

# **Operating Conditions that shorten Gas Engine Oil Life**

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## **Benefits Statement**

Going by Petrosave Laboratory oil analysis database information accumulated over the years, from analyzing oil samples from well over 500 Gas Engines comprising different brands, operating at remarkably different locations and subjected to varying loads, loading procedures and all sorts of operational/maintenance practices; Gas Engine Oil life could span from **under 500 to > 8,000 Hours** depending on Oil quality, Oil Sump Capacity, Operating Loads and even consistence in keeping to OEM specified Oil Make-ups.

## Situation

As one strategy to minimize running cost, it is the drive of every operator to safely extract the most hours during the life of the in-service oil. One Gas Engine OEM, in its service communications to users, recommended 2,000 Hours Oil Drain, however, strongly recommended the use of *Oil Analysis* to more appropriately determine oil change.

This presentation show cases different scenarios for which oil analysis reports produced widely different ODIs even for same Make/Model Gas Engines but operating in different Plants.

For 3 years the power plant gas engine of a Food Processing company in Lagos was operated at 3,000 – 3,500 Hrs ODI without oil analysis backup.

Oil Analysis was installed afterwards and initial results showed that in-service GEO becomes completely degraded under 1,000 Hours; the Company Management was livid.

RETYS SAV	e			Gas Engine	Oil Analysis	s Report	
Client Information							
Company Name:	OK Foods I	.td.		Client Contact:		Mangesh Vaidya	
Company Address:	Off Apapa-	llan Newspape Oshodi Expw		Department: Mobile Phone No.: Email Address;		Maintenance (Power 08063365430 mangesh.vaidya@ol	
				Equipment Operator/		-	
Equipment Information						_	
Equipment Type: Equipment ID Ref.	Gas Gen #1 [Engine S/N: 1044887] N			Component: Make/Type:		Engine JENBACHER / J420GS	
Equipment Make:	JENBACHER L			Lube Oil in use:		Mobil Pegasus 805	
Equipment Year of Manufacture:	2012 O			Oil Brand:		Mobil	
Equipment Location:	OK Foods 1	l, Guardian		Oil Weight:		SAE 40	
							(
	Fresh Oil	Condemina	07 May 2014		<ul> <li>Trend of Actual La 28 January 2015</li> </ul>	11 February 2015	03 March 2015
	Sample	Limit	2549/OKF1/GG#1/01	4195/OKF1/GG#1/02	4278/OKF1/GG#1/03	4389/OKF1/GG#1/04	03 March 2015 4502/OKF1/93#1/05
Engine Operating Hours							
Oil Sample [Hrs]	0	-	1,124	3,997	259	623	1,059
Cumm. Engine [Hrs]	-	-	11,343	15,795	16,103	16,467	16,903
Lube Oil Properties							
Color [Clear, Turbid or Dark]	Clear		Dark	Dark	Dark	Dark	Dark
Viscosity @ 40C [cSt]	125.8	+/- 25%	166.1	153.6	132.4	141.3	148.3
Viscosity @ 100C [cSt]	13.2	≥+3	16	15.2	13.7	14.4	14.8
TBN [mgKOH/g] TAN [mgKOH/g]	6.2 0.3	3.1 + 2.5	2.6	2.5	5.5 0.9	3.8 2.6	2.8
Soot [%]	0%	+ 2.0	0.0%	0.0%	0.0%	0.0%	0.0%
Nitration [A/cm]	0	20	29.3	17.2	2.7	4.9	9.8
Oxidation [A/cm]	0	20	13.5	9.6	2.1	3.1	6.3
Water in Oil [%]	0.00%	0.20%	0.00%	0.00%	0.00%	0.00%	0.00%
Glycol [%]	0.00%	0.02%	0.00%	0.00%	0.00%	0.00%	0.00%
Elemental Analysis							
Wear Metals			-				-
Aluminum, Al [ppm] Copper, Cu [ppm]	0	15 15	0	0	0	0	0
Copper, cd [ppm] Chromium, Cr [ppm]	0	5	0		0	0	0 0 0
Lead, Pb [ppm]	ŏ	20	0		o	0	ő
Iron, Fe [ppm]	0	20	3		0	4	0
Tin, Sn [ppm]	0	5	0	2	0	2	0
Contaminant Metals							
Silicon, Si [ppm]	0	20	0	0	0	0	0
Sodium, Na (ppm) Potassium, K (ppm)	0	20 5	2	3	0	0	6 0
Additive Metal							
A data ve Metal Molybdenum (ppm)		10	0	0	0	0	0

High TAN - causes include increased acid level in natural gas engine oil

Low TBN - causes include Over-extended oil drain intervals, Excessive blowby, Insufficient additive package, Overheating

Service Engineer's Comment:

In-service GEO has served out its useful life; Lubrication Service advised. All engine wear rates within normal limits. Next 250 Hrs oil sampling/analysis to monitor trend.

Earlier fresh oil analysis produced good results showing that quality Gas Engine Oil (GEO) was in use.

Petro Sav	5	Fresh Oil Analysis Report				
Client Information Company Name: Company Address: Date:	OK Foods Ltd. Near Guardian Off Apapa - Ost Isolo, Lagos 27-Jan-15	 Client Contact: Department: Mobile Phone No.: Email Address:	Mangesh Vaidya Maintenance (Power Plant 08063365430 mangesh.vaidya@olamnet.com			
Test	Units	OKF1: Fresh Oil Sample Drum Batch No. C4A0038 Sample Taken: Jan. 26, 2015	Mobil Pegasus 805 Website PDS Info			
Color	Visual	Clear, Brown	NA			
SAE Grade	-	40	40			
Viscosity @ 40C	cSt	124.7	130.			
Viscosity @ 100C	cSt	13.2	13.			
Viscosity Index, VI	-	100	9			
Specific Gravity [SG] @ 15C	kg/m <sup>3</sup>	887	89			
Total Base Number [TBN]	mgKOH/g	6.3	6.			
Total Acid Number [TAN]	mgKOH/g	0.3	0.3			
Flash Point [ASTM D93 Closed Cup]	°C	220	262			
Water	% vol	Nil	N			

Note the TAN level of fresh oil is not available as a Product Data Sheet (PDS) information. However, TAN = 0.3 is typical value, which has been measured at Petrosave Lab for several GEO samples, of authentic sources and correctly meeting other Mobil Pegasus 805 published oil parameters.

# ASTM D92 Open Cup Method

Comment(s)

 In spite of some variations seen in the parameters reported above, it is safe to conclude that the fresh oil sample MEETS the product formulation properties of Mobil Pegasus 805.

- Oil sampling intervals was shortened beginning with 50 Hrs to more closely track the degradation changes in that oil. Results trend confirmed recent observation that parameters such as - oil oxidation, TBN and TAN levels rapidly crossed threshold Limits while the remaining parameters such as Viscosity approached Warning.
- 2. Engine Operators insisted that all running conditions particularly Load levels remained same.
- 3. Investigation shifted to Oil Consumption with specific focus on oil make-up rate. Operators provided total Make-up oil since the last lubrication service and that figure was much smaller than the theoretically calculated Oil Make-up, using the OEM guide of **0.3g of oil per KwH**.

Integrated Services Limited	e			Gas Engine	Oil Analysis	Report		-i
Client Information								
Company Name:	OK Foods L	td.		Client Contact:		Mangesh Vaidya		
Company Address:	Near Guard	lan Newspaper		Department:	1	Maintenance (Power	Plant)	
	Off Apapa -	Oshodi Expwy		Mobile Phone No.:		08063365430		
	Isolo, Lago	5		Email Address:		mangesh.vaidya@ola	amnet.com	
E				Equipment Operator/	Driver:	-		
Equipment Information Equipment Type:	One Feeder			Component:		Engine		
Equipment Type: Equipment ID Ref.				Make/Type:		Engine JENBACHER / J420GS		
Equipment Make:				Lube Oil in use:		Mobil Pegasus 805		
Equipment Year of Manufacture:				Oil Brand:		Mobil		
Equipment Location:	OK Foods 1	, Guardian		Oil Weight:	:	SAE 40		
								Conditio
					<ul> <li>Trend of Actual Lab</li> </ul>			Ок
	Fresh Oil	Condeming	03 March 2015	27 March 2015	20 April 2015	04 May 2015	08 May 2015	O Cau
	Sample	Limit	4502/OKF1/GG#1/05	4718/OKF1/GG#1/06	4813/OKF1/GG#1/07	4916/OKF1/GG#1/08	4922/OKF1/GG#1/09	🔴 Crit
Engine Operating Hours								
Oil Sample [Hrs]	0	-	1.059	50	430	743	792	
Cumm. Engine [Hrs]	-	-	16,903	17,320	17,700	18,013	18,062	
Lube Oil Properties								
Color [Clear, Turbid or Dark]	Clear		Dark	Dark	Dark	Dark	Dark	
Viscosity @ 40C [cSt]	125.8	4-25%	148.3	130.6	139.1	142.4	143.4	0
Viscosity @ 100C [cSt]	13.2	≥ +3	14.8	13.6	14.3	14.4	14.5	8
TBN [mgKOH/g]	6.2	3.1	2.8		4.1	3.4	3.3	8
TAN [mgKOH/g]	0.3	+ 2.5	2.9	0.8	2.2	3.1	3.3	ĕ
Soot [%]	0%	2%	0.0%	0.0%	0.0%	0.0%	0.0%	ō
Nitration [A/cm]	0	20	9.8	2.5	3.6	6.5	6.6	Š
Oxidation [A/cm]	0	20	6.3	0	3	4.4	4.8	
Water in Oil [%]	0.00%	0.20%	0.00%	0.00%	0.00%	0.00%	0.00%	<u>_</u>
Glycol [%]	0.00%	0.02%	0.00%	0.00%	0.00%	0.00%	0.00%	0
Elemental Analysis								
Wear Metals								~
Aluminum, Al [ppm]	0	15	0		0	0	2	<u> </u>
Copper, Cu [ppm]	0	15	0		0	0	0 0 0	
Chromium, Cr [ppm] Lead, Pb [ppm]	0	5 20	0		0	0	0	
Iron, Fe (ppm)	0	20	0		0	0	0	8
Tin, Sn [ppm]	0	5	0		0	0	0	8
Control Hards								
Contaminant Metals		20	0		0	0		0
Silicon, Si [ppm] Sodium, Na [ppm]	0	20	0		0	0	0	8
Potassium, K [ppm]	0	20	0		0	0	0	8
								-
Additive Metal Molybdenum (ppm)	0	10	o	0			0	0

agnostics:

Low TBN - causes include Over-extended oil drain intervals, Excessive blowby, Insufficient additive package, Overheating High TAN - causes include increased acid level in natural gas engine oil

Service Engineer's Comment:

ubrication Service is advised. Subsequent oil sampling/analysis to monitor trend.

- Root cause investigation to resolve the difference revealed that the automatic oil make-up mechanism became faulty and was shut-off while Operators decided on manual oil top-up, which was inefficient.
- 5. While that incident lasted, self-help initiatives by shift supervisors to push oil life >1,000 Hours produced alerts of abnormal wear rates and rapid oil degradation requiring Lubrication Service.

Petrosav Integrated Services Limited	e			Gas Engine	Oil Analysis	Report		
Client Information Company Name: Company Address:	Near Guardian Newspaper Off Apapa- Oshodi Expw y Isolo, Lagos			Client Contact: Department: Mobile Phone No.: Email Address: Equipment Operator/I		Mangesh Vaidya Maintenance (Power 08063365430 mangesh-vaidya@ol		
<b>Equipment Information</b> Equipment Type: Equipment ID Ref. Equipment Make:	Gas Engine Generator [1.4 MW] Gas Gen #1 [Engine S/N: 1044887] JENBACHER			Component: Make/Type: Lube Oil in use:		- Engine JENBACHER / J420GS Mobil Pegasus 805		
Equipment Year of Manufacture: Equipment Location:	2012			Oil Brand: Oil Weight:		Mobil SAE 40		
				Used Oil Samples	Trend of Actual Lab	oratory Tests		Condi
	Fresh Oil	Condeming	06 May 2015	15 May 2015	08 June 2015	25 June 2015	10 July 2015	ŏä
	Sample	Limit	4922/OKF1/GG#1/09	4984/OKF1/GG#1/10	5085/OKF1/GG#1/11	5189/OKF1/GG#1/12	5237/OKF1/GG#1/13	Ŏ or
Engine Operating Hours								
Oil Sample [Hrs]	0	-	792	58	625	996	1,330	
Cumm. Engine [Hrs]	-	-	18,062	18,200	18,767	19,138	19,472	
					,		,	
Lube Oil Properties								
Color [Clear, Turbid or Dark]	Clear		Dark	Dark	Dark	Dark	Dark	
Viscosity @ 40C [cSt]	125.8	+/- 25%	143.4	129.9	137.1	142.3	137.5	•
Viscosity @ 100C [cSt]	13.2	≥ +3	14.5	13.5	14.1	14.4	14.1	8
TBN [mgKOH/g]	6.2	3.1	3.3	6.0	4.4	3.7	3.2	_ <u>Q</u>
TAN [mgKOH/g]	0.3	+ 2.5	3.3	0.5	2.1	2.5	3.2	_
Soot [%]	0%	2%	0.0%	0.0%	0.0%	0.0%	0.0%	
Nitration [A/cm]	0	20 20	6.6	0	2.4	4.7	9.8	8
Oxidation [A/cm]	0.00%	0.20%	4.8	0.00%	0.00%	4	5.3	
Water in Oil [%] Glycol [%]	0.00%	0.02%	0.00%	0.00%	0.00%	0.00%	0.00%	X
Glycol [%]	0.00%	0.02%	0.00%	0.00%	0.00%	0.00%	0.00%	
Elemental Analysis Wear Metals								
Aluminum, Al [ppm]	0	15	2	2	3	4	4	0
Copper, Cu [ppm]	0	15	0	0	4	0	0	ŏ
Chromium, Cr [ppm]	0	5	0	0	0	0	0	Ć
Lead, Pb [ppm]	0	20	0	0	0	0	0	č
Iron, Fe [ppm]	0	20	0	0	0	0	0	8
Tin, Sn [ppm]	0	5	0	0	0	0	0	0
Contaminant Metals								
Silicon, Si [ppm]	0	20	0	0	0	0	0	0
Sodium, Na [ppm]	0	20	0	0	0	0	0	
Potassium, K [ppm]	0	5	0	0	0	0	0	0
Additive Metal								
	0	10	0	0	0	0	0	C

Low TBN - causes include Over-extended oil drain intervals, Excessive blowby, Insufficient additive package, Overheating

Service Engineer's Comment:

In-service of has served out its useful life; Lubrication Service advised. Next 250 Hrs oil sampling/analysis to monitor trend.

Manually topping up a gas engine running 24/7 across shifts by different operators has its setbacks.

Fortunately the Company Management reviewed the situation and the **faulty Automatic Oil Make-up was replaced. Oil Drain Interval gradually reverted to > 2,000 Hours service life.** 

Integrated Services Limited	e			Gas Engine	Oil Analysis	s Report			
Client Information Company Name: Company Address:		lan Newspape Oshodi Expwy		Client Contact: Department: Mobile Phone No.: Email Address: Equipment Operator	/Driver:	Mangesh Vaidya Maintenance (Power Plant) 09063365430 mangesh.vaidya@olamnet.com			
Equipment Information Equipment Type: Equipment ID Ref. Equipment Make: Equipment Year of Manufacture: Equipment Location:	Gas Engline Generator [1.4 MW] C Gas Gen#1 [Engline SiN: 1044867] N JENBACHER L 2012 C			Component: Make/Type: Lube Oil in use: Oil Brand: Oil Weight:		Engine JENBACHER / J420GS Mobil Pegasus 805 Mobil SAE 40			
				Llood Oil Samplar	- Trend of Actual La	horatony Tosta			
	Fresh Oil	Condeming	08 December 2015	11 January 2016	29 January 2016	02 March 2016	08 March 2016		
	Sample	Limit	5995/OKF1/GG#1/20	6109/OKF1/3G#1/21	6217/OKF1/GG#1/22	6377/OKF1/GG#1/23	6400/OKF1/GG#1/24		
Engine Operating Hours									
Oil Sample [Hrs]	0	-	1,020	1,554	1,949	472	606		
Cumm. Engine [Hrs]	-	-	22,561	23,095	23,490	24,163	24,297		
Lube Oil Properties									
Color [Clear, Turbid or Dark]	Clear		Dark	Dark	Dark	Dark	Dark		
Viscosity @ 40C [cSt]	125.8	+ 25%	137	138.8	143.7	135.2	135.7		
Viscosity @ 100C [cSt]	13.2	≥+3	14.1		14.5	13.9	14.0		
TBN [mgKOH/g]	6.2	3.1	4.6		3.9	5.3	5.1		
TAN [mgKOH/g]	0.3	+ 2.5	2.1		2.3	1.6	1.7		
Soot [%]	0%	2%	0.0%		0.0%	0.0%	0.0%		
Nitration [A/cm]	0	20 20	0	2.4	3.3 4.6	1.4	1.7		
Oxidation [A/cm] Water in Oil [%]	0.00%	0.20%	0.00%	4.3	4.b 0.00%	0.00%	2.4		
Giycol [%]	0.00%	0.20%	0.00%	0.00%	0.00%	0.00%	0.00%		
Elemental Analysis									
Wear Metals									
Aluminum, Al [ppm]	0	15	0	0	0	0	0		
Copper, Cu [ppm]	0	15	0	0	0	0	0		
Chromium, Cr [ppm]	0	5	0		0	4	3		
Lead, Pb [ppm]	0	20	0		0	0	3 0 0		
Iron, Fe [ppm]	0	20	0		0	0	0		
Tin, Sn [ppm]	0	5	3	0	0	2	0		
Contaminant Metals									
Silicon, Si [ppm]	0	20	0		0	0	0		
Sodium, Na [ppm]	0	20	0		2	0	0		
Potassium, K [ppm]	0	5	0	0	0	0	0		
Additive Metal									
Molybdenum [ppm]	0	10	0	0	0	0	0		

Service Engineer's Comment:

All engine wear rates within normal limits. Oil is ok for continued use. Next 500 Hrs oil sampling/analysis to monitor trend.

Case Study 2: Lubrication Service – Impact of Partial Drain

First 500 Hrs oil sample taken after Lubrication Service revealed that remaining oil life was less than 40%. Initial thoughts were that operators were only carry out "oil sweetening", a common practice of combining partial drain-out and oil make-up in order to manage limited oil stock; to keep engine safe and running pending when adequate oil replenishment stock is received to enable full lubrication service.

When the operators informed otherwise, root cause investigations driven by oil analysis commenced, and fortunately was quick to connect oil analysis observation to the amount of oil used during Lubrication Service.

Petro Sav	Interview Coss Limited       Imme:     Conour Global Solutions Nigerla tst Floor, East Wing, City Hall 22 - 25, Catholic Mission Street Lagos Island Lagos, Nigerla       Information     Commission       Yp0:     Gas Engine Generator [1160 KW] 0 Flof.       Gen # 15W 32160429] Take:     Commission       Condumins     20 Street       Yp0:     Gas Engine Generator [1160 KW] 0 Flof.       Gen # 15W 32160429] Take:     Condeming 20 Street       Condeming     20 Street       Goaldon:     NBC Plant, Benin       Tating Hours rs]     0       Clear ingine [Hrs]     0       Clear [1]     0       Clear [2]     Clear 15.5       Clear [3]     0       0     25       0     25       0     25       0     25       0     25       0     25       0     25       0     25       0     25       0     25       0     25       0     25       0     25       0     25       0     25       0     25       0     25       0     20       0     20       0     25       0				Gas Engine Oil Analysis Report							
Client Information Company Name: Company Address:	1st Floor, 23 - 25, Ca Lagos Isla	East Wing, City tholic Mission nd	/ Hall	Client Contacts: Department: Mobile Phone No.: Email Address:		Anthony Onwuegbuzie Service - Power Genera 08078391308 <anthony.onwuegbuzi< th=""><th></th></anthony.onwuegbuzi<>						
Equipment Information Equipment Type: Equipment ID Ref. Equipment Make: Equipment Year of Manufacture: Equipment Location:	Gen #3 [S/ Cummins 2010	N 33180429]	160 KW]	Equipment Operator Component: Make/Model: Lube Oil in use: Oil Brand: Oil Weight:		- Engine Cummins / GQSK80-G4 Valvoline Premium Blue Ashland SAE 40						
				Used Oil Sample	s - Trend of Actual L	aboratory Tests						
			20 September 2013 1825/ContourG/Gen#3/12		20 April 2014 2694/Contour(3/Gen#3/14	09 June 2014 2854/Contour@/Gen#3/15	22 July 2015 5354/ContourG/Gen#3/16					
Turbine Operating Hours Oil Sample [Hrs] Cumm. Gas Engine [Hrs]		-	1,000 12,947		500 2003.00	1,500 xxxx x	1,000 27,097					
Lube Oil Properties Appearance [Clear, Turbid, Dark] Viscosity @ 40C [cSt] Viscosity @ 100C [cSt] TAN [mgKOH/g] Itso [mgKOH/g] Insolubles [%] Nitration [A/cm]	119.7 12.8 0.3 5.5 0% 0	+/-20% 4 2.8 1% 25	Dark 169.1 16.2 4.1 1.6 0.0% 23.5	170.8 16.4 4.9 1.4 0.0% 15.2	Dark 139.5 14.2 1.8 4.5 0.0% 0.0	Dark 162.4 15.8 4.4 2.1 0.0% 17.2	Dark 150.3 15 3.3 3.4 0.0% 11.6					
Oxidation [A/cm] Water in Oil [%] Glycol [%]	0.0%	0.2%	18.0 0.0% 0.00%	0.0%	0.0 0.1% 0.00%	14.6 0.1% 0.00%	6.4 0.2% 0.00%					
Elemental Analysis Wear Metals												
Iron, Fe [ppm] Chromium, Cr [ppm] Lead, Pb [ppm] Copper, Cu [ppm] Tin, Sn [ppm] Aluminum, Al [ppm] Molydenum, Mo [ppm]	0	5	0 3 0 7 2 1 0		0 2 0 3 0 0 0	0 0 2 0 0	3 0 96 0 3 0					
Molyboenum, Mo (ppm) Additive/Contaminant Metals Silicon, Si (ppm) Sodium, Na (ppm) Potassium, K (ppm)	0	25 8 10	0 4	0	0	0	0					

High OI Viscosity - causes include Wrong top-up with throker oil, High Oxidaton, High Nitraton, increased Contamination levels, High Inscituties, Volatilization of light-ends, Emulsified water (sludg High Walter Ingress - causes include leaks from Oil Cooler (leaking seats), improper storage, condensation from humid air in the oil reservoir, bearing pedestals

ligh Level of Copper - causes include Bearings, Wrist Pin Bushings, Cam Bushings, Valve Train Bushings, Thrust Washers, Oli Coolers, Oli Pipings, Governors & Oli Pump, Oli Additives

#### Service Engineer's Comment:

Cooling Water Ingress is evidenced by "coolant marker" - Potassium at Caution Level. High Copper, occuring alone, may arise from Oil Cooler leaching. High Oil Viscosity is a product of water emulsifying oil. Urgent Maintenance action advised. Subsequent oil sampling/analysis to monitor trend.

Case Study 2: Lubrication Service - Impact of Partial Drain

- 1. Power Plant operators had a procedure to mechanical drain off oil using a transfer pump. It was important that oil change is done shortly after engine shutdown to ensure that particulate contaminants suspended in the oil are effective removed before they have a chance to settle at obscure corners of the oil galleries & oil sump.
- 2. Safety consideration required that since the oil is still very much hot, pumping device should be used to accomplish this.
- 3. Dip level of the pipe coupled to the suction-side of the pump was wrongly positioned within the oil sump and that resulted to incomplete draining of the used oil.
- 4. Furthermore, without checking to ensure that the drained out oil roughly approximated to the oil sump capacity, operators proceeded to add fresh oil after replacing oil filters.

Such oil changes amount to partial drain which are flagged by oil analysis for rapid oil degradation.

Petro Sav	e			Gas Engine	Oil Analysis	s Report		
Client Information Company Name: Company Address:	1st Floor, I		Hall	Client Contacts: Department: Mobile Phone No.: Email Address: Equipment Operator		Anthony Onwaegbazie Service - Power Genera 0807 8391308 < anthony.onwaegbazi		>
Equipment Information Equipment Type: Equipment ID Ref. Equipment Make: Equipment Year of Manufacture: Equipment Location:		e Cenerator (1 N 33180303) , Benin	160 KW]	Component: Make/Model: Lube Oil in use: Oil Brand: Oil Weight:		Engine Cummins / CQSK80-C4 Valvoline Premium Bluz Ashland SAE 40		
					s - Trend of Actual L			Con
	Fresh Oil Sample	Condeming Limit	08 August 2015 167 S'ContourG/Gen#1/16	-	27 Merch 2015 4774/ContourG/Genil 1/21	15 May 2015 5040/ContourQ/Gen#1/22	21 July 2015 5352/ContourQ/Gonil 1/23	ê
Turbine Operating Hours Oil Sample [Hrs] Cumm. Gas Engine [Hrs]	0	-	500 11,924		300 X X 300 X	500 xxxxx	1,000 27,270	
Lube Oil Properties Appearance [Clear, Tuchid, Dark] Viscosity @ 40C [ci51] TAN [mgKOH4g] TAN [mgKOH4g] Insolutions [K-] Nitration [Arom] Oxidation [Arom] Oxidation [Arom] Water in Oil [%] Gydol [%]	Clear 1197 12.8 0.3 5.5 0% 0 0 0 0.0%	4/-25% 4/-20% 4 2.8 1% 25 25 0.2% 0.02%	Dari 155.4 3.4 3.0 0.0% 7.4 0.0% 0.0% 0.0%	162.5 15.8 4.7 2.2 0.0% 0.20.3 15.8 0.20.3 15.8 0.1%	Dark 152 15.1 3.5 2.3 0.0% 23.6 11.3 0.0%	Dark 146,1 14,7 1,8 2,6 0,0% 20,2 7,1 0,0%	Dark 1452 3 3.6 0.0% 11.7 0.0 0.2% 0.00%	
Bornental Analysis Waar Mearls Ison, Fe (ppm) Chromkum, Gr (ppm) Chromkum, Gr (ppm) Copper, Cu (ppm) The, Sn (ppm) Molybolenum, Al (ppm) Molybolenum, Mo (ppm) Addivectorenimane Mearls	0 0 0 0 0 0 0	20 5 30 15 10 15 10	0 0 10 0 0 0 0	0 0	4 0 40 0 0 0	0 26	0 0 13 3 2 0	
Silcon, Si (ppm) Sodium, Na (ppm) Potassium, K (ppm)	0	25 8 10	0 9 2	7	0	0 18 18	0 4 3	

ow TEN - causes include Over-extended oil drain intervals. Excessive blowby, insufficient additive package. Overheating Hoh Level of Copper - causes include Bearings, Wrist Pin Bushings, Cam Bushings, Valve Train Bushings, Thrust Washers, Ol Coolers, Ol Pipings, Governors & Ol Pump, Ol Additives

High Level of Sodium - causes include OII additive constituent, Coolant additive

ligh Level of Potassium - cause include Coolant additive, Trace element in fuel

#### Service Engineer's Comment:

Deserve this gas engine for Cooling Water ingress; evidenced by "coolant markers" - Potassium and Sodium. High Copper may arise from Oil Cooler leaching ent Maintenance action advised. Subsequent of sampling/analysis to monitor trend.

Case Study 3: Increased Production Plant Load – Impact of Process Expansion

Initially total process load powered by the Gas Engines were 50 - 60% of their combined installed capacities and In-service oil life averaged 10,000 Hours for each engine.

Afterwards, the Company added a new Production Line to existing Power Plant installed capacity. Additional 1050kW load from the new Line was therefore shared across all 3 running Gas Engines.

			ous Engli		lysis Repo		The second second	
GZ Industry Ltd. Agbara Factory Agbara Industrial Estate Lagoe			Email Address:		08077691610 samir.khan@gzik	an.com		
Gen #1 [S/N JENBACHE	1: 0856196/01] R		Component: Make/Model: Lube Oil in use: Oil Brand: Oil Weight:		Engine JENBACHER / J812 Pegasus 705 Mobil SAE 40	GSE		
East Of	Candamian	10 1					10 1.1.00.00	Co
Sample	Limit						x200/GZI/GGE#1/12	6
0	:							5
Clear 126.6 13.3 0.1 5.6 0% 0 0 0.00%	*/-20% 4 2.8 1% 25 25 0.20%	1.2 4.7 0.0% 4.6 0.00%	1.3 4.8 0.0% 0 4.6 0.00%	140.9 14.3 1.2 4.68 0.0% 0 4.5 0.00%	140 114.3 1.4 4.45 0.095 0 4.8 0.0095	1358 14.0 1.4 4.44 0.0% 0 5 0.00%	138.3 14.2 1.5 4.52 0.0% 0 5 5	8
000000000000000000000000000000000000000	15 15 5 30 20	3 0 0 0	0 7 0 0	0 17 3 0 0	0 29 0 23	0 31 0 0 0	0 0 30 2 0 0 0 0	
0	8	74		0	4	00		
	Agbars Fac Agbars Fac Agbars Indi Lagos Gas Engine Gas Flant, i Fresh Oil Sample 0 Clear 126.6 13.3 0.1 5.6 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	Agbara Factory Agbara Industrial Estate Lagos Gas Engine Generator [1/ Gen #1 [SN: 085615807] 	Agbara Faciory Agbara Industrial Estate Lagoe Gas Engine Generator (1.8 MW) Gen II [SN: 05861901] JENNACHER - - Gas Plant, Agbara Factory Fresh Oll Sample Limit 10 April 2012 104505210GE81/7 104505210GE81/7 104505210GE81/7 104505210GE81/7 104505210GE81/7 104505210GE81/7 104505210GE81/7 0 105 10205 104505210GE81/7 104505210GE81/7 0 0 0 0 0 0 0 0 0 0 0 0 0	Agbars Factory Agbars Industrial Estate         Department: Mobile Phone No Equipment Open           Gas Engine Generator [1.8 MV] Gen ff [SNI 045611401]         Component: Make/Model: J2RNA-LER         Component: Make/Model: J2RNA-LER           J2RNA-LER         Ubbe O lin use: - O li Brand: Gas Plant, Agbas Factory         Ubbe O lin use: - O li Brand: 10 April 2012           Fresh OI Sample         Condeming Limit         10 April 2012         27 April 2012 27 April 2012           0         - - -         8,409         8,810           13.3         +(-25%)         136.9         134.5           128.6         +(-25%)         136.9         134.5           13.3         +(-25%)         136.9         134.5           13.6         2.8         4.7         4.8           0%         25         0         0           0         25         4.8         4.8           0.00%         0.00%         0.00%         0.00%           0         15         3         0           0         15         3         0           0         15         0         0         0           0         15         0         0         0           0         15         0         0         0 </td <td>Agbars Factory Agbars Industrial Eatate Lago         Department: Mobile Phone No.: Email Address:           Gas Engine Generator (1.8 NW) Gen TI [SN: 485619601]         Component: Make/Model: JPKBACHER Ubb OI In use: - Oil Brand: Gas Plant, Agbars Factory         Component: Make/Model: JPKBACHER Ubb OI In use: - Oil Brand: Gas Plant, Agbars Factory           Fresh OII Sample         Condeming Limit         10 April 2012 1045/02/UGGE/17         27 April 2012 178 Appiles - Trend 10 April 2012 178 Appiles - Trend 10 April 2012 1045/02/UGGE/18         11 Appiles - Trend 186 Appiles - Trend 196 Appiles - Trend 197 Appiles - Trend 196 Appiles - T</td> <td>Agbars Factory Agbars Industrial Estate         Department: Mobile Phone No.: Base Industrial Estate         Maintenance - Po 08077891010           Lagee         Mobile Phone No.: Base Industrial Estate         Maintenance - Po 08077891010         08077891010           Equipment Operator/Driver:         Equipment Operator/Driver:         -           Gas Engine Generator [1.8 MW]         Component: Equipment Operator/Driver:         Engine JENBACHER Jult2           JENBACHER - Old Brand:         Component: Make/Model:         Engine JENBACHER Jult2           JENBACHER - Old Brand:         Make/Model:         JENBACHER Jult2           JENBACHER - Old Brand:         Make/Model:         Make/Model:           Fresh Ol Sample         Condeming Limit         10 April2012         27 April2012         11 May 2012           0         -         8,409         8,810         9,194         9,853           113.3         +(-25%)         136.9         134.5         140.9         14.0.9           126.6         +(-25%)         136.9         134.5         140.9         14.3           0.0         25         0         0         0         0         0           0         25         0         0         0         0         0         0         0           0.00%</td> <td>Agbars Factory         Department:         Maintenance - Power Plant           Agbars Industrial Eases         Mobile Phone No.:         08077691910           Lages         Email Address:         barnit Khanggarican.com           Jass Engine Generator [1,8 MW]         Component:         Barnit Khanggarican.com           Gen FigNt: 085619401         Make/Model:         JENBACHER / J812085E           JENBACHER         Lube O'li nu se:         Peganus 76           JENBACHER         Lube O'li nu se:         Peganus 76           JENBACHER         O'li Brand:         BAE 40           Fresh Oll         Condeming         10 April 2012         27 April 2012         18 May 2012         13 June 2012         29 June 2012           Sample         Limit         10 April 2012         27 April 2012         18 May 2012         13 June 2012         29 June 2012           Sample         Limit         10 April 2012         27 April 2012         16 May 2012         13 June 2012         29 June 2012           Sample         Limit         10 April 2012         27 April 2012         16 May 2012         13 June 2012         29 June 2012           Sample         Limit         10 April 2012         13 June 2012         13 June 2012         29 June 2012           Sample</td> <td>Agbars Factory         Department:         Maintenance - Power Plant           Agbars Addatrial Estate         Mobile Phone No.:         00077591610           Lages         samit Address:         samit Address:           gas Engine Generator [1.8 MV]         Component:         samit Address:           Gas Engine Generator [1.8 MV]         Component:         Engine           Gen # [15N: 68561940]         Make/Model:         JENBACHER           JENBACHER         Libe O II in use:         Pegauar 705           -         OI Brand:         Mobil           Gas Plant, Agbas Factory         OI Weight:         BAL 80           Fresh OI         Condeming         10 April 2012         27 April 2012         13 June 2012         28 June 2012         19 July 2012           0         -         8,409         8,810         6,194         9,653         10,038         10,513           128,6         +1-255         1365         134.5         140.9         140         135.8         139.3           128,6         +1-255         1365         134.5         140.9         140         135.8         139.3           13.3         +1-255         136.5         134.5         140.9         140         135.8         139.3     </td>	Agbars Factory Agbars Industrial Eatate Lago         Department: Mobile Phone No.: Email Address:           Gas Engine Generator (1.8 NW) Gen TI [SN: 485619601]         Component: Make/Model: JPKBACHER Ubb OI In use: - Oil Brand: Gas Plant, Agbars Factory         Component: Make/Model: JPKBACHER Ubb OI In use: - Oil Brand: Gas Plant, Agbars Factory           Fresh OII Sample         Condeming Limit         10 April 2012 1045/02/UGGE/17         27 April 2012 178 Appiles - Trend 10 April 2012 178 Appiles - Trend 10 April 2012 1045/02/UGGE/18         11 Appiles - Trend 186 Appiles - Trend 196 Appiles - Trend 197 Appiles - Trend 196 Appiles - T	Agbars Factory Agbars Industrial Estate         Department: Mobile Phone No.: Base Industrial Estate         Maintenance - Po 08077891010           Lagee         Mobile Phone No.: Base Industrial Estate         Maintenance - Po 08077891010         08077891010           Equipment Operator/Driver:         Equipment Operator/Driver:         -           Gas Engine Generator [1.8 MW]         Component: Equipment Operator/Driver:         Engine JENBACHER Jult2           JENBACHER - Old Brand:         Component: Make/Model:         Engine JENBACHER Jult2           JENBACHER - Old Brand:         Make/Model:         JENBACHER Jult2           JENBACHER - Old Brand:         Make/Model:         Make/Model:           Fresh Ol Sample         Condeming Limit         10 April2012         27 April2012         11 May 2012           0         -         8,409         8,810         9,194         9,853           113.3         +(-25%)         136.9         134.5         140.9         14.0.9           126.6         +(-25%)         136.9         134.5         140.9         14.3           0.0         25         0         0         0         0         0           0         25         0         0         0         0         0         0         0           0.00%	Agbars Factory         Department:         Maintenance - Power Plant           Agbars Industrial Eases         Mobile Phone No.:         08077691910           Lages         Email Address:         barnit Khanggarican.com           Jass Engine Generator [1,8 MW]         Component:         Barnit Khanggarican.com           Gen FigNt: 085619401         Make/Model:         JENBACHER / J812085E           JENBACHER         Lube O'li nu se:         Peganus 76           JENBACHER         Lube O'li nu se:         Peganus 76           JENBACHER         O'li Brand:         BAE 40           Fresh Oll         Condeming         10 April 2012         27 April 2012         18 May 2012         13 June 2012         29 June 2012           Sample         Limit         10 April 2012         27 April 2012         18 May 2012         13 June 2012         29 June 2012           Sample         Limit         10 April 2012         27 April 2012         16 May 2012         13 June 2012         29 June 2012           Sample         Limit         10 April 2012         27 April 2012         16 May 2012         13 June 2012         29 June 2012           Sample         Limit         10 April 2012         13 June 2012         13 June 2012         29 June 2012           Sample	Agbars Factory         Department:         Maintenance - Power Plant           Agbars Addatrial Estate         Mobile Phone No.:         00077591610           Lages         samit Address:         samit Address:           gas Engine Generator [1.8 MV]         Component:         samit Address:           Gas Engine Generator [1.8 MV]         Component:         Engine           Gen # [15N: 68561940]         Make/Model:         JENBACHER           JENBACHER         Libe O II in use:         Pegauar 705           -         OI Brand:         Mobil           Gas Plant, Agbas Factory         OI Weight:         BAL 80           Fresh OI         Condeming         10 April 2012         27 April 2012         13 June 2012         28 June 2012         19 July 2012           0         -         8,409         8,810         6,194         9,653         10,038         10,513           128,6         +1-255         1365         134.5         140.9         140         135.8         139.3           128,6         +1-255         1365         134.5         140.9         140         135.8         139.3           13.3         +1-255         136.5         134.5         140.9         140         135.8         139.3

#### Diagnostics:

High Level of Copper - causes include Bearings, Wrist Pin Bushings, Cam Bushings, Value Train Bushings, Thrust Washers, Oil Coolers, Oil Pipings, Governors & Oil Pump, Oil Additives High Level of Tin - causes include Surface coating of Piatons, Ownlay of Bearings and Bushings

#### Service Engineer's Comment:

nvestigate alerts on Copper & Tin and carryout corrective maintenance actions. Lubrication service is adviced. Subsequent oil sampling/analysis to monitor trend.

Case Study 3: Increased Production Plant Load – Impact of Process Expansion

Effect of that decision:

- 1. Raised engine load level from earlier 50 -60 % to current 85 – 90% of installed capacity.
- 2. Occasional spikes of "sacrificial metals" Tin, Chrome, Molly in the oil analysis reports occurring particularly during peak and/or shock loads.
- 3. Shortened the life of in-service GEOs in those engines from prior 10,000 Hrs ODI to barely 4,000Hrs today.

One Study observed that gas engine when loaded beyond 80% of its design capacity; results in rapid oil degradation as seen in higher levels of Oxidation and Nitration with associated increases in oil viscosity, TAN level and TBN depletion all of which combine to shorten the oil life.

Integrated Services Limited	B			Gas Engi	ne Oil Ana	lysis Repo	ort 🛄	- A Street	
Client Information Company Name: Company Address:	GZ Industry Ltd. Agbara Factory Agbara industrial Estate Lagos		Client Contact: Department: Mobile Phone Ni Email Address: Equipment Oper		Mr. Samir Khan Maintenance - Power Plant 07045180713 samir.khan@gzican.com jose.sebastian@gzican.com				
quipment ID Ref. Gen # quipment Make: JENB quipment Year of Manufacture: -		Generator [1.8 :: 0856196/01] R Agbara Factory		Component: Make/Model: Lube Oil in use: Oil Brand: Oil Weight:		Engine JENBACHER / J812 Pegasus 806 Mobil 8AE 40	98E		
				Used OI	Samples - Trend	of Actual Laborat	orv Tests		Condit
	Fresh OII	Condeming	28 May 2014	09 July 2014	14 August 2014	26-8ep-14	24 October 2014		OCa
	Sample	Limit	2770/GZI/GGE#1/31	3029/GZI/GGE#1/32	3247/GZI/GGE#1/33	3527/GZI/GGE#1/34	3704/GZI/GGE#1/35	4028/GZI/GGE#1/36	Ocr
Engine Operating Hours									
Oll Sample [Hrs]	0	-	504	735	1,535	2,431	3,101	3,790	
Cumm. Engine [Hrs]	-	-	27,409	27,640	28,440		30,006	30,695	
Lube Oil Properties									
Appearance [Clear, Turbid or Dark] Viscosity @ 40C [cSt]	Clear 122.6	+/- 25%	Dark 136.5	Dark 145	Dark 139	Dark 144.6	Dark 145.9	Dark 145.4	
Viscosity @ 100C [cSt]	122.0	+/-25% ≥+3	130.5		14.2		145.9	145.4	ŏ
TAN [mgKOH/g]	0.3	+ 2.5	1.7	2.9	2.6		3.2	3.5	Ĭ
TBN [mgKOH/g]	6.2		5.1		4.3		3.5	2.8	ĕ
Insolubles [%]	0%	2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	Ō
Nitration [A/cm]	0		0	-	2.2		6.6	9.2	0
Oxidation [A/cm]	0	20	3.6	2.2	3.5		7.1	8.3	
Water in Oli [%] Giycol [%]	0.00%	0.20%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	8
Elemental Analysis									
Wear Mezals									_
Aluminum, Al [ppm]	0		2		3		0	03	8
Copper, Cu [ppm]	0		85		11		9	3	
Chromium, Cr [ppm] Lead, Pb [ppm]	0						6	0	
Iron, Fe (ppm)	0		5		0		5	4	
Tin, Sn [ppm]	0		6		0		0	5	ĕ
Contaminant Metals									
Silicon, Si [ppm]	0		0		0		0	0	
Sodium, Na [ppm] Potassium, K [ppm]	0		2		2		0	0	
Additive Metal Molybdenum [ppm]	0	10		0	0			0	

ow TBN - causes include Over-extended oil drain intervais, Excessive blowby, insufficient additive package, Overheating ligh Level of Tin - causes include Surface coating of Pistons. Overlay of Bearings and Bushings

Service Engineer's Comment:

mediate Lubrication Service is advised. Subsequent 500 Hrs oil sampling/analysis to monitor trend.

Case Study 4: Constant Production Load - Impact of Higher Engine Capacity

### Background

- 1. Pasta Plant factory with operational load averaging 1,500 kW
- 2. Powered by either of two(2) GEJ Gas Engines
  - J612G (1.8kW capacity) &
  - J620G (3.0 kW capacity).
- 3. One Gas Engine runs at a time. The gas engines are run in alternating order.
- 4. Oil change is determined by oil analysis.
- Oil Drain Interval for the J612G averages 1,000 to <2,000 Hrs</li>

Petro Sav	e			Gas Engine	Oil Analysi	is Report		10
Clienz Informazion Company Name: Company Address:	Flour Mills Nig PLC Old Dock Road Apapa, Lagos			Client Contact: Department: Mobile Phone No.: Email Address: Equipment Operator	iDriver:	Mr. Dimas Panaglot Power Plant 08068299141 pvdimas@vahoo.co		
Equipment Information Equipment D Ref. Equipment ID Ref. Equipment Make: Equipment Year of Manufacture: Equipment Location:	Gas Engine Generator Gan HI (1.5 MW) JENBACHER Golden Pasta Plant, Agbara		ra	Component: Make/Model: Lube OI in use: OII Brand: OII Weight:		Engine J812GS Pegasus 805 Mobil SAE 40		
				Liced Oil Sampler	s - Trend of Actual L	aboratory Tests		Condition
	Fresh Oll Sample	Condeming Limit	18 February 2018 6334/Agban/GG#1/28	23 March 2018	08 June 2016		01 November 2018 7411/Agbans/0G#1/30	Ocus
Engine Operating Hours Of Sample [Hrs] Cumm. Engine [Hrs]	0	:	1,663 12,944	544 13,500	1,022 13,978	448 14,451	719 14,722	
Lube Oil Properties Appearance [Ciex, Turbid, Dank] Viscosity (@ 100C [cit] TAN (mgKOHig) Soot (%) Nitration [Alcm] Oxidation [Alcm] Oxidation [Alcm] Oxidation [Alcm] Elemental Analysis	Clear 122.6 13 0.3 6.2 0% 0 0 0.00% 0.00%	+ 25% 2 +3 + 2.5 3.1 2% 20 0.20% 0.02%	Dank 153.3 15.2 3.1 2.4 0.0% 15.5 10.7 0.00%	Dark 145.1 2.3 3.8 0.0% 5.5 5.6 0.00% 0.00%	4.2 2.6 0.0% 9.1	1.8	Dark 150.1 2.3 3.4 0.0% 5.7 7.7 0.00%	000000000000000000000000000000000000000
Wear Metals Auminum, Al (pm) Copper, Cu (ppm) Chromium, Cr (ppm) Lead, Pb (ppm) Iron, Fe (ppm) Th, Sn (ppm)	0	15 15 20 20 5	0 0 8	0 0 0	0	0	0 3 0 0	00000
Contaminant Metals Silicon, Si (ppm) Sodium, Na (ppm) Potassium, K (ppm)	0	20 20 5	0	0	0	0	0 3 0	
Additive Metal Molybdenum (ppm)		10						

Diagnostics:

Service Engineer's Comment:

All engine wear rates normal. In-service GEO is approaching and of its useful service life; oil is ok for continued use. Next 250 Hrs of sampling/analysis advised to determine if Lubrication Service is due. Case Study 4: Constant Production Load – Impact of Higher Engine Capacity

Oil Drain Interval for the J620G averages >7,000 Hrs •

Petro Sav	e			Gas Engine	Oil Analysis	Report		
Client Information Company Name: Company Address:	Flour Mills I Old Dock R Apapa, Lag	oad		Client Contact: Department: Mobile Phone No.: Email Address: Equipment Operator/		Mr. Dimas Panagioti Power Plant 08058299141 <u>pydimas@yahoo.cc</u>		
Equipment Information Equipment Type: Equipment ID Ref. Equipment Make: Equipment Year of Manufacture: Equipment Location:	Gas Engine Gen #2 (3.2 JENBACHE - Golden Pas	MW)		Component: Make/Model: Lube Oil in use: Oil Brand: Oil Weight:		Engine J620GS Pegasus 805 Mobil SAE 40		
	Fresh Oil	Condeming	18 December 2015	Used Oil Samples	s - Trend of Actual La 18 February 2016		01 November 2016	Condition
	Sample	Limit	6043/Agbara/GG#2/25	6175/Agbara/GG#2/26		6490/Agbara/GG#2/28		
Engine Operating Hours Oil Sample [Hrs] Cumm. Engine [Hrs]	0	-	6,309 12,666	6,857 13,266	7,284 13,641	7,632 13,989	380 14,752	
Lube Oil Properties Appearance [Clear, Turbid, Dark] Viscosity @ 100C [cSt] TAN (mgKOHig] TBN (mgKOHig] Soot [%] Nitration [A/cm] Oxidation [A/cm] Water in Oil [%] Giycol [%]	Clear 122.6 13 0.3 6.2 0% 0 0 0 0.00% 0.00%	+ 25% ≥ +3 + 2.5 3.1 2% 20 0.20% 0.02%	Dark 132.9 1.9 5.4 0.0% 0.0 3.0 0.00% 0.00%	Dark 133.2 1.3 1.2 5.3 0.0% 0.0 0.0% 0.00% 0.00%	Dark 133.3 1.3 1.3 5.2 0.0% 0.0 3.1 0.00% 0.00%	Dark 135.8 14.0 1.7 5.2 0.0% 0.0 3.2 0.00% 0.00%	Dark 131.2 13.6 0.8 5.9 0.0% 0.0 2.1 0.00% 0.00%	
Elemental Analysis Wear Metals Aluminum, Al [ppm] Copper, Cu [ppm] Chromium, Cr [ppm] Lead, Pb [ppm] Iron, Fe [ppm] Tin, Sn [ppm]	0 0 0 0	15 15 5 20 20 5	0 2 0 0 0 0 0	0 0 0 0 0 0	0 0 0 8 3	0 0 0 0 0	2 0 3	
Contaminant Metals Silicon, Si (ppm) Sodium, Na (ppm) Potassium, K (ppm)	0	20 20 5	0 0 0	0 0 0	0 0 0	0 0		l ŏ
Additive Metal Molybdenum (ppm)		10	o	0	0	0	0	

Diagnostics No alert seen.

Service Engineer's Comment: All engine wear rates normal. Sample free of external contamination. Analysis indicates proper performance of lubricant and engine of gas generator set. Continue with current oil in the gas engine and sample by the next 500 oil service hours.

### Case Study 5: Low Production Load

- Plastics making factory with process load averaging 950 kW 1.
- 2. Powered by a single GEJ Gas Engine J612G (1.8kW capacity); running at < 60% load capacity.
- 3. Oil change is determined by oil analysis.
- Oil Drain Interval for the J612G averages > 4,500 Hrs ٠

Integrated Services Limited	e			Gas Engi	ne Oil An	alysis Rep	ort		ł
Cilent Information Company Nama: Company Address:	Caesa Plassic Products Ng. Ltd Pice 0, Block E Matori Industrial Essate Badajo Kalasaneo Str. Mushim, Lagos		lg Led	Client Contacts: Department: Mobile Phone Ne Email Address: Equipment Oper	x.:	Mr. Tony Sajnani Plant Utilities - P 08130204255/ 07/ <management@< th=""><th>ower Plant 088327054</th><th>ъ</th><th></th></management@<>	ower Plant 088327054	ъ	
Equipment Information Equipment Type: Equipment ID Ref. Equipment Make: Equipment Date: Equipment Location:	Qan #1 [5/N: 1092025] JENBACHER 2013			Make/Model: Lube Oil in use: Oil Brand:		Engine JENBA CHER / J61 Sentron LD 5000 PetroCanada SAE 40			
				Used OIL	Samples - Trend	of Actual Laborate	ory Tests		Condit O o
	Fresh Oil Sample	Condeming Limit	7-Mar-16 0099/Genta/GC# V2/	29-Mar-16 6409/Garda/GG#1/28	13-Apr-16		1-Sep-16	13-Oct-16 7392/Geete/GG#1/92	ě
Engine Operating Hours									•••
Oli Sample [Hrs] Cumm. Engine [Hrs]	0	-	3,286 11,330	3,582 11,626	3,838 11,882		4,541 12,585	507 13,237	
Lube OII Properties									
Appearance [Clear, Turbid or Dark]	Clear 111.8	+25%	Dark 124.1	Dark 123.4	Dark 124.5	Dark 115.5	Dark 113.5	Dark 117.4	_
Viscosity @ 40C [cSt] Viscosity @ 100C [cSt]	111.8	+25% ≥+3	124.1	123.4	124.5		113.5	117.4	8
TAN [mgKOH/g]	1.1	+ 2.5	2.4	2.5	29		1.4	1.2	ŏ
TBN [mgKOH/g]	4.9	2.5	3.6	3.4	3.1	4.9	4.8	4.9	ŏ
Insolubles [%]	0%	2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	8
Nitration [A/om]	0	20	7.5	8.1	8.0		5.5	5.5	<u> </u>
Oxidation [Vicm] Water in Oil [%]	0.00%	20	3.6	4.0	4.3	0.0	0.0	0.0	8
Glycol [%]	0.00%	0.02%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	8
Bemental Analysis									
Wear Motals Aluminum, Al (ppm)	0	15		0		0			~
Copper, Cu [ppm]	ŏ	15	0	0	0		0	2	K
Chromium, Cr [ppm]	0	5	3	0	4	3	5	0	ŏ
Lead, Pb [ppm]	0	20	a	0	3	0	0	0	Ó
Iron, Fe (ppm) Tin, Sn (ppm)	0	20 5	2	0	5	0	0	0	
Contaminant Metals									
Silicon, Si (ppm)	0	20	0	0	0		0	0	0
Sodium, Na (ppm) Potassium, K (ppm)	0	20 5	4	2	4	0	3	0	8
Additive Metal									
Molybdenum [ppm]	0	10	0	0	o	0	o	0	0

Service Engineer's Comment: All engine waar rates within Limits; analysis indicates proper performance of lubricant and gas engine. In-service GEO is ok for continued use. Next 500 Hrs of sampling/analysis to monitor trend.

Case Study 5: Low Production Load

- 1. Government-owned Water Plant with Pumps load averaging 2,040 kW per Gas Engine.
- 2. 4 x GEJ Gas Engines J620G (3.2kW capacity each) installed; 3 Gas Engines in operation & 1 on stand-by.
- 3. Oil change is determined by oil analysis.
- ODI for each J620G Gas Engine averaged > 10,000 Hrs

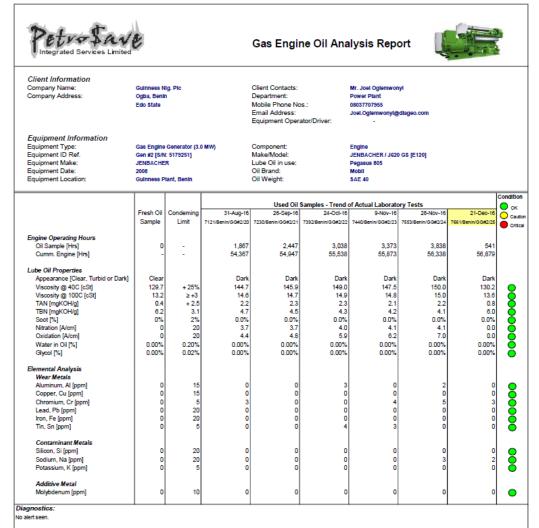
e		Gas Engine Oil Analysis Report								
Independen Akute Ogun State	t Power Plant		Email Address:		Clark Energy 08066802622 / 08 george.laird@cla	022241646 arke-energy.com				
Gen #4 (3.0 JENBACHER 2008	MW) R	Component: Mate/Model: Lube Oli In use: Oli Brand: Oli Weight:			Engline JERBACHER / J620GSE Pegasas 805 Mobil SAE 40					
								Condition		
Fresh OI Sample	Condeming Limit	7-Dec-12 3094kz#GG#423	11-Jan-13 390/Akte/GG#424		8-Mar-13 605/Akute/GG#4/26	23-May-13 914/Akute/GG6427	15-Aug-13 1636/Akuta/GG#428	Caus		
0	:	9,231 17,304	9,919 17,992	10,468 18,541	10,784 18,857	11,297 19,370	388 20,291	-		
Clear 122.6 13.0 0.3 6.2 0% 0 0 0 0.00% 0.00%	+/-25% +/-20% 4 3.1 1% 25 25 0.20% 0.02%	Dark 139.5 14.2 5.0 0.0% 0.0 3.7 0.00% 0.00%	Dark 141.9 14.4 1.2 5.1 0.0% 0.0 3.4 0.00%	1.2 5.1 0.0%	Dark 139.6 14.2 1.1 5.0 0.0% 0.0 4.5 0.10% 0.00%	Dark 142.4 14.4 1.2 5.1 0.0% 0.0 4.1 0.00% 0.00%	Dank 132.1 13.7 0.5 6.0 0.0% 0.0 0.0 0.0 0.0 0.0 0.00%	00000000		
000000000000000000000000000000000000000	15 15 30 20	3 7 2 0 7 7	3 13 0 9 3	21 0 0 3	0 24 0 5 0	0 23 0 5 4	3 7 0 0 0 0	000000		
0	25 8 10	0 4 0	0 0	0	0 0	0	0			
	Atuá Ogus State Ogus State 2005 Power Plant Sample 0 - - - - - - - - - - - - - - - - - -	Ogen State           Gas Englis Generator Gen # (1.0 MW) JENBLACHER 2008           Presh OI Sample         Condeming Limit           0         - - -           Clear 122.6         +i-25%           13.0         +i-25%           0.3         4           6.2         3.1           0%         1.25           0.00%         0.20%           0.00%         0.20%           0         15           0         15           0         15           0         15           0         15           0         300           0         10           0         10           0         25           0         30           0         30           0         30           0         30           0         30	Auto Ogun State Ogun State Ogun State Cas Engine Generator Gas All (2.0 WV) JEXNAC-IER 2005 Presh Ol Condeming Sample Umit 2006 Presh Ol Condeming Sample Umit 2006 9,221 17,304 Olear 122.6 +/-25% 139.5 13.0 +/-25% 139.5 13.0 4 1.5.0 Olear 122.6 1/5 100 0 25 0.0 0 25 0.0 0 0 25 0.0 0 0 15 3 0 15 7 0 0 0 0 15 7 0 30 0 0 0 0 25 0.0 0 0 0 15 7 0 30 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	Akula         Akula         Client Contacts: Department: Mobile Phone Ni Email Address: Equipment Oper           Gas Engine Generator Gen 6 (L0 MW)         Component: Make/Model: JUNNACHER         Component: Make/Model: JUNNACHER           JENNACHER JONS         Used Oll in Used Oll in Strand: 7-Ose-12         Used Oll in JUNNACHER           Presh Oll Sample         Condeming Umit         7-Ose-12         11-Jak-13           0         -         5,231         9,919           -         17,334         17,952           0         -         5,231         9,919           -         17,334         17,952           0         -         5,231         9,919           -         17,334         17,952           0         -         5,231         9,919           -         17,334         17,952           0         -         5,0         0,00           0         25         0,0         0,00           0         25         0,0         0,00           0         0,00%         0,00%         0,00%           0         0,00%         0,00%         0,00%           0         0,00%         0,00%         0,00%	Independent Power Plant         Client Contacts: Department: Open State           Open State         Mobile Phone Nos.: Email Address: Email Address:           Gas Engine Generator Gen # (2.0 MN)         Mate Model: JWNACHER           JWNACHER         Lube Oil nuse: Oil Brand: Power Plant, Abute           Di Condeming Sample         7-0e-12 Limit           7-0e-12 Sample         11-Je-13 JWNACHER           Limit         7-0e-12 JWNACHER           Di Condeming Sample         7-0e-12 Limit           7-0e-12 SoskeawGoevor         500 Abutes Goevor           0         - 17,304           122.6         +1-25% 139.5           122.6         +1-25% 139.5           0         - 17,304           0         - 17,304           0         - 17,304           0         - 122.6           0         - 15           0         0 <td>Independent Power Plant         Client Contacts:         Mr. George Laind           Awin         Department:         Open State         Open State           Open State         Mobile Phone Nos.:         OpenState         OpenState           Gas Engine Generator         Component:         Engine         Department:         OpenState           Gas Engine Generator         Component:         Engine         Jentick.nacklwegi           Equipment Operator/Driver:         Jentick.nacklwegi         Jentick.nacklwegi           ZMMACHER         Lube Oll In use:         Pagesos 868           ZMMACHER         Lube Oll In use:         Pagesos 868           Presh Oll         Condeming         7-0xx-12         11-1xx-13         16-14x-13         8-Max-13           Sample         Limit         308/MaxeGenerging         509/MaxeGenerging         509/MaxeGener</td> <td>Independent Power Plant         Client Contacts:         Mr. George Laird / Mr. Padrick Name           Arkin         Department:         Client Exercy         08065802522 / 08022241646           Department:         Department:         Client Exercy         08065802522 / 08022241646           Department:         Department:         Department:         Department:           Cas Engles Generator         Component:         Engles         Jense State           Cas Engles Generator         Component:         Engles         Jense State           Cas Engles Generator         Component:         Make-Model:         Jense State           JENNACHER         Lube Oil In use:         Pages State         Pages State           JON Presh Oil         Condeming         7-0m-12         15-14-13         State-13         22-May-13           Sample         Limit         JoskazasGener 23         JenseasGener 23         State-13         23-May-13           0         -         5.231         5.915         10.466         10.784         11.257           0         -         5.231         5.915         10.466         10.784         11.257           13.0         +-25%         139.5         14.13         14.24         14.2           13.0</td> <td>Independent Power Plant         Client Contacts:         Mr. George Laird / Mr. Patrick Nashwe           Ataba         Department:         Client Energy           Opun State         Department:         Client Energy           Data         Department:         Department:           Email Address:         peorge.laird / Mr. Patrick Nashwe           Cas Engine Generator         Component:         Department:           Cas Engine Generator         Component:         Department:           Cas Engine Generator         Component:         Department:           Fresh OI         Condeming         Component:         Mean           Prever Plant, Ataba         OII Wright:         RAE 40           Prever Plant, Ataba         OII Wright:         RAE 40           Prever Plant, Ataba         Used OII Samples - Trend of Actasi Laboratory Tests         15Aap-13           Prever Plant, Ataba         Used OII Samples - Trend of Actasi Laboratory Tests         15Aap-13           Clear         5.231         5.915         10.468         10.784         11.297           Ogen - Sazat         9.915         10.468         10.784         11.297         388           Olier         -         17.364         17.992         15Asta         13.65         14.24</td>	Independent Power Plant         Client Contacts:         Mr. George Laind           Awin         Department:         Open State         Open State           Open State         Mobile Phone Nos.:         OpenState         OpenState           Gas Engine Generator         Component:         Engine         Department:         OpenState           Gas Engine Generator         Component:         Engine         Jentick.nacklwegi           Equipment Operator/Driver:         Jentick.nacklwegi         Jentick.nacklwegi           ZMMACHER         Lube Oll In use:         Pagesos 868           ZMMACHER         Lube Oll In use:         Pagesos 868           Presh Oll         Condeming         7-0xx-12         11-1xx-13         16-14x-13         8-Max-13           Sample         Limit         308/MaxeGenerging         509/MaxeGenerging         509/MaxeGener	Independent Power Plant         Client Contacts:         Mr. George Laird / Mr. Padrick Name           Arkin         Department:         Client Exercy         08065802522 / 08022241646           Department:         Department:         Client Exercy         08065802522 / 08022241646           Department:         Department:         Department:         Department:           Cas Engles Generator         Component:         Engles         Jense State           Cas Engles Generator         Component:         Engles         Jense State           Cas Engles Generator         Component:         Make-Model:         Jense State           JENNACHER         Lube Oil In use:         Pages State         Pages State           JON Presh Oil         Condeming         7-0m-12         15-14-13         State-13         22-May-13           Sample         Limit         JoskazasGener 23         JenseasGener 23         State-13         23-May-13           0         -         5.231         5.915         10.466         10.784         11.257           0         -         5.231         5.915         10.466         10.784         11.257           13.0         +-25%         139.5         14.13         14.24         14.2           13.0	Independent Power Plant         Client Contacts:         Mr. George Laird / Mr. Patrick Nashwe           Ataba         Department:         Client Energy           Opun State         Department:         Client Energy           Data         Department:         Department:           Email Address:         peorge.laird / Mr. Patrick Nashwe           Cas Engine Generator         Component:         Department:           Cas Engine Generator         Component:         Department:           Cas Engine Generator         Component:         Department:           Fresh OI         Condeming         Component:         Mean           Prever Plant, Ataba         OII Wright:         RAE 40           Prever Plant, Ataba         OII Wright:         RAE 40           Prever Plant, Ataba         Used OII Samples - Trend of Actasi Laboratory Tests         15Aap-13           Prever Plant, Ataba         Used OII Samples - Trend of Actasi Laboratory Tests         15Aap-13           Clear         5.231         5.915         10.468         10.784         11.297           Ogen - Sazat         9.915         10.468         10.784         11.297         388           Olier         -         17.364         17.992         15Asta         13.65         14.24		

All other engine wear rates within normal limits. Lube is ok for continued use. Next oil sampling due at 20,761 Engine Hours to monitor trend.

Case Study 6: Impact of Oil Sump Size

### Background

- 1. Bottling Plant with operational load averaging 2,400 kW per running Gas Engine
- 2. Powered by either of three(3) GEJ Gas Engines
  - J620G x 2 (3.0kW; Type 6, Class E with extended oil sump]
  - J620G x 1 (3.3 kW; Type 6, Class F; oil fill capacity 176 Gals).
- 3. 2 or 3 gas engines run per at a time; depending on production demands.
- 4. Oil change is determined by oil analysis.
- ODI for Older Model J620 (E Class) averaged 3,500 Hrs



Service Engineer's Comment:

All engine wear rates within normal limits. Oil is ok for continued use. Subsequent oil sampling/analysis to monitor trend.

Case Study 6: Impact of Oil Sump Size

### • ODI for newer J620 (F Class) averaged 1,300 Hrs

The J620 - Type 6, Class F has all the design attributes of modern Engines

- compact size (implying smaller oil sump)
- fuel efficient (burns hotter) and
- primed to deliver more power (support more load)

Above requirements take their toil on the in-service GEO causing

- rapid oil degradation &
- shortened oil service life

Company Address: C Equipment Information Equipment Type: C Equipment D Ref. C Equipment Date: 2 Equipment Location: C	Guinness N Dgba, Benir Edo State Sas Engine Sas Engine Sas I S/N JENBACHE Suinness P Fresh Oil Sample	Generator (3.: 1067361] R lant, BenIn Condeming	3 MW) 29-Sep-16	Client Contacts: Department: Mobile Phone No: Email Address: Equipment Oper Component: Make/Model: Lube Oil in use: Oil Brand: Oil Weight: Used Oil		Mr. Joel Oglemwor Power Plant 0003770785 Joel Oglemwonyt@ Engline JENBACHER / JG2 Pegasus 805 Mobil SAE 40	diageo.com	
Equipment Type: 0 Equipment ID Ref. 0 Equipment Nake: J Equipment Date: 2 Equipment Location: 0 Engine Operating Hours Oil Sample [Hrs] Cumm. Engine [Hrs] Lube Oil Properties Appearance [Clear, Turbid or Dark]	Sen #3 [S/N JENBACHE 2014 Suinness P Fresh Oil	I: 1067361] R lant, Benin Condeming		Make/Model: Lube Oil in use: Oil Brand: Oil Weight:		JENBACHER / J620 Pegasus 805 Mobil	0 GS (F 0610)	
Engine Operating Hours Ol Sample (Hrs) Cumm. Engine (Hrs) Lube Oil Properties Appearance (Clear, Turbid or Dark)			20.0ap.15	Used Oil				
Engine Operating Hours Ol Sample (Hrs) Cumm. Engine (Hrs) Lube Oil Properties Appearance (Clear, Turbid or Dark)			20 Cop 15		Samples - Trend	of Actual Laborate	ory Tests	
Oil Sample [Hrs] Cumm. Engine [Hrs] Lube Oil Properties Appearance [Clear, Turbid or Dark]	Sample			4-Oct-16	17-Oct-16	31-Oct-16	15-Nov-16	28-Nov-16
Oil Sample [Hrs] Cumm. Engine [Hrs] Lube Oil Properties Appearance [Clear, Turbid or Dark]		Limit	7256/Benin/GG#3/33	7287/Benin/GG#3/34	7368/Benin/GG#3/35	7416/Benin/GG#3/36	7488/Benin/GG#3/37	7554/Benin/GG#3/38
Appearance [Clear, Turbid or Dark]	0	-	1,315 13,129	3 13,250	307 13,557	600 13,850	905 14,155	1,220 14,470
Appearance [Clear, Turbid or Dark]								
	Clear		Dark	Dark	Dark	Dark	Dark	Dark
Viscosity (g) 400 [cot]	129.7	+ 25%	156.8	126.3	134.8	142.5	147.3	151.1
Viscosity @ 100C [cSt]	13.2	≥+3	15.4	13.3	13.9	14.4	14.8	15.0
TAN [mgKOH/g]	0.4	+ 2.5	3.1	0.4	1.2	1.5	2.1	2.4
TBN [mgKOH/g]	6.2 0%	3.1 2%	3.0 0.0%	6.1 0.0%	5.4 0.0%	4.2	3.3 0.0%	2.9
Soot [%] Nitration [A/cm]	0%	2%	0.0%	0.0%	0.0%	4.7	6.7	9.9
Oxidation [A/cm]	ŏ	20	7.1	0.0	2.8	4.7	7.1	8.8
Water in Oil [%] Glycol [%]	0.00% 0.00%	0.20% 0.02%	0.00%	0.00% 0.00%	0.00%	0.00%	0.00%	0.00%
Elemental Analysis								
Wear Metals								
Aluminum, Al (ppm)	0	15	0	0	2	0	0	
Copper, Cu [ppm] Chromium, Cr [ppm]	0	15 5	0	0	0		3	
Lead, Pb (ppm)	0	20	ő	0	0			0
Iron, Fe [ppm]	ŏ	20	ŏ	ő	0		Ö	
Tin, Sn [ppm]	0	5	0	0	0	0	3	0
Contaminant Metals								
Silicon, Si [ppm]	0	20	0	0	0			
Sodium, Na [ppm]	0	20	0	0	0			
Potassium, K [ppm]	0	5	0	0	0	0	0	0
Additive Metal								
Molybdenum [ppm]	0	10	0	0	0	0	0	0

Low TBN - causes include Over-extended oil drain intervais, Depieted additives, Excessive blowby, Wrong/insufficient additive package, Overheating

Service Engineer's Comment:

n-service GEO has served out its useful life; Lubrication Service advised. All engine wear rates within Limits. Subsequent oil sampling/analysis to monitor trend.

**Case Study 7:** Impact of Contaminants - *e.g. Cooling Water Ingress* 

That contaminants can compromise the lubrication function of in-service oil and thereby shorten oil life is well known.

The Gas Engine has established 2,000 Hrs ODI trend. However, severe Cooling Water ingress detected after 468 Oil Hrs evidenced by high "coolant markers" – Sodium & Potassium; forced Lubrication Service after just 1,712 Oil Hrs following Mtce repairs.

Integrated Services Limited	e			Gas Engi	ne Oil Ana	alysis Rep	ort 👢		
Client Information Company Name: Company Address:	Independent Power Plant Alsusa, Ikeja Lagoe State Gas Engine Generator (3.0 MW) Gen # [SN: 1072715] JENBACHER 2012 Power Plant, Alausa			Client Contacts: Department: Mobile Phone No Email Address: Equipment Oper		Clark Energy 08076961902 / 08 muhammad.asin	Asim / Mr. Patrick 022241545 n@clarke-energy.com	com	
Equipment Information Equipment Type: Equipment ID Ref. Equipment Make: Equipment Date: Equipment Location:				Make/Model: Lube Oil in use: Oil Brand:		Engine JENBACHER / JG620 F Pegaaus 805 Mobil SAE 40			
				Used Oil S	amples - Trend	of Actual Laborate	orv Tests		Condit
	Fresh Oil 17-Nov-14	Condeming Limit	12-May-14 2581/Alausa/GG#1/4	5-Jun-14 2804/Alausa/GG#1/5	14-Jul-14 3054/Alausa/GG#1/6	13-Aug-14	13-Oct-14 3595/Alausa/GG#1/8	17-Nov-14 3855/Alausa/GG#1/9	Õ a
Engine Operating Hours Oil Sample [Hrs] Cumm. Engine [Hrs]	0		468 2,006	695 2,233	959 2,497	1,201 2,739	1,712 3,192	203 3,531	• cr
Lube Oil Properties Appearance [Clear, Turbid or Dark] Viscosity @ 40C [c3t] Viscosity @ 100C [c3t] TAN [mgKOH/g] TBN [mgKOH/g] Sott [%] Nitration [A/cm] Oxidation [A/cm] Water in 01 [%] Glycol [%]	Clear 129.7 13.2 0.4 6.2 0% 0 0 0 0 0.00% 0.00%	+ 25% ≥ +3 + 2.5 3.1 2% 20 20 0.20% 0.02%	Dark 135.3 13.9 1.7 4.8 0.0% 0.0 5.3 0.00% 0.00%	1.2 4.3 0.0%	Dark 141.9 14.4 2.6 3.8 0.0% 4.1 9.0 0.00% 0.00%	Dark 149.3 14.9 2.7 3.4 0.0% 5.8 9.2 0.00% 0.00%	Dark 151.3 15.0 3.2 2.7 0.0% 8.6 10.3 0.00% 0.00%	Dark 131.3 13.6 0.8 5.7 0.0% 0.0 3.5 0.00% 0.00%	
Elemental Analysis Wear Metals Aluminum, Al [ppm] Copper, Cu [ppm] Chromium, Cr [ppm] Lead, Pb [ppm] Iron, Fe [ppm] Tin, Sn [ppm]	0 0 0 0 0	15 15 20 20 5	0 0 0 8 0	0 3 2 0 10	0 0 0 7 6	2 0 21	0 3 3 3 14 0	0 0 0 3 0	
Contaminant Metals Silicon, Si [ppm] Sodium, Na [ppm] Potassium, K [ppm]	0 0	20 20 5	0 34 0	0 93 0	0 184 41	0 223 25	0 308 6	0 39 0	
Additive Metal Molybdenum [ppm]	0	10	0	0	0	0	0	0	

Service Engineer's Comment.

High Sodium level, though reducing but still persists; no maintenance action advised for now. Oil is ok for continued use. Subsequent oil sampling/analysis to trend.

Case Study 7: Impact of Contaminants - e.g. Cooling Water Ingress

ODI for same J620G reverted to 3,000 Hrs post Mtce Repairs ٠

Petro Sav	e			Gas Engi	ne Oil Ana	alysis Rep	ort	and the second				
Client Information Company Name: Company Address:	Independent Power Plant Alausa, Ikeja Lagos State Gas Engine Generator (3.0 MW) Gen #2 [SiN: 1072710] JENBACHER 2012 Power Plant, Alausa			any Name: Independent Power Plant Client Contacts: Mr. Muh: Nany Address: Alausa, Ikeja Department: Clark En Lagos State Mobile Phone Nos.: 0007695: Email Address: muhamm				Clark Energy 08076961902 / 08 muhammad.asin	Nuhammad Asim / Mr. Patrick Nzekwe K Energy 6961902 / 08022241545 ammad.asim@clarke-energy.com ck.nzekwe@clark-energy.com			
Equipment Information Equipment Type: Equipment ID Ref. Equipment Make: Equipment Date: Equipment Location:				Make/Model: Lube Oil in use: Oil Brand:		Engine JENBACHER / JG620 F Pegasus 805 Mobil SAE 40						
	East Ol	0				of Actual Laborate			Con			
	Fresh Oil Sample	Condeming Limit	12-May-14 2682/Alausa/GG#2/4	5-Jun-14 2805/Alausa/GG#2/5	14-Jul-14 3056/Alausa/GG#2/6		13-Oct-14 3597/Alausa/GG#2/8	17-Nov-14 3855/Alausa/GG#2/9	8			
Engine Operating Hours Oil Sample [Hrs] Cumm. Engine [Hrs]	0	-	457 1,937	710 2,190	1,017 2,497	1,261 2,741	1,725 3,205	194 3,531				
Lube Oil Properties Appearance [Clear, Turbid or Dark] Viscosity @ 40C [cSt] TAN [mgKOH/g] TBN [mgKOH/g] Sott [%] Nitration [A/cm] Oxidation [A/cm] Water in Oil [%] Giycol [%]	Clear 129.7 13.2 0.4 6.2 0% 0 0 0 0.00% 0.00%	+ 25% ≥ +3 + 2.5 3.1 2% 20 0.20% 0.20% 0.02%	Dark 135.8 14.0 1.5 5.0 0.0% 0.0 4.7 0.00%	Dark 139.1 14.2 1.3 4.3 0.0% 2.0 6.5 0.00% 0.00%	Dark 144.2 14.6 3.1 3.8 0.0% 3.3 7.6 0.00% 0.00%	15.0 3.2 3.4 0.0%	Dark 152.8 15.1 3.4 2.4 0.0% 8.0 9.8 0.00% 0.00%	Dark 132.2 13.7 0.9 5.8 0.0% 0.0 3.4 0.00%				
Elemental Analysis Wear Metals Aluminum, Al [ppm] Copper, Cu [ppm] Chromium, Cr [ppm] Lead, Pb [ppm] Iron, Fe [ppm] Tin, Sn [ppm]	0 0 0 0 0	15 15 20 20 5	0 0 0 0 0 0	0	0 0 0 0 0 0 0	3 0 2 0	2 0 0 0 5	0 0 0 0 0				
Contaminant Metals Silicon, Si [ppm] Sodium, Na [ppm] Potassium, K [ppm]	0	20 20 5	0 6 8	4	0 11 17	0 20 40	0 5 0	0 0				
Additive Metal Molybdenum [ppm]	0	10	0	0	0	0	0	0				

Service Engineer's Comment: All engine wear rates within normal limits. Oil is ok for continued use. Subsequent oil sampling/analysis to monitor trend.

Case Study 8: Impact of Fake GEO Brands

### Background

- 1. Some Gas Engine operators, erroneously believe in buying from unauthorized Oil Vendors at cheaper prices
- 2. Often oil drum offered at cheaper price is mere perfect copy of a successful Brand's drum design *"external"* but fails remarkably to match its content quality *"internal"*.
- 3. Such purchases most time put the gas engine to risk, because the quality content of the oil is compromised
- 4. If oil analysis is in place, such poor oil quality may be quickly detected from measuring rapid degradation of key lubricant parameters
- Oil Analysis detected the in-service GEO was both over-Based and over-Acidified, shortening its service life. Fresh oil analysis confirmed, the GEO was fake.

Integrated Services Limited	e			Gas Engine	Oil Analysis	s Report		
Client Information Company Name: Company Address:	OK Plast Lt 7A, illasami Off Isolo Ex Isolo, Lago	aja Scheme, Iti pressway	re Junction	Client Contact: Department: Mobile Phone No.: Email Address: Equipment Operator/		Naresh Lenka Maintenance (Power Plant) 08027936088 nareshinka23@gmail.com 		
Equipment Information Equipment Type: Equipment ID Ref. Equipment Make: Equipment Year of Manufacture: Equipment Location:				Component: Make/Type: Lube Oil in use: Oil Brand: Oil Weight:				
				Used Oil Samples	- Trend of Actual La	boratory Tests		
	Fresh Oil 29-Aug-14	Condeming Limit	12 May 2015 4952/0kP/GG#1/09	09 June 2015 5086/OkP/GG#1/10	12 June 2015 5124/0kP/GG#1/11	13 July 2015 5245/0kP/GG#1/12	23 July 2015	
	29-Aug-14	Limit	4952/OKP/GG# v09	5086/OKP/GC#1/10	5124/OKP/GG#1/11	5245/ORP/GG#1/12	5296/OkP/GG#1/13	
Engine Operating Hours Oil Sample [Hrs] Cumm. Engine [Hrs]	0	-	609 4,909	985 5,285	1,060 5,360	459 5,857	578 5,976	
Lube Oil Properties Color [Clear, Turbid or Dark] Viscosity @ 40C [cSt] TAN [mgKOHg] TAN [mgKOHg] Soot [%] Nitration [A/cm] Oxidation [A/cm] Water in Oil [%] Glycol [%]	Clear 122.8 13.0 0.4 6.2 0% 0 0 0 0.00% 0.00%	+ 25% ≥ +3 + 2.5 3.1 2% 20 20 0.20% 0.02%	Dark 125.5 13.2 1.5 0.0% 0 0 4.6 0.00%		Dark 132.1 13.7 2.6 4.5 0.0% 2.4 5.5 0.00% 0.00%	Dark 130.4 13.6 1.8 5.3 0.0% 4.2 3 0.0% 0.0%	Dark 130.3 13.6 2.1 5.1 0.0% 4.5 3.8 0.00% 0.00%	
Elemental Analysis Wear Metals Aluminum, Al [ppm] Copper, Cu [ppm] Chromium, Cr [ppm] Lead, Pb [ppm] Tinn, Fe [ppm] Tin, Sn [ppm]	0 0 0 0 0	15 15 20 20 5	1 6 0 5 5 0	0	4 5 0 0 0 0 0	0 0 0 0 0	2 0 0 0 0 0 0	
Contaminant Metals Silicon, Si [ppm] Sodium, Na [ppm] Potassium, K [ppm]	0 0	20 20 5	0 83 0	0 55 0	0 74 0	0 15 0	0 26 0	
Sodium, Na [ppm]	-	20	83	55	74	15		

High Level of Sodium - causes include Oil additive constituent, Coolant additive, Road Sall/Dirt, Grease

#### Service Engineer's Comment:

Cooling Water ingress is indicated by presence of Sodium at Critical Level; maintenance action advised. All engine wear metals within Limits. In service GEO is ok for continued use. Every 150 Hrs oil sampling/analysis advised to monitor trend.

### Case Study 8: Impact of Fake GEO Brands

Petro Sa Integrated Services Lim	Fresh Oll Analysis Report					
Client Information Company Name: Company Address: Date:	OK Plast Ltd. 7A, Illasamaja Scher Off Isolo Expresswa Isolo, Lagos 14-Jun-16	Client Contact: Department: Mobile Phone No.: Email Address:	Naresh Lenka Maintenance (Power Plant) 08027936088 nareshlenka23@gmail.com			
Test	Units	Fresh Mobil Pegasus 8 Make-up Oil Tank - Gas Eng Sampled: June 12, 201	ine #1	Mobil Pegasus 805 Website PDS Info		
Color	Visual	Clear, E	Brown	NA		
SAE Grade	-		40	40		
Viscosity @ 40C	cSt		120.7	130.0		
Viscosity @ 100C	cSt		12.9	13.5		
Viscosity Index, VI	-		100	99		
Specific Gravity [SG] @ 15C	kg/m <sup>3</sup>		892	890		
Total Base Number [TBN]	mgKOH/g		6.4	6.2		
Total Acid Number [TAN]	mgKOH/g	l	1.6	0.3		
Flash Point [ ASTM D93 Closed C	°C		215	262 \$		
Water	% vol		Nil	Ni		
Elemental Analysis - Select Iron, Fe Copper, Cu Sodium, Na Potassium, K	ppm		2 3 42 0			

Note the TAN level of fresh oil is not available as a Product Data Sheet (PDS) information. However, TAN = 0.3 is typical value, which has been measured at Petrosave Lab for several GEO samples, of authentic sources and correctly meeting other Mobil Pegasus 805 published oil parameters.

# ASTM D92 Open Cup Method

#### Comment(s)

Fresh oil sample taken from the Make-up Oil Tank of GEJ Gas Engine No. 1 is NOT Mobil Pegasus 805.

Petro\$a Integrated Services Lim	VE	Fresh Oil Analysis Report						
Client Information Company Name: Company Address:	OK Plast Ltd. 7A, Illasamaja Schei Off Isolo Expresswa Isolo, Lagos	Client Contact: Department: Mobile Phone No.: Email Address:	Naresh Lenka Maintenance (Power Plant) 08027936088 nareshlenka23@gmail.com					
Date:	14-Jun-16							
Test	Units	Fresh Mobil Pegasus 805 Sampled: June 11, 2015 Drum Batch No. C220028	Mobil Pegasus 805 Website PDS Info					
Color	Visual	Clear, Brown	NA					
SAE Grade		40	40					
Viscosity @ 40C	cSt	143.8	130.0					
Viscosity @ 100C	cSt	14.5	13.5					
Viscosity Index, VI		100	99					
Specific Gravity [SG] @ 15C	kg/m <sup>3</sup>	898	890					
Total Base Number [TBN]	mgKOH/g	6.7	6.2					
Total Acid Number [TAN]	mgKOH/g	1.8	0.3*					
Flash Point [ ASTM D93 Closed C	°C	215	262 #					
Water	% vol	Nil	Nil					
Elemental Analysis - Select Iron, Fe Copper, Cu Sodium, Na Potassium, K	ppm	9 8 32 0						
		prmation. However, TAN = 0.3 is typical ces and correctly meeting other Mobil P						

# ASTM D92 Open Cup Method

#### Comment(s)

Fresh oil sample taken from Drum [Batch # C220028] is NOT Mobil Pegasus 805.

### Case Study 8: Impact of Fake GEO Brands

Petro Sav Integrated Services Limited	e	Fresh Oil Analysis Report					
Client Information							
Company Name: Company Address:	OK Plast Ltd. 7A, Illasamaja S Off Isolo Expre Isolo, Lagos	Scheme, Itire Junction ssway	Client Contact: Department: Mobile Phone No.: Email Address:	Naresh Lenka Maintenance (Power Plant) 08027936088 nareshlenka23@gmail.com			
Date:	24-Jul-15						
Test	Units		OKPlast: Fresh Oil Sample Drum Batch No. C530044 Sample Taken: July 24, 2015	Website PDS Info			
Color	Visual		Clear, Brown	NA NA			
SAE Grade	-		40	40			
Viscosity @ 40C	cSt		127.8	3 130.0			
Viscosity @ 100C	cSt		13.2	13.			
Viscosity Index, VI	-		97	99			
Specific Gravity [SG] @ 15C	kg/m <sup>3</sup>		887	7 890			
Total Base Number [TBN]	mgKOH/g		6.2	2 6.1			
Total Acid Number [TAN]	mgKOH/g		0.4	۵.3 U			
Oxidation	A/cm			N/			
Flash Point [ ASTM D93 Closed Cup]	°C		214	262 :			
Water	% vol		N	I N			
Elemental Analysis Wear Metals	ppm						
Iron, Fe Chrome, Cr				NA NA			
Chrome, Gr Lead. Pb							
Copper, Cu				NA NA			
Tin, Sn							
Aluminum, Al	· ·			N/			
Contaminant Metals	ppm		1				
Silicon, Si				N/			
Sodium, Na			(				
Potassium, K			(	N/			
Additive Metals	ppm						
Calcium, Ca	· ·		1249	NA NA			
Phosphorus, P	· ·		265				
Zinc, Zn			454	L NA			

\* Note the TAN level of fresh oil is not available as a Product Data Sheet (PDS) information. However, TAN = 0.3 is typical value, which has been measured at Petrosave Lah for several GEO samples, of authentic sources and correctly meeting other Mobil Pegasus 805 published oil parameters. # ASTM DE2 Open Cup Method NA - Not Available as standard Mobil PDS information

#### Comment(s)

In spike of some variations seen in the parameters reported above, it is safe to conclude that the fresh oil sample MEETS the product formulation properties of Mobil Pegasus 805. A Note hat Sodium is measured MII for the Fresh Pegasus 805 sample.

Petro Sav Integrated Services Limited	E			Gas Engine	Oil Analysis	s Report		
Client Information Company Name: Company Address:	OK Plast Lt 7A, Illasam Off Isolo E Isolo, Lago	aja Scheme, Iti pressway	re Junction	Client Contact: Department: Mobile Phone No.: Email Address: Equipment Operator		Mr. Imad Maintenance (Power Plant) 07030030070 dani80_ng@hotmail.com		
Equipment Information Equipment Type: Equipment ID Ref. Equipment Make: Equipment Year of Manufacture: Equipment Location:				Component: Make/Type: Lube Oil in use: Oil Brand: Oil Weight:		Englne JENBACHER / JGC420 Mobil Pegasus 905 Mobil SAE 40	gs-nl	
				Used Oil Semaler	Trend of Anticel Lab	Testa		
	Fresh Oil	Condeming	07 September 2015		12 November 2015	07 December 2015	06 January 2016	
	29-Aug-14	Limit	5562/OkP/GG#V14	5698/OkP/GG#1/15	5849/OkP/GG#V16	5983/OkP/GG#1/17	6084/OkP/GG#1/18	
	, in the second s							
Engine Operating Hours								
Oil Sample [Hrs]	0	-	1,156		2,250	247	634	
Cumm. Engine [Hrs]	-	-	6,554	7,083	7,648	8,059	8,446	
Lube Oil Properties								
Color [Clear, Turbid or Dark]	Clear		Dark	Dark	Dark	Dark	Dark	
Viscosity @ 40C [cSt]	122.8	+ 25%	128.6		138.9	127.9	133.9	
Viscosity @ 100C [cSt]	13.0	≥ +3	13.5		14.2	13.4	13.9	
TAN [mgKOH/g]	0.4	+ 2.5	1.6		2.9	0.5	1.5	
TBN [mgKOH/g]	6.2	3.1	5.6		3.8	6.1	5.4	
Soot [%]	0%	2%	0.0%	0.0%	0.0%	0.0%	0.0%	
Nitration [A/cm]	0	20	3.9		6.1	0	0	
Oxidation [A/cm]	0	20	2.1		3.8	0	0	
Water in Oil [%]	0.00%	0.20%	0.00%		0.00%	0.00%	0.00%	
Glycol [%]	0.00%	0.02%	0.00%	0.00%	0.00%	0.00%	0.00%	
Elemental Analysis								
Wear Metals								
Aluminum, Al [ppm]	0	15	0	0	0	0	0	
Copper, Cu [ppm]	0	15	0		0	0	0	
Chromium, Cr [ppm]	0	5	0		0	0	0	
Lead, Pb [ppm]	0	20	0		0	0	0	
Iron, Fe (ppm) Tin, Sn (ppm)	0	20 5	0		0	0	0	
	Ĭ			Ŭ	Ŭ	Ŭ		
Contaminant Metals			_					
Silicon, Si [ppm]	0	20	0	0	0	0	0	
Sodium, Na [ppm]	0	20	0		6	0	0	
Potassium, K [ppm]	0	5	0	0	2	0	0	
Additive Metal								
Molybdenum (ppm)	0	10	0	0	0	0	0	

Service Engineer's Comment: All engine wear metals within Limits. In-service GEO is ok for continued use. Subsequent 500 Hrs oil sampling/analysis to monitor trend.

## **Other Impacting Factors**

### **Oil Make-up with DEO**

It is common practice in almost all the Power Plants to run Gas Engines as the prime source of power while retaining the Diesel Engines as backup in case of gas supply outage. In a few cases, operators' initiatives to replace properly blended GEO with multigrade DEO had also resulted in shortened oil life.

In some case studies already covered, thinning down of oil viscosity, partly from comparatively lower viscosity & shearing of VI improver additives of multigrade DEO blends, rapid increase in Nitration and associated TAN increase, higher TBN with resultant increase in ash deposits are some of the observations, compelling oil analysis to flag for early oil change.

## **Gas Fuel Quality**

Petrosave Laboratory hopes to commence running GC analysis on gas samples to investigate Industry-wide reduction of Oil life across different Power Plants. Early indications point in direction of quality of Natural Gas supplied to the Nigeria Energy Industry which may not be farfetched, as Gas Vendors struggle to meet market demands against the backdrop of severe gas outages resulting from rampant cases of pipeline vandalization.

## Wrap-up

In conclusion, above case-studies attempted to showcase operating conditions within which gas engine may efficiently and effectively be operated to yield optimum value and good return on its investment.

- 1. Use **OEM approved GEO Brand**, genuinely sourced from authorized Distributor(s)
- 2. Always ensure complete oil drain during every Lubrication Service
  - Include some form of physical inspection; replace oil filters as well
- 3. Ensure **adequate & consistent oil make-up** mechanism
  - Automatic top-up system is recommended
- 4. Extended oil sump size offer oil life extension benefits over standard/compact sumps
  - Ensure contamination monitoring/control in place to avoid ruining large volume of oil in a single incident
- 5. Monitor for early detection of contaminants
  - Make Oil Analysis the preferred tool
- 6. Choose installed Engine Capacity sized for optimal Process Load requirement
  - Operating load, 70 80% of engine capacity advised
  - 70-80% size also capable of accommodating Peak Load & Shock Loads as may arise

Thank You