ENHANCEMENT OF LFG CAPTURE FROM LANDFILL GAS EXTRACTION WELLS AT MUNICIPAL SOLID WASTE LANDFILLS

Harold Barber, P.E., Republic Services, Inc.
Stefan Stamoulis, P.G., Prospector Drilling and Tool Co.
Scott Trebus, P.E., Republic Services, Inc.
Michael Widner, P.G., American Environmental Group, Ltd.

ABSTRACT/INTRODUCTION

The primary purpose of landfill gas (LFG) extraction systems is to prevent the migration of landfill gas. A component of these systems, the actual LFG wells, generates revenue capacity through LFG collection for specific landfills that construct and operate landfill gas-to-energy facilities. Once installed, enhancement options for improved efficiency and consistency are limited. Rehabilitation options for LFG extraction wells with operation challenges are rare. Factors contributing to the limited options for enhancement and rehabilitation of methane recovery wells consist of, but are not limited to: regulatory constraints, lack of innovative technology, capital cost, and facility design and logistics.

Current viable options and methodologies for rehabilitation of LFG extraction wells include: pump installations for watered-in (flooded) wells, solution/pressure-fracturing in wells that have been silted in or clogged, and replacement with a new well(s). Furthermore, the continual placement of waste requires a vertical extension of the well riser. In these situations, efficiency of the Gas Control and Collection System (GCCS) is degraded. Eventually these wells will require total replacement.

Post-perforation of LFG extraction wells provide an additional method to enhance LFG capture from the extraction well without replacement. This technology assists in extending the life, functionality, production, and efficiency of LFG extraction wells in addition to being a progressive step in maintaining compliance, decreasing operational and capital costs, and increasing the capture of landfill gas over time. Post-perforation is a multi-functional approach to well enhancement that can be safely

implemented on wells that are not maintaining standards of environmental compliance, flooded due to elevated entrained liquids, clogged, and wells that require an increase in landfill gas capture due to vertical accumulation of waste.

BACKGROUND

Landfill gas migration was first noticed sometime between 1953 and 1961 (Hickman, 2003) during the national transition and progression from open burning dumps to the municipal solid waste landfills (MSWLFs) of today. Sometime during the late 1950's, lateral movement of LFG from a waste cell into nearby structures was observed. Because of this, the first engineered solution to lateral movement of LFG was designed and implemented in Arlington, MA: a gravel-filled interceptor trench was installed to passively vent LFG moving laterally and away from the landfill and a number of monitoring probes were installed between the trench and the building to monitor the success of the passive control measure (Hickman, 2003).

The first legislation to enact air and subsequential LFG compliance monitoring guidelines was achieved under the Clean Air Act (CAA) of 1970. However, no standards were implemented at this time. The EPA issued "Guidelines for the Land Disposal of Solid Wastes" in 1974 to help facilitate the design and monitoring of landfills but were not recognized as standards, and therefore, not enforceable. It was not until the CAA Amendments were legislated by Congress in 1990 that two regulatory programs, now integral to the solid waste industry, were established: the New Source Performance Standards (NSPS) and National Emissions Standards for Hazardous Air Pollutants (NESHAP). This new regulatory framework set up standards to which all emissions must be monitored.

The New Source Performance Standards (NSPS) have impacted the way in which the solid waste industry operates. The NSPS are intended to promote effective mechanisms for the collection of landfill gas (U.S. EPA, 1996). By mandating new compliance standards that include regular and frequent monitoring, capture of landfill gas, and timely installation of landfill gas collection devices, the amount of LFG emitted into the atmosphere as greenhouse gas since NSPS's inception has declined.

Hazardous air pollutants were also outlined in the CAA Amendments of 1990 but not promulgated, in the form of National Emissions Standards for Hazardous Air Pollutants (NESHAP), until 2003 (Sullivan, 2007). This standard increased reporting requirements from an annual event to semi-annual events and attempted to bring a proactive approach for self and site regulation to the industry.

Greenhouse gas regulations, as they pertain to LFG, are becoming stricter as the industry continues to grow and technologies to mitigate greenhouse gases increase. For example, current reporting of gaseous compounds which potentially contribute to climate change is mandatory as of December 29, 2009, for all MSWLF with the potential to emit greater than or equal to 25,000 metric tons of carbon dioxide equivalents per year (U.S. EPA, 2009). The increasing regulatory trend creates a responsibility for owners of solid waste facilities to comply with new and exacting regulations. This, in turn, has increased the marketability of LFG as a commodity and is now viewed as a new revenue stream. By installing and maintaining efficient LFG extraction wells and LFG-to-energy infrastructure, solid waste facilities can better manage LFG in a more efficient and cost effective manner. Generation, efficient capture, and conversion of LFG to energy have the potential to create income once lost in the form of emissions.

METHODS OF ENHANCEMENT OF LFG EXTRACTION WELL PERFORMANCE

Enhancement of LFG extraction wells is achieved by efficiency in capture of LFG. With a more efficient capture method in place, it can be assumed the volume and flow of LFG capture will be increased. Because of this higher efficiency in capture and flow, it is reasonable to assume that the LFG captured will have a higher percentage of methane. A higher percentage of methane capture is desirable for multiple reasons, particularly to minimize mitigation to the atmosphere as a greenhouse gas and associated financial repercussions, and for monetary gains via gas-to-energy production facilities.

Enhancement of extraction wells can also be accomplished by capturing LFG in higher elevations of the landfill profile and areas where the well risers have been extended to accommodate cell expansion by an increase in the surface area along which LFG is obtained. With the capture of LFG along the total thickness of the cell, the volume of gas captured is greatly increased. An improved surface area to capture LFG is an efficient way to enhance capture and quality (% methane) of LFG from extraction wells.

A third and final method of enhancement of LFG extraction wells is to rehabilitate problem wells, i.e. wells that have been flooded or clogged/pinched and are no longer successful at LFG capture or their production has significantly decreased since installation. Rehabilitation of such underperforming wells mitigates the issue of noncompliance, greenhouse gas emissions and associated costs, and capital costs previously applied to unsuccessful attempts to rehabilitate. Additionally, a rehabilitated well increases a site's total capture and quality of LFG. Ultimately, successful rehabilitation adds to the bottom line instead of being an overhead expense.

POST – PERFORATION – THE NEW TECHNOLOGY TO EFFICENTLY AND EFFECTIVELY ENHANCE WELLS

Historically, options to help LFG extraction well efficiency and attempts to rehabilitate wells were very limited. Typically, pump-installation was used in an attempt to restore flooded, underperforming wells back to a functional state. More often than not, complete LFG extraction well replacement was the only reasonable physical and economical solution.

Recently, a new technology has been developed that successfully rehabilitates underperforming LFG extraction wells and increases efficiency of capture and increases the flow of LFG in other wells. Furthermore, the quality of the LFG captured has shown to have a higher percentage of methane after application of this technology to LFG extraction wells.

Post-perforation is the method and technology developed after observation of the installation, unsuccessful rehabilitation, and well replacement cycle coupled with knowledge of drilling and engineering techniques. The idea to post-perforate LFG extraction wells from inside the well was a realistic solution to an industry age-old problem: the potential to greatly extend the operational life and efficiency of a LFG extraction well. After several years of research, design, and development, the post-perforation theory has proven successful at several locations throughout the Gulf Coast Region. A patent for this technology was recently awarded under the Pilot Program for Green Technologies and Greenhouse Gas Reduction program as a successful, innovative technology that will help to lower greenhouse gases and overall emissions from MSWLFs while increasing capture and flow of LFG which can be recycled and converted into usable, green energy that is sold back into the grid.

Post-perforation is a new approach to rehabilitate wells once thought to be only enhanced by replacement. Post-perforation greatly extends the life of LFG extraction wells and increases capture and flow of LFG almost instantaneously.

Post-perforation is achieved by sending a tool down the inner diameter of the LFG extraction well casing to a desired depth. Once at that depth, the tool generates new apertures in the casing, without compromising the integrity of the well casing, essentially creating a new screened interval. The benefit of this technology is that the new screened interval can be created at any depth within the well (i.e. the original screened interval or above). Post-perforation with a tool specifically designed for LFG extraction wells have shown to be highly successful because the tool can be effectively navigated through slight bends and deflections in the well casing/riser and other well deviations previously determined nonremediable except by replacement. Post-perforation has proven success in HDPE and PVC wells for 6-inch and 8-inch diameter casings.

NSPS facilities are required to operate LFG extraction wells and associated systems to maintain a minimum, regulatory stated, extraction wellhead operating pressure, wellhead oxygen concentration, and wellhead temperature. Post-perforation enhances the ability of a LFG extraction well operating outside of these NSPS parameters, specifically for pressure and oxygen concentration, to return within compliance and operational specifications, in a time efficient manner. By generating new apertures, LFG flow is increased while the extraction capacity of the well is increased and quality of the gas is enhanced.

The generation of apertures in the well casing for flooded wells releases liquid that has built up inside the casing to allow LFG to flow into the well through the liquid via newly generated apertures. Additionally, when extraction wells are vertically extended, post-perforation makes it possible to capture LFG in higher elevations of the waste cell because of the extended surface area of the screen or perforated zone not originally present.

Post-perforation is also safe and successful in volatile and explosive well environments by operating with non-sparking methods. This attribute of the technology to be successful in volatile and explosive environments creates new possibilities to rehabilitate and gain LFG from wells once thought to have too dangerous of an environment to work within, limiting enhancement opportunities.

By generating and/or increasing LFG-to-energy opportunities, the landfill can create new revenue streams from those previously thought an economic drain. Landfill gas has the potential to be a large portion of the biomass energy generated nationwide and contribute to the larger energy grid with minimum integration costs, especially because capture requirements already exist. The cost of electricity generated from landfill gas is generally competitive with other renewable resources (Wiltsee, 2009), confirming the added value of LFG-to-energy infrastructure and well efficiency. Because LFG has to be captured and regulated, the next logical step for most owner/operators would be to collect, convert, and sell LFG to offset the maintenance and regulation costs. Post-perforation increases the amount of LFG accessible and increases the volume and flow to the LFG-to-energy facilities, ultimately contributing to the bottom line.

CASE STUDY

Post-perforation was applied to several LFG extraction wells at a Site in the Metro Houston Area. The five (5) wells, on average, were post-perforated approximately 10.8 feet in length. Generally, the wells were perforated from a depth of approximately fifteen (15) feet below ground surface (ft bgs) to depths between twenty (20) ft bgs and thirty-two (32) ft bgs. All LFG extraction wells were post-perforated in the same day. Results of readings from each of the LFG extraction wells from a time period of three consecutive months prior to post-perforation were compared with results for three consecutive months after post-perforation.

Table 1 (below) is a summary of the average measured flow of all wells post-perforated at the Site for a time period of three consecutive months before post- perforation and three consecutive months after post-perforation.

Table 1: Results for Average Measured Flow of All Wells at Site Pre- vs. Post-Perforation

Well ID	Measured Flow Pre-Perforation (SCFM)	Measured Flow Post-Perforation (SCFM)
Well 1	52.00	62.67
Well 2	18.67	56.33
Well 3	35.00	14.33
Well 4	40.67	44.00
Well 5	29.67	28.67

Figure 1 (below) depicts the average measured flow of all wells at the Site for a time period of three consecutive months before post-perforation was applied versus three consecutive months after post-perforation was applied (numerical values are presented in Table 1 above).

Figure 1: Average Measured Flow Pre- vs. Post-Perforation for all LFG Extraction Wells Perforated at a Site in the Metro Houston Area:

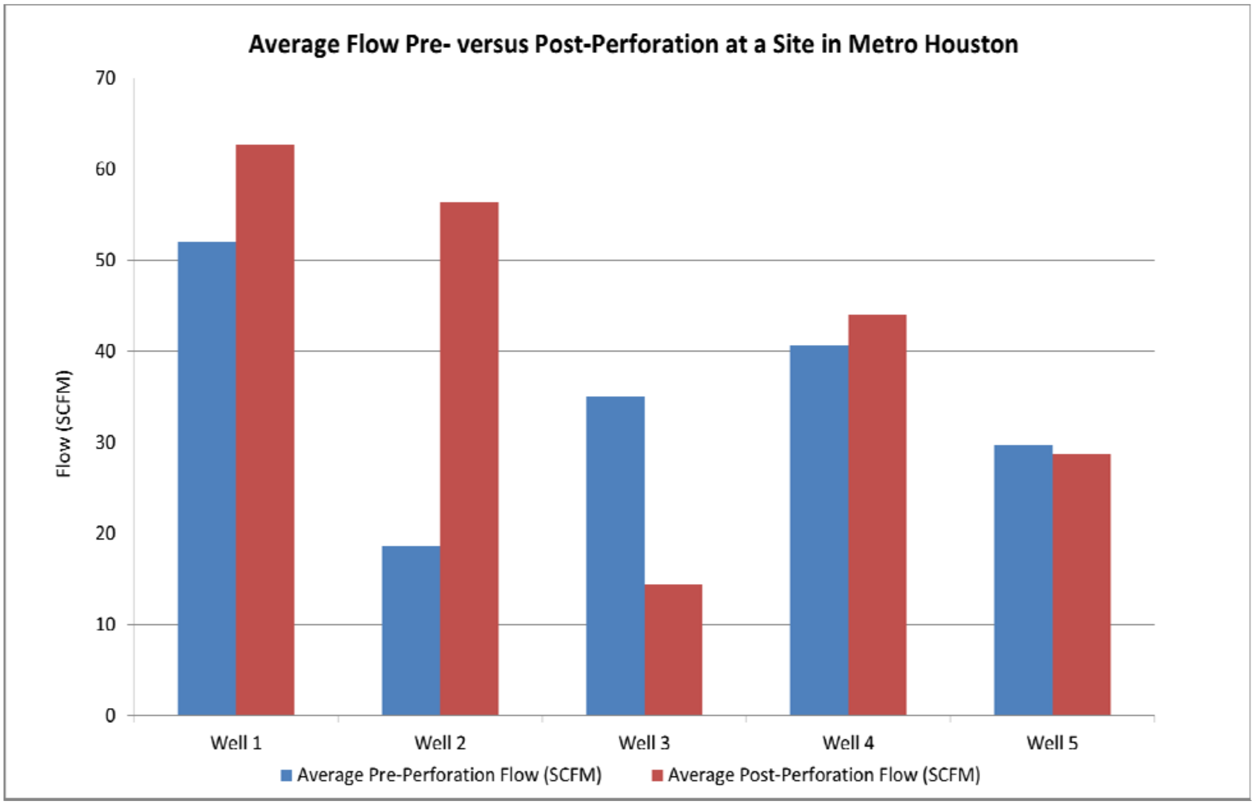

Figure 1 (above) illustrates that post-perforation at the Site successfully increased the volume of flow in three of the five wells post-perforated. Well 2 saw the largest increase in flow volume with an increase of approximately 67%. Well 3 had the least successful results after post-perforation with a flow volume decrease of approximately 59%. Overall, for the five wells post-perforated, the volume of flow increased a total 30.0 standard cubic feet per minute (scfm).

GENERAL TRENDS

Results from four selected landfills with more than five LFG extraction wells post-perforated were analyzed for a general trend after post-perforation was complete. Data from these sites recorded after post-perforation were analyzed and compared to data recorded prior to post-perforation for trends in methane (%), oxygen (%), and flow (SCFM). In each case, analyzed data was compiled and averaged from a time period of three consecutive months before post-perforation and for three consecutive months after post-perforation. This was done to normalize the data in a consistent manner between all four sites. Results of these analyses show that overall, for percent methane, out of thirty-eight (38) wells, half (19) displayed an average increase in percent methane and half (19) displayed an average decrease in percent methane in the LFG. Generally, fifty percent (50%) of wells reported an increase in percent methane after post-perforation was applied.

For percent oxygen of the same thirty-eight (38) wells, twenty-two (22) displayed an average decrease in percent oxygen after post-perforation was applied. Fifteen wells displayed an increase in percent oxygen. Generally, sixty-one percent (61%) of wells reported a decrease in percent oxygen after post-perforation was applied. For wells with oxygen readings above compliance standards (5%), post-perforation successfully lowered percent oxygen below compliance standards in a time efficient manner (i.e. the next event). Furthermore, percent oxygen below compliance was maintained eight months after post-perforation. Additionally, multiple wells reported readings of percent oxygen between 4% and 5% before post-perforation. All of these wells reported significant declines in percent oxygen after post-perforation, with average reported values ranging between 0.27% and 0.52% for a period of at least nine (9) months following post-perforation.

For flow (SCFM) of the same thirty-eight (38) wells, twenty-six (26) reported an increase in flow during the three months after post-perforation was applied. Eleven wells reported a decrease in flow. Generally, seventy-one percent (71%) of wells reported an increase in flow (scfm) after post-perforation was applied.

These trends signify the success of post-perforation when applied to LFG extraction wells on site. Approximately half (50%) of all wells where post-perforation has been applied show an increase in percent methane, approximately 61% show a decrease in percent oxygen, and approximately 71% show an increase in flow (SCFM).

In closing, post-perforation is an exciting new technology that has demonstrated the potential capacity to increase the volume of landfill gas extracted from wells and extend the operational life of LFG extraction wells at a minimal cost. The post-perforation tool will provide methods to ensure a GCCS has the ability to operate at designed specifications, meet environmental compliance standards, and increase flow from extraction wells to the GCCS while maintaining costs savings over well replacement with minimum maintenance and operation costs during the life of the extraction well.

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