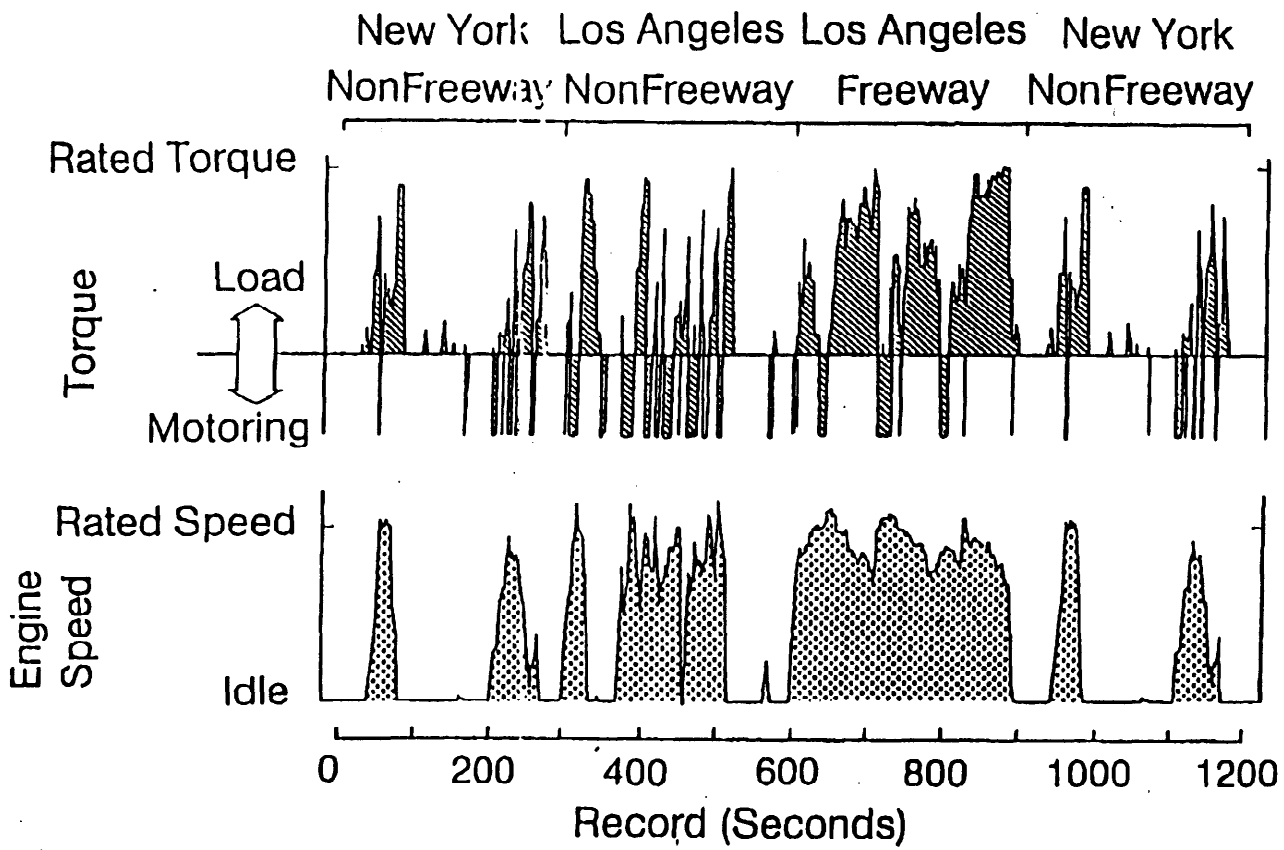
EXHIBIT C



Torque- and Speedflow
USA-Transient-Test cycle for Heavy-Duty-Diesel-Engines

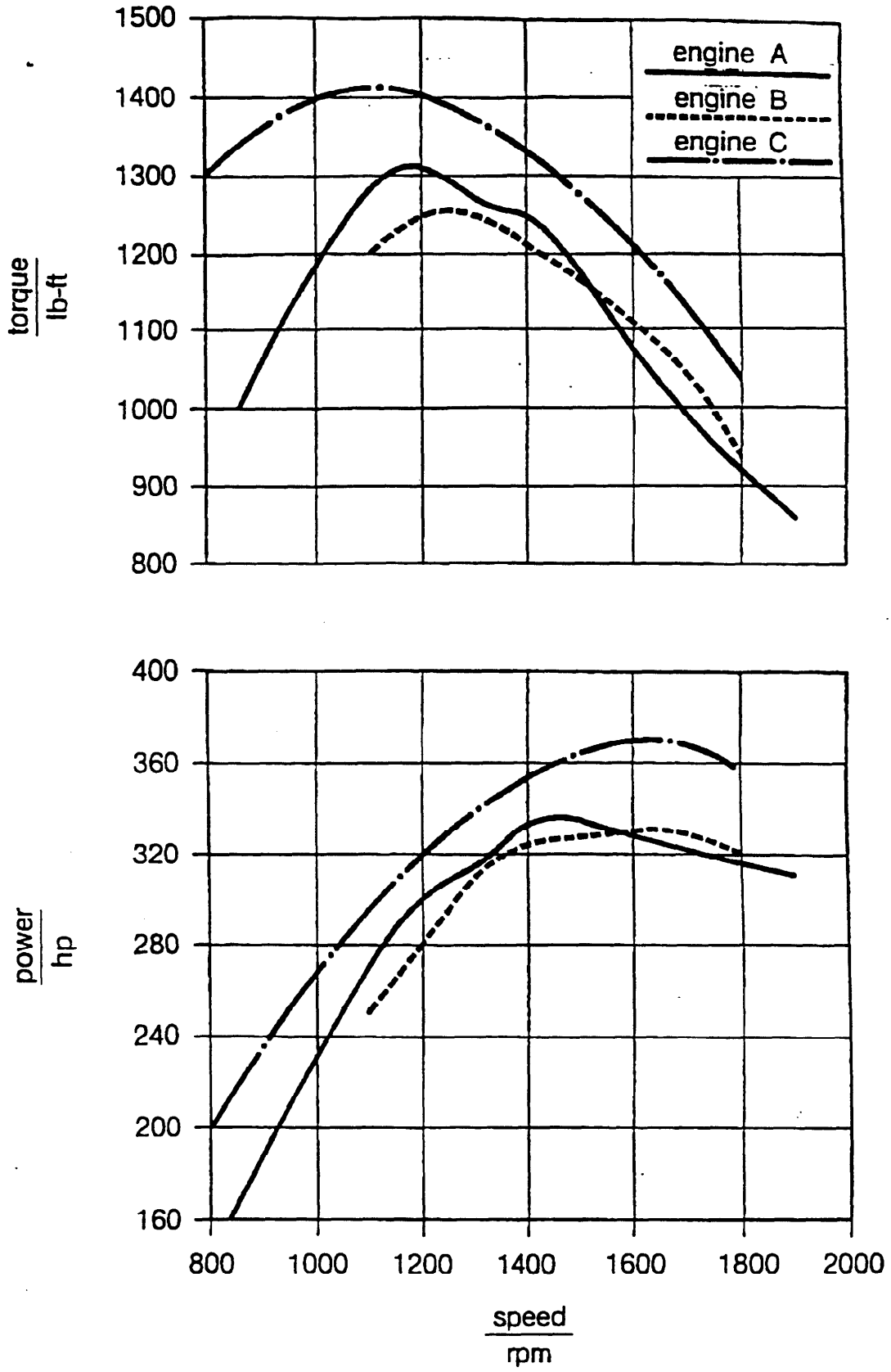
Geschäftsbereich NFZ
Entwicklung

EN/MVT 8710-61

1

820.400.09.063.02.A de-hd

ATTACHMENT A

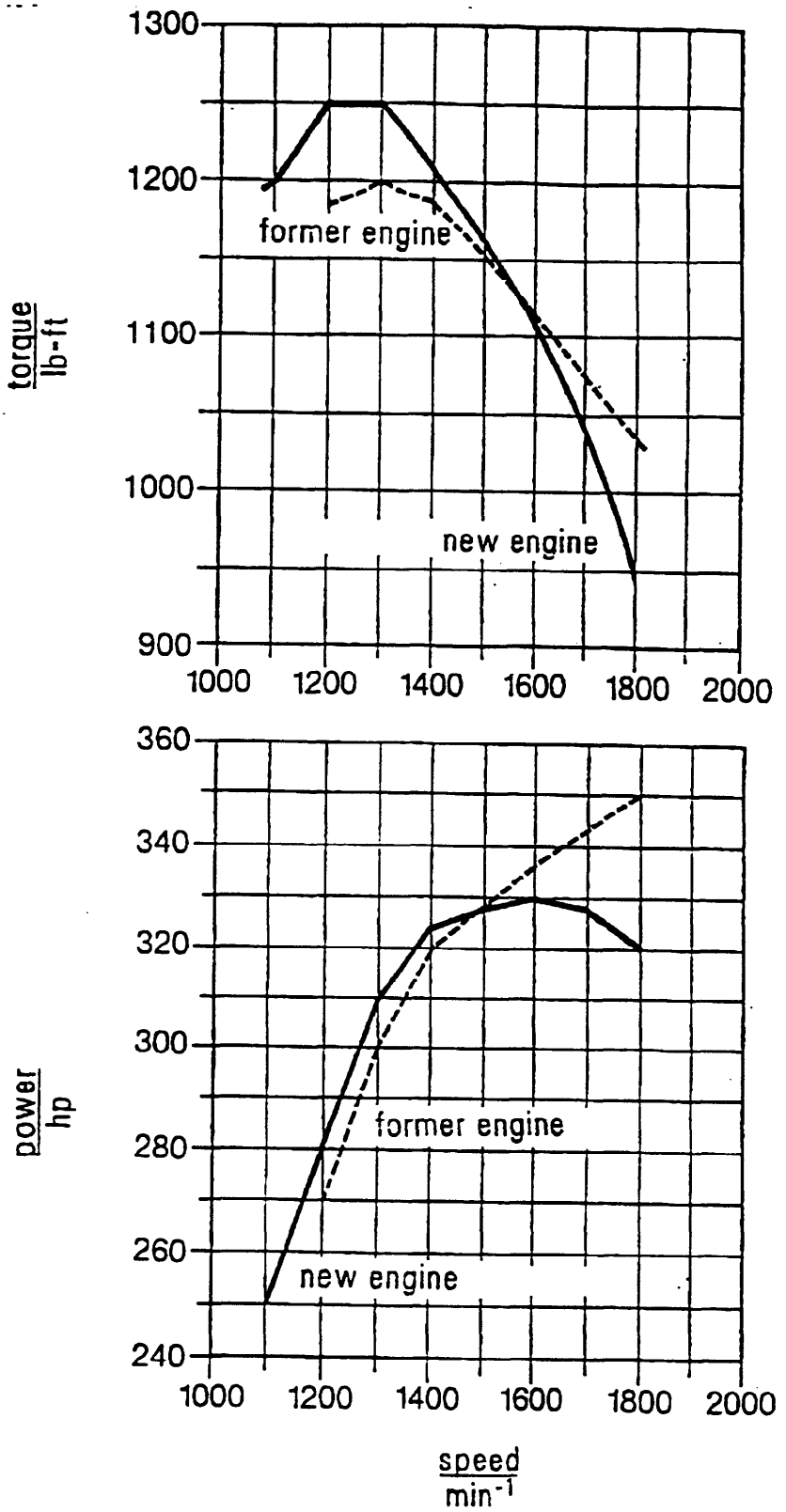


Mercedes-Benz Nutzfahrzeuge Entwicklung

Power and Torque Characteristics of modern US-Diesel-Engines

EN/MVT 9105-05

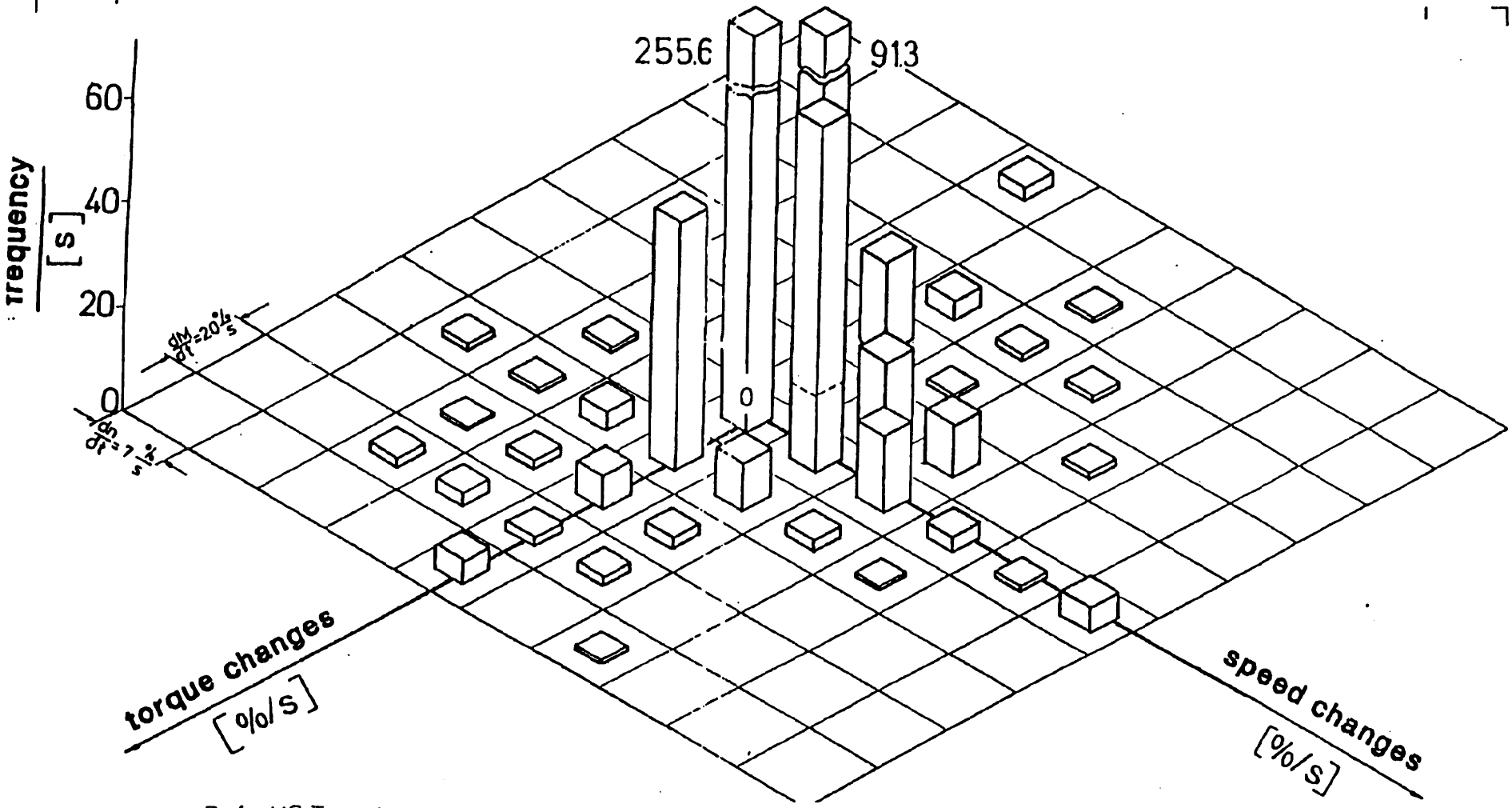
B20 603 06 063 02 A mcc



Mercedes-Benz
Nutzfahrzeuge
Entwicklung

Power and Torque Characteristics of modern US-Diesel-Engines Engine B

EN/MVT 9102-03

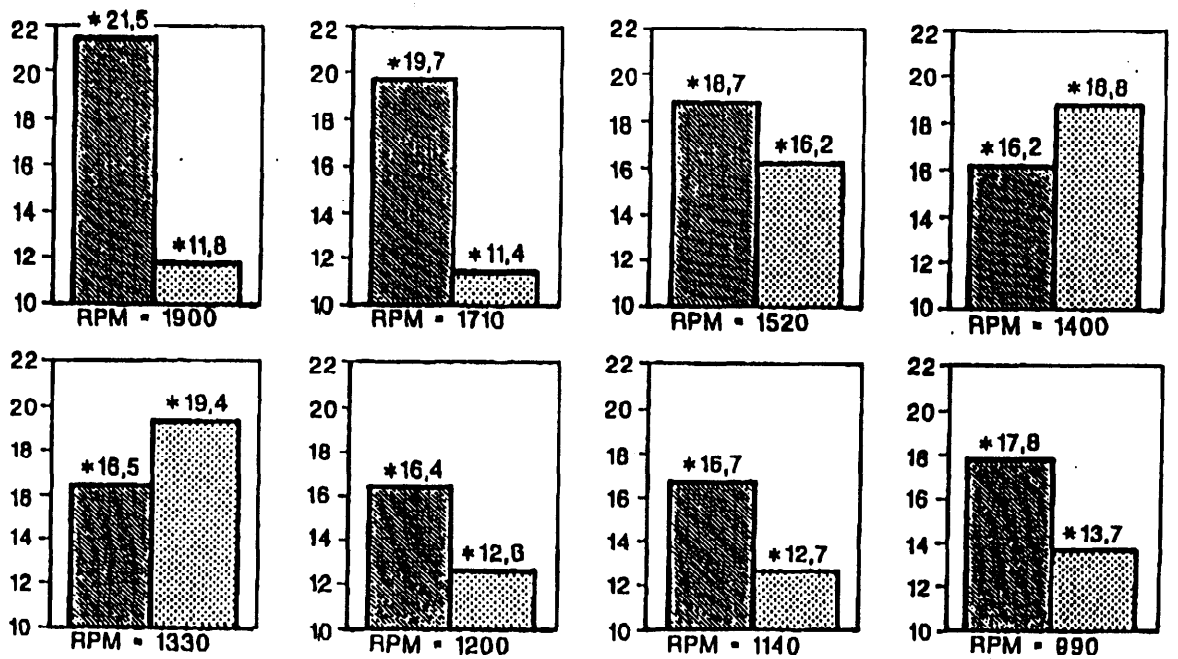


Ref.: US Transienttest vs. ECE R49 13-Mode Cycle, Cornetti, Klein, Fränkle, Stein, SAE880715

Time frequencies of torque and speed changes of US-Transienttest without motoring and idle phases

GB Nutzfahrzeuge
Entwicklung
EN/MT 8710-66e

400.08.083.02 db-hd

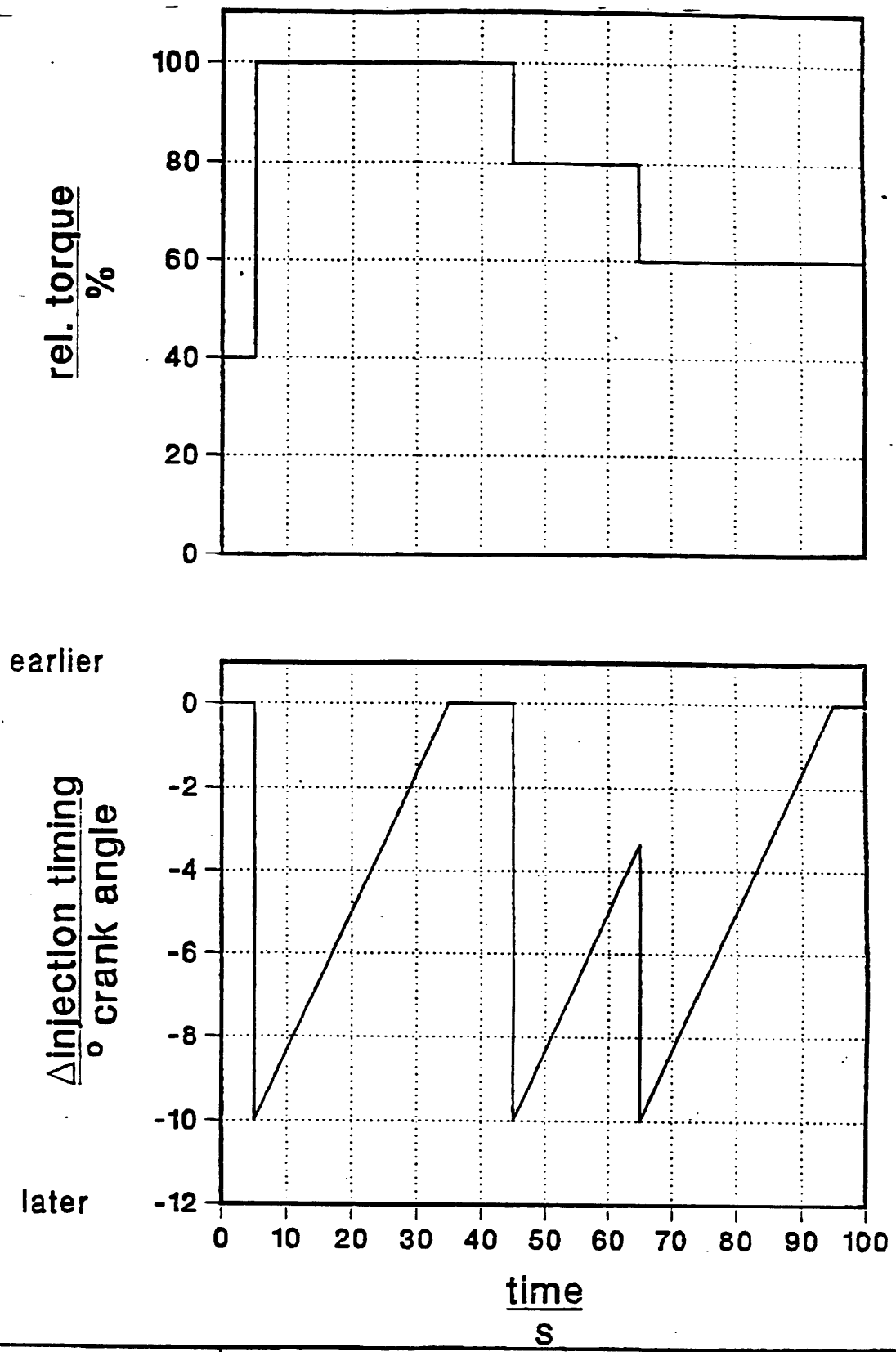


electr.injection start, steady electr.injection start, unsteady *start of ignition °crank before TDC

Mercedes-Benz
Nutzfahrzeuge
Entwicklung

Start of electronic injection at steady and transient full load of modern US-Diesel engines, engine A

EN/MVT 9105-60



Mercedes-Benz
Nutzfahrzeuge
Entwicklung

schematic characteristic of injection timing at constant and transient load (several US engine manufacturers)

EN/MVT 9104-09

EXHIBIT D

THE EFFECT OF ELECTRONIC CONTROLS ON THE TRANSIENT TEST

PREPARED BY:

Michael J. Samulski

August 14, 1991

OUTLINE OF BRIEFING

- Definition of defeat device
- Mercedes-Benz presentation
- Present investigation of designing to the test cycle
- Representativeness of the transient test
- Further investigation of designing to the test cycle
- Conclusions
- Tabular emission and fuel consumption data for the certified 1991 HHDD engines

DEFEAT DEVICE

- "Defeat Device" means an auxiliary emission control device (AECD) that reduces the effectiveness of the emission control system under conditions which may reasonably be expected to be encountered in normal vehicle operation and use, unless

  (1) such conditions are substantially included in the Federal emission test procedure,

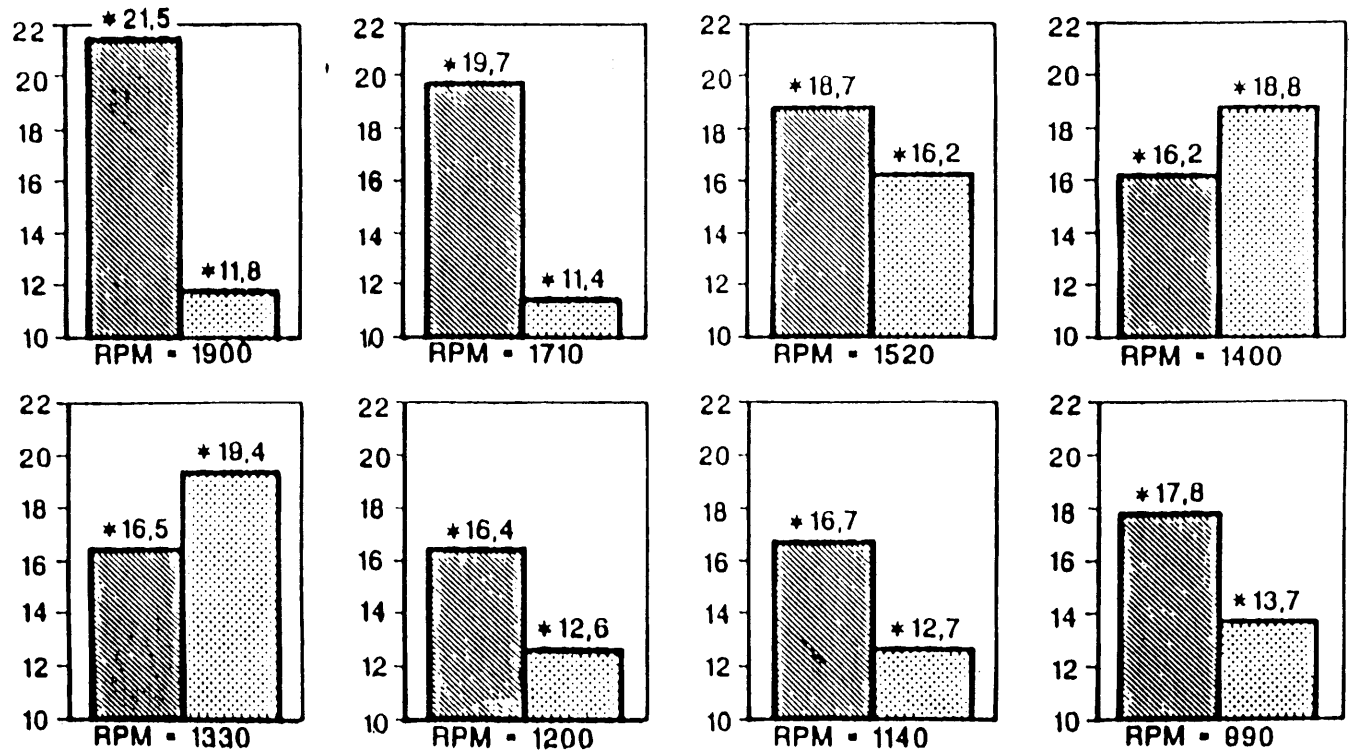
  (2) the need for the AECD is justified in terms of protecting the vehicle against damage or accident, or

  (3) the AECD does not go beyond the requirements of engine starting.

- Any incongruous strategy which is triggered by sensing a change in operating conditions may be a defeat device.

MERCEDES-BENZ PRESENTATION

- The claim was made that U.S. manufacturers are designing their engines strictly to perform well on the transient test by using electronic control to retard the timing during transience
  - When the timing is retarded due to transience, it takes 30 seconds to return to normal
  - Proven with data from a 1991 HHDD engine
  - We suspect Detroit Diesel's Series-60 engines
- The claim was made that the transient cycle is not representative of actual driving
  - Claim: Drivers tend to operate a vehicle at the engine speed (RPM) where the torque is maximized
  - Claim: HHDD engines now reach their peak torques at lower RPM's

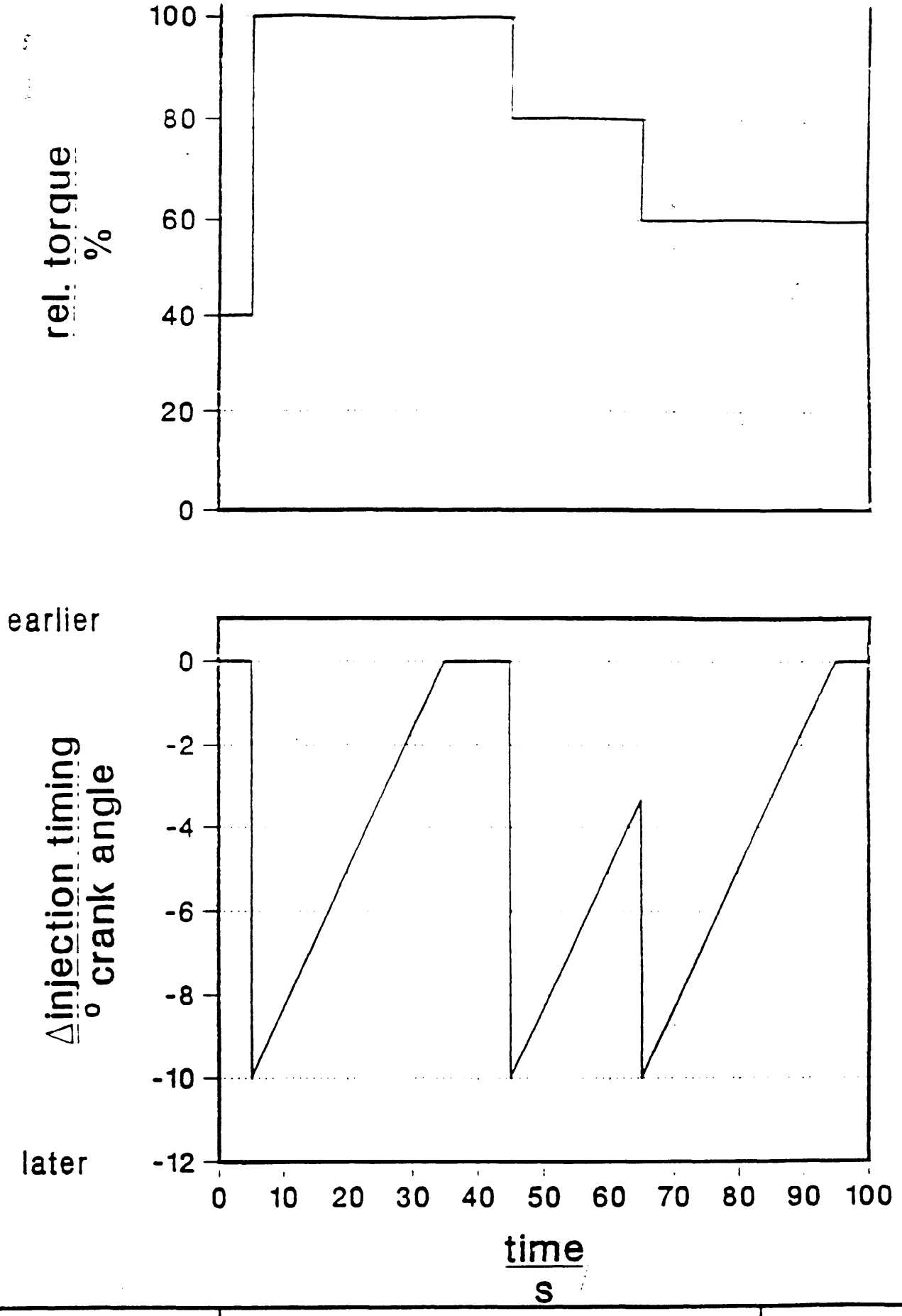


electr.injection start, steady electr. injection start, unsteady *start of ignition °crank before TDC

Mercedes Benz
Nutzfahrzeuge
Entwicklung

Start of electronic injection at steady and transient full load of modern US-Diesel engines, engine A

EN/MVT 9105-60



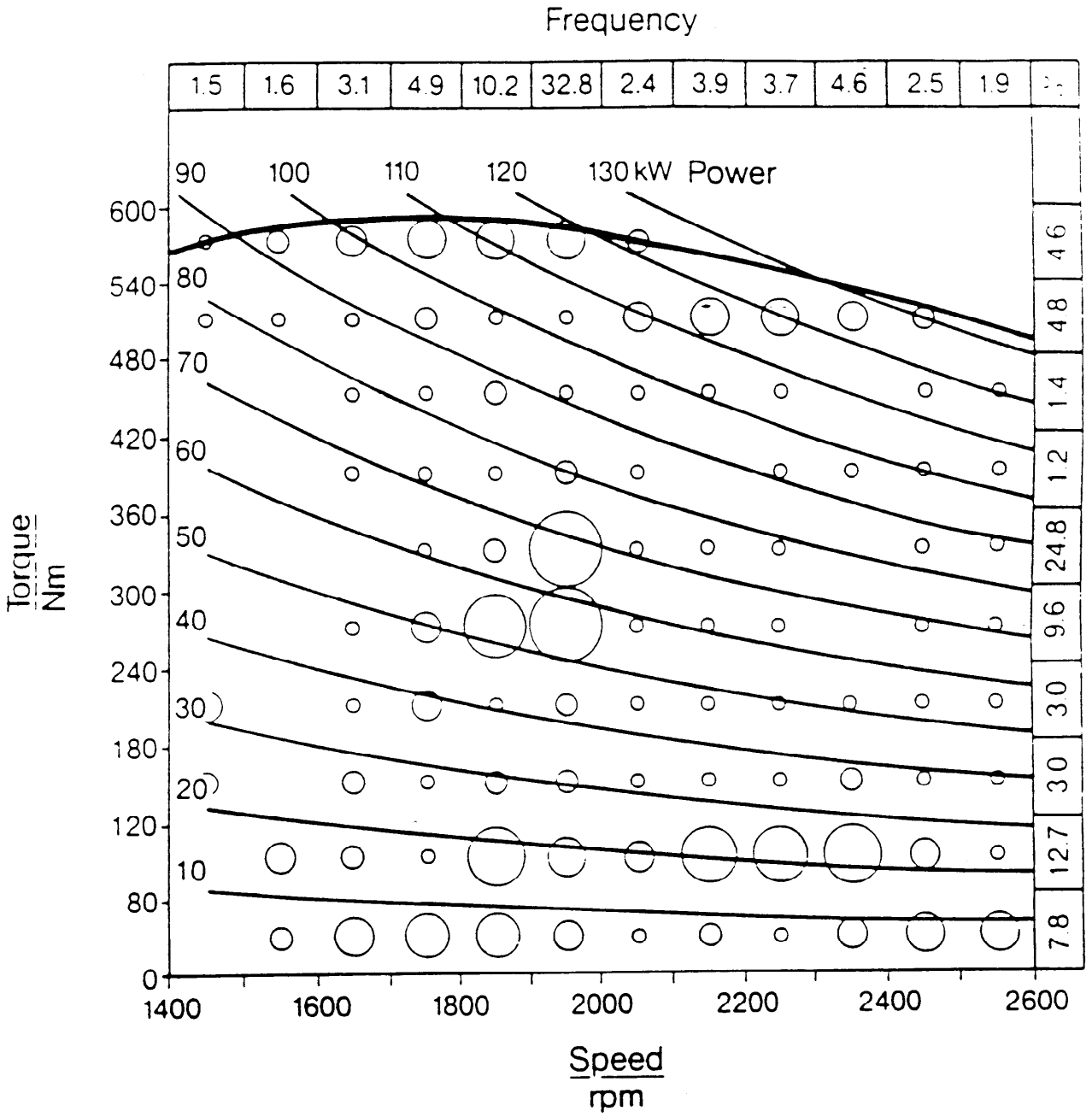
Mercedes-Benz
Nutzfahrzeuge
Entwicklung

schematic characteristic of injection timing at constant and transient load (several US engine manufacturers)

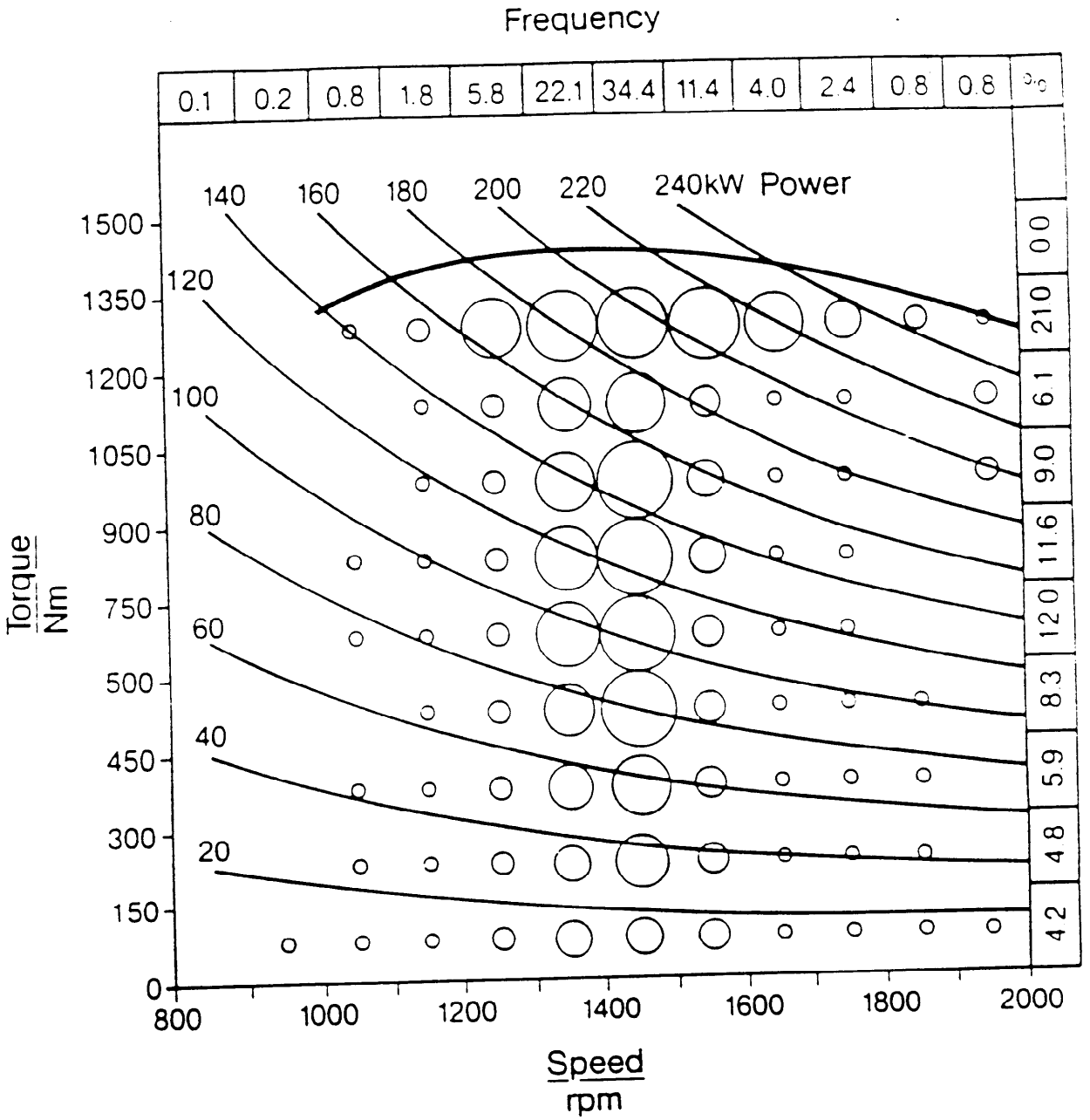
EN/MVT 9104-09

17

820.603.00.063.02 EN/MVT-FI

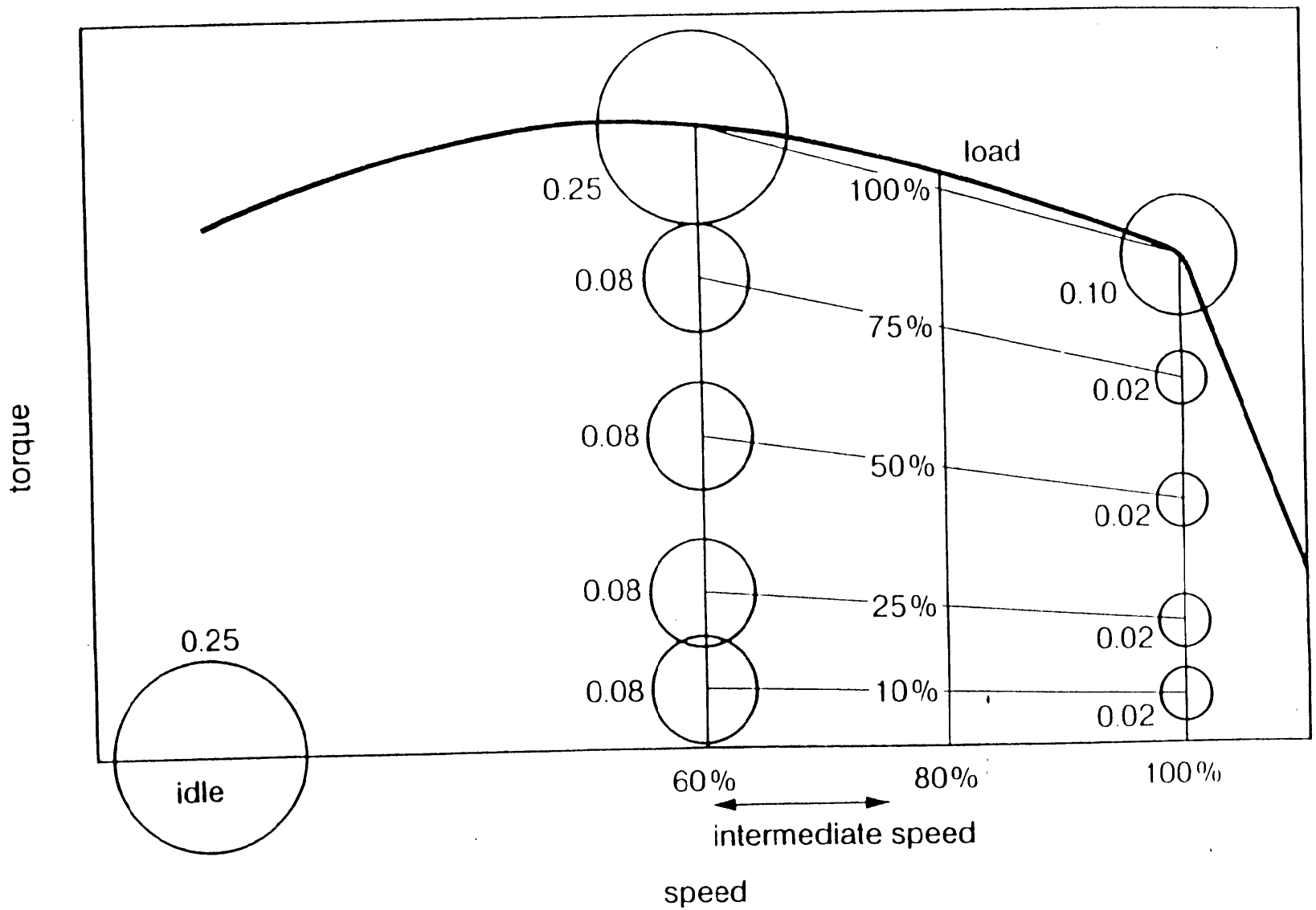


Lit.: Netherlands Delegation to MVEG



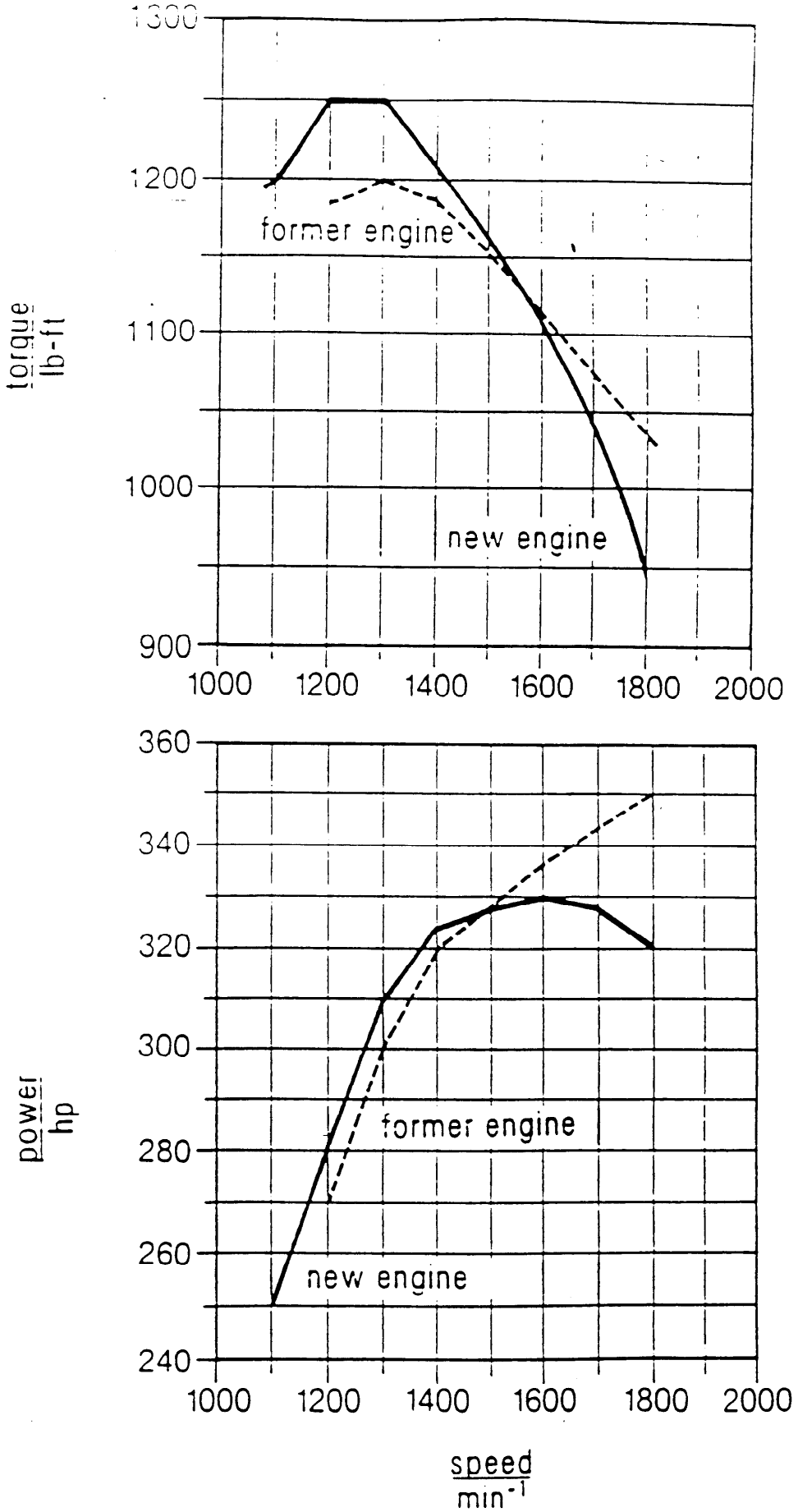
Lit.: Netherlands Delegation to MVEG

Engine map frequencies of



Measuring points and weighting factors of ECE R49 13-mode test

Mercedes-Benz



Mercedes-Benz Nutzfahrzeuge

Power and Torque Characteristics of modern US-Diesel-Engines

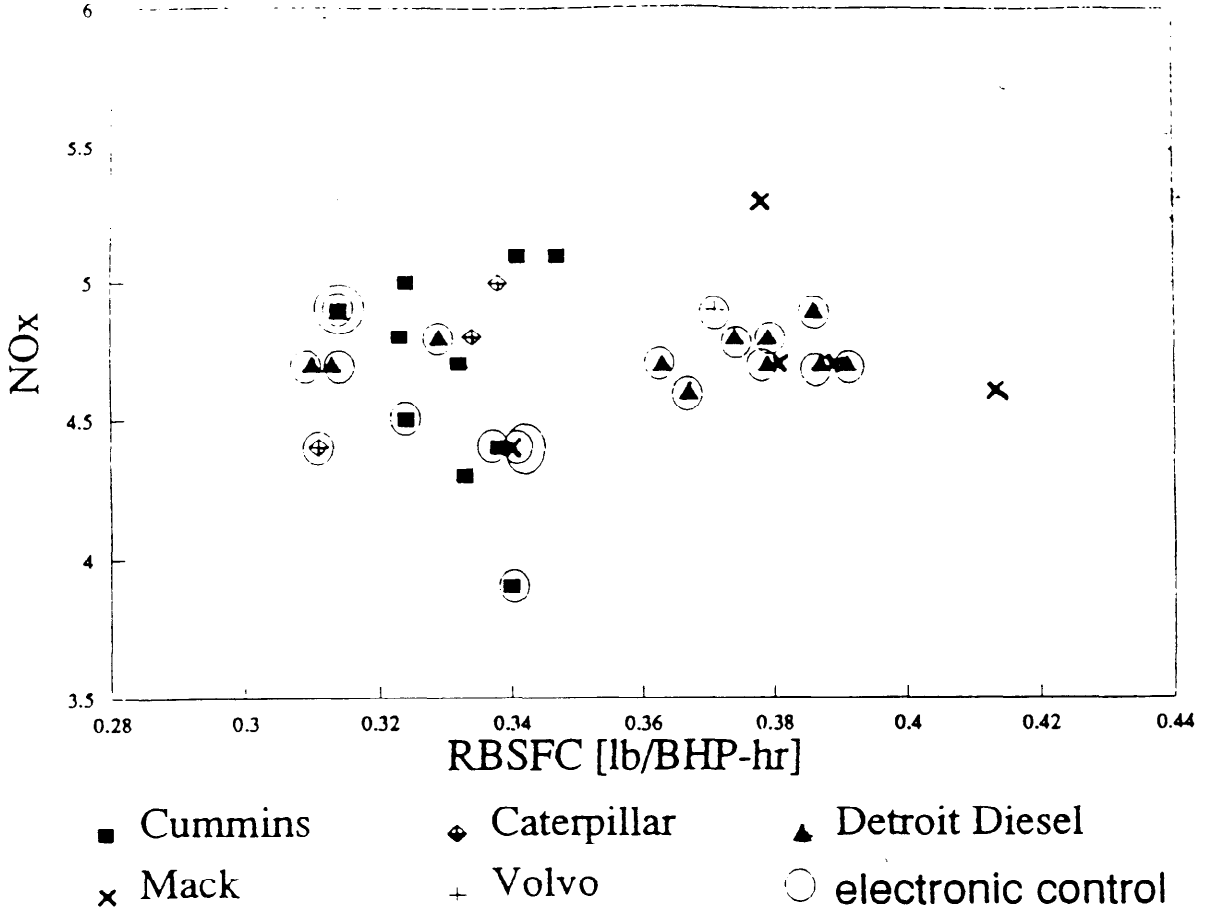
EN/MVT 9102-03

PRESENT INVESTIGATION

- A look at NOx versus fuel consumption
  - An attempt was made to discover a 1991 HHDD engine family with exceptionally low NOx
  - No such engine family was found
- A look at rated brake specific fuel consumption versus cycle brake specific fuel consumption
  - An attempt was made to discover a 1991 HHDD engine family which had an exceptionally poor match between its RBSFC and its CBSFC
  - No such engine family was found

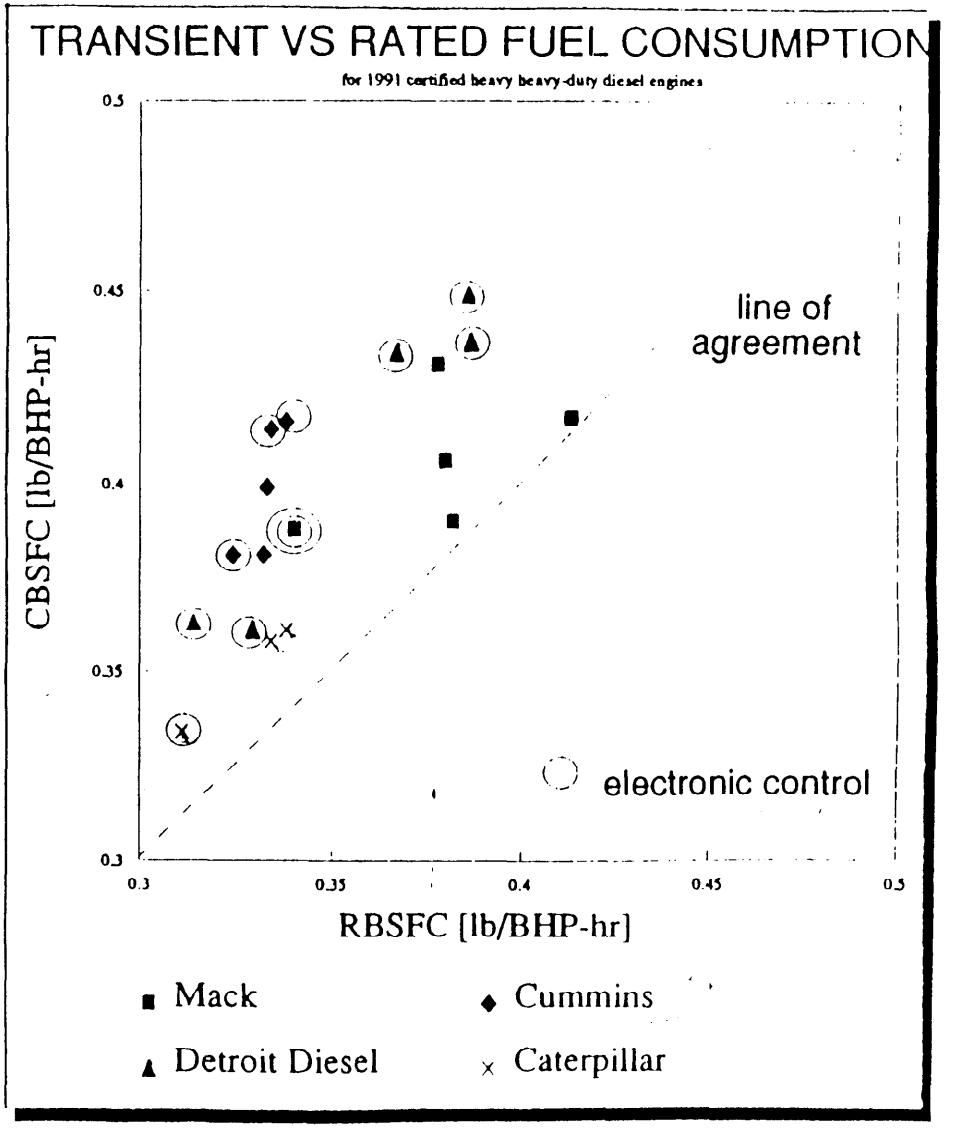
RATED FUEL CONSUMPTION VS. NOx

for 1991 certified heavy heavy-duty diesel engines



	Mack						
RBSFC	0.38	0.413	0.34	0.382	0.38	0.34	0.378
CBSFC	0.406	0.417	0.388	0.39	0.406	0.388	0.431
	Cummins						
RBSFC	0.324	0.332	0.338	0.334	0.333		
CBSFC hot	0.378	0.379	0.413	0.41	0.396		
CBSFC cold	0.402	0.396	0.436	0.44	0.417		
CBSFC	0.381	0.381	0.416	0.414	0.399		
	Caterpillar						
RBSFC	0.311	0.338	0.334				
CBSFC	0.334	0.361	0.358				
	Detroit Diesel						
RBSFC	0.367	0.386	0.387	0.314	0.329		
CBSFC hot	0.427	0.444	0.434	0.362	0.359		
CBSFC cold	0.475	0.483	0.455	0.372	0.375		
CBSFC	0.434	0.449	0.437	0.363	0.361		

weightings are 1/7 cold and 6/7 hot

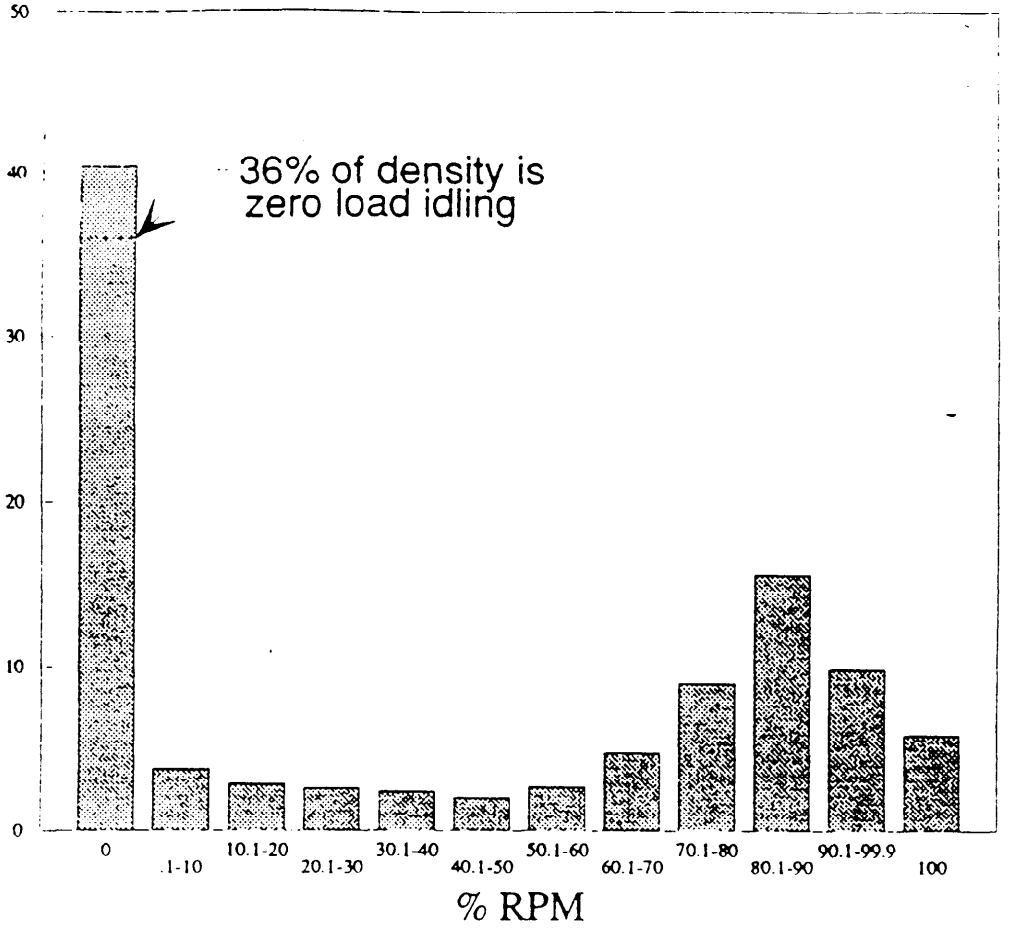


REPRESENTATIVENESS OF THE TRANSIENT TEST

- Cycle distribution of the transient test is
  - concentrated at idle and at 80% RPM
  - based on NY and LA on and off freeway study
- Changes in torque characteristics since the transient test was created are not significant
  - Heavy-duty diesel engines now reach their peak torque at lower RPM's than when the transient test was developed
  - However, the maximum rated RPM's have also been reduced
- The only sections in the Heavy-Duty Diesel transient test cycle which achieve steady-state for more than ten seconds are at idle (zero torque)

ENGINE SPEED DENSITY GRAPH

for Diesel Engine Transient Cycle



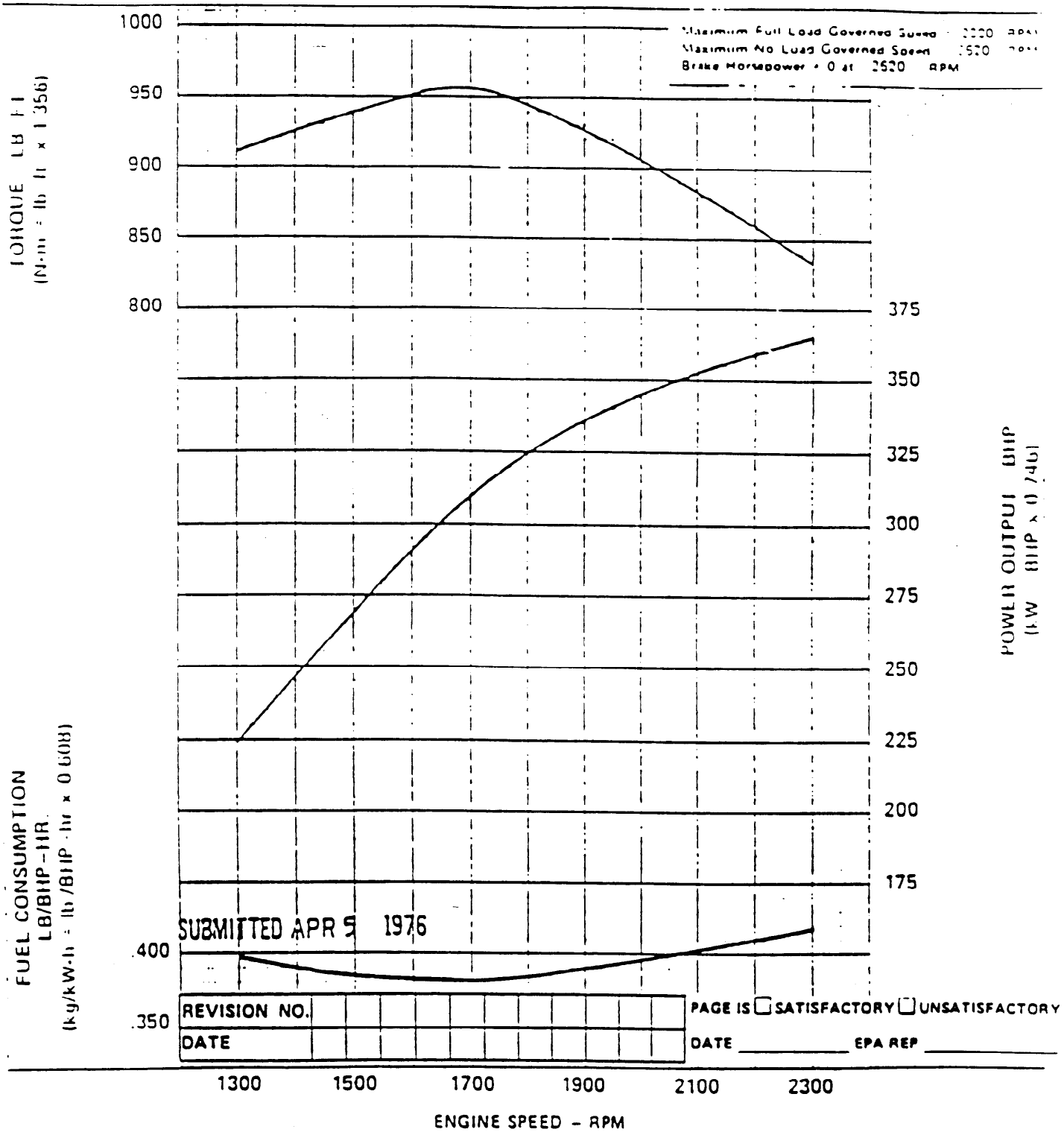
CUMMINS ENGINE COMPANY INC
Columbus Indiana 47201
AUTOMOTIVE PERFORMANCE CURVE

BASIC ENGINE MODEL	CURVE NUMBER
NTF-365	RC 3544-A

ENGINE FAMILY	CPL CODE	DATE	BY
292	2155	8/21/75	[illegible]

DISPLACEMENT 855 in³ / 14.0 litres ASPIRATION Turbocharged
BORE: 5.5 in / 140 mm STROKE: 6.0 in / 152 mm NO. OF CYLINDERS 6
EMISSION CONTROL: AFC FUEL SYSTEM: PT

RATING
HP (kW) @ RPM
365 (272) @ 2300



REVISION NO.	
DATE	

PAGE IS ☐ SATISFACTORY ☐ UNSATISFACTORY
DATE _____ EPA REP _____

Curves shown above represent engine performance capabilities at SAE standard J816b conditions of 500 ft. (150m) altitude (29.00" Hg (736mm Hg) dry barometer), 85°F (29°C) air intake temperature, and 0.38" Hg (9.6mm Hg) water vapor pressure with No. 2 diesel fuel. The engine may be operated without changing the fuel setting up to 7,000 ft. (2 100 m) altitude and 100°F (38 °C). For sustained operation at higher altitudes and temperatures the fuel rate of the engines should be adjusted to limit performance by 4% per 1,000 ft (300m) above 7,000 ft. (2 100m) and 1% per 10°F above 100°F (2% per 11°C above 38°C).

STANDARDS DEPT. CERTIFIED WITHIN 5%: [signature] CHIEF ENGINEER

FORM 2713 Rev 1 75

CUMMINS ENGINE COMPANY, INC Columbus, Indiana 47201 AUTOMOTIVE PERFORMANCE CURVE	Basic Engine Model: L10-310		Curve Number: C-4709	
	Engine Family: D34	CPL Code: 1349	Date: 30Apr90	By: RMM

Displacement: 611 in.^{3} (10.0 litre) Aspiration: TURBOCHARGED & CHARGE AIR COOOLED

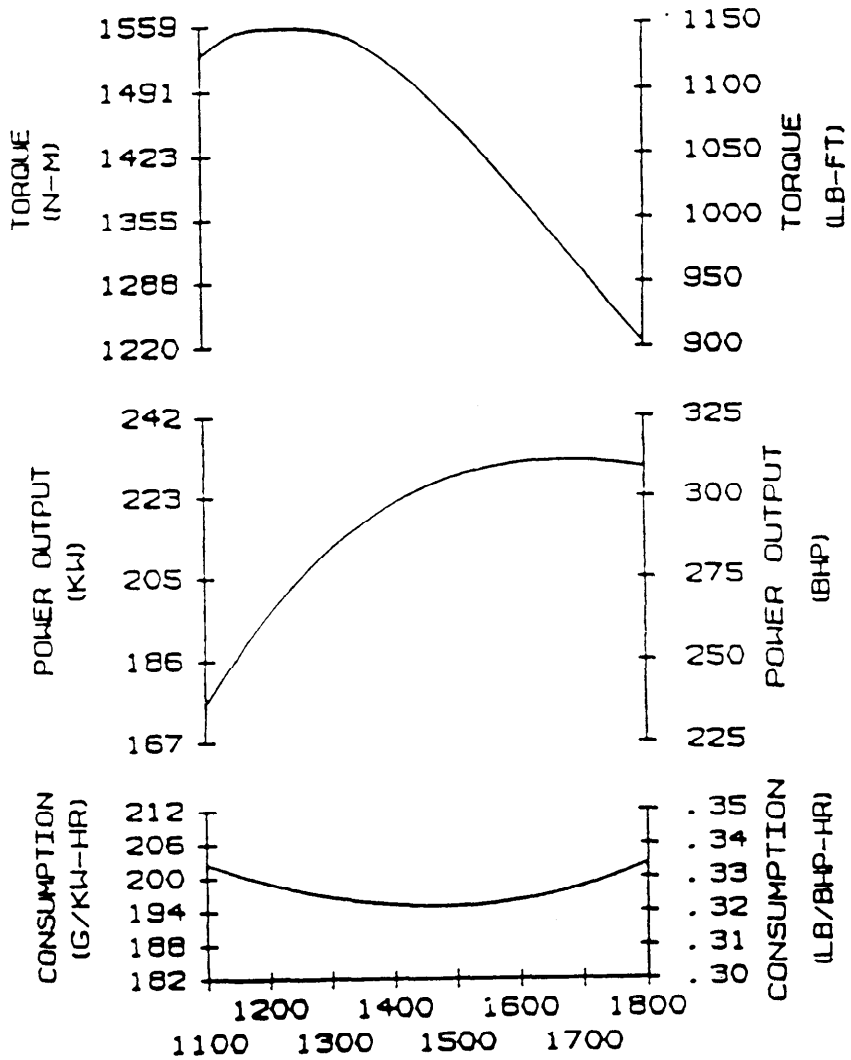
Bore: 4.92 in. (125 mm) Stroke: 5.35 in. (136 mm) No. of Cylinders: 6 BHP (kW) @ RPM

Emission Control: AFC Fuel System: PT-STC Advertised BHP 310 (231) @ 1600

Governed Speed @ 1800

All data is based on the engine operating with fuel system, water pump, lubricating oil pump, air compressor (unloaded), and 10 in H_2O (250 mm) inlet air restriction and with 2.0 in Hg (50 mm) exhaust restriction; not included are alternator, fan, optional equipment and driven components.

Maximum Full Load Governed Speed = 1800 RPM
Maximum No Load Governed Speed = 2106 RPM
Brake Horsepower = 0 @ 2106 RPM



TORQUE		
RPM	lb.-ft	N•m
1100	1130	1532
1200	1150	1559
1300	1148	1556
1400	1125	1525
1500	1076	1459
1600	1018	1380
1700	958	1299
1800	905	1227

POWER OUTPUT		
RPM	BHP	kW
1100	237	176
1200	263	196
1300	284	212
1400	300	224
1500	307	229
1600	310	231
1700	310	231
1800	310	231

FUEL CONSUMPTION		
RPM	lb/BHP-HR	g/kW•hr
1100	.334	203
1200	.327	199
1300	.323	196
1400	.321	195
1500	.321	195
1600	.324	197
1700	.328	200
1800	.334	203

Curves shown above represent gross engine performance capabilities obtained and corrected in accordance with SAE J1349 conditions of 29.61 in (100 kPa) barometric pressure (300 ft (90 m) altitude), 77°FF (25°C) inlet air temperature, and 0.30 in Hg (1 kPa) water vapor pressure with No.2 die fuel. The engine may be operated in a transient mode without changing the fuel setting up to 12,000 ft (3 600 m) altitude and 100°F (38°C). sustained operation at high altitude or temperature the fuel rate of the engine should be adjusted to limit performance by 4% per 1,000 ft (300 m) ab 12,000 ft (3 600 m) and 1% per 10°FF above 100°F (2% per 11°C above 38°C).

TECHNICAL DATA DEPT. CERTIFIED WITHIN 5% CHIEF ENGINEEF

FURTHER INVESTIGATION

- Option 1: acquire and test a number of production engines making note of the fuel consumption and timing

- Option 2: go directly to the manufacturers and ask them if they have the electronic "cycle beating" strategy

CONCLUSIONS

- Electronic controls are being used to tailor and engine's performance to the transient test

- The fuel consumption is inversely related to the Nox emitted

- The transient test is still representative

  - Most drivers will drive at maximum power rather than at maximum torque

  - The % RPM at which maximum power occurs has not changed significantly

- Electronic control may be used to allow the engine to operate "cleaner" during testing than during actual road use

APPENDIX

TABULAR EMISSION AND FUEL CONSUMPTION DATA FOR 1991 CERTIFIED HHDD ENGINES

Here is a table of the HDV diesel engines certified in 1991 under the **heavy** service class.

ENGINE MODEL	M/E*	RATED HP	HC	CO	NOx	PARTICULATES
Cummins Engine Company, Inc.						
LTA10	M	300	0.5	W**	5.0	0.37
L10-330E	E	300	0.2	3.8	4.5	0.21
L10-310	M	310	0.6	1.7	4.7	0.19
	M	310	0.6	2.3	4.8	0.25
L10-310E	E	310	0.3	3.1	3.9	0.28
NTC-350	M	350	0.6	W	5.1	0.49
FLEET 300	M	300	0.4	W	5.1	0.40
N14-460E	E	460	0.3	2.1	4.4	0.22
N14-350E	E	350	0.4	2.1	4.9	0.25
N14-410	M	410	0.5	2.0	4.5	0.19
N14-350P	M	350	0.6	2.3	4.3	0.20
NTC-444	M	444	1.0	W	4.7	0.52
N14-330P	M	330	0.4	2.6	5.4	0.20
Caterpillar Inc.						
3176	E	325	0.2	3.5	4.4	0.25
	E	325	0.2	3.2	4.9	0.17
3306B-ATAAC	M	300	0.7	2.3	4.8	0.44
3406B	M	425	0.2	1.3	5.0	0.25
3406B PEEC	M	460	0.4	1.6	4.8	0.23
Detroit Diesel Company						
6L-71TA DDEC ALCC		330	0.4	1.6	4.6	0.29
	E	240	0.5	1.6	4.8	0.33
6L-71TA DDEC COACH		270	0.6	1.8	4.4	0.30
	E	270	0.5	1.5	4.8	0.30
6V-92TA DDEC	E	300	0.4	2.3	4.9	0.25
6V-92TA DDEC COACH		277	0.4	2.6	4.7	0.31
	E	253	0.4	2.1	4.8	0.25
6V-92TA METHANOL COACH		253	0.8	12.0	3.0	0.06
	E	277	0.4	4.8	2.3	0.06
8V-92TA DDEC	E	370	0.5	1.5	4.7	0.20
	E	450	0.4	1.9	4.7	0.25
SERIES 60, 11.1L		**275**	**0.1**	**2.4**	**4.9**	**0.15**
	E	**350**	**0.1**	**2.2**	**4.7**	**0.13**
SERIES 60, 12.7L		**355**	**0.1**	**2.3**	**4.8**	**0.19**
	E	**450**	**0.1**	**1.8**	**4.7**	**0.18**
	E	**450**	**0.1**	**1.7**	**4.8**	**0.17**

* Electrical/Mechanical Fuel System
** CO Waiver

ENGINE MODEL	E/M*	RATED HP	HC	CO	Nox	PARTICULATES
Mack Trucks, Inc.						
EM7-300	M	300	0.1	W**	4.7	0.20
E7-300	M	300	0.1	W	4.6	0.19
EM7-300	E	300	0.1	W	4.4	0.24
E7-400	E	400	0.1	W	4.8	0.16
EM7-275	M	275	0.1	W	4.7	0.20
EM7-300	M	300	0.1	W	4.7	0.20
E7-400	E	400	0.1	W	4.8	0.15
EM7-300	E	300	0.1	W	4.4	0.24
E9-500	M	500	0.5	W	5.3	0.32
Volvo White Truck Corporation						
TD123EC	E	360	0.3	1.7	4.9	0.21
TD123EB	E	330	0.4	1.6	4.8	0.21
TD123EA	E	300	0.4	1.6	4.9	0.22

* Electrical/Mechanical Fuel System
** CO Waiver

Note: I assume that the units for the emissions are standard.

Ford Motor Company, General Motors Corporation, Hino Motors, Ltd., Mercedes-Benz Aktiengesellschaft, Navistar International Transportation Corp., Perkins Engine Company, and Renault Vehicles Industriels have all certified HDV diesel engines in 1991. They are not listed because none of their engines were in the Heavy intended service class.

Company	Engine Model	Rated hp	at RPM	w/Fuel Rate (lb/hr)	Peak Torque (ft-lbf)	at RPM	w/Fuel Rate (LB/HR)	RBSFC ** (lb/BHP-hr)	CBSFC * (lb/BHP-hr)
Cummins Engine Company	LTA10	315	2100	102	1025	1300	82	0.324	
	L10-330E	340	1600	110	1260	1200	93	0.324	0.381
	L10-310	313	1600	104	1169	1200	90	0.332	0.381
	L10-310	316	1600	102	1178	1200	87	0.323	
	L10-310E	306	1600	104	1140	1200	90	0.340	
	NTC-350	367	2100	125	1226	1300	98	0.341	
	FLEET 300	288	1700	100	1091	1100	79	0.347	
	N14-460E	464	1700	157	1564	1200	117	0.338	0.416
	N14-350E	335	1600	112	1332	1200	100	0.334	0.414
	N14-350P	357	1600	119	1386	1100	96	0.333	0.399
Caterpillar Inc.	3176	325	1800	101	1250	1200	94	0.311	0.334
	3406B	400	2000	135	1400	1200	112	0.338	0.361
	3406B PEEC	425	1800	142	1550	1200	118	0.334	0.358
Detroit Diesel Corporation	6L-71TA DDEC (ALCC)	330	2100	121	1050	1200	91	0.367	0.434
	6L-71TA DDEC (ALCC)	270	2100	101	900	1200	76	0.374	
	6V-92TA DDEC	350	2100	135	1020	1200	82	0.386	0.449
	6V-92TA DDEC	300	1800	109	975	1200	78	0.363	
	6V 92TA DDEC COACH	277	2100	105	880	1200	70	0.379	
	6V 92TA DDEC COACH	253	2100	96	775	1200	61	0.379	
	8V-92TA DDEC	450	2100	174	1425	1200	116	0.387	0.437
	8V-92TA DDEC	370	2100	145	1150	1200	113	0.391	
	SERIES 60-11.1L	350	1800	110	1250	1200	94	0.314	0.363
	SERIES 60-11.1L	275	1800	86	1250	1200	94	0.313	
	SERIES 60-12.7L	450	2100	148	1450	1200	106	0.329	0.361
	SERIES 60-12.7L	355	1800	110	1450	1200	106	0.310	

* Cycle Brake Specific Fuel Consumption

** Rated Brake Specific Fuel Consumption

Company	Engine Model	Rated hp	at RPM	w/Fuel Rate (lb/hr)	Peak Torque (ft-lbf)	at RPM	w/Fuel Rate (lb-hr)	RBSFC ** (lb/BHP-hr)	CBSFC * (lb/BHP-hr)
Mack Trucks Inc.	EM7-300	300	1750	114	1425	1020	95	0.380	0.406
	E7-300	300	1950	124	1083	1200	84	0.413	0.417
	EM7-300	300	1750	102	1425	1020	92	0.340	0.388
	EM7-275	275	1750	105	1305	1020	88	0.382	0.390
	EM7-300	300	1750	114	1425	1020	95	0.380	0.406
	EM7-300	300	1750	102	1425	1020	92	0.340	0.388
	E9-500	500	1900	189	1660	1300	140	0.378	0.431
Volvo White Truck Corporation	TD123EC	356	1900	132	1275	1200	100	0.371	

* Cycle Brake Standard Fuel Consumption

** Rated Brake Standard Fuel Consumption

Note: Caterpillar data taken from 1992 HDV Certification Application (engines used are carry-overs)

APPENDIX 2

1991 Cummins HHDD Engine

Peak horsepower at: $\frac{1800 - 700}{2106 - 700} = 78\%$ RPM

1976 Cummins HHDD Engine

Peak horsepower at: $\frac{2300 - 800}{2620 - 800} = 82\%$ RPM

Where:

Peak horsepower occurs at: $\frac{\text{Max Power RPM - Idle RPM}}{\text{Max Rated RPM - Idle RPM}} = \%$ RPM

There is no significant change between the % RPM at which the engine operates. Therefore, the transient test is still representative for HHDD vehicles.