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NATURAL GAS CHROMATOGRAPH LANDFILL APPLICATION INFORMATION

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NGC Landfill
Application Guide



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1.0 INTRODUCTION TO LANDFILL APPLICATIONS

1.1 Health & Safety Issues

Producing natural gas from existing and newly developed landfills is becoming more feasible each year. A number of issues are driving this technology. Governmental regulatory agencies are becoming increasingly involved as public health and safety concerns, as well as environmental issues, become political factors (see Figure 1). Public health and safety issues range from the annoying (e. g., unpleasant odors), to the truly dangerous (e.g., explosions, fires, ground water contamination and even asphyxiation).

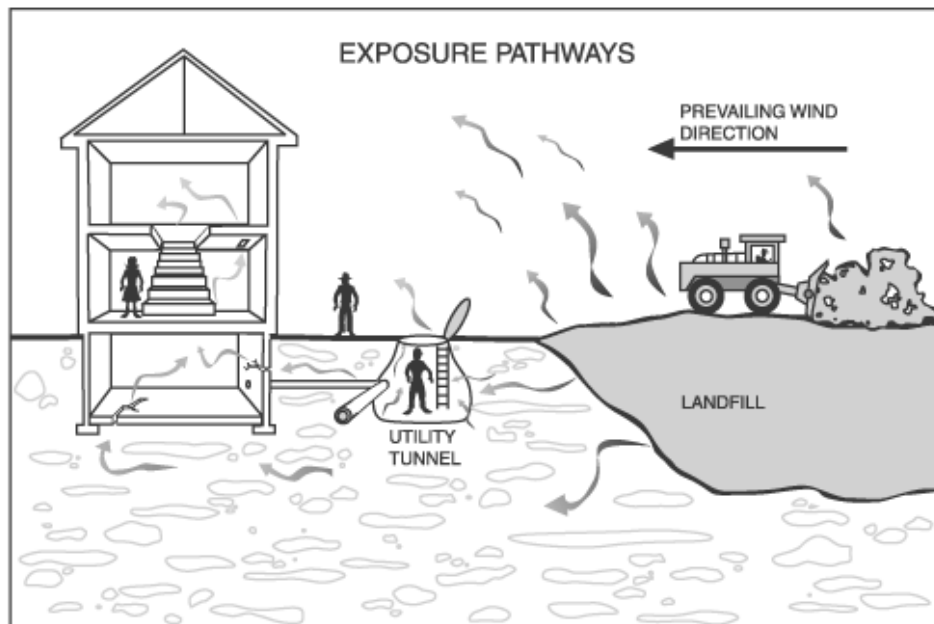


Figure 1 Gas Migration Paths
(Illustration courtesy of ATSDR, an agency of the CDC)

1.2 Passive vs. Active Collection

Landfills typically employ one of two methods to control the migration of landfill gases: passive and active systems. Passive systems rely on natural and man-made migration paths to control gas migration (see Figure 2). Impermeable liners (e. g., clay and/or geosynthetic membranes) can be used on the top, bottom and sides of landfills to create artificial migration paths and prevent the escape of dangerous gases. These barriers can also limit gases venting to the atmosphere and cause those gases to migrate toward collection wells (whether passive or active).

Collection wells (whether active or passive) are strategically placed throughout the landfill site. How many collection sites and their placement depends upon the type of material in the landfill, the well depth, soil compaction, water content and migration paths. Passive collection systems can be flared or use chemical reactions to eliminate any components that might pose a public nuisance or danger.

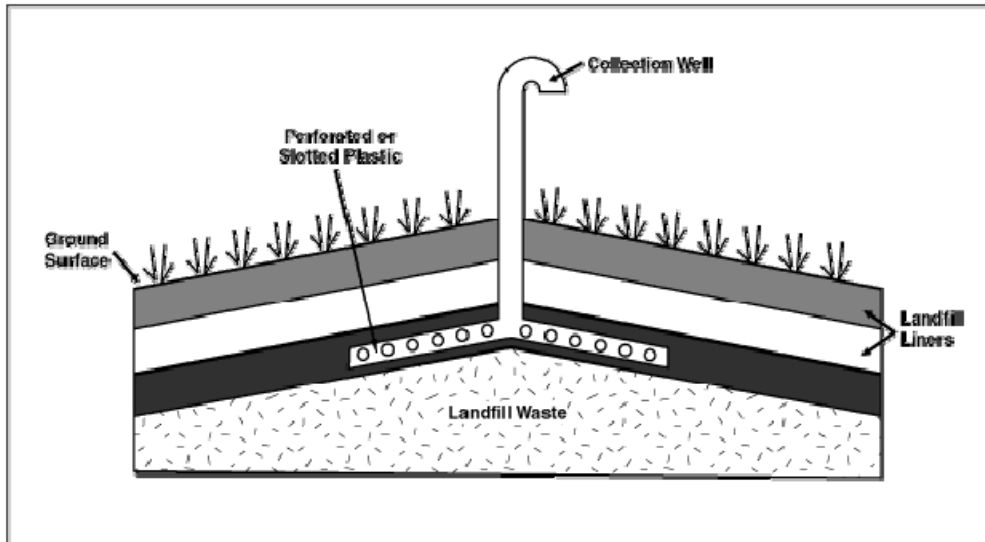


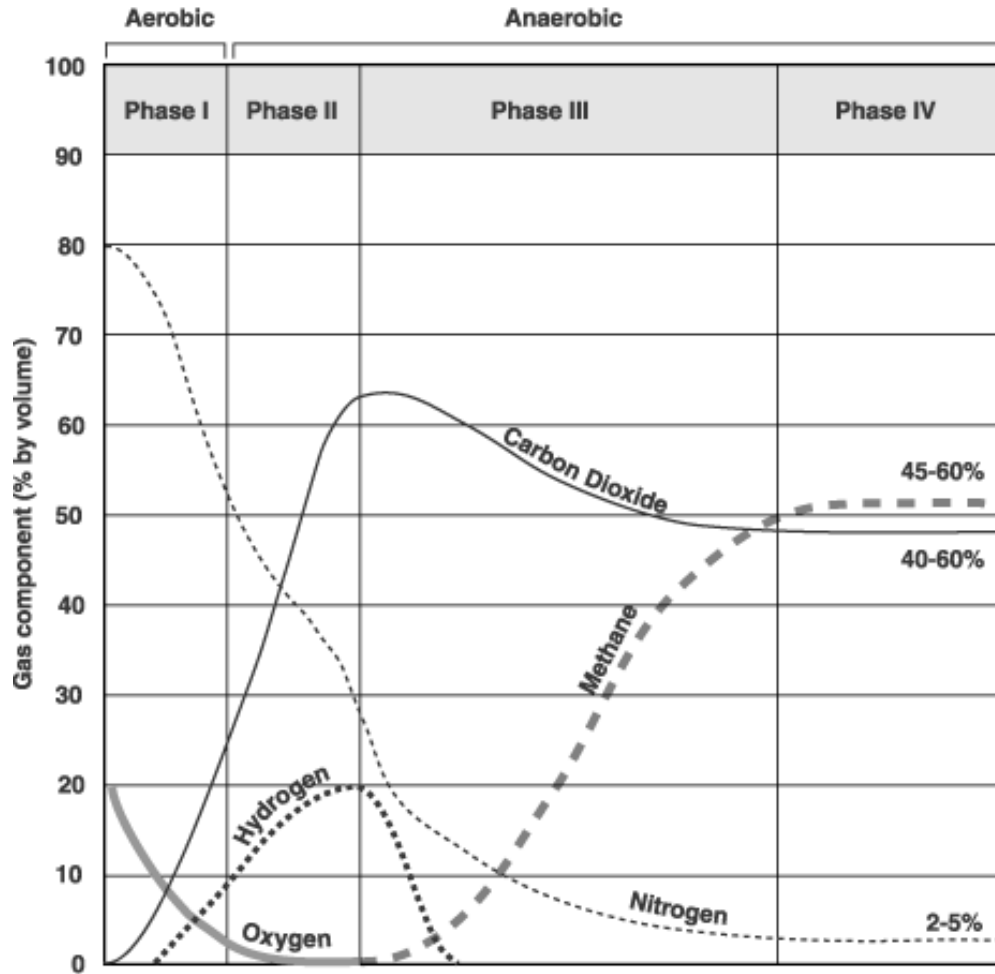
Figure 2 Passive Collection Vent
(Illustration courtesy of ATSDR, an agency of the CDC)

Active collection systems may be employed when it has been determined that the economic benefits might outweigh the system costs. Active systems use the gas produced by the landfill to heat or power nearby facilities. Some systems produce enough energy that it is worthwhile to consider generating electricity and selling it back to the local power grid. Active systems may employ blowers, vacuums, compressors, generators and other specialized equipment to collect and use the landfill gases.

1.3 Life Cycle and Feasibility of Active Collection

A landfill operation has a well-defined life cycle. The life cycle has four phases (see Figure 3):

- 1) The first phase, Phase I, is aerobic (oxygen is present). The output of the landfill is primarily nitrogen with some CO₂ and hydrogen.
- 2) In Phase II (and subsequent), phases are anaerobic (no oxygen present). Phase II produces mostly CO₂ with lesser degrees of nitrogen and hydrogen.
- 3) In Phase III, the CO₂ starts to level off at around 50%, while the methane is increasing rapidly to about 50%. Nitrogen and hydrogen are down around 5%.
- 4) In Phase IV, nitrogen has leveled off to about 2-5%, and CO₂ and methane are fairly constant at about 50% each.



Note: Phase duration time varies with landfill conditions

Source: EPA 1997

Figure 3 Landfill Phases of Operation
(Graph courtesy of the EPA)

1.4 Feasibility Factors

A number of factors can be useful in determining the feasibility of using landfill gases for power generation:

- 1) Does the landfill hold more the 1 million tons of waste?
- 2) What is the waste material?
 - a. Biodegradable waste
 - b. Sewage treatment sludge (raw and/or secondary)
 - c. Slaughterhouse waste
 - d. Food waste
 - e. Organic component of mixed municipal waste
 - f. Biomass (like maize)
- 3) Does the landfill cover more than 40 acres?

- 4) Is the waste at least 35 feet deep?
- 5) Warm, moist climates are better suited than cool, dry climates.
- 6) Is the energy user nearby?
- 7) Industrial guidelines suggest that gas recovery is feasible if the landfill produces 1 million cubic feet of gas per day.
- 8) Average landfill gases typically run about 500BTU/cubic foot. They may require blending before being sold to a local natural gas pipeline.
Typical component breakdown for Landfill applications:
 - a. Methane 54%
 - b. Carbon Dioxide 42%
 - c. Nitrogen 3.1%
 - d. Oxygen 0.8%
 - e. Carbon Monoxide (indicates underground combustion)
 - f. Hydrogen Sulfide typically less than 1%
- 9) Is this an abandoned landfill, or is it still in use? Landfills tend to be most productive in their first 20 years of service, although some continue to produce for 50 years or more.
- 10) Where is the landfill with regard to its life cycle?

The amount of energy that any specific landfill can produce will be dictated by many factors (size, age, materials in the landfill, climate, soil conditions, etc.), but typical installations tend to range between 3 and 8 megawatts. A 6 megawatt plant would produce about 47 million kilowatt-hours per year. This is enough to supply about 3,200 homes.

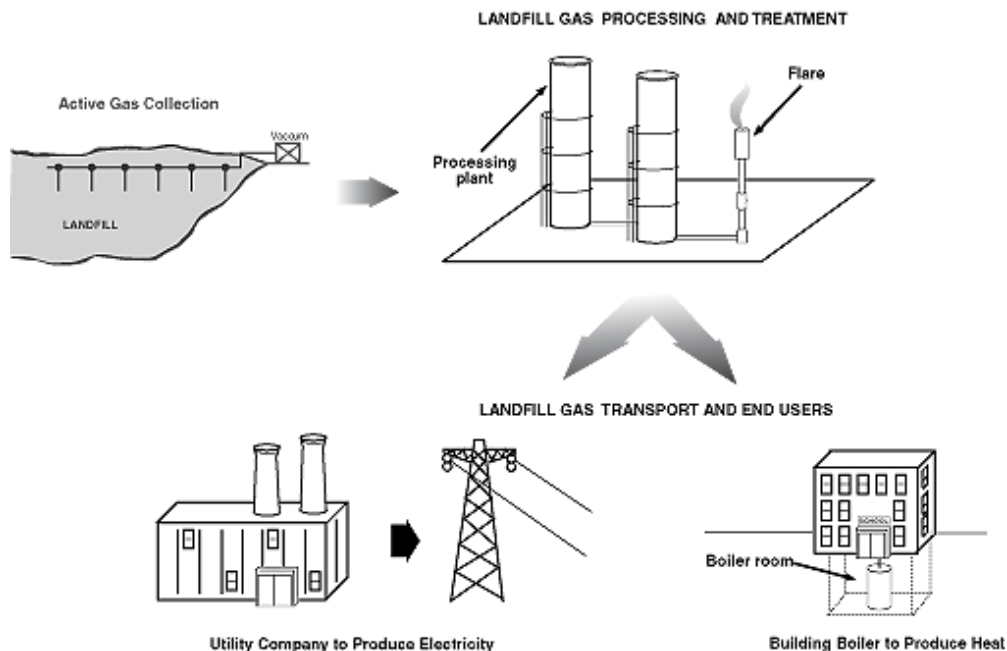


Figure 4 Active Collecting System
(Illustration courtesy of ATSDR, an agency of the CDC)

2.0 LANDFILL APPLICATION SPECIFICATIONS

2.1 Configuration Files for Landfill

Totalflow has created configuration files to support Landfill applications; however, configuration files alone will NOT necessarily turn the NGC into a Landfill application. The chromatograph requires columns specifically designed for the expected process composition. There are also various setup parameters that are not addressed through the configuration files. The Landfill application may also require a Landfill Sample System to provide adequate filtering and proper inlet pressures.

The Landfill application files make the following assumptions:

- Landfill configuration
- 3 possible sample systems
- 1 calibration stream
- NGC Modbus interface on Comm 2 and FCU Modbus interface on Comm 1
- 1 NGC 8203
- 1 FCU with static pressure, differential pressure and temperature input
- Sample probe at the sample point required

2.2 Application Parameters

The following table reflects the parameters that the Landfill chromatograph application is designed to operate with.

Table 2—1 Landfill Application Parameters

Component	Readable Ranges (mole%)	Minimum Detectable Levels MDL (mole%)	Repeatability
Propane+	0.05-100	0.001	+/- 1%
Methane	0.05-100	0.001	+/- 1%
Ethane	0.1-100	0.002	+/- 1%
Carbon Monoxide	0.2-100	0.02	+/- 2%
Carbon Dioxide	0.1-100	0.002	+/- 1%
Nitrogen	0.1-100	0.01	+/- 1%
Oxygen	0.2-20.0	0.01	+/- 1%
Hydrogen Sulfide	0.01-0.12	0.003	±2.0%
Hydrogen	0.5-20	0.2	+/- 1%

2.3 Measurement of H₂S

If measurement of H₂S is desired in an application, special design considerations must be applied in order to obtain an accurate analysis of the H₂S peak. Measurement of H₂S will result in increased system cost versus a system that does not measure and report H₂S.

Increased costs for the inclusion of the H₂S are predicated upon the following factors:

- Calibration Blend and Regulators: The Calibration Blend is designed to closely match the expected process stream. Measurable H₂S range is 100 – 1200 ppm. The blend must be contained within a bottle that is

suitable for the containment of H₂S. Additionally, the regulator must be made of components suitable for use with H₂S.

2.4 Suggested Calibration Blend

Table 2—2 Recommended Calibration Blend for Landfill Applications

Component	Standard Concentration (mole%)
Propane+	0.08
Methane	48
Ethane	0.13
Carbon Monoxide	0.25
Carbon Dioxide	45
Nitrogen	0.50
Oxygen	0.50
*Hydrogen Sulfide	0.035
Hydrogen	5.00

* Only if H₂S is to be measured and reported

3.0 RECOMMENDED SAMPLING SYSTEM

Totalflow sample system designs address low pressure inherent in landfill operation. The NGC8203 requires a flowing pressure between 5-15 PSI at the sample stream inlet for operation. Typical landfill sample system designs use a Di-Vac ® pump to increase the pressure of the sample stream.

Sample systems may include a combination of components and hardware configurations to achieve the desired conditions of the sample. This enables the optimum sample quality of the gas.

Depending on the moisture content of the recovered landfill vapor, there are multiple methods that can be used to increase the pressure and condition the sample for analysis. Below are two such methods:

- Method 1 –Increasing the sample pressure concentrates the stream components and moisture content of the stream. As the stream cools, this concentrate condenses to a liquid state and needs to be eliminated from the sample stream. Liquid can be expelled and drained via a series of separators and filter combinations, prior to GC sampling.
- Method 2 decreases stream moisture prior to the sample pump. Using a chiller system to decrease the dew point of the landfill inlet vapor before the sample is pressured. A portion of the moisture is eliminated before the sample is pressurized. After the pressurization, the stream is maintained above dew point to keep any entrained moisture in the vapor state. Stream temperature should not exceed 131°F. This can be accomplished by the use of a heated enclosure, heat traced sample line or a combination of both.

Sample systems are planned and designed based on site specifications. Close attention to site specifications is important for successful analysis.

FYI



Sample systems vary depending on specifications.



TIP

If the sample pressure is adequate and remains above 15 psig, the 2102024-002 sample conditioning module, in conjunction with a regulated sample probe, can be used.

3.1 Peak Find

The Peak Find process defines where (in elution time) the various component peaks can be expected during analysis. Shifts may cause the analysis process to improperly identify, or miss altogether, one or more process components. Factory configuration files define parameters that allow for a shift of $\pm 7.5\%$. Configuration files establish the column pressures that produced good peak times during factory testing.

Column pressures determine the elution time for the various components. The higher the column pressure, the faster the elution time. With lower column pressures, each component elutes from the sample stream more slowly.

The chromatogram shown in Figure 5 is from C3+-C2 column of the calibration stream. If the user is performing a manual peak find for this column, they should try to target C2 (ethane) to be at 140 seconds $\pm 10\%$ of value. In this example, C2 is at 140 seconds; however, had C2 come out early (i.e., 130 seconds), the user would drop the column carrier pressure to allow the elute time to increase (move peaks to the right). Conversely, if C2 had eluted at 150 seconds, the user should consider raising the column carrier pressure to encourage an earlier elution time (move peaks to the left).

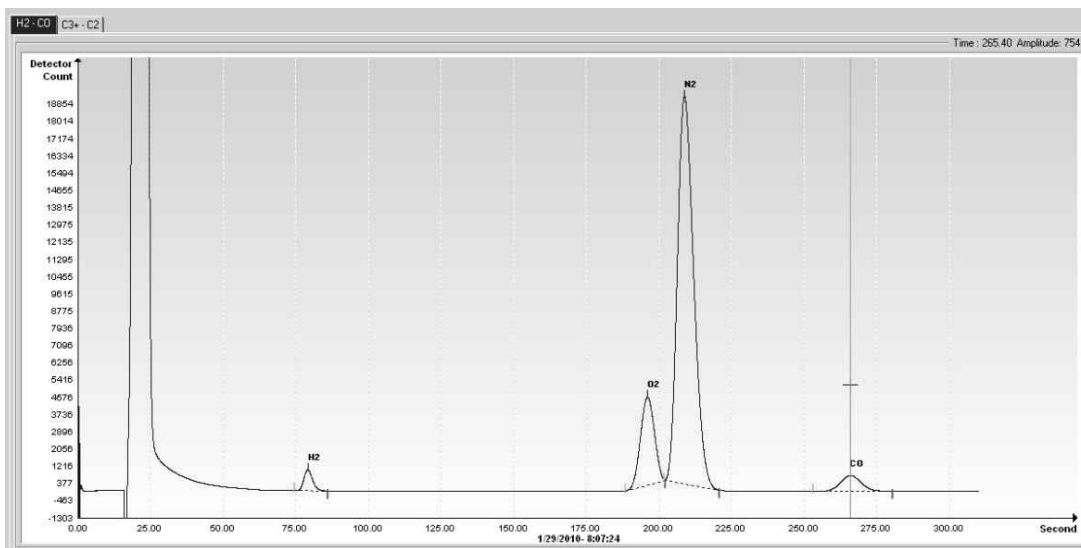


Figure 5 Column C3+ - C2 Calibration Stream

In Figure 6 the chromatogram is from the H2-CO column of the calibration stream. Here, the user would target the CO (carbon monoxide) to elute at 265 seconds $\pm 10\%$ of value. In the example, it is right at 265 seconds. Again, the higher the carrier pressure, the earlier the elution time (move peaks to the left). The lower the carrier pressure, the later the elution time (move peaks to the right). This chromatogram can be zoomed into to illustrate the low concentration of the component.

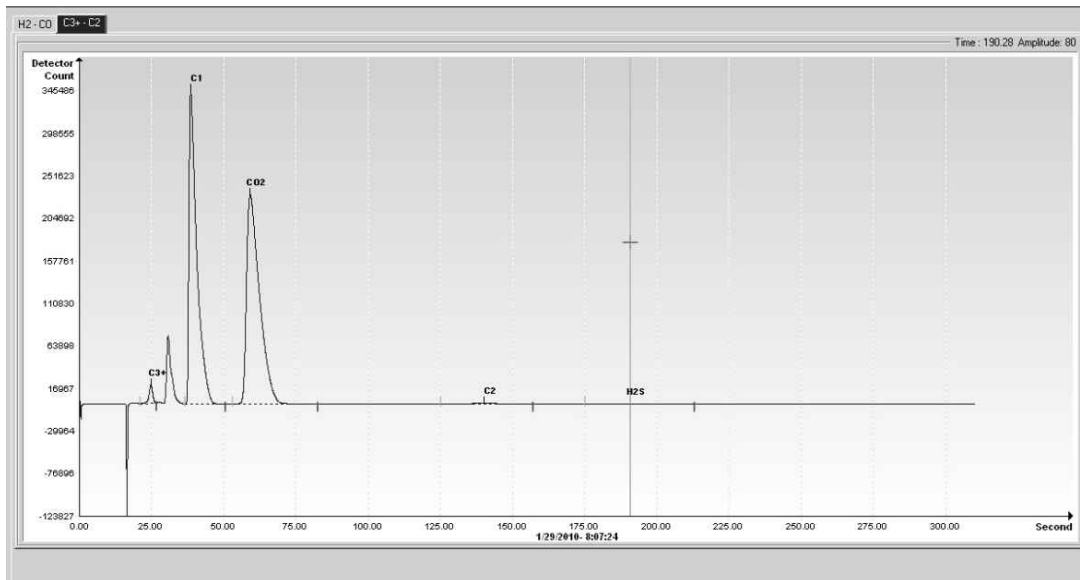


Figure 6 H2 - CO Calibration Stream

3.2 Labeling the Peaks

Several iterations of the Peak Find cycle may be required to properly adjust carrier pressure for the two chromatograms. When the carrier pressure is adjusted properly for the two columns (C2@140 sec. and CO@265 sec.), peaks will auto-label and gate.

By left-clicking and dragging the mouse, the user can zoom into the chromatograms in the Peak Find dialog box. Right-clicking provides several functions that will be helpful if labeling peaks is necessary.

To label a specific peak, the user must zoom in far enough that they can place the mouse's cursor beneath (or within) the specified peak area. The user can then right-click, and then Label Peak. The Manual Peak Label box will display (see Figure 7). Activate the drop-down on Peak Comp, and a component listing will be displayed. Select the appropriate component, and click Label Peak. Next, click the Send Setup button. To view the change, it will be necessary to click the Post Process button. Post Processing may take a few seconds to re-analyze and update the changes.

In this screen shot, the user has zoomed into C3+ -C2, and magnified the O2 and N2 peaks. The N2 peak was mislabeled as a second O2 peak. The user can then click on Label Peak and correctly label the peak as N2. Again, the user will have to click the Send Setup button and then the Post Process button to view the modifications.

If the user right-clicks and there is no Label Peak selection available, verify that gating marks are present on the component peak. The peak should have a green gating mark at the onset of the component and a red gating mark at the end of the component peak. If the gating markers are not present, no labeling will be permitted. Most of the gating issues are caused by peaks not falling in the correct elution time. This can be corrected by changing carrier gas pressures.

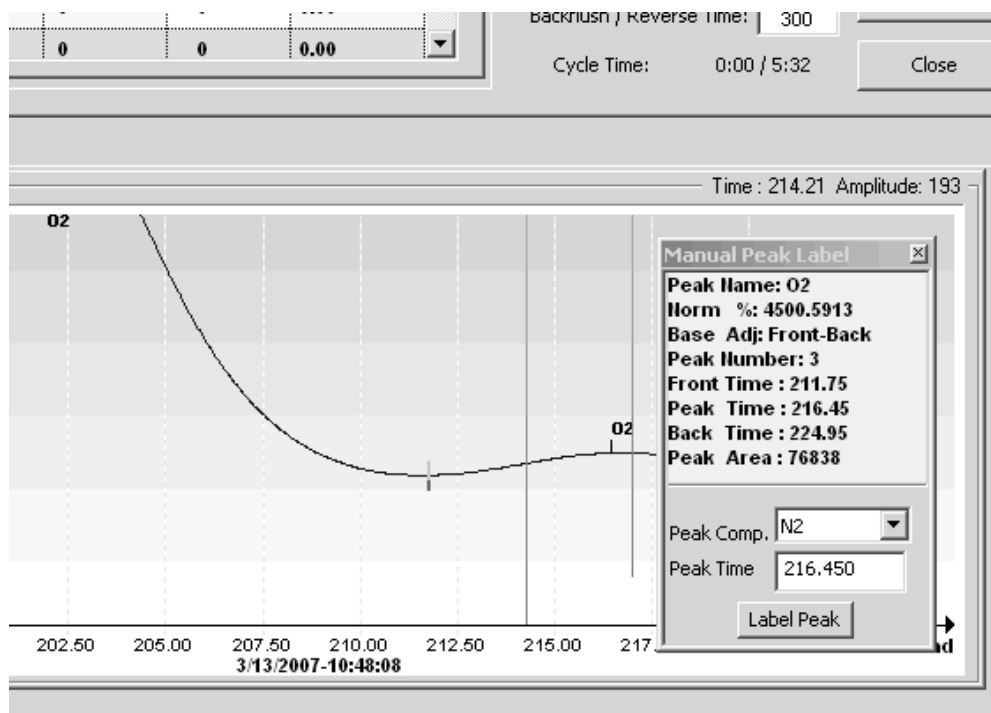


Figure 7 Labeling N2 of the O2N2 Separation

4.0 MANUAL CALIBRATION PROCEDURE

Manual calibration of the NGC is dependent upon a valid peak find. The user will benefit from reviewing the results of the previous peak find operation to insure that the NGC is ready to be calibrated. The user will recall from the previous section that the key components are ethane (C2) and carbon monoxide (CO). Ethane should elute from the C3+-C2 column at about 140 seconds (± 5 seconds). Carbon monoxide should elute out of the H2-CO column at about 265 seconds (± 5 seconds).

One way to determine the validity of the previous peak find operation would be to view the Raw Results/Individual Results section under the Stream used for calibration. Specifically, check Ethane and Carbon Monoxide along with the peak times and the Unnormalized Mole%. A correlation should also exist between the data in this table and the associated chromatogram.

Once it has been determined that the peaks are associated with the right components and that they are eluting at the proper times, the user is ready to run a calibration cycle.

The user should then insure that all components that are to be calibrated are labeled correctly and positioned.

On the Analyzer Operation page (see Figure 8), the user can click on the Cal button. The current cycle will complete, and the calibration cycle will be run.

When the calibration cycle has completed, the user can move into Calibration Results (on their Cal stream) and pull up the Individual Results (see Figure 9). The Unnormalized mole percent of each individual component should be similar to the user's calibration blend.

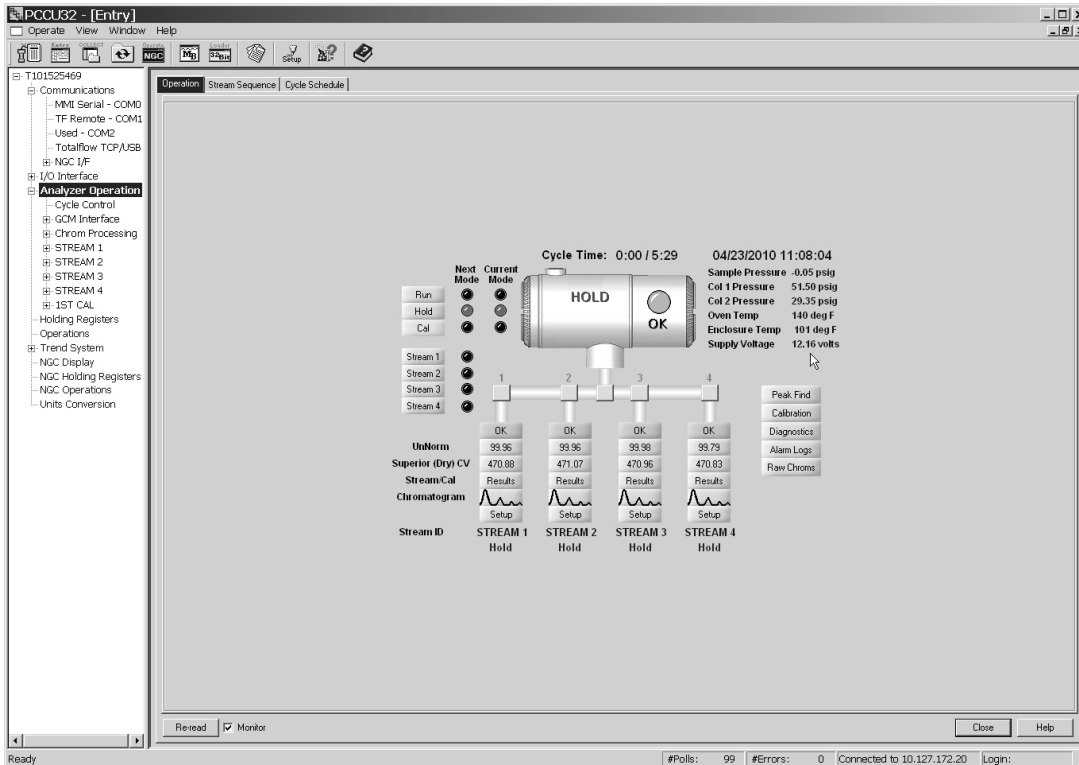


Figure 8 NGC User Interface

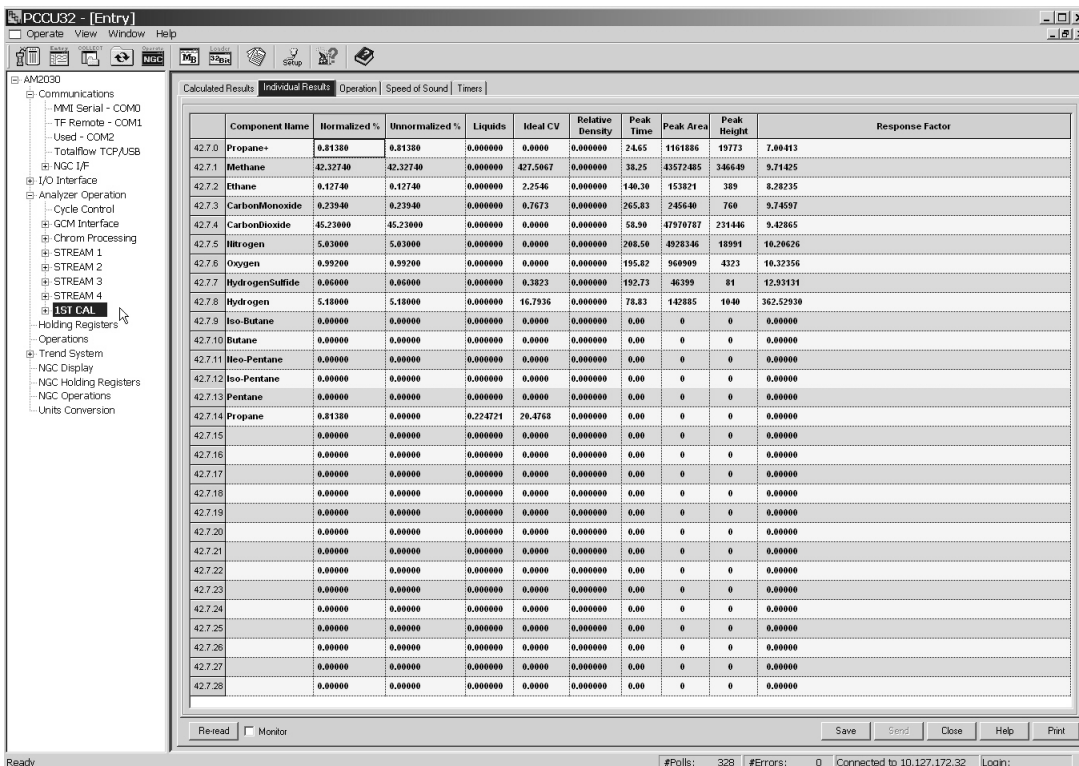


Figure 9 Calibration Results

5.0 MANUAL PEAK GATING

The 8203 has been configured at the factory for the Landfill application. From the NGC graphical interface, select View, and click on Expert. The user will see a warning that denotes that they are electing to operate in Expert mode. Click the Yes button to proceed.

Additionally, the following figures (Figure 10 and Figure 11) will show the user two chromatograms to give them an idea on what components they should expect and where (elution time) those components should be found.

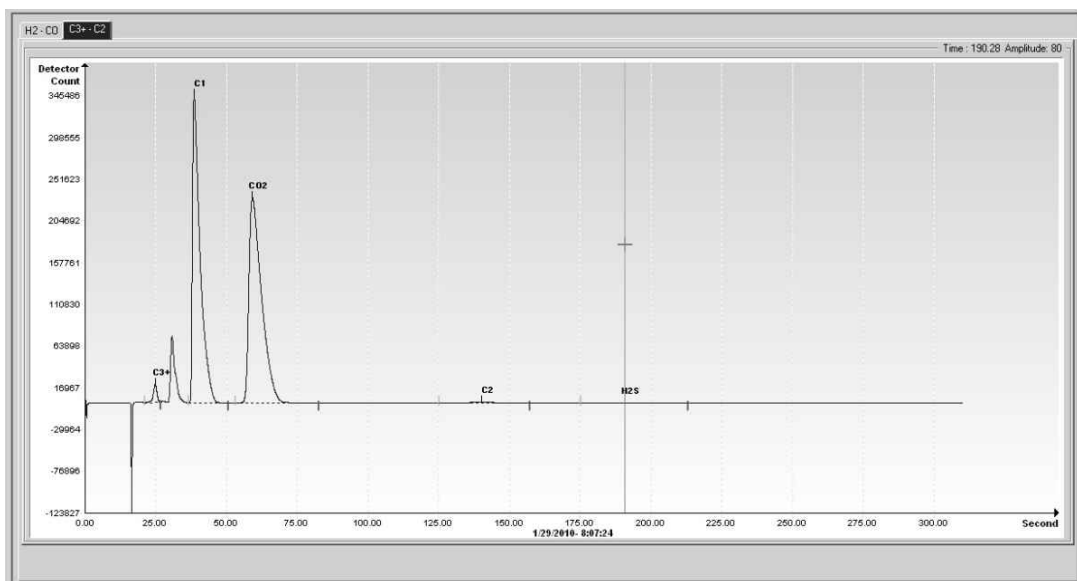


Figure 10 Typical Landfill Chrom C3+ - C2

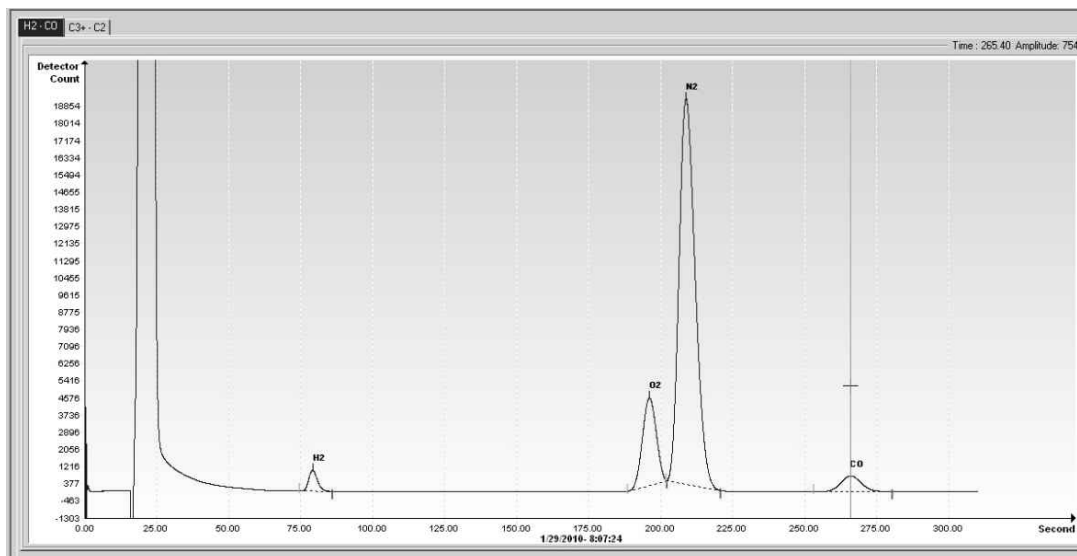


Figure 11 Typical Landfill Chrom-H2-CO

If the user's column pressures are set properly, the chromatograms should be similar to the two shown in Figure 10 and Figure 11.

Additionally, when a chromatogram was ran, the user should receive something that looks similar to Figure 12 and Figure 13.

As the user can see, when comparing the above Chrom (Figure 13) to the previous Chrom (Figure 10), H₂S is not being gated. Because of the low concentration of H₂S, auto-gating failed to gate the H₂S peak. When looking at the example (Figure 10), the user can see that H₂S should be eluting at about 190 seconds. In the next screen shot, the user can see that they have manually (AutoDetect = No) set gates for H₂S at 170 and 230 seconds.

Additionally, another row was added to the Peak Setup table. It is still auto-gating between 18 and 212 seconds, but manual gating was added from 170 to 230 seconds.

	Chrom Processing	Gate On	Gate Off	Slope(Run) Sample Periods	Slope(Rise) Det counts	Min. Peak Area	Front Height Ratio	Auto Detect	Peak Dir	Base Line Start	Base Line end
33.21.0	Yes	19.500	26.750	15	3	3000	0.7500	AutoPeaks	Pos	0.00	6.00
33.21.1	Yes	34.250	50.500	60	3	3000	0.7500	AutoPeaks	Pos	0.00	0.00
33.21.2	Yes	51.000	88.000	100	3	3000	0.7500	AutoPeaks	Pos	0.00	6.00
33.21.3	Yes	115.000	165.000	150	3	3000	0.7500	AutoPeaks	Pos	0.00	6.00
33.21.4	Yes	165.000	235.000	200	3	1000	0.7500	AutoPeaks	Pos	0.00	0.00
33.21.5	No	0.000	0.000	0	0	0	0.0000	AutoPeaks	Pos	0.00	6.00
33.21.6	No	0.000	0.000	0	0	0	0.0000	AutoPeaks	Pos	0.00	0.00
33.21.7	No	0.000	0.000	0	0	0	0.0000	AutoPeaks	Pos	0.00	6.00

Figure 12 Auto Gating

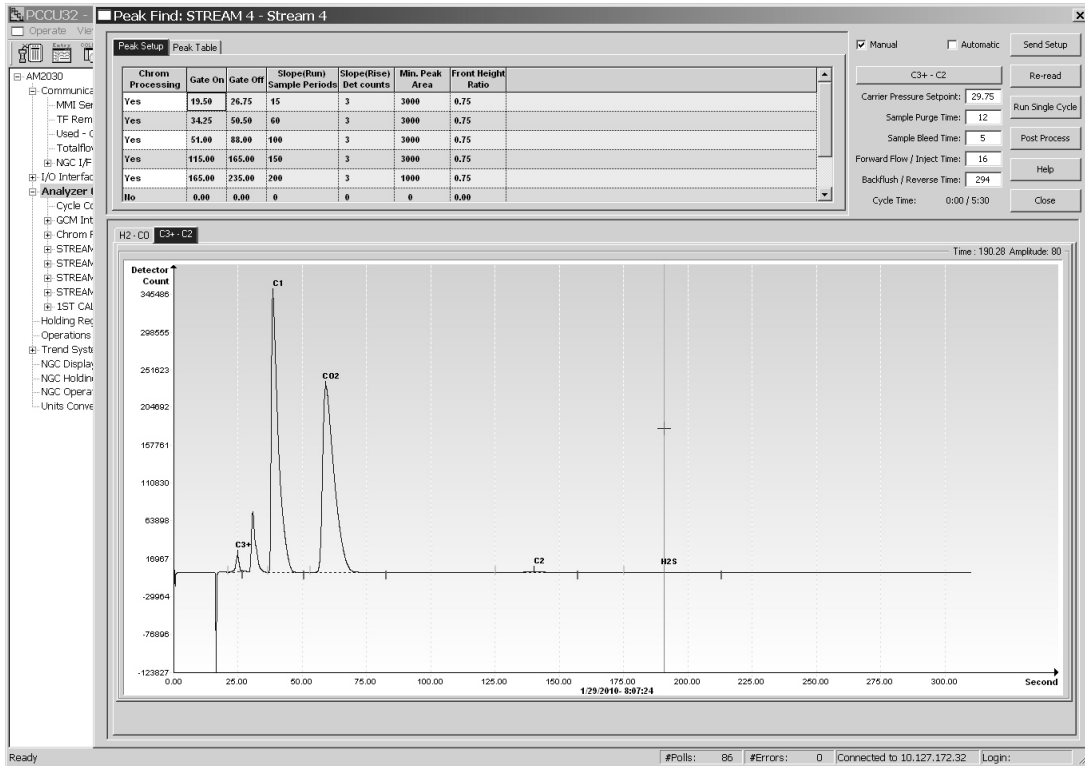


Figure 13 Auto-Gating Chrom-H2-CO



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