Appendix L – Landfill Gas

LANDFILL GAS

This appendix contains multiple sources of information regarding landfill gas.

1. Revised Surface Emissions Monitoring (SEM) Plan for the Site 2 North Expansion. APTIM revised the facility's existing SEM Plan to include the Site 2 North Expansion area and to meet the requirements of the Siting Ordinance. This Plan may be modified as necessary in future revisions to the facility's Landfill Gas Collection and Control System Design Plan, as long as modifications are compliant with the Siting Ordinance.

2. *Landfill Gas Energy Basics*, LFG Energy Project Development Handbook, US Environmental Protection Agency Landfill Methane Outreach Program, June 2017.

3. LMOP and Landfill Gas Energy in the United States, US Environmental Protection Agency Landfill Methane Outreach Program, June 2017.

4. CEC Landtec GEM 2000 Portable Gas Analyzer Flysheet. This is a commonly used gas analyzer used at landfill facility gas extraction and detection wells.

5. Safe T Net 100 Single Point Gas Monitor Flysheet. This is commonly used for continuous monitoring of combustible gases, toxic gases or oxygen at one location for the protection of workers and property.

SURFACE EMISSIONS MONITORING PLAN

INTRODUCTION

40 CFR 60.755(c) requires the landfill gas collection system be operated so that the methane concentration is less than 500 ppm above background at the surface of the landfill. In addition, those areas that indicate elevated concentrations of LFG by visual observation (i.e., cracks or seeps in the landfill's cover and distressed vegetation) must also be monitored. This Surface Monitoring Design Plan specifies the monitoring procedures that will be used to meet the NSPS requirement. This plan includes topographical maps with the monitoring routes and specifies the monitoring procedures that will be followed. Any deviations from the surface monitoring requirements as stated in the NSPS are contained in this plan.

Areas Monitored

The NSPS requires monitoring along the entire perimeter of the collection area and along a serpentine pattern spaced 30 meters apart (or a site-specific established spacing) for each collection area on a quarterly basis. The attached map shows the surface monitoring route proposed for the facility at final grade conditions. The actual route taken while the facility is still active will be included with each quarterly surface scan report, or in other site files.

Areas which will be excluded include:

- Active areas of the site. Active areas are those areas which only have daily cover, and/or are being filled with waste. Active areas of the landfill have a larger volume of equipment and/or refuse trucks which pose an unacceptable health and safety risk to an individual in the area.
- Areas of the site with snow or ice cover. Snow has the potential to cover uneven surfaces in the landfill cover (such as ruts) which could cause the technician to twist or break a leg. Icy slopes are difficult and dangerous to traverse.
- Areas of the site that are undergoing construction or final cover activities. These areas also have a large volume of equipment traffic, which poses a health and safety risk to the technician performing the scan.
- Areas that have membrane liner only in place – limit foot traffic on FML due to slip/fall hazard.

Areas of the landfill with slopes equal to or greater than 4H:1V present a safety hazard to the monitoring technician. The landfill owner/operator shall monitor through remote means any areas determined to be inaccessible (e.g., steep slopes), as required by the conditions of the Siting Ordinance for the Site 2 North Expansion.

Monitoring Frequency

Surface monitoring will be performed on a calendar quarter basis. Monitoring will be rescheduled if it cannot be conducted because temperature conditions are outside the operating range of the instrument and/or other conditions (snow cover, rain storms, etc.) prevent monitoring. The monitoring event will be rescheduled as soon as practical after the original scheduled date.

Surface Monitoring Instrument

The monitoring will be conducted with an organic vapor analyzer, flame ionization detector, or other portable monitor meeting the specifications in 40 CFR 60.755(d):

"The portable analyzer shall meet the instrument specifications provided in section 3 of Method 21 of Appendix A of 40 CFR Part 60 (Method 21), except that "methane" shall replace all references to VOC."

To meet the performance evaluation requirements in section 3.1.3 of Method 21, the instrument evaluation procedures of Section 4.4 of Method 21 shall be used. The performance evaluation results will be documented in an instrument logbook or on a form similar to the one shown in Table A-1.

Surface Monitoring Survey

Immediately before commencing a surface monitoring survey, the instrument shall be calibrated per section 4.2 of Method 21. The calibration gas shall be methane, diluted to a nominal concentration of 500 parts per million in air. Calibrations will be documented in an instrument logbook or on a form similar to the one shown in Table A-2.

The background concentration at the facility will be determined immediately prior to conducting the survey. The background concentration shall be determined by moving the probe inlet upwind outside the boundary of the landfill at least 30 meters from the perimeter wells. The background concentration, measurement location, and basic meteorological conditions will be recorded on Table A-2 (or similar form). Other factors that can affect "background" should be noted and accounted for (such as a nearby landfill, highway, refinery, chemical plant, etc.).

Surface emission monitoring shall be performed in accordance with section 4.3.1 of Method 21, except that the probe inlet shall be placed within 5 to 10 centimeters of the ground and the probe will be moved continuously along the ground. Monitoring will not be performed during extreme meteorological conditions.

Surface monitoring will be conducted around the perimeter of the collection area and the route shown on the topographic map. Areas where visual observations indicate elevated concentrations of landfill gas, such as distressed vegetation and cracks or seeps in the cover, will be monitored.

Any reading of 500 parts per million or more above background at any location shall be recorded as a monitored exceedance and the following actions shall be taken:

i. The location of each monitored exceedance shall be marked and the location recorded. A typical form for documenting monitoring exceedances is included in this plan. Other forms for tracking exceedances may be utilized.

ii. ii. Cover maintenance or adjustments to the vacuum of the adjacent wells to increase the gas collection in the vicinity of each exceedance shall be made and the location shall be re-monitored within 10 calendar days of detecting the exceedance.

iii. If the re-monitoring of the location shows a second exceedance, additional corrective action shall be taken and the location shall be monitored again within 10 days of the second exceedance. If the re-monitoring shows a third exceedance for the same location, the action specified in paragraph (v) below shall be taken, and no further monitoring of that location is required until the action specified in paragraph (v) has been taken.

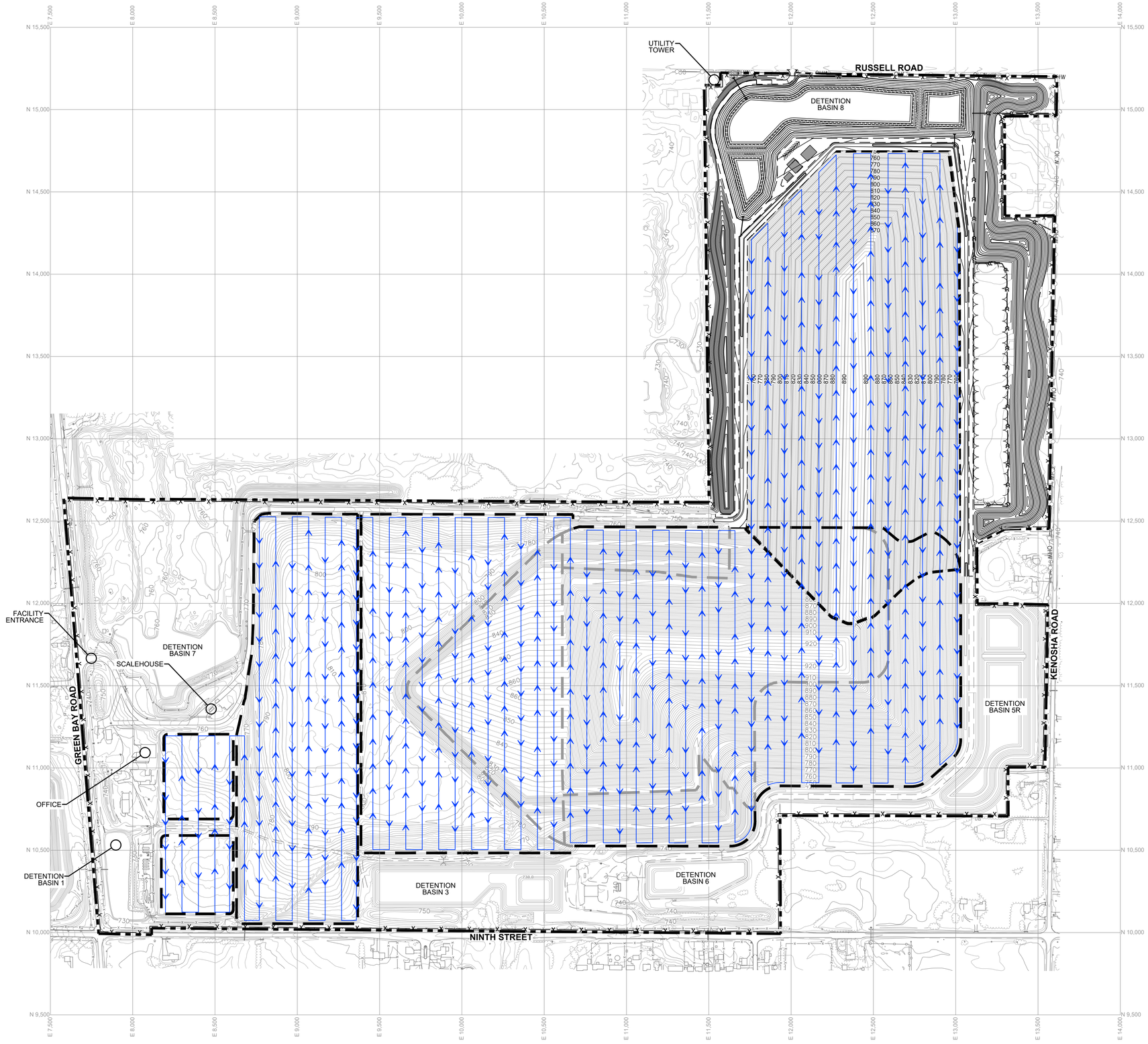
iv. Any location that initially showed an exceedance but has a methane concentration less than 500 ppm methane above background at the 10-day re-monitoring specified in paragraph (c)(4) (ii) or (iii) of this section shall be re-monitored 1 month from the initial exceedance. If the 1-month re-monitoring shows a concentration less than 500 parts per million above background,

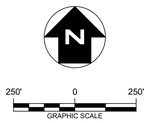
no further monitoring of that location is required until the next quarterly monitoring period. If the 1-month re-monitoring shows an exceedance, the actions specified in paragraph (iii) or (v) shall be taken.

v. For any location where monitored methane concentration equals or exceeds 500 parts per million above background three consecutive times within a quarterly period, a new well or other collection device shall be installed within 120 calendar days of the initial exceedance. An alternative remedy to the exceedance, such as upgrading the blower, header pipes or control device, and a corresponding timeline for installation may be submitted to the Administrator for approval.

Reduced Monitoring Frequency for Closed Landfills

Any closed landfill that has no monitored exceedances of the 500 ppm limit above background in three consecutive quarterly monitoring periods may skip to annual monitoring. Any methane reading of 500 ppm or more above background detected during the annual monitoring returns the frequency to quarterly monitoring. The facility will go to an annual schedule for areas of the site that are at final grade, and certified as closed, once three consecutive quarters with no surface monitoring exceedances have been performed. This alternative monitoring schedule was approved by Region 4 USEPA on July 12, 2004 for an NSPS landfill in Georgia (Applicability Determination Index Control No. 0500087). Currently, the final closed areas are located in Phase 1a, Phase b, "old" Site 2 and sections of the Site 2 Expansion area.



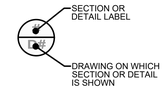


LEGEND

- APPROXIMATE FACILITY BOUNDARY
- APPROXIMATE EXISTING WASTE BOUNDARY
- APPROXIMATE PROPOSED EXPANSION WASTE BOUNDARY
- EXISTING CONTOUR
- EXISTING ROAD
- EXISTING VEGETATION
- EXISTING FENCE
- EXISTING POWER POLE
- EXISTING OVERHEAD WIRE
- EXISTING CULVERT
- PROPOSED CONTOUR
- PROPOSED ROAD
- PROPOSED PERIMETER FENCE
- PROPOSED CULVERT
- PROPOSED DRAIN TILE
- SURFACE SCAN ROUTE

NOTES

1. EXISTING CONTOURS DEVELOPED FROM SITE AERIAL TOPOGRAPHIC SURVEY PROVIDED BY CQM, INC. ON 10/22/2018 EXCEPT STORMWATER MANAGEMENT FEATURES ASSOCIATED WITH SITE 2 EAST (DITCHES AND BASIN 5R). STORMWATER DESIGN GRADES ARE SHOWN FOR THESE FEATURES FOR COMPLETENESS, AS NOT ALL GRADES ARE CAPTURED BY THE TOPOGRAPHIC SURVEY.
2. FOR CLARITY, NOT ALL SITE FEATURES MAY BE SHOWN.
3. CURRENT TOPOGRAPHY MAY DIFFER FROM THAT SHOWN.
4. TOP OF PERMITTED FINAL COVER GRADES ARE SHOWN FOR THE EXISTING LANDFILL (CELLS 6,7, AND 9), WITH THE EXCEPTION OF THE SITE 2 NORTH VERTICAL EXPANSION AREA.
5. THE TOP OF PROPOSED FINAL COVER GRADES ARE SHOWN FOR THE SITE 2 NORTH HORIZONTAL AND VERTICAL EXPANSION. THE PROPOSED VERTICAL EXPANSION AREA FINAL COVER GRADES WILL TIE INTO THE PERMITTED FINAL COVER GRADES OF THE EXISTING LANDFILL AS SHOWN.
6. THE FINAL COVER WILL BE CONSTRUCTED TO BE A MINIMUM FIVE-FOOT THICK.
7. THE SURFACE MONITORING DESIGN PLAN REPRESENTS THE LANDFILL AT FINAL CLOSURE CONDITIONS. SURFACE MONITORING CONDUCTED WHILE THE SITE IS STILL ACTIVE MAY FOLLOW A DIFFERENT ROUTE.



SECTIONS AND DETAIL KEY

REV. NO.	DATE	DESCRIPTION

GFL GREEN FOR LIFE environmental

APTIM Environmental & Infrastructure, LLC

ZION LANDFILL - SITE 2 NORTH EXPANSION
CITY OF ZION, ILLINOIS

SURFACE SCAN PLAN

PROJ. NO.:	631020105
DESIGNED BY:	DAM/BWM/KM
DRAWN BY:	BWM/NV/KM
CHECKED BY:	DAM
APPROVED BY:	DAM
DATE:	MAY 2022
DRAWING NO.	1
	1 OF 1 SHEETS

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Table A - 1
Monitoring Instrument Performance Evaluation
Surface Monitoring Design Plan

40 CFR 60.755(d)(3) requires performance evaluation of response factor, response time and calibration precision according to the section 4.4 of 40 CFR 60 Appendix A, Method 21. The requirements are presented below along with locations to record the evaluations.

Response Factor:
Response factor is the ratio of the known concentration of a VOC compound to the observed meter reading when measured using an instrument calibrated with the reference compound specified in the applicable regulation. Since the monitoring instrument is being used to detect methane and the calibration reference compound is methane, the response factor by definition is one. No further evaluation is required.

Response Time:
Response time is the time interval from a step change in VOC concentration at the input of the sampling system to the time at which 9 percent of the corresponding final value is reached as displayed on the instrument readout meter.

Performance Requirement: Section 3.1.2(b) of Method 21 requires the instrument response time to be equal to or less than 30 seconds.

Evaluation Frequency: Prior to placing instrument into service (for the first time or after it was out of service for maintenance or repair). If modification to the sample pumping system or flow configuration is made that would change the response time, a new test is required prior to further use.

Evaluation Procedure: (Section 4.4.3 of Method 21) Calibrate instrument with the methane calibration gas. Introduce zero gas into the instrument sample probe. When the meter reading has stabilized, switch quickly to the specified calibration gas. Measure the time from switching to when 90 percent of the final stable reading is attained. Perform this test sequence three time and record the results. Calculate the average response time. Use the form below or a similar format to document this procedure.

Date: _____
Operator Name: _____
Facility: _____
Instrument ID: _____
Calibration Gas Conc.: _____
90% of Calib. Gas Conc.: _____

Trial No.	Time to reach 90% gas value
1	_____seconds
2	_____seconds
3	_____seconds
Average	_____seconds

Table A - 1
Monitoring Instrument Performance Evaluation
Surface Monitoring Design Plan
(cont.)

Calibration Precision:

Calibration precision is the degree of agreement between measurements of the same known value, expressed as the relative percentage of the average difference between the meter readings and the known concentration to the known concentration.

Performance Requirement: The calibration precision must be equal to or less than 10 percent of the calibration gas value.

Evaluation Frequency: Must be completed prior to placing instrument into service, and at subsequent 3-month intervals or at the next use whichever is later.

Evaluation Procedure: (Section 4.4.2 of Method 21) Calibrate instrument with the methane calibration gas. Make a total of three measurements by alternately using zero gas and the specified calibration gas. Record the meter readings. Calculate the average algebraic difference between the meter readings and the known value. Divide this average difference by the known calibration value and multiply by 100 to express the resulting calibration precision as a percentage.

Date: _____
Operator Name: _____
Facility: _____
Instrument ID: _____
Calibration Gas Conc.: _____

Trial No.	Meter Reading After Zero Gas	Difference Between Calibration Gas and Meter Reading
1	_____ppm	_____ppm
2	_____ppm	_____ppm
3	_____ppm	_____ppm

Average Difference: _____ppm

Calibration Precision = Average Difference/Calibration Gas Conc. X 100%
= _____ / _____ X 100%
= _____%

Table A - 2
Instrument Calibration and Monitoring Procedures
Surface Monitoring Design Plan

The calibration procedures in section 4.2 of 40 CFR 60 Appendix A, Method 21 must be conducted immediately before commencing a surface monitoring survey. [40 CFR 60.755(d)(4)] Calibration, background readings and monitoring details can be recorded using this form.

Calibration Procedure:
The calibration gas should be methane in air at a nominal concentration of 500 ppm. [See section 3.2 of Method 21 for further calibration gas requirements.]

Assemble and start up the analyzer according to the manufacturer's instructions. After the appropriate warm-up period and zero internal calibration procedure, introduce the calibration gas into the instrument sample probe. Adjust the instrument meter readout to correspond to the calibration gas value. Record the calibration information in the table below.

Background Concentration:
Determine the background concentration by moving the probe inlet upwind outside the boundary of the landfill at a distance of at least 30 meters from the perimeter wells. Record the background concentration and location in the table below.

General Information:
Date: _____
Operator Name: _____
Facility: _____
Instrument ID: _____
Wind Direction: N NE E SE S SW W NW (circle one)
Approximate Wind Speed_____mph
General Weather: _____ ^{o}F,
clear, partly cloudy, overcast, _____ (circle one or write in)
no precip., drizzle, rain, snow, _____ (circle one or write in)

Calibration Information:
Calibration Gas Conc.: _____ppm
Conduct internal zero calibration? Yes No (circle one)
Instrument reading after calibration: _____ppm (should be same as above)
Time of Calibration: ___:___ am pm (fill in and pick one)

Background Concentration Information:
Background concentration upwind of site: _____ppm
Background concentrations downwind of site: _____ppm

Location of background readings:_____

Average of background readings: _____ppm
New Leak Definition (500 ppm + above average): _____ppm

APPENDIX A
40 CFR 60 Appendix A, Method 21

1.0 Scope and Application

1.1 Analytes.

Analyte	CAS No.
Volatile Organic Compounds (VOC).....	No CAS number assigned.

1.2 Scope. This method is applicable for the determination of VOC leaks from process equipment. These sources include, but are not limited to, valves, flanges and other connections, pumps and compressors, pressure relief devices, process drains, open-ended valves, pump and compressor seal system degassing vents, accumulator vessel vents, agitator seals, and access door seals.

1.3 Data Quality Objectives. Adherence to the requirements of this method will enhance the quality of the data obtained from air pollutant sampling methods.

2.0 Summary of Method

2.1 A portable instrument is used to detect VOC leaks from individual sources. The instrument detector type is not specified, but it must meet the specifications and performance criteria contained in Section 6.0. A leak definition concentration based on a reference compound is specified in each applicable regulation. This method is intended to locate and classify leaks only, and is not to be used as a direct measure of mass emission rate from individual sources.

3.0 Definitions

3.1 *Calibration gas* means the VOC compound used to adjust the instrument meter reading to a known value. The calibration gas is usually the reference compound at a known concentration approximately equal to the leak definition concentration.

3.2 *Calibration precision* means the degree of agreement between measurements of the same known value, expressed as the relative percentage of the average difference between the meter readings and the known concentration to the known concentration.

3.3 *Leak definition concentration* means the local VOC concentration at the surface of a

leak source that indicates that a VOC emission (leak) is present. The leak definition is an instrument meter reading based on a reference compound.

3.4 *No detectable emission* means a local VOC concentration at the surface of a leak source, adjusted for local VOC ambient concentration, that is less than 2.5 percent of the specified leak definition concentration. that indicates that a VOC emission (leak) is not present.

3.5 *Reference compound* means the VOC species selected as the instrument calibration basis for specification of the leak definition concentration. (For example, if a leak definition concentration is 10,000 ppm as methane, then any source emission that results in a local concentration that yields a meter reading of 10,000 on an instrument meter calibrated with methane would be classified as a leak. In this example, the leak definition concentration is 10,000 ppm and the reference compound is methane.)

3.6 *Response factor* means the ratio of the known concentration of a VOC compound to the observed meter reading when measured using an instrument calibrated with the reference compound specified in the applicable regulation.

3.7 *Response time* means the time interval from a step change in VOC concentration at the input of the sampling system to the time at which 90 percent of the corresponding final value is reached as displayed on the instrument readout meter.

4.0 Interferences [Reserved]

5.0 Safety

5.1 Disclaimer. This method may involve hazardous materials, operations, and equipment. This test method may not address all of the safety problems associated with its use. It is the responsibility of the user of this test method to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to performing this test method.

5.2 Hazardous Pollutants. Several of the compounds, leaks of which may be determined by this method, may be irritating or corrosive to tissues (*e.g.,* heptane) or may be toxic (*e.g.,* benzene, methyl alcohol). Nearly all are fire hazards. Compounds in emissions should be determined through familiarity with the source. Appropriate precautions can be found in reference documents, such as reference No. 4 in Section 16.0.

6.0 Equipment and Supplies

A VOC monitoring instrument meeting the following specifications is required:

6.1 The VOC instrument detector shall respond to the compounds being processed. Detector types that may meet this requirement include, but are not limited to, catalytic oxidation, flame ionization, infrared absorption, and photoionization.

6.2 The instrument shall be capable of measuring the leak definition concentration specified in the regulation.

6.3 The scale of the instrument meter shall be readable to ±2.5 percent of the specified leak definition concentration.

6.4 The instrument shall be equipped with an electrically driven pump to ensure that a sample is provided to the detector at a constant flow rate. The nominal sample flow rate, as measured at the sample probe tip, shall be 0.10 to 3.0 l/min (0.004 to 0.1 ft^3 /min) when the probe is fitted with a glass wool plug or filter that may be used to prevent plugging of the instrument.

6.5 The instrument shall be equipped with a probe or probe extension or sampling not to exceed 6.4 mm (1/4 in) in outside diameter, with a single end opening for admission of sample.

6.6 The instrument shall be intrinsically safe for operation in explosive atmospheres as defined by the National Electrical Code by the National Fire Prevention Association or other applicable regulatory code for operation in any explosive atmospheres that may be encountered in its use. The instrument shall, at a minimum, be intrinsically safe for Class 1, Division 1 conditions, and/or Class 2, Division 1 conditions, as appropriate, as defined by the example code. The instrument shall not be operated with any safety device, such as an exhaust flame arrestor, removed.

7.0 Reagents and Standards

7.1 Two gas mixtures are required for instrument calibration and performance evaluation:

7.1.1 Zero Gas. Air, less than 10 parts per million by volume (ppmv) VOC.

7.1.2 Calibration Gas. For each organic species that is to be measured during individual source surveys, obtain or prepare a known standard in air at a concentration approximately equal to the applicable leak definition specified in the regulation.

7.2 Cylinder Gases. If cylinder calibration gas mixtures are used, they must be analyzed and certified by the manufacturer to be within 2 percent accuracy, and a shelf life must be specified. Cylinder standards must be either reanalyzed or replaced at the end of the specified shelf life.

7.3 Prepared Gases. Calibration gases may be prepared by the user according to any accepted gaseous preparation procedure that will yield a mixture accurate to within 2 percent. Prepared standards must be replaced each day of use unless it is demonstrated that degradation does not occur during storage.

7.4 Mixtures with non-Reference Compound Gases. Calibrations may be performed using a compound other than the reference compound. In this case, a conversion factor must be determined for the alternative compound such that the resulting meter readings during

source surveys can be converted to reference compound results.

8.0 Sample Collection, Preservation, Storage, and Transport

8.1 Instrument Performance Evaluation. Assemble and start up the instrument according to the manufacturer's instructions for recommended warmup period and preliminary adjustments.

8.1.1 Response Factor. A response factor must be determined for each compound that is to be measured, either by testing or from reference sources. The response factor tests are required before placing the analyzer into service, but do not have to be repeated at subsequent intervals.

8.1.1.1 Calibrate the instrument with the reference compound as specified in the applicable regulation. Introduce the calibration gas mixture to the analyzer and record the observed meter reading. Introduce zero gas until a stable reading is obtained. Make a total of three measurements by alternating between the calibration gas and zero gas. Calculate the response factor for each repetition and the average response factor.

8.1.1.2 The instrument response factors for each of the individual VOC to be measured shall be less than 10 unless otherwise specified in the applicable regulation. When no instrument is available that meets this specification when calibrated with the reference VOC specified in the applicable regulation, the available instrument may be calibrated with one of the VOC to be measured, or any other VOC, so long as the instrument then has a response factor of less than 10 for each of the individual VOC to be measured.

8.1.1.3 Alternatively, if response factors have been published for the compounds of interest for the instrument or detector type, the response factor determination is not required, and existing results may be referenced. Examples of published response factors for flame ionization and catalytic oxidation detectors are included in References 1–3 of Section 17.0.

8.1.2 Calibration Precision. The calibration precision test must be completed prior to placing the analyzer into service and at subsequent 3-month intervals or at the next use, whichever is later.

8.1.2.1 Make a total of three measurements by alternately using zero gas and the specified calibration gas. Record the meter readings. Calculate the average algebraic difference between the meter readings and the known value. Divide this average difference by the known calibration value and multiply by 100 to express the resulting calibration precision as a percentage.

8.1.2.2 The calibration precision shall be equal to or less than 10 percent of the calibration gas value.

8.1.3 Response Time. The response time test is required before placing the instrument into service. If a modification to the sample pumping system or flow configuration is

made that would change the response time, a new test is required before further use.

8.1.3.1 Introduce zero gas into the instrument sample probe. When the meter reading has stabilized, switch quickly to the specified calibration gas. After switching, measure the time required to attain 90 percent of the final stable reading. Perform this test sequence three times and record the results. Calculate the average response time.

8.1.3.2 The instrument response time shall be equal to or less than 30 seconds. The instrument pump, dilution probe (if any), sample probe, and probe filter that will be used during testing shall all be in place during the response time determination.

8.2 Instrument Calibration. Calibrate the VOC monitoring instrument according to Section 10.0.

8.3 Individual Source Surveys.

8.3.1 Type I—Leak Definition Based on Concentration. Place the probe inlet at the surface of the component interface where leakage could occur. Move the probe along the interface periphery while observing the instrument readout. If an increased meter reading is observed, slowly sample the interface where leakage is indicated until the maximum meter reading is obtained. Leave the probe inlet at this maximum reading location for approximately two times the instrument response time. If the maximum observed meter reading is greater than the leak definition in the applicable regulation, record and report the results as specified in the regulation reporting requirements. Examples of the application of this general technique to specific equipment types are:

8.3.1.1 Valves. The most common source of leaks from valves is the seal between the stem and housing. Place the probe at the interface where the stem exits the packing gland and sample the stem circumference. Also, place the probe at the interface of the packing gland take-up flange seat and sample the periphery. In addition, survey valve housings of multipart assembly at the surface of all interfaces where a leak could occur.

8.3.1.2 Flanges and Other Connections. For welded flanges, place the probe at the outer edge of the flange-gasket interface and sample the circumference of the flange. Sample other types of nonpermanent joints (such as threaded connections) with a similar traverse.

8.3.1.3 Pumps and Compressors. Conduct a circumferential traverse at the outer surface of the pump or compressor shaft and seal interface. If the source is a rotating shaft, position the probe inlet within 1 cm of the shaft-seal interface for the survey. If the housing configuration prevents a complete traverse of the shaft periphery, sample all accessible portions. Sample all other joints on the pump or compressor housing where leakage could occur.

8.3.1.4 Pressure Relief Devices. The configuration of most pressure relief devices prevents sampling at the sealing seat interface. For those devices equipped with an enclosed extension, or horn, place the probe inlet at approximately the center of the

exhaust area to the atmosphere.

8.3.1.5 Process Drains. For open drains, place the probe inlet at approximately the center of the area open to the atmosphere. For covered drains, place the probe at the surface of the cover interface and conduct a peripheral traverse.

8.3.1.6 Open-ended Lines or Valves. Place the probe inlet at approximately the center of the opening to the atmosphere.

8.3.1.7 Seal System Degassing Vents and Accumulator Vents. Place the probe inlet at approximately the center of the opening to the atmosphere.

8.3.1.8 Access door seals. Place the probe inlet at the surface of the door seal interface and conduct a peripheral traverse.

8.3.2 Type II—"No Detectable Emission". Determine the local ambient VOC concentration around the source by moving the probe randomly upwind and downwind at a distance of one to two meters from the source. If an interference exists with this determination due to a nearby emission or leak, the local ambient concentration may be determined at distances closer to the source, but in no case shall the distance be less than 25 centimeters. Then move the probe inlet to the surface of the source and determine the concentration as outlined in Section 8.3.1. The difference between these concentrations determines whether there are no detectable emissions. Record and report the results as specified by the regulation. For those cases where the regulation requires a specific device installation, or that specified vents be ducted or piped to a control device, the existence of these conditions shall be visually confirmed. When the regulation also requires that no detectable emissions exist, visual observations and sampling surveys are required. Examples of this technique are:

8.3.2.1 Pump or Compressor Seals. If applicable, determine the type of shaft seal. Perform a survey of the local area ambient VOC concentration and determine if detectable emissions exist as described in Section 8.3.2.

8.3.2.2 Seal System Degassing Vents, Accumulator Vessel Vents, Pressure Relief Devices. If applicable, observe whether or not the applicable ducting or piping exists. Also, determine if any sources exist in the ducting or piping where emissions could occur upstream of the control device. If the required ducting or piping exists and there are no sources where the emissions could be vented to the atmosphere upstream of the control device, then it is presumed that no detectable emissions are present. If there are sources in the ducting or piping where emissions could be vented or sources where leaks could occur, the sampling surveys described in Section 8.3.2 shall be used to determine if detectable emissions exist.

8.3.3 Alternative Screening Procedure.

8.3.3.1 A screening procedure based on the formation of bubbles in a soap solution that is sprayed on a potential leak source may be used for those sources that do not have

continuously moving parts, that do not have surface temperatures greater than the boiling point or less than the freezing point of the soap solution, that do not have open areas to the atmosphere that the soap solution cannot bridge, or that do not exhibit evidence of liquid leakage. Sources that have these conditions present must be surveyed using the instrument technique of Section 8.3.1 or 8.3.2.

8.3.3.2 Spray a soap solution over all potential leak sources. The soap solution may be a commercially available leak detection solution or may be prepared using concentrated detergent and water. A pressure sprayer or squeeze bottle may be used to dispense the solution. Observe the potential leak sites to determine if any bubbles are formed. If no bubbles are observed, the source is presumed to have no detectable emissions or leaks as applicable. If any bubbles are observed, the instrument techniques of Section 8.3.1 or 8.3.2 shall be used to determine if a leak exists, or if the source has detectable emissions, as applicable.

9.0 Quality Control

Section	Quality control measure	Effect
8.1.2	Instrument calibration precision check.	Ensure precision and accuracy, respectively, of instrument response to standard.
10.0	Instrument calibration.	

10.0 Calibration and Standardization

10.1 Calibrate the VOC monitoring instrument as follows. After the appropriate warmup period and zero internal calibration procedure, introduce the calibration gas into the instrument sample probe. Adjust the instrument meter readout to correspond to the calibration gas value.

Note: If the meter readout cannot be adjusted to the proper value, a malfunction of the analyzer is indicated and corrective actions are necessary before use.

11.0 Analytical Procedures [Reserved]

12.0 Data Analyses and Calculations [Reserved]

13.0 Method Performance [Reserved]

14.0 Pollution Prevention [Reserved]

15.0 Waste Management [Reserved]

16.0 References

1. Dubose, D.A., and G.E. Harris. Response Factors of VOC Analyzers at a Meter Reading of 10,000 ppmv for Selected Organic Compounds. U.S. Environmental Protection Agency, Research Triangle Park, NC. Publication No. EPA 600/2–81051. September 1981.

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Harnessing the power of LFG energy provides environmental and economic benefits to landfills, energy users and the community. Working together, landfill owners, energy service providers, businesses, state agencies, local governments, communities and other stakeholders can develop successful LFG energy projects that:

- Reduce emissions of greenhouse gases (GHGs) that contribute to global climate change
- Offset the use of non-renewable resources
- Help improve local air quality
- Provide revenue for landfills
- Reduce energy costs for users of LFG energy
- Create jobs and promote investment in local businesses

LMOP encourages and facilitates development of environmentally and economically sound LFG energy projects by partnering with stakeholders and providing a variety of information, tools and services.

This chapter describes the source and characteristics of LFG and presents basic information about the collection, treatment and use of LFG in energy recovery systems. This chapter also includes a discussion of the status of LFG energy in the United States, a review of the benefits of LFG energy projects and a summary of the current federal regulatory framework. Finally, general steps to LFG energy project development are introduced.

1.1 What Is LFG?

MSW landfills are the third largest human caused source of methane in the United States, accounting for approximately 15.4 percent of U.S. methane emissions in 2015.[2]

LFG is a natural byproduct of the decomposition of organic material in anaerobic (without oxygen) conditions. LFG contains roughly 50 to 55 percent methane and 45 to 50 percent carbon dioxide, with less than 1 percent non-methane organic compounds (NMOCs) and trace amounts of inorganic compounds. Methane is a potent GHG 28 to 36 times more effective than carbon dioxide at trapping heat in the atmosphere over a 100-year period.[1] LMOP uses a methane global warming potential (GWP) of 25 in program calculations to be consistent with and comparable to key Agency emission quantification programs such as the U.S. GHG Inventory.[2]

When municipal solid waste (MSW) is first deposited in a landfill, it undergoes an aerobic (with oxygen) decomposition stage when little methane is generated. Then, typically within less than 1 year, anaerobic conditions are established and methane-producing bacteria begin to decompose the waste and generate methane. Figure 1-1 illustrates the changes in typical LFG composition over time.

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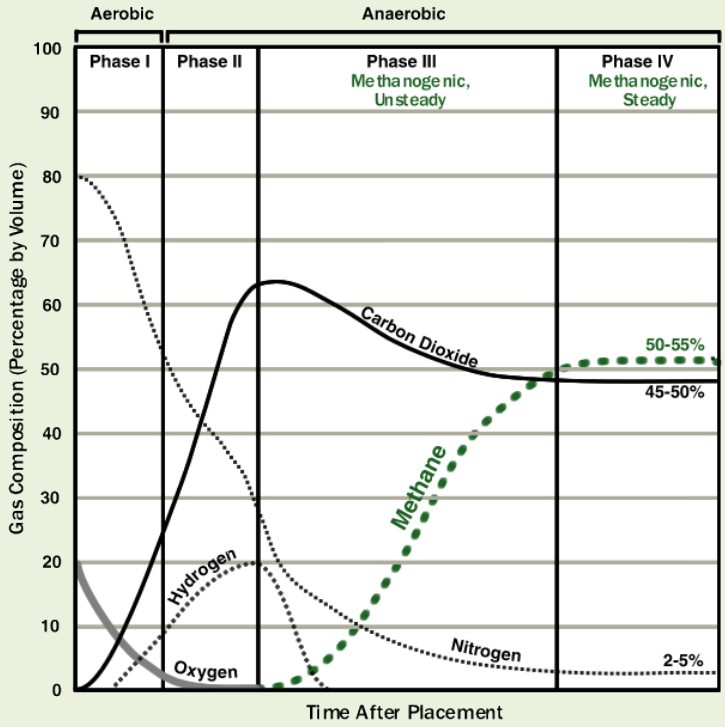
1 In the latest Intergovernmental Panel on Climate Change (IPCC) assessment report (AR5), the methane GWP range is 28 to 36, compared to a GWP of 25 in AR4. https://www.ipcc.ch/report/ar5/.

2 *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2015.* U.S. Environmental Protection Agency. EPA 430-P-17-001. April 2017. https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2015.

More information about national GHG emissions from landfills and other sources is available from EPA's national Greenhouse Gas Emissions website. Additionally, facility-specific emissions data can be viewed using EPA's Facility Level Information on GreenHouse gases Tool (FLIGHT).

Figure 1-1. Changes in Typical LFG Composition after Waste Placement[3]

Bacteria decompose landfill waste in four phases. Gas composition changes with each phase and waste in a landfill may be undergoing several phases of decomposition at once. The time after placement scale (total time and phase duration) varies with landfill conditions.



Phase I: Aerobic bacteria—bacteria that live only in the presence of oxygen—consume oxygen while breaking down the long molecular chains of complex carbohydrates, proteins, and lipids that comprise organic waste. The primary byproduct of this process is carbon dioxide. Phase I continues until available oxygen is depleted.

Phase II: Using an anaerobic process—does not require oxygen—bacteria convert compounds created by aerobic bacteria into acetic, lactic and formic acids and alcohols such as methanol and ethanol. As the acids mix with the moisture present in the landfill and nitrogen is consumed, carbon dioxide and hydrogen are produced.

Phase III: Anaerobic bacteria consume the organic acids produced in Phase II and form acetate, an organic acid. This process causes the landfill to become a more neutral environment in which methane-producing bacteria are established by consuming the carbon dioxide and acetate.

Phase IV: The composition and production rates of LFG remain relatively constant. LFG usually contains approximately 50-55% methane by volume, 45-50% carbon dioxide, and 2-5% other gases, such as sulfides. LFG is produced at a stable rate in Phase IV, typically for about 20 years.

Approximately 258 million tons of MSW were generated in the United States in 2014, with less than 53 percent of that deposited in landfills.[4] One million tons of MSW produces roughly 300 cubic feet per minute (cfm) of LFG and continues to produce LFG for as many as 20 to 30 years after it has been landfilled. With a heating value of about 500 British thermal units (Btu) per standard cubic foot, LFG is a good source of useful energy, normally through the operation of engines or turbines. Many landfills collect and use LFG voluntarily to take advantage of this renewable energy resource while also reducing GHG emissions.

For more information on LFG modeling to estimate methane generation and recovery potential, see Chapter 2.

[3] Figure adapted from ATSDR 2008. Chapter 2: Landfill Gas Basics. In *Landfill Gas Primer - An Overview for Environmental Health Professionals.* Figure 2-1, pp. 5-6. http://www.atsdr.cdc.gov/HAC/landfill/PDFs/Landfill_2001_ch2mod.pdf

[4] Of the MSW generated in 2014, more than 34 percent was recovered through recycling or composting while about 13 percent was combusted with energy recovery. Source: U.S. EPA. 2016. *Advancing Sustainable Materials Management: 2014 Fact Sheet*. Figure 4, p. 5. https://www.epa.gov/sites/production/files/2016-11/documents/2014_smmfactsheet_508.pdf.

1.2 LFG Collection and Flaring

LFG collection typically begins after a portion of the landfill (known as a "cell") is closed to additional waste placement. Collection systems can be configured as either vertical wells or horizontal trenches. Most landfills with energy recovery systems include a flare for the combustion of excess gas and for use during equipment downtimes. Each of these components is described below, followed by a brief discussion of collection system and flare costs.

Gas Collection Wells and Horizontal Trenches. The most common method of LFG collection involves drilling vertical wells in the waste and connecting those wellheads to lateral piping that transports the gas to a collection header using a blower or vacuum induction system. Another type of LFG collection system uses horizontal piping laid in trenches in the waste. Horizontal trench systems are useful in deeper landfills and in areas of active filling. Some collection systems involve a combination of vertical wells and horizontal collectors. Well-designed systems of either type are effective in collecting LFG. The design chosen depends on site-specific conditions and the timing of LFG collection system installation. Figure 1-2 illustrates the design of a typical vertical LFG extraction well, and Figure 1-3 shows a typical horizontal extraction well.

Figure 1-2. Vertical Extraction Well

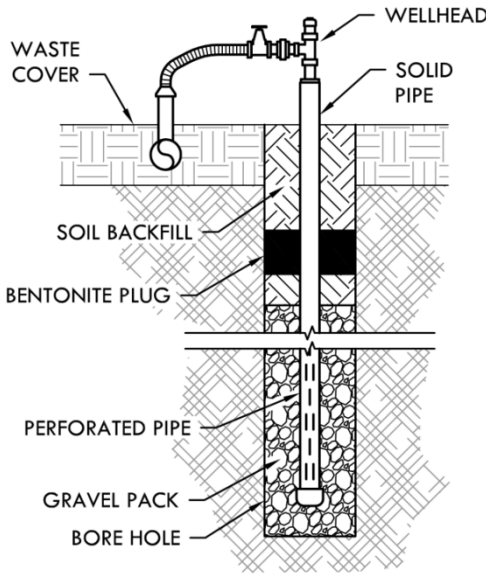
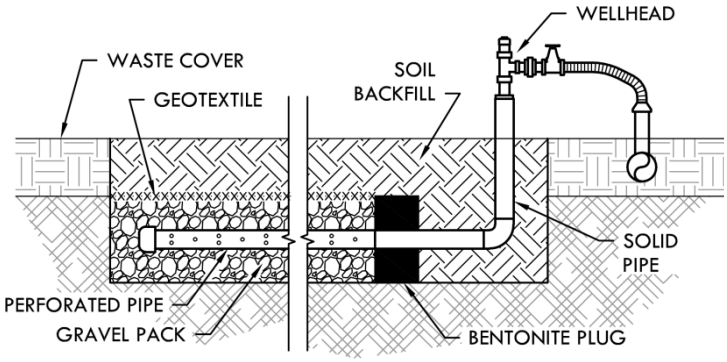


Figure 1-3. Horizontal Extraction Well



Condensate Collection. Condensate forms when warm gas from the landfill cools as it travels through the collection system. If condensate (water) is not removed, it can block the collection system and disrupt the energy recovery process. Techniques for condensate collection and treatment are described in Chapter 3.

Blower. A blower is necessary to pull the gas from the collection wells into the collection header and convey the gas to downstream treatment and energy recovery systems. The size, type and number of blowers needed depend on the gas flow rate and distance to downstream processes.

Flare. A flare is a device for igniting and burning the LFG. Flares are a component of each energy recovery option because they may be needed to control LFG emissions during startup and downtime of the energy recovery system and to control gas that exceeds the capacity of the energy conversion equipment. In addition, a flare is a cost-effective way to gradually increase the size of the energy generation system at an active landfill. As more waste is placed in the landfill and the gas collection system is expanded, the flare is used to control excess gas between energy conversion system upgrades

(for example, before the addition of another engine) to prevent methane from being released into the atmosphere.

As shown in Figure 1-4, flare designs include open (or candlestick) flares and enclosed flares. Enclosed flares are more expensive but may be preferable (or required by state regulations) because they provide greater control of combustion conditions, allow for stack testing and might achieve slightly higher combustion efficiencies (higher methane destruction rates) than open flares. They can also reduce noise and light nuisances.

Figure 1-4. Open (left) and Enclosed (right) Flares

A Closer Look at Collection System Costs

Total collection system costs vary widely, based on a number of site-specific factors. For example, if the landfill is deep, collection costs tend to be higher because well depths will need to be increased. Collection costs also increase with the number of wells installed.

The estimated capital required for a 40-acre collection system designed for 600 cubic feet per minute (cfm) of LFG (including a flare) is approximately $1,143,000, or $28,600 per acre (2013 dollars), assuming one well is installed per acre. Typical annual operation and maintenance (O&M) costs for collection systems are estimated to be $191,000, or $4,800 per acre.[5] If an LFG energy project generates electricity, often a landfill will use a portion of the electricity generated to operate the system and sell the rest to the grid to offset these operational costs. Flaring costs have been incorporated into these estimated capital and operating costs of LFG collection systems, because excess gas may need to be flared at any time, even if an energy generation system is installed.

For more information about the types of LFG collection systems, see Chapter 3.

1.3 LFG Treatment

Using LFG in an energy recovery system usually requires some treatment of the LFG to remove excess moisture, particulates and other impurities. The type and extent of treatment depend on site-specific LFG characteristics and the type of energy recovery system employed. Boilers and most internal combustion engines generally require minimal treatment (usually dehumidification, particulate filtration and compression). Some internal combustion engines and many gas turbine and microturbine applications also require siloxane and hydrogen sulfide removal using adsorption beds, biological scrubbers and other available technologies after the dehumidification step.[6]

Figure 1-5 presents a diagram of an LFG energy project, including LFG collection, a fairly extensive treatment system and an energy recovery system generating both electricity and heat. Most LFG energy projects produce either electricity or heat, although a growing number of combined heat and power (CHP) systems produce both.

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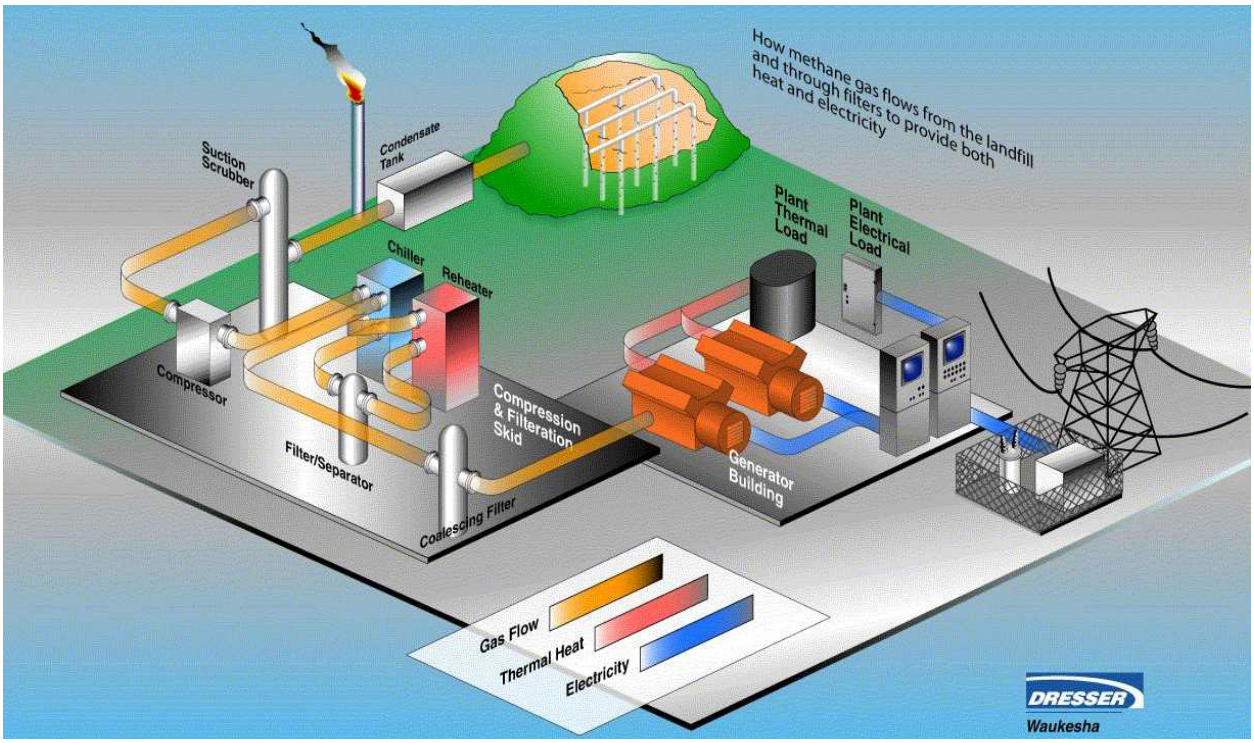
5 U.S. EPA LMOP. *LFGcost-Web*, Version 3.2.

6 Organo-silicon compounds, known as siloxanes, are found in household and commercial products that are discarded in landfills. Siloxanes find their way into LFG, although the amounts vary depending on the waste composition and age. When LFG is combusted, siloxanes are converted to silicon dioxide (the primary component of sand). Silicon dioxide is a white substance that collects on the inside of the internal combustion engine and components of the gas turbine, reducing the performance of the equipment and resulting in significantly higher maintenance costs. See Chapter 3 for further information.

Figure 1-5. LFG Collection, Treatment and Energy Recovery



Graphic courtesy of Dresser Waukesha

The cost of gas treatment depends on the gas purity requirements of the end use application. The cost of a system to filter the gas and remove condensate for direct use of medium-Btu gas or for electric power production is considerably less than the cost of a system that must also remove contaminants such as siloxane and sulfur that are present at elevated levels in some LFG.

For more information about the types of LFG treatment systems, see Chapter 3.

1.4 Uses of LFG

LFG energy projects first came on the scene in the mid- to late-1970s and increased notably during the 1990s as a track record for efficiency, dependability and cost savings was demonstrated. The enactment of federal tax credits and regulatory requirements for LFG collection and control for larger landfills also helped to spur the growth of LFG energy projects, as did other factors such as increased concerns about how methane emissions contribute to global climate change and market demands for renewable energy options.

Every million tons of MSW in a landfill is estimated to be able to produce approximately 300 cubic feet per minute of LFG. Through various technologies, this amount of LFG could generate approximately 0.78 megawatts of power, or provide 9 million Btu per hour of thermal energy.

LMOP's Landfill and LFG Energy Project Database, which tracks the development of U.S. LFG energy projects and landfills with project development potential, indicates that, in June 2017, 634 LFG energy projects are operating in 48 states and 1 U.S. territory. Roughly three-quarters of these projects generate electricity, while the remainder are either direct-use projects where the LFG is used for its thermal capacity or upgraded LFG projects where the LFG is cleaned to a level similar to natural gas. Examples of direct-

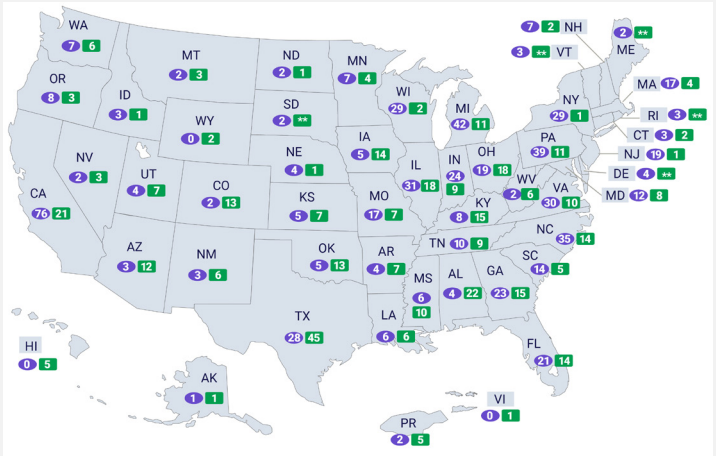
use projects include piping LFG to a nearby business or industry for use in a boiler, furnace or kiln. As illustrated in Figure 1-6, the 634 projects are estimated to generate 17 billion kilowatt-hours (kWh) of electricity and deliver 96 billion cubic feet of LFG to direct end users and natural gas pipelines annually.[7] More information about these projects as well as landfills with potential to support LFG energy projects is available on the Landfill Gas Energy Project Data and Landfill Technical Data page of LMOP's website.

Figure 1-6. Estimated LFG Energy Project Output in the United States (June 2017)

There are numerous examples of LFG energy success stories. Some of these involve LMOP Partners coming together to overcome great odds to bring a project to fruition; others involve the use of innovative technologies and approaches, while still others were completed in record time. To read about some of these projects, see LMOP's LFG Energy Project Profiles and Project Award Winners.

LMOP provides national and state-specific files of operational projects and candidate landfills on its website.

Each file includes basic information about the landfill or project, such as location, data on LFG flow rates, project status and technology type.



Electricity Generation

The three most commonly used technologies for LFG energy projects that generate electricity — internal combustion engines, gas turbines and microturbines — can accommodate a wide range of project sizes. Most (more than 75 percent) of the LFG energy projects that generate electricity use internal combustion engines, which are well-suited for 800-kW to 3-megawatt (MW) projects. Multiple internal combustion engines can be used together for projects larger than 3 MW. Gas turbines are more likely to be used for large projects, usually 5 MW or larger. Microturbines, as their name suggests, are much smaller than gas

[7] U.S. EPA. LMOP Landfill and LFG Energy Project Database. June 2017.

turbines, with a single unit having between 30 and 250 kW in capacity, and are generally used for projects smaller than 1 MW. Small internal combustion engines are also available for projects in this size range.

CHP applications, also known as cogeneration projects, provide greater overall energy efficiency and are growing in number. In addition to producing electricity, these projects recover and beneficially use the heat from the unit combusting the LFG. LFG energy CHP projects can use internal combustion engines, gas turbines or microturbine technologies.

Other LFG electricity generation technologies include boiler/steam turbines and combined cycle applications. In boiler/steam turbine applications, LFG is combusted in a large boiler to generate steam that powers a turbine to create electricity. Combined cycle applications combine a gas turbine with a steam turbine, so that the gas turbine combusts the LFG and the steam turbine uses the steam generated from the gas turbine's exhaust to create electricity. Boiler/steam turbine and combined cycle applications tend to be larger in scale than the majority of LFG electricity projects that use internal combustion engines.

An LFG energy project may use multiple units to accommodate a landfill's specific gas flow over time. For example, a project might have three internal combustion engines, two gas turbines or an array of 10 microturbines, depending on gas flow and energy needs.

For more information about electricity generation technologies, see Chapter 3.

Direct Use

Direct use of LFG can offer a cost-effective alternative for fueling combustion or heating equipment at facilities located within approximately 5 miles of a landfill. In some situations, longer pipelines may be economically feasible based on the amount of LFG collected, the fuel demand of the end user and the price of the fuel the LFG will replace. Some manufacturing plants have chosen to locate near a landfill for the express purpose of using LFG as a renewable fuel that is cost-effective as compared to natural gas.

The number and diversity of direct-use LFG applications is continuing to grow. Project types include:

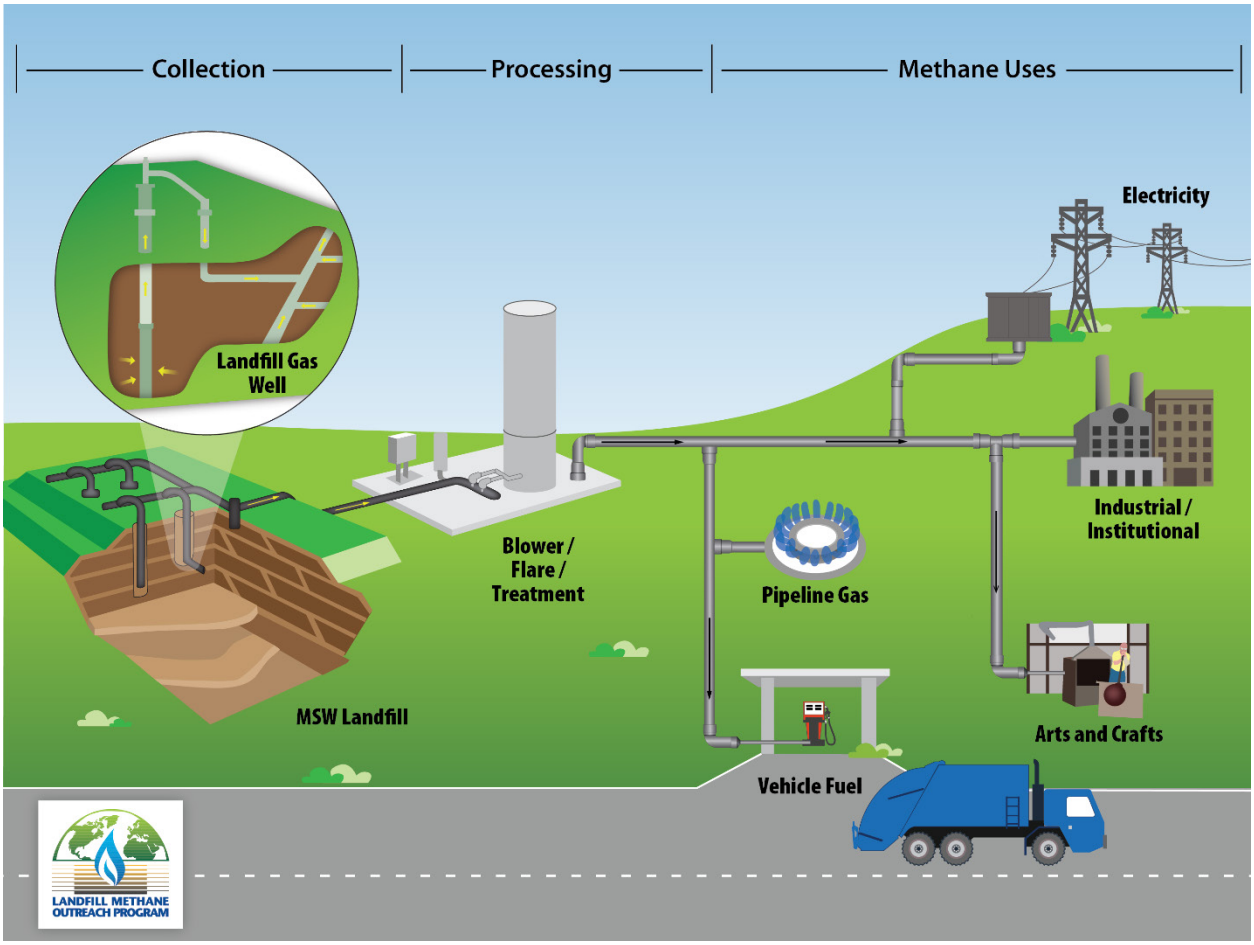
- ***Boilers***, which are the most common type of direct use and can often be easily converted to use LFG alone or in combination with fossil fuels.
- ***Direct thermal applications*****,** which include kilns (cement, pottery or brick), sludge dryers, infrared heaters, paint shop oven burners, tunnel furnaces, process heaters and blacksmithing forges, to name a few. LFG has also found a home in a few greenhouse operations.
- ***Leachate evaporation*****,** in which a combustion device that uses LFG is used to evaporate leachate (the liquid that percolates through a landfill). Leachate evaporation can reduce the cost of treating and disposing of leachate.

The creation of pipeline-quality, or high-Btu, gas from LFG is becoming more prevalent. In this process, LFG is cleaned and purified (carbon dioxide and impurities removal) until it is at the quality that can be directly injected into a natural gas pipeline. Also growing in popularity are projects in which LFG provides heat for processes that create alternative fuels (such as biodiesel or ethanol). In some cases, LFG is directly used as feedstock for an alternative fuel (for example, compressed natural gas [CNG], liquefied natural gas [LNG], or methanol). Only a handful of these projects are currently operational, but several more are in the construction or planning stages.

For more information about direct-use and high-Btu technologies, see Chapter 3.

Figure 1-7 graphically depicts some of the potential end use options for LFG energy projects such as generating electricity, providing medium-Btu gas for heating or other purposes or upgrading the LFG to near pipeline-quality for transportation fuel or other uses.

Figure 1-7. Example LFG End Use Options



1.5 Environmental and Economic Benefits of LFG Energy Recovery

Developing LFG energy projects is an effective way to reduce GHG emissions, improve local air quality and control odors. This section highlights the numerous environmental and economic benefits that LFG energy projects provide to the community, the landfill and the energy end user.

Environmental Benefits

MSW landfills are the third-largest human-caused source of methane emissions in the United States.[8] Methane is a potent greenhouse gas (more than 25 times stronger than carbon dioxide over a 100-year period) and has a short atmospheric life (~12 years). Because methane is both potent and short-lived, reducing methane emissions from MSW landfills is one of the best ways to lessen the human impact on

[8] *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2015*. U.S. Environmental Protection Agency. EPA 430-P-17-001. April 2017. https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2015.

global climate change. In addition, all landfills generate methane, so there are many opportunities to reduce methane emissions by flaring or collecting LFG for energy generation.

Direct GHG Reductions. During its operational lifetime, an LFG energy project will capture an estimated 60 to 90 percent of the methane created by a landfill, depending on system design and effectiveness. The methane captured is converted to water and carbon dioxide when the gas is burned to produce electricity or heat.[9]

Indirect GHG Reductions. Producing energy from LFG displaces the use of non-renewable resources (such as coal, oil or natural gas) that would be needed to produce the same amount of energy. This displacement avoids GHG emissions from fossil fuel combustion by an end user facility or power plant.[10]

GHG Equivalents[11]

The 634[12] LFG energy projects operational in June 2017 reduce approximately 133 million metric tons of carbon dioxide equivalents ($MMTCO_2e$)/year of GHG emissions, which is equivalent to any one of the following:

Carbon sequestered by more than 125 million acres of U.S. forests in one year

or

Carbon dioxide emissions from more than 309 million barrels of oil consumed

or

Carbon dioxide emissions from more than 14.9 billion gallons of gasoline consumed

Direct and Indirect Reduction of Other Air Pollutants. The capture and use of LFG at a landfill improves local air quality in many ways. For example:

- NMOCs that are present at low concentrations in LFG are destroyed or converted during combustion, which reduces possible health risks.
- For electricity projects, the avoidance of fossil fuel combustion at utility power plants means that fewer pollutants are released into the air, including sulfur dioxide (which is a major contributor to acid rain), particulate matter (a respiratory health concern), nitrogen oxides (which can contribute to local ozone and smog formation) and trace hazardous air pollutants.
- LFG energy use helps to avoid the use of limited, non-renewable resources such as coal and oil.
- Although the equipment that burns LFG to generate electricity generates some emissions, including nitrogen oxides, the overall environmental benefits achieved from LFG energy projects are significant because of the direct methane reductions, the indirect carbon dioxide reductions, and the direct and indirect reduction in other air pollutant emissions.

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9 Carbon dioxide emissions from MSW landfills are not considered to contribute to global climate change because the carbon was contained in recently living biomass (is biogenic) and the same carbon dioxide would be emitted as a result of the natural decomposition of the organic waste materials if they were not in the landfill. This logic is consistent with international GHG protocols such as the 2006 Intergovernmental Panel on Climate Change Guidelines for National Greenhouse Gas Inventories, Volume 5: Waste. http://www.ipcc-nggip.iges.or.jp/public/2006gl/.

10 The carbon in fossil fuels was not contained in recently living biomass; rather, the carbon was stored when ancient biomass was converted to coal, oil or natural gas and would therefore not have been emitted had the fossil fuel not been extracted and burned. Carbon dioxide emissions from fossil fuel combustion are a major contributor to climate change.

11 U.S. EPA. Greenhouse Gas Equivalencies Calculator. https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator.

12 U.S. EPA. LMOP Landfill and LFG Energy Project Database. June 2017.

Other Environmental Benefits. Collecting and combusting LFG improves the quality of the surrounding community by reducing landfill odors that are usually caused by sulfates in the gas. Collecting LFG also improves safety by reducing gas migration to structures, where trapped or accumulated gas can create explosion hazards.

LMOP's LFG Energy Benefits Calculator estimates direct methane reductions, indirect carbon dioxide reductions and equivalent environmental benefits for an LFG electricity or direct-use project.

Economic Benefits

For the Landfill Owner. Landfill owners can receive revenue from the sale of LFG to a direct end user or pipeline, or from the sale of electricity generated from LFG to the local power grid. Depending on who owns the rights to the LFG and other factors, a landfill owner may also be eligible for revenue from renewable energy certificates (RECs), tax credits and incentives, renewable energy bonds and GHG emissions trading. All these potential revenue sources can help offset gas collection system and energy project costs for the landfill owner. For example, if the landfill owner is required to install a gas collection and control system, using the LFG as an energy resource can help pay down the capital cost required for the control system installation.

Examples

Electricity Generation and Combined Heat and Power at Catawba County Blackburn Landfill, North Carolina. A public/private partnership to develop an LFG electricity project at Catawba County's Blackburn Landfill in Newton, North Carolina, will generate revenues of $7.1 million for the county over the project's lifetime. The LFG electricity provides Duke Energy (the electricity purchaser) with a renewable energy resource, and the annual GHG emission reductions are equivalent to the carbon dioxide emissions from nearly 342,000 barrels of oil consumed.

Combined Heat and Power at La Crosse County Landfill, Wisconsin. This project, recognized as an LMOP 2012 award winner, involves a public/private partnership between La Crosse County and Gundersen Health System. LFG from the county landfill is transported underground via a 2-mile pipeline constructed underneath Interstate 90 to generate green power for the local grid and to heat buildings and water at Gundersen's Onalaska campus. The sale of LFG provides La Crosse County with new revenue, and Gundersen's Onalaska Campus is 100 percent energy independent. Additionally, the landfill was the first in the state to achieve "Green Tier" status from the Wisconsin Department of Natural Resources.

For the End User. Businesses and other organizations, such as universities and government facilities, may save significantly on energy costs by choosing LFG as a direct fuel source. In addition, some companies report achieving indirect economic benefits through media exposure that portrays them as leaders in the use of renewable energy.

Examples

Direct Use of LFG at General Motors Plant in Indiana. General Motors converted one of three powerhouse boilers at an Indiana plant to use LFG in addition to natural gas. The boiler produces steam to heat assembly plant and process equipment and to drive turbines to produce chilled water and pump water. The facility saves about $500,000 annually in energy costs.

Direct Use of LFG to Reduce Fuel Costs in Springfield, Ohio. Springfield Gas and International Truck and Engine Corporation reached out to the community through public meetings, fact sheets and individual visits to gain support for permitting and developing a direct-use project in Springfield, Ohio. Five years later, International began using LFG in place of natural gas in paint ovens, boilers and other equipment, saving $100,000 per year in fuel costs.

Using LFG to Save Energy Costs at BMW Manufacturing in South Carolina. BMW uses gas from Waste Management's Palmetto Landfill to fuel two gas turbine cogeneration units at BMW's manufacturing plant in Greer, South Carolina. The project saves BMW approximately $5 million annually in energy costs.

LFG Electricity and Heat at Morgan County Regional Landfill in Alabama. Winner of the LMOP 2011 Community Partner of the Year Award, Morgan County Regional Landfill took advantage of premium green power pricing through the Tennessee Valley Authority's Generation Partners program. Project developer Granger brought one Caterpillar 3516 engine online in 2010, and the city brought a second engine online in 2011 for a combined capacity of 1.6 MW. Waste heat from the second engine provides heating to the city's recycling center during the winter.

For the Community. LFG energy project development can greatly benefit the local economy. Temporary jobs are created for the construction phase, while design and operation of the collection and energy generation systems create long-term jobs. LFG energy projects involve engineers, construction firms, equipment vendors, and utilities or end users of the power produced. Some materials for the overall project may be purchased locally, and often local firms are used for construction, well drilling, pipeline installation and other services. In addition, lodging and meals for the workers provide a boost to the local economy. Some of the money paid to workers and local businesses by the LFG energy project is spent within the local economy on goods and services, resulting in indirect economic benefits. In some cases, LFG energy projects have led new businesses (such as brick and ceramics plants, greenhouses or craft studios) to locate near the landfill to use LFG. These new businesses add depth to the local economy.

Examples

Stimulating Local Economies. Construction of a direct-use project using LFG from the Lanchester Landfill in Narvon, Pennsylvania, created more than 100 temporary construction jobs and infused millions of dollars into the local economy. A direct-use project in Virginia requiring a 23-mile long pipeline to transport LFG to Honeywell provided jobs and revenue to the local town (for example, building the pipeline resulted in 22,000 local hotel stays).

Raising Awareness and Saving Money. The EnergyXchange Renewable Energy Center, located at the foot of the Black Mountains in western North Carolina, has brought national attention to the region and its artisans through a small-scale but far-reaching LFG energy project. Glass blowers, potters and greenhouse students have benefitted from the local supply of LFG, through saved energy costs, education and hands-on experience, and recognition of their crafts.

Investing in Schools. The ecology club at Pattonville High School in Maryland Heights, Missouri, suggested that the school board consider using excess LFG from a nearby privately owned landfill in the school's boilers. Feasibility analyses determined that the savings were worthwhile, and a partnership was born. With a loan, a grant and capital from then landfill owner Fred Weber, the direct-use project was brought to fruition and the school began saving about $27,000 per year.

Table 1-1. Estimated Regional Economic Impacts and Job Creation from LFG Energy Project Construction[13]

Estimated Regional (State-wide) Economic Benefits *(Economic and job creation benefits are estimates only and are not guaranteed)*	Typical 3-MW Engine Project	Typical 1,000 scfm Direct-use Project 5-mile pipeline
Direct Effects		
Project expenditures for the purchase of generators, piping, and gas compression, treatment skid and auxiliary equipment	$1.85 million	$1.32 million
Jobs created	6.3	9.5
Indirect Effects		
Economic output, resulting from ripple effects	$4.36 to $4.83 million	$2.8 to $3.11 million
Jobs created, including economic ripple effects	22.3-24.3	20.9-22.0

MW: megawatt scfm: standard cubic feet per minute

For more information about project economics, financing or funding resources, see Chapter 4.
For more information about options when setting up a contract, see Chapter 5.

1.6 Regulatory Framework

Landfills and LFG energy projects can be subject to federal, state and local air quality, solid waste and water quality regulations and permitting requirements. State and local governments typically develop their own regulations for carrying out the federal mandates; therefore, specific requirements differ among states. In addition, project developers should contact relevant federal agencies and state agencies for more detailed, current information and to obtain applications for various types of construction and operating permits. An overview of the federal regulatory framework is presented in Chapter 5. It is important for project developers to review applicable requirements and regulations. Project developers are responsible for ensuring compliance with applicable regulations.

Links to state agencies are available on LMOP's State Agencies page.

MSW landfills are required to report GHG emissions and other data if their annual CH_4 generation is greater than or equal to 25,000 metric tons of CO_2e. Learn more about reporting requirements at EPA's Greenhouse Gas Reporting Program website including specific requirements applicable to MSW landfills (subpart HH).

See Chapter 5 for more information about federal regulations.

[13] U.S. EPA LMOP. *LFGcost-Web*, Version 3.2.

1.7 Steps to Developing LFG Energy Projects

The following section provides a basic overview of nine general steps involved in developing an LFG energy project. More specific details about each of these steps are provided in the remaining chapters of this handbook, as noted below.

Step 1 Estimate LFG Recovery Potential and Perform Initial Assessment

The first step is to determine whether the landfill is likely to produce enough methane to support an energy recovery project. Initial screening criteria include:

- Does the landfill contain at least 1 million tons of MSW?
- Does the landfill have a depth of 50 feet or more?
- Is the landfill open or recently closed?
- Does the site receive at least 25 inches of precipitation annually?
- Does the landfill contain enough organic content to generate sufficient LFG?

Landfills that meet these criteria are likely to generate enough gas to support an LFG energy project. It is important to note that these are only ideal conditions; many successful LFG energy projects have been developed at smaller, older or more arid landfills. If it is determined that the energy recovery option is viable, then it is important to estimate the amount of recoverable gas that will be available over time. EPA's LandGEM can provide a more detailed analysis of LFG generation potential.

An important factor for LFG generation is the organic content of the MSW. Waste composed of high organic content will produce more LFG than waste with lower organic content.

Construction and demolition (C&D) landfills, for example, are not expected to generate large quantities of LFG and are often not viable for an energy generation system.

Details about modeling and estimating LFG flow are presented in Chapter 2.

Step 2 Evaluate Project Economics

The next step is to perform a detailed economic assessment of converting LFG into a marketable energy product such as electricity, steam, boiler fuel, vehicle fuel or pipeline-quality gas. A variety of technologies can be used to maximize the value of LFG. The best configuration for a particular landfill will depend on a number of factors, including the existence of an available energy market, project costs, potential revenue sources and other technical considerations. LMOP's *LFGcost-Web* tool can help with preliminary economic evaluation.

Details about project technology options are presented in Chapter 3.
Chapter 4 outlines the process for assessing project economics and financing options.

Step 3 Establish Project Structure

Implementation of a successful LFG energy project begins with identifying the appropriate management structure. For example, options for managing an LFG energy project include:

- The landfill owner develops and manages the project internally.
- The landfill owner teams with an external project developer so that the developer finances, constructs, owns and operates the project.
- The landfill owner teams with partners (such as an equipment supplier or energy end user).

LMOP can assist with project partnering by identifying potential matches and distributing RFPs.

An overview of the types of contracts used for LFG energy projects is provided in Chapter 5.
See Chapter 6 for more information on project structures and evaluating project partners.

Step 4 Draft Development Contract

The terms of LFG energy project partnerships should be formalized in a development contract. The contract identifies which partner owns the gas rights and the rights to potential emission reductions. The contract also establishes each partner's responsibilities, including design, installation and operation and maintenance. Contracting with a developer is a complex issue, and each contract will be different depending on the specific nature of the project and the objectives and limitations of the participants.

See Chapter 5 to learn about LFG contracts and permitting requirements.
See Chapter 6 for details about selecting project partners.

Step 5 Negotiate Energy Sales Contract (Off-Take Agreement)

The LFG energy project owner and the end user negotiate an energy sales contract that specifies the amount of gas or power to be delivered by the project owner to the end user and the price to be paid by the end user for the gas or power. The terms of the energy sales contract typically dictate the success or failure of the LFG energy project because they secure the project's source of revenue. Therefore, successfully obtaining this contract is a crucial milestone in the project development process. Negotiating an energy sales contract involves the following actions: evaluating the end user's need for gas or power, preparing a draft offer contract, developing the project design and pricing, preparing and presenting a bid package, reviewing contract terms and conditions, and signing the contract. Because contract negotiation is often a complex process, owners and developers should consult an expert for further information and guidance.

See Chapter 5 and Chapter 6 for more information about contracts.

Step 6 Secure Permits and Approvals

Obtaining the required permits (environmental, siting and others) is an essential step in the development process. Permit conditions often affect project design, and neither construction nor operation may begin until the appropriate permits are in place. The process of permitting an LFG energy project can take anywhere from 6 to 18 months (or longer) to complete, depending on the location and recovery technology. LFG energy projects must comply with federal regulations related to both the control of LFG emissions and the control of air emissions from the energy conversion equipment. The landfill owner should contact and meet with regulatory authorities to identify requirements and educate the local officials, landfill neighbors, and nonprofit and other public interest and community groups about the benefits of the project. LMOP's State Agencies page lists websites for state organizations that can provide useful information regarding state-specific regulations and permits.

See Chapter 5 for more information about permits.

Step 7 Assess Financing Options

Financing an LFG energy project is one of the most important and challenging tasks facing a landfill owner or project developer. A number of potential financing sources are available, including equity investors, loans from investment companies or banks and municipal bonds. Five general categories of

financing methods may be available to LFG energy projects: private equity financing, project financing, municipal bond funding, direct municipal financing and lease financing. In addition to financing options, there are a variety of financial incentives available at the federal and state levels. General information about federal, state and local financing programs and incentives is available on LMOP's Resources for Funding LFG Energy Projects page.

See Chapter 4 for more details about financing mechanisms.
Chapter 5 and Chapter 6 review additional considerations related to contracts and partnerships.

Step 8 Contract for Engineering, Procurement, and Construction (EPC) and O&M Services

The construction and operation of LFG energy projects is complex, so it may be in the interest of the landfill owner to hire a firm with proven experience gained over the course of implementing similar projects. Landfill owners who choose to contract with EPC and O&M firms should solicit bids from several EPC or O&M contractors before a contract is negotiated. In most cases, the selected EPC or O&M contractor conducts the engineering design, site preparation and plant construction, and startup testing for the LFG energy project.

Chapter 6 provides more information about coordinating with project partners.

Step 9 Install Project and Start Up

The final phase of implementation is the start of commercial operations. This phase is often commemorated with ribbon-cutting ceremonies, public tours and press releases.

LMOP and Landfill Gas Energy in the United States

U.S. Environmental Protection Agency
Landfill Methane Outreach Program

LANDFILL METHANE OUTREACH PROGRAM

File Last Updated • June 2017

Partnership Program

EPA's Landfill Methane Outreach Program

- Established in December 1994
- Voluntary program that creates partnerships among states, energy users/providers, the landfill gas (LFG) industry and communities

Mission: To work cooperatively with industry stakeholders and waste officials to reduce or avoid methane emissions from landfills by encouraging the recovery and beneficial use of biogas generated from organic municipal solid waste.

LMOP Partners

- Industry Partners
- Community Partners
- Energy Partners
- Endorser Partners
- State Partners

- Join at epa.gov/lmop/join-landfill-methane-outreach-program

- **Benefits of LMOP Partnership:**
  - o Recognition of Partner's commitment to and understanding of renewable energy benefits
  - o Identification on LMOP website – description, contact information
  - o Use of LMOP logo on Partner website (within guidelines)
  - o LMOP support for groundbreaking or ribbon cuttings
  - o Listserv messages from LMOP on LFG-related topics

Landfill Gas Basics

Landfill Gas 101

- LFG is a by-product of the anaerobic decomposition of municipal solid waste (MSW):
  - ~50% methane (CH_4)
  - ~50% carbon dioxide (CO_2)
  - <1% non-methane organic compounds (NMOCs)

- Methane is an important constituent of LFG that can be used for energy
- 1 million tons of MSW generates LFG that could be used to produce*:

~0.78 megawatts (MW) of electricity

-or-

~432,000 cubic feet per day of LFG

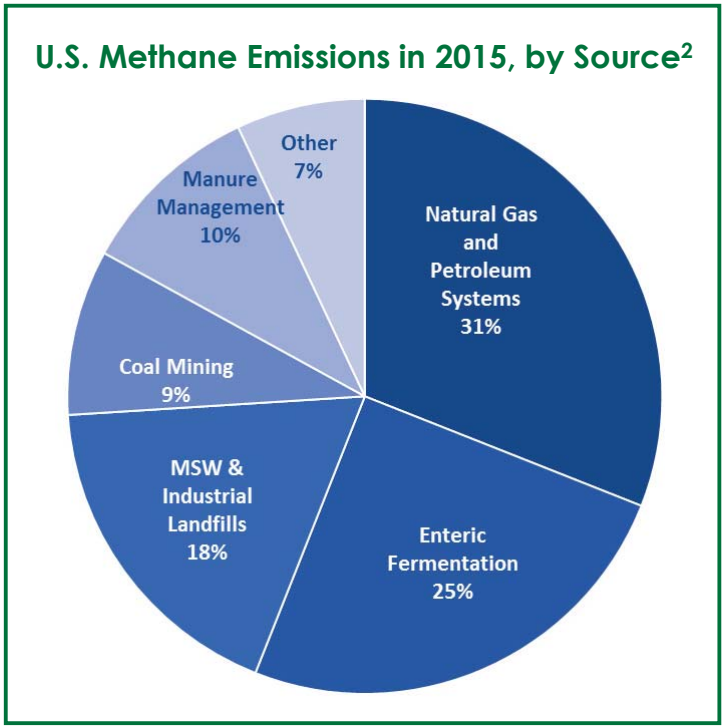
-or-

433,700 gallons of gasoline equivalent (GGEs) per year of CNG

***Source:** *LMOP Interactive Conversion Tool*, U.S. EPA LMOP. epa.gov/lmop/list-publications-tools-and-resources and *LFGcost-Web*, Version 3.2. U.S. EPA LMOP. epa.gov/lmop/lfgcost-web-landfill-gas-energy-cost-model.

Why EPA is Concerned about Landfill Gas

- More than half of the MSW generated in the United States is deposited into a landfill, 52.6% in 2014[1]
- LFG contains hazardous air pollutants and volatile organic compounds, which create health and safety hazards
- MSW landfills are an important source of methane emissions, accounting for ~15.4% of U.S. methane emissions in 2015[2]



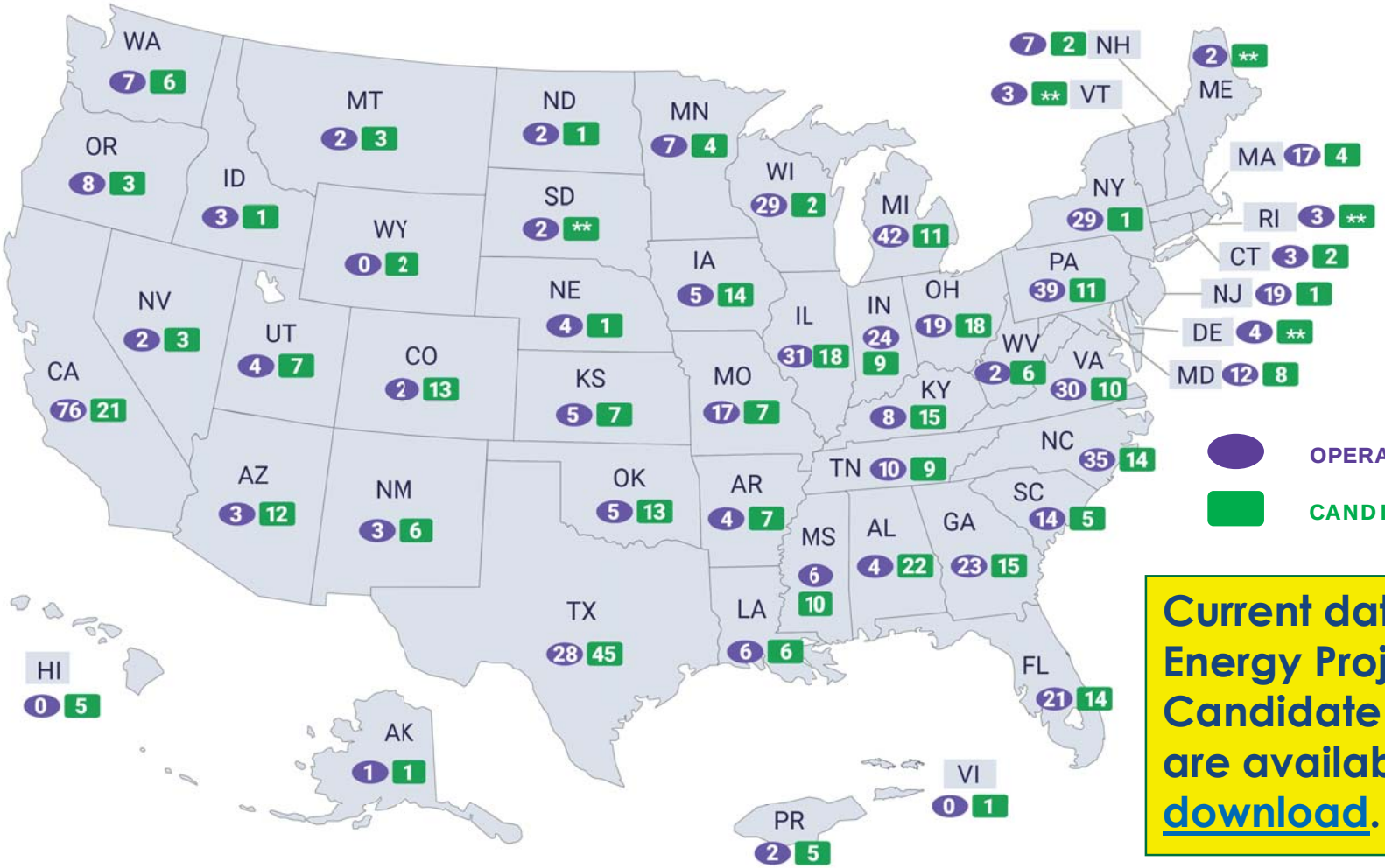
1. Advancing Sustainable Materials Management: 2014 Fact Sheet. November 2016. U.S. EPA. https://www.epa.gov/smm/advancing-sustainable-materials-management-facts-and-figures-report.
2. Inventory of U.S. Greenhouse Gas Emissions and Sinks. April 2017. U.S. EPA. https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks.

LFG Energy Project Development

LFG Energy Basics and Project Development

- LFG is collected from landfills via extraction wells within the waste mass, piping to convey the gas to a central location and a blower system that "pulls" the gas out
- With a heating value of ~500 Btu/scf – it's an energy source!
- The energy content of LFG can be recovered through a variety of technologies and end uses
- LFG energy projects can be developed through different types of agreements and contracts between landfill owners/operators, project development firms, financiers, utilities, direct end users of gas, contractors and others
- LMOP's LFG Energy Project Development Handbook provides more information: https://www.epa.gov/lmop/landfill-gas-energy-project-development-handbook

LFG Energy Projects



Current data on LFG Energy Projects and Candidate Landfills are available for download.

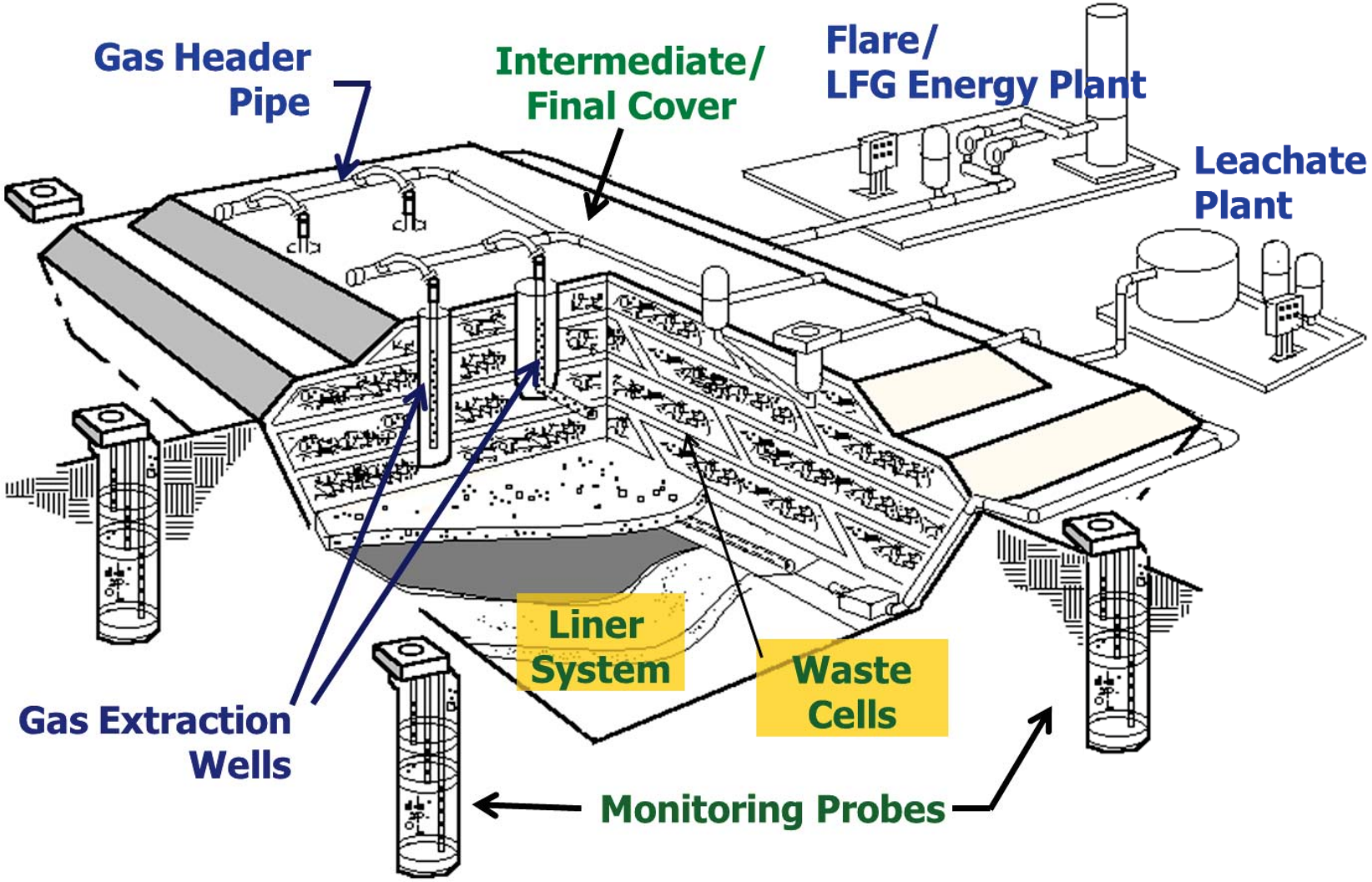
These data are from LMOP's database as of June 2017.

Landfill Gas Energy Co-Benefits

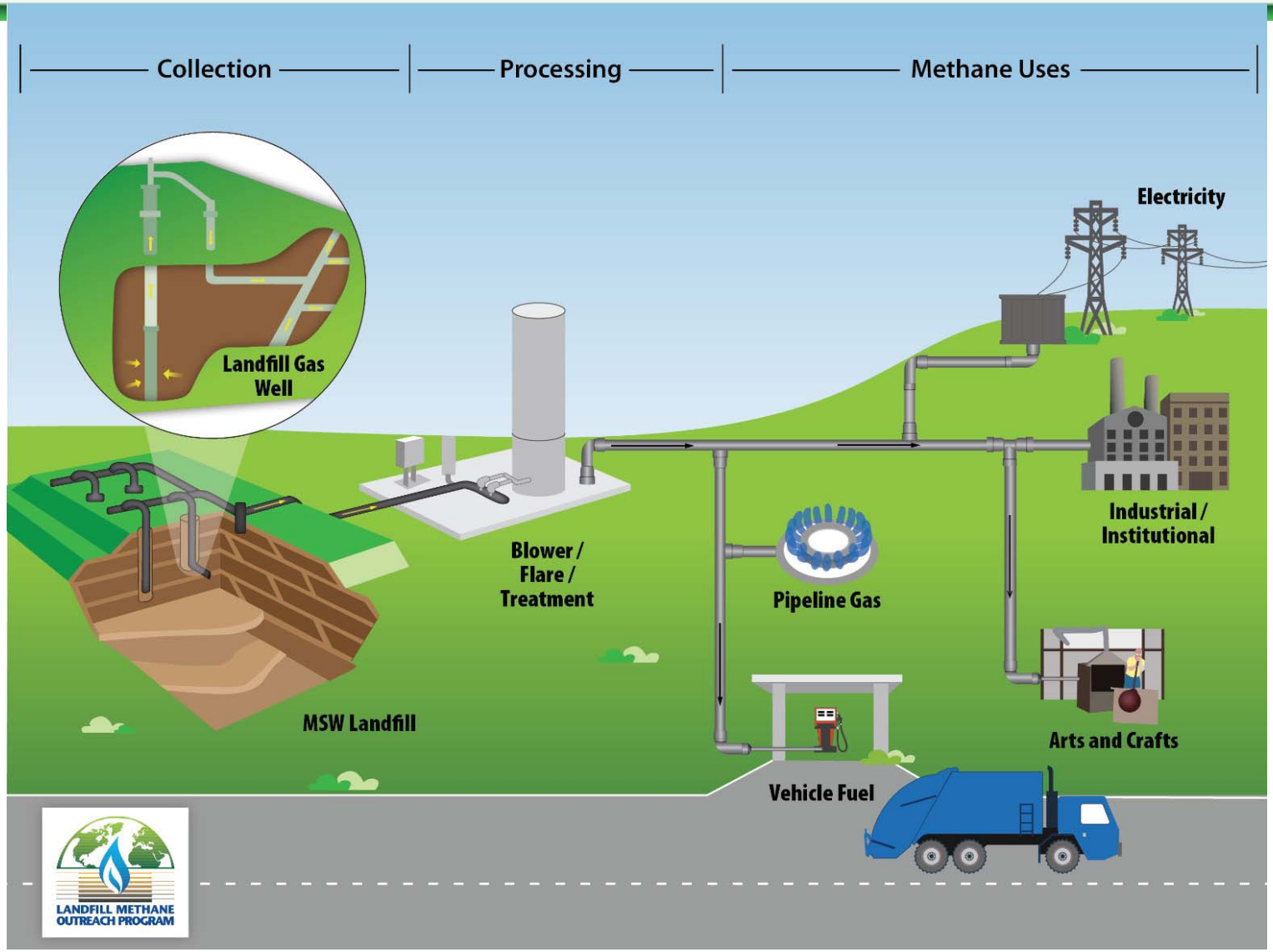
- Local, renewable, consistent source of energy
  - o LFG is produced 24/7 and projects have online reliability of >90%
  - o Reduces demand on conventional power plants
  - o Helps utilities meet RPS requirements

- Economic benefits in the community and beyond
  - o Job creation during construction plus continued operation
  - o Selling LFG (and renewable aspects) is source of revenue
  - o Renewable NG for vehicle fuel costs less than gasoline or diesel
  - o Government and businesses can realize cost savings
- Local environmental benefits
  - o Projects can be part of solution for mitigating landfill odors
  - o Lower exhaust emissions from LFG-sourced NG vehicles

Modern Sanitary Landfill with an LFG Energy Project



LFG End Use Options



Example Electricity Generation Technologies

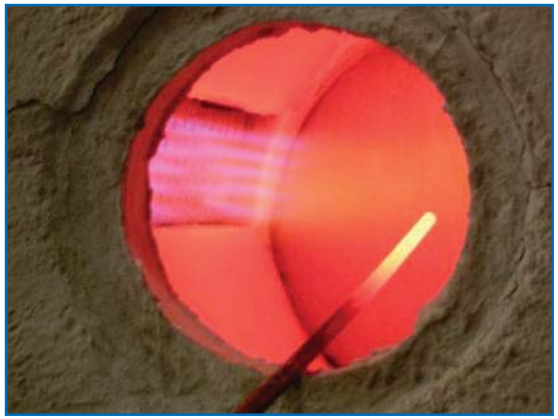
Internal Combustion Engine (range from 100 kW to 3 MW)

Microturbine (range from 30 kW to 250 kW)

Gas Turbine (range from 800 kW to 10.5 MW)

Example Medium-Btu End Uses of LFG

- Boiler applications – replace natural gas, coal, fuel oil
- Glassblowing, pottery, blacksmithing, hydroponics, aquaculture
- Direct thermal (dryers, kilns)
- Leachate evaporation
- Greenhouse
- Infrared heaters
- Ethanol production



Glassblowing - Jackson County, NC

Greenhouse
Jackson County, NC

Infrared Heater - Lorton, VA

Example High-Btu End Uses of LFG

- Natural gas pipeline injection
- Vehicle fuel (CNG, LNG)

High-Btu Pipeline Project
Rochester, NH

CNG Fueling Station
St. Landry Parish, LA

BioCNG System
Dane County, WI

Typical Electric Project Components & Costs

- 3-MW, engine, 15-year project*:
  - Total capital cost = ~$5.25 million ($2013)
    - Gas compression & treatment, engine & generator = ~$5 million
    - Interconnect equipment = ~$250,000
      (interconnect costs can vary widely)
  - Annual operation & maintenance cost (initial year of operation) = ~$626,500/year

Reciprocating Engine – Maysville, KY

***Source:** *LFGcost-Web*, Version 3.2. U.S. EPA LMOP. epa.gov/lmop/lfgcost-web-landfill-gas-energy-cost-model. **Analyses performed using *LFGcost-Web* are considered estimates and should be used for guidance only.**

State-wide Economic Impacts of Constructing 3-MW Engine Project

Direct*

- $1.85 million expenditures
- 6+ jobs

Ripple Effects*

- $4.3 million+ economic output
- 22+ jobs

***Source:** *LFGcost-Web*, Version 3.2. U.S. EPA LMOP. epa.gov/lmop/lfgcost-web-landfill-gas-energy-cost-model. **Analyses performed using *LFGcost-Web* are considered estimates and should be used for guidance only.**

Typical Direct-Use Project Components & Costs

- 800-scfm, 5-mile pipeline, 15-year project*:
  - Total capital cost = ~$3.4 million ($2013)
    - Gas compression & treatment = ~$1,118,000
    - Pipeline = ~$600,000/mile
    - Plus end-of-pipe combustion equipment retrofits, if needed
  - Annual operation & maintenance cost (initial year of operation) = ~$124,600/year

Boiler – Raleigh, NC

*Source: *LFGcost-Web*, Version 3.2. U.S. EPA LMOP. epa.gov/lmop/lfgcost-web-landfill-gas-energy-cost-model. **Analyses performed using *LFGcost-Web* are considered estimates and should be used for guidance only.**

State-wide Economic Impacts of Constructing 1,000-scfm Direct-Use Medium-Btu Project

Direct*

- $1.32 million expenditures
- 9.5+ jobs

Ripple Effects*

- $2.8 million+ economic output
- 20+ jobs

***Source:** *LFGcost-Web*, Version 3.2. U.S. EPA LMOP. epa.gov/lmop/lfgcost-web-landfill-gas-energy-cost-model. **Analyses performed using *LFGcost-Web* are considered estimates and should be used for guidance only.**

Resources for Funding LFG Energy Projects

Sources of Revenue:

- Direct sale of LFG
- Sale of power generated from LFG
- Renewable Energy Certificates (RECs)
- RINs under Renewable Fuel Standard (RFS)
- California Low Carbon Fuel Standard credits
- Greenhouse gas reduction credits

Funding and Incentives:

- Renewable Electricity Production Tax Credit (PTC)
- Federal or state grants
- Low-cost bond programs
  - Clean Renewable Energy Bonds (CREBs)
  - Qualified Energy Conservation Bonds (QECBs)
- Loans
  - U.S. DOE Loan Guarantee program

Regulations that May Affect LFG Energy Projects

- LFG energy projects may be affected by a variety of federal, state or local air quality regulations
- Applicable federal Clean Air Act regulations may include:
  - New Source Performance Standards (NSPS) / Emission Guidelines (EG)
  - Title V
  - Maximum Achievable Control Technology (MACT)
  - New Source Review (NSR)
  - Prevention of Significant Deterioration (PSD)
- For more information, see LMOP's quick reference sheet: epa.gov/lmop/quick-reference-sheet-regulations-affecting-landfills-and-projects

Key LMOP Resources

LMOP Resources

- LMOP Landfill and LFG Energy Project Database
- Tools: *LFGcost-Web*, benefits calculator, conversion tool
- Technical and outreach publications
- Webinars and other events
- Network of 1,000+ Partners
- Listserv – sign up to receive and view message archive

National Landfill and LFG Energy Project Database

Landfill and LFG Energy Project Data

Download details about projects and landfills

Includes data for more than 2,400 U.S. landfills

- Excel files cut the LMOP data in various ways to help you find what you are looking for
- Cross-references EPA's greenhouse gas reporting program (GHGRP)

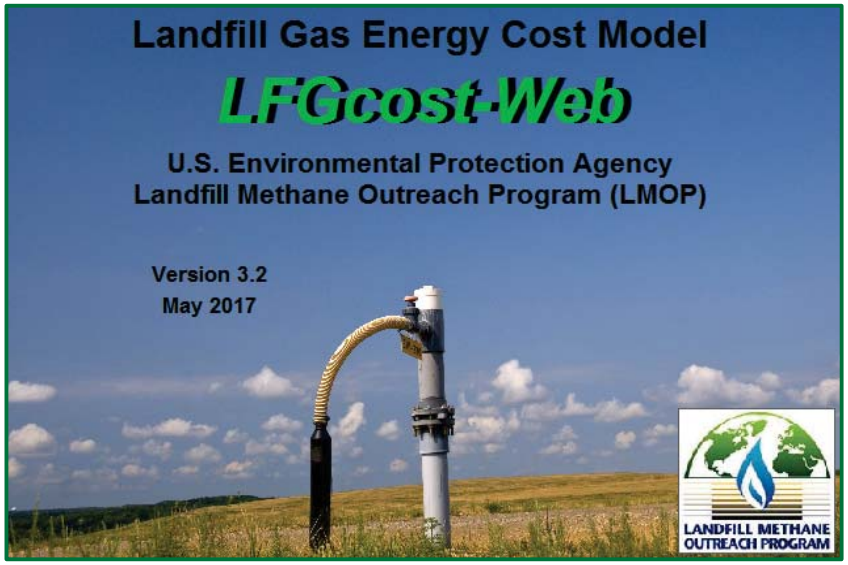
	A	B	C	D	E	F	G	H	I	J	K
1	GHGRP ID	Landfill ID	Landfill Name	State	Physical Address	City	County	Zip Code	Latitude	Longitude	Ownership Type
2	1007341	1994	Anchorage Regional Landfill	AK	15500 E. Eagle River Loop Road	Eagle River	Anchorage	99577	61.293281	-149.60214	Public
3	1007341	1994	Anchorage Regional Landfill	AK	15500 E. Eagle River Loop Road	Eagle River	Anchorage	99577	61.293281	-149.60214	Public
4	1010389	11941	Capitol Disposal Landfill	AK	5600 Tonsgard Court	Juneau	Juneau	99801	58.3528	-134.4947	Private
5		10980	Central Landfill - MatSu Borough	AK	1201 N. 49th State Street Just off the Palmer-Wasilla Highway	Palmer	Matanuska-Susitna	99645	61.59	-149.21	Public
6	1005349	12216	Central Peninsula Landfill (CPL)	AK	46915 Sterling Highway	Soldotna	Kenai Peninsula	99669	60.44714	-151.10369	Public
7		10960	Kodiak Island Borough Landfill	AK	1203 Monashka Bay Road	Kodiak	Kodiak Island	99615	57.80874	-152.40761	Public
8	1004380	11020	Merrill Field Landfill	AK	800 Merrill Field Drive	Anchorage	Anchorage	99501	61.21266	-149.84012	Public
9	1006806	10961	South Cushman Landfill	AK	455 Sanduri Street	Fairbanks	Fairbanks North Star	99701	64.80476	-147.70085	Public
10		11000	Unalaska Landfill	AK	1181 Summer Bay Road	Unalaska	Aleutians West	99685	53.88463	-166.50657	Public
11		27	Athens/Limestone County SLF MSWLF	AL	Strain Road off Highway 31	Athens	Limestone	35611	34.7634	-86.9399	Public
12		16	Bishop Landfill Company	AL	379 Pleasant Grove Cutoff Road	Albertville	Marshall	35950	34.27823	-86.33707	Private
13	1004245	2005	Black Warrior Solid Waste Facility	AL	3301 Landfill Drive						
14		2006	Blount County/Nectar/Hayden LF & TS	AL	2390 Armstrong Loop						
15	1004415	2408	Brundidge Landfill	AL	515 Cleanwater Drive						

LFG Energy Cost Model

LFGcost-Web

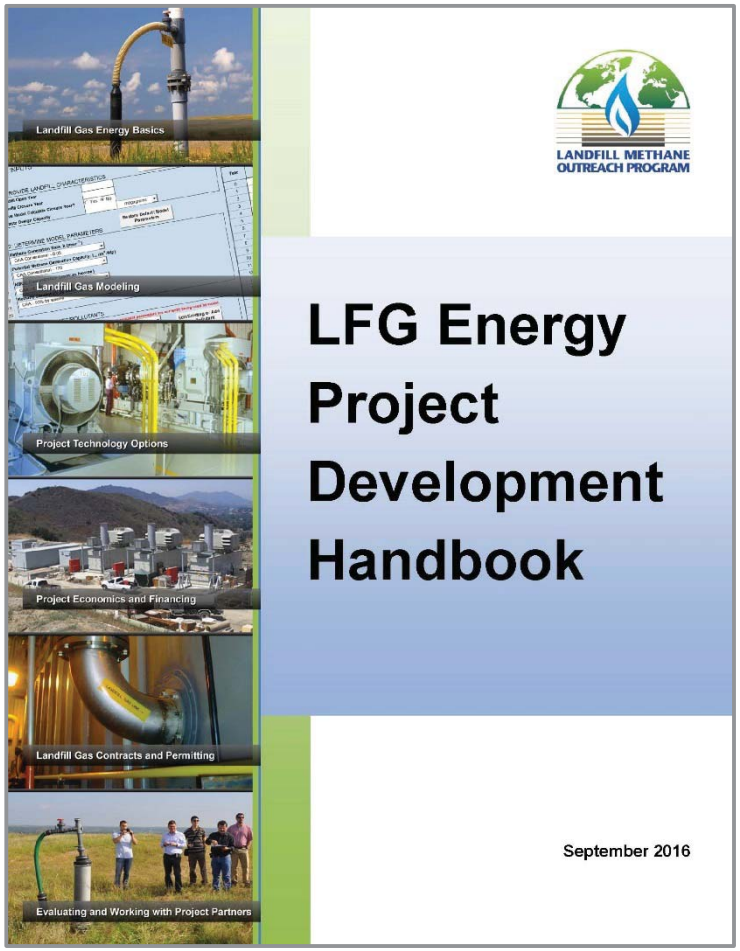
Evaluate the initial economic feasibility of an LFG energy project

- A user-friendly Microsoft® Excel platform
- *LFGcost-Web* can analyze 12 energy recovery project types with or without a gas control collection system



***LFGcost-Web* is available online to all stakeholders and is transparent, allowing users to edit optional inputs**

LFG Energy Project Development Handbook



Project Development Handbook

Improve understanding to develop successful projects

- Provides project-specific considerations
- Helps stakeholders who are new to LFG energy projects
- Highlights useful online resources and successful LFG energy projects

How Can We Work Together?

- Facilitating information sharing – LMOP Database, webinars, listserv messages
- Providing technical information about LFG energy project development and other opportunities to reduce emissions from MSW landfills
- Analyze resource availability through LFG modeling
- Performing initial feasibility analysis using *LFGcost-Web*

LMOP welcomes your feedback on our website, resources, tools, etc.

epa.gov/lmop/forms/contact-us-about-landfill-methane-outreach-program

GO TO WWW.GEOTECHENV.COM

Landfill Gas Monitor

Landtec GEM™ 2000

The GEM™ 2000 is designed for analyzing LFG composition and calculating flow. The GEM™ 2000 combines the capabilities of the now discontinued GA-90 for monitoring gas migration probes and the GEM™ 500 for monitoring gas extraction systems. The GEM™ 2000 is certified intrinsically safe and offers improved speed and accuracy.

FEATURES

- **Diverse Field Applications** – Monitors migration control systems, gas extraction systems, flares, migration probes, and more.
- **Gas Extraction Monitor Mode** – Provides automatic sampling and analysis of gas composition % by volume CH_4, CO_2, O_2 and balance gas, % LEL CH_4, temperature (with optional probe), static pressure, differential pressure, and barometric pressure. Calculates gas flow rates (SCFM) as well as BTU content.
- **Landfill Gas Analyzer Mode** – Provides automatic sampling and analysis of gas composition % by volume CH_4, CO_2, O_2 and % balance gas, % LEL CH_4, temperature (with optional probe), barometric pressure and relative pressure. Can be used for data logging, with user programmed intervals.
- **Easy to Read Display** – Extra large backlit LCD shows up to five gases, atmospheric and gas vacuum pressure, temperature, ID code – all at the same time.
- **Quick Analysis** – Completes sampling and displays gas analysis and flow results in less than one minute.
- **Infrared Gas Analyzer** – Provides accurate measurements of methane (CH_4), and carbon dioxide (CO_2).
- **Gas Temperature** – Read when using optional temperature probe or can be entered manually.
- **Durable Oxygen Sensor** – Provided by the galvanic cell principle, not influenced by other gases (i.e. CH_4, CO_2, CO, SO_2 or H_2S).
- **User Friendly On-Screen Menu** – In each mode the user performs most operations in just two screens.
- **PC Data Downloading** – Provided by RS232 interface with DataField CS software (Release 3.0 or later).
- **Data Storage/Retrieval** – Stores prior measurements taken for each monitoring point, 900 monitoring points total.
- **Date/Time Stamp** – Recorded for all stored data.
- **Prior Data Recall** – Allows user to view prior data for each monitoring point.
- **Methane Analysis** – Displayed as either % CH_4 by volume or LEL CH_4 (Landfill Gas Analyzer Mode only).
- **Durable Construction** – Built of strong, durable plastic material suitable for harsh landfill environments.
- **All Weather Use** – Designed to operate in extremes from 32°F to 104°F. Sealed, weather-tight case.
- **Built-in Adjustable Alarms** – Allows user to set alarm limits for CH_4 and O_2.
- **Rechargeable Batteries** – Internal, rechargeable nickel metal hydride batteries are standard.
- **Operating Time** – Approximately 8 hours with normal pump usage (approximately 10 hours without pump running).
- **Fast Recharge Time** – Approximately 3 hours from complete discharge.
- **Battery Check** – Battery life is continuously displayed.
- **Monitoring Point ID Codes** – Provides alphanumeric identification of monitoring points for data storage and recall.
- **ID Comments** – Allows user to answer up to 3 questions with a list of 9 potential answers each.
- **Imperial vs. SI Units** – Can display measurements in Imperial (USA) or SI (metric) units.
- **Interfaces to DataField Management Software** – Which provides statistical analysis and reporting of LFG data.

SPECIFICATIONS

SENSOR

	Range	Resolution
Methane – CH4	0-70%	0.1%
Carbon Dioxide – CO_2	0-40%	0.1%
Oxygen – O_2	0-25%	0.1%
Pressures		
(diff.)	0-10" W.C.	0.001" W.C.
(static)	0-100" W.C.	0.1" W.C.

Pump Flow Rate – 500 cc/min at nominal flow, 250 cc/min at 80" W.C.

Vacuum – up to 80" W.C.

UL Certified to Class 1, Zone 1, AEx ib d iia T4

TYPICAL ACCURACY

Concentration	% CH_4 by Volume	% CO_2 by Volume	% O_2 by Volume
5% (Lel, CH_4)	±0.3%	±0.3%	±1.0%
Full Scale	±3.0% (70%)	±3.0% (40%)	±1.0% (25%)

CALL GEOTECH TODAY (800) 833-7958

Geotech Environmental Equipment, Inc.
2650 East 40th Avenue • Denver, Colorado 80205
(303) 320-4764 • **(800) 833-7958** • FAX (303) 322-7242
email: sales@geotechenv.com website: www.geotechenv.com

Landtec GEM 2000.indd 01/16/09

GEM2000
GEM2000 Plus

GAS ANALYZER & EXTRACTION MONITOR

OPERATION MANUAL
For
Serial Numbers 10000 and up

For further information contact:

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LANDTEC Release Date: March 5, 2008

Contents

1 Introduction

LANDTEC is the premier manufacturer of products, instruments and software for landfill gas extraction and for regulatory monitoring compliance. LANDTEC has provided the landfill industry with a technologically innovative family of products for more than a decade. These products are the result of field-proven experience in design, operation and maintenance of landfills for environmental compliance.

The GEM2000 and GEM2000 Plus, designed by LANDTEC, are specifically for use on landfills to monitor landfill gas (LFG) extraction systems, flares and migration control systems. Both instruments sample and analyze the Methane, Carbon Dioxide and Oxygen content of LFG. The GEM2000 Plus also samples and analyzes Carbon Monoxide and Hydrogen Sulfide. The readings are displayed and can be stored in the instrument and downloaded to a personal computer for reporting, analyzing and archiving.

The GEM2000 / GEM2000 Plus instrument is shipped in a protective hard case with a foam interior that offers additional protection, transportation convenience and component hardware storage. When properly sealed, the hard case is watertight. The hard case is equipped with a pressure relief valve (located under the handle on the case) that is normally kept closed. If there is a change in elevation, the hard case may not open until the pressure relief valve is opened to equalize internal pressure. When shipping a GEM2000 / GEM2000 Plus back to LANDTEC for calibration or service, always ship it in the hard case to protect unit from damage.

Carefully unpack the contents of the GEM2000 / GEM2000 Plus, inspect and inventory them. The following items should be contained in your package:

- The GEM2000 / GEM2000 Plus instrument
- GEM2000 / GEM2000 Plus Operation Manual
- Registration/Warranty Card
- Soft carrying case with replaceable protective window and carrying strap
- Clear ¼" vinyl sampling hose assembly (5 ft.) with external water trap filter assembly
- Blue ¼" vinyl pressure sampling hose (5 ft.)
- Spare internal particulate filter element
- Polypropylene male connector (hose barb) connects to blue vinyl tubing
- Spare external water trap filter element
- 100-240 volt battery charger
- Software on CD-ROM
- RS-232 serial cable for computer/instrument communications
- Temperature probe (optional)
- Hard carrying case

Complete the Registration/Warranty Card and return it to LANDTEC. The model and serial numbers are located on the back of the GEM2000 / GEM2000 Plus instrument.

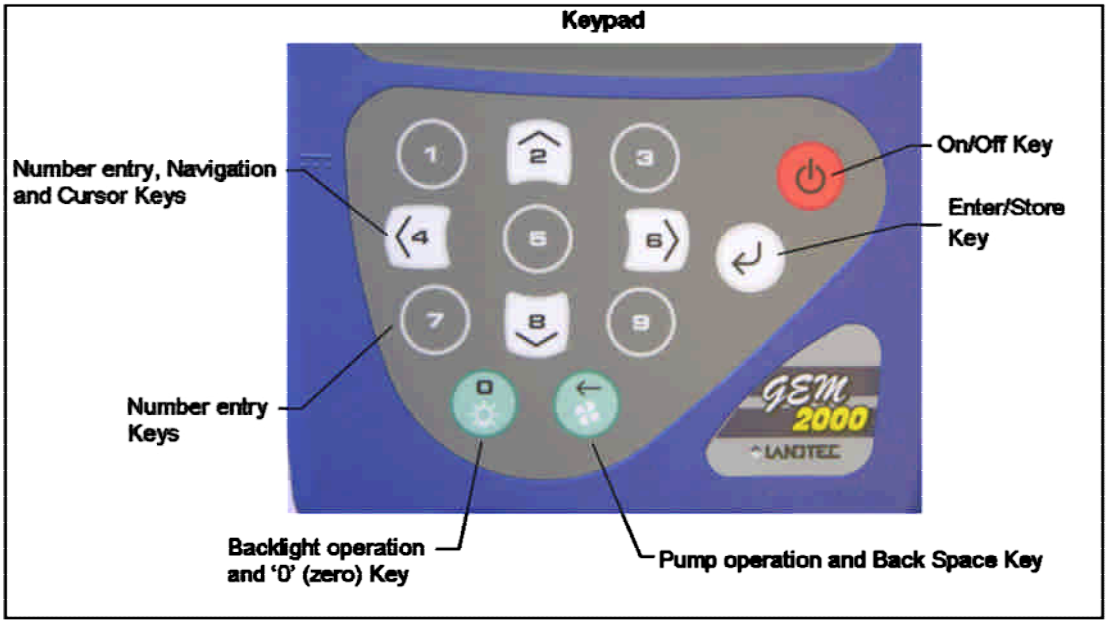
Immediately notify shipping company if the GEM2000 / GEM2000 Plus unit or accessories are damaged due to shipping. Contact LANDTEC immediately if any items are missing.

For questions regarding instrument operation and procedures, please contact LANDTEC at:

Customer Service or Technical Support	(800) 821-0496 Extension 6131
Factory Service	(800) 821-0496 Extension 6141

2 General Operational Features

2.1 Physical Characteristics of the GEM2000 / GEM2000 Plus



2.2 Storage

Do not keep the instrument in the trunk of a car or shed because it may be exposed to temperature extremes.

When not in use, instruments should be kept in a clean, dry and warm environment such as an office.

The instrument batteries should be discharged and fully charged at least once every four weeks regardless of indicated charge state. The discharge function may be carried out with the use of the Data Logging Function in GA mode of operation.

2.3 Battery/Charging

The Battery Charger IS NOT covered by the unit UL certification. Therefore, when connected to the Battery Charger, the instrument IS NOT intrinsically safe and should not be used in confined spaces.

The battery used in the GEM2000 / GEM2000 Plus is a Nickel Metal Hydride manufactured as an encapsulated pack from six individual cells. This type of battery is not so susceptible to “memory effects” as Nickel Cadmium batteries, although it is not recommended that the unit be given short-term charges. When the flashing LED indicates “Trickle Charge” the charging is completed and the unit can be disconnected from the charger.

The battery charger indicates when the unit is charging, charged or if there is a fault. A full charge should take approximately 2 hours.

2.4 Instrument Certification

The GEM2000 / GEM2000 Plus is UL/Sira certified for use in hazardous locations. Specifically certified as to intrinsic safety for use in hazardous locations Class I, Zone 1, AEx ib d IIA T1 (Ta=32°F to +104°F).

For the certification to remain intact it is vital the instructions in this manual are followed closely and repairs of this equipment be carried out in accordance with the applicable code of practice by an approved repair facility. See section 9.2 for a list of authorized repair locations.

It is the responsibility of the operator to determine the protection concept and classification required for a particular application.

2.5 Safety Information

The GEM2000 / GEM2000 Plus is normally used for measuring gases from landfill sites. Inhaling these gases, or gases from other sites may be harmful to health and in some cases may be fatal. It is the responsibility of the user to ensure that he/she is adequately trained in the safety aspects of the gases being used and that appropriate procedures be followed. In particular, where hazardous gases are being used the gas exhausted from the analyzer must be piped to an area where it is safe to discharge the gas. Hazardous gas can also be expelled from the instrument when purging with clean air.

2.6 Turning the Instrument On/Off

When switching the instrument on, a long beep will sound, followed by the LANDTEC logo being displayed and the self-test will commence. Whenever a key is pressed the unit will emit a short ‘beep’ as an acknowledgement. This function cannot be turned off.
When switching the instrument off, the On/Off button must be held down for approximately 2-3 seconds, at

which point a clean air purge will be carried out. If for any reason the instrument 'locks-up' and will not switch off, press and hold the On/Off button for 15 seconds. This will force the instrument to switch off.

2.7 Warm-up Self Test

When switched on, the instrument will perform a predetermined self-test sequence taking approximately 30 seconds, during this time many of the instrument's functions are tested, including:

- General operation
- Pump function
- Gas flow measurement
- Calibration
- Backlight function
- Solenoid function

During the self-test, the following information is also displayed:

- Software version
- Serial Number. Calibration due date.
- Date format.
- Operating language.
- Communication Baud rate.

2.8 Warning and Error Display

During the self-test, if any operational parameters are out of specification or the pre-programmed recommended calibration/service date has passed errors or warnings may be displayed. Only three errors/warnings can be displayed at any time. To ascertain if more errors occurred, use the '∧' and '∨' key to scroll up/down the list, to exit from this screen press the "Enter/Store" key '↵'.

2.8.1 WARNING Displayed

All warnings displayed will be prefixed by the word "**WARNING**' followed by a relevant description. Two types of warnings may be displayed.

1. General warnings that may not have an effect on the instrument's function and those where the self-test has detected a function that is outside the usual programmed operating criteria (e.g. Battery charge low, memory nearly full, etc.).
2. Specific warnings of operational parameters that can affect the performance of the instrument (e.g. O_2 Cell out of calibration, CH_4 out of calibration, CO_2 out of calibration, etc.).

The most likely reason for the errors is either an incorrect user calibration, or sensor failure. If an incorrect user calibration has caused the warning, it should be correctable by way of returning the instrument to factory settings, zeroing or carrying out a user calibration as necessary for the relevant function.

2.8.2 ERROR Displayed

All errors displayed will be prefixed by the word '**ERROR**' followed by a number and description. The errors detected by the self-test are usually caused by a user calibration being out of specification or possibly memory corruption. This will have an effect on the functionality of the instrument and should be corrected before use (e.g. 01 - User cal data, CH_4 reading or channel out of specification, 02 - User cal data, CO_2 reading out of specification).

If any other Warnings or Errors are displayed, contact a LANDTEC Authorized Service Facility for further information.

2.9 Service Information Screen

Upon self-test completion, the GEM2000 / GEM2000 Plus will display service information including when the next manufacturers service is due, what type of service agreement the instrument is under (if applicable), and when the last factory gas check was performed. To exit from this screen press the "Enter/Store" key '↵'.

2.10 Technician ID Screen

The Technician ID screen is displayed after the Service Information screen. While it is not necessary to input a Technician ID it is possible to select a technician from a predetermined list (created in LSGAMS) or input up to four characters to identify the technician performing the readings. This ID will be appended to all readings that are taken until the instrument is turned off. To change the Technician ID simply turn the instrument off and back on again. The Technician ID can be input through a virtual key board shown on the instruments display. Letters or numbers can be selected by using the '∧' and '∨' key to scroll up/down and the '<' and '>' to scroll left and right. Pressing the "Enter/Store" key '↵' will select the highlighted character. Once the Technician ID is selected, or to bypass selecting any characters press the '①' button.

2.11 Gas Reading Screen

After inputting or bypassing the Technician ID, the instrument will go into the Gas Reading screen, also considered the normal operation screen. All operations are carried out from this starting point. The following information is displayed in various boxed sections at this time:

- Current programmed time and date
- Current selected ID code
- Pump status
- Pump run time
- Three main constituent gases – CH_4, CO_2, O_2 (in %)
- Two minor gases – CO & H_2S and indication of H2 (GEM2000 Plus only)
- Balance gas
- Last read time/date (if previous data is in memory)
- Technician ID
- External devices (displays pod type or temperature probe readings when attached)
- % LEL CH_4 (if selected through LSGAM)
- Barometric pressure reading.
- Current relative pressure reading (GA mode only)
- Gas Pod or Temperature Probe reading (if connected)
- Battery Charge graph (5 segment, flashes at 20% remaining)
- Memory Usage graph (5 segment, flashes at 5% remaining)

Other options:

① Menu	Allows access to all instrument user functions.
③ Next ID	Allows the next ID to be selected (if IDs are available).
⑤Measure Flow	For GEM mode only.
⑦Previous Reading	Allows the previous reading of the selected ID to be viewed (if data is available).
↵ Store Reading	Stores the current displayed reading. (GA mode only)

2.11.1 Keypad Lock

After the instrument enters into the Gas Reading Screen, and from this point forward, the keypad can be locked by pressing and holding the backlight key for approximately 2 seconds. A message will display at the bottom of the display instructing you that to release the lock you will need to press and hold the backlight button.

2.12 Optional Gas Pods

Optional Gas Pods are available for use with the GEM2000 / GEM2000 Plus. These pods are available in seven different gases with eight different PPM ranges. Connection to the instrument is made via the data port and exhaust port. The detected PPM level is displayed in the upper right area of the gas read screen and is saved in the same manner as the other gas readings. The Gas Pods are not classified as intrinsically safe they should not be attached or detached from the instrument in hazardous areas.

Gas Type	Range (PPM)	Resolution (PPM)
H_2S	0-50	0.1
	0-200	1.0
	0-5000	35
CO	0-1000	1.0
SO_2	0-20	0.1
	0-100	1.0
H_2	0-1000	1.0
HCN	0-100	1.0

Gas Pods are intended for use as an inexpensive detection means and not for regulatory reporting purposes. If the GEM2000, fitted with a Gas Pod, indicates the presence of the selected gas, further testing should be performed with regulatory approved instrumentation. LANDTEC recommends that field calibration be performed using the relevant gas and concentration, prior to sampling with a Gas Pod. If calibrated properly the accuracy of these Gas Pods are typically 5-10% Full Scale.

2.13 Memory

The instrument's memory is volatile. It is maintained by a battery back-up system, which will maintain the memory while the battery is being changed.

The memory is not to be used as a permanent storage medium and any data should be transferred to a more permanent storage medium as soon as possible. An Instrument should never be stored for prolonged periods with valuable data in its memory.

Although unlikely, sudden shocks, high levels of electromagnetic interference or static discharge may cause memory corruption or loss. If this occurs, the instrument should be Cold Started and the calibration reset to factory settings before further use. **Cold starting will erase all data in the instrument including resetting the time and date to the default value**.

2.13.1 Cold Start

THIS FUNCTION SHOULD BE USED ONLY AS A LAST RESORT.
(For Gas Calibration Error Messages, confirm that Factory Settings and User Calibration are done).

A Cold Start should only be carried out to correct an instrument if no other course of action has proved successful. This function **WILL ERASE** the instrument memory entirely. After a cold start is performed the user will need to reset the instrument to factory settings, perform a field calibration and reset the internal time/date to the default settings. Please note that the time/date may only be updated through the communication software. It cannot be updated manually.

To carry out a cold start, turn the instrument on, before the instrument enters into the self-test screen press and continue to hold the '↵' key until a pass code entry screen is displayed. At this point the '↵' key may be released. Enter the passcode **12345** and press '↵' to confirm.

After the pass-code entry has been accepted, the instrument serial number will be displayed along with the hours in use, pump run time and service dates. There are four options from this screen;

1 - Cold Start
2 - Recover readings
3 - Print readings
0 - Exit

ONLY select option '**1'** if a Cold Start is to be carried out. Press key '**1**' to confirm this operation or press key '**0**' to continue with normal operation. If you select '**1**' to confirm the cold start a message will be displayed confirming the cold start operation and all memory will be cleared. The instrument will continue to the technician ID screen.

2.13.2 Recover Readings

THIS FUNCTION SHOULD BE USED ONLY AS A LAST RESORT.

Recover readings is a low level memory function that should only be used as a last resort if all your readings were inadvertently deleted and you know how many readings you had. This function moves the memory buffer and can cause instrument corruption. Contact LANDTEC before attempting to recover readings.

2.13.3 Print Readings

This function is best performed using an appropriate RS232 cable (included with new instruments, also available from LANDTEC) and the LSGAM software. See section 3.12 Downloading Readings for more detail.

2.14 RF Interference

The gas sensors, especially the Methane sensor, are sensitive to RF interference.

Any device that transmits radio waves can cause your gas readings to fluctuate. Cell phones are the most common cause of the problem. You should never use your cell phone while you are taking gas readings.

3 The LANDTEC System Gas Analyzer Manager Software

3.1 Configuration Options

The GEM2000 and LANDTEC System Gas Analyzer Manager (LSGAM) software can be utilized in a number of ways:

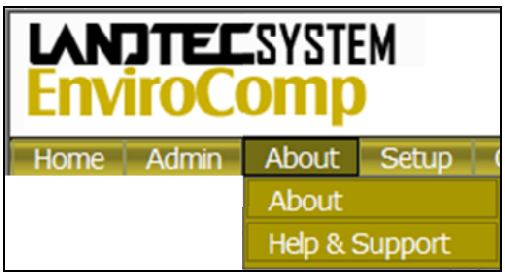
- Configured for operation with the LANDTEC System online service;
- Used offline as a local application storing information on the desktop/laptop computer;
- Used out of the box without software; (this does not allow the user to generate flow rate values or select comments with the instrument and also prevents downloading of readings to the computer. It also does not allow the user to correct the time and date or to clear the memory, unless cold started.)

3.2 Online Users

The procedures included in the section are intended for those connected to the LANDTEC System online service. The LANDTEC System is an online collaboration tool to Collect, Validate, Analyze, and Communicate information based on field data obtained using LANDTEC instrumentation.

If you currently are a registered user on the LANDTEC System, please log in at https://www.landtecsystem.com/. If you are not currently using the LANDTEC System, you may register by contacting LANDTEC in the US: 800-821-0496 or International: +1-909-783-3636.

Online reference for using LANDTEC System Gas Analyzer Manager (LSGAM) with the LANDTEC System can be found under the About → Help & Support menu within the LANDTEC System.



If you do not have login information please contact Technical Support at +1-909-783-3636 extension 6131.

3.3 Offline Users

The procedures included in the section describe use of the LANDTEC System Gas Analyzer Manager (LSGAM) Software while **NOT** connected to the LANDTEC System online service.

3.3.1 Installation with the CD

NOTE: The computer may need some administrative privileges to install the program.

Insert the CD into your CD ROM drive and wait for the setup to auto start. Click on the Launch Setup button and follow the onscreen instructions. Once the software is installed you will have a shortcut icon on your desktop which you will use to start the LSGAM instrument program.

The Java programming is an import part of this software and will be loaded with the CD install. The java icon, shown below, will be in the task tray at the bottom of your computer screen where your time is shown. There will also be a GAM log icon, shown below, that will be created on your desk top during installation.

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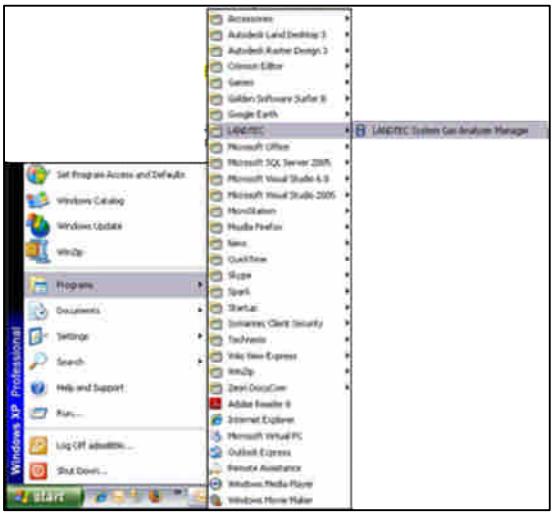
3.3.2 Start Up

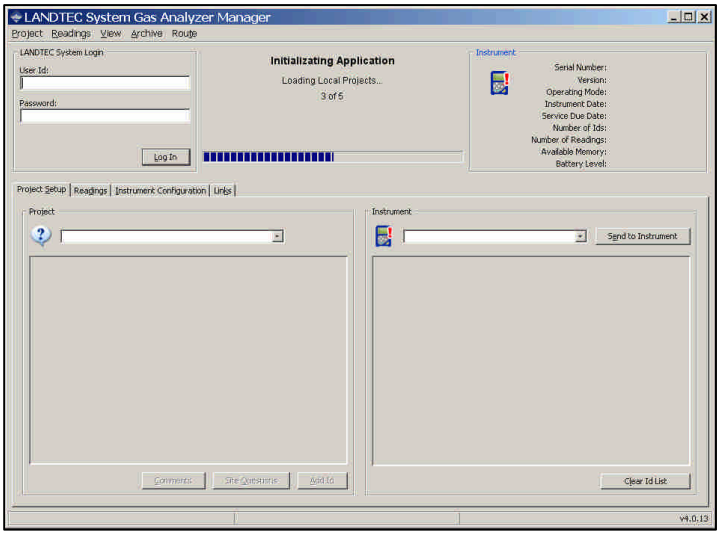
Starting LSGAM can be easily done by doing one of the following:

Double-Click on the Desktop icon.

OR - go to;

Start → All Programs → LANDTEC → LANDTEC System Gas Analyzer Manager



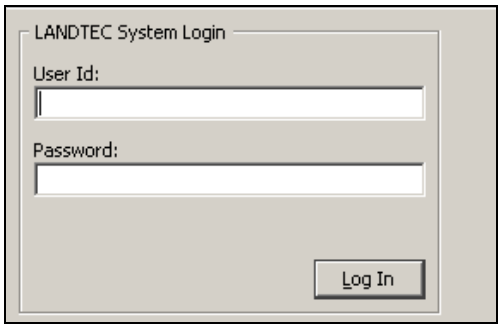


3.3.3 Navigation

The LANDTEC System Gas Analyzer Manager User Interface allows for easy access and navigation to various utilities to use the LANDTEC portable instrument on a day to day basis. The following is a general description of the user interface.

LANDTEC System Login

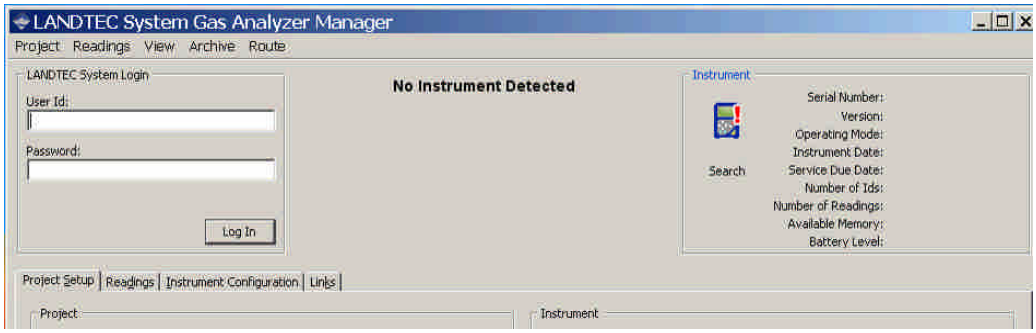
When LSGAM is used with the LANDTEC System online service, the username and password will be entered in the screen below, if you are using LSGSM as a desktop application the User Id and Password fields do not need to be filled in.



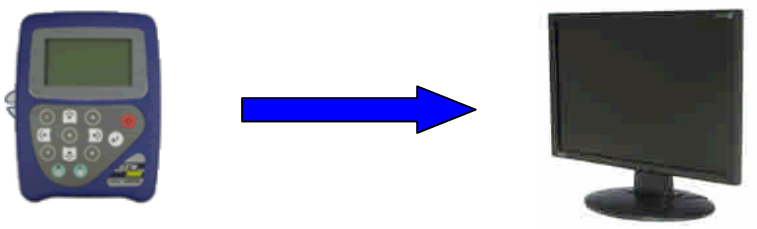
The Progress section indicates the status of the current process. For example, when starting up LSGAM, this will show you the activity of the software.

The Instrument section displays whether or not an instrument is connected. This also downloads the IDs, readings, and comments. If an instrument is found the following is shown:

Instrument Type:
Serial Number:
Version:
Operating Mode:
Instrument Date:
Service Due Date:
Number of IDs:
Number of Readings:
Available Memory:
Battery Level:



3.4 Connecting to the Instrument



1. **Connect the GEM2000 with the RS-232 Download Cable to your Computer**
2. **Instrument must be powered ON and in the Gas Reading screen**
3. **Launch the LSGAM software by clicking on the icon on your desktop**

This is the first screen you will see when starting the program.

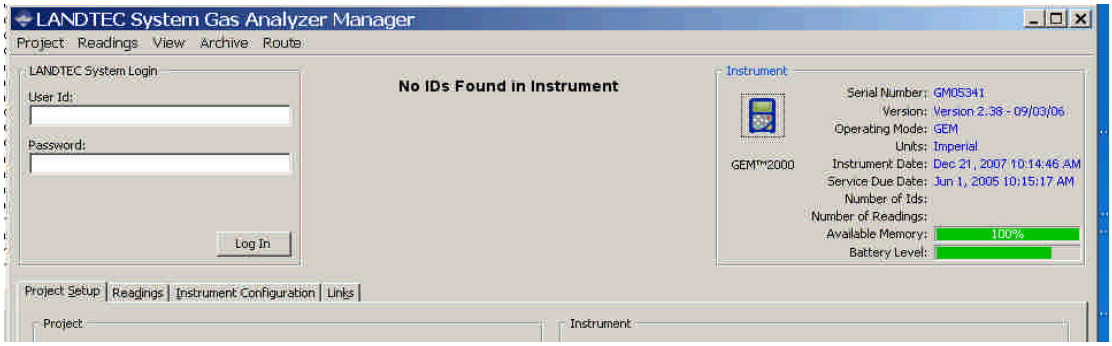
Once the software is installed on your computer with an internet connection this instrument communications program has Auto application updates. This enables you to always have the most current version of the instrument communications LSGAM.

If an update to LSGAM is available, <u>you will see this notice when connected to the internet</u>.

Click on OK this will return you to the desktop and you will then need to click on the  LSGAM shortcut again.

The GEM must be connected to computer and turned ON. It must also be in the Gas Reading screen. The LSGAM software will automatically download any information in the instrument including readings, comments and IDs.

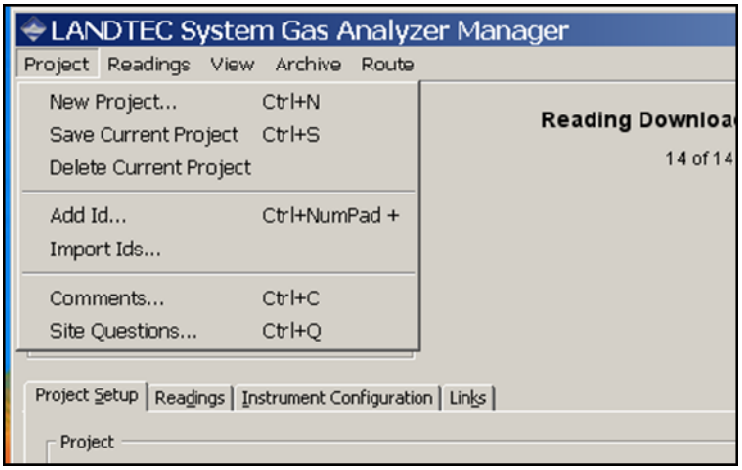
A new instrument containing no information will display only the instrument information: Serial Number, Version, Operating Mode, Instrument Date, Service Due Date, Number of IDs, Number of Readings, Available Memory, and Battery Level.



3.5 Create a Project / Select a Project

Projects are a collection of Device IDs and their associated reading history. A project can be created using LSGAM to contain a group of sequenced IDs and chronological history of instrument readings.

To create a Project, click on the Project menu and select New Project.



Upon selecting **New Project…** you will be prompted to enter a Project Name and select from one of three options.

Create a New Empty Project
This option creates an blank project where you configure all IDs and Comments.

Create a New Project with comments and site questions from a Current Project
Selecting this option allows the user to create a new project that will have the same Comments and Site Questions as an existing project.

Create a New Project from the data in a GEM2000
This option will create a New Project and automatically associate the IDs, Comments, and Site Questions that exist in the connected portable instrument.

3.6 Setup IDs

An ID represents a physical sampling point in the field. An ID can be allocated to field components such as extraction wellheads, gas transmission lines, or passive monitoring probes. LSGAM allows users to configure an ID for each sampling point in order to obtain accurate readings with LANDTEC portable

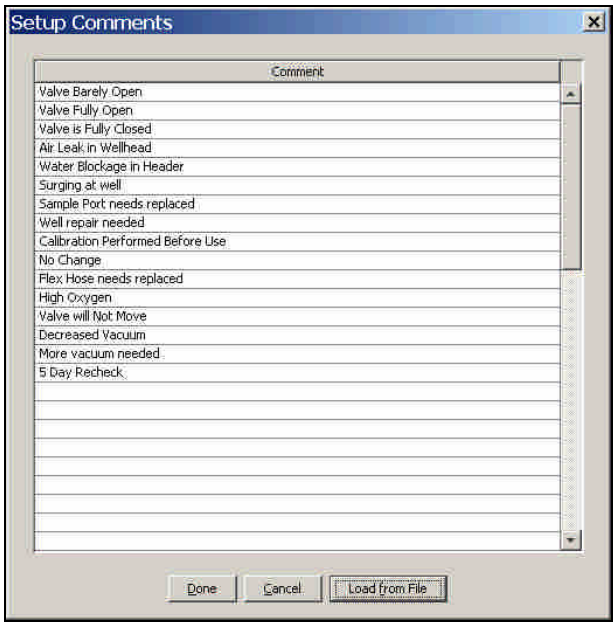
instrumentation

IDs are created, modified, and removed from the Project Setup tab in the software.

3.6.1 Creating Comments

Comments should be setup prior to creating new IDs. The user can define Comments that can be associated with a reading in the portable instrument.

If you selected Create a New Project when creating your project, you will need to click on the Create Comments button. Comments can be entered in this setup screen or loaded from a file and will be displayed in the user interface.



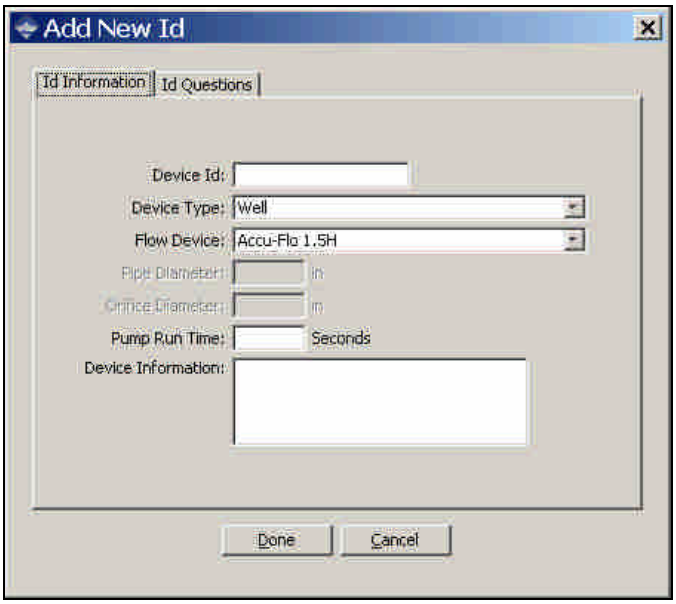
3.6.2 Creating IDs

There are several ways to input IDs to the Project. The following describes each process:

Creating new IDs with LSGAM

To create a new ID using the LANDTEC System Gas Analyzer Manager, Right Click on the left ID pane beneath your active project and select the Add New ID option.

The Add New ID form will be displayed. From the ID Information tab of this form, entry of the following is available:



Device ID: Must be eight (8) alphanumeric character spaces. (For example, LSGW0001)

Device Type:

- Well: An active gas extraction well which may require a flow rate reading.
- Sample Port: A sample point along a gas transmission line that may require a flow rate.
- Probe: A passive gas migration monitoring probe that does not require a flow rate.

The GEM2000 calculates flow rate values specific to each device type (listed above). The available flow devices programmed in GEM mode are listed below.

Flow Device:
Accu-Flo 1.5V
Accu-Flo 1.5H
Accu-Flo 2V
Accu-Flo 2H
Accu-Flo 3V
Accu-Flo 3H
Orifice Plate

- Pitot Tube
- User Input

Orifice Plate WellSide
Accuflo-1.5V-Include System Pressure
Accuflo-1.5H-Include System Pressure
Accuflo-2V-Include System Pressure
Accuflo-2H-Include System Pressure
Accuflo-3V-Include System Pressure
Accuflo-3H-Include System Pressure
Orifice Plate-System Side-Include System Pressure
Pitot Tube-Include System Pressure
User Input-Include System Pressure
Orifice Plate WellSide-Include System Pressure

Pipe Diameter: The pipe inside diameter (ID) is required.

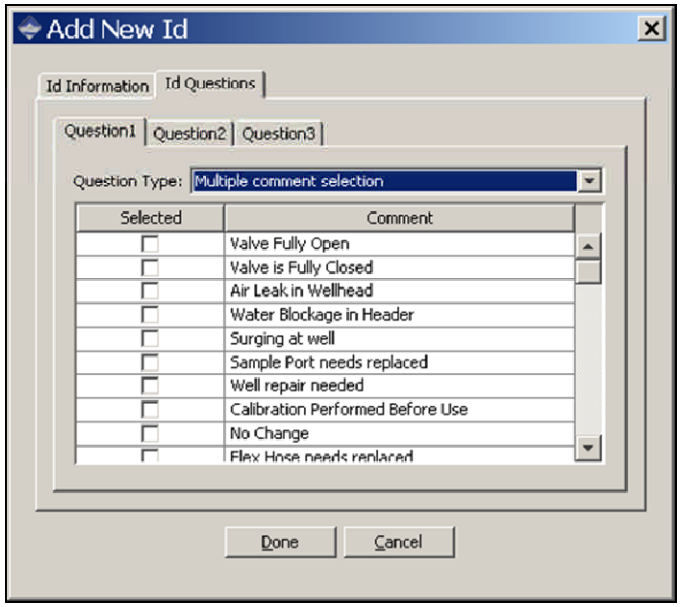
Orifice Diameter: The field for orifice bore diameter is available for all Orifice Plate flow devices.

Pump Run Time: Indicates the duration the GEM2000 pump will run while sampling for the selected ID. Allows the user to enter general information for the device. This can also displayed the GEM2000 instrument.

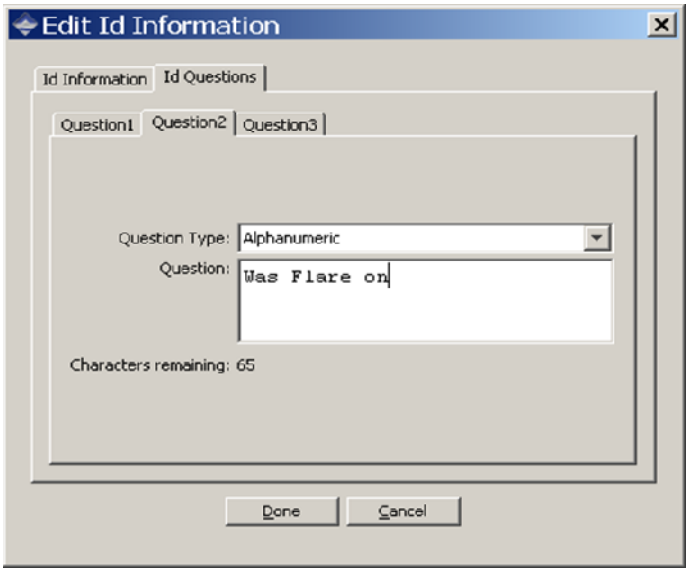
Device Information: Allows the user to enter general information for the device. This will display on the screen of the GEM 2000 instrument.

There are _ Question Types that can be selected:

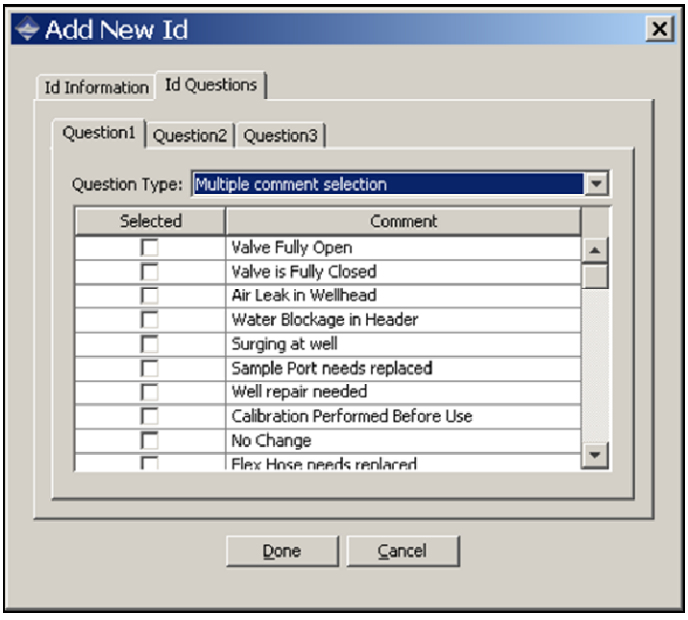
None
Alphanumeric
Numeric
Multiple comment selection
Single comment selection



Users may select up to 8 comments that will be available to the technician to select from when storing a reading with the GEM2000.

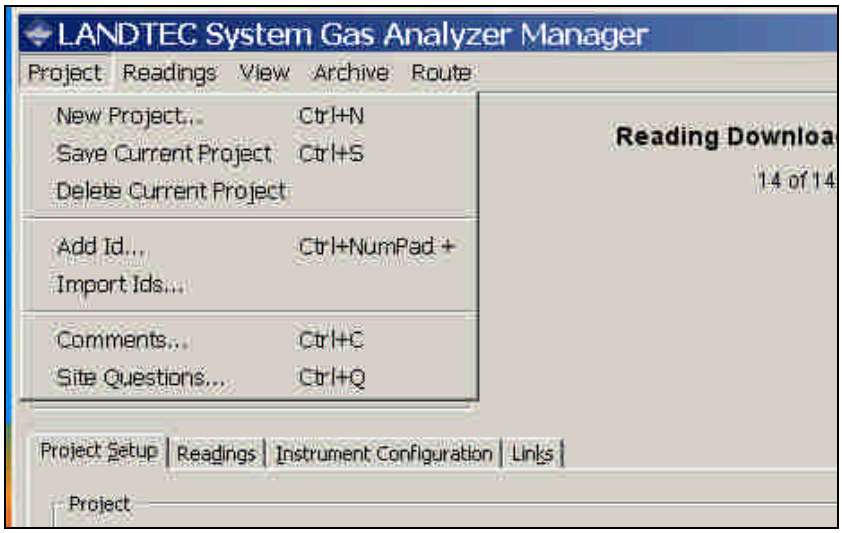


Alphanumeric questions prompt the user to enter a comment on the instrument consisting of letters and numbers.

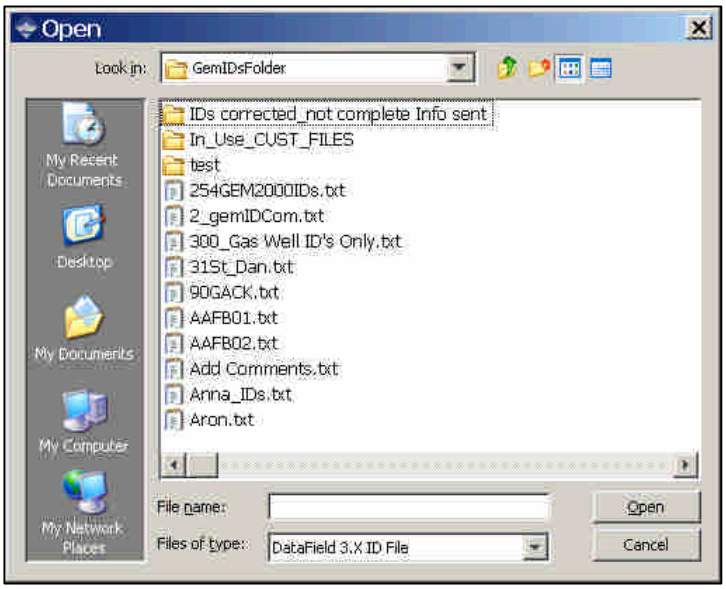


Numeric questions will prompt the user to enter a numeric answer on the instrument with a specified format.

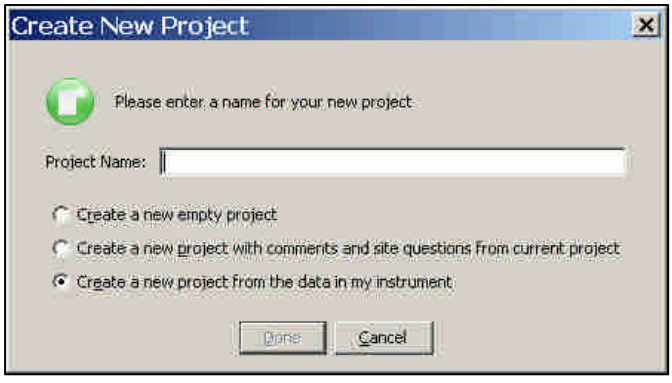
If you have existing ID files from DataField CS v3.2.x, these files can be imported by LSGAM. To begin this operation select the ***Import IDs…*** option from the ***Project*** menu.



Select an ID file generated by DataField CS v3.2.x.



3.6.1 IDS ALREADY IN THE INSTRUMENT:

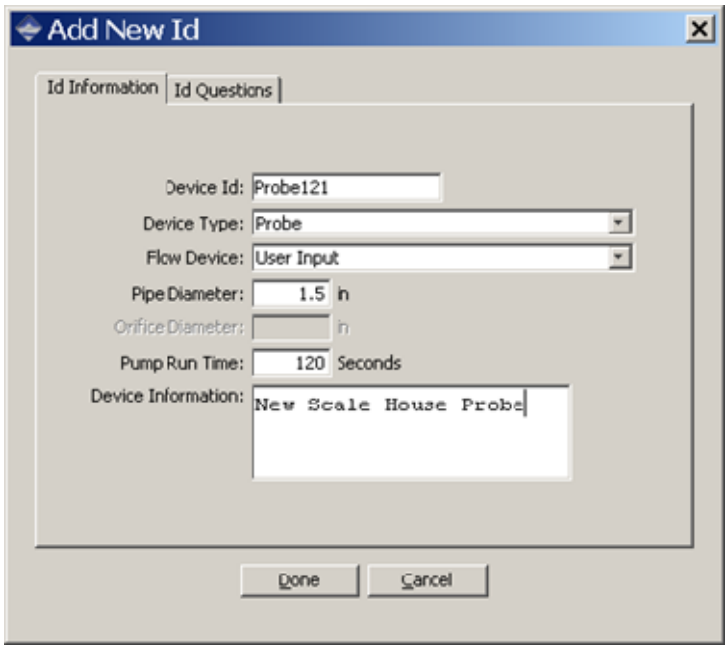


To create a Project based on the information in the GEM2000, select ***Create a new project from the data in my instrument***.

Creating a Device ID that does not measure flow Example- Probe or Sample Port

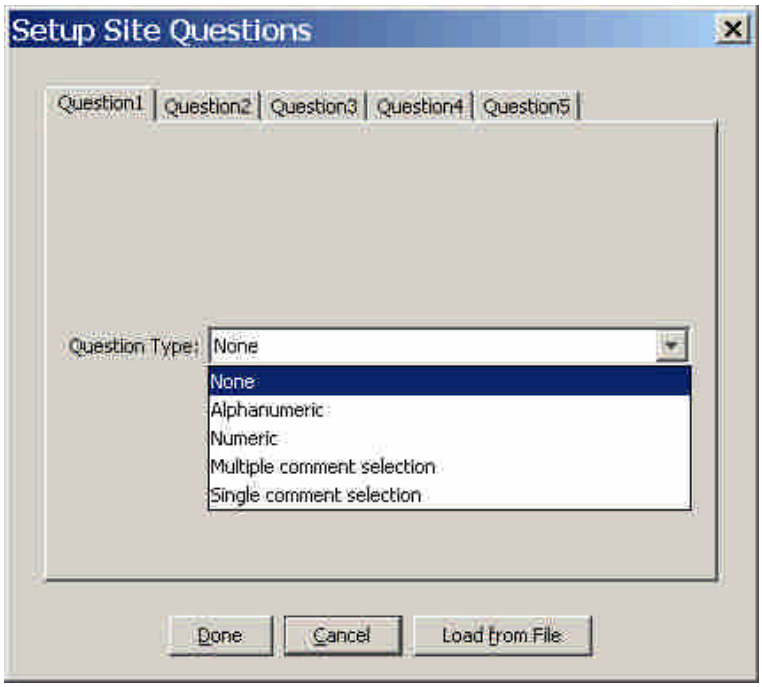
If there is no flow device you will choose User Input. When choosing the User Input option you will need to enter the appropriate pipe inside diameter and pump run time.

This ID is then generally sent to the GA mode [Landfill Gas Analyzer] of the instrument. Because this mode of the instrument does not read flow will not show the pressure readings screens that are in the GEM mode for vacuum and impact pressures.

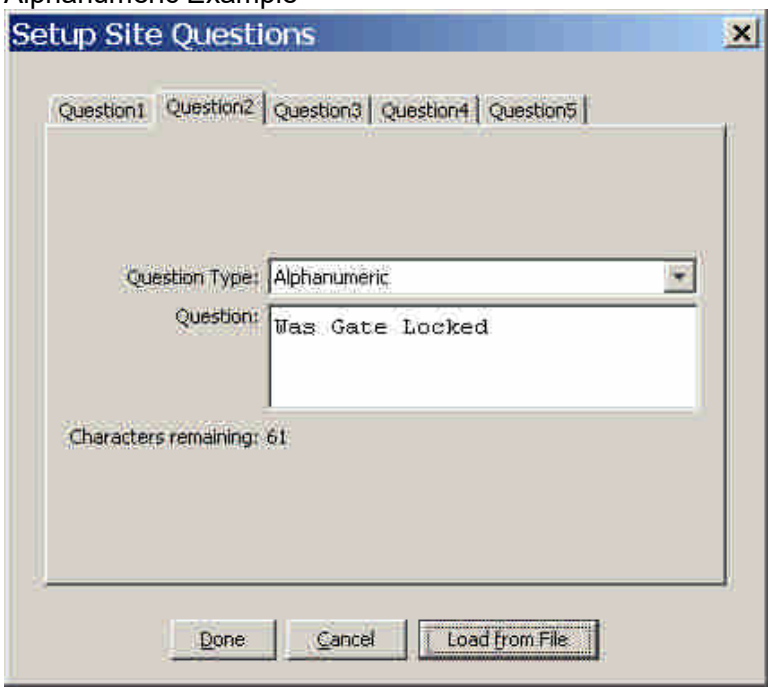


3.7 Creating your site questions

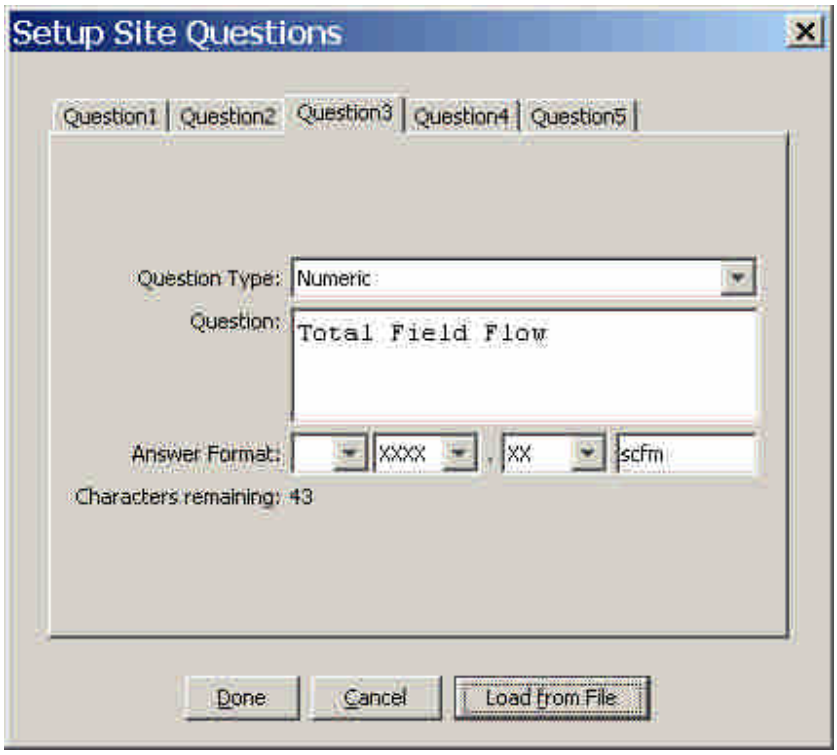
After sending site questions to your instrument they must be updated each time you use the GEM. This is done by going to the menu selection in the GEM and choosing [Update Site Data]
The options for questions are Alphanumeric – Numeric – Multiple or Single comment selection.



Alphanumeric Example

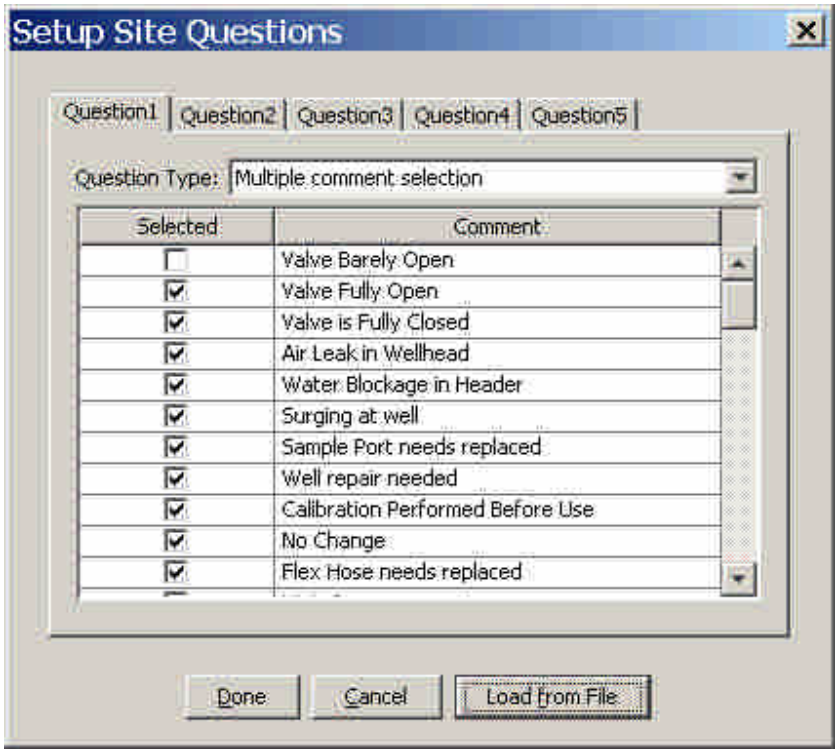


Example of Numeric Question

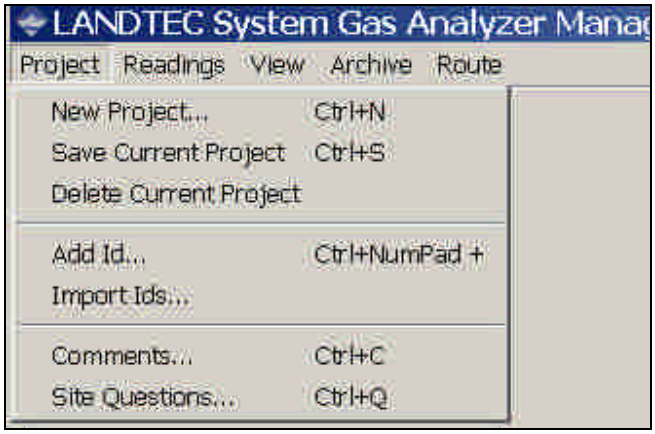


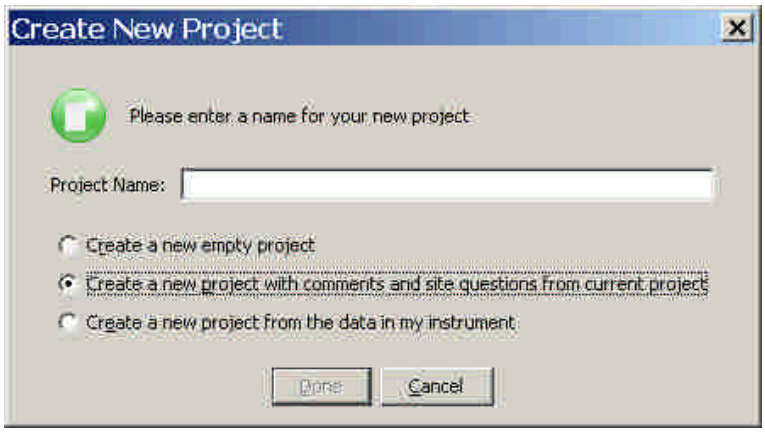
You may use Multiple or Single Comment selections

Using the Comments that were created for this project

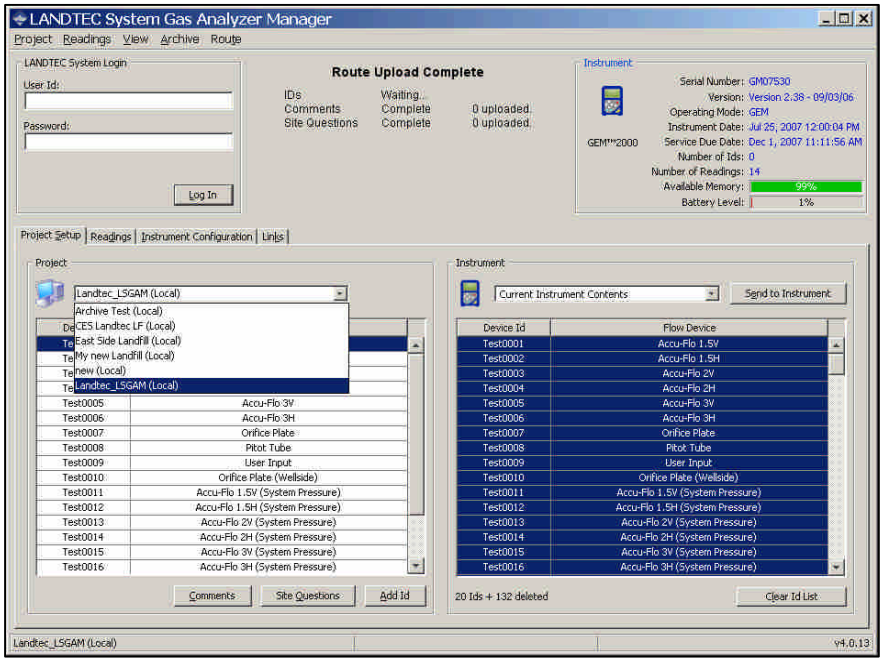


These Site Questions may be used again with another project by selecting the Create New Project and create new project with comments and **site questions** from current project.

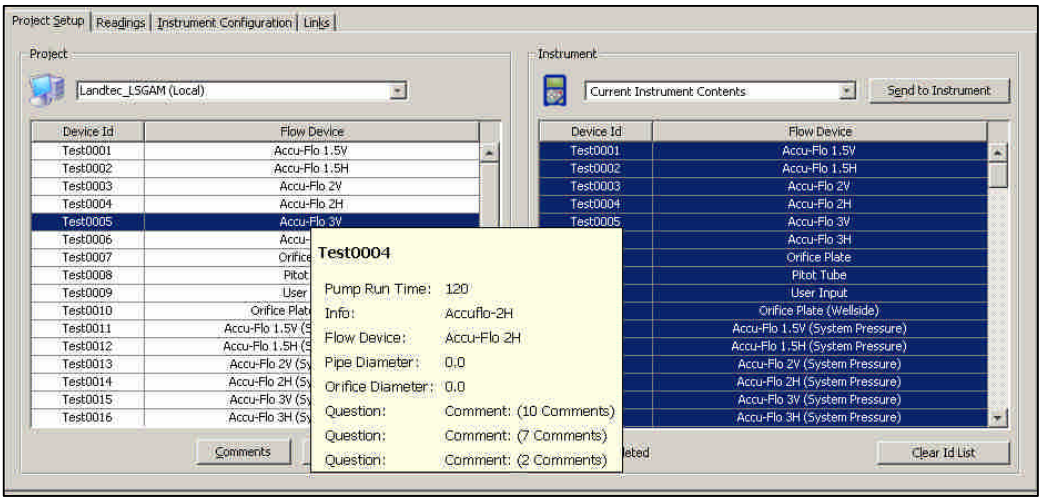




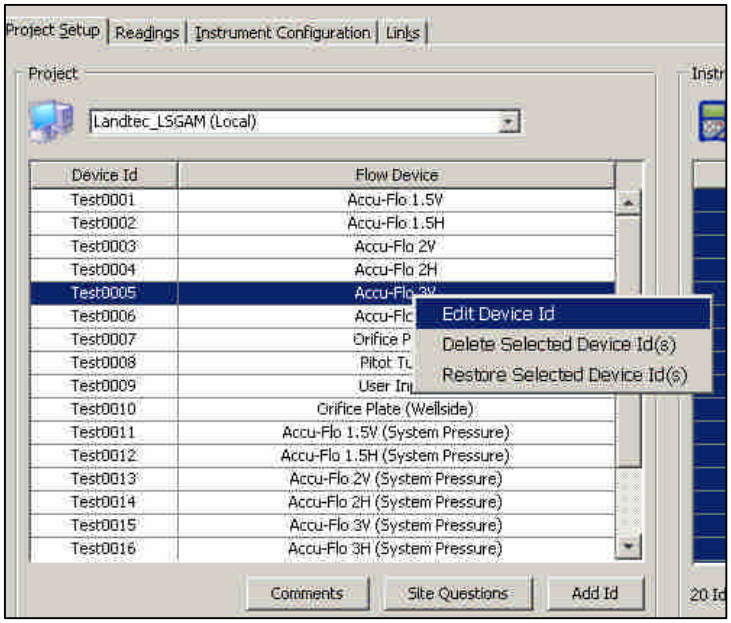
The project will be created and the IDs, Comments, and Site Questions that exist in the instrument will be applied to the new project.



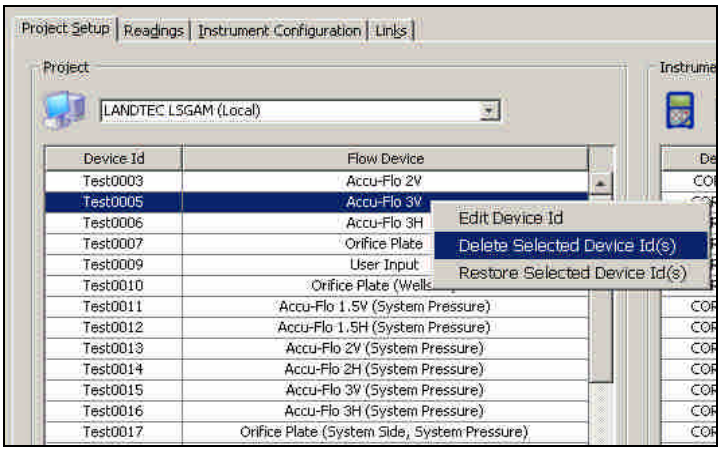
Placing the mouse cursor over a specific device ID will show detailed information about that ID.

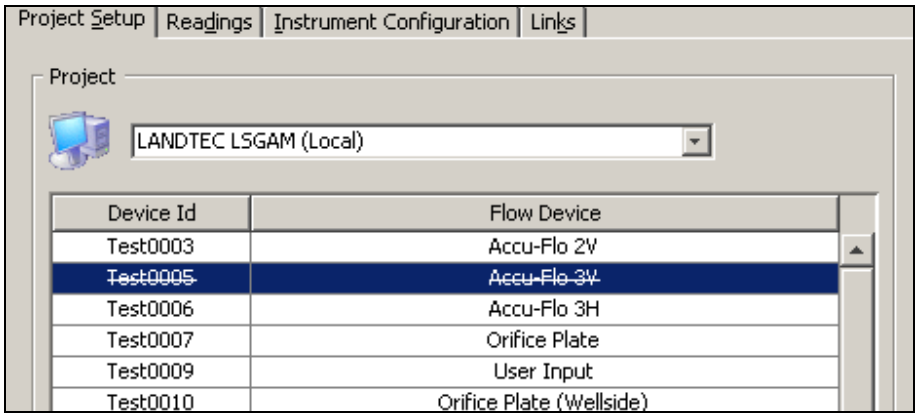


To edit a Device ID, right click on the desired device and select ***Edit Device ID***.



To delete an existing ID, right click on the desired device and select ***Delete Selected Device ID(s)***.





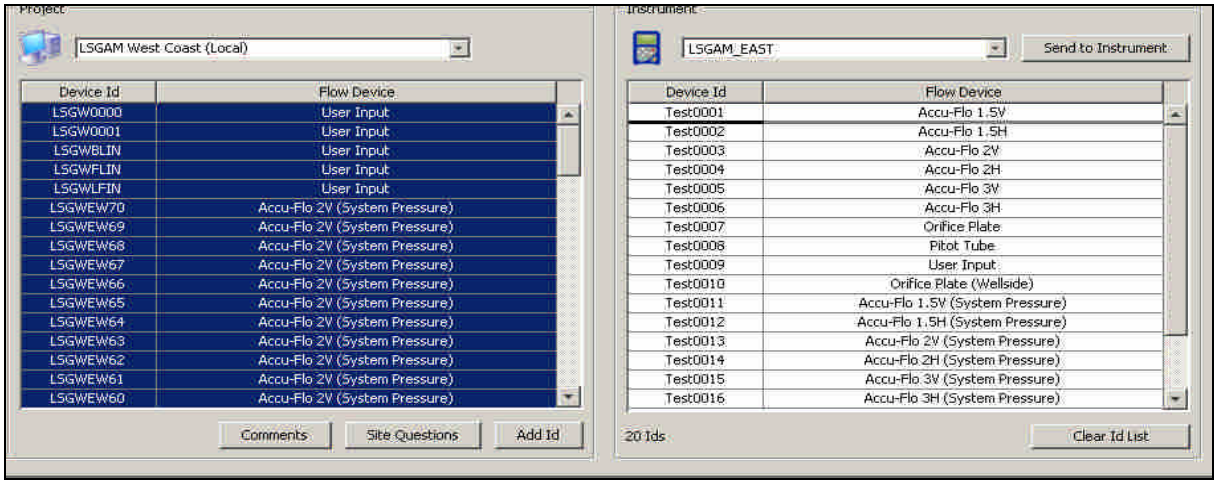
Deleted IDs are displayed with a line through the information on the screen. To restore a deleted ID, right click on the ID and click ***Restore Selected Device ID(s).***

3.8 Sending IDs to the instrument

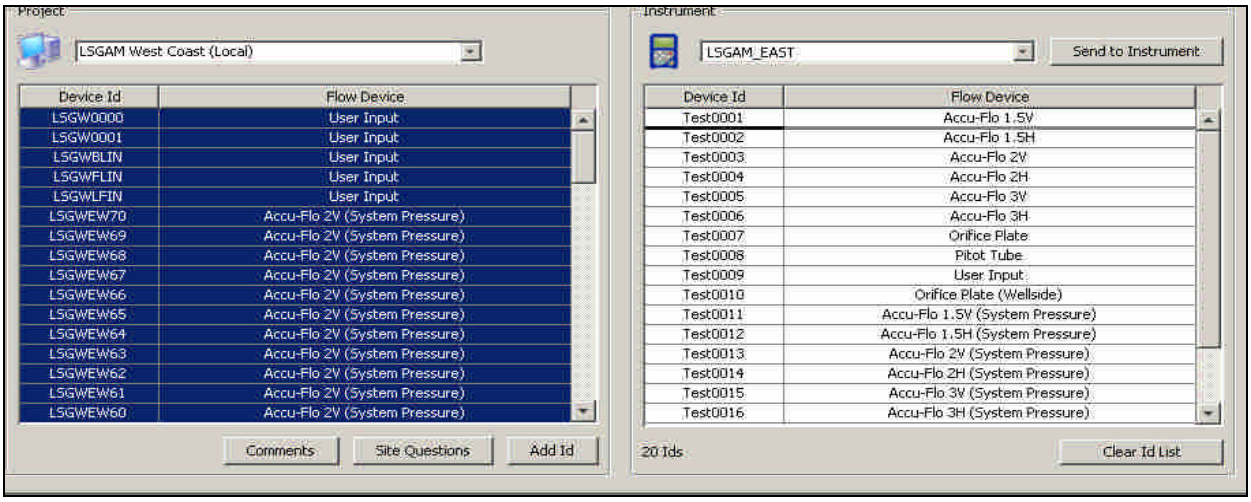
Once IDs have been created in the project, they must be uploaded to the instrument. To perform this operation, select the desired IDs from the left table under the Project name, left click and drag the IDs to the right table.

Place the mouse arrow at the edge of the first cell and hold down the left key. The arrow will change to .

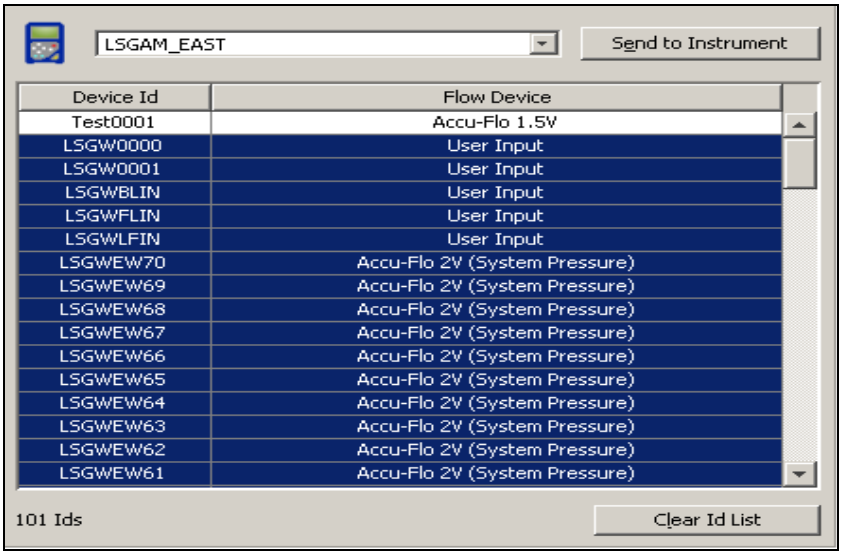
To highlight all, select control, then A on your key board. You can now drag the list to the Instrument side of the screen.



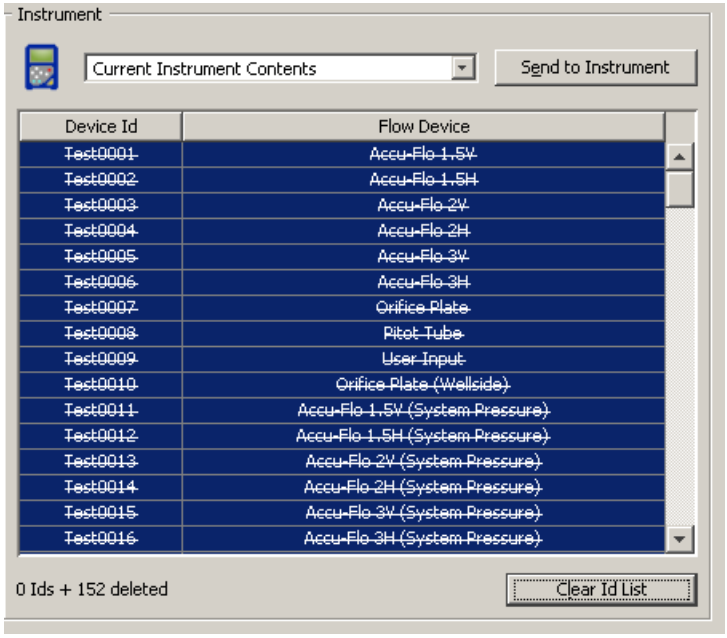
Once you have dragged the list or any selection of IDs to the instrument side, the line will change where you have the arrow and the circle will become a box.



Upon releasing the mouse key your IDs will be in the instrument list. Now select ***Send to Instrument*** button.

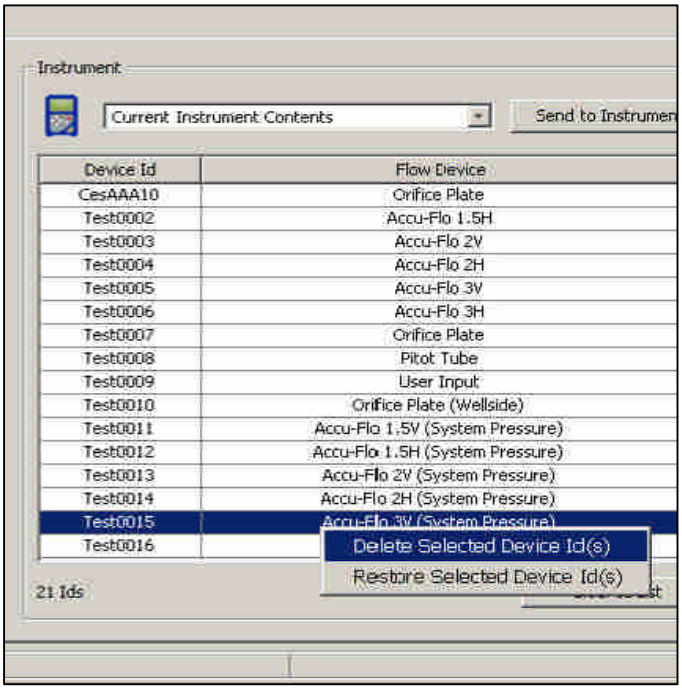


3.8.1 Clearing ID s from your instrument or Deleting a Project



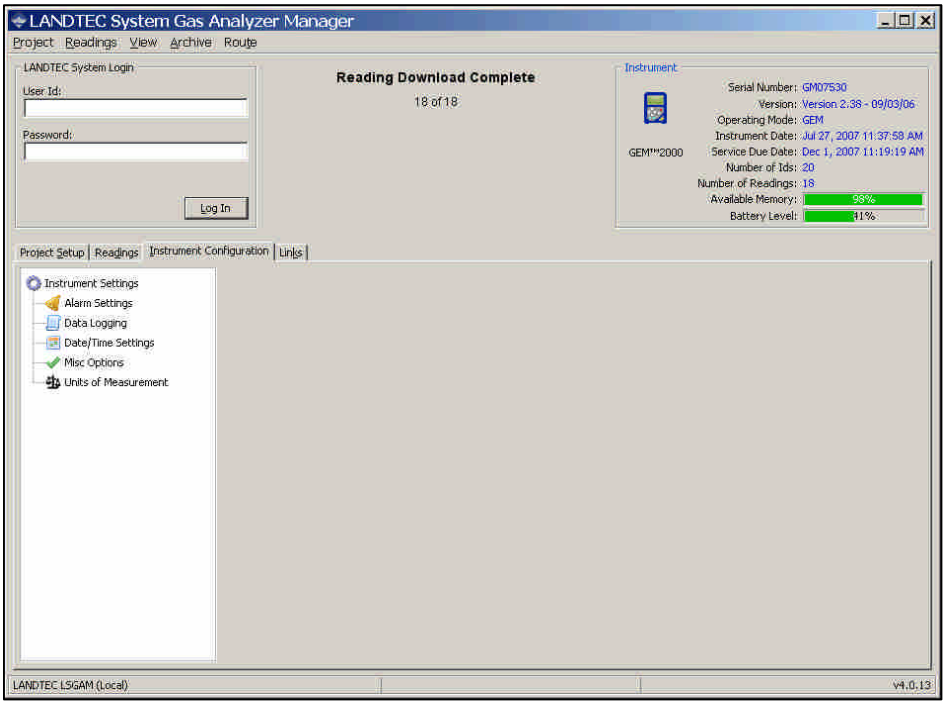
In current instrument contents when selecting the Clear ID List option it will draw lines through the IDS. You then need to select ***Send to Instrument***. This will clear all IDs from the GEM in both the GEM and GA mode.

You may also delete one ID from a list by highlighting the ID RIGHT CLICK with your mouse and select the Delete Selected Device option. If you have selected the wrong ID and deleted then you may select the Restore option to return the ID to the list.



3.9 Instrument Settings

The LANDTEC System Gas Analyzer Manager software allows users to change many of the operational settings of the instrument. To view and change the available settings click on the ***Instrument Configuration*** tab.

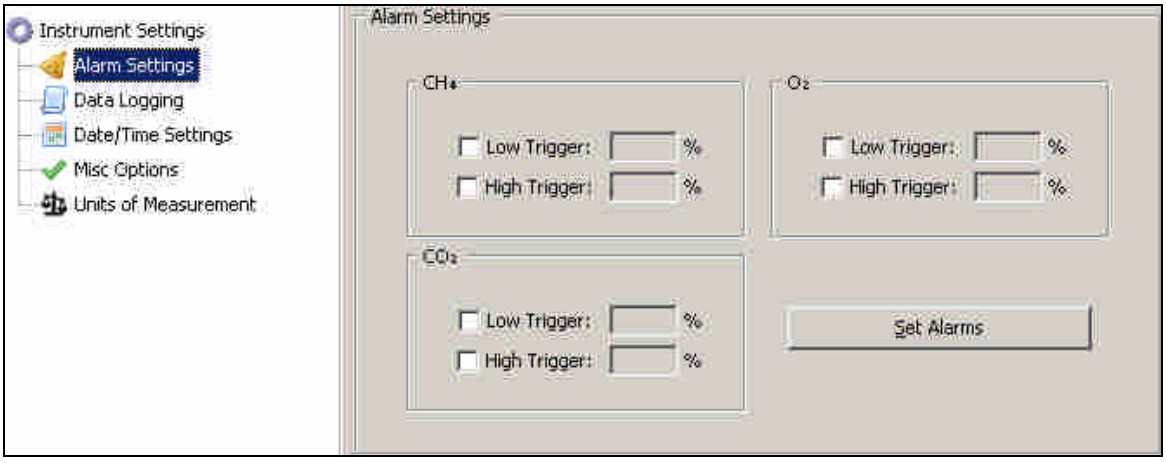


In the Instrument Configuration user interface, there is an Instrument Settings option tree. The Instrument Settings tree allows for easy navigation to the following categories:

Alarm Settings
Data Logging
Date/Time Settings
Misc Options
Units of Measurement

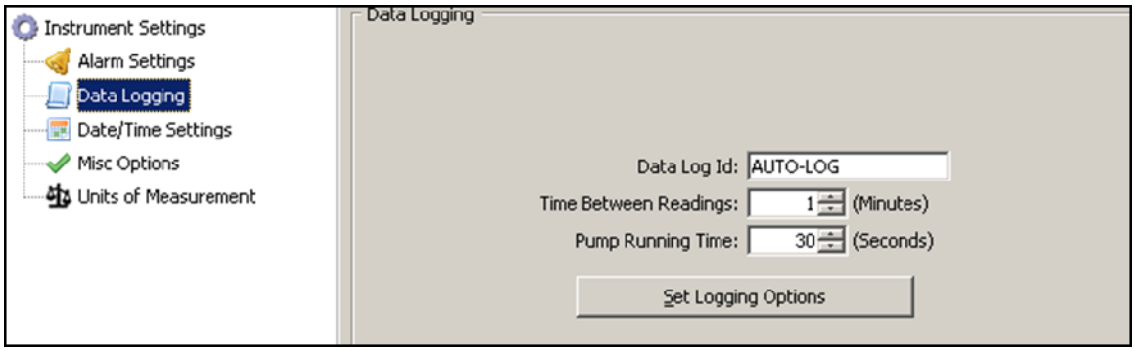
The following sections describe each option category.

3.9.1 Alarm Settings



The Alarm Settings options control the activation and deactivation of the audible alarms in the GEM2000 instrument. Audible alarms can be configured for CH_4, CO_2, or O_2 parameters. Each parameter can be configured with a Low Trigger and/or High Trigger for the alarm. To activate any specific alarm, click and place a checkmark in the desired box. This will activate the entry field to place the value. The values must be 0 – 100.

3.9.2 Data Logging

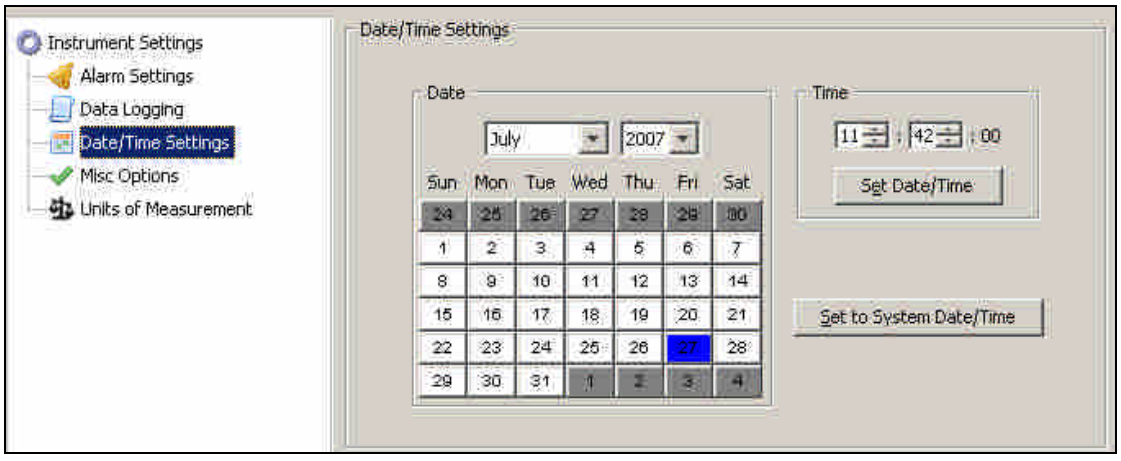


Data Log ID
The Data Logging option allows the user to specify an ID to be associated to readings taken with the Auto-logging feature of the instrument.

Time Between Readings
This value indicates the time from when the pump stops running until the pump begins sampling.

Pump Running Time
This value indicates the duration the pump will be run for sampling.

Date/Time Settings



The **Date/Time Settings** screen allows the user to set the date and time of the instrument.

Setting the Computer's Date and Time
To set the instrument's date and time to that of the computer, click on the Set to System Date/Time button. This will set the calendar and time fields to the current date and time of the computer. Then click the Set Date/Time button to apply to the instrument

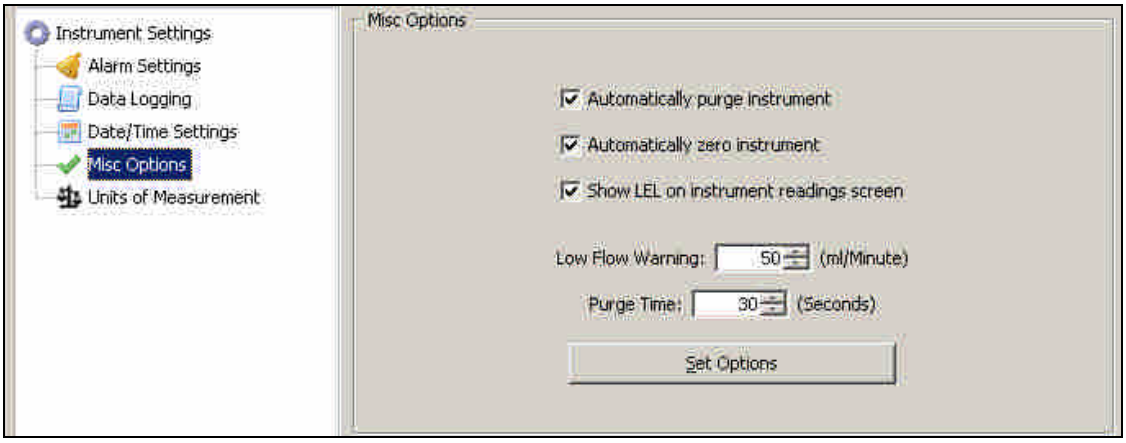
Date
Use the calendar options to select the desired date.

Time
Use the up and down controls to select the desired hour and minutes.

3.9.1 Set Date/Time in the instrument

Click the Set Date/Time button to apply the settings to the instrument

3.10 Misc Options



Under the miscellaneous options interface the user can change the following instrument settings:

Automatically purge instrument
Activates and deactivates the automatic purge feature in the instrument

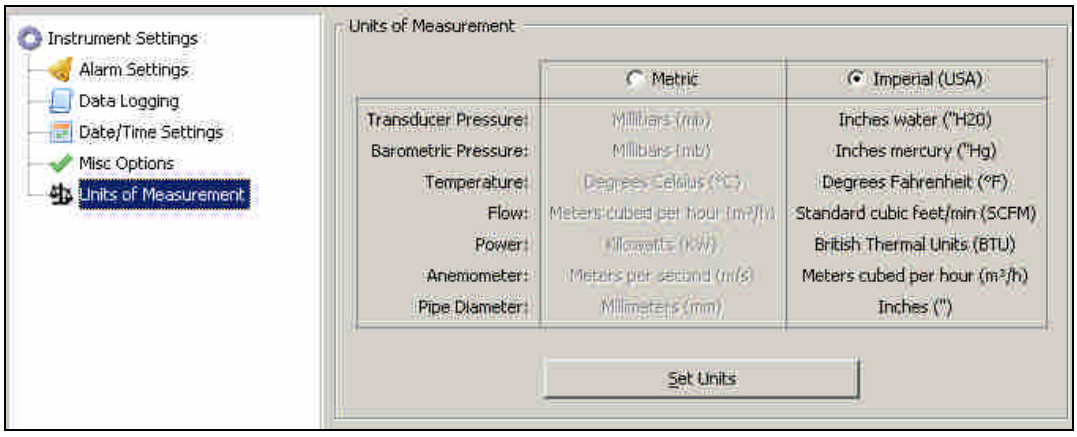
Automatically zero instrument
Activates and deactivates the automatic zero feature in the instrument

Show LEL on Instrument readings screen
Specifies whether or not Lower Explosive Limit (LEL) is displayed on screen, power instrument off and on for change to take effect.

Low Flow Warning
Specifies the point at which the instrument will indicate it is not able to extract the appropriate gas flow for analysis.

Purge Time
Specifies the duration the pump will run when activated by the purge feature of the instrument.

3.11 Units of Measurement



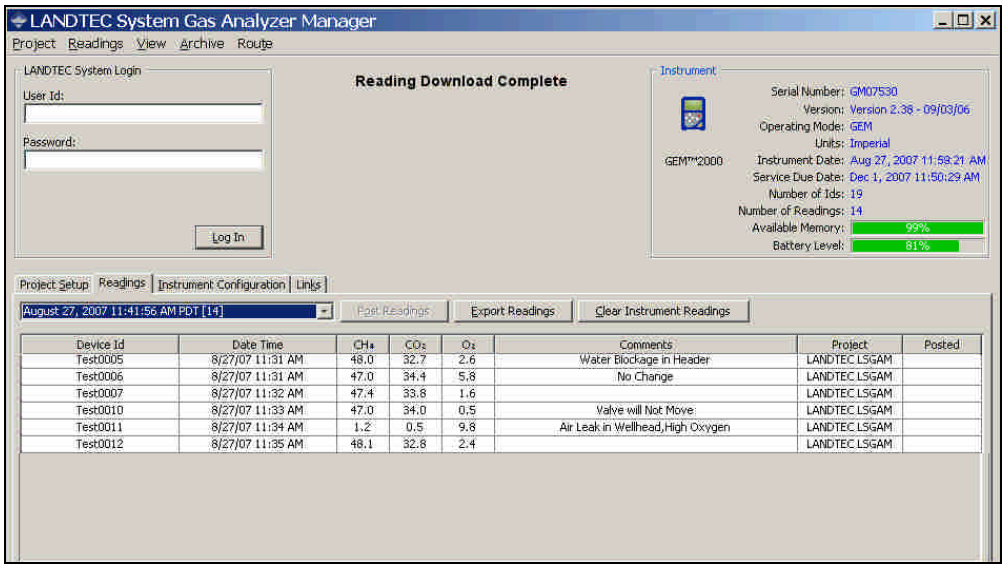
The Units of Measurement interface allows users to select whether to operate the instrument in metric or imperial units. The units for each parameter are displayed on the screen.

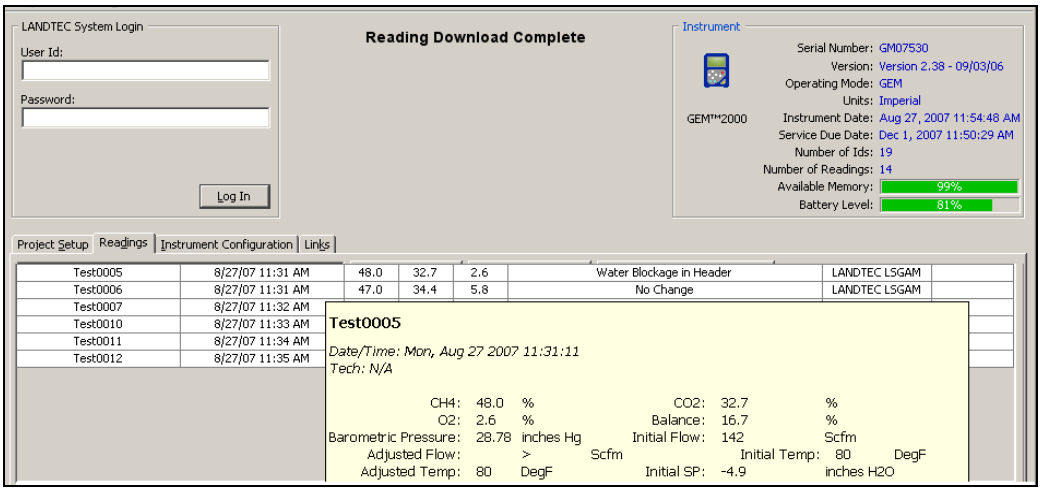
WARNING: *Units of Measure are as critical as the values of the readings stored. Be certain to verify the appropriate Units of Measure for your project prior to making a change to this option. Changing the Units of Measure will* ***NOT*** *convert any existing values stored in the instrument. To avoid confusion, download any stored readings prior the changing the Units of Measurement.*

3.12 Downloading Readings

After successfully creating projects, IDs, and setting appropriate instrument settings, the instrument is ready for field use. When used in the field, ***readings*** are collected and stored within the instrument's memory. The readings consist of the measured, input, and calculated parameters such as CH4, CO2, O2, Gas Temperature, Flow Rate, etc. These readings must be downloaded from the instrument to be reviewed on the computer and stored for review at a later time. This section of the Operation Manual reviews the process of downloading and storing readings from the instrument.

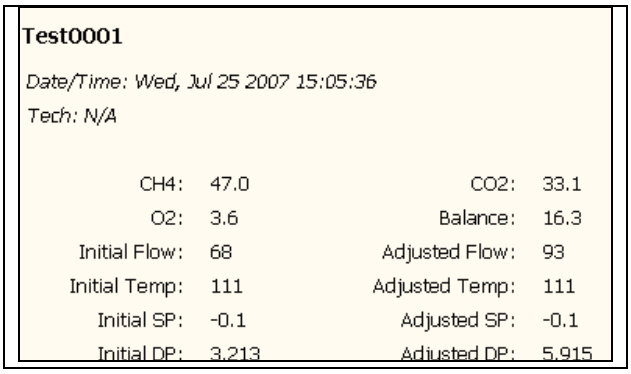
To view your downloaded readings from the instrument, select the Readings tab of the LANDTEC System Gas Analyzer Manager software.





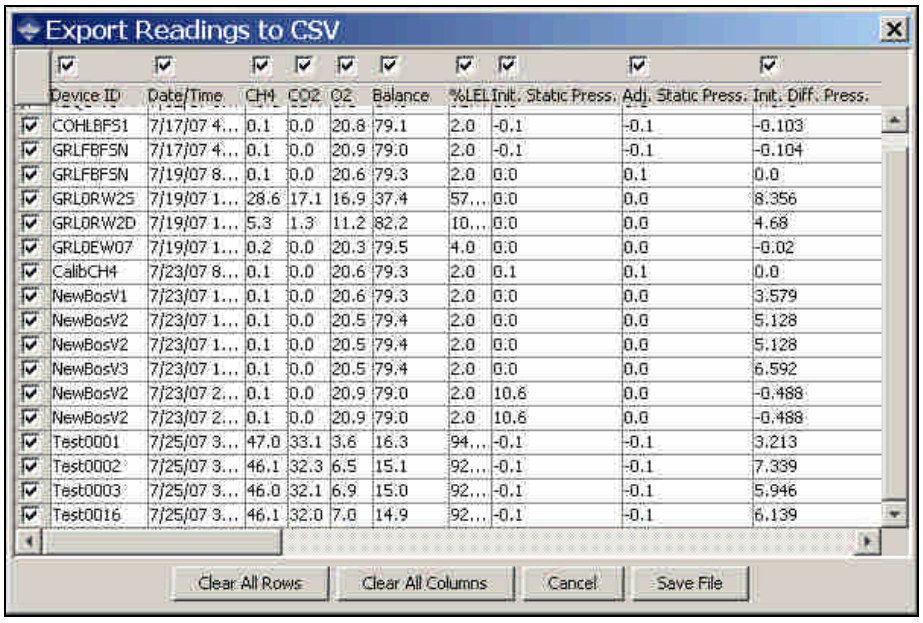
When the instrument is initially detected by the LSGAM software, the readings are automatically downloaded from the instrument, placed in the Readings tab table, and stored in your project previously set up on your computer.

Placing your mouse over a reading will display additional parameters of the reading.

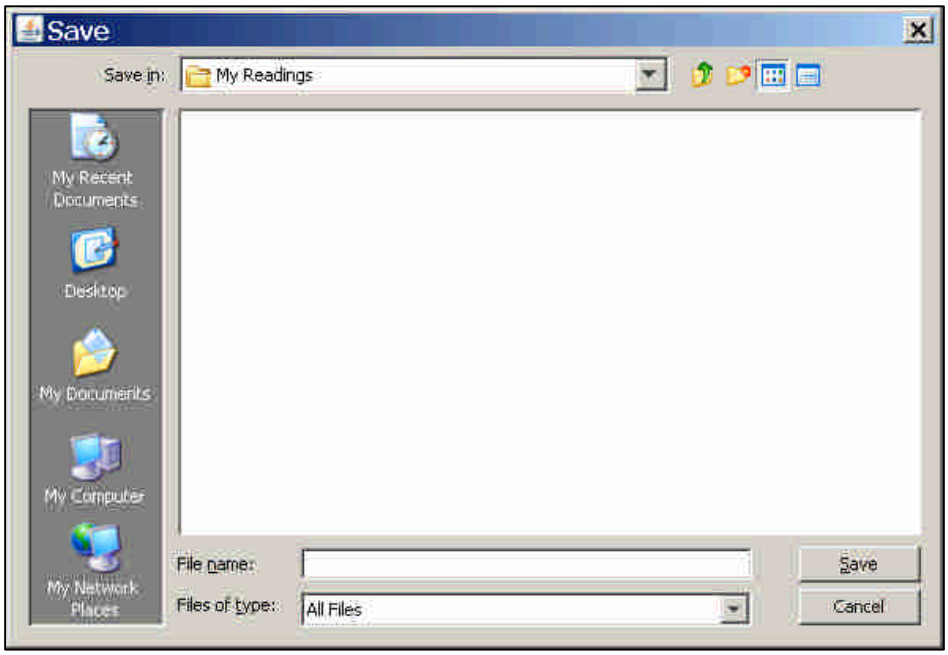


To clear the readings from your instrument, after the readings are downloaded successfully, click the ***Clear Instrument Readings*** button. A prompt will verify the permanent deletion of the readings from the instrument. This will clear information within the GEM and GA Mode **simultaneously**.

To export readings to a file, click the ***Export Readings*** button. This will open the ***Export Readings to CSV*** screen. This interface provides several options described below.



To add or remove a single reading from export, click on a checkbox in the leftmost column.
To add or remove a specific parameter from export, click on the corresponding checkbox across the top.
To clear all rows click the ***Clear All Rows*** button at the bottom of the screen.
To clear all column selections, click on the ***Clear All Columns*** button at the bottom of the screen.
To exit the operation without saving, click the ***Cancel*** button.
To specify a filename and save the selection to a file, click the ***Save File*** button. Clicking this button will open a Save window.



Specify a filename and location then click the Save button. The selected readings will be saved in comma separated value (.CSV) format. The .CSV file may now be opened in another application.

4 General Operations Menu

The following features and functions are selectable from the main menu via key **'① Menu**' from the read gas levels screen. Navigation through the list is via the 2 '∧' and 8 '∨' cursor keys. Selection of the feature is by pressing the '↵' key.

4.1 Zero Transducers

This function allows the user to zero the pressure transducer(s). Upon selection, the current pressure reading is displayed. The operation will be carried out when the '↵' is pressed. When zeroing transducers it is important to allow them to stabilize first so an accurate zero is achieved. If ① is pressed the instrument will return to the gas reading screen without zeroing.

NOTE: Zeroing Transducers may take a few extra minutes in the field, but is a recommended step to ensure the best possible accuracy.

4.2 Update Site Data

Allows the user to answer questions (pre-defined in LSGAM software) relating to the site (e.g. name of operator, weather conditions, etc.). Site Questions are different from Site Comments.

This is covered in detail in section 3.7 of this manual.

4.3 Data Logging (GA mode only)

Enables the user to leave the Instrument unattended to take samples at pre-determined intervals. The reading interval and pump run time may be edited prior to commencing the logging cycle. The ID code may ONLY be set in LSGAM communication software.

Once the logging function is activated, the instrument will carry out a 30 second 'Warm-up' countdown (displayed bottom right) and begin the first sample. After each sample, the unit will automatically sleep to conserve power if the time between the pump ending and the next sample is greater than 30 seconds.

The instrument is reactivated (awakened) during a logging cycle, the LANDTEC logo will be displayed for a few seconds and the Gas Reading screen will be displayed. This will initiate a 30 second countdown to the next sample being taken unless the operator stops the logging function.

4.4 Operating Language

The operating language of the instrument can be set to English, German, Spanish, French, Italian or Brazilian Portuguese through this option.

4.5 View Data

The view data allows the user to see the readings that are in the GEM2000 / GEM2000 Plus memory. Often the amount of data stored is more than can be displayed adequately on one screen so pressing the ⑤ key will allow the user to see additional screens with stored data. The 2 '∧' and 8 '∨' cursor keys will move forward or backwards through the instruments memory. Pressing the ① key will exit to the Gas Reading screen.

4.6 Adjust Contrast

The GEM2000 automatically adjusts the screen contrast according to the ambient temperature to maintain normal viewing.

The contrast can be manually adjusted by using the 4 '<' and 6 '>' cursor keys. The manual contrast setting is stored when the '↵' key is pressed.

4.7 Field Calibration

Whenever carrying out a user calibration function it is important to ensure the correct value is entered. Additionally, in the case of a zeroing function, ensure only certified gas or ambient air is used and no connection is made to a probe or wellhead fitting. The calibration cylinders sold by LANDTEC have a volume of 17 liters. The regulator, sold by same, is set to 0.5 liters per minute and 15 psig maximum. A normal field calibration usually requires the gas to be running for about two minutes.

Upon selecting this option, the Field Calibration screen is displayed. A brief description of the user span calibration procedure and the current reading (row '**R**') and user span calibration gas values (row '**S**') are displayed.
The span gas values may be changed via the '③ **Edit Target Concentrations**' option. Once this option has been selected, **all** the gas values will require entry. Each entry is to be confirmed by pressing the '↵' key. It is important to confirm the concentration of the calibration gas(es) used and enter the value(s) properly.

4.7.1 Zero Channels

Selected from the '**Field Calibration**' - '↵**-Calibration Menu**' allows the relevant reading to be zeroed. When selected, a list of the available options will be displayed, this usually includes CH_4, and O_2, also the Gas Pod (if fitted).

Supply a zero gas mixture to the instrument for the gas to be zeroed. Ensure the reading for the selected gas has settled to its lowest value before selecting the zero function. When the required option is selected, the user zero function will be carried out automatically. The operation will be carried out when the '↵' key is pressed.

4.7.2 Span Channels

Spanning Channels should be carried out prior to use or when the ambient operating temperature changes greater than +/- 20 degrees Fahrenheit. Selected from the '**Field Calibration**' - '↵**-Calibration Menu**', allows the relevant reading to be span calibrated (in accordance with the calibration value entered). When selected, a list of the available options will be displayed, which includes CH_4, CO_2, O_2, (CO & H_2S for the Plus) and Gas Pod (if fitted).

When the required option is selected from the list, the span calibration function will be carried out automatically. When carrying out this procedure, ensure the span calibration procedure (as outlined below) is followed:

1. Apply the relevant known certified gas concentration through the inlet port of the Instrument.
2. Wait until the current gas reading has stabilized.
3. Select the required calibration option via the '↵**-Calibration Menu**'.

4.7.3 Factory Settings

This will clear any user zero and span calibration data. It will also restore the pre-programmed factory settings for **ALL** channels – CH_4, CO_2, O_2 (CO & H_2S for the Plus) or Gas Pod (if fitted) and pressure transducers.

4.7.4 Last Field Cal

Displays the date the last field calibration was carried out (zero or span).

4.8 Mode of Operation

Allows changing instrument between GA mode and GEM mode of operation.

4.9 Information Screen

The information screen will automatically display the following information:

Software Version- Date
Serial Number-GM00000
Date Format- USA
Language- American
Communication- 1920014

4.10 Exit Menu

The Exit Menu simply exits the main menu screen and returns to the gas reading screen.

5 Taking Probe Readings (GA Mode)

LANDTEC classifies non-extraction wells as Probes when **NOT** connected to an active vacuum extraction system. Probes, (commonly known as migration probes), are typically placed on the perimeter of the landfill to test for gas migration or may be placed next to a building or road to test for the presence of Methane. The GEM2000 / GEM2000 Plus instrument may be configured as a Gas Analyzer (GA mode) for sampling probes. To access this function from the gas read screen press '①' for menu and scroll down to **Mode of Operation**, press the '↵' key and highlight **Landfill Gas Analyzer**, pressing the '↵' key again will select GA mode of operation.

5.1 Preliminary Checks

Prior to going to the test site, it is good practice to ensure:

- All necessary ID codes and readings have been uploaded via LSGAM software.
- The time and date are correct.
- The water trap has a clean and dry filter fitted.
- The inlet-port particulate filter is clean and dry.
- A supply of spare filters is available in case of accidental water blockage or contamination.
- The battery has a good charge (minimum 25% charge, even if only a few readings are required).
- The memory has sufficient space available.
- The CH_4, CO_2, and O_2 (CO & H_2S for the Plus or Gas Pod if fitted) readings have been zeroed, without gas concentration present.
- Check the span calibration with a known concentration calibration gas.

Travel to the site with the analyzer in the vehicle's interior - not in the trunk or truck bed, where it may be subjected to extremes of temperature and possible shock damage. Do not place the analyzer against anything hot (e.g. gas extraction pipe, car body or in an unattended car during the summer). This may cause erroneous readings.

When moving around a site, protect the instrument from strong direct sunlight, heavy rain or wind-chill. Strong direct sunlight can raise the temperature of the instrument beyond its operating range. If this occurs, the LCD display will appear almost black and the contrast setting cannot alter the contrast. Typically no permanent damage is done and after the instrument cools the screen will become readable again.

Always use the water trap! If the water trap becomes flooded, change the filter immediately and ensure all tubes are clear before re-use.

5.2 Update Site Data

Prior to taking the readings at a particular site, the Site Data and Technician Login should be updated (if programmed). This is accessed via the General Menu '①' then **'Update Site Data'**. This function removes the need for the site conditions to be recorded manually.

A series of up to five questions can be pre-programmed using LSGAM, see Section 3.7. If Site Questions were uploaded to the instrument, they should be answered at this time. The answers are stored and appended to each reading stored thereafter, until the Site Data is updated for another site.

5.3 Taking Readings – With ID

For this function to be used it is essential that the relevant ID be previously uploaded to the Instrument using LSGAM, see Chapter 3. An ID **cannot** be created by the Instrument alone.

1. When the Read Gas Levels screen is displayed, option **'③ Next ID'** should be selected. A list of stored IDs is displayed for selection via the '∧' and '∨' cursor keys, the 'next' ID on the list is

automatically highlighted. To confirm selection, press the '↵' key. The display may be toggled to display any relevant ID information available; such as a description of the probe location, work to be carried out, etc.

2. A reminder is displayed to disconnect sample tubes, as a clean air purge will automatically remove the previous sample from the instrument. Purge time may be set via LSGAM (default is 30 seconds). Once the '↵' key is pressed, purge will begin and the Read Gas Levels screen will be displayed upon completion. The purge may be aborted by pressing the '①**EXIT**' key.
3. The ID number selected and the pump runtime is displayed in the upper left corner of the read gas levels display.
4. At this point, connect the sample tube (with water trap) from the sample point to the inlet port of the instrument, ensuring the connector 'clicks' into place. Then connect the sample tube to the probe sample port. **Do not connect the sample tube to the probe port before connecting to the instrument as this will cause any pressure in the probe to dissipate and a proper pressure reading will not be taken.**
5. As soon as the connection is made, the relative/static pressure reading will be displayed. No sample is taken from the probe at this time. Once the reading stabilizes and the pump starts, the relative/static pressure reading is stored. The relative/static reading will remain displayed as the pressure last taken.
6. The pump will run for the pre-programmed time and a countdown timer will be displayed. The pump may be stopped or started at anytime by way of the '✇' (pump) key. The reading may be stored at anytime with the use of the '↵' key. When the pump automatically stops this should be used as a prompt to store the reading.
7. Upon storing the reading, any pre-programmed questions will be displayed for response. This may require a numeric, alphanumeric selectable comment, or exclusive comment answer. A maximum of eight selectable and exclusive comments may be entered.
8. Disconnect the sample tubing from the probe and start again at Step 1 for the next probe.

For each reading, the following information will be stored:

- ID code.
- Current time/date.
- Site data (if entered).
- All gas readings and balance (CH_4, CO_2, O_2 (, CO and H_2S for the Plus)).
- LEL CH_4.
- Barometric Pressure.
- Relative Pressure.
- Questions/comments.
- Temperature (if temperature probe is connected).
- Gas Pod (if connected).

When the instrument is switched off, a clean air purge is automatically started for a pre-determined period. This may be aborted with the use of the '↵' key, although it is not recommended.

A tone will sound and a flashing bell will be displayed next to the appropriate gas reading value if a preset alarm condition has been exceeded.

5.4 Taking Readings – Without ID

Gas Readings can be taken without an ID in the instrument by following the instructions below. To create and uploaded IDs to the instrument using LSGAM, see Chapter 3. An ID **cannot** be created by the Instrument alone.

1. From the Gas Reading Screen first select **'③ Next ID'** then press **'⑤ Select No ID**' or, if ID information has not been uploaded to the instrument, an ID list will not be available. In either case, the ID will be displayed and stored as '**- - - - - - - -**'.

2. A reminder is displayed to disconnect sample tubes, as a clean air purge will automatically remove the previous sample from the instrument. Purge time may be set via LSGAM (default is 30 seconds). Once '↵' is pressed, purge will begin and the Read Gas Levels screen will be displayed upon completion. The purge may be aborted by pressing the '①**EXIT**' key.
3. At this point, connect the sample tube (with water trap) from the sample point to the inlet port of the instrument, ensuring the connector 'clicks' in to place.
4. Now connect the sample tube to the probe sample port. **Do not connect the sample tube to the probe port before connecting to the instrument as this will cause any pressure in the probe to dissipate and a proper pressure reading will not be taken.**
5. The pump may be started or stopped at anytime by way of the '✇' (pump) key and a 'time-on' timer will be displayed. The pump should always be stopped using the '↵' key, before storing a reading.
6. Upon storing the reading, a virtual keyboard will be displayed for any alphanumeric comments to be entered.
7. Disconnect the sample tubing from the probe and proceed from step 1 for the next probe.

Except for the ID code information, which will be stored as '**- - - - - - - -**', and probe questions, for each reading the information stored will be the same as that for a reading with an ID.

A tone will sound and a flashing bell will be displayed next to the appropriate gas reading value if a preset alarm condition has been exceeded.

5.5 Temperature Probe Reading

The GEM2000 / GEM2000 Plus has the facility to automatically display and record the probe temperature via an optional Temperature Probe (TP-2000). When the Temperature Probe is fitted to the RS232 Communication Socket, the temperature will be displayed in the read gas levels screen and recorded with all other data. The temperature probe is part of the GEM2000 UL certification and is therefore certified for use under the same conditions as the instrument.

5.6 Cross-Gas Effects

5.6.1 Methane, Carbon Dioxide and Oxygen

The Methane reading is filtered to an infrared absorption frequency of 3.41μm (nominal), the frequency specific to hydrocarbon bonds. Instruments are calibrated using certified Methane mixtures and will give correct readings provided there are no other hydrocarbon gasses present within the sample (e.g. ethane, propane, butane, etc.). If there are other hydrocarbons present, the Methane reading will be higher (never lower) than the actual Methane concentration being monitored.

The extent to which the Methane reading is affected depends upon the concentration of the Methane in the sample and the concentration of the other hydrocarbons. The effect is non-linear and difficult to predict.

The Carbon Dioxide reading is filtered to an infrared absorption frequency of 4.29μm (nominal), the frequency specific to Carbon Dioxide. Therefore, any other gases usually found on landfill sites will not affect the Carbon Dioxide reading.

The Oxygen sensor is a newly developed galvanic cell type and suffers virtually no influence from CO_2, CO, H_2S, SO_2 or H_2, unlike many other types of Oxygen cell.

The infrared sensors will not be "poisoned" by other hydrocarbons. Normal operation will resume as soon as the gas sample has been purged.

Note - there has been one reported incident of a high reading due to the presence of Carbon Disulfide, which has a similar absorption frequency to Carbon Dioxide.

5.6.2 H_2S, CO and other Optional Gas Pods

The Gas Pods used to measure H_2S and CO do suffer from cross-gas effects. Such effects are not accurately specified. However, the following table may be useful as a guide. This table represents how many ppm would be read by a Gas Pod if 100ppm of the interfering gas was applied, (with no other cross-contaminates being present in the sample).

Cell	CO	H_2S	SO_2	H_2	CH_4	CO_2
CO	100	<3	0	<40	0	0
H_2S	<0.5	100	~20	~0.1	0	0

NOTE: All readings are given in parts per million (ppm). The life of an electrochemical cell is determined by exposure to gasses, typical life being one to two years. It is recommended that Gas Pods be field calibrated at regular intervals.

NOTE: Cross-gas effects can be mitigated by employing a filter for the gas not being tested.

5.6.3 GEM2000 Plus Internal Electrochemical Cells for Measuring H_2S and CO

The GEM2000 Plus employs two internal electrochemical cells to measure Hydrogen Sulfide (H_2S) and Carbon Monoxide (CO). Electrochemical cells which measure CO are typically susceptible to cross gas interference by Hydrogen (H_2) and Hydrogen Sulfide (H_2S). Two components that may be present in the Landfill Gas sample. This means that if H_2 and/or H_2S are/is present in the Landfill Gas sample a normal CO electrochemical cell would give an artificially high reading.

The GEM2000 Plus uses a 'hydrogen compensated' CO cell to counteract the interference by H_2. This is why the instrument displays an H_2 channel. H_2 is not directly measured, although a rough value, which is shown as LO, MED or HI, can be interpreted. If the H_2 value is displayed as LO or MED the H_2 compensation will mitigate the H_2 effect on the CO reading, however if the H_2 value is shown as high it is possible that there is more H_2 present than the compensation is capable of adjusting for. If that is the case the CO value may be artificially high due to cross gas interference by the H_2. Additionally, if a HI level of H_2 is encountered then a longer than normal purge time will typically be necessary to clear all the H_2 from the electrochemical cell. It is recommended that after encountering a HI level of H_2 the instrument be purged with clean air until the H_2 channel displays LO. This could take as long as five or ten minutes (if the H_2 channel was over ranged) but is necessary to ensure the subsequent readings are accurate.

The CO cell used in the GEM2000 Plus also utilizes an internal H_2S filter to eliminate H_2S cross gas interference. However, the filter does have a finite capacity. If the filter's capacity is exceeded then the CO cell will be susceptible to cross gas interference by any H_2S that is present in the gas sample. It is quite easy to determine if the capacity of the filter has been exceeded. After all the sample gas has been purged from the instrument, with clean air, and the CO reading is zero, run a certified gas that contains H_2S but not CO (the H_2S calibration gas) through the instrument. If the CO reading remains zero while the H_2S reading increases to the certified value then the internal H_2S filter has remaining capacity. If the CO reading increases with the H_2S reading then the internal filter's capacity has been exceeded and the cell will need to be replaced.

The GEM2000 Plus was designed to read a maximum H_2S concentration of 200ppm and a maximum CO reading of 2000ppm. If the gas sample contains more than the maximum concentration the instrument will be over ranged and display >>> as the reading. If the instrument is over ranged the readings typically stay artificially high for several minutes and will not go back to zero with a normal purge. While over ranging the instrument is not recommended and will slightly shorten the life span of the electrochemical cells the resulting high readings are not permanent. If one of the channels is over ranged it is recommended to purge the instrument, with clean air, until the reading returns to zero. This may take as long as five or ten minutes. The cell may need to be recalibrated but normally the extra long purge is all that is necessary.

6 Taking Extraction Well Readings (GEM Mode)

LANDTEC classifies gas-producing penetrations on landfills as wells when used with vacuum extraction systems and flow determining devices such as the Accu-Flo wellheads, orifice plates or pitot tubes. The GEM2000 / GEM2000 Plus may be configured as a Gas Extraction Monitor (GEM mode) for the purpose of sampling wells and obtaining flow measurements. To access this function from the gas read screen press '①' and scroll down to **Mode of Operation**, press the '↵' key and highlight **Gas Extraction Monitor**, pressing the '↵' key again will select GEM mode of operation.

6.1 Preliminary Checks

Prior to going on site, it is good practice to ensure:

- All necessary ID codes and readings have been uploaded via LSGAM software.
- The time and date are correct.
- The water trap has a clean and dry filter fitted.
- The inlet-port particulate filter is clean and dry.
- A supply of spare filters is available in case of accidental water blockage or contamination.
- The battery has a good charge (minimum 25% charge, even if only a few readings are required).
- The memory has sufficient space available.
- The CH_4, CO_2 and O_2 (CO & H_2S for the Plus or Gas Pod if fitted) readings have been auto-zeroed without gas concentration present.
- Check the span calibration with a known concentration calibration gas.

Travel to the site with the analyzer in the vehicle's interior - not in the trunk or truck bed, where it may be subjected to extremes of temperature and possible shock damage. Do not place the analyzer against anything hot (e.g. gas extraction pipe, car body or in an unattended car during the summer). This may cause erroneous readings.

When moving around a site, protect the instrument from strong direct sunlight, heavy rain or wind-chill. Strong direct sunlight can raise the temperature of the instrument beyond its operating range. If this occurs, the LCD display will appear almost black and the contrast setting cannot alter the contrast. Typically no permanent damage is done and after the instrument cools the screen will become readable again.

Always use the water trap! If the water trap becomes flooded, change the filter immediately and ensure all tubes are clear before re-use.

6.2 Update Site Data

Prior to taking the readings at a particular site, the Site Data and technician login should be updated (if programmed). This is accessed via the General Menu '①'. This function removes the need for the site conditions to be recorded manually. A series of up to five questions can be pre-programmed with the use of LSGAM and answered at this time. The answers to these questions are stored and appended to each reading stored thereafter, until the site data is updated for another site.

6.3 Taking Gas and Flow Readings (GEM Mode)

The GEM mode of operation is designed to allow for gas flow (SCFM) and energy measurements (BTU) to be calculated at the wellhead. This function requires the use of an ID that has been uploaded from LSGAM software with the type of flow device defined. **Gas flow and BTU will not be calculated if this action has not been performed.**

1. When the gas read screen is displayed select **'③ Next ID'**. A list of stored IDs will be displayed for selection via the '∧' and '∨' cursor keys, the 'next' ID is automatically highlighted, to confirm the selection press the '↵' key. The screen may be toggled to display any relevant ID information such as a description of the well location, work to be carried out, etc.
2. A reminder is displayed to disconnect sample tubes, as a clean air purge will automatically remove the

previous sample from the instrument. Purge time may be set via LSGAM (default is 30 seconds). Once the '↵' key is pressed, purge will begin and the Read Gas Levels screen will be displayed upon completion. The purge may be aborted by pressing the '①**EXIT**' key.

3. Connect the sample tubes (with water trap filter) to the wellhead ensuring the gas sample tube and impact pressure tubes are properly oriented. Insert the temperature probe if used.
4. Press the '✇' key to start the sample pump; a countdown timer will be displayed in the upper left area of the display. The pump may be stopped and restarted and any time by pressing the '✇' key. The pump run time is set in LSGAM software. Allow the gas readings to stabilize and press '⑤**Measure Flow**' key, this will store the gas level readings and display the '**PRESSURE READINGS**' screen. Note; a flashing bell will be displayed next to the appropriate gas and a beeping tone will be heard, if a preset alarm condition has been exceeded.
5. The '**PRESSURE READINGS**' screen will prompt the user to disconnect the sample tubes and allow the pressure to stabilize. Once the pressure has stabilized press '↵ **Zero Transducers**'. Press '①' to continue. **Note**; if Accu-Flo wellheads are used this zero function may be performed prior to connecting the sample tubes to the well head by selecting **'①** **MENU**' and highlighting '**ZERO TRANSDUCERS**'. This eliminates the need to disconnect and re-connect the sample tubes on the same wellhead.
6. If a temperature probe is not connected, the user is prompted to manually input the gas temperature, press the '↵' key when entry is finished.
7. The gas flow and energy screen is now displayed showing all the gas level readings taken in the gas read screen as well as the level of gas flow (SCFM) and power (BTU). In addition, Adjusted, Current and Previous (if downloaded) readings are displayed so modifications may be made to the well if required.
8. Pressing '↵ **STORE**' will save the readings to memory. Then, the comments screen (if comments were loaded) will display and allow you to answer questions or select comments about the condition of the well. A total of seven comments and one exclusive comment may be stored with each ID.
9. Press '③ **NEXT ID**' and proceed to the next wellhead. An automatic purge will be performed at this time to ensure the sample has been exhausted from the instrument.

For each reading, the following information will be stored:

- ID code.
- Current time/date.
- Site data (if entered).
- All gas readings and balance gas (CH_4, CO_2, O_2 (CO & H_2S for the Plus)).
- Barometric Pressure.
- Temperature.
- Gas Pod (if connected).
- Gas flow (SCFM) and Power (BTU).
- Comments and exclusive comment.

When the Instrument is switched off, a clean air purge is automatically started for a pre-determined global period. This may be aborted by pressing the '↵' key, although we do not recommend this action.

7 Field Operations

7.1 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 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 Oxygen 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 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.

As air is introduced into the landfill, the Oxygen is initially converted to Carbon Dioxide and residual Nitrogen 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 Carbon Dioxide is an intermediary step. Because Carbon Dioxide levels may fluctuate depending on the changing concentrations of the other constituent gases, Carbon Dioxide levels are not evaluated directly but are considered in light of other data.

In evaluation of residual Nitrogen, 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 Carbon Dioxide and the Oxygen 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 in the LFG, (about 1 percent, usually much less). This may affect field monitoring response factors, but otherwise it can be ignored.

7.2 Subsurface Fires

If very large quantities of air are introduced into the landfill, either through natural occurrence or overly aggressive operation of the LFG system, a partly unsupported subsurface combustion of the buried refuse may be initiated. Subsurface fire situations are difficult to control or extinguish once started, present health and safety hazards, and 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, Carbon Dioxide, and Hydrogen Sulfide are indicators of poorly supported combustion within the landfill.

7.3 Techniques for Controlling Landfill Gas

There are many techniques for controlling landfill gas extraction. These techniques represent tools, which are used together to control landfill gas. 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.

7.3.1 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.

7.3.2 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.

7.3.3 Controlling by Gas Composition

This method determines Methane, Nitrogen (balance gas) and other gas composition parameters 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 gas parameters, such as Carbon Monoxide, 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 and analysis at some fixed location 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, cost, and probably most important, 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.

7.3.4 Controlling by Flow Rate

This is a more exacting 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 volumetric quantity of landfill gas and the volumetric quantity 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 x percent Methane) or the quantity of BTUs recovered per hour (LFG flow x percent Methane x BTUs per cubic foot of Methane x 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 Oxygen 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.

7.4 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 cannot be overemphasized.

7.5 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 GEM2000 or magnehelic) or other device(anemometer/velometer)
- Velocity head (P or PT) (from GEM2000 or pitot tube and magnehelic)
- Wellhead gas flow (from GEM2000, 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.

7.6 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 GEM2000 or magnehelic)
- Velocity head (P or Pt) (from GEM2000 or pitot tube and magnehelic)
- Wellhead gas flow (from GEM2000, 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.

7.7 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.

Conditions within the landfill favor Methane production. Following are well field adjustment criteria and typical conditions for consideration:

- Methane quality (ranging from 26 percent upwards)
- 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

7.8 Establishing Target Flows

The goal is to establish a target flow which will likely produce the best possible Methane quality and minimum Oxygen 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, thus, well over-pull. These effects may not be immediately apparent.

Well adjustment 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.

7.9 Well Field Optimization

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

7.10 Migration Control—Dealing with Poor Methane Quality

If Methane and Oxygen 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 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.

7.11 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.
- Avoid well “over-pull” and maintain of a healthy anaerobic state within the landfill.
- Optimize LFG recovery for energy recovery purposes.
- Control nuisance landfill gas 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 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.

8 Troubleshooting

Problem	Corrective Action/Reason
Unit does not turn on or operation is erratic	Battery charge is too low-recharge batteries. Unit is too hot - cool down unit and try again. Contact Factory Service.
"Flow Fail" is displayed and an audible alarm is heard	The inlet is blocked. Remove blockage and retry. The particulate filter or water trap filter needs replacing.
Readings taken are not what was expected	Unit may be out of calibration. Calibrate unit with known gas concentration. Water trap or particulate filters are clogged. Replace filter(s).
Readings swing up or down wildly as they are being taken	Cell phones and other sources of RF interference can affect Methane readings. Don't use your cell phone while taking readings.
Unit displays***** or >>>>>	These symbols are substituted when the measured reading is out of range of the instruments capabilities in some fields or when a value needs to be entered manually such as temperature.
Oxygen reading is high on all wells	Check that the water trap housing is screwed on tight. Check or replace O-rings on the water trap and instrument inlet. Check the wellhead inset for cracks, replace O-ring on insert. Field calibrate Oxygen channel.
Unit will not download readings or an error occurs while downloading.	Verify that the communications software is the right version for the instrument being used. Check that the proper serial port is selected in the software. Contact Factory Service.
Methane and Carbon Dioxide readings drift	Perform a field calibration and check well again. Verify cal gas is flowing when regulator is turned on. Verify all connections are tight and filters are not clogged. Contact Factory Service.
Oxygen readings drift	Perform a field calibration - zero and span. Contact Factory Service.
Black screen displayed when unit turned On	Charge unit over night and try again. Unit too hot - cool down and try again. Try adjusting contrast level. Contact Factory Service.
Nothing happens when the Gas Pod is installed	Remove and re-seat the Gas Pod. Contact Factory Service.
Temperature does not update when temperature probe is installed	Check the probe fitting is fully seated. Check the probe plug is screwed together tightly. Contact Factory Service.

9 Service & Maintenance

9.1 Factory Service

LANDTEC is the ONLY authorized service center for the GEM™2000 / GEM™2000 Plus instruments. Factory service includes but is not limited to the following;

General operations
The main functions of the gas analyzers operation are checked to ensure that they are within specification.

Barometric pressure reading
The barometric pressure reading is checked to ensure it is within specification. This is carried out by way of comparing the atmospheric reading against a known standard. If necessary, reprogramming is quoted.

Static and differential pressure readings
The static and differential pressure transducers are checked to ensure they are within specifications. This is carried out by comparing instrument readings to a known standard, applying a known pressure and noting both readings. If necessary, reprogramming will be quoted.

Pump functionality (flow and vacuum)
All flow and vacuum functions of the internal pump are checked to ensure the operation is within specification.

Water ingress/blockage
The internal filters are checked for cleanliness and moisture ingress to ensure they are not contaminated.

Flow fail setting
The flow fail function is checked to ensure proper operation within the specified limits.

Gas pod and Temperature probe connectivity reading
The connectivity of the gas analyzer is checked to ensure correct operation and reading performance with accessories.

Computer controlled gas check
Inward and outward gas checks are carried out by way of connecting the gas analyzer to a custom built computer controlled 'gas checking rig' and proprietary software. At the inward stage, two sets of readings are taken - one using the customer's calibration settings and a second set using factory calibration settings. During this process a range of gases are used that span the reading range of the gas analyzer.

Structural and aesthetics check
The instrument is checked for cracks, scratches and broken or missing pieces.

9.2 Factory Service Facilities

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9.3 User Maintenance

This instrument is designed to be low maintenance and rugged however field calibrations are recommended prior to use or when the ambient operating temperature of the instrument changes more than +/- 20 degrees Fahrenheit. See section 4.7 for further information on field calibrations. Additionally it may be necessary to change the user accessible filters and o-rings from time to time.

There are two user accessible filters, the particulate filter is located in the back of the instrument, see section 2 for location, and the water trap filter which is part of the included hose kit. There are four user changeable o-rings, one on the particulate filter cover, one on the outside of the water trap filter housing, one on the inside of the water trap filter housing, and ones on the ends of the male quick connect fittings included on the hose kits.

10 Technical Specifications

10.1 Physical

Weight	4.4 lbs.
Size	L 2.48" x W 7.48'' x D 9.92".
Case material	Anti-static ABS.
Keys	Membrane panel.
Display	Liquid Crystal Display 40 x 16 characters. Fiber optic woven backlight for low light conditions.
Filters	User replaceable integral fiber filter at inlet port and external PTFE water trap filter.

10.2 General

Certifications	UL Certified to Class 1, Zone 1, AEx Ib d IIa T4
Temperature measurement	With optional probe 14°F to 167°F.
Temperature accuracy	±0.4ºF (± probe accuracy).
Visual and audible alarm	User selectable CO_2, CH_4 and O_2 Min/Max levels via LSGAM CS software.
Communications	RS232 protocol via download lead with variable baud rate.
Relative pressure	±250 mbar from calibration pressure

10.3 Power supply

Battery type	Rechargeable Nickel Metal Hydride battery pack containing six 4AH cells. **Not user replaceable**. Lithium Manganese battery for data retention.
Battery life	Typical use 10 hours from fully charged condition.
Battery charger	Separate intelligent 2A battery charger powered from AC voltage supply (110-230V).
Charge time	Approximately 2 hours from complete discharge.
Alternative power	Can be powered externally for fixed-in-place applications only. Contact LANDTEC for further information.
Battery lifetime	Up to 1,000 charge/discharge cycles.

10.4 Gas Ranges

Detection principle	CO_2 and CH_4 by dual wavelength infrared cell with reference channel. O_2 (and CO & H_2S in Plus) by internal electrochemical cell.
Oxygen cell lifetime	Approximately 18 months in air.
Typical Accuracy 0 - Full Scale	**Gas** **0-5% volume** **5-15% volume** **15%-FS** **CH_4** ±0.3% ±1% ±3% (100%) **CO_2** ±0.3% ±1% ±3% (60%) **O_2** ±1% ±1% ±1% (21%) **CO & H_2S in Plus Instruments** ±10%FS from 0-Full Scale
Response time, T90	CH_4 ≤20 seconds CO_2 ≤20 seconds O_2 ≤20 seconds

Range	CH_4 0-70% to specification, 0-100% reading. CO_2 0-40% to specification, 0-100% reading. O_2 0-25% CO (in Plus Instruments) 0-2000ppm H_2S (in Plus Instruments) 0-500ppm

10.5 Pump

Typical flow	300 cc/min.
Flow fail point	50 cc/min approximately.
Flow with 200 mbar vacuum	250 cc/min approximately.
Vacuum	70 inches H_20.

10.6 Operating Conditions

Operating temp range	32°F to 104°F.
Relative humidity	0-95% non-condensing.
Atmospheric pressure range	700-1200 mbar. Displayed in Inches of Mercury (5.9 – 35.4“Hg). Not corrected for sea level.
Atmospheric pressure accuracy	±5 mbar approximately.
Case seal	IP65.

10.7 Optional Gas Pods

Typical Accuracy (Subject to User calibration).	**Gas**	**0-Full Scale**
	CO	±10% FS
	H_2S	±10% FS
	SO_2	±10% FS
	H_2	±10% FS
	HCN	±10% FS
Response time, T90	CO	≤60 seconds
	H_2S	≤60 seconds
	SO_2	≤60 seconds
	H_2	≤60 seconds
	HCN	≤60 seconds
Range	CO	0-500ppm
	H_2S	0-50 or 0-200ppm
	SO_2	0-20 or 0-100ppm
	H_2	0-1000ppm
	HCN	0-100ppm

Product Specifications

Safe T Net 100
Single Point Gas Monitor

Continuous monitoring control system

Optional Accessories

- Duct mounting adapter (combustibles)
- Explosion proof, air aspirated pump (combustibles)
- Line cord with cable bushing (8 ft.)
- DC power supply with backup battery
- Signal horn, 115 VAC (weatherproof, non-hazardous areas)
- Red beacon, 115 VAC (non-hazardous areas)
- Calibration kits

Overview

Thermo Electron's Safe T Net 100 is the ideal instrument for continuous monitoring of combustible gases, toxic gases or oxygen at one location for the protection of workers and property. Microprocessor-controlled electronics provide simple operation and complete flexibility for selecting alarm logic and alarm thresholds. Thus, it is highly suitable for a wide variety of industrial and commercial applications.

Key Features

- Low maintenance, simple operation
- Two user settable alarms points and replays for activating external devices
- Reliable, field-proven detectors (sample-draw or diffusion style available)
- Durable weather and corrosion proof, NEMA 4X enclosure
- Industry standard 4 to 20 mA output provides interface to recorders, dataloggers and plant-wide control systems
- External amplifier models, with internal amplifier versions available for oxygen, LEL, carbon monoxide and hydrogen disulfide

A wide range of transmitters are available:

Standard Transmitter

FX-SMT (LEL) (combustible)

FX-SMT (oxygen/toxic)

Sample-Draw Transmitter

Safe T Net 100 Product Specifications

Power

AC Input	100 to 130 VAC, 50/60 Hz *or* 200 to 260 VAC, 50/60 Hz (specify input when ordering)
DC Input	12 to 16 VDC (1A maximum)

Output

Recorder	4 to 20 mA, 400 Ohm impedance maximum
Alarm Relays	One set of SPDT (Form C) contacts for each alarm level (Warn/Alarm and Fail conditions)
Audible Alarm	Case-mounted buzzer, 94 db at 1 ft., pulsing for Warn and Alarm, continuous for Fail
Display	Three digit, red LED
Status Indication	Four color coded LED's *Fail* **Yellow** - Sensor malfunction, down scale reading, open sensor wiring *Pilot* **Green** - Instrument powered on *Warn* **Orange** - Low level threshold exceeded *Alarm* **Red** - High level threshold exceeded

Controls

Potentiometer	Zero, Span, Warn and Alarm levels. Alarm delay adjustment
Push Buttons	Case-mounted external reset switch, resets latched alarms and acknowledges Warn alarms. Internal calibration alarm disable (5 min.) Warn and Alarm level display, alarm delay display
Alarm Logic	Latching or auto-resetting (switch selected). Increasing or decreasing alarm (switch selected). Time delay 0-16 sec. (adjusted by potentiometer)
DIP Switches	Alarm logic and relay operation

Environmental

Operating Temp.	-4°F to 113°F (-20°C to 45°C)
Relative Humidity	0 to 95% RH, non-condensing

Physical

Dimensions	10.94" (L) x 8.5" (W) x 6.5" (H) 278mm (L) x 216mm (W) x 165mm (H)
Weight	6.2 lbs. (2.3 kg)
Enclosure	Rating NEMA 4X, gray fiberglass with blue panel overlay
Conduit Connection	3/4 in. NPT, two hubs provided
Wire Terminations	Screw type terminal blocks, 12-gauge wire maximum

Area Classification

General purpose (combustible gas detectors can be mounted remotely in hazardous areas)

Approvals

Combustible gas sensor (part# 61-0101) approved for Class I, Division 1, Groups A, B, C and D

Gas	Formula	Standard Range
Ammonia	NH_3	0 to 100 ppm
Arsine	AsH_3	0 to 1.00 ppm
Carbon Monixide	CO	0 to 500 ppm
Chlorine	Cl_2	0 to 5.00 ppm
Chlorine Dioxide	ClO_2	0 to 2.00 ppm
Combustibles	several	0 to 100% LEL
Combustibles	several	0-5000 ppm
Diborane	B_2H_6	0 to 1.00 ppm
Fluorine	F_2	0 to 10.0 ppm
Hydrogen Chloride	HCl	0 to 30.0 ppm
Hydrogen Cyanide	HCN	0 to 50.0 ppm
Hydrogen Fluoride	HF	0 to 15.0 ppm
Hydrogen Sulfide	H_2S	0 to 100 ppm
Nitric Oxide	NO	0 to 100 ppm
Nitrogen Dioxide	NO_2	0 to 20.0 ppm
Oxygen	O_2	0 to 30.0% Vol.
Ozone	O_3	0 to 1.00 ppm
Phosphine	PH_3	0 to 1.00 ppm
Silane	SiH_4	0 to 15.0 ppm
Sulfur Dioxide	SO_2	0 to 20.0 ppm

Lit_STN100EID_12/04

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