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DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION

AERONAUTICAL RESEARCH LABORATORY

MELBOURNE, VICTORIA

Technical Note 10

EXTENSION OF OIL SERVICING INTERVALS FOR THE LEOPARD AS-1 POWER PACK

by

G. G. McVea
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Approved for public release.

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SUMMARY

The condition of the engine and transmission oils was determined at three monthly intervals for a period of 24 months for five armoured Leopard vehicles operated routinely by the 1st Armoured Regiment, Puckapunyal. For the trial vehicles, the maximum operating hours was 270 and the minimum 56. All oil samples from the trial vehicles remained within specification requirements for new oil as determined by viscosity, total base number and pentane insoluble content. A small increase in the viscosity of both the engine oils and the transmission oils was recorded over the period of the trial, but all determinations remained well below the maximum specified for new oil. There was no indication of storage or standing deterioration of the oils during the two year period and it was concluded that vehicle operating hours was the sole criterion for the variations that were determined. It was recommended that oil change intervals could be extended to a minimum of 300 operational hours or two years elapsed time.

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1. BACKGROUND

Extension of oil change intervals to two years for the Leopard Main Battle Tank (MBT) is under consideration by NATO countries. At the 15th International Leopard Vehicle Technical Working Group meeting [1], a final report was provided on a European trial which involved the extension of oil change intervals for Leopard vehicles to periods in excess of two years when operating with a multigrade 15W40 oil (Nato 0-236). Results for 800 oil samples from more than 200 vehicles were summarized in this report. No unacceptable deterioration of the oil or abnormal wear in the vehicles was found for oil change intervals extending up to 30 months.

In Australia, a single grade SAE-30 oil, OMD-115 (Nato 0-238) is used for crankcase lubrication of AS-1 Leopard Powerpacks rather than the Nato O-236 oil. Current Army practice is to change the lubricant in the Leopard AS-1 every 6 months or 1000 km. This interval was based on recommendations by the engine manufacturer (MTU), that the oil be changed after 5000 litres of fuel had been consumed, which is approximately 1200 km for Australian operation conditions. Extension of the oil change interval would not only reduce expenditure on replacement oil, but also allow greater flexibility in servicing requirements for the vehicles. This study, on the feasibility of extending the oil change intervals in the Leopard AS-1 vehicles when operating with OMD-115 oil under Australian conditions, was carried out at the request of the Australian Army Maintenance Engineering Agency (MEA).

2. CRANKCASE OIL DETERIORATION

Modern diesel engine oils are formulated to provide lubrication and corrosion protection for the current generation of high performance diesel engines. Effective lubrication and wear minimization is provided by a combination of fluid hydrodynamic factors and surface modification following chemical interaction between oil components and metal surfaces. Corrosion protection is achieved by neutralization of corrosive combustion products which may be deposited in the oil and also from the interactions between oil constituents and metal surfaces.

Effective hydrodynamic lubrication is a function of the ability of the oil to form a liquid film between the moving components. The viscosity is the major oil property in determining this ability. The viscosity range over which hydrodynamic lubrication will occur is limited. Too high or too low a viscosity for the engine design will not allow an effective liquid film to remain between moving components. With engine operation, the viscosity of the oil may be reduced by shearing of larger oil molecules, by shearing of polymer molecules formulated in the oil as viscosity improvers or by dilution with lower viscosity fuel. An increase in oil viscosity may follow from degradation and polymerization of the oil molecules and by deposition of fuel combustion products in the oil. The deposition of soot in the fuel has been shown to be a factor in increased oil viscosity [2]. The significance of soot deposition in the crankcase oil of diesel engines is recognized by the formulation of engines oils with significant detergency properties. The 'D' in the 'OMD' designation indicates an oil, mineral, containing a detergent additive.

Acid combustion products deposited in the oil are generally considered by the oil industry to be the major factor in determining crankcase oil change periods. The presence of sulphur species in the fuel, which are oxidized to components which form sulphuric acid in the oil, may lead to high rates of engine corrosion. The significance of the sulphur content of the fuel is recognized by oil formulators, acid neutralizing additives being an important part of the formulation. Recommended crankcase oils for use with high sulphur fuels contain higher proportions of acid neutralizing materials as measured by the total base number (TBN) of the oil.

Measurement of the viscosity and the "latent acidity" of the oil are the major means of determining the deterioration of crankcase oils in service. "Latent acidity" may be determined as the change in Base Number of the oil, by direct measurement of carbonyl absorptions in the infrared spectra which may be associated with acid products [3], or by measurement of the concentrations of acid dissolved metal species in the oil [4]. The change in viscosity, total base number and total insolubles have been determined for five Leopard vehicles which were operated for periods up to two years without changing the oil in the crankcase and gearbox assemblies.

3. FIELD PROGRAMME

3.1 Vehicles

Five Leopard vehicles were included in this trial at 1st Armoured Regiment, Puckapunyal. These comprised three Main Battle Tanks (MBT), one Recovered Vehicle (ARVM) and one Bridge Layer (AVLB). These vehicles represented a cross section of the Leopard fleet and were used routinely during the trial period.

3.2 Oils

The crankcase oil was OMD-115, a monograde SAE30 diesel engine oil qualified to MIL-L-2104D. This is the standard diesel engine crankcase oil used by the Australian Army for almost all diesel powered vehicles. The transmission oil was 0X47, a monograde SAE10 hydraulic transmission fluid to Detroit Diesel Allison specification TES 122.

3.3 Oil Samples

Oil samples were to be taken from the engine and transmission assemblies at the six monthly service and thereafter every three months. Sampling valves were fitted to the trial vehicles with sampling procedures being specified to ensure that uncontaminated and representative samples were obtained for analyses.

4. LABORATORY ANALYSES

The viscosity was measured at 40°C and 100°C with capillary viscometers by the method of ASTM D445. A potentiometric method according to ASTM D2896 was used to determine the total base number of the oil. Insoluble materials were precipitated from the oil by dilution with pentane following the procedure of ASTM D893. Centrifuging the oil/pentane solution separated the solids which were dried and determined gravimetrically.

5. RESULTS

Results for this trial are shown for each vehicle in Tables 1 to 10. The operating hours for each oil sample in shown in Figure 1. Variations in the engine oils parameters are shown graphically in Figures 2 to 5.

6. DISCUSSION

6.1 Engine Oils

Viscosity increases were less than 10% for all engines in this trial. The viscosity of the engine oils remained within the specification limits for unused SAE30 grade OMD-115 engine oil (maximum 12.5 mm^2 sec^{-1} and minimum 9.3 mm^2 sec^{-1} at 100°C). The maximum viscosity determined was 11.8 mm^2 sec^{-1}, which was significantly less than the maximum allowed for new oil.

Further evidence for the small amount of degradation of the oils is seen in measurements of the viscosity index (VI). The VI is a measurement of the variation of viscosity with temperature. The larger the value, the smaller the change in viscosity with temperature. The specification for OMD-115 oil calls for a minimum value of 75. Oil from all vehicles showed a small increase in VI over the period of the trial. These results would suggest that there was no breakdown of the VI additive in the oil. Any deterioration of the lubricating oil would appear to have arisen from a small amount of oxidation of the basestock oil itself to possibly form polymer material with natural VI properties. This material would cause a small increase in the viscosity at the higher temperature and a small increase in the VI.

Only one sample of the engine oils indicated a decrease in viscosity during the sampling period. The decrease was reversed in the sample from the same vehicle during the next time period, when a small increase in viscosity was recorded. There was no evidence that the decrease in viscosity was caused by fuel dilution.

The increase in concentration of pentane insolubles was less than 1% for all trial samples. Previous studies have shown that an increase in the concentration of fuel combustion carbon particles (soot) in the oil was the major factor in determining the life of the engine oil [2]. The soot, measured as the major component of the pentane insolubles, causes an increase in the viscosity of the oil. Neither the pentane insolubles nor the viscosity increased significantly in the samples from the trial.

Very little decrease in total base number (TBN) was recorded for the samples over the period of the trial. These results would indicate that the oil is still providing adequate protection against engine chemical corrosion from acid combustion products.

The results obtained in this study were comparable with results reported in Appendix 2.1.6 to Annexe A of reference 1. The multigrade oil used in the European study also remained satisfactory for continued operation after the two year period.

6.2 Transmission Oils

Transmission oils are not subject to deterioration by deposited soot or acid combustion products. The major factors are changes in viscosity from oil oxidation and possibility shear of base oil molecules. Oil oxidation may be accelerated by operating the vehicles under heavy loads, causing the transmissions to become overheated.

Changes in viscosity of all the transmission oils were less than 10% after 24 months of operation. The small change would indicate that oil oxidation and shear processes were not a determining factor in the oil condition in the transmission assemblies during the trial period. All oil samples showed a small increase in viscosity from that of the original oil in the assemblies.

The increase in the pentane insoluble content of the transmissions oils was less than 0.20%. The presence of oil degradation products, wear metals and ingested airborne particulate matter were not significant in the oil condition.

The results from this study of the transmission oils was again similar to the much larger study in Europe [1]. Over the two year period, the viscosity of the transmission oils increased slightly and the amount of insolubles remained low.

7. CONCLUSIONS.

The criteria for acceptable oil life are generally based upon viscosity change, insolubles build-up, water contamination and depletion of additives. Results from the engine oils of the trial vehicles showed that deterioration was insignificant after operation for up to 269 hours over a period of 24 months. For the parameters determined in this study, all oil samples met the specification requirements for the original unused oil.

The usage rate of the vehicles was relatively low over the trial period. After 24 months, all oils meet the requirements of unused oil which would suggest that there was considerable oil life remaining. There was no indication that storage ageing from oil remaining in the vehicles over the two year period was contributing to its deterioration. These results are consistent with previous studies of the deterioration of the oil in Army Mack Trucks [2]. Vehicles which had travelled small distances over a period of two years showed little deterioration of the oil. For the trucks, the major factor in oil deterioration was the engine operation hours. An increase in pentane insolubles and an associated increase in the viscosity of the oil was correlated with operating hours of the oil.

8. RECOMMENDATIONS

1. Elapsed time was not found to be a significant factor in the deterioration of the oil for the vehicles in this trial. Increasing the oil drain interval to 2 years is recommended, especially for low usage vehicles.

2. As variations in oil parameters over a period up to 269 operational hours were within specification limits for new oil, it may be concluded that minimum risk will arise from extending oil change intervals to 300 hours.

3. Insufficient deterioration occurred in the engine and transmission oils in this trial to gauge the maximum operational life of these oils. Based on the limited number of vehicles and samples in this trial, conservative recommendations have been put forward.

9. REFERENCES

1. Proceedings 15th International Leopard Vehicle Technical Working Group Meeting, 1985. Germany, 18-22 March.

2. McVea, G.G. 1983. "Lubricant Deterioration in the Army Mack Truck During Extended Operation". Materials Research Laboratory, OCD Report No. 83/9.

3. Coates, J.P and Setti, L.C. 1985. "Infrared Spectroscopic Methods for the Study of Lubricant Oxidation Products", ASLE Trans, **29**, pp 394 - 401.

4. Golden, G.S. 1971. "The Determination of Iron in Used Lubricating Oils" Applied Spectroscopy, **25**, 668.

FIGURE 1

Operating Hours with Oil

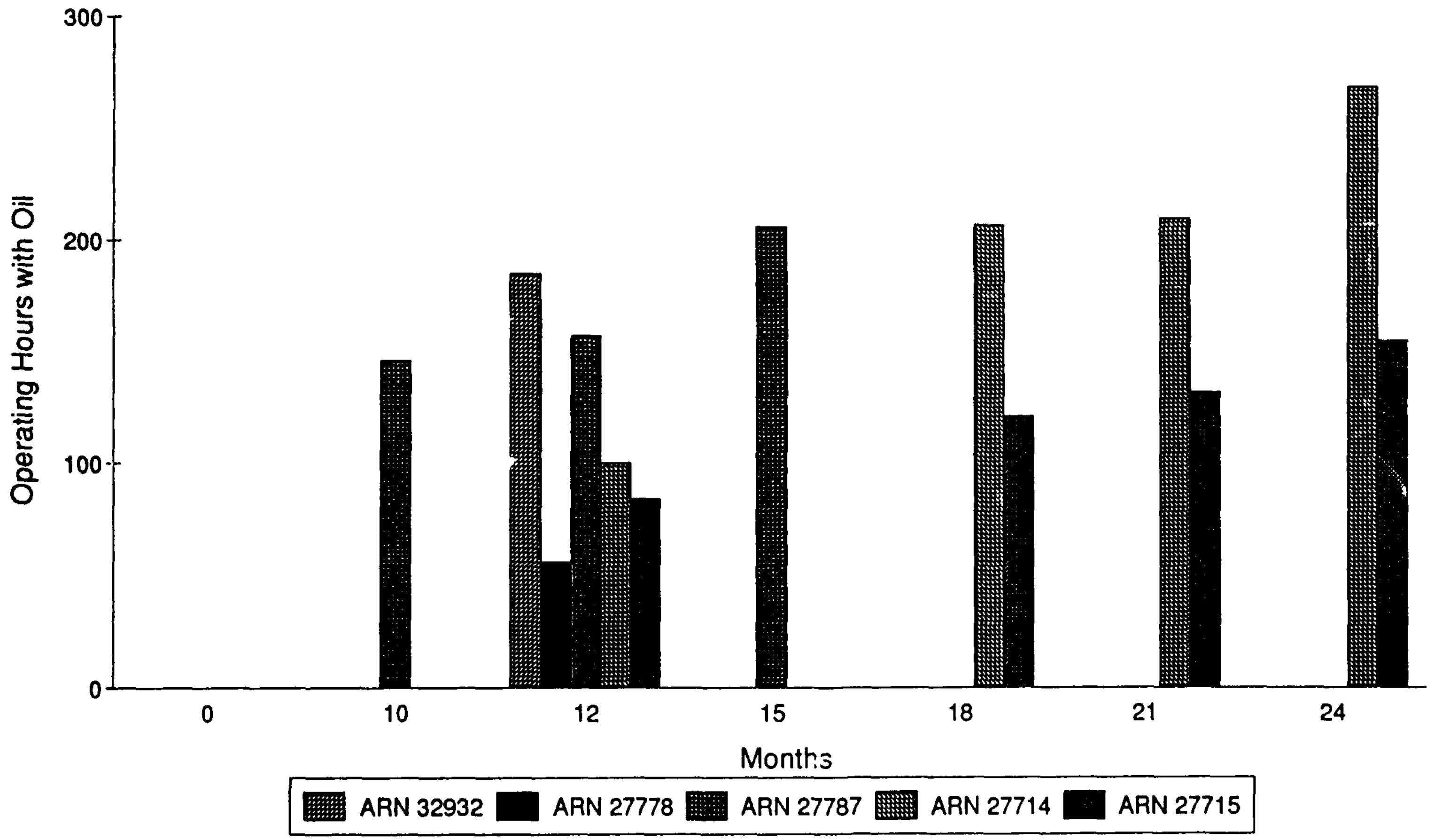

FIGURE 2

Variation of Total Base Number

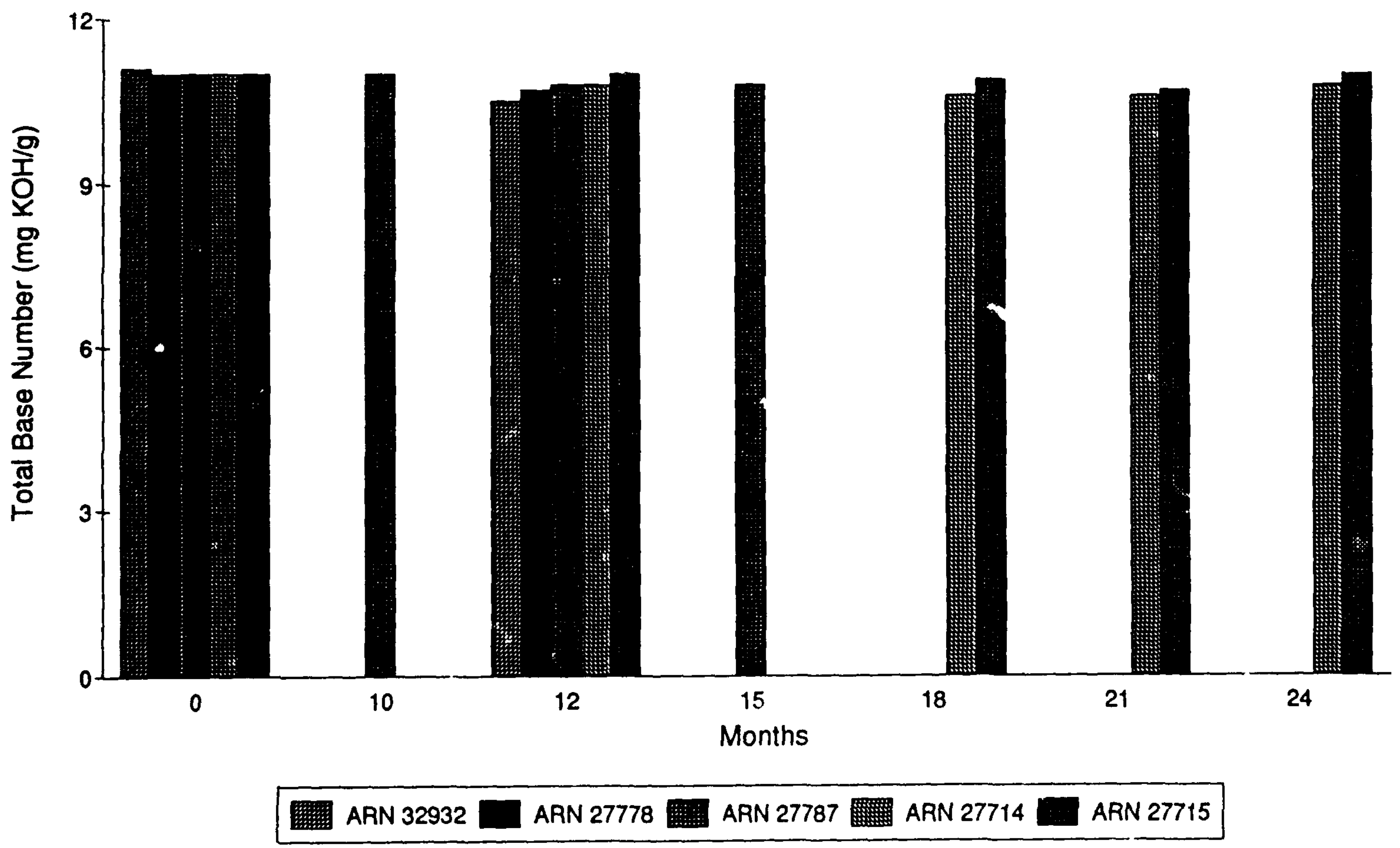

FIGURE 3

Total Insolubles in Oil

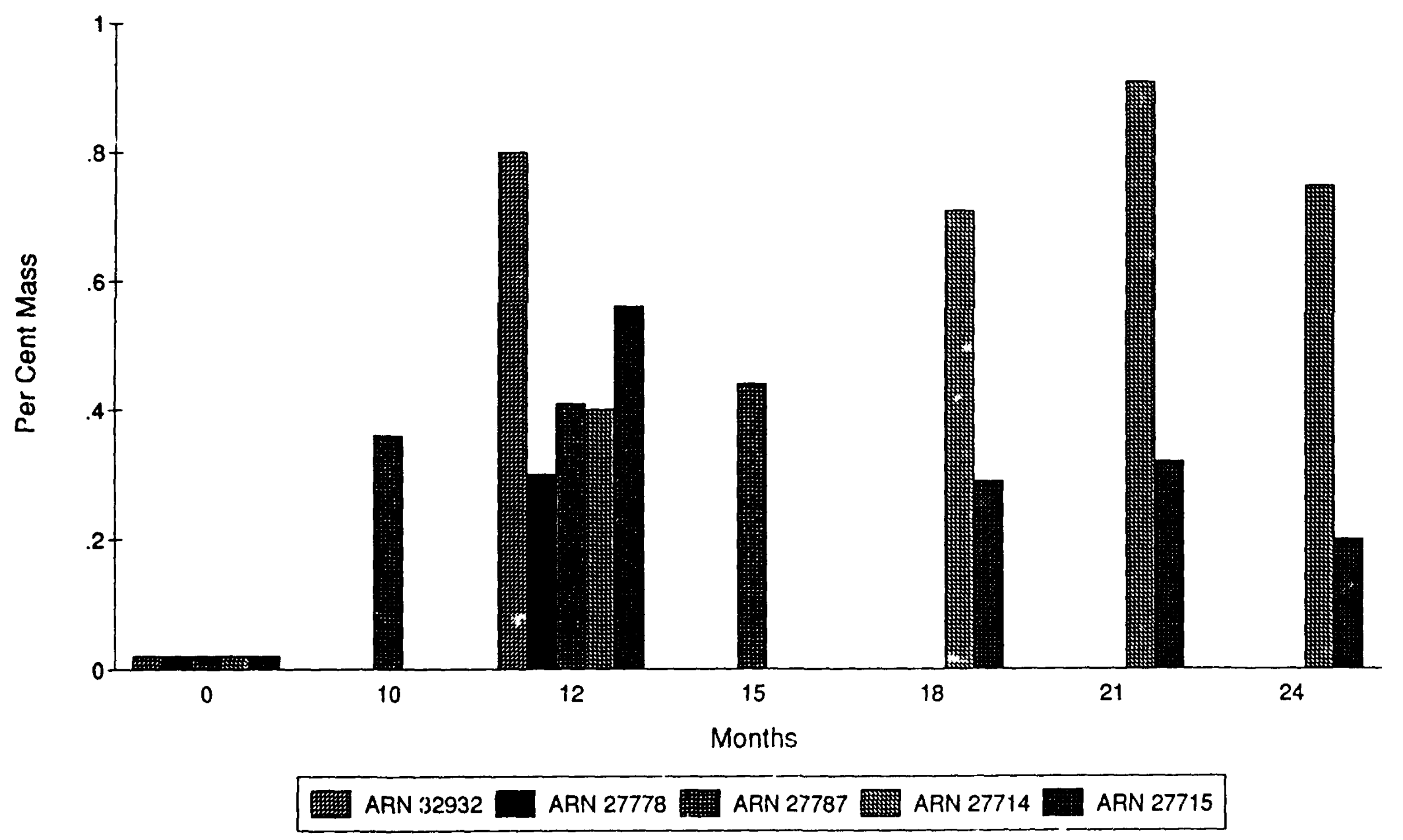

FIGURE 4
Oil Viscosity

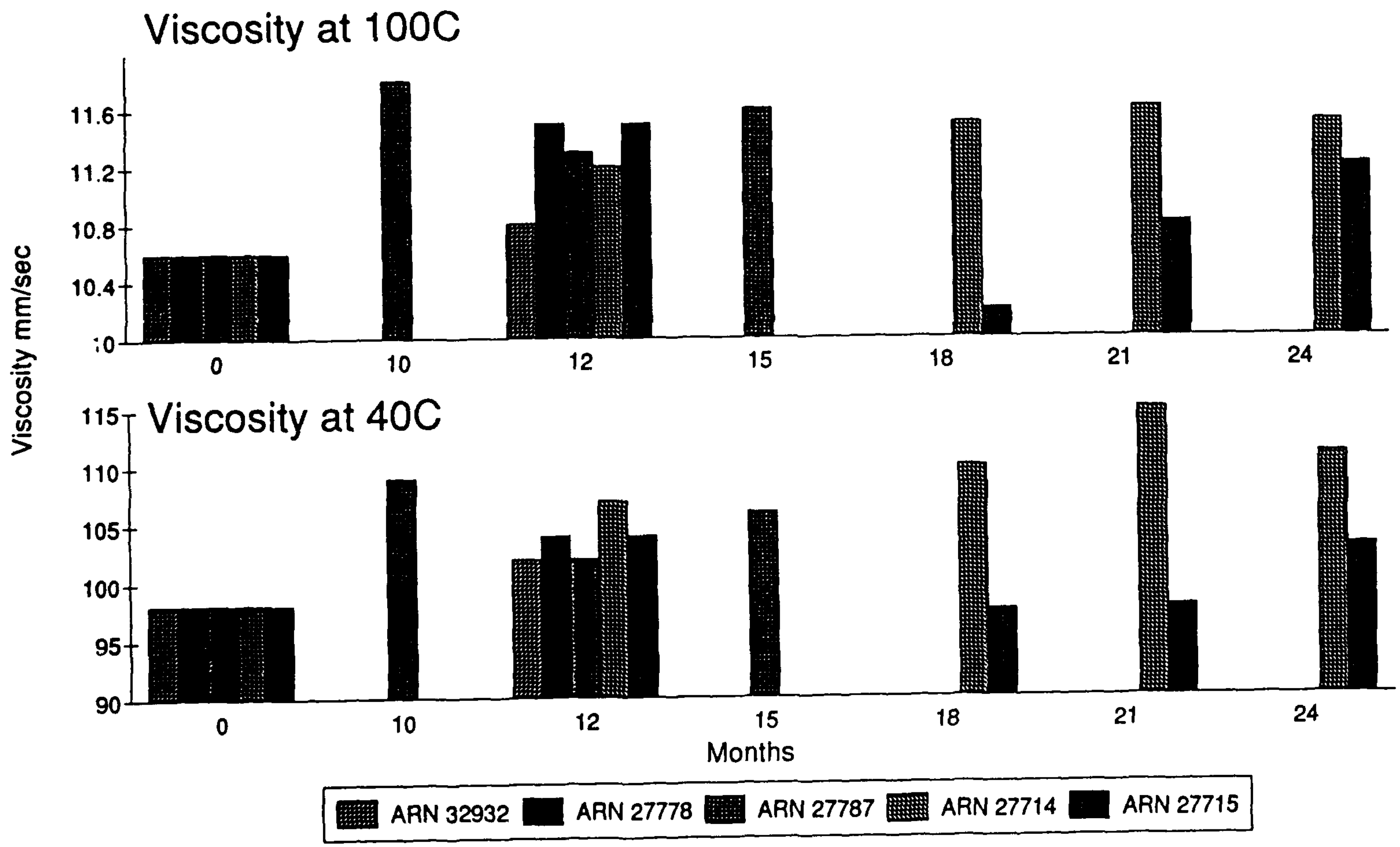

FIGURE 5

Viscosity Index

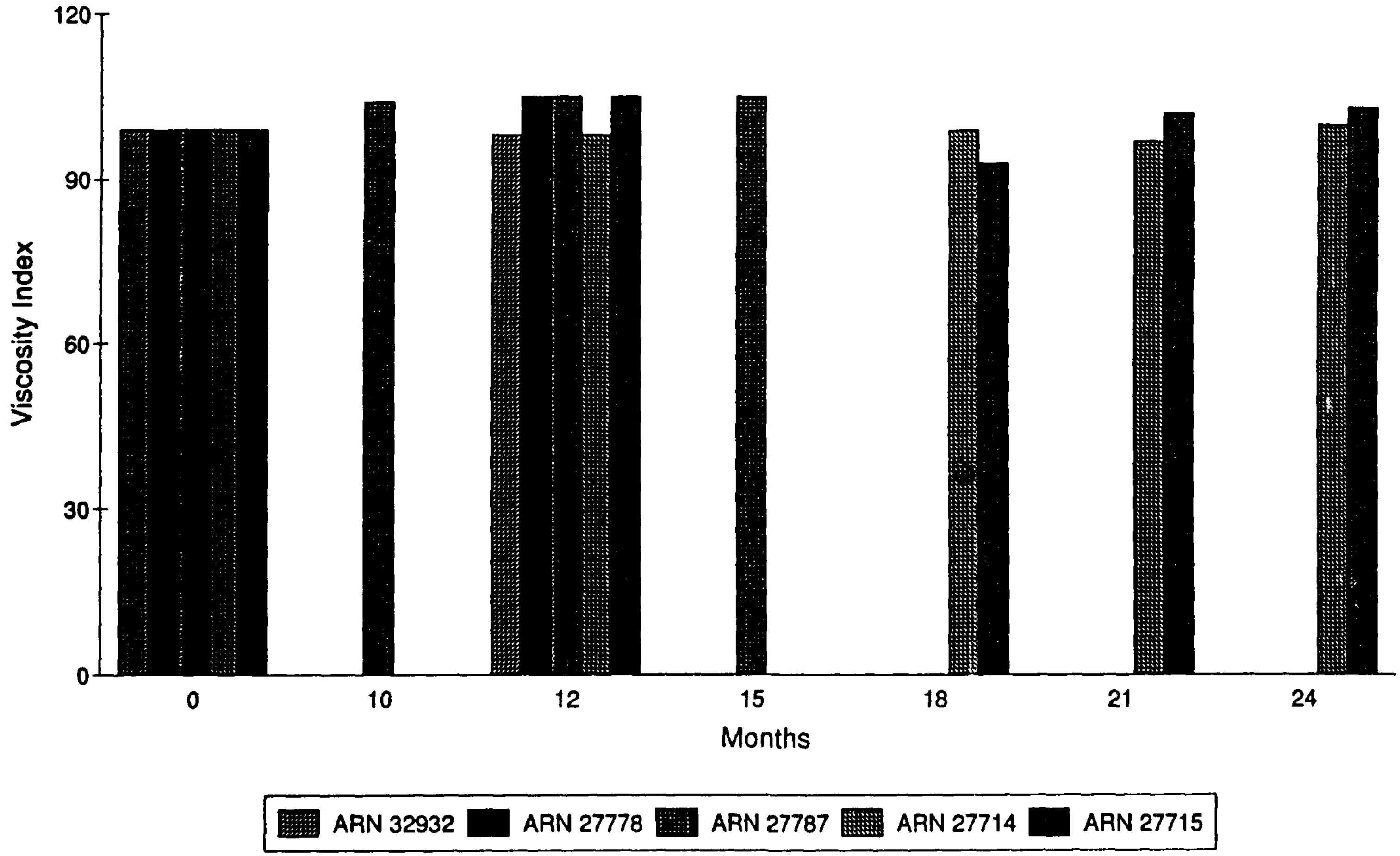

TABLE 1

ENGINE OILS

Vehicle No. ARN 32932 **Engine No.** **5381**

SAMPLE DATE	JUL 1988	JUN 1989
HOURS ON OIL	0	185.0
TBN mg KOH/g	11.1	10.5
TOTAL INSOLUBLES (Mass %)	0.02	0.80
VISCOSITY		
@ 40°C ($mm^2 sec^{-1}$)	98.1	102.0
@ 100°C ($mm^2 sec^{-1}$)	10.6	10.8
VISCOSITY INDEX	99.0	98.0

Note: Rear main engine seal failed, 41 litres of top up oil was added. Engine in for repair - trial completed.

TABLE 2

ENGINE OILS

Vehicle No. ARN 27778 **Engine No.** 6494

SAMPLE DATE	JUL 1988	JUN 1989
HOURS ON OIL	0	56.0
TBN mg KOH/g	11.0	10.7
TOTAL INSOLUBLES (Mass %)	0.02	0.30
VISCOSITY		
@ 40°C ($mm^2 sec^{-1}$)	98.1	104.0
@ 100°C ($mm^2 sec^{-1}$)	10.6	11.5
VISCOSITY INDEX	99.0	105.0

Note: Transmission failed - trial completed.

TABLE 3

ENGINE OILS

Vehicle No. ARN 27787 **Engine No. 5763**

SAMPLE DATE	MAR 1989	DEC 1989	MAR 1990	JUN 1990
HOURS ON OIL	0	146.0	157.0	206.0
TBN mg KOH/g	11.0	11.0	10.8	10.8
TOTAL INSOLUBLES (Mass %)	0.02	0.36	0.41	0.44
VISCOSITY				
@ 40°C ($mm^2 sec^{-1}$)	98.1	109.0	102.0	106.0
@ 100°C ($mm^2 sec^{-1}$)	10.6	11.8	11.3	11.6
VISCOSITY INDEX	99.0	104.0	105.0	105.0

TABLE 4

ENGINE OILS

Vehicle No. ARN 22714 **Engine No. 5417**

SAMPLE DATE	JUL 1988	JUN 1989	DEC 1989	MAR 1990	JUN 1990
HOURS ON OIL	0	100.0	207.0	210.0	269.0
TBN mg KOH/g	11.0	10.8	10.6	10.6	10.8
TOTAL INSOLUBLES (Mass %)	0.1	0.4	0.71	0.92	0.75
VISCOSITY					
@ 40ºC ($mm^2 sec^{-1}$)	98.1	107.0	110.0	115.0	111.0
@ 100ºC ($mm^2 sec^{-1}$)	10.6	11.2	11.5	11.6	11.5
VISCOSITY INDEX	99.0	98.0	99.0	97.0	100.0

TABLE 5

ENGINE OILS

Vehicle No. ARN 22715 **Engine No. 5587**

SAMPLE DATE	JUL 1988	JUN 1989	DEC 1989	APR 1990	JUN 1990
HOURS ON OIL	0	84.0	121.0	132.0	155.0
TBN mg KOH/g	11.0	11.0	10.9	10.7	11.0
TOTAL INSOLUBLES (Mass %)	0.1	0.56	0.29	0.32	0.20
VISCOSITY					
@ 40ºC ($mm^2 sec^{-1}$)	98.1	104.0	97.5	97.8	102.5
@ 100ºC ($mm^2 sec^{-1}$)	10.6	11.5	10.2	10.8	11.2
VISCOSITY INDEX	99.0	105.0	93.0	102.0	103.0

TABLE 6

TRANSMISSION OILS

Vehicle No. ARN 32932 **Engine No. 5771**

SAMPLE DATE	JUL 1988	JUN 1989
HOURS ON OIL	0	185.0
TOTAL INSOLUBLES (Mass %)	0.01	0.20
VISCOSITY		
@ 40°C ($mm^2 sec^{-1}$)	34.5	34.8
@ 100°C ($mm^2 sec^{-1}$)	5.5	5.5
VISCOSITY INDEX	105.0	104.0

Note: Due to engine seal failure the powerpack was removed for repair - trial completed.

TABLE 7

TRANSMISSION OILS

Vehicle No. ARN 27778 Engine No. 6327

SAMPLE DATE	JUL 1988	JUN 1989
HOURS ON OIL	0	56.0
TOTAL INSOLUBLES (Mass %)	0.01	0.10
VISCOSITY		
@ 40°C (mm^2 sec^{-1})	34.6	34.2
@ 100°C (mm^2 sec^{-1})	5.5	5.4
VISCOSITY INDEX	105.0	101.0

Note: Transmission failed - trial completed.

TABLE 8

TRANSMISSION OILS

Vehicle No. ARN 27787 **Engine No. 5750**

SAMPLE DATE	MAR 1989	DEC 1989	MAR 1990	JUN 1990
HOURS ON OIL	0	146.0	157.0	206.0
TOTAL INSOLUBLES (Mass %)	0.01	0.03	0.03	0.05
VISCOSITY				
@ 40ºC ($mm^2\ sec^{-1}$)	34.6	35.8	35.0	36.2
@ 100ºC ($mm^2\ sec^{-1}$)	5.5	5.6	5.5	5.7
VISCOSITY INDEX	105.0	104.0	102.0	107.0

TABLE 9

TRANSMISSION OILS

Vehicle No. ARN 27714 **Engine No. 6369**

SAMPLE DATE	JULY 1988	JUNE 1989	DEC 1989	MAR 1990	JUNE 1990
HOURS ON OIL	0	100.0	207.0	210.0	269.0
TOTAL INSOLUBLES (Mass %)	0.01	0.02	0.06	0.06	0.08
VISCOSITY					
@ 40°C ($mm^2\ sec^{-1}$)	34.6	34.5	36.6	35.4	36.7
@ 100°C ($mm^2\ sec^{-1}$)	5.5	5.6	5.8	5.9	5.8
VISCOSITY INDEX	105.0	111.0	109.0	120.0	109.0

TABLE 10

TRANSMISSION OILS

Vehicle No. ARN 27715 **Engine No.** 5889

SAMPLE DATE	JULY 1988	JUNE 1989	DEC 1989	APR 1990	JUNE 1990
HOURS ON OIL	0	84.0	121.0	132.0	155.0
TOTAL INSOLUBLES (Mass %)	0.01	0.06	0.06	0.08	0.09
VISCOSITY					
@ 40°C ($mm^2 sec^{-1}$)	34.6	34.7	35.6	37.5	36.6
@ 40°C ($mm^2 sec^{-1}$)	5.5	5.5	5.5	5.9	6.0
VISCOSITY INDEX	105.0	104.0	100.0	110.0	119.0

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