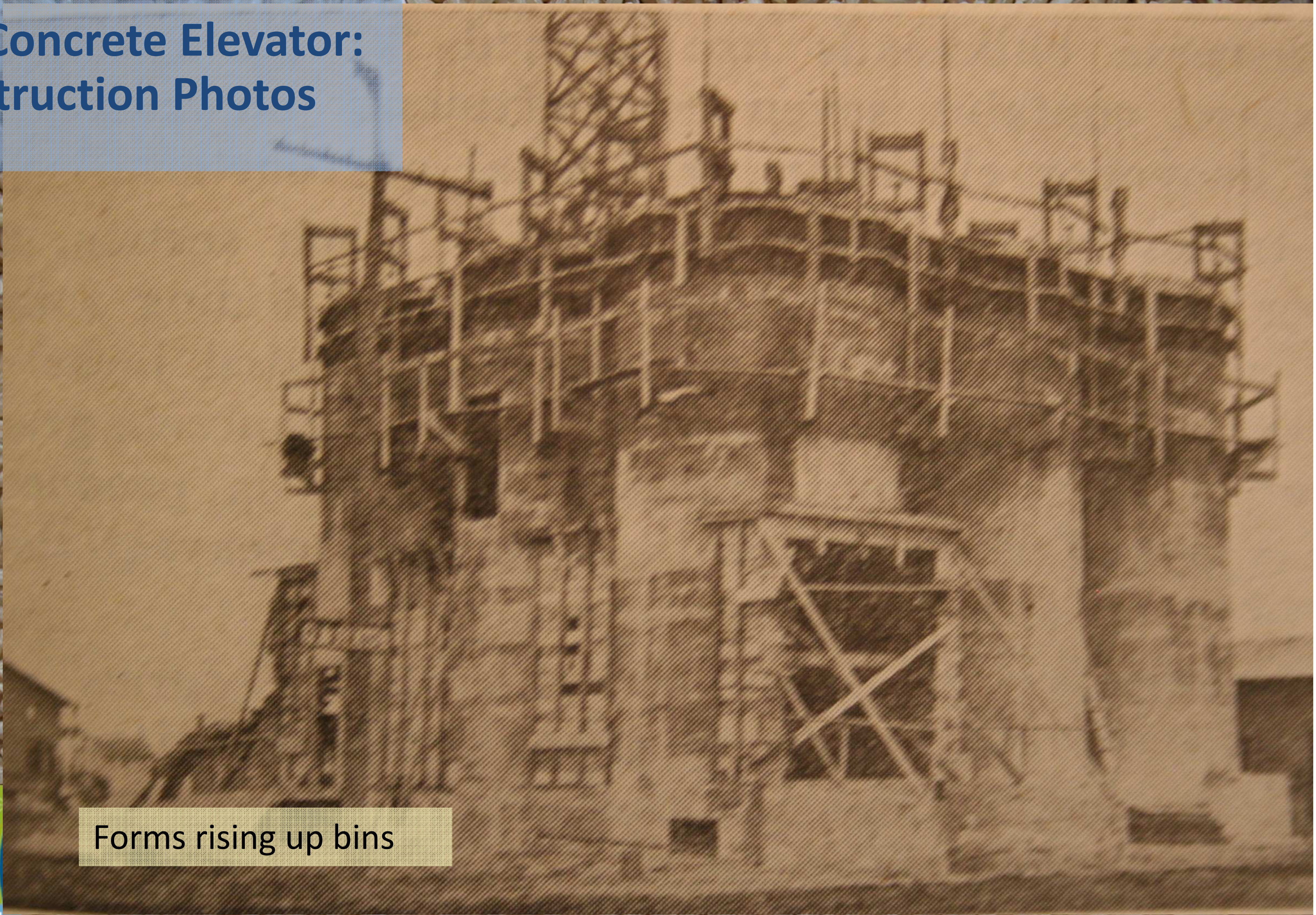
The Concrete Elevator: Improvements on Haglin's Design

Screw jacksupported on vertical rod



The Concrete Elevator: Construction Photos



Forms rising up bins

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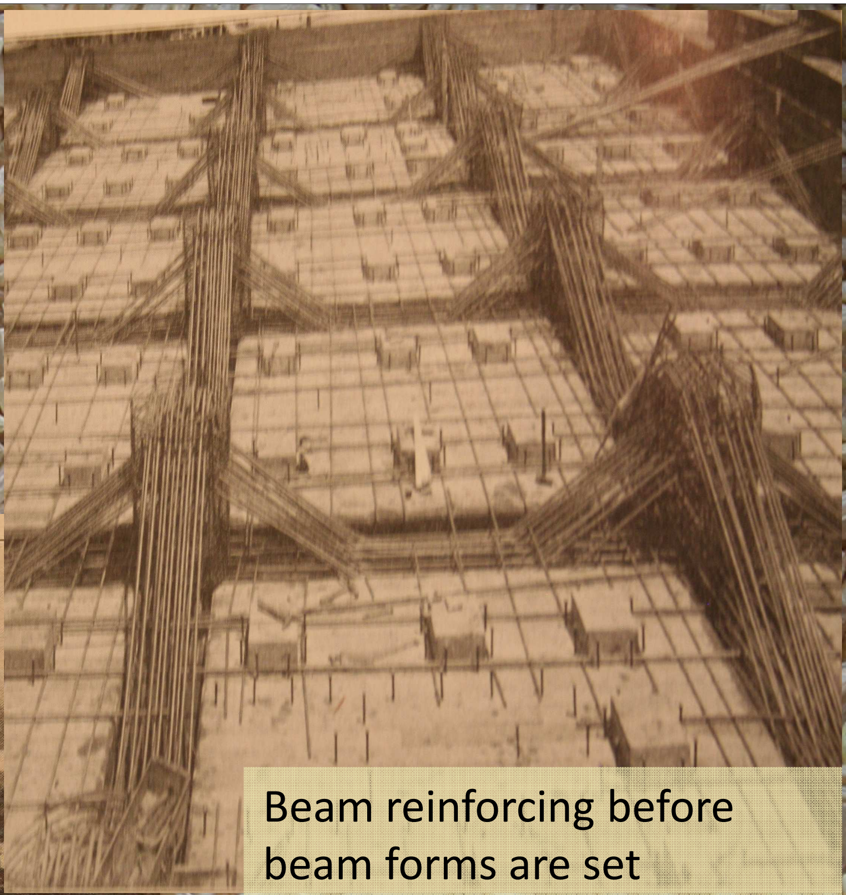
The Concrete Elevator: Construction Photos


Beam reinforcing before beam forms are set


Bin floors on supporting piers

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The Concrete Elevator: Design

How to prevent this..

The Concrete Elevator: Design

$$L = \frac{wR}{f}\left[1 - \frac{1}{e^{\frac{kfh}{R}}}\right] \ldots\ldots\ldots\ldots\ldots\ldots$$

where—

- L = unit horizontal pressure,
- w = unit weight of grain, (50 pcf)
- R = ratio area of cross-section : perimeter
- f = coefficient of friction of filling on walls, (0.42)
- k = ratio of horizontal to vertical pressure, (0.60)
- h = depth of filling,
- D = diameter of bin,
- e = constant, usually taken = 2.7183.

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The Concrete Elevator: Design

The two variables on the right side of the equation are:

- h, the depth of the grain; and
- D, the bin diameter.

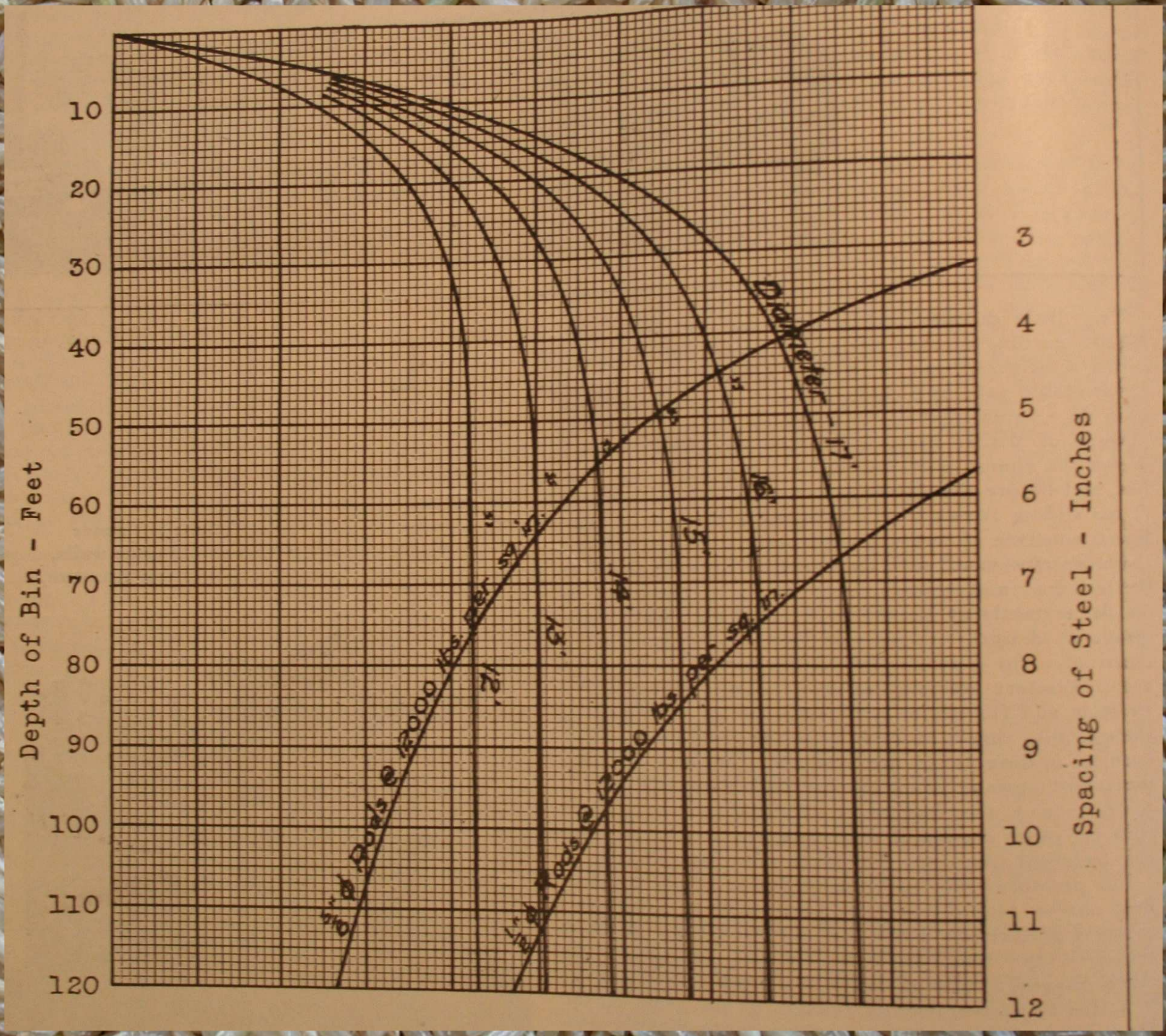
Inserting the constants and simplifying the equation give:

L=30*D*(1-1/h)

- As "h" approach increases, L approaches 30*D.
- Therefore, the maximum lateral pressure on the bins is 30 times the diameter.
- Pressure, L, is in psf; the diameter is in feet.
- Maximum pressure is reached @ h = 2 ½ - 3 * bin diameter

The Concrete Elevator: Design

- It can also be shown that the Bursting Pressure,
  T = 0.5*L*D
- And that the required area of horizontal steel,
  As = T/fs = 0.5*L*D/fs
- Designers used a nomograph to select spacing of horizontal bars.



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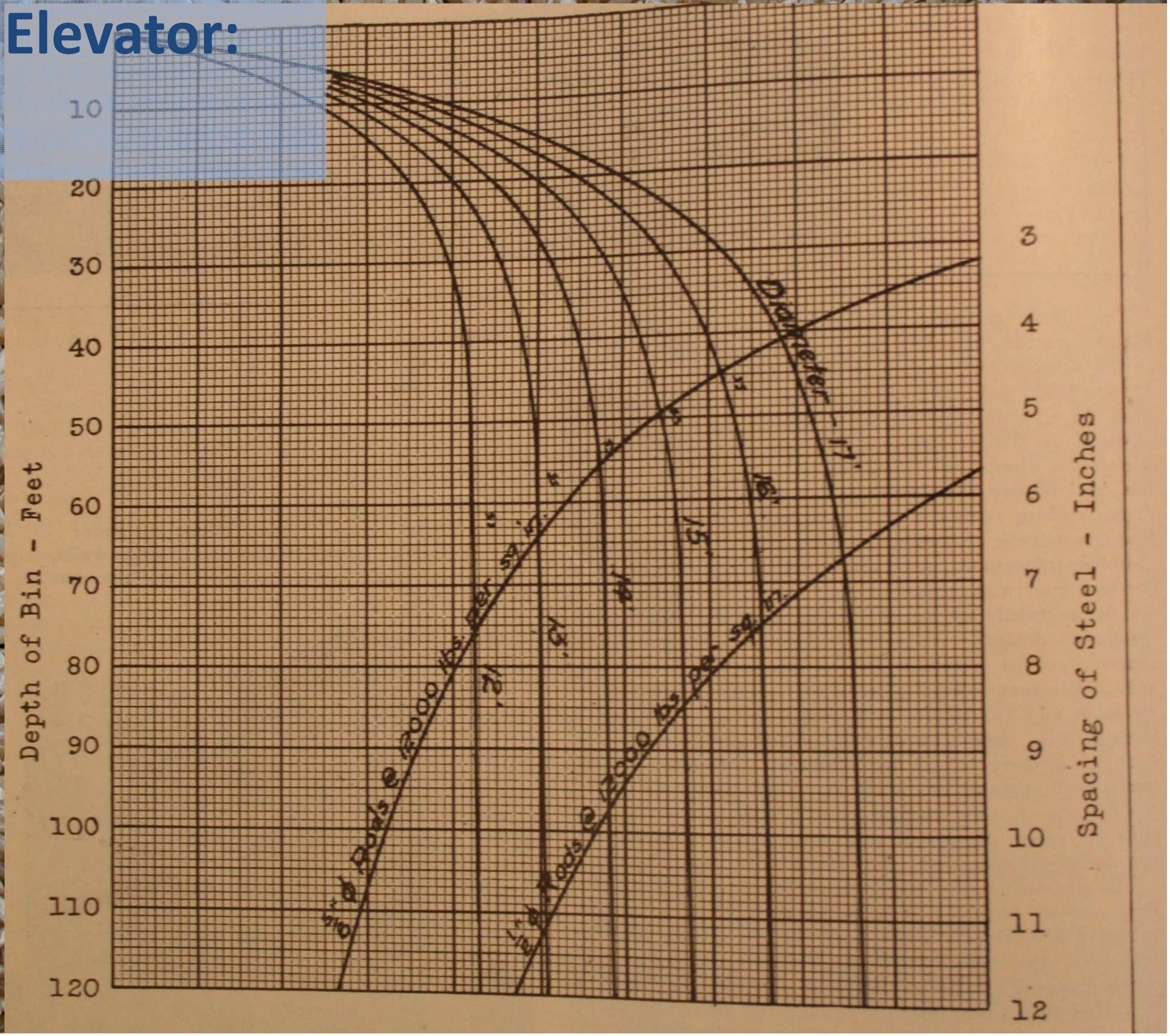
The Concrete Elevator: Design

Steps:

1. Choose a height
2. Move across to a desired diameter.
3. Move up diameter to desired rebar size
4. Move across to required spacing.



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The Concrete Elevator: Notable Failures

Haglin's Duluth elevator:

- Bins – 33' diameter x 104' tall
- Bins separated by 6' long connecting walls, enlarging interstitial bins and increasing loads against outside face of the bins.

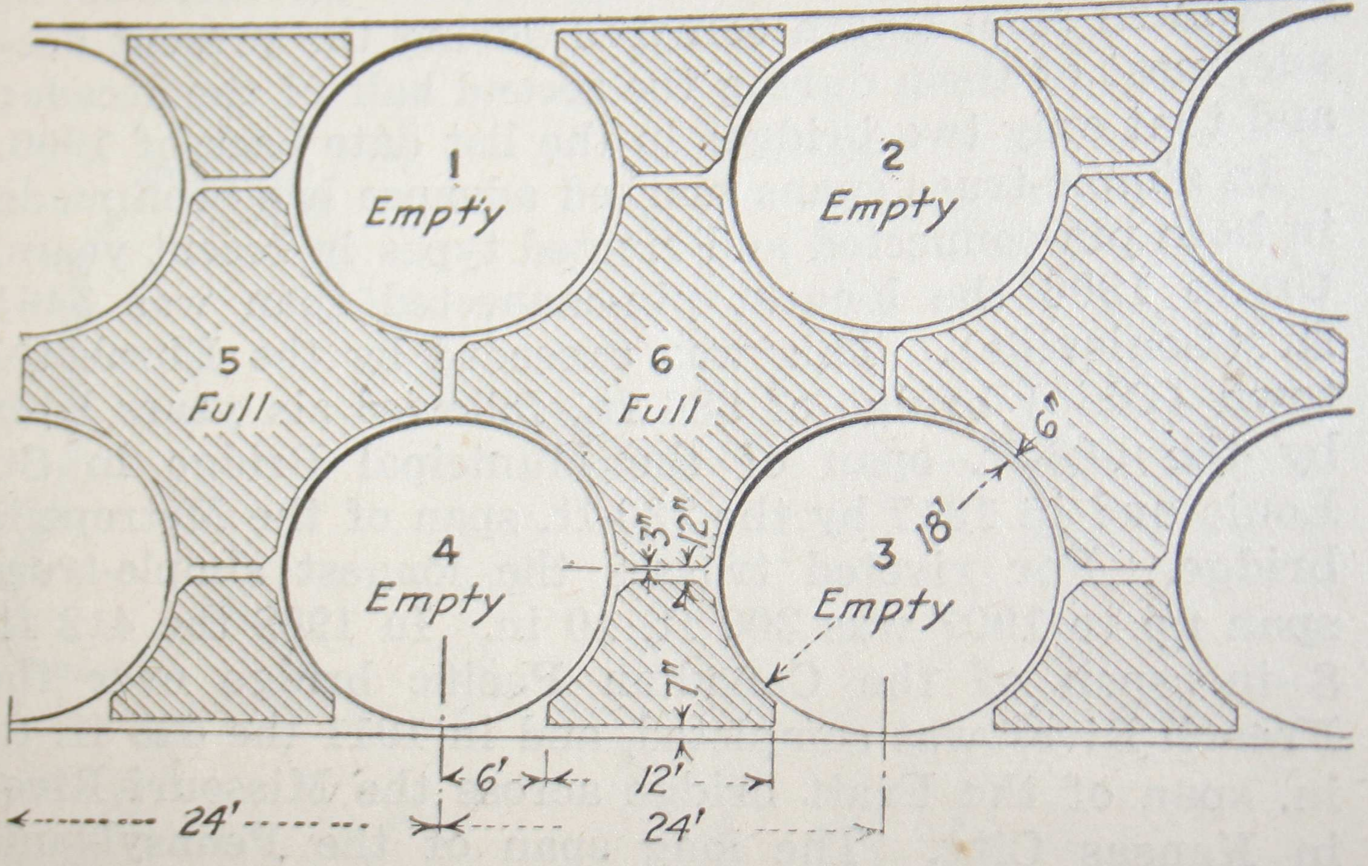
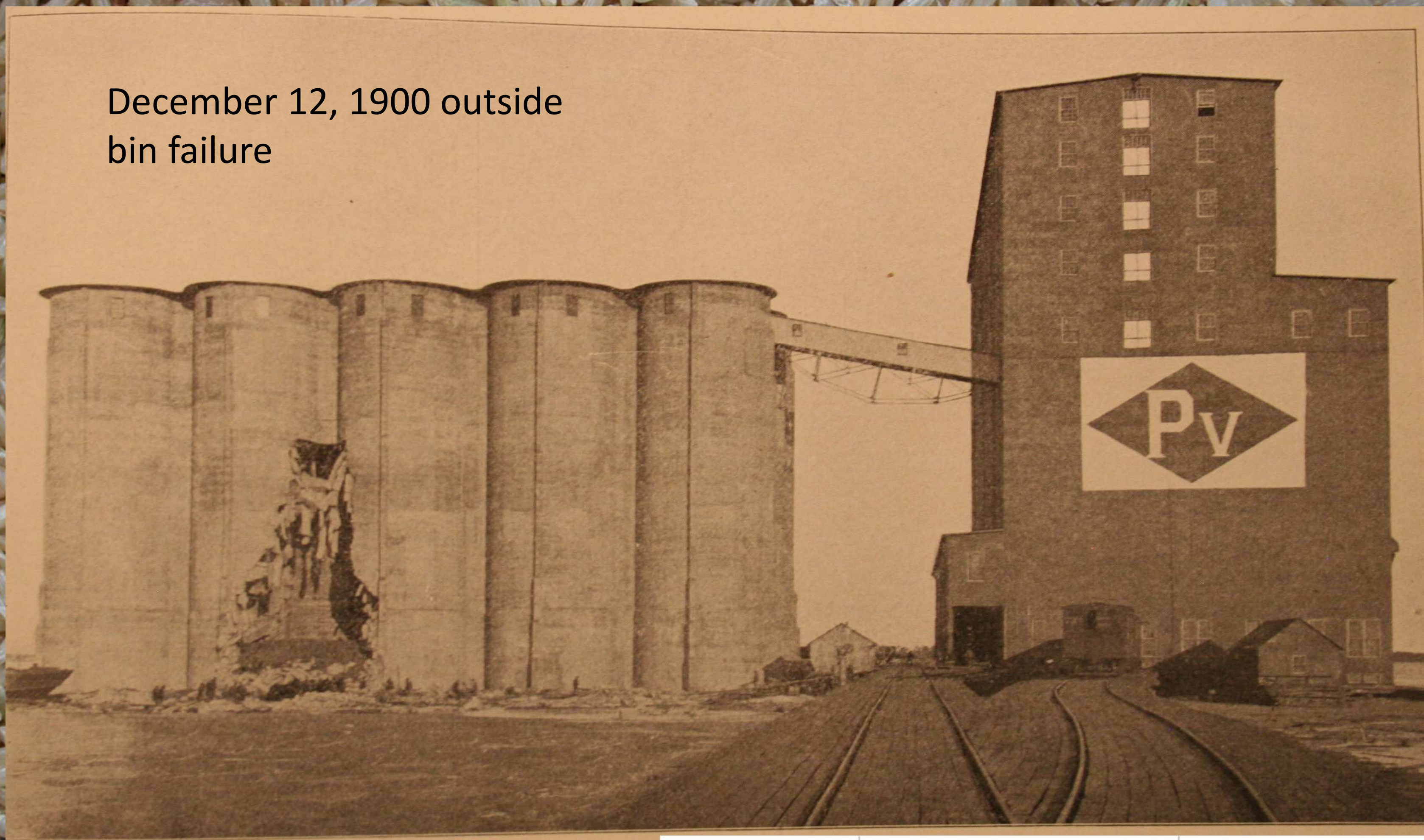


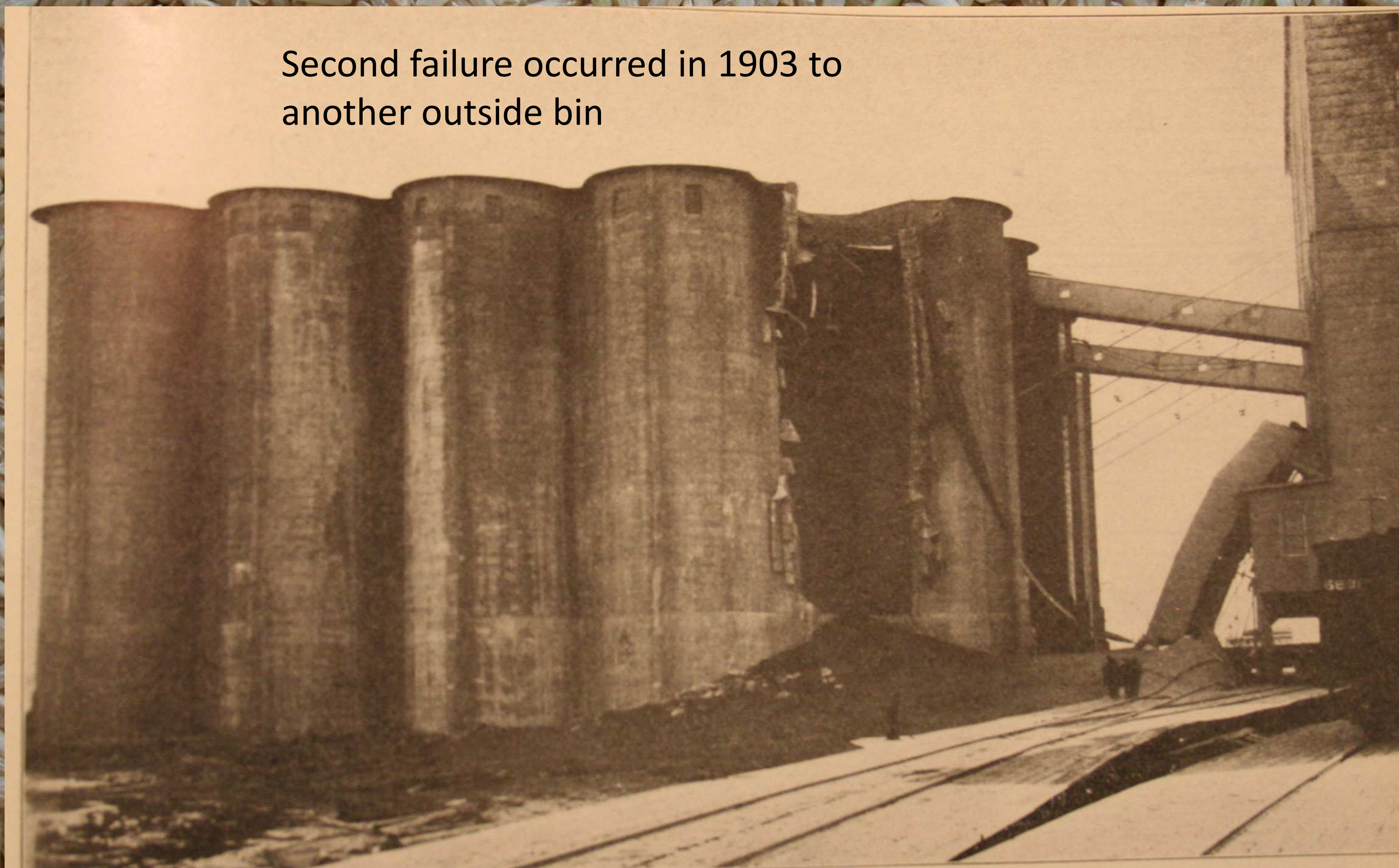
FIG. 1. TYPICAL ARRANGEMENT OF GRAIN ELEVATOR WITH SPREAD SYSTEM OF BINS

The Concrete Elevator: Notable Failures



December 12, 1900 outside bin failure

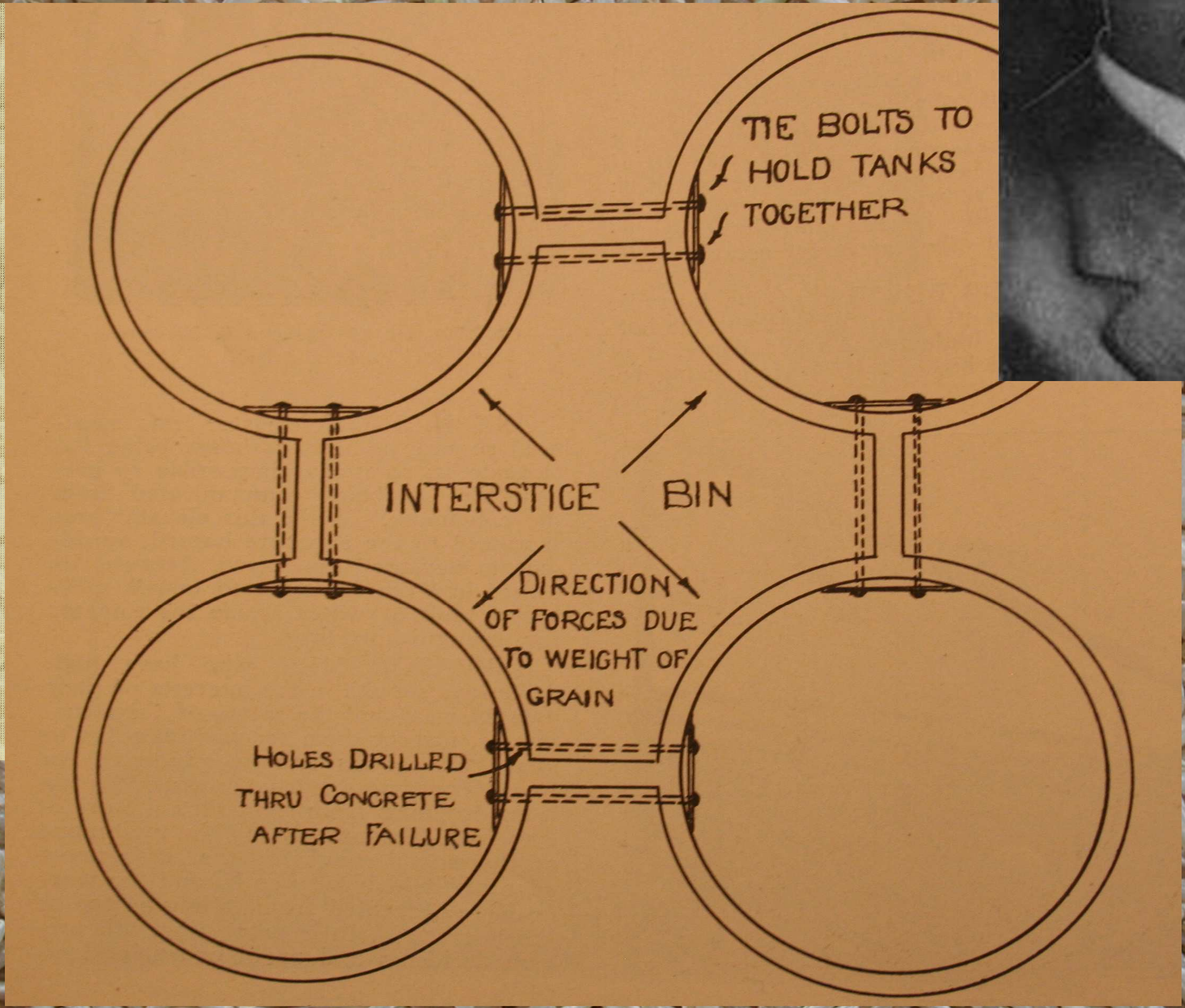
The Concrete Elevator: Notable Failures



Second failure occurred in 1903 to another outside bin

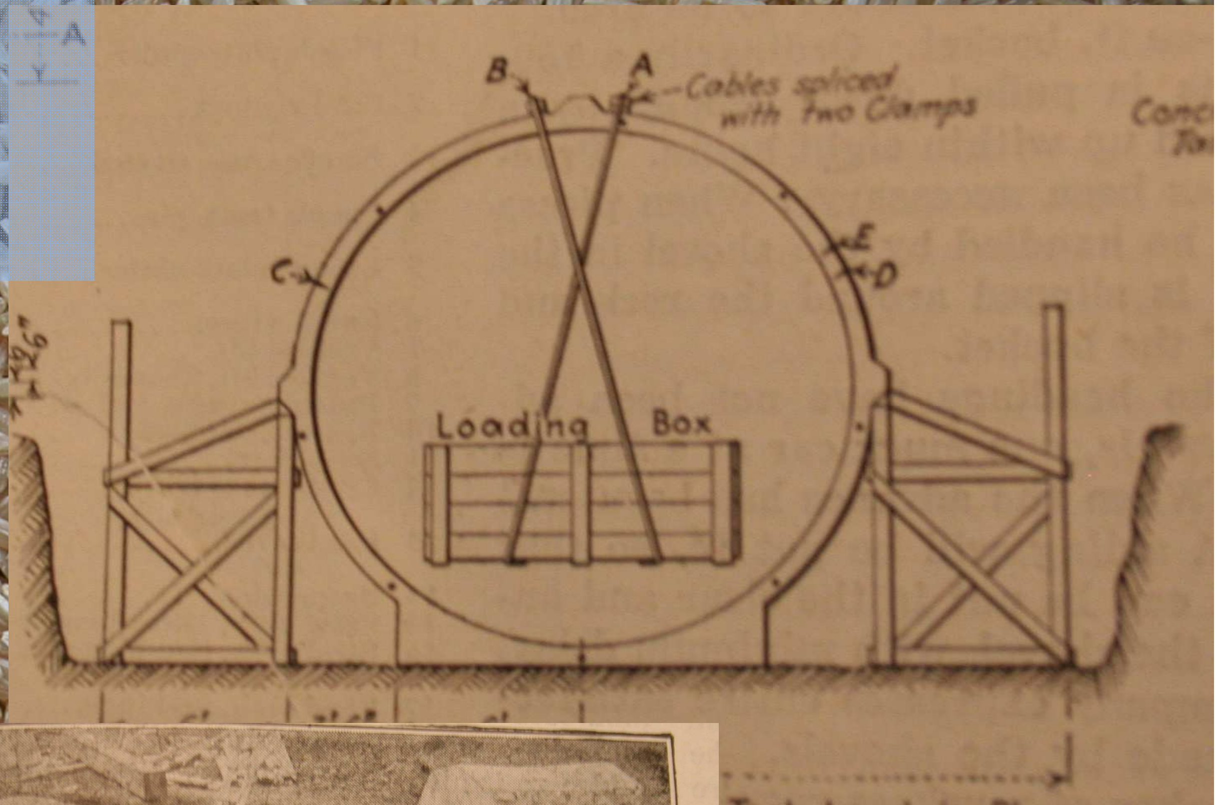
The Concrete Elevator: Notable Failures

Cause of failure:
C.A.P Turner:
1. Bins loaded as arches.
2. Connecting walls insufficiently stiff to resist rotation at joint
3. Allowed curved wall to rotate, reducing (-) moment, increasing (+)



The Concrete Elevator: Notable Failures

University of Minnesota Testing:
- Loaded a ring to failure
- Determined that bins have sufficient capacity to resist interstitial loads (as an arch) equal to main bin loads



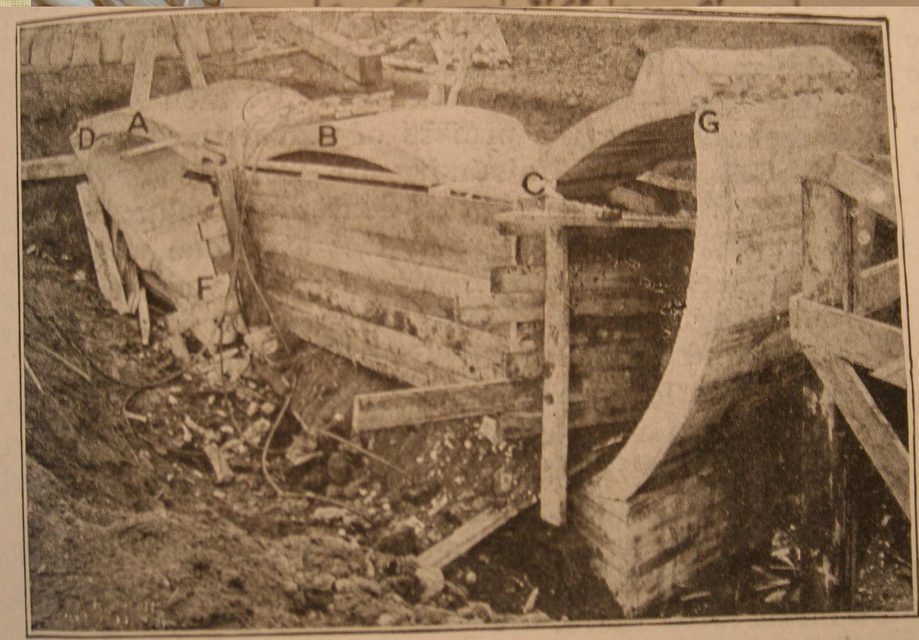
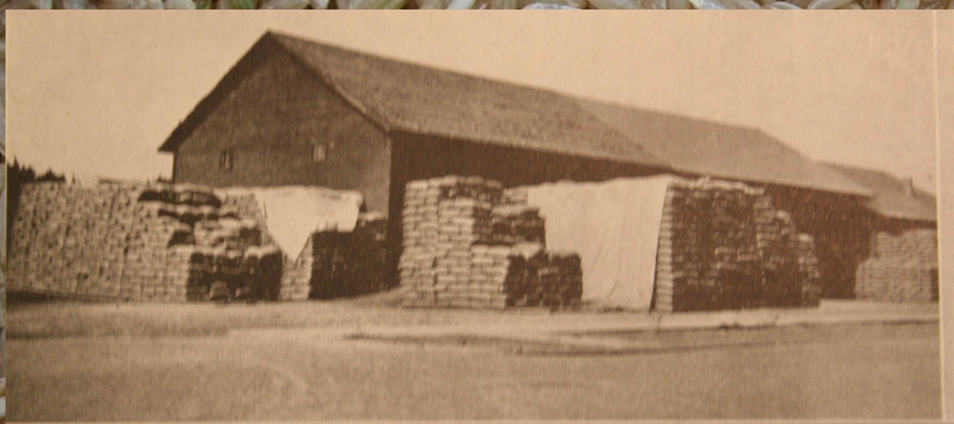


FIG. 3. CONCRETE RING AFTER TEST TO DESTRUCTION

Conclusion



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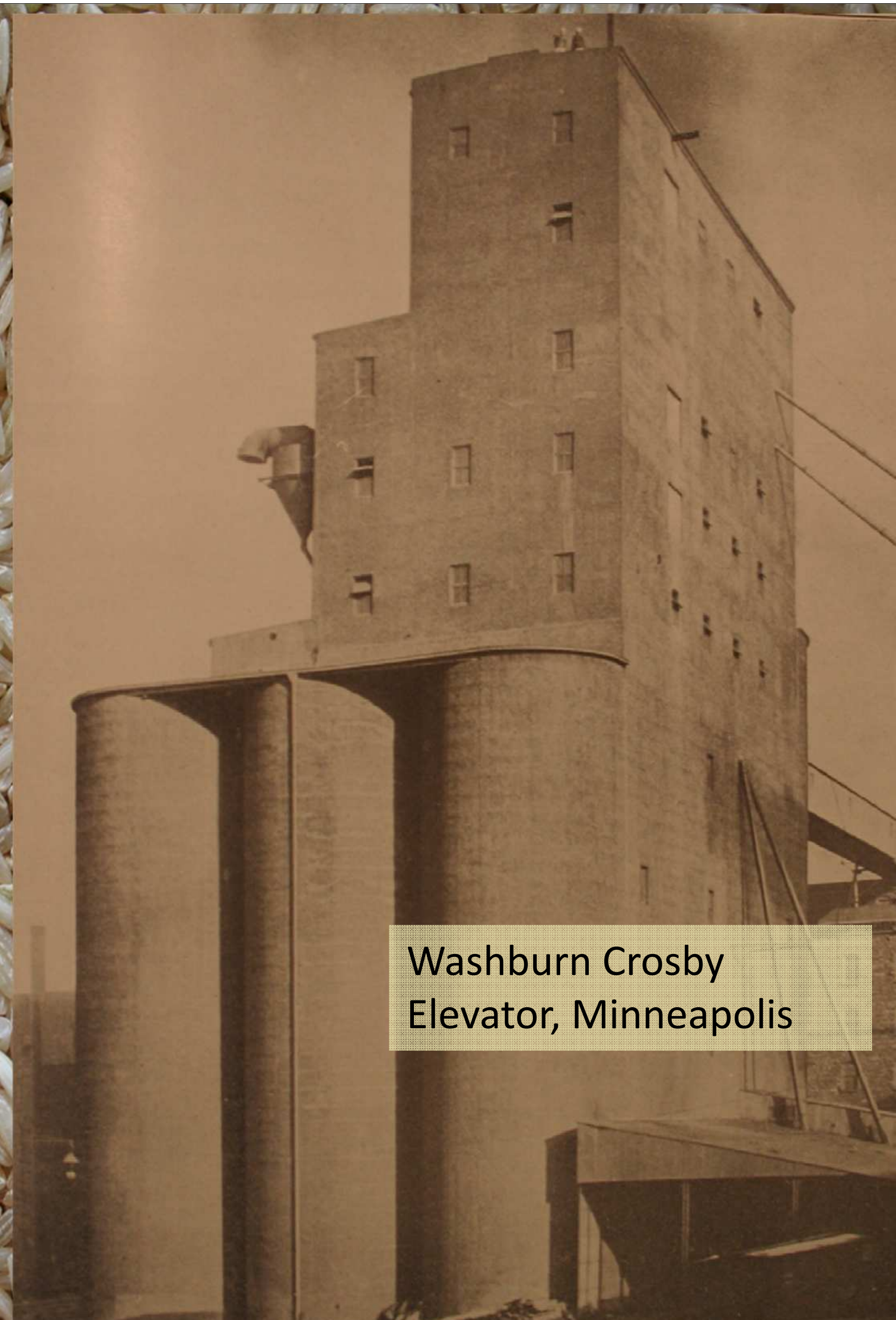

Washburn Crosby Elevator, Minneapolis

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