DEPARTMENT OF MECHANICAL ENGINEERING

TEAM Big Dirt
Soil Sampling Robot

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Motivation, Goal, Impact

Problem Statement

- Farmers must sample soil yearly to measure nutrient and pH levels.
- Multiple 1-cup samples per acre.
- Manual sampling is tedious, costly, and labor-intensive

Goal

- Automate soil sampling and storage to save farmers time and labor.
- Note: Navigation was not a focus this semester.

Impact

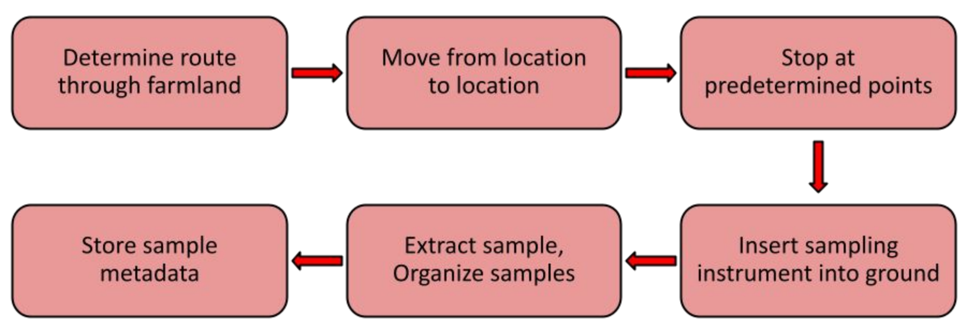
- Saves 55+ hours of manual labor annually for our stakeholder.
- Across Maryland's 2M+ acres, automation could save ~1 million hours of labor per year.

Requirements

Functional Requirements

- Autonomous farmland navigation
- Autonomous soil sample collection and storage
- Location and timestamp tracking for each sample
- 3.5+ hours runtime without refueling/maintenance
- Collect 2–5 samples per acre

Product Functions



Design Specifications

- Runtime: ≥ 3.5 hours
- Size: ≤ 4' × 4' × 4'
- Sampling time: ≤ 1 minute/sample
- Sampling depth: 6–8 inches
- Sample volume: ≥ 8 fl oz

Final Design

Subassemblies:

(1) Frame

- Galvanized steel beams, L-bracketed and welded for strength
- Rectangular base with vertical supports
- Polyethylene sheet top

(2) Storage

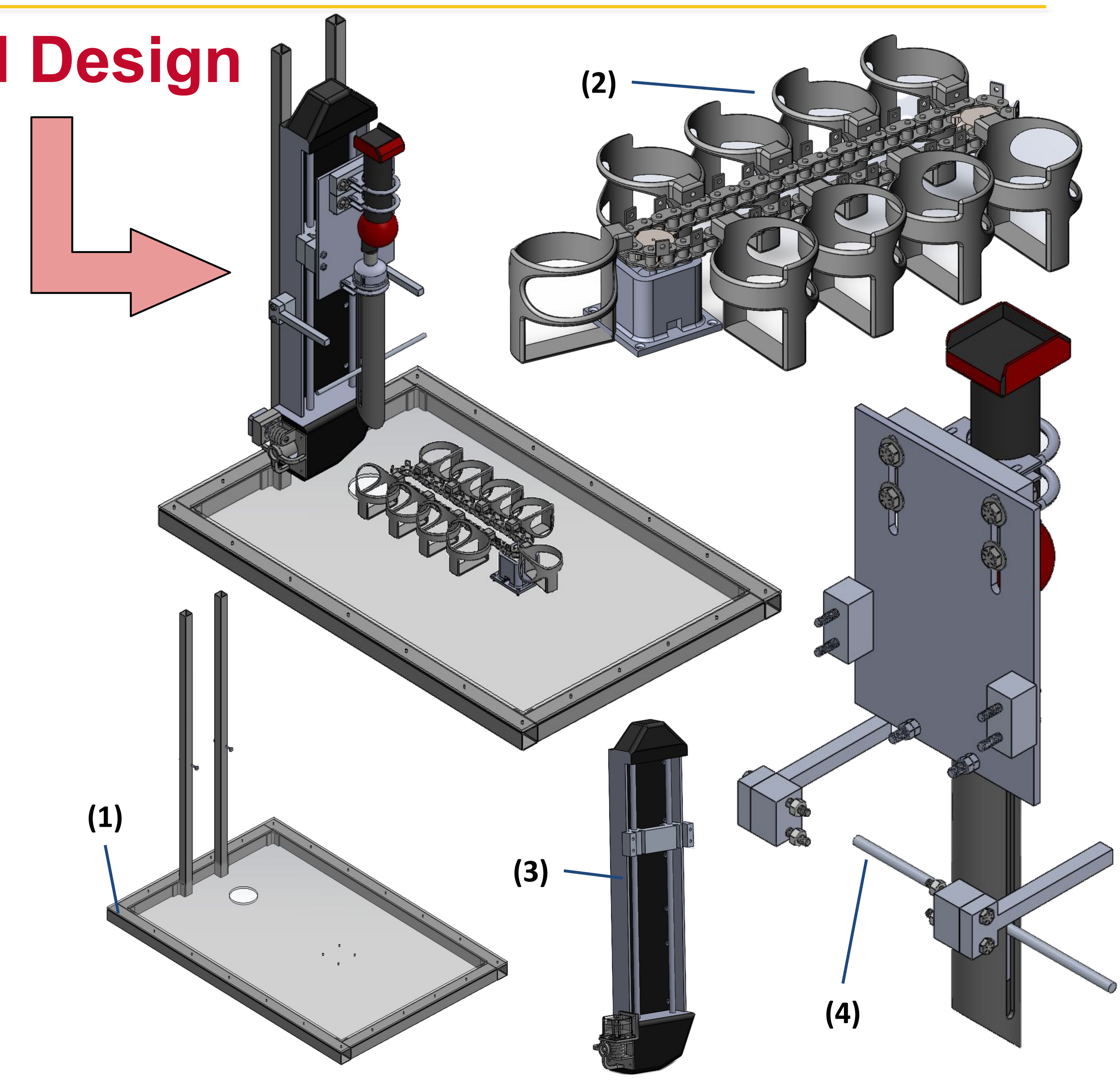
- 9 soil collection cups mounted on a chain with two sprockets
- Stepper motor drives one sprocket; the other free-spins
- Design allows soil to fall directly into cups without moving the sampler

(3) Height Adjustment Mechanism

- Belt-driven linear actuator (~70 cm span)
- Stepper motor + 20:1 worm gearbox for holding torque without power
- Converts motor rotation into linear probe motion

(4) Sampling Mechanism

- Mounting plate with U-bolted auto hammer and probe tube
- Auto hammer reduces insertion force
- Disk and arms eject soil into positioned storage cups during probe ascent

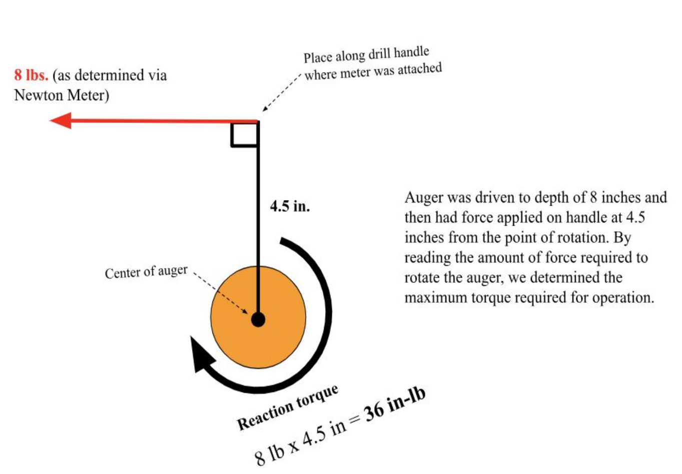


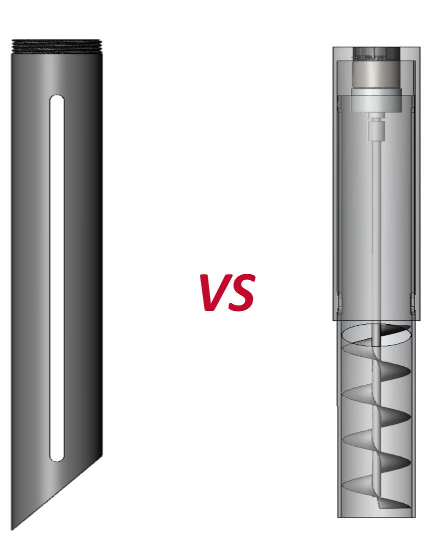
Design Calculations & Decisions

Sampling Mechanism

- Probe Tube: Lower extraction force, easy to clean. Insertion aided by auto hammer.
- Auger: Easier insertion but much higher extraction force; harder to clean.

→ Selected **Probe Tube** for easier sample removal and simpler design

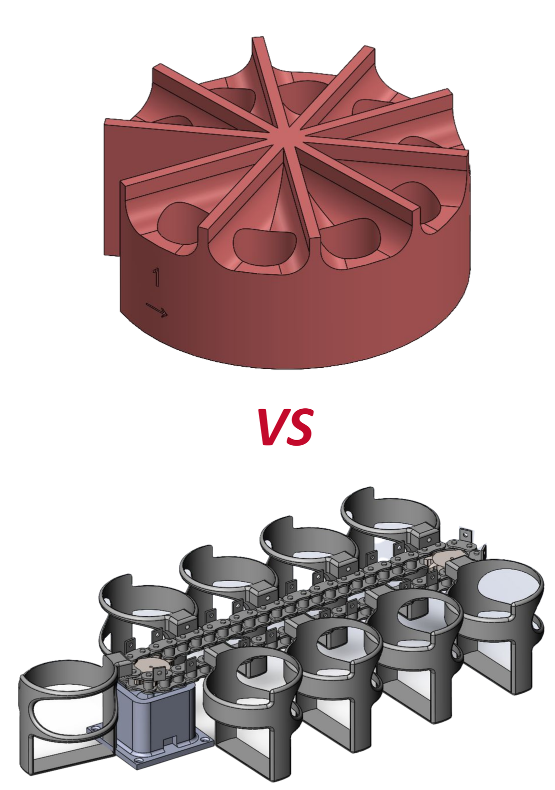




Storage Subsystem

- Revolving System (w/ or w/o Chain): Simple, scalable, and space-efficient.
- Conveyor Belt: Better density but more complex to implement.

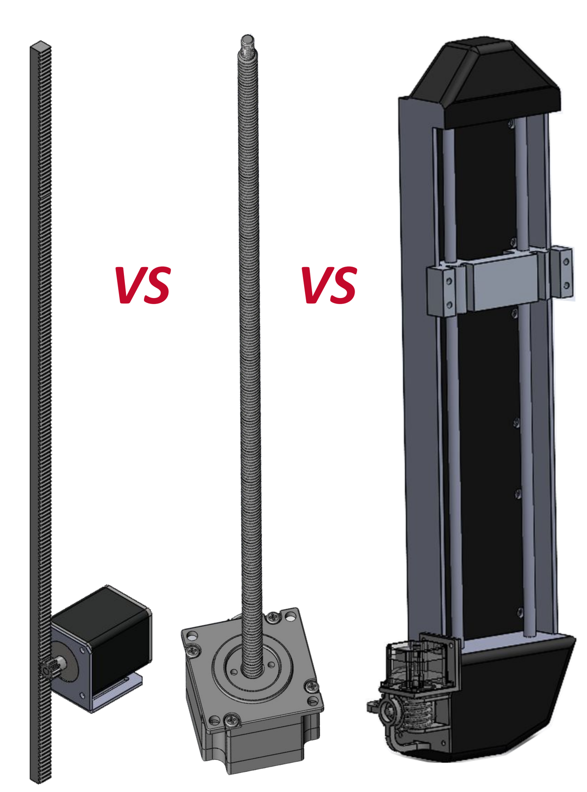
→ Selected **Revolving Storage with a chain** for simplicity and reliable operation.



Height Adjustment Mechanism

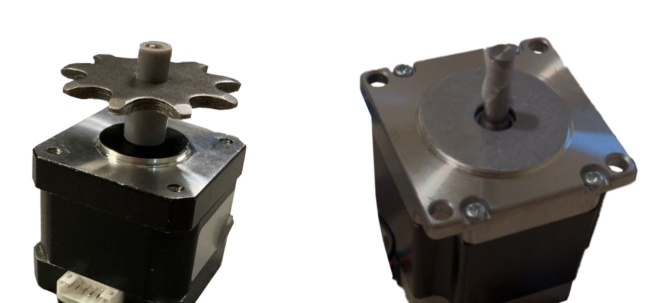
- Rack & Pinion: Easy control, difficult fabrication.
- Lead Screw: Good force transmission, limited length options.
- Belt Drive: Robust, scalable, compatible with worm gearbox (no holding torque needed).

→ Selected **Belt-Driven Linear Actuator** for robustness and scalability.

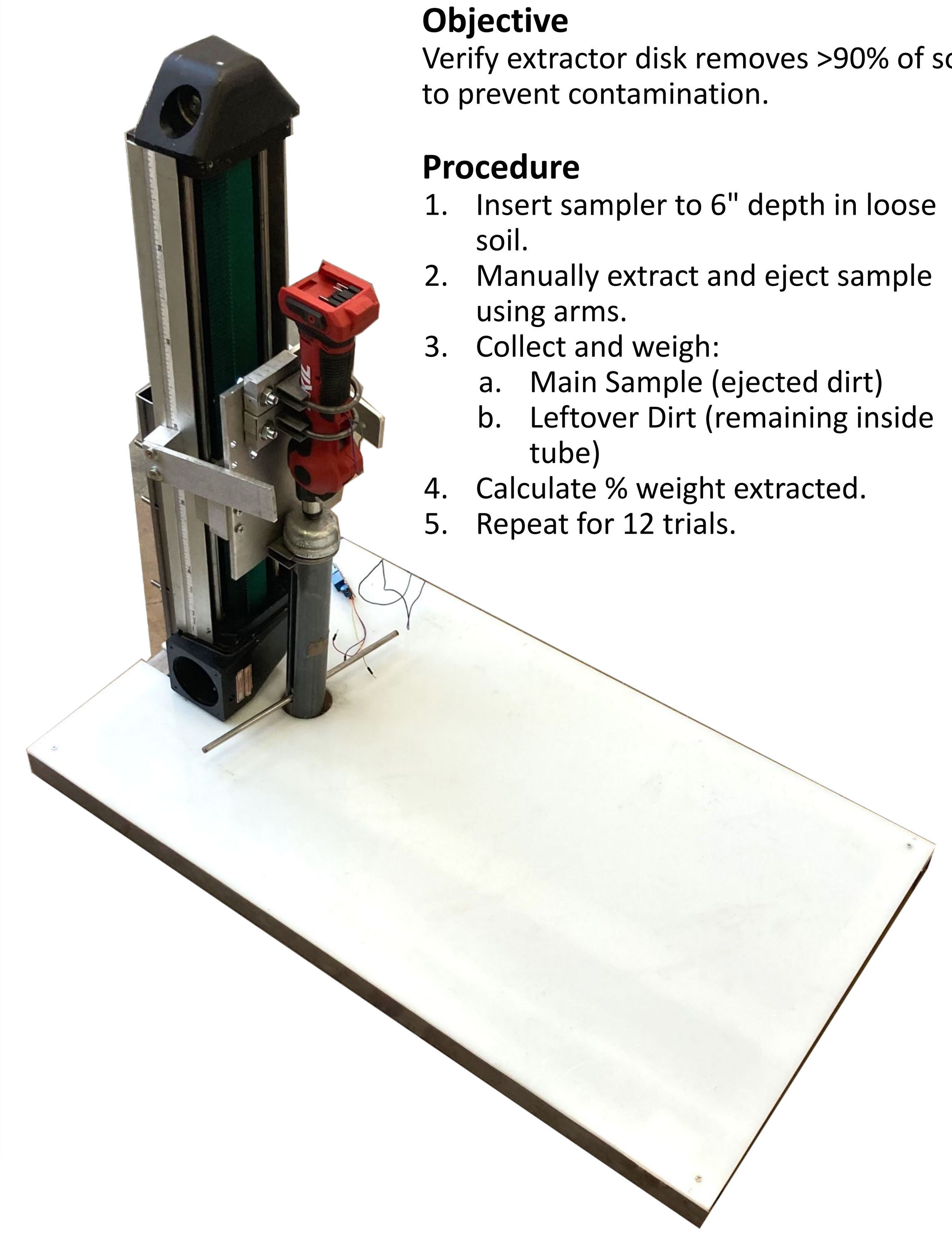


Calculations

- Drive Motor: 13 nCm at 1400 rpm
  - Based on geometry, force, speed
- Sampler Motor: 3 nCm at 80 rpm
  - Based on mass, friction
- Belt Width: 1.02 cm
  - Based on insertion force, material strength
- Battery: 12V, 18 Ah
  - Based on sampling energy needs and distance between samples



Prototype & Test Results



Testing: % Weight Removed During Extraction

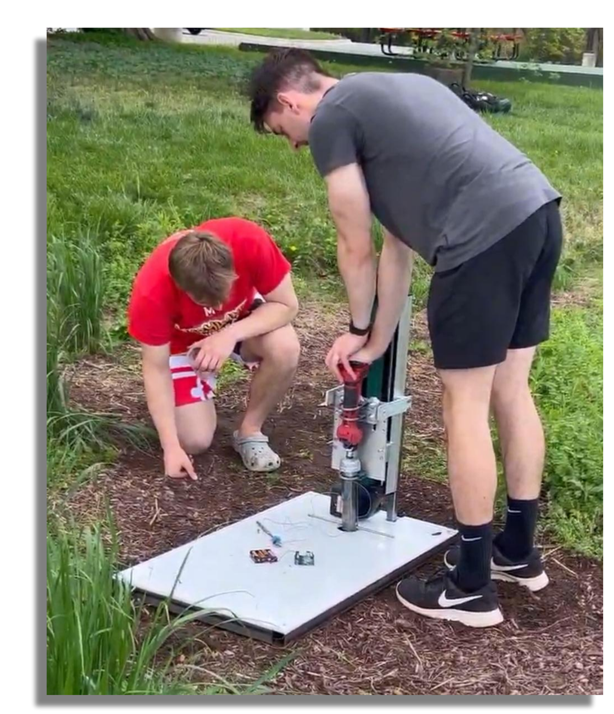
Objective

Verify extractor disk removes >90% of soil to prevent contamination.

Procedure

1. Insert sampler to 6" depth in loose soil.
2. Manually extract and eject sample using arms.
3. Collect and weigh:
   a. Main Sample (ejected dirt)
   b. Leftover Dirt (remaining inside tube)
4. Calculate % weight extracted.
5. Repeat for 12 trials.

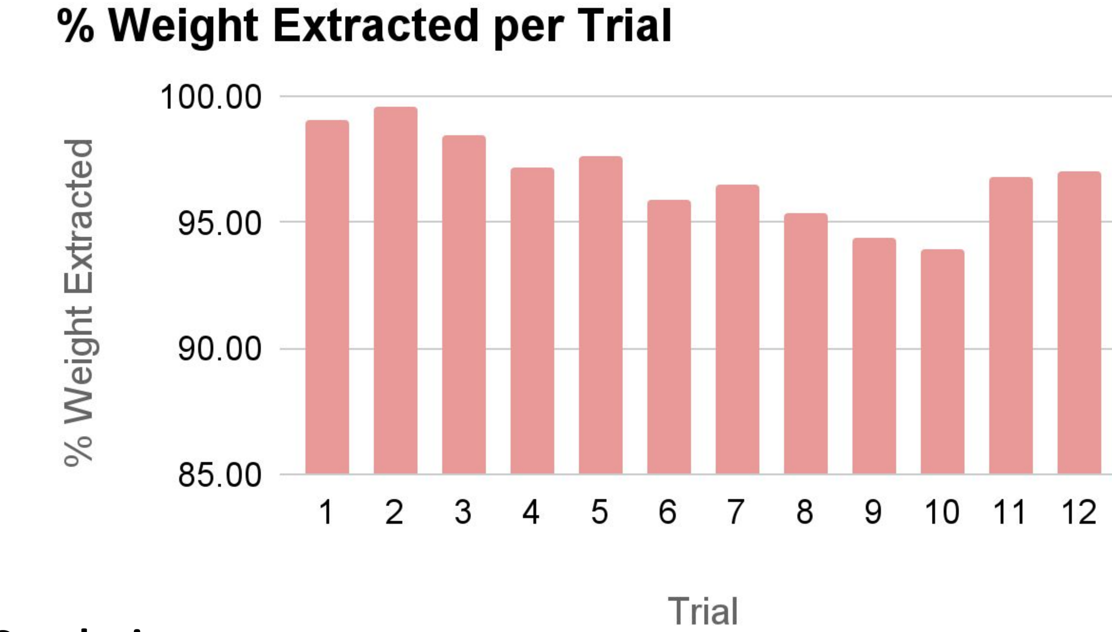
Setup



Results

Trial	Main Sample Weight (g)	Leftover Weight (g)	% Weight Extracted
1	172	1.7	99.02
2	201	0.8	99.60
3	149	2.3	98.48
4	159	4.6	97.19
5	162	4	97.59
6	134	5.8	95.85
7	178	6.5	96.48
8	144	7	95.36
9	113	6.7	94.40
10	177	11.4	93.95
11	147	4.9	96.77
12	164	5	97.04
Average	158.33	5.06	**96.81%**
Variance	532.42	7.97	**3.04%**

% Weight Extracted per Trial



Conclusion

- Achieved 96.81% average soil removal.
- No redesign needed; disk and tube clearances are effective.
- Confirmed consistent and reliable extraction performance.