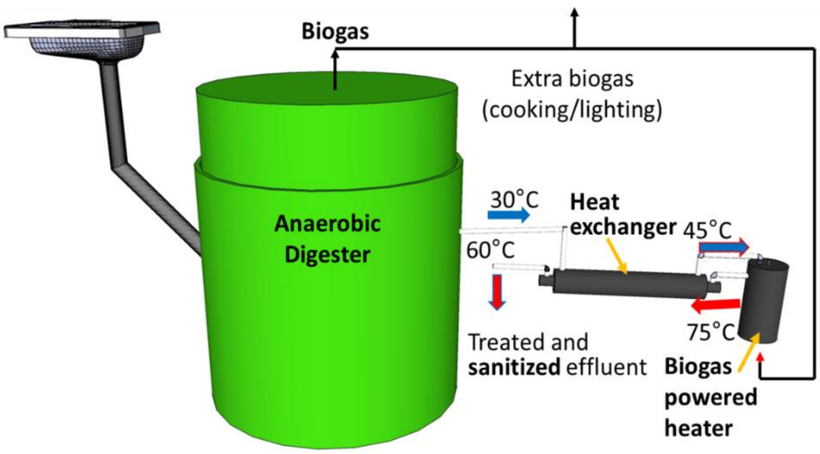
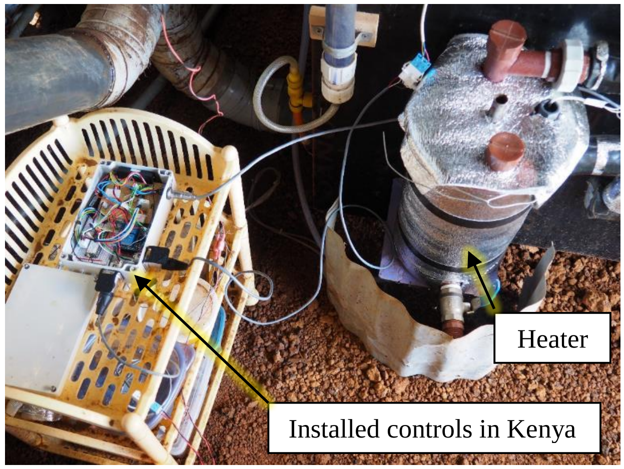
Prepared by: Aaron Forbis-Stokes December 1, 2016

ADPL Control System Overview Document

Project Overview

The Anaerobic Digestion Pasteurization Latrine (ADPL) is a concept developed by the Professor Marc Deshusses research group in the Department of Civil & Environmental Engineering. The ADPL provides sanitation by treating human waste in an anaerobic digester, followed by pasteurization of the treated effluent in a heater/heat recovery system powered by biogas produced by the anaerobic digester. The system operates by capturing the energy inherent to fecal sludge and using that energy to power its own sterilization. A schematic of the process is shown below. This project has been implemented with local partners in Eldoret, Kenya; Chennai, India; and Toledo, Philippines (pictured below in order left to right).









Controls Overview

The motivation of the controls system is to provide continuous, remote data collection and to improve the efficiency of heater operation. The Particle Electron is used to record temperatures in the heating system and liquid flow leaving the anaerobic digester. This data is transmitted to an online server (http://dash.dukeadpl.com/). The temperature probe inside the heater is used to control the operation of a gas valve and igniter to ensure the liquid in the heater remains in the target range of 65-75 °C. The system is powered by a ***20W solar panel*** which charges a ***motorcycle battery (~30Ah)***. Preliminary tests show that ***average power consumption is 1.42W*** throughout the day.

Hardware
Temperatures are measured using liquid immersion ***NTC thermistors (10kΩ resistance*** at 25 °C). Thermistors are placed at the inlet of cold chamber of heat exchanger (HXCI), outlet of cold chamber of heat exchanger (HXCO), inside heater (HTR), inlet of hot chamber of heat exchanger (HXHI), and outlet of hot chamber of heat exchanger (HXHO). The Dwyer I2-1B062 is used in HTR. The remaining locations use Vishay NTCAIMME3C90373 thermistors.

Liquid flow is measured using a tipping bucket flow meter where each tip of the bucket corresponds to ~300-350 mL of digester effluent. A magnet is place on the upper arm of the cantilever, and each tip is measured using a ***magneto-sensor***. The sensor has a variable resistance that is ≥500kΩ in the resting state and ≤10kΩ when the magnet passes the sensor. The maximum count frequency is 20 Hz. A ***one-shot monostable pulse generator*** (Linear Technology TimerBlox, LTC6993-1) is used to lengthen the pulse width. The pulse duration leaving the TimerBlox is 2 seconds.

The Particle reads temperature in the heater every 2.5 minutes. If heating temperature is <68 °C, the ***motorized ball valve*** (CWX-15Q, CR-02, 3-wire; ***12VDC, 167mA***) is opened and igniter is turned on for 1 second. If temperature is >72 °C, the valve is closed, and the igniter timer sequence is stopped. If the temperature is 68-72 °C, the valve remains in its current state. If the valve is opened, the igniter runs on the 15 minute timer.

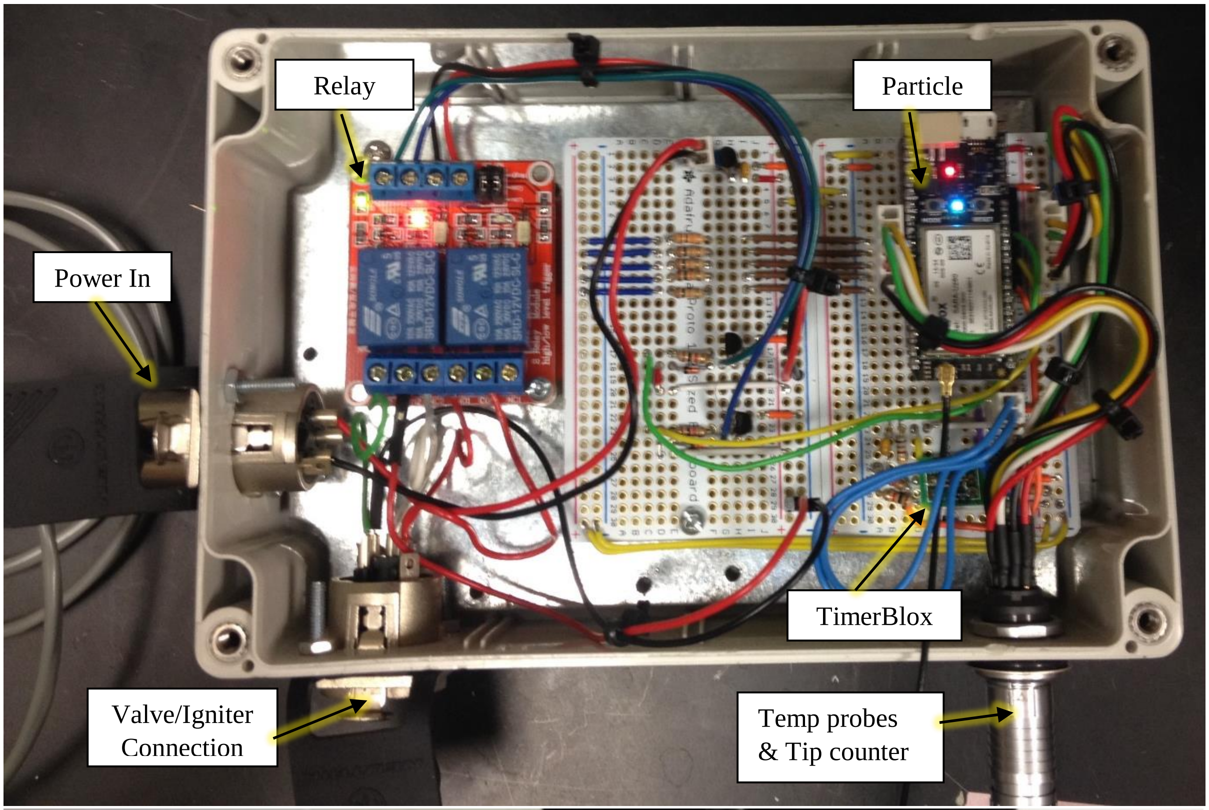
The igniter is an ***off-the-shelf electronic igniter replacement kit*** (Brinkman). An igniter module is powered by a ***1.5VDC*** (AA) battery (***280-320mA***) and sends out ***10kVDC*** to three igniter leads using a high voltage transformer.

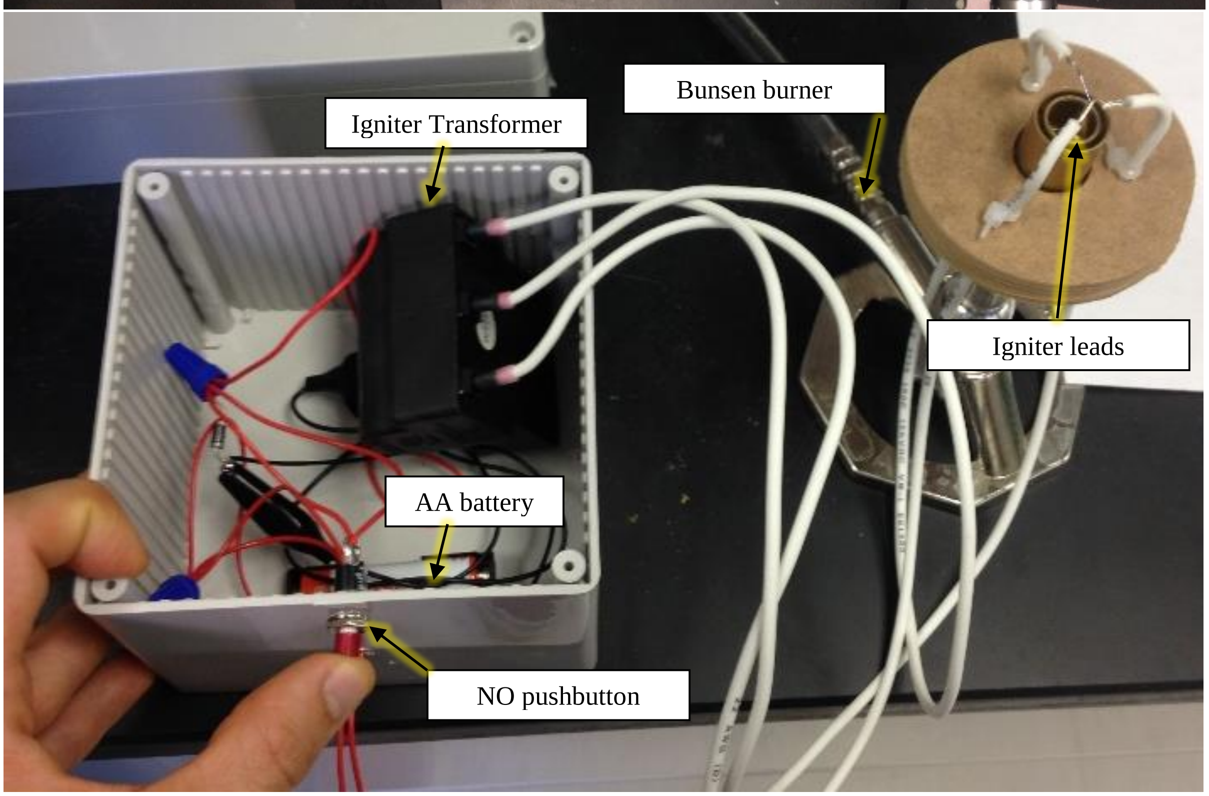
The system in India is an atypical implementation that uses a 12V, 6A pump to transport fecal sludge into the digester. The pump is included in the wiring diagram and software, but it will not be replicated in future implementations.

The microcontroller, circuit board, and relays are all housed in a Hammond watertight ABS enclosure (1554HGY) and mounted on a galvanized steel panel. External hardware is connected to the enclosure using Neutrik XLR connectors, and Molex connectors are used to connect wires.

The wiring schematic is prepared in a separate document. See “ADPL Controls System Wiring Schematic.”

Constraints & Priorities
This control system is part of an onsite fecal sludge treatment system targeting low-income communities. The final treatment system must be completely off-grid and available at a cost of less than $0.05 per user per day (including capital and operational expenses). Thus, the control system must be ***inexpensive, use minimal power***, and have a ***robust design*** that can be reliably implemented in ***rugged outdoor environments with no local electrical expertise***.


Relay
Particle
Power In
TimerBlox
Valve/Igniter
Connection
Temp probes
& Tip counter


Bunsen burner
Igniter Transformer
Igniter leads
AA battery
NO pushbutton