



**University of Idaho**

College of Engineering

# **AUTOMATED BIOCHAR INJECTION SYSTEM**

## **MEAN CLEAN WATER MACHINE**

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# ACKNOWLEDGEMENTS

- **Sponsor:** Gregory Möller Ph.D.
- **Clients:** Martin C. Baker  
Gregory Möller Ph.D.
- **Lead Instructor:** Dev Shrestha Ph.D.
- **Graduate Mentor:** Jacob Miller
- **Additional Counsel:** Daniel Strawn, Ph.D.  
Rodney Cook
- **Team Support:** Allie



# VALUE PROPOSITION

## CURRENT OPERATION/ PURPOSE:

- ❑ Continuous Up-flow Sand Filtration System which addresses water security and nutrient pollution.
- ❑ Addition of biochar (created by burning wood products and other organic materials at anoxic conditions) results in carbon negative process.
- ❑ Biochar removes contaminants from the wastewater, including phosphorous.
- ❑ Biochar is used to fertilize soil and retain moisture.
- ❑ Currently requires manual biochar dosing.



# VALUE PROPOSITION

## AUTOMATED INJECTION PROPOSITION:

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- ❑ Create automatic dosage system for biochar.
- ❑ Allow for further innovations and create options for future experiments.
- ❑ Integrate cohesively with existing Clean Water Machine in an accurate, controlled, and recorded manner.
- ❑ Address settling, clogging, and mixing issues regarding biochar.



# SPECIFICATIONS

## FUNCTIONAL:

- ❑ Dose wet or dry biochar with 15% accuracy (within 1.5 mg; no under-dosing).
- ❑ Operate quieter than 60 dB at maximum capacity.
- ❑ Detect and account for variability in temperature, moisture content, and consistency.
- ❑ Maintain biochar at constant conditions (temperature, moisture content, and texture).
- ❑ Maintain ease of mobility as well as modular construction for maintenance.

# SPECIFICATIONS

## MECHANICAL:

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- ❑ Pipe will withstand flow rate and pressure of 15 gal/min and 25 psi respectively.
- ❑ Must fit within a 8 ft tall x 2 <sup>3</sup>/<sub>4</sub> ft wide (normal to handrail) x 2 <sup>1</sup>/<sub>6</sub> ft long (parallel to handrail) area, while maintaining full accessibility.
- ❑ Total system will not exceed 300 lbs with empty hopper.
- ❑ Clear materials used where possible with engraved labels and touch screen display.
- ❑ Stainless Steel required where corrosive elements contact.
- ❑ Operate for 8760 hours without scheduled maintenance; only 5-minute checks daily.
- ❑ Biochar supply in hopper must last 3 days minimum without refilling.

# SPECIFICATIONS

## ELECTRICAL:

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- On the Machine
  - 110 or 208V
  - 4-20mA signal
- On the PLC
  - 100-240 VAC external power
  - 12-24 VDC external power/ 24 VAC external power
  - USB, ethernet, RS-232, RS-485 communication standards



# SPECIFICATIONS

## ENVIRONMENTAL:

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- Consistently operate in conditions ranging from 20 to 100% humidity.
- Maintain function throughout temperatures ranging between at least 36 and 110 °F (preferably 32 to 80 °F or 0 to 27.67 °C).
- Must withstand corrosion (constant contact with water, ferric chloride, and ozone).
- Must withstand freezing conditions and keep water from solidifying (include a drain-plug at key points of system).



# PROOF OF CONCEPT

## VENTURI CALCULATIONS

Flow Rate Into Tank:		
Q <sub>in</sub> :	1	gal/min
V <sub>in</sub> (1/4in):	6.536	ft/s
V <sub>in</sub> (3/4in):	0.726	ft/s
Flow Rate Out of Tank:		
V <sub>out</sub> (1/4in):	20.765	ft/s
V <sub>out</sub> (3/4in):	19.723	ft/s
Q <sub>out</sub> (1/4 in):	3.177	gal/min
Q <sub>out</sub> (1/4 in):	3.018	gal/min

Injector Performance Table													 <small>REV 2014</small>	
Water Suction Capacity														
Operating Pressure PSIG		Model 584 ½" & ¾" Threads		Model 684 ¾" Threads		Model 878-03 1" Threads		Model 885X-03 1" Threads		Model 1078-03 1" Threads		Model 1583 1½" Threads		
Injector INLET	Injector OUTLET	Motive Flow GPM	Water Suction GPH	Motive Flow GPM	Water Suction GPH	Motive Flow GPM	Water Suction GPH	Motive Flow GPM	Water Suction GPH	Motive Flow GPM	Water Suction GPH	Motive Flow GPM	Water Suction GPH	
15	0	3.6	28.1	6.1	26.1	6.3	87.3	6.2	135	9.5	101	18.6	225	
	5		27.9		26.1		62.1		83.1		79.9		163	
	7		28.0		25.0		45.4		58.0		64.6		124	
	10		13.9		12.8		23.6		19.1		34.2		86.5	
	12		*(13.5)		11.0		*(13.0)		7.0		*(12.5)		7.2	*(11.0)

Injector Inlet: 15 psi

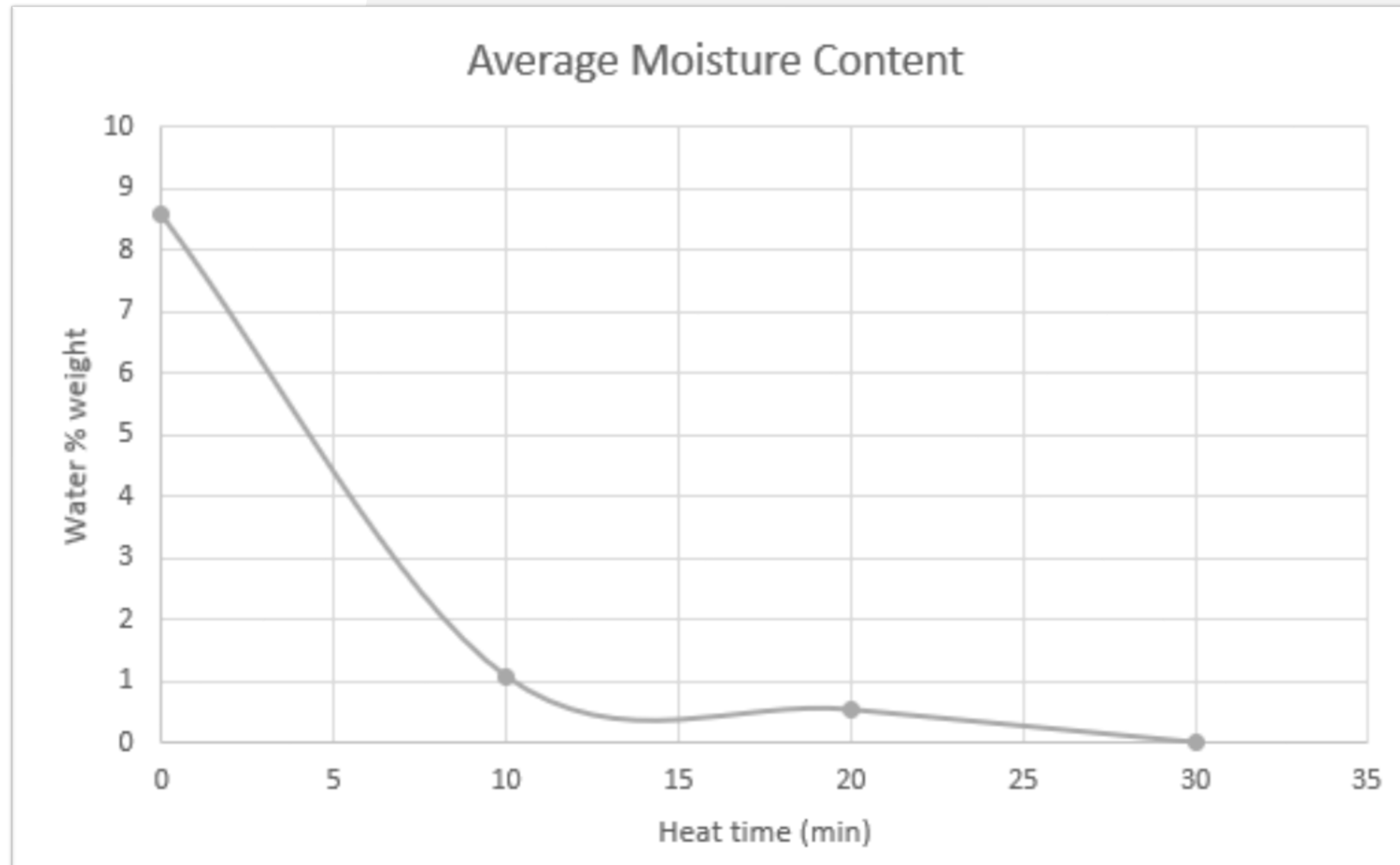
Injector Outlet: 12 psi

Motive Flow: 6 gal/min minimum

Water Suction: 60 gal/hr (1 gal/min) minimum

# PROOF OF CONCEPT

## BIOCHAR MOISTURE CONTENT:



$$Q = mC_{p \text{ BC}} \Delta T$$

$$C_{p \text{ biochar}} = 1.4 \text{ kJ/kg-K}$$

# PROOF OF CONCEPT

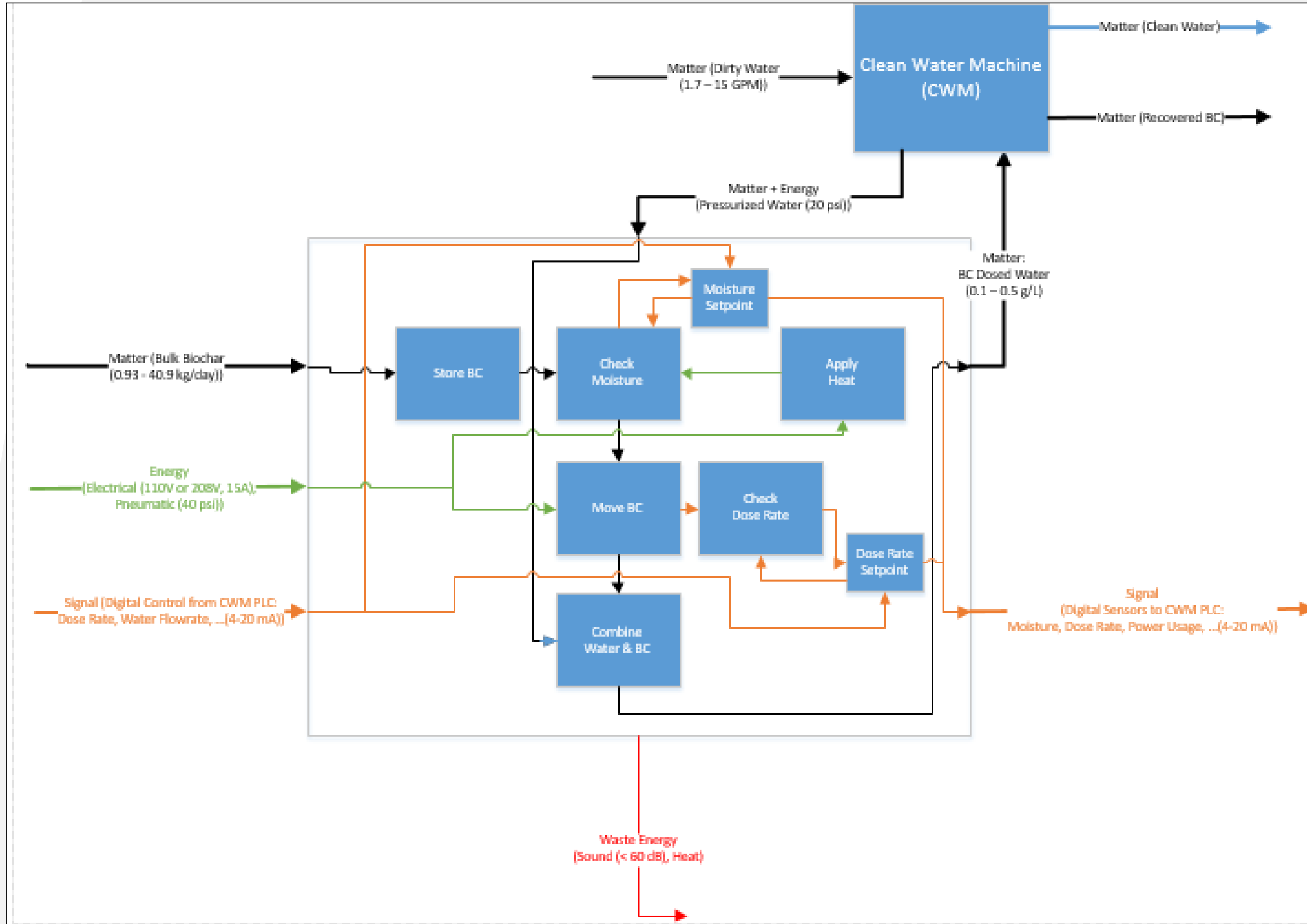
## FLUIDIZED BED:

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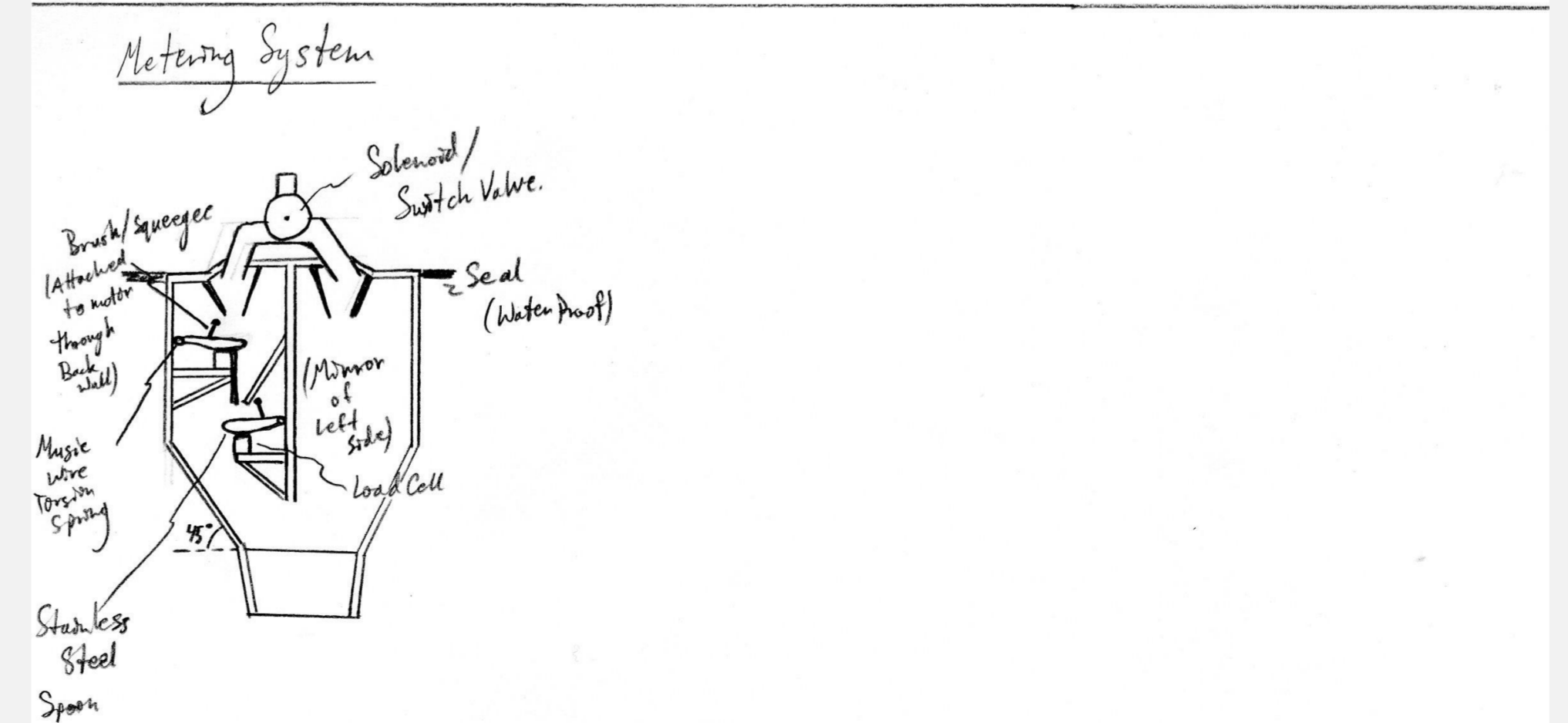
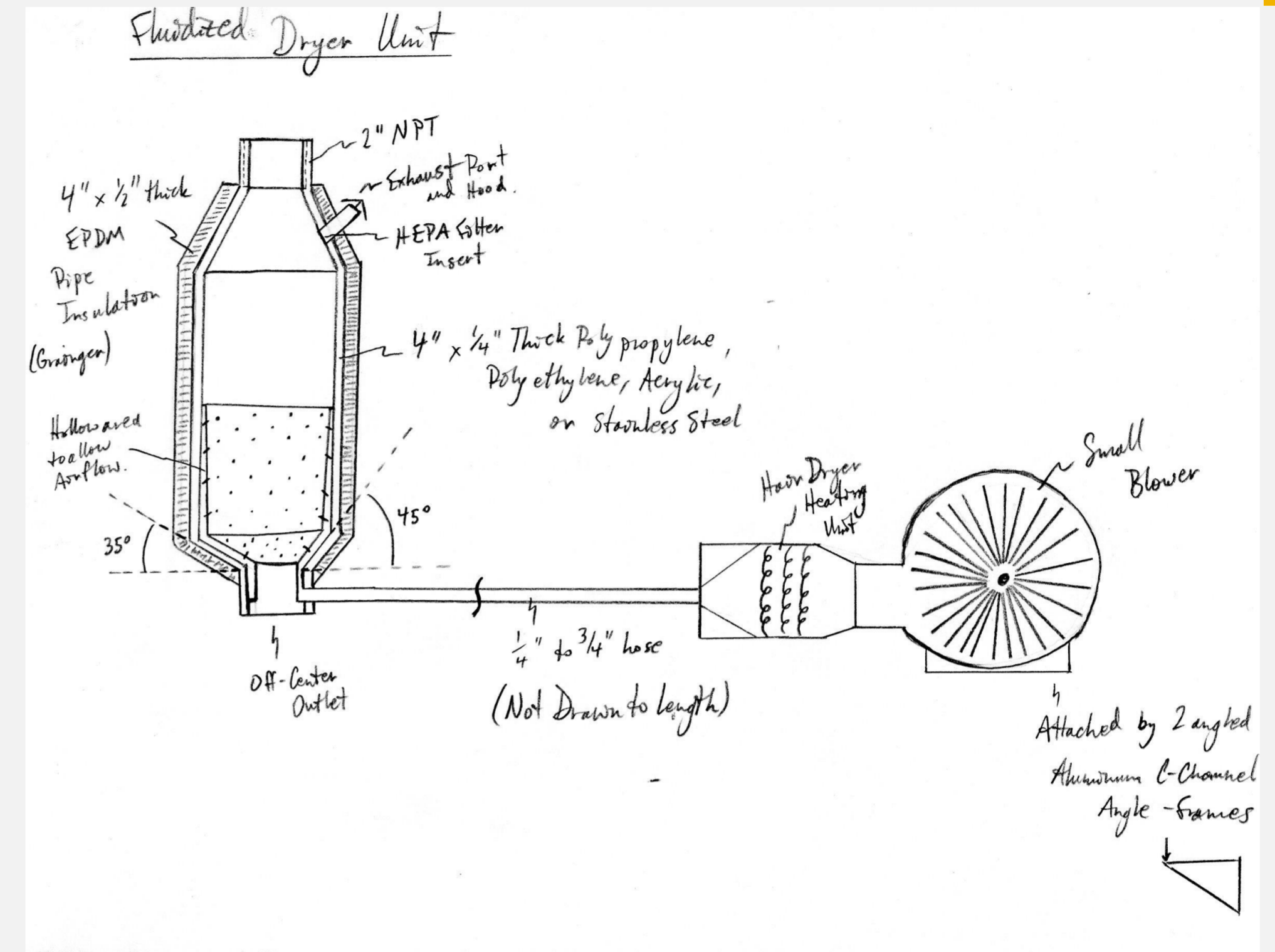
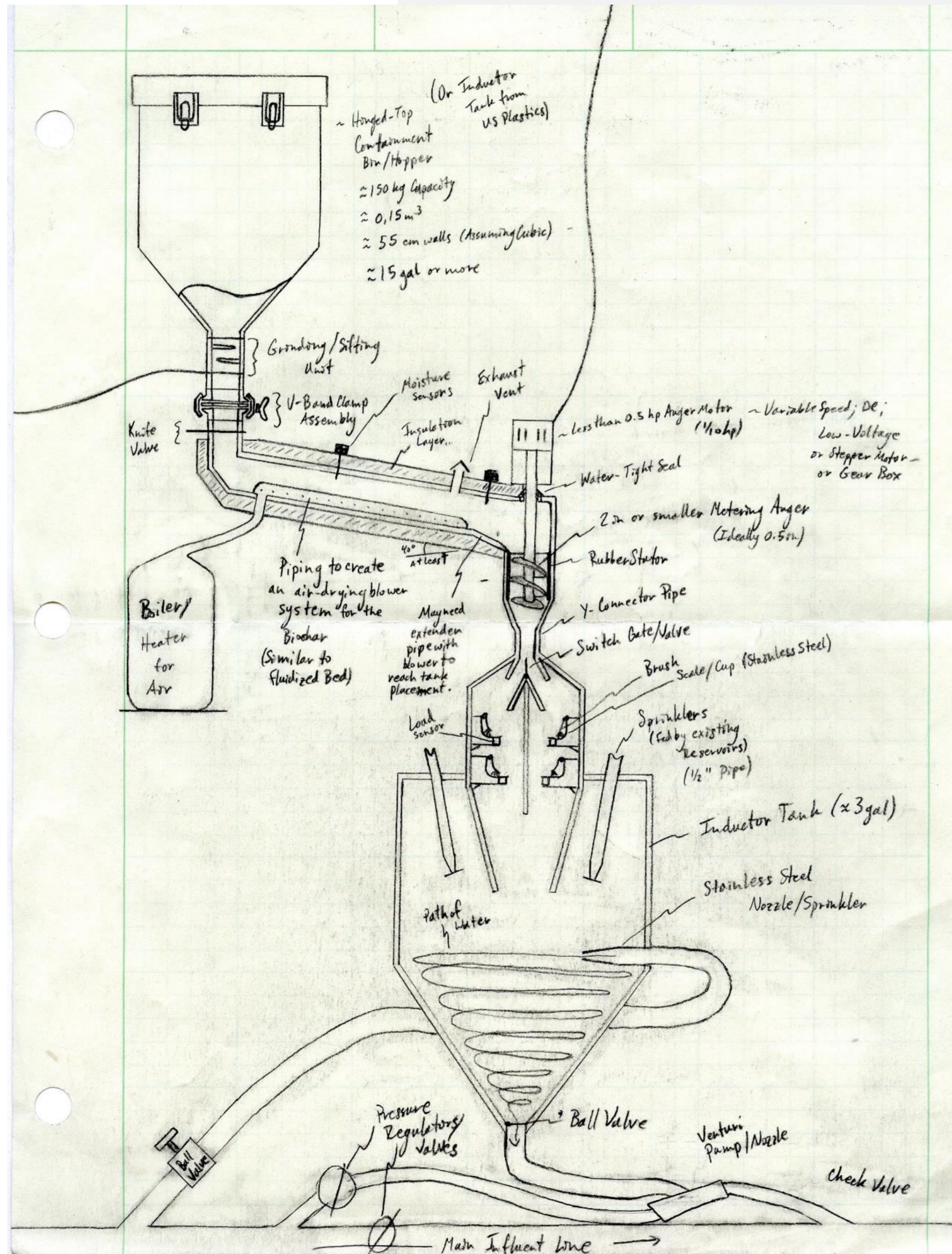
- Addition of heated air to reduce moisture
- Air flow removes clumps



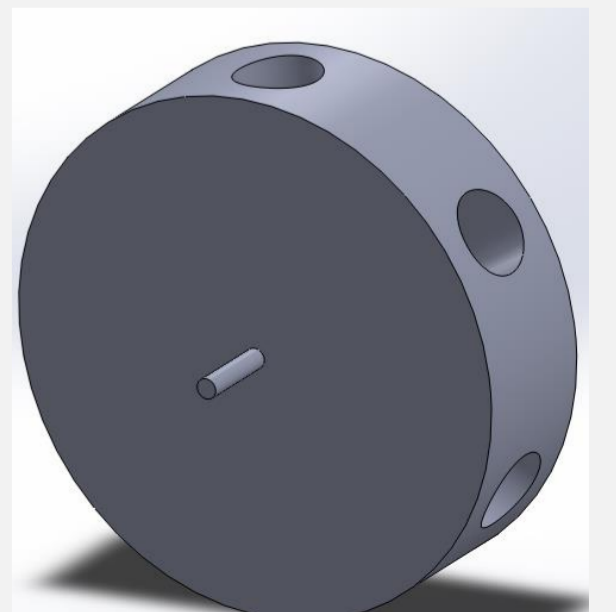
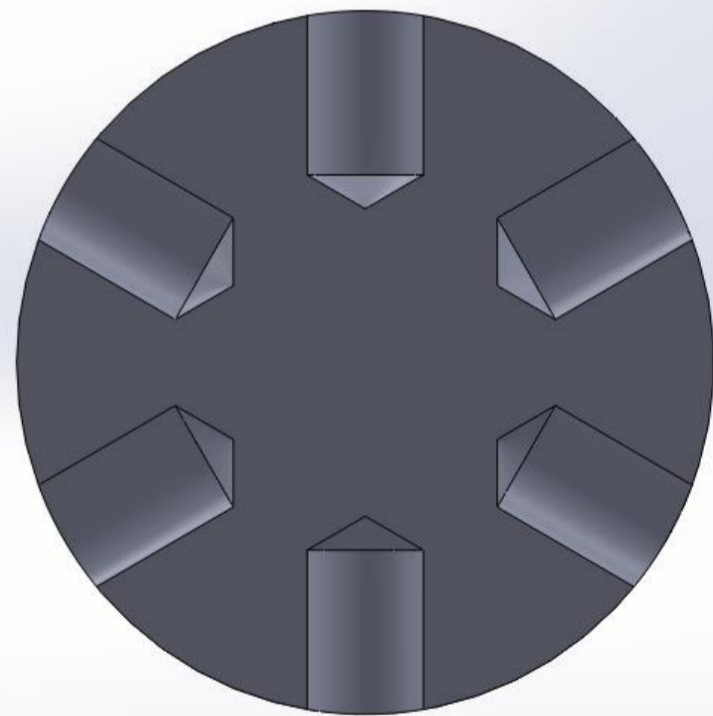
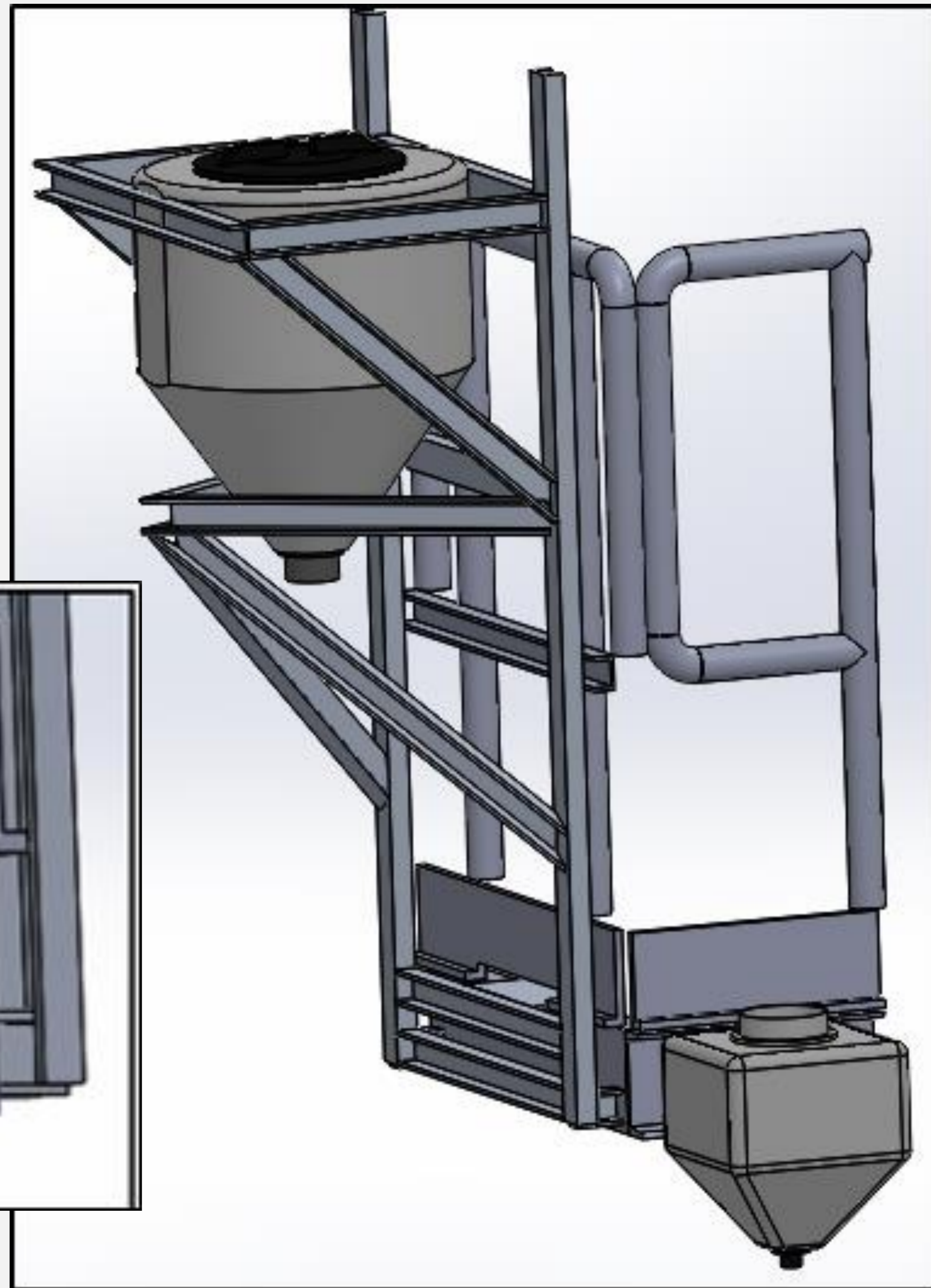
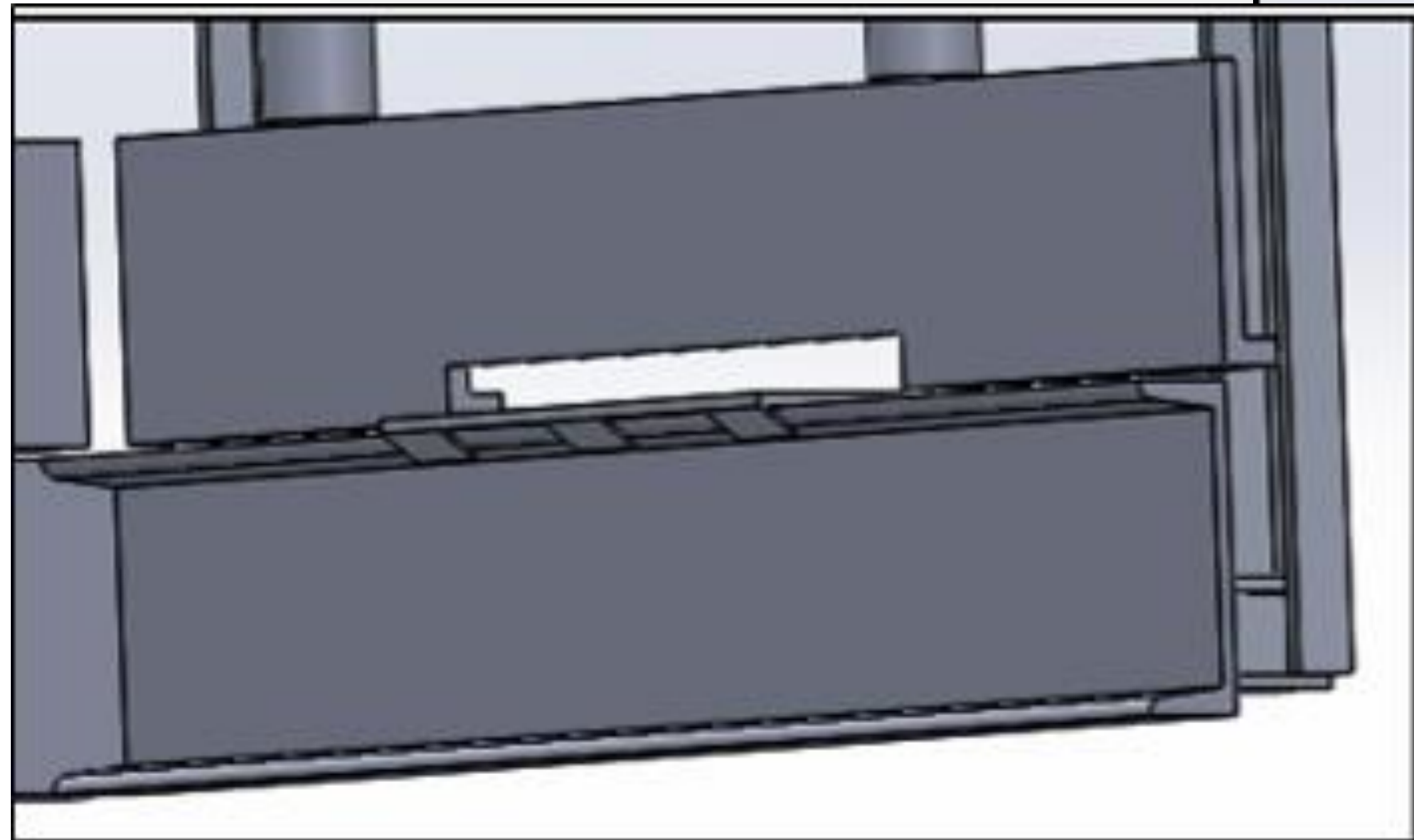
# SYSTEM FLOW DIAGRAM



# SYSTEM DRAWING



# FINAL DESIGN



# DESIGN VALIDATION



Requirement	Test	Test subject	Target Date	Result	recommendation
Operating at less than 60dB at full capacity	Use a sound sensor to record a full cycle of the system, and verify signal remains below maximum sound level	Functional prototype	3/5/2019	N/A	N/A
15% accuracy dosing	Have BC dump into separate receptical and weigh on a scale to verify accuracy of dosage dispenser	Functional prototype	3/5/2019	N/A	N/A
Must account for variability in BC moisture content	Use a high-accuracy moisture sensor to detect moisture of several batches of BC after processing through system, and compare discrepancies	Functional prototype	3/5/2019	N/A	N/A
Must account for variability in BC consistency and texture	Manually, visually inspect BC for clumping and inconsistencies in texture; should be no particles larger than 0.25 inches	Functional prototype	3/5/2019	N/A	N/A
Must account for variability in BC dose-rate	Run system through 5 different dose rates, have BC dump into separate receptical, and weigh on a scale to verify accuracy of dosage dispenser	Functional prototype	3/5/2019	N/A	N/A
Must account for variability in BC temperature	Use a high-accuracy temperature sensor to detect temperature of several batches of BC after processing through system, and compare discrepancies	Functional prototype	3/5/2019	N/A	N/A
Dosage must withstand pressure of 20 psig	Use pressure gauge on output pipe to verify it expels BC mixture at desired pressure	Functional prototype	3/5/2019	N/A	N/A
Touch-screen must last 24-hours without recharging	Unplug touchscreen and wait 24-hours; intermittently activate screen (once every 8 hours) to simulate use; after total time period, activate screen and verify use	Functional prototype	3/5/2019	N/A	N/A
Must operate within conditions ranging from 20-90% Humidity	Design tests in sealed containers or rooms where humidity level can be adjusted and run system to verify function	Functional prototype	3/5/2019	N/A	N/A
Refill no more than once every 3-days	Run system for 72 hours straight with maximum dose-rate and verify that the BC supply will last	Functional prototype	3/5/2019	N/A	N/A





# PROJECT PROGRESS

## BUDGET:

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Supplies	Cost	Total
Automation Direct I/O	\$557	
Arduino	\$78	
15 Gallon Inductor Tank	\$150	
High Torque Motor	\$40	
4 Gallon Rinse Tank	\$104	
Moisture Sensors	\$80	
Venturi Nozzle	\$70	
University Overhead	\$54	
		\$1078

# RISK MANAGEMENT

## Coal dust explosion

Solution:

- Heating element under 80 C
- Exhaust and filter
- Pressure release vent

## Biochar handling

Solution:

- Safety protocol
- Suggestions for future development



# THANK YOU, ANY QUESTIONS?

