Field Operations

Landfill Gas Generation

A brief overview of the theory of landfill gas generation and methane recovery follows. Initially, when decomposable refuse is placed into a solid waste landfill, the refuse is entrained with air from the surrounding atmosphere. Through a natural process of bacterial decomposition, the Oxygen (O_2) from the air is consumed and an anaerobic (Oxygen free) environment is created within the landfill. This anaerobic environment is one of several conditions necessary for the formation of Methane (CH_4).

If O_2 is reintroduced into the landfill, those areas are returned to an aerobic (Oxygen present) state and the Methane producing bacteria population is destroyed. A period of time must pass before the productive capacity is returned to normal. Since there is some Methane of a given quality within the landfill void space, a decline in Methane quality is only gradually apparent depending upon the size of the landfill.

Carbon Dioxide (CO_2) is also produced under either an aerobic or anaerobic condition. Under static conditions, the landfill gas will be composed of roughly half Methane and half Carbon Dioxide with a little Nitrogen (N_2).

As air is introduced into the landfill, the O_2 is initially converted to CO_2 and residual N_2 remains. Measurement of residual Nitrogen is usually a good indicator of the anaerobic state of the landfill; however, it cannot be directly measured. It can, however, be assumed and estimated using a subtraction basis as the balance gas. Hence, the measurement of CO_2 is an intermediate step. Because CO_2 levels may fluctuate depending on the changing concentrations of the other constituent gases, CO_2 levels are not evaluated directly but are considered in light of other data.

In evaluation of residual N_2, allowances must be made if there has been any air leakage into the gas collection system or if there has been serious over pull. If enough air is drawn into the landfill, not all Oxygen is converted into CO_2 and the O_2 is apparent in the sample.

It is ideal to perform routine analysis of individual wells, as well as an overall well field composite sample, by a gas chromatography. This is not always practical at every landfill.

Under some conditions there may be a small amount of hydrogen (H_2) in the LFG, (about 1 percent, usually much less). This may affect field monitoring response factors, but otherwise it can be ignored.

Subsurface Fires

If very large quantities of air are introduced into the landfill, either naturally or through overly aggressive operation of the LFG system, a partly unsupported subsurface combustion of the buried refuse may be initiated. Subsurface fires are difficult to control or extinguish once started; they present health and safety hazards; and they can be quite costly. Therefore, prevention by good operation of the collection system and maintenance of the landfill cover, is the best course of action. The presence of Carbon Monoxide (CO), CO_2, and Hydrogen Sulfide (H_2S) are indicators of poorly supported combustion within the landfill.

Techniques for Controlling Landfill Gas

There are many techniques for controlling landfill gas extraction. The Accu-Flo wellhead is designed to work with all of these techniques. Below is a discussion of the individual techniques, how to use them, and their limitations. Reliance on only a few of the techniques discussed can lead to misinterpretation of field data and improper operation of the well field. Later the best use of these techniques to optimize landfill gas control will be discussed.

Controlling by Wellhead Valve Position

Unless the valve handle is calibrated for a given flow rate, this method is unreliable. The position of the valve handle alone does not provide sufficient information about the well to control it. It is useful to note the relative position of the valve, and essential to know which valves are fully open or fully closed.

Controlling by Wellhead Vacuum

This technique relies on the relationship of well pressure/vacuum to flow for a given well. Reliance upon this method, however, can be misleading. This is because the square root relationship between flow and pressure is difficult to affect while performing day-to-day well field adjustments. As decomposition, moisture, and other conditions change, this method shows itself to be inadequate and imprecise.

Controlling by Gas Composition

This method measures CH_4, CO_2, O_2 and other gases at wellheads and at recovery facilities using portable field instruments and, sometimes, analytical laboratory equipment. Complete knowledge of gas composition (i.e., major fixed gases: Methane, Carbon Dioxide, Oxygen and Nitrogen) is desirable. It is also necessary to check other gases , such as Carbon Monixide, to fully evaluate the condition of the well field.

Reliance on this information can lead to improper operation of the well field. Indications of excessive extraction often do not show up right away. This method often leads to a cycle of damage to the methane producing bacteria population and then to over-correction. This cycling of the well and producing area of the landfill is not a good practice. It leads to further misinterpretation of the condition of the well field and has a disruptive effect on the operation of the well field.

The use of analytical laboratory instrumentation such as a gas chromatograph is a valuable supplementary tool to verify gas composition. This normally requires collection of samples at the wellhead followed by transportation to a lab where the equipment is located. The drawbacks of this method as a primary means of obtaining information for well field adjustment are the time expended, the cost, and probably most important, the lack of responsiveness to the needs of the well field for timely adjustment. The laboratory equipment required is also very costly.

Some analysis is recommended for verification of field readings from time to time. It is recommended a monthly sample of the composite gas be taken at the inlet to the flare or gas recovery facility.

Controlling by Flow Rate

This is a more precise technique for determining and adjusting gas flow at individual wells. It requires using a fixed or portable flow measurement device at each wellhead to obtain the data needed to calculate volumetric (or mass) flow rates. It is normally convenient to use cubic feet per minute or per day, as a standard unit of measure for volumetric flow.

It is important to distinguish between the volume of landfill gas and the volume of Methane extracted from each well and the landfill in total. The two variables are somewhat independent of each other and it is the total quantity of Methane extracted we are interested in. It is possible for the total quantity of landfill gas extracted to increase while the total quantity of Methane extracted decreases. To monitor this, the quantity of Methane extracted (LFG flow × percent CH_4) or the quantity of BTUs recovered per hour (LFG flow × percent CH_4 × BTUs per cubic foot of CH_4 × 60 minutes per hour) can be calculated. It is conventional to measure BTUs per hour as a unit of time. There are approximately 1012 BTUs of heat per cubic foot of pure Methane (like natural gas), although this figure varies a little among reference texts.

Measuring flow is an essential part of monitoring and adjusting a well field. The well should be adjusted until the amount of Methane recovered is maximized for the long term. A greater amount of Methane or energy can usually be recovered over the short term; however, this ultimately leads to diminishing returns. This is seen in stages as increased CO_2 and gas temperature and later as increased O_2 from well over-pull. In time, the Methane will also decline. This is the result of a portion of the landfill, usually at the surface, being driven aerobic. In this portion of the landfill, the Methane producing bacteria will have been destroyed (due to the presence of oxygen). With the Methane-producing capacity of the landfill reduced, the pore space in the area no longer producing may become filled with landfill gas equilibrating (moving in) from an unaffected producing area. This leaves the impression that more gas can be recovered from this area, and may lead to the operator opening the well or increasing flow.

Well field Monitoring

The frequency of LFG well field monitoring varies depending upon field requirements and conditions. Normal monitoring frequency for a complete field monitoring session with full field readings (suggested normal and abbreviated field readings list follows) will vary from typically once a month to once a week. Well field monitoring should not normally be extended beyond one month. The importance of regular, timely monitoring can not be overemphasized.

Typical Field Readings

- Name of person taking readings
- Date/time of each reading
- Methane (CH_4)
- Oxygen (O_2)
- Carbon Dioxide (CO_2)
- Balance Gas (primarily Nitrogen N_2)
- Wellhead gas temperature (flowing)
- Ambient air temperature
- Static pressure (PS) (from GEM or magnehelic) or other device (anemometer/velometer)
- Velocity head (P or PT) (from GEM or pitot tube and magnehelic)
- Wellhead gas flow (from GEM , or pitot tube & magnehelic, or anemometer/velometer)
- Wellhead adjustment valve position (initial and adjusted)
- New wellhead vacuum and flow information after adjustment
- Calculation of each well's LFG and Methane flow and sum total
- Observations/comments

Additionally, Carbon Monoxide (CO) or Hydrogen Sulfide (H_2S) readings may be taken if problems are suspected. Supplementary monitoring once to several times a week may be performed using an abbreviated form of field readings.

Abbreviated Field Readings

- Name of person taking readings
- Date/time of each reading
- Methane (CH_4)
- Oxygen (O_2)
- Wellhead gas temperature (flowing)

- Ambient air temperature
- Static pressure (PS) (from GEM or magnehelic)
- Velocity head (P or Pt) (from GEM or pitot tube and magnehelic)
- Wellhead gas flow (from GEM , or pitot tube and magnehelic, or anemometer/velometer)
- Wellhead adjustment valve position (initial and adjusted)
- New wellhead vacuum and flow information after adjustment
- Observations/comments

Line vacuums and gas quality may be taken at key points along the main gas collection header and at subordinate branches. This helps to identify locations of poor performance, excessive pressure drop, or leakage. Perform systematic monitoring of the well field, taking and logging measurements at each wellhead and major branch junction in the collection system.

During monitoring, examine landfill and gas collection system for maintenance issues. Record needed maintenance or unusual conditions. Examples of unusual occurrences or conditions are unusual settlement, signs of subsurface fires, cracks and fissures, liquid ponding, condensate/leachate weeping from side slopes, surface emissions and hot spots, and liquid surging and blockage in the gas collection system. Field readings should be kept in a chronological log and submitted to management on a timely basis.

Well Field Adjustment Criteria

There are several criteria used in well field adjustment. The primary criterion is Methane quality. Methane quality is an indicator of the healthy anaerobic state of the landfill and thus proper operation of the LFG collection system. However, a decline in the healthy productive state of the landfill is usually not immediately apparent from Methane quality. Due to this several criteria must be considered at once.

Following are well field adjustment criteria for consideration.

- Methane quality (ranging from 26 percent upwards)
- The degree to which conditions within the landfill favor Methane production. Typical conditions include:
  - pH
  - temperature
  - general overall quality
  - moisture conditions
  - waste stream characteristics
  - placement chronology
  - Insulation characteristics
- Oxygen quality (ranging below 1 percent, preferably less then ½ percent)
- Landfill cover porosity and depth in the proximity of the well
- Landfill construction factors including:
  - type of fill
  - size and shape of refuse mass
  - depth of fill
  - compaction
  - leachate control methods
- Seasonal, climatic, geographical, and recent weather, or other considerations, including seasonally arid or wet conditions, precipitation, drainage, groundwater
- Surrounding topography and geologic conditions
- Proximity of the well to side slopes (within 150 to 200 feet and less may require conservative operation of the well)
- Nitrogen (typically 8 to 12 percent and less)
- Temperature (between ambient and about 130 ˚F)

- LFG and Methane flow from the wellhead
- Design of the gas collection system
- Landfill perimeter gas migration and surface emission control, or energy recovery objectives
- Diurnal fluctuation (day to night) of atmospheric pressure

Establishing Target Flows

The goal is to establish a target flow which will likely produce the best possible methane quality and minimum O_2 levels while maximizing the recovery of landfill gas. Typically, small adjustments are made in flow to achieve and maintain quality objectives. The well must not be allowed to over pull. High well temperatures, (130° to 140° F and greater), are an indication of aerobic activity and therfore of well over-pull. These effects may not be immediately apparent.

Well adjustments should be made in as small an increment as possible, preferably an increment of ten percent of the existing flow or less. There may be obvious conditions when this is not appropriate, such as when first opening up a well or when serious over-pull is recognized. Every effort should be made to make adjustments and operations as smooth as possible. Dramatic adjustments, or operating while switching between a high flow mode and a well shutoff mode, should be avoided.

Well field Optimization

Every effort should be made to continuously locate and correct or eliminate conditions (e.g., gas condensate, surging and blockage, settlement) that inhibit efficient operation of the gas collection system. This allows well monitoring and adjustment to be significantly more effective.

Migration Control—Dealing with Poor Methane Quality

If Methane and O_2 quality objectives cannot be maintained at a given well, such as a perimeter migration control well, then an attempt should be made to stabilize the well as closely as is practical, avoiding significant or rapid down-trending of Methane or up-trending of Oxygen.

It is not uncommon for perimeter migration control wells to be operated at less than 40 percent Methane or greater than one-percent Oxygen. It should be recognized that these wells are likely to be in a zone where some aerobic action is being induced, and that there is some risk of introducing or enhancing the spread of a subsurface fire. Sometimes a judicious compromise is necessary to achieve critical migration control objectives or because existing conditions do not allow otherwise. Such situations should be monitored closely.

Well field Adjustment—Purpose and Objectives

The objective of well field adjustment is to achieve a steady state of operation of the gas collection system by stabilizing the rate and quality of extracted LFG in order to achieve one or several goals. Typical reasons for recovery of LFG and close control of the well field are:

- Achieve and maintain effective subsurface gas migration control.
- Achieve and maintain effective surface gas emissions control.
- Assist with proper operation of control and recovery equipment.
- Avoidance of well over pull and maintenance of a healthy anaerobic state within the landfill.
- Optimize LFG recovery for energy recovery purposes.
- Control nuisance landfill gases odors.
- Prevent or control subsurface LFG fires.
- Protect structures on and near the landfill.

- Meet environmental and regulatory compliance requirements.

Well field adjustment is partly subjective and can be confusing because it involves judgment calls based on simultaneous evaluation of several variables, as well as a general knowledge of site specific field conditions and historical trends. Well field evaluation and adjustment consist of a collection of techniques, which may be used, in combination, to achieve a steady state of well field operation.

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