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August 14, 2012

Re: Shell Gulf of Mexico Inc. Noble *Discoverer* – Chukchi Sea
Application to Revise Outer Continental Shelf Prevention of Significant Deterioration
Permit to Construct: No. R10OCS/PSD-AK-09-01
Application Supplement

Shell Gulf of Mexico, Inc. submits this supplement to the application to revise Outer Continental Shelf Prevention of Significant Deterioration Permit to Construct No. R10OCS/PSD-AK-09-01 submitted to EPA on June 28, 2012.

Based on information and belief formed after reasonable inquiry, I certify that the statements and information in this submission are true, accurate, and complete.

Please contact Pauline Ruddy (907-771-7243) or Chris Lindsey (907-771-7262) if you have any questions.

Thank you.

Susan Childs
Alaska Venture Support Integrator, Manager

Enclosure(s):

1) Clarifications and Supplements to Application for Air Quality Permit Revision
2) Excel Workbook to Support Supplement No. 9

Cc:
Chris Lindsey, Shell
Pauline Ruddy, Shell
Lance Tolson, Shell
Natasha Greaves, EPA Region 10
Dave Bray, EPA Region 10
Eric Hansen, ENVIRON

Shell OCS Oil Exploration Program
Discoverer Drilling Program in the Chukchi Sea
Clarifications and Supplements to
Application for Air Quality Permit Revisions

1. Discoverer generator and Nanuq emission test results.

Shell provided emission test results to EPA staff by email on July 27, 2012. The test results support Shell's permit revision request.

2. DEC emission control costs.

The revision application estimates that the total cost to procure, engineer and design, install, and commission the DEC emission controls was around $23.5 million. The following clarifies the basis for this estimate.

The costs include efforts begun in December of 2009 and concluding in October of 2010 to retrofit the main generator engines on the Discoverer with Selective Catalytic Reduction (SCR) control systems and oxidation catalysts. As discussed in the application, DEC Marine AB was selected to provide the equipment for these control systems and procurement, installation, commissioning and testing of these of these systems was conducted during this time period. The capital cost for the actual equipment reflected only a small percentage of the total cost. Capital costs for the system were approximately $750,000. Installation of the systems required considerable engineering design in order to establish a feasible system for installation of the control systems within the limited space of the Discoverer. A total of $1.5 million was expended in this engineering design phase. An additional $4 million was spent in installation which occurred over several months from approximately January of 2010 through May of 2010. An additional $2 million was spent commissioning and conducting air emission testing of the system between May of 2010 and October of 2010. The total for these costs is $8.25 million, but these were not the major cost of the efforts which occurred during this time period.

Shell does not own the Discoverer drill ship, but rather has an agreement to lease the ship from its owner, at the time Frontier (the drill ship is now owned by Noble Drilling). Although Shell's agreement allowed them to make modifications to the drill ship to accommodate the air emissions requirement of the permit, Shell was required to pay Frontier a lease rate equivalent to $125,000 per day during the period the ship was taken out of commercial service to accommodate the modifications. The major purpose of the ship modifications in this time period was to add the emission control system, but Shell used the opportunity of the ship being out of service to make other modifications unrelated to the emission control system. Thus the entire cost of leasing the ship during this period cannot be attributed to the addition of the emission controls, although the emission control was the major activity during this time period. Shell

engineers estimate that approximately 120 days of the total period between December 2009 and October 2010, when the ship was out of service and being leased by Shell to make the modifications, was being spent directly on the addition of the emission control systems. The net result 120 days x $125,000/day = $15,000,000. The total of $23.25 million when the drill ship leasing costs are added to the direct costs of the control system retrofitting and testing was then rounded up to $23.5 million to account for miscellaneous costs. This formed the basis for the estimate of $23.5 million given in the text of the application.

3. E-POD system costs.

The revision application estimates the cost of removing the DEC control equipment and installing the E-POD units exceeded $7 million. Table 1 below provides an accounting of the costs incurred during the E-POD system installation and testing. This detailed cost accounting was developed after the time the application was prepared and the initial estimate of $7 million was developed. As the table shows, actual costs when tabulated were actually almost $15 million, more than twice the $7 million estimate provided in the application – largely because the initial estimate did not include the ship lease "day rate" and some of the shipyard costs.

Table 1. Noble Discoverer E-Pod Cost 2012

Description	Cost
01. Engineering / Procurement / Logistics	
a. Zentech Engineering	$206,188
b. La. Machinery - Epods/AMOX/Spares/Commissioning	$3,217,246
c. Transportation from New Mex. To Seattle	$22,820
03. Remove and Install Epods	
a. Lump Sum with Exception of Scaffolding	$3,080,000
b. Electrical Support	$483,336
c. Exhaust Modifications	$132,000
d. Maintenance Platform	$215,600
e. Insulation	$75,991
f. Engineering Changes & Change Orders	$703,363
g. Scaffolding	$216,827
h. Pre-Commissioning / Commissioning	$171,477
04. Shipyard Overhead	
a. Dock Rental (Services)	$22,176
b. Shore Power	$10,615
c. Warehousing	$52,442

Table 1. Noble Discoverer E-Pod Cost 2012

Description	Cost
d. Sewage (Included w/Dock Services)	$0
e. Mooring	$5,913
f. Fire Protection (Included w/Dock Services)	$0
g. Crane/Forklift Services	$343,714
05. Sunday & Holiday Incentives – Vigor	$328,608
06. Rig Day Rate	$4,954,400
07. Project Management & Inspection	
-Shell	$191,000
-Noble	$400,000
TOTAL	**$14,833,715**

4. Emissions source test data supporting Shell's decision to abandon the DEC Marine AB units and replace them with E-POD controls.

The PSD permit issued for the Shell drilling program with the Discoverer Drill Ship in the Chukchi Sea required that Shell install a Selective Catalytic Reduction (SCR) Unit and an Oxidation Catalyst on the Discoverer Generator Engines (FD1 – FD6). Among other requirements, the controlled generator engines were required to meet an emission limit of 0.50 grams per kilowatt-hour (g/kW-hr) for oxides of nitrogen (NOx) and an emission limit of 0.127 g/kW-hr for particulate matter (PM). Compliance with these emission limits was to be demonstrated at different loads using standard emission source testing methods.

Shell selected DEC Marine AB to provide the control equipment. The equipment was installed in Subic Bay in the Philippines between December 2009 and May, 2010. Emission source testing was conducted in September and October of 2010 in Singapore. A total of 67 emission source tests were conducted between September 11, 2010 and October 27, 2010. The tests addressed different pollutants, different operating loads and different emission configurations. Table 2 is a summary of all the tests conducted during this two month period; dashes in the table indicate testing of that pollutant was not conducted.

The majority of the tests conducted in 2010 were conducted on Unit 5 (56 tests). There were also tests on Unit 1 (2 tests), Unit 3 (8 tests) and Unit 4 (1 test). Although the engines are rated at a somewhat higher output, given the age of the engines, the drillship owner, Frontier (previous owner of the rig at time of testing), had forbidden the operation of the engines at higher than 800

kW, so the 800 kW level was considered full load. 400 kW and 600 kW were considered 50% and 75% load, respectively.

As the test data show, compliance with the PM emission limit and the NOx emission limit was very difficult to achieve. There were 56 tests for NOx during this period and only 20 of them showed compliance with the NOx emission limit. The difficulty in meeting the NOx emission limit had raised concerns with Shell about the capability of the DEC Marine SCR system to control NOx emissions to the permit level.

Of greater concern was that only 4 of 21 tests for PM conducted during the testing showed compliance with the particulate emission limit. Examination of these 4 tests shows that none of these tests were reflective of acceptable operation conditions. For two of the tests the oxidation catalyst was turned off and an “Ultra Burn” system was added to the system. There were no simultaneous measurements of NOx during these two compliant PM tests and other tests with the Ultra Burn system in operation had shown NOx emission rates above the NOx emission limit, unless the oxidation catalyst was turned off. Although the two compliant PM tests showed lower PM emissions, other tests with the Ultra Burn system did not show lower PM emissions, and ultimately, the Ultra Burn system was judged to not improve emissions.

The other two tests that showed compliance with the PM emission limit were both under conditions of reduced load and one of them had simultaneous NOx emissions that exceeded the emission limit for NOx. The only case in which both PM and NOx compliance was attained was at 75% load and involved turning off the soot blowers for the SCR system. Since this is not a realistic operation scenario, the conclusion was that simultaneous attainment of the PM and NOx emission limits was not possible with the DEC Marine SCR and oxidation catalyst. At that point the decision was reached to suspend further testing of the DEC Marine system and search for alternative control systems that had a greater potential to show compliance with the emission requirements.

Table 2. Emission Test Summary for Discoverer with DEC Marine AB Emission Control Equipment

Date	Engine	Load (kW)	PM Emis. (g/kW-hr) Limit = 0.127	NOx Emis. (g/kW-hr) Limit = 0.5	CO Emis. (g/kW-hr) Limit = 0.179	NH_3 Slip (ppm) Limit = 5	Comments
09/11/2010	5	800	-	**2.4**	0.089	-	
09/11/2010	5	600	-	**1.4**	0.023	-	
09/11/2010	5	400	-	**0.9**	0.007	-	
09/12/2010	5	400	-	**1.0**	0.000	-	
09/13/2010	5	800	-	**2.2**	0.056	-	>5-10% Opacity
09/13/2010	5	400	-	**1.3**	0.041	-	>25% Opacity
09/13/2010	5	800	-	**2.6**	0.016	-	
09/14/2010	5	400	-	**1.0**	0.000	-	
09/14/2010	5	800	-	**2.2**	0.054	-	
09/14/2010	5	400	-	**1.4**	0.035	-	
09/15/2010	5	800	-	**2.1**	0.055	-	Ultra Burn
09/15/2010	5	400	-	**1.2**	0.030	-	Ultra Burn
09/15/2010	5	800	-	**1.6**	**0.269**	-	Ultra Burn-partial Ox Cat
09/15/2010	5	400	-	**0.7**	**0.396**	-	Ultra Burn-partial Ox Cat
09/15/2010	5	600	-	**1.1**	**0.367**	-	Ultra Burn-partial Ox Cat
09/16/2010	5	800	-	0.4	**0.410**	-	Ultra Burn-No Ox Cat
09/16/2010	5	600	-	0.3	**0.398**	-	Ultra Burn-No Ox Cat
09/16/2010	5	400	-	0.3	**0.648**	-	Ultra Burn-No Ox Cat
09/17/2010	5	800	**0.194**	-	-	-	Ultra Burn-No Ox Cat
09/17/2010	5	400	**0.232**	-	-	-	Ultra Burn-No Ox Cat

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09/17/2010	5	800	0.115	-	-	-	Ultra Burn-No Ox Cat
09/17/2010	5	400	**0.161**	-	-	-	Ultra Burn-No Ox Cat
09/18/2010	5	800	0.116	-	-	-	Ultra Burn-No Ox Cat
09/18/2010	5	400	**0.160**	-	-	-	Ultra Burn-No Ox Cat
09/18/2010	5	800	**0.131**	-	-	-	Ultra Burn-No Ox Cat
09/18/2010	5	400	**0.151**	-	-	-	Ultra Burn-No Ox Cat
09/19/2010	1	800	**0.216**	-	-	-	No-Ultra Burn/w Ox Cat/Front half only
09/19/2010	1	400	**0.136**	-	-	-	No-Ultra Burn/w Ox Cat Front half only
10/17/2010	5	800	-	**6.6**	0.024	-	Temp Range on Med Temp catalyst is 375-475 C, Max of 500 C.
10/17/2010	5	800	-	**4.1**	0.000	-	Temp Range on Med Temp catalyst is 375-475 C, Max of 500 C.
10/17/2010	5	800	-	**2.1**	0.038	-	Temp Range on Med Temp catalyst is 375-475 C, Max of 500 C.
10/17/2010	5	800	-	0.5	0.025	-	Temp Range on Med Temp catalyst is 375-475 C, Max of 500 C.
10/17/2010	5	800	-	0.3	0.019	-	Temp Range on Med Temp catalyst is 375-475 C, Max of 500 C.

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10/17/2010	5	800	-	0.2	0.019	-	Temp Range on Med Temp catalyst is 375-475 C, Max of 500 C.
10/17/2010	5	800	-	0.2	0.013	-	Temp Range on Med Temp catalyst is 375-475 C, Max of 500 C.
10/17/2010	5	600	-	**6.4**	0.046	-	Temp Range on Med Temp catalyst is 375-475 C, Max of 500 C.
10/17/2010	5	600	-	**4.1**	0.035	-	Temp Range on Med Temp catalyst is 375-475 C, Max of 500 C.
10/17/2010	5	600	-	**1.2**	0.000	-	Temp Range on Med Temp catalyst is 375-475 C, Max of 500 C.
10/17/2010	5	600	-	0.1	0.000	-	Temp Range on Med Temp catalyst is 375-475 C, Max of 500 C.
10/17/2010	5	600	-	**1.0**	-	-	This test done to confirm that the NH3 conversion to Nox phenom exists.
10/17/2010	5	400	-	**6.2**	0.052	-	
10/17/2010	5	400	-	**3.1**	0.026	-	
10/17/2010	5	400	-	0.2	0.000	-	
10/18/2010	5	800	-	**6.9**	0.113	0.0	

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10/18/2010	5	800	-	0.4	0.017	0.5	
10/18/2010	5	800	**0.190**	0.4	0.000	0.0	These PM results were with the SCR soot blowing system ON
10/18/2010	5	400	**0.200**	0.3	0.000	0.0	These PM results were with the SCR soot blowing system ON
10/20/2010	3	800	-	**5.6**	0.052	0.0	
10/20/2010	3	800	-	**2.1**	0.000	**5.9**	
10/20/2010	3	800	-	**2.4**	0.000	2.2	
10/20/2010	5	600	-	**6.6**	0.009	-	
10/20/2010	5	600	0.124	0.2	0.026	0.0	These PM results were with the SCR soot blowing system OFF
10/20/2010	5	700	**0.191**	0.2	0.017	0.0	These PM results were with the SCR soot blowing system OFF
10/20/2010	5	400	**0.169**	-	-	-	These PM results were with the SCR soot blowing system OFF
10/21/2010	3	600	**0.177**	**1.5**	0.052	1.5	These PM results were with the SCR soot blowing system OFF & with the original catalyst
10/21/2010	3	600	-	**1.5**	0.052	1.7	

Table 2. Emission Test Summary for Discoverer with DEC Marine AB Emission Control Equipment

Date	Engine	Load (kW)	PM Emis. (g/kW-hr) Limit = 0.127	NOx Emis. (g/kW-hr) Limit = 0.5	CO Emis. (g/kW-hr) Limit = 0.179	NH_3 Slip (ppm) Limit = 5	Comments
10/21/2010	3	600	-	**1.6**	0.061	1.6	
10/21/2010	3	400	**0.193**	**1.0**	0.017	1.0	These PM results were with the SCR soot blowing system OFF & with the original catalyst
10/21/2010	3	700	**0.305**	**2.0**	0.017	1.0	These PM results were with the SCR soot blowing system OFF & with the original catalyst
10/22/2010	4	600	0.124	**3.1**	0.000	0.0	These PM results were with the SCR soot blowing system ON & with the original catalyst
10/22/2010	5	600	**0.184**	0.2	0.035	0.0	This test was done at 100% urea injection with soot blowing ON
10/22/2010	5	600	**0.188**	0.5	0.044	0.0	This test was done at 115% urea injection with soot blowing ON
10/27/2010	5	600	-	0.2	0.026	0.6	This test was done with 15 PPM fuel WITH Amergy additive

Table 2. Emission Test Summary for Discoverer with DEC Marine AB Emission Control Equipment

Date	Engine	Load (kW)	PM Emis. (g/kW-hr) Limit = 0.127	NOx Emis. (g/kW-hr) Limit = 0.5	CO Emis. (g/kW-hr) Limit = 0.179	NH_3 Slip (ppm) Limit = 5	Comments
10/27/2010	5	600	-	0.2	0.026	0.6	This test was done with 15 PPM fuel WITH Amergy additive
10/27/2010	5	600	-	0.2	0.026	0.6	This test was done with 15 PPM fuel WITH Amergy additive
10/27/2010	5	400	-	0.2	0.017	0.0	This test was done with 15 PPM fuel WITH Amergy additive
10/27/2010	5	400	-	0.2	0.017	0.6	This test was done with 15 PPM fuel WITH Amergy additive

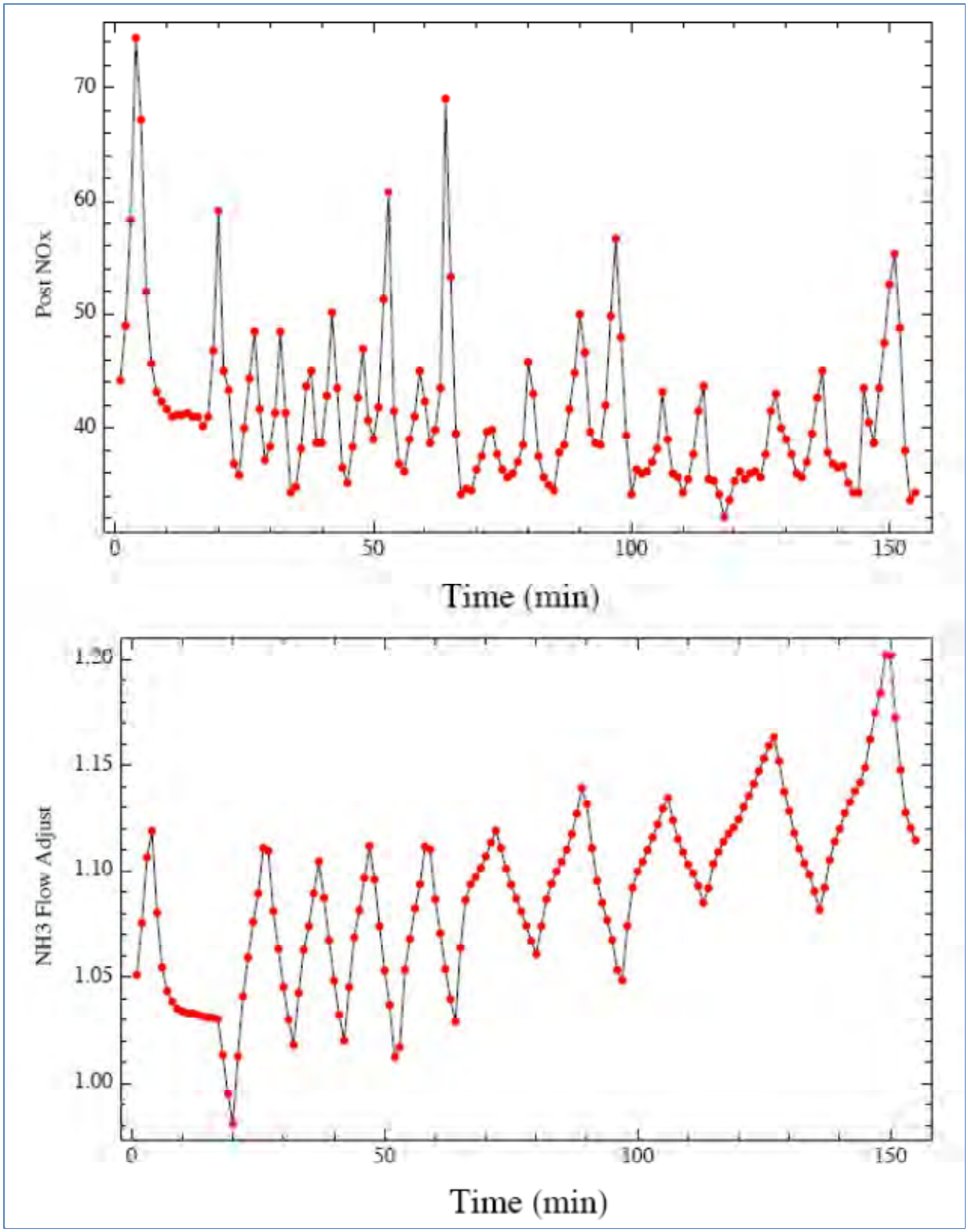
5. Instability of control system when attempting to attain high NOx removal rates.

The revision application to revise Permit No. R10OCS/PSD-AK-09-01 (p. 10) refers to instability at controls levels higher than around 93%. The following clarifies this statement and provides supporting data.

The control system is designed to adjust inlet urea feed rates to attain different levels of NOx control. Since added urea can result in increased ammonia emission (ammonia "slip") the control system is designed to minimize the quantity of urea fed only to that necessary to maintain the intended level of NOx control. The manufacturer's experience with the E-POD systems has indicated that attempting to increase the NOx control level above 90% can result in instability in the system. The instability results as the system increases urea feed rate to the point where ammonia slip increases from the system. The system detects the increased ammonia slip but does not distinguish it from increased NOx emissions and hence treats it as an increase in NOx emissions and adds more urea, further increasing the amount of ammonia slip. This "feedback" system continues until the system senses the instability and resets itself, whereupon the process starts over.

This instability was seen in the testing of the E-POD system at NC Machinery in Tukwila. When an attempt is made to attain levels in the regime of low ammonia slip and low NOx emissions, the system oscillates in instability as ammonia feed rates are alternatively increased and decreased in an attempt to reach an unattainable position in curve. Figure 1 shows the simultaneous time-dependent plots of NOx exhaust rate (here in ppm) and ammonia flow adjustment. The "sawtooth" nature of these curves is indicative of the instability in the system as it attempts to find a control level of NOx that cannot be met without increase ammonia slip.

Figure 1. Simultaneous Plot of E-POD NOx Exhaust and Ammonia Feed Rate



6. Sizing of E-POD on Unit 2.

The following clarifies why the E-POD on Unit 2 was not able to take advantage of the approximately 18 inches of space between the engine and the unit. On engine # 2, the installation was originally planned to be the same as engines 1, 3, 4 & 5. After the vessel came into the shipyard, and Shell engineers were able to scaffold up and make a better evaluation, they found that a major cable tray, which is two tiers of cable tray and electrical cables that run from the switchgear room to the forward end of the vessel and up to the control house, was located in this space. Cables in the tray include some of the major power cables to the control room, anchor winches and electric motors on the forward end of the ship and there was no slack in the cables to allow for movement. These cables are large gauge, high-voltage cables that cannot be spliced or junctioned due to vessel class society rules. To move the tray, the cables would have to have been re-run completely, which would have required redesign, class approval, procurement and installation of the high-voltage cabling – work that was not feasible from a scheduling or cost perspective.

7. Clarification as to why the E-POD on Unit 6 wasn't designed for horizontal installation.

Shell considered the feasibility of installing the E-POD on Unit 6 horizontally rather than vertically. However, the space between the mezzanine deck and the top of the engine would not allow it. It would have placed the E-POD so close to the top of the engine, the mechanics would have had to remove the E-POD to do normal maintenance work on the engine block and on the E-POD. There are maintenance openings on the E-POD that would have been blocked by either the engine or the mezzanine deck above. This E-POD weighs over 5,000 pounds. The engineering and operations personnel determined that this position was not technically feasible. At this point Shell determined a location to place the E-POD vertically, similar to engines 1 through 5. However, there is a major longitudinal girder running just inboard of the E-POD, so to get the exhaust out of the E-POD, and clear the longitudinal girder, it had to be slightly dimensionally smaller. For this reason, the Unit 6 E-POD was designed slightly shorter than E-PODs for engines 1, 3, 4, and 5.

8. Potential to emit for ammonia.

This section estimates NH3 mass emissions if the 5 ppm permit limit is removed. Without a short-term permit limit, we must estimate potential NH3 emissions using worst-case emissions assumptions, with consideration given to operating restrictions that apply to the Discoverer generators. The Discoverer is limited to 120 days of drilling, and aggregate electrical generation is limited to 3,872 kWe. To provide conservative emissions estimates, we can apply the test results for 100 percent load, which almost always resulted in the highest emission factor expressed as grams per kilowatt hour (g/kWe-hr).

Because the six engines can physically generate more than 3,872 kWe, we can assume that power generation duty is evenly distributed among the engines with the longer E-PODs (those with lower NOx emissions) and the remaining allowable power generation is assigned to FD-2. Table 3 identifies annual NH3 emissions of 1.8 tons based on 24 hours of operation at full load (except FD-2 and FD-6) for 120 days per drill season.

Table 3. Summary of Mass Ammonia Emissions

Unit	Ammonia @ 100% Load	Load	Short Term		Annual Mass Emission
	lb/kWe-hr	kWe	lb/hr	lb/day	tpy
FD-1	0.0009	800.0	0.72	17.28	1.04
FD-2	6.37E-05	672.0	0.04	1.03	0.06
FD-3	2.51E-04	800.0	0.20	4.82	0.29
FD-4	1.95E-04	800.0	0.16	3.74	0.22
FD-5	1.58E-04	800.0	0.13	3.03	0.18
FD-6	1.08E-04	0.0	0.0	0.0	0.00
SUM		3,872.0	1.25	29.90	**1.8**
Electrical Power Output Limit (kWe)		3,872.0			

9. Spreadsheet supporting requested NOx limit based on test data plus two standard deviations.

EPA has requested the spreadsheet used to prepare the table requesting the NOx limit based on test data plus two standard deviations. The electronic spreadsheet is submitted electronically under separate cover.

10. Permit revision application Section 3, Rated Capacity for Emission Units.

Section 3 of the revision application identifies limits on operating capacity of engines and proposes monitoring. Shell confirms the requested capacity limits for the Discoverer and Nanuq, which serve to assure the existing physical restrictions on these engines described in the application to revise Permit No. R10OCS/PSD-AK-09-01.

Shell has concluded, however, that operating restrictions are not necessary for the Icebreaker #1 vessel, because Condition N.4 in the current permit already limits operation of the propulsion engines to no greater than 80 percent of rated capacity. In addition, Shell has concluded that all

of the proposed monitoring identified in revision application Section 3 is unnecessary because the current permit already imposes monitoring sufficient to assure compliance with capacity limits. Conditions C.9.4, N.13.3, and Q.9.4 require monitoring of load and fuel use, and Condition A.15 requires reporting of deviations.

11. Supplemental information supporting Shell's request to revise Condition Q.9.7 (regarding calculating actual emissions from the Nanuq propulsion and generator engines).

The June 28, 2012 revision request regarding revision to Condition Q.9.7 (Nanuq actual emission calculation) is restated here.

> *Each day, calculate and record for the previous calendar day, the emissions of NOX, PM2.5 and PM10, in pounds per hour and pounds per day using the highest emission factor for each tested engine collected under Condition Q.8.5 and fuel usage data collected under Condition Q.9.4, unless power level is monitored on at least a 15-minute frequency, in which case an appropriate load-based emission factor collected under Condition Q.8.5 can be used.*

Shell is requesting that the actual emissions from the Nanuq propulsion and generation engines be calculated by the same method as is allowed for the Discoverer prime generators (Condition C.9.5), the ice management vessels (Conditions N.13.12 and O.13.12) and the supply vessel (Condition P.5.7). This method uses per-engine power-level specific emission factors to calculate actual emissions. This requested calculation of emissions using a power-level specific emission factor will provide a more accurate tracking of actual Nanuq emissions. Previously, two of the four engines did not measure power output directly, but only fuel consumption and the relationship of fuel consumption to power level on those two engines was not demonstrated. Following the June 2012 stack tests on those two engines, that relationship is now apparent. As a result, the current permit requires a calculation of emissions that is now unnecessarily conservative (higher than the actual emissions) because power level is now known for all four of the Nanuq engines.

Nanuq has two direct-drive propulsion engines (N1 and N2) and two generator engines (N3 and N4). The power levels of the generator engines is being measured directly (as kWe) on a 10-minute frequency, as is required for the Discoverer prime generators and ice management engines (the supply vessel is required to measure fuel consumption on a 15 minute frequency, to be converted to a power level), so all of the identical operational data is already available from the two generator engines, and use of the load-specific emission factors is already justified for these two generator engines.

The Nanuq propulsion engines are direct drives and do not have power measurements in the form of electrical power. But they do have fuel consumption measurements on a 10-minute frequency and the June 21 through June 27, 2012 Nanuq engine stack tests demonstrate that these fuel consumption measurements are an excellent surrogate for power level measurements. The relevant results of those stack tests are tabulated on the attachment.

Fuel consumption as a function of power level is plotted from that data and the graphs are shown on the attachment. A linear regression of the two plots for N1 and N2 are calculated and the resulting linear equation is provided along with the correlation coefficient (r^2). The correlation coefficients are 0.9997 for both, which is an excellent correlation. Therefore, fuel flow is an excellent surrogate measurement for power output of the propulsion engines. Tracking load through fuel consumption is very precise, and therefore tracking of load through fuel consumption is essentially as good as tracking by electrical power output. Shell requests that these equations be allowed to define load of the propulsion engines during operation and as a function of the measured of fuel flow, and that the load-specific emission factors be used to estimate actual emissions from N1 and N2.

A revised Condition Q.9.7 to accept tracking of N1 through N4 actual emissions using measured load by either fuel consumption or electrical power output and load-specific emission factors is provided here.

Revised Proposed Condition Q.9.7

> *Each day, calculate and record for the previous calendar day, the emissions of NOX, PM2.5 and PM10, in pounds per hour and pounds per day using the ~~highest~~ emission factor for each tested engine collected under Condition Q.8.5 and load data collected under Condition Q.9.4. Load will be determined from fuel usage for N1 and N2, and directly from electrical load for engines N3 and N4. Emissions shall be calculated for each ten-minute load reading for each engine.*

Species	Units	E-POD	Load	Max	Mean	Std. Dev.
NOx	g/kW-hr	1345	Low	0.99	0.61	0.22
			Medium	0.68	0.42	0.19
			High	0.78	0.43	0.25
			Composite	0.99	0.49	0.23
		26	Low	1.86	1.34	0.29
			Medium	1.40	1.21	0.17
			High	1.28	1.20	0.07
			Composite	1.86	1.25	0.20
NH3	ppm	1345	Low	65.9	17.2	17.4
			Medium	86.6	34.0	30.4
			High	105.9	38.6	34.7
			Composite	105.9	29.9	29.2
		26	Low	9.5	6.8	1.8
			Medium	14.1	9.3	4.4
			High	12.7	8.5	2.6
			Composite	14.1	8.2	3.1

Mean + 1 Std. Dev.	Mean + 2 Std. Dev.	Max + 1 Std. Dev.	Max + 2 Std. Dev.
0.84	1.06	1.21	1.44
0.61	0.79	0.87	1.05
0.67	0.92	1.03	1.28
0.72	0.95	1.22	1.45
1.63	1.93	2.15	2.45
1.39	1.56	1.58	1.75
1.27	1.34	1.35	1.42
1.45	1.65	2.06	2.26
34.6	51.9	83.2	100.6
64.4	94.8	117.0	147.4
73.3	108.0	140.6	175.3
59.1	88.3	135.0	164.2
8.6	10.4	11.3	13.1
13.8	18.2	18.5	22.9
11.0	13.6	15.2	17.8
11.3	14.5	17.2	20.3

Long E-POD NO_x Data

UID	Run	Engine	Mode	Nox (g/kW-hr)	Load (%)
1-1	1	1	Low	0.41	0.5
2-1	2	1	Low	0.25	0.5
3-1	3	1	Low	0.31	0.5
1-3	1	3	Low	0.56	0.5
2-3	2	3	Low	0.55	0.5
3-3	3	3	Low	0.61	0.5
1-4	1	4	Low	0.62	0.5
2-4	2	4	Low	0.63	0.5
3-4	3	4	Low	0.99	0.5
1-5	1	5	Low	0.69	0.5
2-5	2	5	Low	0.88	0.5
3-5	3	5	Low	0.84	0.5
1-1	1	1	Medium	0.21	0.75
2-1	2	1	Medium	0.18	0.75
3-1	3	1	Medium	0.18	0.75
1-3	1	3	Medium	0.56	0.75
2-3	2	3	Medium	0.53	0.75
3-3	3	3	Medium	0.47	0.75
1-4	1	4	Medium	0.40	0.75
2-4	2	4	Medium	0.24	0.75
3-4	3	4	Medium	0.33	0.75
1-5	1	5	Medium	0.68	0.75
2-5	2	5	Medium	0.63	0.75
3-5	3	5	Medium	0.62	0.75
1-1	1	1	High	0.19	1
2-1	2	1	High	0.16	1
3-1	3	1	High	0.15	1
1-3	1	3	High	0.39	1
2-3	2	3	High	0.49	1
3-3	3	3	High	0.15	1
1-4	1	4	High	0.30	1
2-4	2	4	High	0.48	1
3-4	3	4	High	0.51	1
1-5	1	5	High	0.78	1
2-5	2	5	High	0.78	1
3-5	3	5	High	0.74	1

Load	Max (g/kW-hr)
Low	0.99
Medium	0.68
High	0.78
Composite	0.99

Load	Max (g/kW-hr)
Low	1.86
Medium	1.40
High	1.28
Composite	1.86

UID	Composite
1-1	0.2698667
2-1	0.1977667
3-1	0.2138333
1-3	0.5040333
2-3	0.5266333
3-3	0.4078
1-4	0.4389667
2-4	0.4522
3-4	0.6117
1-5	0.7161153
2-5	0.7668952
3-5	0.7365179

Short E-POD NO_x Data

UID	Run	Engine	Mode	Nox (g/kW-hr)	Load (%)
1-2	1	2	Low	1.86	0.5

UID	Composite

2-2	2	2	Low	1.49	0.5
3-2	3	2	Low	1.30	0.5
1-6	1	6	Low	1.16	0.5
2-6	2	6	Low	1.09	0.5
3-6	3	6	Low	1.14	0.5
1-2	1	2	Medium	1.40	0.75
2-2	2	2	Medium	1.40	0.75
3-2	3	2	Medium	1.30	0.75
1-6	1	6	Medium	1.08	0.75
2-6	2	6	Medium	1.03	0.75
3-6	3	6	Medium	1.06	0.75
1-2	1	2	High	1.25	1
2-2	2	2	High	1.28	1
3-2	3	2	High	1.25	1
1-6	1	6	High	1.15	1
2-6	2	6	High	1.15	1
3-6	3	6	High	1.11	1

1-2	1.5036667
2-2	1.3885667
3-2	1.2841667
1-6	1.131095
2-6	1.0913747
3-6	1.1031241

E-POD 1345: NO_x					
Mean (g/kW-hr)	Std. Dev. (g/kW-hr)	Mean + 1 Std. Dev. (g/kW-hr)	Mean + 2 Std. Dev. (g/kW-hr)	Max + 1 Std. Dev. (g/kW-hr)	Max + 2 Std. Dev. (g/kW-hr)
0.61	0.22	0.84	1.06	1.21	1.44
0.42	0.19	0.61	0.79	0.87	1.05
0.43	0.25	0.67	0.92	1.03	1.28
0.49	0.23	0.72	0.95	1.22	1.45

E-POD 26: NO_x					
Mean (g/kW-hr)	Std. Dev. (g/kW-hr)	Mean + 1 St. Dev. (g/kW-hr)	Mean + 2 Std. Dev. (g/kW-hr)	Max + 1 Std. Dev. (g/kW-hr)	Max + 2 Std. Dev. (g/kW-hr)
1.34	0.29	1.63	1.93	2.15	2.45
1.21	0.17	1.39	1.56	1.58	1.75
1.20	0.07	1.27	1.34	1.35	1.42
1.25	0.20	1.45	1.65	2.06	2.26

	Long E-POD NH_3 Data				
UID	Run	Engine	Mode	NH3 (ppm)	Load (%)
1-1	1	1	Low	12.73	0.5
2-1	2	1	Low	65.87	0.5
3-1	3	1	Low	36.62	0.5
1-3	1	3	Low	6.66	0.5
2-3	2	3	Low	5.69	0.5
3-3	3	3	Low	6.79	0.5
1-4	1	4	Low	10.52	0.5
2-4	2	4	Low	10.40	0.5
3-4	3	4	Low	8.54	0.5
1-5	1	5	Low	15.05	0.5
2-5	2	5	Low	12.93	0.5
3-5	3	5	Low	14.64	0.5
1-1	1	1	Medium	72.71	0.75
2-1	2	1	Medium	86.61	0.75
3-1	3	1	Medium	84.71	0.75
1-3	1	3	Medium	7.35	0.75
2-3	2	3	Medium	8.10	0.75
3-3	3	3	Medium	8.82	0.75
1-4	1	4	Medium	16.62	0.75
2-4	2	4	Medium	45.80	0.75
3-4	3	4	Medium	21.65	0.75
1-5	1	5	Medium	17.05	0.75
2-5	2	5	Medium	19.37	0.75
3-5	3	5	Medium	19.12	0.75
1-1	1	1	High	76.22	1
2-1	2	1	High	89.76	1
3-1	3	1	High	105.86	1
1-3	1	3	High	11.87	1
2-3	2	3	High	8.67	1
3-3	3	3	High	58.40	1
1-4	1	4	High	34.92	1
2-4	2	4	High	15.50	1
3-4	3	4	High	12.89	1
1-5	1	5	High	15.86	1
2-5	2	5	High	16.34	1
3-5	3	5	High	16.76	1

	Short E-POD NH_3 Data				
UID	Run	Engine	Mode	NH3 (ppm)	Load (%)
1-2	1	2	Low	4.57	0.5

2-2	2	2	Low	5.74	0.5
3-2	3	2	Low	6.05	0.5
1-6	1	6	Low	6.94	0.5
2-6	2	6	Low	8.31	0.5
3-6	3	6	Low	9.48	0.5
1-2	1	2	Medium	5.22	0.75
2-2	2	2	Medium	6.02	0.75
3-2	3	2	Medium	4.81	0.75
1-6	1	6	Medium	14.07	0.75
2-6	2	6	Medium	12.99	0.75
3-6	3	6	Medium	12.96	0.75
1-2	1	2	High	7.35	1
2-2	2	2	High	6.53	1
3-2	3	2	High	5.56	1
1-6	1	6	High	12.67	1
2-6	2	6	High	9.03	1
3-6	3	6	High	9.56	1

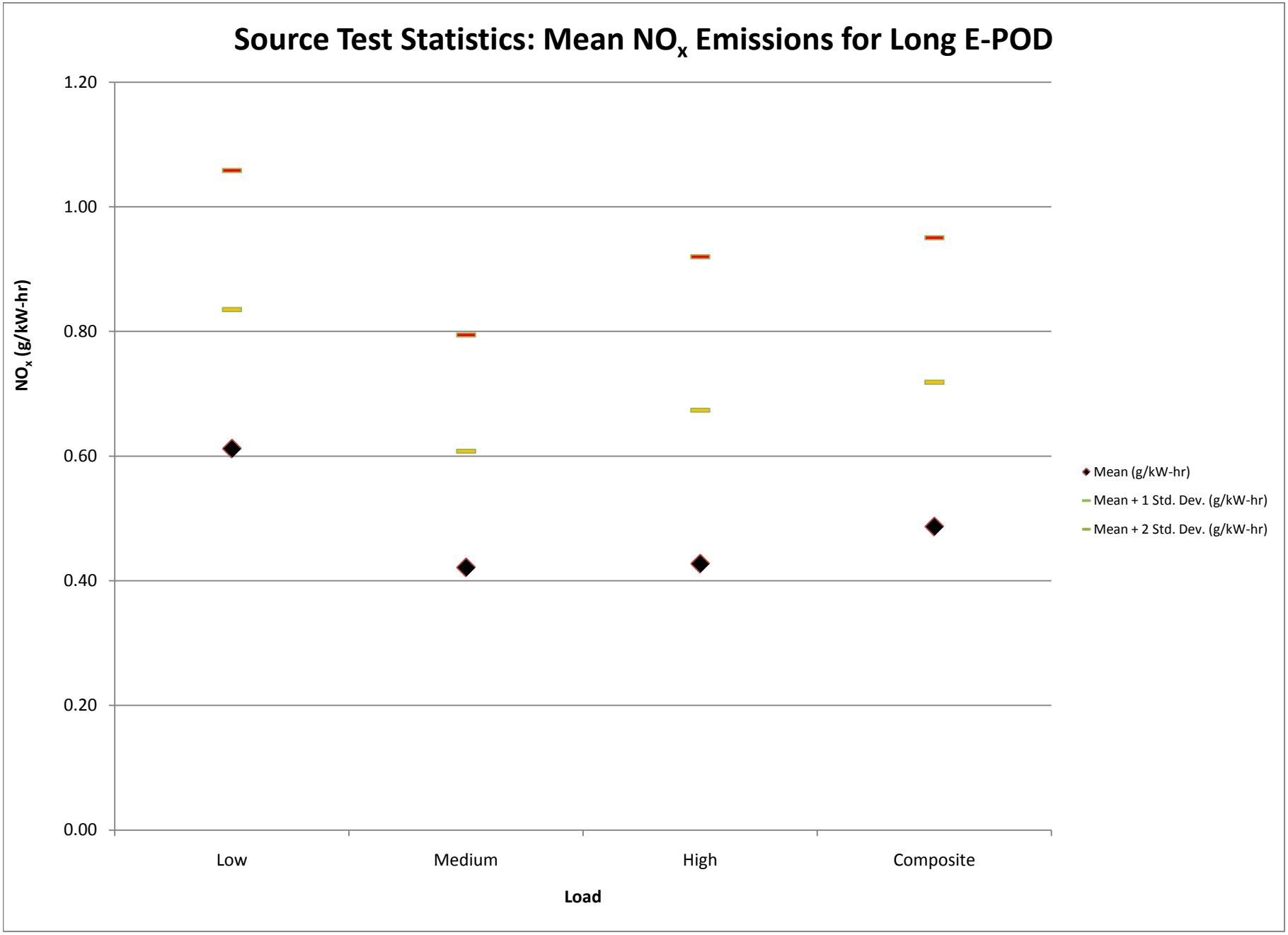
Long E-POD: NH_3							
Load	**Max (ppm)**	**Mean (ppm)**	**Std. Dev. (ppm)**	**Mean + 1 Std. Dev. (ppm)**	**Mean + 2 Std. Dev. (ppm)**	**Max + 1 Std. Dev. (ppm)**	**Max + 2 Std. Dev. (ppm)**
Low	65.87	17.20	17.35	34.56	51.91	83.22	100.58
Medium	86.61	33.99	30.41	64.40	94.80	117.02	147.42
High	105.86	38.59	34.72	73.30	108.02	140.58	175.29
Composite	105.86	29.93	29.17	59.10	88.27	135.03	164.20

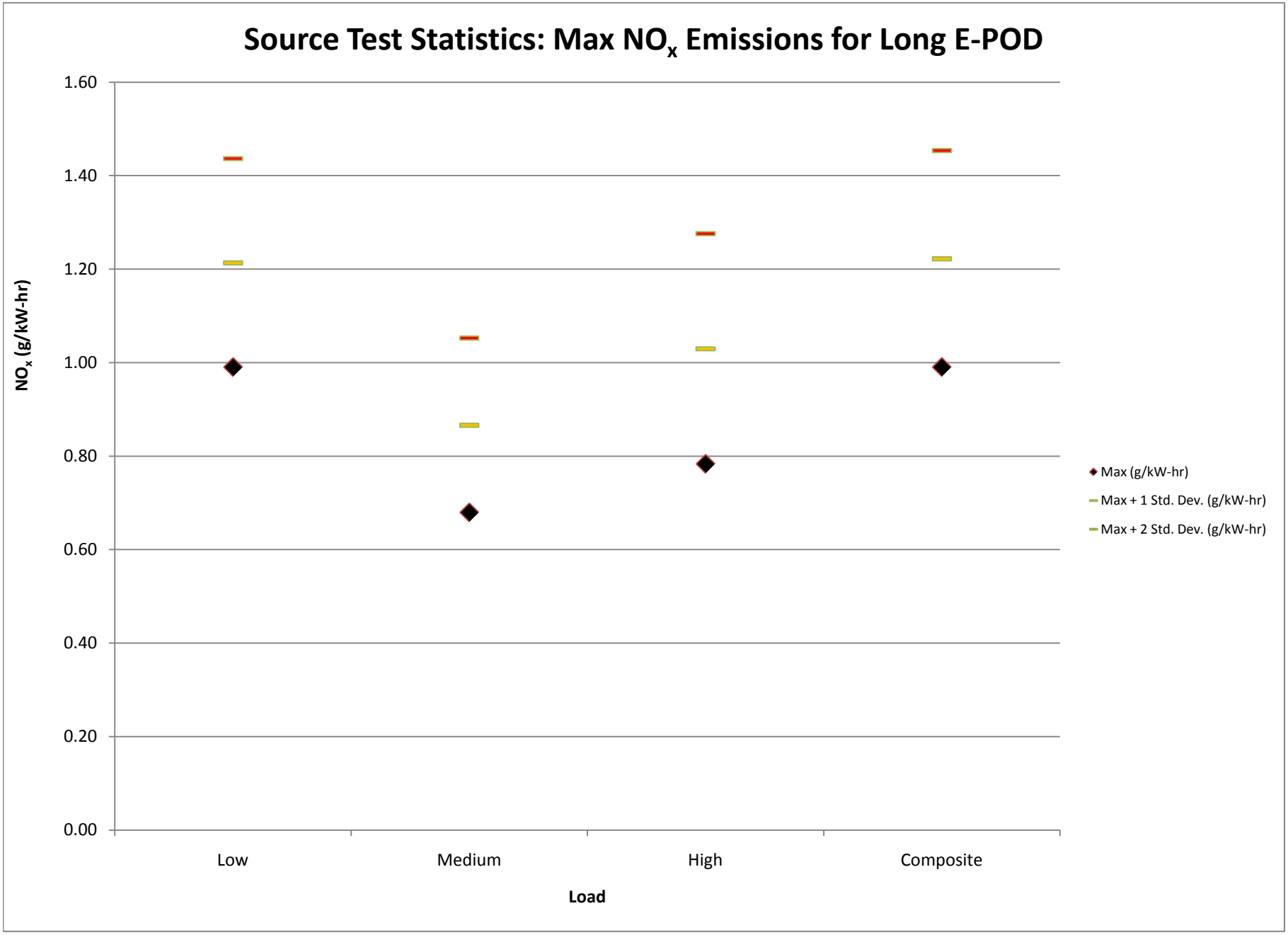
Short E-POD: NH_3							
Load	**Max (ppm)**	**Mean (ppm)**	**Std. Dev. (ppm)**	**Mean + 1 St. Dev. (ppm)**	**Mean + 2 Std. Dev. (ppm)**	**Max + 1 Std. Dev. (ppm)**	**Max + 2 Std. Dev. (ppm)**
Low	9.48	6.85	1.80	8.64	10.44	11.28	13.07
Medium	14.07	9.35	4.41	13.76	18.17	18.48	22.89
High	12.67	8.45	2.55	11.00	13.56	15.22	17.78
Composite	14.07	8.21	3.12	11.33	14.45	17.19	20.31

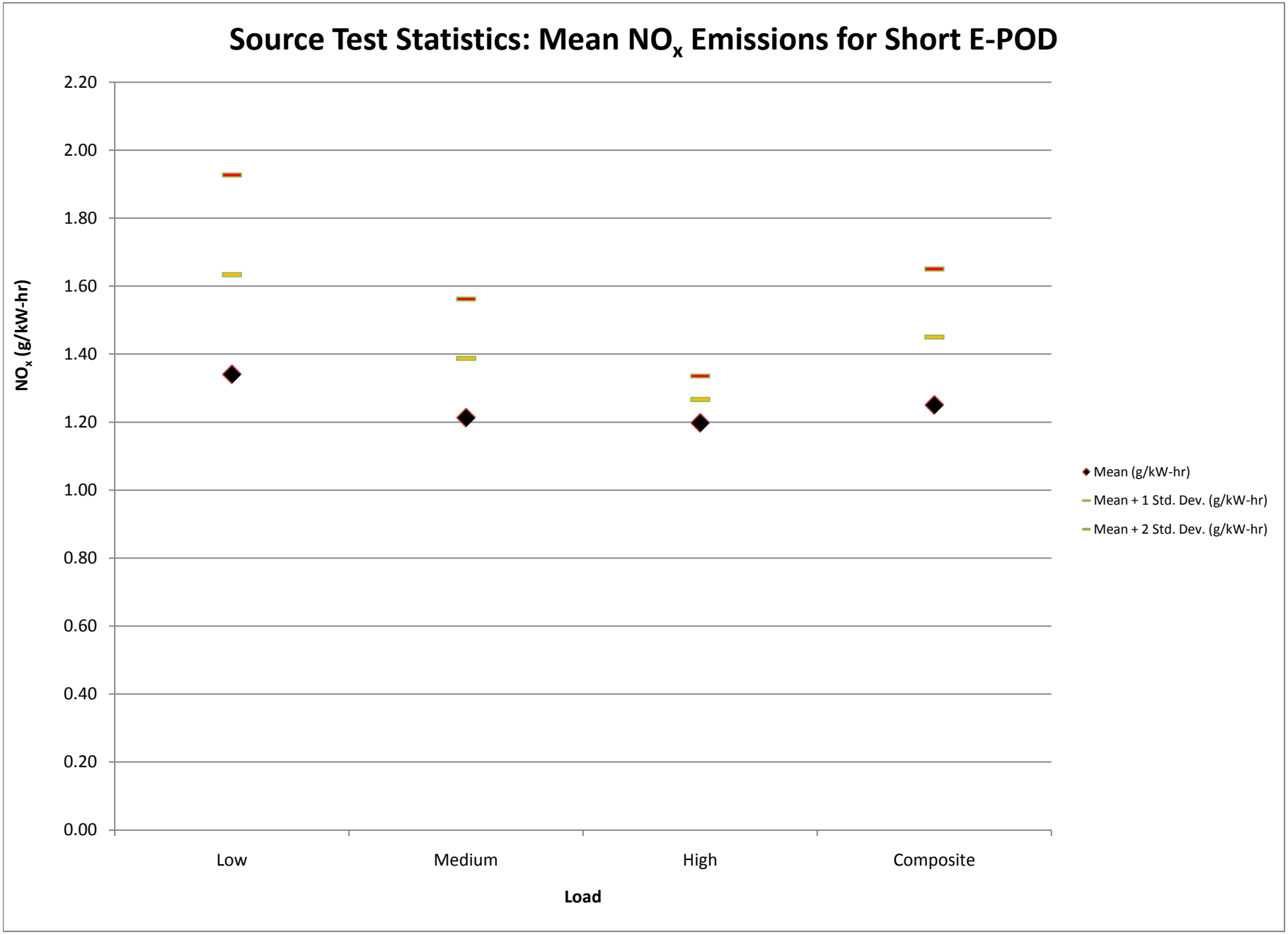
UID	Composite
1-1	53.886667
2-1	80.746667
3-1	75.73
1-3	8.6266667
2-3	7.4866667
3-3	24.67
1-4	20.686667
2-4	23.9
3-4	14.36
1-5	15.986667
2-5	16.213333
3-5	16.84

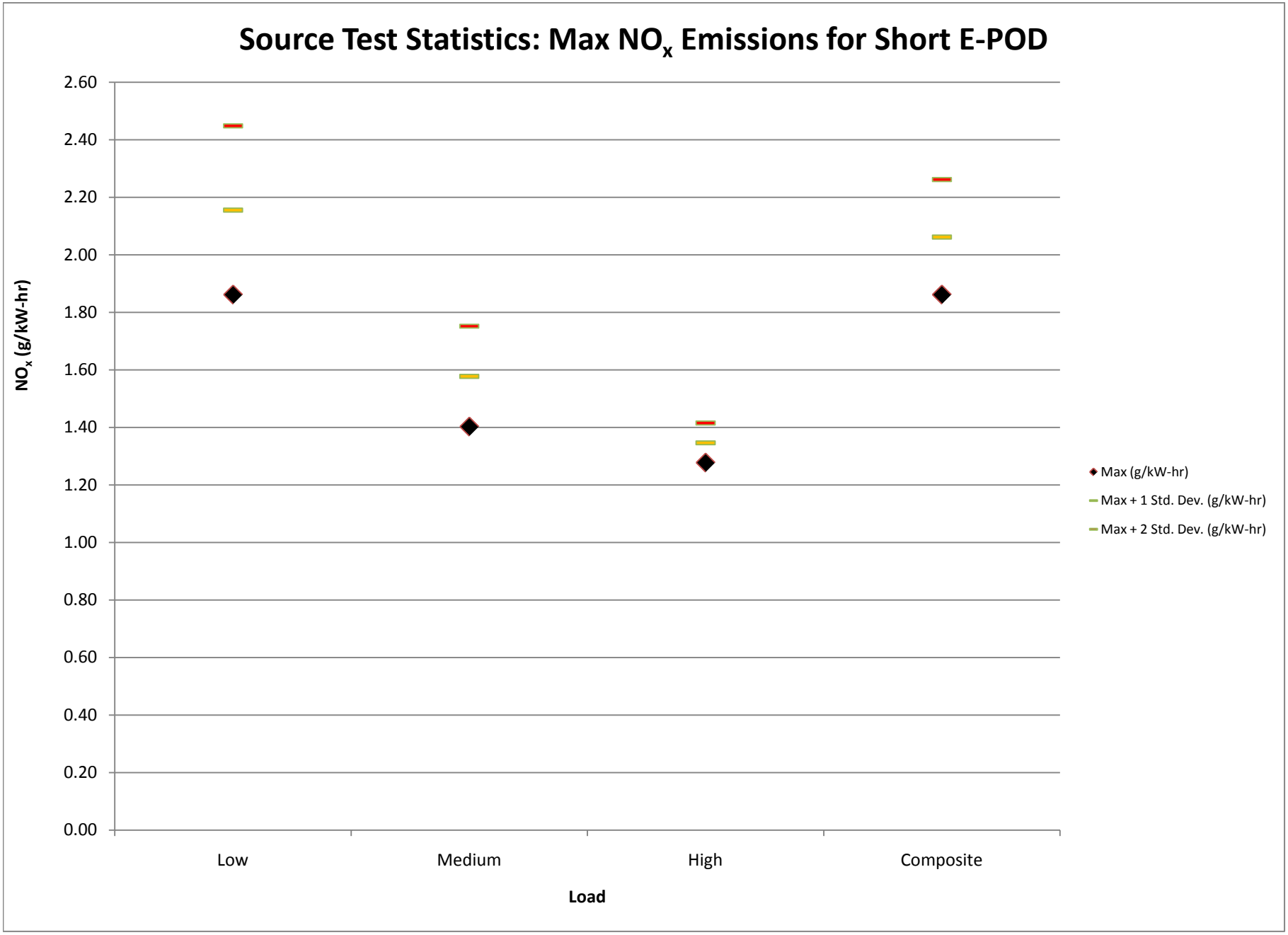
UID	Cmposite

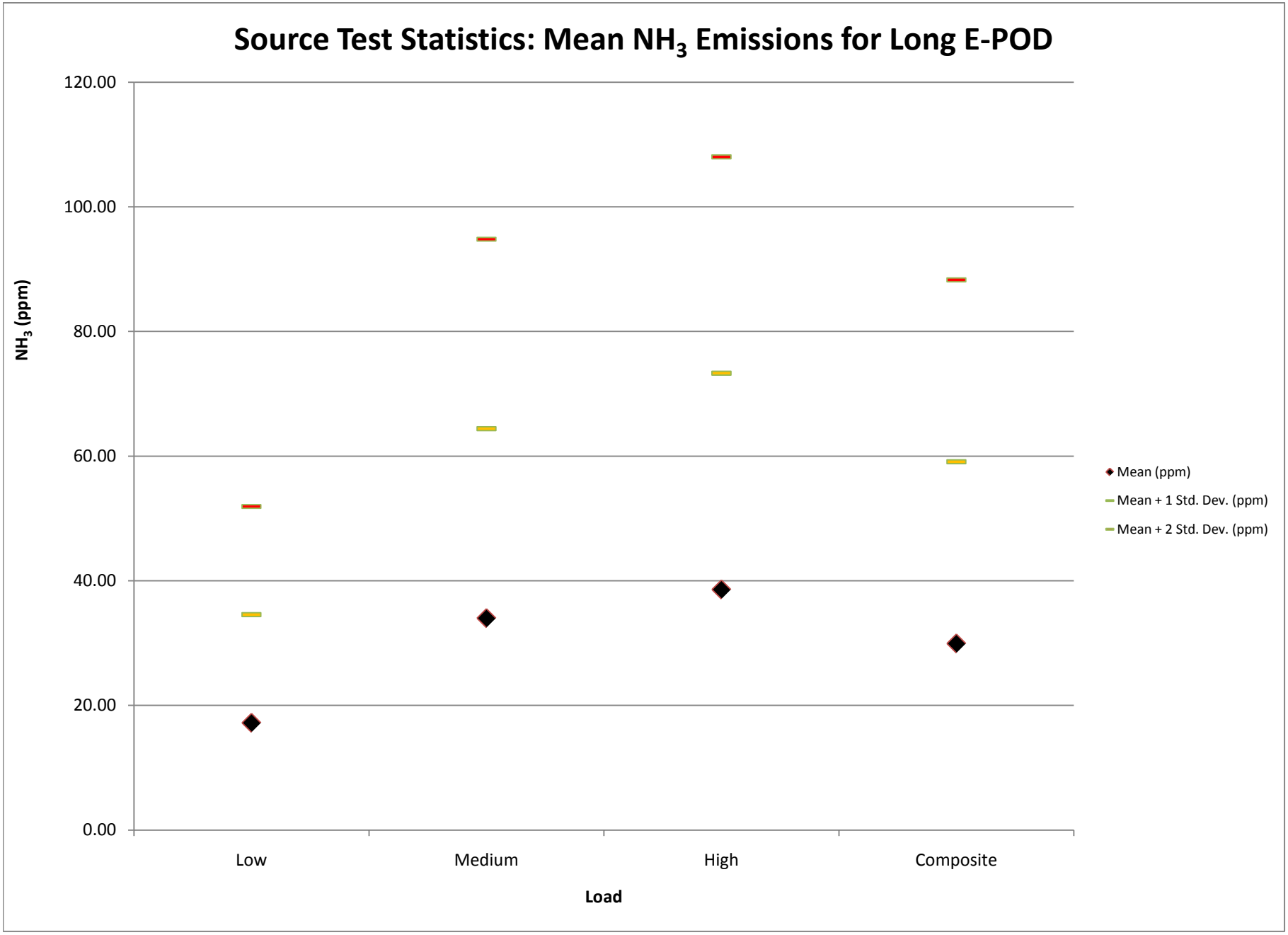
1-2	5.7133333
2-2	6.0966667
3-2	5.4733333
1-6	11.226667
2-6	10.11
3-6	10.666667

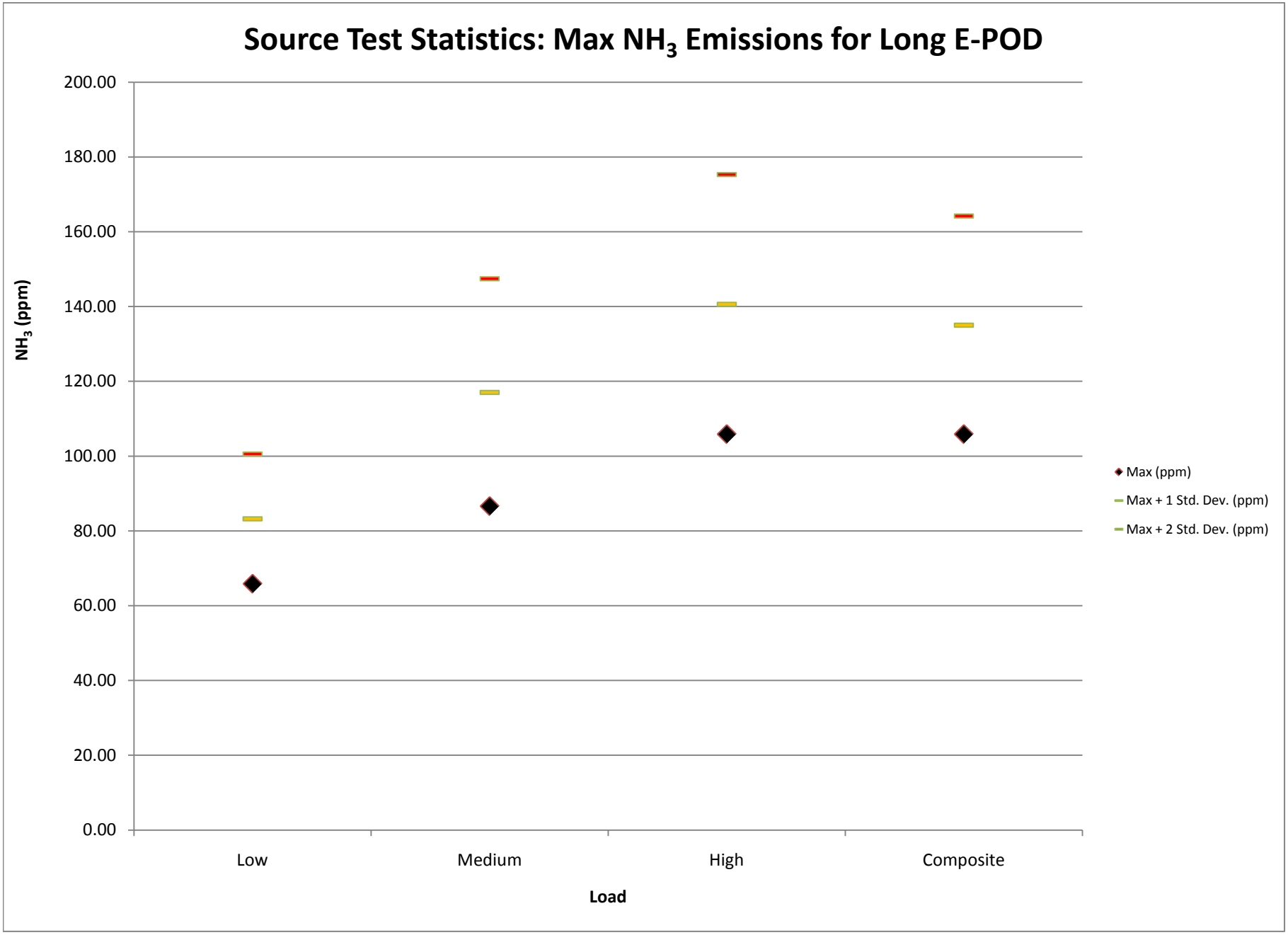

Source Test Statistics: Mean NOx Emissions for Long E-POD
NOx (g/kW-hr)
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Low
Medium
High
Composite
Load
Mean (g/kW-hr)
Mean + 1 Std. Dev. (g/kW-hr)
Mean + 2 Std. Dev. (g/kW-hr)

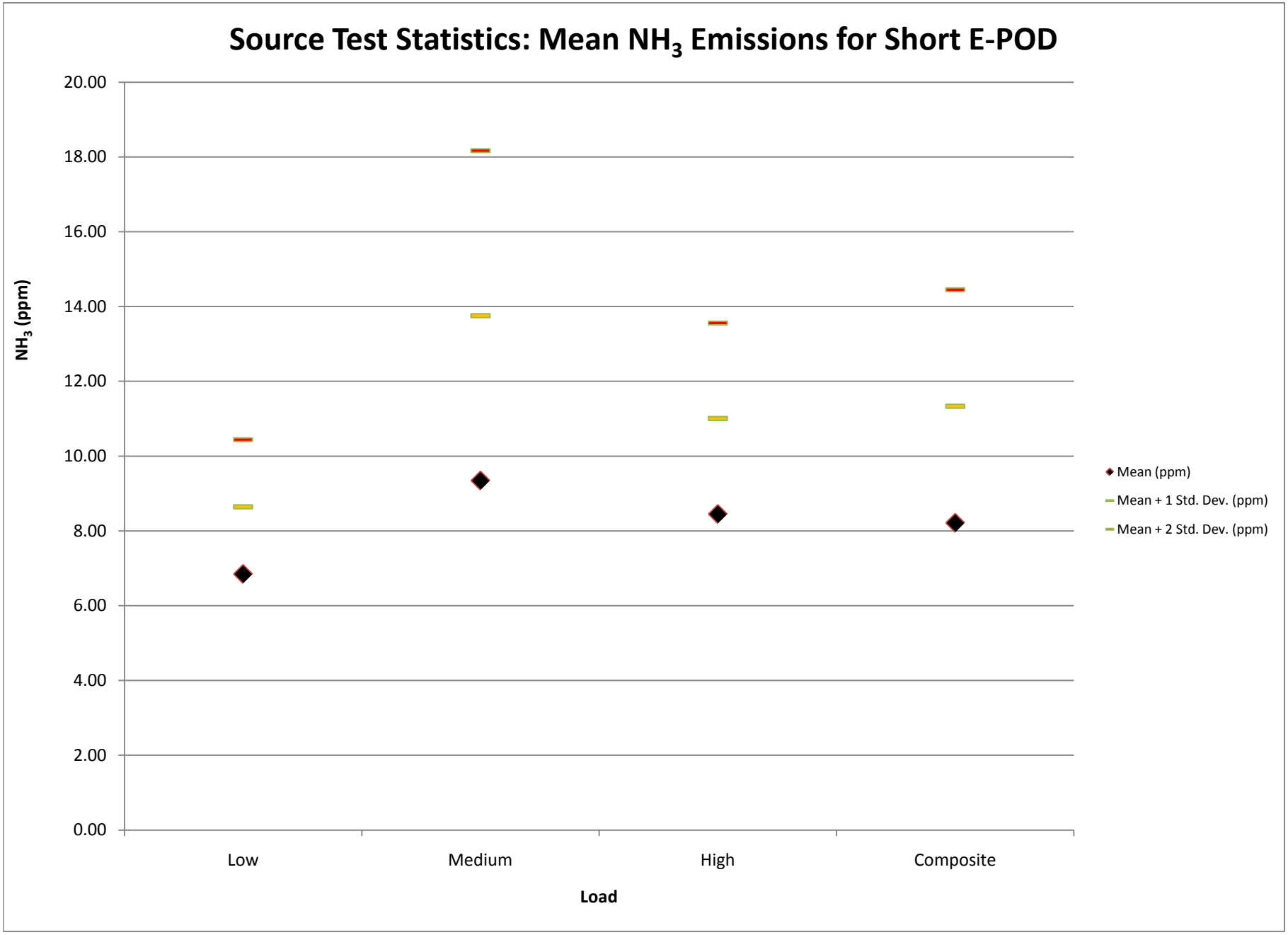

Source Test Statistics: Max NOx Emissions for Long E-POD
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
NOx (g/kW-hr)
Low
Medium
High
Composite
Load
Max (g/kW-hr)
Max + 1 Std. Dev. (g/kW-hr)
Max + 2 Std. Dev. (g/kW-hr)

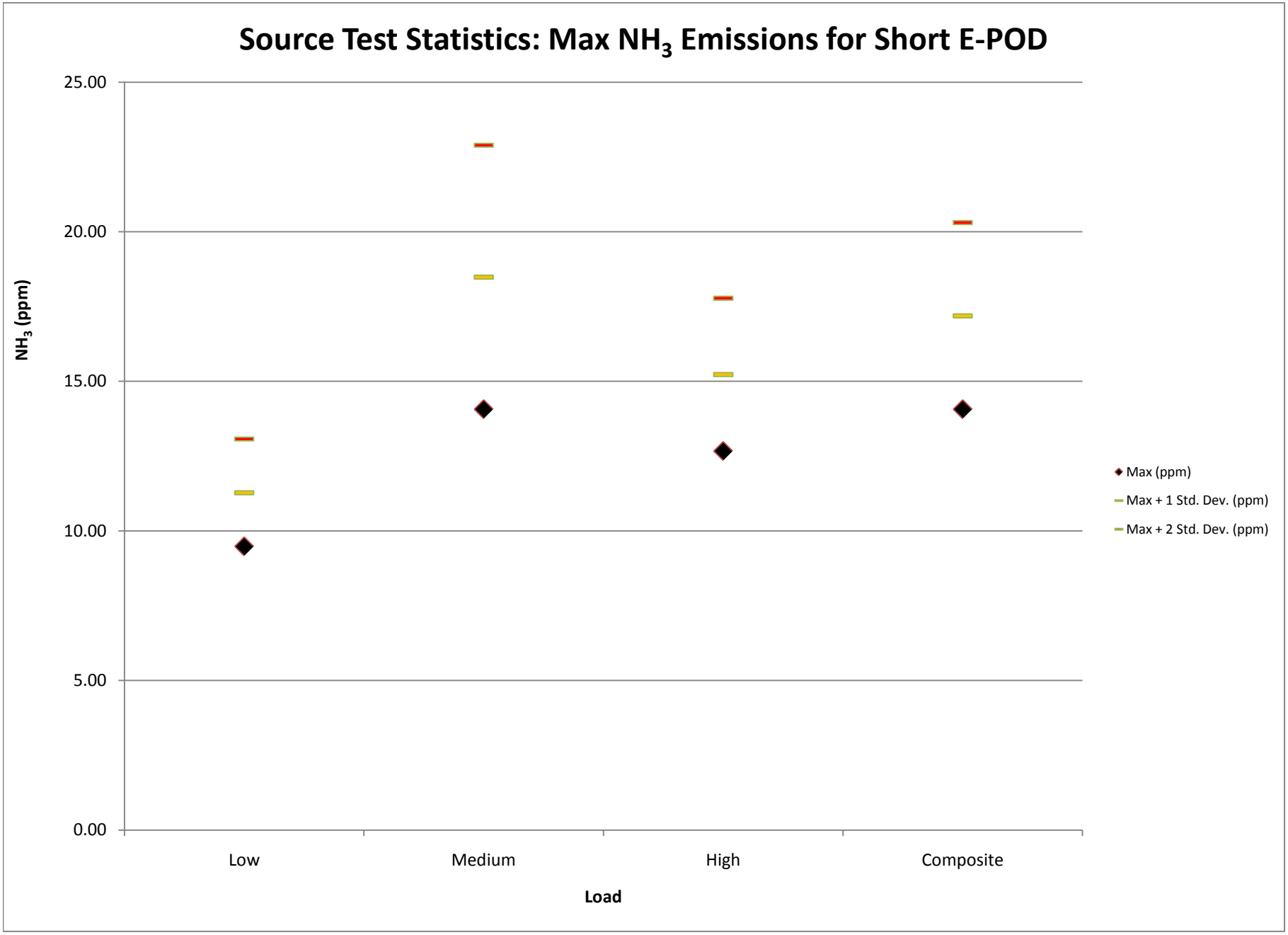

Source Test Statistics: Mean NOx Emissions for Short E-POD
NOx (g/kW-hr)
2.20
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Low
Medium
High
Composite
Load
Mean (g/kW-hr)
Mean + 1 Std. Dev. (g/kW-hr)
Mean + 2 Std. Dev. (g/kW-hr)

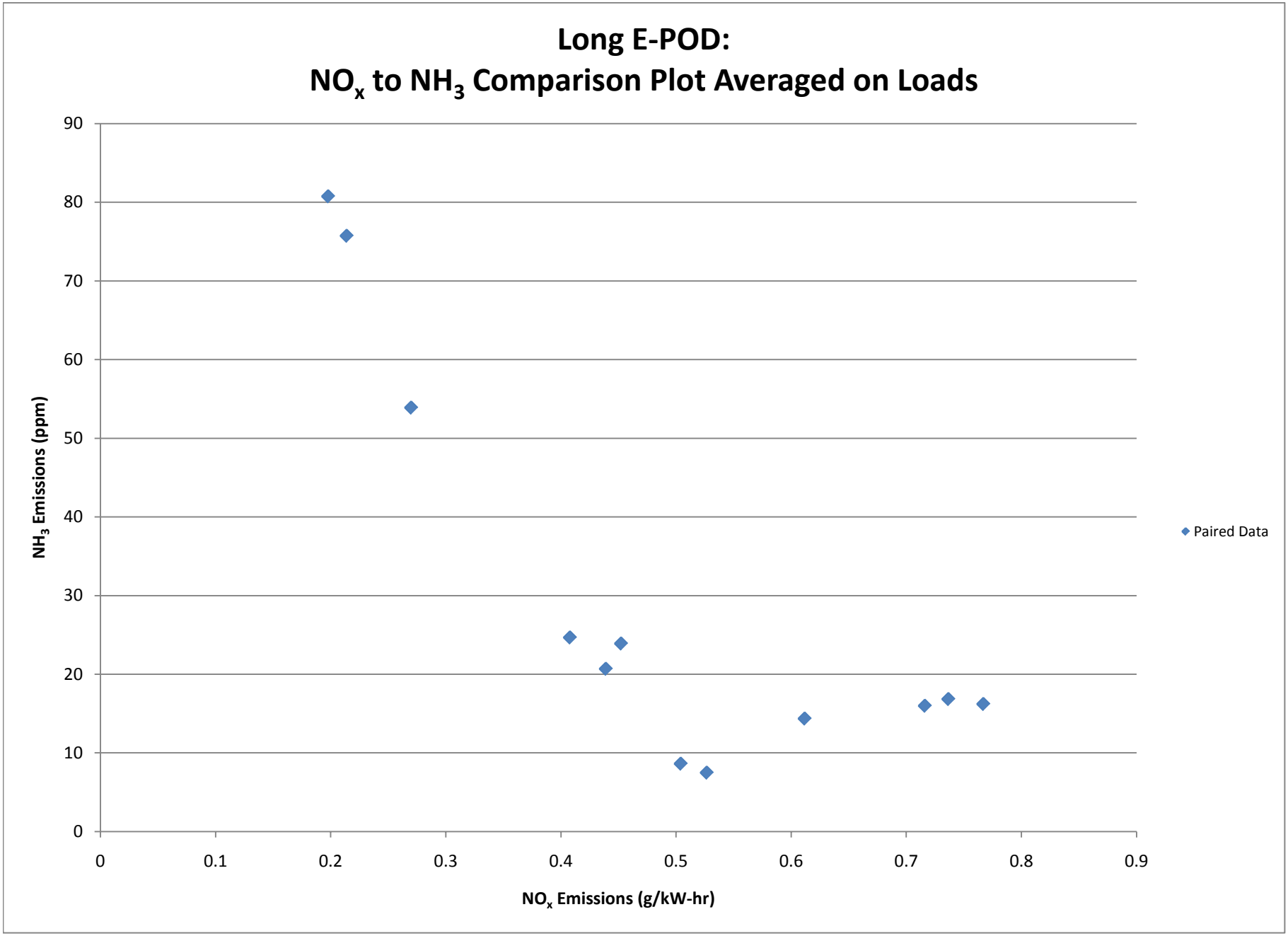

Source Test Statistics: Max NOx Emissions for Short E-POD
NOx (g/kW-hr)
2.60
2.40
2.20
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Low
Medium
High
Composite
Load
Max (g/kW-hr)
Max + 1 Std. Dev. (g/kW-hr)
Max + 2 Std. Dev. (g/kW-hr)

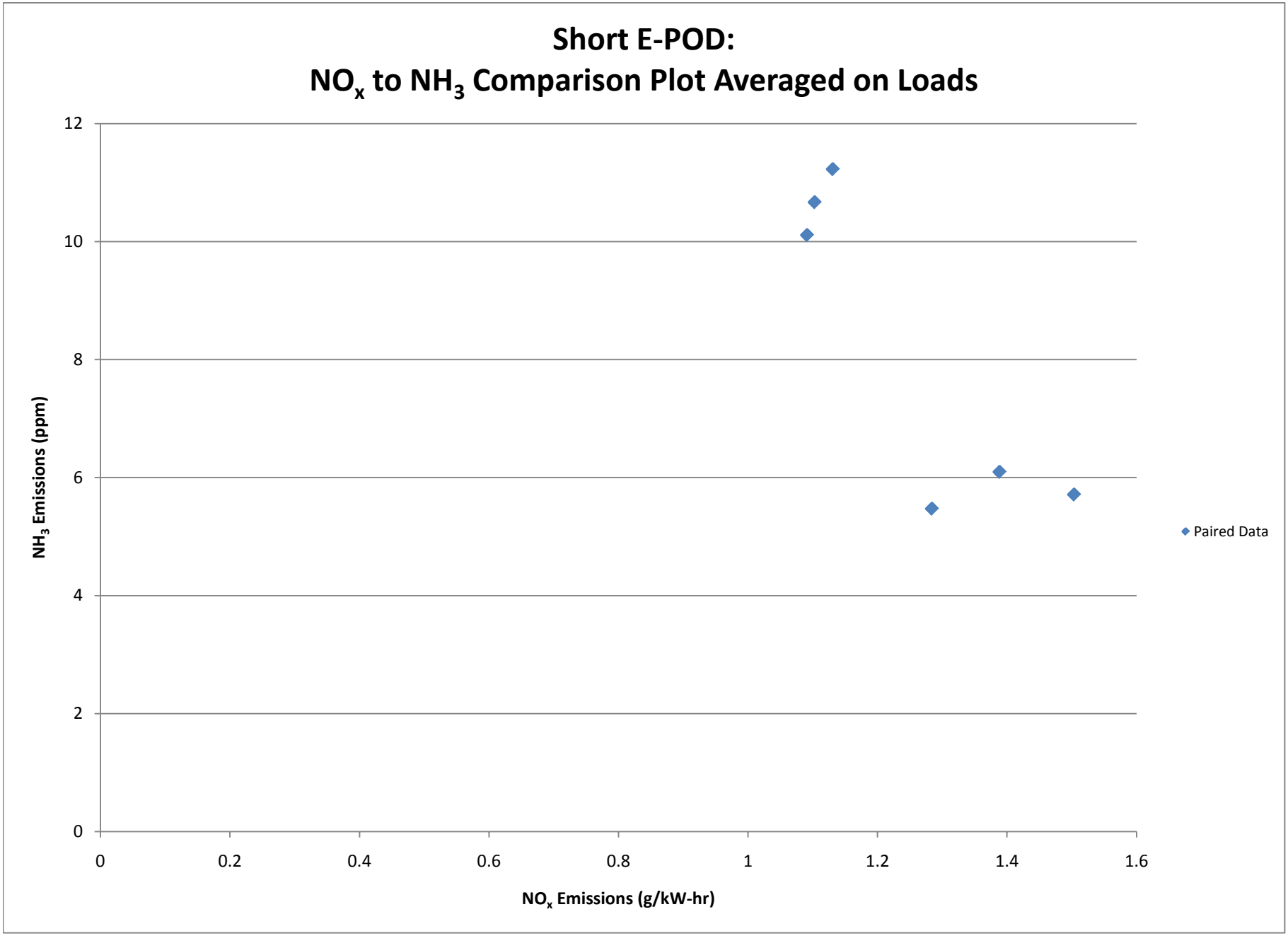

Source Test Statistics: Mean NH3 Emissions for Long E-POD
120.00
100.00
80.00
60.00
40.00
20.00
0.00
NH3 (ppm)
Low
Medium
High
Composite
Load
Mean (ppm)
Mean + 1 Std. Dev. (ppm)
Mean + 2 Std. Dev. (ppm)

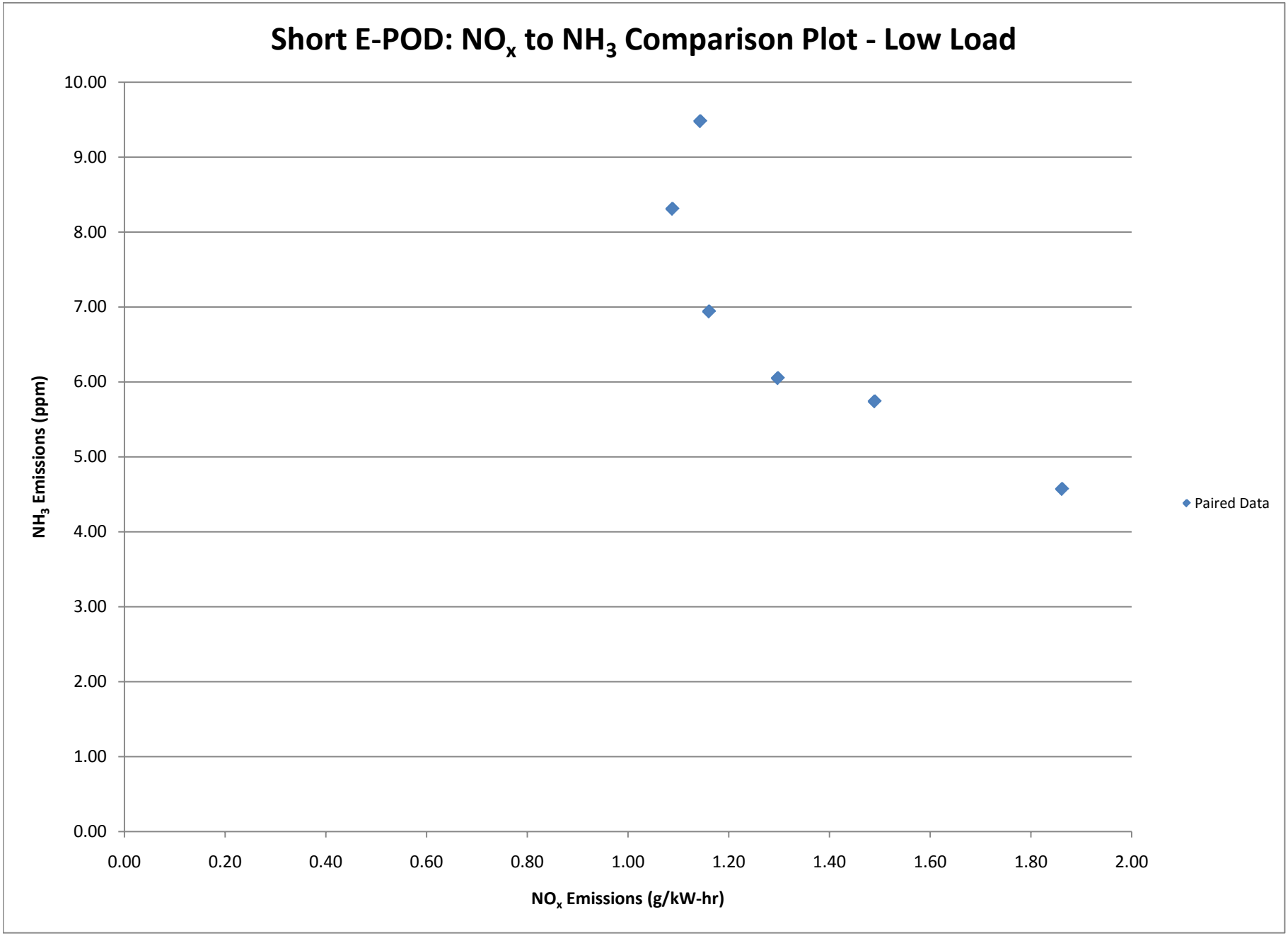

Source Test Statistics: Max NH3 Emissions for Long E-POD
NH3 (ppm)
200.00
180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
Low
Medium
High
Composite
Load
Max (ppm)
Max + 1 Std. Dev. (ppm)
Max + 2 Std. Dev. (ppm)

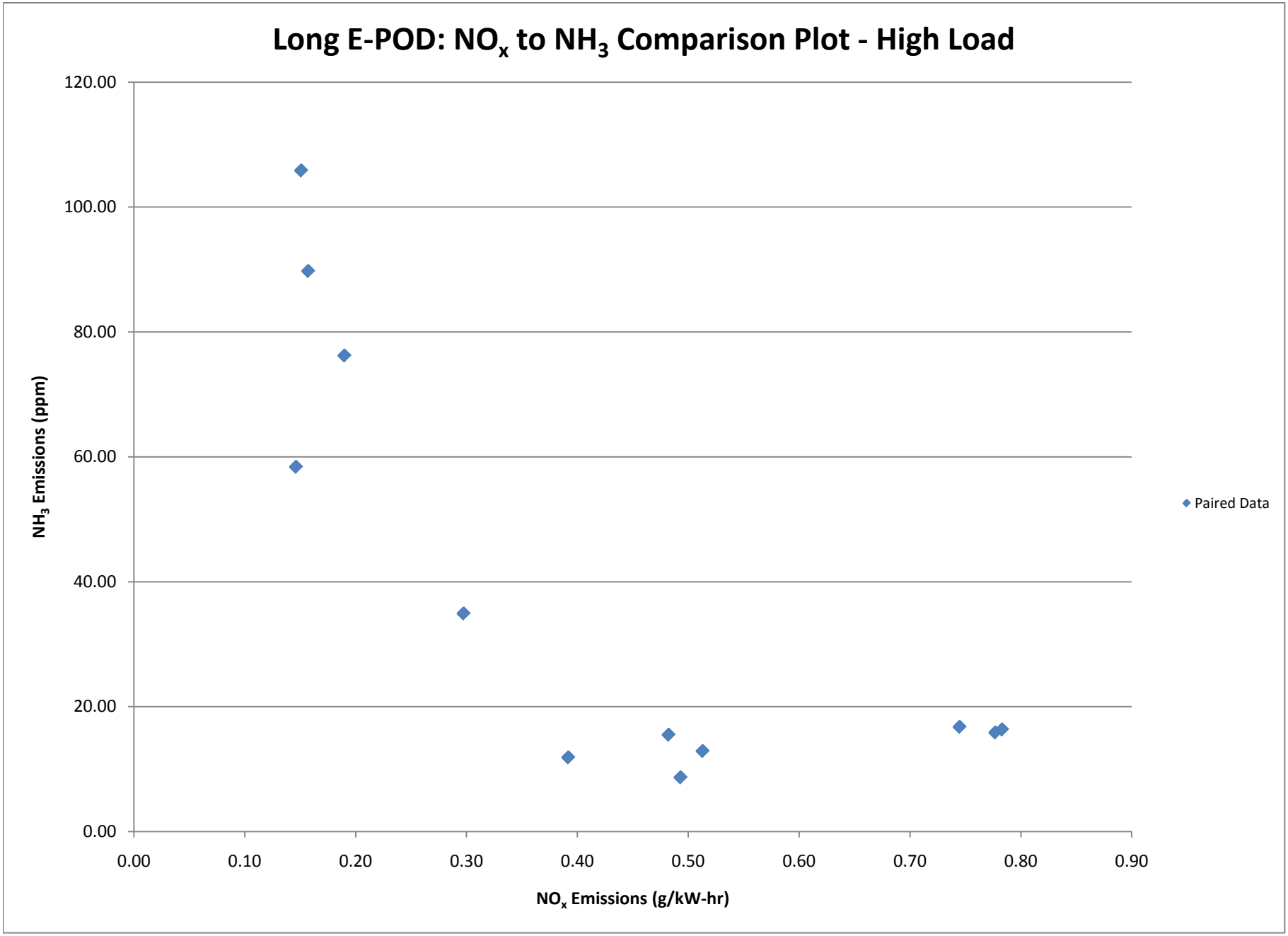

Source Test Statistics: Mean NH3 Emissions for Short E-POD
NH3 (ppm)
20.00
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
Low
Medium
High
Composite
Load
Mean (ppm)
Mean + 1 Std. Dev. (ppm)
Mean + 2 Std. Dev. (ppm)

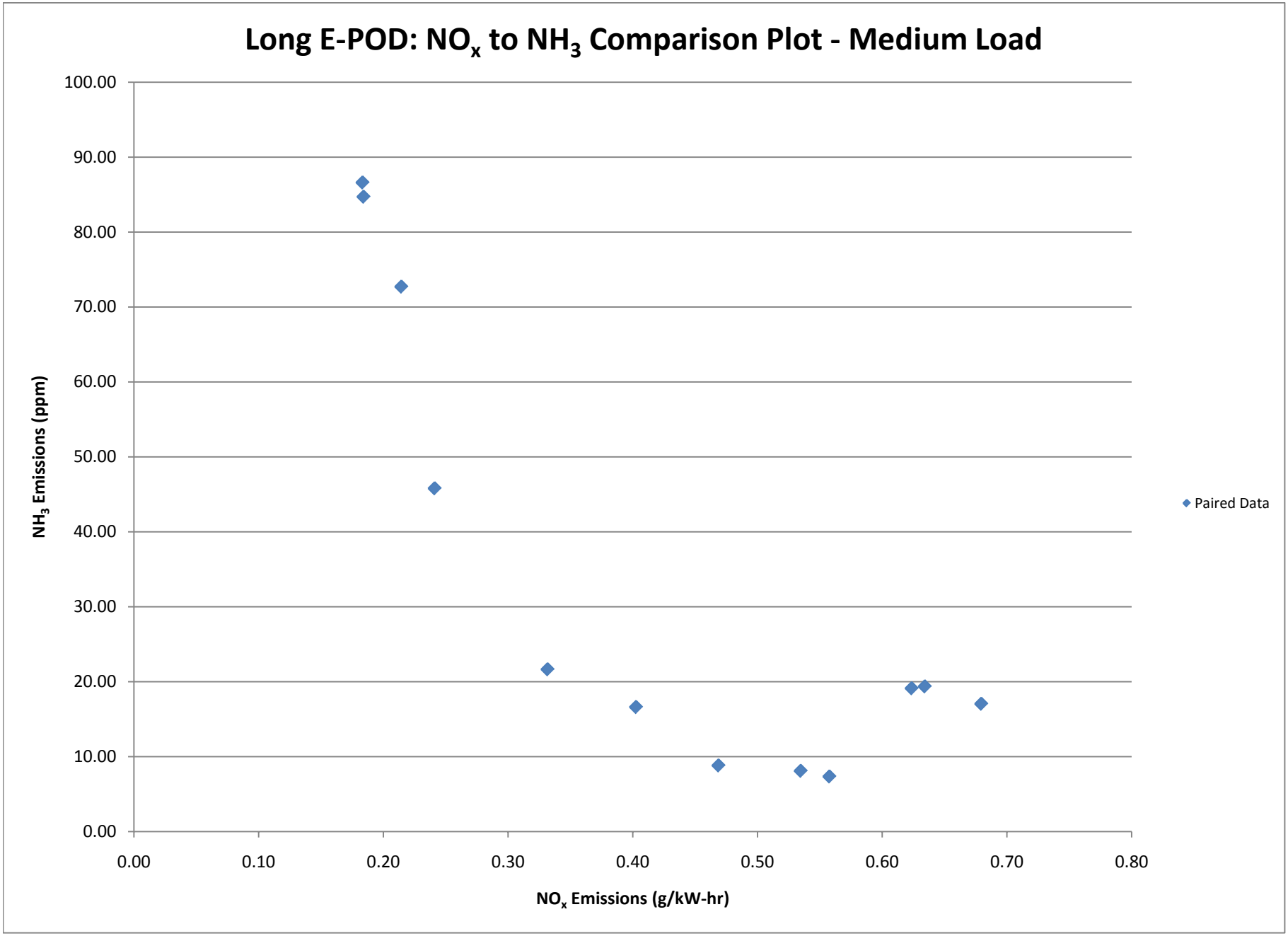

Source Test Statistics: Max NH_3 Emissions for Short E-POD
25.00
20.00
15.00
10.00
5.00
0.00
NH_3 (ppm)
Low
Medium
High
Composite
Load
Max (ppm)
Max + 1 Std. Dev. (ppm)
Max + 2 Std. Dev. (ppm)

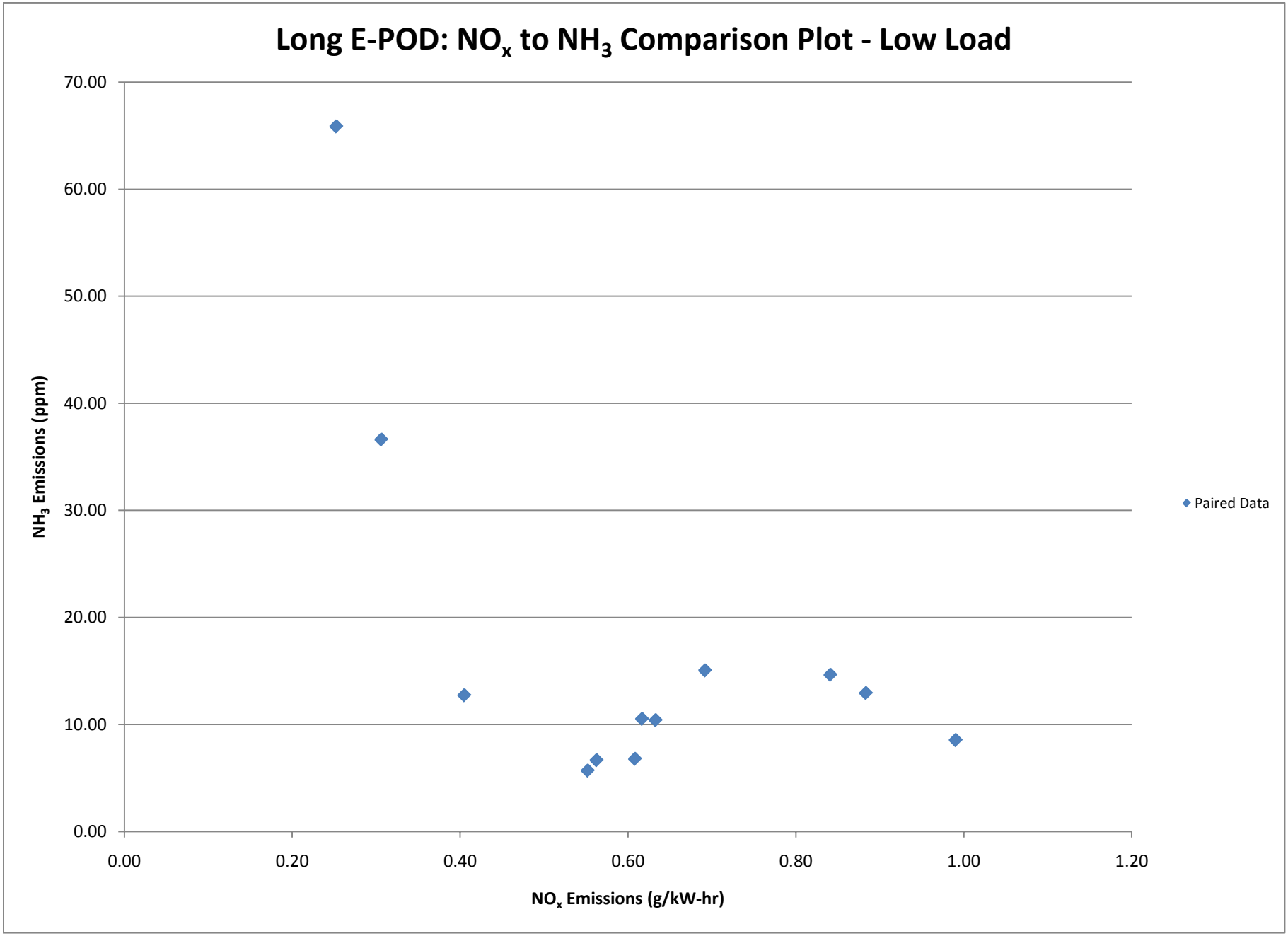

Long E-POD:
NOx to NH3 Comparison Plot Averaged on Loads
NH3 Emissions (ppm)
90
80
70
60
50
40
30
20
10
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
NOx Emissions (g/kW-hr)
Paired Data

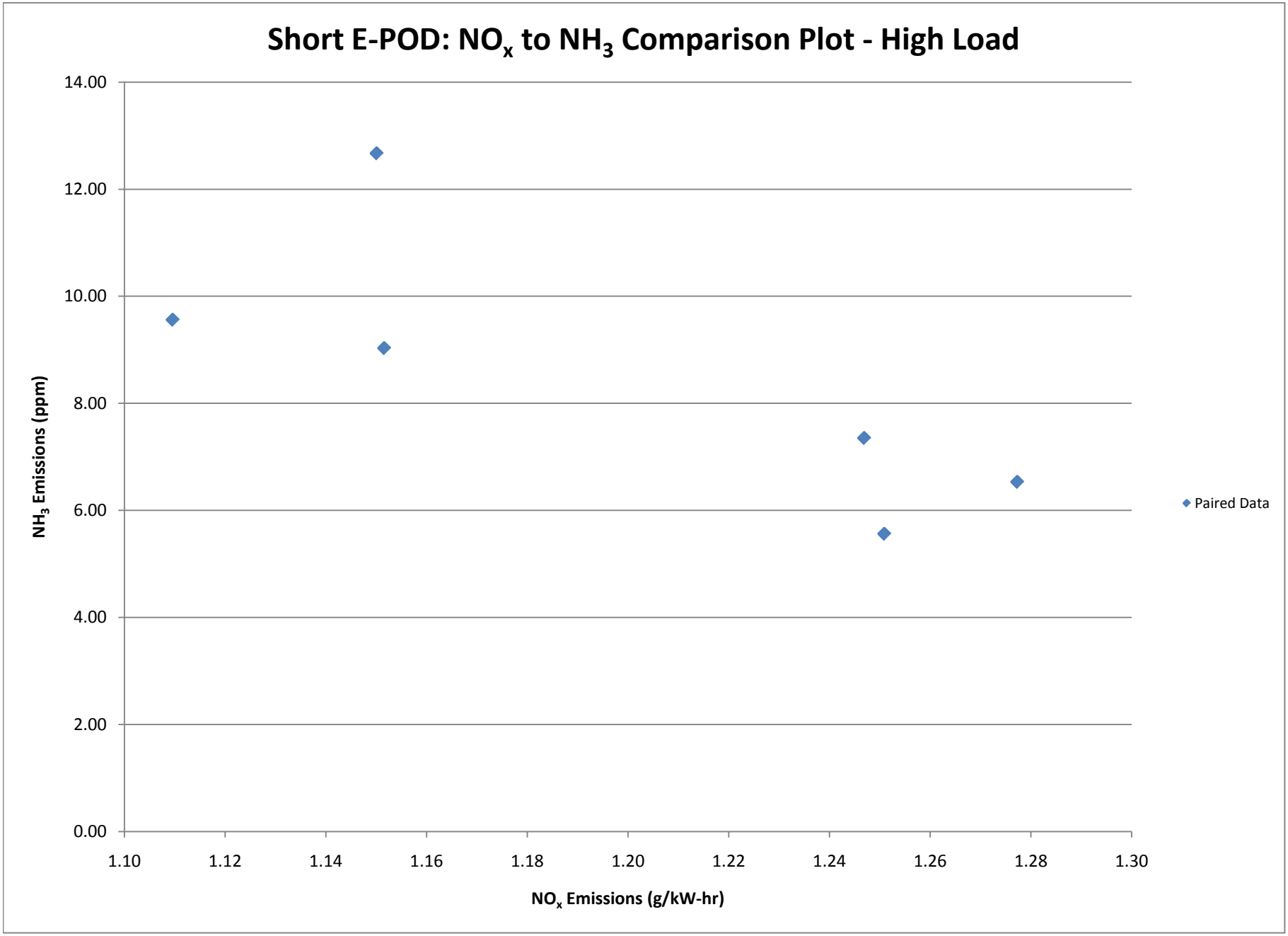

Short E-POD:
NOx to NH3 Comparison Plot Averaged on Loads
NH3 Emissions (ppm)
12
10
8
6
4
2
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
NOx Emissions (g/kW-hr)
Paired Data

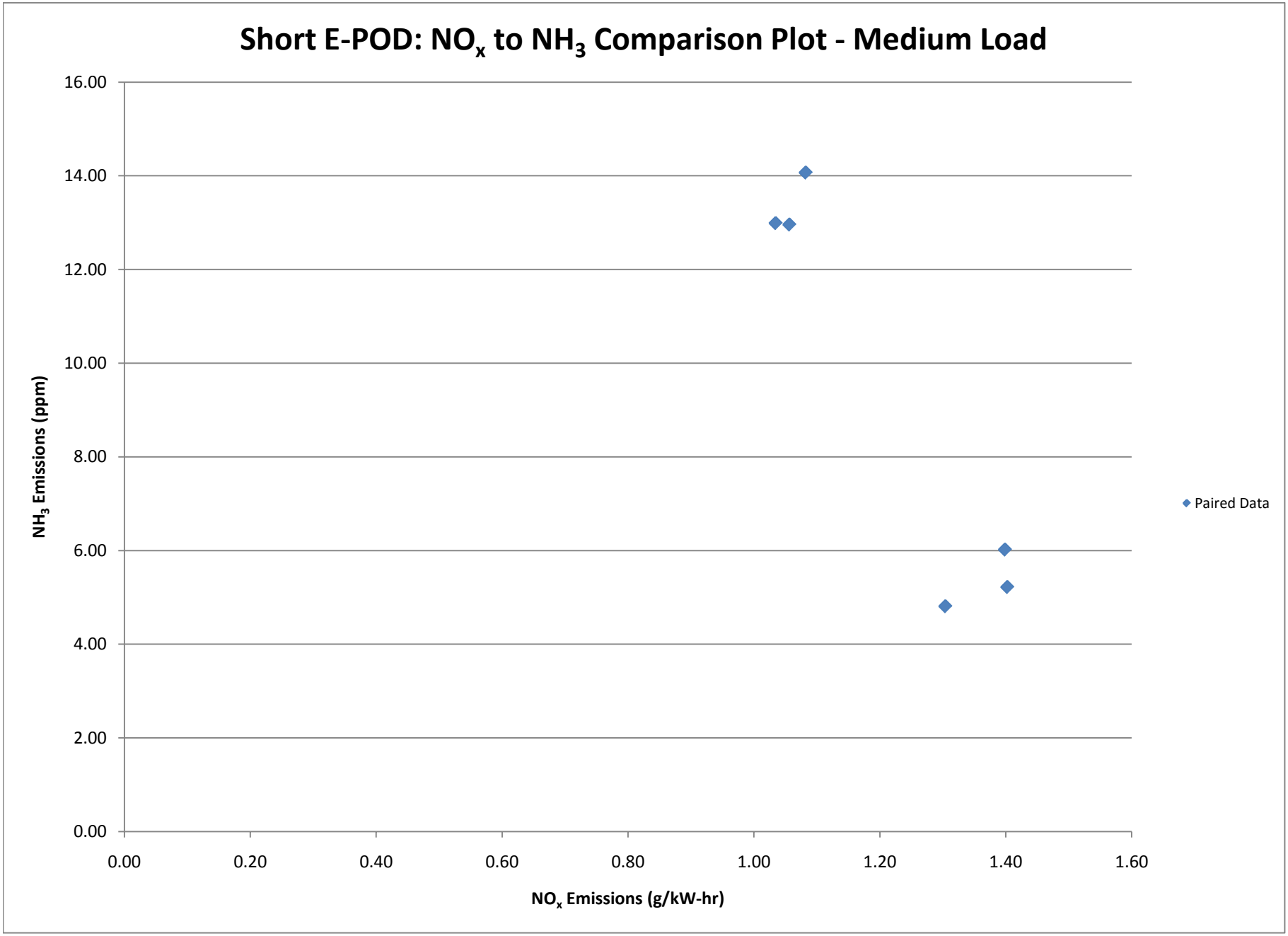

Short E-POD: NOx to NH3 Comparison Plot - Low Load
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
NH3 Emissions (ppm)
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
NOx Emissions (g/kW-hr)
Paired Data


Long E-POD: NOx to NH3 Comparison Plot - High Load
120.00
100.00
80.00
60.00
40.00
20.00
0.00
NH3 Emissions (ppm)
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
NOx Emissions (g/kW-hr)
Paired Data


Long E-POD: NOx to NH3 Comparison Plot - Medium Load
NH3 Emissions (ppm)
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
NOx Emissions (g/kW-hr)
Paired Data


Long E-POD: NOx to NH3 Comparison Plot - Low Load
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
NH3 Emissions (ppm)
0.00
0.20
0.40
0.60
0.80
1.00
1.20
NOx Emissions (g/kW-hr)
Paired Data


Short E-POD: NOx to NH3 Comparison Plot - High Load
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
NH3 Emissions (ppm)
1.10
1.12
1.14
1.16
1.18
1.20
1.22
1.24
1.26
1.28
1.30
NOx Emissions (g/kW-hr)
Paired Data


Short E-POD: NOx to NH3 Comparison Plot - Medium Load
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
NH3 Emissions (ppm)
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
NOx Emissions (g/kW-hr)
Paired Data

			FD1			FD2			FD3			
			Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	
		high	17.60	14.46	13.73	111.00	116.50	118.60	36.68	45.74	13.82	
	NOx	medium	18.18	15.74	15.73	121.20	119.80	111.30	48.46	46.36	41.29	ppm
		low	28.94	18.17	21.49	132.10	108.30	93.75	40.75			
100		high	0.19	0.16	0.15	1.26	1.28	1.25	0.39	0.49	0.15	
0.75	NOx	medium	0.21	0.18	0.18	1.40	1.40	1.30	0.56	0.53	0.47	0.5 g/kW-hr
0.5		low	0.41	0.25	0.31	1.86	1.49	1.30	0.57			
		high	22			6.84						
	NH3	medium				4.64						5 ppm
		low				3.89						

		FD4			FD5			FD6			
		Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	
	high	30.83	49.81	50.98	80.18	79.24	75.44	106.70	106.80	102.20	
NOx	medium	37.26	22.36	31.04	62.45	58.49	56.98	93.57	92.94	92.19	ppm
	low	45.56	45.84	71.40	52.09	63.91	60.86	84.47	79.48	81.92	
	high	0.30	0.48	0.51	0.77	0.78	0.74	1.14	1.14	1.10	
NOx	medium	0.40	0.24	0.33	0.68	0.63	0.62	1.08	1.03	1.06	0.5 g/kW-hr
	low	0.62	0.63	0.99	0.69	0.88	0.84	1.16	1.09	1.14	
	high										
NH3	medium										5 ppm
	low										

Long E-POD

Short E-POD

1.13
1.06
1.13

Engine Test Data: NOx (g/kW-hr)

	FD1				FD3		
	Run 1	**Run 2**	**Run 3**	**Average**	**Run 1**	**Run 2**	**Run 3**
high	0.19	0.16	0.15	**0.17**	0.39	0.49	0.15
medium	0.21	0.18	0.18	**0.19**	0.56	0.53	0.47
low	0.41	0.25	0.31	**0.32**	0.56	0.55	0.61
	FD4				**FD5**		
	Run 1	**Run 2**	**Run 3**	**Average**	**Run 1**	**Run 2**	**Run 3**
high	0.30	0.48	0.51	**0.43**	0.78	0.78	0.74
medium	0.40	0.24	0.33	**0.33**	0.68	0.63	0.62
low	0.62	0.63	0.99	**0.75**	0.69	0.88	0.84
	FD2				**FD6**		
	Run 1	**Run 2**	**Run 3**	**Average**	**Run 1**	**Run 2**	**Run 3**
high	1.25	1.28	1.25	**1.26**	1.15	1.15	1.11
medium	1.40	1.40	1.30	**1.37**	1.08	1.03	1.06
low	1.86	1.49	1.30	**1.55**	1.16	1.09	1.14

	Load averages
Average	FD1, FD3, FD4, FD5
0.34	0.43
0.52	0.42
0.57	0.61

	Composite average
Average	FD1, FD3, FD4, FD5
0.77	
0.65	0.49
0.81	

	Composite average
Average	FD2 & FD6
1.14	
1.06	1.25
1.13	

Engine Test Data: NH3 (ppm)

	FD1				FD3		
	Run 1	**Run 2**	**Run 3**	**Average**	**Run 1**	**Run 2**	**Run 3**
high	76.22	89.76	105.86	**90.6**	11.87	8.67	58.4
medium	72.71	86.61	84.71	**81.3**	7.35	8.1	8.82
low	12.73	65.87	36.62	**38.4**	6.66	5.69	6.79
	FD4				**FD5**		
	Run 1	**Run 2**	**Run 3**	**Average**	**Run 1**	**Run 2**	**Run 3**
high	34.92	15.5	12.89	**21.1**	15.86	16.34	16.76
medium	16.62	45.8	21.65	**28.0**	17.05	19.37	19.12
low	10.52	10.4	8.54	**9.8**	15.05	12.93	14.64
	FD2				**FD6**		
	Run 1	**Run 2**	**Run 3**	**Average**	**Run 1**	**Run 2**	**Run 3**
high	7.35	6.53	5.56	**6.5**	12.67	9.03	9.56
medium	5.22	6.02	4.81	**5.4**	14.07	12.99	12.96
low	4.57	5.74	6.05	**5.5**	6.94	8.31	9.48

	Load averages
Average	FD1,FD3,FD3,FD4
26.3	38.59
8.1	33.99
6.4	17.20
	Composite average
Average	FD1,FD3,FD3,FD4
16.3	
18.5	29.93
14.2	
	Composite average
Average	FD2 & FD6
10.4	
13.3	8.21
8.2	

Note: Data should be provided in identical format and use units of g/kW-hr. Data highlighted in green are QA'd values.

Engine Test Data: NO_x (g/kW-hr)

	FD1				FD3				Composite average
	Run 1	**Run 2**	**Run 3**	**Average**	**Run 1**	**Run 2**	**Run 3**	**Average**	**FD1, FD3, FD4, FD5**
high	0.19	0.16	0.15	0.17	0.39	0.49	0.15	0.34	
medium	0.21	0.18	0.18	0.19	0.56	0.53	0.47	0.52	
low	0.41	0.25	0.31	0.32	0.56	0.55	0.61	0.57	

	FD4				FD5				Composite average
	Run 1	**Run 2**	**Run 3**	**Average**	**Run 1**	**Run 2**	**Run 3**	**Average**	**FD1, FD3, FD4, FD5**
high	0.30	0.48	0.51	0.43	0.78	0.78	0.74	0.77	All Loads
medium	0.40	0.24	0.33	0.33	0.68	0.63	0.62	0.65	
low	0.62	0.63	0.99	0.75	0.69	0.88	0.84	0.81	

	FD2				FD6				Composite average
	Run 1	**Run 2**	**Run 3**	**Average**	**Run 1**	**Run 2**	**Run 3**	**Average**	**FD1, FD3, FD4, FD5**
high	1.25	1.28	1.25	1.26	1.15	1.15	1.11	1.14	
medium	1.40	1.40	1.30	1.37	1.08	1.03	1.06	1.06	
low	1.86	1.49	1.30	1.55	1.16	1.09	1.14	1.13	
									All Loads

Data for FD1-4 received June 17, 2012
Data for FD5 and FD6 received June 18, 2012

Note: Data should be provided in identical format and use units of ppm. Data highlighted in green are QA'd values.

	Engine Test Data: NH_3 (ppm)								
		FD1			FD2			FD3	
	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3
high	76.22	89.76	105.86	7.35	6.53	5.56	11.87	8.67	58.40
medium	72.71	86.61	84.71	5.22	6.02	4.81	7.35	8.10	8.82
low	12.73	65.87	36.62	4.57	5.74	6.05	6.66	5.69	6.79

		FD4			FD5			FD6	
	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3
high	34.92	15.50	12.89	15.86	16.34	16.76	12.67	9.03	9.56
medium	16.62	45.80	21.65	17.05	19.37	19.12	14.07	12.99	12.96
low	10.52	10.40	8.54	15.05	12.93	14.64	6.94	8.31	9.48