Biomass Reactor

Gas Cylinder With Can Test #3

Author	Date of Last Edit & Publish	Document Version
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1.0 Introduction

A similar experiment to “Gas Cyl With Can Test 2” was conducted with some small, easily implemented changes made to improve the functionality of the system and to gather some useful data for use in future experiments.

The experiment ultimately failed to achieve a complete feedstock to charcoal reaction. Some evidence of partial charring was present, and a dark liquid was collected from the “cyclone filter”. Further analysis is needed to say definitively what the causes of failure were but the intuitively obvious areas to begin investigation include:-

- Reactor temperature
- Feedstock moisture content

(in no particular order)

1.1 Goals for This Report

- Discern the reasons for failure and to make implementable recommendations to overcome problems found.
- Evaluate the data collected, identify problems in the conducted method and make recommendations for improved data collection in the future.

2.0 Changes made to the system for Experiment #3

There were some problems identified in Experiment #2 with regards to heat loss and flame temperature. Small and cheap physical alterations were made.

In Experiment #2, the foil covered wooden board used as a cover was heated significantly, to the point of destruction. To prevent this, in Experiment #3, saucepans (Fig 2.1) were filled with water and placed on top of the board in an effort to limit the maximum heat build-up within the wood.

Fig 2.1 Photograph showing the physical state of the reactor after the experiment was completed

2.1 Physical Changes to Experiment Setup

Physical changes were made to increase overall reactor temperature and further stifle heat loss.

2.1.1 Exhaust Location

Exhaust for the post combustion gases was at the rear of the reactor, in Experiment #2. It was suspected that the residence time of these hot gases could be increased by changing the exhaust size and location, allowing more heat to transfer into the reactor vessel before being vented to the atmosphere.

The original exhaust was a single 60mm diameter cut-out at the rear, 12 o'clock. The exhausts for this experiment, Experiment #3, were two 25mm diameter cut-outs at the 9 and 3 o'clock positions of the gas cylinder and two partial 60mm diameter cut-outs at the 5 and 7 o'clock positions.

Post combustion gases were also able to escape through the gap between the gas cylinder and corresponding cut-out in the wooden board. The gap was crudely sealed by excess tinfoil crushing into shape.

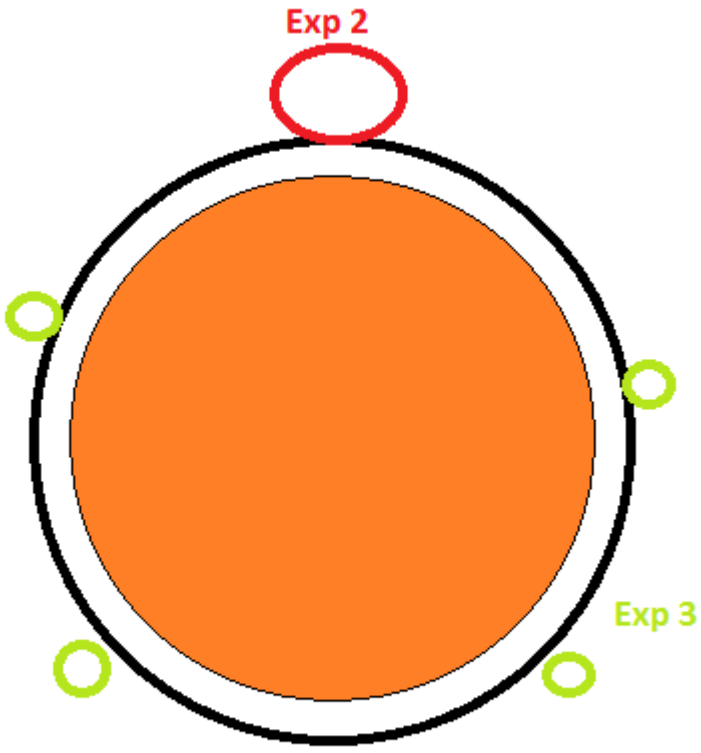

Fig 2.2 Diagram showing the relative positions of the exhaust holes in Experiment #2 and Experiment #3

2.1.1 Air Intakes

All experiments to date have been unable to utilize a maximum flow rate of fuel available from its source, is this case the source is a standard 15 kg bottle of Butane regulated to a maximum output pressure of 7 bar (unit).

More air inlets were drilled at the base of the exterior can.

2.2 Changes Made for Data Collection

Previous experiments did not provide any useful data or numbers for the purpose of making calculations. More effort is needed to standardise the process in order to gain reliable knowledge of fuel consumption and efficiency of the mass conversion (mass to charcoal) process.

- The feedstock is to be mostly the same material and prepared by cutting it into regular shapes and sizes
- The feedstock can is to be filled in a regular pattern.
- The feedstock is to be weighed before and after to measure mass transfer
- One of the saucepans used for regulating the wood temperature contains a fixed volume of environment temperature tap water and has its temperature monitored at regular intervals until it reaches 50ºC. This data can be used to calculate an approximate total rate of heat lost through the wood.

3.0 Logged Timeline of Events

(See separate table for recorded water temperatures)

0h 0m	• Started with flame at highest setting – Snuffed because of low oxygen ○ Added 7 more 7mm holes to air inlets
5m	• Visible steam from fibreglass insulation (surrounding exterior
14m	• Flame snuffed. Reduced fuel pressure slightly • Vapour escaping from yellow cylinder
33m	• Fuel pressure dropping. Reopened to highest setting • Rear pan water starting to vapour
1h 11m	• Feedstock can exhaust is hot to touch
1h 32m	• Oil (?) in jar. Dark liquid. Table spoon? • Slow but regular drips
1h 51m	• Wooden board is starting to fail (Fig 3.1) ○ The board cannot support the bending moment caused by its own weight. A piece of 25mm square box section was clamped at two points along its edge to provide support.
2h 21m	• Board smells charring/smokey
2h 32m	• Hose is cold and the oil has stopped flowing. Tried increasing the flame slightly.
2h 39m	• Oil has started again • Hose is warm again
2h 58m	• “First visible fumes are with oil” (sic) (?)
3h 07m	• Smokey smell is stronger – Not nice
3h 38m	• Oil substance is slowing
3h 47m	• Oil is slower but regular
3h 54m	• 40 drops per minute
4h 08m	• Board is glowing red hot in places (Fig 3.2) • Poured some water on it to cool
5h 02m	• Fuel is at maximum available pressure, cylinder is beginning to empty.
5h 23m	• No more signs of oil drips • Some light fumes • Hose is cold
5h 35m	• Experiment stopped. • No more signs of oil production and low available fuel.

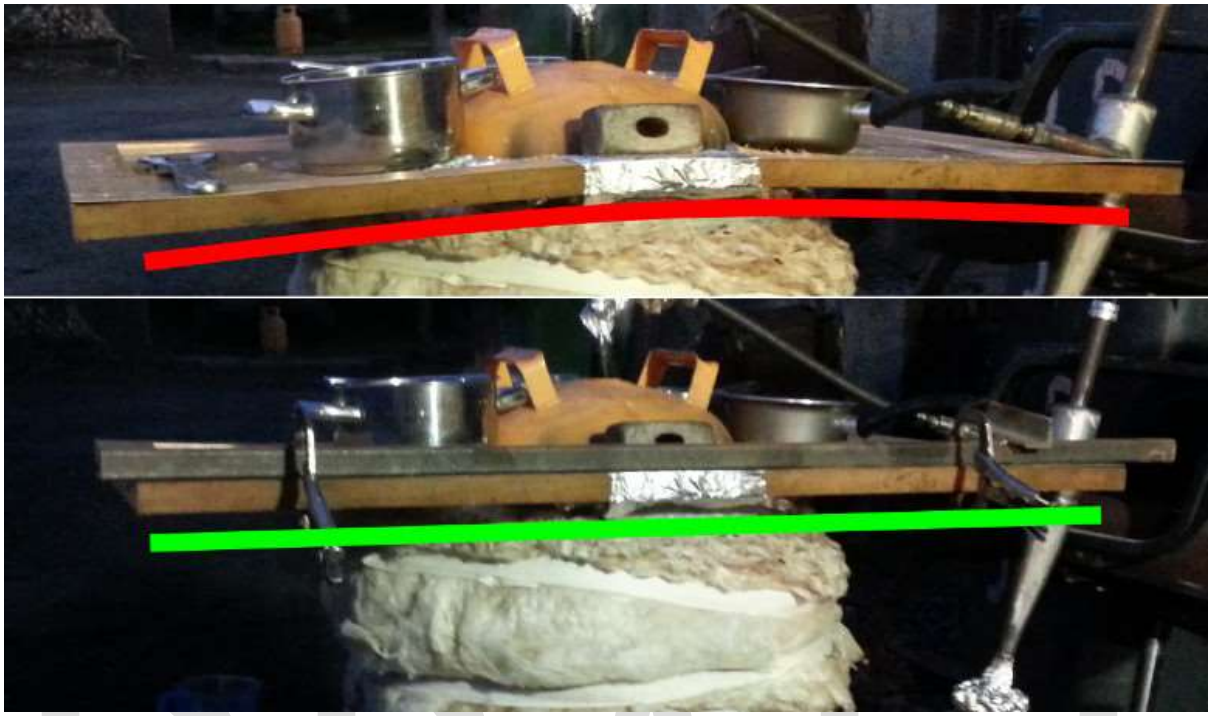

Fig 3.1 Photograph showing the failure of the wooden board (top image) and the solution to extend its lifetime (bottom image)

Fig 3.2 Photograph showing the cover board glowing red hot before being extinguished with water

4.0 Results

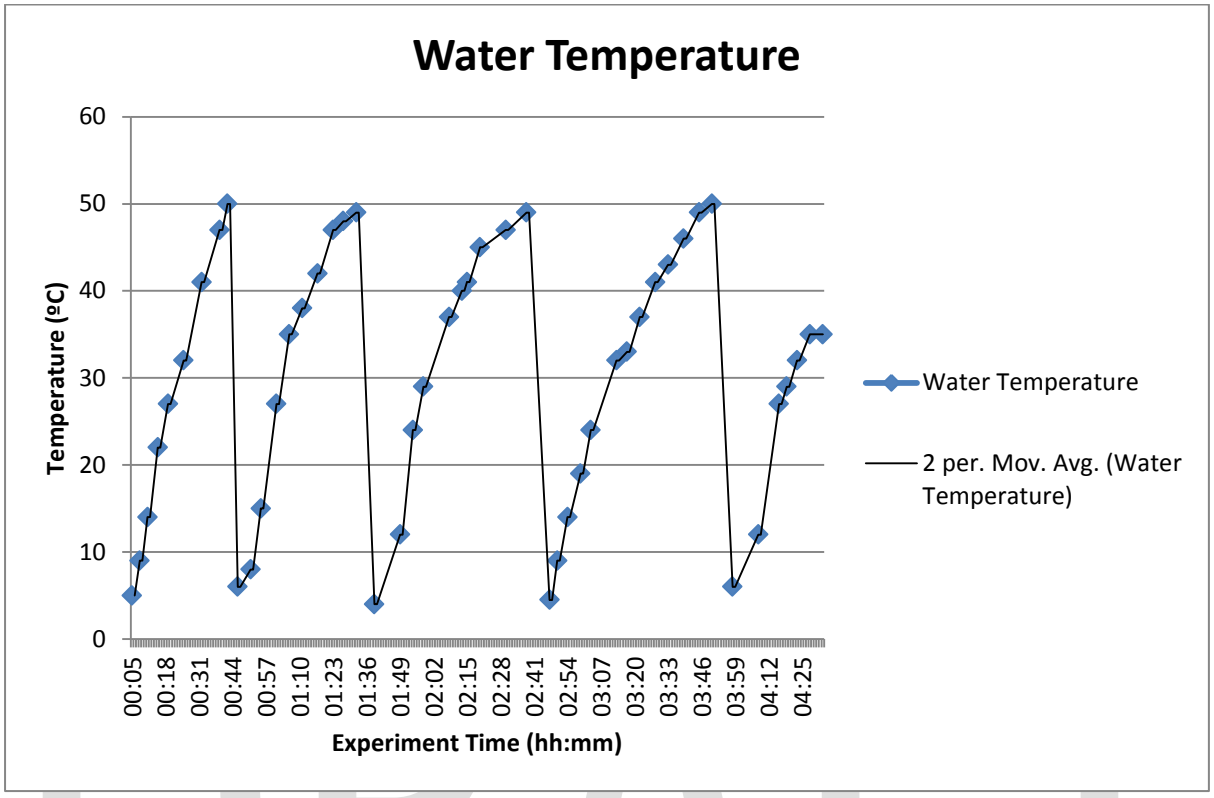

Fig 4.1 Chart showing measurements of water temperatures against the experiment time

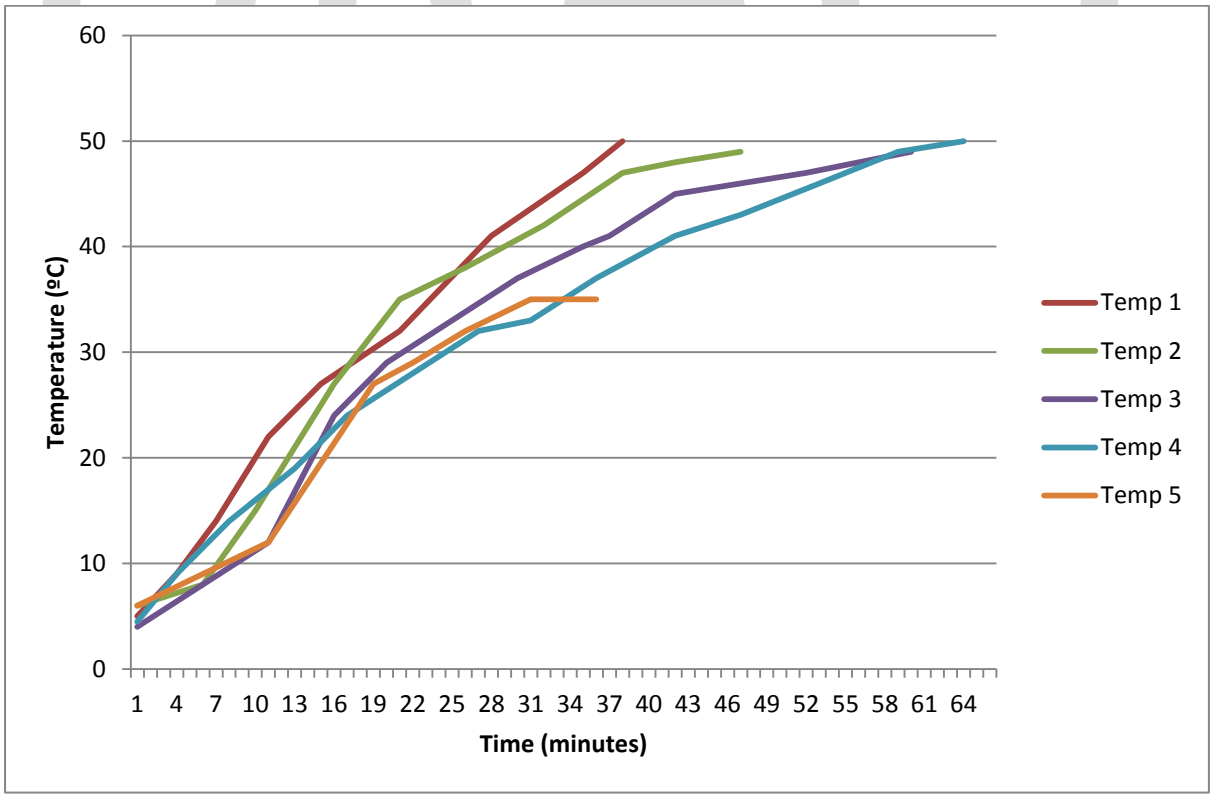

Fig 4.2 Chart showing all 5 plotted on top of each other for comparison.

5.0 Analysis & Discussion

- Reactor temperature
    - Pyrolysis reaction occurs in the region of 449ºC to 510ºC [1]. An incomplete reaction indicates that the feedstock did not reach a temperature, throughout, within this boundary for long enough.
    - Inadequate experiment design means lots of heat is lost to the environment. An attempt was made to measure the rate of heat loss from the surface of the wooden top.
    - Inadequate experiment design means that the combustion area was uncontrolled. Flame, intensity and alignment, was monitored and approximated by a human with the goals:
        - Point flame at the centre of the cylinder's base.
        - Regulate fuel (Butane) into the combustion chamber at the maximum rate possible without the flame being asphyxiated.
- Feedstock moisture content
    - The material used as feedstock had an unmeasured moisture content and was described as "very damp"
    - Weighing the feedstock can before and after the experiment indicated that approximately 1 kg of unspecified product had been removed.
    - Opening the feedstock can after the experiment (after cooling) revealed a significant presence of moisture inside – visible droplets on interior surface
        - Leaving the feedstock can opened in a warm and dry room for 7 days resulting in a further mass reduction of 400 grams.

Fig 4.2 - As the experiment progresses, the rate at which the water heats up decreases (Temp 1 being the first and earliest pot of water, Temp 5 being the latest and final pot of water). This shows that the heat transfer rate to the pot reduced over time, (Is this a case of the fuel pressure, and therefore flame temperature, gradually reducing?)

6.0 Conclusions

7.0 References

1. http://www.uaex.edu/publications/PDF/FSA-1052.pdf - FSA1052-PD-6-09N - University of Arkansas – Division of Agriculture