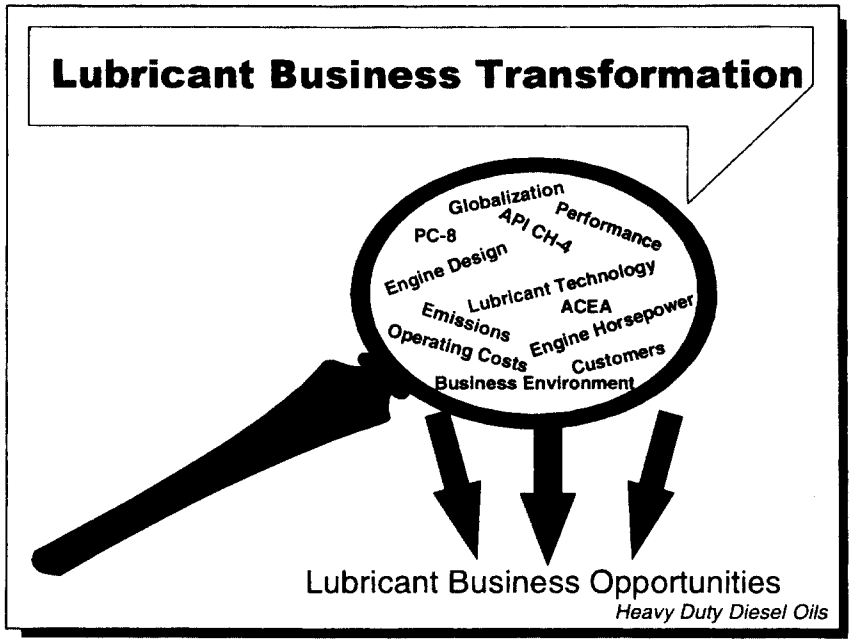
특별강연

1998 FUTURE DIRECTIONS
(Engine Oil, Motor Oil)

Joseph Chai

TECHNICAL MANAGER, LUBRIZOL

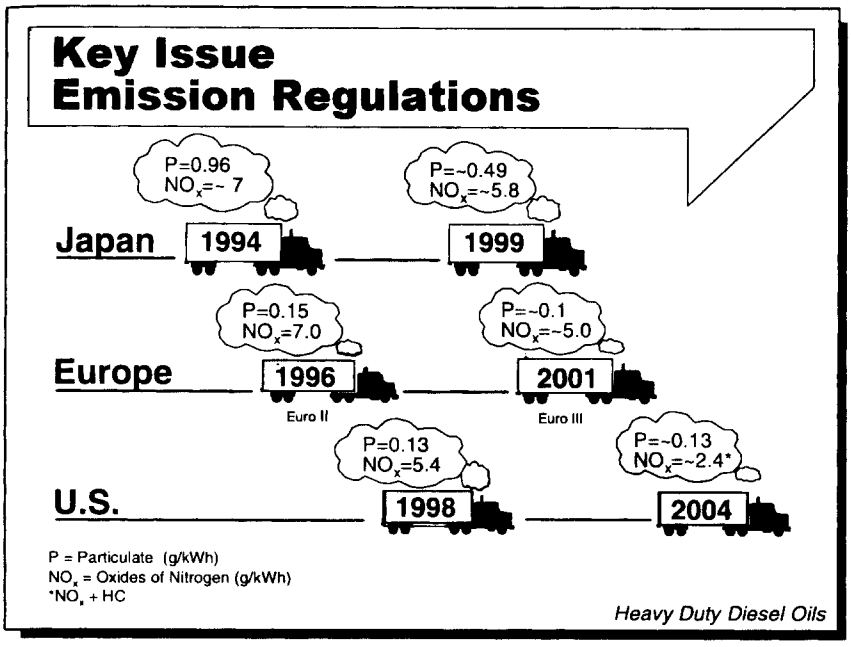


Technical and business transformations are reshaping the business of Diesel engine builders, Diesel lubricant marketers and additive companies. Key issues facing engine builders and end users under these transformations include:

- Emission regulations
- Vehicle operating costs
- Evolving business environments

With these challenges come opportunities. For equipment builders and lubricant marketers, these include:

- Lubricants meeting global performance requirements
- High value lubricant applications
- Profitable new businesses



Emission regulations continue to be a main focus in Diesel engine and lubricant design. As a result, there have been dramatic reductions in Diesel engine emissions.

1997 model Diesel engines in the U.S. emitted one-sixth the level of particulates and half the level of NO_x as engines manufactured in 1988. Emission standards in 1998 will require an additional 20% reduction in NO_x.

In Europe, Euro II 1996 emission requirements called for a reduction in particulate levels by nearly 60% and NO_x levels by more than 10% compared to 1993 requirements.

Future emission standards will continue to have a major impact on the industry. As the chart shows, tighter emission regulations are planned in the U.S., Europe and Japan.

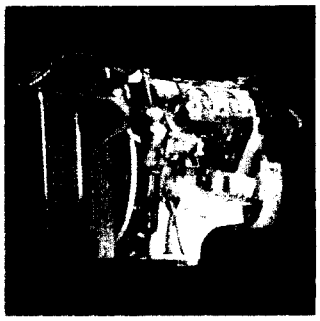
Also, the changes in emission test methods, which are currently under discussion in the U.S., could significantly impact engine and lubricant design in the future.

Impact on Worldwide Engine Designs

Common Strategies for Meeting Emission Targets

Increased Injection Pressure

Retarded Fuel Injection Timing



Articulated (Fe/Al) Pistons

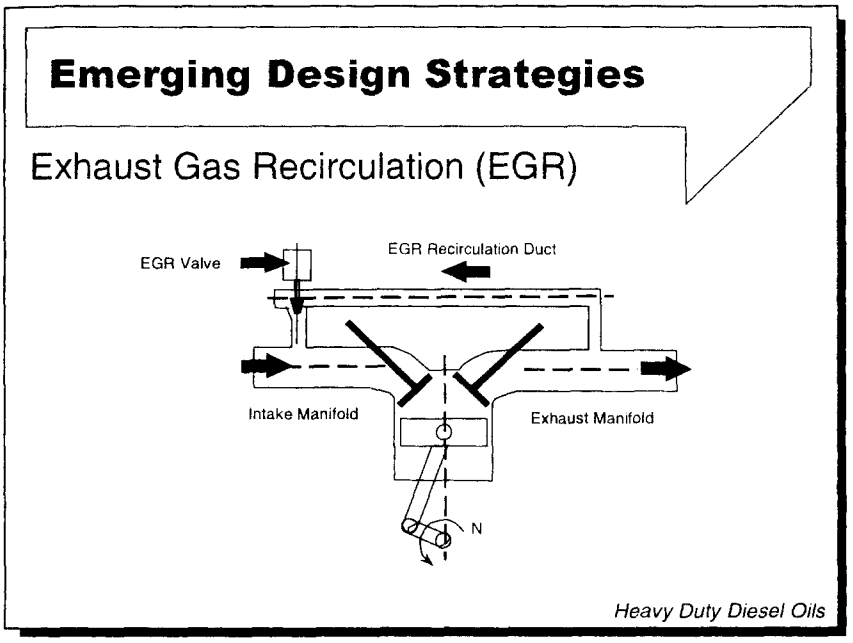
Exhaust Gas Recirculation (EGR)

Heavy Duty Diesel Oils

To meet emerging emission targets, engine designers around the world are adopting some of the same approaches. Some examples include:

- Increased fuel injection pressures to improve combustion efficiency and reduce particulate emissions.
- Use of two-piece (Fe/Al) pistons. The iron head allows for much higher injection pressure and higher top ring positions to reduce crevice volumes and further reduce particulate emissions. Other results include significantly higher top ring and top groove temperatures.
- Retarded fuel injection timing to reduce combustion temperature and minimize the formation of NO_x. This dramatically increases the soot loading of the Diesel engine lubricant.

A common design approach under evaluation to address future emission targets is Exhaust Gas Recirculation (EGR) which will demand significantly more performance from the Diesel engine lubricant.



EGR has been used in light-duty, gasoline engines for a number of years to meet emission targets. Application of EGR to Diesel engines presents new challenges. Preliminary work with EGR in heavy duty Diesel engines shows that soot levels increase dramatically. This means the Diesel engine lubricant will have to do a better job of controlling soot-induced viscosity increase and reducing soot-induced engine wear.

Improvements in corrosion protection will likely be another focus for future Diesel engine lubricants as EGR can dramatically increase the potential for corrosion of critical engine parts.

Other strategies under evaluation for addressing future emission requirements include:

- Further increases in injection pressures
- Development of "De-NO_x" catalysts
- Fuel/water emulsions
- Selective Catalyst Reduction (SCR)

Fuel/water emulsions are being used commercially in France. SCR based on urea is being applied to stationary engines and is being investigated for on-board vehicular applications in association with sensors.

Key Issue
Equipment Builder – Industry Evolution

- Business Growth
  - International
  - Partnerships
- Redefined Business Scope
  - Guaranteed "Lifetime" Engine Costs
  - Expanded Services
- Increased Risk

Heavy Duty Diesel Oils

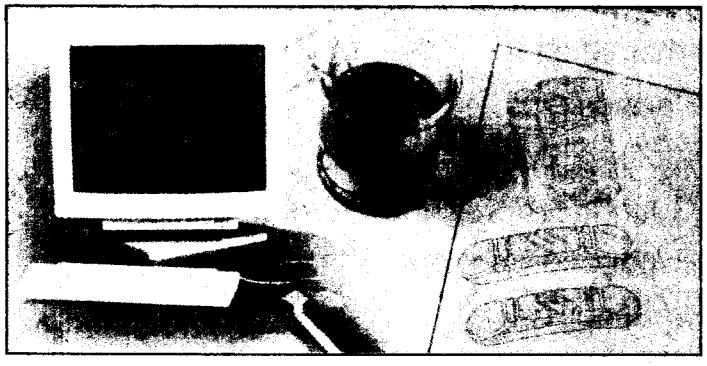
Equipment builders face a business environment that is growing more complex. Many of today's largest markets have limited growth potential. This has resulted in an increased focus on international expansion and partnerships. Availability of high performance lubricants is one common concern expressed as equipment builders expand internationally.

The scope of the equipment builder's business is evolving to address opportunities and needs in today's market. For example, one emerging trend in the U.S. is for engine manufacturers to guarantee the lifetime operating and maintenance costs of a Diesel engine. This goes beyond the initial purchase price and warranty coverage that has been the primary basis for selling engines.

Many equipment builders also offer expanded services such as full service leasing, to satisfy a broader range of customer needs.

Although these activities offer exciting potential for growth, they also increase an organization's exposure to risk. Lubricants are playing an increasingly important role in helping engine builders address these risks.

Product Development Issues

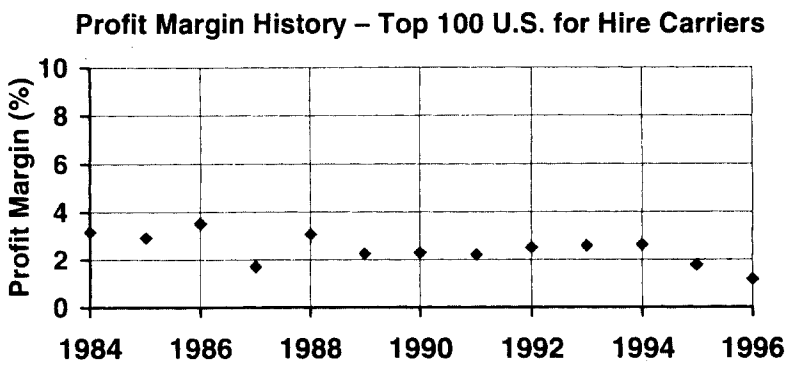


Heavy Duty Diesel Oils

To meet these challenges, getting the right Diesel engine lubricant for the application is vital. Lubricant performance is a much more important consideration in the engine design process than ever before.

One leading U.S. engine manufacturer states, "lubricants are a critical backbone to the operation of the engine." Another adds, "we now include engine oil as a component in engine design work. We rely more heavily on the capability of engine oils to provide the durability and drain intervals that our customers require."

Key Issue
Operating Costs

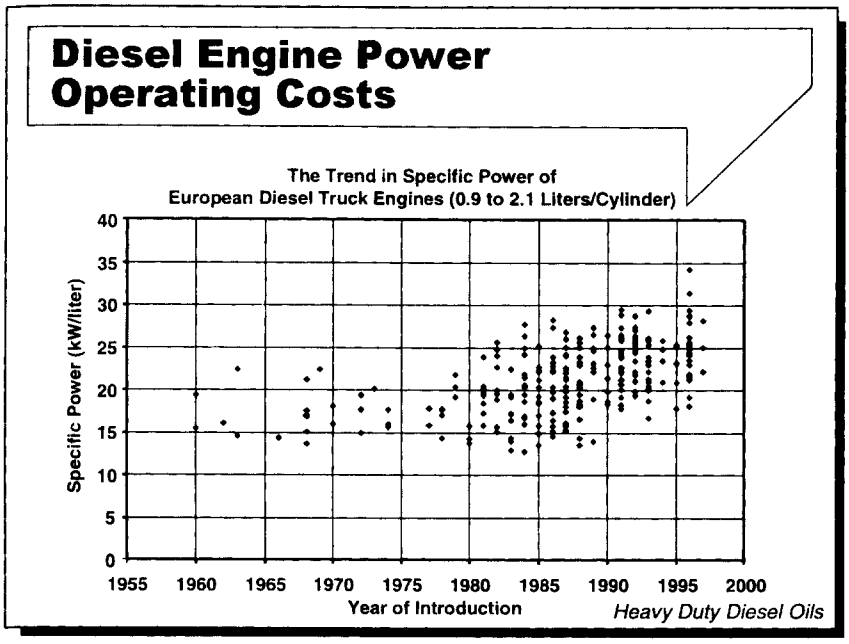


Source: Commercial Carrier Journal

Heavy Duty Diesel Oils

In many markets, the trucking business is extremely competitive. To illustrate, the plot shows the average profit margin of the top 100 for hire carriers in the U.S. has been at, or below 2.5% since the late 1980's. This environment places sharp focus on efficiency and cost reduction.

Aerodynamic designs, weight reductions and electronic engine controls to increase fuel economy are a few ways of how equipment builders have responded to this need. Extended engine durability and increased maintenance intervals are other examples. Specially designed oil filtration systems and systems for consumable/combustible engine oils are approaches being evaluated to further extend service intervals and reduce maintenance costs.



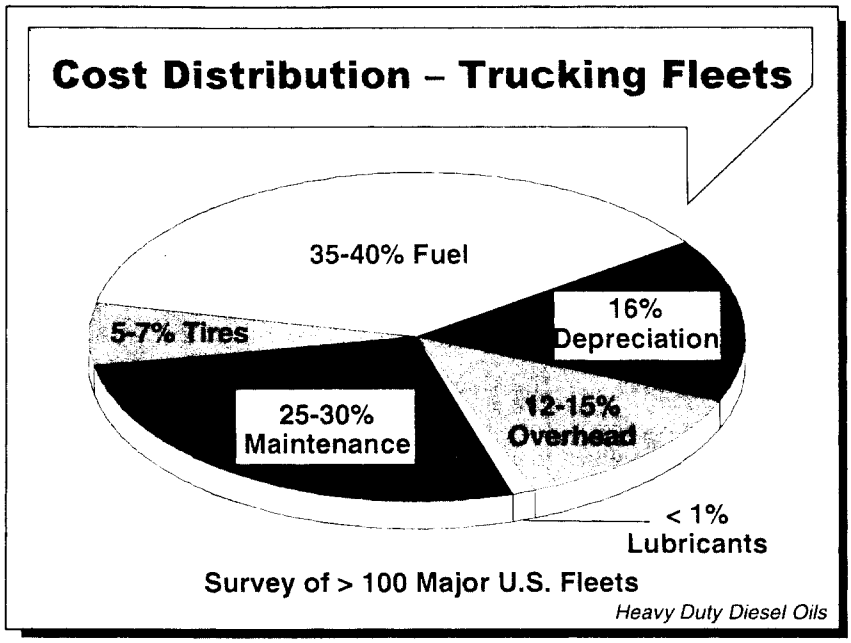
Improved efficiency is one of the primary reasons for increased engine horsepower seen in many of today's markets. The chart shows the upward trend in power for European engines.

In the U.S., the average horsepower rating of all heavy duty engines produced is approximately 370 hp. The average was approximately 350 hp in 1990. Moreover, in the mid 1980's average Diesel engine horsepower in the U.S. increased ~2 hp per year. By 1990, the rate was ~5 hp per year. Today, Diesel engine horsepower is increasing at a rate of 7-8 hp per year. The recent introduction of 600 hp engines indicates the upward trend will continue.

There are a number of reasons for the increased engine power. One is driver preference. In a survey of approximately 450 drivers in the U.S., approximately one-third of whom were owner-operators, 82% said they preferred engines with 450 hp or more.

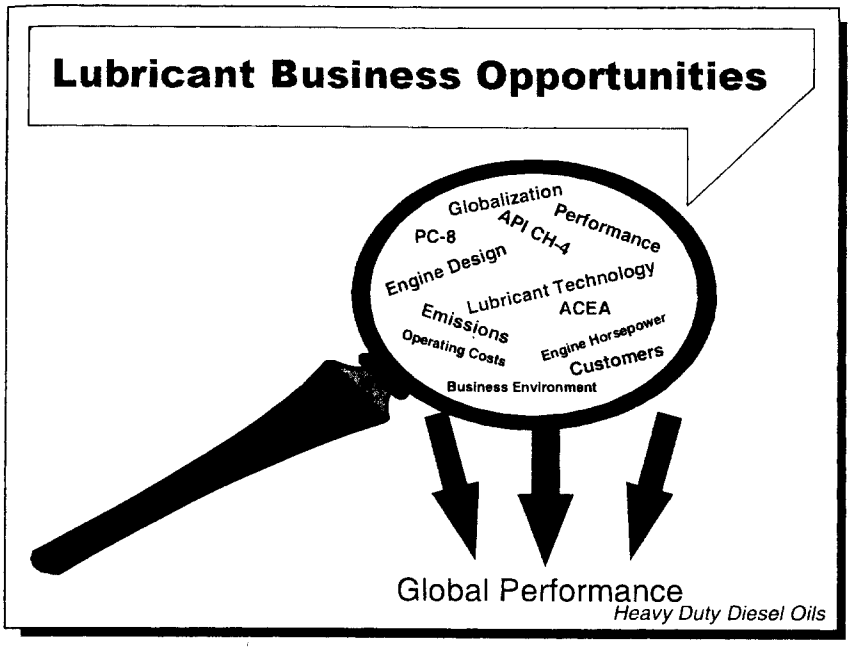
The key motivator, however, is cost efficiency. Not only do higher horsepower engines command more value at trade-in, they also allow for increased hauling productivity by reducing shifts and enabling the driver to maintain higher average speeds, especially on hilly terrain.

Source for U.S. data: Heavy Duty Trucking



When total operating costs are considered, lubricants represent a very small portion of the costs for a heavy duty truck fleet. However, lubricants can have a significant impact on other operating cost elements.

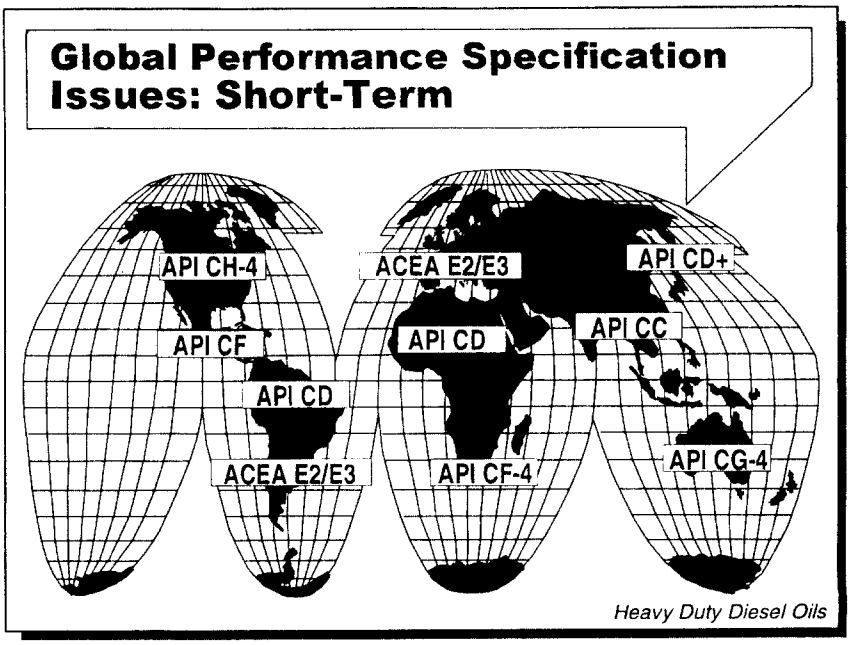
Any cost reduction that can be derived from the performance of the engine lubricant has great value to the vehicle operator. High performance lubricants can significantly reduce maintenance costs through increased engine durability and engine life. High performance lubricants are also critical in order for an engine manufacturer to guarantee the lifetime operating costs of an engine.



Common engine design strategies requiring common engine lubricant performance, focus on reduced worldwide emissions and advances in lubricant technology are creating a drive toward a global performance platform for Diesel engine lubricants. More and more, lubricant marketers are finding OEMs and end users demanding oil that can meet a wider variety of global performance requirements.

Some global engine manufacturers envision a global Diesel engine lubricant specification. This would enable them to gain knowledge of, and confidence in, the quality of lubricants available in the various international markets. Opportunities exist for the lubricant technology that can meet a variety of international performance requirements.

In the next few pages, current and future specifications as well as advances in Diesel lubricant performance are discussed.



Today, different performance needs exist in different geographical regions. For example, as the U.S. market transitions from API CG-4 to API CH-4 in 1998, some developing markets are moving from API CC to API CD for mainline lubricants.

There are many reasons for differences in the Diesel engine lubricant performance level among different markets. Lubricant drain intervals can a have a significant impact as shorter drain intervals partially compensate for lower quality lubricants. Age of the vehicle fleet and severity of the application in a given market also determine which lubricants are most suitable.

Cost is a significant issue. In many cases the economic conditions in a market cannot support the cost of the latest Diesel engine lubricant technology. Due to lower labor costs in developing areas, it may be more economical for the vehicle owner to use a less costly lubricant and a shorter oil change interval.

Emerging Performance Standards

Test Requirement Comparisons

	API CH-4	Proposed ACEA E3-98	Proposed ACEA E5-99	Proposed PC-8
Soot Control	Mack T-8	Mack T-8	Mack T-8	Mack T-8
Wear Protection	Cummins M11 Mack T-9 RFWT	OM 602A	OM 602A Cummins M11 Mack T-9	Cummins M11 Mack T-9
Piston Deposits	Caterpillar 1P Caterpillar 1K	OM 364LA	OM 441LA	Caterpillar 1M-PC

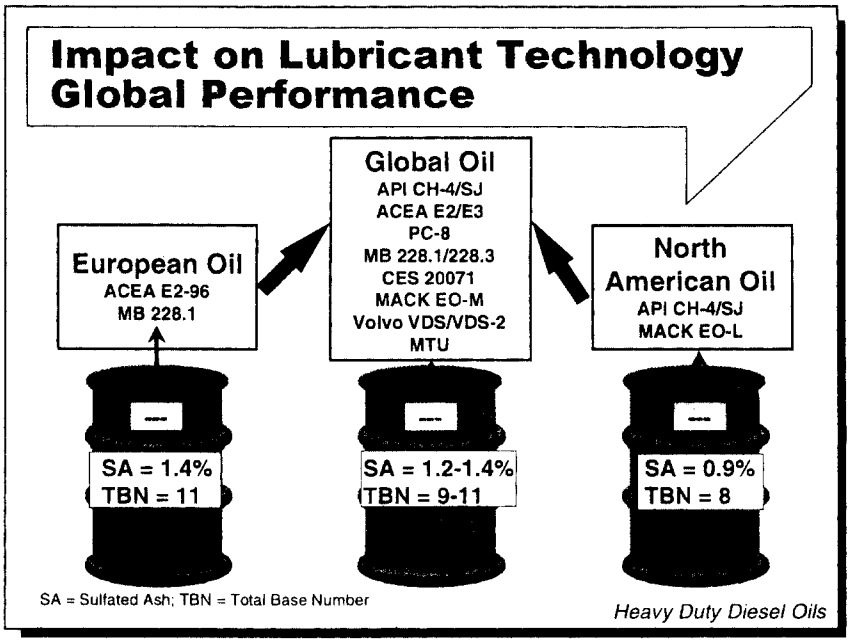
NOTE: Performance categories under development and subject to change

Heavy Duty Diesel Oils

There are many similarities among the requirements in the new performance categories being developed in Europe, Japan and the U.S. For example, PC-8 and some of the new ACEA Sequences will likely include many of the API CH-4 tests from the U.S. including the Mack T-8, Mack T-9 and Cummins M11.

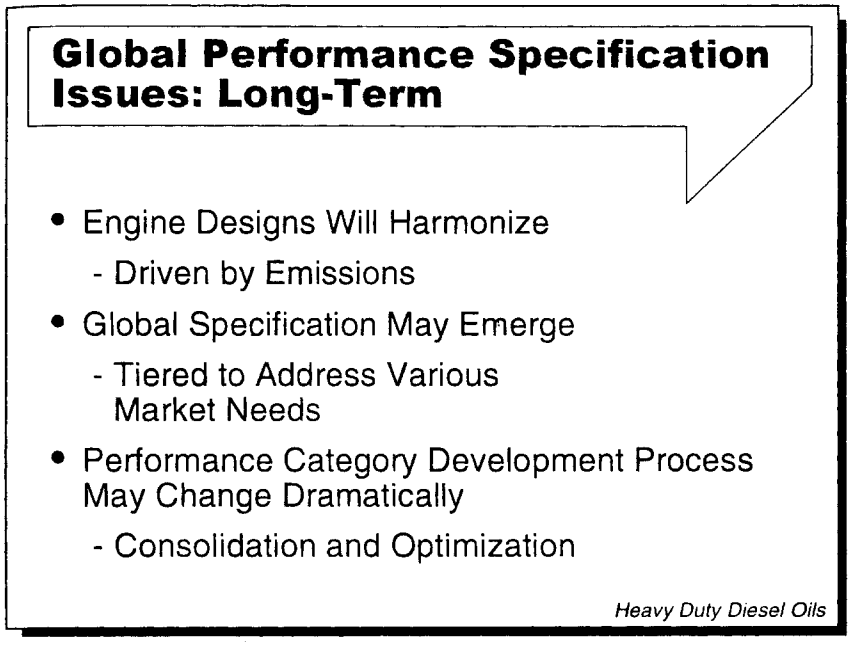
There are also some significant differences in performance requirements. For example, the OM 364LA will be the preferred test for measuring piston deposits in the new ACEA E3 Sequence for 1998. In the U.S., API CH-4 will include the Caterpillar 1P and Caterpillar 1K tests. However, in the Asia Pacific region, the Caterpillar 1M-PC test will be included in PC-8 because Japanese engines operate at lower temperatures than the conditions simulated by the Caterpillar 1P.

Also, it is believed that the Mack T-8 limits proposed for API CH-4 and the new ACEA Sequences are too severe and do not reflect the needs of heavy duty Diesel engines built by Japanese OEMs.



The globalization of engine and vehicle manufacturers is well documented and continues to evolve. The various acquisitions that have occurred and the alliances that have formed present opportunities for high performance Diesel engine lubricants.

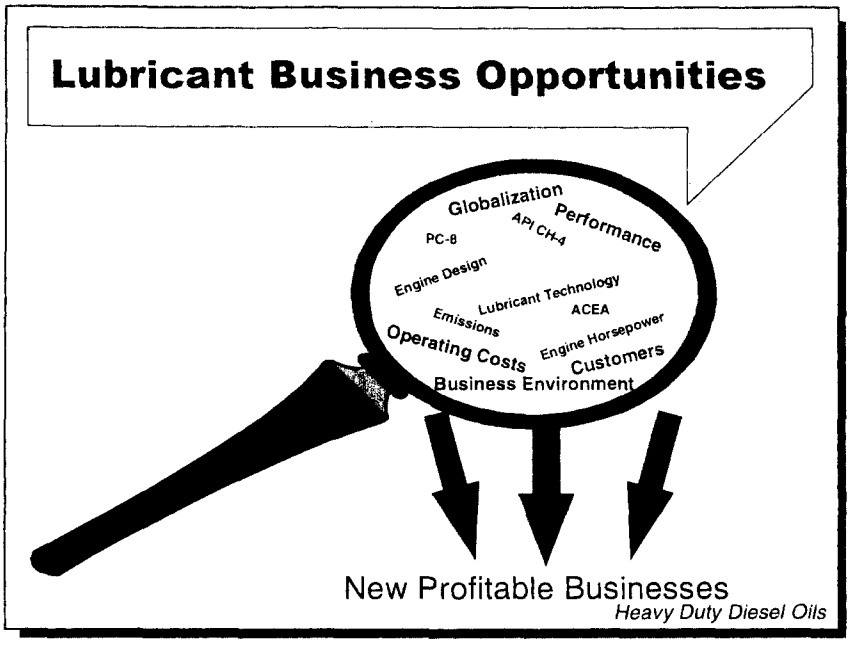
The chart shows how lubricants are evolving to address these needs. Although there are exceptions, the U.S. market has been dominated by 8 TBN, <1.0% sulfated ash oils. In contrast, European and Japanese formulations have typically carried higher TBN and ash levels. However, advances in Diesel lubricant additive technology are allowing for use of a single oil to meet a wider variety of performance requirements at moderate TBN and ash levels.



Significant gaps exist that prevent a global specification from being defined. Despite this fact, as engine design strategies continue to align in order to meet even tighter emissions standards, a global performance specification may begin to take shape. Led by Daimler-Benz, the European engine manufacturers are advocating a common emission test cycle for Europe, Japan and the U.S. The development and acceptance of such a cycle may drive global specifications.

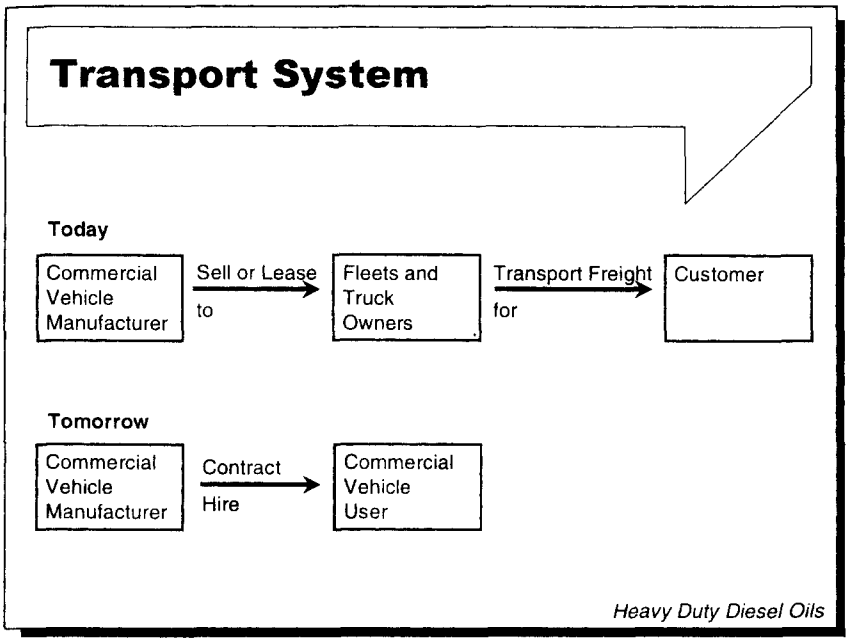
Whatever the timing for a global specification, different performance and cost needs will exist within different markets. Therefore, a tiered global performance standard(s) may be defined to satisfy a variety of cost/performance relationships.

Significant changes to the current specification development and lubricant evaluation processes could occur with the advent of global performance specifications. Addressing redundancies or inconsistencies among the various administrative bodies and testing protocols, might offer improved efficiency. Redesigning such processes by taking the best that each process has to offer, has interesting possibilities.



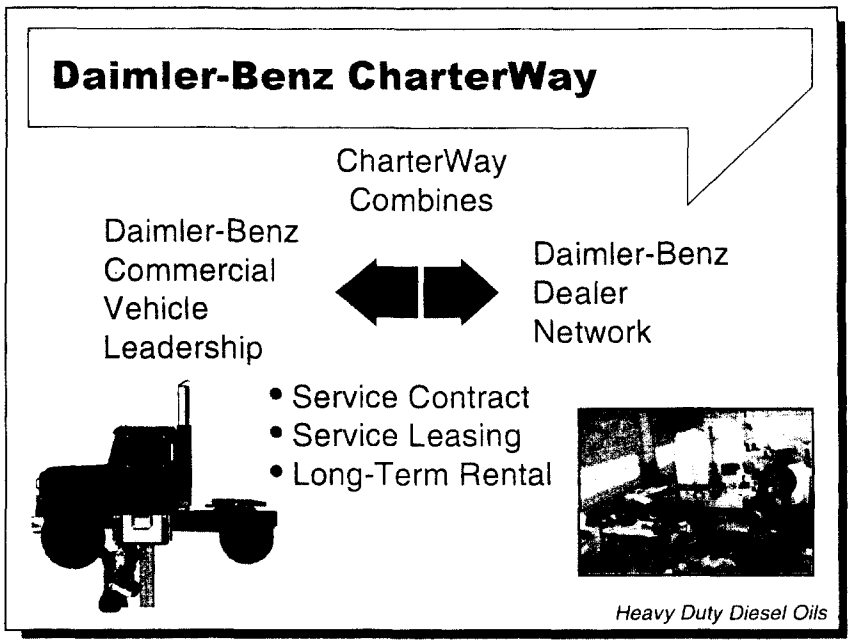
In the interest of profitable business growth, many companies are evaluating how best to use their unique skills and resources to extend the scope of their businesses. In some cases, companies are entering or creating completely new businesses.

Equipment manufacturers are uniquely positioned to understand and serve vehicle owner's needs. Application of this knowledge creates new business opportunities.



The majority of today's truck manufacturers sell to individual truck owners, small fleets and large leasing fleets with over 100,000 vehicles. This transport industry is highly competitive and includes both short and long-haul fleets with equipment trade cycles as short as 2 years and as long as 20 years. Class 8 trucks in the U.S. operate up to 250,000 miles (400,000 km) per year, 3,000-5,000 hours per year on the road (same number of hours idling), consume 75,000-115,000 gallons (284,000-435,000 liters) of fuel, use over 400 liters of engine oil and operate 300,000 miles (500,000 km) without tune-up. Dependability, reliability, safety and profitability are of high priority. Due to the critical shortage of drivers and maintenance personnel, especially in the U.S., these are difficult to achieve.

Manufacturers of commercial vehicles are starting to avail themselves of challenges and opportunities afforded by the contract hire market.



In 1992, Daimler-Benz, the leading European manufacturer of commercial vehicles, established an international contract hire service called "CharterWay". CharterWay combines Daimler-Benz commercial vehicle leadership and the expertise of the Daimler-Benz dealership network. The purpose of the program is to provide cost-effective vehicle acquisitions and support the users of commercial vehicles. An operator has the benefit of using vans and trucks without the need of ownership. Vehicle maintenance, all servicing and testing are done at the 2,500 Daimler-Benz commercial dealerships. Only Daimler-Benz approved operational fluids are used. The CharterWay program offers service contracts, service leasing and long-term rentals. All three contain the same base modules.

CharterWay Base Modules

- Maintenance Work Including Oils and Greases
- Repair Work to Chassis, Running Gear and Powertrain
- Statutory Inspections and Tests
- Replacement of Major Components
- Vehicle Management

Heavy Duty Diesel Oils

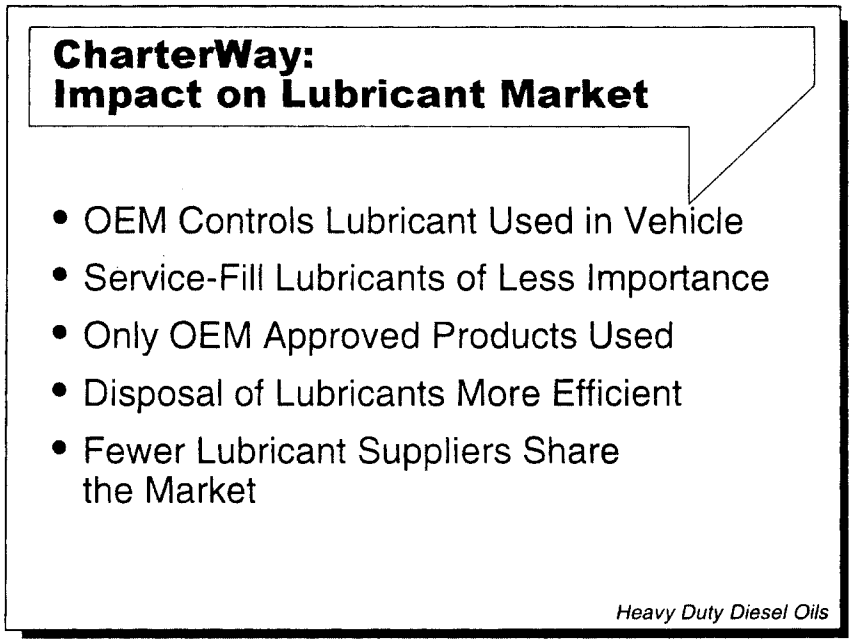
All modules can be done at any of the Daimler-Benz dealerships using a customer service card. There are several advantages for the customer offered by the CharterWay service contract:

Optimum maintenance and repairs of vehicles will minimize risk of down-time, maximize in-service hours and enhance resale value.

Cost transparency and cost control in the vehicle fleet will ensure that vehicle costs remain calculable and that no additional costs are incurred due to unforeseen repairs.

Administrative costs for the fleet will be reduced by including, coordinating and monitoring all maintenance work and statutory inspections and tests.

There is less risk in carrying out international haulage work. In an emergency, the customer can use the services of any authorized Daimler-Benz service station in Europe without the need for cash payment.



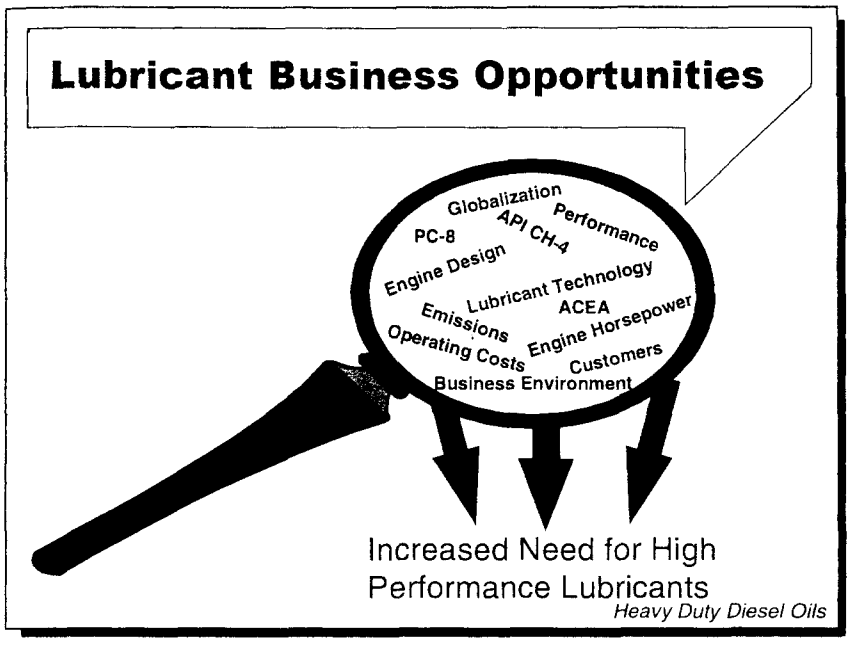
If more and more OEMs follow the example of Daimler-Benz, what could be the impact on the lubricant market?

Vehicle manufacturers will have more control over which lubricant is used in the vehicle.

The service market as we know it may have less importance.

Accelerated consolidation may result in fewer lubricant suppliers participating in the market.

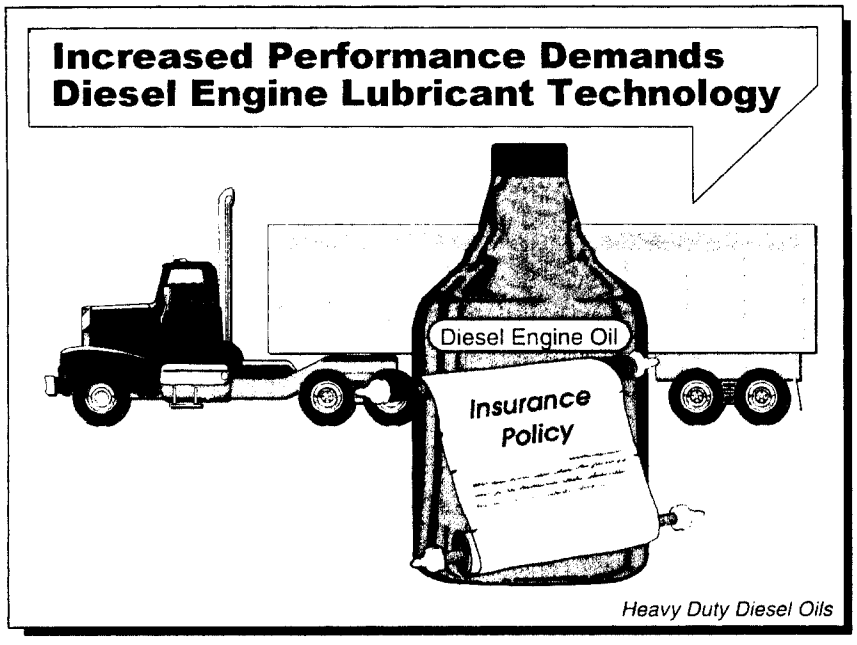
Disposal of used lubricants may become more efficient.



Engine design changes and new performance demands are increasing the need for innovative, high performance lubricants. The value of such Diesel engine lubricants will continue to grow in importance. Engine builders are relying more than ever on lubricant performance to address tough design challenges. Vehicle operators count on high performance lubricants to reduce overall operating costs.

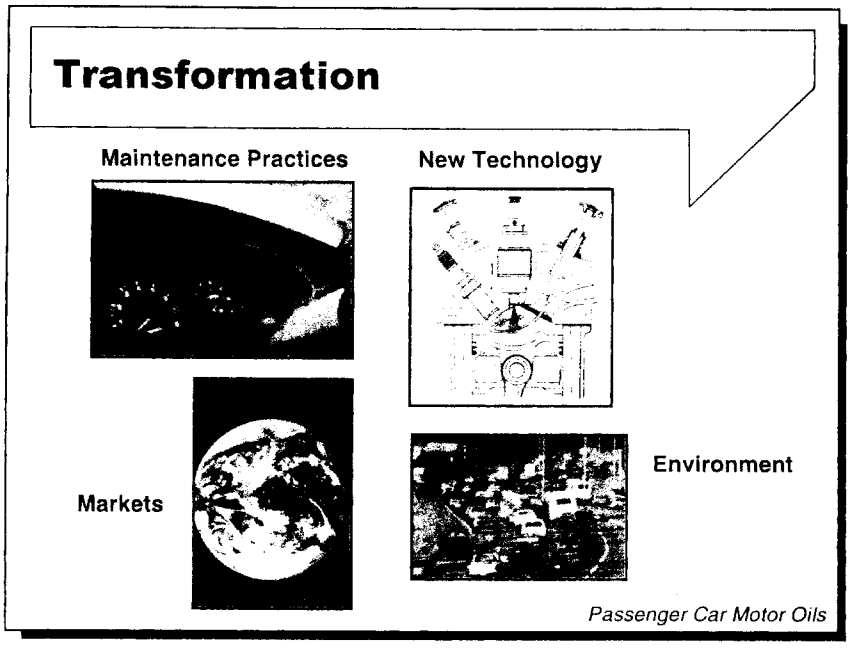
In the future, EGR, higher horsepower engines and higher operating temperatures are just some examples of drivers that will place higher demands on engine lubricants.

The globalization trend will certainly continue, if not accelerate, in the future. Engine manufacturers and fleet owners need the high performance and flexibility offered by an engine oil meeting a wide variety of specifications. Lubricant formulators are already responding to this important need.



The ultimate goal for Diesel engine builders and vehicle operators is a trouble-free vehicle. High performance lubricants are a very cost-effective form of insurance to help meet these goals in an environmentally-friendly manner.

Tremendous opportunities exist for the lubricant marketer that can quickly respond to equipment builder and end user needs by offering the high performance engine lubricants the future will demand.

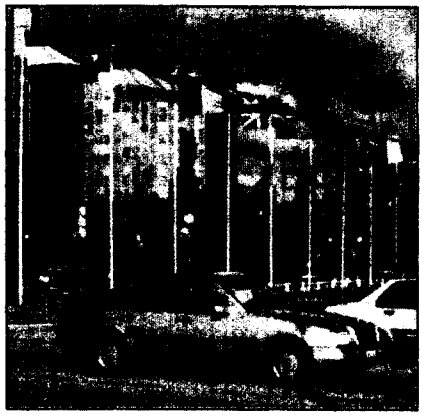


Motor oil and additive marketers must look for efficiencies as they position themselves for changes in the seemingly mature motor oil market. They must keep pace with the buying and maintenance practices of consumers, environmental concerns that drive regulations and economic conditions that can fluctuate rapidly. Success will require responding to these changes in a way that gives customers value and shareholders a competitive return on investment.

Automakers will also be drivers of change. They will require the improvement of motor oils, particularly with respect to fuel economy performance and minimizing any harmful effects on emissions. All will eventually demand extended maintenance intervals. Furthermore, the successful manufacturers will develop engine portfolios that go beyond today's internal combustion engine, creating new challenges for the lubricant industry.

This section will look at the changing performance of motor oils in the near-term. It will also review the key issues being considered for next generation oils and the engines they will be formulated to lubricate.

ACEA Oil Performance

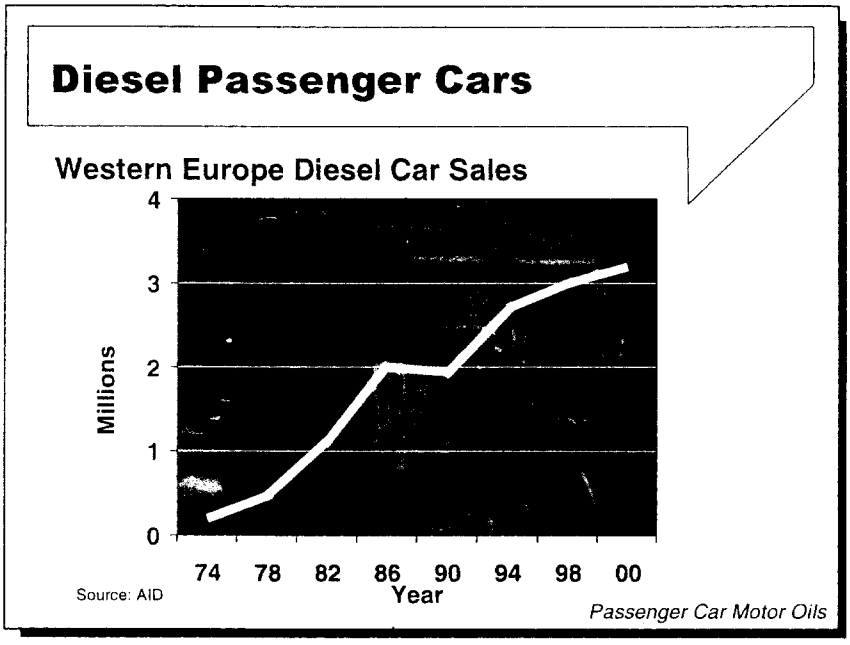


Passenger Car Motor Oils

Changes in European oil category definitions are targeted to occur every two years. These changes represent that either new engine tests have replaced older ones with no intended shift in oil performance or that a deliberate shift in performance has occurred.

In any case, the differences will be invisible to the consumer buying the oil as product labels designating the Association of European Automotive Manufacturers (ACEA) performance will no longer reflect the year of ACEA performance issue. For example, rather than reading "ACEA A3-96/B3-96", consumer nomenclature will simply read "ACEA A3/B3".

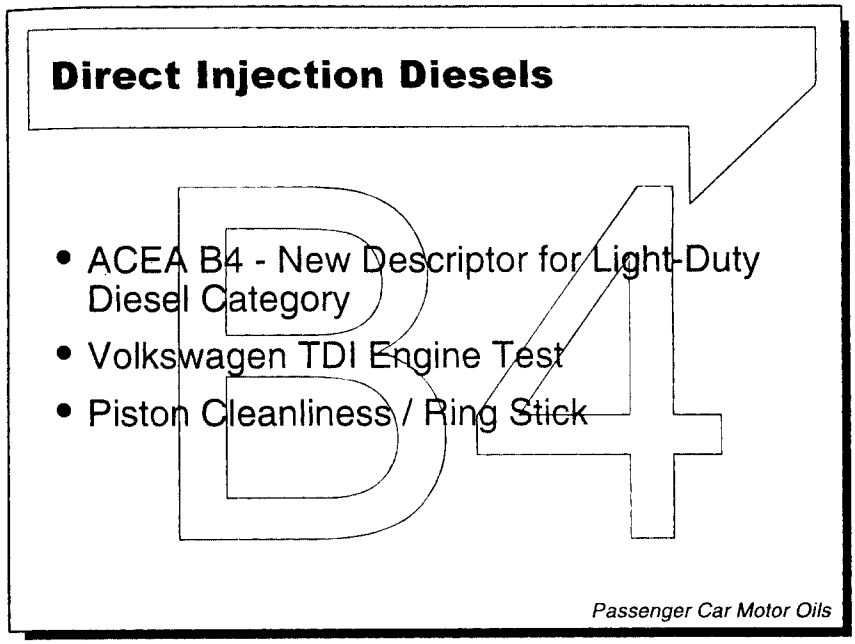
ACEA-98 oils entering the market this year will be similar in performance to today's ACEA-96 gasoline engine oils with the exception that ACEA A1 will now incorporate an embedded fuel economy requirement as determined by the MB M111E FE engine test. This represents the first time that an ACEA minimum performance standard includes a fuel economy performance test.



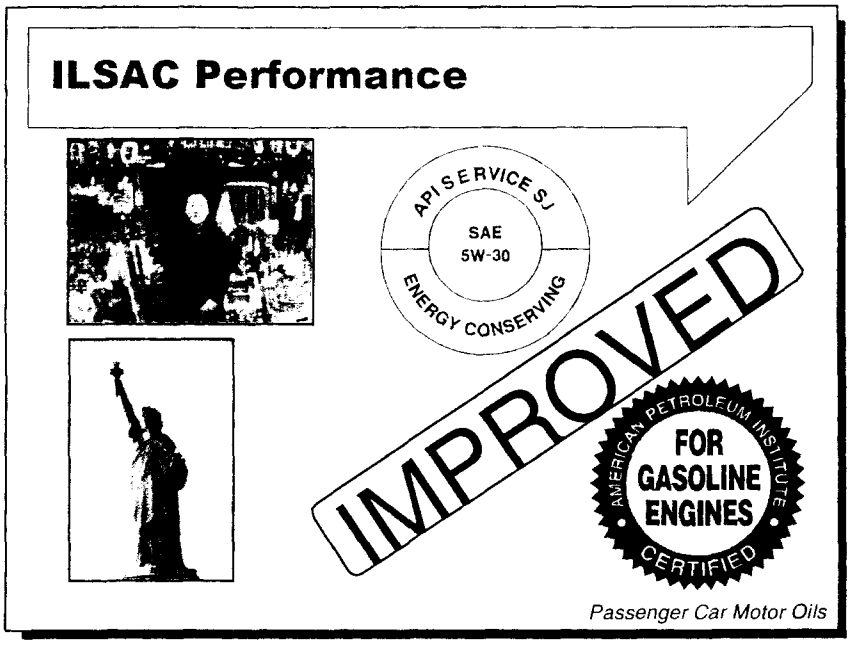
Records are being set in Europe with respect to the number of Diesel passenger cars being sold. In 1998, new Diesel car sales are expected to surpass three million for the first time. This will result in a market share of 23%. By 2004, that is likely to climb to 33%.

Aiding this enormous growth is the explosion of new high-tech direct-injection (DI) models, which offer reliability, improved power density and enhanced fuel efficiency. All of the large manufacturers have or will soon introduce DI Diesel engines.

The expertise for formulating oils for light-duty Diesel engines clearly resides in Europe. Because the high-tech Diesel is destined for other locations around the world, capitalizing on this "local" knowledge will ensure that these markets have the proper lubricants in place.

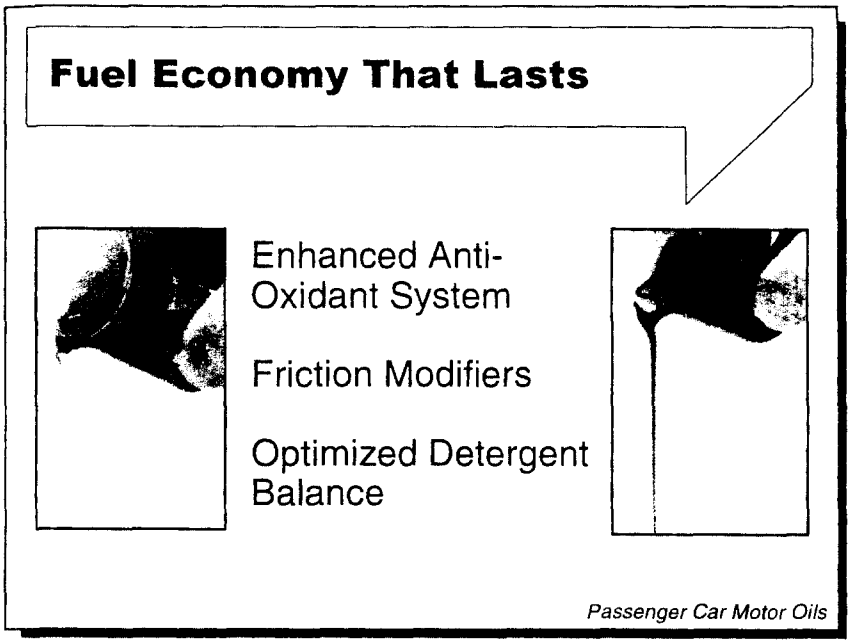


Beginning in 1998, an oil category will exist that is designed specifically for DI Diesel engines. ACEA B4 is the descriptor given to this new light-duty Diesel category established to assess an engine oil's ability to provide suitable high temperature deposit protection. Piston cleanliness and ring sticking are measured in the Volkswagen 1.9 liter TDI (81kw) engine test to assess ACEA B4 performance. The CEC Engine Lubricants Technical Committee granted "T" (tentative) status to this new test procedure in October 1997.



In the year 2000, a new generation of oils endorsed by Japanese and U.S. automakers under the International Lubricant Standardization and Approval Committee (ILSAC) will be available. Although this new category, ILSAC GF-3, will carry the identical "starburst" labeling of its predecessor, performance will be enhanced relative to GF-2.

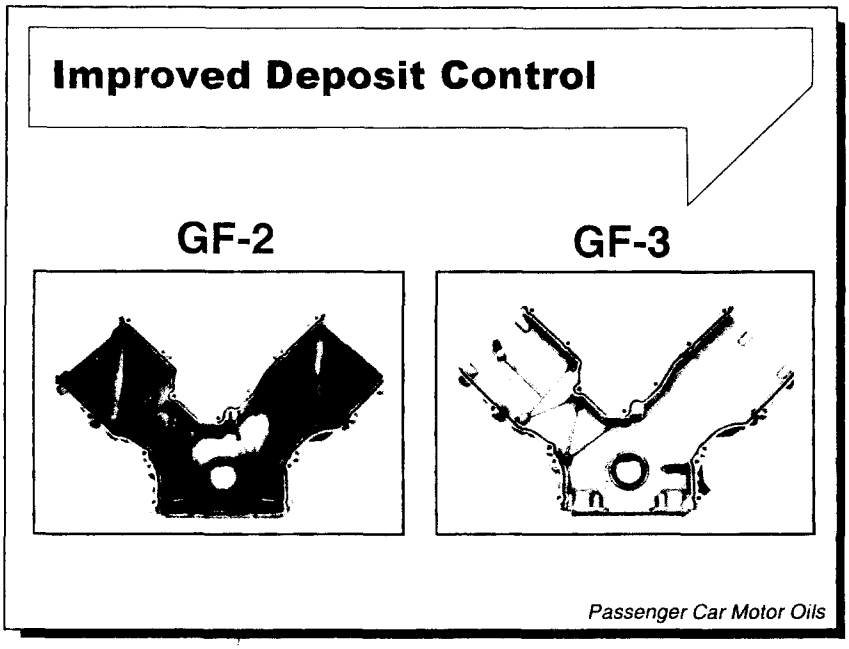
There are two key reasons for introducing this new category. First, using the Society of Automotive Engineers (SAE) as a forum, industry determined oils should provide fuel economy benefits for a longer time in the engine, be tested to ensure they do not harm emission systems and give overall improved performance, including better high temperature deposit protection. Second, every major bench and dynamometer test used to measure product performance is changing due to either a lack of parts, need to shift away from leaded fuel, need to test in a more current engine or new performance requirements.



In the future, fuel economy benefits will be required from oil both when it is new and when it is "aged". This ensures high performance throughout the entire maintenance cycle.

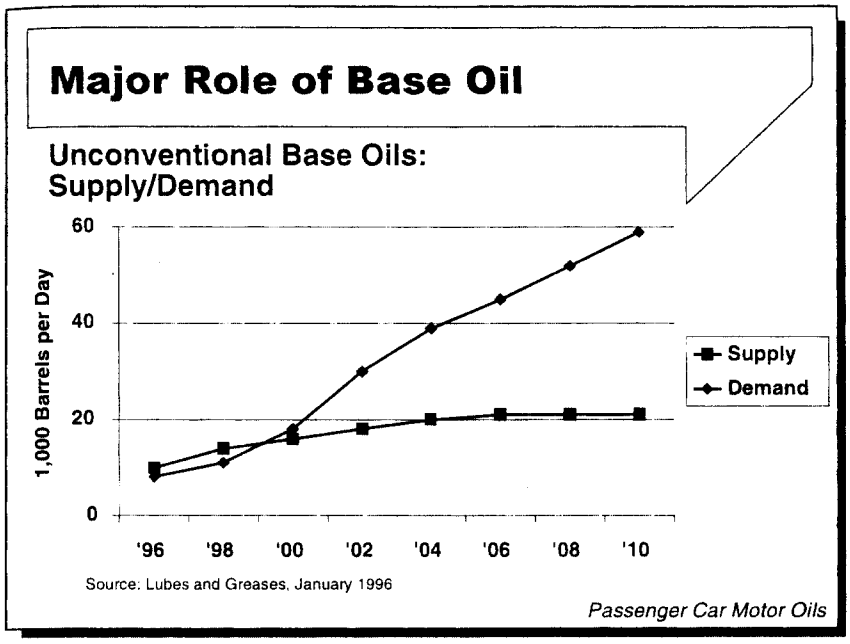
One key to enhancing fuel economy will be controlling viscosity increase due to oxidative thickening and volatility of light-ends. GF-3 oils using unconventional base stocks will have built-in advantages in thermal and oxidative stability and volatility control. However, supplemental antioxidants will also be delivered via the additive system.

Field tests show the advantage of proper friction modifier selection. If development of the new Sequence VIB fuel economy test proves successful, formulations of tomorrow will witness a comeback of friction modifiers. Detergent selection and balance can also have a significant impact on fuel economy performance. The net result of these formulating enhancements could yield noticeable improvement in efficiency relative to today's oils even after 4,000 miles aging. An improvement of only 1% equates to average savings of 0.28 mpg based on today's U.S. car fleet. After 50,000 miles, this would equate to savings of 18 gallons (68 liters) per vehicle. It also represents reductions in CO_2 emissions. To OEMs, it translates into tens of millions of dollars in savings by helping them meet regulations such as U.S. CAFE.



The detergent systems of tomorrow are expected to provide superior piston deposit control and ring stick protection. In one test, an engine run to 100,000 miles (160,000 km) using an ILSAC GF-2 capable oil had 33% stuck rings. Oil designed to better protect against high temperature deposits yielded only 2% stuck rings after the same mileage. A combination of 7,500 mile (12,000 km) and 10,000 mile (16,000 km) oil drain intervals was used in each case.

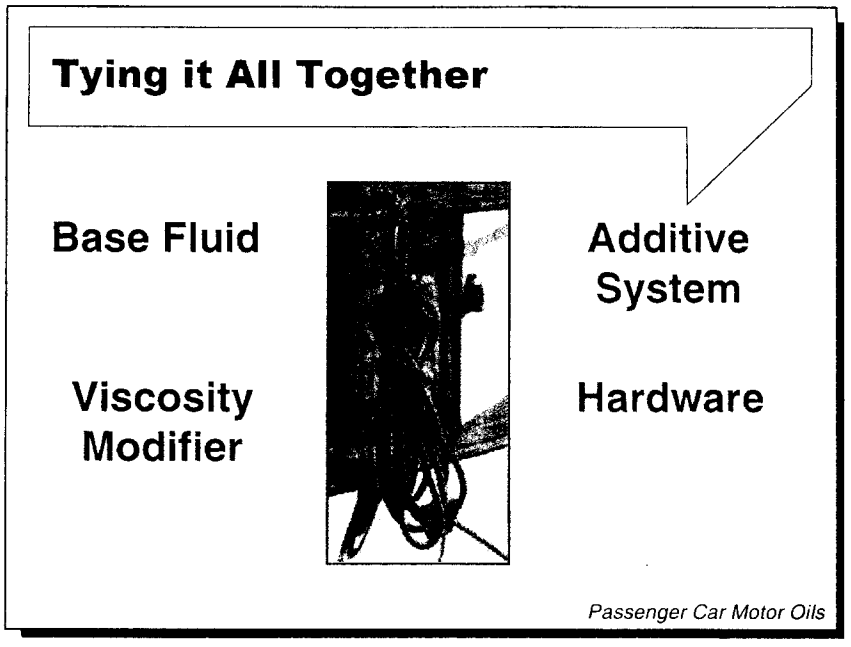
The photographs above are from the actual field tests. The timing chain cover on the left represents oil capable of meeting today's ILSAC motor oil specification. The cover on the right used oil that was enhanced with a detergent. Although dependent on the tests and limits that define final performance, ILSAC GF-3 and future specifications are likely to result in cleaner engines and provide improved fuel economy.



In view of the future demand for higher quality motor oils, base oils have taken on an added dimension of strategic interest to the lubricant industry.

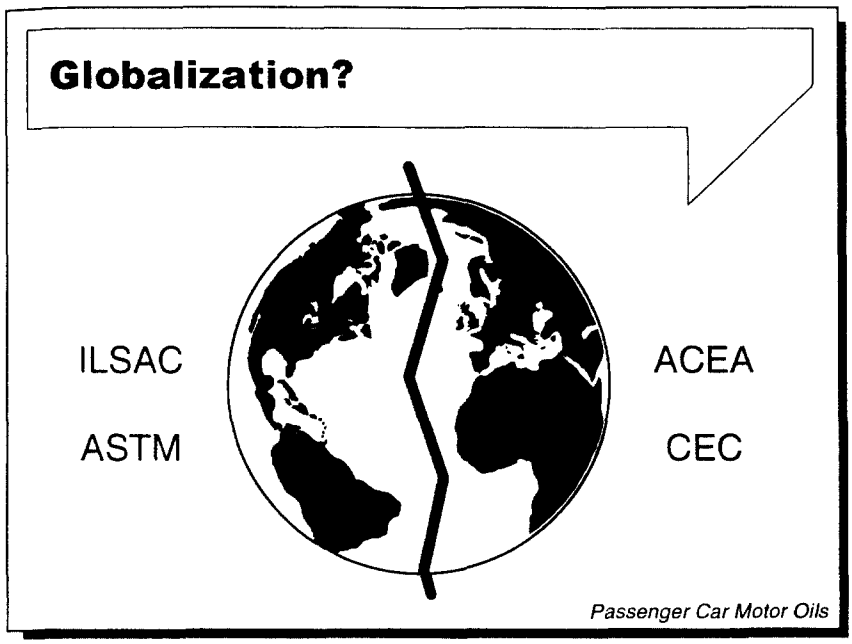
Low temperature requirements have become more demanding. Volatility limits will continue to become more stringent. There is also an impending need for greater oxidative stability as discussions of longer maintenance periods and more durable fuel economy continue. To meet these requirements, the base oils of tomorrow will come from more highly refined solvent processes or improved hydroprocessing techniques.

When coupling these performance attributes with the availability of new processes and the global supply-demand scenario, it is clear that traditional supply lines will undergo a transition. Producers will upgrade processes and marketers will rationalize their base stock portfolios. Despite the growth of unconventional base stocks as shown in the graph above, demand is expected to exceed supply by the turn of the century, when the next generation of performance specifications is implemented.



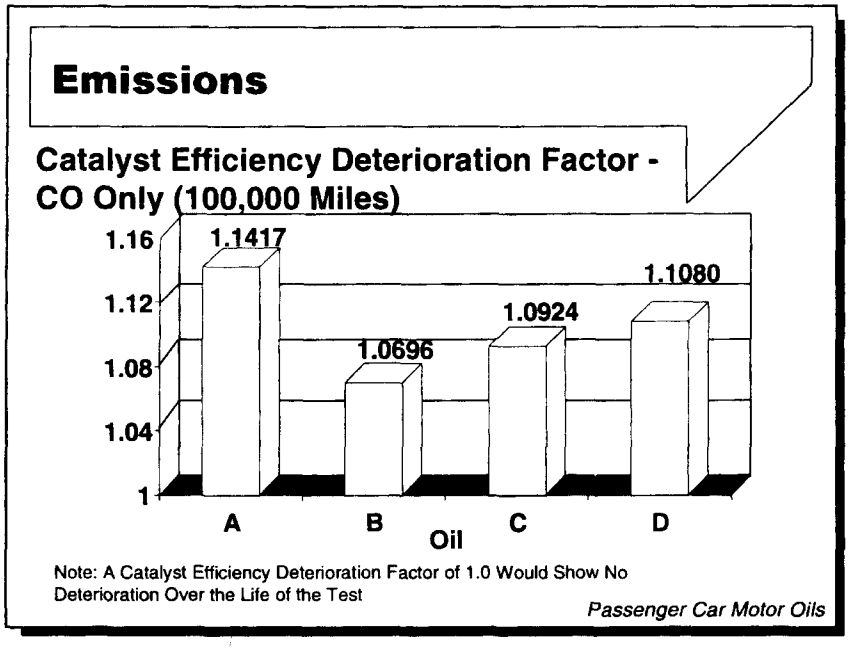
In the past, lubricant performance has relied heavily on additive systems. However, contributions from the neat base oil have become critical in defining the overall makeup of motor oil's final formulation. As the global base oil slate changes, additive systems will have to be designed to work across all base oil types. For example, many hydroprocessed oils show very good oxidative stability, but can lack solvency properties for sludge and deposit forming materials as well as some additive structures. Therefore, the additive system must have the ability to reduce deposit formation. This mating of base oil, viscosity modifier and additive chemistry represents the increasing "total formulation" approach to designing motor oil. Further into the future, this concept will advance to a "performance systems" approach.

As technical transformation occurs in the equipment industry, that is, as new metallurgy, coatings, emission systems, low friction components and engine operating conditions evolve, it only makes sense to understand lubricant appetites of the new hardware. This will require an innovative perspective and challenge industry stakeholders to keep ahead of the business and technology changes in the engine market.



Globalization is obviously a major transformation in business. Automakers and suppliers are working to become more efficient as global entities. This includes oil and additive marketers producing products that can meet the needs of a wider range of global consumers.

It was the intention of ILSAC to have GF-3 be a "worldwide" oil. After all, engines are built and shipped around the world. The vehicles often go to markets separated by thousands of miles, but not always separated by dramatic temperature differences or driving habits that might impact lubricant performance. Despite the global market, no deliberate change will be made to the ILSAC specification to make it a more accepted category worldwide. No such change will occur to the ACEA Sequences. The ACEA sequences do, however, continue to include ASTM tests such as the Sequence IIIE and VE. Better understanding among the global stakeholders is needed to make global transformation a reality.

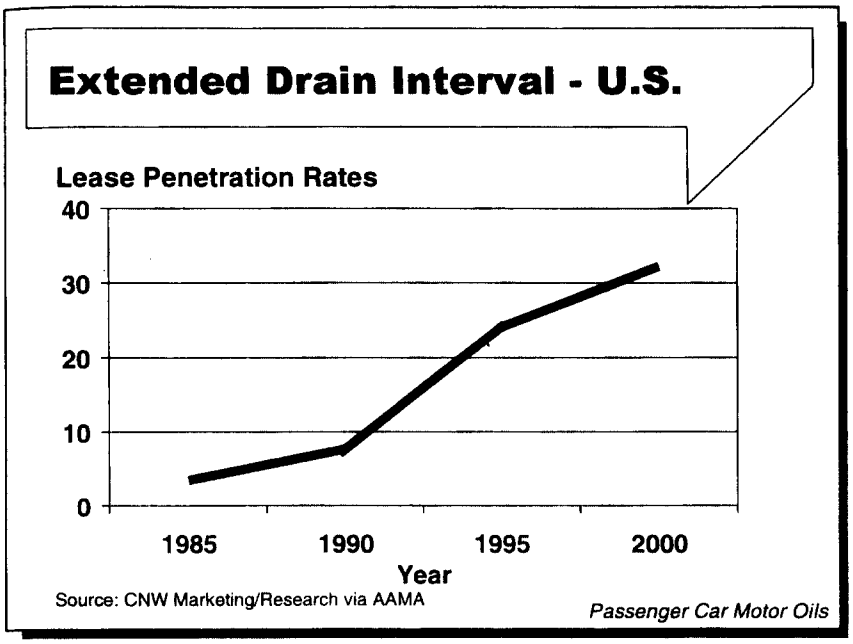


All stakeholders want to ensure that chemicals in motor oil, particularly phosphorus, do not harm catalytic emission systems. However, there is no means of accurately measuring the relationship between an oil formulation and its relative impact on emissions.

In determining the composition of motor oil, all the tradeoffs need to be considered. Simply dropping phosphorus levels can have negative implications on both engine durability and fuel economy. Detergent systems have actually been found to protect catalyst performance under certain conditions.

Results from a Lubrizol 100,000 mile (160,000 km) field test also showed that different detergents have varying effects on catalyst performance. In this 15 vehicle, four oil formulation test, catalytic converters were evaluated over a 100,000 mile (160,000 km) period. No effect on the rate of catalytic efficiency deterioration for total hydrocarbons or NO_x could be detected. Only the rate for CO was effected.

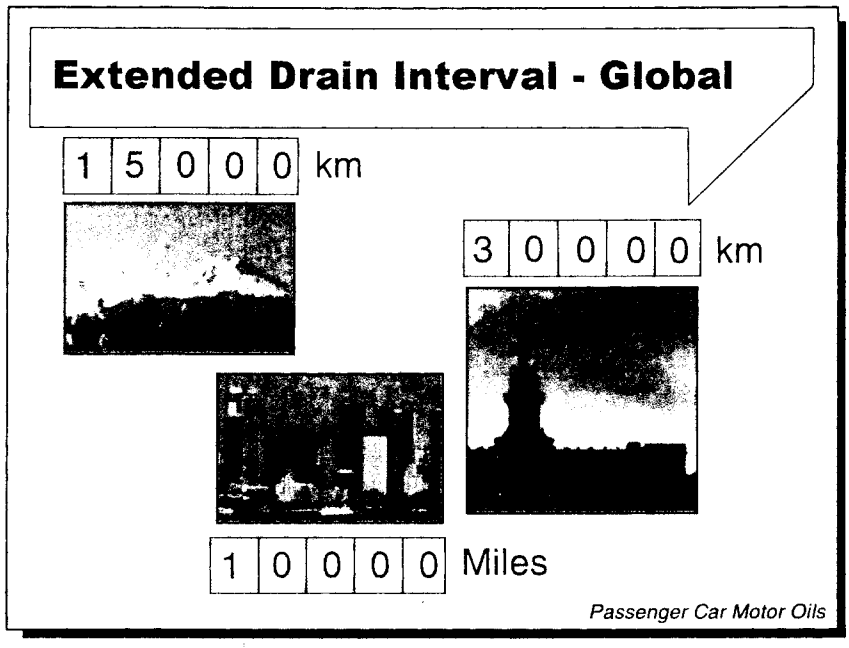
ASTM has gained knowledge, but initial efforts to develop such a test have not been successful. This has led to use of the same low phosphorus level, maximum 0.10% by weight, for the proposed phosphorous limit of ILSAC GF-3.



Initially, it was ILSAC's intention to have GF-3 oils provide extended drain capability. That concept was later modified with the understanding that manufacturers would set maintenance recommendations on an individual basis, and that overall GF-3 performance would be an improvement over today's oils.

In the U.S., one concern over how long oil can protect an engine stems from the growing trend to lease vehicles as shown above. While only 3.5% of vehicles were leased to consumers in 1985, nearly one-third will be leased by the year 2000. Do people who lease vehicles maintain them as if they owned them? Several manufacturers worry the answer is "no." This would be especially disturbing to those companies extending warranties on previously owned vehicles, such as General Motors' Certified Used Vehicle Program.

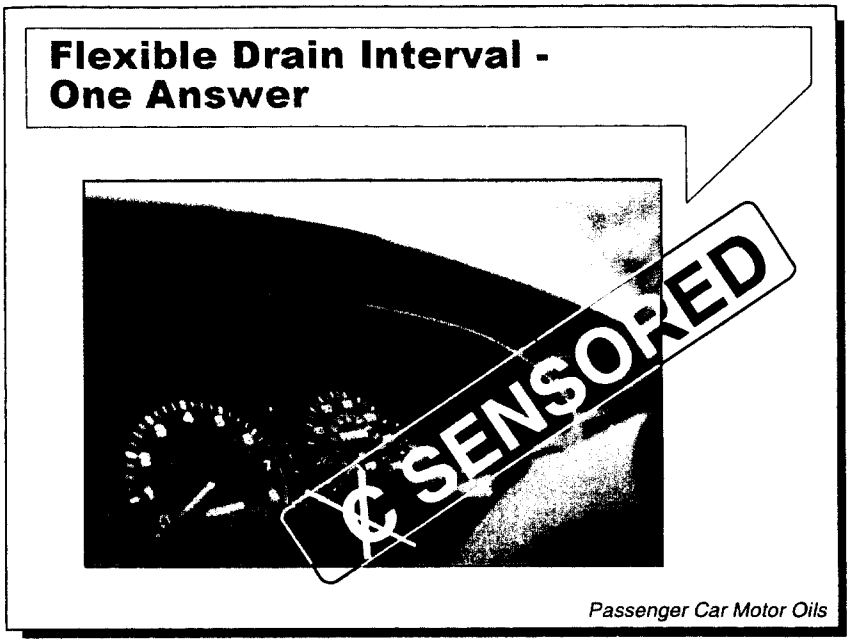
A survey conducted by Ford Motor Company of U.S. and Canada revealed that 40% of oil changes occur at 3,000 miles (4,800 km) and that 95% of all oil changes occur by 7,500 miles (12,000 km). 3,000 mile changes are what manufacturers recommend for severe-service driving conditions. The report indicates leased vehicles were suspected of being poorly serviced. It is also important to note that the survey indicated most consumers were likely to purchase longer lasting oils, even at significantly higher prices.



The extension of maintenance intervals for motor oil is a controversial issue among oil marketers, additive companies and automakers. For normal service, vehicle manufacturers recommend approximately 33% longer oil drain intervals in Europe using ACEA certification than they recommend in the U.S. Also, many European manufacturers are already extending the recommended drain interval for oils carrying their individual approval. This is being done as a means to establish a consumer driven market advantage, particularly for fleet sales.

The impact of oils designed to extend service intervals needs to be fully understood, particularly the effect on fuel economy durability. The fuel economy goal is not to just meet higher levels at the federal vehicle certification point of 4,000 miles, but rather to provide improvement up to the moment the oil is recommended for change. Engine durability and cleanliness is also a concern. However, this may be easier to overcome from an oil-formulating standpoint than the fuel economy challenge.

All engine manufacturers consider maintenance intervals very carefully. The issues discussed above as well as environmental risks and consumer preference will be assessed.

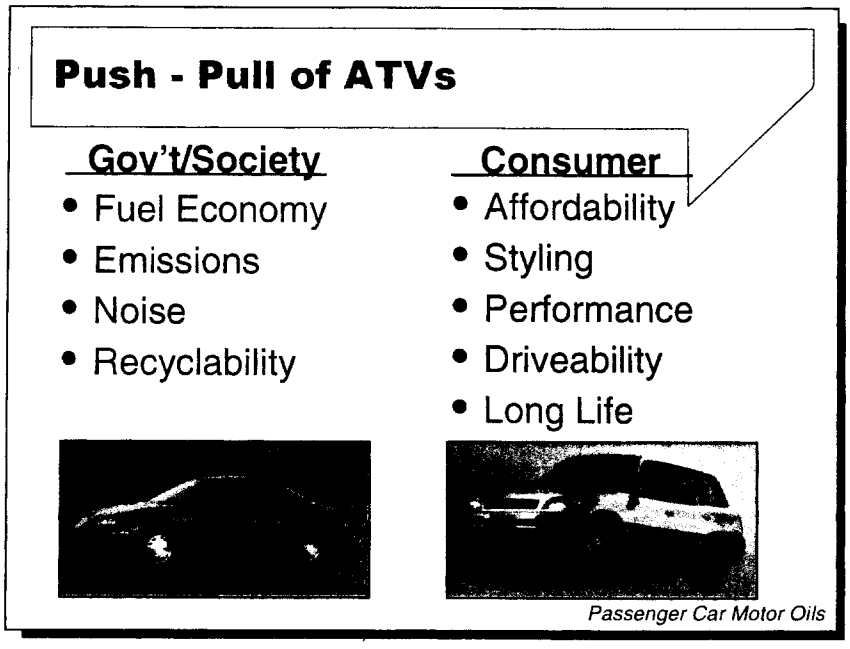


One answer to the issue of proper drain interval is the use of on-board sensing devices. It is a common objective of sensor developers to provide a quick, reliable and cost-effective means of detecting when oil needs to be changed. An optimum drain interval as determined by a sensor would ensure the longevity of equipment while reducing the cost and waste disposal due to unnecessary oil changes.

Today, some OEMs do not list a recommended service interval but rather defer to an oil indicator light on the dashboard. This type of signal to the driver is typically an estimate of the oil condition based on engine oil and coolant temperature, speed, distance traveled, time elapsed since last service, etc. However, direct monitoring of the oil condition will be needed to achieve an optimum drain interval.

Research in this area will continue. Many of the on-board monitoring techniques that are underway measure a physical or electrical property of the oil. Developers generally establish a correlation between the sensor signal and a failure mode of the oil. Electrical properties such as permittivity and conductivity are affected by the presence of polar molecules such as soot, acids and water.

To date, it is recognized that a single sensor cannot detect all failure modes.



Newspapers, magazines, books, conferences and boardrooms are filled with discussions over which Advanced Technology Vehicle (ATV) will emerge as "the" vehicle of tomorrow. Electric? Diesel/electric hybrid? DI gasoline? DI Diesel? Fuel cells? Or the conventional internal combustion engine?

Many issues including fuel economy, emissions, noise and recyclability are expected to "push" ATVs into the marketplace. Others are expected to "pull" the technology from the vehicle manufacturers. Without consumer demand for a product, is it very difficult to convince a producer to provide it? As Ford Motor Company stated, "Offer the right vehicle with the right fuel at the right time to meet customer needs." The key will be matching cost and utility such that value is added for the consumer.

Future Vehicles

"...unpredictability demands that a company build its technology strategy as a well-balanced portfolio."

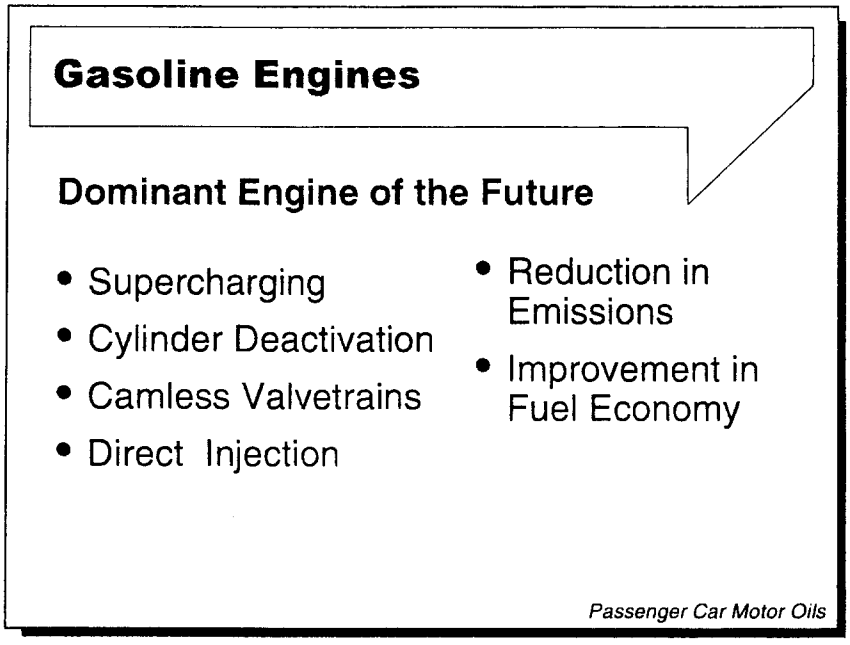
John F. Smith, Jr.
CEO, General Motors Corp.

Passenger Car Motor Oils

Many of the uncertainties facing the oil industry also impact the vehicle industry. How an OEM determines its vehicle/powertrain mix can depend on geo-political scenarios that could impact fuel availability, changes in consumer lifestyles and preferences, research successes and environmental issues. This uncertainty makes it very difficult to predict the makeup of the future vehicle population.

A "well-balanced portfolio" ensures a vehicle manufacturer that it can respond to different situations. It also creates a knowledge base that can be transferred to existing core technology. For example, lessons learned during the development of advanced technology vehicles such as electrics and hybrids, are being applied to existing and near-term vehicle programs. Mr. Smith, quoted above, goes on to say that "There are two primary challenges, technical feasibility – making the technology work to meet a set of customer requirements, and commercial viability – making the technology work at a cost that gives customers real value..." Economics will drive what vehicles are on the roads of the future.

In 1997, there were an estimated 385,744 alternative fueled vehicles in the U.S. This represents 2.8% of the vehicle population and an increase of 54% from 1992. Many of these vehicles, however, are capable of running on such fuels as ethanol, but in reality they are only run on gasoline by the end user.



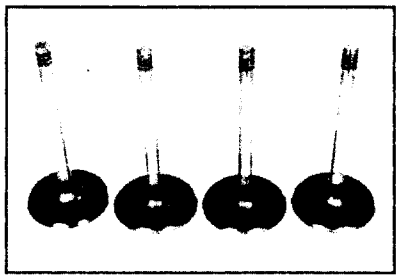
The dominant engine for the foreseeable future is the reciprocating internal combustion engine. This power plant still has considerable opportunity for refinement and is much more affordable than alternatives. Furthermore, with the advent of U.S. Tier II emission regulations in 2004, light-duty vehicles will emit between 95-99% less emissions compared to pre-control vehicles of the early 1970s.

Significant changes will occur over the next five to ten years. Technologies that expand the operating range of an engine will be employed to improve fuel economy. These include, but are not limited to, DI lean burn engines, high pressure supercharging, cylinder deactivation and even camless valvetrains. Most of these options will require consideration from a lubrication point of view.

Advances in engine design could provide a significant improvement in fuel economy. One manufacturer of DI gasoline engines has claimed that fuel economy improvements of 20% or higher may be achieved with this new engine technology.

DI Gasoline Engines

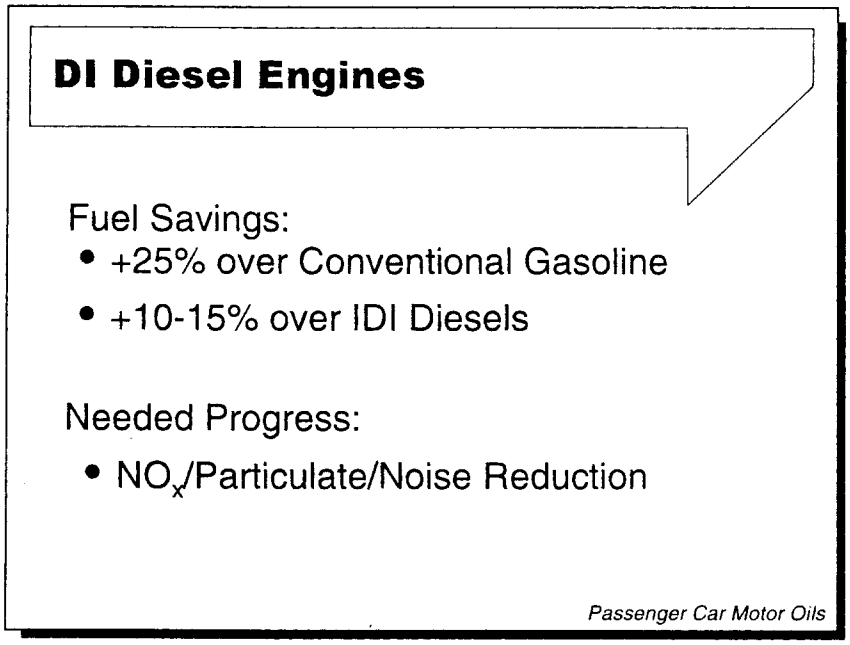
- Benefit!!!
  + 20% Fuel Savings
- Concerns???
  - EGR
  - IVD
  - Soot



Passenger Car Motor Oils

The gasoline engine technology with the greatest potential for fuel efficiency is DI. Conservative estimates claim a 20% benefit in moving to this technology with many citing at least 30% improvement. Because of the upcoming fuel economy regulations in Japan, several OEMs there have begun to market DI gasoline engines. To make this a viable global technology, progress is necessary in the area of NO_x and particulate exhaust treatment.

Like its Diesel counterparts, DI gasoline engines will incorporate exhaust gas recirculation (EGR). The resulting oxidation, nitration and soot formation leads to a series of concerns not typically considered when formulating gasoline motor oils. Furthermore, in conventional spark ignited engines, a fuel-air mixture flows over the intake valves and may clean any oil-related deposits which may form there. This is no longer the case when fuel is injected directly into the cylinder. This represents another potential concern when formulating oils for this application. However, to date, no manufacturer of DI gasoline engines is recommending a tailored lubricant.

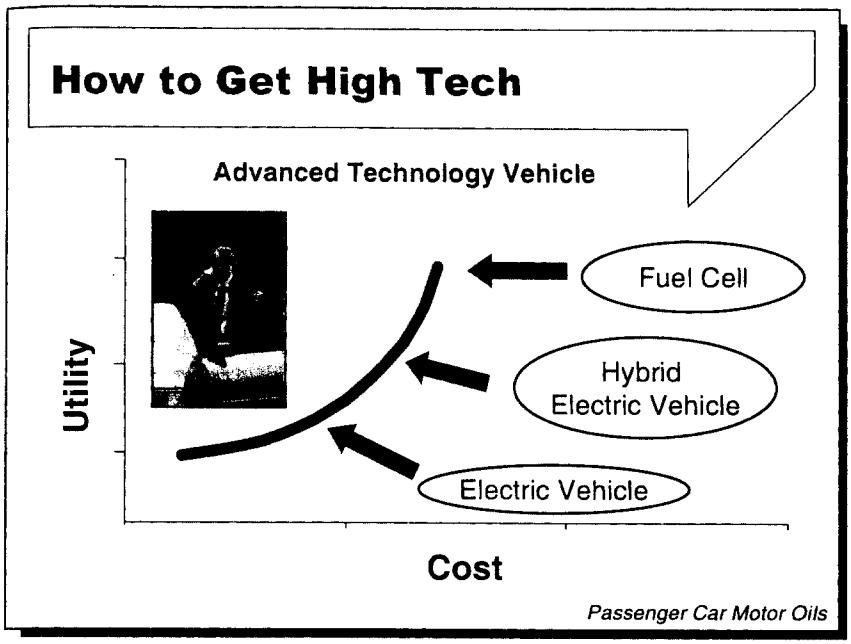


It has been established that an enormous market for light-duty Diesels exists in Europe. The large fuel savings offered by the Diesel engines relative to gasoline engines are not of value to the U.S. consumer because of the low price and availability of gasoline. Despite this fact, the light-duty Diesel is getting more and more attention and is the engine of choice for the Partnership for a New Generation of Vehicles (PNGV) in the U.S. and the so-called (3 liter/100 km) car in Europe. Whereas indirect injection Diesels offer a fuel savings up to 15% compared to a conventional gasoline engine, DI boosts that figure by another 10%.

This concept is being further developed through such innovations as common rail DI. The common rail system provides a single source of high pressure fuel to all the injectors. Fuel injector timing is electronically controlled to provide better delivery and improved combustion.

As with the DI gasoline engine, advanced De-NO_x catalyst technology is required to make this a key engine in the future. Attention must also be given to control of particulates.

This technology is becoming more and more refined and is taking position to make enormous gains around the globe.



For any product to be accepted by consumers, it must provide an acceptable level of utility relative to cost. The vehicle market is no exception.

Hybrid vehicles are making significant progress. Toyota's new Prius, which incorporates a 1.5 liter gasoline engine and an electric motor, became available for sale in Japan in late 1997. Because two power plants are more expensive than one, and because of the predominant use of gasoline or Diesel engines in hybrids, there will be little impact on the lubricant industry in the near-term.

Nearly all major automakers have an electric vehicle in their portfolio. There are cities and governments around the world that support their use. However, cost, battery weight and ranges typically of no more than 150 miles (240 km) will limit this vehicle to specific applications such as in vehicle fleets.

Fuel cells, electrochemical devices combining hydrogen and oxygen to produce electricity with zero emissions, low noise and high energy efficiency, have made significant progress over the last several years. Although neat hydrogen is being pursued in some quarters for safety and fuel availability reasons, methanol or gasoline is the likely first choice as the near-term hydrogen source for fuel cells. Significant efforts directed at cost and size will have to continue to make this a competitive alternative.