IMPACT OF TROPICAL ENVIRONMENT ON LUBRICANT MANUFACTURING

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ABSTRACT

The use of machines for manufacturing purposes involves interaction of metallic parts against each other and the working medium. Frictional forces generated by this movement result in wear, erosion and corrosion of the articulating parts. Lubricants are therefore employed to reduce the effects of the frictional forces. The effectiveness of the lubricants has been shown to be a function of the ambient operating conditions. Most lubricants used in Nigeria are imported. A study was done to assess the compatibility of SAE 30 as automobile engine lubricant for the Tropical environment. The rainy and harmattan seasons were simulated in the laboratory and the oil was tested.

Analysis of Rheological properties of the virgin and used lubricants samples showed that SAE 30 performed satisfactorily under the harmattan conditions but failed noticeably in the rainy season conditions. This difference in performance can be attributed to the manufacturing process which neglected the distinct peculiarities of the rainy and the harmattan seasons of the tropics. In subsequent work, other oils are intended to be similarly analyzed.

INTRODUCTION

Internal combustion engines and the myriads of industrial and domestic machines have metallic components that rub, roll, or slide on each other in the course of their operation. Some of these machines fail prematurely due to lack of proper lubrication of the contacting surfaces. Where sufficient amount of lubricating oil is available, the effectiveness of such lubricant is affected by the blending efficiency and the appropriateness of its application. The ambient operating conditions (the weather conditions) under which the lubrication is carried out also affect its performance. The prevailing weather condition in Nigeria is the tropical environment and is characterised by low and high relative humidity within the temperature range of $15^{0C - 400C}$

and the prevailing wind factor. The general classification of the weather is commonly called the Harmattan Season (low humidity and 150C - 300C) and the Rainy Season (high humidity

and 250C - 400C). These two seasons can have profound effect on the performance of any given lubricating oil.

Lubrication of machines must therefore be guided by appropriate selection of oil or grease (Sote, 1994) for the right season. It is important that manufacturers of the various grades of lubricating oil test their products under the existing weather conditions (seasons) of the target market. This will help prevent premature failure of parts and thus reduce the attendant low capacity utilization of plants and equipment. This work was directed at establishing if a single grade of lubricant will perform adequately under the two seasons in Nigeria. Should significant compositional and/or physical changes occur during the use of the same lubricating oil in the same machine given same normal mechanical operations under different ambient conditions harmattan season or rainy season; these changes can be attributed to the ambient operating environment. The findings will also assist manufacturers and consumers of lubricant in product line configuration and technology adaptation for high performance and affordable products.

The research was aimed at the Nigerian environment and SAE 30 (Regal 32) transmission oil was selected for the investigation. Tests based on boundary lubrication conditions and the conditions typifying harmattan and rainy seasons were carried out.

METHODS AND MATERIALS

(1) Tropical Environments and Lubrication Test Method

Understanding the tropical environment is essential in the formulation of lubricant for use within it. It is also important to mention that most of the lubricants used in Nigeria are imported and blended to standard grades. According to the report in Financial Standard (June 17, 2003) one out of every seven cans of lubricating oil is fake. The fakeness could be due to adulteration or misapplication of the products. This risk of fake products is amplified by the inherent characteristics of the tropical environment: the rainy and dry seasons loaded with dust, high humidity, windy conditions, and toxic vapours. Lubrication is indeed a challenge.

(a) Lubrication Test And Analysis

A laboratory analysis of the lubricating oil, SAE 30 (Regal 32) was carried out before the test to establish a reference point for comparing the effects of the tropical environment on the lubricant. The virgin oil, SAE 30, was then introduced into a test rig developed according to the American Society of Lubrication Engineers' Classification of Triba-testing System (Czichos, 1978), at the University of Agriculture, Makurdi (Oseni , 2002). The rig uses automobile axle kit to analyse boundary lubrication properties. The rig can test both journal and bearing kits which are commonly found in automobile engines. The Rig shall herein after be referred to as UAM-RIG.Hydraulic oil and transmission oils could be tested. Samples were drawn from the rig every thirty minutes for visual, physical and chemical analysis of the oil.

(b) Simulation Of The Tropical Ambient Environment

Since the main aim of the project was to test the performance of the lubricating oil under tropical environment, it was necessary to simulate:

- The Harmattan season (windy, low humidity and temperature range between 150C - 300C).
- The Rainy season (high humidity and temperature range between 250C - 400C).

The low humidity tests were carried out at an average temperature of 220C and a relative humidity of 55 percent. These conditions were achieved by the use of dehumidifiers and Airconditioners. The UAM test rig was water cooled. Similarly, the high humidity test was carried out at an average temperature of 320C and 85 percent relative humidity typical of the rainy season. A fine spray system introduced water into the test environment while the dehumidifier was turned off or a combined winter/summer air conditioner can as well be used. Temperature and hygrometer readings were allowed to remain steady at the test conditions stated above. Samples were drawn every 30 minutes for both Field Test and Multi-element (quantitative) analysis.

(2) Field Test

The changes in physical characteristics such as colour, appearance and odour were observed. To most machine and automobile engine users, the Field Tests form basis for oil-change. To ensure reliable assessment of these characteristics, the samples were collected and stored in transparent vials. The temperature within the test room was measured using a thermometer and the value of the relative humidity was read from the hygrometer. A capillary viscosity bath was used to determine the viscosity. The samples were then subjected to Multi-element analysis to determine the rate of metal wear.

(3) Quantitative Analysis

The quantitative tests were carried out at the facilities of:

Tractor and Equipment Nigeria Limited,

Fluids Analysis Technology and Marketing, Port Harcourt

The choice of the above organization was based on its professional expertise and comprehensive nature of the test equipment in their facilities:

- Oil quality assessment and engine conditions were automatically analysed and appropriate warnings issued.
- Elemental concentrations for eleven elements (associated with oil quality and performance) were carried out.
- Water and fuel contamination of the oil were measured.
- The viscosity of the oil was also determined.
- The original oil and the samples from each test were analyzed.

RESULTS

The results of the Visual and Multi-element analysis of the original oil sample SAE 30 (Regal 32) and the test samples are presented. Lubricants manufactured for use in Europe and America have been tested against the prevailing environments in their designated regions (Wills, 1980). Some of the test conditions used for the lubricants are presented in Table 1, for High Temperature Tests. Also displayed in the table are conditions used in the present research to represent the Rainy Season (high temperature and humidity). Table 2 shows similar data for Low Operating Temperature and low humidity the corresponding to the Harmattan Season conditions.

Visual Analysis

Gradual change(s) in the visual characteristics of the oil were observed as the loading and the environment impact on the oil. The golden colour of the virgin oil (as received sample) gradually faded to dark, non-transparent and sluggish fluid as shown in Plates 1 and 2.

Plate 1 represent the Harmattan Season conditions with Sample F representing the fresh oil and H1, H2, and H3, representing samples drawn at 30 minutes interval beginning with H1. In Plate 2, S1 - S3 represent the samples taken under The Rainy Season test conditions: high humidity and high temperature.

Multi-Element Oil analysis: A more scientific way of assessing the lubricant quality is the use of Multi-element analysis. This test provides information on metal particles concentration, oxidation level of the oil, presence of water and fuel in the oil and the viscosity of the oil.

The original (Fresh) Oil Analysis: Table 3 is the result of the analysis of the fresh oil. This result will form the basis for comparison of the experimental samples.

Harmattan Season Test Samples Analysis: Three samples were analyzed under this condition. The results for the first sample, H1 is shown in Table 4. Analysis of H2 and H3 appear in Tables 5 and 6, respectively.

Rainy Season Test Samples Analysis: The results from the High humidity-High temperature tests are shown in Tables 7 - 9. The concentrations of most elements increased significantly and the quantity of iron in the samples could be used to determine the mechanical wear rate of the contacting surfaces.

DISCUSSION

The results from the various tests on SAE 30 under tropical environment show that the oil performed differently in the rainy and harmattan seasons. Observable effects of the environments on the oil is discussed below.

The Test Conditions

The test conditions using the UAM-RIG appear in Tables 1 and 2 and favourably compares with the test sequence used in Europe and America. The ambient air conditions, particularly the humidity, were the factors that showed significant differences. These are the environmental factors prevailing under field test. Differences in the results can therefore be attributed to the observed differences in the environments.

Virgin Oil Analysis

Analysis of virgin SAE 30 showed a total metal concentration of 821ppm, with iron (Fe) at 1ppm and zinc (Zn) at 796ppm. Also analyzed were virgin SAE 140 and AW68 (both TEXACO products) which gave Fe concentration of 11ppm and 0ppm, respectively. The Zn concentrations were 784ppm and 785ppm, respectively.

The virgin oil analyses were all instrumentally evaluated and found to be acceptable and normal. These values formed the reference point for evaluation of the SAE 30 test samples.

Diagnostic Warnings On SAE 30 Samples

Virgin SAE 30 was not contaminated with water or fuel. The instrumental diagnostic output certified the oil as normal (Table 3).

Under Low Humidity-Low Temperature test conditions, the samples showed no contamination with neither water nor fuel. At 30 minutes (Table 4) the diagnostic remarks indicated that all readings are acceptable, even though Fe has increased to 38ppm. Further increase was observed in the concentration of Fe at 60 and 90 minutes. At 60 minutes (Table 5) the instrument warned that the increase in iron content to 73ppm should be reported. At 90 minutes, the value increased to 109ppm (Table 6). Similar warning was also given. There was no call for change of oil or the filter for these set of tests. It implies that the oil was effective for the harmattan conditions and would require a longer service life before the change of oil warning is recorded.

Test run under High Temperature-High Humidity yielded very high iron concentration in the oil. At 30 minutes (Table 7) slight water contamination was noted and the Fe content was 462ppm from the initial 1ppm recorded for the fresh oil. It should also be noted that this value (462 ppm) is 4.24 times the concentration at the end of 90 minutes in the harmattan condition. The instrument called for change of oil and filters. At 60 minutes (Table 8) and 90 minutes (Table 9), the Fe concentrations were 623ppm and 827ppm respectively. The instrumental diagnoses called for oil and filter changes at 60 minutes and complete engine and compartment flushing at 90 minutes.

It is important to note that only 9.96% increase in the total metal concentration was observed after 90 minutes test run under the harmattan conditions. However, 178.44% increase was observed for the rainy season tests at 90 minutes.

Performance Evaluation

Mechanical Wear Analysis: The change in the iron concentration is a good indicator of the wear characteristics of the components. Table 10 is a summary of the iron concentration in the samples. Both sets of samples show significant increase in the amount of iron (Fe) compared to the virgin oil sample. An increase of ten times was observed in the High temperature - High humidity samples over the corresponding harmattan samples. It shows that SAE 30 is not effective under high temperature and high humidity environment.

Corrosion Wear Analysis: The lead (Pb) concentration was monitored and treated as a function of the corrosion of the components. The average lead content in the samples appear in Table 11. It can be seen that the test at High Temperature-High Humidity had more lead compared with the Low Temperature-Low Humidity samples. The corrosion wear is therefore more significant in the rainy season.

Oxidation of the Lubricant: Copper (Cu) is an oxidation promoter which is present in the lubricant as additive. The changes in the copper concentration reflect the oxidation tendency. Table 12 shows the comparative values of copper in both sets of test. The Rainy Season tests showed higher copper concentration than the harmattan tests. From Plate 2, the colour of the samples are darker than those in Plate 1; an indication that less oxidation occurs during the harmattan season.

Deoxidant and Anticorrosion: The presence of Zinc (Zn) as an additive in oil lubricants serve as deoxidant and anticorrosion agents. Table 13 shows the profile of zinc in the samples. The fresh oil contained 796 ppm of Zinc. It is seen that the harmattan test condition gave rise to reduction in the zinc content while the rainy season conditions showed increase in the zinc content.

Defoamant: Silicon (Si) content is a measure of the defoaming characteristics of the lubricant. The silicon concentration increased under both tests conditions but more increase was observed in the rainy season test samples, as shown in Table 14. The breakdown of the silicon component of the oil is higher in the rainy season.

Dispersant: Dispersant effect (characteristics) of the lubricant is monitored by the concentration of the calcium (Ca) in the oil. Table 15 shows the effect of the test conditions on the calcium concentration in the lubricant. Less calcium concentration is observed in the harmattan season.

The above results confirm that SAE 30 is a good and high performance oil for harmattan environment. Poor performance is observed for the rainy season as more calcium concentration is reported.

CONCLUSION

- There is a marked difference between the performance of SAE 30 in the harmattan and the rainy seasons.
- Under boundary lubricating conditions, SAE 30 performed more efficiently in the harmattan season than the rainy season.
- Frequent oil change will be necessary if SAE 30 is used during the rainy season.

- Severe metal wear is associated with SAE 30 under high humidity conditions.
- It is not economical to use SAE 30 in the rainy season due to the frequent rate of oil change necessary to prevent engine failure.
- Different grades of oil blended in conformity with the separate ambient conditions will give a safer and longer service life and high performance. Maintenance engineers should therefore be alert to changes in the ambient conditions for the purpose of inspection and maintenance.
- There is a high risk of component failure in the rainy season if oil change is not carried out frequently.
- Engineers engaged in lubricant manufacturing need to carry out lubricant field test in the tropical environments to enable formulation of lubricants that will be efficient and economical.

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Air temperature 22^0C
Engine speed   2850 rpm
Relative humidity 55%
Test oil   SAE 30
F = Fresh oil
H1 = Sample at 30 minutes
H2 = Sample at 60 minutes
H3 = Sample at 90 minutes

(Time Hours)
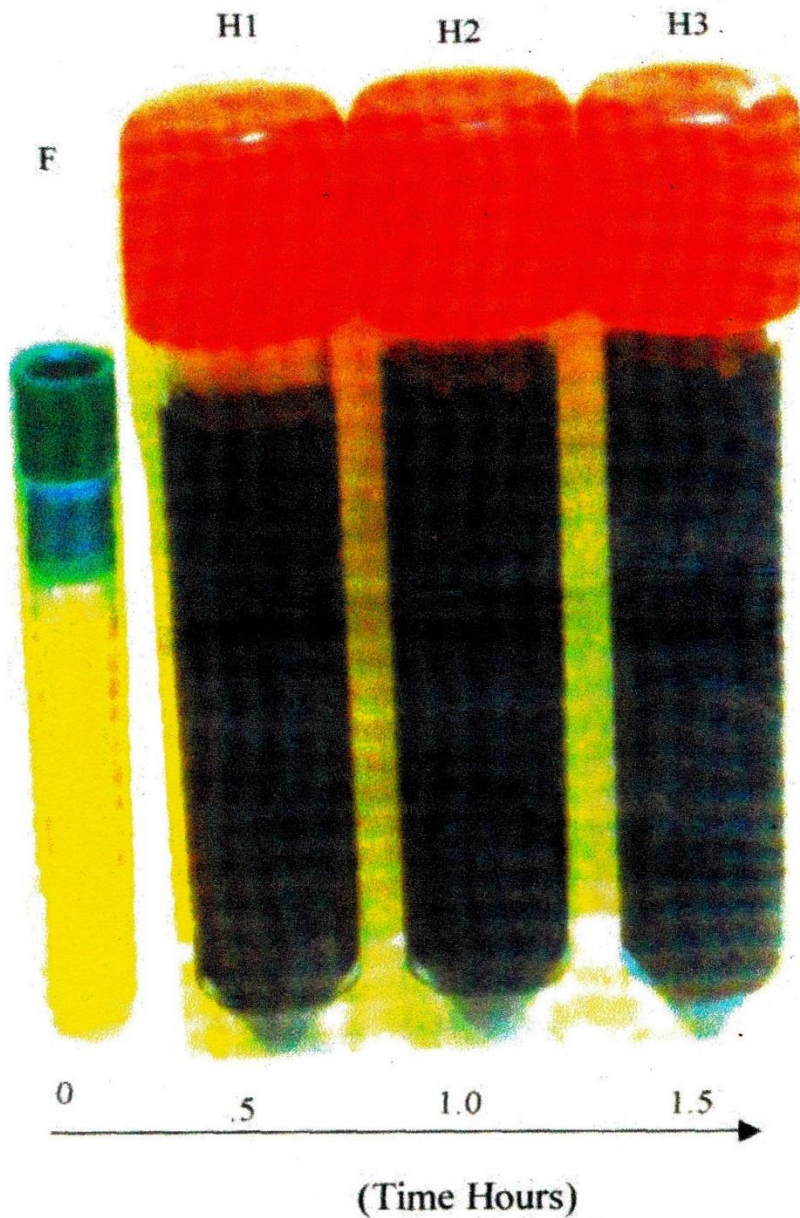
Plate 1:   Physical Changes of SAE 30 IN THE HARMATTAN SEASON
                 TEST CONDITIONS

Air temperature 32^0C
Engine speed   2850 rpm
Relative humidity   85%
Test oil   SAE 30
F = Fresh oil
S_1 = Sample at 30 minutes
S_2 = Sample at 60 minutes
S_3 = Sample at 90 minutes
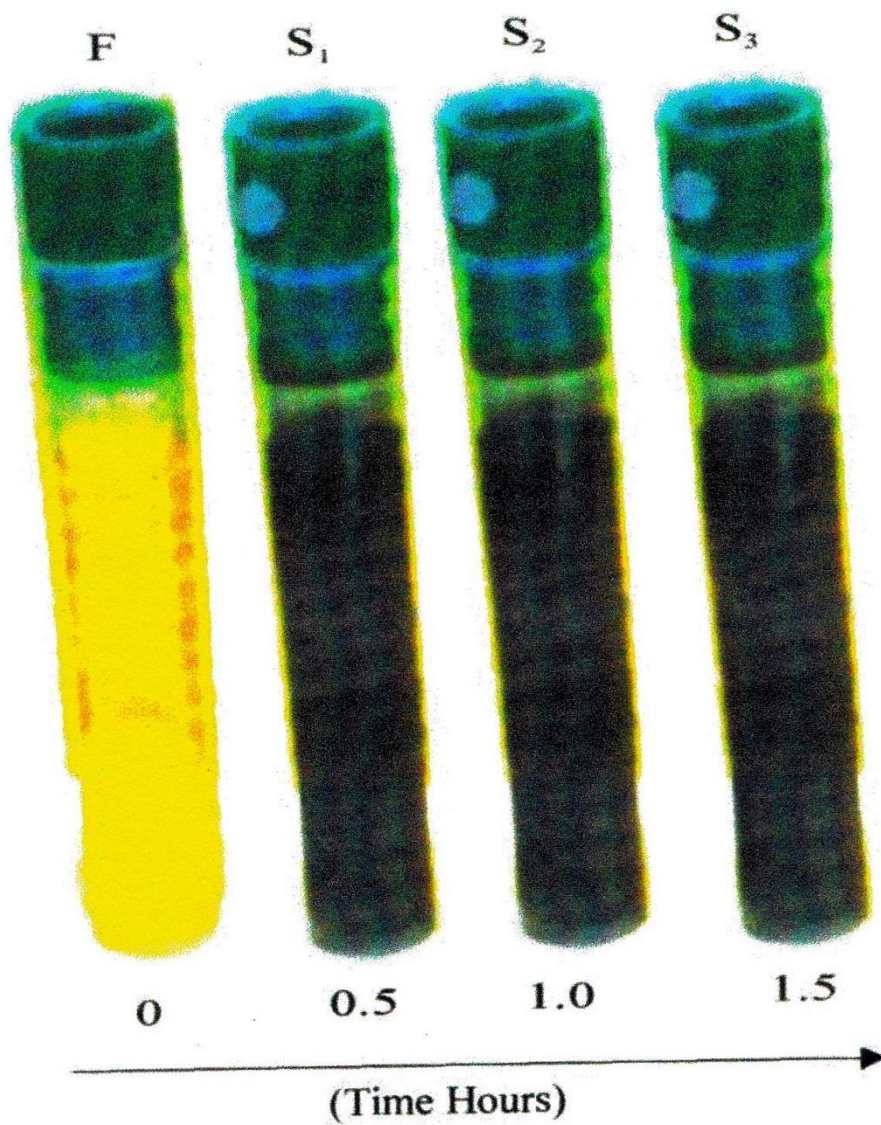
Plate 2:   Physical Changes of SAE 30 IN THE RAINY SEASON TEST CONDITIONS.

TABLE 1

SELECTED TEST CONDITIONS FOR LUBRICANTS: HIGH TEMPERATURE TEST

TEST IDENTIFICATION	TEST SEQUENCE		
	AV – B*	I – H*	PRESENT WORK S1 – 3
MAIN AREA OF USE	EUROPE	USA	NIGERIA
TEST ENGINE	PETTER	CATERPILLAR	UAM – RIG
AIR TEMP ^{0}C	75	77	32
AIR HUMIDITY	-	-	85
SPEED, RPM	2250	1800	2850
COOLANT OUTLET TEMP ^{0}C	100	71	75

*ADAPTED FROM (WILLS, 1980).

TABLE 2

SELECTED TEST CONDITIONS FOR LUBRICANTS:
LOW TEMPERATURE TEST

TEST IDENTIFICATION	TEST SEQUENCE		
	VD*	CECL-04-A-70*	PRESENT WORK H1 – 3
MAIN AREA OF USE	USA	EUROPE	NIGERIA
TEST ENGINE	FORD 4-CYL	FAIT FORD	UAM-RIG
AIR TEMP ^{0}C	-	25	22
AIR HUMIDITY	80	-	55
SPEED, RPM	2500	2500	2850
COOLANT OUTLET TEMP ^{0}C	68	25	30

*ADAPTED FROM (WILLS, 1980).

TABLE 3

SAE 30 VIRGIN OIL

SAMPLE NAME:	Virgin Oil (Fresh)
OIL TYPE:	SAE 30
MANUFACTURER:	TEXACO
VISCOSITY:	145Cp

ELEMENT		CONCENTRATION (PPM)
Copper	(Cu)	2
Iron	(Fe)	1
Chromium	(Cr)	1
Lead	(Pb)	2
Aluminium	(Al)	1
Silicon	(Si)	2
Molybdenum	(Mo)	0
Tin	(Sn)	2
Manganese	(Nn)	0
Zinc	(Zn)	796
Calcium	(Ca)	14

Contaminants

Water   Nil

Fuel   Nil

Diagnostic Warning/Remarks:

Normal Condition

TABLE 4

SAE 30 - SAMPLE H1
LOW HUMIDITY-LOW TEMPERATURE TEST AT 30 MINUTES

SAMPLE NAME: H1
OIL TYPE: SAE 30
MANUFACTURER: TEXACO
VISCOSITY: 160cP

ELEMENT		CONCENTRATION (PPM)
Copper	(Cu)	17
Iron	(Fe)	38
Chromium	(Cr)	0
Lead	(Pb)	1
Aluminium	(Al)	3
Silicon	(Si)	11
Molybdenum	(Mo)	2
Tin	(Sn)	0
Manganese	(Nn)	1
Zinc	(Zn)	729
Calcium	(Ca)	14

Contaminants

Water   Nil

Fuel   Nil

Diagnostic Warning and Remarks:

All readings are acceptable.

TABLE 5

SAE 30 - SAMPLE H2
LOW HUMIDITY-LOW TEMPERATURE TEST AT 60 MINUTES

SAMPLE NAME:	H2	
OIL TYPE:	SAE 30	
MANUFACTURER:	TEXACO	
VISCOSITY:	160cP	

ELEMENT		CONCENTRATION (PPM)
Copper	(Cu)	24
Iron	(Fe)	73
Chromium	(Cr)	1
Lead	(Pb)	3
Aluminium	(Al)	6
Silicon	(Si)	21
Molybdenum	(Mo)	5
Tin	(Sn)	2
Manganese	(Nn)	1
Zinc	(Zn)	786
Calcium	(Ca)	23

Contaminants

Water   Nil

Fuel   Nil

Diagnostic Warning/Remarks:

Iron is reportable.

TABLE 6

SAE 30 - SAMPLE H3
LOW HUMIDITY-LOW TEMPERATURE TEST AT 90 MINUTES

SAMPLE NAME:	H3	
OIL TYPE:	SAE 30	
MANUFACTURER:	TEXACO	
VISCOSITY:	185cP	

ELEMENT		CONCENTRATION (PPM)
Copper	(Cu)	28
Iron	(Fe)	109
Chromium	(Cr)	2
Lead	(Pb)	4
Aluminium	(Al)	11
Silicon	(Si)	31
Molybdenum	(Mo)	8
Tin	(Sn)	3
Manganese	(Nn)	2
Zinc	(Zn)	675
Calcium	(Ca)	38

Contaminants

Water   Nil

Fuel   Nil

Diagnostic Warning/Remarks:

Iron is reportable.

TABLE 8

SAE 30 - SAMPLE S2
HIGH TEMPERATURE-HIGH HUMIDITY TEST AT 60 MINUTES

SAMPLE NAME: S2
OIL TYPE: SAE 30
MANUFACTURER: TEXACO
VISCOSITY: 145cP

ELEMENT		CONCENTRATION (PPM)
Copper	(Cu)	90
Iron	(Fe)	623
Chromium	(Cr)	5
Lead	(Pb)	11
Aluminium	(Al)	36
Silicon	(Si)	119
Molybdenum	(Mo)	35
Tin	(Sn)	6
Manganese	(Nn)	7
Zinc	(Zn)	873
Calcium	(Ca)	88

Contaminants

Water   Nil

Fuel   Nil

Diagnostic Warning/Remarks:

Wear metals are unacceptable.

Change the oil and filter(s).

TABLE 10

IRON (Fe) CONCENTRATION AND MECHANICAL WEAR PROFILES IN PROCESSED OIL

SAMPLE IDENTIFICATION	IRON (Fe) CONCENTRATION			
	0 MIN.	30 MIN.	60 MIN.	90 MIN.
FRESH OIL	1	1	1	1
HARMATTAN (H1 - H3)	1	38	73	109
RAINY SEASON (S1 – S3)	1	462	623	827

TABLE 11

LEAD (Pb) CONCENTRATION AND CORROSION WEAR PROFILES IN PROCESSED OIL

SAMPLE IDENTIFICATION	LEAD (Pb) CONCENTRATION			
	0 MIN.	30 MIN.	60 MIN.	90 MIN.
FRESH OIL	2	2	2	2
HARMATTAN (H1 - H3)	2	1	3	4
RAINY SEASON (S1 – S3)	2	12	11	16

TABLE 12

COPPER (Cu) CONCENTRATION AND OXIDATION PROMOTER PROFILES IN PROCESSED OIL

SAMPLE IDENTIFICATION	COPPER (Cu) CONCENTRATION			
	0 MIN.	30 MIN.	60 MIN.	90 MIN.
FRESH OIL	2	2	2	2
HARMATTAN (H1 - H3)	2	80	90	136
RAINY SEASON (S1 – S3)	2	17	24	28

TABLE 13

ZINC (Zn) CONCENTRATION AND DEOXIDANT/ANTICORROSION PROFILES IN PROCESSED OIL

SAMPLE IDENTIFICATION	ZINC (Zn) CONCENTRATION			
	0 MIN.	30 MIN.	60 MIN.	90 MIN.
FRESH OIL	796	796	796	796
HARMATTAN (H1 - H3)	796	729	786	675
RAINY SEASON (S1 – S3)	796	587	873	923

TABLE 14

SILICON (Si) CONCENTRATION AND DEFOAMANT PROFILES IN PROCESSED OIL

SAMPLE IDENTIFICATION	SILICON (Si) CONCENTRATION			
	0 MIN.	30 MIN.	60 MIN.	90 MIN.
FRESH OIL	2	2	2	2
HARMATTAN (H1 - H3)	2	11	21	31
RAINY SEASON (S1 – S3)	2	95	119	154

TABLE 15

CALCIUM (Ca) CONCENTRATION AND DISPERSANT PROFILES IN PROCESSED OIL

SAMPLE IDENTIFICATION	CALCIUM (Ca) CONCENTRATION			
	0 MIN.	30 MIN.	60 MIN.	90 MIN.
FRESH OIL	14	14	14	14
HARMATTAN (H1 - H3)	14	14	23	38
RAINY SEASON (S1 – S3)	14	157	88	111