Diamond K Feeds, LLP
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507-689-2058

Project Title: Diamond K Feeds Methane Digester Project
Milestone Number 5

RDF Contract Number: EP-51 Report Date: Mar 21, 2014

Congressional District: Minnesota 1st

Project funding provided by customers of Xcel Energy through a grant from the Renewable Development Fund.

**Executive Summary:**

Photo 1: The third, fourth and fifth generation members of the Kreidermacher Family all work together to keep the family farm running smoothly.

Diamond K Feeds, LLP is a five generation family owned dairy farm located near Altura, Minnesota. The dairy is operated by Alan and Patricia Kreidermacher along with their children and grandchildren. The preservation of this farm and the future of family farming is very important to the Kreidermachers who wish to insure the protection of the soil, water and air as well as to increase the economic value of their business. These things must go hand-in-hand to insure the future of agriculture which has always been one of the foundations of this country. The American farmer produces some of the highest quality and most readily available food in the world. With an ever-increasing population the growing demand must be met in a sustainable and economically viable way.

Photo 2: Cows at the dairy are fed a high forage diet consisting mainly of chopped haylage and corn silage produced on the farm.

The Kreidermachers installed a complete-mix anaerobic digester, which was funded in part by a Cycle two RDF grant, to produce methane gas from dairy livestock wastes. This use of methane gas from livestock waste for the production of electricity is a stepping stone in the future of green energy and an additional source of revenue for our country's agricultural producers. With this process we are embarking on a journey to enhance the value of agriculture in our country to provide both food and fuel for an ever-increasing world population. We must find ways to produce more food and energy to supplement our finite natural resources. This use of livestock waste is a perfect example of the things we need to do to develop new sources of energy. On December 31, 2013 the project was commissioned and began generating electricity.

Methane gas produced in the decomposition of manure is captured and turns a waste product into a resource rather than an ozone depleting compound. This is a two-fold benefit environmentally in that the methane is used up before it enters the atmosphere and it is a source of green power reducing the use of natural resources or the need for foreign purchases. The product that remains after the gas is removed is valuable as a soil amendment on crop land which replaces commercial fertilizers. As compared to raw manure, the solids removed from the digester have gone through a composting process to make it ready immediately for plant uptake, a process that normally has to take place over a three year period in the soil. This lessens the impact of livestock waste as a fertilizer because it is much less likely to be washed away since it does not remain in the soil for such a long period of time. Once the manure has gone through the digestion process, the potential to pollute has been reduced by 90%. Manure from 1,000 cows will be no more of a threat to the environment than the manure from 100 cows.

Once the manure has digested for 22 to 24 days, the optimum time frame for methane collection, the effluent is sent to a separation building where the solids are separated from the liquid. The solids are collected and used as bedding in our cattle barns eliminating the need for commercial bedding products.  The liquid is stored until the proper time for application to our crop land for use as fertilizer. This starts the cycle all over again to provide both food and fuel for use by everyone. Diamond K is striving to position itself as a viable and sustainable dairy production business for the future of the family members currently involved and for the 8 fifth generation Kreidermachers being raised there as well.


Photo 3:  The young ones at Diamond K, both 2-legged and 4-legged are always hungry.

**Project Benefits:**

This project has proven to be valuable both environmentally and economically in many ways (See Attachment A).  Methane is the byproduct of any anaerobic decomposition of organic materials.  Manure is removed from the cattle barns three times each day.  This collection schedule and immediate introduction to the anaerobic digester will avoid nearly all the potential and customary methane emissions.  All of the methane will be captured and burned either in the engine-generator to produce electricity or in the by-pass flare. Through this process, the system effectively removes a powerful greenhouse gas from the environment.  The sale of the electricity provides a new source of revenue for the dairy. The digested solids that are used for bedding eliminate the transportation costs and environmental issues that result from purchasing and transporting commercial bedding products.  The excess hot water that will be used for cleaning and heating reduce the need for energy used to currently heat water for those purposes.

The first and foremost benefit of this project is the production of electricity from the livestock waste.  We will be producing 250kW per hour round the clock.  This electric production is valuable because of the need for additional sources of green power to supplement the power produced currently with the use of natural resources.  With the world population growing at an ever increasing pace, we need to find additional sources of power production to meet the needs of the public.  Electric production from livestock waste will also add $84,000 per year to the local economy as the dollars will be circulated throughout the area.  The use of the separated solids is an economic benefit to the dairy saving $37,180 per year by replacing purchased sawdust and an environmental benefit because there is no need for transportation of the bedding products.   Additional benefits to the dairy operation will be $7,000 saved from the use of hot water created by the cooling of the engine to replace water heated by conventional methods.

The value of using livestock waste for the production of energy is also evident in various ways. Livestock waste is readily available on a continual basis, so very little fossil fuels are necessary for the production of the energy both as feedstock and also in transportation costs when the digester is located at the livestock site. No crop land is taken out of production for the procurement of the feedstock. The liquid that remains is still available as a natural fertilizer, but in an enhanced state. An anaerobic digester system helps reduce the potential for non-point source pollution by providing the farm with a treated effluent suitable for crop fertilization. The properties of digested effluent are significantly different than raw manure. The nutrients in raw animal manure as excreted by the cows are distributed between inorganic and organic forms. Inorganic nitrogen (primarily ammonia) is readily available for plant uptake. However, the nutrients in the organic forms must be converted to inorganic forms before they are available for crop use. This conversion is accomplished by naturally occurring microorganisms. When raw manure is spread on the field, the rate of conversion is highly variable depending on soil temperature and moisture. The process has been proven to take up to three years to complete in this way. Until the process is complete, the unconverted nutrients laying free on or in the soil pose a much greater risk of leaching through the soil which can become a source of nitrate pollution in ground water.

The natural fertilizer still has all of the nutrients that are so valuable for crop production but during the digestion process any pathogens and weed seeds are destroyed making the product even more valuable. With the weed seeds destroyed the need for herbicides to kill weeds is greatly reduced which is an environmental benefit as well as an economic value to the farmer. We are estimating a 25% reduction in herbicide cost. The second benefit to the public is the elimination of methane gas and hydrogen sulfide ($H_2S$) from the animal waste. Both of these are considered a threat to the environment. The methane is burned in an internal combustion engine which exhausts carbon dioxide ($CO_2$). The $CO_2$ which replaces the methane is 20 times less damaging to the ozone layer. The $H_2S$ is being reduced at our dairy from 4,500 ppm to below 800 ppm. Air is injected at a calculated rate into the digester which mineralizes the $H_2S$ and keeps that out of the atmosphere as well.

A digester vessel provides a controlled, steady state environment for the conversion of the nutrients to take place. The digester consistently produces this uniform liquid fertilizer from the raw manure input. In addition, digestion increases pH, which enhances a more rapid plant uptake of nutrients by the soil and lowers the chances of leaching these nutrients into groundwater. This dependability of manure treated anaerobically will provide for better application strategies to meet state and federal water quality protection requirements.

Biochemical oxygen demand (BOD) is the amount of oxygen required for microbial metabolism of organic compounds in water. The reduction of BOD in the digested manure is reported to be between 80% and 90%. This means that if digested liquid were in water the potential for fish and other marine life being harmed is far less adding another reason digested liquid is a safer product to use as fertilizer on our crop land.

Equally important, the effluent can be spread on newly cut fields without killing or stunting the emerging second crops of alfalfa or other hay species. This allows for a longer nutrient balanced effluent application season giving us better control over the application and reduces impacts on waste storage requirements for the farm. Additionally, the nutrient uptake is improved throughout the entire growing season. This technique allows the spreading of manure during the entire growing season, meaning smaller amounts can be spread more often, all while improving nutrient utilization within the watershed.

The digestion process also kills any pathogens that may be in the raw manure and also weed seeds that have been secreted by the animal. The reduction of weed seeds results in a decreased need for herbicides to control weeds in the crops which is better for the environment and a cost saving for the producer.

Air quality is protected since the manure is contained in the covered and airtight vessel of the digester until bacteriological treatment has taken place. Treated effluent is discharged with greatly reduced bacterial and odor levels. Anaerobic digestion will virtually eliminate offensive odors including in storage ponds and field application. Odor reduction has been measured at existing digester systems in the 90% to 95% range making animal agriculture more public friendly.

Photo 4: A very simple, but very precise, introduction of a measured amount of oxygen into the digester vessel converts the $H_2S$ from a gas to a granule.

The digester will meet the requirement of controlling the farm's $H_2S$ emissions by utilizing the introduction of oxygen into the digester vessel. The oxygen causes the conversion of the $H_2S$ gas into a granule which is contained within the slurry and spread out on the fields. $H_2S$ as a gas is a pollutant but in granular form is not an issue environmentally.

**Project Lessons Learned:**

This project took nine years to complete. Most livestock producers do not have the financial resources to take on a project of this magnitude so finding sources of financing takes considerable time. Normal day to day activities on the farm can be in a constant state of upheaval during construction and the financing is a burden because the project cost grew with the length of time. Anaerobic projects also involve many different entities which also increases project complexity and creates delays if coordination is not on target. Therefore, projects such as this need to have adequate contingency funds for cost overruns and strong project management to coordinate schedules.

This type of project is very valuable both economically and environmentally, but it needs to be streamlined so that the agricultural community can adopt this in a timely manner. As stated earlier, most livestock producers don't have the financial resources to do a project of this type without outside financial assistance. This process takes a lot of time.

Once the digester vessel has been constructed and filled with manure the next step is to bring the temperature up to 100 degrees. The colder the temperature at that time, the more fuel it will take to reach this. The estimated cost to bring the digester up to temperature is $35,000 using liquid propane. Once the cover was placed on the digester the gas began collecting immediately. In order to save the cost of the liquid propane we purchased a used boiler for $8,000 that could be adapted to operate on the methane gas from the digester. Now that the engine is running the digester is heated with the hot water that comes off the engine cooling jacket. The boiler will be a backup for use if needed when the engine is being serviced or is off line for any other reason.

**Usefulness of Project Findings:**

The $H_2S$ is being metered and has already shown a reduction from 4,500 ppm down to less than 800 ppm which is an acceptable level for manufacturer warranty on the engine. This shows that a digester can be a solution to the $H_2S$ emissions that come from livestock waste. The methane gas is completely eliminated through burning it either in the engine or the by-pass flare. The use of a digester to mitigate $H_2S$ is, so far, the only known process which does the job and also provides income to the producer. All other procedures are strictly expense to the producer. For example, we are getting the job done using a $450.00 air pump compared to an $H_2S$ scrubber which costs between $80,000.00 and $100,000.00.

The composting of the manure that occurs in the digester vessel makes the effluent a safer product for use on the crop land, improving our manure management practices and allowing us to continue to farm in a sustainable way. Once the manure has gone through the digestion process and the gas is removed there is very little odor that remains making the storage and application of the effluent a much more public friendly product.

The solid particles that are separated out of the effluent are a very nice, soft bedding product for use in the cattle stalls. The digestion process has made them into a sterile product which is much more suitable for use with dairy cows to keep the bacteria levels down in the stalls. This means that the stalls will be less likely to contribute to mastitis in the cow's udders making the milk we produce high quality for use in processing dairy products for public consumption. The use of these solids as bedding also eliminates our need to purchase bedding products from outside sources. This lowers our cost for this product and since the products are produced on site there is no transportation necessary. This is a value not only for us as far as expense goes, but also environmentally by eliminating the fuel consumed by the semi trucks delivering the products and the wear and tear on the roads from the truck travel.

The hot water that comes off the cooling jacket on the engine will be more than necessary to keep the digester heated so we will be able to use this excess hot water in our dairy to replace the hot water heated with fossil fuels. This will save us money on fuel costs and will lower our dependence on foreign oil. Hot water is used throughout our dairy for cleaning the milking equipment, heating the dairy parlor and utility room, heating the newborn calf barn, the mechanic shop and the house. The production of electricity here at the farm will lower our utility cost helping us to keep our cost of production on the dairy down which will help us achieve a higher net income which will be used to bolster the local economy.

With the digester we will have the option of accepting outside sources of feedstock. This will allow us to add to our income stream from tipping fees. Outside sources of fats and sugars (for example bakery waste or used fryer oil) are very good products to produce gas and putting them through the digester will keep these products out of the landfills.

Livestock production in our country has gradually evolved to larger, more concentrated operations to gain efficiency and lower cost of production just like other businesses. With this, though, comes the responsibility to make sure that our natural resources are protected. Our digester will help us to achieve this by making the waste from the animals a much safer product both for storage and application.

**Technical Progress:**

The project consists of a 106’ X 18’ foot round concrete complete mix digester vessel, collection gutters at the ends of our cattle barns, a 30’ x 30’ x 12’ concrete influent pit, a series of underground piping, a 74’ x 40’ separation building and a 40’ x 50’ electrical building (See Attachment B).

Photo 5: Manure is scraped into the collection gutters three times each day.

At the end of the three cattle barns 8' deep collection gutters with a 2' x 10' opening were constructed. All of these gutters are connected with an underground 24" PVC pipe that flows by gravity to a central collection pit. The manure is agitated in the collection pit and pumped using a 6" piston pump with a 5 HP motor through an underground pipe to the digester vessel.

Photo 6: The manure flows by gravity from all of the collection gutters into the central collection pit.

As each gallon of manure is added to the digester an equal amount comes out and flows to a new 30' x30' x 12' concrete effluent pit.

Photo 7: The digested slurry flows into a pit from which it is pumped to the separator building.

The digester vessel  holds 1,137,892 gallons of waste. A complete mix digester was selected since this would be easier to manage then a plug flow.  For best gas production the digester needs to be at 100 degrees to be conducive to the bacteriological process occurring.  A complete mix agitates the product in the vessel and maintains a more even temperature since new feedstock is blended with the heated slurry. The live bacteria that provide the digestion process are exposed to more product since the bacteria don't move on their own.  The ideal retention time for the optimum production of methane is 22 to 25 days.  The digester vessel is sized for the volume of manure that would be generated by 1,375 cows to achieve that retention time.  With our current number of cows at the site the manure remains in the digester for a longer period of time until we can achieve full population of animals.

Photo 8: The skid on the right side of the photo brings the gas into the engine room.  The one on the left circulates the hot water.

As stated, the digester needs to maintain a 100 degree temperature for optimum for methane gas production.  This is accomplished by using hot water which comes from the cooling of the engine that produces the electricity. Hot water is recovered from the engine cooling jacket and exhaust and circulated to a heat exchanger to heat the digester. This water flows in a continuous loop of underground piping and is reused over and over cooling the engine, then heating the digester and then back to cool the engine again. This keeps water usage to a minimum and utilizes the heat of the engine rather than fossil fuel to keep the digester heated. The water coming off the engine cooling jacket is approximately 180 degrees so there is an excess of BTUs which will be directed to the dairy facility. There it will be used to replace water heated by fossil fuels that is necessary for cleaning the milking equipment and heating the building. This will result in reduced energy consumption and expense for the dairy.

Photo 9: Digested slurry is processed through a screw press separator located in the separator building. Solids are also collected and stored in this building.

The digested slurry is pumped out of the effluent pit to a 70’ x 40’ separation building where the liquid is squeezed out with a screw press separator and flows to our existing storage ponds to be held until the proper time for spreading on the crop land. The solid particles that remain are used for bedding in the cattle free stalls eliminating the need for purchased bedding products which reduces expense for the dairy. Roughly 20% of the slurry is solid particles which reduces the volume of waste that needs storage. When fully operational there will be excess solids that will be available for sale to other dairies or as a composted fertilizer product. This will add an additional source of revenue to the dairy.

Photo 10: The solid particles separated out of the digested slurry are a soft, sterile and odorless product for use as cattle bedding.

Photo 11: The cows rest comfortably in their stalls bedded with the separated solids.

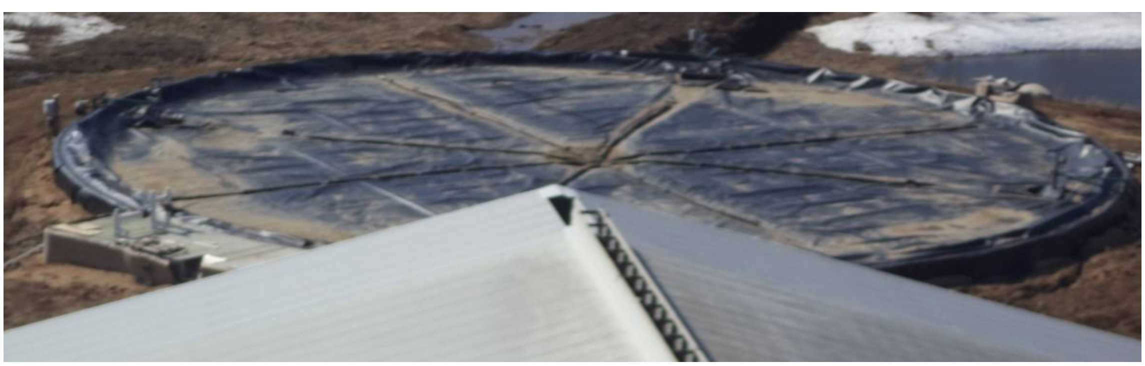


Photo 12: The digester vessel is a round concrete structure covered with a specially designed, sealed, floating insulated cover to capture the gas.

The methane gas that forms during the digestion process rises to the top of the digester and is captured in a specially designed, sealed, floating insulated cover and flows through an underground 8" PVC pipe 350 feet to the new 40’ x 50’ engine building.  A small turbine pump inside the engine building pulls the gas from the digester and concentrates the methane gas to a combustible fuel that is metered, pressurized and pumped to the 1,462 cubic inch biogas fueled engine-generator.  The engine produces up to 300 kilowatts per hour of electricity from this fuel and delivers it to an interconnection point to the grid for public consumption.  There is no storage for the gas produced in the digester.  If the engine is being serviced or is otherwise off line the gas is burned through a flare constructed a safe distance away from the dairy.

Photo 13: A flare has been constructed a safe distance away to burn the gas if the engine is being serviced or otherwise off line.

As soon as the cover was in place on the digester vessel we were able to use the methane gas to power a boiler that started the heating process in the digester.  This allowed us to eliminate the need for the purchase of liquid propane or other fuel for this purpose saving the dairy approximately $35,000.  The boiler will be available as a back-up heat source to keep the digester heated if the engine is off-line for any reason.


Photo 14: This boiler was purchased and retrofitted to burn the gas collected in the digester. It was used to bring the digester up to temperature initially and will be available for back up heat if needed.

The original pair of Caterpillar engines proposed were replaced with one Guascor engine which will produce up to 300 kWh of electricity (See Attachment C). The farm is projected to use approximately 35% of what we produce. The remainder will be sold to Xcel Energy for use on the grid. The electricity sold will provide power for approximately 472 average homes. This engine has a lower RPM rate and is more efficient than other available internal combustion engines therefore producing more electricity per BTU than comparable engines. Our generator building has been built with a spot for a second engine when we finish the expansion of our dairy and are able to utilize the full capacity of the digester.

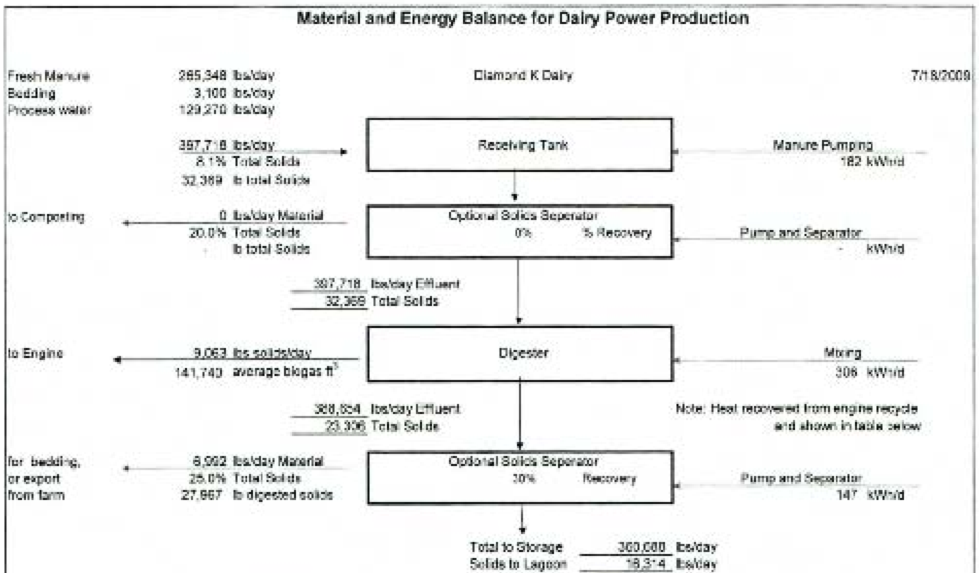

Photo 15: A Guascor engine is used to generate electricity from the methane.

Generation of electricity began at 3:03 pm on December 31, 2013. The engine was commissioned and the interconnection agreement was signed on January 2, 2014.

We are very happy to have this project up and running and believe it will be a very positive addition to our business. However, had it not been for the $H_2S$ violation, and the need to satisfy that, we are not sure we would have gone through with it because of the time and money involved.

## Legal Notice

Attachment A – Material and Energy Balance

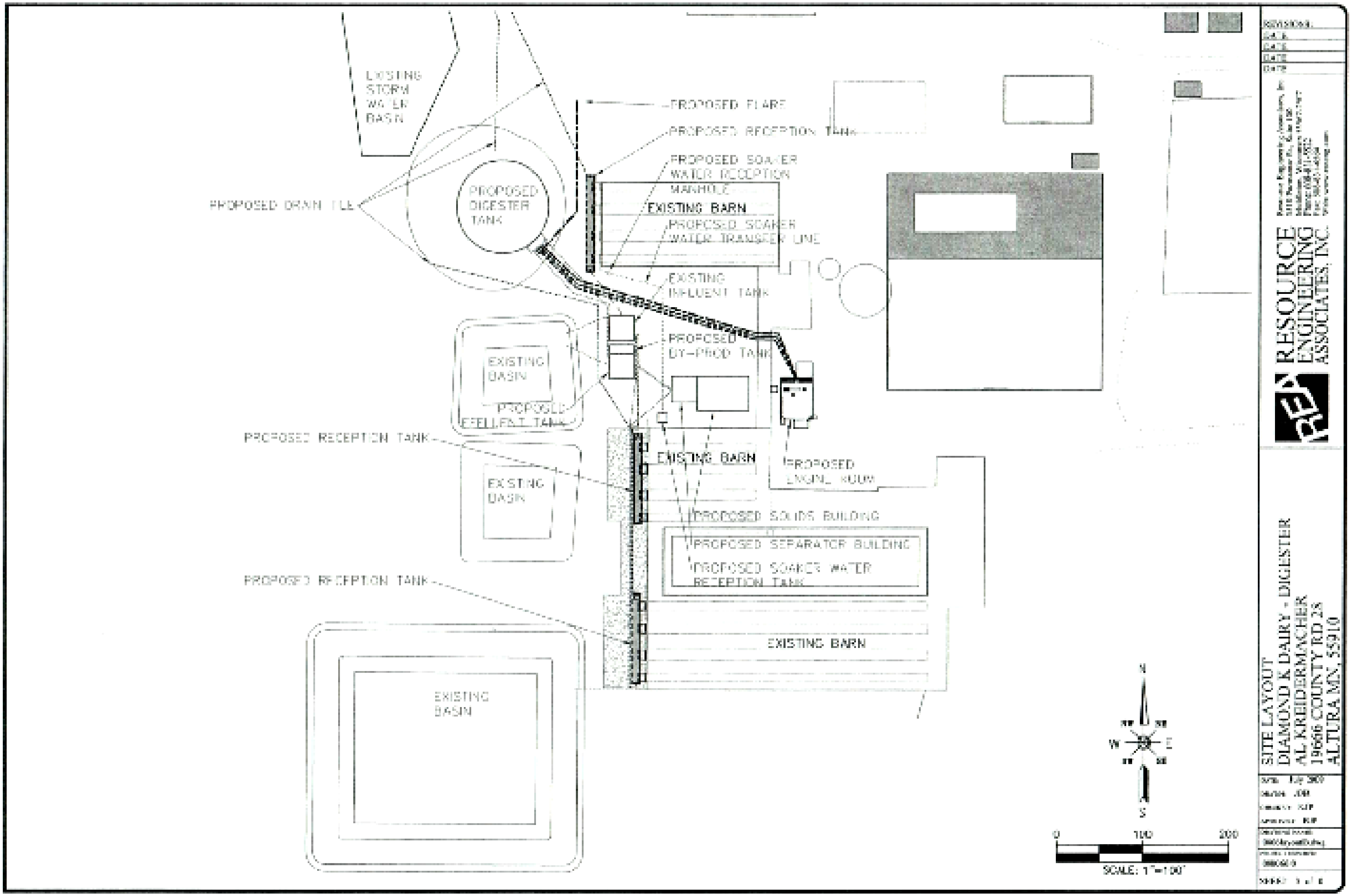



| Mass Balance | lb/d | lb/d | % |
|---|---|---|---|
| Solids from Cows | 32,369 | | |
| Pre Digester Solids Recovery | | - | 0% |
| Solids into digester | 32,369 | | |
| Solids to Gas | | 9,063 | 28% |
| Post Digester Solids Recovery | | 6,992 | 22% |
| Solids to Lagoon | | 16,314 | 50% |
| TOTAL | | 32,369 | 100% |

| Energy Balance-Genset | BTU/day | BTU/day | % |
|---|---|---|---|
| | Production | Use | |
| New Btu Produced | 85,044,200 | | |
| kWh Produced | | 29,017,081 | 34% |
| Radiated heat loss | | 6,803,536 | 8% |
| Generation Parasitics | | 2,321,366 | 3% |
| Hot water for digester or radiator | | 38,269,890 | 45% |
| Exhaust/other losses | | 8,632,326 | 10% |
| TOTAL | 85,044,200 | 85,044,200 | 100% |

| Energy Balance-Kilowatts | kWh/day | kWh/day | % |
|---|---|---|---|
| | Production | Use | |
| New Btu Produced 85,044,200 | | | |
| kWh Produced | 8,504 | | |
| Manure Pumping-NEW | | 182 | 2% |
| Predigester Separating-NEW | | - | 0% |
| Digester Mixing-NEW | | 306 | 4% |
| Post Digester Separating-NEW | | 147 | 2% |
| Power - Onsite usage/Sale | | 7,870 | 93% |
| TOTAL | 8,504 | 8,504 | 100% |

Attachment B – System Layout



Attachment C – Engine Specifications

| GROUP | | PRODUCT INFORMATION | INDEX |
|---|---|---|---|
| IC | GAS | IC-G-B-24-074 | 1 |
| | POWER RATING | DATE 09-05-07 | DEP. 2 |

| | | | |
|---|---|---|---|
| ENGINE: | SFGLD 240 | SPEED: | 1200 |
| JACKET WATER TEMPERATURE(ºF): | 194 | FUEL TYPE: | Sewage Gas |
| INTERCOOLER WATER TEMP(ºF): | 131 | | |

| | | | | | |
|---|---|---|---|---|---|
| APPLICATION: | | | CONTINUOUS | COMPRESSION RATIO: | 11.8:1 |
| COOLING SYSTEM: | | | TWO CIRCUITS | REGULATION: | Electronic |
| | | | | IGNITION TIMING: | 8º |
| EXHAUST MANIFOLD TYPE: | WATER COOLED | | | MAX. BACK PRESSURE: | 18 "H2O |
| EMISSIONS: | | | | | |
| | NOX | gr/bhph | 2 | AMBIENT CONDITIONS ISO 3046/1: | |
| | CO | gr/bhph | <2.2 | Atmospheric pressure ("Hg)= | 30 |
| | NMHC | gr/bhph | <1 | Ambient temperature (ºF)= | 77 |
| | | | | Relative humidity (%)= | 30 |

| POWER RATING (4) | | | NOMINAL | PARTIAL LOADS | | |
|---|---|---|---|---|---|---|
| LOAD | | % | 100% | 80% | 60% | 40% |
| MECHANICAL POWER | (3, 4, 5) | BHP | 448 | 359 | 270 | 180 |
| BMEP | | psi | 203 | 1624 | 1218 | 812 |
| FUEL CONSUMPTION | (1) | Btu/bhp-hour | 6733 | 6910 | 7330 | 8190 |
| THERMAL EFFICIENCY | | % | 37.8 | 36.9 | 34.7 | 31.0 |
| HEAT IN MAIN WATER CIRCUIT | (1) | BTU/min | 12862 | 10919 | 9497 | 7734 |
| HEAT IN SECONDARY WATER CIRCUIT | (1) | BTU/min | 5403 | 4151 | 3071 | 2275 |
| HEAT IN CHARGE COOLER | (1) | BTU/min | 2800 | 1877 | 1024 | 455 |
| HEAT IN OIL COOLER | (1) | BTU/min | 2602 | 2275 | 2047 | 1820 |
| HEAT IN EXHAUST GASES (77 ºF) | (1) | BTU/min | 12170 | 10236 | 8303 | 6369 |
| HEAT IN EXHAUST GASES (248ºF) | (1) | BTU/min | 9071 | 7722 | 6360 | 4964 |
| EXHAUST GAS TEMPERATURE | (1) | ºF | 748 | 774 | 801 | 842 |
| HEAT TO RADIATION | (1) | BTU/min | 810 | 796 | 682 | 569 |
| CARBURETION SETTINGS (2) | | | | | | |
| $O_2$ TO EXHAUST(DRY)(ONLY A REFERENCE) | | % | 7,6 | 7,3 | 7,0 | 6,5 |
| MASS FLOWS | | | | | | |
| INTAKE AIR FLOW | (1) | lb/h | 3680 | 2900 | 2270 | 1640 |
| EXHAUST GAS FLOW (WET) | (1) | lb/h | 3960 | 3210 | 2510 | 1820 |

**NOTES:**

1. 100% LOAD TOLERANCES:
   FUEL CONSUMPTION ±5%,
   COOLING CIRCUIT AND EXHAUST GASES ± 15%, RADIATION ±25%
   EXHAUST TEMPERATURE ±20ºC, MASS FLOWS ± 10%.
2. THE ENGINE PERFORMANCE DATA, TIMING ADVANCE AND CARBURETION SETTINGS ARE VALID FOR A GAS THAT FULFILS THE REQUIREMENTS DEFINED IN IC-G-D-30-001, IC-G-D-30-002 AND IC-G-D-30-003
3. NET POWER, MECHANICAL PUMPS NOT INCLUDED.
4. POWERS ARE VALID FOR AMBIENT TEMP.< 77ºF AND AN ALTITUDE OF < 1640ft.OTHER CONDITIONS IN IC-G-B-00-001
5. OVERLOAD NOT ALLOWED
6. THE SPECIFICATIONS AND MATERIALS ARE SUBJECT TO CHANGE WITHOUT NOTIFICATION
7. A ENGINE WITH INLET OR OUTPUT RESTRICTION OVER PUBLISHED LIMITS, OR WITH INADEQUATE MAINTENANCE OR INSTALLATION CAN MODIFY POWER RATING DATA.

| Nuevo | Cod.: C | Elab: | kll13 | Version: 6.0/23042007 | 1/1 |
|---|---|---|---|---|---|