FACILITY DESIGN

MAXIMIZING EFFICIENCY AND THROUGHPUT

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TODAY'S OUTLINE

- Today's objectives
- Introduction/goals
- Historical perspectives
- Facility overview
- Efficiencies in design, construction, & operations
- Final thoughts

TODAY'S OBJECTIVES

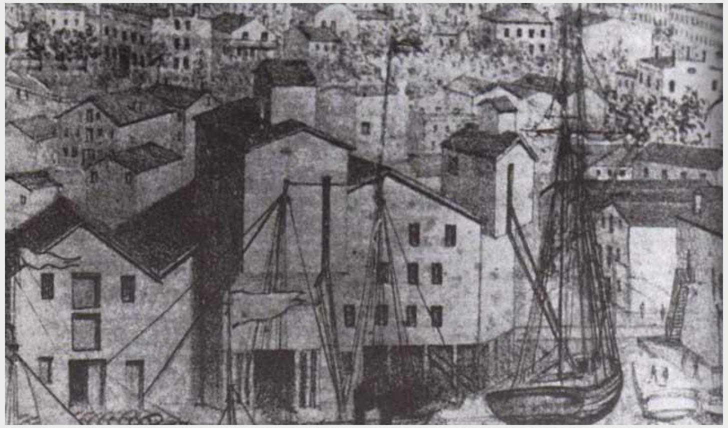
- Many existing facilities upgrade each year
- Many new facilities constructed each year
- Continual need to service grain industry
- Design data, information & procedures vital
  - Substantial focus on farm-scale
  - Commercial-scale scientific knowledge needs more
    - Anecdotal
    - Proprietary

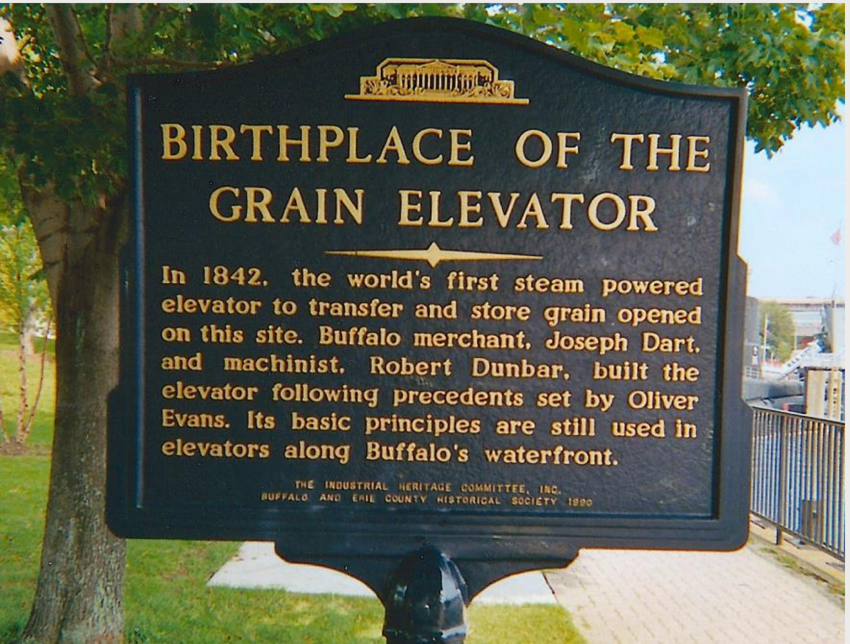
INTRODUCTION

- Overarching goals for grain storage facilities
  - Protect grain
    - Weather, insects, rodents, birds, mold
  - Maintain quality after harvest
    - Storage cannot improve upon quality
    - But: poor storage can result in poor quality (deterioration)
  - Repository for local grain supplies
  - Shipping point to end-use destinations via
    - Trucks, rail cars, ships

HISTORICAL PERSPECTIVES

- 1842
  - Buffalo, NY
  - Joseph Dart
  - First wood elevator
    - 50,000 bu

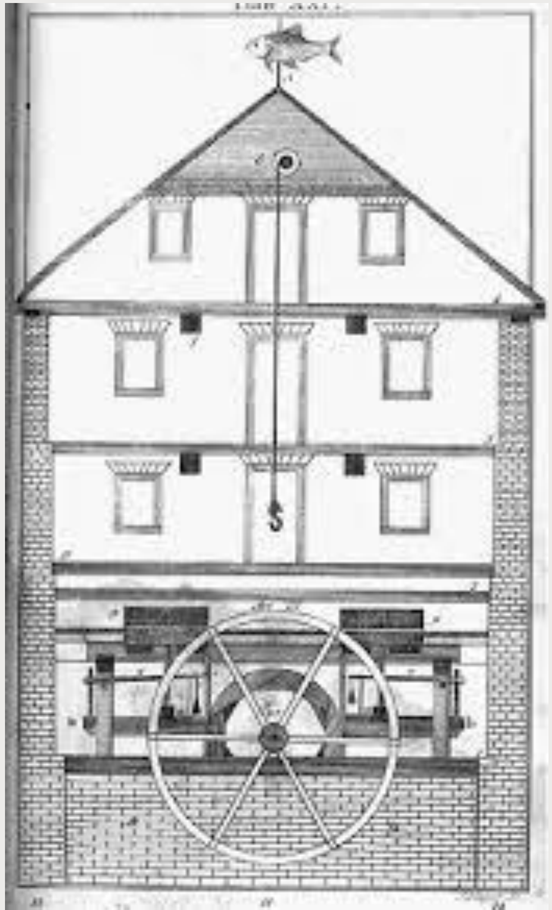


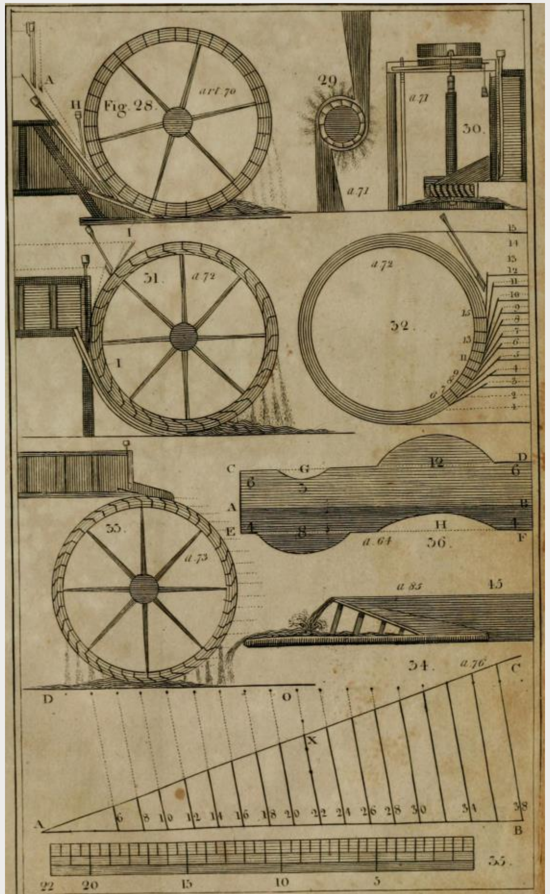


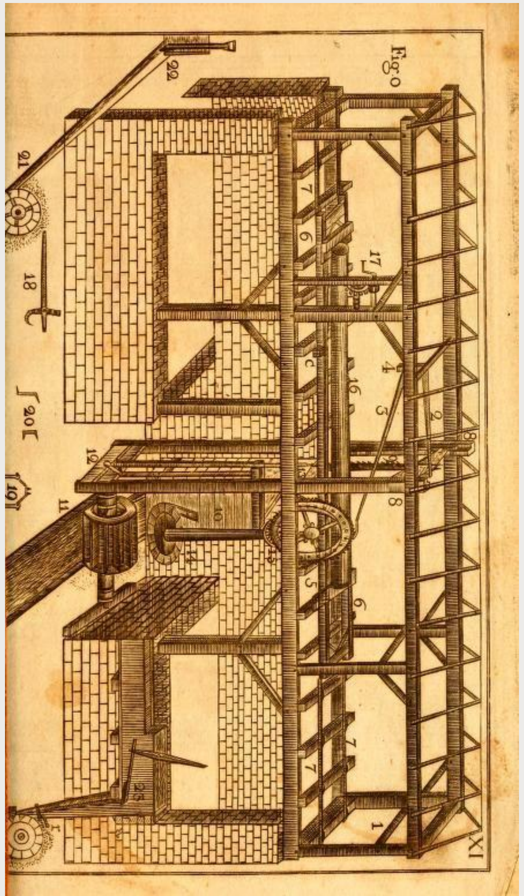
- 1899
  - Minneapolis, MN
  - F.H. Peavey & C. F. Haglin
  - Experimental slip-formed concrete silo
    - 68 ft high, 20 ft diameter
    - “Peavey’s Folly”

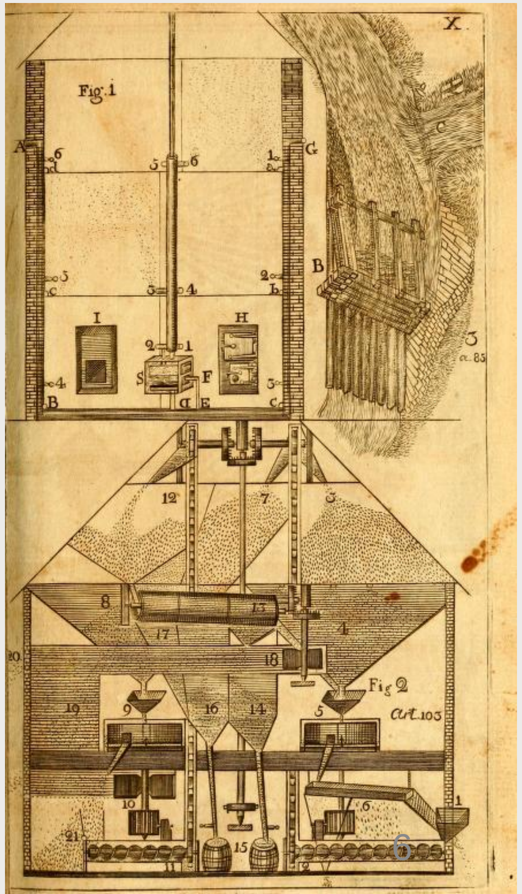
HISTORICAL PERSPECTIVES

- The Young Mill-Wright and Miller’s Guide
    - Oliver Evans & Thomas Ellicott, 1795









FACILITY OVERVIEW

- Modern facilities have much greater
  - Storage capacities
  - Equipment capacities
  - Yearly throughputs
  - Dust control systems
  - Automations & controls
  - Safety measures

FACILITIES – FARM SCALE

FACILITIES – FARM SCALE

FACILITIES – CO-OP SCALE

FACILITIES – COMMERCIAL SCALE

FACILITIES – COMMERCIAL SCALE


CLIPPER

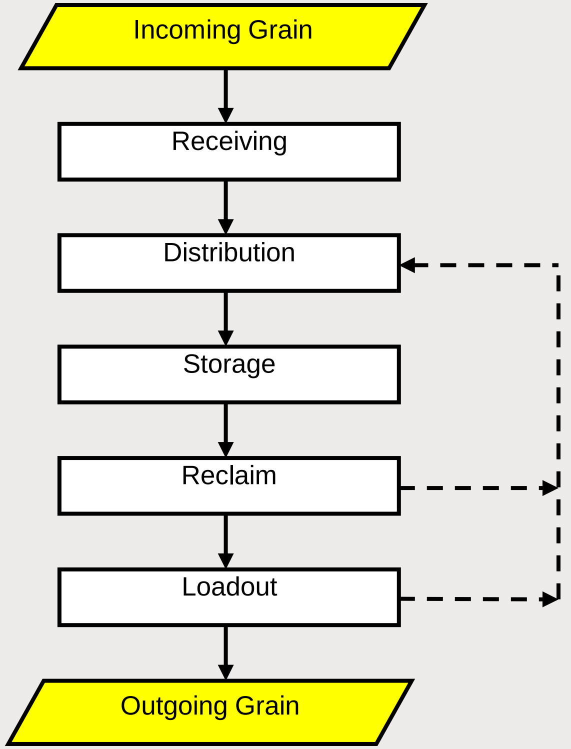

CLIPPER

FACILITY OVERVIEW

- Regardless of type, arrangement, or size
  - Proper selection, sizing, and location are essential to successful grain storage
    - All components must work together
    - Only as strong as the weakest link
      - Only as fast as your slowest operation
    - Want an efficient operation
- Commercial facilities
  - Typically handle more than 20,000 bu/hr
  - Can store from several thousand, up to several million, bushels at one time

FACILITY OVERVIEW

- Many common components and systems
  - Primary components
    - Receiving
    - Distribution
    - Storage
    - Reclaim
    - Loadout
  - All facilities utilize these components
    - Many of these can drive design choices



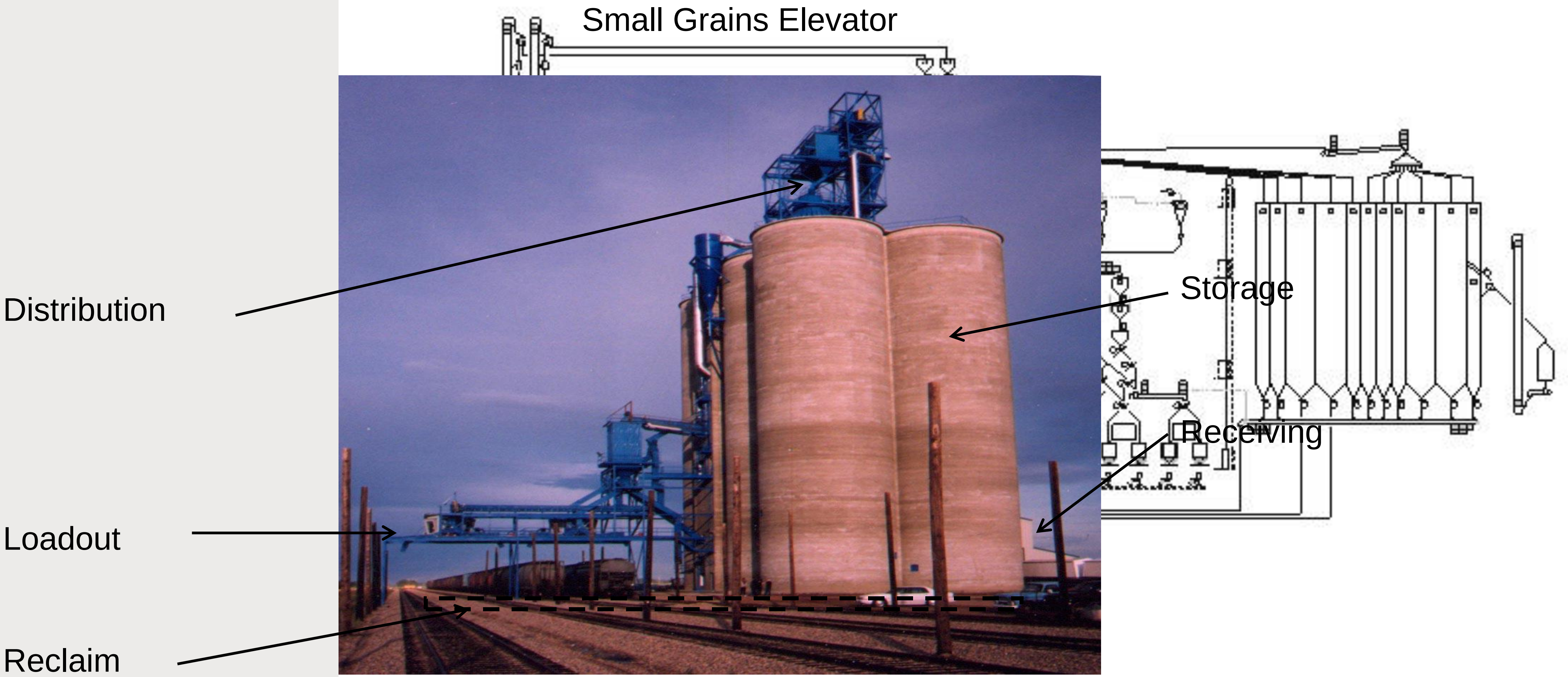
FACILITY OVERVIEW

- Many common components and systems
  - Secondary components
    - Cleaning
    - Aeration
    - Drying
    - Dust control
    - Sampling
    - Instrumentation and controls
  - Not all facilities utilize these components to the same degree
    - Don’t drive the design choices

FACILITY OVERVIEW

Large Grains Elevator

FACILITY OVERVIEW

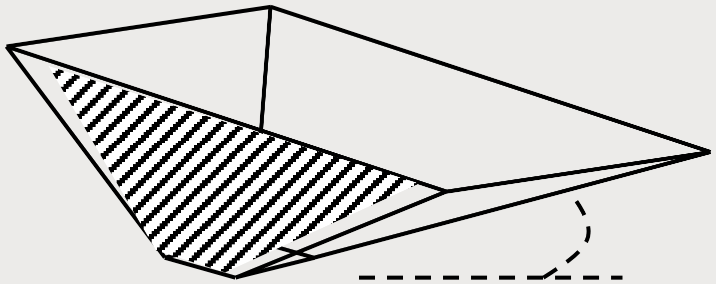


FACILITY OVERVIEW

- Many types, arrangements, and sizes are available for commercial operations
  - Choices depend on
    - Individual client needs and requirements / opinions
    - Operational flexibility
    - Future expansion
    - Creativity and imagination
    - <u>Cost</u>
  - Efficiencies in design, construction, & operations

RECEIVING SYSTEMS

- Purpose
  - Introduce incoming grain into the storage facility
    - Transfer grain to distribution system
    - Grain typically delivered with wagons or trucks (rail cars)
- Design considerations
  - Maximize throughput; minimize wait (esp. harvest)
  - Hopper volume: up to 1000 bu or more
  - Capacity: ~ 20,000 bu/hr
    - Orifices, gates, spouts, conveyors
  - Valley angle: > angle of repose
    - Limiting factor, not side/face slopes



RECEIVING SYSTEMS

	Angle of Repose (°)			Bulk Density (lb/ft^3)			Aerodynamic Transport Velocity (ft/min)	
Grain	Range		Average	Range		Average	Range	
Barley	24	35	28	36	48	42	3300	
Corn	21	26	23			45	3150	3300
Milo	20	33	26	40	45	43	3300	
Oats	24	32	28	25	35	30	2400	2700
Rice	31	41	36	32	36	34	3300	
Sorghum	27	33	29	32	46	39	3300	
Soybeans	22	35	28	45	50	48	3600	
Wheat (durum)	22	25	23	45	48	47	3300	
Wheat (red)	19	38	25	45	48	47	3300	

RECEIVING SYSTEMS

- Design considerations

Probe & scale location

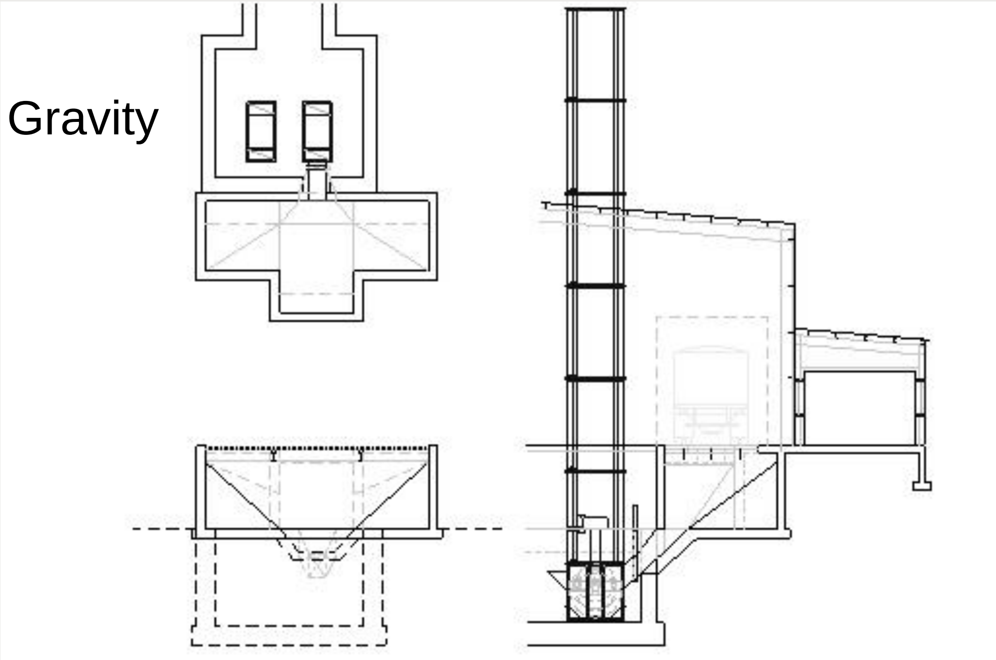
Grate opening area

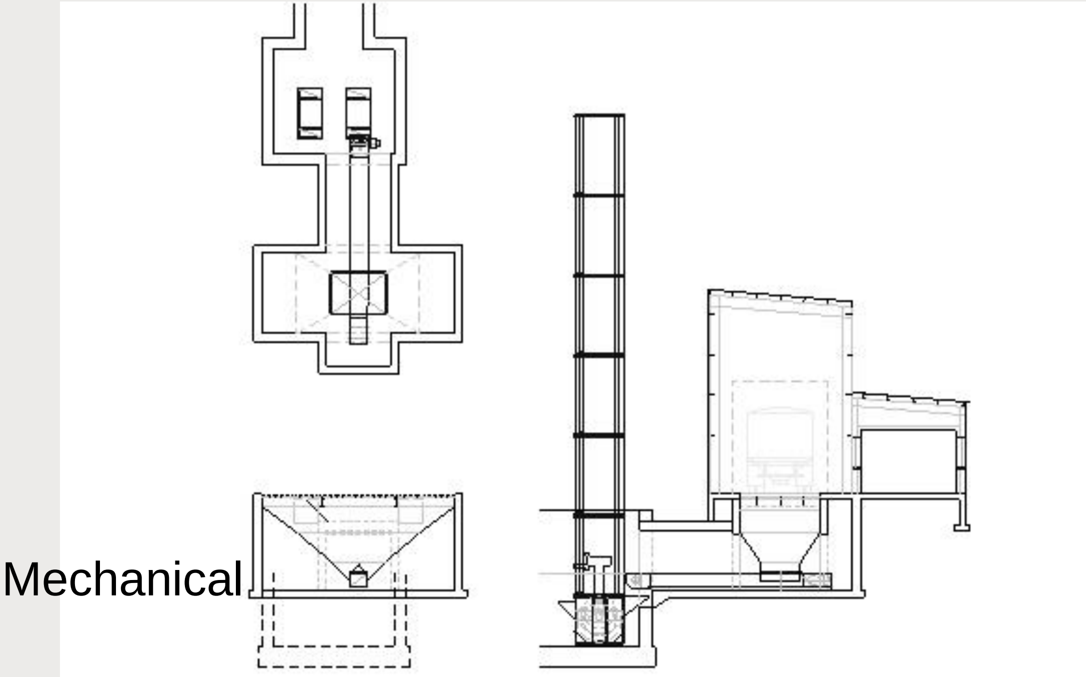
Above ground vs. underground

RECEIVING

- 2 most common types

- Tradeoffs
  - Gravity
    - Deeper pit, or
    - Higher receiving floor
  - Conveyor
    - Shallower pit
    - Carryover
    - Maintenance





RECEIVING

YOU SHOULD MODEL YOUR SYSTEM

MAX THEORETICAL DAILY INBOUND = 200,000 BU

Receiving leg too large
Receiving leg adequate
Receiving leg too small

Can measure these

	BASE CASE - AN EXAMPLE			
	TASK	TIME (sec)	TIME (min)	TIME (h)
	Scale time	30	0.5	0.008
	Drive time	30	0.5	0.008
	Probe time	60	1	0.017
	Drive time	30	0.5	0.008
	Dump time	180	3	0.050
	Slack time	30	0.5	0.008
	Drive time	0	0	0.000
	Scale time	0	0	0.000
	TOTAL CYCLE TIME / TRUCK	360	6	0.100
	Work Day	36000	600	10.000
	Trucks / H	10.0		
	Trucks / Day	100.0		
	Capcity / Truck (bu/truck)	1000.0		
	Inbound / Day (bu/day)	100000.0		
	Receiving Flow (bu/time)	5.56	333.33	20000
	Receiving Leg Capacity (bu/h)	20000		
Actual Dump	Hopper/Pit Size (bu)	1000		
	Hopper fills	1		
	Pit Empty Time	180	3	0.050
Theoretical Dump (no pit restriction)	Gate flow (bu/h/in2)	100		
	Gate area 2 - 26" x 54" (in2)	2808		
	Grain flow (bu/h)	280800		
	Time to Empty Truck	12.821	0.214	0.004

RECEIVING SYSTEMS

MAX THEORETICAL DAILY INBOUND = 200,000 BU

We can examine scale/probe locations

	BASE CASE				SIMULTANEOUS SCALE/PROBE				SIMULTANEOUS SCALE/PROBE & NO SLACK AT DUMP			
	TASK	TIME (sec)	TIME (min)	TIME (h)	TASK	TIME (sec)	TIME (min)	TIME (h)	TASK	TIME (sec)	TIME (min)	TIME (h)
	Scale time	30	0.5	0.008	Scale time	0	0	0.000	Scale time	0	0	0.000
	Drive time	30	0.5	0.008	Drive time	0	0	0.000	Drive time	0	0	0.000
	Probe time	60	1	0.017	Probe time	60	1	0.017	Probe time	60	1	0.017
	Drive time	30	0.5	0.008	Drive time	30	0.5	0.008	Drive time	30	0.5	0.008
	Dump time	180	3	0.050	Dump time	180	3	0.050	Dump time	180	3	0.050
	Slack time	30	0.5	0.008	Slack time	30	0.5	0.008	Slack time	0	0	0.000
	Drive time	0	0	0.000	Drive time	0	0	0.000	Drive time	0	0	0.000
	Scale time	0	0	0.000	Scale time	0	0	0.000	Scale time	0	0	0.000
	TOTAL CYCLE TIME / TRUCK	360	6	0.100	TOTAL CYCLE TIME / TRUCK	300	5	0.083	TOTAL CYCLE TIME / TRUCK	270	4.5	0.075
	Work Day	36000	600	10.000	Work Day	36000	600	10.000	Work Day	36000	600	10.000
	Trucks / H	10.0			Trucks / H	12.0			Trucks / H	13.3		
	Trucks / Day	100.0			Trucks / Day	120.0			Trucks / Day	133.3		
	Capcity / Truck (bu/truck)	1000.0			Capcity / Truck (bu/truck)	1000.0			Capcity / Truck (bu/truck)	1000.0		
	Inbound / Day (bu/day)	100000.0			Inbound / Day (bu/day)	120000.0			Inbound / Day (bu/day)	133333.3		
	Receiving Flow (bu/time)	5.56	333.33	20000	Receiving Flow (bu/time)	5.56	333.33	20000	Receiving Flow (bu/time)	5.56	333.33	20000
	Receiving Leg Capacity (bu/h)	20000			Receiving Leg Capacity (bu/h)	20000			Receiving Leg Capacity (bu/h)	20000		
Actual Dump	Hopper/Pit Size (bu)	1000			Hopper/Pit Size (bu)	1000			Hopper/Pit Size (bu)	1000		
	Hopper fills	1			Hopper fills	1			Hopper fills	1		
	Pit Empty Time	180	3	0.050	Pit Empty Time	180	3	0.050	Pit Empty Time	180	3	0.050
Theoretical Dump	Gate flow (bu/h/in2)	100			Gate flow (bu/h/in2)	100			Gate flow (bu/h/in2)	100		
(no pit restriction)	Gate area 2 - 26" x 54" (in2)	2808			Gate area 2 - 26" x 54" (in2)	2808			Gate area 2 - 26" x 54" (in2)	2808		
	Grain flow (bu/h)	280800			Grain flow (bu/h)	280800			Grain flow (bu/h)	280800		
	Time to Empty Truck	12.821	0.214	0.004	Time to Empty Truck	12.821	0.214	0.004	Time to Empty Truck	12.821	0.214	0.004

Receiving leg too large | Receiving leg adequate | Receiving leg too small

RECEIVING SYSTEMS

MAX THEORETICAL DAILY INBOUND = 200,000 BU

We can examine size of trucks

EFFECT OF TRUCK SIZE	SIMULTANEOUS SCALE/PROBE			
	TASK	TIME (sec)	TIME (min)	TIME (h)
	Scale time	0	0	0.000
	Drive time	0	0	0.000
	Probe time	60	1	0.017
	Drive time	30	0.5	0.008
	Dump time	180	3	0.050
	Slack time	30	0.5	0.008
	Drive time	0	0	0.000
	Scale time	0	0	0.000
	TOTAL CYCLE TIME / TRUCK	300	5	0.083
	Work Day	36000	600	10.000
	Trucks / H	12.0		
	Trucks / Day	120.0		
	Capcity / Truck (bu/truck)	500.0		
	Inbound / Day (bu/day)	60000.0		
	Receiving Flow (bu/time)	2.78	166.67	10000
	Receiving Leg Capacity (bu/h)	20000		
Actual Dump	Hopper/Pit Size (bu)	1000		
	Hopper fills	0.5		
	Pit Empty Time	90	1.5	0.025
Theoretical Dump (pit not restriction)	Gate flow (bu/h/in2)	100		
	Gate area 2 - 26" x 54" (in2)	2808		
	Grain flow (bu/h)	280800		
	Time to Empty Truck	6.410	0.107	0.002

SIMULTANEOUS SCALE/PROBE			
TASK	TIME (sec)	TIME (min)	TIME (h)
Scale time	0	0	0.000
Drive time	0	0	0.000
Probe time	60	1	0.017
Drive time	30	0.5	0.008
Dump time	180	3	0.050
Slack time	30	0.5	0.008
Drive time	0	0	0.000
Scale time	0	0	0.000
TOTAL CYCLE TIME / TRUCK	300	5	0.083
Work Day	36000	600	10.000
Trucks / H	12.0		
Trucks / Day	120.0		
Capcity / Truck (bu/truck)	1000.0		
Inbound / Day (bu/day)	120000.0		
Receiving Flow (bu/time)	5.56	333.33	20000
Receiving Leg Capacity (bu/h)	20000		
Hopper/Pit Size (bu)	1000		
Hopper fills	1		
Pit Empty Time	180	3	0.050
Gate flow (bu/h/in2)	100		
Gate area 2 - 26" x 54" (in2)	2808		
Grain flow (bu/h)	280800		
Time to Empty Truck	12.821	0.214	0.004

SIMULTANEOUS SCALE/PROBE			
TASK	TIME (sec)	TIME (min)	TIME (h)
Scale time	0	0	0.000
Drive time	0	0	0.000
Probe time	60	1	0.017
Drive time	30	0.5	0.008
Dump time	180	3	0.050
Slack time	30	0.5	0.008
Drive time	0	0	0.000
Scale time	0	0	0.000
TOTAL CYCLE TIME / TRUCK	300	5	0.083
Work Day	36000	600	10.000
Trucks / H	12.0		
Trucks / Day	120.0		
Capcity / Truck (bu/truck)	1500.0		
Inbound / Day (bu/day)	180000.0		
Receiving Flow (bu/time)	8.33	500.00	30000
Receiving Leg Capacity (bu/h)	20000		
Hopper/Pit Size (bu)	1000		
Hopper fills	1.5		
Pit Empty Time	270	4.5	0.075
Gate flow (bu/h/in2)	100		
Gate area 2 - 26" x 54" (in2)	2808		
Grain flow (bu/h)	280800		
Time to Empty Truck	19.231	0.321	0.005

Receiving leg too large | Receiving leg adequate | Receiving leg too small

RECEIVING SYSTEMS

MAX THEORETICAL DAILY INBOUND = 200,000 BU

We can examine dump time

EFFECT OF DUMP TIME	SIMULTANEOUS SCALE/PROBE				SIMULTANEOUS SCALE/PROBE				SIMULTANEOUS SCALE/PROBE			
	TASK	TIME (sec)	TIME (min)	TIME (h)	TASK	TIME (sec)	TIME (min)	TIME (h)	TASK	TIME (sec)	TIME (min)	TIME (h)
	Scale time	0	0	0.000	Scale time	0	0	0.000	Scale time	0	0	0.000
	Drive time	0	0	0.000	Drive time	0	0	0.000	Drive time	0	0	0.000
	Probe time	60	1	0.017	Probe time	60	1	0.017	Probe time	60	1	0.017
	Drive time	30	0.5	0.008	Drive time	30	0.5	0.008	Drive time	30	0.5	0.008
	Dump time	180	3	0.050	Dump time	150	2.5	0.042	Dump time	120	2	0.033
	Slack time	30	0.5	0.008	Slack time	30	0.5	0.008	Slack time	30	0.5	0.008
	Drive time	0	0	0.000	Drive time	0	0	0.000	Drive time	0	0	0.000
	Scale time	0	0	0.000	Scale time	0	0	0.000	Scale time	0	0	0.000
	TOTAL CYCLE TIME / TRUCK	300	5	0.083	TOTAL CYCLE TIME / TRUCK	270	4.5	0.075	TOTAL CYCLE TIME / TRUCK	240	4	0.067
	Work Day	36000	600	10.000	Work Day	36000	600	10.000	Work Day	36000	600	10.000
	Trucks / H	12.0			Trucks / H	13.3			Trucks / H	15.0		
	Trucks / Day	120.0			Trucks / Day	133.3			Trucks / Day	150.0		
	Capcity / Truck (bu/truck)	1000.0			Capcity / Truck (bu/truck)	1000.0			Capcity / Truck (bu/truck)	1000.0		
	Inbound / Day (bu/day)	120000.0			Inbound / Day (bu/day)	133333.3			Inbound / Day (bu/day)	150000.0		
	Receiving Flow (bu/time)	5.56	333.33	20000	Receiving Flow (bu/time)	6.67	400.00	24000	Receiving Flow (bu/time)	8.33	500.00	30000
	Receiving Leg Capacity (bu/h)	20000			Receiving Leg Capacity (bu/h)	20000			Receiving Leg Capacity (bu/h)	20000		
Actual Dump	Hopper/Pit Size (bu)	1000			Hopper/Pit Size (bu)	1000			Hopper/Pit Size (bu)	1000		
	Hopper fills	1			Hopper fills	1			Hopper fills	1		
	Pit Empty Time	180	3	0.050	Pit Empty Time	180	3	0.050	Pit Empty Time	180	3	0.050
Theoretical Dump (pit not restriction)	Gate flow (bu/h/in2)	100			Gate flow (bu/h/in2)	100			Gate flow (bu/h/in2)	100		
	Gate area 2 - 26" x 54" (in2)	2808			Gate area 2 - 26" x 54" (in2)	2808			Gate area 2 - 26" x 54" (in2)	2808		
	Grain flow (bu/h)	280800			Grain flow (bu/h)	280800			Grain flow (bu/h)	280800		
	Time to Empty Truck	12.821	0.214	0.004	Time to Empty Truck	12.821	0.214	0.004	Time to Empty Truck	12.821	0.214	0.004

Receiving leg too large | Receiving leg adequate | Receiving leg too small

RECEIVING

MORE EFFICIENT	SIMULTANEOUS SCALE/PROBE			
	TASK	TIME (sec)	TIME (min)	TIME (h)
	Scale time	0	0	0.000
	Drive time	0	0	0.000
	Probe time	60	1	0.017
	Drive time	30	0.5	0.008
	Dump time	96	1.6	0.027
	Slack time	0	0	0.000
	Drive time	0	0	0.000
	Scale time	0	0	0.000
	TOTAL CYCLE TIME / TRUCK	186	3.1	0.052
	Work Day	36000	600	10.000
	Trucks / H	19.4		
	Trucks / Day	193.5		
	Capcity / Truck (bu/truck)	1600.0		
	Inbound / Day (bu/day)	309677.4		
	Receiving Flow (bu/time)	16.67	1000.00	60000
	Receiving Leg Capacity (bu/h)	60000		
Actual Dump	Hopper/Pit Size (bu)	1000		
	Hopper fills	1.6		
	Pit Empty Time	96	1.6	0.027
Theoretical Dump (pit not restriction)	Gate flow (bu/h/in2)	100		
	Gate area 2 - 26" x 54" (in2)	2808		
	Grain flow (bu/h)	280800		
	Time to Empty Truck	20.513	0.342	0.006

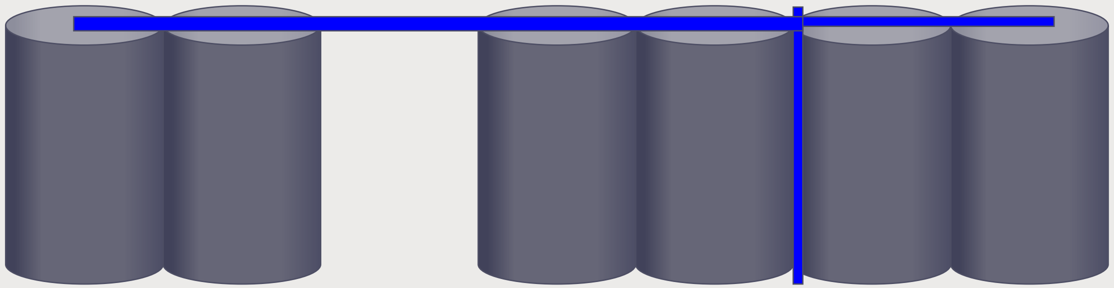
Receiving leg too large
Receiving leg adequate
Receiving leg too small

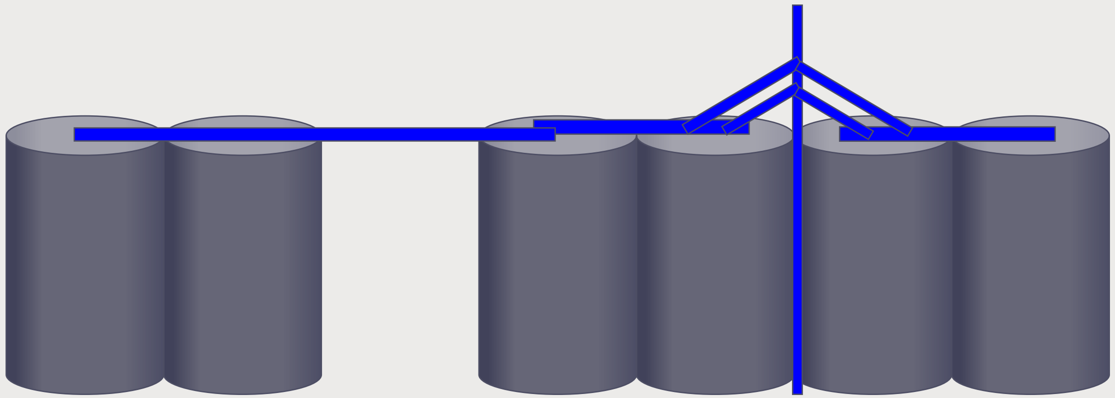
DISTRIBUTION SYSTEMS

- Purpose
  - Transport grain to appropriate storage locations
    - Bucket elevators: vertical transfer
    - Drag or belt conveyors: horizontal transfer
      - Screw conveyors seldom used
    - Distributors & spouting: various transfers
      - Square vs. round; lined vs. unlined
- Design considerations
  - Equipment must be sized ≥ receiving rate
  - Volumetric throughput (bu/h)
  - Power consumption (hp)

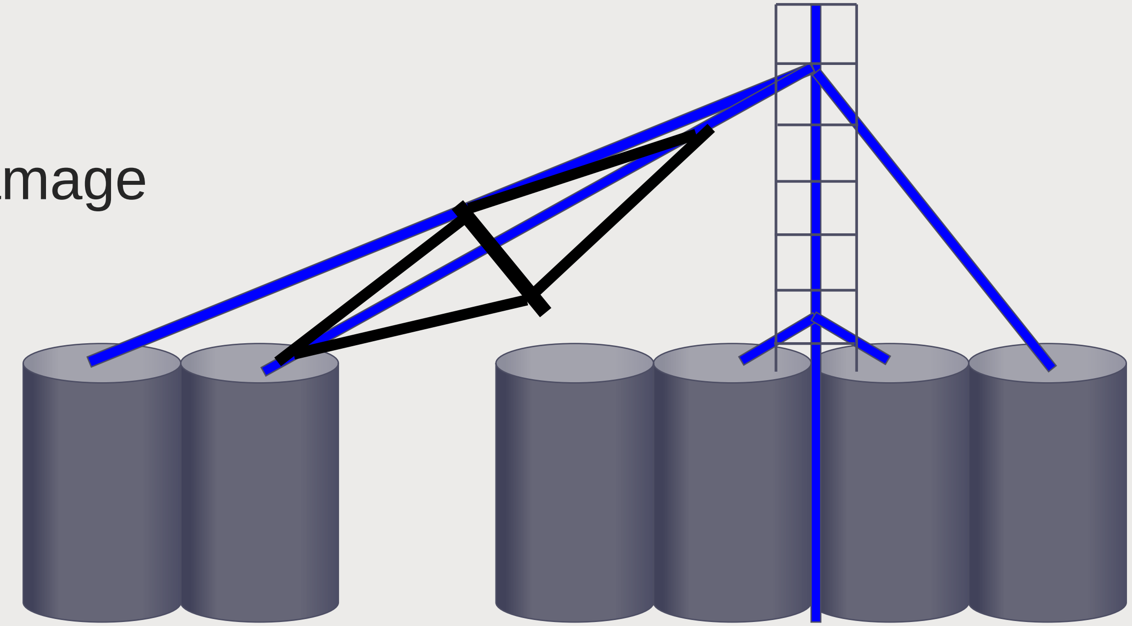
DISTRIBUTION SYSTEMS

DISTRIBUTION SYSTEMS





- Which is best?
- Trade-offs
- Motor hp vs. tower/support steel vs. grain damage
- World’s tallest bucket elevator
  - Cement in China
  - 600 t/h
  - H = 575 ft tall
  - P = 450 hp



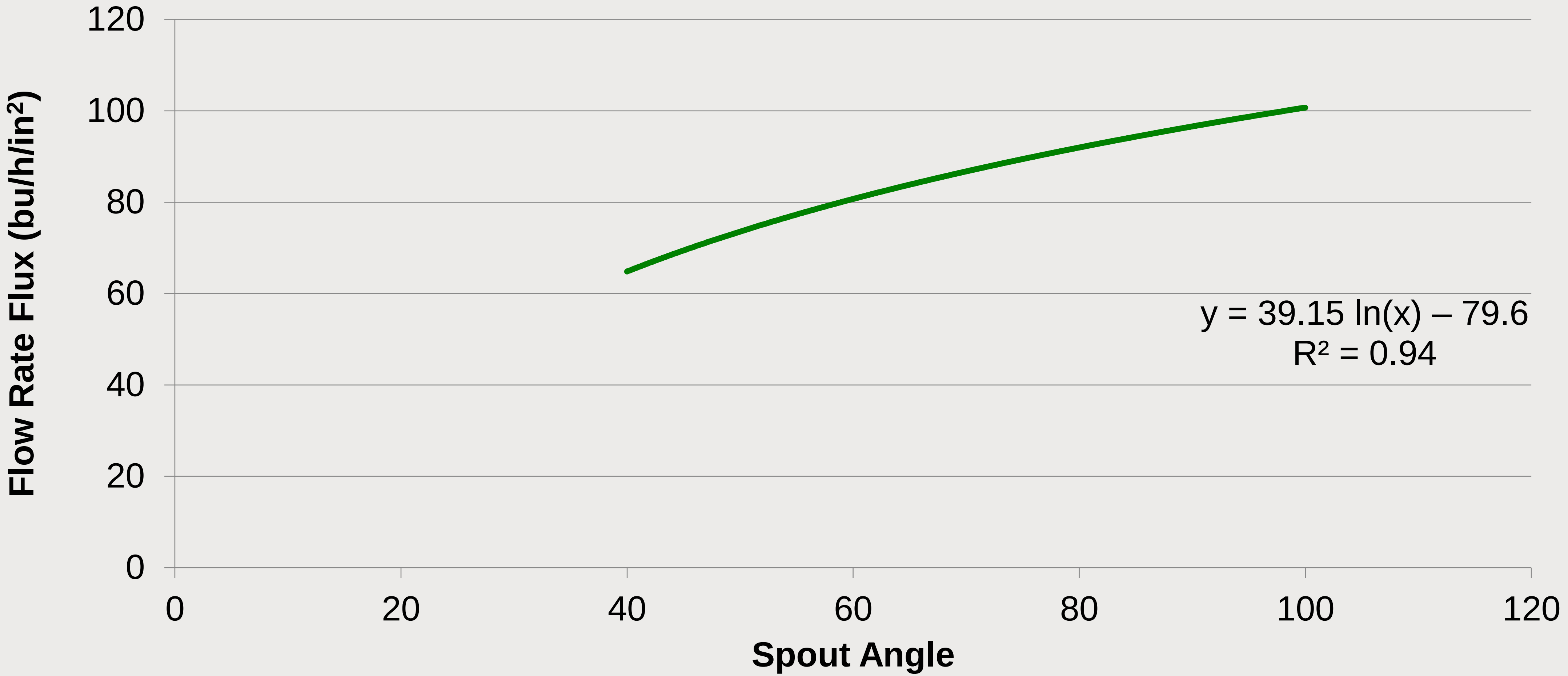
DISTRIBUTION SYSTEMS

- Spout angles

Product	Min	Preferred
Whole Grains	37	40
Ground Grains	50	60
Ground Feed	50	60
Wet Pelleted Feed	50	60
Dry Pelleted Feed	40	45
Fines/Dust	50	60

Flux	Situation
60 bu/h/in^2	40 deg. slope (10 on 12), whole grains
75 bu/h/in^2	45 deg. slope (12 on 12,) whole grains
100 bu/h/in^2	Vertical spouting

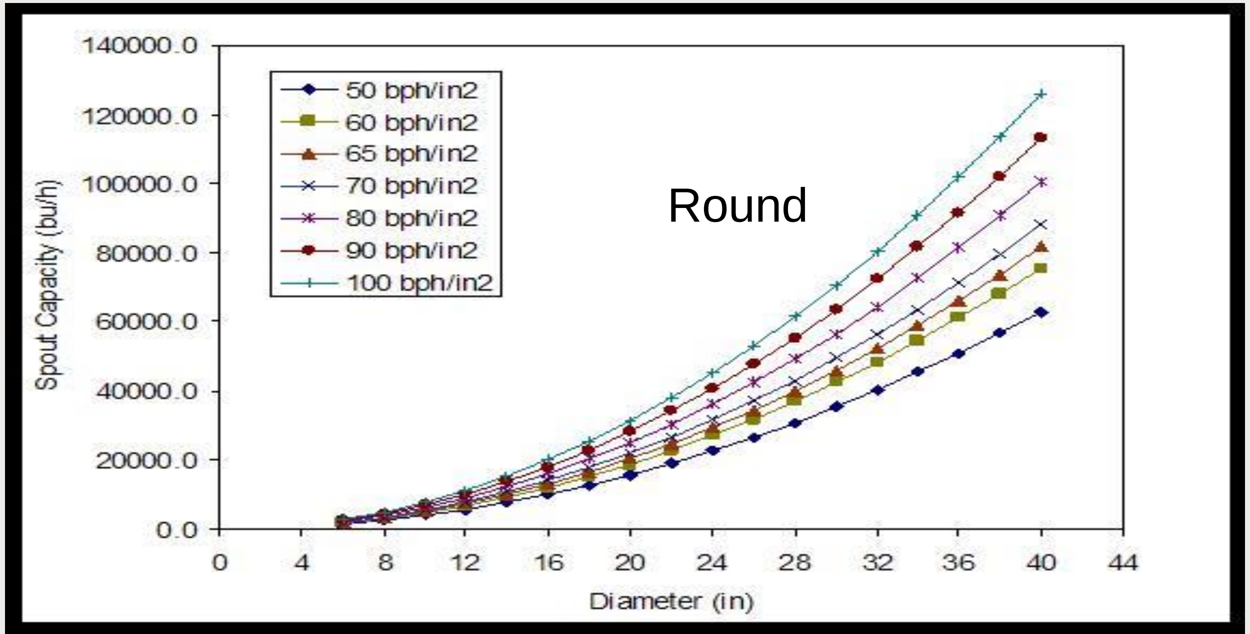
DISTRIBUTION SYSTEMS

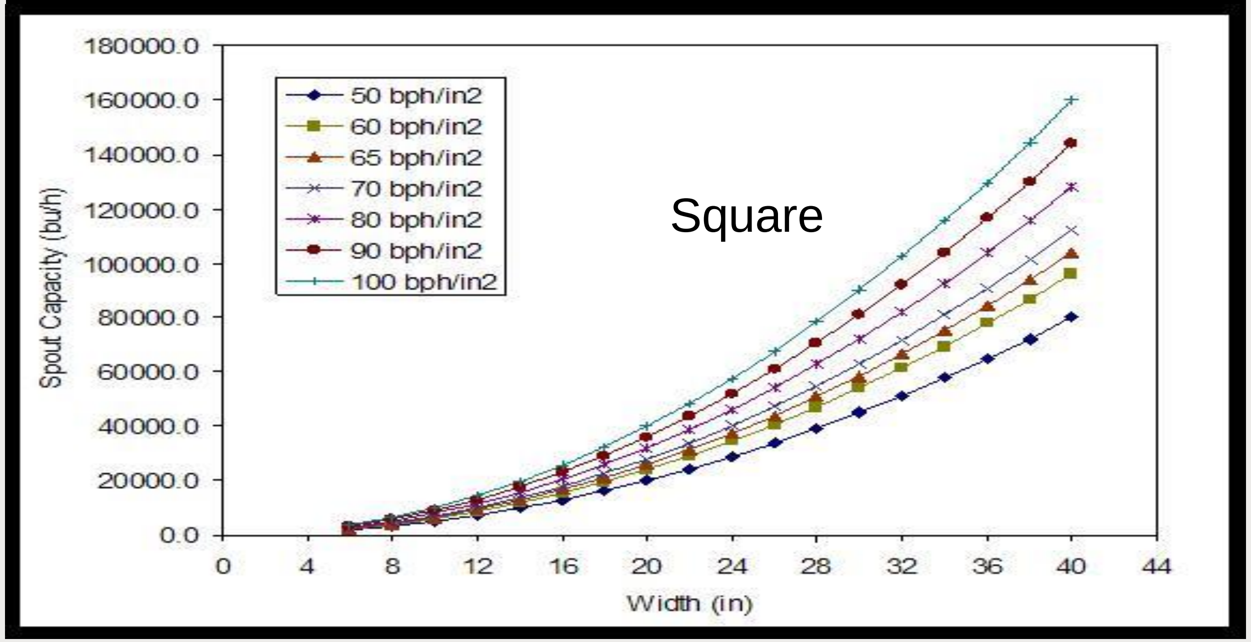


Steeper slope = greater flow rate

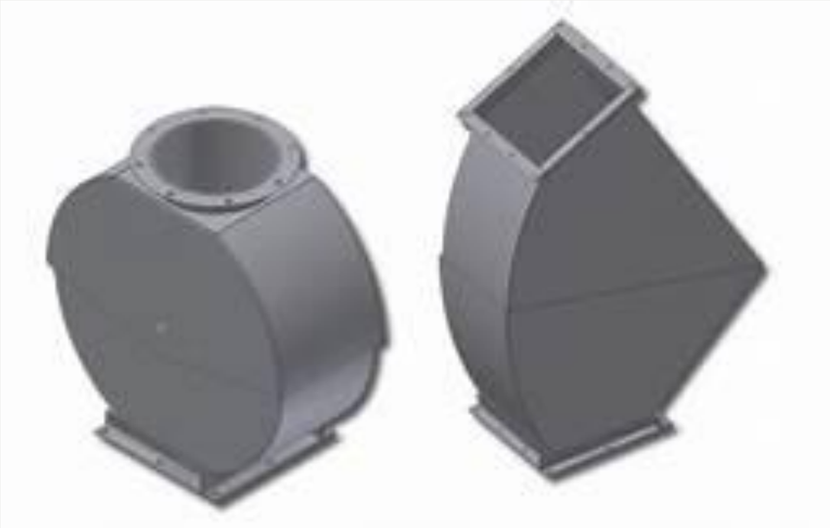
DISTRIBUTION

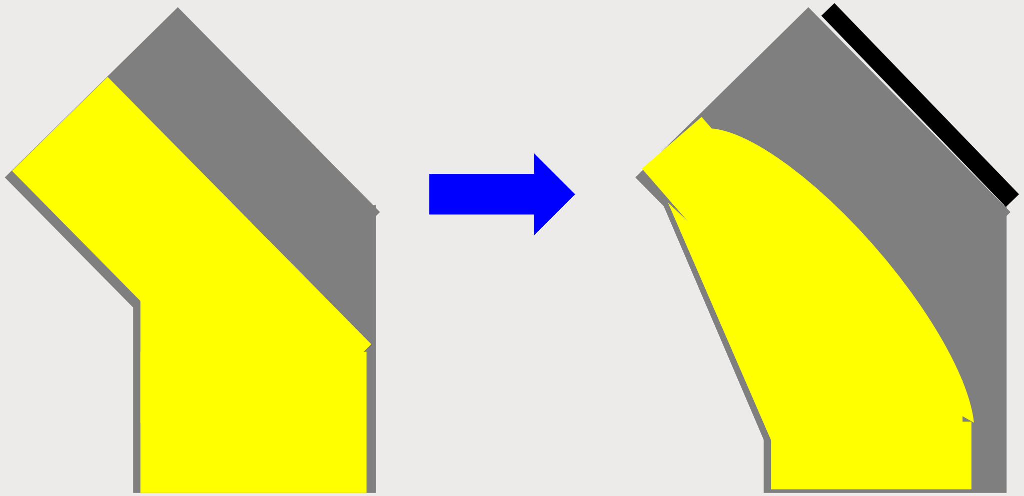
- Spout angle vs. angle of repose
  - Grain: 40º to 50º
- Spouting flow rate flux (bu/h/in^2)
  - Spout size, shape, length, angle, liner
  - Grain size, shape, length, moisture, friction with spout wall
- Steeper slope = greater flow rate
- Generally industry nomographs for this information

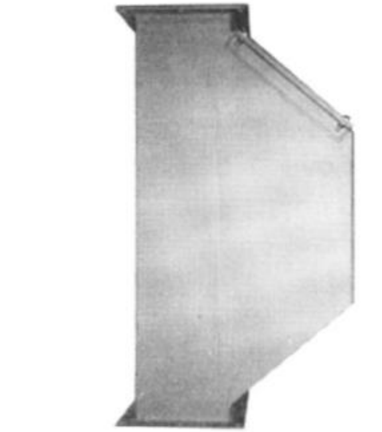


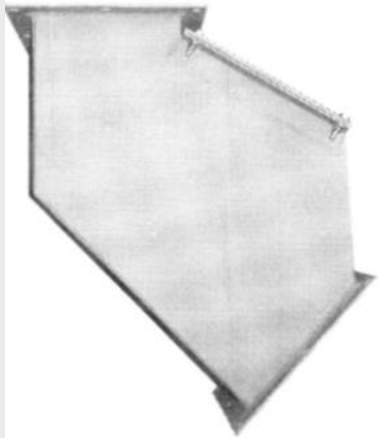


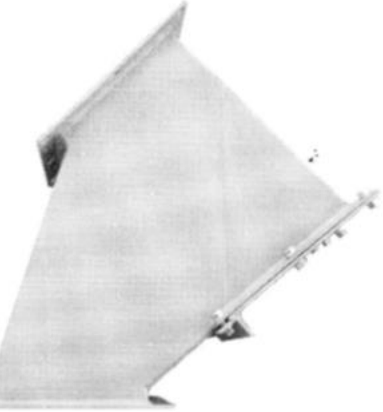
DISTRIBUTION SYSTEMS

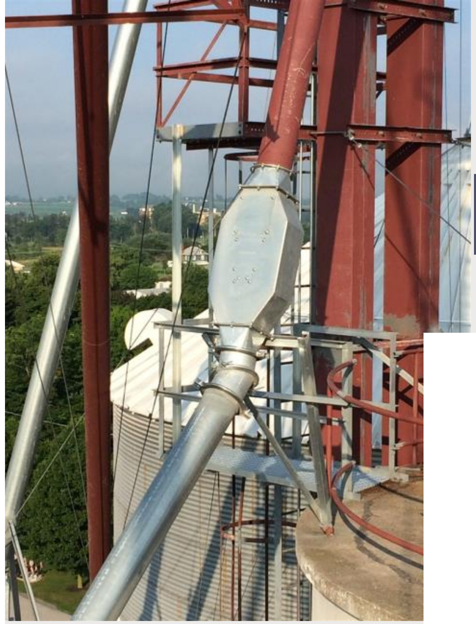












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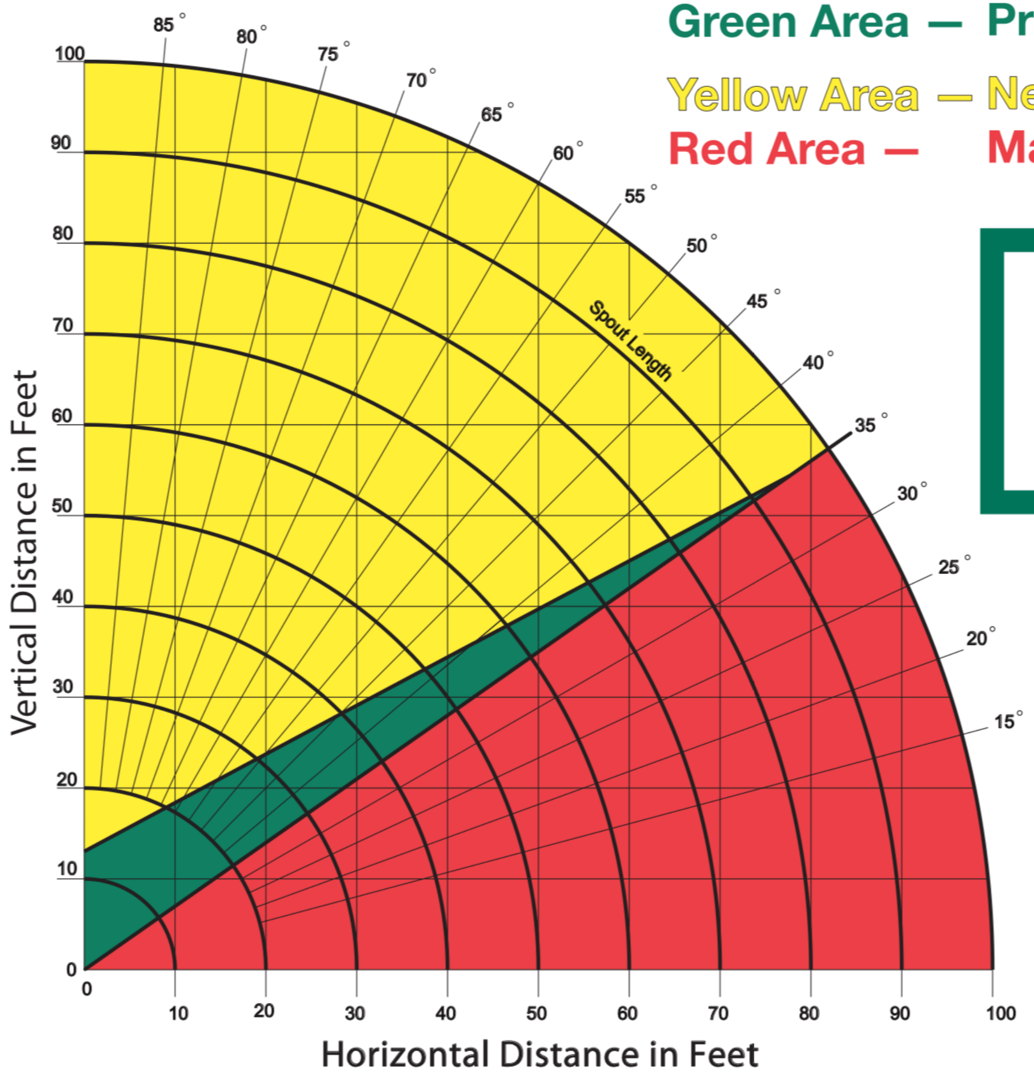


Green Area — Preferred Area VELOCITY 1750 FEET PER MINUTE OR LESS

Yellow Area — Need Inline Flow Retarders

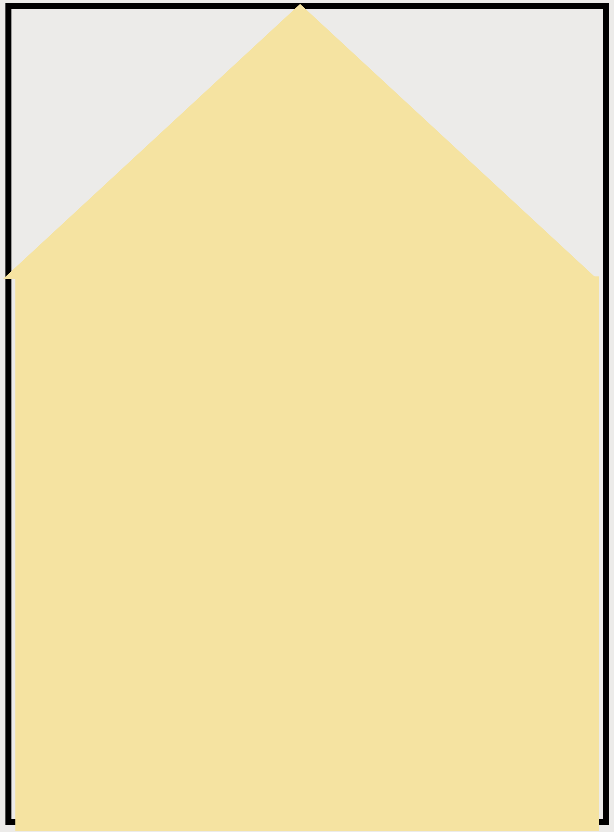
Red Area — Material will not flow

Velocity Chart

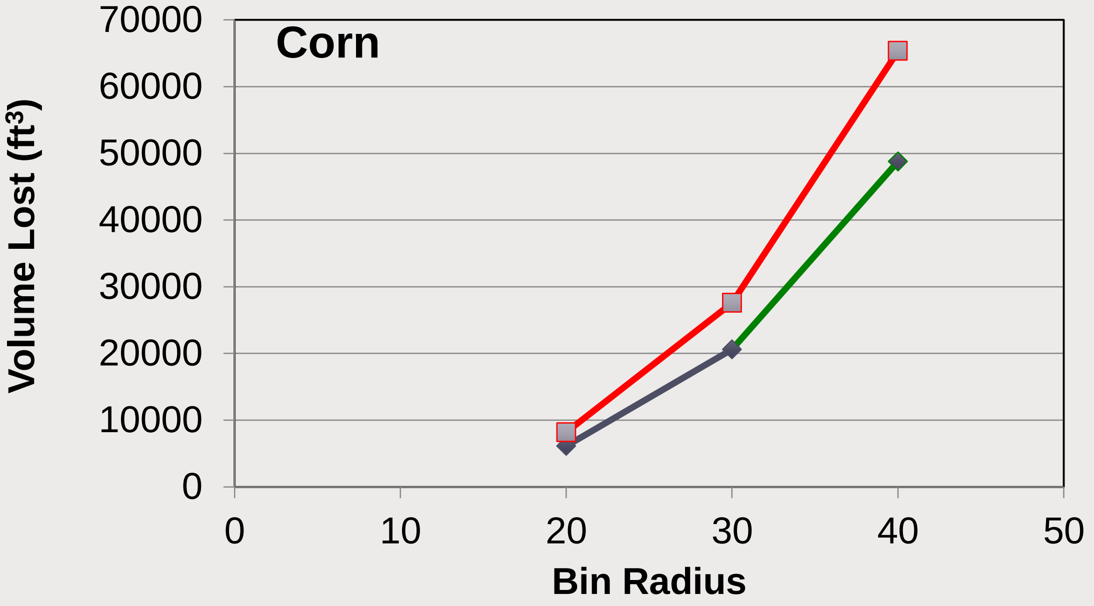
To be used in layout and selection of velocity reduction equipment.

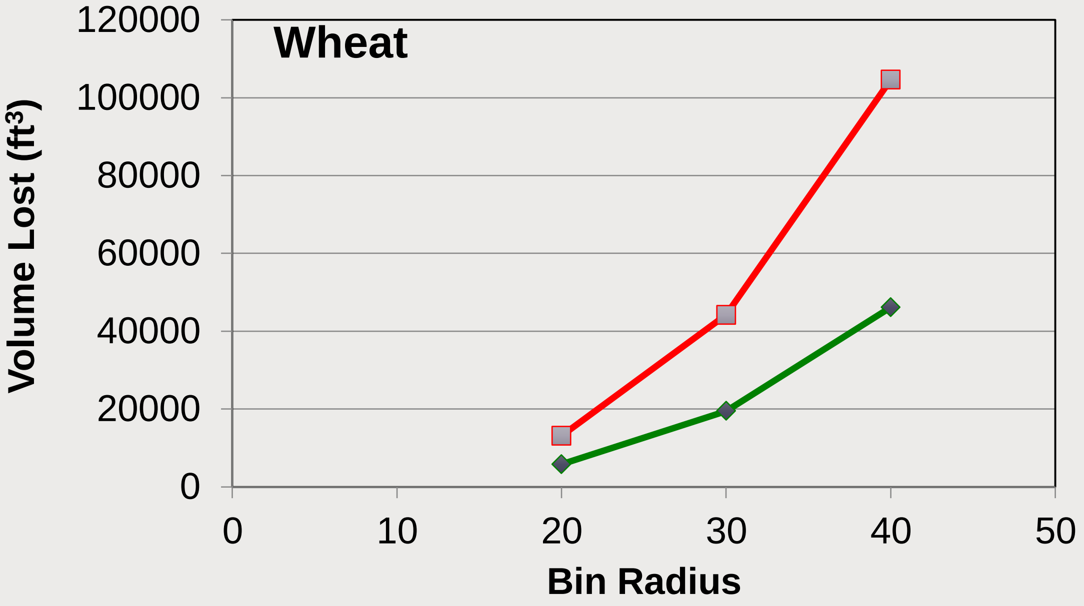
STORAGE SYSTEMS

- Many options are available
  - Silos, bins, flat storage
    - Capacity will be affected by bin fill & grain properties
      - Type of grain
      - Moisture content
      - Angle of repose
      - Number of conveyor discharges
      - Location of conveyor discharges
  - Will never achieve “level full”



STORAGE SYSTEMS





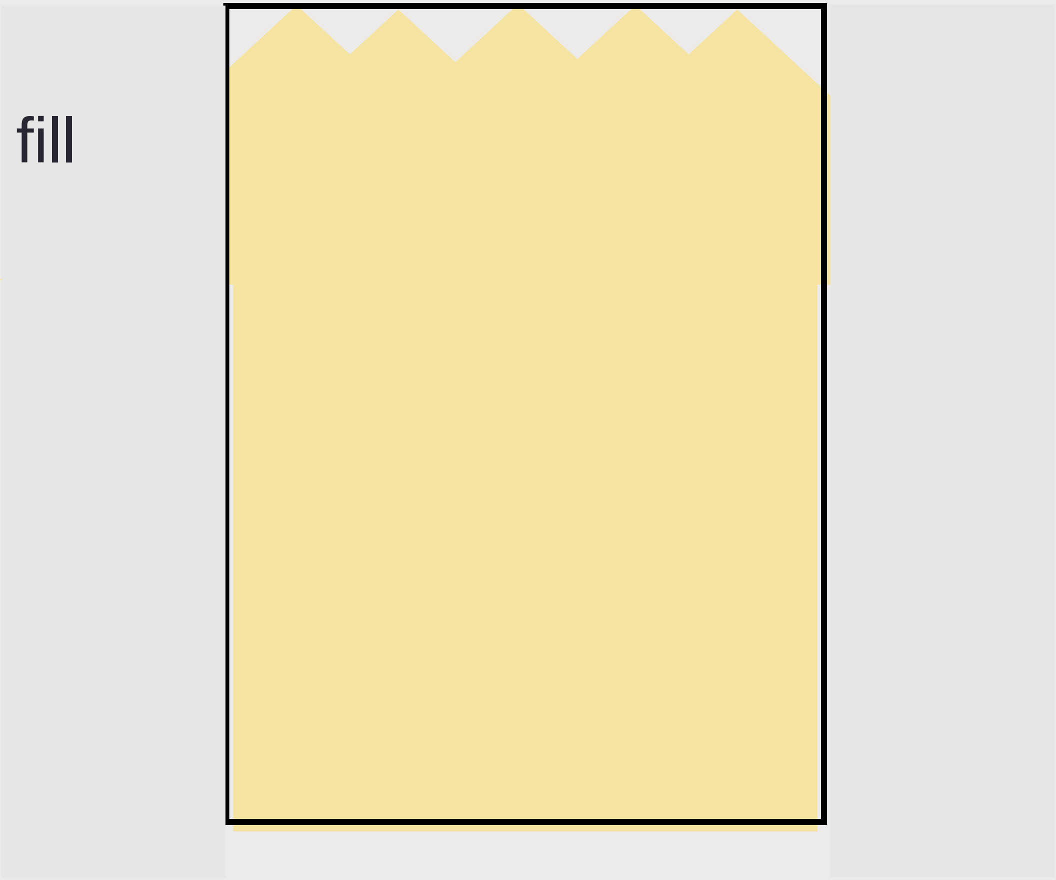
AoR Min = 20º
AoR Max = 26º

AoR Min = 19º
AoR Max = 38º

Wet bins: design for high AoR
Dry grain: design for average AoR

STORAGE SYSTEMS

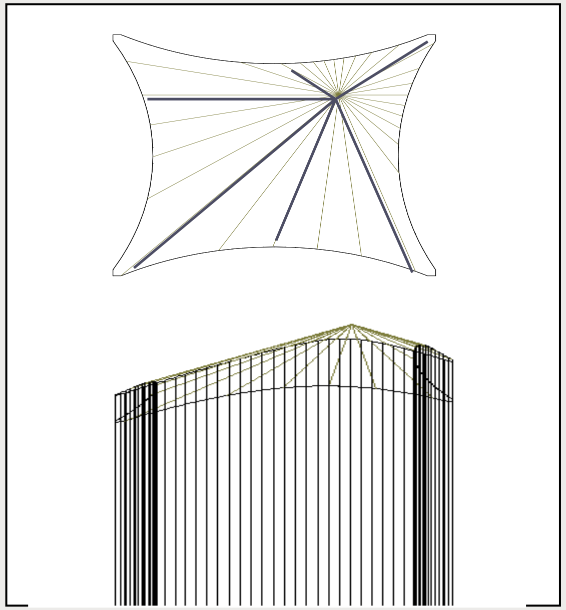
- Will never achieve “level full”
  - Multiple fill points will make more effective fill
  - Decreases unused bin space
    - More effective capacity



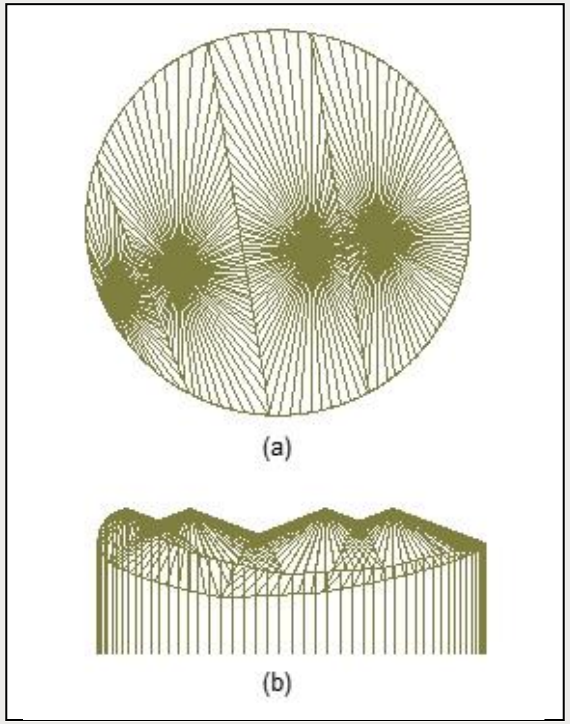
STORAGE SYSTEMS

- Effective storage volumes
  - Can be optimized by top fill: number of inlets, locations
  - Affected by angle of repose
    - CAD solid modeling essential

Interstice bin



Round bin



End of Part 1