Desiccant Treatment of Landfill Gas for Seasonal and Intermittent Use Applications

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ABSTRACT

Although small landfills can generate significant quantities of landfill gas (LFG), beneficial reuse of this LFG may be difficult, or even impossible, at many sites due to the lack of a nearby LFG user facility. Traditional methods of cleaning, dewatering, drying and delivering LFG to a user facility are sometimes cost prohibitive when only seasonal uses are available in the vicinity of a landfill. However, if a cost effective method of delivering the LFG is developed, even seasonal use of the LFG can be deemed significant.

This paper will present and discuss how LFG from small landfills can be successfully compressed, treated and dried in an innovative system utilizing a dual tower, two type desiccant and filtration system. The treated LFG was then delivered through pipelines for use as a building space heating fuel or as a process fuel in nearby facilities. Since the heating load or process load at the facilities is seasonal and/or cyclical, the LFG treatment system was designed for minimal capital costs, minimal maintenance, ease of startup and shutdown, and simplified, unattended operation.

This paper will discuss the design and operation of the LFG treatment and delivery system, the modifications made to the existing system, and new heaters and process fuel burners to accommodate the use of LFG.

SYSTEM PARAMETERS

It is generally accepted practice that a LFG usage project can be feasible at landfills where the LFG flow is in the range of 200 to 1000 standard cubic feet per minute (scfm) with methane content of approximately 50%. It has also been traditionally necessary that a suitable LFG user facility be located within a 'reasonable' pipeline distance from the landfill for the delivery of the LFG to the user to be economically feasible. For projects where electricity is the best production option, the landfill must be located within a reasonable distance of a utility connection or at a facility where onsite usage is a possibility. In either case, the LFG must be cleaned and compressed for delivery to the end user. Although cleaning and compression equipment can be quite costly, an economy of scale would make such systems viable in many 'high flow' situations.

In addition, many small to moderate sized landfills can produce a sufficient quality of LFG for an extended period of time but the gas flow rates are not high enough to support a high capital expenditure for a LFG processing facility. Even when the LFG flow is sufficient, the demand for the LFG can be seasonal or fluctuating due to similar demand swings.

USAGE OPTIONS

In the past, LFG that was generated in small flow quantities at small landfills was treated as a nuisance and would simply be flared onsite because no sufficient market for the LFG existed. Whether the flow was too low, the user too far away or projected electrical revenues were not economically viable; LFG reuse projects at these landfills were usually thought to be not feasible. However, in many cases, limited LFG user facilities did exist. These limited use facilities could be in the form of a seasonal heating load, cyclical manufacturing production schedules, or simply a small, but steady demand. In many cases, the user was no further than the landfill's own back yard. Many of these landfills are located adjacent to other municipal facilities that could be a prime candidate for LFG reuse such as vehicle repair facilities, offices or other seasonal or cyclical use applications.

THE SOLUTION

The need clearly existed for a small, relatively inexpensive, straightforwardly designed, reliable and easy to operate LFG treatment system to fill this gap. A system that could clean LFG to an acceptable quality in small flow rates for seasonal, cyclical or small loads. By breaking down the requirements for cleaning and compression of LFG, it was shown that three basic conditions needed to be met;1) removal of particulate matter 2) removal of water, and 3) compression. If these conditions could be met individually or in combination in a small, low capital cost, low maintenance cost system, avenues for the use of LFG that were formerly closed could be opened.

Taking each challenge separately, it can easily be seen that each could be achieved by using readily available equipment and combine three systems to construct a master system. It has been demonstrated for many years that removal of particulate matter can be accomplished through filtration. However the use of filtration is not always possible if the particulate matter was still in a vapor phase as it passed through the filters. Water removal from a compressed air stream was also a commonly practiced science. Chilling of a gas below its dewpoint was very effective in water removal. The benefit of the chilling was that the particulate matter 'washed out' with the water as it was removed from the gas flow. Compression of the gas stream was another commonly achievable process, with many options of compressors or high pressure blowers available to accomplish the task. By taking items that were relatively 'off the shelf' components, a viable small scale LFG treatment system was envisioned.

As anyone with any experience in LFG handling knows, LFG does not act like air. LFG is combustible and corrosive, varies in density, and can be of unknown composition. Despite these characteristics, LFG does possess many of the same characteristics of air. With careful thought and engineering, it was felt that standard compressed air system components could be modified to allow for treatment of these difficult to handle LFG flows.

SYSTEM COMPONENTS

The first challenge to be addressed was thought to be the easiest – compression. Since standard design compressors and high pressure blowers have been used for many years for air flow, certainly they could be adapted for use in a LFG situation. This assumption proved to be correct in two ways; 1) LFG did behave much the same as air in a strictly compression sense and 2) certain compressors and high pressure blowers had been used many times or LFG with great success.

The next challenge was water removal. In conditions of pretty much any humidity level, the act of compressing air will result in a 'wet' air flow. The traditional method for removing this water from the compressed air stream has been through cooling or chilling the air. Cooling can be accomplished through the use of an air to air heat exchanger where the ambient air temperature is consistently below the desired dewpoint of the compressed air. In cases where cooling may not be achievable, chilling is employed. Chilling involves the use of a refrigeration system to further lower the dewpoint of the compressed air. However, many compressed air systems use a unique combination of cooling and desiccant water removal that eliminates the cost and complexity of chilling.

By using a desiccant system, where the desiccant is consumed as it removes moisture from the LFG flow stream, chilling was completely eliminated. Depending on the degree of moisture removal desired, either a single or dual tower desiccant system can be used. The desiccants chosen are salt based, highly hydroscopic materials that are contained in sealed vessels and react with the LFG to entrap and remove moisture. The resultant stream is salty water that is drained from the bottom of each vessel continuously while they are in operation. Typically, each vessel is filled with desiccant at the beginning of the heating season or operational cycle and from then on operates basically unattended, except to check the desiccant levels.

The reaction in the towers is really quite simple. As the moisture laden LFG passes through the desiccant filled tower, the LFG contacts the desiccant and the moisture acts to dissolve the desiccant. As this action occurs, the water moisture becomes liquid and freely drains by gravity from the bottom of the tank. As an added bonus, particulate matter in the LFG that is formed as the water changes phase washes 'down the drain' with the dissolved desiccant and liquid water.

DESICCANT TREATMENT SYSTEM

A LFG desiccant treatment system starts at a diversion valve that is usually located on the LFG flare system. LFG is diverted from the flow, either in full or partial flow conditions and piped to the system compressor. The compressor usually raises the LFG pressure to 5 – 20 psig and temperature to 100 – 125 degrees F. depending on the end use demands. From the compressor outlet, the LFG passes through an air to LFG heat exchanger where the temperature of the compressed LFG is dropped to generally below 90 degrees F. At this point, the change of phase from vapor to liquid of the LFG moisture begins and some liquid is drained from the heat exchanger through an inline moisture separator. Beyond the heat exchanger, the LFG enters the desiccant tower. It is in this tower that the main reaction of moisture removal occurs. In cases where a lesser LFG quality can be tolerated, this would be the only stage of liquid removal. In the majority of cases, a second desiccant tower is used to further 'polish' the LFG. This second tower uses a more highly hydroscopic desiccant. The two desiccant towers are fitted with bypass valves to allow operation of the system should addition of desiccant be necessary during an operating campaign. Following the desiccant towers, a final filter is used to ensure that maximum particulate removal from the LFG has been achieved and that carryover of desiccant dust has been minimized.

The components of the system are pressure rated according to the service conditions. Interestingly, as the desiccant towers are commonly used in compressed air systems, they are ASME code stamped for a working pressure of 150 psig. In contrast, the heat exchangers, which are custom engineered for each application are rated at a minimum of 15 psig, or higher, depending on system requirements. It was found that by using standard desiccant towers that are designed for compressed air service, a savings could be realized over custom pressure rated vessels.

In a dual tower desiccant system, the first tower is filled solely with desiccant. The desiccant is in a small ball shape, slightly smaller than a golf ball, and is shipped in 50 lb bags. Since it is not extremely reactive, no special handling conditions, other than keeping the bags dry, are required. The second tower is of a slightly different design. As the LFG flows upward through the desiccant towers, a layer of ceramic pieces is placed at the bottom of the bed and the desiccant is placed over this layer. Since the second step desiccant is highly hydroscopic, it is shipped in tightly sealed plastic pails to prevent premature degradation of the desiccant. The second stage desiccant is identical in appearance; therefore, care must be taken to not mix the two.

The entire desiccant based system can be factory fabricated on a single (for small systems) or multiple (for larger systems) steel skids that can be easily hauled on site and quickly placed into operation. By factory fabricating and skid mounting the systems, all mechanical and electrical components can be thoroughly checked prior to shipment, thereby reducing field erection, startup and commissioning time.

DESICCANT SYSTEM OPERATION

Operation of the entire desiccant system is quite simple. At the beginning of the season or operating campaign, the descant towers are filled and sealed shut. The inlet heat exchanger fan is then started to establish its operation. Then the inlet and outlet system valves are opened and the system compressor is started. At startup, the drain valves and drains are checked for proper and free flowing operation and once this is completed, the system is operational. Only periodic checking of the system is necessary. Any interruptions in operation are signaled to a central location and maintenance is performed as necessary. At the end of the season or operating campaign, the startup sequence is reversed; isolation valves are shut and the system can sit, unattended, until the next operating campaign.

LFG USAGE SYSTEMS

Combustion of LFG in any type of burner requires that the burner be specifically designed or modified for combustion of LFG. A derating of the burner is typically required because the methane content of LFG hovers around the 50% range while natural gas is typically 97% - 99+% methane. This volume of other gases in LFG limits the flow of methane through the burner orifices and the burner is then either derated or a larger capacity burner must be used.

For building heating applications, radiant tube burners are the burners of choice. These burners are individually thermostatically controlled for heat output and heat input is controlled with a flame rod. Automatic ignition is used for unattended operation. These burners are typically designed to operate on a 100% LFG flow. Co-firing with natural gas is a possibility, although not necessary due to the on/off operating cycle. Prior to initiation of heating system operation it is required that each burner and flame rod be cleaned, inspected and replaced as necessary for reliable operation

In larger systems for industrial processing or furnace heating, the nozzle mix burner is usually the burner of choice. These burners mix fuel and air as both are fed under moderate pressure into the burner nozzle where they are mixed and ignited. These burners usually require up to 10% natural gas co-firing because they operate in a fully modulating condition and the small flow of natural gas evens out the combustion and allows for a smoother ramping or transition in firing capacity.

CONCLUSIONS

Firing of LFG in small, seasonal and/or cyclical operations is no longer beyond the reach of LFG systems. A system of cooling, desiccant drying and filtration can efficiently and cost effectively allow LFG to be used in a variety of applications ranging down to these very low flows of intermittent operation. With standard off the shelf components and straight forward system engineering, these systems can be assembled, delivered and placed into operation rapidly and cost effectively. LFG use is no longer bound by the ties of large flow requirements through long pipelines to large combustion facilities or through the use of capital intensive electrical generation facilities.

QUALIFICATIONS AND EXPERIENCE OF THE PRINCIPAL AUTHOR/PRESENTER

Mr. Curro is a principal engineer, senior solid waste engineer and the landfill gas discipline leader with CDM Smith in Boston, Massachusetts. He has more than 40 years' experience in solid waste projects, concentrating on landfill gas, waste combustion and field operations. He has served as the lead design engineer for landfill gas extraction, compression, flaring, beneficial use and transmission systems. He has written and presented a number of papers at various national and regional conferences.

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