Biomass Automated Densification Device

B.A.D.D.!

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The Need

- $70 million dollar "Biofuels Initiative" project funded by the state of Tennessee
- The plant being constructed will have the capacity to produce 5 million gallons of cellulosic ethanol each year
  - Requires approximately 170 tons of biomass per day

How will the plant efficiently receive this large quantity of material? How has this been done before?

Cotton Module Builders

- Cotton logistics were aided by development of module builder
- Their Function
  - Compress cotton / reduce volume
  - Aid in transportation of large quantities of material

Module Trucks

- Engineered to load module without shearing
  - Backs up while chains roll module onto platform
  - Platform at 15° with ground
- Transports modules from field to gin

A Switchgrass Solution?

- Cotton module builders greatly helped the cotton industry
- Can farmers get more out of purchased cotton equipment?
- We know we can build them, but will they stay together?

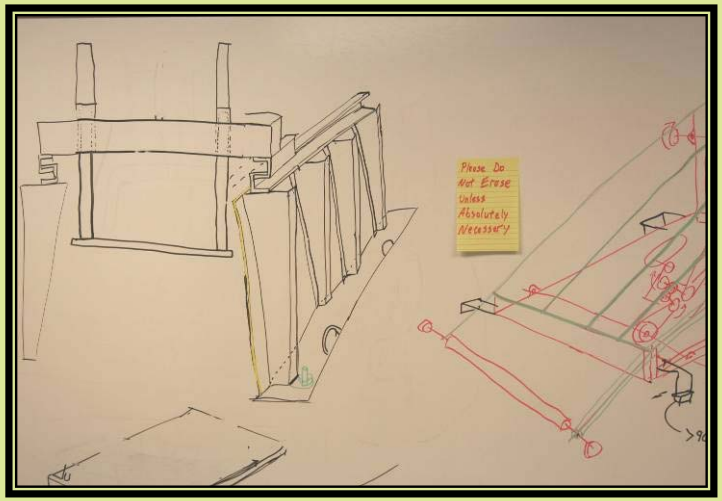
Need and Project Purpose

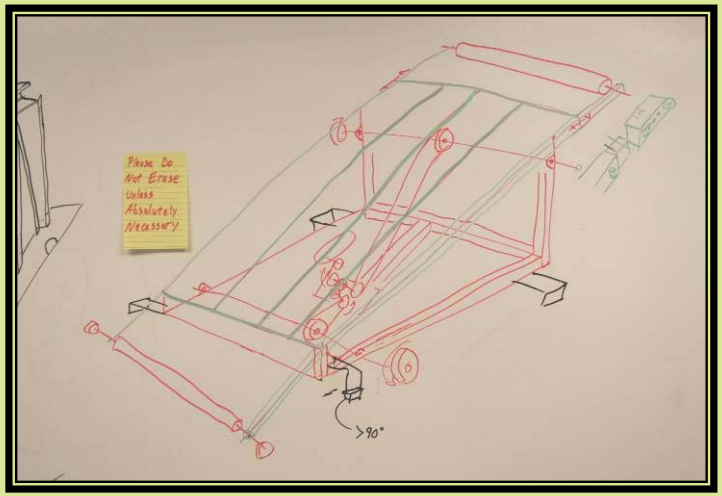
- Need: A research tool to investigate switchgrass module building / loading at a smaller scale
  - Scaling it Down:
    - It takes a lot of time and switchgrass to build a full size module!
    - Use Dimensional Analysis and Similitude to make a Mini-Module
- Purpose:
  - Design, Build, and Test a "tabletop" model of a module builder
  - Design, Build, and Test a device to simulate a module loading truck

Criteria for Success

- Cotton
  - Similar module density
  - Module builder can be removed without disturbing module
  - Module can be successfully loaded
  - Systematically determine tamping pattern
  - Use sensors to examine pressure distribution
- Switchgrass
  - Judge differences in module integrity during removal and loading
  - Follow tamping process perfected with cotton
  - Compare parallel data between switchgrass and cotton

Design Process



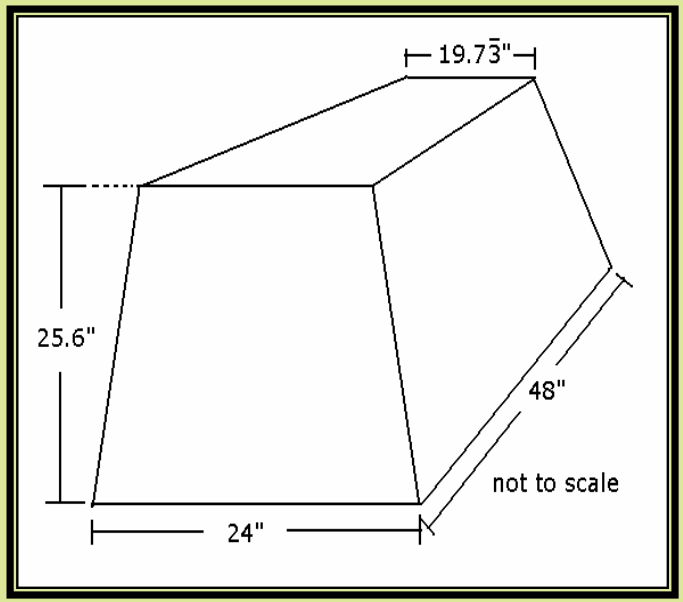


- Conceptualization and Brainstorming
- Design and AutoCAD
- Procurement and Fabrication
- Testing and Experimental Design

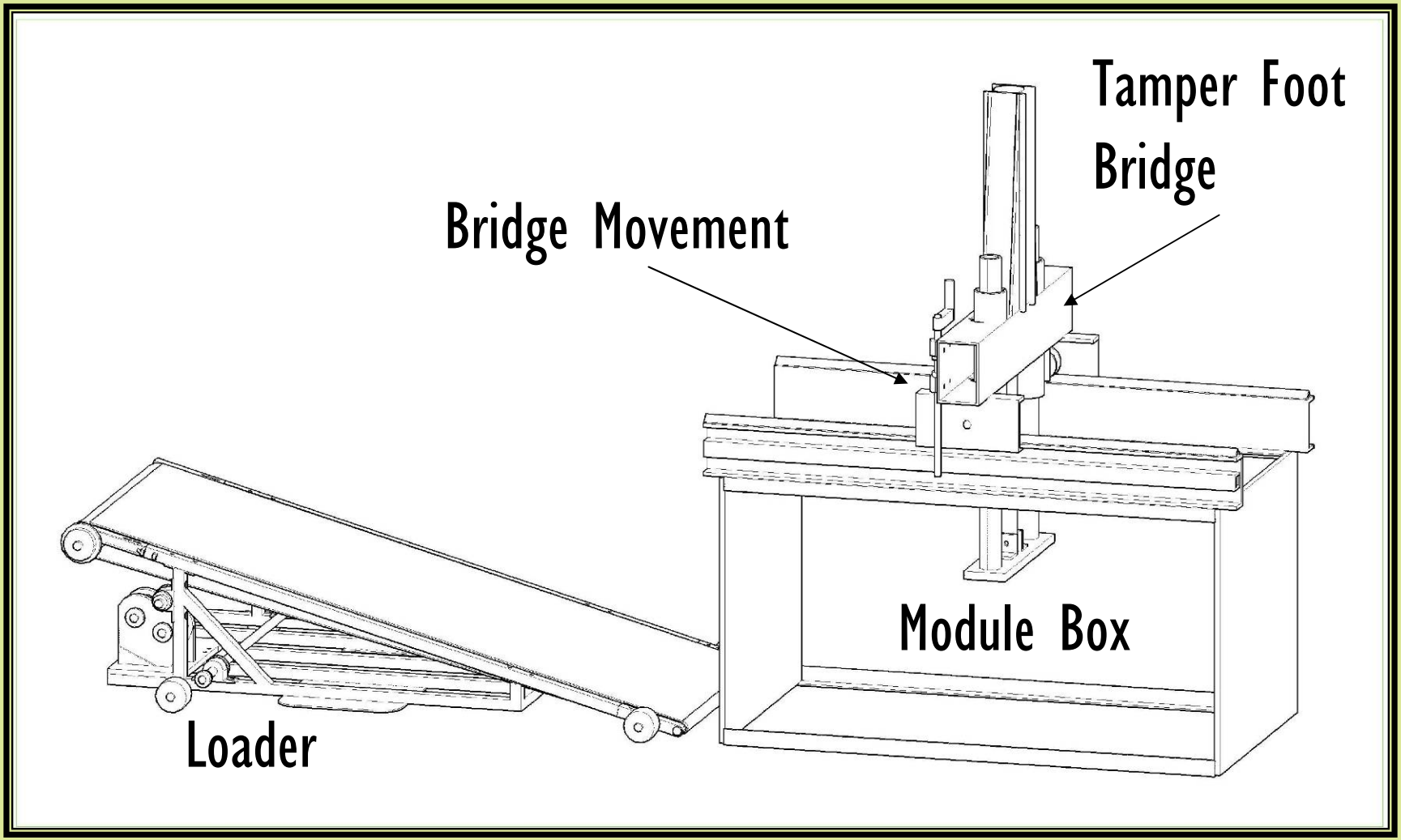
- We integrated many engineering areas in this project:
  - Dimensional Analysis
  - Hydraulic Circuit Design
  - Power Transmission
  - Strength Analysis
  - Electronics

Dimensional Analysis and Similitude

- Does the model represent a field size module builder?
  - Width and height 1:3.75 scale
    - Wall effect minimized
  - Tamper foot pressure
    - 11 psi
  - Tamper foot speed
    - 18 inches per second
  - 1:12 module wall angle
  - 15 degree loading angle

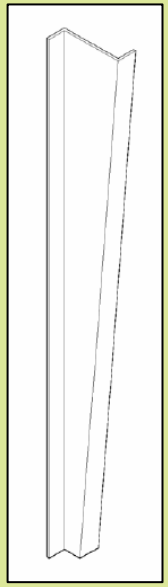


System Components



Module Box

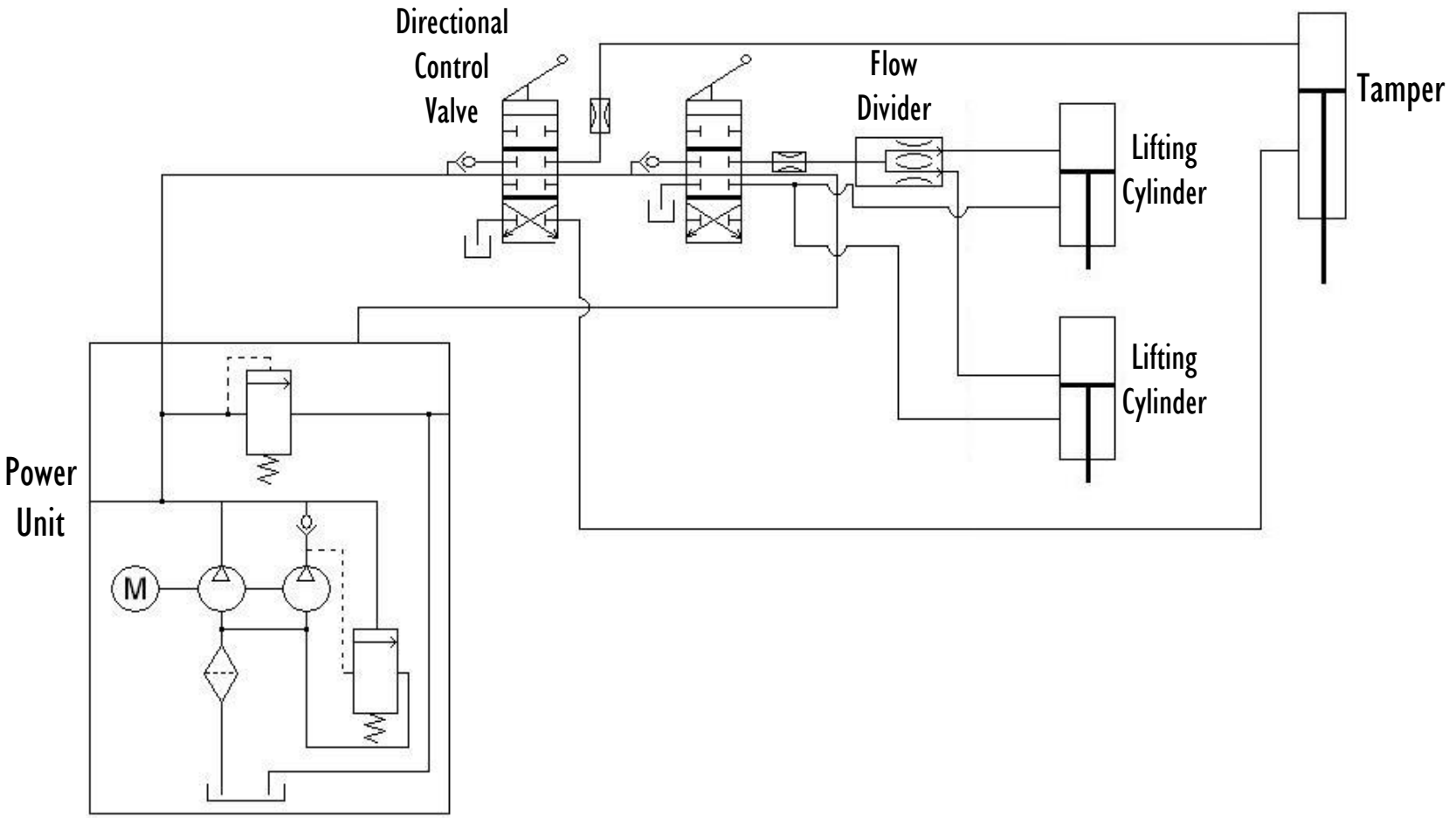
- Z-rib design creating 1:12 wall angle
- Easy-to-remove door with locking pins
- Hydraulics lift box evenly
- Lexan walls to visualize compression



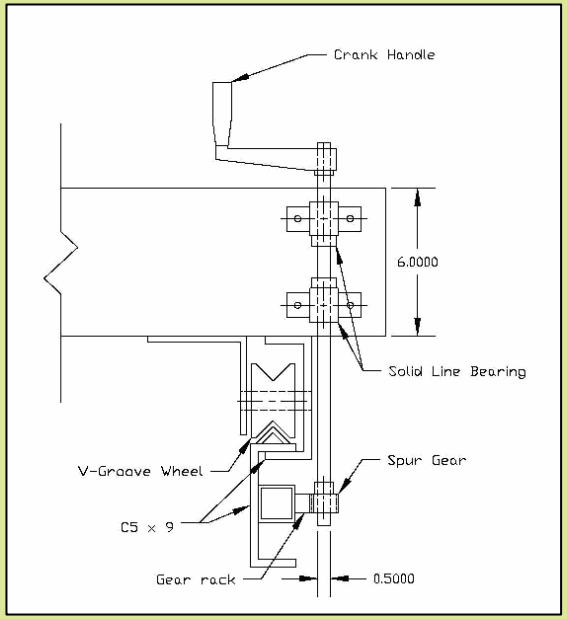
Tamper Design

- Tamper foot sized from dimensional analysis
- Bridge sized to support an 11 psi pressure on biomass
- Tamper operated hydraulically
  - Guide rails ensure perfectly vertical movement

Hydraulic Schematic



Bridge Movement

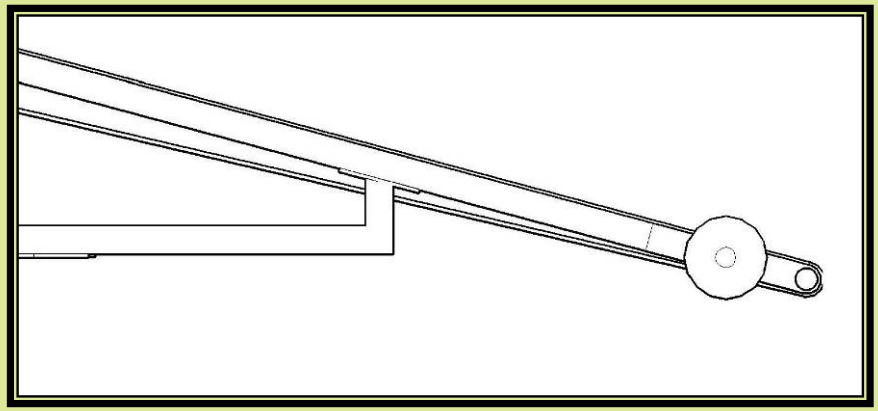


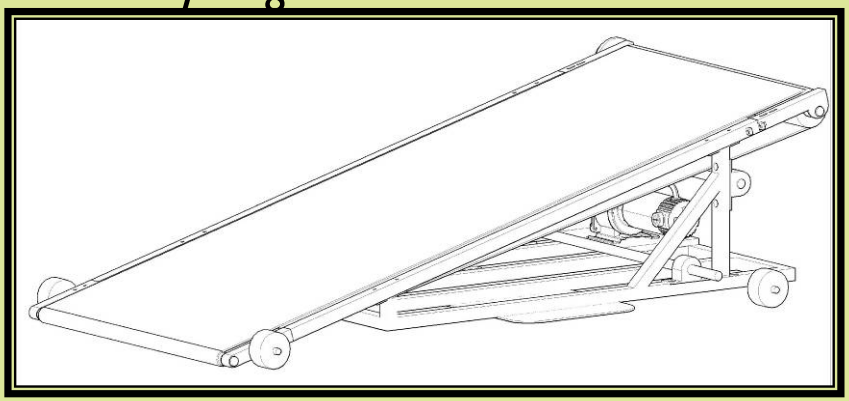
- Resists downward tamper force
- Moves tamper bridge along module
- Hand operated crank follows mounted gear rack
- V-groove wheels on angle track keep bridge aligned
- C-channel selected for fit and strength
- Rubber stoppers at ends for safety

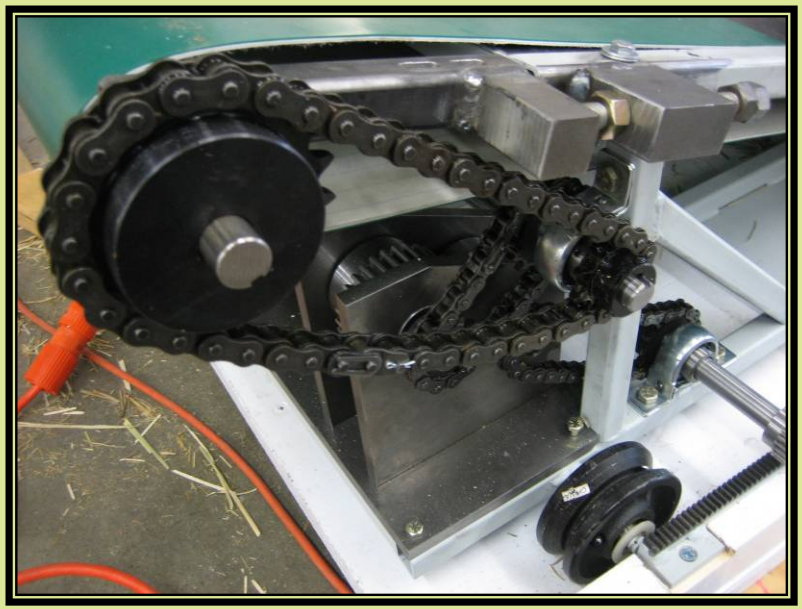
Loader

Loader

- Optimized to pick up module
  - 15° ramp angle
  - Belt pulley chosen for very small front nose
  - Belt speed harmonized with forward speed of loader
- Spur gears for positive traction
- Motor, chain drive selected to work together for precise speed
- Perfectly aligned forward movement





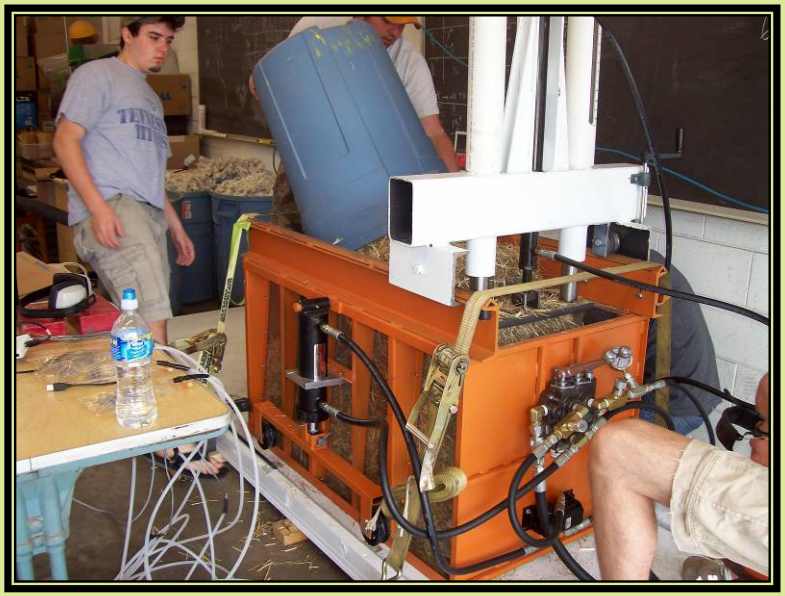


Testing

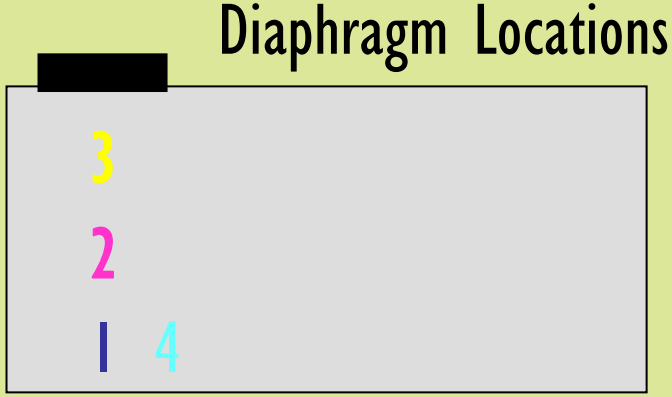
- Density
  - Weight per volume
- Tamping Pattern
  - Field observation
  - Calculation / Energy approach
- Fill Depth
  - Amount added before tamping
- Tamping Pressure
  - 11 psi field and model
- Pressure Profile
  - Pressure transducer testing

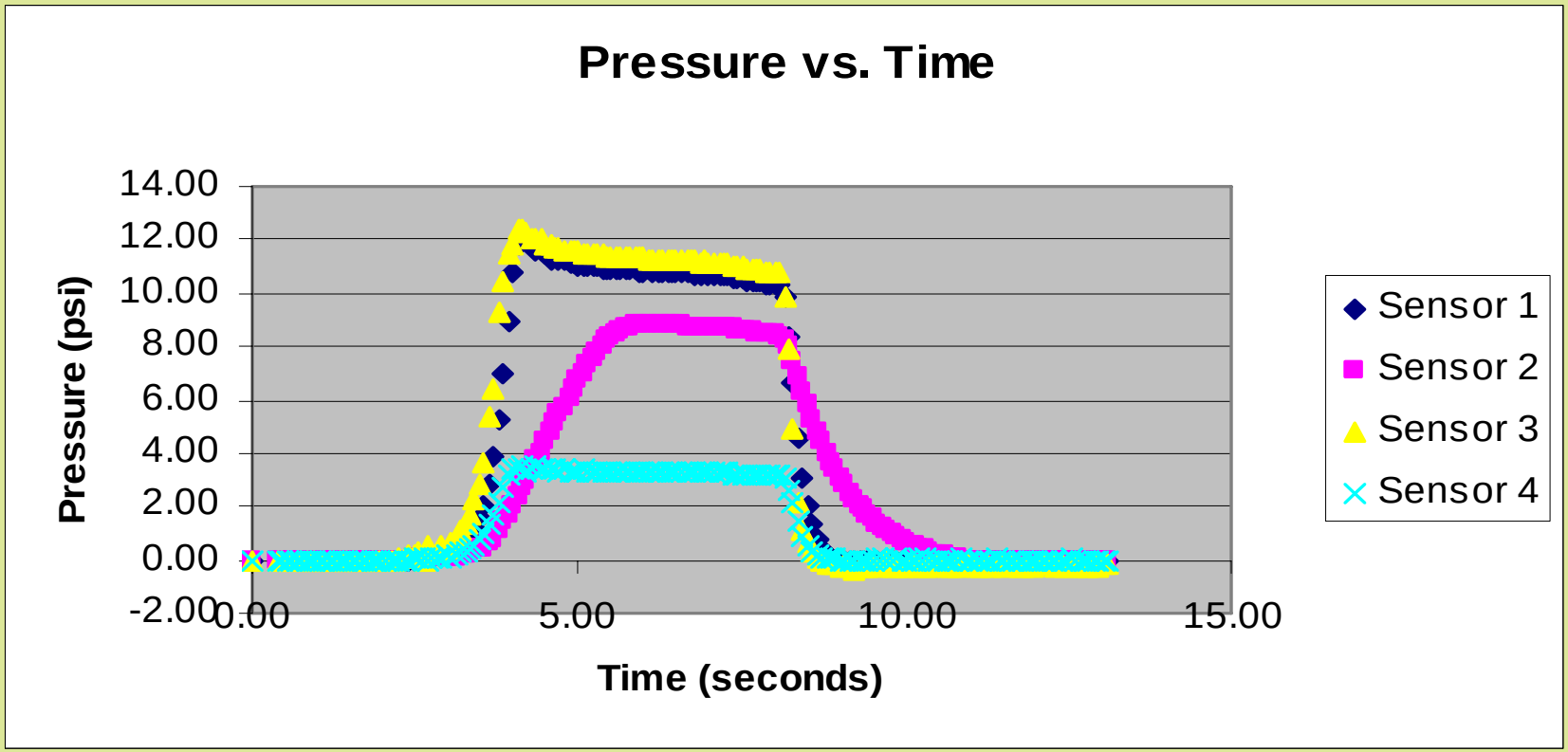
Pressure Profile

- Use pressure transducers to generate a pressure profile for both cotton and switchgrass

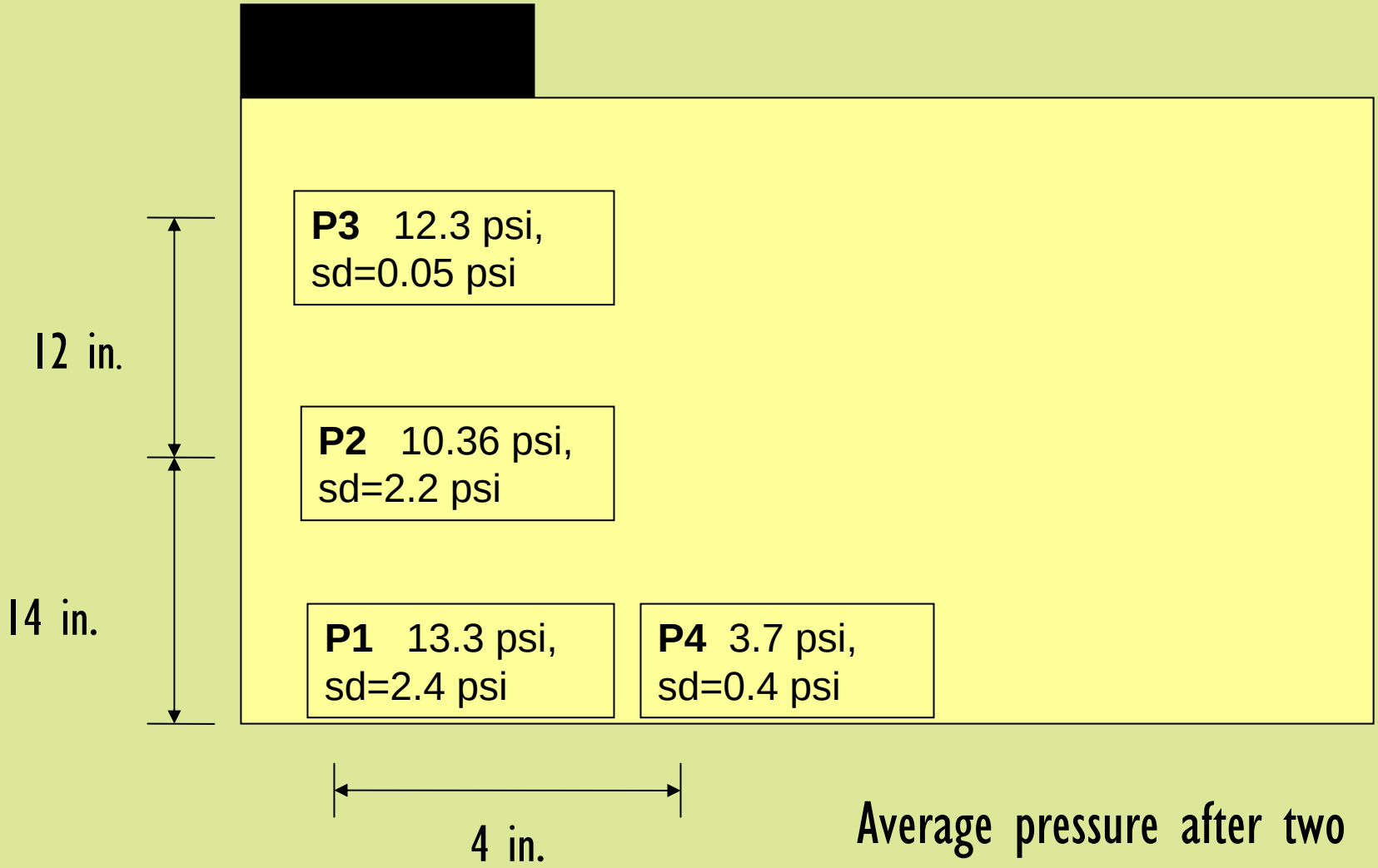


Testing Results Cotton



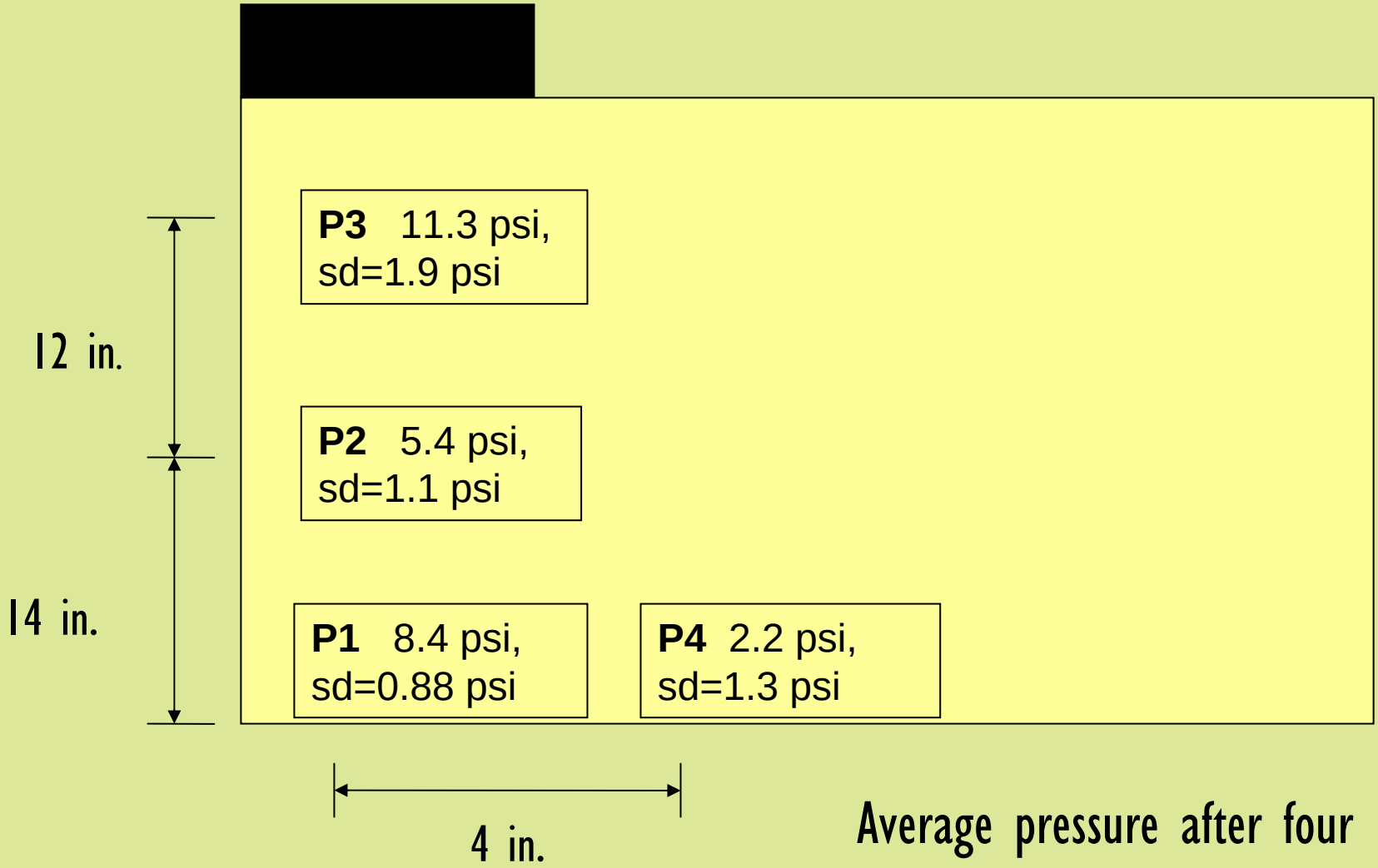


Testing Results Cotton



Average pressure after two repetitions

Testing Results Switchgrass



Average pressure after four repetitions

Next Generation Considerations

- Tandem wheels on bridge for more even bridge movement
- Gear guard on loader
- Automated clamps to hold down builder while operating
- User Manual / Safety Stickers
- Create array of many sensors for detailed pressure profile data

How This Tool Will Be Used

- To identify issues with making modules of switchgrass
- To investigate the effects of:
  - Switchgrass chop length
  - Moisture content
  - Novel additives
  - Number and duration of tamps
- To improve the integrity of switchgrass modules

Conclusions

- Met criteria for success
  - Simulates a full-scale module builder
    - Module density within desired range
      - Cotton Module 7.5 pounds per cubic foot
      - Switchgrass Module 4.8 pounds per cubic foot
    - Module holds together
    - Module loads without breaking apart

Special Thanks

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Wet - Switchgrass
NO SMOKING
Questions?