Sensor Development, Spring 2017

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May 19, 2017

Abstract

This semester, the Sensor Development subteam modified and recalibrated the fluidized bed solids concentration sensor. This sensor enabled the High Rate Sedimentation (HRS) team to determine the concentration of suspended clay particles in a running flocculation recirculator. In addition, the team fabricated a submersible sensor to determine the depth and concentration of the sludge layer in a sedimentation tank. This sensor functions in the same way as the fluidized bed solids concentration sensor, with the added characteristic that the photometer is fixed to the end of a PVC tube.

Introduction

The Sensor Development subteam was founded to assist the Anaerobic Fluidized Bed (AFB) Reactor and Upflow Anaerobic Sludge Blanket (UASB) wastewater subteams in improving the efficiency of their apparatus. The Fall 2016 Sensor Development subteam built and tested both a biogas sensor and a fluidized bed solids concentration sensor. This semester, the Sensor Development subteam shifted its focus to assisting the High Rate Sedimentation (HRS) subteam.

The Spring 2017 Sensor Development subteam focused on two projects. The first was a fluidized bed solids concentration sensor to measure clay particle concentrations in the high rate sedimentation (HRS) process. The fluidized bed solids concentration sensor was a modification of the sensor created in Fall 2016. In particular, the Sensor Development subteam created a calibration curve to determine the relationship between concentration and absorbance. This allows the HRS team to determine clay concentrations within their apparatus without removing water for sampling.

The second project was a submersible solids concentration sensor attached to the end of a PVC tube and designed to measure the height of the sludge blanket in the sedimentation tank. Like the previous sensors, the submersible sensor consists of a photosensor and an LED. This submersible sensor is lowered into the sedimentation tank through an aperture in the Honduras treatment plant with a 5.08 cm (2 in) diameter. Upon reaching the top of the sludge blanket, the submersible sensor will display a predetermined "dark voltage" reading because the density of the sludge blanket will prevent the photosensor from detecting any light from the LED. At this point, the known height of the sedimentation tank and the distance the tube has been lowered can be used to determine the depth of the sludge blanket.

Literature Review

A photosensor detects changes in light intensity by an emitted light source. The main components of the photosensor are: a light source, a phototransistor, an amplifier, and a signal converter (Figure 1). The light source transmits light to the phototransistor. The phototransistor then analyzes changes in illuminance as the concentration of clay particles is increased in fixed increments (Frigyes et al., 2017).

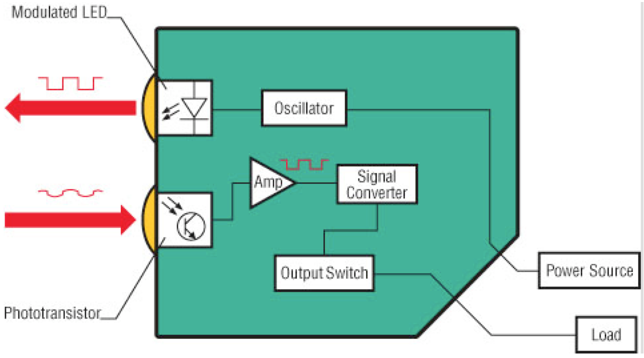

Figure 1: Electrical diagram of a typical photosensor. The main components include the phototransistor, LED light source, amplifier, and signal converter.

TEMT6000 Ambient Light Sensor

The specific photosensor that the fluidized bed solids concentration sensor utilized was the TEMT6000 Ambient Light Sensor made by SparkFun (Figure 2). The TEMT6000 Ambient Light Sensor is an NPN transistor (Figure 3). The phototransistor is only sensitive to the visible spectrum, wavelengths from 390 nm to 700 nm. The built fluidized bed solids concentration sensor worked with devices requiring 3.3 V to 5 V (Bartlett, 2016), and was attached to a 1 cm by 1 cm breadboard.

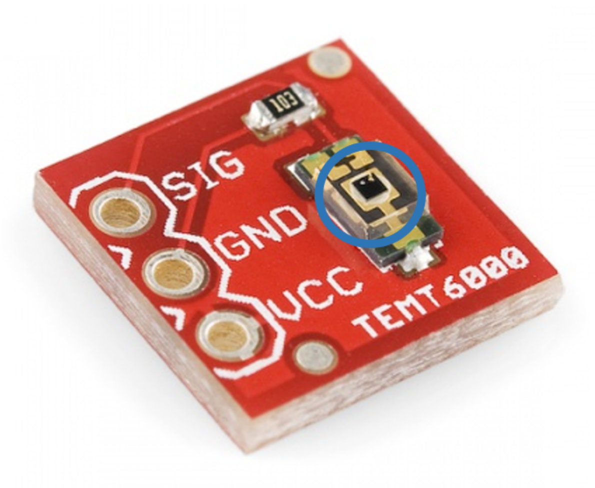

Figure 2: The TEMPT6000 breakout board contains three pins: SIG, GND, and VCC. SIG is the output voltage from the divider circuit. GND is the ground voltage in the circuit of 0 V. VCC is the collector voltage and should not exceed 6 V. Enclosed in the blue circle is the phototransistor, which detects light (Bartlett, 2016).

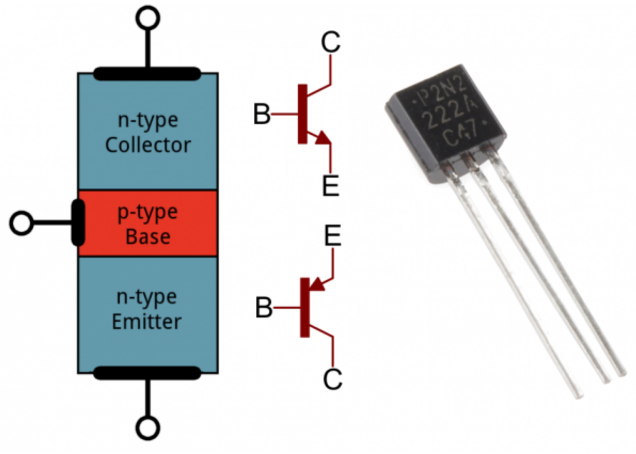

Figure 3: The TEMT6000 Ambient Light Sensor contains an NPN transistor, which passes electrons from the emitter to the collector. As the incoming light on the p-type Base increases, it allows more current to flow from the n-type Collector to the n-type Emitter (Bartlett, 2016).

Circuit Design

The TEMT6000 Ambient Light Sensor was designed in a voltage divider circuit, which changes a large voltage into a smaller voltage by adding resistors in series. The TEMT6000 phototransistor is one of the resistors in the series (Figure 4); as the light source changes, the output voltage from the divider circuit changes accordingly. The output voltage returned is recorded and used to analyze changes in light (Bartlett, 2016).

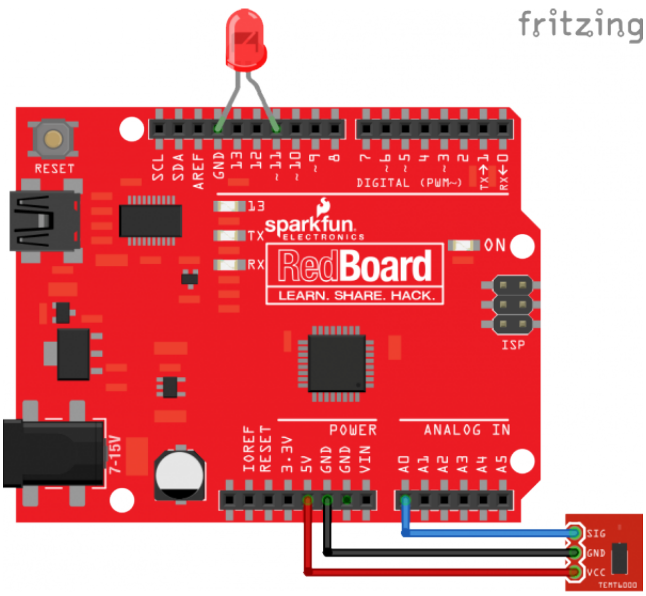

Figure 4: Diagram of the circuit setup. The TEMT6000 Ambient Light Sensor and LED light are attached to wires soldered to the circuit board (Bartlett, 2016).

Light Detection

The TEMT6000 Ambient Light Sensor measures illuminance in lux (lx). Illuminance is the total amount of visible light emitted by a light source, called luminous flux, with units of lumens (lm) over area (meters squared). As the illuminance increases, the phototransistor detects brighter light, and the current through the circuit increases. As the illuminance decreases, the light becomes dimmer, and the current decreases (Figure 5).

It is important to distinguish between light illuminance and light intensity. Light intensity is the absolute magnitude or "true brightness" of the light source, and is constant as long as the brightness of the LED light source is fixed. In contrast, illuminance is the apparent magnitude of brightness. Illuminance is dependent on the distance between the light source and sensor, which in this experiment is held constant. It is also dependent on the optical properties of the medium through which the light travels. Thus, changes in illuminance can be related to changes in clay concentration (Bartlett, 2016).

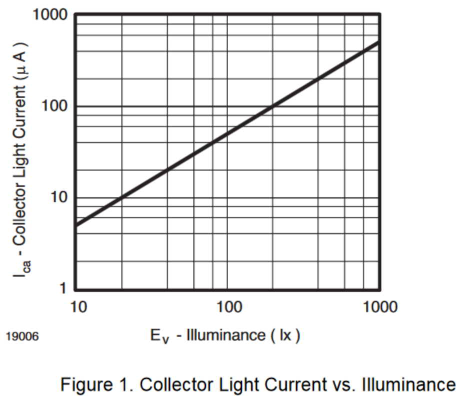

Figure 5: The graph shows the relationship between the current at the collector in microamperes and the illuminance in lux (Bartlett, 2016).

Beer-Lambert Law

Beer's Law was used to determine the solids concentration. Beer's Law relates the amount of light absorbed and scattered with the medium composition and the distance that the light travels. The law is expressed as the equation:

$$K_z = K_0 e^{-az} \tag{1}$$

K_z represents the amount of light (K) that reaches a certain depth, z. K_0 is the light at the surface of the medium, and a is the extinction coefficient, which is the amount of radiation absorbed (Allaby, 2007). Beer's Law establishes a linear relationship between the concentration of a species and its absorbance. The absorbance is typically calculated using transmittance, which is measured experimentally. In terms of concentration and absorbance, Beer's Law can also be expressed by the equation:

$$A = \epsilon \cdot b \cdot c \tag{2}$$

where A is the absorbance measured, ϵ is the wavelength-dependent molar absorptivity coefficient ($M^{-1} \cdot cm^{-1}$), b is the length of the path traveled by the light, and c is the concentration.

However, the linear relationship between concentration and absorbance established by Beer's Law can be affected by several factors. High concentrations of particulates can cause electrostatic interactions between particles, which may cause the absorptivity coefficients to deviate (Allaby, 2007). Another limitation to Beer's law is that it does not account for the scattering of light due to the particulates in solution.

Previous Work

Sensor Development Fall 2016

The Sensor Development subteam's role in the Anaerobic Fluidized Bed (AFB) subteam's experiments was to develop a sensor to measure the precise concentrations of granules in the AFB apparatus. To fabricate the sensor, a 2.54 cm outer diameter four-way PVC was cross-cut laterally with an LED light mounted on one end and a photosensor mounted on the other (Figure 6). The more particles between the light and photosensor, the lower the intensity of the light being received, and therefore the lower the ProCoDA voltage readings were (Figure 7, Figure 8). These readings were used to calculate the light absorbance. According to Beer's law, absorbance and concentration are directly proportional, and the idea was to plot calculated absorbance against the known concentration for a linear relationship.

However, running the tests revealed that even very small granule concentrations would drop readings close to the dark-voltage reading, which indicated that almost no light was able to pass though the tube. It was hypothesized that the intensity of light produced by the LED was too low for accurate readings (Pozo et al., 2016).

The photosensor was connected to an external circuit board (Figure 9). The circuit board contained ports for the LED and photosensor, and an ethernet cable, to connect the circuit board to a computer.

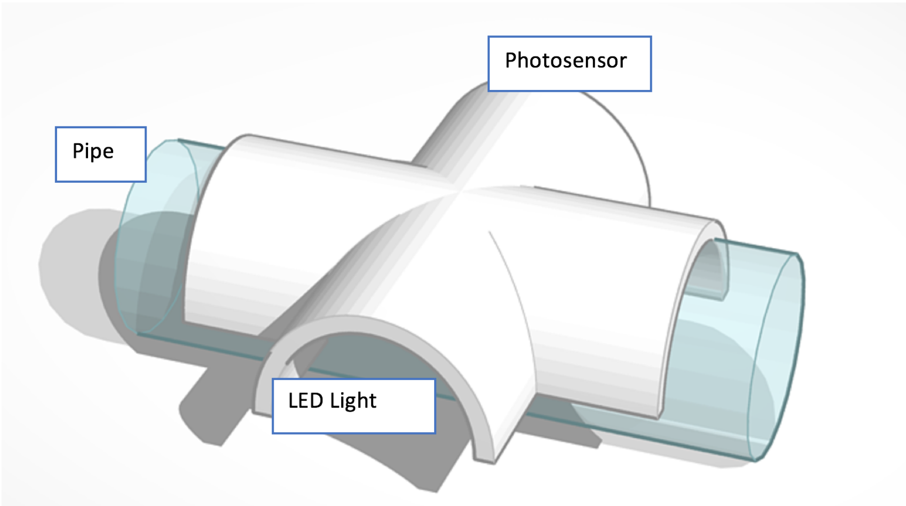

Figure 6: The 2.54 cm (1 in) outer diameter PVC cross was cut laterally, with the LED and photosensor affixed to opposite ends.

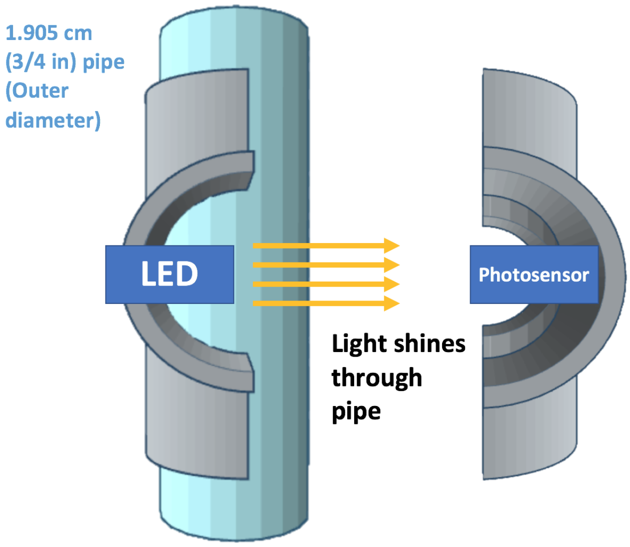

Figure 7: Light from the LED light passes through the pipe and is received by the phototransistor.

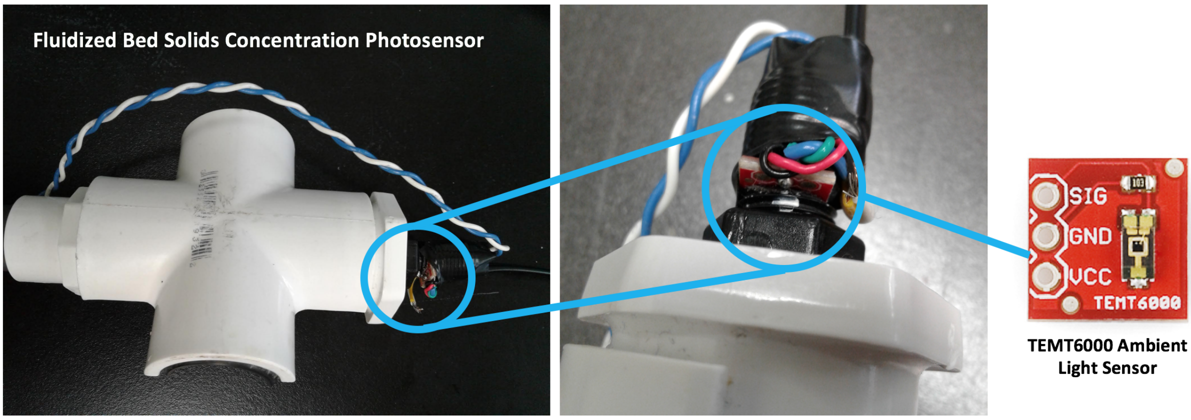

Figure 8: The TEMT6000 Ambient Light Sensor was affixed to the fluidized bed concentration sensor at one end. Light sensor photo from Bartlett (2016).

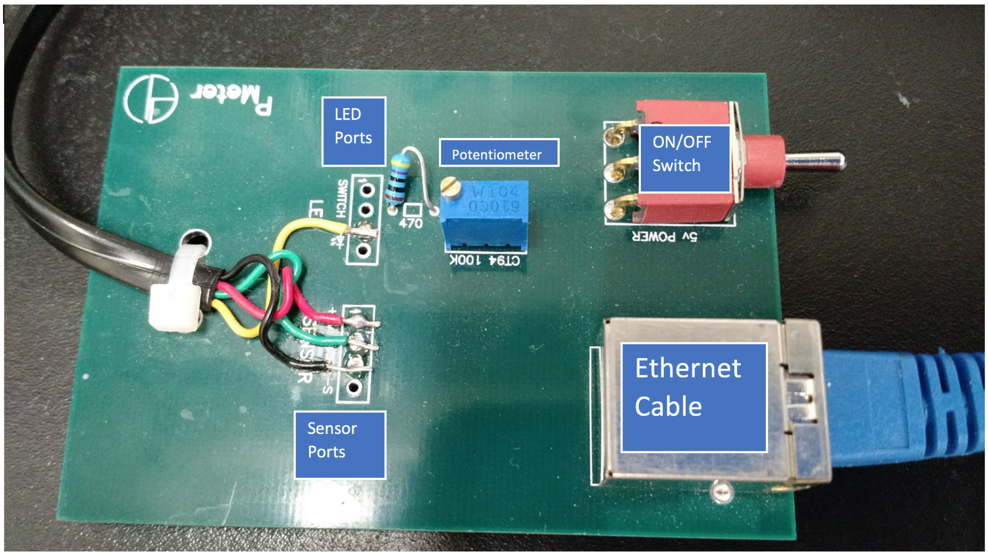

Figure 9: Completed circuit board. The ethernet cable connects the circuit board to the computer. The potentiometer allows the light intensity to be adjusted. By turning the screw, the brightness of the LED can be increased or decreased. The wires in the sensor ports are soldered to the TEMT6000 Ambient Light Sensor, and the wires in the LED ports are soldered to the LED light.

This semester, the subteam applied the same fluidized bed solids concentration sensor and methods to measure the concentration of clay particles in the High Rate Sedimentation apparatus.

High Rate Sedimentation (HRS)

AguaClara has worked on the high rate sedimentation process since Fall 2015. In the water treatment process, sedimentation allows particles to settle down and then be removed from the water. This process is often time-consuming. To decrease settling time, the HRS team has experimented with different methods of lowering effluent turbidity.

The Fall 2016 AguaClara sedimentation design included a dense floc blanket and functional plate settlers. The HRS team confirmed that a highly concentrated floc blanket is associated with a lower effluent turbidity. In addition, a greater floc blanket height decreases the effluent turbidity (Qi et al., 2016).

The HRS team required a sensor to simplify the process of measuring the floc blanket concentration and effluent turbidity for each experiment run. The sensor team found that the fluidized bed solids concentration sensor could be modified to fulfill the needs of the HRS team.

Methods

Fluidized Bed Solids Concentration Sensor

Testing Apparatus

In order to determine the calibration curve, the fluidized bed solids concentration sensor was calibrated using a testing apparatus, which modeled the dimensions of the HRS floc blanket recirculators. The testing apparatus consisted of a 0.61 m long polycarbonate tube, with a 1.9 cm inner diameter (Figure 10). One end of the tube was sealed off with a PVC cap, while the other end was left open. A removable cap was fabricated in order to seal off the tube when mixing the clay particles.

Figure 10: The experimental apparatus modeled after the High Rate Sedimentation recirculator.

Sensor Design

To modify the fluidized bed solids concentration sensor for the HRS apparatus, 3 mm thick rubber rings were attached with solvent to the inside of the cross to adjust to the 2.54 cm outer diameter pipes of the HRS recirculators. To measure the absorbance through the pipe, the sensor was attached to the pipe, and the two halves were clamped together (Figure 12).

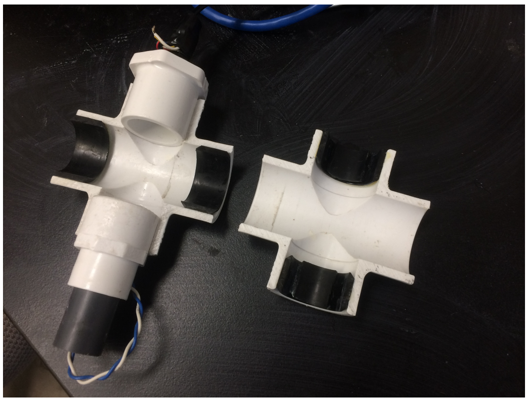

Figure 11: The fluidized bed solids concentration sensor was modified to fit the HRS apparatus by adding rubber rings to account for the smaller pipe size.

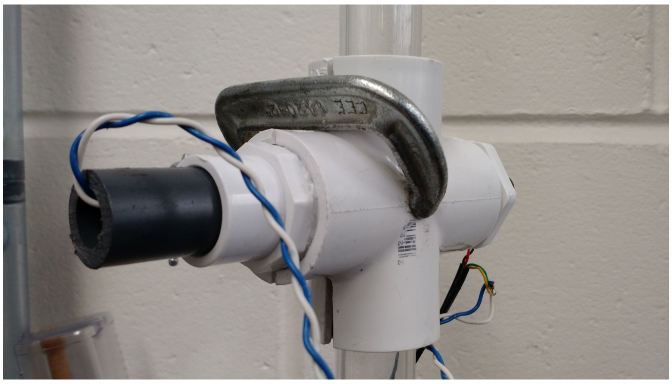

Figure 12: A clamp was used to hold the two halves of the fluidized bed solids concentration sensor in place.

Procedure

First, the blank voltage was measured to determine the maximum light penetration of water in the apparatus, with a clay concentration of 0 g/mL. For this measurement, 100 mL of water was poured into the testing apparatus, and the LED light was switched on. This value served as the baseline for later clay concentration readings. Then, the LED light was switched off, and the dark voltage, the voltage at which no light penetrates through the tube, was measured.

Concentrations ranging from 0.0005 g/mL to 0.3 g/mL were tested to create the calibration curve. Samples were prepared by massing kaolinite clay, and mixing the clay samples with 100 mL of water. Samples at 0.0005 g/mL, 0.0010 g/mL, and 0.0015 g/mL were prepared by dilution. The clay and water mixture was poured into the testing apparatus, and the tube was shaken vigorously to ensure homogeneity. The LED was switched on, and ProCoDA was used to record the voltage of the photosensor at each sample. The procedure was repeated for each of the three trials.

For the three trials of the conducted experiment, sensor height was held constant at 21.6 cm. This was crucial because the clay particles settled quickly. Changing the placement of the photometer on the tube even slightly would give radically different concentration readings.

Similarly, the volume of clay solution was held constant at 100 mL to minimize the differences in light entering the LED-sensor system through the top or bottom of the vertical tube setup.

Submersible Solids Concentration Sensor

The next project was the submersible solids concentration sensor, which measures the height and the concentration of the sludge blanket in the sedimentation tank. The submersible sensor was a modification of the fluidized bed solids concentration sensor created for the HRS subteam (Figure 13).

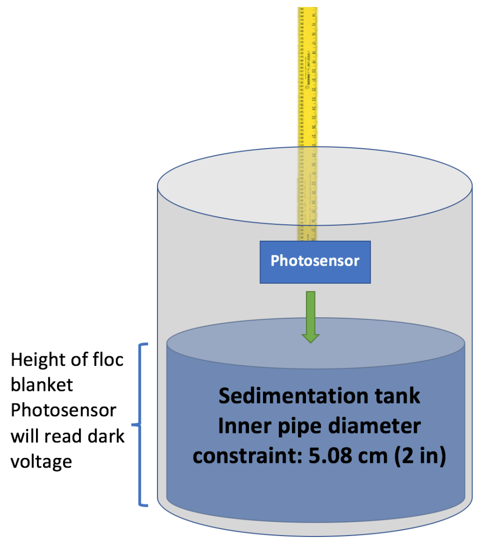

Figure 13: The design for the submersible solids concentration sensor. The design was subject to a 5.08 cm (2 in) diameter constraint set by the size of the pipe through which the sensor is to be lowered.

Sensor Design

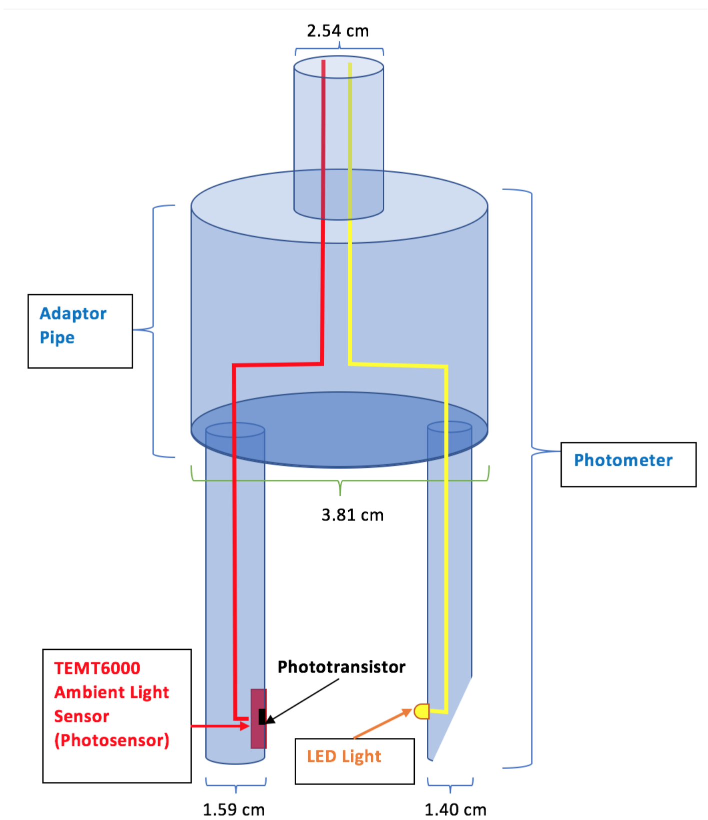

Figure 14: The schematic for the submersible sensor, which consists of a photometer attached to a 2 m long pipe. The photometer is the adaptor and the two pipes containing the photosensor and the LED. The photosensor is the TEMT6000 Ambient Light Sensor, which contains a phototransistor to detect light.

The submersible sensor consisted of a photometer attached to the end of a marked 2 meter long pipe. The photometer consists of an adaptor pipe, which connects two adjacent pipes, one containing the LED, and one containing the TEMT6000 Ambient Light Sensor (Figure 14). As the sensor is lowered into the sedimentation tank, water will pass between the LED and the photosensor. When the sensor reaches the sludge blanket, which is highly concentrated, the sludge blanket blocks all light from reaching the photosensor, and therefore the photosensor reads the dark voltage. At this point, the height of the sludge blanket can be obtained from markings on the tube.

As with the fluidized bed solids concentration sensor, the submersible sensor can also output the range of voltages between dark and blank, and uses this to determine floc particle concentrations within the sedimentation tank. Floc concentrations have a broad variety of applications within the Honduras treatment plants. This information can be used by plant operators to determine the rate of floc blanket formation, and therefore decide how often to drain the tank for maximum efficiency. It can also be used to optimize coagulant doses, as high doses of coagulant are known to lower floc blanket concentrations.

Fabrication

The submersible sensor consisted of a 2 m pipe to encase the wires, an adaptor pipe, and two smaller pipes containing the LED and photosensor (Figure 14). The adaptor piece was fabricated using a 3.81 cm (1.5 in) outer diameter PVC pipe. This piece was used to connect the smaller pipes containing the photosensor and LED to the 2 m long pipe. Two disks were cut to seal the top and bottom of the adaptor. In the top disk, a hole was drilled through the center to fit a 2.54 cm (1 in) pipe. In the bottom disk, a 1.40 cm (35/64 in) hole was drilled for the pipe containing the LED, and a 1.59 cm (5/8 in) hole was drilled for the pipe containing the photosensor. The two pipes which encased the LED and photosensor were cut to approximately 20 cm long. A 1.40 cm outer diameter, clear PVC pipe was cut diagonally and a 5 mm diameter hole was drilled for the LED.

Silicone sealant was used to both secure and waterproof the LED in the 1.40 cm outer diameter pipe. Silicone sealant was also used to secure the photosensor within the 1.59 cm outer diameter pipe and seal the end of the 1.59 cm pipe. Two layers of silicone were required for the tube containing the photosensor. The first layer was used to hold the sensor in place, as in Figure 15. A second layer was then used to prevent water from leaking onto the photosensor. On the side of the photosensor containing the phototransistor, a gap was left between the first and second silicone layers so that the silicone would not block light from the phototransistor.The other side of the photosensor was completely filled in with silicone.

In addition to being water-resistant, safe to use with technology, and reasonably priced, silicone has a high viscosity that allows it to dry in place. Essentially, it does not require a stopper to prevent flow into unwanted sections of the tube. This simplification in design is beneficial when considering potential mass production of the apparatus.

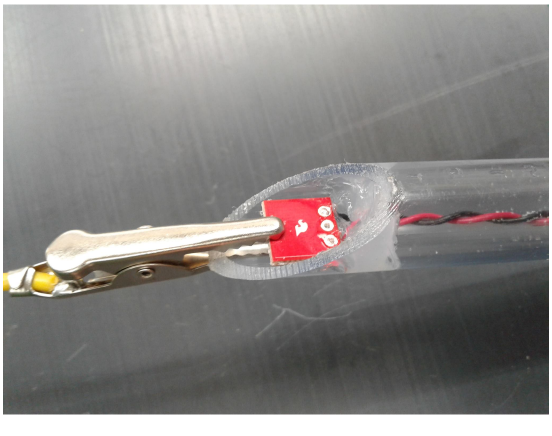

Figure 15: A small clip was used as a clamp to hold the photosensor in place while the clear, waterproof silicone dried. This picture was taken before an additional layer of silicone was used to cover and thus waterproof the top and bottom of the photosensor. A gap was left between the first and second layers so that the silicone would not block light from the phototransistor.

The adaptor connected the end of a 2.54 cm (1 in) outer diameter PVC tube and two smaller pipes. PVC compression couplings were used to attach multiple tubes to create a total length of 2 m. The compression couplings allow the 2 m long pipe to be disassembled for easier storage and transportation. The tubes were marked so that the depth of the sludge blanket can be read from the markings. Wires went through the tubes to connect the sensor to a computer, which allowed data to be collected by ProCoDA.

In an ideal design, the path through which light travels from the LED light source to the phototransistor would be a direct one, and any surface through which the light travels would be flat. This would ensure that no light produced by the LED is lost on its way to the phototransistor. However, light from the LED passes through the curved surface of the 1.59 cm outer diameter pipe containing the photosensor before reaching the phototransistor. Loss of light due to reflection and refraction by the curved pipe can be compensated for with an increase in LED brightness. Because the distance between the LED and phototransistor is small, loss of light due to pipe curvature can be deemed negligible.

Results

In general, as the concentration of clay increased, the voltage reading of the phototransistor decreased (Figure 16). The blank voltage in each trial was around 1.042 V. The dark voltage was around -1.042 V. The voltage dropped rapidly as the concentration increased; even as small concentrations of clay were added to the testing apparatus, the voltage decreased to values almost reaching the dark voltage. This meant that even small concentrations of clay prevented much of the light from transmitting through the tube to the phototransistor. As a result, the voltage-concentration curve appeared to have an asymptotic trendline.

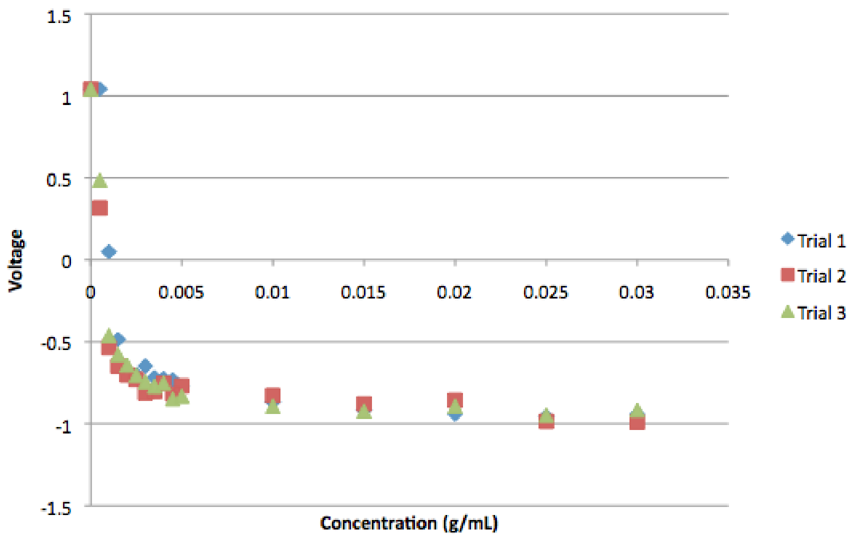

Figure 16: As the clay concentrations were increased, the voltage received by the photosensor decreased.

The following equation was used to calculate the light absorbed, using voltage readings:

$$Absorbance = -\log\left(\frac{sample - dark}{blank - dark}\right) \tag{3}$$

This equation is derived from the relationship between transmittance and absorbance. The transmittance equation is:

$$T = \frac{I}{I_0} \tag{4}$$

where T is the transmittance of light, I_0 is the initial light intensity, and I is the intensity of light that passes through the sample. Absorbance in relation to transmittance is as follows:

$$A = -\log(T) \tag{5}$$

Therefore, absorbance is inversely proportional to transmittance (Delgado et al., 2014). In other words, the more light that is absorbed by the sample, the less light is transmitted through to the photostransistor. This relationship is apparent in the experimental data, which shows that as the concentration increases, the absorbance increases. As more clay is added, the water becomes more opaque and the clay particles absorb and scatter light, which prevents much of the transmitted light from reaching the photostransistor.

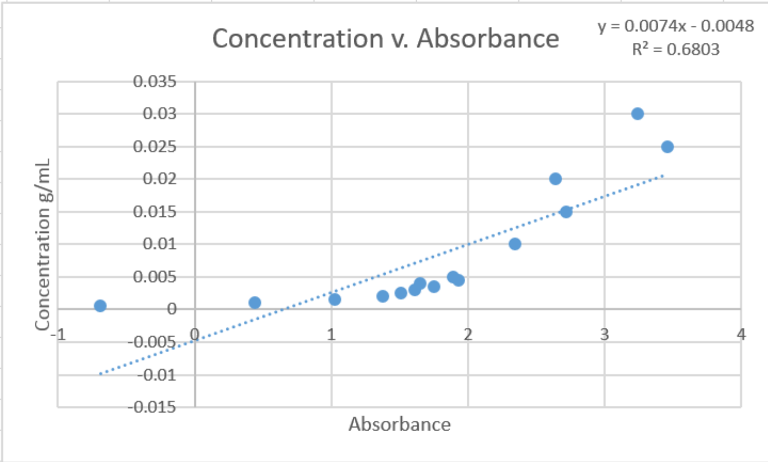

Figure 17: The linear trendline has a relatively small coefficient of determination (R-squared = 0.603, P=0.2971), which shows the limitation of Beer's law for clay particles. The relationship between concentration and absorbance does not follow a linear trendline.

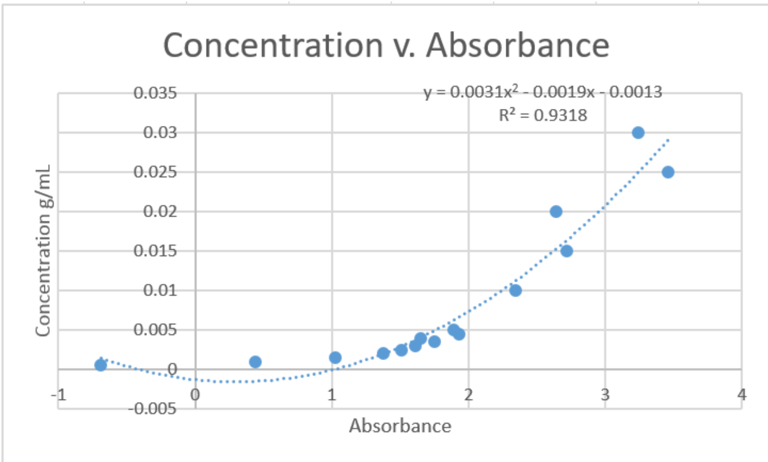

Figure 18: The polynomial trendline fits the relationship between concentration and absorbance well, with an R-squared value of 0.9318.

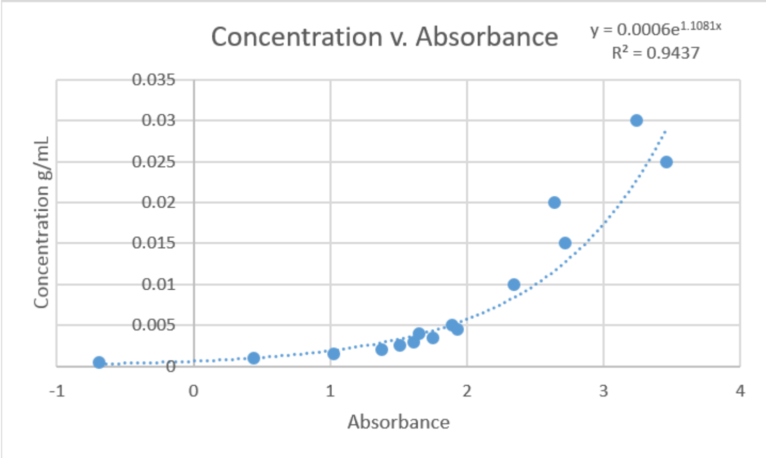

Figure 19: The exponential trendline shows the best fit for the relationship between concentration and absorbance (R-squared = 0.9437).

Using the trendline equation, the team wrote a MathCAD file to calculate the concentration by inputting the voltage obtained from ProCoDA.

Analysis

According to Beer's Law, absorbance and concentration are directly proportional in the ideal photoelectric sensor experiment. However, in the case of this experiment, the linear trendline was not the best fit line for the relationship between concentration and absorbance (P = 0.2971) (Figure 17). Since a P-value of 0.05 was established for significance, it is concluded that concentration and absorbance do not follow a linear relationship. However, the concentration-absorbance curve does show a clear positive correlation, so other trendlines were considered to determine the best fit line.

Comparison of Clay and Floc Particles

One factor that contributed to the formation of an absorbance-concentration curve with an exponential trendline was the size of the the individual clay particles. Because the particles are large in relation to the cross-sectional area detected by the phototransistor, the absorbance values were highly sensitive to changes in clay concentration while the concentrations were very low. In addition, the white color of the clay allowed the clay to reflect some of the light. Although the phototransistor is meant to detect the light passing directly through a given medium, it is likely that some of the light it received had instead been reflected multiple times to be redirected back in the direction of the phototransistor by chance. Thus, the sensor readings were higher than they may have been for particles that were either darker or individually smaller. These factors may also have contributed to the differences in the data accumulated across the three trials.

Clay particles within the High Rate Sedimentation apparatus form a flocculated blanket and are on the whole larger than the clay particles used in this experiment. However, in previous research, the difference between clay particles and flocs was found to be negligible at low concentrations, with a discrepancy of approximately 5 percent. Since the High Rate Sedimentation recirculators operate at a fairly low concentration, the difference between the properties of clay particles and flocs can be ignored, and the experimental data collected using clay particles can be used to determine the calibration curve. In creating the calibration curve, the subteam focused on a range of concentrations between 0 and 0.005 g/mL. This allowed the subteam to use a linear calibration curve to relate concentration and absorbance.

Theoretical Concentration Calculations

In order to confirm accuracy, the fluidized bed solids concentration sensor was tested on the HRS recirculator. The HRS team initially worked with a straight 1 m recirculator, and later changed the design to a trapezoidal recirculator. Voltage readings were recorded at various heights along the recirculator due to slight differences in concentration throughout the pipe (Figure 20). Voltage readings were then inputted into the MathCAD program (Figure 21).

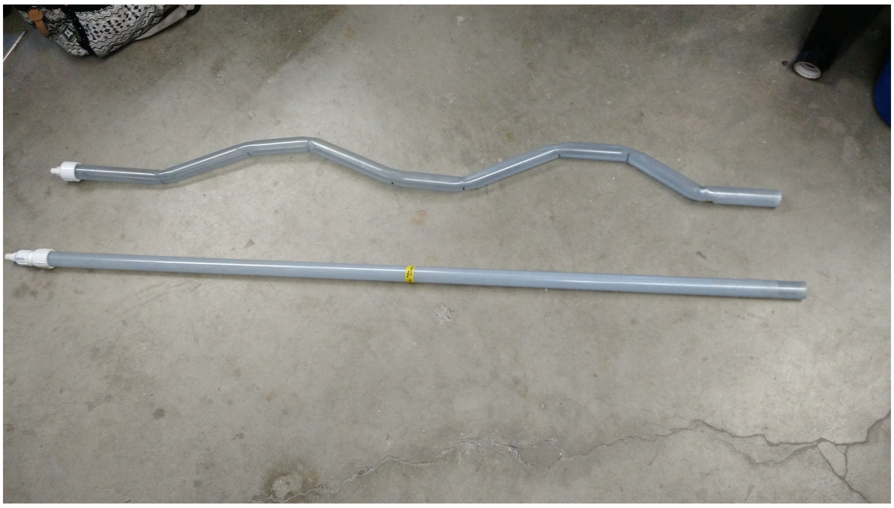

Figure 20: The HRS team worked with two different recirculator geometries: trapezoidal (top) and straight (bottom).

$$V_{Blank} := 1.04297$$
$$V_{Dark} := -1.03925$$
$$V_{Sample} := -1.039249999999999$$
$$Abs := -\log\left(\frac{V_{Sample} - V_{Dark}}{V_{Blank} - V_{Dark}}\right)$$
$$Abs = 15.273$$
$$Concentration := .0006e^{1.1081 \cdot Abs}$$
$$Concentration = 1.343 \times 10^{4}$$

Figure 21: The MathCAD program used to calculate concentration from voltage readings taken from the HRS recirculator using the equation from the best-fit trendline.

The following proportion relating the velocity of water upflow, rate of floc blanket formation, input clay concentration, and output floc concentration was used to calculate theoretical concentration of the floc blanket for the straight and trapezoidal recirculators separately (Figure 22). In these calculations, it was assumed that floc concentrations throughout the recirculators were uniform.

$$V_{up}C_{in} = V_{FB}C_{FB}$$

Figure 22: The equation used to calculate the concentration of flocs in the floc blanket, C_{FB} in the HRS recirculator.

The upflow velocity of water was taken to be 3 mm/s, and the input concentration was taken to be 0.17 g/L, which was converted from 100 NTU by the HRS team (Figure23).

$$t_{FB} = x \text{ hr}$$
$$H_{FB} = x \text{ m}$$
$$V_{up} = 3 \text{ mm/s}$$
$$C_{in} = 0.17 \text{ g/L}$$

Figure 23: The constants were inputted into the equation above to calculate the theoretical concentration of flocs in the HRS recirculator. The trapezoidal recirculator had a height, H_{FB}, of 1.05 m, while the straight recirculator had a height of 1 m. The trapezoidal recirculator had an estimated settling rate, V_{FB}, of 1-2 hours, and the straight recirculator had an estimated settling rate of 3-5 hours.

For the straight recirculator, the time required to form a floc blanket of 100 cm was estimated to range from three to five hours. The concentration of flocs was calculated to range from 0.005508 g/mL to 0.00918 g/mL.

To calculate the concentration of flocs in the trapezoidal recirculator, the time required to form a floc blanket of 105 cm was estimated to range from one to two hours. The concentration of flocs was calculated to range from 0.0017486 g/mL to 0.003497 g/mL.

The concentrations obtained through photometer readings of the HRS trapezoidal recirculator were higher than those of the straight recirculator. In contrast, the concentrations obtained with calculations based on estimated rates of floc blanket formation were higher for the straight recirculator. This is because the equation 22 does not account for the geometry of the recirculator.

Conclusions

The fluidized bed solids concentration sensor created last semester was modified to fit the needs of the HRS team. To calibrate the photometer, voltage readings were taken for a range of clay concentrations between 0.0005 and 0.03 g/mL. These voltages were converted to absorbance values, and a plot relating absorbance and concentration was created. The absorbance-concentration curve was fitted to an exponential trendline, and the equation generated was used to create a scale converting voltage readings from the photometer to units of concentration. This scale can be used to directly measure clay concentrations in the HRS recirculators.

The concentration values obtained from the photometer matched theoretical calculations based on equation 22. Overall, the fact that the estimates and data fall within the same order of magnitude signifies that the sensor readings are reasonable.

To optimize the sedimentation process, the HRS team ran multiple tests while varying factors such as tube geometry and coagulent dosage. The sensor can be used to efficiently monitor the effects of these variations on floc blanket density. Photometer tests conducted on the straight and trapezoidal HRS recirculators indicated that the clay concentration was higher in the latter, supporting the HRS team's hypothesis that the trapezoidal recirculator creates a denser floc blanket.

The rate of floc blanket formation (V_{FB}) and upflow water velocity (V_{up}) in the theoretical calculations were rough estimates obtained from the HRS team. To further confirm the accuracy of the fluidized bed solids concentration sensor, more precise values for these constants are needed.

Future Work

The next step is to test the submersible sensor on a floc blanket sample and to modify the design according to results and usability. Thereafter, a 2 m long rod joined by PVC compression couplings will be attached to the already-assembled lower portion of the submersible sensor.

The submersible sensor will be calibrated in the future, in order to convert voltage readings obtained by the photometer into floc blanket concentrations. Using the same calibration procedure as the fluidized bed solids concentration sensor, voltage readings will be recorded at several concentrations to create a calibration curve.

The current design of the submersible sensor utilizes ProCoDA, a computer program. However, the ideal sensor setup would be portable and would not require a computer. This can be achieved by adding an interface which will directly display the concentration readings converted from the measured voltage readings. Adding a battery to power the sensor would also make it portable.

For usability in treatment plants, the ideal submersible sensor setup would have the capacity to store readings in a format convenient for sending to an external, online database. Consideration of data storage is important because Internet access is intermittent in the communities in which AguaClara has partnered with. Reliable data storage within the submersible sensor itself would provide a convenient means of organized record-keeping for plant operators, and provide data transparency for AguaClara members outside the immediate vicinity of the plant.

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Semester Schedule

Task Map

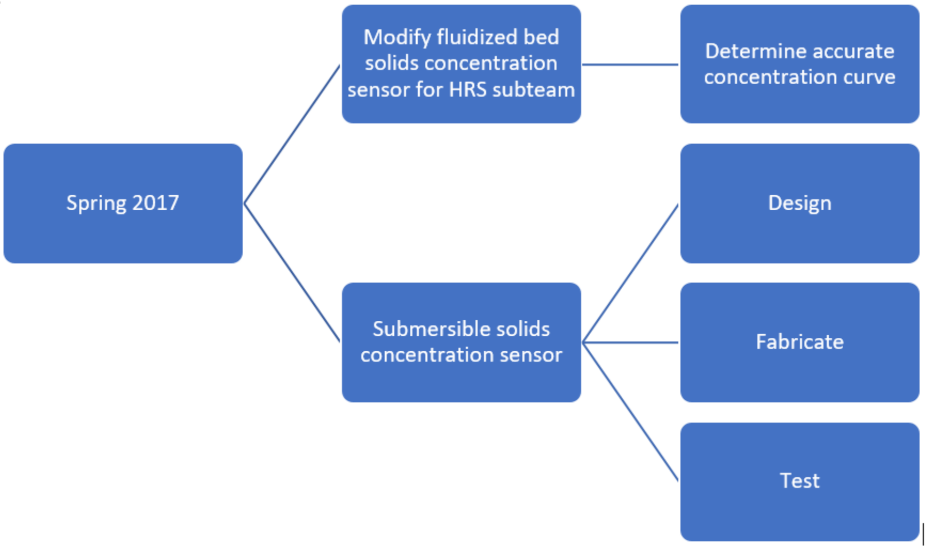

Figure 24: Task Map

Task List

1. Fluidized bed solids concentration sensor for High Rate Sedimentation subteam
   (a) ✓Build a new testing apparatus. It should be the same as the tube used in the high rate sedimentation apparatus. Thus, the data collected and the calibration curve created can be used to determine the concentration of clay in real situation.
   (b) ✓Modify sensor for high rate sedimentation. Add rubber rings to sensor to fit smaller pipe diameter.
   (c) ✓Determine accurate calibration curve. By using this curve, the team can write a MathCAD program for user to input the voltage reading, and thus, get the exact concentration of clay in the HRS apparatus.
2. Submersible solids concentration sensor
   (a) ✓Design the submersible sensor.
   (b) Fabrication.
   (c) Test the submersible sensor using a testing apparatus.

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Manual

Experimental Methods

Calibration Procedure

1. Prepare clay samples that give readings from approximately blank voltage to dark voltage.In our case, readings for concentrations of 0 g/mL to 0.005 g/mL were taken at intervals of 0.0005 g/mL, and readings from 0.005 g/mL to 0.03 g/mL were taken in intervals of 0.005 g/mL.
2. Attach the sensor and keep LED light source off. Record this as the dark voltage.
3. Attach the sensor and turn the LED light source on at maximum intensity (where it should remain for the rest of the trials). This is the blank voltage.
4. Repeat for all prepared samples.