BACT for Lean Burn Digester Gas Fired Internal Combustion Engines

Addendum to January 24, 2008
Digester Gas IC Engine White Paper entitled
Concerning BACT: CO Emissions from Digester Gas Fired Lean Burn Engines

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REVISITING BACT FOR LEAN BURN DIGESTER GAS FIRED IC ENGINES

Preface

The purpose of this paper is to address additional information and lessons learned since the development of the February 21, 2008 BACT determination for lean burn (LB) digester gas (DG) engines. In addition, the recommendations in this determination make the BACT determination for LB DG engines more structurally consistent with the March 5, 2009 BACT determination for LB landfill gas (LFG) engines.

Introduction

On January 24, 2008, the District published a White Paper which addressed BACT for CO emissions from digester gas fired lean burn engines. This paper was developed in response to significant challenges digester gas engine operators were having achieving the 2.65 g/bhp-hr BACT standard on an ongoing basis due to normal engine performance degradation from siloxane deposition. The aforementioned paper recommended a new approach to BACT which established the previous 2.65 g/bhp-hr standard as an initial "clean engine" standard; added an action standard of 3.45 g/bhp-hr (implying that the engine performance might require special attention; and a not to exceed (NTE) standard of 3.77 g/bhp-hr, which represented the normal statistical 3 sigma boundary based on BAAQMD digester gas engine source tests.. The BACT recommendation also included an aggressive source testing schedule – weekly monitoring tests coupled with a mandatory annual top-end or overhaul maintenance event.

We have reopened the BACT discussion for LB DG engines as a result of lessons learned from the following:

- Existing DG engine source test results (per the original DG BACT White Paper)
- Working discussions with operations representatives of Oro Loma Sanitary District, Delta Diablo Sanitary District, Napa Sanitation District, and Bay Power Systems.
- 8 months of weekly monitoring events at source S-11 at Napa Sanitation District.

The goal of this review is to incorporate the information gleaned from the above sources and also to make the lean burn digester gas BACT determination more consistent (in the appropriate areas) with the LFG BACT determination of 03-05-200. Details follow.

Napa Sanitary District Weekly Testing/DG ICE Lessons Learned

The BACT review for digester gas fired IC engines was originally undertaken to address the difficulties experienced by Napa Sanitation District (NSD) in the operation of their DG cogeneration engine S-11, a 607 BHP Waukesha 2900 GL turbocharged and intercooled engine, designed to fire digester gas and/or natural gas. In general NAPA was able to comply with all emission requirements with the exception of CO. This is not

unlike other wastewater plants and/or landfills conditioned to 2.65 g/bhp-hr for CO emissions. As discussed in both the digester gas and landfill gas white papers, over time, the NOx BACT emission standard(s) have been regulated downward, along with the CO BACT standard. The process changes necessary to reduce NOx emissions tend to create conditions which favor increased CO emissions. For this reason compliance with lower CO limits has been consistently problematic.

In addition, as discussed in the previous papers, siloxane in waste gases forms glass-like deposits on combustion surfaces resulting in reduced combustion efficiency and uniformity, greater emissions variation and overall higher emissions with time. This degradation must be addressed in a way that allows for some degradation to occur so as to allow the waste gas conversion to energy to remain economically viable and therefore attractive over the alternative of flaring the waste gas which benefits no one.

Once the lean burn DG BACT standard was revised, the requirements were adopted into the change of condition application for engine S-11 at NSD. Based on the revised permit conditions, engine S-11 has operated since 3rd quarter 2008, and at this point it is appropriate to address the lessons learned from this operation as well as the recently revised landfill gas BACT standard and the lessons gleaned from extensive discussions with digester gas operations representatives from Oro Loma Sanitary District, Delta Diablo Sanitary District, Napa Sanitary District and Bay Power.

Since NSD restarted engine S-11 in clean condition in August, 2008, test data has been gathered for 28 weeks of operation, each test consisting of 30 minute averaging periods representing a total of 3375 total data points. The total data, showing all data points during each source test is shown in Appendix B. While the CO and NOx emissions data are in the expected ranges, the data shows how engine variation generally increases with time, while the emissions also tend to trend upwards. A comparison of the new NSD data with historical Bay Area POTW DG engines also indicates that the previously chosen NTE limit and the action standards is still consistent and should be used for DG fired LB IC engines. This data is presented in Appendix C.

In addition, we have learned that all digester gas engines are not operated the same. Some digester gas engines operate at very low RPM levels, between 900 and 1100 RPM. These engines are capable of operating in a very stable low-emissions fashion for up to five years or more, particularly if siloxane treatment systems are employed. Long run times are especially sought after for digester gas engines, since these engines are typically smaller than the comparable landfill gas engines with more frequent maintenance having a negative impact on operating economics. Digester gas engine operators have suggested that longer maintenance intervals should be allowed as long as the engine emissions are below condition limits.

Summary and Recommendation

The experience of Napa Sanitary District operating their digester gas engine under the revised conditions confirms that digester gas engines do generally perform at their best

after maintenance events and that combustion performance tends to deteriorate as siloxane deposits form throughout the combustion surfaces. Further, the test data confirms the appropriateness of the NTE and Action standards developed previously by statistical evaluations of the historical source test data.

The form of the standard can be improved by addressing certain other findings and to make the standard structurally similar to the BACT standard for landfill gas engines, revised March 5, 2009. The recommendations are as follows.

1) At present, there is not sufficient data to determine if certain DG engines are biased toward low NOx or low CO emissions as in the case of LFG engines. Therefore, we do not recommend paired standards for NOx and CO as in the case of LFG engines. Instead, we recommend keeping the statistically developed NTE standard of 3.77 g/bhp-hr as well as the action standard of 3.45 g/bhp-hr. The initial (post-maintenance event) standard remains at 2.65 g/bhp-hr, which must be demonstrated by a compliance demonstration source test.

2) Requiring a top-end or major maintenance event on a yearly basis, whether needed or not, may be unnecessary and inappropriate – particularly for the typically smaller digester gas engines that may be operating well within their established limits. Digester gas engine operators report consistent operation of their engines up to 60 months, when used in conjunction with siloxane removal systems on low RPM engines. In the case of Napa Sanitation District, the cost for a recent top end maintenance event in July 2008 was almost $20,000.

   Landfill gas engines are allowed longer operating periods as long as the engines are operating within emission standards, and this course is appropriate for digester gas engines as well. For digester gas engines, the action level is 3.45 g/bhp-hr. Compliance with this action level may be demonstrated by either the equivalent ppm standard from regular monitoring or by conducting a full compliance source test.

   Similar to the landfill gas BACT determination, we are recommending allowing the digester gas engine operator to run the engine for an economic period of time as long as CO emissions remain below the action standard. Once the action standard has been exceeded, the operator may either conduct a full compliance demonstration source test to determine if the emissions exceed the g/hp-hr limit of 3.45 g/bhp-hr or may choose to take the engine out of service and have maintenance performed (returning the engine to the initial BACT standard) within 12 months of the CO exceedance. For engines feeding digester gas that is <u>not</u> treated to remove siloxanes, we are recommending a maintenance event at a frequency of at least every 26,000 hours of engine operation or 36 calendar months after the most recent baseline maintenance event. The baseline maintenance

event is conducted to return the engine to the initial CO emission limit. This assumes that during the operating period the engine met all emission standards and CO emissions did not exceed the action level.

As an incentive to install digester gas siloxane removal or reduction equipment, we are recommending a maintenance event frequent for engines feeding digester gas that is treated to remove or reduce siloxanes of at least 43,000 hours of engine operation or 60 calendar months after the most recent baseline maintenance event. Again, this assumes that during the operating period the engine met all emission standards and that CO emissions did not exceed the action level.

3) The established lean burn digester gas CO NTE level will remain as is at 3.77 g/bhp-hr. All emission calculations for cumulative increase, etc would be based on this value. Once the ppm equivalent NTE limit is exceeded, like the action level, the operator has the option of performing a full compliance demonstration source test to determine if the CO emissions exceed 3.77 g/bhp-hr or must shutdown the engine for maintenance (to return the engine to the initial BACT standard) within 30 days.

4) Require monthly emissions monitoring rather than weekly monitoring, since the monthly frequency is adequate to observe emission trends and engine performance. A comparison between weekly and monthly monitoring scenarios is shown in Appendix C. This data from Napa as well as the daily landfill gas data from Altamont was considered recently when the monthly monitoring frequency was established for landfill gas fired engines. These graphs show that monthly monitoring is adequate in determining engine performance trends, and that weekly monitoring is not necessary. Monthly testing adequately shows emissions trends, and is a cost-effective way to plan for engine maintenance events.

5) Annual source testing will continue to be required, although the engines need to be returned to the initial BACT standard based on the engine emissions performance, as noted previously, or at least after the maximum maintenance frequency allowed as noted in item 2, above.

6) The ppm equivalent standard for the purposes of monthly monitoring should be based on digester gas methane content of 60% (proven by DG tested heating values) and thermal efficiency should be higher than for landfill gas engines. For the purpose converting from g/bhp-hr to ppm landfill gas engines are assumed to operate at 30% gross efficiency. Digester gas engines have a higher heat content and the fuel is more stable than landfill gas, therefore digester gas engines should be at least as efficient, if not more efficient, than the landfill gas engines. For the purposes of converting from g/bhp-hr to ppm @ 15% oxygen, an engine

efficiency of 31% will be used for digester gas engines, particularly since engine manufacturers typically quote up to 35% efficiency.

Proposed Sample Conditions for Implementation of Revised BACT Standard

The following sample permit conditions represent the requirements for NOx, CO, testing and maintenance as per the enclosed BACT standard (Appendix A), and may be used as a template for permit development.

1. Nitrogen Oxide (NOx) Emission Limits:

   NOx emissions shall not exceed 1.25 g/bhp-hr of NO_x (calculated as NO_2). The owner or operator may demonstrate compliance with this part by having a NO_x concentration at the engine exhaust of no more than 86 ppmv of NO_x, corrected to 15% oxygen, dry basis. An exhaust concentration of more than 86 ppmv of NO_x shall not be deemed a violation of this part, if the owner or operator conducts a Part 3a Compliance Demonstration Source Test within 30 days of measuring the NO_x concentration excursion, and this source test demonstrates NO_x emissions do not exceed 1.25 g/bhp-hr. (Basis: BACT)

2. Carbon Monoxide (CO) Emission Limits:

   a) Initial and/or Post Maintenance Event CO Limit: Upon startup after an engine maintenance event, carbon monoxide (CO) emissions from each engine shall not exceed 2.65 g/bhp-hr.

   b) Not to Exceed (NTE) Limits: Ongoing CO emissions shall not exceed 3.77 g/bhp-hr. The owner or operator may demonstrate compliance with this part by having a CO concentration at the engine exhaust of not more than 429 ppm of CO, corrected to 15% oxygen, dry basis. An exhaust concentration of more than 429 ppm of CO shall not be deemed a violation of this part, if the owner or operator complies with one of the following requirements within 30 days of measuring the CO concentration excursion. (Basis: BACT)

      i) Conduct a Part 3a Compliance Demonstration Source Test, which demonstrates that CO emissions do not exceed 3.77 g/bhp-hr, or
      ii) Shutdown the engine as soon as possible, but within 30 days and perform a maintenance event to achieve an emission level of less than or equal to 2.65 g/bhp-hr.

      An exhaust CO concentration that exceeds 3.77 g/bhp-hr, based on a Part 3a compliance demonstration test, shall be deemed a violation of this section, requiring the operator to shutdown the engine as soon as practicable to conduct an engine maintenance event to return the engine to the initial CO limit of 2.65 g/bhp-hr.

For the purpose of these permit conditions, the term maintenance event is meant to refer to the situation-specific maintenance required to return the engine emission performance to the initial CO limit.

3. Testing and Monitoring Requirements:

In order to demonstrate compliance with applicable standards of Parts 1 and 2, the owner or operator shall comply with all of the following testing and monitoring requirements.

a) Compliance Demonstration Source Test (initial, annual and post maintenance source tests): The owner or operator shall ensure that a District-approved compliance demonstration source test is conducted within 360 hours of each initial startup or post maintenance startup of each engine and annually thereafter. Annual source tests shall be conducted no later than 12 calendar months after the previous source test, shall be conducted while the engine is operating at conditions representative of normal operation, and shall determine all items identified in Parts 3a(i-vi), below. The owner or operator shall notify the District Source Test Section at least 7 days in advance of each source test. Compliance demonstration test reports shall be submitted to the Source Test Section within 60 days of the test date. The compliance demonstrate source test shall determine and report the following information:

   i. Total flow rate of gaseous fuel to each IC Engine (dry basis);
   ii. Concentrations (dry basis) of carbon dioxide (CO_2), nitrogen (N_2), oxygen (O_2), methane (CH_4), and total non-methane organic compounds (NMOC) in the combined gaseous fuel burned in each IC Engine;
   iii. Exhaust gas flow rate from each IC Engine (dry basis);
   iv. Concentrations (dry basis) of NO_x, CO, CH_4, NMOC, and O_2 in the exhaust gas from each IC Engine;
   v. Emissions rate of NO_x and CO in units of grams of pollutant/brake horsepower-hour.
   vi. CO, NO_x and O_2 concentrations in the exhaust from each engine shall be measured in tandem using the portable gas analyzer method used for the monthly emissions monitoring required by Part 3b.

b) Monthly (Portable Analyzer) Emission Monitoring Test: The owner or operator shall conduct an emissions monitoring test on a calendar month basis. The interval between required monthly monitoring events shall be at least 15 days. This monthly test shall determine concentrations of NO_x and CO in units of ppmv @ 15% oxygen using a District approved portable analyzer. All emission monitoring tests shall be conducted with the engine operating either at conditions representative of normal operation unless otherwise specified. The analyzer shall be calibrated, maintained, and operated in accordance with the manufacturer's specifications and recommendations. NO_x and CO

readings at 15% oxygen shall be averaged over a consecutive 15-minute period. (Basis: Regulations 2-1-403, 9-8-501, and 9-8-503)

The owner or operator may elect to perform a part 3a compliance demonstration source test in lieu of or in addition to any monthly monitoring test. If a compliance demonstration source test is performed, the results in units of g/bhp-hr shall be used in preference to monthly ppm monitoring results.

c) Monitoring and testing analytical accuracy is ten percent (Basis: Source Test Section policy)

4. Maintenance Requirements: The owner or operator shall conduct an engine maintenance event in accordance with the following maintenance frequencies:

a) Overhaul Frequency; CO emissions >392 ppm CO @ 15% oxygen (3.45 g/bhp-hr equivalent): In the event that the monthly emission monitoring test indicates emission levels greater than the action limit of 392 ppm CO at 15% oxygen (3.45 g/bhp-hr equivalent), the owner or operator may either accept the test result and comply with the maintenance event frequency in this subpart, or elect to perform a compliance demonstration source test to determine the engine emission levels in g/bhp-hr. If a compliance demonstration source test is performed, the results in units of g/bhp-hr shall be used in preference to monthly ppm monitoring results for determining if engine emission levels exceed the action limit.

If the engine emissions are determined to exceed the action limit, the owner or operator shall perform an engine maintenance event to return the engine to the initial CO limit of 2.65 g/bhp-hr within 12 calendar months of the source test date (or monthly monitoring test date) showing CO emissions exceeded the action limit.

b) Overhaul frequency; CO emissions ≤ 392 ppm CO @ 15% oxygen (3.45 g/bhp-hr equivalent): In the event that the digester gas treatment system does not include siloxane reduction systems, and the routine monthly emission monitoring tests do not exceed the action limit of 392 ppm @ 15% oxygen (3.45 g/bhp-hr equivalent), the owner or operator shall perform an engine maintenance event to return the engine to the initial CO limit of 2.65 g/bhp-hr at the following frequencies:

i. Facilities with Siloxane DG Treatment Systems (carbon adsorption or equivalent): Maximum interval between engine maintenance events shall not exceed 43,000 hours or 60 calendar months of operation, whichever comes first, as long as all other applicable pollutant standards are met.

ii. Facilities without Siloxane DG Treatment Systems: Maximum interval between engine maintenance events shall not exceed 26,000 hours or 36 calendar months of operation, whichever comes first.

For the purpose of complying with this part, the engine shall be considered to operate for a calendar month if the engine is operated with digester gas feed for more than 372 hours in any calendar month. (Basis: Regulation 2-1-403)

5. The owner or operator shall keep the following records on site in a District-approved log.

a) Monthly (calendar) records of the amount and hours of operation on each type of fuel combusted at the source.

b) Monthly monitoring test results including, date, averaging time and NOx, CO concentrations converted to 15% oxygen basis.

c) Records of all compliance source tests performed including the instrument calibrations and comparative handheld monitoring test results.

Records shall be made available to the APCO, upon request, for a period of at least two years after record entry.

APPENDIX A

BAY AREA AIR QUALITY MANAGEMENT DISTRICT Best Available Control Technology (BACT) Guideline

Source Category

Source:	**IC Engine – Digester Gas Fired**	**Revision:**	**2**
		Document #:	**96.5.2**
Class:	**> 50 Hp Output**	**Date:**	**5/14/2009**

Determination

Pollutant	BACT 1. Technologically Feasible/ Cost Effective 2. Archived in Practice	TYPICAL TECHNOLOGY
POC	1. 0.6 g/bhp-hr[a] 2. 1.0 g/bhp-hr[a]	1. n/s[a] 2. Lean Burn Technology[a]
NOx	1. 1.0 g/bhp-hr[a] 2. 1.25 g/bhp-hr[a, c]	1. n/s[a] 2. Lean Burn Technology[a]
SO_2	1. n/s[a] 2. 0.3 g/bhp-hr[a]	1. Digester gas treatment w/ > 80% H_2S removal[a] 2. Digester gas pretreatment to remove H_2S[a,f]
CO	1. 2.1 g/bhp-hr[a] 2. a) Initial Standard[b,c, e, f]: 2.65 g/bhp-hr. b) Not to Exceed (NTE) Standard [d, e, f, h, i]: 3.77 g/bhp-hr c) CO emissions based/minimum overhaul schedule. [d, e, f, h, i].	1. n/s[a] 2. Lean Burn Technology[a]
PM_{10}	1. n/d[a] 2. n/s[a]	1. n/d[a] 2. Digester gas pretreatment[a,f]
NPOC	1. n/a[a] 2. n/a[a]	1. n/a[a] 2. n/a[a]

APPENDIX A

References & Notes

a. BAAQMD Published Waste Gas IC Engine BACT Determination, 6-2-1995, Revision 3.

b. BAAQMD Permit Application #16907, 1-29-2008.

c. Source test required within 60 days of engine startup after baseline maintenance event.

d. Ongoing compliance demonstrated by monthly ppm monitoring (with handheld analyzer for NOx and CO:

- NOx Limit: 1.25 g/bhp-hr (as NO2) = 86 ppm @ 15% oxygen
- Action CO Level: 3.45 g/bhp-hr = 392 ppm @ 15% oxygen
- Not To Exceed (NTE) Level: 3.77 g/bhp-hr = 429 ppm @ 15% oxygen

If the action level of 3.45 g/bhp-hr (392 ppm @ 15% oxygen) is exceeded, engine must be shutdown for maintenance within 12 months of the CO excursion.

Exceeding the CO NTE of 429 ppm @ 15% oxygen triggers either

1) Full compliance source test to determine g/bhp-hr NOx and CO emissions (note: if the compliance source test demonstrates engine CO emissions exceed 3.77 g/bhp-hr the District has cause to issue a violation notice and the engine must be shutdown as soon as practicable for maintenance event), or
2) Operator must shutdown engine within 30 days for maintenance.

Notes:

1) ppm to g/bhp-hr conversions based on DG methane content of 60% and engine mechanical efficiency of 31% (gross heat input to shaft horsepower). The owner or operator may request a revised ppm equivalent level based on site specific engine and digester gas characteristics.
2) Analytical accuracy of monitoring and testing methods is ten percent.

e. Minimum engine maintenance frequency-facilities <u>without</u> siloxane removal systems: Engine baseline maintenance event to return the engine to initial CO standard may be deferred until 26,000 hours or 36 calendar months of operation after the most recent source test, whichever comes first, if all standards are met, and CO emissions do not exceed the action level.

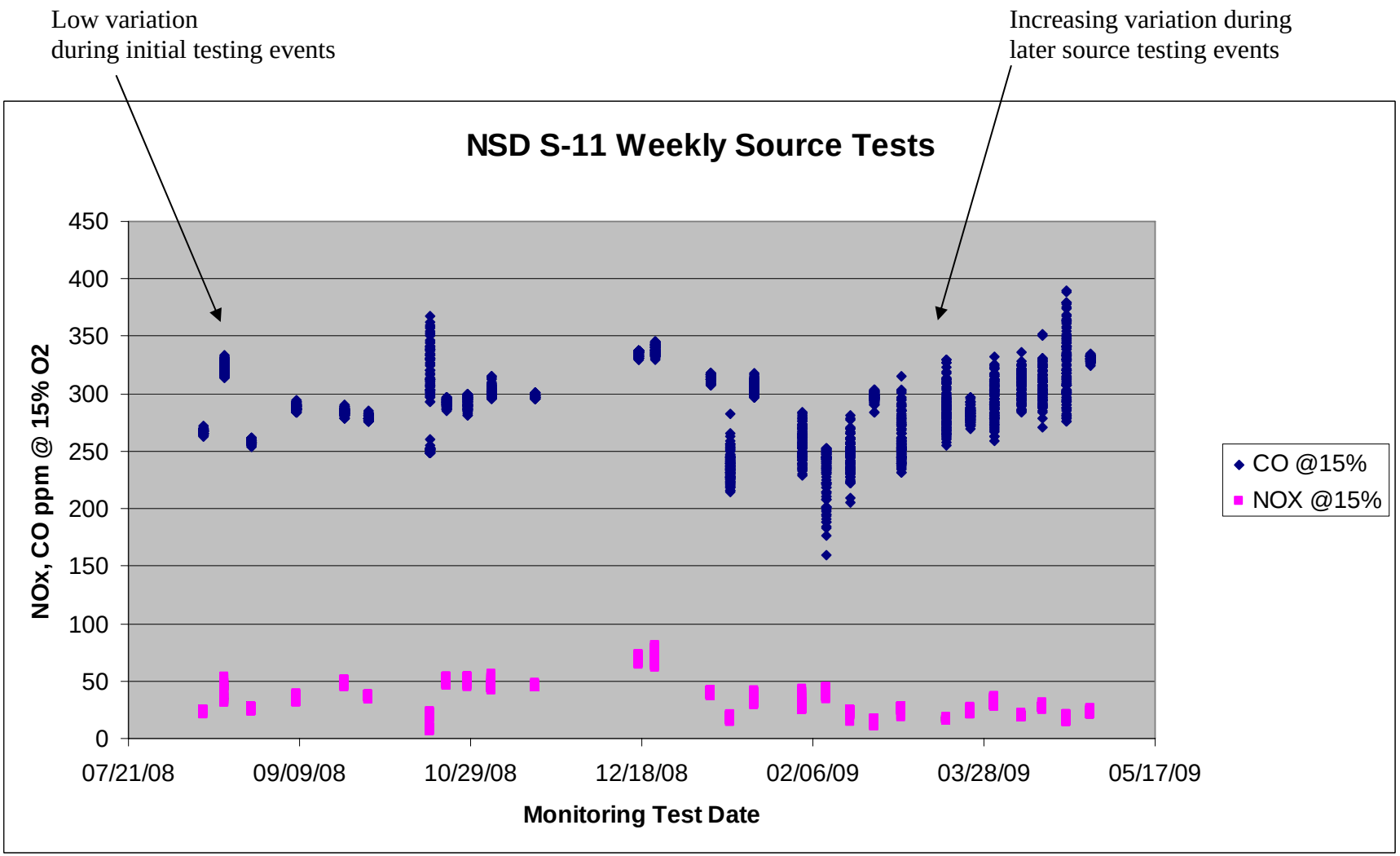
f. Minimum engine maintenance frequency-facilities <u>with</u> siloxane removal systems (carbon adsorption or equivalent): Engine baseline maintenance event to return the engine to initial CO standard may be deferred until 43,000 hours or 60 calendar months of operation after the most recent source test, whichever comes first, if all standards are met, and CO emissions do not exceed the action level.

g. Digester gas pretreatment: Ferric chloride injection into wastewater and/or addition of iron salts to digester sludge and/or iron sponge filtration of digester gas.

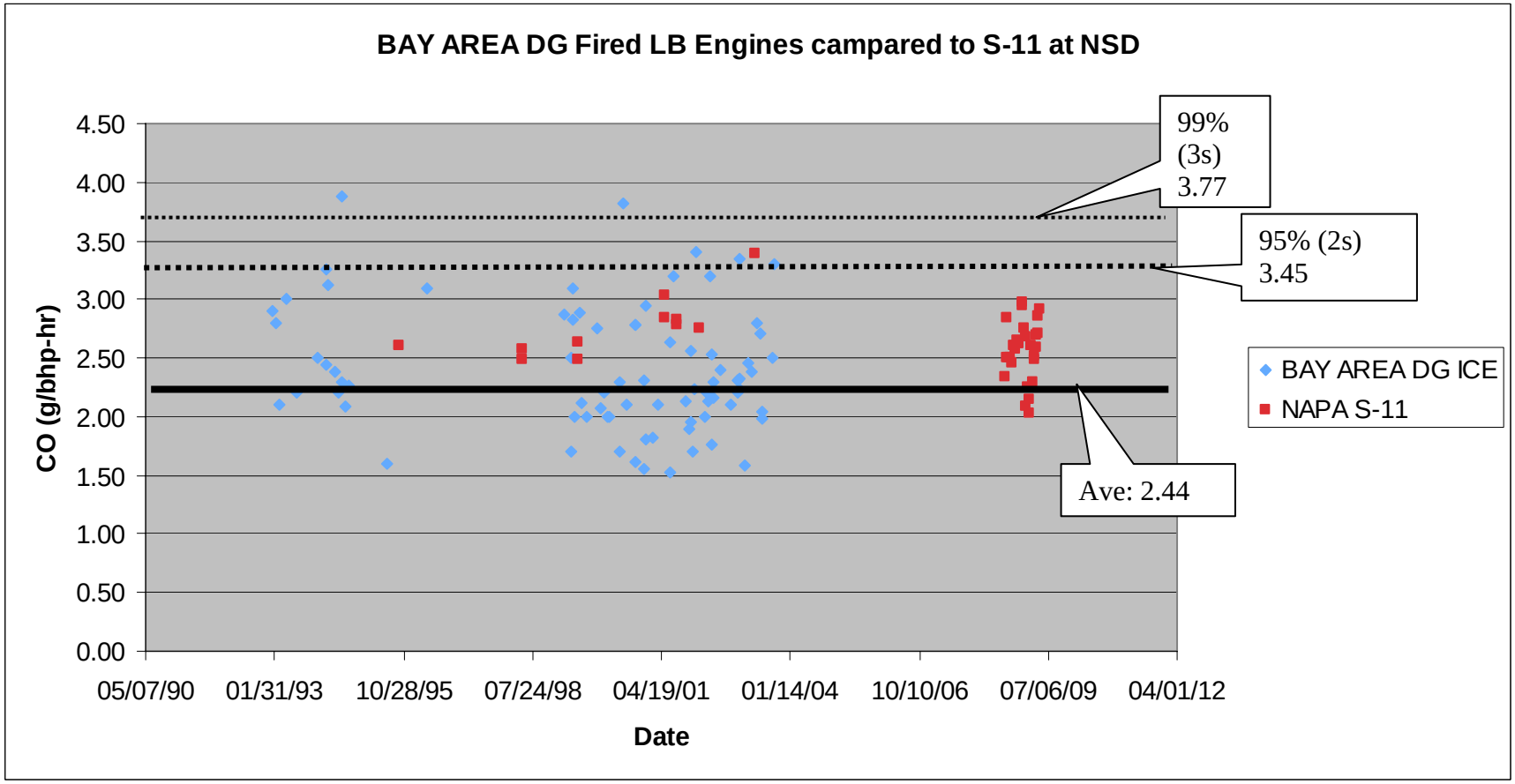
h. White Paper, Concerning BACT: CO Emissions From Digester Gas Fired Lean Burn Engines, BAAQMD, 1-24-2008.

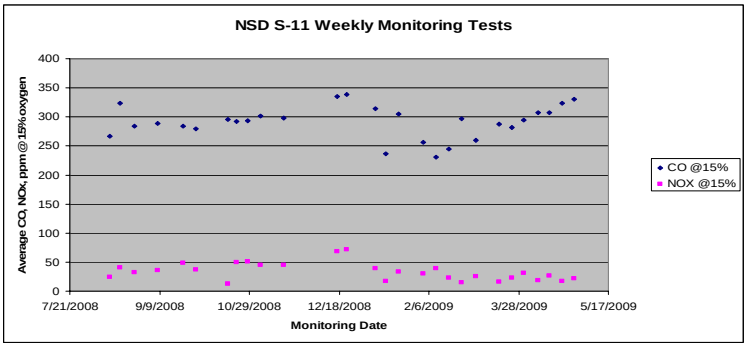
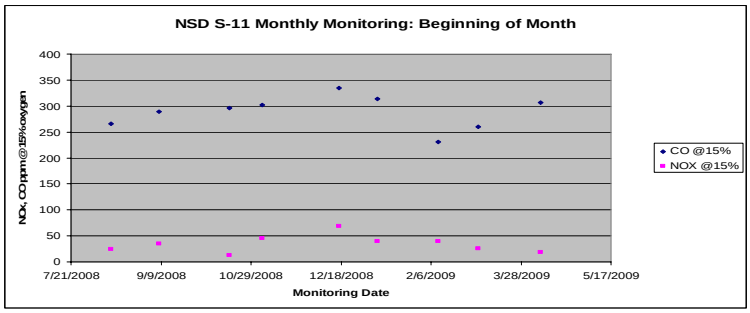
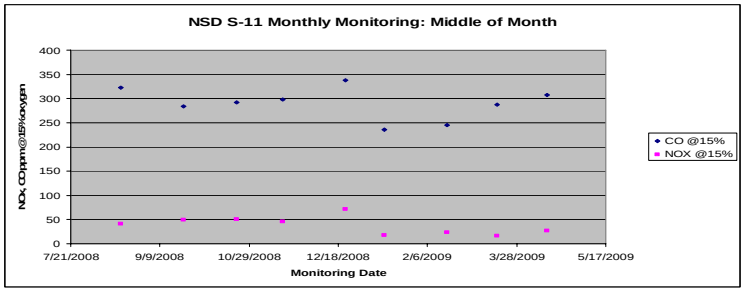
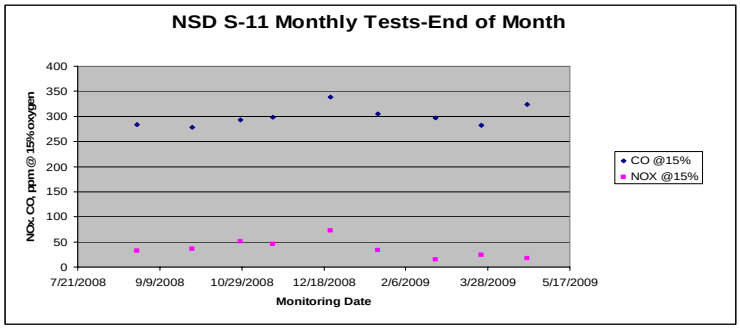
i. Addendum to White Paper: Concerning BACT: CO Emissions From Digester Gas Fired Lean Burn Engines, BAAQMD, 5-14-2009.

APPENDIX B


Low variation
during initial testing events
Increasing variation during
later source testing events
NSD S-11 Weekly Source Tests
NOx, CO ppm @ 15% O2
450
400
350
300
250
200
150
100
50
0
07/21/08
09/09/08
10/29/08
12/18/08
02/06/09
03/28/09
05/17/09
Monitoring Test Date
CO @15%
NOX @15%

APPENDIX C


BAY AREA DG Fired LB Engines campared to S-11 at NSD
CO (g/bhp-hr)
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
05/07/90
01/31/93
10/28/95
07/24/98
04/19/01
01/14/04
10/10/06
07/06/09
04/01/12
Date
99% (3s) 3.77
95% (2s) 3.45
Ave: 2.44
BAY AREA DG ICE
NAPA S-11

APPENDIX D

Monthly vs Weekly Monitoring Events Comparison