Takachar Hot Test (In-Depth) Documentation

This is the 1st point of hot test documentation listed below. An overview of all test data, parameters, and takeaways can be found at point 4.

1. Written documentation here 2. Timeline spreadsheet/Safety Check in Dropbox
3. Raw data in Dropbox 4. Data overview in *this* sheet

Hot Test #1 - 6/1/21

- It was a bit challenging to get the fire started at first. It took ~50 min to finally get the biomass to catch on fire using motor oil, paper and cardboard.
    - It was difficult for the biomass to catch on fire
    - It was also difficult to control the hopper air input because of the strong winds.
- Once the biomass began to catch on fire, we started the auger motor.
    - -Codesys Input: 4 RPM (which translates to about 0.4 RPM)
    - Throughout the hot test, we heard minimal grinding compared to previous tests we did where we just ran the auger without any biomass.

        - The reduced grinding could possibly be due to the heat of the reaction.
        - It could also possibly be due to the charred biomass filling in the gaps of the reactor.
    - The average motor current was about 5 Amps, with a peak around 9 Amps (previous peaks were around 13 Amps)
- Before the thermocouples reached steady state, there was smoke coming out of the hopper, the chimney and the char box opening (the char box itself was filled with smoke)
    - To combat the smoke in the beginning, we kept the profire ignitor on as well as the secondary and primary blowers (~3500 RPM)
- Both primary and secondary blowers were kept around 3000-5000 RPM throughout the hot test
- There was smoke coming out of the hopper consistently throughout the hot test.
    - We kept the lid to the hopper on at all times except to load in more biomass.
    - To solve this issue, we are going to move the primary blowers up in the reactor so that they are located in the section beneath the chimney.
- Around 11:30 the propane igniter stopped working. The profire box was displaying a message that said 'No flame detected' and it was not responding to the start/stop command on Codesys
    - The ignitor may have stopped working due to the heat of the reactor, which could have made it difficult to detect a flame.
    - After the hot test and the cool-down period, the ignitor worked fine and was responsive to my Codesys commands.
    - Even without the propane ignitor, the exhaust coming from the chimney remained clear and not smoky.
- The thermocouple temperatures reached a steady state around 12 pm, which was about an hour after the initial fire was started.
- From 12 pm to 1 pm, the scale reading increased from 3.1 kg to 4.85 kg (an increase of 1.75 kg)
    - We were loading in 7 lbs of biomass about every 10 min (~40 lbs/hr or ~20 kg/hr)
        - When loading in biomass, we noticed that when the hopper was full, the smoke coming out of the hopper was minimal. This could be because the biomass blocks the air coming in from the hopper when it is full.
    - Yield was about 8.75%
- Around 12 pm, charred embers began spilling out of the space where the reactor connects to the char box
    - To resolve this issue, we poured water on the hot embers and sealed the opening with aluminum tape
    - Outside of this issue, the charbox itself seemed to work fine. There was minimal spillage outside of the oil drum.




- It is important to be vigilant about places where wires and tape could potentially melt

Hot Test #2 - 6/2/21

- Primary blowers were moved one notch higher in the reactor
- It took much less time today to ignite the biomass (~5 min)
    - The team used paper soaked in motor oil and burrowed in the biomass in the auger
    - We also opened the air holes towards the bottom of the reactor so that air could flow in
- Once the biomass caught fire, we closed the air holes and began moving the auger at an input of 4 RPM (which translates to about 0.2 RPM)
- Not long after starting the auger, we tried to light the propane ignitor however, that caused the laptop to disconnect from the IFM and the ignitor's flame shut off after about 45 sec
    - After speaking with Carlos from Profire, we think the flame detector on the ignitor may be damaged from the heat of the reactor and so we are most likely going to have someone from Profire come out to the test site and help troubleshoot this issue
- After the propane igniter stopped working, we turned on the primary air to 2500 RPM, which is the speed they stayed at until the end of the test
- About 20 min after we started the flame, the smoke coming out of the chimney stopped and turned to clear exhaust
- About 30 min after we started the test, we noticed that there were hot particles coming out of the chimney and so we turned the secondary air to 3500 RPM
    - After a while, there seemed to be much fewer particles coming out
- Overall, there seemed to be less smoke coming from the chimney, hopper, and char box than in the previous test
- At one point during the test, the chimney seemed to be leaning to one side, causing a slight gap between the chimney and the reactor
- There was still a strong flame towards the bottom of the reactor near the hopper
    - There were also flames coming out near the bottom bearing because we forgot to cover some of the holes
- Throughout the test, we added about 7 lbs of biomass into the hopper every 10 min
    - From 2-3pm, we input about 42 lbs of biomass and we got 7 lbs of output (~17% mass yield)

- Reduced smoke, but noticeable particulates

- Some smoke escaping from char box initially

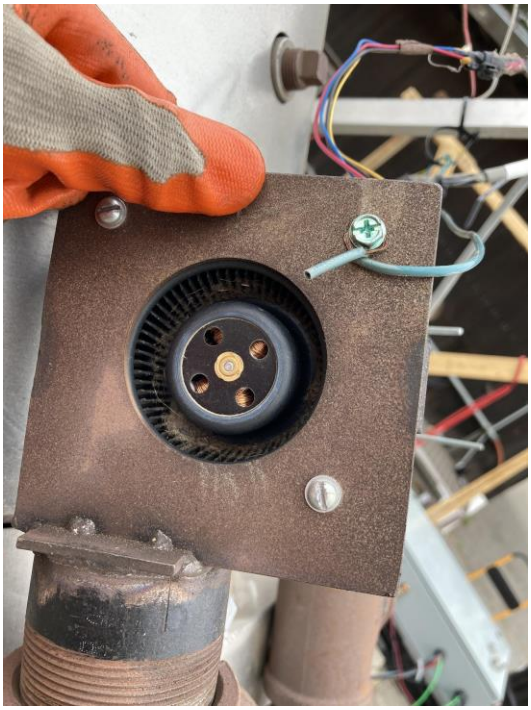
- Minimal smoke from hopper

- Chimney came unseated

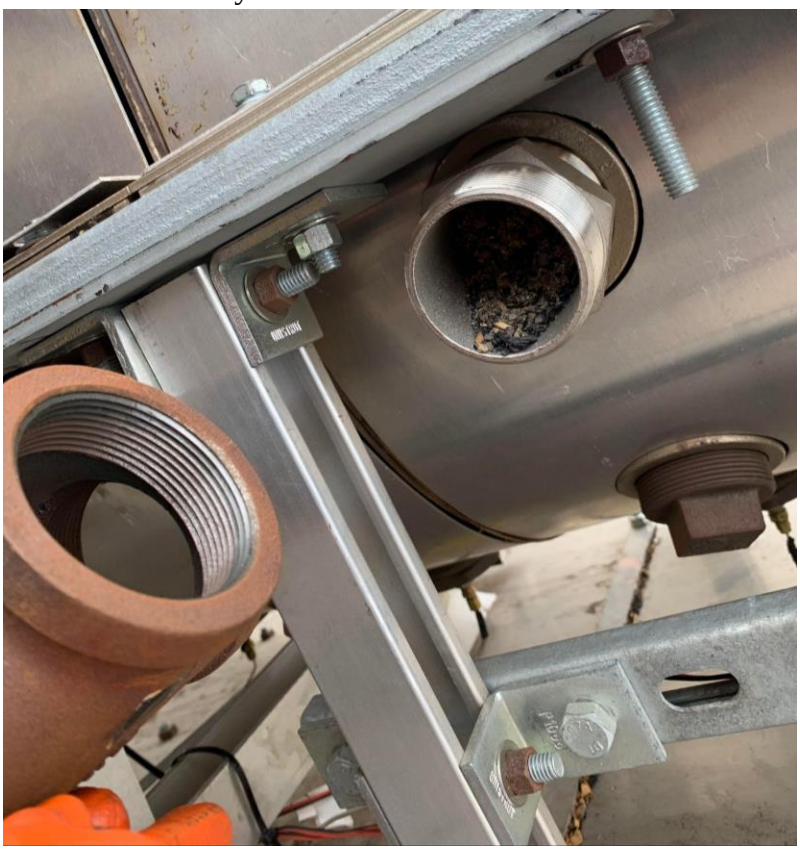
- Final product

Next Day After Hot Test #2:

- Deforming metals due to thermal expansion - dissimilar metals and unequal expansion coefficients



- Debris build up at blower inlets. Better practice to face blower inlets downward to avoid debris entry



- Blower inlet seemed to be partially blocked by char/biomass

Hot Test #3 - 6/3/21

- The motor was run with an input of 8 RPM (which translates to about 0.6 RPM)
- The flare ignitor was not used at all during this test
- It took ~5 min to light the biomass on fire in the hopper
    - We used lighter fluid and paper to start the fire. We also opened the bottom air holes.
- We initially started moving the motor at 8 RPM (0.6 RPM)
    - There was smoke coming out of the chimney when we first started the motor however, we turned up both the primary and secondary blowers to get rid of the smoke
- About ½ an hour after the test started, the motor stopped working because the auger got stuck. We believe the auger got stuck because the increased speed of the motor caused the biomass fire to go out.
    - To resolve this issue, we opened up some of the 2” holes in the middle of the reactor to disperse some of the biomass. We also used lighter fluid to ignite a flame through the holes in the middle of the reactor. After we started the fire in the middle of the reactor, we reversed the auger, then moved it forward at a slower RPM of 4 (0.2 RPM).
- After about 20 min of running the motor at 4 RPM (0.2 RPM), we increased the speed of the auger to 8 RPM (0.6 RPM) as well as the primary and secondary blowers
    - Primary blowers were set to 5000 RPM and secondary blowers were set to 6000 RPM
- Throughout the test, there were embers flying out from the top of the chimney. To resolve this issue, we reduced the speed of the secondary blowers to 5000. In the future, we will try to put a wire mesh over the chimney.
    - These embers are a safety hazard for both the environment around the reactor as well as those working close to the reactor.
- At one point during the test, we also saw flames coming out of the top of the chimney and so we increased the secondary blowers to 6500 and reduced the primary blowers to 3000.
- During the test, there was also significant smoke coming out of the char box.
    - We think the smoke in the char box may have affected the connectivity of the webcam we have installed in there.
    - This issue of smoke from the char box could potentially be resolved if we moved the chimney up in the reactor and if we redesigned the char box to be more air-tight.

- We noticed that there was almost no smoke coming out of the hopper and the flame location seemed to move up in the reactor (away from the hopper).
    - The chimney was radiating significantly stronger heat than in previous tests and we think this may be because we added insulation to the bottom of the chimney.
- At one point during the test, we needed to open up the char box to replace the oil drum.
    - The process took about 15 min, but there was a lot of smoke and we weren't sure if the char was on fire or not.
- The feed rate was about 7 lbs every 3 min
    - From 1:40-2:40 pm, we inputted 147 lbs of biomass and the scale weight increased by 35.5 lbs.
    - This gives us a mass yield of about 24%

- Smoke emissions during ramp up

- Significant smoke and fumes of melting plastic from char box

- Red hot embers emitting from chimney. Flames also visible at times beneath calling.

- Visible flames in chimney

- Unknown liquid dripping from char box. Cold to the touch (accidentally dripped on Ryan)

- Improved insulation at chimney

- Embers from reactor melting clothing and burning skin - safety hazard!

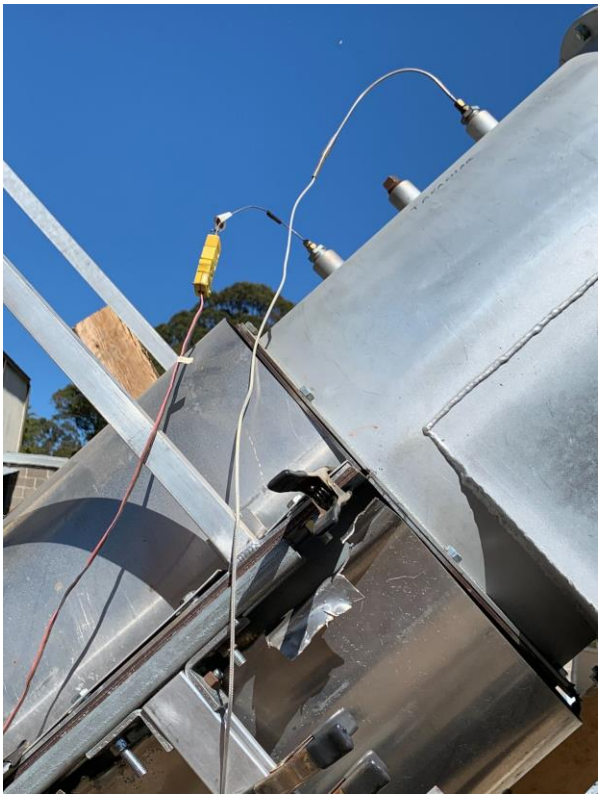
- Removed secondary blowers before leaving to avoid heat damage

Hot Test #4 - 6/10/21

- The goal of this test was to run the motor at 8 rpm with mesh installed at the top of the chimney and a new cooling mechanism installed
- To begin this test, we started the motor at a lower RPM (6 RPM input = 0.4 RPM) and ignited the fire in the side holes of the reactor directly below the chimney. It took about 5 min to start the fire.
- As the fire was starting, we noticed smoke coming out from the chimney and so we increased the RPM of the secondary blowers to 3000, which seemed to cause a decrease in chimney smoke.
- Once the fire started, we increased the primary blowers to 3000 RPM.
- About 20 min after the test started, we increased the primary blowers to 4000 RPM to help the fire continue.
- Around this time, we noticed more smoke coming out of the chimney and so we turned the secondary to 4500 RPM
- During this test, there were still embers coming out of the chimney even though it was covered with wire mesh. We may need to add another layer of mesh to decrease the size of the holes for the embers to come out of.
- At this point, we also lowered the primary blowers back down to 3000 RPM because the fire was getting quite large.
    - Since the fire was so large, we noticed that the bottom of the chimney was quite hot. To reduce this radiating heat, we could add more insulation to the chimney.
- During this test, there was minimal to no smoke coming out of the hopper. We also did not keep the hopper lid on during this test.
    - This could explain why the end product seemed to be more charred than in previous tests.
- About an hour after starting the test, we increased the motor speed to 0.6 RPM and gradually increased the blower RPMs (primary to 3000 and secondary to 6000 - same conditions as the previous test)
    - Our input rate was about 7 lbs every 6 min, which is slower than our previous 0.6 RPM test.
- At this point during the test, we noticed that there was some smoke coming from between the last two pieces of the reactor as well as the oil drum.
    - To minimize the smoke, we sealed the gaps in the tubing and oil drum with caulk.
- After 1 hour and 30 min, we decided to switch out the oil drum.
    - When we removed the lid from the oil drum, there was some smoke but not a lot.
    - The smoke coming out of the reactor was slightly black, which could indicate that the biomass was being burned too much.
    - In addition, the product cooled very quickly and was safe to touch with bare hands about 10 mins after being disconnect from the reactor.

        - The product from this test also looks slightly more charred than previous products.
- About 2 hours after starting the test, we reached steady-state and continued for about ½ an hour after that.
    - 10:40-11:30 - 77 lbs inputted into the reactor ad 17.3 lbs out
    - ~22.5% mass yield

- Smoke from the chimney



- Location on a reactor where smoke was leaking from

- Smoke coming out of small gaps of cooling mechanism

- Final product

Hot Test #5 - 6/14/21

- The goal of this test was to run the motor at 8 rpm with double mesh installed on the top of the chimney
- Before starting the test, we replaced the insulation surrounding the bottom part of the chimney.
- We started the motor off at a lower speed (6RPM) in order to prime the reactor and catch the biomass on fire.
    - We used the same method of squirting lighter fluid into the side holes of the reactor directly below the chimney.
    - There was some smoke coming out of the chimney during the process of lighting the biomass however, the amount of smoke decreased after increasing the secondary blowers.
- For this test, we used Adam's new data logging code, which worked well except we could not view the temperature data while the code was running.
- About ½ an hour after starting the test, we increased the motor speed to 8 RPM (which is actually 0.6 RPM

- We kept the primary blowers at 2000 RPM until the end of the test and the secondary blowers were at 3500 RPM until the shutdown.
- For the majority of the test, the emissions from the chimney were clear and we did not encounter any embers, which leads us to conclude that the new mesh did its job.
- For this test, we also made sure to cover the hopper inlet when we were not loading biomass and we did not observe any smoke coming out of the inlet.
    - We also did not observe any smoke leaking out of the reactor or oil drum tubing.
- During this test, the chimney became very hot and started turning green in color.
- About an hour after starting the test, we noticed black smoke coming out of the chimney, and shortly after that, we saw flames coming out of the bottom of the chimney.
    - Upon seeing the flames, we turned off the motor and doused the flame with water as well as a fire extinguisher. This killed the flame.
    - We suspect that the fire may have been seeping through holes between the chimney and the adapter, which we think may have been caused by corrosion and stress.
- After letting the reactor sit for a while, we removed the initial oil drum and replaced it with another one while also turning on the motor in order to empty out the reactor.
    - There was some smoke that came out of the oil drum when we switched it out however, the oil drum itself was cool enough for us to touch with our bare hands. We think this may be indicative of a “dead zone” near the top of the reactor where the biomass is able to cool significantly before being deposited in the oil drum.

- Chimney changing colors

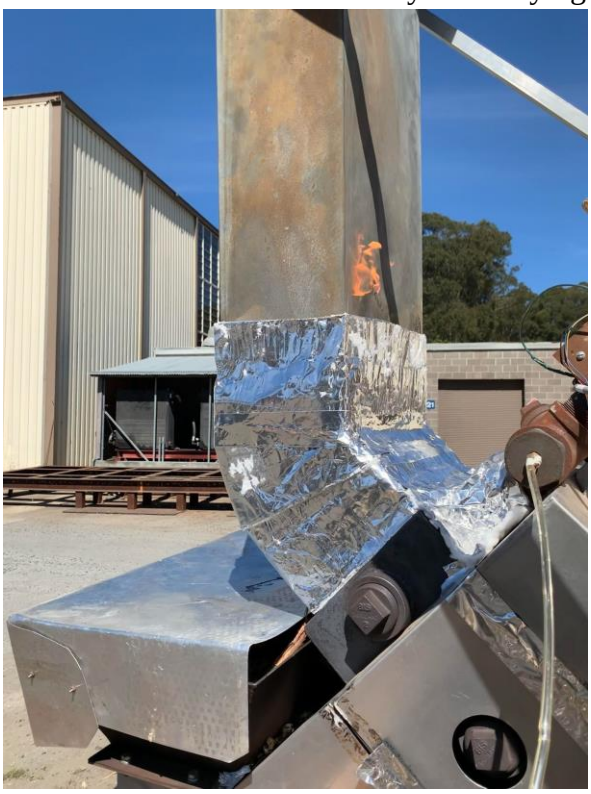
- Black smoke from chimney

- Chimney base after shut down (we think most of this damage is due to corrosion and stress)

Hot Test #6 - 6/16/21

- For this test, we had a new chimney base installed, as well as new chimney insulation at the bottom of the chimney.
    - The new insulation was thinner than the insulation used in previous tests
- We set the motor RPM to 6 RPM as we tried to start the fire from the side holes directly beneath the chimney. After the flame started, we noticed that it seemed to move upwards in the reactor and was no longer located directly below the chimney.
    - As the fire was getting started, we noticed some smoke coming out of the top of the chimney.
- About 20 min after starting the fire in the reactor, the motor got stuck and so we stopped the motor, reignited the fire under the chimney, removed some biomass from the hopper, and then moved the auger forwards and backward until it became unstuck.
    - We think the auger may have gotten stuck because the flame was located higher up in the reactor than usual.
- Once the auger was moving again, we turned the speed back to 6RPM.
- About 20 min after getting the motor going again, we noticed flames coming out of the bottom of the chimney and black smoke coming from the top of the chimney and so we increased the secondary blowers, which caused the flames to increase. Once we lowered the speed of the secondary blowers, the flames seemed to die down a bit.
    - Right before we saw the flames, we had covered the hopper with its lid and once we opened it up, we saw that all the biomass inside the feeder was on fire.
    - The chimney was also extremely hot and was turning green like in the last hot test.
    - We believe that these flames may be due to the mesh on top of the chimney preventing good airflow through the chimney duct, which forces gases to find other spaces to escape from.
    - These flames could have also been caused by the transfer of heat from the chimney (which was less insulated than in previous tests) to the hopper lid, which then caused the biomass inside to catch on fire.
- After the flames died down, we uncovered the hopper as well as the oil drum and noticed that smoke was coming out of both ends of the reactor.
    - On the hopper end, there was smoke coming out of the hopper as well as the section directly below it.
- About an hour after starting the test, we concluded the test and let the auger continue to turn with the blowers at a low RPM until the auger was empty.

- Smoke from the chimney while trying to start the fire



- Flame at bottom of the chimney

- Flame near hopper

- Chimney discoloration

- Fire in hopper

Hot Test #7 - 6/21/21

- The goal of this hot test was to see what happens when the mesh in the chimney is positioned lower in the rectangular duct.
- For this hot test, we started the auger at 4 RPM and loaded in wood chips. Once there were significant wood chips, we attempted to start the fire from the side holes that are between the chimney and the hopper.
    - These side holes are lower in the reactor than the holes we normally light the fire from. The ones we normally use were too difficult to uncover.
- About 15 min after starting the hot test, we noticed significant white smoke coming out of the hopper and so we stopped the auger and poured water into the hopper to try to cool down the wood chips.
    - We are not exactly sure what caused this smoke. It could be due to the fact that we started the fire from a lower position than where we normally start it. It could also be due to the fact that we lowered the mesh in the chimney stack.

    - When we turned the auger motor back on, we turned down the blower speed and noticed dark smoke coming out of the top of the chimney.
- After about 30 min of waiting for the smoke coming out of the hopper to decrease, the fire seemed to die down and so we attempted to light the fire again through the hole where the right primary blower was located.
    - As we were reigniting the fire, there was smoke coming out of the top and bottom of the chimney.
    - During this time, we also noticed smoke leaking through some of the cracks in the output chute as well as the hopper and some openings between different parts of the reactor.
- About 45 min after the fire reignited, the wood chips in the hopper seemed to get stuck at the bottom and they were not moving upwards.
    - After we ended the test, we realized that during this time the auger was moving backwards.
- Around this time, we disconnected the laptop from the PLC, which caused the blowers to ramp up to max RPM. The increase in blower speed led to an intense fire in the hopper, which burned a hole through the hopper lid.
    - At this point, we shut off the breaker for the blowers, which caused the secondary blowers to melt and malfunction.
    - We then disconnected all the blowers and plugged their holes.
    - We also realized that the auger had been moving backwards and so the auger was bent out of place.
- After this, we stopped the hot test.

- Smoke from hopper


- Hole in hopper lid

- Charred biomass in hopper


- Smoke from side of reactor

- Dark smoke from chimney

- Burned out blowers

- Bent auger

- Mesh from inside chimney

Hot Test #8 - 6/22/21

- For today's hot test, we removed the mesh from the chimney duct to see if it had any effect on the hopper catching on fire.
    - We also had to replace the secondary blowers and move them to the side ports, facing the same way as the primary blowers.
    - We also had a new hopper lid that was designed to be similar to our previous one.
- We started the fire from the hole for the right primary blower, directly below the chimney. Once the fire was started, we turned the motor speed to 6RPM.

    - There was noticeable smoke coming out of the top of the chimney when we first started the test.
- About ½ an hour after the test started, we noticed some embers coming out of the top of the chimney but they did not burn anyone and quickly disappeared.
- Around this time, we noticed that the reactor and chimney were very hot and so we turned down the primary and secondary blowers to 2000 and then to 1300.
    - The chimney was extremely hot and began changing colors.
    - We think we may be able to better control the heat if we insulate more of the chimney.
    - We also noticed a little bit of smoke coming from the bottom of the chimney.
- During this time, we also felt the oil drum and it was cool to the touch.
- Before ending the test, we ramped up the motor speed to 10 RPM and the reactor ran fine with no issues.
    - There was a little black smoke coming out of the chimney however, it went away when we turned up the secondary blowers to 3000 RPM.
- The hopper never caught on fire during this time, which leads us to believe that the mesh we were using before was blocking the airflow in the chimney and causing the hopper to catch on fire.
- While waiting for the reactor to cool, there was significant smoke coming out of the top of the chimney; however, it seemed to disappear when we turned the secondary blowers up to 4000 RPM.
    - When we opened up the oil drum, there was a little bit of smoke but then it disappeared.

- New hopper lid

- Chimney changing color

- Final product - mix of charred and not as charred wood chips

Hot Test #9 - 6/23/21

- For this hot test, we put the mesh back into the chimney configuration and attempted to light the biomass on fire from the holes above the primary blower holes. We also used our new hopper lid, which is thicker than our previous one and is made of galvanized steel. We also had the secondary blowers in the left and right side of the reactor, rather than being parallel with the reactor.

    - It took us a little longer to start the fire from the holes that were higher in the reactor and so we tried lighting the fire from the right primary blower hole in addition to the higher holes. We also increased the RPM of the secondary blowers, which seemed to help get the fire going.
- Once the fire was started, we saw minimal smoke from the chimney but there was some leaking out the bottom and top. We also saw some smoke leaking out from the chute.
- During this test, we noticed that the chimney was very hot and started changing colors.
    - At this time, there was some smoke coming from the hopper while we were loading in biomass but not a significant amount.
    - We also noticed some flames leaking through the cracks in the bottom of the chimney and so we turned down the blowers.
- Throughout the test, we noticed a flame at the base of the hopper ; however, it never caught the entire hopper on fire and we never saw significant smoke from the hopper.
    - Because we couldn't recreate the same results from Monday's test, it is difficult to definitively say that the mesh caused the fire in the hopper.
- We stopped the test about 2 hours after starting.

- Small fire at base of hopper

- Final product

Hot Test #10 - 6/24/21

- For this test, the mesh is still installed at the bottom of the chimney and all the blowers are in the same place as our previous test. The goal of this test is to gradually increase the speed of the blowers and observe if/when the hopper catches on fire.
    - We ran the motor speed at 6 RPM for the entirety of the test.
    - We also started the fire from the same right primary blower hole as we did yesterday.
- To get the fire going, we started the primary blowers at 2500 RPM and then lowered them down to 1300 RPM once the fire was going.
    - We noticed some smoke coming from the top and bottom of the chimney during this time.
- After about 20 min, we increased the blowers from 1300 to 1800 RPM.
    - During this test, we noticed a growing gap between the chimney base and the reactor. Through this gap, we could see the flame below the chimney.
        - When we tried to close this gap with caulk, some black smoke came out of the top of the chimney.
    - During this time, there wasn't that much smoke coming from the hopper, only some coming from the bottom and top of the chimney.
- After about 15 min at 1800 RPM, we increased the blower speed to 2300 RPM.
    - Around this time, we started to notice more smoke coming from the hopper and less coming out of the chimney.

    - We also saw some flames coming out of an opening between reactor pieces near the base of the chimney.
    - At this time, we took temperature of different parts of the reactor:
        - Hopper Lid: 80 C
        - Bottom of chimney: 473 C
        - Insulation higher up from chimney: 50 C
        - Support beams for chimney: 100 C
        - Port plugs: 400 C
        - Outlet: 40 -50 C
    - About 20 min after increasing the blower speed, we took off the hopper lid and there was intense smoke as well as fire coming from the hopper. There was not really any smoke coming from the chimney at this time.
- Because of the fire and smoke from the hopper, we turned down the blowers to 1800 RPM.
    - The smoke was then split between the hopper and the chimney for a while with dark smoke coming out of the chimney. After a few min, the intense smoke started coming out of the hopper again however, we did not see a fire.
- After about 30 min, we lowered the blowers again back to 1300 RPM however, we saw a lot of black smoke coming from the chimney and so we raised the secondary air to 2000 RPM.
    - During this time, there was still a significant amount of smoke coming from the hopper. We noticed that more smoke came out when the feeder was less full of biomass.
- At one point, we noticed that the left primary blower stopped running and was smoking significantly so we unplugged it and stopped the test.
    - We think the connection to the blower may have failed, causing it to stop spinning.
- While the reactor was cooling down, we noticed that smoke continued to escape from the hopper and the chimney

- Fire coming from gap in between reactor pieces

- Gap at base of chimney

- Smoke from hopper

- Smoke from side of reactor

- Final product

- Burned blower

Hot Test #11 - 6/28/21

- After lighting the fire on (on the hole of the main blower), blower melted due to installing it before turning it on, causing hot smoke to rush out to the fan

- The hot test stopped 30 minutes after it starts because the auger was stuck; after we checked it turned out that the auger motor seemed broken

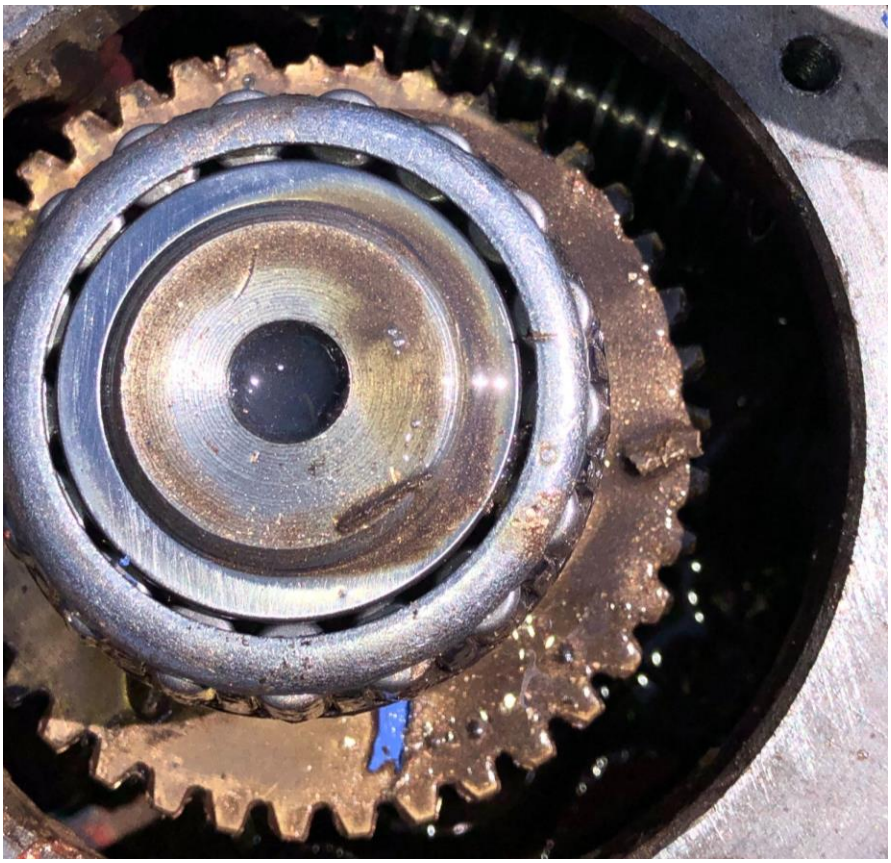
- For the rest of the day, we worked on installing the backup motor which we had quite a difficulty in mounting, but went well hooking the electronics onto the system

Hot Test #12 - 6/29/21

- Backup motor stalls a lot during the test. We had to run the auger on reverse for several seconds then back to pass through stalls. Due to this, we had to not overfeed the auger which results in low yield/hr.
- Also, the fire is very hard to maintain for the primary blower position (which is a notch above the chimney). Relighting the fire did not solve the issue at all
- We did a second test where we had the all blowers running on 3000 rpm. Fire was able to be maintained through the hot test
- Motor wire burnt off at the wire nut; we had to stop the test. We rewired them using a solder

- Second test results:

- After the test, we opened the broken main motor and saw the gear of the motor was grounded.



Hot Test #13 - 7/1/21

- To cope with low torque and minimum yield constraints due to the backup motor, we used almond shells as fuel.
- Starting the fire's difficulty is similar to wood chips
- Throughout the hot test, black smoke comes out of the chimney plentifully, especially at lower speed (primary 2000 rpm secondary 2500 rpm). Turning the primary blowers higher at 3000 rpm and secondary to 4000 rpm seems to reduce the black smoke, but not eliminate it.
- When we had the secondary blowers to 4000 rpm, we saw charred fuel from the hopper, but no smoke coming out of hopper was seen

    - At 11:19, roughly 15 minutes after turning up the secondary, smoke was barely coming out of the chimney, and the chimney was at 290℃.
    - However, more and more smoke can be seen coming out the hopper as time goes on as the char spreads closer to the hopper (11:48 the entire hopper is charred)
- The reactor's temperature went to an extreme:
    - Chimney exceeds thermometer maximum temperature
    - Chute Tube 44 ℃
    - Top Chute Joint 74 ℃
    - Bottom Chute Joint 73 ℃

- The chimney is bent and oxidized; we should wait until a new chimney is installed before doing another hot test

- 30 minutes after the last fuel feed, the chimney has cooled down to < 100 ℃.
- However, the auger was stuck. We did not know when it happened, but the feeder is not empty (image below)

Hot Test #14 - 7/6/21

- The goal for this day was to see if a lower primary blower setting would prevent a positive pressure in the feeder. In addition, we are testing the functionality of the drum lid adapter and its effect on scale measurements.
- This test uses almond shells as fuel.
- Lighting the fire was difficult at first as it took us 4 tries. Although, we found a method that works effectively. First, add some lighter fluid to the biomass. Second, light the fire by using a lighter. Third, add in more lighter fluid to the open fire. Fourth, take the far end of the blower and subject the fire to air for a minute or two. Lastly, when you are sure that the fire will keep burning, secure the blowers back into the reactor. Note: Make sure that the blowers stay on in order to prevent hot gas from melting the blower.
- We started the test with both the primary and secondary blowers at 3000 RPM, and we varied the speed of the auger.
- During the start, we set the auger speed to 1 RPM as we wanted the almond shells to reach the level at which we wanted to start the fire. Then, we set the auger speed to 0 RPM whenever we wanted to light the fuel.
- Throughout the test, there was a frequent reappearance of smoke, which may be due to the many attempts at lighting a fire which ended up dying anyways.
- It was difficult to get the chimney to a high temperature during this test, maybe due to multiple failed attempts at lighting and keeping the fire alive.
- Ultimately, after we found a way to effectively light and keep the fire going, not long after a primary blower malfunctioned and melted.

- The test was stopped due to the blower malfunction.
- The resulting output are uncharred almond shells with a hint of charred ones, which are most likely the results of the multiple attempts at lighting the fuel.

- Takeaways: We learned of an effective method of lighting fuel (more specifically almond shells) which we would be applying to future tests in order to determine its efficiency.
- What to do next: We would need to repeat a similar experiment with the same goals after fixing the damaged primary blower.

Hot Test #15 - 7/8/21

- The goal of this test is to continue to observe the effect of a lower primary blower speed (2000 rpm) in preventing a positive pressure at the feeder. Additionally, we are continuing to observe the efficacy of the chute interface and addressing any scale measurement issues.
- To start this test, about 25 lbs of wood chips were used to heat the reactor before the almond shells were added. This was to address the difficulties during the 7/6/21 test with getting the almond shells lit and the reactor to temperature.
    - During this time, the primary and secondary blowers both started at 1500, but the primaries were lowered to 1300 and the secondaries were raised to 2000 to try to clear out the dark smoke from the chimney.

- After switching to almond shells, the first twenty 7 lb buckets added were from the 7/6/21 test and had some charred shells. These were all added before steady state was reached.
    - During this time, the fire was relit successfully in the preheated reactor using the method discussed from the 7/6/21 hot test.
    - Smoke was observed coming out of the bottom of the chimney by the insulation as well as a very large, dark plume from the top of the chimney with the primaries at 2500 and secondaries at 2000.
    - At 10:34, the primaries and secondaries were cranked up to 3500 and 5000 respectively to try to clear the smoke plume pictured below. At around 10:40, the smoke out of the top of the chimney started to noticeably decrease. After about 20 minutes at these high blower speeds, the smoke had decreased, so both the blowers were lowered back down to 2000 at 11:03.
    - In the future, starting the test with higher blower speeds may help to reach temperature and clear up a thick smoke plume, and then the blowers can be lowered to the desired speed.

- At 11:28, we switched to fresh buckets of almond shells for the rest of the test (Steady state was noted at 11:31).
    - During this time, the primaries and secondaries both started at 2000. Embers and some charred bits were seen at the base of the auger in the feeder along with smoke from the feeder.


- At 11:33, an open flame was observed in the feeder and a bucket of almond shells was used to quench the fire. In the future, the feeder level should be maintained as full as possible during testing.
- At 11:39, there were flames at the base of the chimney. The extinguisher was used.

    - At 11:52, there were flames observed at the top of the chimney. The secondary blowers were increased to 3000 and by 11:54, the flames were no longer visible
- After about 40 minutes of steady state testing, the secondary blowers were increased to 4000 to observe any changes to the chimney. No noticeable change in temperature of the chimney was observed.
- Overall, during steady state, smoke was consistently seen leaking from the chute interfaces and coming out of the feeder. The smoke out of the chimney was found to only be visible intermittently.
    - There seemed to be a correlation between adding buckets and plumes of smoke from the chimney when we were letting the feeder get almost empty between refills; however, after more focus was put on keeping the feeder full, the same correlation was not evident.
- Char Results:
    - Drum 1:

    - Drum 2 (during steady state):

    - Drum 3:

- Yield: Yield was calculated using the total weight in the drums after testing was complete. The scale was incorrectly logging the weights during the test, so that plotted data could not be used.
    - It is important to note there may be errors due to the fact that we started with wood chips before transitioning to the almond shells, so the wood chips are included in the yield. Other errors could be attributed to the use of shells leftover from the previous test that included a percentage of already charred shells.
- Takeaways: It is helpful to bring the reactor up to temperature first for difficult to light materials such as almond shells. If the smoke is problematic at the start, increasing the blower speeds as the chimney gets up to temperature helps to clear it. Keeping the feeder as full as possible should be more of a focus moving forward.
- What to do next: Assess integrity of chimney after fire at base, the need for changes to the chute connections, and the scale logging problem.

Hot Test #16 - 7/15/21

- The goal of this test is to attempt the first test using rice hull, determine the best way to light the material, and observe any differences between rice hull and almond shells. This test should also look at the new chute elbow/damper system.
- The test started with about 28 lbs of wood chips in order to heat up the reactor.
    - There was immediate smoke out of the base of the chimney and light colored smoke out of the top of the chimney.
    - About 10 minutes later, the smoke out of the chimney darkened (pictured below), so the secondary blowers were ramped from 4000 to 5000 rpm. The smoke out of the top of the chimney seemed to improve.

- There was also smoke coming out of the feeder when the biomass level dropped to just above the screw along with smoke out of the lid of the drum and the chute connections. There was also a new smoke leak from the corners of the connection of the chute to the main body of the bioreactor (difficult to see smoke in picture but can see corners where it's leaking).

- We then transitioned to the rice hull for a little over 20 lbs worth.
    - The smoke was not noticeably dark during this time, but there was still smoke out of the feeder and previously mentioned chute connections.
- The fire went out, so we then transitioned back to wood chips to continue heating up the reactor to temperature before continuing with the rice hull.
    - The chimney base started making cracking noises, but there was no visible smoke out of the top (just by the base). A fire started on the insulation at the base of the chimney. The fire burnt through the insulation and stopped, but flames were seen within the chimney (pictured below). The damper was also removed.

- Due to safety concerns regarding the current chimney set-up, the test was stopped and steady state was not reached.

- Results:

- Takeaways: Ramping the blowers up to 5000 seemed to prevent a dark smoke plume from the top of the chimney in comparison to the plume of the last almond shell test. There were noticeable new holes at the base of the chimney due to corrosion and the new damper system which may have led to the fire. The new elbow held up well even with the flames in the chimney. There are also still points struggling with leakage of smoke near the chute system. The fire extinguisher was not filled and ready for this fire -- it may be helpful to have a safety checklist before tests to prevent oversights like this in the future.
- What to do next: Remove spacer/damper system to prevent extra openings at the base of the chimney, address leakage of smoke by the chute (use clamps on drum during next hot test, seal holes on interface of chute/body of reactor), order new chimney, aim to start next test with primary blowers at 5000 and secondary at 2500 to obtain good smoke plume before ramping down

Hot Test #17 - 7/16/21

On Friday, July 16, 2021, we conducted a hot test using rice hulls with the goal of achieving steady state. The test lasted about 2.5 hours and steady state was ultimately achieved briefly.

Warming up the Reactor:

_____At 1:29 PM a 7-pound bucket of wood chips was put in the reactor and the auger was set to 0.4 rpm to move the wood chips up the reactor. A second bucket of wood chips was put in the feeder at 1:37 PM, and three minutes later the wood chips were lit using a blow torch from the hole created when primary blower A was removed. Blower A was then secured back in place, the primary blowers were set to 2500 rpm, and the secondary blowers were set to 5000 rpm. The auger was set to 0.6 rpm. At 1:42 smoke was seen coming from the chimney, and one minute later a third bucket of wood chips was put into the feeder.

The amount of smoke emanating from the chimney increased over the next few minutes, and then at 1:47 the auger was stopped and primary blower A was removed to relight the wood chips. The auger was started again and the amount of smoke coming from the chimney decreased until 1:54.

Testing with Rice Hulls

_____At 1:54 a 9.4-pound bucket of rice hulls was emptied into the feeder, and at that time the thermocouple in the chimney read 73 degrees Celsius. 4 minutes later more lighter fluid was added after the amount of smoke coming from the chimney decreased; it was suspected that the rice hulls might have put out the fire in the reactor. Over the next 10 minutes a small amount of light gray smoke was coming from the chimney as 20.5 pounds of rice hulls were added to the feeder.

At 2:07 ash started coming out of the top of the chimney, and at 2:08 the gasket wrapped around the elbow started to burn. Over the next 5 minutes the gasket was retaped around the chimney but wouldn't stay on so it was completely removed from the chimney, as shown in the pictures below:

At 2:15 ash started coming from the base and top of the chimney, and continued to come from the chimney for the next 20 minutes. From 2:17 to 2:30 25.7 pounds of rice hulls were fed to the reactor at an average of around 4 minutes between buckets.

At 2:32 the auger stalled. It was then stopped on Codesys, set to move in reverse at 0.6 rpm, and then set again to 0.6 rpm in the forward direction; this temporarily fixed the problem. Over the next 15 minutes the amount of smoke coming from the base and top of the chimney increased slightly to a moderate amount, and a small amount of light gray smoke started coming from the place where the reactor connects to the chute.

At 2:47 the power switch on the extension cord into which the electrical box was plugged was accidentally hit, and the blowers and auger switched off. The power was quickly turned back on and at 2:50 Codesys was restarted and the reactor was started up again. Over this same time period 19 pounds of rice hulls were fed to the reactor at 5 minute intervals, but the feeding stopped once the power to the reactor was shut off.

The fire stopped when the blowers were shut off, and at 2:53 the fire was restarted using a blow torch and lighter fluid through the primary A hole. The chimney was still very hot at this point, and the temperature gun got a reading of 340 C.

At 2:57 rice hulls were again fed to the reactor - 5 pounds - and until 3:08 roughly 4-pound buckets were added to the feeder at intervals of 1-2 minutes. When the hulls were poured into the feeder some charred hulls were seen in the feeder region. Additionally, a small amount of smoke was seen coming from the top of the chimney and flames were seen at the base of the chimney.

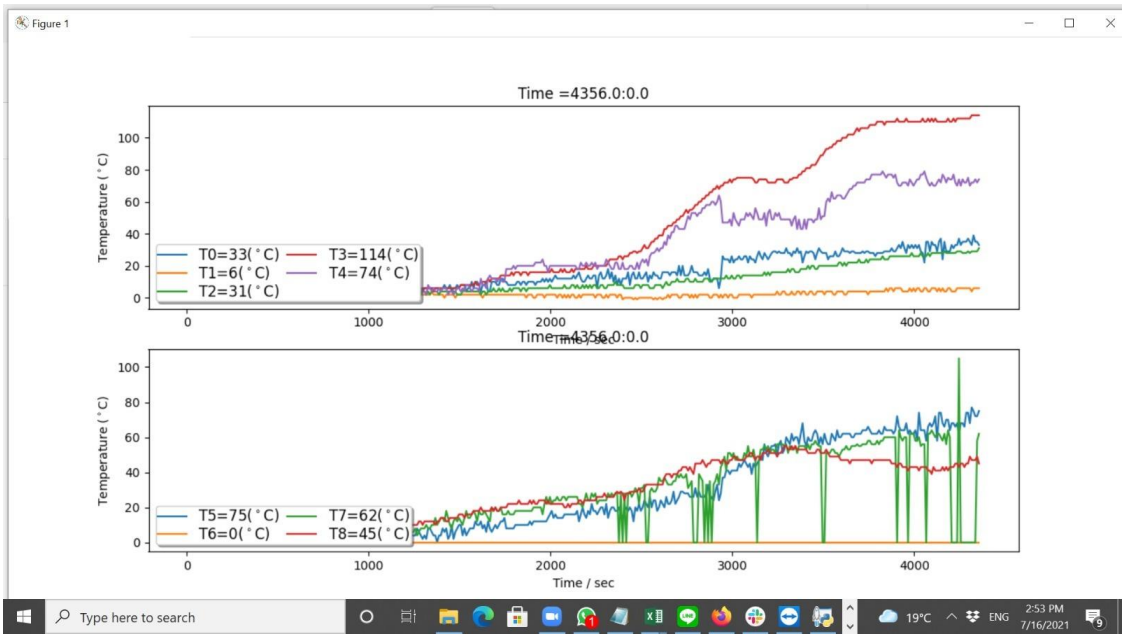
At 3:11 the oil drum was switched out, and after that new smoke was seen coming from the chute and from where it connected to the oil drum. The amount of smoke coming from the

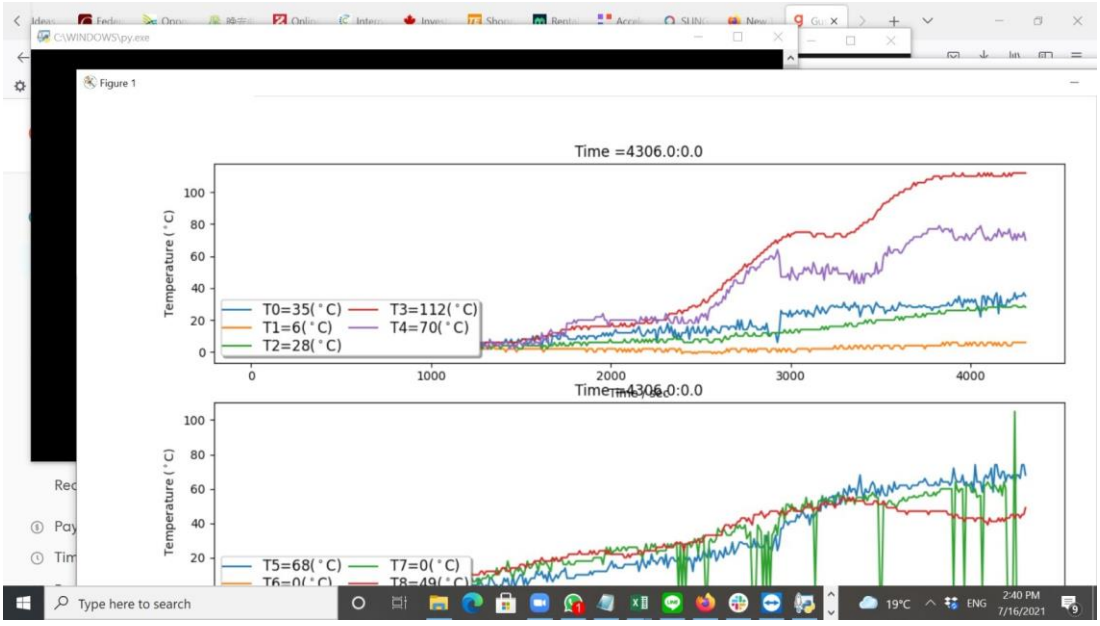
chimney also increased and more flames were seen at the elbow of the chimney. From 3:13 to 3:26 25.13 pounds of rice hulls were fed to the reactor in average quantities of about 6 pounds at about 4 minute intervals.

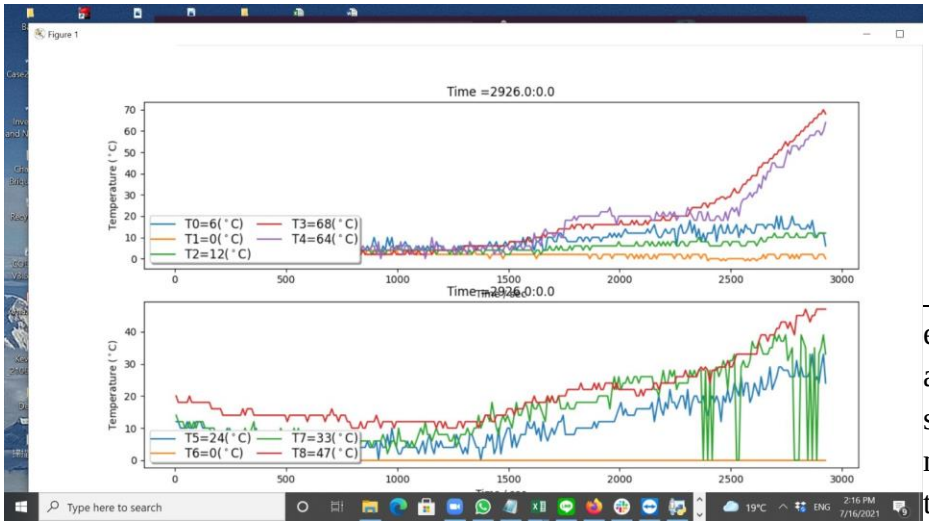
From 3:26 to 3:30 about 4 pounds of rice hulls were fed to the reactor at one minute intervals (a total of 15.6 pounds). At 3:34 the auger stalled again. Over the next 20 minutes, the auger would be stopped and reversed for about 10 seconds, then set forward again at 0.6 rpm, only to work for a few moments and then stall again. At 3:45 7.2 pounds of rice hulls - the last bucket - were fed to the reactor, and then 10 minutes later the auger and blowers were stopped.

Smoke continued to come from the chimney for the next 20 minutes after the auger and blowers were stopped as the reaction came to an end. The area was then cleaned up. After the first drum of hulls cooled enough, the following picture was taken of the char:

The following graphs show the reactor temperature as recorded by the thermocouples throughout the reaction:







The goal of the experiment was achieved in that steady state was achieved, if momentarily. While that is a positive takeaway, there were considerable concerns raised throughout the test. The amount of ash coming from the chimney during the test was considerable and needs to be addressed; the smoke coming from the elbow of the chimney and the chute also need to be fixed; and the problem of the auger repeatedly stalling towards the latter half of the test also needs to be solved.

Key Takeaways:

1. Steady state was achieved momentarily, and therefore the test's goal was achieved
2. The amount of ash coming from the base and top of the chimney is concerning and needs to be addressed
3. The smoke coming from the chute and base of the chimney needs to be fixed
4. The auger's stalling also needs to be fixed

Hot Test #18 - 7/20/21

- The goal of this test is to test the newly installed finer mesh at the chimney outlet to see how well it prevents escaping ash, while keeping blower speeds the same as the previous hot test. There is also a focus on the openings at the base of the chimney and whether the added caulking and gasket prevented leaks in that area.
- Smoke out of feeder:

- Smoke with feeder top closed:

- Flames in feeder at end of test:

- Drum 1:

- Post-test fine mesh:

- The result of this hot test was as expected. The fine mesh causes additional positive pressure which ends up causing a lot of smoke to come out of the feeder. We would need to use a different mesh (medium mesh) in future tests in order to prevent smoke coming out of the feeder.

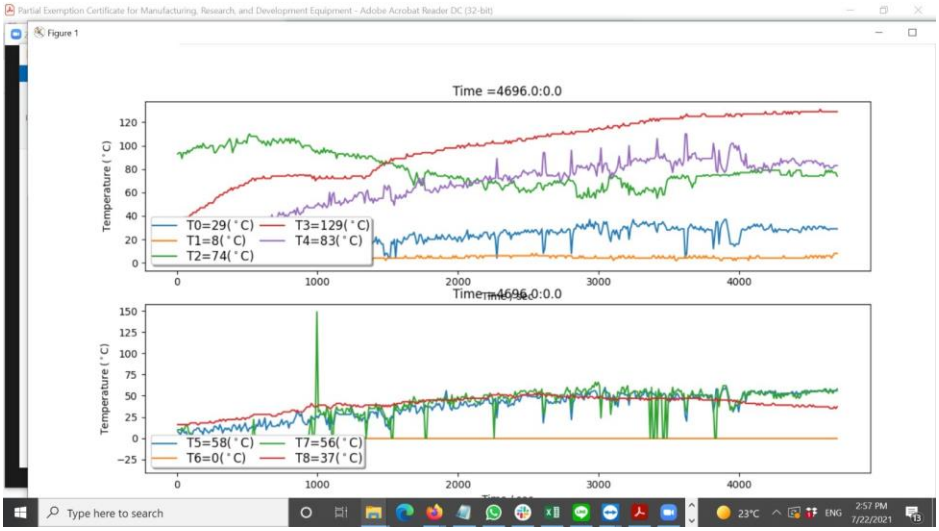
Hot Test #19 - 7/21/21

- The goal of this test is to return to the previously installed medium mesh and test a new position of the primary blowers, directly underneath the secondary blowers. This is to test if positioning the primary blowers above the level of biomass in the auger prevents ash from being blown upward through the chimney.
- Two attempts were made to preheat the reactor with wood chips and then switch to rice hull using the same techniques to light the reactor as previous tests.
- The level of the rice hull seemed to go about halfway up the new primary blower inlet in the auger.
- Each time the fire would catch for a maximum of ~10 minutes and then it would go out again.

- It was observed that it only seemed like the top layer of biomass in the auger would burn.
- There was no ash observed from the chimney, but the reactor was never lit for a sufficient amount of time.
- Takeaways: The new positioning of the primary blowers prevented the biomass from sufficiently catching on fire.
- What to do next: Pause rice hull testing for the time being and return to testing wood chips with the previous primary blower positioning.

Hot Test #20 - 7/22/21

- This test was using the stronger indian motor for the first time and returned to woodchips
- The first problem was the auger stopping sporadically. Further investigation found that this was a bad cable for the engage wire
- While running the test it would sometimes trip the breaker, but also once stalled without tripping the breaker indicating the 8A limit is too low to prevent damage to the gearbox
- As the auger kept stalling we realized that the biomass coming out was not charred and that there was nearly 110 lbs of biomass potentially stuck in the reactor
- This was odd because the reactor was still hot. To prevent damaging the auger more we shut down the reaction and let the rest of the biomass burn off



Hot Test #21 - 7/23/21

- This test started out well. The woodchips burn fast, and the reactor warmed up quickly.
- There was no dark smoke appearing, and white smoke was only evident a few times, only during the initial phases of the test and when we turned down the primary blower speeds from 2500 to 1500 RPM.
- Since the reactor went up to temperature, clear smoke was appearing just after 17 minutes from the start of the test.

- We found an effective way of starting the fire for woodchips. First stop the auger and then add some lighter fluid inside of the reactor, then light the fire using a lighter or a blowtorch. Then, add more lighter fluid before holding the blowers and subjecting it to the flame. Use 2500 RPM to keep the fire alive. After 1 to 2 minutes, fasten the blowers back to the reactor and let the fire spread for another 2 minutes before starting the auger again.
- We had some issues with the gearbox where its coupling appears to be squeezed, and so we stopped the auger and fixed this issue. We realigned and reinstalled the assembly promptly and the gearbox/auger was fixed.

Incorrect Assembly Correct Assembly

- Although, there was another issue we came across during the test, where the top section of the auger was disconnected from the rest of the auger. This may be due to a loose bolt coming off or because the bolts were sheared off, due to the malfunctioning spherical bearing that got stuck and accumulated biomass at the top.


Disconnected auger

- Before conducting another test, we need to remove the damaged spherical bearing, install a new one on the top protruding shaft of the auger, identify the cause of the bolt detachment, rebolting the disconnected auger section, and then identify the cause of this issue and document it.

Hot Test #22 - 7/29/21

- Motor 6 RPM
- The goal of this test is to reach a steady state and help determine the blower speed at which we can maintain no smoke from the feeder. For this test, blower speeds of 1500 rpm for both primary and secondary were tested.
- There was intermittent dark smoke out of the chimney before steady state was reached.
- Steady state was reached and maintained for about 30 minutes. No smoke was observed out of the feeder.
- Smoke leaks were seen at the corners of the chimney and out of the collar around the bearing.
    - The corners of the chimney were addressed with caulk during the test and saw no more leakage after that.

  - The leakage from the bearing should be addressed using aluminum tape before the next test.
- At the end of the test, the biomass in the feeder dropped below the blade and a flame was seen in the feeder. The flame was put out with water.
- Steady State Char:

- Takeaways: An RPM of 1500 for the blowers is sufficiently low in preventing smoke from the feeder.
- What to do next: The next tests with wood chips should increase the blower speed to see the maximum rpm without smoke emerging from the feeder. Additionally, the auger speed should be incrementally increased to see the max feed rate we can achieve with wood chips.

Hot Test #23 - 7/30/21

- The goal of this test was to get a basepoint for coconut shells and reach a steady state. The blowers were kept constant at 1500 rpm. Steady state was observed with the auger at both 6 and 8 rpm.
- The plugs were stuck in the normal primary blower inlets before starting the test.
    - The primary blowers were moved to the inlet two below the secondary blowers initially.
    - Once the reactor got hot we were able to remove the plugs and move the primary blowers back to the original spot.
- Dark colored smoke was observed out of chimney when warming up the reactor with wood chips

- The coconut shells were lit through pouring lighter fluid on 6 coconut shells placed in the feeder and setting them on fire through the feeder inlet.
- Steady state was achieved and maintained with the auger at 6 rpm for about an hour.
    - The input rate was at an average of about 15 kg/hr with an output rate of about 6 kg/hr for an average yield of around 40%.
- Steady state was then achieved and maintained for about 30 minutes with the auger at 8 rpm.
    - The temperature readings from the thermocouple were the same at 8 and 6 rpm.

The input rate achieved an average of about 43 kg/hr with an output rate of about 9.5 kg/hr for an average yield of around 22%.

- The output rate/yield may be unreliable as we are skeptical of the scale readings
  The scale would decrease in weight over time at some points?
- A flame was seen climbing up at the top of the chimney at the very end of the test.

RPM 6 Char (RPM 8 looks the same):

- Takeaways: The temperature does not change as expected when the auger speed is increased from 6 to 8.
- What to do next: Try to replicate the test to see if the same steady state can be reached at 8 rpm (around 340 deg C at T3) -- then, increase auger speed again and see effect. May want to see if increasing secondary blowers helps flame in the chimney during the next test.

Hot Test #24 - 8/2/21

- The goal of this test was to replicate the results of Hot Test #23 when primary blowers were at 2500 rpm and auger speed at 8 rpm, testing primary blower speed at 1500 rpm and 2500 rpm and testing whether increasing secondary blower speed would solve the fire at the chimney.
- An issue occurred during pre-heating the auger where the chimney does not seem to get hot and is constantly spewing out smoke. The chimney gets warm enough by burning wood chip long enough and switching to coconut shells bring the chimney temperature high very soon
- 

- We first ran the test at primary 1500 rpm and achieved a steady state at 240 ℃ and maintained it for at least 30 minutes; feed rate at 46 kg/hr and yield of 42%.
- Then, we increased the primary blower speed to 2500 rpm and achieved steady state at 315 and maintained it for 30 minutes. Overall feed rate was 48 kg/hr and ~14 kg/hr (30% yield)
- On both parts of test, we could usually observe flame and black smoke from the top of the chimney. We tried increasing secondary blower speed to mitigate this but to no avail. However, there does not seem to be an immediate impact due to the flame other than the radiant heat around the hopper area.

- What to do next: Try increasing auger speed and test how much the auger can handle while maintaining the char quality

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Hot Test #25 - 8/3/21

- The goal of this test was to achieve a feed rate of around 100 kg/hr with coconut shells. We achieved between 90-95 kg/hr for both steady states. We started with primaries at 3000 and secondaries at 4000 and the auger at 8 rpm. The auger speed changed a few times and was ramped up to 10 and then 12 rpm, which it stayed at for the majority of the test.
- Because of the presence of dark smoke and flames from the chimney - as well as a flame from a gap in the base of the chimney, the secondaries were ramped up to 6000, 7000, and then 8700. Ramping the secondaries up to 8700 reduced the flames and smoke coming from the chimney but didn't completely solve the problem; having blowers that can exceed 8700 rpm would have been nice and allowed us to see the effects of increasing secondary speeds even more.
- For the last 45 minutes of the test we decreased primaries to 2500. This again decreased the amount of black smoke coming from the chimney and reduced the size of the flame in the chimney, but did not completely remedy the problem.

- There was a consistent leak in the chute throughout the test, with smoke coming from the areas where the chute connected to the reactor, where the chute connected to the drum lid, the plastic wrapping, and where the plastic wrapping connected to the chute.
- Afterwards, when removing the last drum to seal it, coconut oil that had accumulated on the chute plastics caught on fire as it was suddenly exposed to oxygen. This caught the chute on fire and melted through the plastics in a dangerous fire. For future tests, we should be cautious about the fire hazards of accumulated coconut oil.
- The char output was roughly 22% and 27% for the first and second steady states respectively. We got a very strong feed rate during this test. The main issues to make this speed sustainable is preventing smoke leakage from the chute, feeder, and everywhere and preventing chimney fire. Both of these could be attributable to higher secondary air speeds. Surprisingly the auger and motor fared fine.

Chimney flame (primaries 3000, secondaries 6000):

Feeder smoke (primaries 3000, secondaries 8700):

Feeder smoke (primaries 2500, secondaries 8700):

Leakage points (side of reactor and flame at base of chimney):

Drum 1 Char:

Drum 2 Char:

Hot Test #26 - 8/4/21

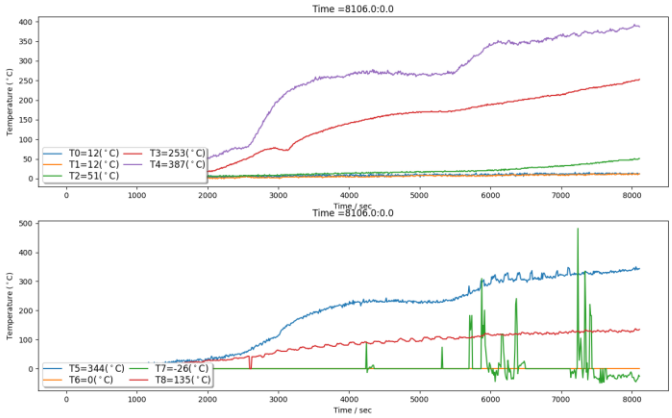
- The goal of this test was to determine what primary blower speeds created a feeder smoke condition. This condition was ultimately reached at primary speeds of 4500 rpm. Initial parameters were primaries at 1800, secondaries at 3000, and auger at 6 rpm. The auger stayed at 6 rpm for the entire test, the secondaries were decreased to 2500 rpm after 15 minutes and stayed there for the rest of the test, and the primaries were increased throughout the test. With primaries at 3500 rpm there was no feeder smoke, and once they were ramped up to 4500 rpm the feeder smoke condition was quickly achieved. The primaries were then lowered back to 3500 rpm and the feeder smoke stopped.
- There was a small-to-moderate amount of light colored smoke coming out of the top of the chimney at the beginning of the test, but that cleared up after about 20 minutes. 30

minutes into the test there were a few embers leaving the top of the chimney, but that only lasted for about 10 minutes.

- The average feed rate for the test was 82.5 lb/hr, and the test went on for 2 hours and 50 minutes. The yield was 18.9%
- The takeaway is that primary air over 4000 causes smoke to come from the feeder in this configuration. Next, to help resolve this, we will try a reactor configuration with a moved chiney and larger feeder

Hot Test #27 - 8/6/21

- The goal of this test was to validate that moving the chimney didn't completely disrupt our ability to produce char. In addition, we kept the primaries in the same location as previous tests with wood chips and tried similar blower and auger values to before to isolate the variable of the moved chimney and larger hopper.
- The throughput for an auger RPM of 6 was 65-70 lb/hr. This is slightly less than expected, probably because the larger hopper pronounced the bridging problem. We had to unclog the feeder every 8-10 min or so. However, with 24lb buckets there was much less time feeding the reaction.
- The overall yield was 23% for primaries at 1500 and 11.5% for primaries at 4000. The char looked the same as previous tests above (well-charred for both settings)



The first steady state (purple) was for primary blowers at 1500 and the second for primaries at 4000.

The large hopper significantly reduced the work needed to load the hopper significantly. Two on the hot test had as much down time as working time. However, there is lots of arching as seen above.

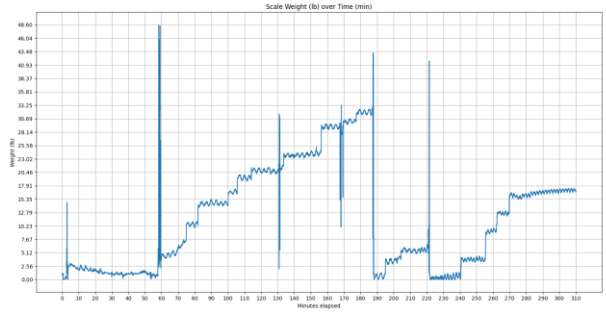
For the moved chimney and larger feeder:
Pros: much less work loading buckets, moved combustion region means no chance of feeder catching fire, tall feeder blocks smoke when full
Cons: feeder is arching more aggressively, output char is much hotter than before (although it cools off given time), auger had more resistance with more raw biomass inside

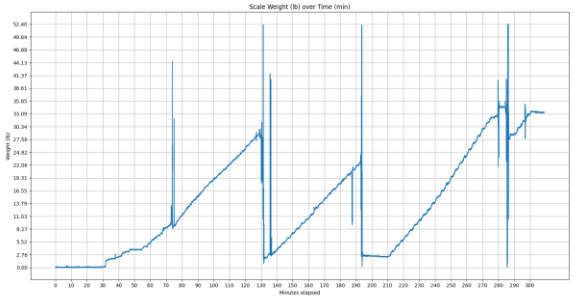
The arching issue might be able to be resolved, however the other pros and cons are somewhat inherent to the design change.

Hot Test #28 - 8/9/21

- The goal of this test is to check whether embers and smoke come out from chimney and feeder respectively, and whether moving the primary blowers from S10 to S9 has any effect on it.
- We use rice hulls from the test as woodchip is running low
- The test is run at setting: Primary 2500rpm, Secondary 4000 rpm, Auger 6 rpm for the whole test, and changing the primary position is done mid-test.
- We found that for primary at position S8, embers come out abundantly at the direction of the chute but almost no embers at the feeder direction. Later on, the ember stopped and ash comes out instead.
- After moving the primary to S9, the ash seemed to be worse. Additionally, smoke is leaking right above blower B. Smoke can also be seen coming out of the feeder abundantly when rice level is moderate. To deal with this, we had to maintain rice level to almost full consistently.
- Noteworthy: chute works perfectly. No smoke leaking from the chute-oil drum and only small amounts can be seen from the reactor-chute connection. Changing the drum was also seamless as the chute was flexible and light enough.

- From first drum, we can see the output char to be very evenly well charred





- These are graphs of the scale reading over time. The first is from before this test where mass would build up and collapse causing a stepped curve. The second graph is with the new corrugated chute from McMaster. The mass flow was much more consistent resulting in a nearly linear curve. TLDR: The new chute has much better mass flow and/or scale readings.

- The new chute
- The first picture below is char with primary RPM at 1500, the second is at 2500

- Starting up we saw some embers (for woodchips startup),
- Later we only saw ash issues for both primary blower positions. It got worse when we moved the blower from S10 to S9 (config B). Lowering the primaries saw an improvement in the ash output
- We saw smoke from the feeder when moving the primary to S9, but it stopped after lowering to 1500

- There was ratholing for the rice hulls, but it wasn't stable so it would always collapse. The smoke would come from the ratholes when they appeared
- No matter how low the secondaries went, we didnt see dark smoke or flame in the chimney. The hottest temperature was with secondaries at 2250 (ratio of secondary to primary of about 1.5), higher was air rich and lower was fuel rich.
- The input/output rate: average input rate 29.1 kg/h, steady state 2500 rpm(input 30.9 kg/h output 9.9 kg/h / 32.2%), steady state 1500 rpm (input 77.5 kg/h output 13.1 kg/h / 37.4%)

Hot Test #29 - 8/10/21

- The goal for today's test is to see whether changing secondary blowers would result in reduction, or even elimination, of the outcoming ash from the chimney and smoke from feeder. Primary and secondary blower's position do not change from the last test's setting (primary at S9), and primary and auger setting is kept constant at 2500 rpm and 6 rpm respectively.
- Ash roughly got worse with higher secondaries (more ash ~4500). When we dropped back down from 8000 to 4000 basically eliminated the ash. Overall worse than yesterday
- After ramping up the secondaries very high the smoke from the feeder got very bad. This happened after the secondaries exceeded ~5000. Afterwards, even after reducing the secondaries the feeder smoked aggressively and smoke poured out of reactor seams. To prevent this, we shouldn't overdo the secondary speeds.
- Maybe 15 min into stopping the test the feeder completely caught on fire, even when covered.
- Flame was also seen coming out of the opening at the chimney
- Input rate was at 36.2 kg/h

Hot Test #30 - 8/11/21

- Goal was to fix the ash problem. Moving the primary blower to S3 was able to stop nearly all of the ash from the chimney. Presumably this change is due to the moved blower.
- The rice was also harder to get lit than usual but we were able to do it eventually
- However, with this resulting in more smoke coming from the feeder, the combustor temperature was lower than usual (500s vs 700s)
- The charring for the husks was low for 1500, decent at 2000, and well charred at 2500
- There was definitely more smoke today than other tests, probably because the chimney was so far away from the combustor region.
- There was a problem with smoke from the feeder compared to other tests. There was no smoke at a primary of 1500, a transition at 2000, and full smoke from the feeder at 2500. The configuration that solved the ash plume limits how high the primary blowers can go before the feeder smokes.
- The char output was still warm, but not as hot as yesterday
- *What causes the ash plumes?* Leading theory is the primaries circulate and push up the husks and with this configuration is has more time to settle before being blasted by the secondaries up the chimney
- *Idea:* Same distance and different angle will determine whether the angle or distance is more important to the ash plume
- Yield: 43.1% (70.1 lb/h input and 30.24 lb/h output), steady state at 80 C according to runscale_RFS.py plot

Hot Test #31 - 8/12/21

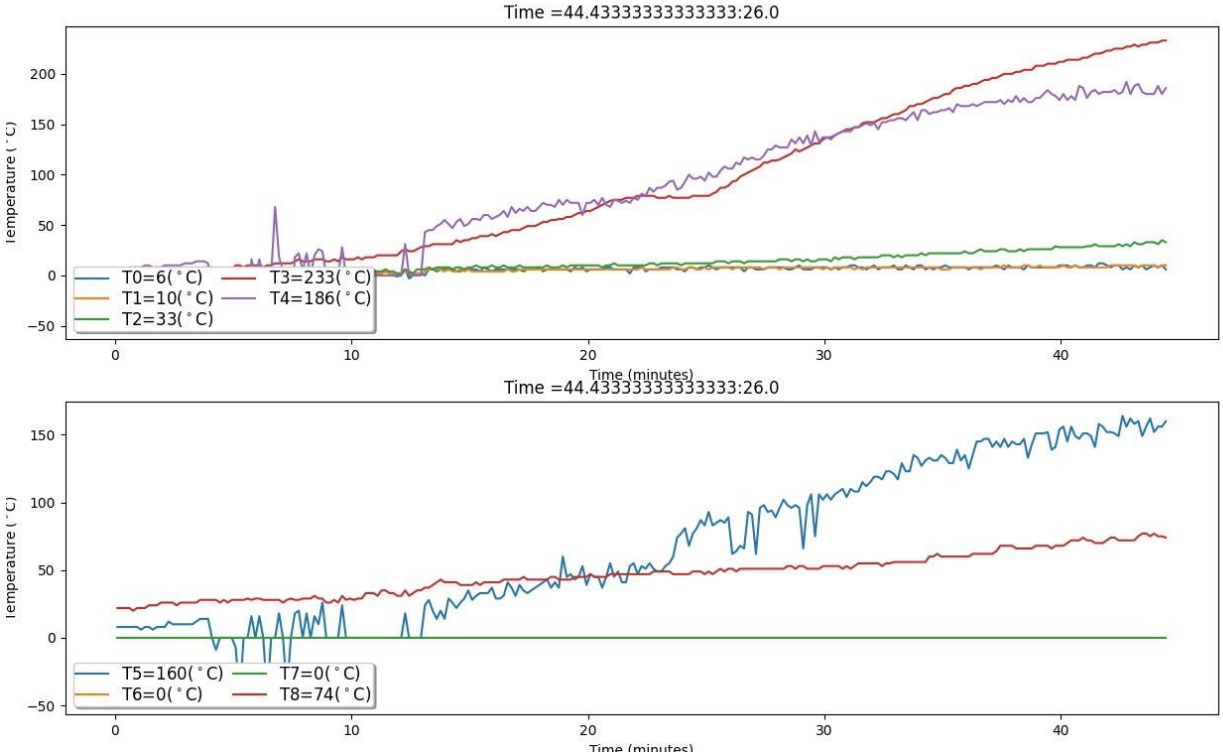
- Goal was to achieve well-charred almond shells. We ultimately did achieve our goal, with at least 90-95% of output being completely charred.
- Primary was in position S10 and secondaries in S1. Auger was set to 6 RPM for the entire test.
- Initially, primaries were set to 3000 rpm and secondaries were set to 4000 rpm. This resulted in a large amount of mostly white (slightly yellow) smoke coming from the feeder and yellow smoke from the top of the chimney.
- After 30 minutes secondaries were changed to 5000. The chimney smoke decreased a little bit and became more white, but was still slightly yellow. Feeder smoke persisted.
- After another 15 minutes the secondaries were lowered back down to 4000 rpm. After a few minutes of this a plume of yellow smoke and a flame came out of the top of the chimney. Feeder smoke persisted.
- After 15 minutes of this secondaries were ramped up to 5000 rpm again.
- 4 minutes later secondaries were changed to 4500 rpm. The chimney smoke subsequently died down but there was still a significant amount of white feeder smoke.
- Soon after this steady state was achieved. Combustor temperature was ~825 C. Feed rate was 133 lb/hr (60 kg/hr). The output was well-charred and warm but cool enough to touch.
- 30 minutes after first steady state was achieved, primaries were changed to 2500 rpm and secondaries were changed to 3500 rpm and then 4500 rpm 10 minutes later. Second steady state was achieved. Combustor temperature was ~800 C.

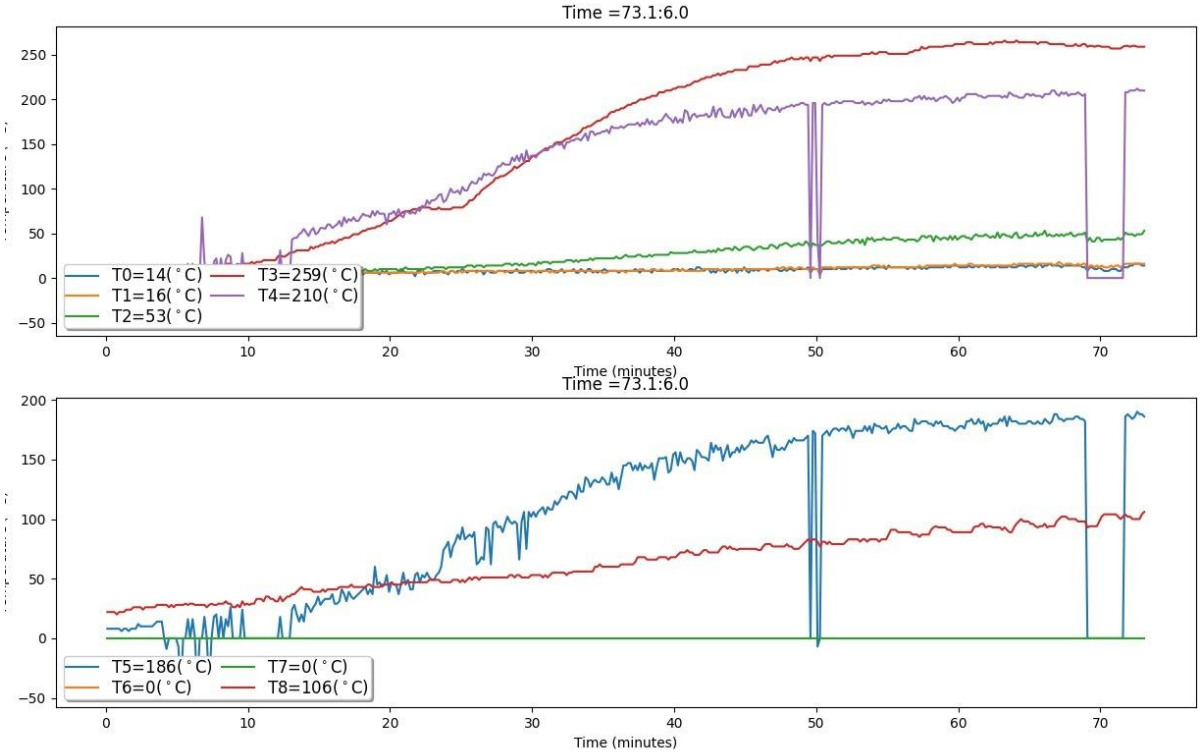
Takeaways:

Shells a bit different from last time - seems softer, outer shellsBigger hopper this time - affected feeder level and smoke last time, smoke was really bad this time, wasn't as bad - pretty bad in the beginning but lighter, but got better last time, it was brownish smoke last time we had covered the feeder, not this time smoke was better, getting rid of it around 2500feeder smoking worse than it was last time last batch of almond shells, bulk density was higher (smaller particles)primary same spot as last time we moved the chimney up 18 inches
we also had older motor (Nissei) last time with almond shells

a sample at 3000 a sample at 2500 somewhere in-between is the threshold for feeder smoke
drum weight around 25 when we changed
inconclusive, but maybe mild dependence of feeder smoke on secondary air
auger seems to be working hard, more than coconut shells, about the same as wood chips or rice husks
combustor temperature 500-600C
takes a long time for the almond shell volatiles to react
feedrate = 133 lb/hr = 60 kg/hr (almost double of rice hulls)
6 RPM = 0.35 RPM

Char coming out - warm enough to touch





Hot Test #32 - 8/13/21

- The goal of this experiment was to achieve two more steady states with almond shells by changing the primary speeds while keeping the same auger speed and primary position. We achieved one steady state with primaries at 3500 rpm but saw a concerning amount of dark smoke from the chimney, and so we stopped the test before reaching another steady state.
- Primary was in S10 and secondary was in S1. Primaries were set to 3500 rpm and secondaries were set to 4500 rpm. Auger set to 6 rpm. From the moment the fire started there was a significant amount of dark smoke coming from the top of the chimney and white smoke coming from the feeder.
- After 15 minutes the secondaries were ramped up to 5000 rpm. The dark smoke persisted - a yellow-brown color - and may have actually gotten worse.

- 
- 12 minutes later the secondaries were increased to 5500 rpm. The chimney smoke seemed to improve slightly but plumes of dark smoke were still seen. Additionally, ash and the occasional ember began to come out of the top of the chimney. Steady state was achieved at these settings, with combustor temp getting up to ~700 C. Dark smoke still intermittently came from the top of the chimney and the feeder smoke was consistently substantial. Two times flames were seen from the top of the chimney during this period. Steady state input was 104 lb/hr (~47 kg/hr). Output was well-charred, with almost 100% char rate.

- 
- After about 40 minutes at steady state the primaries were dialed down to 2000 rpm and the secondaries were lowered to 4000 rpm. At first the smoke appeared to get better but then a significant amount of dark smoke started coming from the top of the chimney - about the same amount as seen with primaries at 3500 and secondaries at 4000, worse than with primaries at 3500 and primaries at 5500. Feeder smoke improved somewhat.
- 10 minutes later secondaries were increased to 5000 rpm. Feeder smoke improved more, but there was still a lot of smoke from the top of the chimney, most of it lighter in color.
- After 3 minutes secondaries were increased to 5500. This did not affect the chimney smoke much at all.
- 15 minutes later the primaries were changed to 3000 and secondaries to 4500 rpm, but soon after the experiment was stopped because of the aggressive amount of chimney smoke.

Key takeaways:

- Steady state achieved
- Way too much chimney smoke, makes the experiment not reproducible (not desirable to reproduce).
- Feeder smoke was also an issue specific to almond shells, wasn't as prolific as when testing with rice, coconut shells, wood chips.

Hot Test #33 - 8/16/21

- The goal of this test was to see if changing the primary position solved our ash problem. The test was ended early because of concerns about the amount of smoke coming from the chimney (previous test got us a smoke complaint).
- Auger was at 6 rpm, primaries were at 1500, and secondaries started at 2500. There was almost immediately smoke coming from the chimney. It was a “normal” amount and we wouldn’t have stopped the test ordinarily but because we didn’t want to get another complaint we stopped the test after changing the secondary speeds to 3000, 3500, and 2000 rpm without any real effect on chimney smoke.
- Average input during the 40-minute test was 140 lb/hr (63 kg/hr). Yield not relevant, the output was barely (~10%) charred.

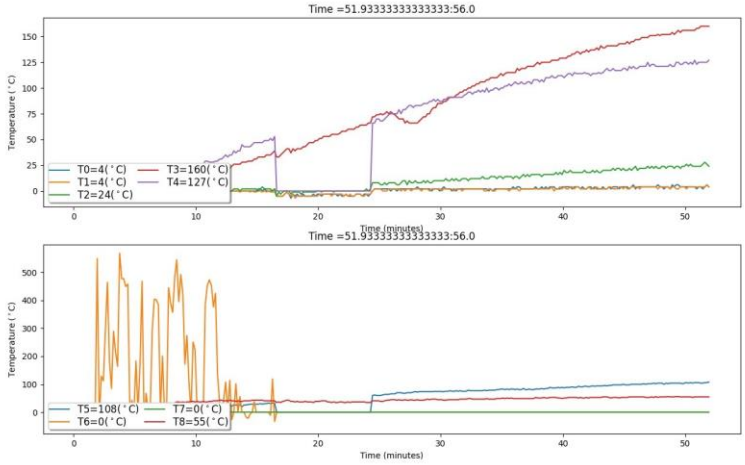
Hot Test #34 - 8/18/21

- Completed another rice hull test. The chimney smoke was MUCH better than before with the ignitor in place.
    - Two things changed: we put the primaries higher closer to the chimney, and we started off the secondaries lower. Starting the secondaries lower was Carlos' recommendation to avoid quenching the torch.
- The combustor got hot much faster and the igniter turned off when it was sufficiently warm. As we approached steady state we had to keep increasing the secondary seed to avoid smoke.
- At steady state these higher blower speeds caused lots of smoke leakage and inlet smoke, inlet smoke remained the biggest concern as the test progressed
- At startup the ash was pretty bad, but once the combustor got hot and we raised the secondaries the ash went away
- Auger was at 6, primary at 2000 -> 1500 once feeder started smoking, secondaries 1200->3500
- 
- One place we noted smoke from the open joint on the ingiter (where it mixes gas and air?)

- 
- Char from steady state at primary: 2000 secondary 3500

Hot Test #35 - 8/19/21

- The intention of this test 1) we've found that 1500 primary underchars and 2000 causes feeder smoking so hopefully 1750 is perfect and 2) can we emulate yesterday's smoke-free ash-free test.
- We ran at 6 auger, 1750 primaries, 3500 secondaries, the yield was 40.6%
- *The smoke prevention process* worked perfectly, there was almost no smoke the entire test. Idle secondaries as the test starts and turn on the propane igniter, when the combustor temperature is over ~550C there should be no more smoke and the igniter should have turned off if in temperature control mode. Then ramp up the secondaries to avoid fuel rich conditions. If there is dark smoke increase the secondaries until it goes away
- We saw a bit of ash during the test but it was fleeting. For the most part there was surprisingly no ash. This could be partly because of the new blower and chimney arrangement, but we also think that less wind at the testing site could also be responsible
- Maybe 10 minutes into steady state we started seeing increased problems with smoke from the inlet and leaking from the reactor. This got particularly bad when the feedstock was low. It is unclear whether the increased smoke leakage is due to growing cracks in the reactor on a higher pressure from the test parameters.

- 

- The ramp up the steady state, in a separate data log the steady state persists for 35 min or so.
- Key takeaways:
    - Steady state achieved
    - 1750 primaries and <= 3500 secondaries saw occasional dark smoke from chimney, but for the most part the smoke prevention goal was achieved.
    - 1800 primaries and 3500 secondaries saw less severe dark smoke from chimney as well as minor feeder smoke when the feeder was <= half-full with biomass
    - Steady state input was 78.2 lb/hr (35.5 kg/hr) with an output of 31.8 lb/hr (14.5 kg/hr) for a yield of 40.7%

Hot Test #36 - 8/20/21

- The goal of this test was to see if we could replicate the no ash condition seen in previous tests with the newly installed unclogged medium mesh in the chimney.
-  clogged medium mesh from 8/19

- We used the same profire start up technique with the secondaries idling until the Profire turns off and then ramping up to around 3500.
- The primaries were tested at 1800 to see if we could split the difference between the not charred enough at 1500 and feeder smoke at 2000.
- The auger was set at 6 rpm.
- A severe ash problem was observed and a few embers were also seen escaping the top of the chimney. The test was shut down before steady state due to this.

Hot Test #37 - 8/20/21

- The goal of this test was to see if we could emulate the no ash conditions seen during the clogged mesh period through using fine mesh.
- The startup technique using the Profire with idling secondaries was again used with the secondaries being ramped up to 2500 once the Profire turned off.
- The auger was set to 6 rpm.
- The primaries were set to 1800 rpm initially and ramped up to 2500 because the fire would not stay lit with primaries at 1800. Once the Profire turned off the primaries were dialed back to 1300 rpm.
- The finer mesh was not properly installed and as a result ash was falling down the side of the chimney; with the finer mesh two smaller pieces (not big enough to cover the entire chimney) were put over the top of the chimney such that each piece covered half of the chimney and minimally overlapped in the middle. The mesh pieces were not screwed into the chimney, and the chimney cap did not provide enough downward pressure/weight to prevent the pieces from slightly lifting up off the chimney. As a result, there was a gap between the mesh and the chimney where the two mesh pieces met at the middle of the chimney; this is where the ash came from.

Hot Test #38 - 8/24/21

- The goal of this test was to determine whether or not fine mesh solved the ash problem that we had been experiencing in previous rice hull tests.
- We initially had some problems lighting the fire, probably due to a lighter fluid shortage and because we were lighting rice hulls directly instead of warming up the reactor with wood chips first.
- Primaries were set to 2500, secondaries set to idle, Profire turned on, and auger at 6.
- Once the reactor was warm, massive chunks of ash-looking material started shooting out of the top of the chimney. Because we had fine mesh on, we think it was coming from the chimney cap.

- Test was shut down soon after, with Profire still on, blowers at idle, and auger at 10.
- Key takeaways:
    - Some difficulty keeping rice hulls lit
    - Minimal smoke, but test may not have been long enough to determine whether or not fine mesh helps with smoke
    - Some ash, some chimney cap flakes were a serious problem

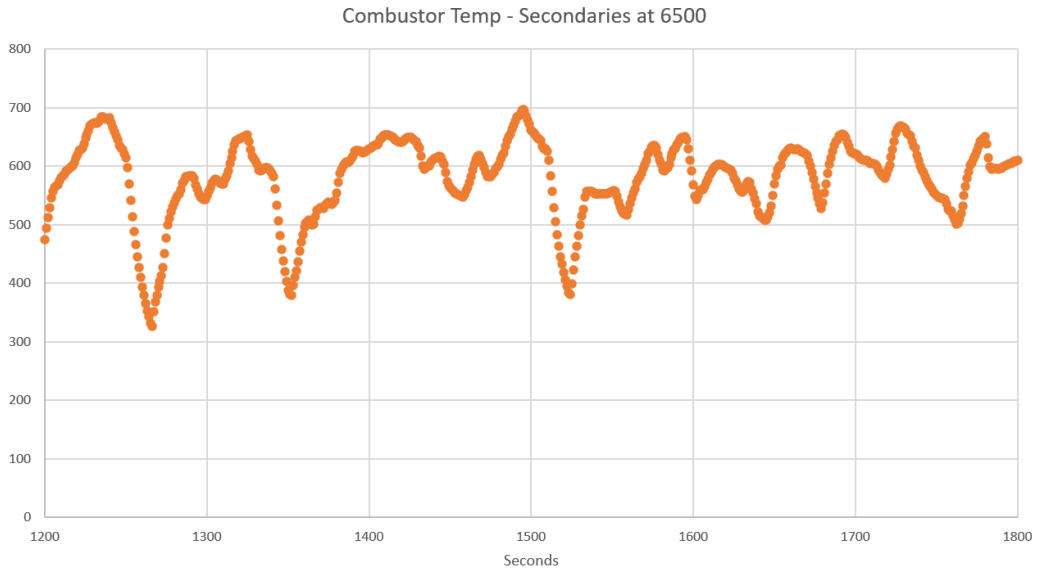
Hot Test #39 - 8/24/21

- The goal of this test was to complete a test with rice hulls after “fixing” the chimney cap by removing as many of the fragments that were shooting out of the cap in the previous test.
- The fragments were removed through a combination of hitting the cap with a mallet and wiping the inside of the cap down with a napkin and by hand.
- The primaries were initially set to 2500 rpm with secondaries at idle, Profire turned on, and auger at 6.
- Once the fire was started and had stayed lit for more than a few minutes, the primaries were turned down to 2000.
- Once the Profire turned off, the secondaries were ramped up to 2500, and then further increased to 3500, 4000, and finally 4500 because of chimney smoke.
- Because of persistent chimney smoke, test was to be shut down and primaries were dialed back to idle. This improved chimney smoke almost immediately.
- Primaries were then ramped up to 1800 in an effort to continue the test, but the chimney smoke again worsened such that primaries were set back to idle.
- Differences with previous tests that may have an effect on smoke:
    - Auger was stopped for a while due to a wire connection issue with the fire fully lit inside the reactor without us knowing
    - More lighter fluid was used than usual due to difficulty lighting
    - Took more time between profire turning off and ramping up secondaries than usual
    - Took out profire and plugged hole after it turned off

- Key takeaways:
    - Ash was not a problem throughout the test
    - Chimney cap (cowling) held up, no fragments shot out during the test
    - Smoke was a problem with primaries >=1800, but with primaries at idle rice didn't char.
    - Changing secondaries between 2500 and 4500 didn't have a huge impact on chimney smoke.
    - Most of the smoke was light-colored, occasionally there was a plume of dark smoke.

Hot Test #40 - 8/26/21

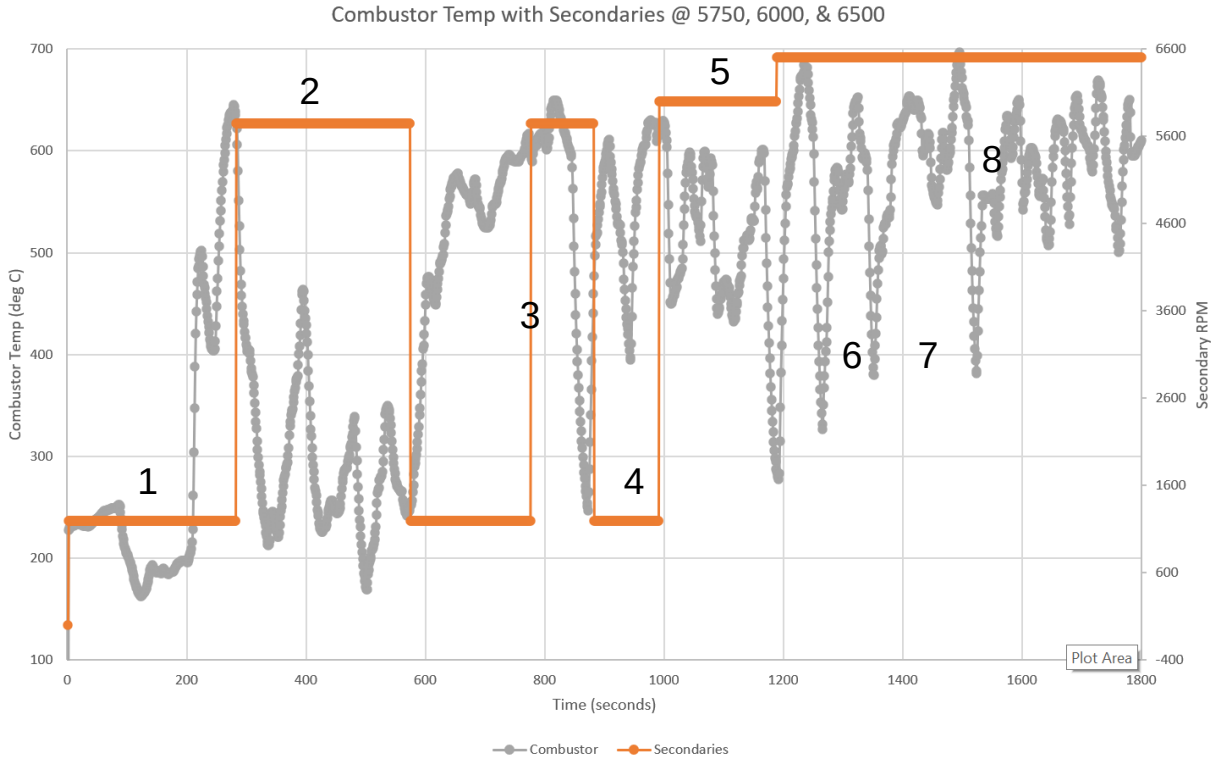
- The goal of this rice hull test was to change the secondary blower speeds with primaries at 2000 to eliminate chimney smoke.
- Primaries were set to 2500, secondaries to idle, Profire on to light fire
- Once fire was lit primaries were dialed down to 2000 and secondaries ramped up to 5750 - this 5750 value was found by scaling 1200-primary and 3500-secondary combination from the previous test. Profire was turned off and auger set to 6.
- After 10 minutes with these settings the fire was suspected to have gone out so the Profire was put back in and turned on.
- The Profire remained in for 14 minutes and was turned on and off twice - it was turned off when the combustor temperature reached around 600 C and back on because the combustor temperature would rapidly decrease to around 300 C.
- Once the Profire was taken back out with the reaction stabilizing and the combustor temperature back at ~600 C, the secondaries were ramped from idle to 6000. There was a small amount of light gray chimney smoke and significant amount of feeder smoke even with the hopper full with these secondaries. The combustor temperature also dropped quickly to ~350-400 C, so the secondaries were increased to 6500. Throughout the test there was persistent smoke leaking from the reactor body below the base of the chimney, on the sides of the reactor body near the chimney base, and just above the inlet.
- With secondaries at 6500, the combustor temperature cycled between mid-300s and high-500s to low-600s C every few minutes. When the combustion temperature dropped a plume of smoke would be seen from the top of the chimney. There was heavy feeder smoke still, and the region above the hopper where the rice hull ratholing occurred was warmer than usual (suggesting that combustion could be occurring in or right below the hopper). Light chimney smoke persisted.
- After 20 minutes with the secondaries at 6500 the right-side secondary (closest to shed) melted and so the test had to be stopped. Blowers were idled; Profire was put in but would not start so was taken back out and the inlet was plugged; auger was set to 10 to run rice hulls through reactor quickly; un-charred rice hulls were shoveled out of hopper and a region of completely charred hulls were seen in the feeder; feeder cover and damper were put on/in.



- Key takeaways:

- Scaling primary-secondary combination and then further ramping up secondaries minorly improved chimney smoke, but resulted in heavy feeder smoke.
- With secondaries at 6000 and 6500, the combustor temperature cycled between mid-300s and mid-500s to low-600s C.-- seems to almost cyclically drop from steady around 600 to 300 (see graph above)
- Heavy feeder smoke and the charred region in the hopper (shown above) also noticed.
- The two above notes suggest that the combustion zone was lower in the reactor than expected - close to the hopper - we think that the reaction may have been occurring below the primaries, and then when the hot rice hulls reached the combustor they spiked its temperature but rapidly cooled such that the combustor temperature dropped to the 300s. This could either be caused by the high secondaries blowing out the reaction or the hulls could have gone through complete combustion and were already cooling when they got to the combustor region. We don't think that complete combustion was occurring because the output rice hulls were not well-charred.

- The melted secondary blower could have been due to a very hot reactor body - the blower was facing towards the body and the reaction was likely occurring directly under the blower - or smoke/flames could have crawled down the blower (we think that's less likely given how high the blowers were). The intense feeder smoke occuring may also have contributed to the damage.



1. Start same as previous tests with profire -- successfully ramps up temp, so we ramp up to "ideal" (based off of previous success at 2000 & 3500) secondaries @ 5750 RPM.
2. Combustor temp quickly drops when secondaries are ramped up - try again from beginning to see if it is replicated.
3. Turn profire back on and secondaries back on idle -- successfully ramps up temp again. Ramp secondaries back up to 5750 and see the same phenomena again -- Combustor temp drops rapidly.
    a. Visibly during testing we see grayish chimney smoke - so we assume we are fuel rich and need to ramp up secondaries higher.
4. Use profire again to try to get the combustor back up to temperature -- when it switches off ramp up to 6000 RPM secondaries this time.
5. Smoke clears for a little bit. Then combustor temp quickly drops again and see dark smoke
    a. Assume this means we are fuel rich, so we ramp up secondaries higher to 6500 RPM.
6. We observed a cycling of smoke when combustor temp drops significantly -- this cycle is exactly half an auger rotation.
7. This cycle lasts the length of a whole auger rotation.

8. There is a possibility that this is where the secondary melted. It also seems to even out after this point which is interesting.

   Thoughts:
   Based off of how hot the biomass in the feeder was and how it looked like the biomass was being eaten away right at the center, we believe that combustion may have been occurring right below the feeder. We have seen this happen in other rice hull tests with high secondaries (8/10)

   This, in combination with the temperature drops seen when ramping up the secondaries, makes us think the high secondaries are pushing the combustion zone down toward the feeder.

   With this in mind, we think the smoke cycling may be due less to cycling of fresh biomass into the area below the chimney and more likely the burning material being blown out and cooling down as it reaches the chimney. - unlikely (smoke does not reflect what is directly under the chimney but the entire reaction)

   Possible solutions (looking at 8/9, 8/10, 8/11, 8/18, 8/19, 8/20, 8/24, 8/26):
   - Decrease the secondaries
     - Possibility that proportionality works the opposite way
       - Increasing primaries leads to the need for less secondaries?
   - Have seen more chimney smoke issues since switching to fine mesh- don't think this needs to be changed- cannot see how finer mesh could lead to more chimney smoke (could see how it could lead to less)

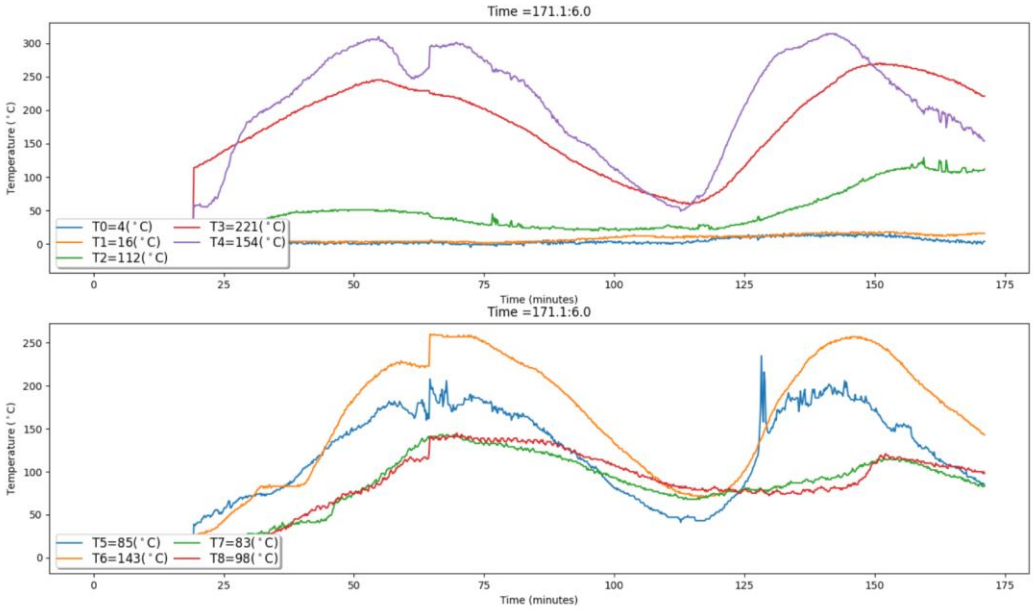
Hot Test #41 - 10/29/21

- Throughout most of the test, embers and ash were shooting out of the chimney. The embers always burned out before hitting the ground. Turning down the secondaries reduced the amount of embers from the chimney.

Hot Test #42 - 11/2/21

- Completed testing today with primaries at 2500 and secondaries between 3000 and 4000 for smoke management - The auger speed was varied to accommodate for flowability issues.
- The chips that we chipped at JDSF were used for this reaction. Drier ones that were stored at RFS were used first then the wetter ones.
- EnergyCell batteries damaged either due to dropping one or loose connection - need to troubleshoot so they were not used today
- SimpliPhi seems to work in conjunction with the solar panel for this very sunny day
  - it powered 5 hours of hot test with only 20% discharged

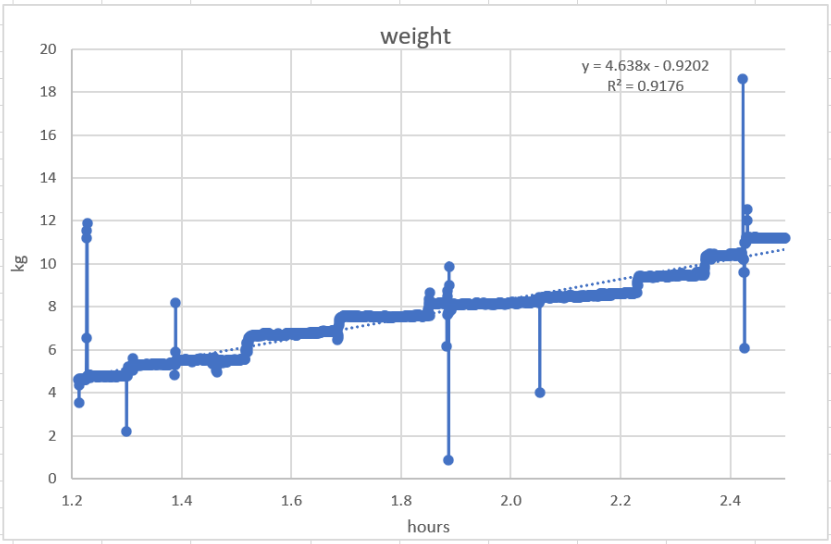
- one of the secondary blowers (Blower C) still not working, it is stuck at 8700
    - For this test, just used one secondary
        - Assumption: One secondary at 7000 ~= Two secondaries each at 3500
- Started with the auger at 6 at the beginning, weren't seeing any movement of biomass into combustion zone and the fire kept dying out
    - we were having a hard time monitoring and resolving the bridging with the huge hopper, very difficult to keep auger flights full of biomass
- we moved to 10 RPM - it was pulling a little better from underneath the hopper, but still less biomass than usual within auger
- combustion temp was able to stabilize for 20-30 minutes but then the temp started falling again
    - 10 rpm in combination with less biomass inside the reactor may have been quick to sustain a reaction or too little biomass to allow combustion to travel from flight to flight
- decreased the speed back to 6 RPM to see if it was moving too quick for reaction
    - temp rose again then stayed at that higher temp



- Throughout test, chimney smoke mostly clear and there was no feeder smoke
- There was a lot of embers from chimney but they would burn out before hitting anything
    - Some even fell in hopper and nothing would catch on fire

- We also had more difficulty with biomass getting stuck in the chute
    - A whole was burned into the chute where it was sitting

	kg/hr
	4.637968751
error	0.028806781



- The char produced was consistently charred with slightly larger pieces than the previous test. (uncharred pieces are from the shutdown period)

Key Takeaways:

- feeding for large hopper = less than ideal
- flow through the reactor very inconsistent, erratic = hard to determine steady state
- The Simpliphi battery was able to power around 5 hours worth of hot testing during a particularly sunny day.
- The biomass was not only bridging over the inlet, but also over each auger flight.
- Difficulty maintaining flow into oil drum through chute

Moving forward:

- Replace chute
- Address ember and ash issue from chimney

Hot Test #43 - 12/10/21

- First test back at RFS with Reactor Configuration C (30 degree). The old chute did not work with the height of the oil drum so a temporary plastic was installed for the sake of hot testing (see below)

- Old tan oak chips were first used to warm up, then JDSF chipped chips were used to continue the preheating process. Once the reactor got up to a high temperature we switched to PG&E chips to try to obtain a steady state.
- The goal of this test was to see if changing the reactor angle improves flowability of the PG&E Chips.
- The primaries were set at ___ and the secondaries varied from ___ to ___. The auger motor was kept at 6 for most of the test.
- The flow into the oil drum was much improved at the 30 degree angle. The biomass that made it to the end fell freely into the drum. However, it did not seem to improve much mobility for feeding or throughout the body of the reactor for PG&E chips in particular. We saw considerable compaction and larger sticks getting stuck between the auger blades and the wall of the reactor at the top portion of the reactor where it switches from rectangular to circular top. The sticks getting stuck seem to be due to discontinuities within the auger blade. The sticks will fall between those gaps making it easier for the auger blade to run over it and get stuck. This resulted in complete failure of the coupling and distortion of the gearbox output shaft for this test.



- Another Important thing to note from this test was the fact that even with a raging fire in the body the PGE chips were too wet to maintain a significant reaction and get any charring.
    - The moisture and drop in temperature also resulted in a severe smoke issue from the chimney. In comparison, we didn't have really any smoke during start up with the tan oak or JDSF chipped chips. Smoke only started once the PGE chips got into the combustion zone.
    - A fire could be sustained for the PGE chips at 6 rpm but when we increased to 8 or 10 the fire would immediately die out.
    - May help to try a slower speed in the future for moist biomass
- Complete charring was seen for the tan oak and JDSF chips (left) as seen below but any PGE chips (right) that made it through were almost completely uncharred.

Hot Test #44 - 1/4/22

Goal: Get new Bay Area team up and running; get rice hulls ready for Samuel's demonstration while waiting for gearbox-related repairs

Wanted to replicate 8-18-2021 (primary 1800, secondary 3500, motor ~0.6 RPM but we ended up running at 0.4 RPM b/c reaction seemed to go out at 0.6 RPM – we could see unburned rice hulls through the cracks below the chimney – fill the compartment and stopped the reaction)

The change: 45 deg (8-18-2021) à 30 deg (today)

Rainy, had difficulty lighting, 3-4 times with rice hulls (primary 2000, secondary 1200)

Then we did with paper, and went out

The successful one was with kindling (wood chips on the ground) + paper – after lunch (after weather cleared)

We added kindling at 1:53, primary 1800 secondary 1300

We observed sooty output from the chimney and inside the combustor zone (no fire observed), and decided to ramp up primary (1800) to get the fire started hotter

We had a lot of smoke till around 2:30

Increased secondary to 4500 – to get fuller combustion on smoke

Just before 2:30, combustor fire went out briefly – alternated between fire and smoke – synchronized with auger speed

Reactor was heating up pretty well, but not yet at steady state

We saw ash from the chimney, decided to decrease secondary to 3500 – ash situation seemed to improve

Electrical fire at 3:10 – little crimp connecting motor's white wire to PLC's thin black wire burned out. We stopped the motor. Kept blower near idle (1200, 2500).

PLC disconnected during cooling, and Austin was unable to reconnect. Had to restart computer.

Blower B (primary, left side) kept behaving erratically, randomly – need to set idle to 1300 for slightly better result

Feed rate (rice husks) for 8-18 was 86.5 lb/hr

Feed rate (rice husks) for today was 18 lb/hr. We consumed about 3 full packs of 50 lb of rice husks during the test, about half of which during the second half. However, motor wasn't always turning when the reactor was being heated up.

MotorCmdSpd failed to log – need to recode Codesys.

MotorTorq also failed to log – need to rewire Indian motor drive to Brother motor drive.

Moving forward -

Austin to replace burned-out connector and purchase more lighter fluid (which we ran out)

Kevin to look into reprogramming Codesys to log MotorCmdSpd

Hot Test #45 - 1/5/22

Goals: Speed up ignition by using wood chips before rice hulls, Determine flow rate at 30 degree angle, Demonstrate steady state operation.

The day started with blower issues, blower b was running at full speed, and not responding to commands. We replaced the blower, but the problem persisted, indicating a bad connection in the plug.
In the meantime we went ahead with 3 blowers 2 Primary 1 secondary.

We started by loading 9.4 lb of wood chips to warm up the reactor, followed by rice hulls. The rice hulls seemed to move up the reactor through the chips, so when it came time to light we decided to add more wood chips through the side port, along with paper and lighter fluid. Flames seemed to die out, and we saw wood chips in the combustion area, so more lighter fluid was added and the reaction was relit. Upped primaries to 2000 for initial lighting, then 3000 when relit to establish a strong flame. After that it burned well for the rest of the test. To reduce ash from the chimney we raised the secondaries and lowered the primaries. As we were trying to reach steady state the auger jammed and eventually tripped the torque limiting feature. When the motor jammed the red ‘error’ bar in codesys would turn grey. We reset the controller by clicking “auger motor enable” twice. Then we could run the auger backwards, and eventually forwards. This happened many times, making the effective flow through the reactor very slow. After starting, the reaction burned very cleanly, with almost no visible smoke. Though there were some ash/charred rice hulls coming from the chimney. We ended up being at steady state for about half an hour, and seemed to create some decent char.

Tomorrow, the machine should be opened up to clear potentially stuck chips that are causing noise/friction. And the blower connection should be checked to fix the issue.

Hot Test #46 - 1/7/22

Goals: See if rice husks would run smoothly using previous conditions, but with a cleaned and adjusted auger (lifted up).

Added rice hulls and ran them up to combustion area, added wood chips, bark, paper, and lighter fluid through port S1 to get combustion going and lit it. One point auger seemed to make it die down, just added lighter fluid. Stopped auger let fire get going Lots of ash throughout the test. Occasional, brief but substantial smoke plumes from chimney, every couple minutes. Seemed to be running pretty well, aside from ash, and some smoke. Auger started jamming. Not just end dropping, something must have pushed it down from the top, possibly from where biomass drops in from hopper onto auger. (Hypothesis) raw biomass conveyed up until combustion chamber. Auger seems to break free at higher RPM we tried to .6 and 1. Worked for a while. Broke it free with 1.5 RPM. Running more smoothly without biomass. Decided to shut it down.

Future: could try reactor in different configuration. If the hypothesis is the auger getting jammed because of too much biomass at the beginning, move the chimney down so that combustion happens sooner or change angles. Or shift primary air down on notch. Higher risk and smoke closer to the hopper. Misalignment might not have that much effect on torque. Might just be material jamming things.

Biomass pushing against the end since no more room left in oil drum

Hot Test #47 - 1/10/22

Objective: To see if relocating the blowers to an earlier position would make the reaction happen lower and improve flowability.

Lit with wood chips on top or hulls. Seemed to be burning well initially, but a little while after the auger was started the flames were weaker.
Temp was barely increasing, however there was a lot of smoke so we increased the blowers to try to get more complete reaction.

When we removed the first drum, rice hulls were barely charred. As we continued to run the auger it started to stall from over torque. Looking in the upper side ports the reactor body was almost completely full of hulls.

Our thinking is that we didn't let it get hot enough before starting the auger, or the air from the primaries was flowing around the hulls and along the square corners. This second hypothesis was generally supported, as we found charred hulls along the sides of the reactor.

Next: Try this configuration again, but let it heat up for longer before starting the auger. Or as a bigger move we could move the chimney down to lower the combustion area.

Hot Test #48 - 1/11/22

Objective: To repeat the configuration from the previous hot test but allow more time for the combustion to start and run the primaries at a higher speed to ensure that full combustion occurs.

Started it in a similar manner to the previous test, let it sit and get hot for longer this time. Seemed to get nice and hot and was burning very well. Was burning lower in the reactor which was what we intended for this test.

As it heated up, it started jamming repeatedly until we eventually stopped the test and let it cool down. That seemed to fix the jamming issue which leads us to our current working hypothesis that the jamming problems we've been having have been heat related issues that get worse the hotter it is and get better the cooler it is. Combustion heat may be warping some part of the inside of the reactor which is causing it to jam. That is what we are thinking so far.

When the reactor was jamming, it seemed to jam in particular spots so we marked the spots where it repeatedly was jamming consistently and it looks like 4 spots.

For next steps going forward, we have decided to take the reactor apart and see if there are any obvious irregularities at those 4 spots we marked where the reactor is getting jammed.

Hot Test #49 - 1/14/22

Objective: To test repairs, and ideally reach steady state.

Jamming seemed to be related to the thermal distortion of the upper section between the hopper and the chimney, as well as one of the lower sections pinching in at the side. We used an angle grinder to remove some material where the auger was scraping. We also tried to flex the lower section outwards as we reassembled to get some clearance.

After reassembly we ran a hot test to see if the repairs had improved the jamming issue. They did not. It immediately started making noise when we started the auger (cold) and very shortly after we got the fire lit it jammed completely. We ended up removing as many hulls as we could from the hopper end and letting the rest go out.

Next steps will be dismantling again to see what we missed on the previous repair.

Hot Test #50 - 1/19/22

Objective: Same as last time

Upon disassembly we found that one corner of the small square section below the chimney on the right side was coming into contact with the auger. We reassembled it with a slightly different orientation. Running the hot test, the auger was running noticeably smoother. We started by loading hopper with rice hulls and running auger to the cubustion area before stopping to light. Loaded wood chips and paper through port and lit with lighter fluid.

Initially the auger ran pretty smooth, but as it heated up the jamming returned. It did get burning nice and hot before jamming though. Primaries were at 3000 just after lighting, and then at 3500 briefly to establish flame.
Secondaries started at 1300 and were then set to 3500 for the remainder.

Once the jamming started we repeatedly ran the auger backwards and forwards to free it. The flames seemed solid throughout, and the char looked pretty good at the end.

Next steps would be replacing the warped piece, the top section between the hopper and the chimney. And potentially taking the reactor completely apart to fix alignment issues.

Hot Test #51 - 1/26/22

Objective: Repeat previous test conditions to determine if auger jamming has been solved and can reach steady state.

Before the test started, there was an error with the fans running quicker than supposed to. This was fixed quickly and did not cause any further problems.

Overall the system ran smoothly, approximately around 14:09 the ager started to stick, and eventually started coming to a stop. To remedy the situation, Austin took an allen wrench and manually pulled the motor till it became unstuck. Though this did work, this process was required every rotation, during most of the trial was at 0.4 rpm, requiring the unstucking needed every two minutes. This happened until 14:55, then the motor started running with out needing an allen wrench.

We were able to reach steady state for approximately 20 minutes. Eventually we started to see yellow smoke coming from the hopper. To remedy this the agar speed was increased to 0.6. The problem ended up being from the barrel being too full at 12.65 kg, the plastic cover caught fire. For future reference it is best to not let the barrel get over 11 kg.

Hot Test #52 - 1/28/22

Objective: To run a hot test using the new motor.

The new motor was installed, though there were some groans during the test the ager did not get stuck and there was minimal noise coming from the system. There were some problems, getting the system hot enough. The flames were not evenly distributed and had a tendency to stay more on the left side. At one point the flames seemed to become anemic however this was fixed with manipulation with blower speed and ager speed. The temperature was increasing steadily, and it looked as if a good test would be achieved.

Steady state was never achieved and only ~4kg of yield was obtained and was not completely charred. The test had to end early due to flames coming out of the combustion chamber crack. The hulls had started going up the chimney, the reason for this was not found, possibility with the new engine maybe the speed of the was not dialed in properly.

One interesting thing to note is that for the majority of the test not much smoke came out of the chimney and insteady bellowed out of the cracks of the unit. The two main locations were the gap before the combustion chamber and the hopper, the combustion chamber had the most.

After the debrief with Kevin thoughts of what may be happening is instead of the chemical reaction just occurring in the combustion chamber, it may be occurring throughout the system. This may account for the unevenness of the char product.

Hot Test #53 - 1/29/22

Objective: To repeat previous hot test with extended preheating to better establish reaction

Test was run

Hot Test #53 - 1/31/22

Objective: Try the primaries at 1750 to see if we can balance complete charring with minimizing the ash.

Hot Test 1

The result of the charr was mixed ~75-85% was charred, the remaining raw.

Hot Test 2

The goal of the second test was to try and yield a better result than that of the first test. Instead of a mixed yield to get an even char. The primary blowers were increased to 3000 to try and get a strong flame. Approximately 8 minutes after the initial light the auger was turned off and on intermittently in 30 sec intervals for about 4 minutes. The thought was that this would create movement, but not put the flame out. The auger was turned on to 6 rpm and within 3 minutes of doing this a flame all the way across the system was achieved.

Throughout the test there was a lot of smoke, an indication that not all of the rice hulls were being charred. Blowers were upped and lowered to try and fix this problem however the yield was still mixed. Ideas of slowing the auger down to allow for ample time of charring was shared in the debrief, but with the excess time it would take may not be a viable solution for farms. During the debrief an idea of changing the blower locations was shared. The reason for this was during the test it seems that the rice hulls are in a larger amount on the left hand side. Due to the larger quantity the top layer is thought to be getting charred by the flame but the bottom layer is not. By changing blower locations the hope is that the flame will be able to charr a larger amount of the rice hulls. Tomorrow this idea will be tested

The charr at the end of this hot test was still mixed, though did seem to be slightly more charred than test #1. A notable and odd event that did occur in this test were weird temperature readings. The time that this did occur was toward the end of the test after a barrel switch lots of ash started coming out. Farther up (after the combustion chamber) the auger was cooler than the area before the combustion chamber. On a normal hot test these temperature differences are normally switched.

Hot Test #54 - 2/1/22

Objective: To test new primary blower position with left side blower. S10 and B12 positions for primary blowers.

Goal of this hot test was to see if moving the primary blower from S10 on both sides to the opposite side's blower being in the B12 position. Reasoning behind this was that we noticed that the biomass inside the reactor would tend to form a slanted slope where it was a much higher level on the side facing the bench and a much lower level on the side opposite. So having the primary blower on the opposite side at S10 we thought was mainly blowing air directly into the

reactor and it would immediately find the easiest path out without helping move rice hulls or really promote the fire growth. We thought having it at this lower level would help the fire growth more, help decrease the 2 channel flow we saw where fire on one side and smoke on the other side, as well as move biomass around more inside to help promote more even burning for biochar.

We had lots of ash throughout most of the test with periods of higher ash and periods of lower ash but it seemed to almost always be present to some extent. We checked the biochar during the test and it seemed to be looking very good however when we checked it again in just about 10 minutes later, the biochar seemed much much worse as if it was less than 50% decently charred. Seemed like efforts of moving the blower into a lower position did not help with making more even biochar throughout. Saw some smoke coming from hopper area and eventually dealt with issues with fire going out and trying to relight it but it didn't really work well. New motor seemed to work very well.

Next test would be focused on woodchips as fuel and would be conducted without Austin.

Hot Test #55 - 2/3/22

Objective: To run a wood chip hot test on the new motor.

There were multiple attempts to light the wood chips with lighter fluid, paper, and bark. It was noted that the bark was pretty flammable but burned too quickly and not steadily enough, unlike the paper. Turning on the auger seemed to help by getting new fuel into the combustion chamber. Additionally, we were unable to reach any kind of clean burn. There was a lot of ash and smoke throughout the entire test (mostly from the chimney with some from the juncture between the chimney and combustion chamber). The smoke problem we tried to solve by upping the primaries and secondaries but to no avail.
Auger was used almost exclusively to get more material to the combustion chamber and to get the flame there: the burning was a bit behind the chamber.
We tried to relight 5-6 times.
Even with adjustments though, the temperature eventually dropped and continued to drop with more adjustments and we were unable to achieve a steady state.
At the end however, we ramped up the primaries to 7000 which seemed to get the flames very consistent and to an acceptable level. They were then ramped down to 6000 to see what the threshold for fan speed and consistent flames were. This worked until the auger was turned on and the flames died out.

The main issue seemed to be the woodchips not being dried out enough and then smothering the flame either physically or with steam (they still looked pretty wet when loading them into the trash can for weighing). Even after being left out to dry, only the topmost layer (<½ inch) was dry. The chips were then spread as thin as possible on the tarp to dry.

Hot Test #56 - 2/4/22

Objective: To be able to light wood chips from the previous hot test.

The previous hot test there was difficulty in lighting the damp wood chips. In today's test different tactics were tried to see if the media could be lit in this condition. Since wood chips were left in the system the wood chips used were from the previous day.

A bucket of wood chips was prepared and weighed in case of more being needed as the experiment continued. Even with them being put out in an even thinner layer over night, the wood chips were still moist. During the lights the primaries were set at 7000, and the secondaries 2000.

Throughout the process the system was relit a total of four times; the last and final attempt was the most successful. The process that was used was four handfuls of dry wood chips, paper bag from trader joes, eucalyptus tree bark, light fluid, and a torch. This change in process may not have led to the longevity of this fire, more than likely the slightly dryer media from the previous lighting attempts.

There was large amounts of thick white smoke coming from the chimney and cracks of the system. The excess smoke was believed to be the result of moisture from the moisture from the wood chips being released. Smoke at various times was witnessed escaping even from the barrel.

After the fourth relight the temperature was able to rise, but was very slow going. As soon as the auger was turned on the fire immediately became anemic and the auger was stopped. Upon observations from physically touching the system, overall the system was mostly cold. The underside had the most warmth. Laterally the difference was noticeable with the left side being cold and the right side having some warmth.

Once the temperature seemed to consistently rise once again the auger was turned on and was maintained with the primaries 5000 and secondaries at 7500. For about 10 minutes things were going well, however a hole developed in the hopper on the left side about 15.7 kg of wood chips were added to the hopper just enough to cover the hole. With the wood chips there seems a tendency to not drop into the machine evenly and more care will be needed in the future.

The primaries and secondaries were upped to 8700 in an attempt to revive the fire. This was unsuccessful and the hot test was ended. Final observations: the wood chips that were able to pass through the system were still wet and upon disengaging the fans the fan on the C coupler was not turning. Upon further inspection this was due to the fan not being connected appropriately, it is uncertain if this was the case for the entire test.

Hot Test #56 - 2/4/22

Objective: To run a hot test with wood chips that had been dried out through the weekend.

This day started out with getting wood chips from the previous hot test out of the reactor. This was accomplished by initially running the auger backwards. Afterwards backwards and forwards was done to unstick the media and most of the wood chips were able to be pushed out the exit.

During the hot test the initial lighting was unsuccessful, the need for more fuel was needed. In the future the auger will run a bit longer. With the second attempt at light was successful a solid flame was established. The entire time the system was running there were large plums of thick white smoke. The reading on the temperature gauges were going up and down as well. The reason is believed to be due to the moisture of the wood chips. With each rotation and dump of the new wood chips in the combustion chamber there was additional moisture being added and dampening of the flame.

As the wood chips ran through the system there was not a lot of char, however the wood chips were thoroughly dry. An observation that was noticed was that not a lot of wood chips were coming out the same rate in which they were being put in. Overall this created a few problems for us.

One big problem was that the auger would get stuck and pop the breaker. There needed to be a continuous resetting of the breaker. The auger would need to be reversed before going forward once again. The wood chips were accumulating in the middle of the system, causing the auger to stick and not being charred evenly. After discussion we believe the problem is due to damp media. The following solutions will be explored: black trash bags are covering the raw wood chips overnight to prevent condensation from developing on them creating excess moisture. When the initial ignition is started more patience is needed in order to guarantee that the system is getting hot enough. Not only char the wood chips more effectively, but also combat sticking of the auger, as well as, not having the fire be greatly affected by moisture that maybe still on the media.

Hot Test #58 - 2/8/22

Objective today was to be a bit more patient – let the reactor warm up a bit before starting the auger. The hypothesis is that with the reactor sufficiently warmed up, it should admit wetter biomass stably, without crashing the auger.

Result: We were able to keep the reactor hot for a while with relatively dry biomass. Primary air was around 3500 -> 4000. Secondary 5000 -> 7000. Dry wood chips burned quite cleanly. When we switched to wet wood chips from inside the shed, there was a marked increase in the

smoke from the chimney. Attempts were made to titrate the secondary air but the smoke persisted. Eventually the flame near the reaction zone was replaced by unreacted / partially reacted wood chips, and the auger jammed. Reaction was stopped at that point.

Observations:

During start-up, it is a fine balance when to turn the auger on and when to stop. The key is to observe the flaming front near the combustion zone. When smoke starts emerging from the cracks near the hopper as well as the hopper proper, it is often a sign that we should move the auger. When the chimney becomes less clear and more smoky, it is often a sign that the auger should stop.

Wetter wood chips had problem flowing down the hopper and needed prodding with a metal stick. Normally it is a sign to prod when the hopper starts to smoke, indicating a widening gap underneath. When we feed too much wet wood chips (~20 kg+), it becomes difficult to prod through.

When the auger circuit breaker trips sometimes it is not necessary to reverse it. Simply flip the circuit breaker and often the auger will continue.

Hot Test #59 - 2/9/22

Objective: 1. To try the blowers out at a lower rpm and be more patient with the fire start up in order to eliminate ash emissions from chimney. 2. Provide initial fuel with dry wood chips, then add “wet” wood chips to see if the temperature of the system could be contained at maximum blower RPM beyond what was attempted yesterday.

Results: 1. Ash was reduced but not eliminated at lower blower RPMs. 2. Even blowers running at 8700 was insufficient to overcome the smoke from moisture of wet biomass. However, between auger getting stuck and smoky spells, we managed to achieve somewhat of a steady state.

The initial set-up of this test was to keep track of the moisture of the wood chips used in the test. The first and second batch were dry wood chips to establish a good flame. To ensure that the flame was strong the blowers were started at 2000/3000 (which proved somewhat insufficient)

and 2500/4000, care was taken to move the media so there was enough fuel before lighting. Once the fuel was lit, further patience in not moving the auger until the flame was well established. The time this took was ~ 20 minutes before the auger was moved continuously.

A lesson that was learned while establishing the flame is the following: 1. When the smoke is coming out of the hopper (with dry freshly dumped wood chips) this is an indication that the flame is moving down the hopper. In order to remedy this one must move the auger forward. 2. When there is thick white smoke coming out of the chimney this is an indication that the flame is dying out. To fix this while establishing a flame stopping the auger is a good fix. If this is occurring in the middle of a run, the preferred tactic is to increase the blower rpms. This will increase the strength of the flame without slowing down production.

Once the flames were established wet media was added to the hopper. Unfortunately the moisture meter was not working properly and the measurement of moisture was unavailable. When the wet media was added there was a noticeable decrease in the flame strength, however with nurturing the flame (increase blowers, start or stopping of the auger) this was able to be remedied.

We did achieve steady state for a short amount of time. The results from the dry wood chips in the beginning was a mixed char, but was dry. However, the more damp wood chips did get hot, but were still damp. This shows that there is a need for a dryer for wet media. This is currently in the works.

Problems that occured today, as the run continued the auger shut down multiple times and had to be restarted via flipping of the breaker. When this action was unsustainable due to the auger sticking, the auger had to be moved backwards, before being moved forwards again. “Holes” within the media contained in the hopper would develop. An indication that this was occurring was excess smoke coming from the hopper in the middle of the run. This was remedied by taking a metal shaft and poking the wood chips in the hopper. Once the hole locations were found, then covering them. The holes mostly appeared on the right side of the hopper, but a couple of times occurred on the left. Running the blowers at high rpms did result in embers coming out of the system. This unfortunately caused one of the embers to land on the head of an intern. This resulted in the ember burning a hole through the cap, burning some of their hair off. In the future lower rpms of the blowers may prevent this problem.

Big takeaways from today, the blower location will be changed for the next test. The reason for this is the current location of the primary blowers is thought to be providing air in the superficial layer of the biomass, resulting in uneven charring even in the first batch of dry biomass with good reaction/flame. By moving it to the underside of the system hopefully will result in the flames ability to have more coverage. This will enable us to have a more homogenous char with the wood chips.

Hot Test # 60- 2/11/22

Objective: Test the primary blowers at B9 and B7, to attempt to achieve a homogenous char.

Result: Char was still not very homogeneous. It was a bit difficult to start from the B7/B9 position - just had to be patient before turning the auger too quickly which would quench the flame.

The initial start up of the system today was not smooth. The PLC had to be turned off and on a couple of times before the auger started working successfully. Before the restarts, the fans were working just fine, but the auger was not. The only observation that was out of the ordinary is that the grounding wire belonging to the motor was not securely fastened to the structure. It is not believed that this was the cause.

The ignition of the fire required a few relights. The first attempt's lack of success was due to not having enough fuel. The flame seemed to be continually smothered. This happened after moving the auger forward, the wood chips would fall on top of the flames, weakening them. After seeing large plums of thick white smoke the fire seemed to once again have died. At this point we walked away from the system to meet our neighbors in the work space next door. After about 5 minutes we returned to once again a flame. Lesson that was learned is to be more patient. The fire was then babysat with the starting and stopping of the auger and blower adjustments to keep the fire viable. Blower adjustments included dialing back the blowers they were believed to be diluting the hot gas.

While observing the flame several interesting observations were made: 1. The flame seemed to favor the left side. A hypothesis for the reasoning behind this phenomenon was, there tends to be more fuel on the left side. Since the locations of the blowers were moved to the underside of the system the side with less biomass allows for more oxygen flow, while the right side is more impeded. 2. While the flame was all the way across the system and observation of flame, black smoke, then the black smoke disappearing quickly. This is an indication of the burning off of volatiles. 3. Two different colored flames were observed for a short time. The “lower” flame was orange, the primary combustion. Up above at the entrance of the chimney was a bluish white flame. This was the second combustion, the blue color is due to the syngas combustion. This blue flame would disappear when there was smoke.

As the hot test was run the auger would continuously shut down. This required it to be run backward for ~10-20 seconds then sent forward again. The motor was marked to see if there was a specific spot the stopping would occur. This was not the case, during the shutdown process the auger was run until there were very little wood chips in the system. Though there was on scrap sound and occasional groans, there was no stopping. Due to this, it is thought that the cause of the auger stopping may be two reasons: 1. When observing the output wood chips they were still wet. The wet media may have been causing the auger to get stuck and shut off. 2. We purposefully did not load the system to be completely full. Due to the air gaps in the system not all of the wood chips were moving forward, some were falling backwards. This may have caused the auger to stick as well.

Notable observation: the left side seemed to be more charred than the right side. When removing the primary blowers there was a stack of charred and ashed media. So the air from the primary blowers was being preheated before going into the system. After removing the primary blowers from this location be sure to cap. There were some hot woodchips escaping and may cause a fire hazard if not done.

At the end of the reaction, char and ash were observed at the bottom of the primary air pipes. We suspect that whatever wood chips that fell into the pipe probably combusted there, preheating the air as it enters into the reactor. This is an advantage.

One challenging part is that the Berkeley shed wood chips contain significant fines, which may have impeded air from distributing far into the reactor, thereby resulting in inhomogeneous char.

Hot Test # 61- 2/12/22

Goal: (a) Do the same test as yesterday, but pile the hopper higher. See if the fluid pressure will force solids through without jamming the auger. (b) Test the “park chips” pile gathered from Richmond Park to assess its flowability.

Result: (a) Wetter biomass (in the morning) resulted in smoky spells and intermittent auger motion (we stopped the auger periodically while waiting for smoke to clear). But generally the reaction proceeded well with only two short auger circuit breaker trips. Steady state was achieved. Output char was partially charred (around 60%). (b) Park chips were significantly drier and we didn’t observe the smoky spells. The output char was also more homogeneous (around 80% charred).

Other observations - For wet wood chips, there may be two potential ways of control. First is by modulating the auger speed – that is, whenever there is significant smoke or whenever flame disappears from the viewing port / crack, stop the auger till the chimney burns clearly again. Second, which we attempted today but are unsure if successful, is to maintain constant auger speed, but to modulate the primary/secondary air. This could be done as during the smoky period there tends to be very little ash.

Our control strategy today is to start hot (6000/6000 air) and then gradually reduce. The hot ash emerging from the chimney compels us to reduce air blower RPM. But if the RPM is too low (around 1500 primary for park wood chips and 2500 primary for the slightly wetter first batch of sun-dried wood from Berkeley shed), then the reaction becomes anemic and sometimes prone to smoke. There is a fine balance between the two.

At the end, when the oil drum is emptied, there was significant smoke (reaction) still occurring inside the oil drum, probably because air can freely enter due to the empty reactor body.

Hot Test # 62- 4/1/22

Objective: To set a base point for rice hulls in the new configuration for rice hulls. Also compare our tests to India to determine if there is a difference in body shape of system in effectiveness and increase in problems.

The initial igniting process was very anemic and had to be re-done. Since the rice hulls do not ignite easily the fire must be ran very hot initially then the rice hulls added in. This was accomplished by adding one trash can full of wood chips then starting the fire with lighter fluid, a propane torch, and a bernzomatic torch. This method was successful and our rice hulls were able to be ignited. The blowers were at 4000 primary and 5000 secondary.

As the test ran smoke escaped through the hopper and cracks through out the system as well as the chimney. Due to the proximity of the combustion chamber to the hopper. A lot of diligence was needed to run this test. There was a priority to prod the hopper to find any gaps in the media. There was a lot of bridging today, an indication that this was occurring was excess white smoke coming from the hopper, followed by it turning a pale-yellow color. There was a great need for rice hulls to be continuously replenished to guarantee that oxygen would be cut off at the entrance and the hopper would not ignite.

During the test there was ash, then eventually hot embers, followed by flames coming from the cracks of the hopper mostly the area were the hopper and combustion chamber meet facing the sky.

As the test continued to get very hot there was an attempt to decrease it by lowering the blowers to 3000/4000. After this was done flames started coming out of the system cracks in 3 places:

When the blowers were raised back to 4000/5000 the flames eventually went out.

The flame was very strong once steady state was reached, and at the end of the run the char looked really homogenized. However due to the fire running so hot added complications. A port was opened on the left side which the flame jumped out and the wires of Blower A caught fire and the entire system shut down. We immediately took the blowers off as quickly as possible and plugged the ports.

Initially the PLC was not responding after many attempts to turn it back on. The primary blower that was damaged was to be unplugged. Initially the secondary blower was unplugged not the needed one. The PLC was able to be ran with the blower breaker turned off. When the correction was made and Blower A was disconnected. The PLC was able to work with the blower breaker turned on.