GAS RECOVERY AND UTILIZATION FROM MUNICIPAL SOLID WASTE LANDFILLS

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INTRODUCTION

Landfill gas recovery and utilization can be a viable energy resource. This gas, which is composed mostly of methane, carbon dioxide and minor amounts of non-methane organic compounds (NMOCs), is generated by anaerobic degradation of the municipal solid waste (MSW) in place. Although landfills are required to place a clay cap over the MSW to contain the gas generated, as well as to minimize environmental exposure to any other biological and chemical hazards, the cap can be breached by many mechanisms, including; gas migration through and around the cap, leachate migration, rain water erosion and heavy equipment activities. Therefore, MSW gas will eventually migrate out of landfills and be emitted to the atmosphere. Air emissions of NMOCs and methane from landfills are of concern, as there are over 6000 active MSW landfills nationwide as of 1987 with the potential to emit annually over 283,000 tons of NMOCs and over 12 million tons of methane (1). In addition, there are over 32,000 closed solid waste disposal facilities in the United States, many of these facilities having received MSW (2).

Gas recovery systems installed at landfills have been proven to effectively capture high quality gas (greater than 500 Btu/cubic foot). New Source Performance Standards (NSPS) for new and existing MSW landfills have thus been proposed by the US Environmental Protection Agency which outline minimum control requirements for gas recovery and subsequent combustion or utilization of the NMOCs in the landfill gas. These rules are proposed as 40 CFR Parts 51, 52 and 60, Standards of Performance for New Stationary Sources and Guidelines for Control of Existing Sources: Municipal Solid Waste Landfills; Proposed Rule, Federal Register, May 30, 1991.

Landfills required to comply with this proposed rule will be any new or operating landfill with the potential to emit more than 167 tons of NMOCs/yr (150 Megagrams/year) and closed landfills that have accepted waste since November 8, 1987. Assuming an average gas generation potential of 230 cubic meters/megagram (7374 cubic feet/ton) and an average NMOC concentration of 8,000 ppm NMOC (as hexane) in the landfill gas, any landfill that has or is accepting over 50,000 tons of MSW/year (45,400 Megagrams/yr) or that has a total of 750,000 tons of MSW in place would be required to comply with the proposed rule (1). A landfill of this size will generate approximately 280,000 cubic feet of landfill gas per day or, assuming 500 Btu/cubic foot in the gas, 5.8 MMBtu/hr. Testing the actual NMOC concentrations and gas flow rate from the landfill to show that the landfill gas emissions are actually under the threshold is possible and the procedures to show this are also outlined in the NSPS.

Landfills of the size mentioned will be required to show that their emissions are below 167 tons/year threshold of NMOCs by source testing, or the minimum gas collection and combustion requirements of the pending NSPS, which is referred to as "Best Demonstrated Technology" (BDT) to control the NMOC emissions, must be implemented. BDT is the combination of an active gas collection system and a combustion device with 98% NMOC combustion efficiency. Figure 1 shows a diagram of a model landfill with an active gas collection system, an energy recovery unit and two types of combustion flares (open and enclosed) (3). The diagram also shows other necessary ancillary equipment for gas recovery and utilization, such as a slurry cut-off wall, a leachate collection system and perimeter vents. A landfill with the equipment illustrated would be expected to comply with the proposed NSPS.

DISCUSSION

The minimum requirement for complying with the proposed rule in terms of simplicity of operation is an active gas collection system and an open flare. Candle flame type open flares are relatively inexpensive to install and operate. However, it is not possible to accurately sample air emissions from open flares. In addition, the open flare has no defined residence time at temperature and is aesthetically unpleasant due to the sight of the candle flame. Open flares are also difficult to control and can be subject to flame out during high winds. Therefore, it is difficult to predict the air emissions from open flares over an extended period of time, although the open flare is a dramatic improvement over venting landfill gas directly to the atmosphere.

Alternatively, enclosed flares; 1) provide for stack emissions measurement, 2) have a defined residence time, and 3) keep the flame hidden. This is due to the defined combustion chamber created by the stack of an enclosed flare. They also provide better mixing and temperature control in the combustion chamber, assuring more complete combustion. Therefore, the enclosed flare can be expected to perform with more dependability in keeping air emissions to a minimum than an open flare.

A deficiency of both types of flares is that they do not make use of the landfill gas as a fuel (energy) source. There are two major types of heat engine electrical generation systems that are capable of utilizing landfill gas for electrical power generation. The two types are reciprocating internal combustion engines and gas turbines. There are several advantages and disadvantages to each utilization option.

Reciprocating Engines

Reciprocating engines are popular due to their flexibility, low capital cost, low gas pressure and small size (base units start at 0.8 MW (1200 HP)). It is easy to add and subtract units with variations in the landfill gas generation or the size of the collection system and they operate with iow maintenance costs. In addition, when the reciprocating engines are operated at low operating pressure (12 - 30 psi), there is less gas compression condensate to handle and treat than if operating at high operating pressure (60 - 160 psi). The disadvantage of reciprocating engines are their relatively low combustion efficiencies as compared to turbines; 80% for internal combustion engines compared to 99+% for gas turbines. This results in low overall efficiencies for power generation and relatively higher air emissions for the same amount of gas combusted.

Gas Turbines

Gas turbines have the advantage of being highly efficient systems for electrical power generation, which results in relatively low air emissions. However, these two advantages come at the expense of several disadvantages; high capital and operating cost, limited flexibility, larger base capacity and higher maintenance costs than reciprocating engines, and the creation of large amounts of gas condensate. The gas compression condensate must often be treated as a hazardous waste. In addition, the turbines need a dependable gas source to operate efficiently. Both types of systems, turbines and reciprocating engines, are most efficiently operated when a flare is used as a back-up and/or as a supplemental combustion source to respond to fluctuations in landfill gas generation.

Air Emissions Comparison

The air emissions generated from the landfill operations are obviously of highest concern when the landfill gas is vented directly to the atmosphere. The addition of an active gas collection system and combustion control system of the types mentioned above relieve this concern dramatically. Once installed, the emissions from an active gas collection system itself are near non-existent due to the negative pressure maintained in the system and the relatively non-porous landfill cap. Only infrequent cases of gas well maintenance or isolated landfill gas pockets breaching the cap would likely cause any significant amount of emissions. Minor amounts of volatile organic compound (VOC) emissions are generated from condensate water collected from gas collection system pumps, exposed manholes and vents, water storage tanks and turbine or reciprocating engine compressors, as the water will contain a small percentage of soluble and insoluble VOCs.

A comparison of the emissions from the three combustion sources discussed, enclosed flares, reciprocating interal combustion engines and gas turbines, is shown in Table 1. Data for the table was generated from averaged actual compliance stack testing using the number of tests shown in the title block for each type of unit tested. The emissions data shown as referenced for each type of combustion system is from reference (3). Data has been included for both low pressure and high pressure reciprocating internal combustion engines. The enclosed flare data can be used to estimate the emissions for an untested open flare, assuming well-maintained operation and temperature control.

There are several points to note when comparing the emissions data for the landfill gas combustion units discussed.

1) The sulfur dioxide emissions for the turbines and the reciprocating engines were quite low, just as they are for natural gas combustion. This is expected as landfill gas is typically low in sulfur, usually below 200 ppm in total sulfur compounds. Sulfur dioxide was not measured in the test data shown for the enclosed flare. The reference information shows an average value of 0.006 lbs/MMBtu for flares, reciprocating engines or turbines.

2) Carbon monoxide (CO) emissions were found to be relatively high for the reciprocating engines and the enclosed flares, while being low for the gas turbines. This

can be an important consideration if the landfill is located in a metropolitan area which is non-attainment for CO. The turbine option is, therefore, a good possibility for many metropolitan areas of the United States.

3) Nitrogen oxides (NOx) emissions were higher for the reciprocating engines compared to the gas turbines and the enclosed flare. The reference data showed the same trend, although the NOx emissions for the actual reciprocating engine tests averaged over 3 times higher than for the reference data. It is unknown why this was the case.

4) The NSPS for new and existing MSW landfills has indicated that the VOC destruction efficiency for the flare, the reciprocating engine and the gas turbine is expected to be greater than 98%, if the systems are operating properly at appropriate operating temperatures. Note the low or not detected VOC emission values for the three combustion systems shown in Table 1.

5) In general, the actual test data matched the reference information quite well, especially the general trends of the data comparing the various sources. The largest deviation of the actual data from the reference data was the higher NOx and CO emissions for the reciprocating engines than shown in the referenced data. Consideration for the carbon monoxide emissions and nitrogen oxide emissions, which could be of major significance in metropolitan areas of non-attainment for CO and ozone must be taken into account concerning air quality compliance issues.

References

1. Federal Register, Standards of Performance for MSW Landfills, Vol. 56, No. 104, May 30, 1991.

2. Federal Register, 53 FR 33324, August 30, 1988.

3. Air Pollution Engineering Manual, Air and Waste Management Association, edited by A.J. Buonicore and W.T. Davis, Van Nostrand Reinhold, pages 863-73, New York, 1992.

TABLE 1
EMISSIONS DATA FOR LANDFILL GAS COMBUSTION AND UTILIZATION SYSTEMS

3.8 MW TURBINES (44 MMBtu/hr) (2 turbines tested - 6 tests conducted)				
	NOX	**SO2**	**CO**	**VOC**
Average Maximum Minimum	0.098 0.118 0.044	0.015 0.035 0.00	0.006 0.010 0.004	0.008 0.009 0.005
Gas Turbine[a] Reference Data	0.053	0.006	0.025	NA
1200 HP High Pressure Reciprocating Engines (9.3 MMBtu/hr) (1 engine tested - 4 tests conducted)				
	NOX	**SO2**	**CO**	**VOC**
Average Maximum Minimum	0.536 0.763 0.361	0.013 0.018 0.007	0.704 0.818 0.552	0.098 0.111 0.082
1200 HP Low Pressure Reciprocating Engines (9.3 MMBtu/hr) (6 engines tested - 19 tests conducted)				
	NOX	**SO2**	**C0**	**VOC**
Average Maximum Minimum	0.734 0.936 0.429	0.073 0.204 0.008	0.519 0.685 0.236	0.060 0.075 0.050
Internal Combustion[a] Reference Data	0.222	0.006	0.518	NA
78 MBtu/Hr Enclosed Flare (2 flare tested - 6 tests conducted)				
	NOX	**SO2**	**CO**	**VOC**
Average Maximum Minimum	0.019 0.020 0.017	NM NM NM	0.089 0.106 0.059	ND ND ND
Enclosed Flare[a] Reference Data	0.01	0.006	0.116	NA

NOTES:
ND - Not Detected NM - Not Measured NA - Not Available

All Data is Listed as Lbs/MMBtu
VOC Data listed as Total Hydrocarbon Emissions
[a]Reference: Air Pollution Engineering Manual, AWMA, 1992.
Calculations assume 1 Ft^3 of LFG = 500 Btu. Assumed efficiency for turbine was 43%.
Assumed efficiency for reciprocating engines was 32%.

FIGURE 1

DIAGRAM OF A MSW LANDFILL WITH GAS COLLECTION AND RECOVERY SYSTEMS