THE DOUBLING OF OIL DRAIN INTERVALS ON A DAEWOO DE12T/TI ENGINE

Ian M Cox - Glacier Filter Products
I.J. Chung - Daewoo Heavy Industries
R.F. Williams - T&N Technology

The 1990's have seen a quantum shift in global attitudes to the rate of use of natural resources and the disposal of hazardous wastes. Individuals and corporate bodies have all become more aware of the environment resulting in legislation to reduce hazardous waste.

One primary area of attack has been the reduction of hazardous waste from internal combustion engines, through the control of both tailpipe emissions and oily waste. Daewoo Heavy Industries, who manufacture a range of industrial and commercial diesel engines have worked with Glacier Filter Products to reduce the amount of drain oil generated by increasing the oil drain period through the fitment of a Glacier centrifugal bypass oil cleaner.

A series of engine tests were conducted at T&N Technology by Glacier on a six cylinder, 11 *l* turbodiesel engine supplied by Daewoo. Various filtration options were investigated, the objective being to double the standard oil drain interval. Oil analysis results showed conclusively that the fitment of a Glacier bypass oil cleaning centrifuge does enable the doubling of oil drain intervals on this engine.

INTRODUCTION

Since the mid 1980's there has been a steady rise in public awareness of a wide range of environmental issues. Diesel engines - once seen as a clean alternative to petrol - came to be viewed by public and politicians alike as gross polluters, resulting in pressure both from legislation and public opinion for diesel manufacturers to clean up their acts (1). Figure 1 illustrates this trend with the progression of European diesel tailpipe emissions legislation.

The pressure has been not only on tailpipe emissions however but on reducing the amount of total waste generated by diesel engines. This has led to a focus on reducing the amount of waste oil and oily filters associated with the life of a unit. Operators have also put pressure on manufacturers to reduce the total life cost of such engines. Manufacturers have responded by reducing the number of service parts and by extending service intervals and component life.

The extension of oil drain intervals is a key factor in addressing these issues and it is one which many manufacturers are actively pursuing. Extending drain intervals presents a number of problems however; contaminants accumulate in the lube oil

Federal-Mogul Oil Conditioning Systems: Winterhay Lane, Ilminster, Somerset TA19 9PH, England.
Tel: (+44) 0460 53221 Fax: (+44) 0460 55597 Telex: 46175 GLAMET G

which eventually define the lubricant life, both directly through particulate wear and viscosity increase, and indirectly through the depletion of the oil's additive package and the formation of harmful
chemical compounds (2). Field experience has been shown to support the considerable body of research evidence that lubricant contamination control is the dominant factor in determining effective lubricant life (3) (4) (5).

When Daewoo Heavy Industries faced the desire to extend oil drain intervals on their DE12T/TI 11*l* diesel engine they tackled the issue by contacting Glacier Filter Products (a T&N Group Company) to investigate the possible use of a centrifugal bypass oil cleaner (6) to control contaminant build up over the extended drain period. Unlike barrier filtration techniques the centrifuge removes particles based on density differences rather than size and hence it can remove contaminants down to sub-micron levels. This enables carbonaceous products of combustion to be effectively removed, greatly aiding viscosity control (7).

An engine test programme was set up by Glacier at their central R&D facility, T&N Technology near Rugby, in conjunction with Daewoo in order to determine to what degree oil drain intervals for the DE12T/TI engine could be extended using a Glacier centrifugal oil cleaner.

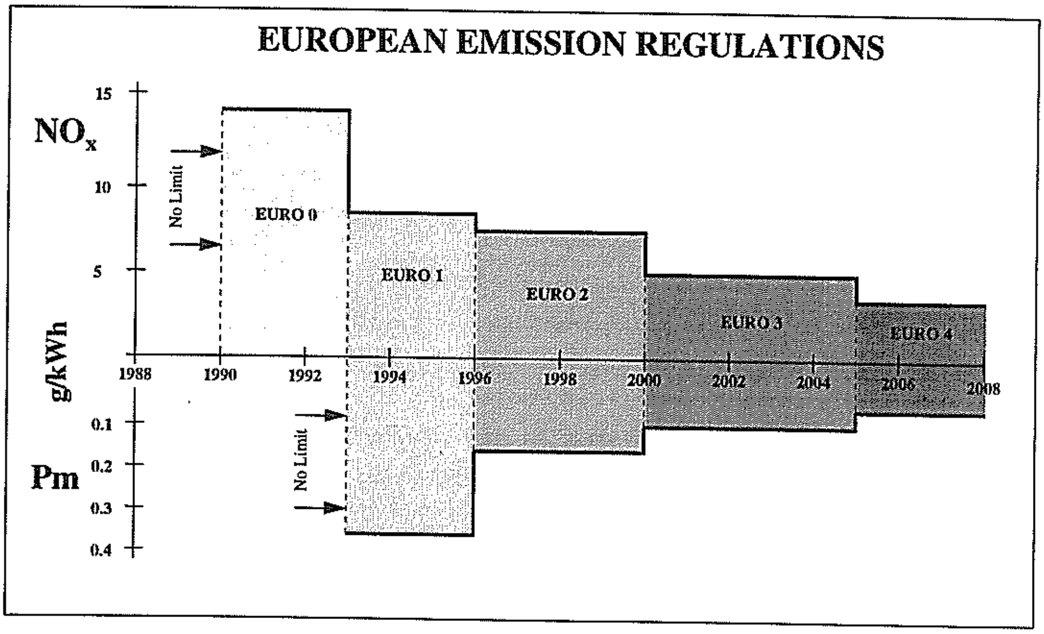

Figure 1. European Emissions Regulations

THE DE12T/TI ENGINE

Daewoo manufacture a wide range of diesel engines at their plant in Inchon, Korea, including high speed diesels of the truck and automotive type ranging from 25 kW to over 400 kW. The DE12T/TI engine sits in the middle of this range as can be seen from table 1 and figure 2, the engine specifications.

Typical applications for this engine include buses, dump trucks & excavators as well as stationary and marine use. It was in vehicle applications however where Daewoo perceived the greatest need for an extension of service interval.

Table 1. Main engine specifications

Specification	DE12T
Type:	4 stroke, turbocharged, water cooled, vertical in - line, direct injection diesel.
Cylinders:	6
Compression Ratio:	16.5:1
Lube Oil Capacity:	20*l*
Standard Oil Filtration	Single 40μm abs. paper cartridge
Cooling Water Capacity:	19*l*
Fuel Injection Timing:	14° BTDC
Fuel Injection Pump:	In - line (PE - P)
Governor:	RFD Type
Bore x Stroke:	123mm x 155mm
Displacement:	11.1*l*
Maximum Power (DIN 70020):	212kW @ 2200r.p.m.
Maximum Torque (DIN 70020):	999Nm @ 1400r.p.m.

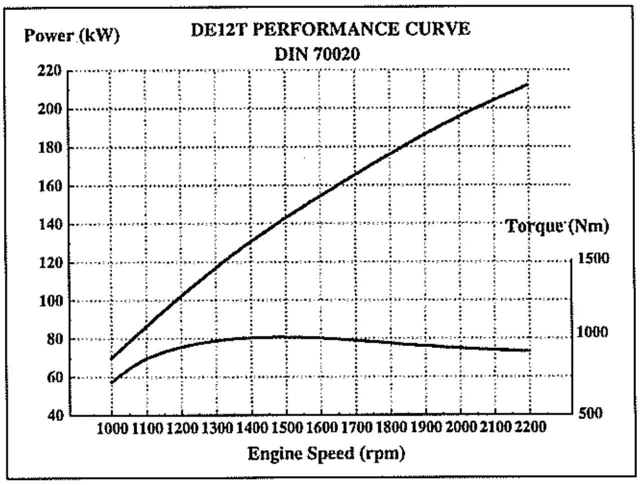

Figure 2. Engine performance curves

THE CENTRIFUGE AND SCREEN

Three filtration regimes were investigated in this series of tests. They were as follows:

- Standard full flow filter only
- Standard full flow filter with bypass centrifuge
- Full flow metal mesh screen with bypass centrifuge

The standard filtration system on the engine was a single cartridge type full flow paper media filter. For the second and third tests a Glacier model GF050 disposable rotor type centrifuge was fitted to the engine block. Oil to feed the centrifuge was taken from the main gallery and returned to the sump under gravity.

How the centrifuge works

Unlike a media filter the oil cleaning centrifuge does not rely on a barrier to trap particulate matter. Instead oil is fed through a vertical spindle onto which is mounted a rotor. Oil flows through the rotor and exits at the base via a pair of tangentially opposed nozzles. The thrust generated by the exiting oil causes the rotor to spin at speeds of up to 8,000r.p.m. (for this size of rotor). The motion of the rotor causes the contaminated oil flowing through it to be subjected to a significant centrifugal force. Particles which have a higher density than the base oil are separated out to form a dense, hard "cake" around the inner wall of the rotor leaving the clean oil to return to the sump.

The centrifuge has one distinct advantage over media bypass filtration methods in that its cleaning efficiency remains virtually constant over its life, there not being any media barrier to block or bypass valve to open (8).

Since the oil gives up all its energy to rotate the rotor, once it has left the nozzles it must be allowed to drain back to the sump under gravity. This makes the device ideally suited for bypass filtration where a small proportion of the total oil flow (≈ 10%) is taken from the main circuit, filtered to a high cleanliness level and returned to the sump in a continuous loop.

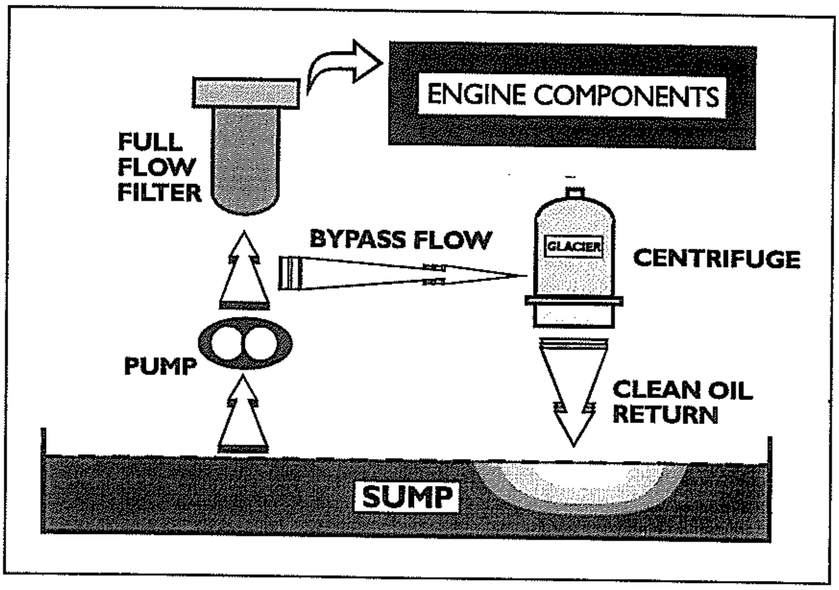

Figure 3. The theory of bypass filtration.

The full flow screen

Since the centrifuge relies on density differences it is able to remove very small particles. Analysis of sludge collected by centrifuges (9) shows particles typically from 0.1μm to 100μm with 80% of the particles being below 5μm in size. This ability to remove the small harmful debris combined with the large dirt holding capacity offered by the centrifuge makes it possible to alter the way full flow filtration is viewed.

With a centrifuge in the system the full flow filter is reduced to the role of an "insurance policy" to stop the occasional large piece of debris which would cause catastrophic failure if it were to reach the engine's working parts. This role can be fulfilled by a relatively coarse filter and this allows the use of a fairly compact metal screen type unit (10). The use of a relatively coarse full flow metal screen allows long filter service intervals since it will need to retain fewer particles and also gives the possibility of fully cleanable filtration systems.

In the second phase of these tests a full flow screen which had an absolute rating of 60μm was fitted in place of the standard paper cartridge. Glacier manufacture a range of similar screens using woven stainless steel wire mesh housed in a long life stainless steel canister. The element is removable for cleaning via a patented bayonet - type fitting. A special screen was produced for the Daewoo engine to fit the existing full flow filter mounting head, the surface area of the mesh used was calculated from the engine oil flow to give the appropriate pressure drop characteristics.

ENGINE TEST PROCEDURE

Engine testing was conducted on a fully enclosed test bed using a Froude - Cosine water brake dynamometer. The engine was appropriately instrumented and the following parameters were logged throughout the test:

- Power
- Torque
- Blowby
- Oil Consumption
- Oil Level
- Fuel Temperature
- Oil Temperature
- Water Temperature
- Exhaust Temperature
- Air Cleaner Depression
- Centrifuge Rotor Speed

Test cycle

Three tests were run on the engine. Initially the standard engine was run with full flow paper filtration for 150hrs (the standard drain interval). Two further runs were made, both of 300hrs duration, one with paper full flow filtration plus a bypass centrifuge and one with a 60μm full flow screen plus a bypass centrifuge. For all three runs the test cycle was as follows:

- Maximum Power 25 mins
- Idle 5 mins
- Maximum Power 25 mins
- Idle 5 mins
- Maximum Torque 25 mins
- Idle 5 mins
- Maximum Torque 25 mins
- Full Speed, No Load 5 mins

Normal service activities such as adjusting the valve lash were conducted at intervals as specified for the engine by Daewoo.

Oil

The oil used in the tests was **Shell Rimula X 15W40,** a good quality "CD" rated turbo diesel engine oil common amongst fleet users and meeting the Daewoo oil specification. For each test the sump was initially filled to the maximum mark on the dipstick. The level was checked every 24hrs however no oil was added until the level reached the "low" mark. The sump was then topped up with fresh oil to the "low" mark every 24hrs for the remainder of each test.

OIL ANALYSIS

A 50ml oil sample was taken every 24hrs for analysis by an independent oil analysis laboratory. Centrifuge debris from the second and third tests was also collected and analysed.

Oil analysis techniques

A series of standard techniques (11) were used in the analysis of the samples from these tests. These included the following:

- Spectrographic analysis by ICP. This was used to give an indication of the levels of individual elements within the oil. It is most useful for heavier elements and gives good results for wear metals and ingested contaminants. ICP does not however give a clear picture of particulate contamination levels since it is relatively insensitive to particles larger than about 2μm.
- FTIR or "Infra-Red Analysis". This technique gives information about the relative levels of different substances within the oil by measuring the relative absorbency of different wavelengths of infra red light. This technique is good for identifying compounds and gives good results with additive elements.
- Total Insolubles by the Modified Blotter Spot method. A physical method used to give a direct reading of the total amount of insoluble material within the oil. The method is quick and accurate. With diesel oil samples there is a good correlation between total insolubles values and soot.
- Physical analysis. A range of standard physical tests for factors such as viscosity and water content.
- Chemical analysis. A range of standard chemical tests for factors such as TBN and nitration.

Oil analysis results

A large amount of data was generated from the analysis of the samples from the three tests. A selection of the more relevant data are presented here. All the remaining data however followed the same trends and no anomalous results were found.

Figure 4 shows the total insolubles levels in the oil (by modified blotter spot technique) over the duration of the three tests. It can be clearly seen that the level of insolubles rises faster in the engine with standard filtration than in either of the tests where a bypass centrifuge was fitted. It is also clear that the levels of insolubles reached by the engines with a centrifuge at 300hrs operation were still lower than the level achieved by the standard filtration system after 150hrs of operation.

The curves for the engine test conducted with the centrifuge and paper filter and the engine test with centrifuge and metal screen are very similar. This indicates that the reduction in the level of insolubles from a standard engine is due to the bypass centrifuge and that the full flow filter is playing a minor role in controlling these particles.

The shape of the two centrifuge curves also shows a "plateau" effect after about 200hrs. This is not unusual since the efficiency of a centrifugal oil cleaner is inversely proportional to oil cleanliness. It is therefore possible to reach a semi equilibrium point where the contaminant removal rate is similar to the rate of contaminant generation. In this situation chemical and thermal effects would be more likely to determine the life of a lubricant rather than contamination.

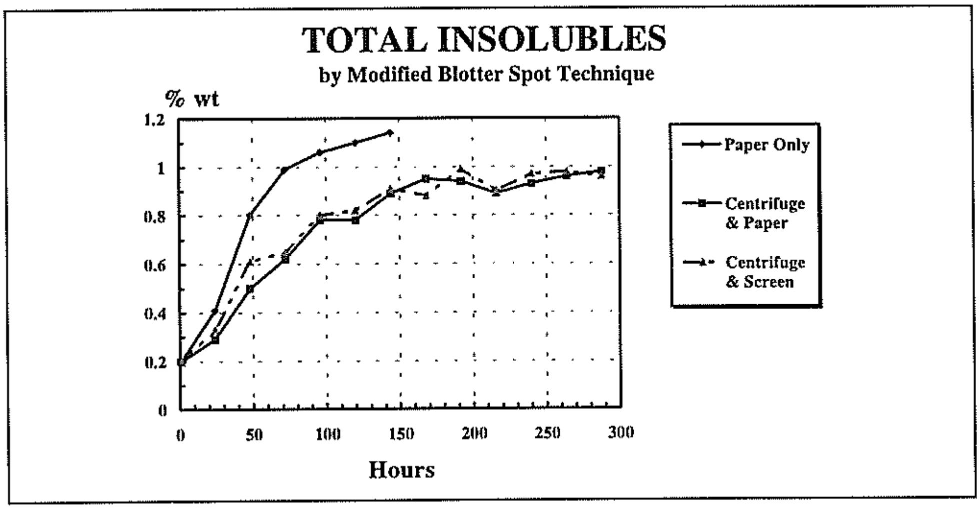

Figure 4. Total insolubles levels.

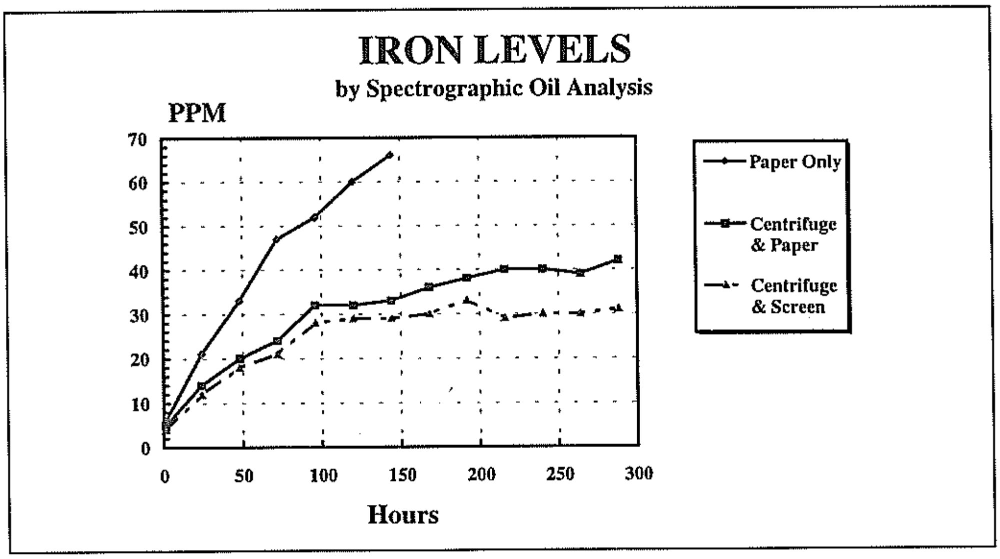

Figure 5. Iron levels (spectrographic).

Figure 5 shows the effect of the different filtration systems on the level of iron in the lubricating oil. Iron is a key indicator of engine wear and is normally the primary metallic element found in diesel engine oil (10). It can be clearly seen that as with the total insolubles the levels of iron in the two engines fitted with centrifuges are significantly lower than in the engine fitted with a standard filtration system.

Figure 6 is a plot of the spectrographic analysis results for lead in the lubricating oil. Lead is a prime constituent of big-end and main bearing materials and its presence in the oil in large quantities is a sign of bearing wear. It can be seen from figure 6 that although the overall levels of lead are low in all three tests there is significantly less observed in the two engines with centrifuges fitted.

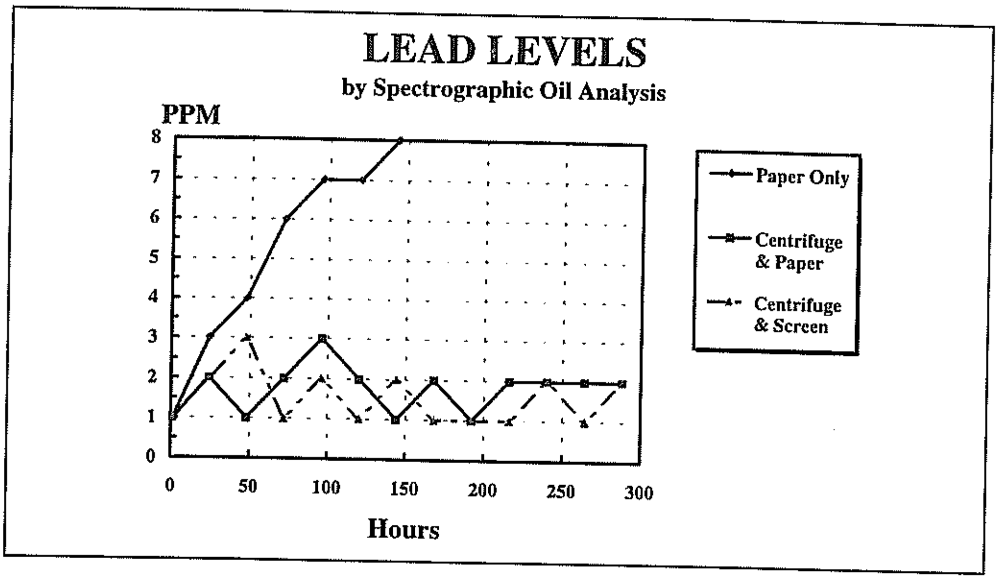

Figure 6. Lead levels (spectrographic).

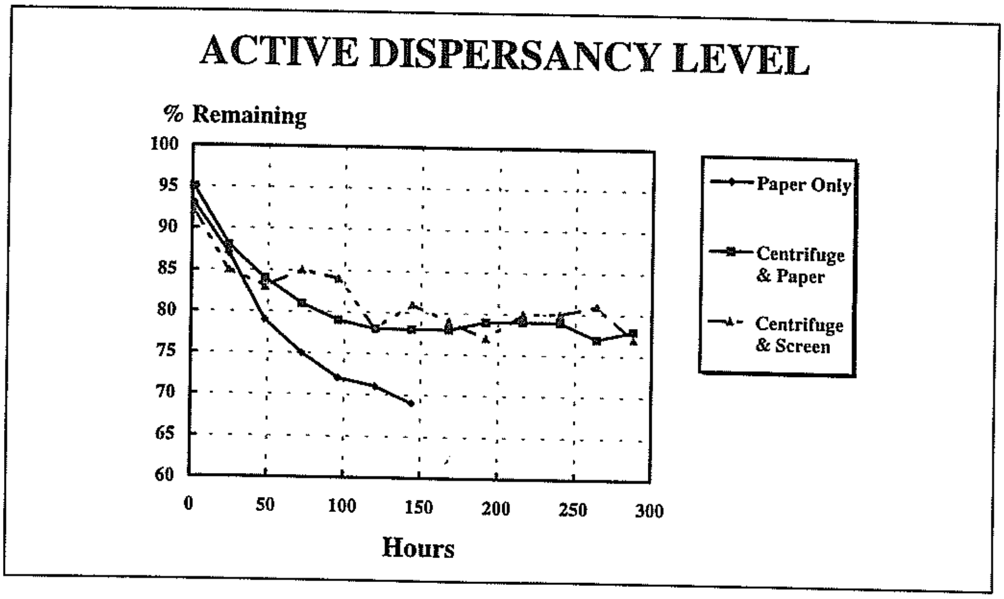

Figure 7. Remaining active dispersancy levels.

The significant difference between the curves for lead is probably due to a combination of reduced bearing wear achieved through reduced overall contamination and the fact that the high density of lead makes it easy to remove with the centrifuge. This result also shows no appreciable difference between the engine with centrifuge and paper filter and the engine with centrifuge and metal screen.

The removal of significant amounts of contaminant from an engines oil system reduces the rate of contaminant generation and hence makes a considerable impact on the long term cleanliness of the system (12). Figure 5 illustrates this effect well with a large proportion of the relatively dense iron particles being removed by the centrifuge

Figure 7 is a plot showing the rate of depletion of active dispersancy additive, one of the key components in the oil additive package, over the three tests. Dispersancy additives, together with detergency additives control the way in which contamination and particularly combustion products are held within the oil (13). Detergents are designed to prevent deposits from building up on engine surfaces whilst dispersants prevent the agglomeration of smaller particles (particularly soot) into larger more destructive clusters. Both these additives are "active" and are consumed from the oil package during use. By removing more of the soot and other contaminant particles prior to them becoming fully saturated with dispersancy molecules it can be seen that the centrifuge system helps to prolong the life of the dispersancy package.

CENTRIFUGE DEBRIS ANALYSIS

In addition to the oil, the rotors from the two centrifuge tests were analysed (9). The rotors were fully drained and weighed. The initial rotor weight was then subtracted from the total to give a contaminant weight. Because of the high centrifugal forces generated by the rotors during operation the contaminant collected contains very little residual oil and the drain and weigh technique has been found to give a very good measure of the total contaminant removed from the oil. The results are ,as follows:

Table 2. Centrifuge rotor deposits.

Test Designation	Weight of Contaminant in Rotor
Centrifuge with paper full flow filter	350g
Centrifuge with metal mesh screen	387g

From the results in Table 2 (above) the theoretical total insolubles level for an engine run for 300hrs without a centrifuge fitted can be calculated at approximately 3.15%, assuming a mass of oil in the sump of 17,673g.

The increased mass of contaminant captured by the rotor in the engine with the full flow metal screen was due to the larger pore size of the metal screen allowing the centrifuge access to a larger size range of debris than the system fitted with the paper filter.

CONCLUSIONS

The results of the oil analysis from the three engine tests show that the useful life of the lubricating oil in a Daewoo DE12T/TI engine can safely be extended by at least 100%, under the quite severe load and speed conditions imposed by this test cycle, by the fitment of a bypass centrifuge either in conjunction with a full flow paper filter or full flow metal mesh screen. A significant reduction was observed in the levels of all major contaminants within the lubricating oil in the engines fitted with a bypass centrifuge compared to a standard engine filtration system. Reduced levels of iron and lead seen in the centrifuge engines also indicate a probable reduction in engine wear.

The use of a full flow metal mesh screen in combination with a bypass centrifuge has been shown to give results comparable with a full flow paper filter and bypass centrifuge system. This indicates that the critical part of the system with regard to controlling oil cleanliness is the bypass centrifuge. This result also makes possible the use of totally cleanable filtration systems, by using cleanable long life coarse metal screens in full flow applications to overcome the problems of age deterioration associated with paper and similar media.

There are many engines of this size and type in the global marketplace and with the demand for longer service intervals rising the ability of a manufacturer to offer extended drain intervals through this technology is sure to bring commercial as well as environmental benefits.

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