GASIFICATION OF CATASTROPHIC LOSSES

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Abstract

A transportable gasifier was fabricated and tested with the goal of on-site processing of large quantities of animal carcasses and plant materials resulting from agricultural emergency events. The dual-chamber, semi-batch-mode, fixed-bed gasifier converts the biomass material into an inert ash and a combustible synthesis gas in two primary combustion chambers (PCCs). This mixture is then burned in two secondary combustion chambers (SCCs). Heat generated in the SCCs serves to maintain temperatures of the PCCs. Fuel oil was used as auxiliary fuel to maintain temperatures in the SCCs. Temperatures within the unit ranged from 1200 to 1800 °F (649 to 982 ºC). The unit was tested at a rendering facility during the period from March 3-6, 2008. Samples were taken and analyzed for several targets including combustion gases, particulate matter, metals, acid gases, dioxins/furans, leachable metals in the ash residues, and amino acids in the ash residues. Emissions of the measured pollutants were at relatively low levels, and the ash passed the toxicity characteristic leaching process (TCLP) test. In addition, emissions of carbon monoxide and total hydrocarbons correlated very well with the average temperatures of the two PCCs. These observations suggest that for emergency response deployment, the PCC temperatures may potentially be used as a surrogate monitoring parameter to assure minimization of emissions.

Introduction

The U.S. Department of Defense (DoD) Technical Support Working Group (TSWG), in collaboration with the U.S. Environmental Protection Agency (EPA) and the U.S. Department of Agriculture's Animal and Plant Health Inspection Service (USDA/APHIS), built a transportable gasifier with the goal of processing large quantities of animal carcasses and plant materials resulting from agricultural emergency events. This unit may be useful for other homeland security-related events as an on-site treatment/disposal process. This gasifier converts the biomass material into an inert ash and a combustible synthesis gas that is burned in a secondary combustion chamber.

This paper describes an emissions test that was performed to characterize gasifier operation. Testing occurred during the period from March 3-6, 2008, at the Valley Protein rendering facility located in Rose Hill, NC. During these tests (Lemieux, 2008, Lemieux et al., 2009), the gasifier was operated by the manufacturer on two different biomass feedstocks: 1) a mixture of poultry and swine carcasses; and 2) bales of wheat straw (BGP Inc., 2008). The prototype gasifier was intended to be capable of being operational in less than 24 hours after arrival at the site and to have the capability to process 25 tons per day of contaminated animal carcasses or plants.

The objective of these tests was: 1) to demonstrate system throughput; and 2) to determine the emission rates and concentrations of the target constituents by sampling the stack gases resulting from the combustion of the synthesis gas produced in the prototype gasifier. This paper only addresses the results of the tests with the poultry and swine carcasses. The complete data set from the source emissions testing can be found in a published EPA report (Lemieux, 2008).

Experimental

The BGP-D1000 gasifier (BGP, Inc.) is designed to process 25 tons per day of feed material, using a series of chambers, each with different fuel/air stoichiometry. Two independent PCCs, operating sub-stoichiometrically, feed into two independent SCCs, thus achieving a quasi-steady-state operating mode. Heat from the SCCs provides the hearth with thermal energy. The thermal inertia of the hearth prevents significant PCC temperature loss when high water content materials are charged onto the hearth. The unit operates on natural draft without requiring an induced draft fan. Up to eight units can be used together with one macerator to achieve larger capacities, up to approximately 200 tons per day, comparable to other large capacity fixed-site technologies. The macerator is used to grind the animal carcasses into a size capable of being pumped to the feed distribution system and deposited onto the hearths. The macerator was loaded using a ”skid steer” type front end loader with a nominal bucket capacity between 500 and 600 lb. The gasifier is designed to operate 24 hours per day for an extended period of time before any maintenance shutdowns would be required, provided that the auxiliary fuel tanks are refilled.

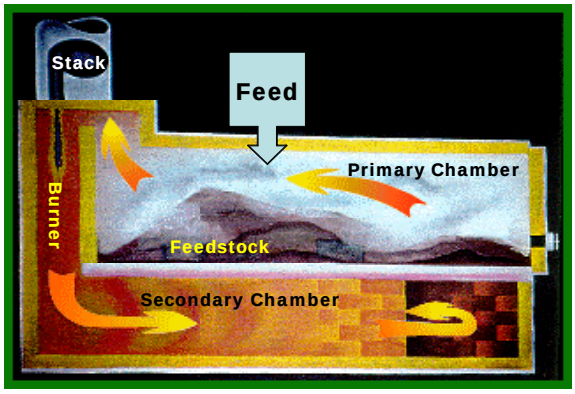

Figure 1. Gasifier Concept Schematic (Courtesy BGP, Inc.)

The gasifier unit is equipped with a telescoping stack (34-inch diameter and approximately 12 feet high) projecting above the gasifier. A 34-inch diameter dilution air inlet at the base of the stack allows for control of the natural draft that draws the air through the PCCs and draws the combustion gases through the SCCs.

Four burners (two were redundant) each capable of firing 8 gal/hr of No. 2 fuel oil were mounted in the duct between the PCC and SCC (i.e., two burners on each side). These burners provided initial heat to make the hearth hot enough to initiate gasification in the PCCs. The burners also provided process control to maintain predetermined temperatures in the SCCs. Each burner was fed from a fuel tank mounted on the trailer.

The gasifier unit was designed with a reservoir at the back end of the primary chamber to collect ash from the hearths. An ash removal auger was supposed to periodically remove the ash to be collected in metal bins outside the gasifier. However, the ash removal auger was damaged during startup and did not work throughout the tests. There was no way to quantify the amount of ash produced in the process.

The primary sampling location was the stack of the gasifier. An ambient total particulate sampler located near the dilution air inlet quantified the contribution of the dilution air to the stack particulate loading. The target stack gas constituents and parameters of interest are:

- Particulate matter (PM);

- Metals;
- Acid Gases (HCl/Cl_2);
- Dioxins/furans;
- Combustion gases (oxygen (O_2), carbon dioxide (CO_2), carbon monoxide (CO), nitrogen oxides (NO_x), sulfur dioxide (SO_2), and total hydrocarbons (THC);
- Periodic grab samples of the gasification product gas in the PCCs (i.e., synthesis gas) through sampling ports near the exit of the left primary chamber (when looked at from the end with the doors);
- Temperatures and flow rates at all sampling locations and within the system where practical; and
- Ash after it was augered. However, the auger failed during startup. Therefore, ash was pulled out the front (through the open doors with a rake) when the manual 'push back' was occurring.

Results

Figure 2 shows average carcass feed rate for test days 1 through 3. The unit was operating at approximately 30-40% of its design capacity during the tests. The average carcass feed rate over all runs was 0.32 tons/hr, which was about 1/3 of target. Because of the lower feed rate, fuel usage ranged between 11 and 16 gal/hr, which was close to the nominal firing rate of the burners. Lower fuel usage would probably have been achieved had the throughput been closer to the design capacity.

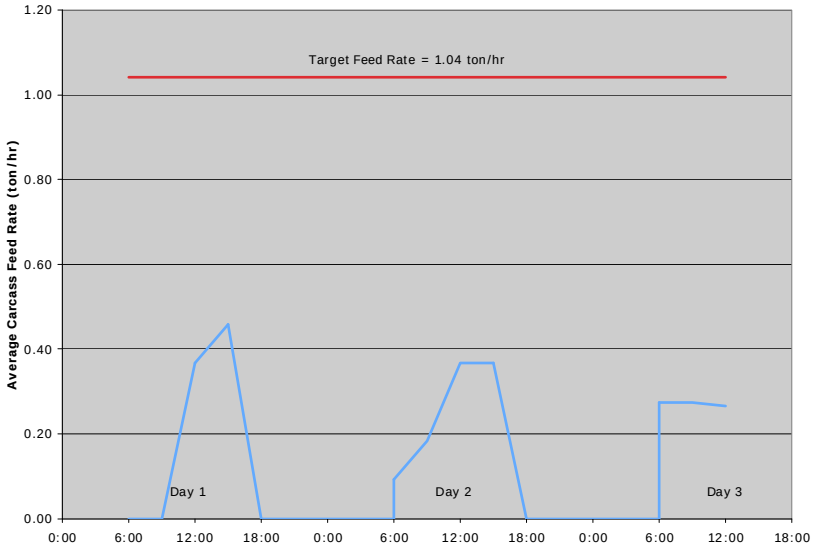

Figure 2. Average Carcass Feed Rate

Table 1 lists the gas concentrations measured by the Continuous Emission Monitors (CEMs) over the test days while animal carcasses were being fed.

Table 1. CEM Average Measurements, Dry Basis

Test Day	Time	Stack O_2 (%)	Stack CO_2 (%)	Stack CO (ppm)	Stack NO_x (ppm)	Stack SO_2 (ppm)	Stack THC (ppm)	SCC O_2 (%)	SCC CO_2 (%)
1	10:21-13:55	17.4	2.6	0	34	12	0	13.2	6.4
1	14:52-17:52	16.7	3.1	19	39	42	6	11.9	7.3
2	8:12-11:12	17.0	3.0	0	34	30	0	10.8	7.9
2	12:09-15:09	16.2	3.7	0	41	70	4	9.8	8.6
3	8:59-11:59	16.4	4.0	0	41	75	0	6.5	10.8
3	12:57-15:57	16.5	3.9	N/A*	42	62	0	7.3	10.6

* - N/A - Not Available - CO monitor operating at SCC exit

Taking the average emissions of each pollutant in pounds per hour and dividing by the average carcass feed rate (0.32 tons/hr) yields the estimated emissions in emission factor units, as used in the EPA's AP-42 Emission Factor Database (U.S. EPA, 1995). These results are shown in Table 2.

Table 2. Estimated Emissions

Pollutant	Average lb/hr	Average lb/ton of carcass
Total Filterable Particulate	0.297	0.93
PM_{10}	0.297	0.93
Organic Condensable Particulate	0.022	0.07
Inorganic Condensable Particulate	0.120	0.37
Total Particulate	0.439	1.37
Hydrogen Chloride	0.27	0.84
Chlorine as Cl_2	0.173	0.54
Antimony	ND	ND
Arsenic	1.04E-05	3.25E-05
Barium	5.16E-05	1.61E-04
Beryllium	ND	ND
Cadmium	1.08E-04	3.38E-04
Chromium	6.11E-05	1.91E-04
Cobalt	ND	ND
Lead	5.50E-05	1.72E-04
Manganese	4.69E-05	1.47E-04
Mercury	ND	ND
Nickel	1.00E-04	3.13E-04
Selenium	4.11E-05	1.28E-04
Silver	7.23E-06	2.26E-05
PCDD/F Total	1.24E-09	3.88E-09
PCDD/F TEQ	1.75E-11	5.47E-11

ND = Not detected.

Conclusions

A prototype transportable gasifier, developed by BGP for the Department of Defense Technical Support Working Group, was tested in the field in March 2008. The gasifier is intended to thermally process contaminated animal carcasses and plant matter.

Samples were taken and analyzed for several targets including:

- Fixed combustion gases, including oxygen, carbon dioxide, carbon monoxide, total hydrocarbons, sulfur dioxide, and oxides of nitrogen;

- Particulate matter, including total filterable particulate, condensable particulates, PM_{10}, and particle size distributions;
- Metals;
- Acid gases;
- Polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzofurans;
- Leachable metals in the ash residues; and
- Amino acids in the ash residues.

The unit was deployed in the field in a rapid manner, and was operational to perform the necessary emissions testing described in the Quality Assurance Project Plan in spite of having less than a week for initial startup and shakedown. This truncated shakedown schedule resulted in several operational issues that should be addressed through minor design modifications, discussed in the Engineer's Report (BGP Inc., 2008).

The operational issues of concern that impacted the emissions testing included:

- Failure of the ash removal auger contributed to a feed rate limitation; the on-board ash reservoir was sufficient, however, to last through the duration of the tests without requiring manual ash removal;
- Inefficient distribution of animal matter on the hearths in the primary chamber limited the unit's maximum throughput to approximately 32% of the design capacity; this limitation was partially due to the lack of a surge tank in the feed system resulting in charges entering the gasifier that were equal to the amount of material fed to the macerator, and partially due to cost constraints limiting the number of valves through which the material was fed;
- Air infiltrated into the primary chambers through some unknown mechanism, and the analyzed synthesis gas did not bear a resemblance to synthesis gas from other gasification processes, possibly due to air migrating from the secondary chambers through gaps in the hearth to the primary chamber in the vicinity of the sampling port, turbulent mixing from the burner zones, or an overabundance of air being pulled in through the ports in the doors;
- Emissions of the measured pollutants were at low levels, and the ash passed TCLP. There were slightly elevated emissions of cadmium, the source of which is unknown. Cadmium may be present in the materials of construction of the gasifier or macerator, since animal carcasses are not known to contain large amounts of Cd and the fuel oil did not contain any Cd;
- There are no emissions standards with which to compare this type of gasifier unit, although emissions of most pollutants were well below the EPA's New Source Performance Standards for small municipal waste combustors. The particle size distributions show that the vast majority of the emitted particulate matter was smaller than 0.5 microns.

Emissions of carbon monoxide and total hydrocarbons correlated very well with the average temperatures of the two primary chambers. This very important observation suggests that for emergency response deployment, the primary chamber temperatures could be used as a surrogate monitoring parameter to assure minimization of emissions. Additional testing should investigate this potential advantage.

Amino acid analysis of the ash yielded non-detects for all target analytes. The presence of amino acids would indicate that undestroyed proteins may have passed through the system. Since no

amino acids were measured, the gasifier unit could be capable of destroying prions that could potentially cause Transmissible Spongiform Encephalopathy (TSE), although no prion-containing material was fed during these tests.

Because the gasifier unit is simple and produces low emissions, it is important to gain a better understanding of the reactions taking place in the primary chambers. The low emissions may or may not persist as the unit is brought up to its full operating capacity. In addition, operation at full capacity may result in significant reduction in auxiliary fuel usage. It is hoped that minor design changes can be implemented and further testing at full capacity be conducted.

Disclaimer

The U.S. Environmental Protection Agency through its Office of Research and Development managed the research described here. It has been subjected to the Agency's review and has been approved for publication. Note that approval does not signify that the contents necessarily reflect the views of the Agency.

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