

PARAMINS

EXXON CHEMICAL
PERFORMANCE PRODUCTS
GROUP

LUBRICANTS FOR LOW EMISSION DIESEL ENGINES
PRESENTATION TO THE KOREAN SOCIETY
OF LUBRICATION ENGINEERS

SEOUL, 18TH NOVEMBER, 1988

BY

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EXXON CHEMICAL JAPAN LTD.

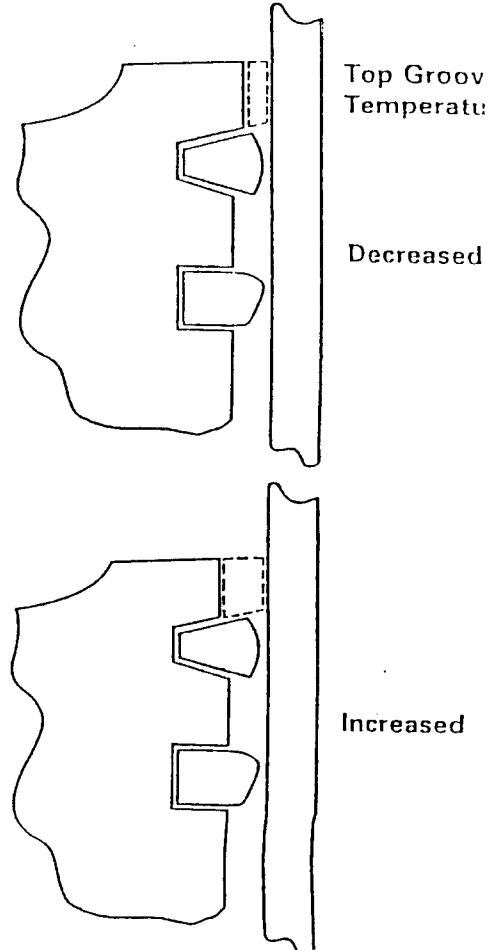
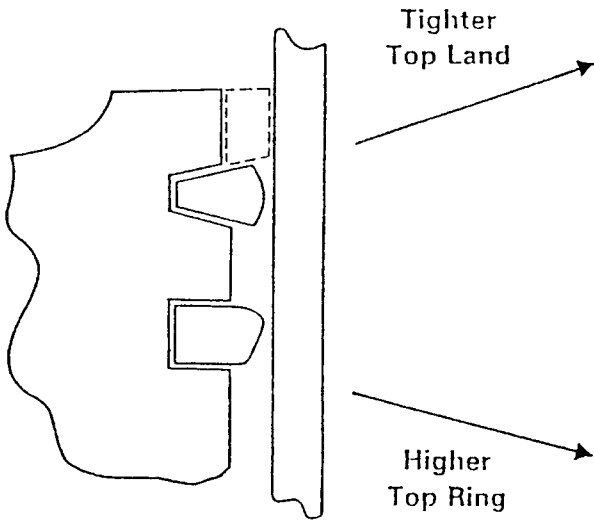
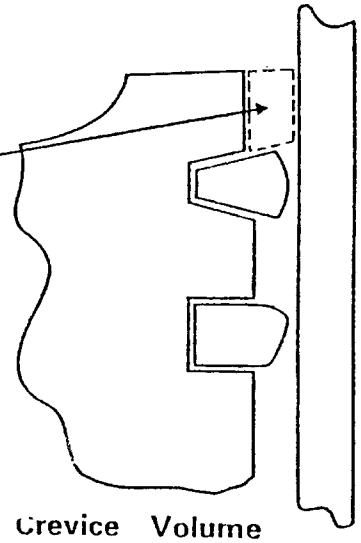
THE NEW CHALLENGE - LOW EMISSION DIESELS

- o CONTINUED PUBLIC CONCERN FOR CLEAN ENVIRONMENT
- o AUTO EMISSION LEGISLATION IN PLACE IN MANY COUNTRIES
- o DIESEL EMISSION CONTROLS BEING TIGHTENED
- o DIESEL ENGINE DESIGN WILL CHANGE
- o SIGNIFICANT INFLUENCE ON FUELS AND LUBES
- o MULTIGRADE SPHD CE OILS PROVIDE GOOD STARTING BASE
- o LOWER ASH DIESEL LUBES MAY BE FUTURE TREND

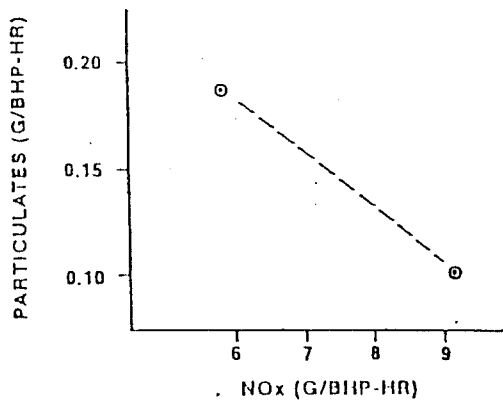
| Date | NO _x (g/bhph) | HC (g/bl/ph) | Particulates (g/bhph) | CO (g/bhph) |
|---------|-----------------------------|-----------------|--------------------------|----------------|
| Current | 10.7 | 1.3 | — | 15.5 |
| 1988 | 10.7 | 1.3 | 0.6 | 15.5 |
| 1991 | 5.0 | 1.3 | 0.25* | 15.5 |
| 1994 | 5.0 | 1.3 | 0.1 | 15.5 |

*0.1 for Inner city buses

Emissions Legislation



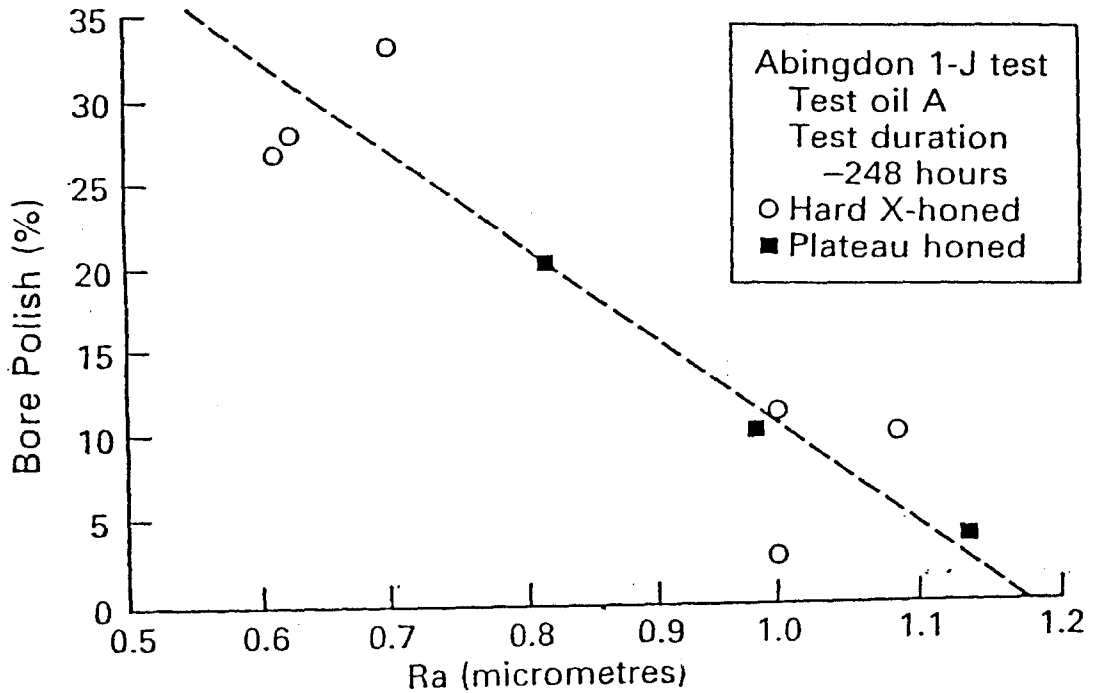
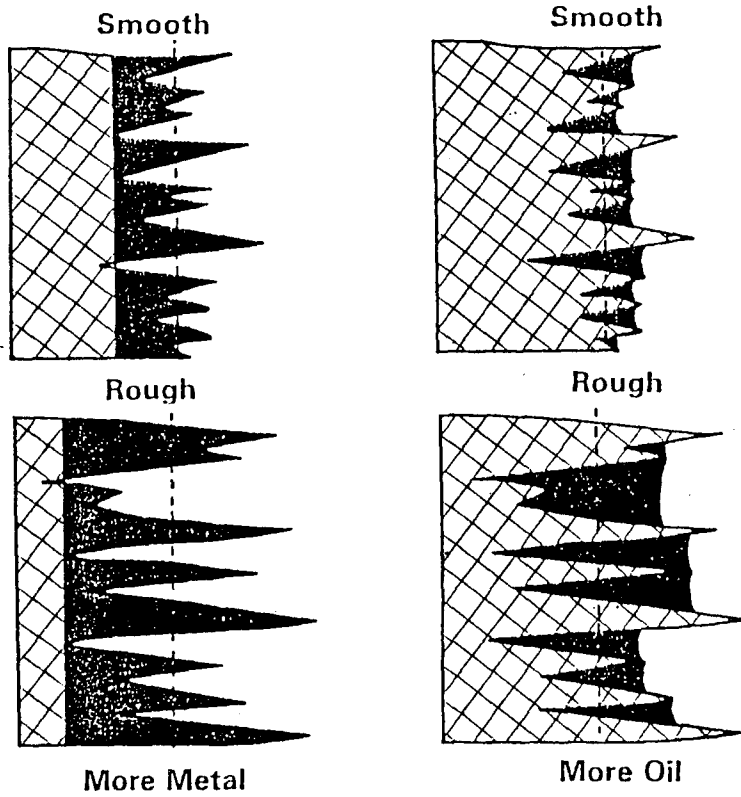
PARTICULATES/NO_x TRADE-OFFS

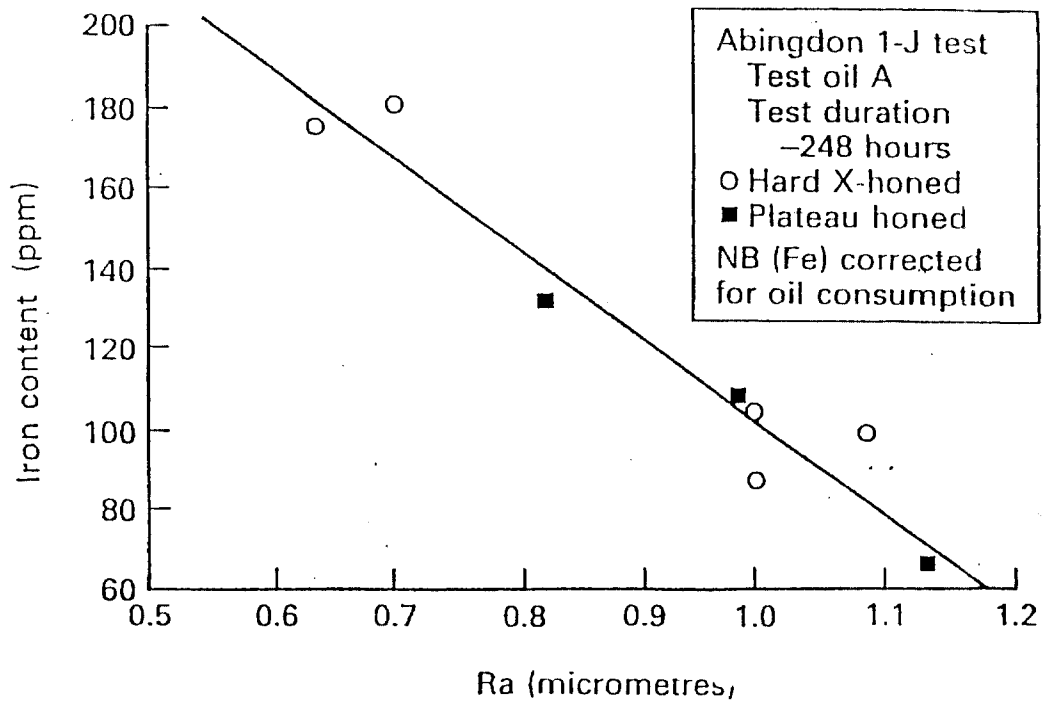
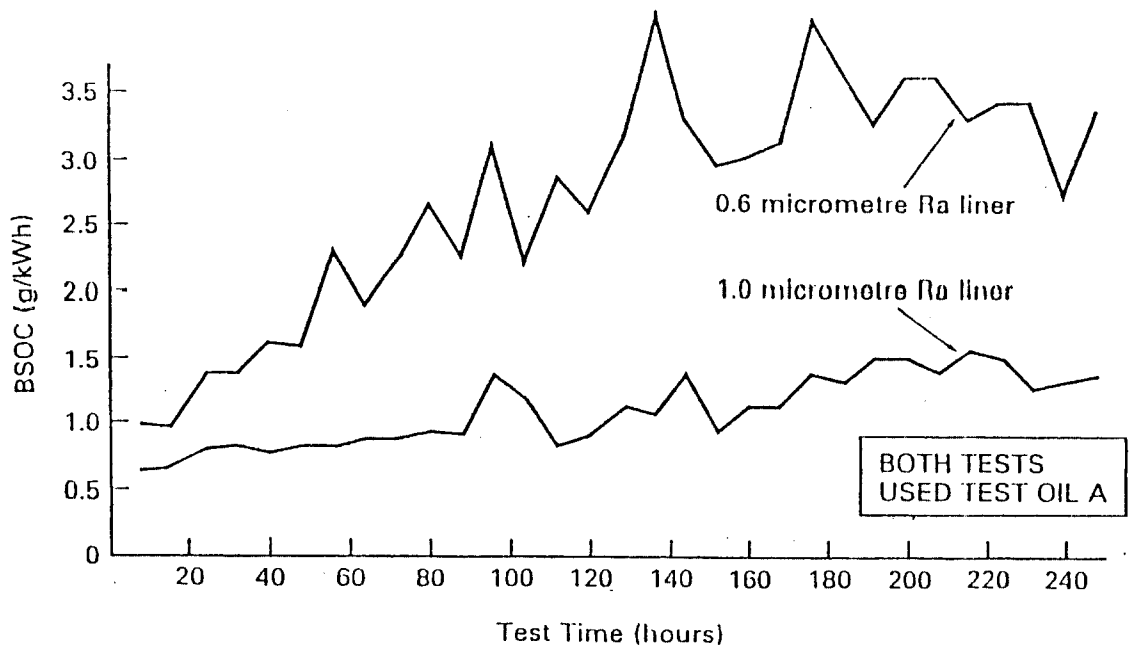


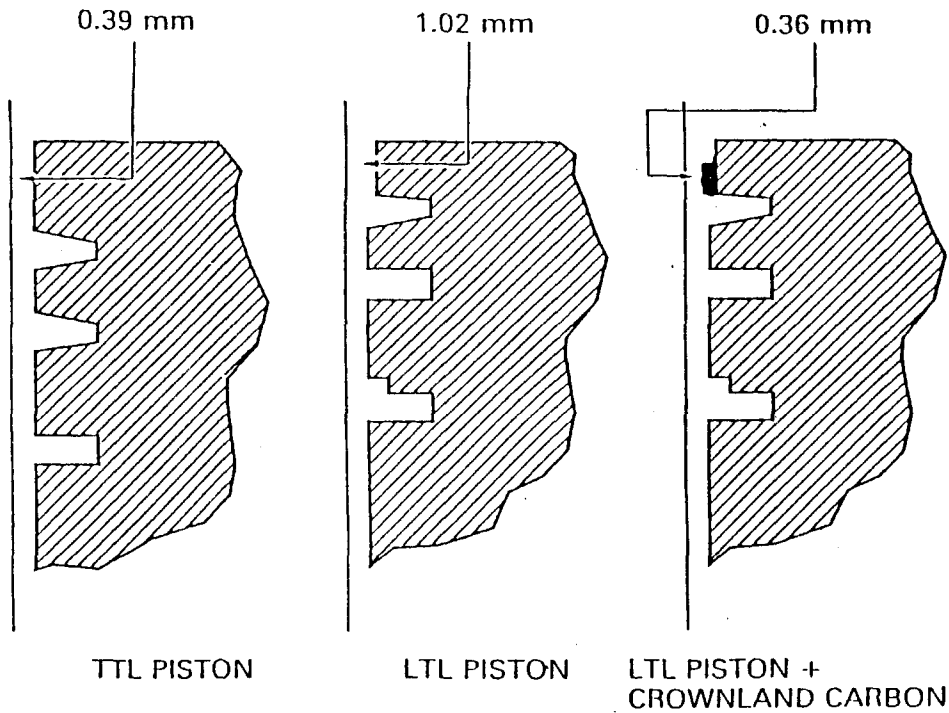
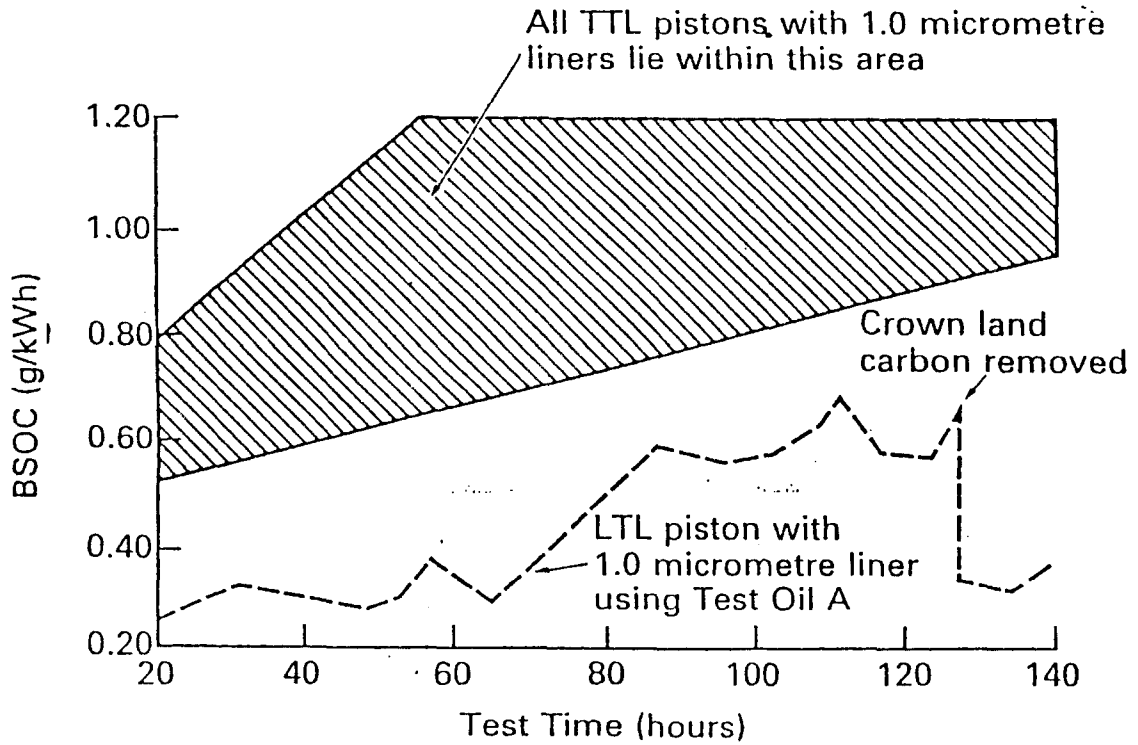
SOURCE: Ricardo

PARAMINS RESEARCH DEMONSTRATES IMPORTANCE OF LINER SURFACE FINISH AND TOP LAND CLEARANCE

- o CATERPILLAR 1-J SINGLE CYLINDER ENGINE USED
- o CAT. 1Y540 PISTON REFLECTS DESIGN TRENDS
 - TIGHT TOP LAND
 - HIGHER BMEP
- o CAT 1-J EVALUATES
 - PISTON DEPOSITS
 - BORE POLISHING
 - OIL CONSUMPTION
- o PREDECESSOR OF CAT 1-K ENGINE TEST NOW UNDER DEVELOPMENT







HIGH PERFORMANCE SAE 15W-40 DIESEL ENGINE LUBRICANTS PROVIDE SIGNIFICANT BENEFITS TO TRUCK FLEET

- Reduction of Fuel Costs
- Less Engine Maintenance and Downtime
- Vehicles on the Road Longer Through Improved Durability-
Reduction in Capital Requirements
- Overall Reduction in Operating Costs – More Profit

DISPELLING A FEW MISCONCEPTIONS

**Reduction of Oil Pressure
With Multigrades**

**Quantity of Oil is Maintained
Via Positive Displacement Pump.
Multigrades Correctly Provide
Lower Resistance to Flow**

**Shorter Oil Drains Allows
Use of Low Quality Oils**

**The Correct Balance and
Level of Additives Must be
Present in the Critical Zones**

SETTING THE RECORDS STRAIGHT

Single Grades are "Thicker"
Than Multigrades

- At Piston/Ring Operating Temperatures Multigrades are More Viscous
- Faster Lubrication at Low Temperatures

Multigrades Become Thinner
and Give Higher Oil Consumption

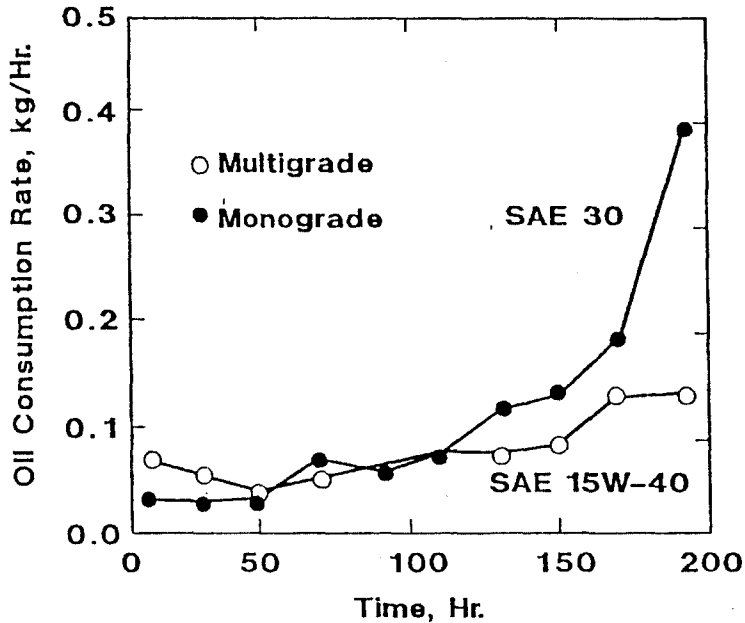
- Today's Viscosity Improvers are More Resistant to Shear and Mechanical Degradation
- Multigrades Give Lower Oil Consumption Than Single Grades in the Field

IMPORTANCE OF CONTROLLING OIL CONSUMPTION

- Low Oil Consumption → Good Engine
Low Deposits
Low Bore Polish
- High Oil Consumption → Poor Engine
High Deposits
High Bore Polish
- Oil Consumption Best Indicator of Durability
and Engine Life

MULTIGRADE OILS OUTPERFORM MONOGRADES

Cummins NTC 400 Test Data



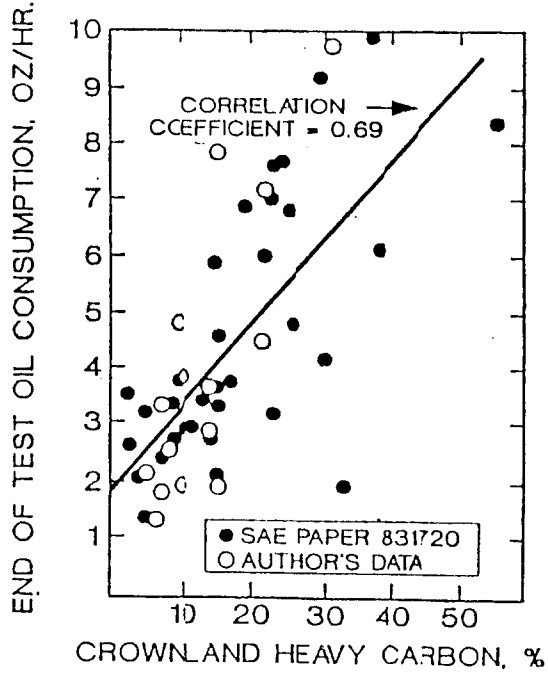
• Multigrades Control Oil Consumption Better

CURRENT HEAVY DUTY ENGINE TARGETS RESPOND TO A LOWER ASH/DISPERSANT TYPE OIL

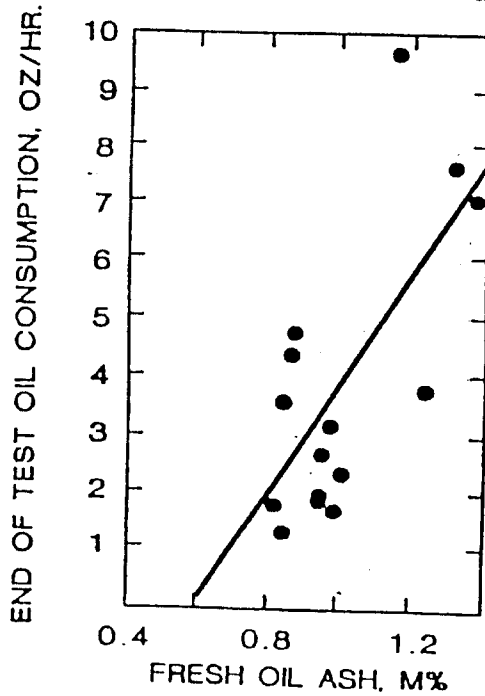
CE SPECIFICATION

| | |
|----------------------|--|
| CUMMINS NTC-400 TEST | LOWER CROWNLAND DEPOSIT TARGET |
| MACK T-7 | CRANKCASE SOOT BUILD UP CONTROL |
| MACK T-6 | PISTON DEPOSIT BUILD UP |
| CATERPILLAR 1-G/2 | PISTON TOP GROOVE FILL AND RING ZONE LACQUER CONTROL |
| L-38 TEST | BEARING WEIGHT LOSS |

NTC 400 OIL CONSUMPTION DEPENDENT ON CROWNLAND ASH



CUMMINS NTC 400 TEST RESPONDS TO LOWER ASH HD OILS



CE PERFORMANCE OF LOW ASH OIL 0.5 WT. %

| | | <u>LIMIT</u> |
|--------------------------|-------|--------------|
| <u>L-38</u> | | |
| BWh | 34 | 40 MAX |
| <u>1-G/2</u> | | |
| TGF | 54 | 80 MAX |
| WTD | 204 | 300 MAX |
| <u>T-6</u> | | |
| MACK MERITS | 112 | 90 MIN |
| <u>T-7</u> | | |
| VIS. INCREASE RATE cSt/H | 0.009 | 0.040 MAX |
| <u>NTC 400</u> | | |
| FINAL OIL CONS. #/H | 0.17 | 0.30 MAX |
| CROWNLAND CARBON, % | 9 | 25 MAX |
| 3rd LAND DEMERITS | 12 | 40 MAX |

FIELD TEST CONDITIONS

ENGINE: NTC 400 BIG CAM 3
OIL DRAIN: 18,000 MILES
FILTER CHANGE: 18,000 MILES
SERVICE: 80,000 LBS
INSPECTION: 250,000 MILES

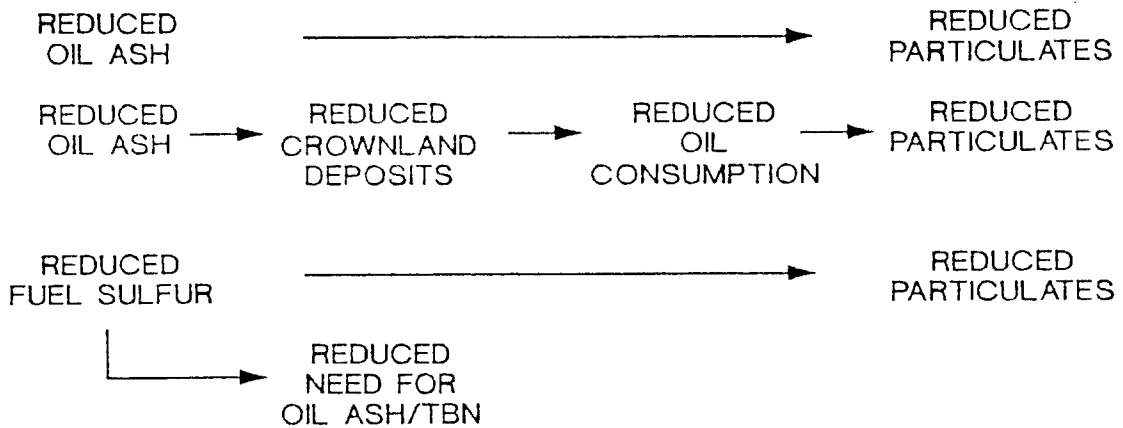
OIL TESTED

| ASH, WT% | 0 | 0.5 | 2.0 |
|----------|--------|--------|--------|
| GRADE | 15W/40 | 15W/40 | 15W/40 |

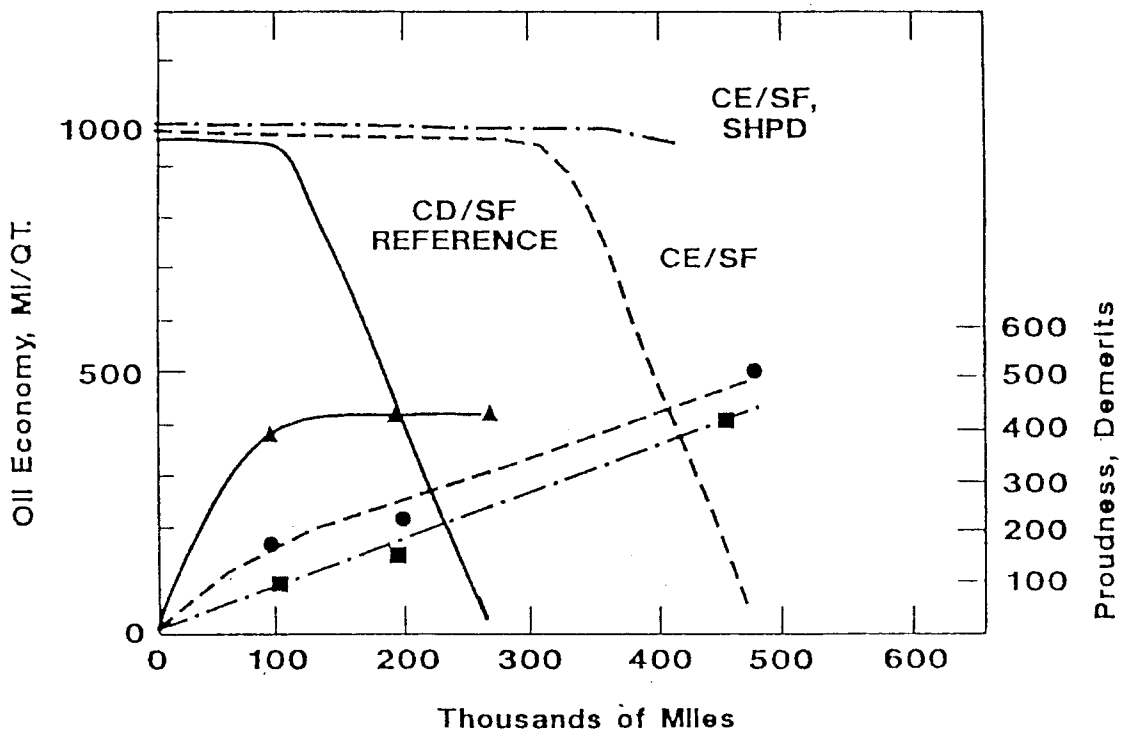
FIELD TEST DEPOSIT SUMMARY

| | <u>ASHLESS OIL</u> | <u>0.5 WT% ASH OIL</u> | <u>2.0 WT % ASH OIL</u> |
|---------------------------------|------------------------|----------------------------|-----------------------------|
| <u>PISTON</u> | | | |
| #1 GROOVE, % | 26 | 66 | 83 |
| CROWNLAND POLISHED CARBON, % | 0 | 19 | 48 |
| TOTAL PISTON DEMERITS | 178 | 208 | 165 |

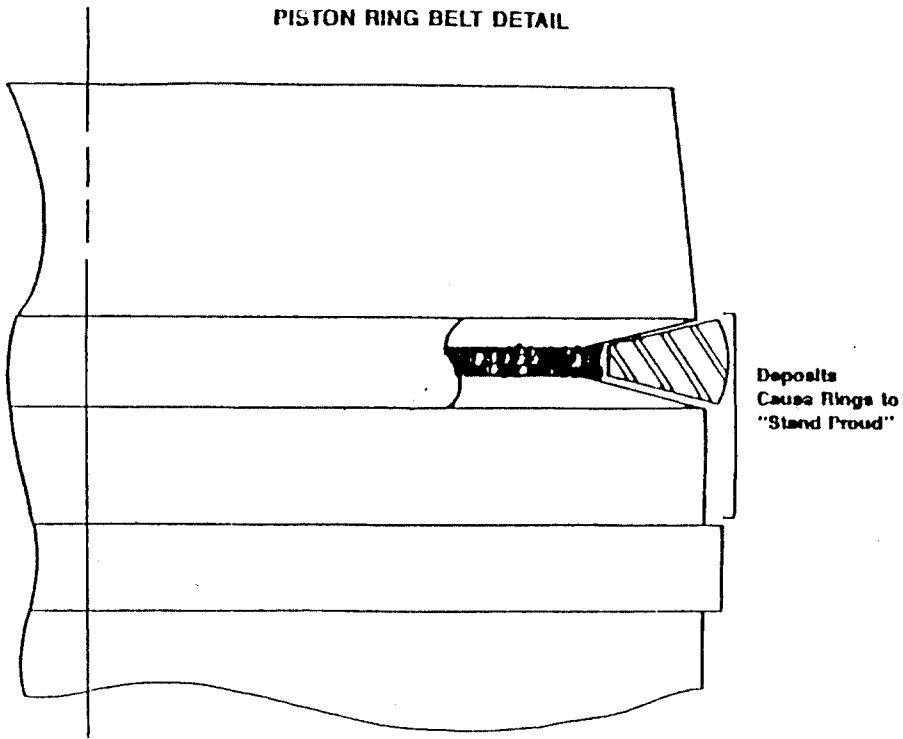
LOW ASH MAY BE KEY IN MEETING FUTURE PARTICULATE TARGETS



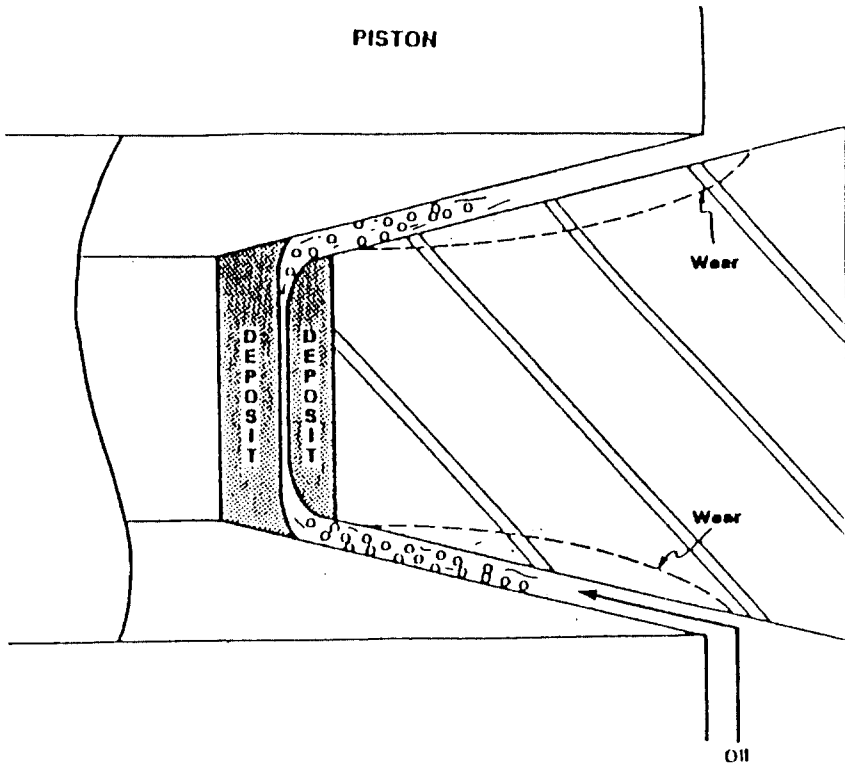
MACK OIL ECONOMY AND PISTON PROUDNESS



PISTON RING BELT DETAIL



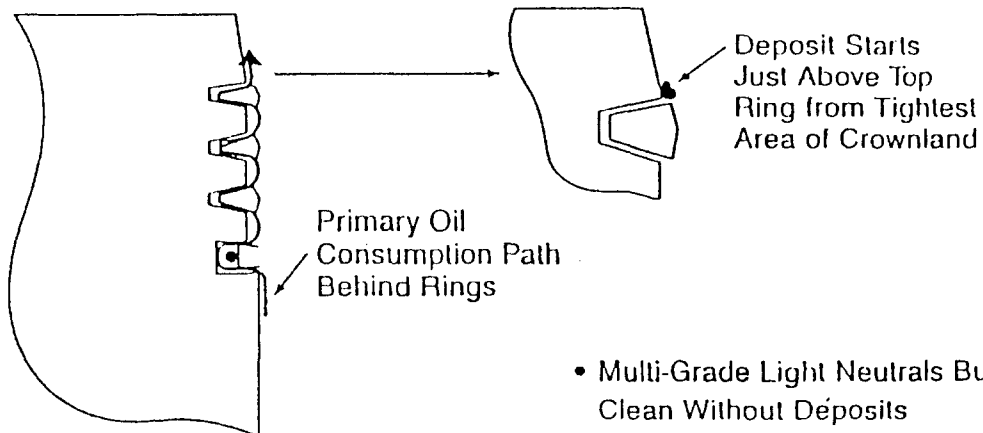
PISTON



Why are Monograde Engine Oils More Severe for NTC400 Oil Consumption?

- Monogrades are more prone to build up to Crown Land Carbon Deposits.
- Greater feed rates to Crown Land and Combustion Chamber area.
- Poorer burning characteristics than oil containing basetock neutrals.

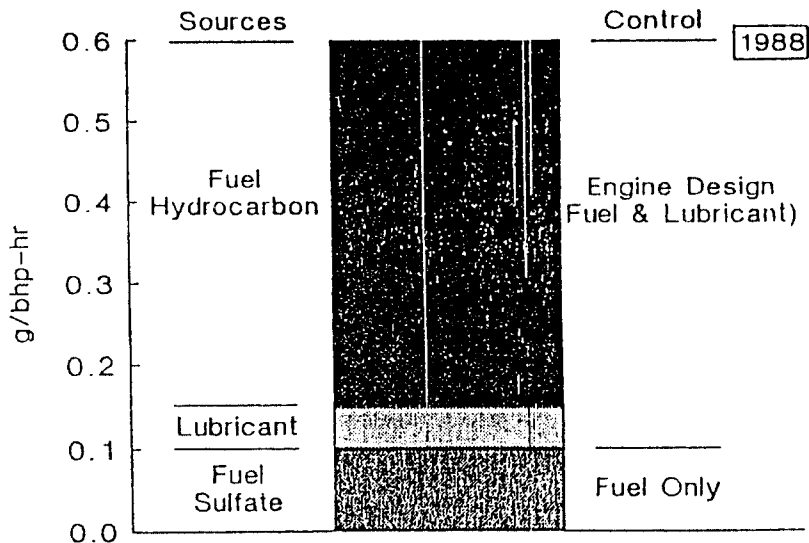
Crownland Deposit Formation



Given Correct Hardware-
Rings, Liners, Pistons

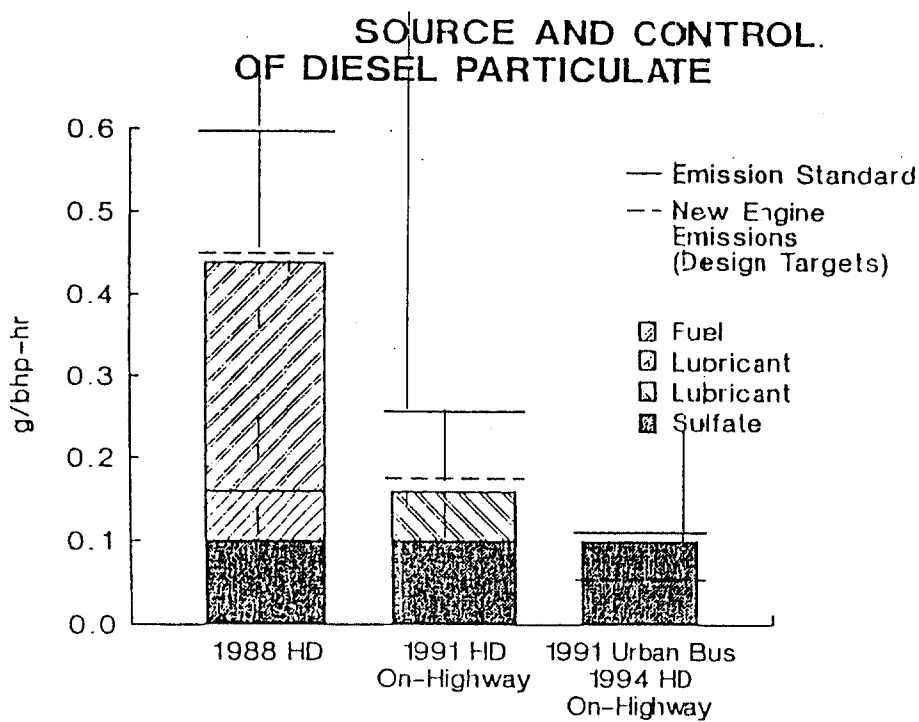
- Multi-Grade Light Neutrals Burn Clean Without Deposits
- Heavier Neutrals in 30 and 40 Grades Decompose Leaving Deposits

SOURCE AND CONTROL OF DIESEL PARTICULATE



Source: Cummins

SOURCE AND CONTROL OF DIESEL PARTICULATE



Source: Cummins

IMPLICATIONS OF EMISSION REQUIREMENTS

- Reduced Fuel Sulfur Reduces Need for TBN
- Reduced Fuel Sulfur to 0.05% May Reduce Engine Wear
- Lubricant Ash Content May be Significant Contributor to Particulate Emissions
- Raised Ring/Reduced Crevice Volume will Increase Deposit Sensitivity of Future Engines - Additive will Need to Provide Better Deposit Control
- Properly Formulated Low Ash Oils can Reduce Crownland Deposits
- Premium Quality Low Ash Lubricants will be Required for Emission-Controlled HD Engines

METHANOL FUELLED BUSES PLANNED IN U.S.

- o CITY BUSES HAVE TO MEET 1994 TRUCK EMISSION IN 1991
- o DETROIT DIESEL HAS 95% OF TOTAL NORTH AMERICAN BUS BUSINESS
- o DETROIT DIESEL HAS DEVELOPED NEW METHANOL ENGINE WHICH MEETS 1991 EMISSION STANDARDS
- o DETROIT DIESEL PLANS ARE CONDUCTING RESEARCH WITH THEIR NEW METHANOL ENGINE
- o DETROIT DIESEL WILL BE ONLY OEM TO USE METHANOL IN 1991 AND ONLY FOR BUS FLEETS
- o METHANOL USE MIGHT BE EXTENDED TO MEET THE 1994 EMISSION TARGETS

CONCERNS OF DETROIT DIESEL ON METHANOL DIESEL ENGINE

- o CURRENTLY FIELD TESTING WITH 6V92T ENGINES ON METHANOL
- o ENGINES SUFFER FROM COMBUSTION CHAMBER DEPOSITS, INJECTOR DEPOSITS AND SEVERE LINER SCUFFING
- o INJECTOR BLOCKING COMES FROM ASH IN THE OIL
- o THE ENGINE ENDURANCE IS LIMITED TO 200 K MILES AGAINST EPA REQUIREMENT OF 290 K MILES
- o DETROIT DIESEL ARE CONDUCTING FIELD TESTS ON THEIR NEW METHANOL ENGINES
- o MEOH FUEL SUPPLY WILL BE NEEDED
- o U.S. GOVERNMENT MAY DELAY 1991 BUS EMISSION REQUIREMENT

JAPANESE EXHAUST EMISSION STANDARDS

FOR DIESEL POWERED SMALL TRUCKS AND BUSES (ABOVE 2.5 TONS)

| | <u>1987</u> | <u>1988</u> | <u>1989</u> | <u>1994</u> |
|---------------|-------------|-------------|-------------|----------------|
| NOx (IDI) PPM | 390 | 390 | 350 | 350 |
| NOx (DI) PPM | 610 | 610 | 500 | 500 |
| PARTICULATE | - | - | - | ENFORCEMENT(?) |

FOR DIESEL POWERED SMALL TRUCKS AND BUSES (1.7 - 2.5 TONS)

| | | | | |
|---------------|-----|-----|-----|----------------|
| NOx (IDI) PPM | 390 | 350 | 350 | 350 |
| NOx (DI) PPM | 610 | 500 | 500 | 500 |
| PARTICULATE | - | - | - | ENFORCEMENT(?) |

FOR DIESEL POWERED SMALL TRUCKS AND BUSES (BELOW 1.7 TONS)

| | | | | |
|-------------|---------|----------|----------|----------------|
| NOx | 390 PPM | 1.2 G/KM | 1.2 G/KM | 1.2 G/KM |
| PARTICULATE | - | - | - | ENFORCEMENT(?) |

FUTURE HD OILS FOR JAPANESE LOW EMISSION DIESELS

- o CONSIDERABLE ACTIVITY RE DEVELOPMENT OF LOW EMISSION DIESELS
- o EMPHASIS ON NOX BUT PARTICULATE CONTROLS BEING CONSIDERED FOR 1994
- o EGR INTRODUCED FOR SMALL DIESELS AND MAY COME FOR MEDIUM SIZED TRUCKS
- o LOW S FUEL BEING SEEN AS KEY ROUTE TO LOWER EMISSIONS
- o EA INITIATED STUDY OF EFFECT OF FUEL S ON EGR AND PARTICULATES
- o OEMS AND A CATALYST MANUFACTURER EVALUATING PARAMINS ZERO AND SHPD DIESEL OILS

HOW THE JAPANESE OEMS ARE MEETING 1991 EMISSION LIMITS

- o PARTICULATE TRAPS MAY NOT BE USED
- o ENGINES BEING REDESIGNED TO MEET U.S. LIMITS

| <u>DESIGN TECHNOLOGY</u> | <u>EFFECT</u> |
|----------------------------------|-------------------------------------|
| TURBO/SUPER CHARGER | CLEAN COMBUSTION |
| INTERCOOLER | REDUCE NOX/IMPROVE FE |
| 4 RINGS | REDUCE OIL CONSUMPTION |
| TIGHTER LAND | REDUCE OIL CONSUMPTION AND EMISSION |
| ELECTRONIC CONTROL UNIT INJECTOR | REDUCE PARTICULATE |
| HIGH PRESSURE INJECTION | REDUCE PARTICULATE |
| SPECIAL PISTON | CLEAN COMBUSTION |
| ACOUSTIC INDUCTION SYSTEM | CLEAN COMBUSTION |
| EGR | REDUCE NOX |
| AMMONIUM USAGE | REDUCTION OF NOX |

OIL CONSUMPTION FOR JAPANESE HD ENGINES IS LOWER

OIL CONSUMPTION, GR/HP, HR

| | |
|------------------------------|-----------|
| HINO (CLASS 6, DI) | * |
| DETROIT DIESEL (CLASS 6, DI) | 0.1 - 0.2 |
| CUMMINS (CLASS 6, DI) | 0.8 |
| EUROPEAN HD DIESELS | 0.5 - 0.6 |
| | 0.2 - 2.0 |

* THIS CORRESPONDS TO 5000 KM/L.

- o 10W30 MULTIGRADE OILS ARE PREFERRED IN JAPAN
- o WITH VERY LOW OIL CONSUMPTION SOME ASH MAY BE NECESSARY EVEN WITH LOWER SULFUR FUEL

JAPANESE CATALYST DEVELOPMENT

PARTICULATE TRAPS TO MEET 1994 EMISSION LEGISLATION

- o CURRENT HD TRAPS ONLY LAST 100 HOURS
- o SIDE-WALL CERAMIC HONEYCOMB-BAFFLED SYSTEM
- o TRAP PLACED AFTER THE TURBOCHARGER
- o CARBON PARTICLES OXIDISED AND TRAP REGENERATED
- o LUBRICANT ASH BLOCKS UP CATALYST
- o TESTS WITH ASHLESS DIESEL OIL
- o FUEL S POISONS TRAPS-LOW S DESIRABLE
- o EGR MAKES SITUATION WORSE WITH RECYCLED S

SUMMARY

- o DIESEL EMISSION CONTROLS BECOMING MORE SEVERE
- o MAJOR CHANGES IN DIESEL ENGINE DESIGN EXPECTED
- o SOME MEOH MAY BE USED
- o FUEL S EXPECTED TO DECREASE
- o LESS NEED FOR HIGH TBN OILS
- o LOW ASH OILS HAVE BEEN DEMONSTRATED
- o LOWER OIL CONSUMPTION EXPECTED
- o EMISSION CONTROL TIMING MAY BE RELAXED TO GIVE MORE TIME