Innsbrook Technical Center
5000 Dominion Boulevard
Glen Allen, Virginia 23060

VIRGINIA POWER

May 2, 1994

Mr. Gregory L. Clayton
Virginia Department of Environmental Quality
300 Central Road, Suite B
Fredericksburg, Virginia 22401

Dear Mr. Clayton:

On August 30, 1993 Virginia Power applied for a permit to install an emergency standby diesel-powered generator at the North Anna Nuclear Power Station (registration number 40726). The permit was issued on October 20, 1993. Subsequently, Jim Cassada of Virginia Power and Terry Darden of DEQ had several telephone conversations during which they discussed certain emission limits in the permit which differ from those requested in our application. Mr. Darden was very helpful and cooperative, and expressed a willingness to reconsider the emission limits if Virginia Power could provide justification for the use of test data provided by the manufacturer (Caterpillar) rather than generic emission factors, and justification for the safety factors Caterpillar added to the emission data to establish guarantee values. Attached is a Caterpillar memorandum which addresses those issues.

The differences between the emission limits requested in the application (which are the values guaranteed by Caterpillar) and those contained in the permit are as follows:

- The short-term emission limit for NO_x (114.4 lb/hr) is lower than that guaranteed by Caterpillar (157.2 lb/hr).
- The short-term and annual emission limits for TOC (3.3 lb/hr and 1.2 TPY at 700 hr/yr operation) are lower than those guaranteed (6.7 lb/hr and 1.68 TPY at 500 hr/yr operation, or 2.35 TPY at 700 hr/yr operation).
- The SO_2 emission limits in the permit appear to be exactly half the values requested in the application. We believe the values in the application are correct, based on the heat input capacity and fuel sulfur content numbers given in the permit.

In addition, the short-term emission limit for PM_{10} (1.8 lb/hr) is less than that originally guaranteed by Caterpillar (1.9 lb/hr) based on a 50% factor added to the nominal test data to account for variability in the engines and the tests. However, Caterpillar has subsequently re-examined the factor and determined that a factor of 40% is adequate. Therefore, we are not requesting that the emission limit for PM_{10} be revised.

C001 1/1

We believe the attached Caterpillar document will answer your questions about the basis of Caterpillar's emission rate data. If additional technical information is required, please contact Jim Cassada at (804) 273-3010. Thank you for your assistance.

Very truly yours,

A. W. Hadder

A. W. Hadder
Manager
Air Quality

cc: U.S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, D.C. 20555

Re: North Anna Power Station
Units 1 and 2
Docket Nos. 50-338 and 50-339
License Nos. NPF-4 and NPF-7

NRC Senior Resident Inspector
North Anna Power Station

CATERPILLAR

Interoffice Memorandum

Plant Or Office	Department	Attention
Destroy	File Until (Date)	

Facility

Date February 10, 1994

Plant/Office Large Engine Center

Department 3600 Project Services

Attention D E Davis

SUBJECT: CATERPILLAR 3612 EMISSIONS DATA

The emission values provided are primarily based on laboratory measurements on similar 3600 engines. The lab measurements were made on development engines located at the Caterpillar Technical Center in Mossville, Illinois. These engines are equipped with production hardware in the areas of importance for emissions (injector nozzles, turbochargers, heads, valves, cams, etc.). The data from lab engines are supplemented with data from the field.

The 3600 is a modular engine. It uses separate cylinder heads and unit injectors so the combustion chamber is identical for 6, 8, 12 and 16 cylinder configurations. The 6 and 12 cylinder engines share turbochargers (one on the 6 and two on the 12) as do the 8 and 16 cylinder engines. The turbochargers used on the 6 and 12 are smaller than the 8 and 16 but the turbochargers are matched so that the intake manifold pressure is similar. The flow per cylinder and the air-fuel ratio are therefore similar.

TEST METHODS FOR GASEOUS EMISSIONS

NOx - a chemiluminescent analyzer with nitrogen dioxide converter is used which is consistent with EPA Method 7E.

Hydrocarbons (gaseous organic compounds) - a flame ionization analyzer is used which is consistent with EPA Method 25A.

CO - A non-dispersive infrared analyzer (NDIR) is used which is consistent with EPA Method 10.

Exhaust flow - inlet air flow and fuel flow are measured. Exhaust flow is the sum of the air and fuel flows.

Quality control is consistent with EPA requirements for on-highway truck engines. Additional quality control includes a carbon balance of fuel inlet carbon vs. the measured exhaust carbon (CO, HC, CO_2) to check the measuring systems.

TEST METHOD FOR PARTICULATES

Caterpillar has developed a special measuring system for particulate emissions called the Steady State Particulate System (SSPS). The Steady State Particulate System was designed to measure diesel particulate in a manner compatible with EPA Method 5 without back-half wash. Diesel particulate are very small (about 0.3 micron) and do not exhibit significant inertia effects so isokinetic sampling is not necessary (EPA method for truck diesel engines do not use isokinetic sampling). SSPS samples similar to method 5 in that the exhaust sample is pulled through a filter held at 120 deg C and the filter is weighed before and after sampling. SSPS was found to correlate with Method 5 in lab tests (field experience will be covered later)

DATA USED FOR EMISSION VALUES PROVIDED

The emission values provided for the 3612 are based on tests on a 3606 conducted March 21, 1990 at the Caterpillar Technical Center. These tests are covered in an internal Caterpillar report, 3606 High Speed Emissions Correlation with 3608 by DA Spurgeon. The 3612 is essentially two 6 cylinder engines sharing a crankshaft so the data is applicable to both engines. The test data are given on Sheets A and B. Caterpillar has computerized test cells which store the data electronically. The data on Sheets A and B are modified slightly for injection timing (21 to 21.5 degrees) based on data taken from other engines. Plotted data are shown on Sheet C. Emissions units are usually reduced to grams/brake-horsepower hour (g/bhp-hr) since this has been the historic unit chosen by EPA for regulating engines and allows comparing engines of various power (brake power is the power from the output shaft of the engine)

The published emission data sheet is given on Sheet D. The emission values for this sheet are chosen conservatively.

COMPARISON OF LAB RESULTS TO FIELD DATA

Caterpillar is not normally provided with emission test data from the field unless there is some problem. The following is the field data we have on the 3600

Almega Corp. of Bensenville, Illinois measured nitrogen oxide emissions on a 3608 generator set engine located at the Caterpillar plant in Pontiac, Illinois on Oct. 9, 1987 using EPA Method 7 (grab sample colorimetric method). The 3 runs were 46.4, 38.8, and 51.2 lb/hr for an average of 45.5 lb/hr (7.38 g/bhp-hr)(see Sheet E). Caterpillar had run the same set-up at the Technical center on April 6, 1987 giving 51.2 lb/hr (8.26 g/bhp-hr) (see Sheet F-printer problems did not allow printing of full sheet).

Environmental Technologies International of Honolulu, Hawaii tested eight 3616 engines on the island of Guam for particulates (Method 5) and nitrogen oxides (Method 7E). The measured values are given on Sheet G. The NOx ranged from 6.34 to 7.37 for an average of 7.02 g/bhp-hr compared to a nominal value of 7.20 g/bhp-hr provided from lab testing. The particulates included a very high emission measurement for Old GMH Unit 2 which was reduced to a value consistent with the others on a repeat test. It is likely the high values was due to accumulated soot or rust blown out the stack during this initial running. Soot can accumulate in stacks during light load running and are then blown out when operated at full load. The average excluding the high value is 0.217 g/bhp-hr compared to a nominal of 0.32 g/bhp-hr based on lab measurements with the Caterpillar Steady State Sampling System.

Measurements on a 3616 at Algona, Iowa on August 4, 1993 gave higher than expected particulate emissions. An emission rate of 0.367 g/bhp-hr was measured using Method 5 (front half) compared to a nominal lab value of 0.12 g/bhp-hr. Repeat measurements were made on October 15, 1993 by Almega Corp. which gave a value of 0.078 g/bhp-hr. The early high values are believed to be due to scale and/or accumulated soot blowing out the stack. During engine warm-up, large particles (about 1 mm) accumulated on surfaces near the stack. Diesels do not produce particles of this size.

Caterpillar measured particulates at the Algona site with the Steady State Particulate System in parallel with the Method 5 measurements. The SSPS gave 0.075 g/bhp-hr vs 0.078 for Method 5.

These tests confirm that the emission values provided from the laboratory engines are valid for actual engines in operation.

VARIABILITY

Emission measurements are inherently variable. This variability must be accounted for when providing "not-to-exceed" values for emission permits.

Our standard tolerances are:

NOx	15%
CO	30%
HC	30%
Particulates	40%

These tolerances are less than what were sent on August 4, 1993 (20% NOx, 35% HC & CO, and 50% particulates). The higher tolerances had been revised down in early 1993 but there was a miscommunication internally.

The tolerances are based on Caterpillar experience on truck engines that must meet not-to-exceed emission standards, field measurements, and literature information.

Flow Tolerance

Exhaust flow measurement error directly effects the emission rate. Measuring the exhaust flow with EPA Method 2 is prone to errors. For instance, at the high stack velocity common with diesels (30 m/s), the flow measurement is very sensitive to Type S pitot probe orientation. A 10 degree error can give about 10% velocity error. The probable tolerance for exhaust flow is estimated at 3-5% at best.

NOx Tolerance

The data from the 3616 engines at Guam give a coefficient of variation of 5.2 % of the mean NOx value. The coefficient of variation (COV) is the standard deviation divided by the mean value. The Guam data was taken with a chemiluminescent analyzer (EPA Method 7E). This COV is consistent with truck engine emission variability (chemiluminescent analyzers are used).

NOx measurements at the Caterpillar Pontiac plant with the grab sample/phenoldisulfonic acid/colorimeteric procedure (EPA method 7) give a coefficient of variation of 59% based on the three measurements of 46.4, 38.8, and 51.2 lb/hr. Method 7 uses an average of the 3 samples so the COV would be reduced, but only to about 30%. Diesel engines produce very stable NOx concentrations at steady load, the variation must be attributed primarily to the measuring system.

The emission values with tolerances are intended to be "not-to-be exceeded". For a normal distribution, 97.7% of the samples would be less than the average + 2 standard deviations. Based on the use of EPA Method 7E (chemiluminescent) with its lower variability and the flow error probability, a tolerance of 15% was selected for NOx. This would be low for EPA Method 7 (grab sample).

Particulate Tolerance

The literature reports very high variations with Method 5. Licata and Egdall in The Precision of Source Emission Measurement Methods report coefficients of variations of up to 40% for particulate concentrations about 10 times what are found with diesels (see Sheet H). The Method 5 procedure has many potential sources of error or contamination and is very dependent on the skill of the operators.

The particulate measurements at Guam give a 106% coefficient of variation if the asterisked point is included (see Sheet G). It is obvious that this is not a normal distribution if this point is included. We believe the high value is due to accumulated material in the stack. Excluding this point reduces the COV to 7.3%.

Truck engine tests give coefficient of variations of 5-14%.

Considering the high tolerances reported by some and including tolerance for exhaust flow, a tolerance of 40% was selected.

Hydrocarbon Tolerance

No field data are available on hydrocarbon emissions on the 3600. The coefficient of variation observed in truck engine lab tests is 8-12%. A tolerance value of 30% was selected based on the truck engine data (taken in well controlled conditions) and considering flow error and lack of field experience.

Carbon Monoxide

No field data are available on CO emissions on the 3600. The coefficient of variation in truck lab tests is about 6%. A tolerance value of 30% was chosen due to lack of field data and due to the low basic CO emissions of the diesel engine.

John R. Gladden

J R Gladden
Sr Project Engineer
3600 Product

s93.1 inquiry\meth2.sam

PART LOAD EXHAUST EMISSIONS AT 900 RPM (EPA SUB PART D)

FILE: DF02019 DATE: 21-MAR-90 OBS: SPURGEON
RACK CAL: FAMILY (EPA):
TURBINE DIA: FLOW TIME: NSG/NOZ AREA: 101.7
ENGINE MODEL: 3606-DITA NO: 007X3
BORE: 200.0 MM STROKE 300.0 MM CYLS: 6
TEST CON AIR TO ENGINE OR TURBO COMPR - TEMP: 24. DEG C
PRESS: 96.0 KPA ABS AT EACH DATA POINT
FUEL-TYPE: 1E262 TEMP: 46. DEG C
BARO: 99.0 KPA AFTERCOOLING: SCAC-50C
INJ TIME DEG BTC: 21.0 DEG ADV: 0.00
TURBO MODEL: VTC254A - SEE REMARKS
NO: 1 LOCATION: REAR
REMARKS TURBO: VG11/HF10/HA04-HG00/EF10/EA03
7C3596 HIGH SPEED MOL CAM
2350 EMISSIONS DATA (REF DF02014 PART LOAD PERF)

CELL: 502 FILE NO: 00000-000 DYNO CON:
CODE (EPA):
DANIELS AIR FLOW: PIPE DIA:
COMB CHAMB PISTON: CRATER:
CR: 13.00 NOMINAL PC: ORIF:
FUEL SYST TYPE: LUCAS-UI PUMP DIA: 21.0 MM
CHECK TYPE: GROUP NO:
FUEL NOZZ PART NO: LUCAS TYPE: D.I.
ORIFICES- NO: 10 DIA: .465MM ANGLE: 145 DEC
FUEL LINES ID AND LENGTH-EXTERNAL: X
INTERNAL: X
EXH MAN TYPE: SPLIT PART NO:
PUBDATA GEN APPL:
AUTO SP APPL:

DATA POINT		1.	2.	3.	4.	5.	7.
BEAM	N-M	3512.0	7630.4	10566.7	14181.9	18300.6	22050.9
AVE RPM	RPM	900.	900.	900.	900.	900.	900.
BMEP	KPA	398.3	797.1	1190.0	1590.0	2074.0	2500.0
POWER	KW	331.00	662.42	995.57	1320.63	1724.10	2077.53
FUEL RATE	GM/MIN	1426.50	2469.56	3491.70	4501.02	5732.45	6920.52
BSFC (MASS BASIS)	GM/KW-HR	258.395	223.605	210.440	203.262	199.485	199.860
TURBO SPEED (L)	KRPM	10.6	15.5	20.1	23.9	27.6	30.5
AIR FLOW (L/L-PR)	KG/HR	3511	4649.	6170.	7077	10111.	12217.
SMOKE		0.031	0.041	0.022	0.015	0.011	0.011
RACK POSITION OBSERVED	MM	-9.300	-3.617	1.676	6.600	12.669	17.926
OIL PRESSURE	KPA	492.63	487.26	484.70	482.77	480.61	477.29
FUEL PRESSURE	KPA	702.42	689.03	675.77	663.21	645.77	628.65
INLET AIR (L/L-PR)	DEG C	22.1	22.5	23.2	23.0	24.2	24.0
AIR TEMP FROM COMPR(L/L-PR)	DEG C	45.7	65.9	95.0	120.2	165.2	[illegible]
WATER TEMP TO AFTCOOLER	DEG C	52.2	53.9	50.2	51.0	49.7	[illegible]
WATER TEMP FROM ENGINE	DEG C	85.0	84.0	85.6	87.5	85.9	87.4
OIL TO BEARINGS	DEG C	81.0	81.6	81.6	82.0	82.4	82.9
EXH TEMP TO TURBO (LF)	DEG C	391.3	496.4	547.3	572.1	587.2	600.9
EXH TEMP TO TURBO (LR)	DEG C	379.6	490.0	541.0	560.9	586.4	607.3
EXHAUST STACK TEMP	DEG C	332	400	430	443.	436	435
FUEL TEMPERATURE	DEG C	40.4	40.3	40.3	40.3	40.1	40.3
INLET AIR RESTRICTION (L)	KPA	-3.60	-3.67	-3.63	-3.65	-3.61	-3.59
EXHAUST STACK PRESSURE	KPA	-0.19	-0.12	-0.07	0.01	0.21	0.54
AIR PRES FROM COMPR (L)	KPA	11.05	40.92	82.62	133.56	200.32	264.45
EXH PRES TO TURBO (LF)	KPA	12.49	[illegible]	44.69	[illegible]	114.10	157.75
EXH PRES TO TURBO (LR)	KPA	13.56	26.56	49.25	75.60	124.33	[illegible]
PEAK CYLINDER PRESSURE	KPA	6500.	8750.	11000.	13500.	16000.	18250.
CO2 (DRY)	PERCENT	5.20	6.90	7.40	7.30	7.50	7.50
CO (DRY)	PERCENT	0.014	0.017	0.014	0.013	0.011	0.014
NOX (DRY)	PPM	1637.	2152.	2091.	2061.	1913.	1772.
HC (WET)	PPM	275.	315.	335.	270.	220.	190.
DEW POINT TEMPERATURE	DEG C	-1.4	-1.3	-1.2	-1.3	-1.3	-1.2
DEW POINT PRESSURE	KPA	0.5	0.5	0.5	0.5	0.5	0.5
BAROMETER	KPA	99.84	99.81	99.80	99.79	99.75	99.73
CYL 6 PEAK PRESS-KPA		6750.0	9000.0	11250.0	13750.0	16250.0	18500.0
IGN TIMING - DEG		7.000	8.000	10.000	11.000	11.000	13.000
PUMP 1 DYN INJ TIM - DEG		20.000	20.000	20.000	20.000	20.000	20.000
CYLINDER PRESSURE		6500.0	8750.0	11000.0	13500.0	16000.0	18250.0
IGN DELAY - DEG		13.000	12.000	10.000	9.000	9.000	7.000
PUMP INJ DUR - DEG		11.000	15.000	19.000	23.000	28.000	33.000
PUMP1 PEAK INJ P - MPA		75.000	90.000	105.000	123.000	120.000	140.000
COMPRESSION PRESS - KPA		3250.0	4250.0	5250.0	6750.0	8500.0	10060.0

CURRENT SECTOR IS 1. 1 OF 1. 1 - CURRENT DIRECTION IS >

3600 LAC TESTS
1/1

SHEET A

------- OUTPUT ------- *Power bhp*

DATA POINT		*444*	*888*	*1335*	*1782*	*2312 bhp*	*2787 bhp*
DATA POINT		1.	2.	3.	4.	5.	7.
AVE RPM	RPM	900.	900.	900.	900.	900.	900.
BMEP	KPA	398.3	797.1	1198.0	1598.8	2074.0	2500.0
POWER	KW	331.00	662.42	995.57	1328.63	1724.10	2077.53
POWER (CORR. FOR J1349 85)	KW	331.62	665.61	1009.84	1352.31	1759.33	2127.45
FUEL RATE	GM/MIN	1426.58	2469.56	3491.78	4501.02	5732.45	6920.52
BSFC (MASS BASIS)	GM/KW-HR	258.595	223.685	210.440	203.262	199.485	199.868
BSFC (MASS) (J1349 85)	GM/KW-HR	258.111	222.612	207.465	199.704	195.498	195.178
AIR FLOW (CORR) (TOTAL)	KG/HR	3507.	4644.	6163.	7869.	10100.	12204.
EXHAUST MASS	KG/HR	3593.	4792.	6373.	8139.	10444.	12619.
SMOKE (CORR. TO 75 GRAINS)		0.039	0.051	0.020	0.020	0.016	0.015
AIR/FUEL RATIO		40.97	31.34	29.42	29.14	29.37	29.39
FUEL TO AIR RATIO		0.02441	0.03191	0.03399	0.03432	0.03405	0.03402
EPA FUEL/AIR RATIO		0.0245	0.0322	0.0344	0.0340	0.0340	0.0340
% DIFF F/A		0.14	0.51	0.98	1.12	1.70	1.06
VOLUMETRIC EFFICIENCY	PERCENT	85.72	113.54	150.71	192.45	247.12	298.65
PARTIC. (75 GR. - 82 EQN.)	GM/HR	105.7	169.2	153.2	163.3	186.7	221.4
RACK POS FROM C/L	MM	-9.580	-3.617	1.676	6.680	12.669	17.926
INLET MANIFOLD AIR PRES	KPA (ABS)	99.84	99.81	99.80	99.79	99.75	99.73
INLET AIR TEMP	DEG C	22.1	22.5	23.2	23.0	24.2	24.0
WET TO DRY CONVERSION		0.954	0.940	0.936	0.936	0.936	0.936
KNOX CORRECTION FACTOR		0.904	0.900	0.900	0.907	0.906	0.905
PEAK CYLINDER PRESSURE	KPA	6300.	8750.	11000.	13500.	16000.	18250.
BAROMETER	KPA	99.84	99.81	99.80	99.79	99.75	99.73
HUMIDITY	GRAINS	24.	24.	24.	24.	24.	24.
CO2	PERCENT	5.20	6.90	7.40	7.50	7.50	7.50
CO	PPM	140.	170.	140.	130.	110.	140.
NOX AS NO	PPM	1637.	2132.	2091.	2061.	1913.	1772.
HC	PPM	200.	335.	350.	209.	235.	203.
CO	GM/HR	463.	734.	790.	943.	1017.	1563.
CO2	GM/MIN	4504.4	7004.7	11041.7	14249.4	18165.6	21931.0
NOX AS NO	GM/HR	5801.	9957.	12762.	16015.	18957.	21199.
HC	GM/HR	470.7	714.4	1006.0	1033.0	1073.0	1119.7
CORRECTED TO 75 GRAINS HUMIDITY							
NOX AS NO	GM/HR	5245.	9039.	11506.	14525.	17175.	19104.
		18.11	*15.60*	*13.30*	*11.10*	*11.39*	*10.55*
FED. REG. VOL. 42 NO. 174, SEPT. 8, 1977		*1.04*	*0.827*	*0.598*	*0.529*	*0.440*	*0.561*
		1.06	*0.805*	*0.754*	*0.580*	*0.464*	*0.402*

g/bhp hr NO2 corrected
g/bhp hr CO
g/bhp hr HC

------- OUTPUT -------

DATA POINT		1.	2.	3.	4.	5.	7.
AVE RPM	RPM	900.	900.	900.	900.	900.	900.
BMEP	KPA	398.3	797.1	1198.0	1598.8	2074.0	2500.0
SMOKE		0.031	0.041	0.022	0.015	0.011	0.011
SMOKE (CORR. TO 75 GRAINS)		0.039	0.051	0.020	0.020	0.016	0.015
PARTIC. (75 GR. - 82 EQN.)	GM/HR	105.7	169.2	153.2	163.3	186.7	221.4
EXHAUST	SCFM	1727.4	2304.0	3064.0	3913.3	5021.7	6067.5
KNOX CORRECTION FACTOR		0.904	0.900	0.900	0.907	0.906	0.905
VENTILATION CO2	SCFM	34131.	59550.	84610.	109455.	140520.	169001.
VENTILATION CO	SCFM	4595	7337	8804.	9406.	10305	15040.
VENTILATION NO2	SCFM	214905	371406	470094.	601420.	716994	802454
VENTILATION NO2 - 75	SCFM	194289	337225	434066	545401.	649501	726105
BAROMETER	KPA	99.84	99.81	99.80	99.79	99.75	99.73

3600 LAB
TC STS

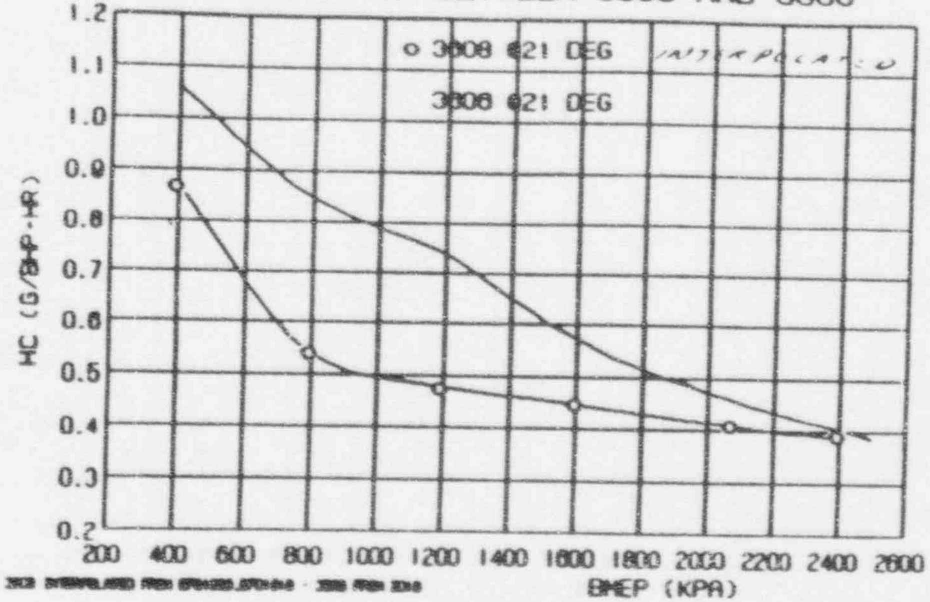
* NOTE: EXHAUST, VENTILATION CO2, CO, NO2, AND NO2 - 75 HAVE BEEN
CURRENT SECTOR IS 2. 1 OF 3. 1 - CURRENT DIRECTION IS

2/2

900 RPM

HYDROCARBON EMISSIONS

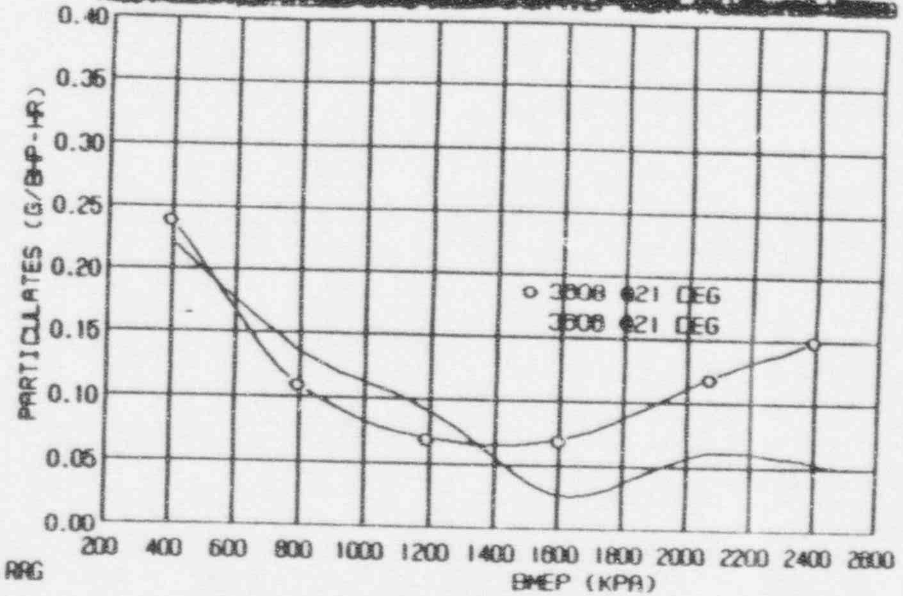
CORRELATION BETWEEN 3606 AND 3608



900 RPM

MEASURED PARTICULATE MATTER - MODIFIED MTD 5

DOES NOT INCLUDE "BACK HALF WASH" PARTICULATES

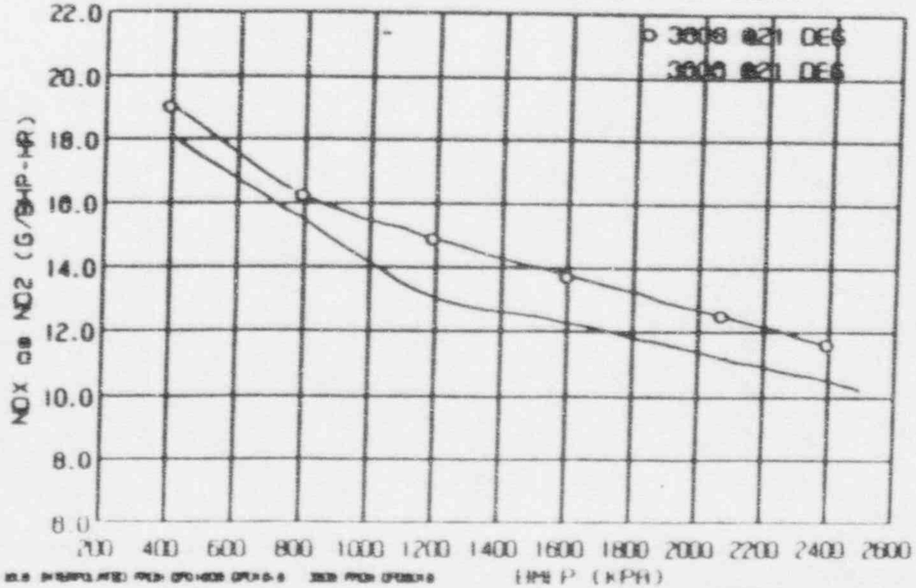


DAS RAG

900 RPM

NITROGEN OXIDE EMISSION LEVELS (as NO2)

CORRELATION BETWEEN 3606 AND 3608

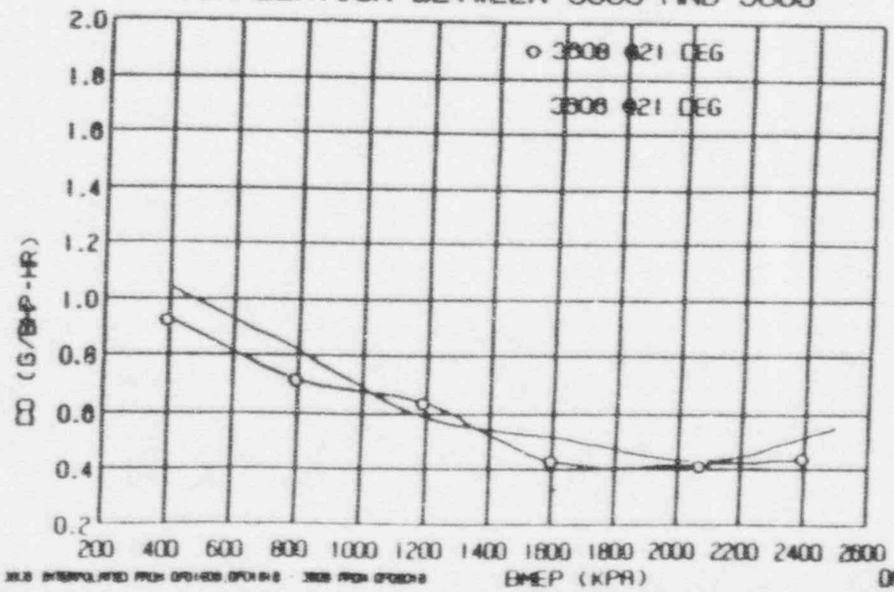


DAS

900 RPM

CARBON MONOXIDE EMISSIONS

CORRELATION BETWEEN 3606 AND 3608



DAS

Sheet 8
D.A. Spurgeon
6/5/90

3600 EMISSIONS 12 CYLINDERS

STANDARD TIMING 21.5 DEGREES
MOL CAM FUEL SULFUR 0.2 % DISTILLATE
TURBOCHARGER: VTC254

ENGINE SPEED rpm	900	900	900	900	900	900	900
ENGINE POWER bkW	4180	3800	3460	3140	2356	1570	786
ENGINE POWER bhp	5605	5096	4640	4211	3159	2105	1054
BMEP kPa	2514	2286	2081	1889	1417	944	473
BRAKE SPECIFIC EMISSIONS g/bhp-hr							
NOx (as NO2)	10.6	11.2	11.5	12.1	13.1	17.9	18.7
Hydrocarbons	0.40	0.43	0.47	0.50	0.64	0.81	1.05
Carbon Monoxide	0.56	0.48	0.42	0.47	0.55	0.73	1.05
Sulfur Dioxide	0.60	0.60	0.60	0.60	0.62	0.65	0.74
Particulates	0.10	0.10	0.10	0.10	0.18	0.28	0.42
BRAKE SPECIFIC EMISSIONS g/bkW-hr							
NOx (as NO2)	14.2	15.0	15.4	16.2	17.6	24.0	25.1
Hydrocarbons	0.54	0.58	0.63	0.67	0.86	1.09	1.41
Carbon Monoxide	0.75	0.64	0.56	0.63	0.74	0.98	1.41
Sulfur Dioxide	0.80	0.80	0.80	0.80	0.83	0.87	1.00
Particulates	0.13	0.13	0.13	0.13	0.24	0.38	0.56
EMISSION RATE g/hr							
NOx (as NO2)	59418	57074	53359	50951	41389	37687	19711
Hydrocarbons	2242	2191	2181	2105	2022	1705	1107
Carbon Monoxide	3139	2446	1949	1979	1738	1537	1107
Sulfur Dioxide	3341	3037	2765	2509	1949	1361	785
Particulates	561	510	464	421	569	590	443

Sulfur dioxide emissions are proportional to fuel sulfur.
Values are nominal and do not include tolerances for engine to engine or instrumentation variation.

file s89.3 data/exc/06s900 jrg Nov-91

The Almega Corporation

SUMMARY OF EMISSION TEST DATA

TABLE: 1

PLANT: Caterpillar Inc., Pontiac, Illinois

SOURCE: Stationary Diesel Engine 3608

OPERATOR: M. R. Jackson

REPETITION #:	1	2	3
TEST DATE:	10/9/87	10/9/87	10/9/87
TEST TIME:	4:00-5:00AM	5:00-6:00AM	6:00-7:00AM
STACK GAS			
Temperature, average °F	728.5	753.0	754.5
Velocity average fps	117.8	117.8	115.1
Volume flow x scfh db x 10^6	0.399	0.387	0.384
acfm	16,005	15,998	15,635
% CO_2	6.0	6.0	5.5
O_2	13.5	13.5	13.5
Moisture %	6.5	7.0	6.1
NITROGEN OXIDE			
Concentration x 10^{-6} lb/scf db	116.2	100.0	133.6
ppm	974	837	1,119
Emissions lbs/hr	46.4	38.8	51.2
AUDIT SAMPLE			
NO_x concentration ppm			
calibration gas	350		
audit samples	346		

METHOD 7E

SHEET F

*DUT -------
...LO. EXHAUST EMISSIONS AT 900 RPM (EPA SUB PART D)
... DF0009I DATE: 07-APR-87OBS: T.R.DAWSO CELL: 501
K CALS 0
BINE DIA: 297.74 MSG/NOZ AREA: 133.2
INE MODEL: 3608 DITA NO: 8MC245
BORE: 280 MM STROKE 300 MM CYLS: 8
T COND AIR TO ENGINE ON TURBO COMPR - TEMP: 24.4248
PRESS: 96 ABS AT EACH DATA POINT
FUEL-TYPE: 1E262 TEMP: 39.0057
BARO: 99.6832 AFTERCOOLING: SEP CIR
TIMING DEG BTC: 16.5 DEG DEG ADV: NONE
RO MODEL: VG15 RFO9 WG10 EF21
NO: 1 LOCATION: REAR
ANKS LTL PISTON - INLET VALVE LUBRICATION
MOL CCW CAMSHAFT.
(-1.20 MM) 119.4 MM GAGE DIMENSION.

COMB CHAMB PISTON: 7C4518
CR: 13.0 NOMINAL
FUEL SYST TYPE: UNIT INJECTOR PUMP DIA: 21.0
GROUP NO: 7C3854
FUEL NOZZ
ORIFICES- NO: 10 DIA: 0.465 MM ANGLE: 145 DEG
FUEL LINES ID AND LENGTH-
EXH MAN TYPE: BELLOWS-PULSE-DRY PART NO: 7C4522
UNKNOWN
AUTO
1800 / kW

		1.	2.	3.	4.	5.	6.	7.
A POINT		1.	2.	3.	4.	5.	6.	7.
RPM	RPM	900.	901.	901.	901.	901.	901.	901.
P	KPA	399.9	802.0	1201.0	1603.1	1890.5	2077.3	2285.9
ER	KW	443.50	889.56	1332.37	1778.7	2097.5	2305.10	2536.87
ER (CORR. FOR J1349 85)	KW	446.04	894.65	1340.27	1790.1	2111.0	2322.52	2560.21
L RATE	GM/MIN	1883.10	3249.45	4567.20	5904.2	6922.0	7635.07	8499.11
C (MASS BASIS)	GM/KW.HR	254.7	219.1	205.6	199.1	198.0	198.7	201.0
C (MASS) (J1349 85)	GM/KW.HR	253.2	217.9	204.4	197.8	196.7	197.2	199.1
FLOW (COMPR) (TOTAL)	KG/HR	4154.	5989.	8368.	11030.	13026.	14236.	15510.
AUST MASS	KG/HR	4267.	6184.	8582.	11384.	13441.	14694.	16020.
RE (CORR. TO 75 GRAINS)		.098	.070	.041	.043	.037	.038	.046
/FUEL RATIO		36.77	30.73	30.33	31.15	31.37	31.08	30.42
L TO AIR RATIO		.02719	.03255	.03296	.03211	.03188	.03217	.03287
FUEL/AIR RATIO		.0254	.0305	.0306	.0297	.0297	.0297	.0304
EFF F/A		7.26	7.24	7.47	8.38	7.61	6.63	8.44
RECTED POWER	KW	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RECTED BSFC	GM/KW.HR	0.0	0.0	0.0	0.0	0.0	0.0	0.0
UMETRIC EFFICIENCY	PERCENT	93.10	102.54	105.92	107.11	107.61	107.60	107.66
TIC. (75 GR. - 82 EUR.)	GM/HR	251.6	277.1	261.7	346.8	385.3	422.7	525.5
R POS FROM C/L	MM	-10.443	-4.497	.681	5.568	9.401	12.019	15.091
ET MANIFOLD AIR PRES	KPA (ABS)	106.15	138.45	186.29	246.14	291.66	320.86	351.77
ET AIR TEMP	DEG C	24.2	24.2	24.3	24.6	24.6	24.6	24.6
TO DRY CONVERSION		.952	.943	.943	.945	.945	.945	.943
R CORRECTION FACTOR		.900	.905	.904	.903	.903	.904	.905
K CYLINDER PRESSURE	KPA	5600.	7800.	9900.	12200.	13900.	14600.	15700.
OMETER	KPA	99.70	99.70	99.70	99.69	99.67	99.67	99.66
IDITY	GRAINS	25.	24.	24.	24.	24.	25.	25.
	PERCENT	5.41	6.53	6.61	6.38	6.38	6.38	6.53
	PPM	178.	152.	109.	145.	120.	113.	134.
NO_x AS NO	PPM	645.	1237.	1329.	1215.	1192.	1149.	1063.
	PPM	283.	185.	192.	176.	159.	146.	134.
	GM/HR	767.	916.	912.	1619.	1572.	1632.	2108.
	GM/MIN	5942.5	10288.5	14469.5	18696.6	21936.8	24200.5	26936.9
NO_x AS NO	GM/HR	3796.	7969.	11897.	14566.	16775.	17626.	17933.
	GM/HR	586.3	550.2	793.6	973.1	1020.8	1055.9	1037.5
RECTED TO 75 GRAINS HUMIDITY								
AS NO	GM/HR	3417.	7209.	10759.	13157.	15167.	16111.	16235.

LAC DATA RUN
AT SAME CONDITIONS
AS PONTIAC PLANT
3608 TESTED BY
ALMEGA, CORP

2812 bhp => 8.26 g/bhp.h.

15167 g/h ... = 51.2 lb/h

. REG. VOL. 42 NO. 174, SEPT 8, 1977

EMISSION MEASUREMENTS ON 3616 ENGINES AT GUAM

Engine	Date	NOx g/bhp-hr	PARTICULATES g/bhp-hr
Old GMH Unit 1	5/20/93	7.11	0.210
"	5/26/93	6.99	0.231
Old GMH Unit 2	5/15/93	6.59	1.23 *
"	5/19/93	7.30	0.238
Talofofo Unit 1	5/21/93	6.34	0.226
Talofofo Unit 2	6/23/93	6.78	0.221
GPA Unit 1	6/14/93	7.21	0.193
"	7/14/93	7.30	--
GPA Unit 2	6/13/93	7.37	0.218
"	7/14/93	7.12	--
Tumon Unit 1	6/24/93	7.22	0.209
"	7/15/93	6.85	--
Tumon Unit 2	6/25/93	7.06	0.219
	Average:	7.02	0.329 0.217 excluding *

* Rust, mill scale, and/or accumulated soot in muffler probably gave high value.

SHEET N

BETWEEN TEAM VARIATIONS
FOR PARTICULATE EMISSIONS

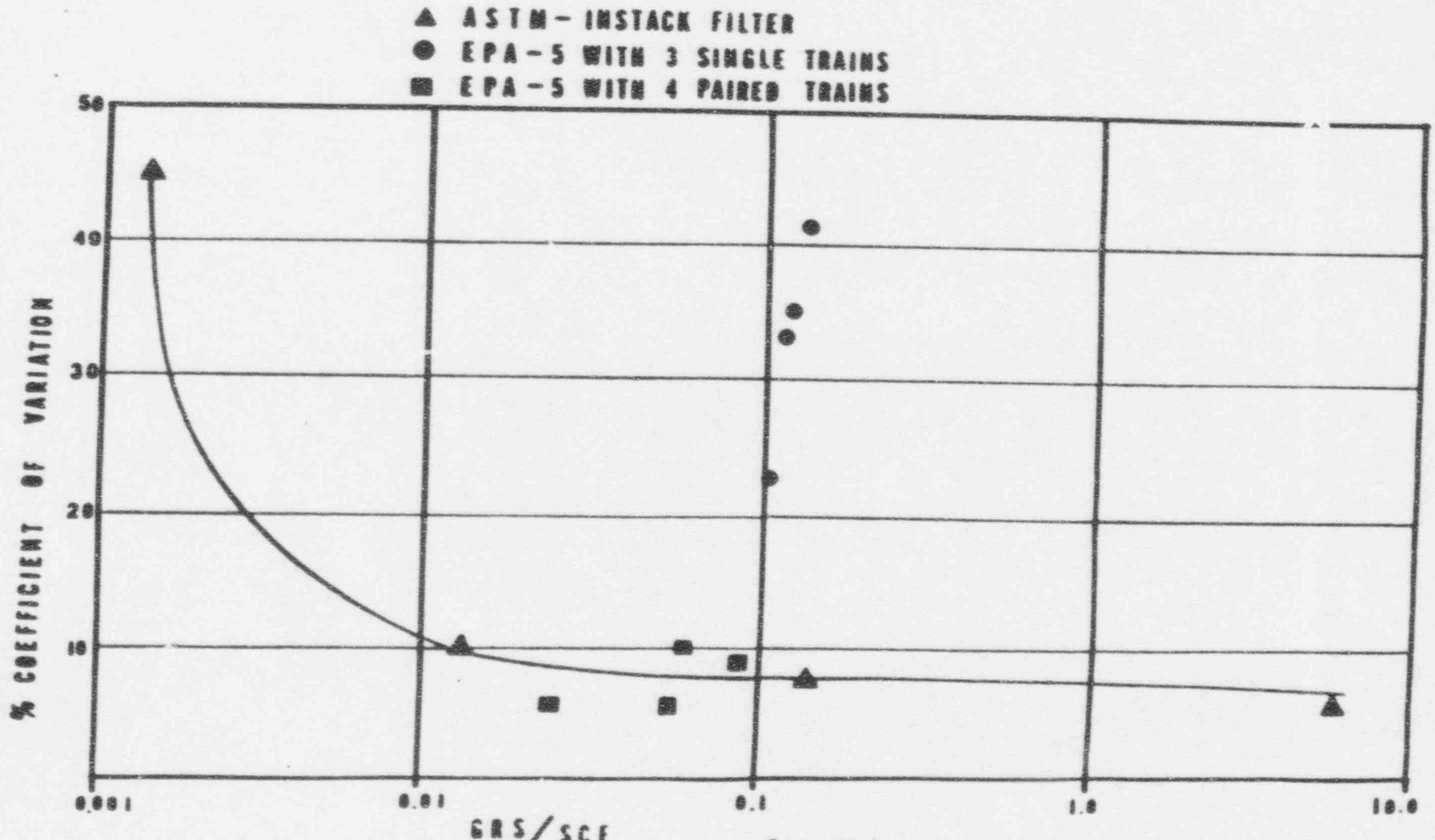


FIG. NO.1