

LUBRICANT DEVELOPMENT TO MEET THE CHALLENGE OF EUROPEAN EMISSIONS CONTROL LEGISLATION



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The following article is a summary of a presentation given on behalf of the BLF by Colin Middleton, BLF Vice President, Marketing and Communications, at the Institute of Road Transport Engineers Conference at Telford last May. As part of the agreed Marketing and Communications initiative, the BLF will become increasingly involved in presentations to suitable organisations on lubricant-related topics.

This article describes how American API and European CCMC and ACEA specifications have been driven by the impact of Emissions control legislation both sides of the Atlantic since the mid- 80's. The approaches and evolution in engine designs to achieve the legal limits set for Emissions Control will be described, as will the lack of harmonisation of world-wide oil/fuel standards. Consensus on the latter would benefit Transport Engineers, the lubricants industry and particularly the OEMs. Historical examination of the US API categories highlights a progressive reduction in the life cycle of each category coupled with very substantial costs increases in testing costs. The API CD requirement introduced in 1995 remained in force for some 30 years before being updated; the associated test costs were some \$21K, whereas the forthcoming PC - 7 category for emission controlled engines with extended drain is only likely to survive some 4 years, at an estimated test cost of some \$435K.

The development funding costs of the 88 tests needed to achieve and verify PC-7 currently stand at \$1.78 million for the US lubricants and chemicals industries and \$250,000 for the engine manufacturers association.

On the European scene the original CCMC Sequences were introduced in 1983. Revisions taking place in 1989 (after 6 years) covered updated Emissions control and long drain specifications. In 1991 CCMC (Common Market Constructors Committee) was dissolved and replaced by ACEA.

(European Association des Constructeurs Européens d' Automobiles)

- ACEA was set up to replace CCMC sequences to remove tests that were obsolete and/or no longer available.
- Ensure that new sequences contain tests and classes that are suitable for ACEA members current and future needs IN Petrol, light duty and heavy duty diesel categories.
- Establish an Oil Quality Management system which was both externally auditable and supported by the appropriate test data.

The European Engine Lubricants Quality Management system (EELQMS) for short, is made up of:-

- The Motor Manufacturers (ACEA)
- The Additive Manufacturers (ATC)
- The Lubricants Marketeers (ATIEL)
- Test Developers (CEC) (Co-ordinating European Council) (Test Standardisation)

This is the most significant step forward to ensure the lubricants industry produce products that definitely meet OEM requirements.

ACEA sequences form the basis of a European Quality Management system for engine lubricants EELQMS is supported by all interested parties as demonstrated.

- All participants must be ISO 9000
- Test laboratories to be EN 45001 approved
- Both are externally auditable plus all relevant test documentation
- All Engine tests must be pre-registered since 1/10/95

i.e. no more "meets the requirements of", it either "does or it doesn't".

The benefits of ACEA performance requirements to the Fleet Operator may be summarised as follows:

Long drain: ACEA requires performance testing of lubricants to provide the engine protection necessary to allow drain intervals to be extended.

Greater fuel economy: Currently more relevant to petrol oil engine sequences

Lower Emissions - key driving force behind ACEA - 96 performance levels

Lower maintenance costs - ACEA requirements for Engine wear and soot/sludge control protection reduces engine deterioration and power loss i.e. performance retention.

ACEA categories cover 3 main types Petrol, light and heavy duty diesel. This presentation concentrates on Heavy Duty Diesel sequences E1, E2 and E3.

The 3 designations represent increasingly severe service for lower maintenance longer drain and conserved engine performance retention leading to maintained emissions over the life of the vehicle. Modern Euro 2 heavy duty engines are different from those which concerned CCMC in the past. Viscosity increase due to soot formations is a critical factor to be discussed shortly, hence the inclusion of the MACK T-8 test, until a suitable European test is determined, verified and the repeatability established. Mercedes Benz wear tests are relevant to all sequences due to the adoption of the OM364A and OM602A engine tests at MB227, MB228.1, MB228.3 and MB228.5 levels as indicated.

The need to harmonise fuel and lubricants specifications on a global basis would be beneficial to all industry groups affected by the changes due to:

- The escalating costs of multiple test approvals.
- International power train exchanges
- Increasing demand for modern lubricants in many new and developing markets
- Commonised power train design complexity.

To achieve standardisation a '3 tier' system for fuels and lubes is proposed each tier being related to the technology of the engine using the fuel or oil.

With time the performance of each tier would be increased. The lowest tier would become progressively restricted to a reducing percentage of the market as the developing countries made their standards more restrictive.

The development of a commonised specification between API and ACEA would be particularly beneficial to the UK market due to the large population of US parentage engines and less dependence on European truck engine builders in comparison with other European countries.

However, it would be unrealistic to expect harmonisation to be achieved before the year 2010. Whereas the desire to achieve standardisation exists particularly amongst global OEM's the influence currently exerted by regional OEM's in terms of specific engine tests both in and outside ACEA, CEC, API, ASMT and JAMA will continue to frustrate the process of harmonisation until well into the next millennium and probably beyond 2010.

The BLF believe that the proper selection of tests and limits could cost effectively achieve the goals of the OEMs for international harmonisation and provide a cost effective and focused means of significantly improving oil quality.

It would be as well to now review the multiple factors facing the lubricant developers which in many instances technically compete against each other in the desire for universal all embracing products which, as will be discussed, is becoming increasingly difficult to achieve.

The key driving force is of course, emissions control. This has had a direct impact on:

- API / ACEA specifications and updates
- OEM Engine design parameters and evolution
- Fuel lubricity and economy
- Long drain and base oil selection criteria

All ultimately have a stress impact on the lubricant.

The primary challenge of Emissions Control legislation is the trade off between particulate

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matter (Soot) and Nitrogen Oxide Emissions reduction.

Many engine manufacturers have adopted Retarded Injection Timing as a means of controlling NOx but this increases soot loading on the engine as a consequence. This phenomena can be aptly illustrated when we look at the impact of reduced NOx on API performance Categories.

As NOx is reduced, soot increases.

The current development of API PC-7 due in 1998 also includes 3 additional tests of CAT 1P, MACK T-9 and Cummins M11 all of which concentrate on Soot and Sludge Control, filter pressure drop and consequential component wear.

In Europe controls on particulates and NOx emissions have been reduced by 72% and 37.5% respectively in a time frame of only 6 years.

Since 1988 significant step changes in emissions control have taken place in most Heavy Duty Diesel Engine designs. Satisfactory Naturally Aspirated direct injection engines in 1988 have to incorporate, Turbo-intercooled, after cooled, Reduced Sulphur fuel and electronic injection (EUI) to meet a 6 fold reduction necessary to meet the 1991 level. Piston redesign to reduce oil consumption and optimised combustion were needed to achieve the 1994 level.

The particulate and NOx levels for the proposed 1998 limits will require significant development of most European Engines. The law of diminishing returns is now coming into play. After treatment methods such as EGR, De-NOx catalysts and particulate traps do all have an impact on Cost, soot loading lubricant stress and Engine performance retention.

The vast cost associated with engine development and the validation and implications of each desired change results in a steady evolution of each engine over time. There are currently 9 major options all having a direct impact on Emission Control, lubricant stress and as a consequence, long drain potential.

Most EURO 2 Emission control engine builders have adopted **HIGH PRESSURE** fuel injection and **RETARDED TIMING**, Mercedes Benz and MAN are no exception. Volvo, Scania and RVI have also fitted **RE-DESIGNED PISTONS** - Incorporating high top ring and **TIGHTER BORE CLEARANCES**.

However the impact on the lubricant combines soot loading with thermal and piston deposits. The reduced oil consumption limits top up between drain intervals thus preventing additive replenishment to combat thermal and piston deposit formation.

The nine major step change options for EURO 2 and beyond revolve around timing and injection, piston/combustion chamber design, and after treatment.

High Pressure Injection and Retarded Injection Timing (RIT) tend to go hand in hand as the former provides improved combustion, less particulate matter and more NOx the latter reduces peak temperature, produces less NOx but more particulate matter. Hence RIT increases soot loading potential whereas High Pressure Injection increase the possibility of sludge through higher temperature combustion. The combination provides potential balance for optimum efficiency in achieving Emissions Control.

PILOT INJECTION and **WATER INJECTION** both reduce peak combustion temperature and reduce NOx. The former reduces fuel dilution potential of the lubricants. A PLUS where as the latter can result in emulsification of the oil reducing film thickness - Oil and Water do not mix!

EXHAUST GAS RECIRCULATION (EGR) is a technology that can be employed to achieve post-Euro 3 emission limits, such as those expected for Euro 4 (of under 3g/kwh NOx) EGR and pilot injection are likely to be the best technological developments with minimum fuel consumption deterioration.

Possible concerns over the use of EGR in heavy duty engines (apart from complexity and cost) relates mostly to increased component wear. Solutions to reduce wear include rapid warm up (or no EGR when cold). Centrifugal Oil filtration, appropriate ring/liner/bearing design and material specification and advanced lubricant formulations

DE-NOx CATALYSTS and **PARTICULATE TRAPS** : For Euro 3 deadlines, widespread after-treatment for truck engines is not considered feasible. While the adoption of oxidation catalysts and particulate traps or filters are thought to be inevitable in the longer term much research and development of electrically-regenerated, fuel fired or catalysed (by using fuel additive) options is continuing.

Running costs over the vehicle life continue to be the most important competitive issue of OEMs, with fuel consumption and maintenance requirements of major impact. There is a continued trend in higher specific power outputs that leads to increased load carrying capability. Although extended drain periods are desirable these are likely to remain at current levels due to the trend in reducing oil consumption, sump size and the implications of EGR.

Emissions control has given a dramatic impetus to the development of engine design over the past 10 years. A typical example of EURO 2 type engine development would be Volvo.

Increased combustion efficiency and emission control improvements through multi valve heads, overhead cams and Electronically Controlled Unit Injection (EUI).

Power output and torque has increased by 16.6% and 27% respectively.

A 50% increase in oil drain intervals and a 40% reduction in oil consumption combined with a small reduction in sump capacity again emphasise the substantial increase in stress upon the lubricant. Lubricant stress has increased by 300% since 1990!

Over the last 10 years average oil consumption in heavy duty diesels has reduced by more than 70% hence 3½ times less additive replenishment potential.

Other change forces include:

Diesel Fuel lubricity (due to low sulphur fuels) resulting in potential fuel pump wear and injector problems without appropriate fuel additive additions. Such additive and by-products of combustion must be compatible with the lubricants

Euro 3 and especially beyond pose a significant challenge in terms of potential fuel economy deterioration. With further injection retardation not acceptable and emphasis on achieving low NOx emission, the PM/NOx trade off is

essentially superseded by a fuel economy/NOx choice.

Oil Viscosity is an area of investigation to reduce drag through the adoption of 10W/5Ws - see the latest MB 228.5 specification.

However, viscosity choices will compound the escalation in cost of lubricant development and testing. Long drain could now be reaching its ceiling unless significant improvements in particulate control reduction and removal can be achieved.

The European lubricants market is now divided into 5 main product types governed by price at the low end and long drain potential within Euro 2 engines at the top end with Ultra high performance Diesel (UHPD) oils developing to meet Mercedes 228.5.

Clearly Fleet Management in the light of today's events have to review their perceived value of lubricants and consider the implications of the price/quality trade off on a reduced oil consumption.

Although a few manufacturers are still looking at extended drain beyond 100,000 km this is likely to be the ceiling for sometime and is only achievable using true UHPD type products, using non-conventional semi or fully synthetic base oils.

The dramatic step change between MB 228.3 and MB 228.5 in at least doubling the drain period is only achievable in the latest engine design and with an oil that meets the latest most stringent OM 364A test limits on cleanliness and wear reduction as a consequence.

The latest specification is heading to near perfection; with bore polishing down to less than 1µ; cylinder wear down to 2 microns; and piston cleanliness improvement of a further 30% plus to 50.

The evolution and stringency of the OM 364A test limits over the years has had a dramatic impact on both engine and lubricant design and forms the basis of all ACEA quality sequences for Heavy Duty Diesel engines.

The formulation parameters to meet 228.5 require an SAE 10W40 viscosity grade, part synthetic/hydro cracked based formulation and a significant increase in additive treatment levels by over 33% against current quality top tier SPHD oils to 228.3 specifications.

Basestock and additive system selection becomes much more critical in Euro 2 and beyond type engines for long drain application to 100,000 kms conventional quality base oils will deteriorate due to high temperature breakdown over time.

A combination of hydro-cracked and PAOs is likely to be the preferred option due to low temperature flow rates at start up and their purity with respect to resistance to high temperature breakdown and oxidation.

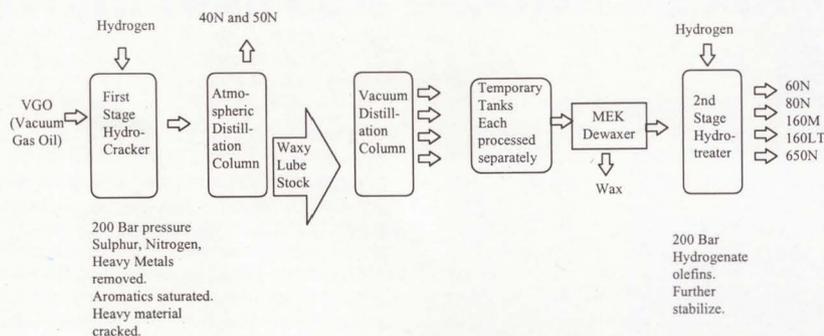
Esters although excellent on cleanliness due to natural solvency their cost and availability in volume combined with seal and additive compatibility problems are likely to remain a luxury for such applications

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Conventional : White Oil Stream



Due to differences in the selectivities of the two processes, there are differences in the composition and properties of base oils derived from this process and those resulting from the more conventional solvent de-waxing process.

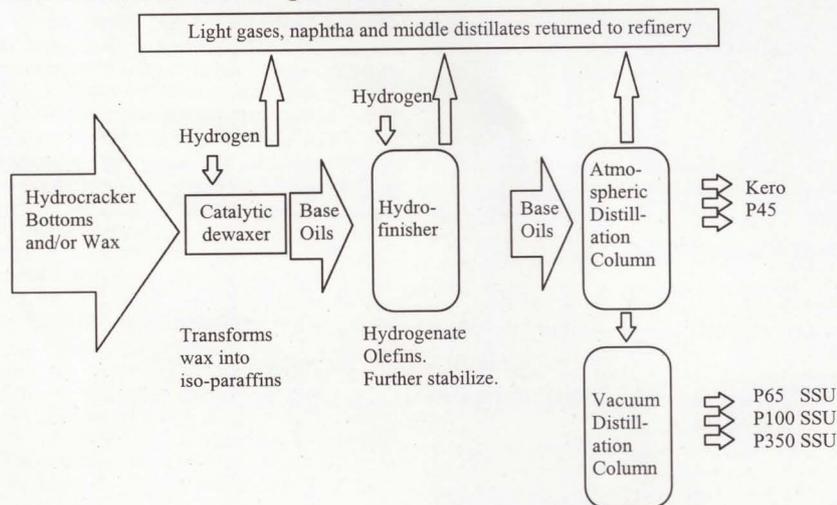
ISO DEWAXING

In the more recent iso de-waxing process, linear paraffins are isomerised to branched paraffins but remain in the same boiling range. Hydrocracked waxy feedstock is fed to the Catalytic Iso-Dewaxer and undergoes further molecular restructuring. This process only became viable following the development of a suitable catalyst by Chevron, since previously-tried catalysts had too low a yield. The product is then subjected to very sharp fractionation which yields a final base oil with low volatility. The result is to improve both de-waxed oil yields and at the same time to retain the favourable characteristics of very high viscosity indices. BLF members who attended the recent Overseas Technical Visit were able to witness this new innovation when visiting the Petro-Canada plant near Toronto, which has a capacity of over 250,000 tonnes/year.

At one time, it was considered that only synthetic products produced under strictly-controlled polymerisation conditions could meet the requirements demanded by increasingly higher-performance lubricants specifications. It is now evident that modern refining technology can yield mineral oil-derived basestocks which can almost equate to the physical characteristics of many synthetic fluids and at a considerably lower price.

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New Process : Iso-Dewaxing Stream



ISO-DEWAXED HYDROCRACKED BASE OIL COMPARISON WITH EXISTING BASE OILS

	9 cSt @ 40 C				
	ASTM METHOD	NAPHTHENIC OIL	NEW ISO-DEWAXED	SOLVENT REFINED	TECH WHITE OIL
Density @ 15 °C	D1298	0.895	0.829	0.845	0.841
Viscosity @ 40 °C	D445	9.04	8.9	10	8.8
Viscosity Index	D2270	41	100	100	100
Pour Point °C	D97	-51	-36	-9	-21
Flash Point COC °C	D92	144	176	150	168
NOACK @200 °C 1 hr	IP 421	NA	14.5	>18	>18
Aniline Point °C	D611	77	105	85	96
Carbon Type	D2140				
Analysis					
Aromatics Ca %		11	<1	4	2
Naphthenic Cn %		46	26	28	32
Paraffinic Cp %		43	74	68	66
FDA(b)		FAIL	PASS	FAIL	PASS

	4 cSt @ 40 C				
	ASTM METHOD	NAPHTHENIC OIL	NEW ISO-DEWAXED	SOLVENT REFINED	TECH WHITE OIL
Density @ 15 °C	D1298	0.860	0.8275	0.821	0.817
Viscosity @ 100 °C	D445	1.400	1.400	1.46	1.56
Viscosity @ 40 °C	D445	4.000	3.796	3.84	4.2
Viscosity @ -40 °C	D445	206	138	SOLID	SOLID
Pour Point °C	D97	-51	< -57	-9	0
Flash Point PMCC °C	D93	115	125	122	
Flash Point COC °C	D92				130
Aniline Point °C	D611	70	87.5	85	92
Carbon Type Analysis	D2140				
Aromatics Ca %		9	<1	4	<1
Naphthenic Cn %		37	37	26	30
Paraffinic Cp %		54	63	70	70
FDA(b)		FAIL	PASS	FAIL	PASS