

One Shaft Gas Turbine Certified Test Report

Date of Test 2019-06-08
Model Taurus™ 60
Version 7301S

	<u>Gas Producer</u>	<u>Reduction Gearbox</u>
Serial Number	OHE19-T0489	GBE19-81956
Part Number	ET731S-S0G00H00	E196800-206-960
Purpose of Test	OVERHAUL	FACILITY
Test Specification	ES2091	ES2091

Approvals

Test Data Verification
Test Engineer


for Ramsland, Alison

2019-Jun-08
Date

Product Acceptance
Product Engineer


Butler, Brian

2019-Jun-09
Date

Solar Turbines

A Caterpillar Company

SolarTurbines Incorporated
215 Centre Park Blvd
DeSoto, TX 75115
(972)228-5500

Solar Turbines Incorporated

COMBUSTION COMPONENTS

GAS PRODUCER

Gas Producer Serial Number:
Gas Producer Part Number:

OHE19-T0489
ET731S-S0G00H00

Combustion Components

Combustor Liner

Serial Number:
Part Number:

APR19-98862
303999-200

Fuel Injectors

Part Number:

E210006-102

In-line Orifice

Part Number:

NA

NOTE: All overhauled engines are manufactured with components that support an overhaul cycle. If additional information about the overhauled engine is required, please contact the local district office for assistance.

CATERPILLAR CONFIDENTIAL, GREEN

**CORRECTED PERFORMANCE
AND SOLONOX EMISSIONS
TEST SUMMARY
GAS FUEL**

Solar Turbines - DeSoto, Texas
One-Shaft Gas Turbine Certified Test Report
Corrected to Sea Level, No Duct Losses, 60% Rel. Humidity and Standard Temp.

Equipment Summary

Date	2019-06-08	Time	10:31 AM	Version	7301S
GP S/N	OHE19-T0489	Std Temp	80	CS Curve	PT30006A
RGB S/N	GBE19-81956	Match Temp.	59	Test Spec	ES2091
Fuel Type	Gas			Data Pt.	3

Corrected Performance Summary

<u>Parameter Name</u>	<u>Units</u>	<u>Results</u>	<u>Min</u>	<u>Max</u>
Corrected NGP	%	100.0	99.9	100.1
Corrected Power	kW	4785	4617	
Corrected Heat Rate	Btu/kW-hr	11341		11930
Corrected TRIT	°F	1887	1882	1888
Final IGV Angle	°	5.0	4.5	5.5
Thermal Efficiency	%	30.088		

Engine Parameters

<u>Parameter Name</u>	<u>Units</u>	<u>Results</u>	<u>Min</u>	<u>Max</u>
Air Inlet Temperature	°F	85.4		
T2 Spread	°F	7.3		10.0
Corrected T5	°F	1259.4		
T5 Base	°F	1265.6		
T5/T3	ratio	0.7327	0.6520	0.7580
T5 Delta	°F	35.9		150.0
Corrected T7	°F	930	904	
T7 Delta	°F	3.1		20.0
Corrected Mass Flow	lb/s	44.5		47.1
P2/P1	ratio	11.5	11.5	
PCD	psig	145.9		

Lube Oil System Parameters at Full Load

<u>Location</u>	<u>Pressure</u>	<u>Flow</u>	<u>Data Pt.</u>	<u>5</u>
			<u>Min</u>	<u>Max</u>
Brg. 1 & RGB	51.2 psi	62.5 gpm	43.4	60.7
Brg. 2 & 3	47.1 psi	37.4 gpm	28.6	40.1
Lube Oil Temperature		139.3 ° F	110.0	155.0
Lube Oil Pressure Limits			45.0	65.0
GP Thrust Brg. Temperature		191.4 ° F		230.0
Tank Vent Pressure		1.21 in. H2O		6.5

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GP S/N	OHE19-T0489	Std Temp	86	CS Curve	PT30006A
RGB S/N	GBE19-81956	Match Temp.	59	Test Spec	ES2091
Fuel Type	Gas			Data Pt.	5

Gas Emission Summary

Parameter Name	Units	Full Load	50% Load	
Datapoint #		5	7	
Date		2019-06-08	2019-06-08	
Time		10:55 AM	11:33 AM	
Corrected NGP	%	100.0	100.0	
Corrected Power	kW	4718	2225	
Corrected Heat Rate	Btu/kW-hr	11434	15430	
Corrected TRIT	°F	1898	1806	
Corrected Mass Flow	lb/s	43.9	27.3	
T5/T3	Ratio	0.7334	0.7480	
PCD	psig	143.8	83.9	
T1 Average	°F	85.8	88.2	
Corrected T5	°F	1269.1	1235.4	
T5 Delta	°F	35.0	46.0	
T7 Average	°F	976	1092	
T7 Delta	°F	3.1	3.6	
Gas Pilot	%	3.0	3.0	
Emission Summary				Limit
NOx	ppmv 15% O2 Corr.	7.5	4.3	25.0
CO	ppmv 15% O2 Corr.	0.5	1.0	50.0
HC	ppmv 15% O2 Corr.	0.3	0.2	25.0
O ₂	%	15.6	15.5	
CO ₂	%	3.0	3.0	

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RGB S/N	GBE19-81956	Match Temp.	59	Test Spec	ES2091
Fuel Type	Gas			Data Pt.	5

Full Load Bearing Gap Voltages

Parameter Name	Units	X	Y
Bearing 1	VDC	-7.6	-9.2
Bearing 2	VDC	-9.0	-8.7
Bearing 3	VDC	-8.8	-9.0
		AXI 1	AXI 2
GP Axial	VDC	-9.9	-10.4

TAURUS 60
GAS TURBINE DATA PLATE

Model No.	TAURUS 60
Version	7301S
Engine PN	ET731S-S0G00H00
Serial No.	OHE19-T0489
*Power (G/L)	5200 / NA kW
NGP (rpm)	14951 60 Hz / 14944 50 Hz
NPT (rpm)	NA
IGV Setting	+5.0 DEG
^T5 Base (G/L)	1266F / NA
Setpoint Full Load (G/L)	1250F / NA
*ISO Values, ^Uncompensated	
T5 Comp#	120902-6
Injector Compensator	210009-1200
Trim Bal K/P Hole#	19.0

ENGINE SoLoNOx DATA PLATE

GAS	Serial No.	OHE19-T0489		
	LOAD	Pilot (%)	T5 (°F)	TPZ (°F)
	100%	3.0	1236	NA
	50%	3.0	1236	NA

LIQUID	LOAD	Pilot (%)	T5 (°F)
	100%	NA	NA
	65%	NA	NA

Engineer's Note: - A transient pilot orifice (PN 124427-3202) and a fixed pilot orifice (PN 124427-3402) drilled for 3% flow are required for units that have a fixed pilot system and need to be shipped with engine.

**CORRECTED PERFORMANCE
TEST DATA
GAS FUEL**

Solar® Turbines

A Caterpillar Company

Test Data Report

	Gas Producer	Reduction Gearbox	Data Pt.	3
Serial Number	OHE19-T0489	GBE19-81956	Date	2019-06-08
Part Number	ET731S-S0G00H00	E196800-206-960	Time	10:31 AM
Purpose of Test	Overhaul	Facility		
Model	TAURUS 60			
Version	7301S			
Test Specification	ES2091			
CS Curve	PT30006A			
Test Engineer	Ramsland, Alison			
Product Engineer	Butler, Brian			
Test Technician	NA			

RUN INFORMATION

K_FUEL_TYP	Natural Gas			
T_AMB	81.5	°F	K_N_GP_100	14951 rpm
HUMIDITY	63.9	%	K_NUM_SHAFT	1
P_BARO	29.11	in Hg	STD_TEMP	80.0 °F
K_ENGCON	7301		K_T_MATCH	59.0 °F

ENGINE OUTPUT

PCT_N_GP	100.6	%	CORR % NGP	100.0	%
N_GP	15035	rpm	CORR_NGP	14953	rpm
TRIT	1907.5	°F	CORRTRIT	1886.6	°F
PWR_SHP	6034	Hp	CORR_HP	6709	Hp
PWR_GEN_KW	4499	kW	CORR_KW	4785	kW
WM_AIR	42.4	pps	COR_WM_AIR	44.5	pps
SFCMBTU	54.3	MMBtu/Hr	CORR_SFC	11341	Btu/kW-Hr
T2_0_AVG	710.1	°F	CORR_T2	699.1	°F
T5_1_AVG	1276.4	°F	CORR_T5	1259.4	°F
T7_1_AVG	951.5	°F	CORR_T7	930.0	°F
P2_P1	11.5	ratio	T5/TRIT	0.7327	ratio
ANGL_IGV	5.0	°	BASE_T5	1266	°F

FUEL: NATURAL GAS OR LIQUID

K_FUEL_TYP	1	Natural Gas	T_NG_01	64.0	°F
SG_NG	0.586		T_NG_02	64.2	°F
WV_NG_01	55.33	cfm	P_NG_01	235.8	psig
WV_NG_02	55.32	cfm	P_NG_02	233.6	psig
WM_NG_01	2596.0	pph	LHV_NG	20235	Btu/lb
WM_NG_02	2570.7	pph	HHV_NG	989	Btu/scf
WM_NG_AVG	2583.3	pph			
PCT_DEL_NG	1.0	%			

Test Data Report

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Serial Number	OHE19-T0489	GBE19-81956	Date 2019-06-08
Part Number	ET731S-S0G00H00	E196800-206-960	Time 10:31 AM

LUBE OIL

PD_SMP	1.20	in H2O	T_OIL_MAN	139.4	°F
P_OIL_INLT	51.2	psig	WV_OIL_INLT	62.6	gpm
P_OIL_COMP	47.0	psig	WV_OIL_COMP	37.5	gpm

COMPRESSOR INLET / VENTURI

T_VNTRI	84.7	°F	P_AMB	14.30	psia
T1_0_01	85.4	°F	PT1_0_01	-7.69	" H ₂ O
T1_0_02	85.0	°F	PT1_0_02	-7.64	" H ₂ O
T1_0_03	85.4	°F	PT1_0_03	-7.66	" H ₂ O
T1_0_04	85.9	°F	PT1_0_04	-7.64	" H ₂ O
T1_0_AVG	85.4	°F	PT1_0_AVG	-7.50	" H ₂ O
T1_0_SPR	0.9	°F	PT1_0_SPR	0.09	" H ₂ O
			P1_0_PKG	-8.04	" H ₂ O
P1_1_01	-82.20	" H ₂ O	P_VNTRI_01	-30.65	" H ₂ O
P1_1_02	-87.55	" H ₂ O	P_VNTRI_02	-30.89	" H ₂ O
P1_1_03	-85.52	" H ₂ O	P_VNTRI_03	-30.48	" H ₂ O
P1_1_AVG	-85.09	" H ₂ O	P_VNTRI_04	-30.78	" H ₂ O
Delta T1-TV	0.77	°F	DPV_AVG	-30.46	" H ₂ O
P_VNTRI_PLNM	-0.51	" H ₂ O	DPV_SPR	0.41	" H ₂ O

COMPRESSOR DISCHARGE

T2_0_01	707.9	°F	PCD	145.9	psig
T2_0_02	707.3	°F	PTC	122.2	psig
T2_0_03	712.1	°F	P2/P1	11.5	ratio
T2_0_04	710.3	°F			
T2_0_05	709.5	°F			
T2_0_06	714.6	°F			
T2_0_AVG	710.1	°F			
T2_0_SPR	7.3	°F			

Test Data Report

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Part Number	ET731S-S0G00H00		E196800-206-960	Time	10:31 AM

TURBINE PARAMETERS

T5_1_01	1291.4	°F	T5_1_AVG	1276.4	°F
T5_1_02	1283.8	°F	T5_1_MAX	1302.0	°F
T5_1_03	1275.9	°F	T5_1_MIN	1240.5	°F
T5_1_04	1264.8	°F	T5_1_SPR	61.5	°F
T5_1_05	1240.5	°F	T5_1_DEL	35.9	°F
T5_1_06	1302.0	°F			
T_GP_TBRG_01	192.2	°F	T_GP_TBRG_02	185.8	°F

EXHAUST TEMPERATURES AND PRESSURES

T7_1_01	950.4	°F	T7_1_11	954.2	°F
T7_1_02	949.2	°F	T7_1_12	951.0	°F
T7_1_03	949.6	°F	T7_1_13	952.5	°F
T7_1_04	948.4	°F	T7_1_14	952.0	°F
T7_1_05	950.2	°F	T7_1_AVG	951.5	°F
T7_1_06	951.6	°F	T7_1_MAX	954.4	°F
T7_1_07	953.4	°F	T7_1_MIN	948.4	°F
T7_1_08	954.4	°F	T7_1_SPR	6.0	°F
T7_1_09	950.8	°F	T7_1_DEL	3.1	°F
T7_1_10	952.7	°F			
P7_1_01	1.14	" H ₂ O	P7_1_06	1.35	" H ₂ O
P7_1_02	1.29	" H ₂ O	P7_1_07	1.06	" H ₂ O
P7_1_03	1.28	" H ₂ O	P7_1_AVG	1.21	" H ₂ O
P7_1_04	1.13	" H ₂ O	P7_1_SPR	0.29	" H ₂ O
P7_1_05	1.24	" H ₂ O			

PERFORMANCE PARAMETERS

EA_THRM	30.09	%
ETT	0.896	
Ecomp	0.854	
WQ31CC	139.9	
WQ51EC	450.1	
WQ10C	753.4	
Heat Balance	0.9849	ratio

SOLONOX PARAMETERS

T_IGVSP_PLC	1000.00	°F	PCT_COR_LOAD	104	%
BASE_T5	1265.6	°F	PCT_NG_PIL	3.00	%

VIBRATION PLOTS

VIBRATIONS LIMITS

Location	OVERALL LIMIT	ROTOR FREQUENCY LIMIT	NOTES
Bearing #1	3.5 mils (P-P)	2.3 mils (P-P)	(1) (2) (5)
Bearing #2	3.5 mils (P-P)	2.3 mils (P-P)	(1) (2)
Bearing #3	3.5 mils (P-P)	2.3 mils (P-P)	(1) (2)
Compressor Fwd	0.28 in/sec (RMS)	0.17 in/sec (RMS)	(1)
Reduction Gearbox	0.28 in/sec (RMS)	NA	(4)
RGB Accelerometer	16G (RMS)	NA	(3)

(1) Readings are valid from 15 to 2000 Hz.

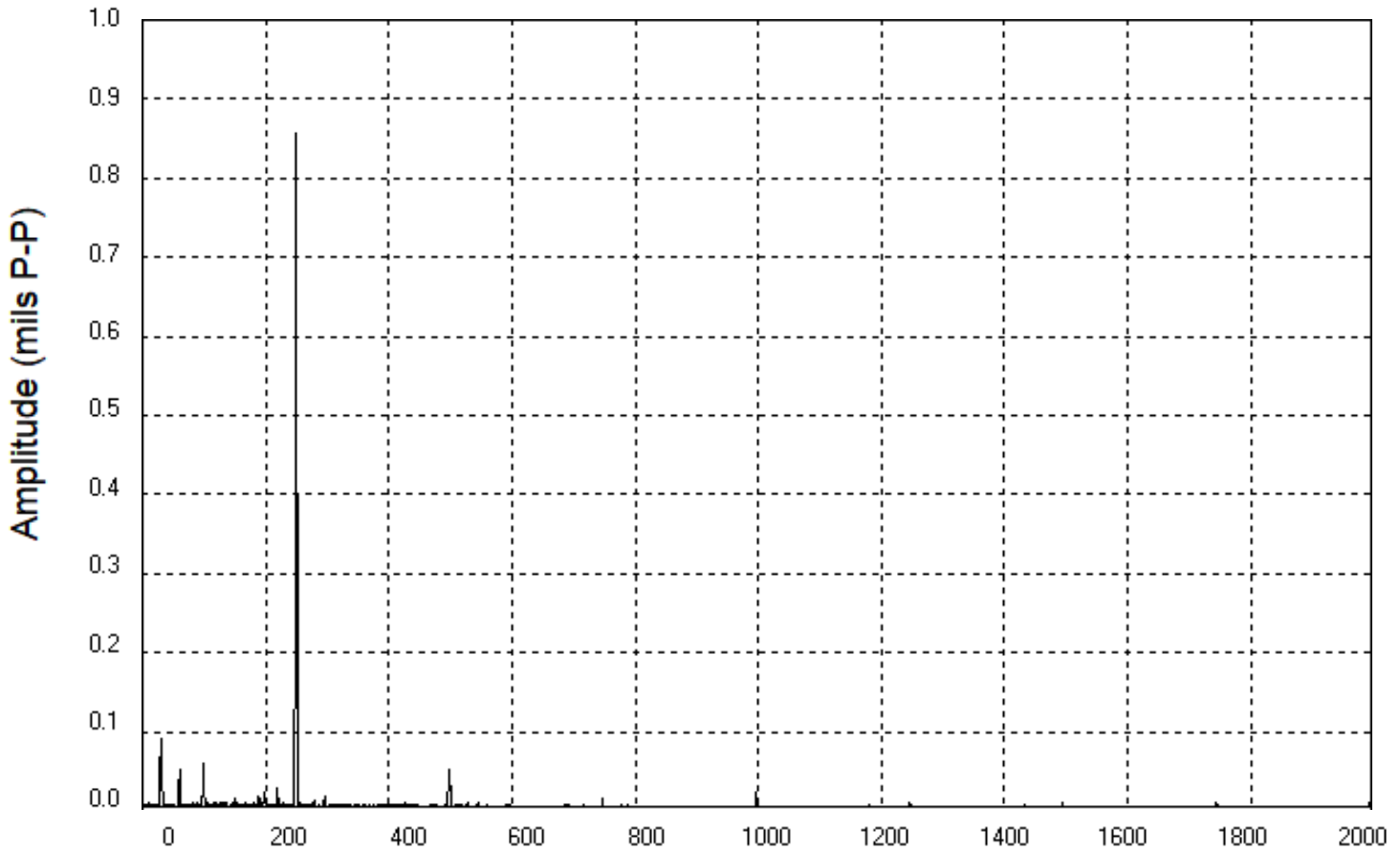
(2) Vibration limits at frequencies other than running speed are limited to 0.5 mils (P-P).

(3) Readings are valid from 15 to 12000 Hz.

(4) Readings are valid from 15 to 1000 Hz.

(5) Gearbox frequency limits at Bearing #1: 30, 60 and 98.7 Hz (60 cycle) or 25,50,82.2 Hz (50 cycle) are 2.0 mils P-P at 1E and 1.5 mils P-P for harmonics.

GP SN: OHE19-T0489



Channel: BRG 1Y PROX

Comments: Full Load with Vibes

Overall Vibration Level Between 5 Hz and 2000 Hz: 1.1542 mils P-P

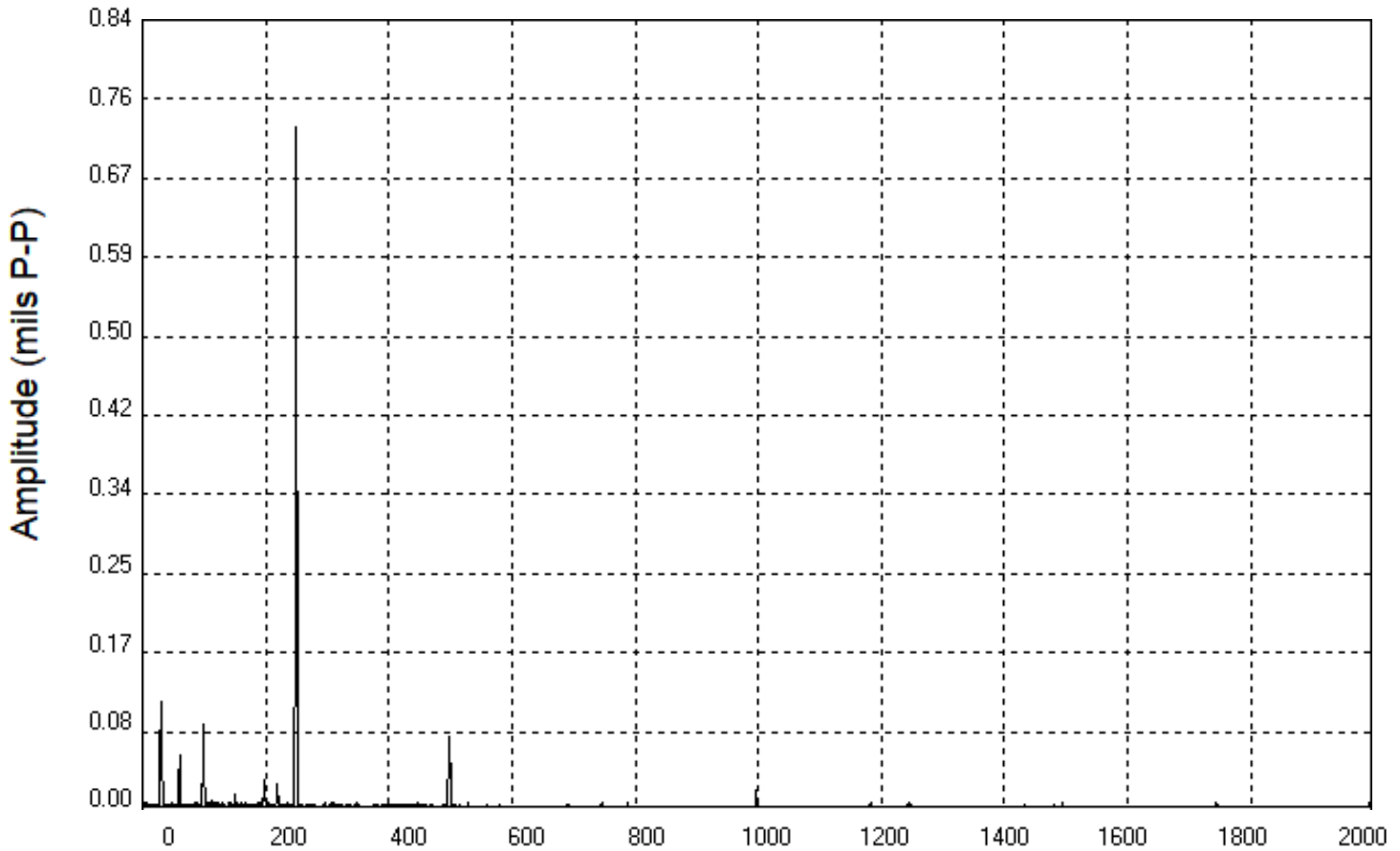
DP#: 6 N_GP 14945 RPM; N_RGB 1799 RPM; T_OIL_MAN 139 °F

Peak	Freq	Amp
1	248.8	0.8573
2	30.0	0.0920
3	98.8	0.0587
4	60.0	0.0527
5	498.8	0.0508

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GP SN: OHE19-T0489



Channel: BRG 1X PROX

Comments: Full Load with Vibes

Overall Vibration Level Between 5 Hz and 2000 Hz: 0.9934 mils P-P

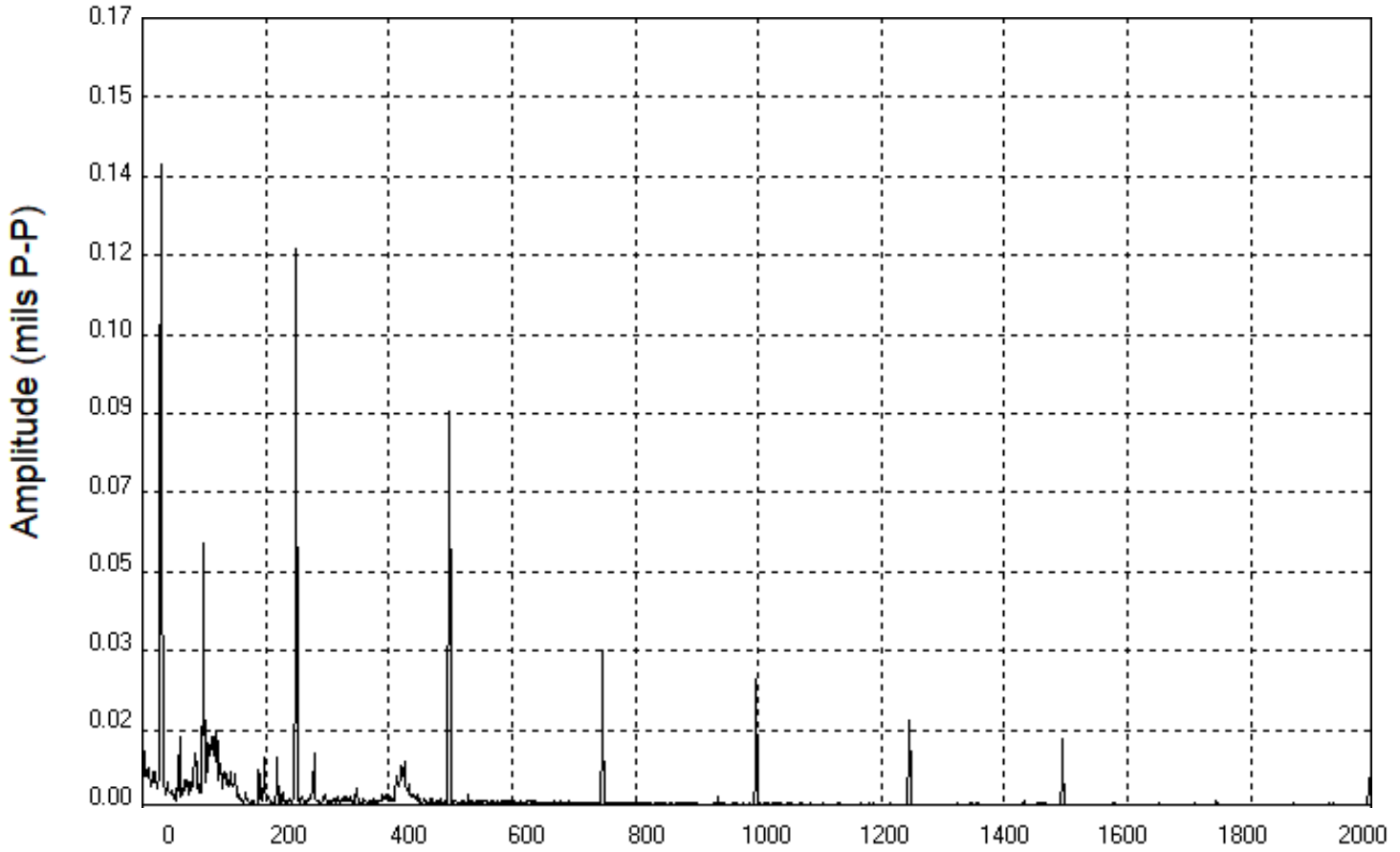
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Peak	Freq	Amp
1	248.8	0.7264
2	30.0	0.1151
3	98.8	0.0923
4	498.8	0.0784
5	60.0	0.0601

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GP SN: OHE19-T0489



Channel: BRG 2Y PROX

Comments: Full Load with Vibes

Overall Vibration Level Between 5 Hz and 2000 Hz: 0.2913 mils P-P

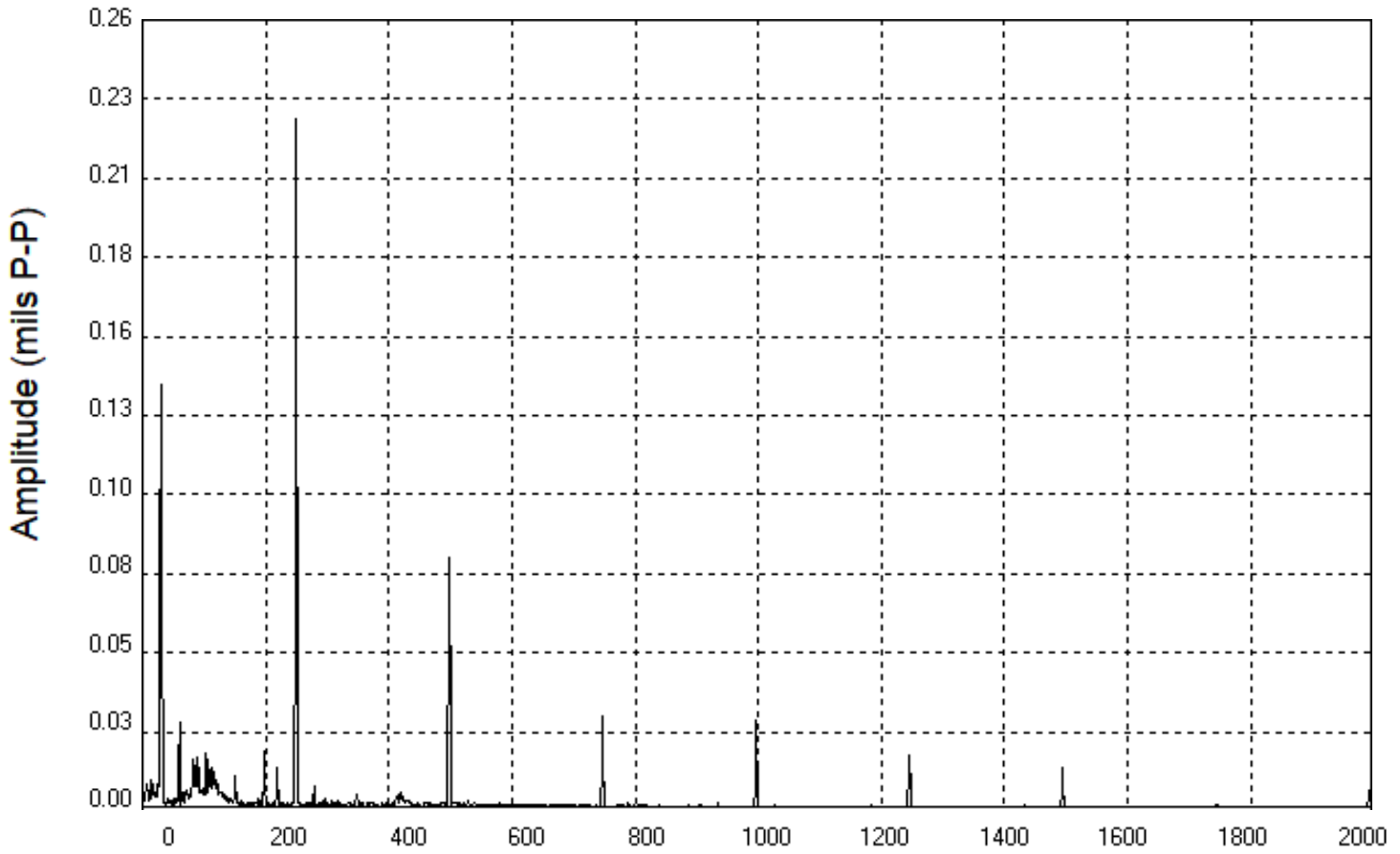
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Peak	Freq	Amp
1	30.0	0.1386
2	248.8	0.1205
3	498.8	0.0854
4	98.8	0.0572
5	747.5	0.0339

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GP SN: OHE19-T0489



Channel: BRG 2X PROX

Comments: Full Load with Vibes

Overall Vibration Level Between 5 Hz and 2000 Hz: 0.382 mils P-P

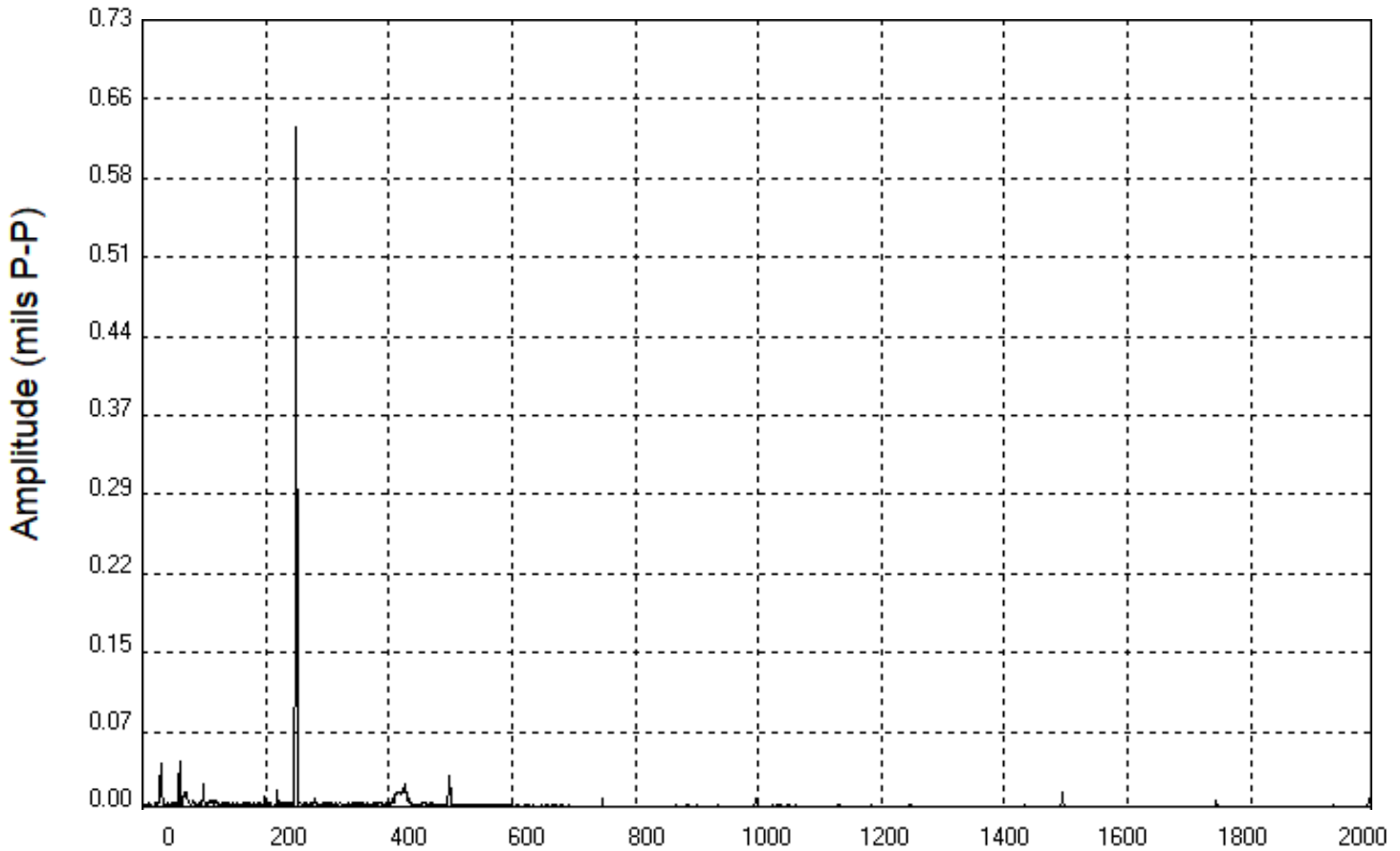
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Peak	Freq	Amp
1	248.8	0.2275
2	30.0	0.1404
3	498.8	0.0833
4	747.5	0.0308
5	996.3	0.0298

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CATERPILLAR CONFIDENTIAL, GREEN

GP SN: OHE19-T0489



Channel: BRG 3Y PROX

Comments: Full Load with Vibes

Overall Vibration Level Between 5 Hz and 2000 Hz: 0.8541 mils P-P

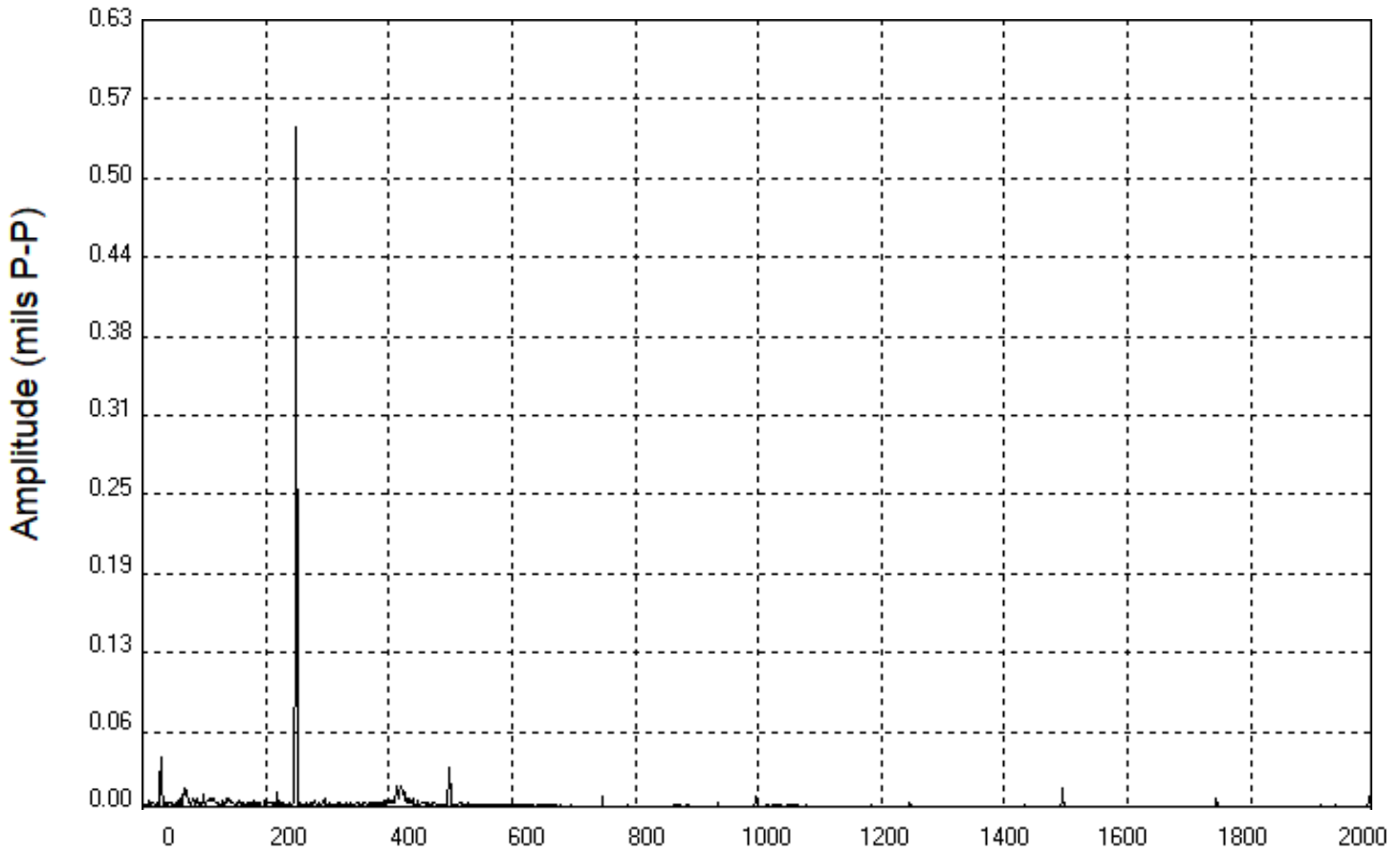
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Peak	Freq	Amp
1	248.8	0.6315
2	60.0	0.0465
3	30.0	0.0430
4	498.8	0.0330
5	425.0	0.0256

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GP SN: OHE19-T0489



Channel: BRG 3X PROX

Comments: Full Load with Vibes

Overall Vibration Level Between 5 Hz and 2000 Hz: 0.7365 mils P-P

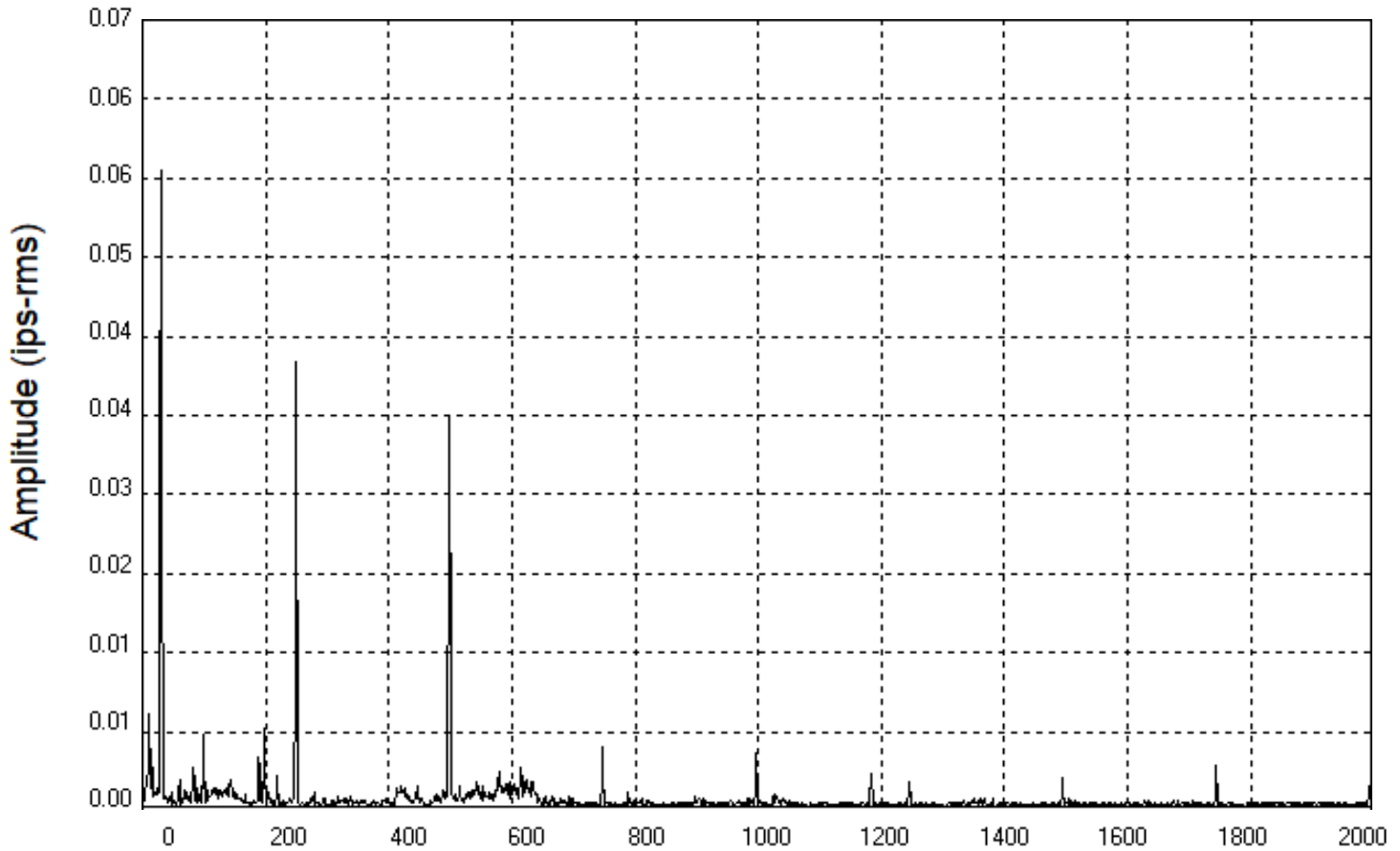
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Peak	Freq	Amp
1	248.8	0.5444
2	30.0	0.0426
3	498.8	0.0350
4	418.8	0.0202
5	1495.0	0.0175

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CATERPILLAR CONFIDENTIAL, GREEN

GP SN: OHE19-T0489



Channel: GP FWD HORZ VEL

Comments: Full Load with Vibes

Overall Vibration Level Between 15 Hz and 2000 Hz: 0.1061 ips-rms

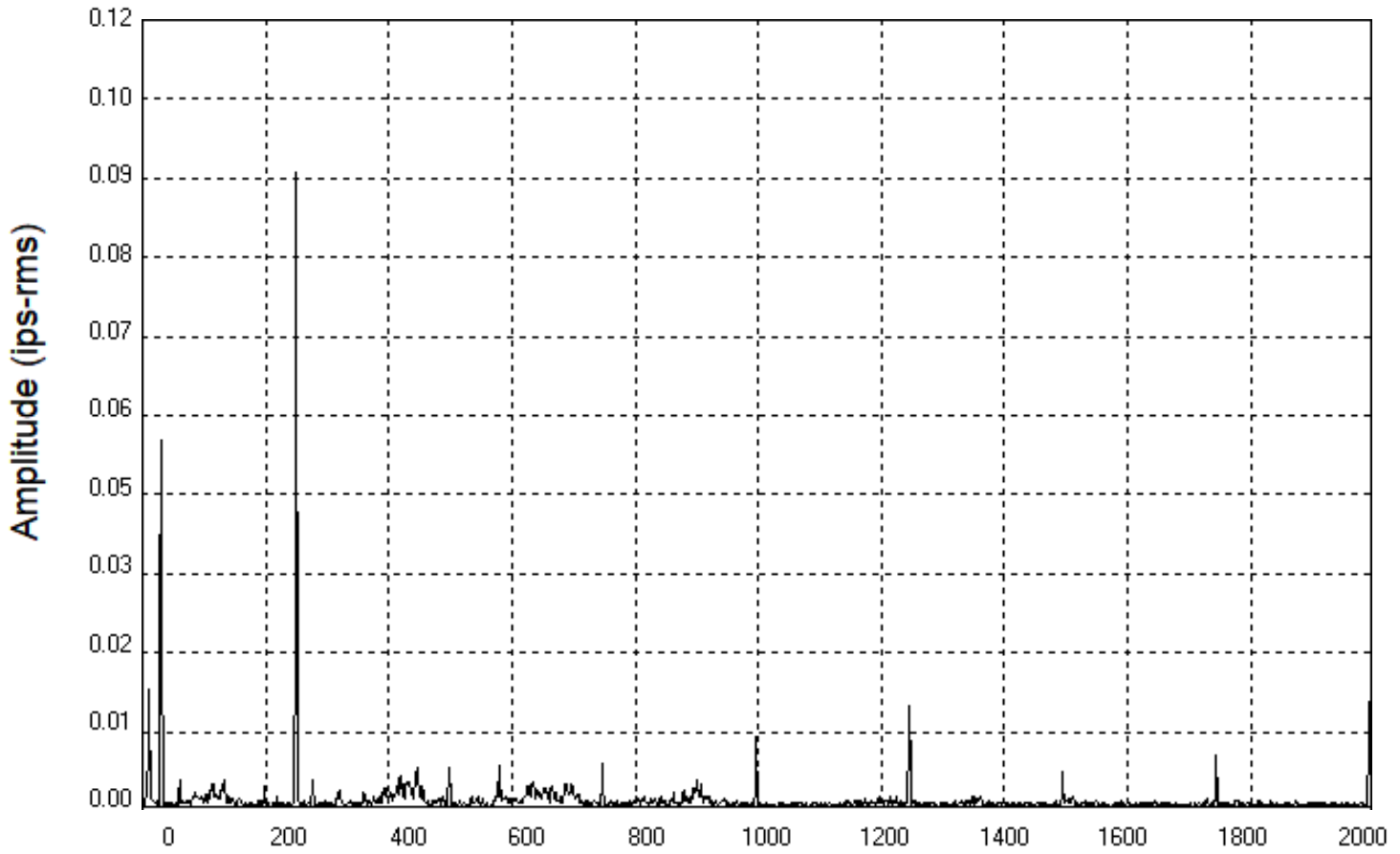
DP#: 6 N_GP 14945 RPM; N_RGB 1799 RPM; T_OIL_MAN 139 °F

Peak	Freq	Amp
1	30.0	0.0566
2	248.8	0.0397
3	498.8	0.0351
4	197.5	0.0072
5	98.8	0.0067

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GP SN: OHE19-T0489



Channel: GP AFT VERT VEL

Comments: Full Load with Vibes

Overall Vibration Level Between 15 Hz and 2000 Hz: 0.1558 ips-rms

DP#: 6 N_GP 14945 RPM; N_RGB 1799 RPM; T_OIL_MAN 139 °F

Peak	Freq	Amp
1	248.8	0.0928
2	30.0	0.0538
3	1993.8	0.0158
4	1246.3	0.0154
5	996.3	0.0108

Captured On: 6/8/2019 11:01:33 AM

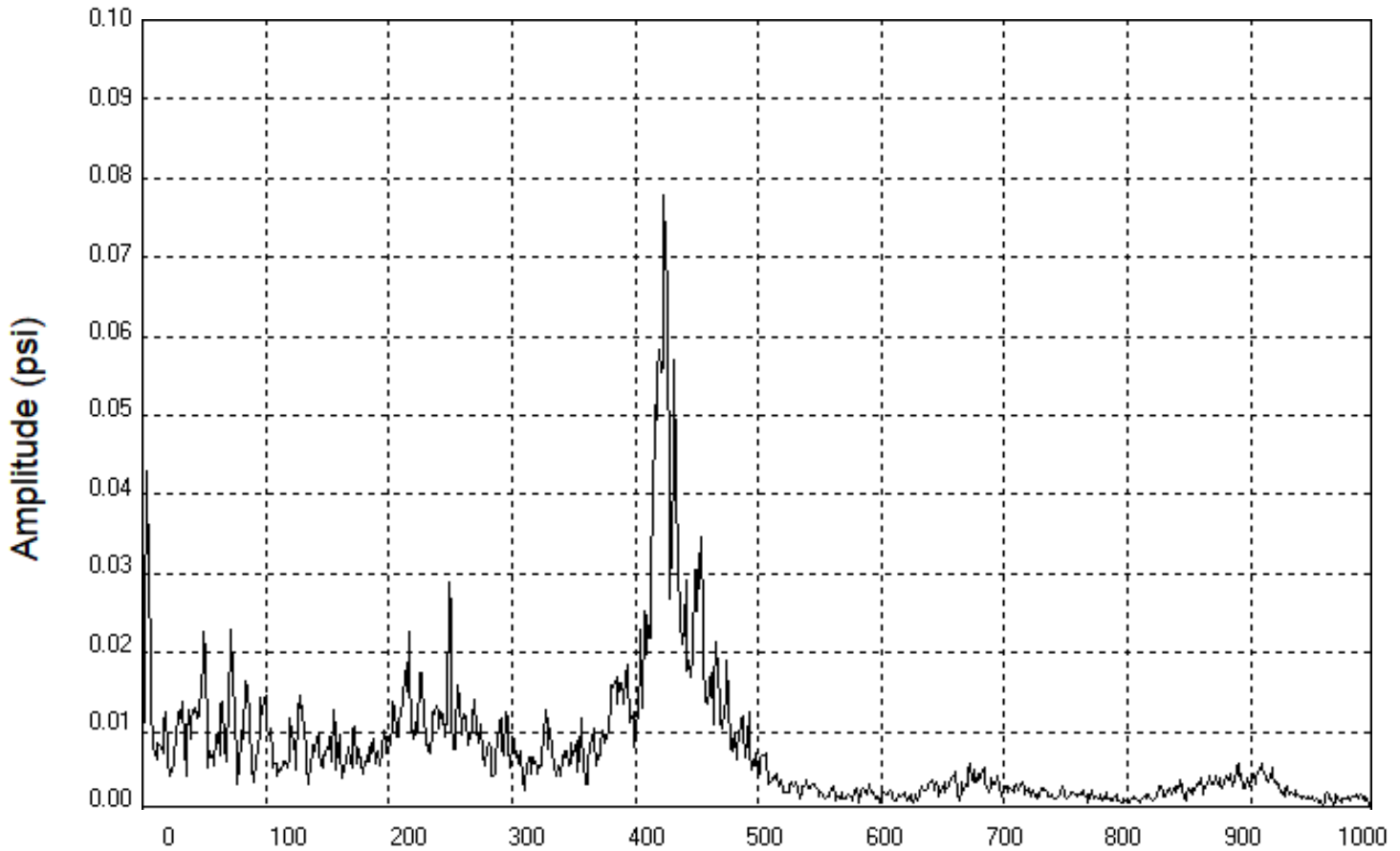
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Combustor Oscillations

Freq. Range	Overall Limit	Discrete Peak	Notes
10 - 100 Hz (Band 0)	0.4 psi (rms)	0.2 psi (rms)	(1)
100 - 250 Hz (Band 1)	0.4 psi (rms)	0.25 psi (rms)	(1)
250 - 750 Hz (Band 2)	0.4 psi (rms)	0.25 psi (rms)	(1)
750 - 1000 Hz (Band 3)	0.4 psi (rms)	0.15 psi (rms)	(1)

(1) Readings are valid between 10 and 1000Hz.

GP SN: OHE19-T0489



Channel: Comb OSC

Comments: Full Load Performance with Comb Osc and Emissions 3% Pilot ,
Overall Vibration Level Between 10 Hz and 1000 Hz: 0.3196 psi

DP#: 5 N_GP 14943 RPM; N_RGB 1799 RPM; T_OIL_MAN 139 °F

Peak	Freq	Amp
1	423.8	0.0779
2	432.5	0.0569
3	453.8	0.0346
4	248.8	0.0289
5	72.5	0.0228

BAM Range	pk Freq	pk Amp	OA
10:100	72.5	0.02	0.0961
100:250	248.8	0.03	0.1135
250:750	423.8	0.08	0.282
750:1000	908.8	0.01	0.0375
100:1000			0.3052

Captured On: 6/8/2019 10:58:52 AM

CATERPILLAR CONFIDENTIAL, GREEN

GP SN: OHE19-T0489



Channel: Comb OSC

Comments: 50% Load , 3% pilot with Emissions and Comb Osc

Overall Vibration Level Between 10 Hz and 1000 Hz: 0.1166 psi

DP#: 7 T_OIL_MAN 139 °F; N_GP 14945 RPM; N_RGB 1799 RPM

Peak	Freq	Amp
1	422.5	0.0133
2	211.3	0.0128
3	445.0	0.0125
4	237.5	0.0108
5	242.5	0.0104

BAM Range	pk Freq	pk Amp	OA
10:100	17.5	0.01	0.0519
100:250	211.3	0.01	0.0668
250:750	422.5	0.01	0.0786
750:1000	890.0	0.00	0.0194
100:1000			0.1048

Captured On: 6/8/2019 11:36:37 AM

CATERPILLAR CONFIDENTIAL, GREEN