COMPARISON OF INDUCED SLUDGE BED (BLANKET) ANAEROBIC REACTOR TO VERTICAL PLUG FLOW TECHNOLOGY FOR ANIMAL MANURE DIGESTION[1]

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ABSTRACT

The purpose of this study was to compare Induced Sludge Bed Anaerobic Reactor (IBR) (Hansen, Hansen, 2005) animal manure digestion technology to Vertical Plug Flow (VPF). In 2008 an IBR system at Sunderland Dairy Farm in Chester, Utah was repaired and retrofitted by Utah State University (USU), Extension, Utah Science, Technology and Research Initiative (USTAR), and Sunderland Dairy Farm. This was the first time research has compared IBR and VPF digester performance at a single site in a side-by-side situation at a commercial dairy operation. The retrofit of the four 30,000 gallon vertical steel tank system provided for system upgrades, repairs from over pressurization, and implementation of design modifications. This included: solids separation, over pressurization bypass, commercial gas pressure regulation, gas handling skid, gas flare, etc. To accommodate research objectives, the retrofit converted two of the four existing IBR tanks to VPF, and gas measurement instrumentation was installed. IBR technology has significantly out performed traditional VPF. Methane gas production from IBR is 41.9% higher than VPF and an ANOVA test shows that this is highly significant at the $p \geq 0.05$. Gas quality (CO_2) from IBR is 11.5% better than VPF and ANOVA is also highly significant at $p \geq 0.05$. Hydrogen sulfide (H_2S) levels from IBR are 20.6% lower than VPF and ANOVA is again highly significantly at $p \geq 0.05$. Continued monitoring is needed to further document seasonal ambient temperature effect and other operational parameters on the performance and gas quality for the two technologies.

INTRODUCTION

Increasing global demand for energy, political unrest, speculation about energy supply, and drastic increases in prices have heightened interest in developing locally available, alternative energy sources from agriculture. In response to on-going interest to improve the treatment of animal manure and to develop alternative agricultural energy sources, Utah State University's patented IBR technology has received publicity as a more efficient, high tech approach. Proponents claim that an IBR system shortens retention time to as low as 5 days, treats solids from 2-10%, decreases storage requirements, is more consistent and reliable, is easier to control, and produces more methane (Watts, 2007). The use of IBR and other digester technologies with alternative energy components has not yet been commonly adopted by most commercial

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agricultural operations. However, many producers are beginning to consider alternative energy projects due to the energy crisis.

IBR is a new anaerobic digestion technology being used vertical steel tanks, which are housed inside an insulated building. This technology consists of a complex system of natural and bio-gas boilers, shell and tube heat exchanger, pumps, valves, computer controls, and associated gas, plumbing and electrical subsystems. In the system, animal manure is heated to 100-105^0 F to maximize biological activity. This process produces bio-gas which contains approximately 70% methane (CH_3) and 30% carbon dioxide (CO_2). Bio-gas is used as fuel for an engine coupled with an induction generator capable of producing electricity for distribution on the grid. Electrical utilities are increasingly interested in alternative energy projects that are perceived to being "green" in nature as a result of public concerns over coal fired power plant CO_2 emissions and effect on global atmospheric temperatures,

In September 2004 Utah State University entered into a contract with Sunderland Dairy Farm of Chester, Utah to construct a manure digester to produce methane gas and generate electricity using new IBR technology. IBR had recently been developed and was being patented by a university-based agricultural research program (Hansen, Hansen, 2005). In June, 2004 IBR was licensed by USU to Andigen, LC, (Watts, 2007) a private spin-off company who was commercializing the technology. The Sunderland project was initially financed by a $300,000 Conservation Innovation Grant USDA-NRCS, $280,000 from Sunderland Dairy Farms Inc., and in-kind labor. However, the project was significantly underfinanced. The digester portion of the project was completed, but only operated for several months. It was shut down in the fall of 2006 by the owners due to serious safety concerns and a variety of problems. USU Extension agreed in April of 2007 to assist the university in initiating corrective measures. From June 2007 to January 2008, USU conducted an independent evaluation, reengineered design flaws, formulated a retrofit plan, obtained $243,000 in additional funding, and entered into a new Memorandum of Understanding with cooperator.

METHODS

The existing IBR tank system at Sunderland Dairy consisted of four 13.5' x 32', 30,000 gallon steel tanks housed in a 2,025 sq. ft. insulated steel building. The steel tank creates a totally sealed anaerobic environment. Each has an internal steel cone shaped septum near the top of the tank, which is unique to the IBR design (Figure 1). The septum creates a control barrier for the upward movement of manure, fiber and bio-gas. It also creates a cavity for gas accumulation and foam dispersal. The tanks have a top mounted maintenance hatch with window and other exterior ports for gas collection, float switches, manure injection and effluent release. The interior septum has a 24" maintenance access hatch and a 6-8" opening in the top of the cone with a rotating auger to reduce plugging potential from a fiber mat that accumulates under the septum. Circulating steel arm and drag chain mechanism is installed in the top of the tank to the septum auger (Figure 1) to breakup bubbles causing foam accumulation.

The tanks have a double outlet and p-trap assembly that provides a liquid gas seal and provides for effluent release from the tank. A low pressure disk pump, located in an exterior manure collection pit, continuously injects raw manure into the bottom of the tanks through an in-feed manifold system. The pump is operated with a frequency drive that causes flow surges and turbulence for better heat transfer in the heat exchanger. Each tank receives a 9-12 gal/min charge of manure over a 4-15 minute period of time (16 minutes for 5 day retention). Computer software controls the pneumatically actuated in-feed ball valves in a rotation between tanks to assure each tank receives the same quantity of manure over time. Manure injection into the bottom of the tank causes a corresponding release of treated effluent from the p-trap in the top of the tank. The effluent is collected in a waste water manifold system and is drained away to a typical dairy lagoon. Bio-gas is captured in the septum and piped through a gas manifold system to electrical generation equipment or flare.

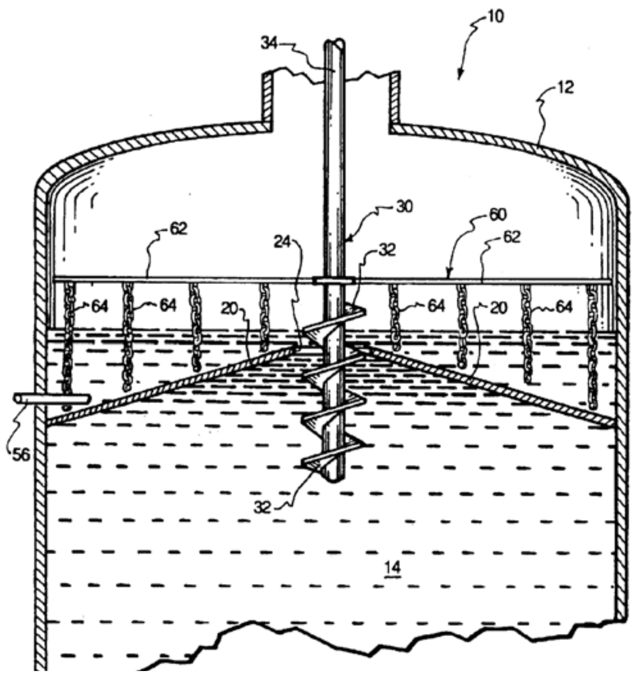

Figure 1. Induced Sludge Bed Anaerobic Reactor (IBR) tank diagram (Hansen, Hansen. 2005).

The system retrofit converted two of the existing IBR tanks to VPF tanks. This provided the first opportunity for a side-by-side research comparison of the two technologies at the same location, with the same equipment and same uniform manure flow to reduce variability. The conversion of two of the existing IBR tanks to VPF was accomplished by removing the maintenance access hatch in the septum, enlarging the auger opening without flexible orifice assembly and cutting three strategically located 24” diameter openings in the septum. These openings negate the effect of the IBR septum and allow gas and digesting manure to flow unobstructed upwards through the tank to the gas collection cavity above the septum. This is the primary difference between the IBR and VPF technologies. After research is complete, these three openings in the two VPF tanks will be closed and flexible orifice installed to restore IBR function. During the retro fit, manure supply plumbing was rerouted to provide separation by existing screw press separators prior to manure entering the system. This solved chronic plugging and over pressurization problems.

The digester performance testing has been accomplished using a mass flow meter to record cumulative gas flow from each tank. Gas quality is determined by composition of CH_4 and CO_2 and is measured daily or weekly depending on performance cycle by spot check using a fyrite gas analyzer. H_2S levels are also measured daily or weekly by spot check using by gas detector tubes.

RESULTS AND DISCUSSION

Somewhat erratic gas production (Figure 2) and gas quality (Figure 3 & 4) were expected and observed after digester startup and during initial performance testing. There were no significant differences observed between the technologies during the first 45 days of operation. During this time, biological activity stabilized, research team became more proficient interpreting performance data and adjusting system parameters.

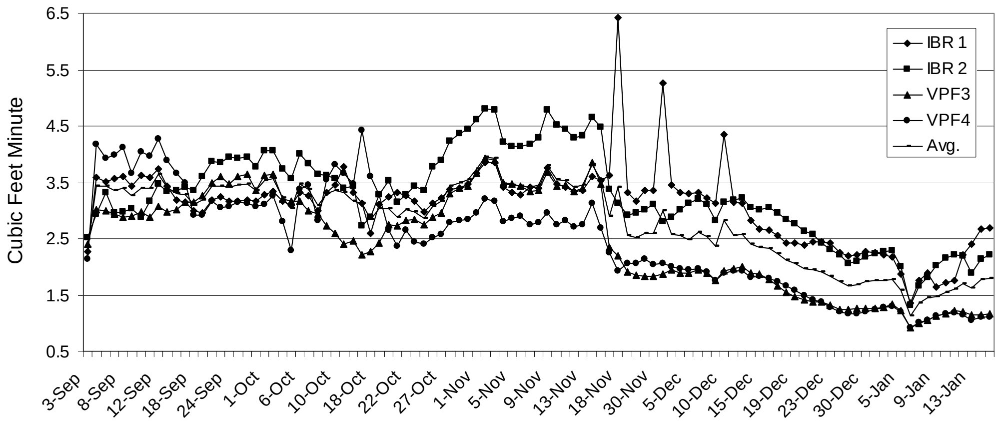

Figure 2. Comparison of total gas production, continuously recorded by mass flow meters, between two IBR and two VPF manure digester tanks at Sunderland Dairy Farm.

Little difference in gas production was observed until backflow check valves were installed in the gas line at the top of each tank on November15th. Undetected gas flow had been occurring between tanks through the bio-gas manifold. Excessive foaming was observed in IBR tank 1, which has caused occasional, inaccurate spikes in gas measurement readings. These have been identified and accounted for. Minor equipment malfunctions including stuck check valves on the in-feed manifold were also identified and isolated. Decreasing ambient temperatures during winter months have caused a corresponding gradual decrease in manure temperature and consequently a steady declining in gas production from both systems. Temperatures reached their lowest levels on January 4th and 5th during a period of -22 to -17^{o} F below zero respectively. Tank temperatures decreased below 90^{0} F on December 20th and has remained about 83^{0} F during the coldest weather. Ambient temperature decrease has decreased manure temperature coming into the system to about 32^{0} F. Average gas production from December 11th to January15th for the IBR system was 2.36 cu. ft./min. compared to VPF producing 1.36 cu. ft./min. IBR produced 42% more gas than VPF and ANOVA test is highly significant $p \geq .05$.

The quality of bio-gas produced in these digesters is primarily determined by the percent concentration of CO_2 and CH_4, which is inversely related. From November 15th to January 13th the average CO_2 produced by the IBR system was 30.7% compared to 34.7% by VPF for the same time period (Figure 3). IBR technology produced 11.5% less CO_2 than VPF. The ANOVA test is highly significant at $p \geq 0.05$.

Hydrogen sulfide (H_2S) is present in bio-gas, but in greatly reduced concentrations. From November 12th to January 13th the average H_2S produced by IBR was 0.69% compared to 0.96% by VPF for the same time period (Figure 4). IBR technology produced 20.6% less H_2S than VPF. The ANOVA test is highly significantly at $p \geq 0.05$. Colder winter ambient temperatures and internal tank temperatures of less than 100^0 F appear to have an effect resulting in higher concentrations of H_2S production from both technologies. Continued monitoring and further analysis is needed to document ambient temperature effect on IBR performance and gas quality. At this point in time digester system is operating continuously with only routine maintenance. The research team will continue to conduct experiments with the goal to provide a comprehensive review of these two digester technologies.

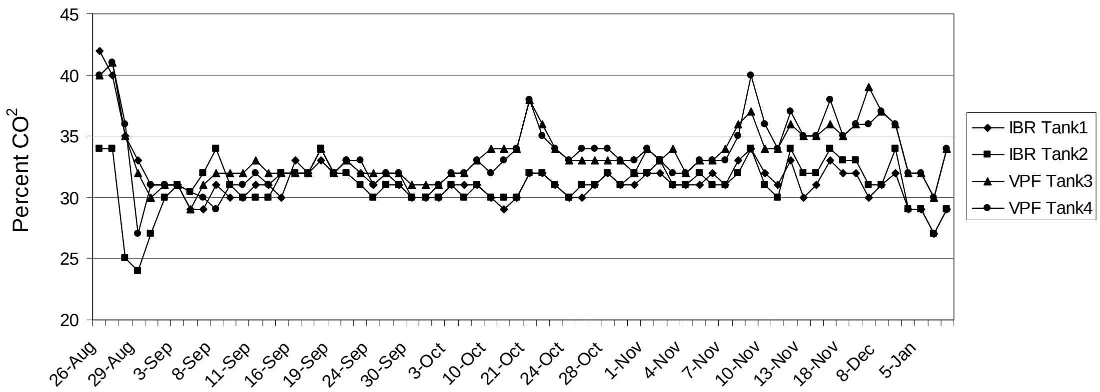

Figure 3. Comparison of carbon dioxide (CO_2) content between two IBR and two VPF manure digester tanks at Sunderland Dairy Farm.

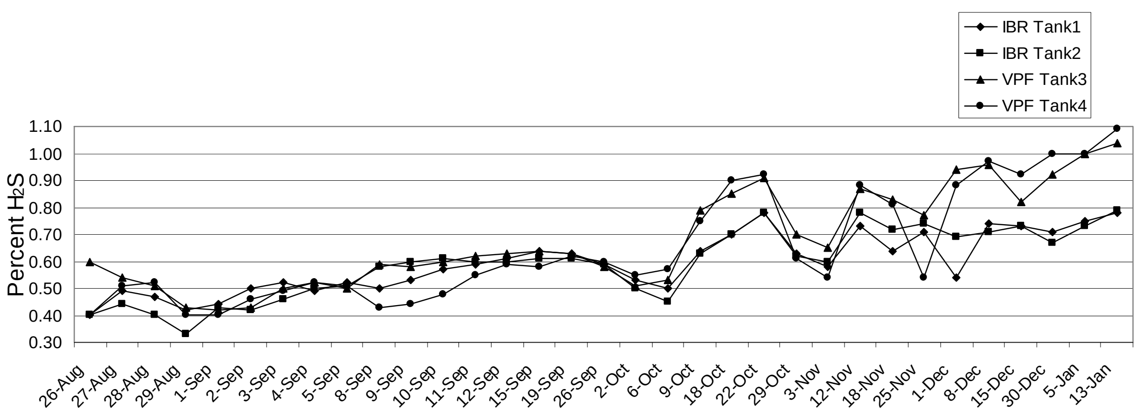

Figure 4. Comparison of hydrogen sulfide (H_2S) content of two IBR and two VPF manure digester tanks at Sunderland Dairy Farm.

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