Questions to answer: [Aim for 225 words per section] [Also work on your slides]

1. What is the problem? [Kabir]

Anaerobic digestion is a method that helps convert organic load into a mixture gas mainly composed of methane (CH4) and carbon dioxide (CO2) through the action of bacteria. Anaerobic Digesters have been traditionally used for waste treatment since the produced methane is a useful source of energy. Anaerobic digesters are considered a complex system which usually undergoes failure. It is mostly due to one of the several problems such as high maintenance costs and the constant requirement of monitoring the foaming of the digest. Some foam is always present in anaerobic digesters which is a result of methane production in an anaerobic process. Generally, acids produced during the process lower the surface tension of an anaerobic digester. This allows for greater quantities of gas to be trapped at the surface of the digest which would lead to loss of several important gases. The foam can be controlled if monitored and seen at the right time during the process. The process is mainly used for the production of biogas, which is mostly methane gas. Methane, in a purer form, is known as natural gas when piped into our homes and businesses, so biogas can be used as an energy source. Hence, this process is of great importance.So, our system will be useful in testing the digestate during all stages of Anaerobic digestion in a very efficient manner.

1. How are we solving the problem with our device? [Ritchie]

Our team has designed a device to monitor the foaming characteristics and colour of the digestate. The device takes in a sample of the Digestate from the tank and shows the user a picture of the digestate sample and the thickness of the foam.

1. How a user would operate the device

-Our AD sample tester is a portable cylindrical device, it has a handle which allows the user to move the device around

-at the top of the device, there’s a threaded tube which allows the device to be fastened to the tap

-First, the user should securely fasten the device onto the tap. Then turn on the power and follow the instructions on the interface to go through the testing process

- after the test is complete, the user can clean the device

- First, switch the power off, then remove the device from the tap

- open the cover at the bottom to let the liquid out

-Finally, flush the device from the top to bottom with cleaning agent, then rinse it with water in a similar way

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1. Explain the functionalities of each part
   1. User interface (phone) [John]

There is a power on switch for the device, which acts as our reliable physical stop/ start function. There will also be an LED turning on to indicate the device is powered, hence the analysis preparations can begin.

Using a web app as the main point of control, the device is able to be remotely controlled using a mobile phone. By utilising a local area network wifi, live streaming of data is available over any devices that has access to a web browser. The layout of the web-app follows the flow of operation of the user, with options to return to their previous selection.

Pressing ‘Enter Sampling’ allows the user to prepare an appropriate sample and the environment needed for the testing. It then prompts the user to fill the flask to an appropriate mass, using the onboard scale and limit checking system. The user can change the rotation of the servo, and show the camera view. If the tilt, acceleration or velocity of the inertial measurement unit is too high, an error message will be displayed. If all conditions are met, the ‘Start Analysis’ button will perform image processing to output digestate colour and the associated foam length. Lastly, a download report button will allow the user to download a pdf file containing the results.

* 1. Load cell, Servo [Jason]

In the proof of concept, the implementation of a servomotor was intended to allow the rotation of the vial containing the digestate and foam.

**[Gif of servomotor moving and Gif of servomotor stuttering wait for Ling, so prepare the code]**

By utilizing hardware based timed sampling, accurate rotational positioning was achieved, and jittering, which software based introduced, was eliminated

**[Foam image at different perspectives? Think again, just grab some foam images of different characteristics…]**

This enables the Pi-camera to capture images at multiple rotational positions to ensure consistent digestate and foam levels, and by extension, improves analysis.

However, from empirical testing, it was observed that in most situations, a significant difference in height was not detected. Hence the servomotor was not implemented. However, to combat cases of significant foam height variance, a secondary camera has been installed to compensate for this.

**[Diagram of tap and CAD design, like Ritchie’s is okay]**

In addition, with how the device works, by attaching itself to the reactor’s straight tap that dispenses the digestate, it minimizes variation in foam height and encourages flatness.

**[Photo of the CAD Design wait for a 2nd camera to be in the CAD]**

Therefore, in our final proposed mechanical design, a servomotor was not implemented. This provides a more robust design as lack of moving components results in increased longevity of the device and reduced maintenance.

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**[Photo of load cell in proof-of-concept and in the CAD?]**

The load cell permits weight measurement of the digestate. Weight from the digestate is converted to a downwards force, which apply small amounts of tension and compression at the top and bottom of the load cell. This translates to minute changes in resistance, that when implemented into a Wheatstone bridge, will produce a measured voltage. This signal after calibration, consequently, outputs the measured weight of the digestate.

* 1. Camera, pi computer [Ling]

The design comes equipped with a raspberry pi which serves as the brain of the device. It can directly communicate with our web app and allow the user to control various device functions remotely and intuitaively.

The raspberry pi Model 4B is chosen for this purpose as it is computationally powerful and would reliably execute any user inputs with little delay while also being extremely light weight at 50 grams.

To help analyze the digestate, we utilize the light-weight pi camera which will be directly connected to raspberry pi module and provide live high resolution images of the extracted digestate.

Firstly, by making effective use of efficient pre-existing AI methods, the background is removed to help reduce background interference during image analysis, greatly increasing the analysis accuracy.

Then by leveraging various computer vision techniques and utilizing our custom trained foam detection neural network, crucial characteristics of the digestate are detected, including, but not limited to region of foam, amount of foam, colour of foam, and the colour and amount of the digestate liquid.

These information are displayed in an intuitive way to the user through the mobile web app, where annotations of images taken directly from the pi camera can be viewed.

1. How the future device relates to the proof of concept? [Xavier]

Hi, my name is Xavier and I will show you through the main strengths of our design, and discuss modifications from our proof of concept.

Our design was created to be lightweight, portable, robust, and as safe as possible for our customers to use.

Let’s dive in.

\*Many competitor products involve removing the digestate from the reactors, placing this into some temporary capsule, and then transporting this digestate to the testing instrument. \*This is poor practice because it is slow, may result in a loss of temperature and digestate state change, and also exposes employees to potential spillages, which can carry hazardous gases and pathogens.

**\***Our design has flipped this, and instead we bring our instrument to the digestate and remove required human and digestate interaction. \*From the get go, this has two major benefits, being:

* Time saved for workers from not having to move the digestate itself; and
* Reduction in the risks of spills occurring.

So, how is this achieved?\*

We have done this through designing our unit so that it is screwed into bioreactor release valves that are required at customer sites. \*Valve heads will be modular and we will customise to our client needs, meaning the instrument can work at any customer site, all over the world.

\*For the general design, let’s highlight the main value adds to our customers:

* The unit is made of a Lightweight, but sturdy hard plastic outer shell
* there is a Comfortable rubber grip for easy transporting
* The instrument is well-sized, with a at 20cm round diameter, meaning it is small and compact
* The Total unit height is 24 cm, meaning it is easy to store on workplace shelves.
* It has an expected manufactured and assembled weight of 2.5kg, perfect for carrying purposes
* Battery operated, with an expected 24 hours of live testing before requiring recharging
* Designed for easy assembly and servicing

\*As discussed previously, the design has two solenoid valves on either end of the central glass vial unit that control the fluid entering and exiting. \*This allows fluid to be tapped directly from bioreactors, without any user intervention in between, and is tested immediately. \*The glass uses the same concept as double-glazed windows, with a thick, outer layer, and a thin, inner layer of glass with a sealed gap of air between. At 100mL of digestate in the vial, the fluid is halfway up the container \*The double glazed effect serves to insulate the digestate and maintain it in the mesophilic state during testing, and also serves to add extra strength to the glass container.

Now that digestate is in the container, how do we get it out?

\*Compared to our competitors, the removal of tested digestate is simple, fast, and above all safe. This is accomplished through a simple, three stage process. \*First, the user attaches a digestate waste bag, a product that we will design and sell to customers, to the bottom of the unit. \*Next, the user will select the “remove waste” button after testing has finished, and the contents will be emptied out. \*Finally, the user seals the bag, removes it from the container, and disposes of it into an appropriate hazardous waste bin.

\*On top of added safety and time-saving benefits, the other major benefits of our product design are that:

* \*Compared to standard tabletop designs, it does not need a flat surface to rest on;
* \*Cannot be interrupted from knocks or movement, as it is screwed into place;
* \*Does not require any heating and only requires insulation, as the digestate is immediately tested after it leaves the reactor, reducing costs;
* \*That it opens the opportunity for an ongoing sales relationship with the customer through the need to purchase digestate waste bags;
* \*And finally, there are minimal active and moving components, meaning that not only manufacturing, but also service costs will be reduced from the lack of components that are likely to break down.

Our design will save customers time, provide robust analysis, and be the safest product on the market.

**End recording**

**Now, moving on to how this design differs from the proof of concept.**

As mentioned previously, the servomotor used in the proof of concept did not make it into the final design. The advantage of having a rotating fluid container is that it reduces the risk of uneven foaming being undetected, as the camera would be able to survey angles at the same height.

Through empirical testing on the proof of concept, it was found that by surveying from two angles, both at 90 degrees from each other, this allowed sufficient information to accurately estimate the foam in the fluid container. Therefore, to reduce costs and expected mechanical failures in the field, the servomotor was replaced with a second camera at 90 degrees from the other. This ensures a robust, cheaper product that still gains the required information for diagnostic purposes.

Furthermore, as the risk of bumps or knocks actually moving the unit is very low, the IMU was not included in this design.

1. How do we stand out from the competition (**cost and specs need to be mentioned**)? [Xavier]