CHAPTER 5
Operation and Maintenance

5.1. **Introduction.** An operation and maintenance plan for a landfill gas collection system must be prepared that addresses the following:

- Extraction wells.
- Gas monitoring probes.
- Condensate collection and treatment.
- Flare station.

A site-specific monitoring program should be established that is flexible and performance based. Landfill gas needs to be monitored on a regular basis to enable adjustments to be made to the wells to maximize extraction, prevent migration, and minimize drawing oxygen into the landfill. The procedures need to be regularly evaluated as changing climatic and operational conditions can have an effect on the results obtained. More detailed information on the operation and maintenance of landfill gas collection systems can be found in the reference entitled "Landfill Gas Operation and Maintenance Manual of Practice."

5.2. **Extraction Wells.**

5.2.1. *Composition of Air.* Knowledge of the composition of air can be used as an aid in monitoring and adjusting the flows from gas extraction wells. The following lists the components of air:

- Nitrogen N_2 78.084%
- Oxygen O_2 20.947%
- Argon Ar 0.934%
- Carbon Dioxide CO_2 0.033%
- Neon Ne 18.2 parts per million
- Helium He 5.2 parts per million
- Krypton Kr 1.1 parts per million
- Sulfur dioxide SO_2 1.0 parts per million
- Methane CH_4 2.0 parts per million
- Hydrogen H_2 0.5 parts per million
- Nitrous Oxide N_2O 0.5 parts per million
- Xenon Xe 0.09 parts per million
- Ozone O_3 0.07 parts per million
- Nitrogen dioxide NO_2 0.02 parts per million
- Iodine I_2 0.01 parts per million
- Carbon monoxide CO trace

- Ammonia NH_3 trace

As can be seen above, nitrogen, oxygen, argon, and carbon dioxide are the predominant components (99.998%) of air. The ratio of nitrogen to oxygen is 3.8:1. The ratio of total air to oxygen is 4.8:1. This knowledge can be used to estimate the amount of air intrusion through the cover or to check for leakage into the collection piping.

5.2.2. *Monitoring.* Balancing a LFG extraction well system is best accomplished by monitoring the well field regularly. Each well should be monitored at least monthly for gas composition, vacuum, flow, and gas temperature. The monitoring should be more frequent if the gas is used as fuel in an energy recovery project. Gas composition measurements may include percentages of methane, carbon dioxide, oxygen, nitrogen and contaminant/balance gases. If excessive vacuum is applied to a gas well, air intrusion through the cap or well seals will occur. This phenomenon is called over pull. Over pull kills anaerobic bacteria and may increase the chance for an underground fire. The best way to monitor for air intrusion at extraction wells is to check the concentration of nitrogen. Any amount of nitrogen gas in a well is a sign of air intrusion. Unfortunately, monitoring for nitrogen gas requires analysis by a gas chromatograph, which is time consuming and expensive. The presence of oxygen is also an indicator of air intrusion, however, oxygen is stripped away as it travels through the refuse by bacteria; therefore, the concentration of oxygen measured at the wellhead is typically reduced and is not an exact measure of air intrusion.

5.2.3. *Balancing Techniques.* Techniques for balancing a group of LFG extraction wells include the following.

5.2.3.1. *Valve Position.* Valve position gives a very rough indication of flow rate.

5.2.3.2. *Wellhead Vacuum.* Wellhead vacuum can provide a very rough estimate of radius of influence and flow rate.

5.2.3.3. *Gas Flow Rate.* Gas flow rate is often measured using a fixed device such as a Pitot tube, orifice plate or by some portable measurement device such as an anemometer. The required flow rate at each well is generally determined empirically based on gas composition readings.

5.2.3.4. *Gas Composition.* Methane, nitrogen, and oxygen are the key parameters measured. Carbon dioxide is often measured in order to indirectly determine nitrogen content since nitrogen is difficult to measure. Carbon monoxide can be monitored as an indicator of a landfill fire if the gas temperature begins to rise.

5.2.3.5. *Gas Temperature.* Rising gas temperature measured at a well is another sign of air intrusion. Typically, gas temperatures greater than 55^{o} C (131^{o} F) indicate some air intrusion is occurring in the waste and the flow rate should be reduced.

5.2.3.6. *Summary*. The best way to balance an individual landfill gas extraction well is by monitoring some or all of the parameters listed above, plotting trends over several monitoring events and reviewing the trends to pick the setting that meets the goals of your extraction system.

5.2.4. *Primary Well Field Monitoring.* Primary wells are those wells located within the landfill boundaries. The frequency of landfill gas well field monitoring will vary depending upon field requirements and conditions. Normal monitoring frequency for a complete field monitoring session will vary from once a week to once a month Well field monitoring should not normally be extended beyond once a month for active systems.

5.2.5. *Perimeter LFG Migration Control.* Perimeter collection wells are located at the edge of the landfill to prevent the off-site migration of gas. Perimeter systems extract poor quality LFG that is often high in oxygen due to air intrusion at the interface of the landfill and native soil. Operating objectives for the perimeter system are different than the primary wells of a LFG extraction system. The perimeter system provides a final opportunity to capture gas before it escapes from the landfill. The frequency of monitoring is based on the perceived threat to the public from the off-site migration of gas. Some perimeter migration systems are monitored daily if perimeter LFG monitoring probe readings are above established limits. In other cases, the perimeter system is monitored at the same frequency as the rest of the extraction system.

5.2.6. *Barometric Pressure.* The amount of gas escaping from a landfill surface changes as atmospheric pressure varies, even when the gas production rate is constant. Methane concentrations and landfill gas pressure measurements in a monitoring probe may be influenced by changes in barometric pressure. There may be a delay of several hours before equilibrium occurs and this should be taken into consideration when assessing the collected data.

5.2.7. *Leachate Blockage of Extraction Wells.* Leachate blockage of LFG extraction wells is occasionally a problem. Leachate in the well is either the result of a high water table or perched liquid that is migrating along a low permeable daily cover soil or a low permeability waste and draining into the well. Once liquid is in the well, it usually drains out slower than it drains in, creating a high leachate level in the well. The following procedure for clearing wells clogged with leachate is suggested (Michels 1998):

- Discontinue gas extraction.
- Remove the leachate using a temporary down-hole pump or a vacuum truck for wells that are less than 6.096 m (20 feet) deep.
- If leachate continues to flow into the well or it takes more than five days to remove all the liquid, then a permanent method of leachate collection is probably required.

Permanent dual LFG/leachate extraction systems typically include the following:

- One well casing for LFG extraction and leachate extraction
- LFG extraction wellhead installed at the top of the well casing
- Pneumatic or electric pump installed in the well casing (pneumatic pumps are most common due to the explosive environment)
- Discharge headers.

Discharge of the LFG and leachate from the well is typically combined into one header. However, if the LFG and leachate are combined in one header, typically the header is a larger diameter than if it were simply transporting LFG. In addition, condensate dropouts or low points in a combined header system must be enlarged to allow for the added liquids.

5.2.8. *Landfill Fires.* Spontaneous combustion is the process by which the temperature of a material is increased without drawing heat from an outside source. In landfills, the process occurs when the waste is heated by chemical oxidation via aerobic biological decomposition to the point of ignition. Landfill fires are most easily controlled by limiting air intrusion into the landfill which will minimize aerobic activity. Atmospheric air is 21% oxygen and 79% nitrogen. Gas composition typically is measured with a portable gas analyzer. The readings will be in percent methane, carbon dioxide, and oxygen. The balance is assumed to be nitrogen. The nitrogen-to-oxygen ratio for atmospheric air is 79/21 = 3.76. Gas extraction wells are monitored in order to evaluate system performance. If the oxygen content reaches 3.2% or the nitrogen content is 12% ($3.2 \times 3.76 = 12$ %) sufficient air intrusion may be occurring to start a landfill fire. If the following is noted during the monitoring of extraction wells, it should be a signal to technicians that conditions are potentially favorable for a landfill fire to occur and increased monitoring or corrective action should be taken:

- Oxygen content is increasing and exceeds 3.2 percent by volume.
- Nitrogen content is increasing and exceeds 12 percent.
- Gas temperature is increasing and exceeds 60^{o}C (140^{o}F).

The following parameters are evidence of fire within the landfill:

- Gas temperature exceeds 75^{o}C (167^{o}F).
- Rapid settlement of the cover system.
- Carbon monoxide levels are greater than 1000 ppm.
- Combustion residue is present in the LFG Lines.

Landfill fires can be prevented by:

- Decreasing the extraction rate which will decrease air intrusion.
- Preventing air intrusion by decreasing the air permeability of the landfill cover.
- Increasing the monitoring frequency of the extraction wells and probes.

If a fire occurs, fire control may be accomplished through the injection of nitrogen or CO_2 into the landfill to suffocate the fire. Extraction of landfill gas should also be terminated to prevent oxygen from being drawn into the landfill (Israel 2000).

5.2.9. *Vertical Profiling.* A perimeter gas extraction well will typically penetrate several geologic layers with each layer exhibiting different properties. Landfill gas will flow to the well through the path of least resistance (usually through the coarser soils). Vertical profiling within the extraction well can be used to determine what geologic strata methane or other landfill gases are traveling through. The profiling involves using a probe to take continuous gas samples and measuring the gas velocity at all levels throughout the length of the well. The results may help provide a better picture of where additional extraction wells should be screened to minimize off-site migration of landfill gas.

5.2.10. *Inspection and Maintenance.* Inspection and maintenance should be performed during each sampling event. Each gas extraction well and monitoring probe should be inspected for damage. Any damage should be noted on the field sampling record and repaired. Piping and associated equipment should be inspected for damage and settlement. Piping runs may develop low spots due to differential settlement. Additional drains or drip legs will need to be installed at these low spots if they occur. Piping needs to be checked for leaks and degradation due to UV exposure. Plastic pipes manufactured without UV resistance may need periodic painting/coating to prevent cracking due to UV degradation.

5.3. **Gas Monitoring Probes.**

5.3.1. *Monitoring Procedures.* The reference entitled "Landfill Gas Operation and Maintenance Manual of Practice" provides excellent information on monitoring landfill gas perimeter probes and interpretation of the collected data. Monitoring probes are typically placed outside the waste mass and are normally located at the property boundary or the point of regulatory compliance. Gas monitoring probes are typically tested for the following parameters:

5.3.1.1. *Probe Gas Pressure.* The vacuum/pressure should be recorded by connecting the pressure gauge to the quick connect valve.

5.3.1.2. *Gas Concentrations.* Leak check the entire sample train. Purge the probe of two volumes of gas and then record the appropriate gas concentrations (methane, carbon dioxide, oxygen, nitrogen, hydrogen sulfide, etc.).

5.3.1.3**.** *Water Level.* This should be recorded if applicable.

5.3.1.4. *Summary.* The technicians name, date, time, ambient temperature, weather conditions, barometric pressure, and probe number are also typically monitored during a sampling event. As mentioned previously, landfill gas is a collection of air pollutants including non-methane organic compounds (NMOCs). Periodic monitoring of specific NMOCs may also be required to verify they are not migrating off-site.

5.3.2. *In-probe Acceptable Levels.* In-probe methane levels should be monitored with an infrared landfill gas analyzer. A methane concentration greater than 5 percent in a monitoring probe indicates the potential for explosive conditions. Adjustments to the gas collection system's operating procedures should be made if methane levels exceed some specified level (typically 0.5 to 5 percent) at the perimeter of the landfill or in structures such as vaults, manholes, sumps or buildings.

5.3.3. *Monitoring Frequency.* The frequency at which probes are monitored is typically once per week to once per quarter. However, when gas concentrations exceed acceptable levels, probes will be monitored at an increased frequency (as frequently as once per day). If well readings indicate gas is escaping off-site, consideration should be given to monitoring off-site structures to ensure landfill gas is not building up in these structures. Examples of structures that should be monitored include basements, crawl spaces, wells, sumps, subsurface vaults, and any other location where gas could potentially collect.

5.3.4. *Enclosed Structure Monitoring.* Gas monitoring must be conducted in any on-site enclosed structures located on top of or adjacent to the landfill. Enclosed areas that contain a potential sparking device (wiring, electrical motor, etc…) should also be monitored routinely. Buildings are typically monitored at least quarterly with a hand held gas meter at the following locations:

- The base of each exterior wall.
- Underground utility lines leading into the building.
- Ambient air in each room of the building.

A continuous monitoring device, with alarm, should be installed in structures that are frequently occupied. Methane concentrations should not exceed 25 percent of the lower explosive limit (1.25 percent methane).

5.3.5. *Surface Emission Monitoring.* Surface emission monitoring is typically performed at large municipal landfills that do not have a geosynthetic barrier in the landfill cover. Surface emission monitoring is not commonly performed on USACE projects because the waste typically found in military landfills does not produce large amounts of gas. A summary of surface emission testing procedures can be found in the reference entitled "Landfill Gas Operation and Maintenance Manual of Practice."

5.4. **LFG Monitoring Equipment.** Common portable measuring instruments for pressure include micromanometers and magnehelic gauges. A combustible gas indicator (CGI) can be used in above grade monitoring situations when there is sufficient oxygen for the instrument to operate correctly. Below grade monitoring and situations where oxygen has been displaced by landfill gas require use of an infrared landfill gas analyzer. A photoionization detector or portable field gas chromatograph should be used to monitor for low level toxic air contaminants that may exist in landfill gas. Several specific instruments are common to LFG control systems that should be considered during design. These include:

- Combustible gas indicators (CGI).
- Photoionization detector/Infrared landfill gas analyzers.
- Process gas chromatographs (GC).

Process GCs can be used for onsite monitoring. However, this is an expensive option because laboratory facilities and trained chemists are required for monitoring operations. CGIs operate on two different principles, catalytic oxidation and thermal conductivity. Some CGIs operate by both methods; however, surface emission sampling will focus on the catalytic oxidation method, as the thermal conductivity detection method is used primarily for gas measurements in migration probes. The catalytic oxidation type of CGI measures the concentration of a combustible gas in air, indicating the results in parts per million or in percent of the LEL. Often these readings are taken in conjunction with oxygen readings. These instruments operate by the detection method of a platinum filament being heated by the combustion of the gas being sampled. The increase in heat changes the resistance of the filament that results in an imbalance of the resistor circuit called the "Wheatstone Bridge." This imbalance is measured via the analog or digital scale of the unit. Some CGIs have two scales, one measuring in parts per million by volume (ppmv) and the other in percent of the LEL. Limitations to this equipment are as follows:

- The reaction is temperature dependent and is, therefore, only as accurate as the incremental difference between calibration and ambient sampling temperatures.
- Sensitivity is a function of the physical and chemical properties of the calibration gas therefore methane should be used as the calibration standard.
- The unit will not work in oxygen deficient or oxygen enriched atmospheres.
- Certain compounds such as leaded gas, halogens, and sulfur compounds can damage the filament. Silicone will destroy the platinum filament. Since LFG contains some halogenated (chlorinated) hydrocarbons, the meter should be calibrated often to methane and serviced yearly if it used on a routine basis to monitor methane surface emissions. In addition, if the meter contains an oxygen cell, this cell can be fouled by the carbon dioxide found in LFG and replacement of the cell may be required frequently.

Advantages are that CGIs are small and portable, self-contained for field use, have an internal battery, are easy to use and typically are intrinsically safe.

5.4.1. *Combustible Gas Indicator/Thermal Conductivity Method.* High concentrations of methane (greater than 100% of the LEL or 5% methane) are measured with a combustible gas indicator using a thermal conductivity (TC) sensor. This type of sensor is often used with a catalytic oxidation sensor in the same instrument. The catalytic sensor is used to detect concentrations less than 100% of the LEL and at higher concentrations, the TC sensor is used to measure up to 100% gas by volume. The TC sensor is composed of two separate filaments, heated to the same temperature. Combustible gases enter only the TC side of the filament; the other filament (compensating) maintains a steady heated temperature. Incoming gases cool the TC filament and as the filament temperature decreases, the resistance across the Wheatstone bridge also decreases, resulting in a meter reading. Instruments using a TC sensor do not require oxygen for a valid reading, as burning of the gas is not involved.

Combustible gases vary in their ability to cool the TC filament. Methane absorbs heat well and efficiently cools the filament and is the calibration gas of choice when using the instrument to measure methane in landfill gas. However, since landfill gas is comprised of a combination of different gases, readings on the meter will vary depending on the concentration of the other gases in the sample. Gases which cool the filament more effectively than methane (as the calibration gas) will display a higher percent gas reading than is actually present. The converse is also true, that gases, which are less effective in cooling the filament, will display a lower percent gas reading than is actually present. It is important to realize that certain gases can cool the filament and not be combustible. Carbon dioxide absorbs heat readily and can produce a false positive reading. Meter sensitivity to carbon dioxide varies from manufacturer to manufacturer and one should be very familiar with the technical information supplied with the equipment. With some meters, calibration with a methane/carbon dioxide mixture can help alleviate the interference of carbon dioxide.

There must be sufficient oxygen present in the atmosphere being analyzed for a CGI to work correctly. Therefore, the CGI is a poor instrument selection for monitoring explosive conditions (methane concentrations) directly in landfill gasses because oxygen levels can be very low.

5.4.2. *Flame Ionization Detector (FID)/Organic Vapor Analyzer (OVA).* FIDs measure many organic gases and vapors. Some FIDs are commonly referred to as Organic Vapor Analyzers or OVAs. FIDs operate by a sample being ionized in a detection chamber by a hydrogen flame. A current is produced in proportion to the number of carbon atoms present. There are two modes of operation, the survey mode and the gas chromatograph (GC) mode. For methane surface emissions, the survey mode is used if both are available on the instrument. Since the sensitivity of the instrument depends on the compound, methane should be used as the calibration standard. These instruments are less rugged in the field than the CGIs and require hydrogen gas cylinders for use.

The advantages to the FIDs are fast response in the survey mode, wide sensitivity (1 to 100,000 ppm), and some models offer a telescopic probe with cup intake that minimizes operator exposure to LFG and minimizes the effects of windy conditions at the site. The "cup" probe design can also serve to reduce the near surface dilution effects of the wind by providing a small sampling chamber when the probe is held normal to the surface.

5.4.3. *Infra-Red (IR) Analyzer.* Infrared is a range of frequencies within the electromagnetic spectrum. The infrared frequencies act to set the molecules of chemicals into vibration. Chemicals have a vibration energy that is specific to that chemical (gas). When the gas interacts with IR radiation, it absorbs a portion of the IR energy. The absorption spectrum for that gas is the pattern of vibrations from the atoms/functional groups, along with the overall molecular configuration. Specific gases will demonstrate optimal absorption within a small IR range. Since absorption ranges have been classified for different gases, it is possible to filter out all but a small part of the spectrum and measure the gas known to be present. The advantage of IR analyzers is that the high carbon dioxide levels found in landfills will not affect methane readings.

Most IR analyzers are single beam spectrophotometers. Portable IR meters available for the field are capable of measuring up to 100% by volume methane and carbon dioxide. The concentrations of these gases are detected by infrared absorption. Oxygen concentration is measured by an electrochemical cell. These meters are designed to measure large concentrations of methane and carbon dioxide and are not sensitive at concentrations less than 0.5%. A field calibration gas should be used to verify the accuracy of the monitoring results. A combination gas of 15% methane and 15% carbon dioxide is a common mixture when using the equipment to test migration probes. Higher concentrations of calibrant gases should be used if monitoring levels in gas extraction wells.

5.5. **Condensate Collection and Treatment.** Disposal of gas condensate is an issue common to most landfill sites in humid climates. Methods of disposal for LFG condensate include the following.

5.5.1. *Treatment.* Landfill gas condensate can be collected from the various condensate collection points and treated prior to release. When a liner system is present, condensate is commonly combined with landfill leachate and disposed of in the same manner as the leachate.

5.5.2. *Injection/Recirculation.* Subtitle D regulations allow leachate and condensate recirculation if the landfill has a composite liner system. Recirculation employs the absorptive properties of the MSW to hold the condensate within the material. However, once the MSW reaches field capacity or decomposes, condensate recirculation in that portion of the site is no longer effective and will short-circuit directly into the leachate collection system. Condensate injection/recirculation is being practiced at numerous sites and is accomplished primarily through drainage into the collection well field at moisture traps.

5.5.3. *Aspiration into the LFG Flare.* This method of condensate disposal consists of spraying it directly into a LFG enclosed flare (i.e., incineration). This technology can typically destroy up to 1 gpm of condensate. The popularity of this method of disposal is increasing. Aspiration of condensate into LFG flares has been accomplished on several sites and promises to be an efficient and effective method of condensate disposal, provided the condensate is non-hazardous. Flare destruction efficiency is dependent on: flare temperature, flare residence time, and turbulence. Tests must be conducted to ensure that condensate aspiration will not cause an unsatisfactory drop in operating temperature of the flare. Analysis of gas condensate quality, pre-aspiration flare emissions quality and emission quality during aspiration are typically required. Condensate is transferred from a liquid state to vapor upon aspiration into the flare. This requires approximately 12,000 Btu's of energy per gallon of condensate. With the aspiration of condensate into the flare unit, draft velocities are created during condensate evaporation that could significantly change the retention time on which the original flare design was based. Recent applications of condensate aspiration, however, have not caused a decrease in destruction efficiencies. Only enclosed flame flares provide adequate residence time for condensate aspiration.

5.5.4. *Summary.* Data that have been published shows that the aqueous phase of LFG condensate generally passes the TCLP regulated limits. If a non-aqueous phase liquid is present in the condensate, this fraction has been found to fail ignitability testing. Landfills that have been operating principally as municipal landfills are rarely found to have a significant non-aqueous phase fraction.

In preparing the proper management plan for condensate, it should first be determined if the condensate contains two phases. If the condensate does have a non-aqueous phase, management plans should include a phase-separation process to separate the non-aqueous phase liquids from the aqueous phase fraction.

5.6. **Flare Station.** Maintenance and inspection of a blower/flare station is commonly performed on a weekly basis. Activities include LFG flow rate alteration, mechanical repair, lubrication, pilot/auxiliary fuel refill and equipment cleaning. The gas flow rate at the station may need to be adjusted due to changes in the landfill gas flow rate or to eliminate off-site migration. Partially opening or closing the valve on the blower inlet side usually accomplishes flow rate adjustments. The following paragraphs describe additional monitoring requirements associated with various components of a blower/fare system.

5.6.1. *Blower*

5.6.1.1. *Monitoring Requirements.* Inspection of this unit should include reading the flow rate and pressure of the system and comparing these measurements to a standard curve developed by the manufacturer to determine whether the blower is operating within a safe range for the equipment. The pressure drop across the blower should also be monitored using magnehelic gages at entrance and exit ports on the blower. The blower should also be inspected and monitored according to manufacturer's specifications for the unit.

5.6.1.2. *Frequency*. Monthly inspections should be made, unless recommended otherwise by the manufacturer, to ensure that operating parameters are within expected ranges. After the first year and every second year thereafter (at a minimum), comprehensive inspections by a representative of the manufacturer should be made to determine if parts are wearing at an excessive rate. Should the equipment warranties recommend more frequent inspection, this frequency should be upgraded to the recommended levels.

5.6.2. *Flame Arrestor*

5.6.2.1. *Monitoring Requirements.* Monitoring of the flame arrestor consists of measuring the head loss across the flame arrestor to ensure that operating head losses are not significantly above or below the losses expected for the unit. In general, flame arrestors require little maintenance (cleaning) and are rarely replaced in operating systems.

5.6.2.2. *Frequency*. Inspection of the flame arrestor can be infrequent since it does not have any moving parts. Monthly inspections conducted with several other portions of the gas collection and flaring system will be adequate.

5.6.3. *Flare*

5.6.3.1. *Monitoring Requirements.* The flare unit should be capable of operating at >98 percent destruction requirement efficiency (DRE) for methane. In addition to DRE monitoring, the flare inlet should be inspected for:

- Gas-flow rates.
- Gas supply pressure.
- Minimum operating temperatures.
- Influent gas parameters including CH_4, CO_2, and O_2.

5.6.3.1.1. Manufacturer's recommendations for minimum and maximum values for these parameters should be determined for the specific flare unit. Manufacturers typically specify a minimum supply pressure for a given flow rate. Inspection should include referencing operating parameters of flow rate and pressure drop against the design curve established for the flare. Inspection should verify that a sufficient delivery pressure is being supplied for the observed flow rate.

5.6.3.1.2. The temperature of the flare unit should be monitored to ensure that this parameter is being maintained. The CH_4 content and flow rate of the influent gas should be inspected as described below. Excessive operating temperatures should not occur since the flare unit should be designed with automatically adjusting air intake louvers. However, if excessive temperatures (i.e. > 980 C (1800 F)) are observed, controls for these louvers should be inspected.

5.6.3.1.3. Gas parameters including CH_4, O_2 and CO_2 should be inspected to insure that the operating concentrations are within acceptable ranges for the flare.

5.6.3.2. *Frequency*. Monthly monitoring is recommended unless suggested otherwise by the manufacturer. Additional operating parameters including gas flow rates; gas supply pressure; minimum operating temperature; and inflow LFG parameters should be monitored more regularly.

5.7. **Maintenance Requirements.** The operation and maintenance (O&M) of a LFG management system should be structured to maintain the operation goals (i.e., 98 percent reduction of NMOC). An O&M program can be divided into the following categories:

- Routine O&M.
- Non-routine maintenance.
- Emergency services.

5.7.1. *Routine Maintenance*. A Routine maintenance program includes periodic maintenance and preventive maintenance. During routine maintenance, testing and checking of the following components should be performed:

- Extraction wells.
- Collection header.
- Monitoring wells and probes.
- Oil change on blower.
- Flame arrestor cleaning.
- Condensate handling.
- Gas detection system.
- Pilot/auxiliary fuel.

Pilot/auxiliary fuel refilling and equipment cleaning should be performed at least weekly. In particular, the combustion mechanism will require regular cleaning to assure that the gases are burned completely. Air and oil filters should be checked and changed routinely after a specific number of hours as recommended by the manufacturer. This will prevent more costly and time-consuming repairs down the line. Preventive maintenance includes blower bearing lubrication and flame sensor cleaning.

Regular oil and lubrication changes should also be performed on the blower, compressor, gearbox, and combustion systems. This will help ensure that the process operates smoothly and efficiently, and it also reduces the chance of costly downtime associated with larger repairs.

5.7.2. *Non-Routine Maintenance.* Non-routine maintenance activities consist of corrective repair or maintenance of work identified during the routine inspection. These may include:

- Repair or replacement of failing components.
- Testing and adjusting the collection system if air intrusion is observed.

5.7.3. *Emergency Services.* Emergency services are those requiring immediate response to prevent human injury, property damage, or regulatory non-compliance. These activities may include:

- Responding to system failure or shut down.
- Executing contingency plans, if required.

5.7.4. *Equipment Calibration.* The instruments used for measurements are customarily correct to within a certain percentage of the "true" value. This accuracy is generally expressed by the instrument's manufacturer as the "inherent error of the device." Instrument calibration does not lead to elimination of error; it does allow the equipment to provide representative numbers for the subject measurement to the best of the machinery's ability. Routine calibration and servicing are necessary to assure the quality of measurements made using these instruments. Permanently installed equipment used for measurements should be calibrated according to the manufacturer's recommendations and the quality assurance program.

5.7.5. *System Adjustments Based on Monitoring Data.* Landfill operators have to adopt a variety of monitoring parameters, techniques, and frequencies to balance the vacuum system so as to collect as much gas as practicable and or contain the LFG in all parts of the landfill. For example, the gas flow rate at the station may need to be adjusted due to landfill aging. Partially opening or closing the valve on the blower inlet side or adjustments at individual extraction wells usually accomplishes adjustments of flow rate.

5.8. **Record Keeping and Contingency Plan.** All inspection and maintenance records must be saved and kept at a location that is easily accessible. If measured methane levels at the compliance points are in excess of regulatory levels or the flare emissions are out of compliance, then the facility must report the results to the appropriate regulatory agency and take steps to correct the situation. An increased frequency of monitoring must then be made until the situation is corrected.