



Development of lubricating oil for enhancement of oil drain interval for diesel engines

Presented By
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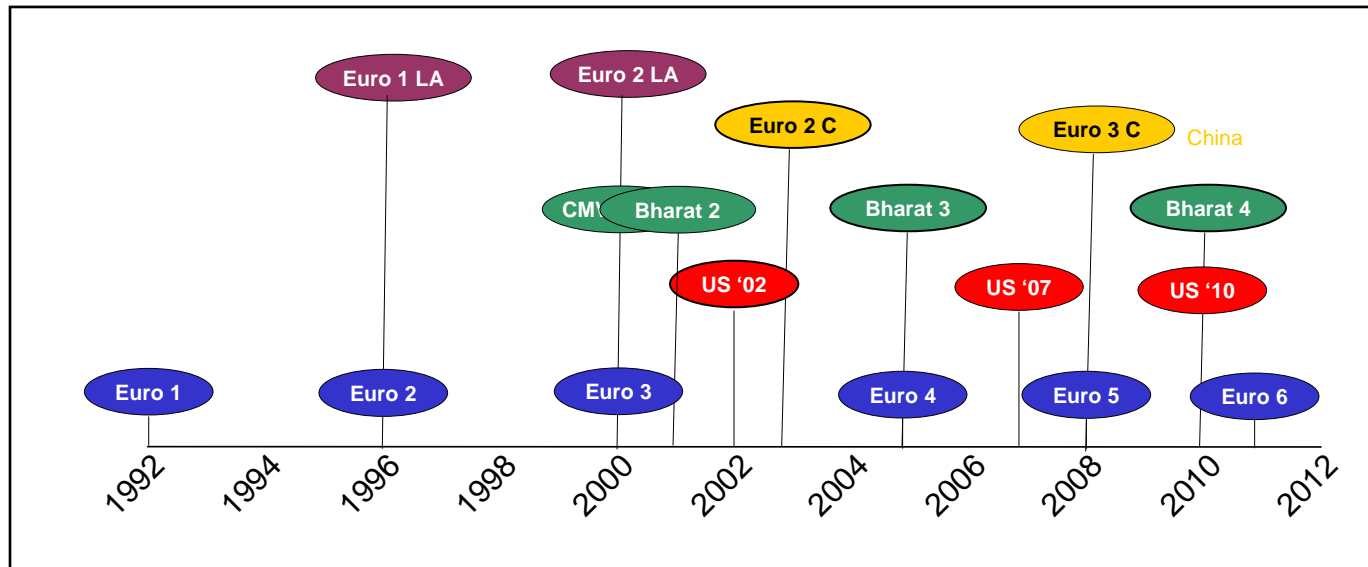
TATA MOTORS, PUNE, INDIA

Drivers for increasing oil drain intervals

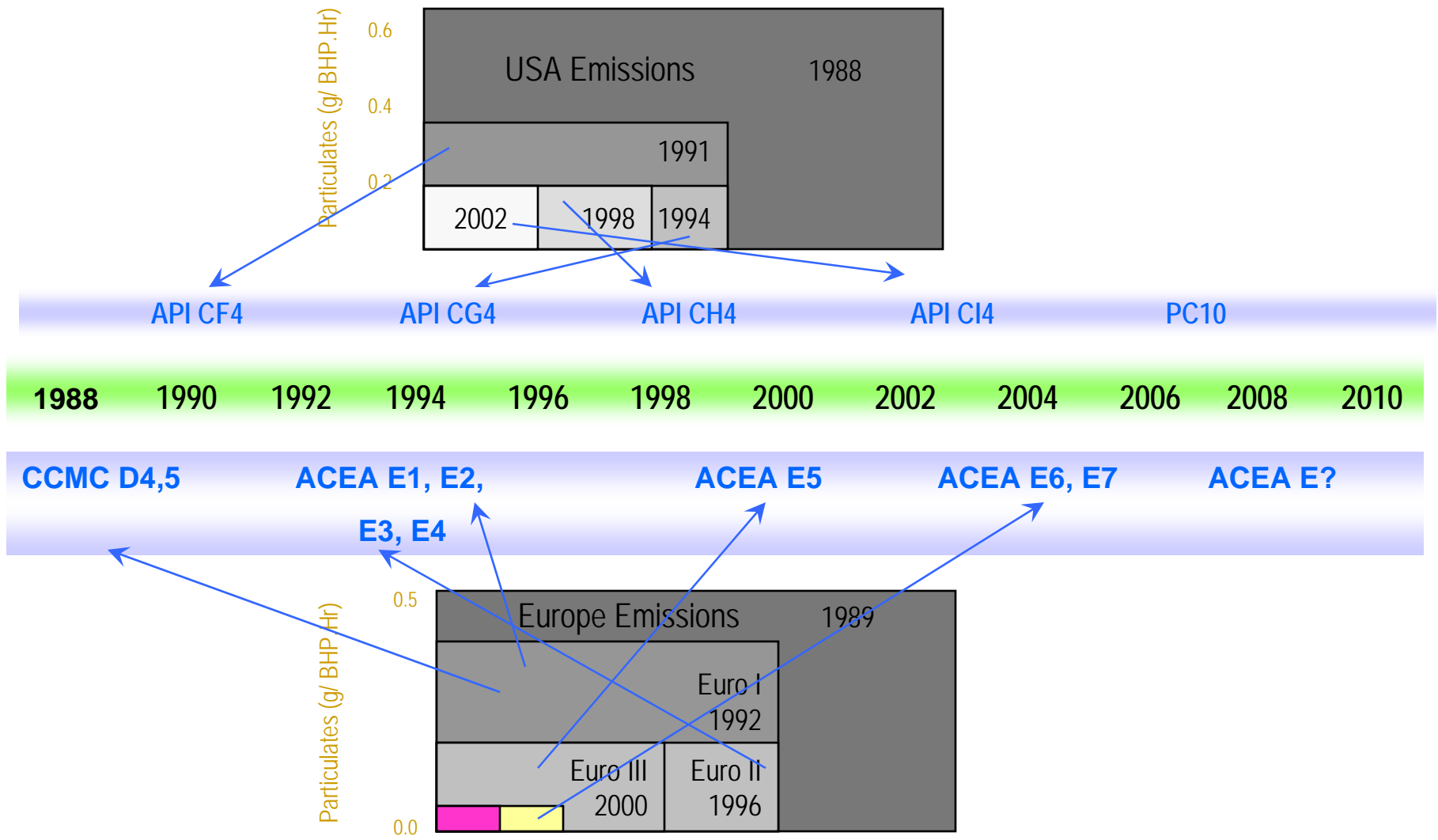
Durability and oil change interval – Market requirement

Cost of Operation - Maintenance and fuel economy

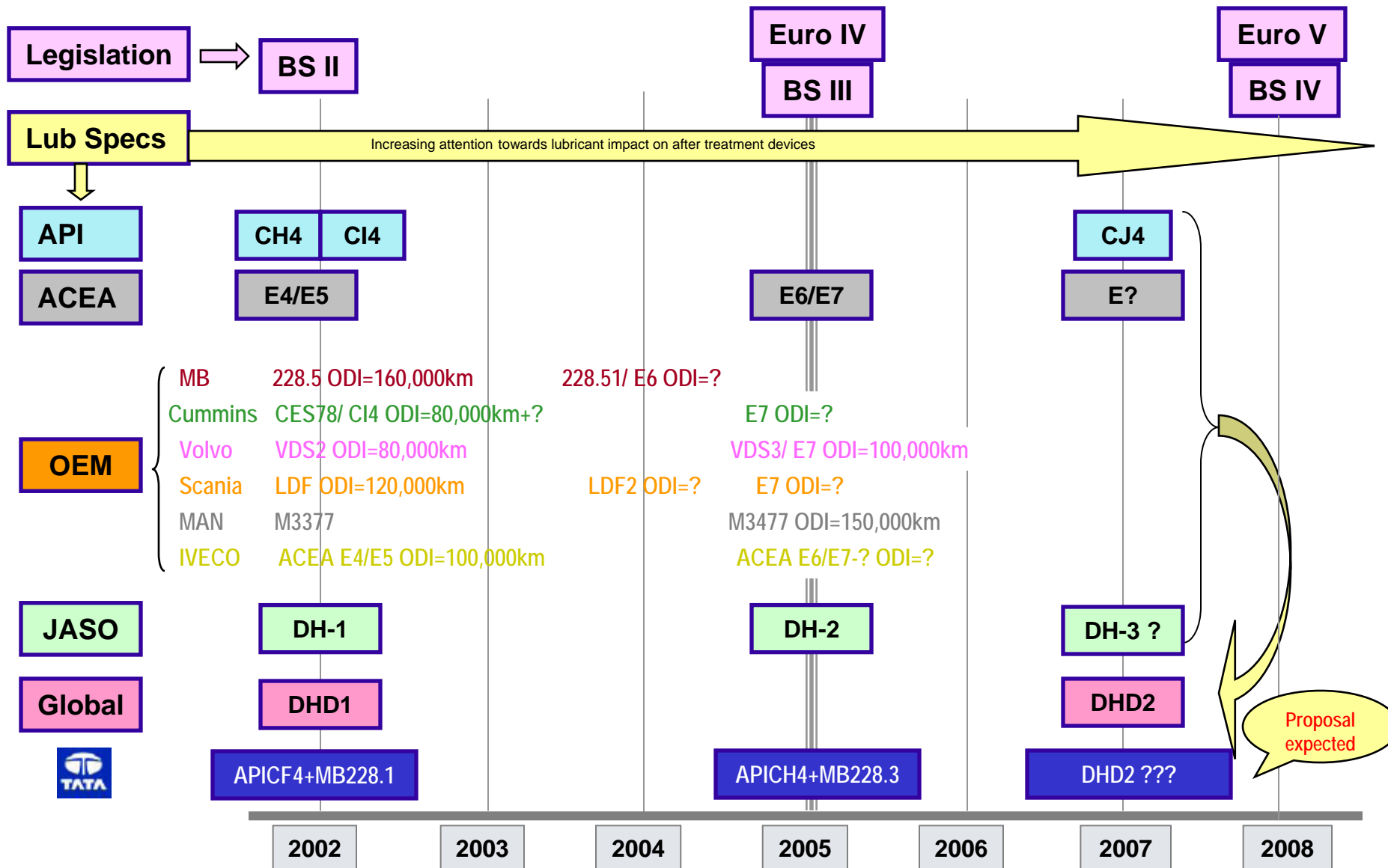
Emissions: Global driver – different timing



Introduction of new oil specifications is closely linked to emission legislation

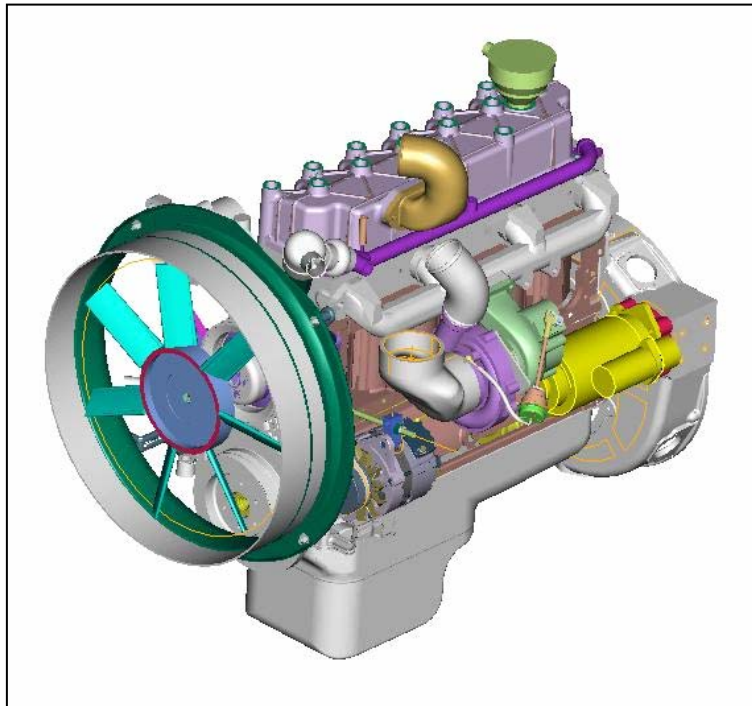


Specs. driven by Emission Legislation in Mature Markets



Specifications of test engines

5.67 ltr engine



Inline 6 cylinders

Bore X Stroke = 97 X 128

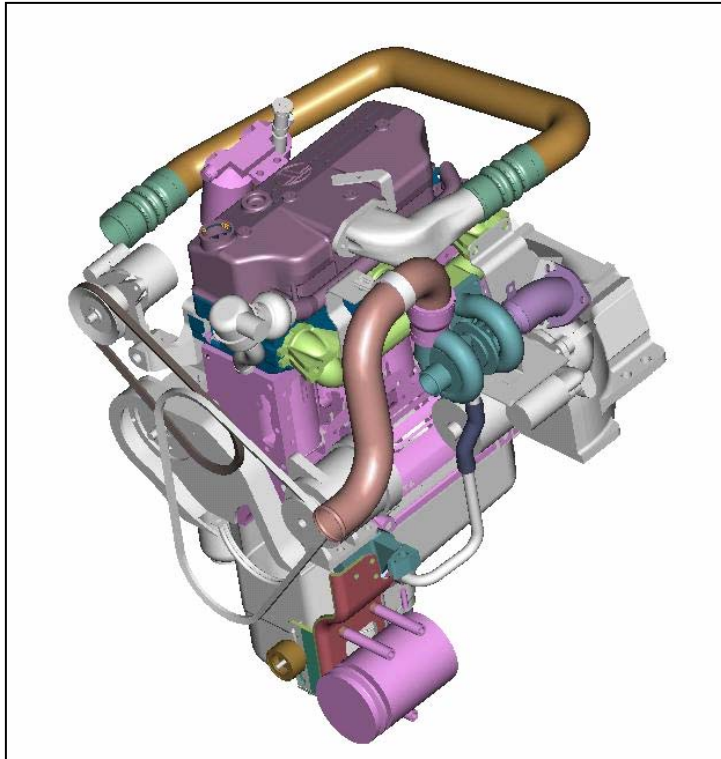
Displacement = 5.67 liters

Oil sump capacity = 14 liters

Specifications	
Power	130 Ps @ 2400 rpm
Torque	410 N-m @ 1400 rpm
Features	<ul style="list-style-type: none"> • Turbocharged • Inline mechanical FIP • No after treatment devices • No EGR
Application	HCV GVW 16 MT

Specifications of test engines

3.78 ltr engine



Inline 4 cylinders

Bore X Stroke = 97 X 128

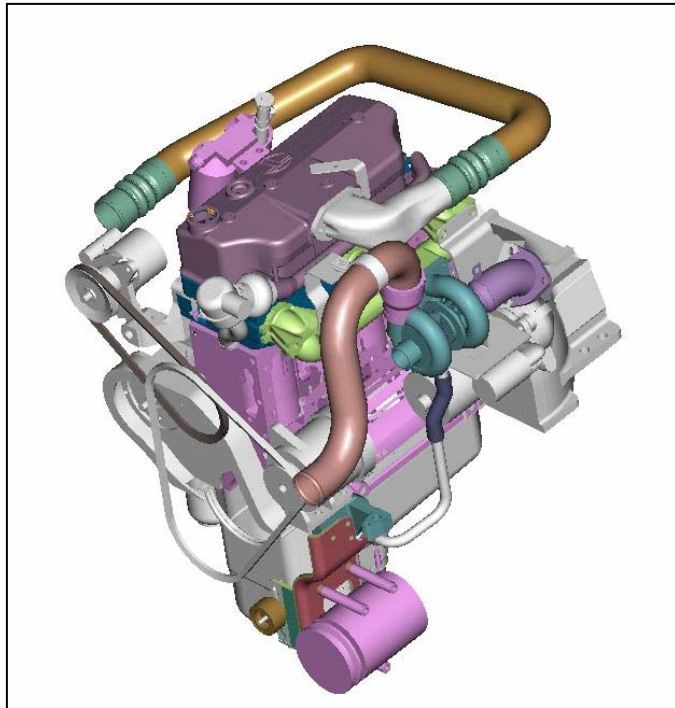
Displacement = 3.78 liters

Oil sump capacity = 9 liters

Specifications	
Power	90 Ps @ 2800 rpm
Torque	265 N-m @ 1800 rpm
Features	<ul style="list-style-type: none"> • TC • Inline mechanical FIP • No after treatment devices
Application	<p>MCV GVW 7 MT</p>

Specifications of test engines

2.95 ltr engine



Inline 4 cylinders

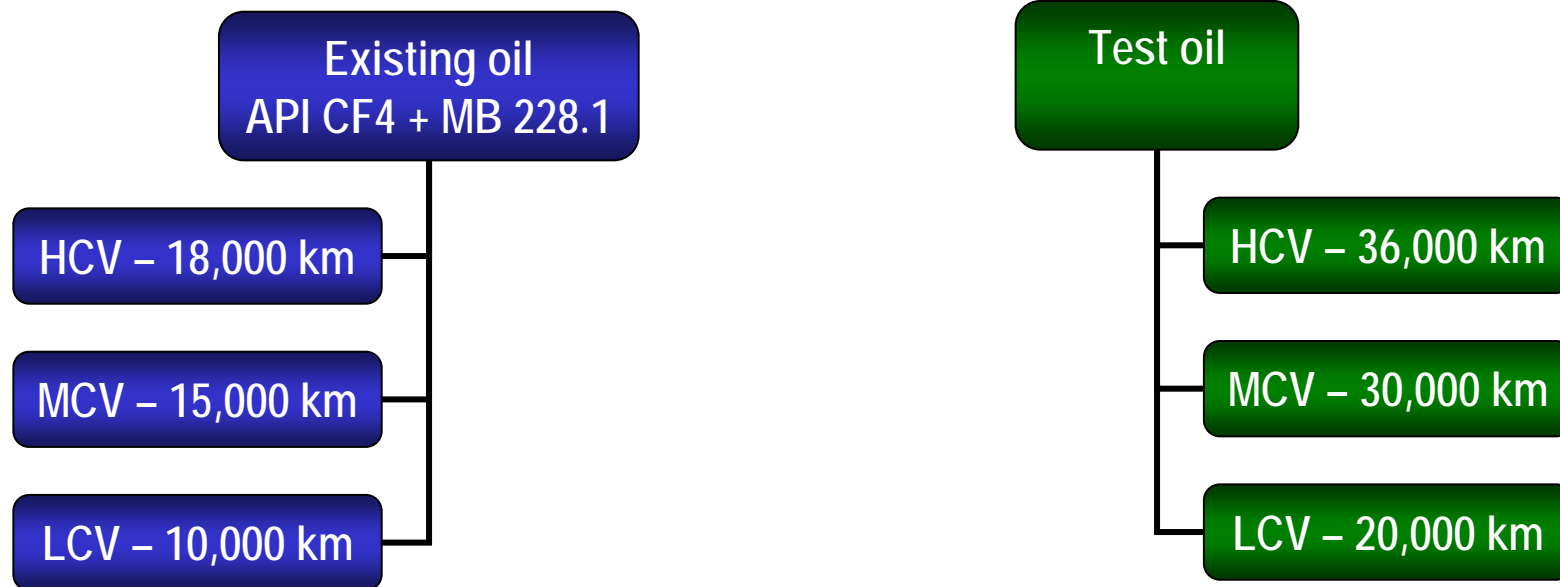
Bore X Stroke = 97 X 100

Displacement = 2.95 liters

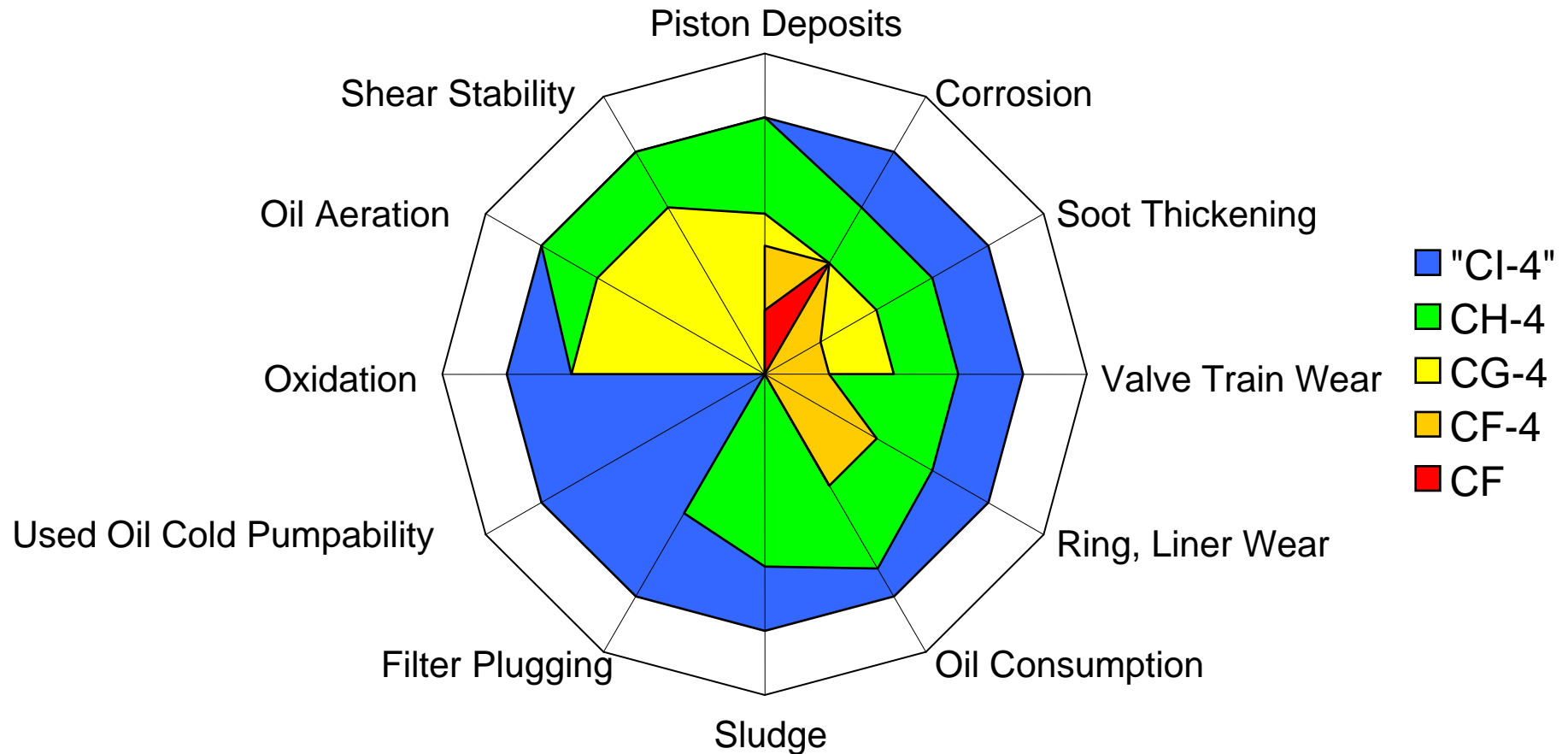
Oil sump capacity = 7 liters

Specifications	
Power	71Ps @ 3200 rpm
Torque	185 N-m @ 1800 rpm
Features	<ul style="list-style-type: none"> • TC • Inline mechanical FIP • No after treatment devices
Application	LCV GVW 5.7 MT

Comparison of oil drain intervals (ODI)

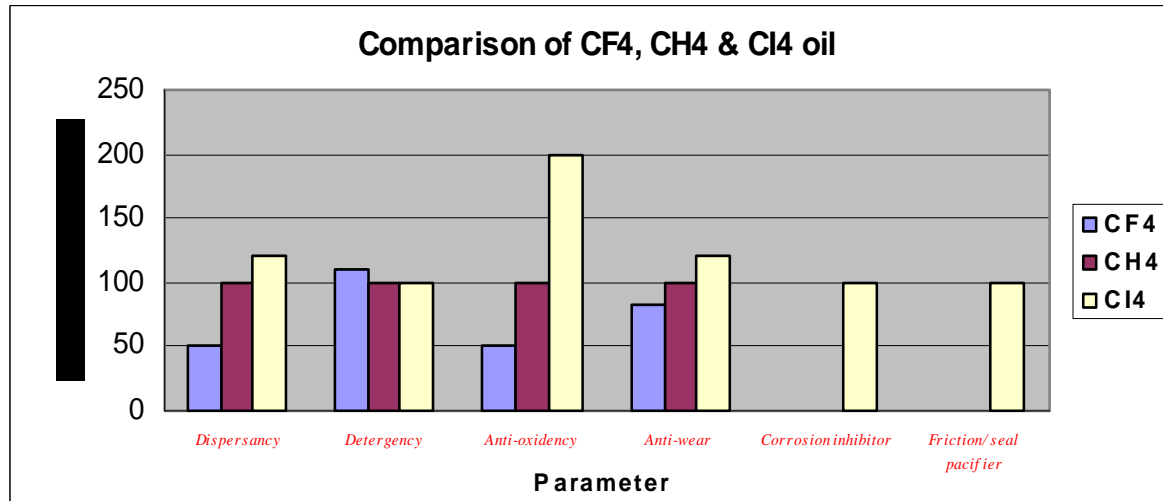


Basis of selecting test oil



- CI4 is specially for EGR application – high soot loading.
- Cost concern.
- CI4 oil was approved by API in Oct'02.

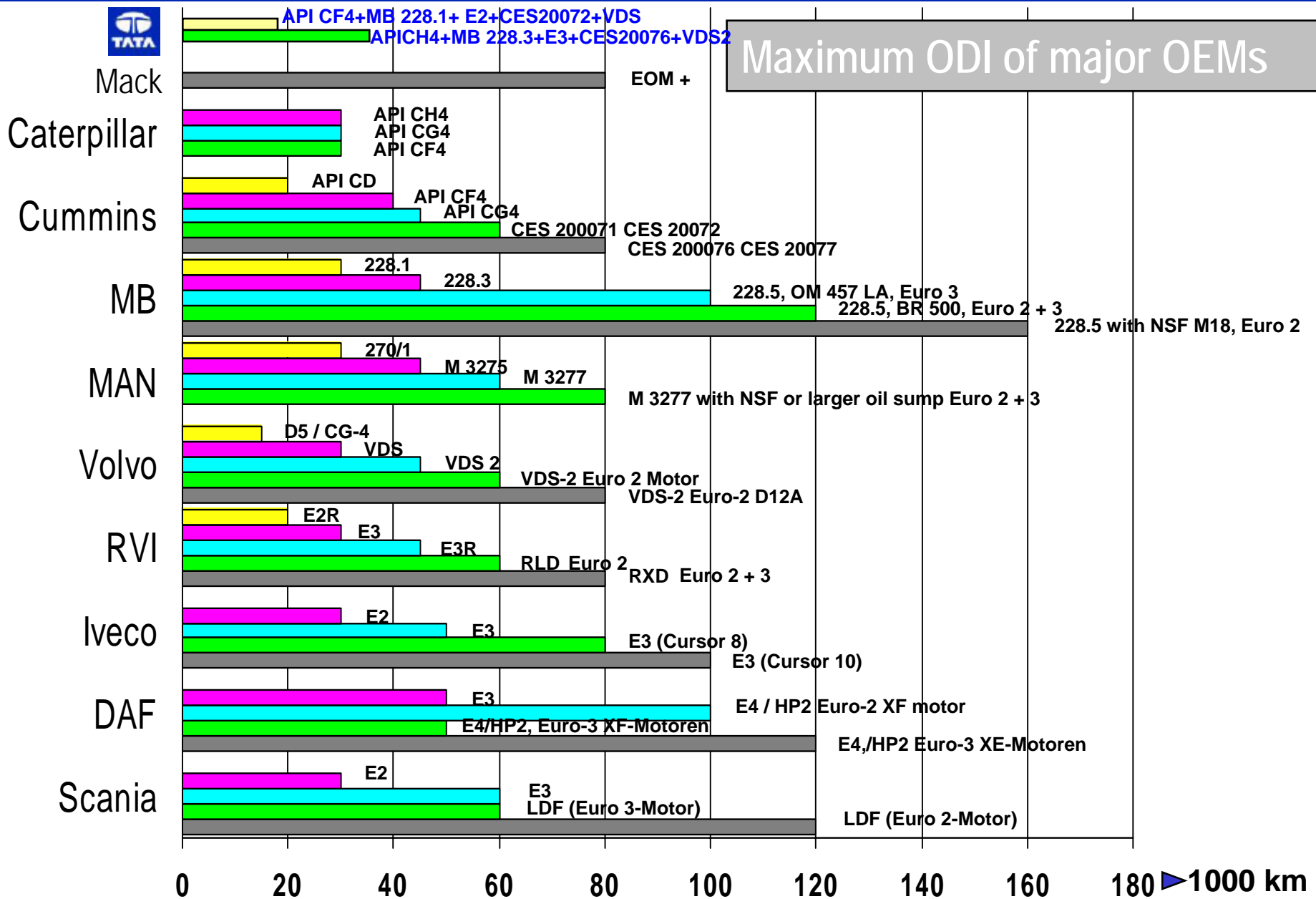
Performance comparison of CF4, CH4 & CI4 oil*



* Source: Additive manufacturers

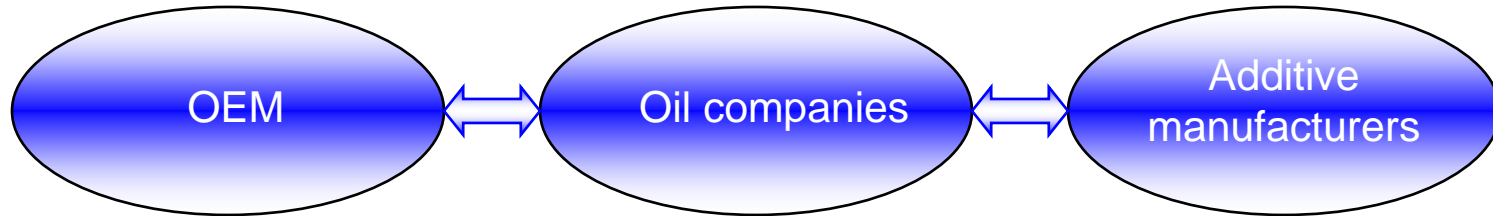
Parameter	Existing CF4 oil	Test item CH4 oil	CI4 oil
Dispersant (Mannich bases)	51.8	100	120
Detergent (Ca, Mg, SA)	110.5	100	100
Anti-oxidation (Zn, ZnDTP, P)	50	100	200
Anti-wear (Ph)	81.8	100	120
Corrosion inhibitor (ZnDTP)	No	No	Yes
Friction/ seal pacifier	No	No	Yes

CI 4 oil exceeds the performance of CF4 & CH4 oils & can be used to increase ODI further !!!

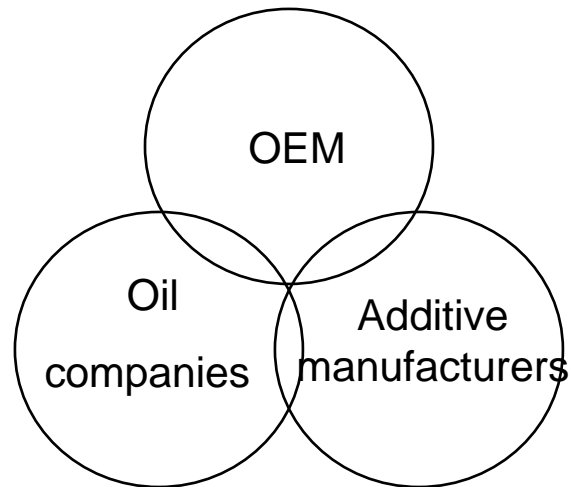


Methodology adopted

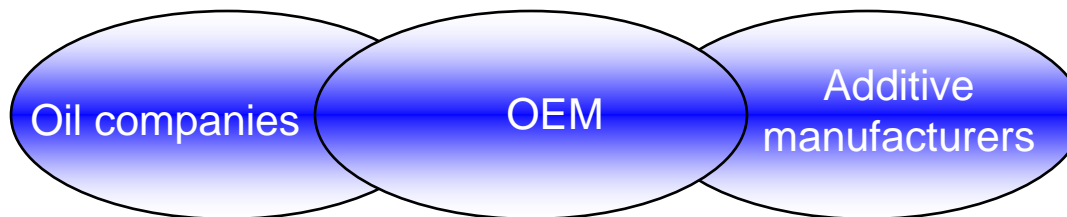
Traditional Operating Model



Collaborative Model (Present work)



Research Model

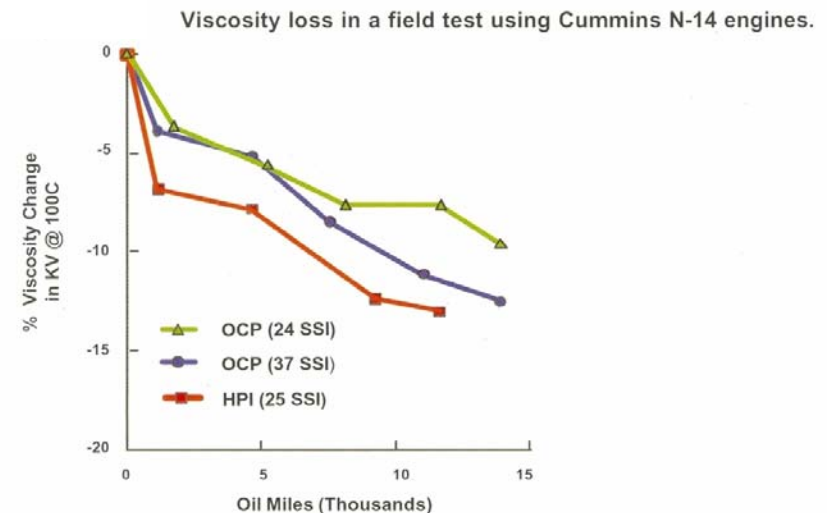
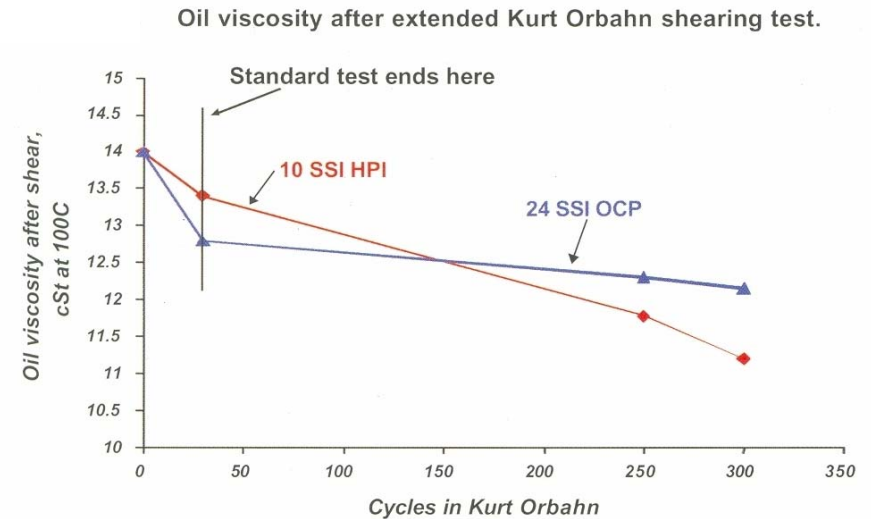


Test oil details

Parameter	Oil A	Oil B
Viscosity grade	15W40	15W40
Credentials	API CH4/ SJ MB 228.3 CES 200 076 ACEA E3/ B3/ A3 VDS2 MAN 3275 Mack EO-M plus	API CH4/ SJ MB 228.3 CES 200 072 ACEA E3/ B4/ A3 VDS2 MAN 3275 Mack EO-M
Base oil	Esso AP/ E Group I	Esso AP/ E Group I
Additive package Treat rate	14.1% (All Calcium chemistry)	14.1% (Ca-Mg Chemistry)
VM	Shear stable non-dispersant olefin copolymer (NDOCP) (7.75 %) 25 SSI & 35 SSI	Shear stable non-dispersant olefin copolymer (NDOCP) (9.94 %) 24 SSI
PPD	Polymethacrylate (0.4%)	Polyalkyl methacrylate (0.2%) PPD1 Polyalkyl methacrylate (0.2%) PPD2

Comparison of Viscosity Index Improver with 24 SSI & 35 SSI in Oil A

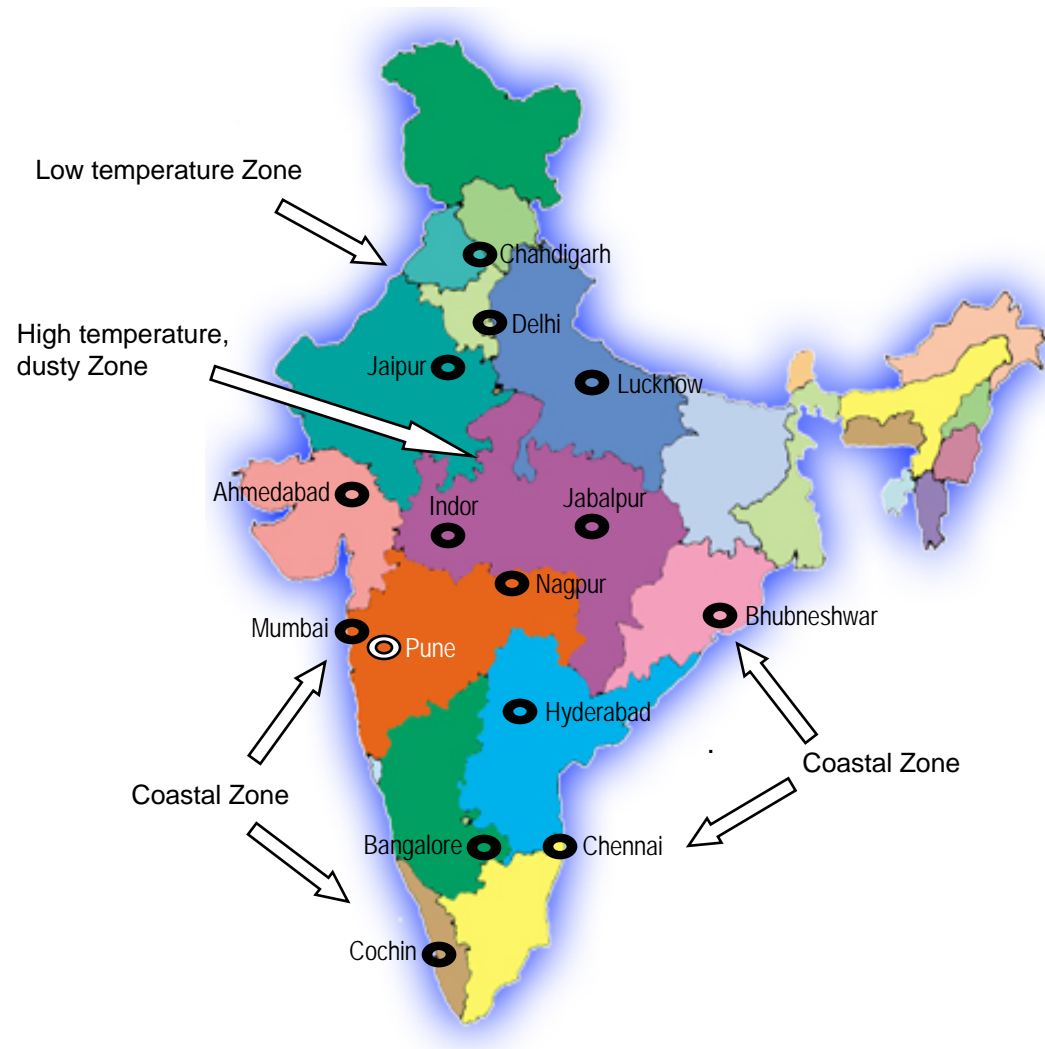
- Data from Oronite paper indicates Olefin Co-polymer (OCP) is better than Hydrogenated Poly-isoprene (HPI) & 24 OCP is better than 37 OCP.
- Results with test oil reveals the same. 25 OCP proved to be better than 35 OCP with regard to shearing.
- Values after shear (90 cycles) - stay in grade was insisted based on ACEA E6/ E7 requirement for long drains.
- Effect of SSI is prominent in test engines due to less soot loading, less oxidation & slight diesel dilution.
- In view of the above, 25 SSI was finalized for Oil A.



Comparison of PPDs in Oil B

- PPD 1: oil does not meet MRV (mini rotary viscometer) yield stress specification (< 35 Pascal) with batch to batch variation in base oil.
- PPD 2: meets MRV yield stress specification with batch to batch variation in base oil & also in alternate base stocks of Group II type.
- Hence, PPD 2 was finalized for Oil B.

Ground locations for field trial



Testing Protocol



41 vehicles

(Engine life of 70K to 150K km)

15 locations in India

11	13	17
5.67 liters	3.78 liters	2.95 liters
72,000 km	60,000 km	40,000 km
+ 20% extra	+ 20% extra	+ 20% extra

7 nos. of 5.67 liter engines

(3 New with CF4 + 2 New with CH4 + 2 Old with CH4)

Dynamometer testing for 1200 hrs each

550 nos. of oil samples collected & analyzed



Test engine details

- **Engine 1**
(Low OC, High temp)
Oxidation
5.67 ltrs Euro I (Oil A)
OC = 45 gm/hr, BB = 35 lpm max
Cast iron oil cooler - Max oil temp. at sump = 115 deg. C
- **Engine 2**
(High OC, Low temp)
Low stress
5.67 ltrs Euro I (Oil A)
OC = 65 gm/hr, BB = 35 lpm max
Aluminum plate type oil cooler - Max oil temp. at sump = 105 deg. C
- **Engine 3**
(Low OC, High BB)
Thermo-oxidation
5.67 ltrs Euro I (Oil A)
OC = 20-25 gm/hr, BB = 55 lpm max
Aluminum plate type oil cooler - Max oil temp. at sump = 105 deg. C
- **Engine 4**
(Low OC, High BB)
Thermo-oxidation
5.67 ltrs Euro I (Oil A + B)
OC = 20-25 gm/hr, BB = 55 lpm max
Aluminum plate type oil cooler - Max oil temp. at sump = 105 deg. C
- **Engine 5/ 6/ 7**
(Low OC, High BB)
Thermo-oxidation
5.67 ltrs Euro I (Existing oil)
OC = 20-25 gm/hr, BB = 55 lpm max
Aluminum plate type oil cooler - Max oil temp. at sump = 105 deg. C

Parameters monitored

Oil

- 1) Viscosity
- 2) Soot
- 3) TBN
- 4) TAN
- 5) Additive elements (Ca, Zn, S, Mg, P, Na, B)
- 6) Wear metals (Fe, Al, Cr, Cu, Pb, Si)

Engine

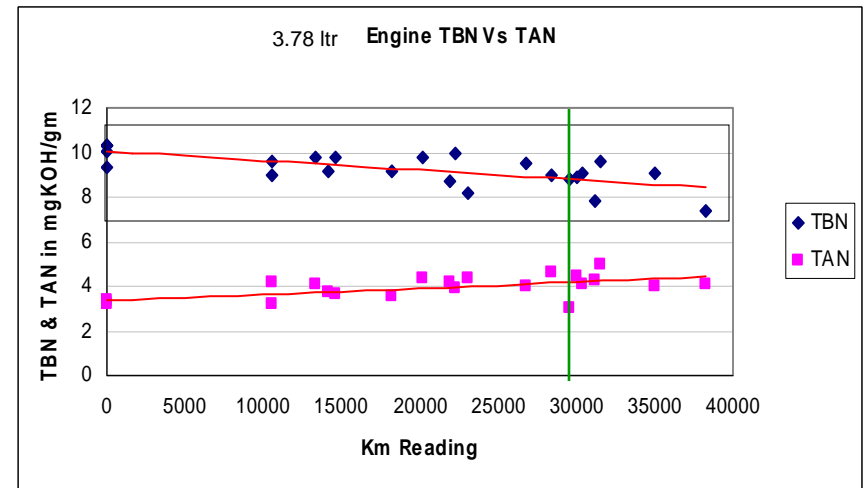
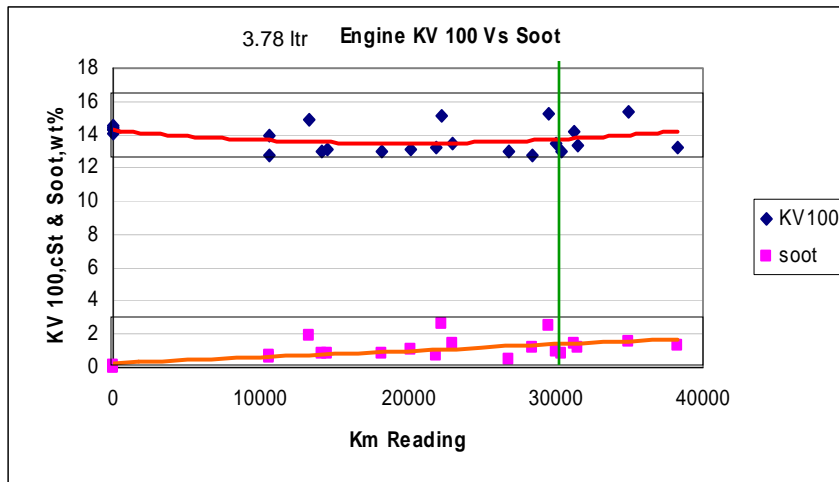
- 1) Performance
- 2) Oil consumption & Blow-by
- 3) Pressure drop across oil filter
- 4) Condition of engine components (Power train & Valve train)

Discard limits – Bench mark values

Parameter	OEM 1	OEM 2	OEM 3	OEM 4	OEM 5	OEM 6	TATA MOTORS
KV100 (cSt)	Be in grade	Be in grade	Be in grade	+/- 3 of new	Be in grade	+/- 4 of new	Be in grade
Fuel dilution	---	---	5 %	4 %	---	5.5 %	---
TBN mgKOH/gm	---	---	1 min	50% of new	2 min	2.5 min or 50% of new	5 min or 50% of new
TAN mgKOH/gm	< TBN	< TBN	< TBN	< TBN	< TBN	2.5 no. increase	5 max or 2.5 no. increase
Fe (ppm)	10 ppm/10K km (36 ppm/36K km)	15 ppm/10K km (54 ppm/36K km)	200	100	10 ppm/10K km (36 ppm/36K km)	100	200
Al (ppm)	---	---	30	30	0.4 ppm/10K km (1.44 ppm/36K km)	30	30
Cr (ppm)	---	5			0.4 ppm/10K km (1.44 ppm/36K km)	25	20
Cu (ppm)	---	10	50	50	5	50	40
Pb (ppm)	---	10 ppm/10K km (36 ppm/36K km)	40	40	3	40	25
Si (ppm)	5 ppm/10K km (18 ppm/36K km)	5 ppm/10K km (18 ppm/36K km)	20	20	---	20	40

** Source - Additive suppliers

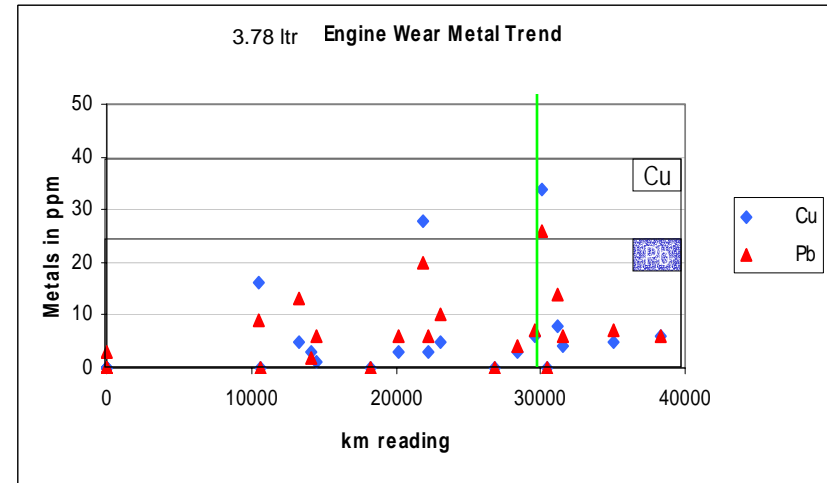
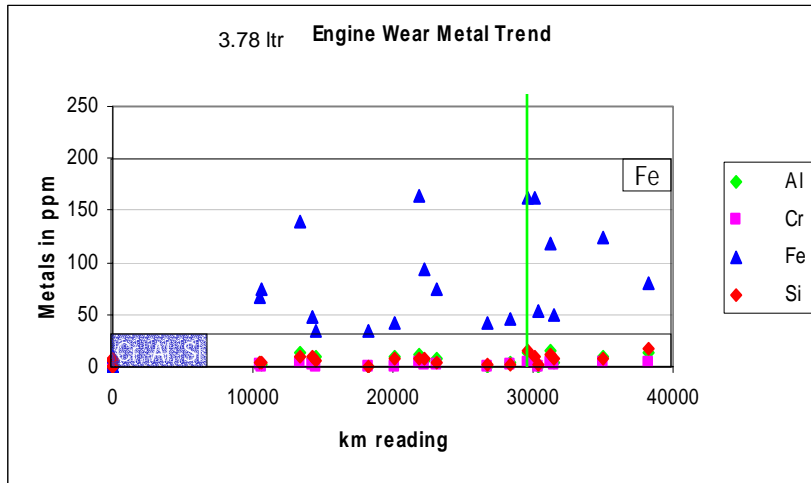
Graphical representation of basic oil properties from field trial



- Viscosity is within limits (12.5-16.3 cSt).
- Soot in oil is within limits of 3%.

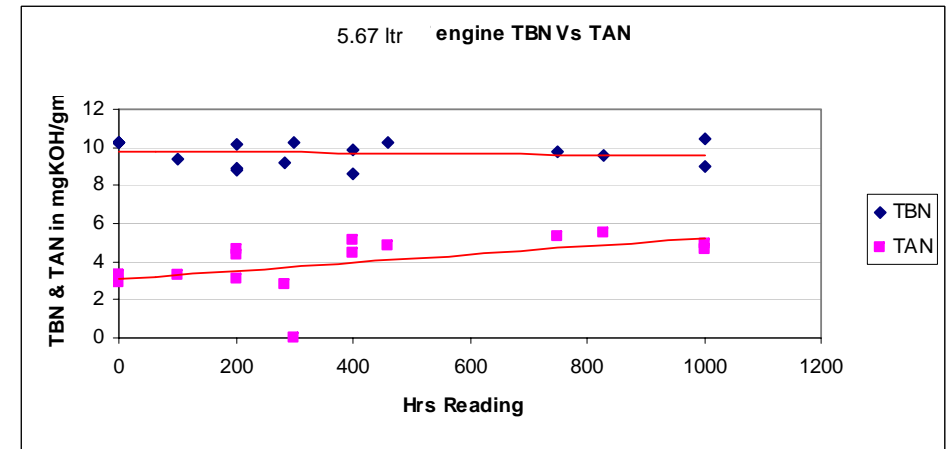
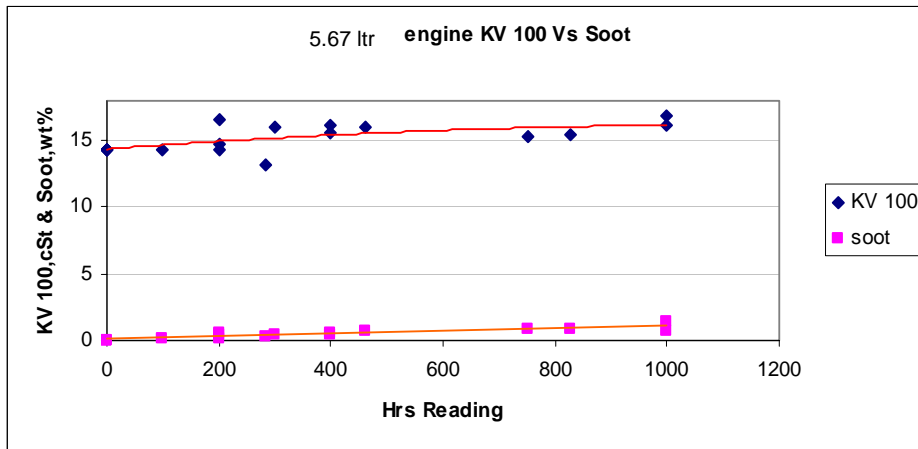
- TBN is within limits (7 min)
- TAN is less than TBN.

Graphical representation wear metals from field trial



All wear metals are within acceptable limits

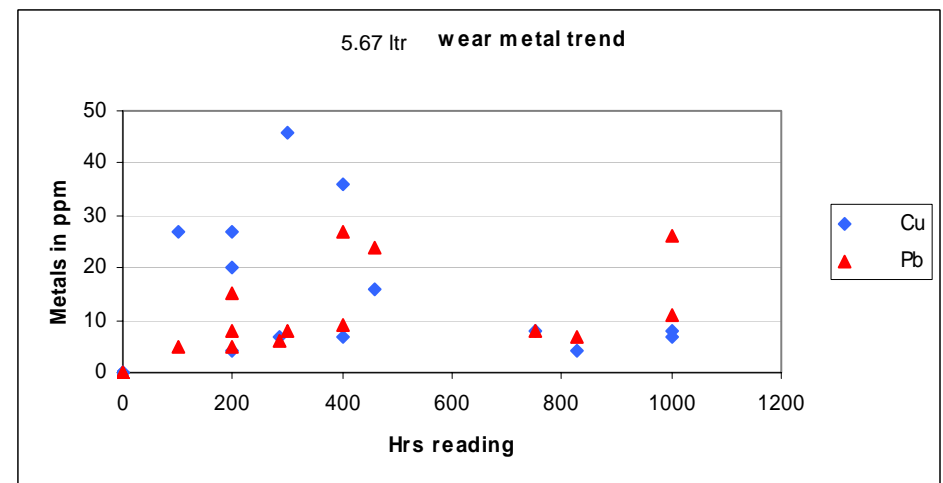
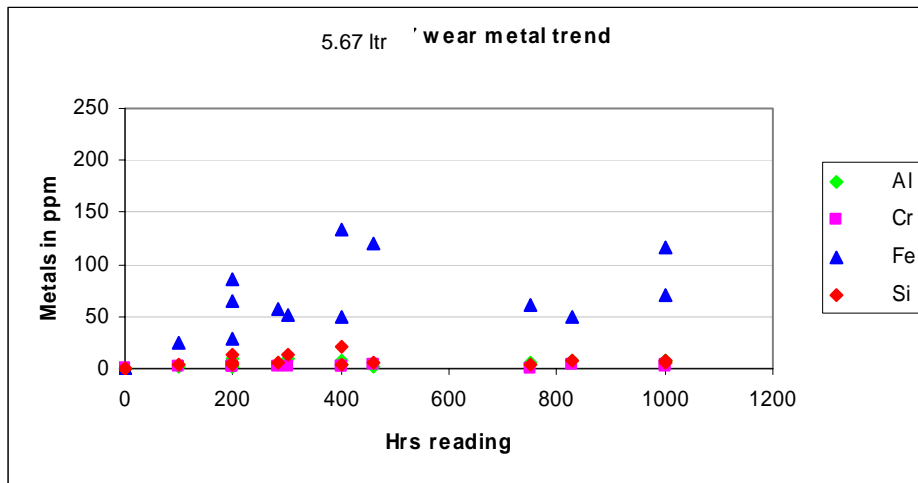
Graphical representation of basic oil properties from dyno testing



- Viscosity is within limits (12.5-16.3 cSt).
- Unlike field trials, KV100 shows increasing trend which is due to daily oil top up.
- Soot in oil is within limits of 3%. (1.4% max, which is less as compared to field)

- TBN is within limits (7 min)
- TBN is almost same during the test due to daily oil top up.
- TAN is less than TBN.

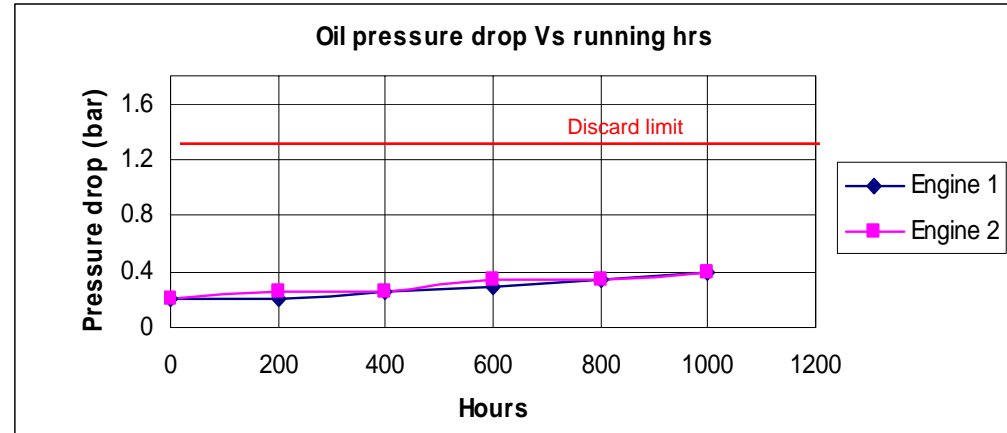
Graphical representation wear metals from dyno testing



- All wear metals are within acceptable limits
- High wear metal concentration in the initial period is due to running-in effect of green engines.

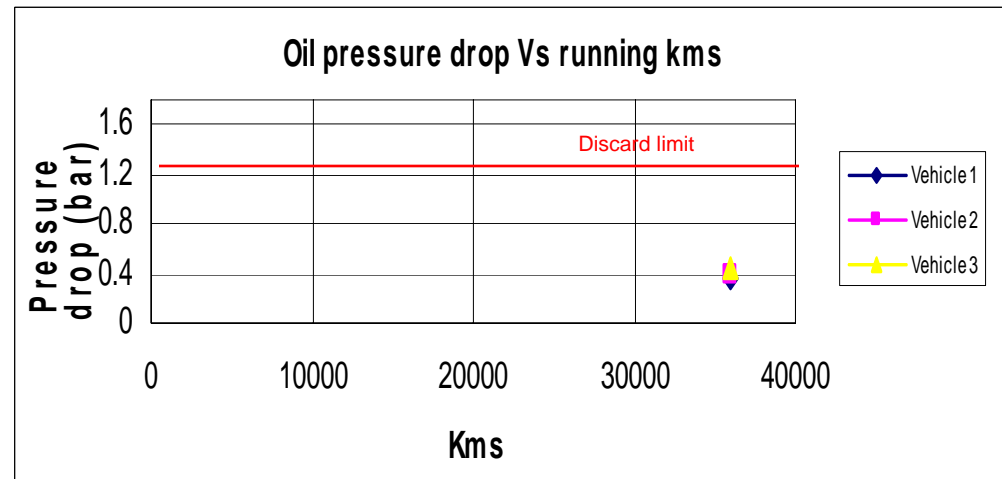
Trend analysis of oil pressure drop across oil filter cartridge

- Maximum pressure drop across oil filter cartridge of 5.67 ltr engine is observed to be 0.4 bar against 1.35 bar allowable drop (75% of 1.8 bar – relief valve opening pressure).



- Five filters tested at supplier's end for pressure drop & found to be satisfactory.

- Indication of better dispersency of CH4 oil.



Comparative weight loss & wear data from dynamometer testing

Bearings:

MB shell wt. loss with CF4 oil as compared to CH4 oil 429 mg

CP shell wt. loss with CF4 oil as compared to CH4 oil 100 mg

Piston rings:

Oil ring wt. loss with CF4 oil as compared to CH4 oil 300 mg

5.67 ltr engine oil consumption reduction with CH4 oil 20%

(Back to back testing)

Oil consumption data with CH4 oil from field trial indicates slight reduction/ comparable figures with CF4.

Fuel consumption data from field trial indicates slight improvement/ comparable figures with CF4.

Crank shaft:

MB journal wear with CF4 oil as compared to CH4 oil Avg. 6 microns

CP wear with CF4 oil as compared to CH4 oil Avg. 5 microns

Cam shaft:

Lobe wear (exhaust) with CF4 oil as compared to CH4 oil 1 micron

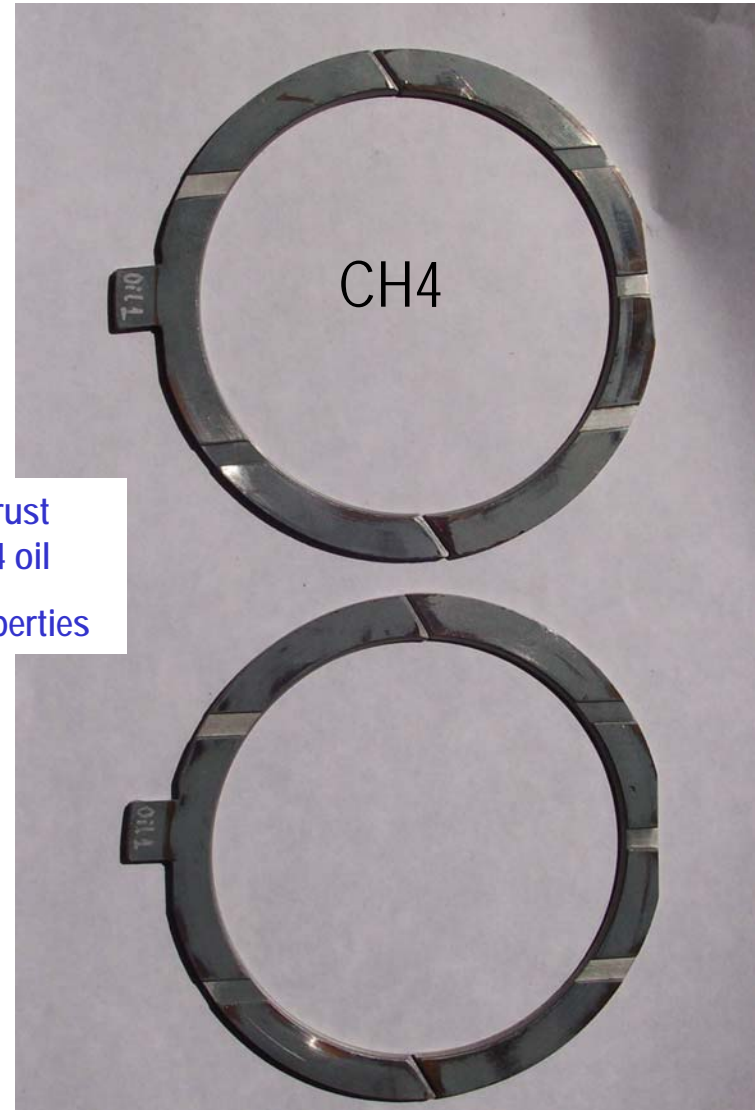
Condition of engine components at the end of test (1200 hrs)



Cleaner piston pins with CH4 oil

Better dispersivity

Condition of engine components at the end of test (1200 hrs)



Lesser wear of thrust bearings with CH4 oil
Better anti-wear properties

Condition of engine components at the end of test (1200 hrs)

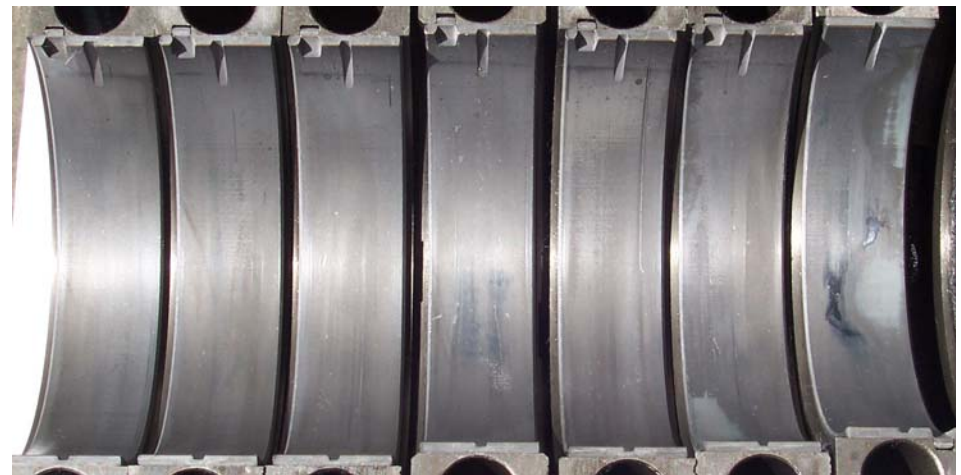


CF4



CH4

Lesser wear & cleaner MB shells with CH4 oil
Better anti-wear & anti-oxidant



Condition of engine components at the end of test (1200 hrs)



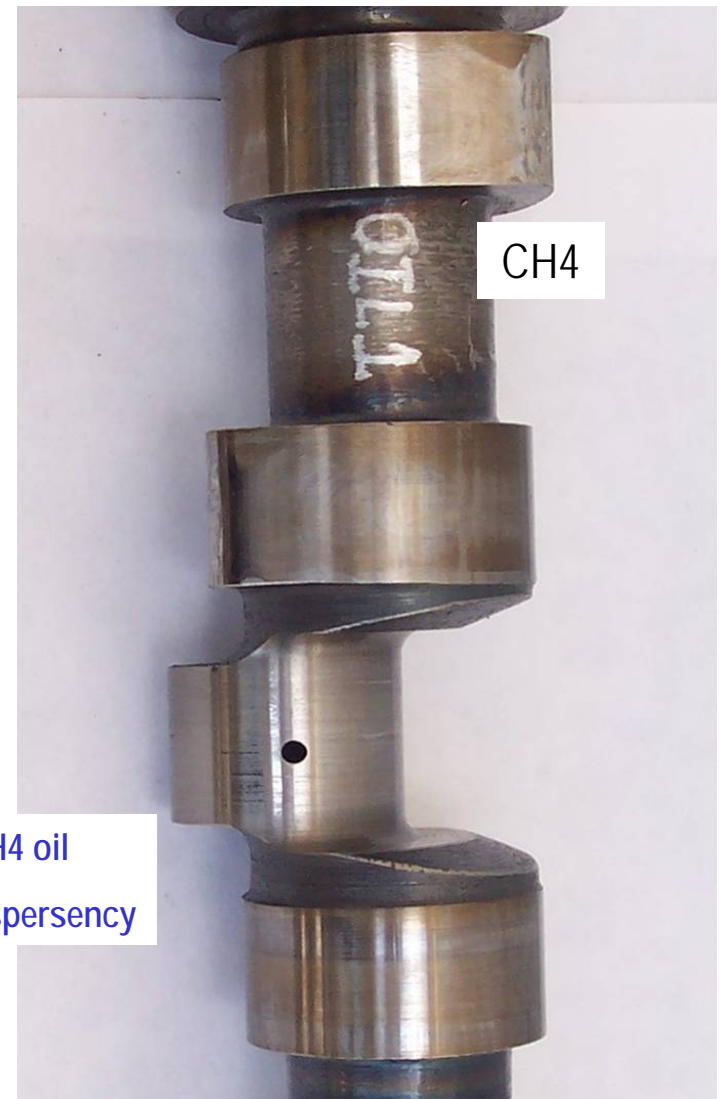
Condition of engine components at the end of test (1200 hrs)



Less wear of valve stem tip with CH4 oil

Better anti-wear & soot handling

Condition of engine components at the end of test (1200 hrs)

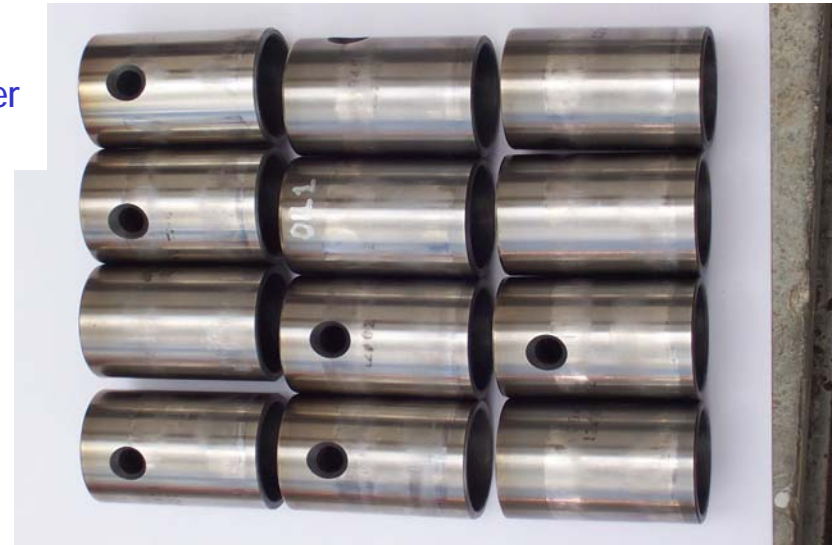


Cleaner cam shaft with CH4 oil
Better anti-oxidant & better dispersency

Condition of engine components at the end of test (1200 hrs)



Less wear &
cleaner tappets
with CH4 oil



Better anti-
oxidant & better
anti-wear

Condition of engine components at the end of test (1200 hrs)

CF4



CH4



Cleaner piston underskirt with CH4 oil
Better sludge control

Condition of engine components at the end of test (1200 hrs)



Cleaner piston ring grooves & lands with CH4 oil
Better deposit control & OC retention

Condition of engine components at the end of test (1200 hrs)

CF4



CH4



Cleaner piston pin bore with CH4 oil

Better deposit control

Summary

- Methodology of working with Additive manufacturers helped to cut down the time required for oil development.
- Oil A & Oil B can be used for LCV, MCV & HCV, Euro I/ Euro II for double oil drain interval (ODI) without filter change. Along with increase in ODI, condition of components indicate improvement in life.
- Even with increase in cost of oil, customer will be benefited due to double ODI. (details in next slide).
- Trials on Euro III vehicles are in progress & data available so far is encouraging.
- Trials with alternate base stocks (Group II) are also in progress.
- Oil A using Group II base stocks is also being evaluated for passenger car application.
- Euro IV engines may need different oil based on after-treatment devices used & emission strategies implemented.

Benefits to Customer

Oil type	Existing oil	Test Item oil	Benefits
Drain interval	18000 kms	36000 kms	Double ODI Double up time
Cost of oil	Rs. 100 / lit	Rs. 125 / lit (max)	CH4 cost may further reduce
Duration	108000 kms	108000 kms	For comparison
ODI	6	3	Good for longer trips
Total oil required	16.5 x 6 = 99 lits = Rs. 9900 (A)	16.5 x 3 = 49.5 lits = Rs. 6187 (A)	50% oil saving
Top up	5 lit / 18000 km x 6 ODI = 30 lit = Rs. 3000 (B) <i>(0 lit for 'no top up' condition = Rs. 0)</i>	5 lit / 18000 km x 3 ODI = 30 lit = Rs. 3750 (B) <i>(1.8 lit/18000 km x 3 ODI = 10.8 lit = Rs. 1350)</i>	Today's situation Calculations with reduced OC
A + B	Rs. 12900 <i>(9900+0 = Rs. 9900)</i>	Rs. 9937 <i>(6187+1350 = Rs. 7537)</i>	22.96 % Saving (23.86 %)
Overheads	Oil filter cartridge + labour = (Rs. 182 + Rs. 125) x 6 = Rs. 1842	Oil filter cartridge + labour = (Rs. 182 + Rs. 125) x 3 = Rs. 921	50 % saving

Future scenario

Situation

- Better road infrastructure
- Less sulfur fuel
- Reduced overloading
- Better air/oil filtration

Effect on oil

- Less time to cover ODI resulting in less duration of using the same oil.
- Better TBN retention, more oil life.
- Less soot, better engine life.
- Less silica in oil, less Fe.

Conclusions

- ✓ Double oil drain interval.
- ✓ Engine life improvement.
- ✓ Better OC retention due to cleaner pistons & rings.
- ✓ Avg. 23% oil cost saving.
- ✓ 50% reduction in overheads
- ✓ Environmental protection.

References

Presentations by following oil companies/ Additive manufacturers to Tata Motors:

- Tata Motors In-house research data
- British Petroleum
- Bharat Petroleum Corporation Ltd.
- Castrol India/ UK
- Chevron Oronite
- ExxonMobil
- Gulf
- Hindustan Petroleum Corporation Ltd.
- Indian Additives Ltd.
- Indian Oil Corporation Ltd.
- Infineum
- Lubrizol India/ USA
- Motul Lubricants
- Shell Lubricants



Thank you