PARAMINS

# GASOLINE ENGINE BLACK SLUDGE - OCCURRENCE, CAUSES & TESTING

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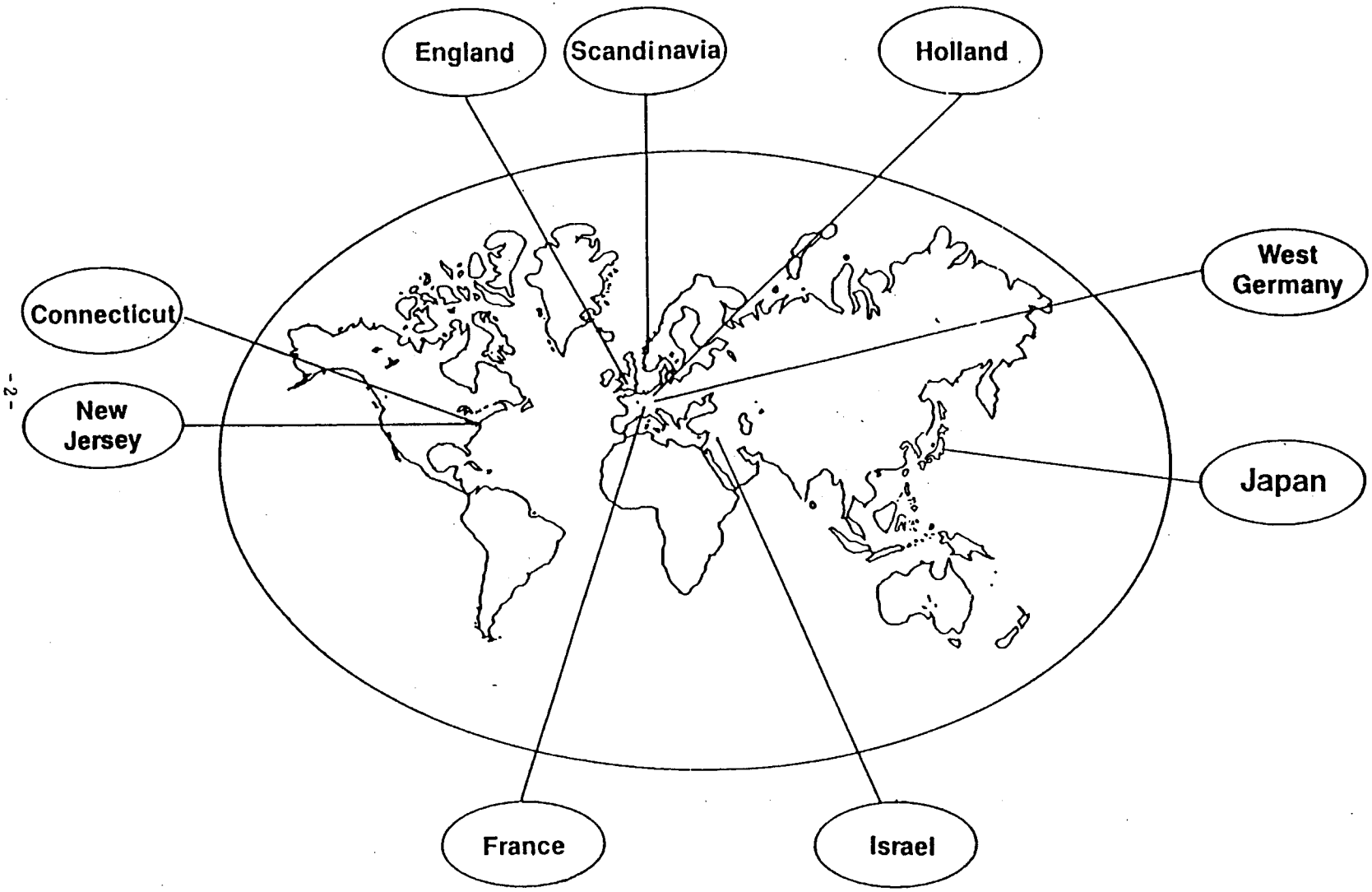
# GLOBAL SLUDGE OCCURENCE



# RECENT EXAMPLES OF FIELD SLUDGE

| MANUFACTURER | U.S. A | U.S. B | U.S. C |
|---|---|---|---|
| YEAR | 1984 | 1984 | 1980 |
| ENGINE | 351 CID V-8 | 318 CID V-8 | 3.8L V-6 |
| MILEAGUE | 62-72 K MILES | 50-60 K MILES | 56 K MILES |
| COMPLAINT | HIGH OIL CONS. LOW OIL PRESS. CONNECTING ROD KNOCK | LOW OIL PRESS. | HIGH OIL CONS. EXHAUST SMOKE |
| SERVICE | POLICE | POLICE | CONSUMER |
| ROCKER ARM COVER SLUDGE | 3.7-5.5 | 6.0-6.5 | 5.3 |
| VALVE DECK SLUDGE | 4.6-6.8 | 4.5-5.5 | 2.6 |

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# RECENT EXAMPLES OF FIELD SLUDGE

| | EUROPE | | |
|---|---|---|---|
| MANUFACTURER | D | E | F |
| YEAR | 1981-1984 | 1984-1984 | 1983 |
| ENGINE | 2.3 & 2.6L S-6 | 2.8/2.3L 1-4 | 1.3L 1-4 CVH |
| MILEAGE | 25-30 K MILES | 35-45 K MILES | 40 K MILES |
| COMPLAINT | TOP END NOISE CAM LOBES WORN FOLLOWERS DESTROYED | ROUTINE MAINTENANCE | TOP END RATTLE STUCK LIFTERS |
| SERVICE | CONSUMER | CONSUMER | CONSUMER |
| ROCKER ARM COVER SLUDGE | 5.3-7.5 | 5.0-6.0 | -0.7 |
| VALVE DECK SLUDGE | 5.4-7.6 | 5.5-6.5 | 8.9 |



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# ANALYSIS OF 15W40 SF/CC USED OIL FROM SLUDGED CAR

| | FRESH OIL | USED OIL (FROM SLUDGED EUROPEAN ENGINE) |
|---|---|---|
| KV100 C | 14.1 | 744 |
| TBN | 8.6 | 2.1 |
| TAN | 2.0 | 5.3 |
| PH | 7.8 | 4.7 |
| HEPT. INSOL | 0 | 9.7 |
| FLASH PT C | 214 | 158 |
| FE, PPM | 0 | 1030 |
| IR R-O-$NO_2$ PEAK (1660) | LOW | VERY HIGH |

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## COMPARISON OF U.S. AND EUROPEAN SLUDGE

| | U.S.A. | | EUROPE | |
|---|---|---|---|---|
| APPEARANGE | AMORPHOUS | LAYERED | LAYERED | AMORPHOUS |
| COMPOSITION % | | | | |
| OIL | 35 | 54 | 51 | 27 |
| OXIDIZED/NITRATED OIL | 44 | 34 | 25 | 57 |
| HIGH MOL. WT. OXIDATION PRODUCTS | 11 | 6 | 18 | 9 |
| CARBON | 9 | 4 | 5 | 6 |
| INORGANICS (Ca/Mg/Zn/Pb) | 1 | 2 | 1 | 1 |

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# THE PROBLEM

- FORMATION OF LARGE AMOUNTS OF SLUDGE DEPOSITS
- BLOCKS OIL PUMP PICK-UP FILTER AND OTHER OIL JETS
- CAN OCCUR AFTER SEVERAL OIL DRAINS
- USUALLY WITH MANY SHORT JOURNEYS (5-15KM) AND OCCASIONAL LONG HIGH-SPEED TRIPS
- OIL DRAINS NORMALLY GREATER THAN 8,000 KM
- LARGELY OCCURS WITH ENGINES WITH CLOSED VENTILATION SYSTEMS (FOUL - AIR VENTED)
- WORSE WITH ENGINES WITH COOL ROCKER COVERS?
- CAN OCCUR WITH ALL OIL QUALITIES UP TO SF/CC



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## BLACK SLUDGE

## COMMENTS ON CAUSES

- ENGINE DESIGN

  RECYCLE OF BLOWBY THROUGH ROCKER BOX TO INTAKE

- CHANGES IN FUEL
- REDUCTION IN LEAD
- OPTIMIZATION OF LUBES FOR VD TEST
- NITRATION OF LUBE
- DRIVING REGIME



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DAIMLER BENZ M102E2285 HOUR TEST CONDITIONS
(BATCH 4 FUEL)

PHASE 1 75 HOURS 3800 R.P.M. FULL LOAD

PHASE 2 150 HOURS CYCLE 150 X 1 HOUR CYCLE

1 HOUR CYCLE WITH VARIOUS TEMPERATURES

| STAGE | TIME(MIN) | | SPEED(R.P.M.) | LOAD(N) | DRIVING CONDITION |
|---|---|---|---|---|---|
| 1 | 3 | | 2200 | 64 | TOWN DRIVING/3RD GEAR/HIGH NOX |
| 2 | 1 | | 780 | 0 | IDLE |
| 3 | 18 | | 3800 | 210 | HIGHWAY DRIVING/5TH GEAR/LOW NOX |
| 4 | 1 | 1HR | 780 | 0 | IDLE |
| 5 | 7 | | 5500 | 170 | MAX SPEED/4TH GEAR/HIGH NOX |
| 6 | 3 | | 2200 | 64 | TOWN DRIVING/3RD GEAR/HIGH NOX |
| 7 | 5 | | 680 | 3 | IDLE WITH AT IN DRIVE |
| 8 | 22 | | 680 | 3 | IDLE WITH AT IN DRIVE |



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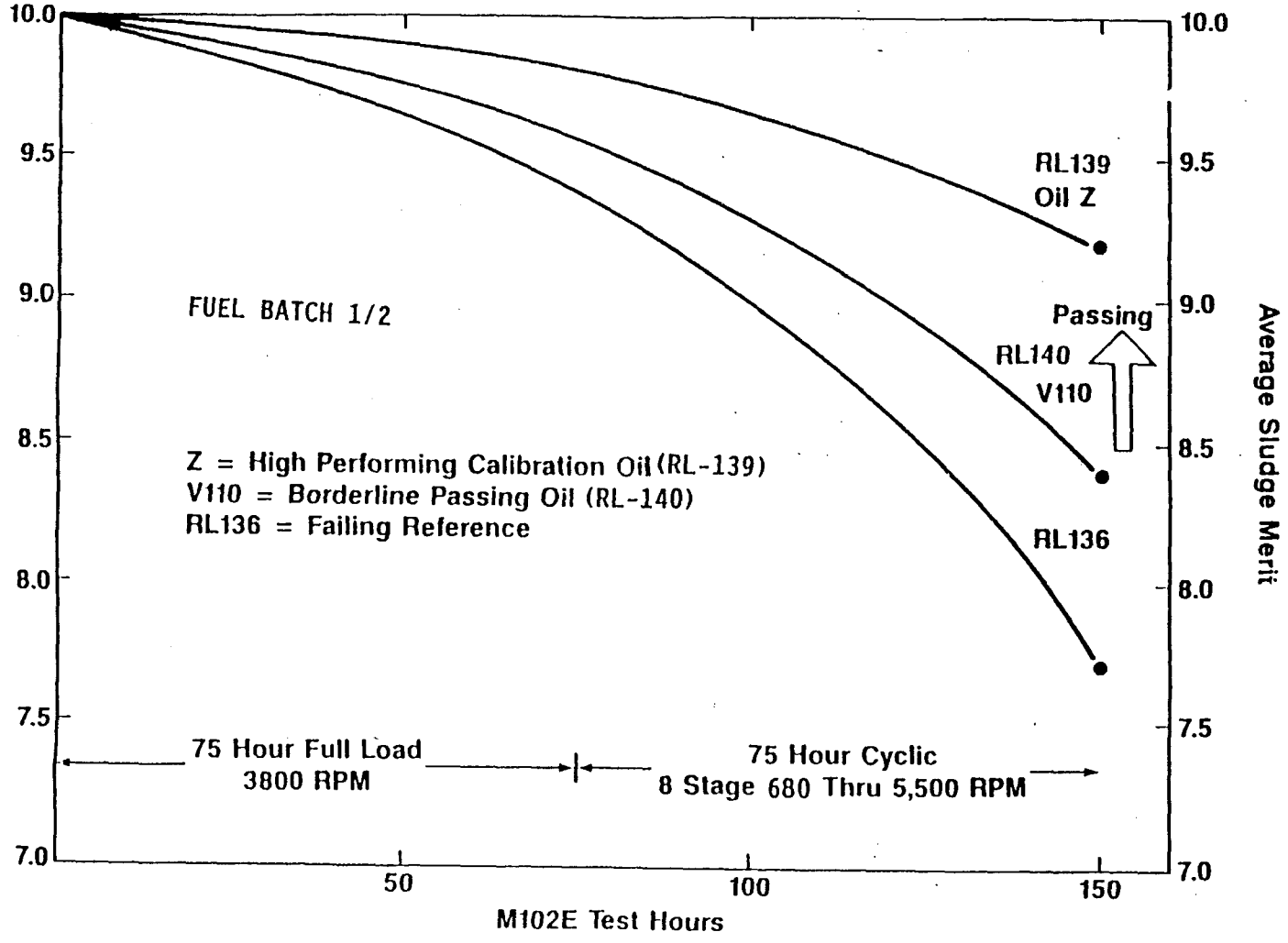
# M102E 150 HOUR SLUDGE TEST



# FUEL QUALITY IS A MAJOR INFLUENCE

- o FUEL QUALITY AFFECTS SLUDGE RESULTS IN M102E, VD AND VE
- o LACK OF KNOWLEDGE RE INFLUENCING FACTORS
- o GASOLINE ADDITIVES UNDER SUSPICION
- o ALCOHOL IN FUEL DOES NOT CAUSE SLUDGE
- o FUEL FACTORS CAUSING SLUDGE MAY BE:
  - LOW VAPOUR PRESSURE
  - HIGH AROMATICS
  - HIGHER UNSATURATES
  - LOWER VOLATILITY/BOILING POINT
- o MAY BE SIMILAR CAUSES TO INJECTOR FOULING?
- o EUROPEAN REFINERIES INCREASING CRACKED COMPONENT$
  - IS THERE A RELATIONSHIP WITH SLUDGE FORMATION?

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## M102E TESTING OF BATCH 4 FUEL PREBLEND

| TEST LAB | TEST OIL | AVERAGE SLUDGE 150 HRS | AVERAGE SLUDGE 225 HRS |
|---|---|---|---|
| 1 | RL-136 | 7.8 | 7.6 |
| 2 | RL-140 | 8.96 | 8.39 |
| 3 | RL-140 | 9.0 | 8.6 |
| 4 | RL-140 | 8.9 | - |

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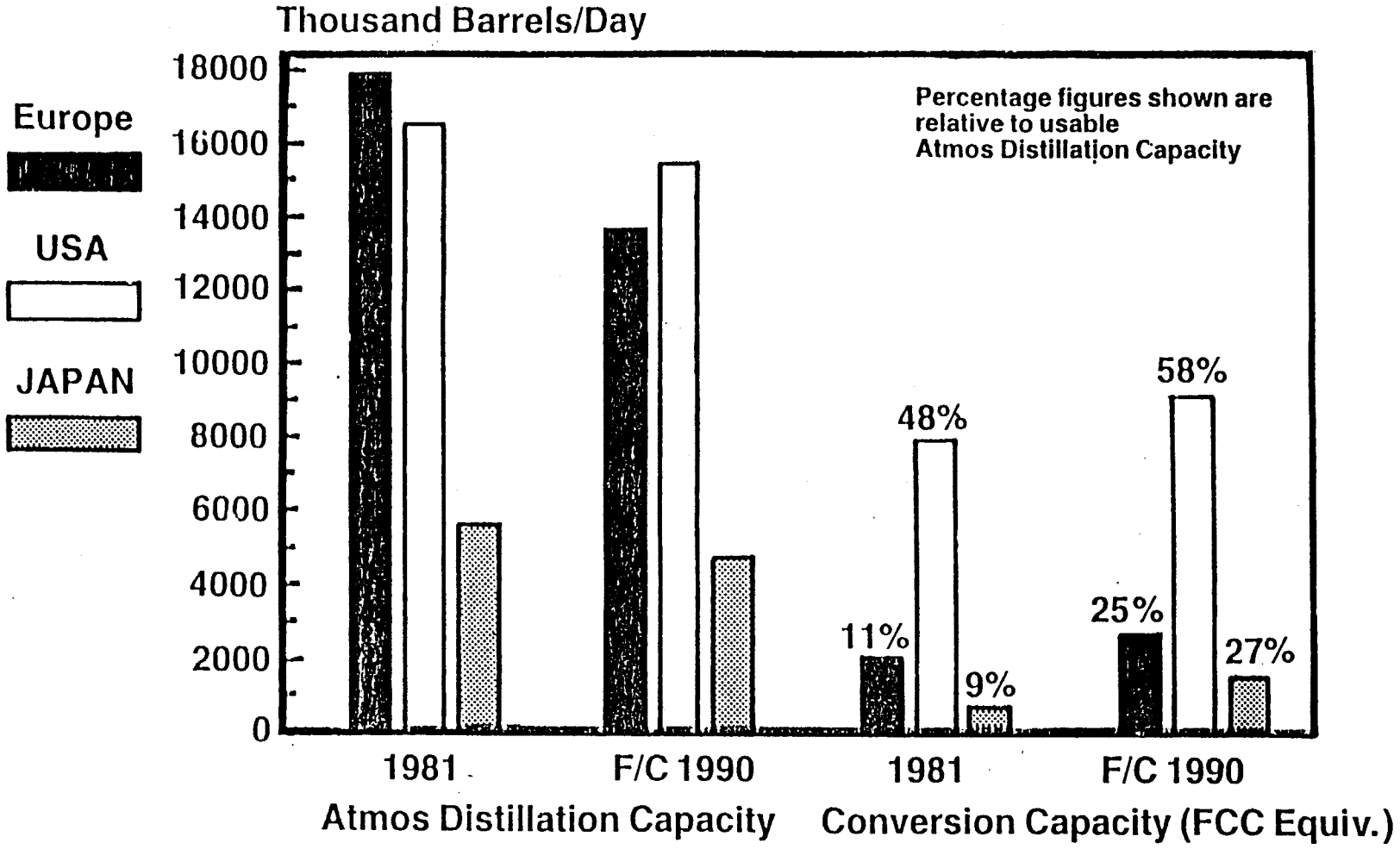
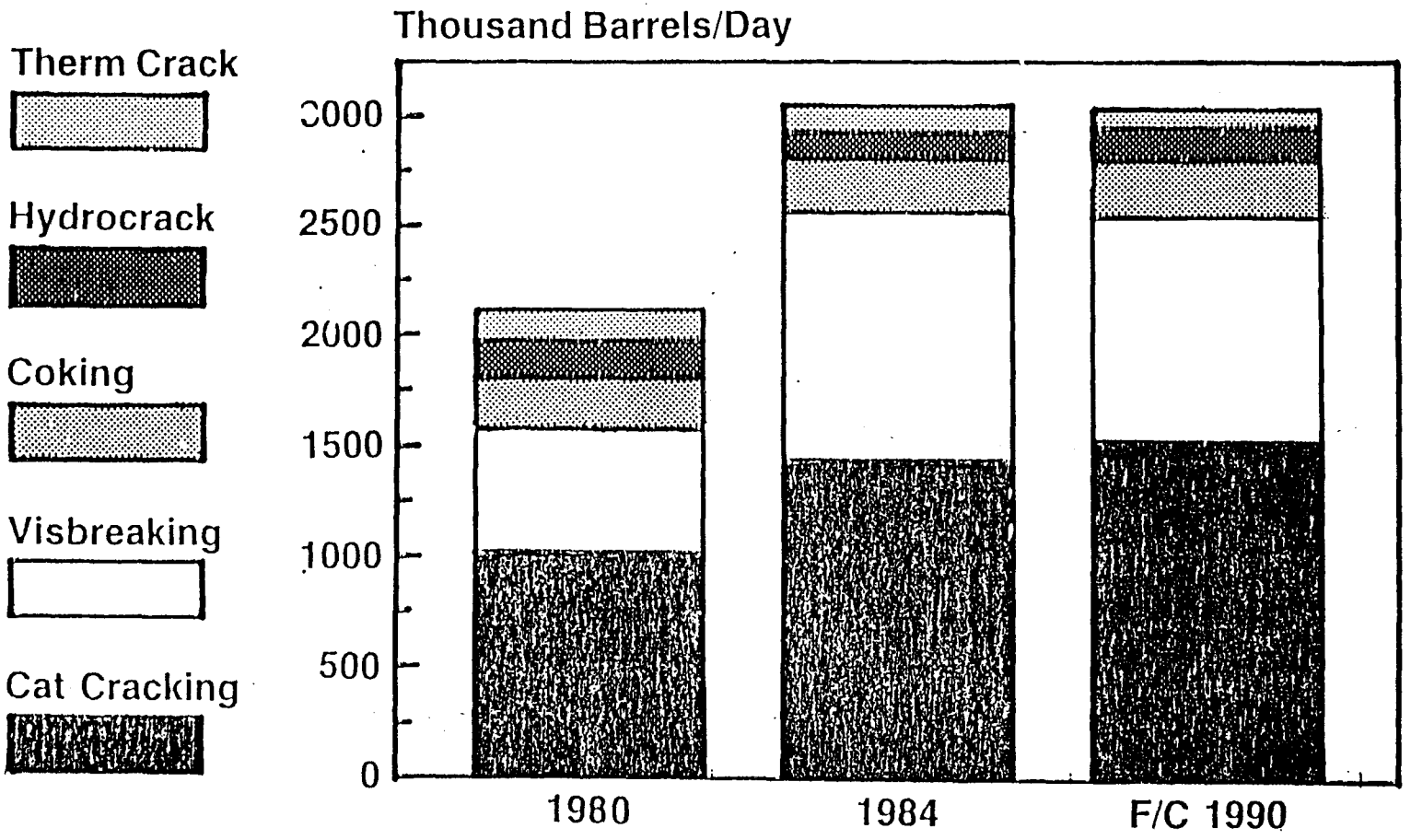
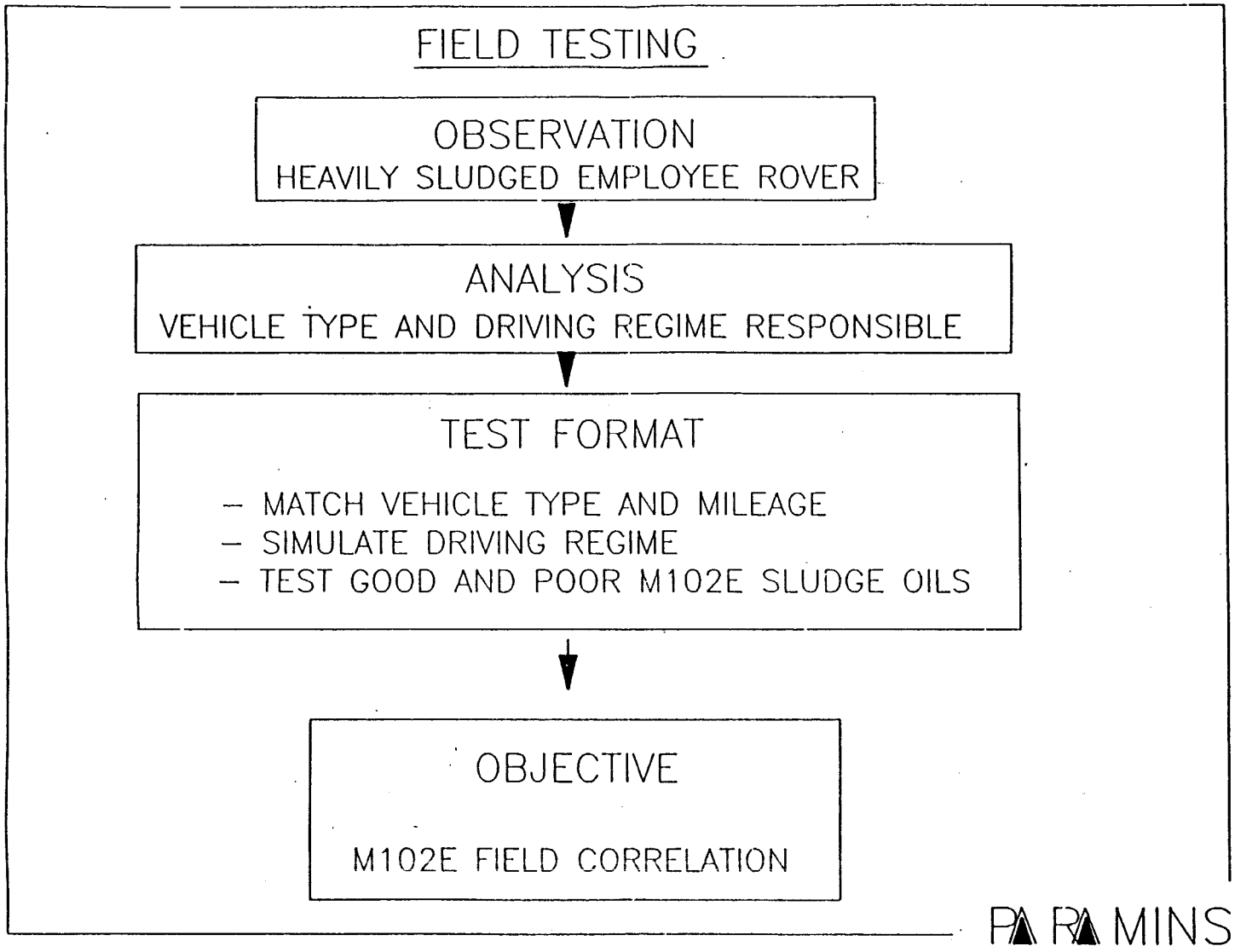
# REGIONAL REFINING CAPACITY FORECAST



# EUROPEAN CONVERSION CAPACITY BREAKDOWN

## Forecast Investment by Process Type




FIELD TESTING
OBSERVATION
HEAVILY SLUDGED EMPLOYEE ROVER
ANALYSIS
VEHICLE TYPE AND DRIVING REGIME RESPONSIBLE
TEST FORMAT
– MATCH VEHICLE TYPE AND MILEAGE
– SIMULATE DRIVING REGIME
– TEST GOOD AND POOR M102E SLUDGE OILS
OBJECTIVE
M102E FIELD CORRELATION
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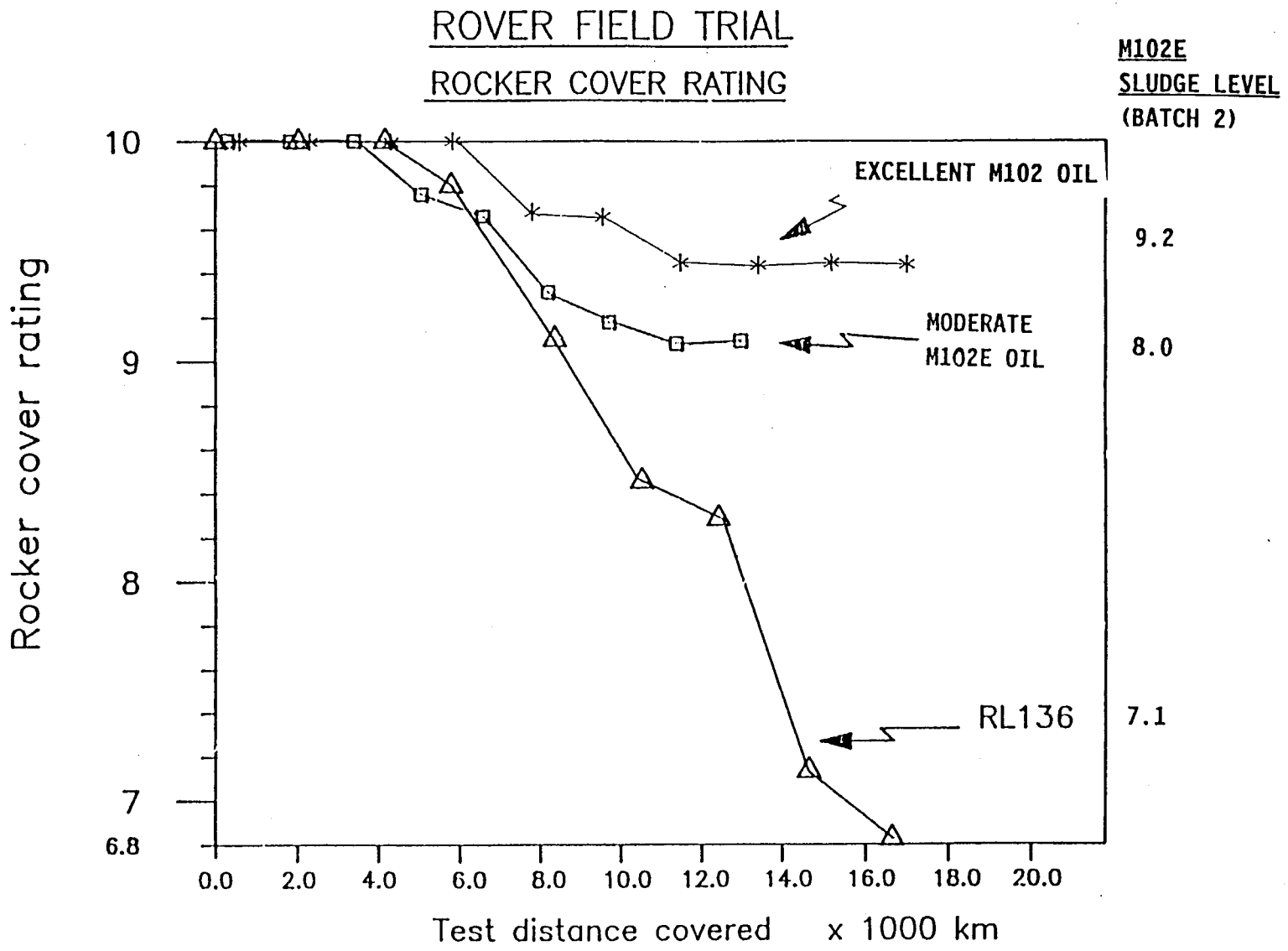
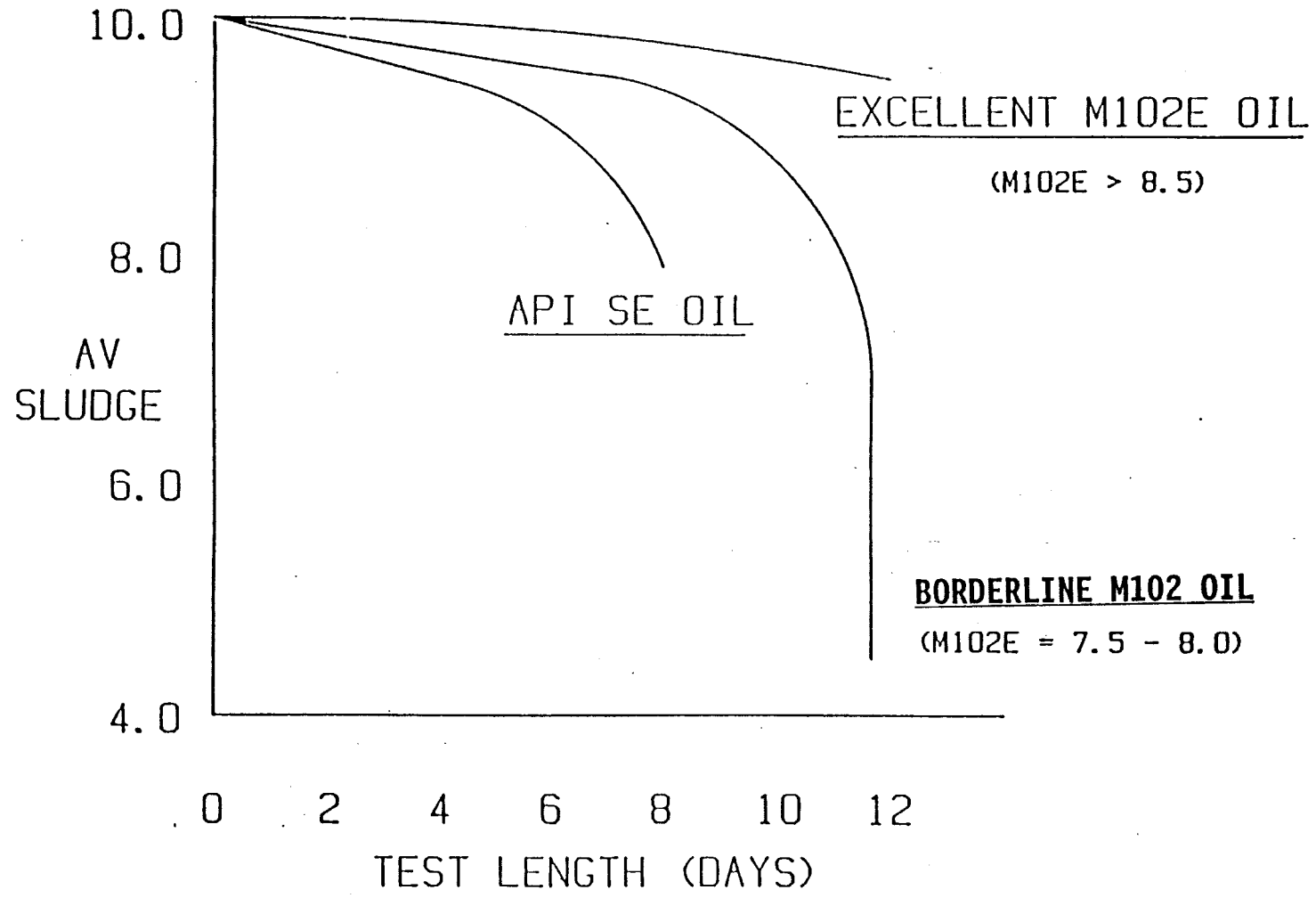

ROVER FIELD TRIAL
ROCKER COVER RATING
M102E
SLUDGE LEVEL
(BATCH 2)
EXCELLENT M102 OIL
9.2
MODERATE
M102E OIL
8.0
RL136
7.1
Rocker cover rating
10
9
8
7
6.8
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
Test distance covered x 1000 km

# M102E - SIMILARITY TO 5E TEST (PV-2)



# COMPARISON OF SLUDGE TEST CONDITIONS

| | V-D | | | VE | | |
|---|---|---|---|---|---|---|
| OIL CHARGE (OZ.) | 160 | | | 124 | | |
| OIL CHANGE AFTER BREAK-IN | YES | | | NO | | |
| EGR OPERATIONAL | YES | | | NO | | |
| BLOWBY RATE (CFM) | 1.8 | | | 2.0 | | |
| IDLE SPEED (RPM) | 750 | | | 600 | | |
| BLOWBY HEAT EXCHANGER | YES | | | NO | | |
| WATER-COOLED CAM COVER | NO | | | YES | | |
| ENGINE DESIGN (2.3L) | CARBURETED | | | FAST-BURN FUEL INJECTION | | |
| TEST LENGTH (HOURS) | 192 | | | 288 | | |
| TEST CONDITIONS (STAGE) | I | II | III | I | II | III |
| OIL (°F) | 175 | 187 | 120 | 155 | 210 | 115 |
| COOLANT (°F) | 135 | 155 | 129 | 125 | 185 | 115 |
| RAC (°F) | – | – | – | 85 | 85 | 85 |
| IGNITION TIMING | 46 | 46 | 10 | 28 | 28 | – |

## PROGRAM 1 - A DESIGNED SERIES OF TESTS TO COMPARE THE M102E WITH THE PV-2 (VE)

- 4-TEST STATISTICAL DESIGN ($2^2$ FACTORIAL)
- 2 VARIABLES AT 2 LEVELS

| | LEVEL | |
|---|---|---|
| | + | - |
| DI DISPERSANCY OCP TYPE | HIGH DISPERSANT | LOW NON-DISPERSANT |

- DI PACKAGES SIMILAR WELL-PROVEN TECHNOLOGY
- M102E TESTS USED HIGH SHEAR STABILITY VISCOSITY MODIFIER (VM) AND MIXED Mg/Ca DETERGENTS IN 15W40 OIL.
- PV-2 (VE) TESTS* USED LOW SHEAR STABILITY VM AND ALL Mg DETERGENTS IN 10W40 OIL

  * 12-DAY PHASE IX PROCEDURE

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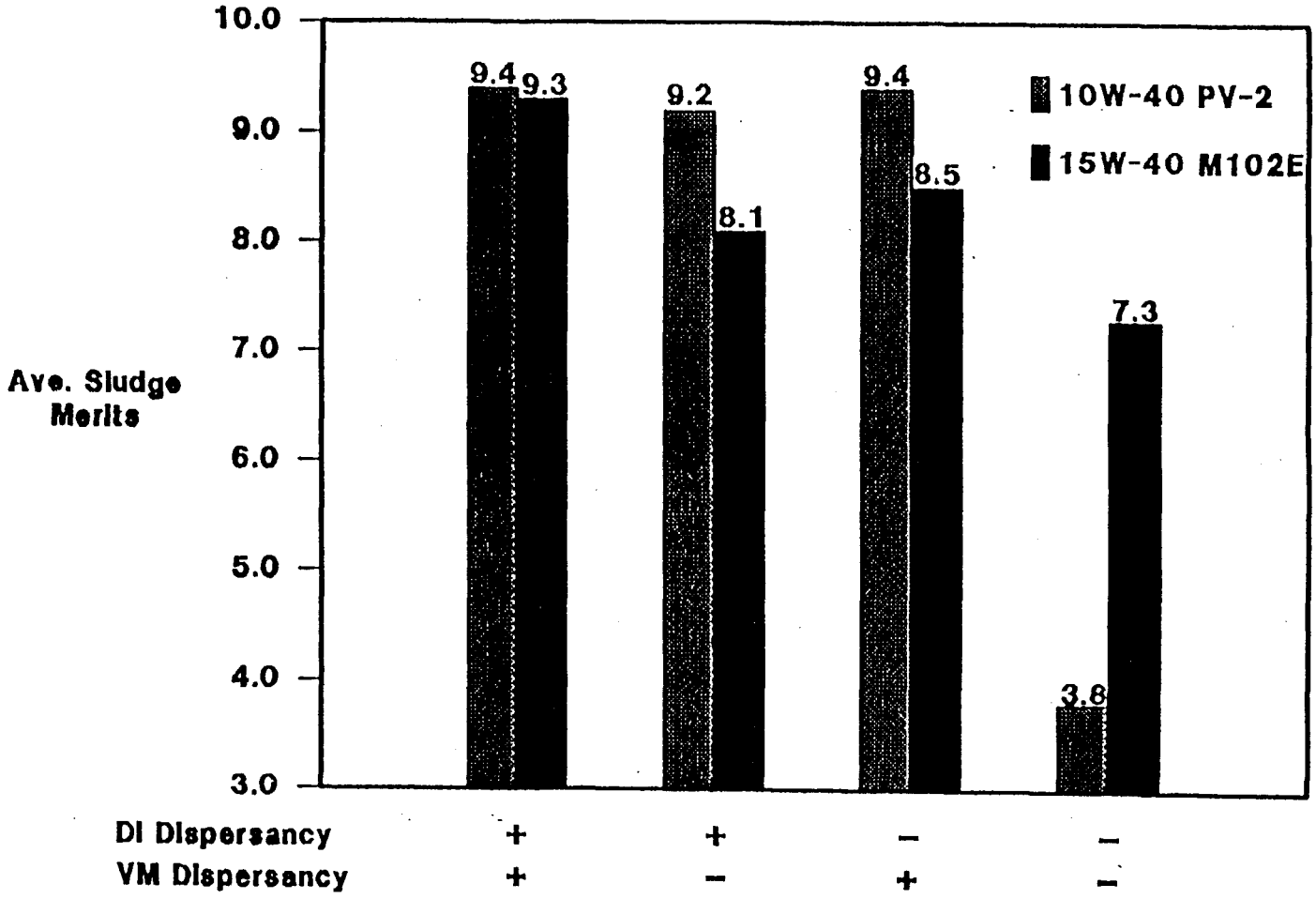
# COMPARISON OF PV-2 TO M102E RESULTS FOR PROGRAM I VARIABLES



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## CONCLUSIONS FROM PROGRAM 1

- o SIGNIFICANT BENEFITS IN SLUDGE PERFORMANCE FOR OILS WITH HIGHER DISPERSANCY IN PV-2 (VE) AND M102E
- o DISPERSANT OCP (MFOCP) WILL GIVE GOOD RESULTS EVEN WITH LOW LEVELS OF DISPERSANT
- o ROCKER ARM COVER SLUDGE RATING GREATLY IMPROVED WITH DISPERSANT OCP
- o PV-2 VARNISH RATINGS NOT SIGNIFICANTLY DIFFERENT FOR ALL OILS TESTED
- o SATISFACTORY PV-2 AND M102E RESULTS CAN BE OBTAINED WITH NON-DISPERSANT OCP IF DI IS BALANCED ACCORDINGLY



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## PROGRAM 2 - IMPACT OF VISCOSITY GRADE ON SLUDGE TESTS

### PV-2 TESTS

- 10W40 MOST SEVERE VISCOSITY GRADE FOR V D TEST
- SAME ALL Mg DI USED AS PROGRAM 1
- SAE 30 OIL CHOSEN AS MILDEST VISCOSITY GRADE
- NON-DISPERSANT OCP USED

### M102E TESTS

- 10W30 COMPARED WITH 15W40 AND 10W40
- SAME MIXED Mg/Ca DI AS PROGRAM 1
- DISPERSANT OCP USED WITH HIGH DISPERSANT LEVELS



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# PROGRAM 2 PV-2 RESULTS

| VISCOSITY | 30 | 30 | 10W40 | 10W40 | |
|---|---|---|---|---|---|
| DISPERSANT LEVEL | HIGH | LOW | HIGH | LOW | |
| OCP VI | - NOT PRESENT - | | - NON-DISPERSANT - | | |

## PV-2 (VE) RESULTS

| | | | | | POSSIBLE LIMITS |
|---|---|---|---|---|---|
| AVER. SLUDGE | 8.7 | 4.9 | 8.7 | 4.3 | 9.0 MIN. |
| RAC SLUDGE | 6.9 | 1.8 | 8.0 | 3.7 | 8.0 MIN. |
| AVER. VARNISH | 6.4 | 6.4 | 5.8 | 5.9 | 5.2 MIN. |
| PISTON VARNISH | 7.3 | 7.0 | 6.8 | 7.2 | 6.7 MIN. |

## CONCLUSIONS

- NO SIGNIFICANT DIFFERENCE BETWEEN VISC. GRADES
- HIGH DISPERSANT LEVEL REQUIRED
- 10W40 TESTS MORE SEVERE THAN PROGRAM 1

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# PROGRAM 2 M102E RESULTS

| VISCOSITY | 10W30 | 15W40 | 10W40 |
|---|---|---|---|
| DISPERSANT LEVEL | HIGH | HIGH | HIGH |
| VISCOSITY MODIFIER | ←----------DISPERSANT OCP----------→ | | |

## M102E RESULTS (225 HOUR/BATCH 2 FUEL)

| | | | |
|---|---|---|---|
| AVER. SLUDGE | 8.8 | 9.3 | 9.1 |
| RAC SLUDGE | 9.0 | 8.7 | 9.1 |



## CONCLUSIONS

- NO SIGNIFICANT DIFFERENCE BETWEEN VISC. GRADES
- DISPERSANT OCP GIVES EXCELLENT RESULTS

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## PROGRAM 3-EFFECT OF VISCOSITY MODIFIER TYPE

- HIGH DISPERSANT OCP VM WAS COMPARED WITH COMMERCIAL DISPERSANT POLYMETHACRYLATES (D PMA 2 AND 3)
- DISPERSANT PMA VM'S TESTED SHOWED MUCH LOWER POTENCY IN THE M102E AND PV-2 TESTS
- OTHER COMMERCIAL DISPERSANT OCP VM'S ALSO SHOWED LOWER POTENCY
- FULL DETAILED RESULTS WILL BE PUBLISHED IN AN SAE PAPER BY CARROLL AND ROBSON AT THE TORONTO MEETING IN NOV.



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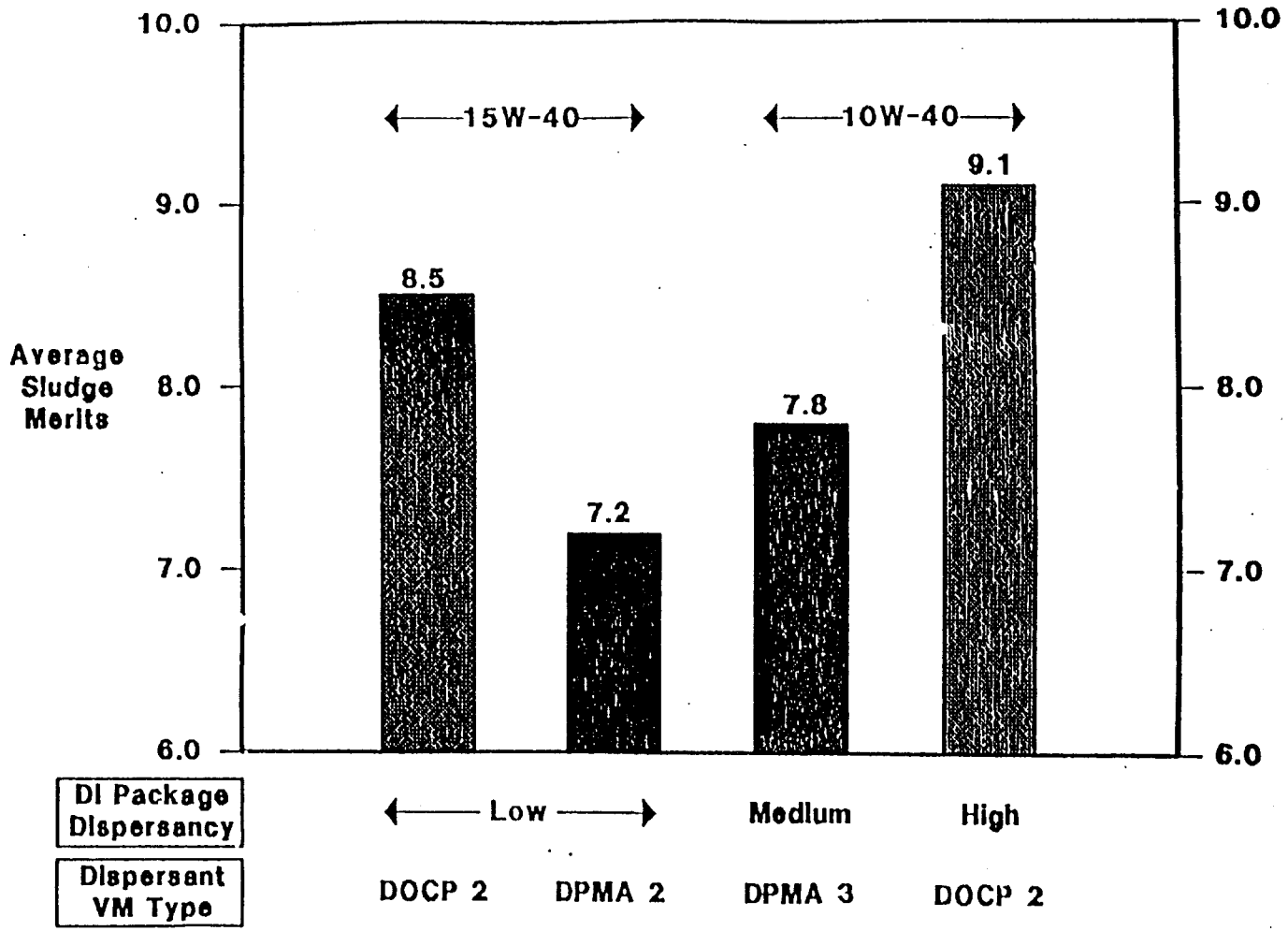
PROGRAM 3

## COMPARISON OF DISPERSANT VISCOSITY MODIFIERS IN THE M102E



## SUMMARY

1. GASOLINE ENGINE SLUDGE IS A MAJOR WORLDWIDE PROBLEM
2. U.S. AND EUROPEAN SLUDGE HAVE SIMILARITIES
3. STOP-GO DRIVING AND LONGER OIL DRAINS MAKE THE PROBLEM WORSE
4. FUEL IS A MAJOR INFLUENCING FACTOR
5. INCREASED USE OF CRACKED COMPONENTS MAY BE CAUSE
6. SLUDGE CAN BE REPRODUCED IN CONTROLLED FIELD TESTS
7. DAIMLER BENZ M102E AND FORD PV-2 (VE) TESTS HAVE BEEN DEVELOPED TO OVERCOME PROBLEM BY HIGHER OIL QUALITY
8. THE M102E AND PV-2 RESPOND IN A SIMILAR WAY TO INCREASED DISPERSANCY
9. HIGH DISPERSANT OCP VISCOSITY MODIFIERS APPEAR TO HAVE UNIQUE ADVANTAGE IN BOTH TESTS

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