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MATADOR

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Task 2:
Testing methods for vehicles with conventional and alternative drive lines

Institute for Automotive Engineering

Working document

Evaluation of the Renault Express Electrique over six different driving cycles

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Contence

1. General

A Renault Express Electrique with a conventional drive line has been evaluated by IAE over a range of six different drive cycles. Each cycle was driven once, with a fully charged battery. From the measurement results the energy consumption and the cycle length were examined. This document contains a brief description of the measurement procedure, a reflection of the measurement results an d a interpretation of the results.

2. Measurement procedure

In table 2.1 the cycles which were used during the measurement programme (driving cycle definitions see ref.: 1), are given.

Cycle definition		a_{MAX} [m/s²]	a_{MIN} [m/s²]	S_{TOTAL} [m]	t_{TOTAL} [s]
NECD		1,0	-1,0	11,007	**1180**
JAP10-15		0,8	-0,8	4171	**660**
USFTP		1,9	-1,8	17,763	**1877**
Hyzem	Urban	2,2	-2,1	3,470	**559**
	Rural	2,4	-4,6	11,224	**842**
	Highway	3,2	-4,0	46,205	**1803**

Table 2.1 Minimum and maximum accelerations during defined driving cycles

For each cycle a set of parameters has been recorded (see §3). For the test sequence two procedures are available, an European and an American procedure:

1. The procedure of the European Standard EN1986-1: Electrically propelled road vehicles - Measurement of energy performances, describes an test procedure with a 24h period:
   1.1. The vehicle is charged according to the normal, prescribed procedure by the manufacturer;
   1.2. At time: t_0, the procedure starts with unplugging the vehicle from the mains (grid);
   1.3. Within 4h from t_0 the test procedure on the dynamometer has to be started;
   1.4. The vehicle must be reconnected to the mains (grid) within 30 min. after the test on the dynamometer;
   1.5. The vehicle must be moved to and from the dynamometer (if necessary) without the use of it's own

power source;
1.6. The vehicle must disconnected after 24h from t_0, during this time the energy from the grid must be recorded.
2. The SAE J1634 procedure, has a slightly different test sequence:
2.1. The vehicle shall be soaked at ambient temperature (20°C – 30°C) for a time t_0: 12h≤ t_0 ≤ 36h;
2.2. During this soaking time the vehicle must be connected to the mains;
2.3. The soak must not end before the vehicle batteries are fully charged;
2.4. Within 1h from t_0, the test on the dynamometer must start;
2.5. Within 1h from t_0, the vehicle must be reconnected to the mains (grid), with a minimum of 12h and at least until the vehicle batteries are fully charged;
2.6. The vehicle must be moved to and from the dynamometer (if necessary) without the use of it's own power source.

Since both test sequences have similarities, the European procedure was followed with a 24h cycle of testing, charging, soaking and conditioning.

Both procedures give similar methods in case the vehicle does not meet the desired speed profile:
Fully press the accelerator pedal and operate the vehicle at maximum power during such occurrences.

3. Measured and calculated parameters

The measured parameters were, all at 10Hz sample frequency:
1. Traction battery:
 1.1. Current (I);
 1.2. Voltage (U);
2. Speed of the dynamometer;
3. Speed of the vehicle.

The energy consumption from the grid (E_G) has been recorded manually.

From the recorded data some parameters have been calculated:
1. Energy from the charger into the batteries: $E_{B,C}$ [kWh];
2. Capacity from the grid into the batteries: $E_{I,C}$ [Ah];
3. Energy from the batteries during the driving: $E_{B,DC}$ [kWh];
4. Capacity from the batteries during driving: $E_{I,DC}$ [Ah];
5. Covered distance during driving: S_{DC} [km];
6. Average (arithmetic mean value) battery voltage during driving: U_A [V];
7. Energy Consumption, relative to the grid EC_G [kWh/km];
8. EC_G-Ratio, related to the EC_G of the NEDC: R_E [-];
9. Charging efficiency: η [-];
10. Energy Consumption, relative to the batteries EC_B [kWh/km];
11. Energy Consumption, relative to the grid $EC_{B,I}$ [Ah/10km];
12. Failure time: f [%] (according ref. 2).

USED FORMULAS:

Energy to or from the batteries, $E_{B,i}$ [kWh]: $E_{B,i} = \int_{t=t_1}^{t=t_2} U(t) * I(t) * dt$

Capacity to or from the batteries, $E_{I,i}$ [Ah]: $E_{I,i} = \int_{t=t_1}^{t=t_2} I(t) * dt$

i = C: C(harging); =DC" D(riving the) C(ycle).

Covered distance during driving, S_{DC} [km]: $S_{DC} = \int_{t=t_1}^{t=t_2} v(t) * dt$

Energy Consumption, relative to the grid, EC_G [kWh/km]: $EC_G = \frac{E_G}{S_{DC}}$

For comparison of the energy consumption with the momentary legislative test cycle, the NEDC, the EC_G-Ratio has been calculated: , the EC_G of the NEDC related to one of the other cycles, R_E [-]: $R_E = \frac{EC_{G,\,Cycle}}{EC_{G,\,NEDC}}$

Charging efficiency, η [-]: $\eta = \frac{E_{B,\,C}}{E_G}$

Energy Consumption, relative to the batteries, EC_B [kWh/km]: $EC_B = \frac{E_{B,\,C}}{S_{DC}}$

Energy Consumption, relative to the grid, $EC_{B,I}$ [Ah/10km]: $EC_{B,\,I} = \frac{E_{I,\,C}}{S_{DC}} * 10{,}0$

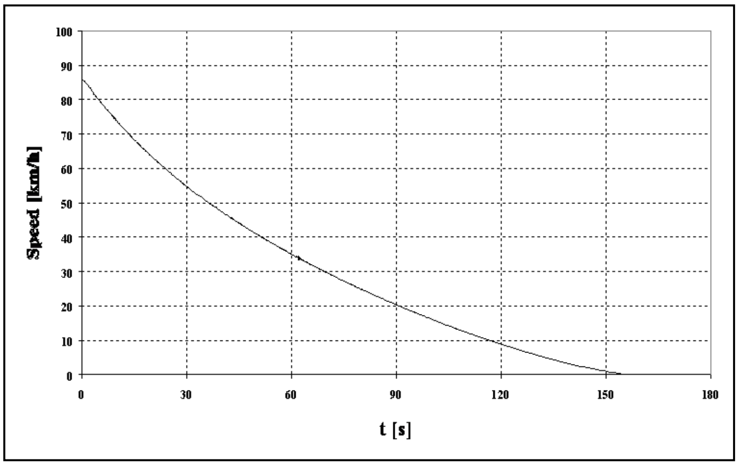
Failure time [%]: $f_T = \frac{t_{FAILURE}}{t_{TOTAL}} * 100\%$

4. Vehicle parameters

Table 4.1 gives a review of the main vehicle parameters of the Renault Express.

Manufacturer specifications		**Controller**	
Gross weight	1235 kg, 1630 kg max.	Manufacturer	ABB
Curb weight	1337,0 kg	Controller	High frequency chopper
Pay Load	395 kg, excluded 1 pers.	Recuperative deceleration	1,0 m/s², Recuperative braking
Maximum Speed	95 km/h	**Vehicle Batteries**	
Range	40 – 70km	Manufacturer	-
Drive Line		Type	Pb-Gel
Engine Manufacturer	ABB / GN 21	Open battery voltage	120 V
Engine type	DS – VB	Capacity	140 Ah
Driving axle	Front axle	Weight	325 kg
Nominal Power	22 kW at 2000 1/min	**Charger** (from the grid)	
Maximum Torque	125 Nm	Manufacturer	-
Open battery voltage	120 V	Supply voltage	220 V
Max. rotational speed	7000 1/min	Max. charging current	22 A (typical)

Table 4.1 Vehicle specifications



In all standards test procedures a coast down of the vehicle has to be performed in order to determine the road load of the vehicle. The coast down was made under real conditions on the road. The measured data is used as input for the roller dynamometer. The coast down curve of the Renault Express Electrique is shown in figure 4.1.

Figure 4.2 shows the Renault Express on the dynamometer.

Figure 4.1 Coast down curve of the Renault Express

5. Results

In table 5.1 the results are given over the six different cycles:

Cycle Name	E_G	$E_{B,C}$	$E_{I,C}$	$E_{B,DC}$	S_{DC}	E_I	U_A	EC_G	R_E	η	EC_B	$EC_{B,I}$	f_T
	[kWh]	[kWh]	[Ah]	[kWh]	[km]	[Ah]	[V]	[kWh/km]	[-]	[-]	[kWh/km]	[Ah/10km]	[%]
Hyzem Rural	3,85	3,03	23,899	2,04	10,924	19,597	112,5	0,35	1,03	0,79	0,19	17,94	15,44
Hyzem Urban	1,12	0,82	6,388	0,53	3,390	4,885	119,0	0,33	0,96	0,74	0,16	14,40	0
Hyzem High Way	16,10	12,21	96,556	8,28	36,633	83,411	102,1	0,44	1,28	0,76	0,23	22,8	69,27
NEDC	3,63	2,67	21,075	1,72	10,580	16,203	114,3	0,34	1,00	0,74	0,16	15,32	7,71
US-FTP	5,22	4,01	31,913	2,76	17,608	26,220	113,4	0,30	0,86	0,77	0,16	14,89	3,30
JAP 10-15	1,05	0,80	6,225	0,55	4,181	4,901	119,1	0,25	0,73	0,77	0,13	11,72	0

Table 5.1 Results of the energy measurements over 6 different test cycles

In figure 5.1 the energy consumption relative to the grid (EC_G [kWh/km]) is shown and in figure 5.2 the energy consumption ratio is given for the six different cycles. Figure 5.2 is showing the difference in energy consumption of the Renault Express compared to the legislative cycle: the NEDC.

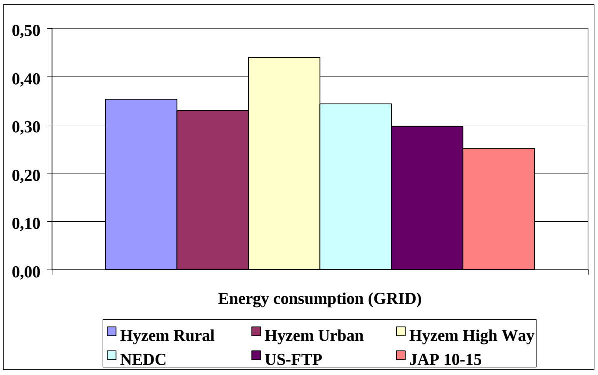


Figure 5.1 EC_G for six different cycles

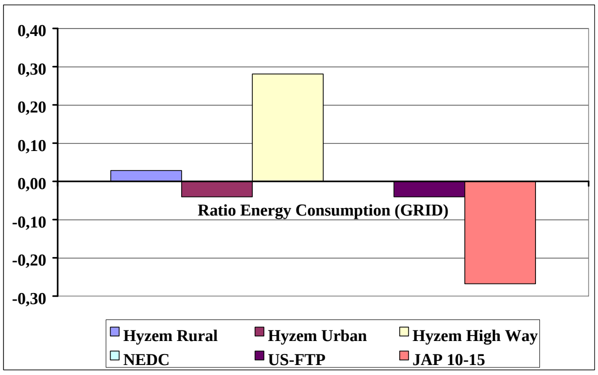


Figure 5.2 Energy consumption relative to the NEDC

6. Concluding remarks

The influence of the drive cycle on the energy consumption (EC) is relatively low. An exception is the Hyzem High Way cycles, which shows a significantly higher EC. This high EC is due to the failure time during this cycle. Since this value is high, the vehicle has been operated at maximum power during a relatively long period, causing the high EC.
The opposite effect is found in the results of the measurements with the Japanese 10-15 cycle. The deceleration level of this cycle are relatively low (see table 2.1). This is directly transferred into a low EC value.

The efficiency of the onboard charger is varying. There is no direct relation to the EC per cycle, the average value is 0,76, with a standard deviation of 2½% (0,02).

The effects of a rather “rough” driving pattern with high level deceleration periods and a representative driving patterns and a “moderate” driving pattern, with low level deceleration periods can be seen when comparing the results of the Hyzem Rural cycle and the NEDC (**the** legislative cycle for Europe):
Though the actual covered distance for these cycles are similar, approximately 10,75 km, the EC_B is significantly different: the high demanding Rural cycle uses 16% more energy.

Based on the high-level deceleration periods, the recuperation potential during the Hyzem Rural is higher than that of the, rather low-level NEDC. But the acceleration level of the Hyzem Rural is significantly higher than that of the NEDC, it could have been expected that the EC_G are similar.

Since the vehicle uses 16% more energy on the Hyzem Rural cycle than on the NEDC, one could conclude that the regeneration efficiency during deceleration periods on a driving cycle, are less efficient.

7. References

1. MATADOR, Task 2: Testing methods for vehicles with conventional and alternative drive lines, **Inventory of Test Procedures: State of the art and Problems**, TNO Road-Vehicles Research Institute, in co-operation with ENEA, HTA and IKA, September 1998, MATADOR/TASK2/TNO/1998/4/TR.

2. MATADOR, Task 2: Testing methods for vehicles with conventional and alternative drive lines, **Failure time and energy consumption of vehicles**, Hochschule für Technik und Architektur, Biel, MATADOR/TASK2/HTA/2000/03/PU

Appendix i Test results of the Hyzem Rural cycle

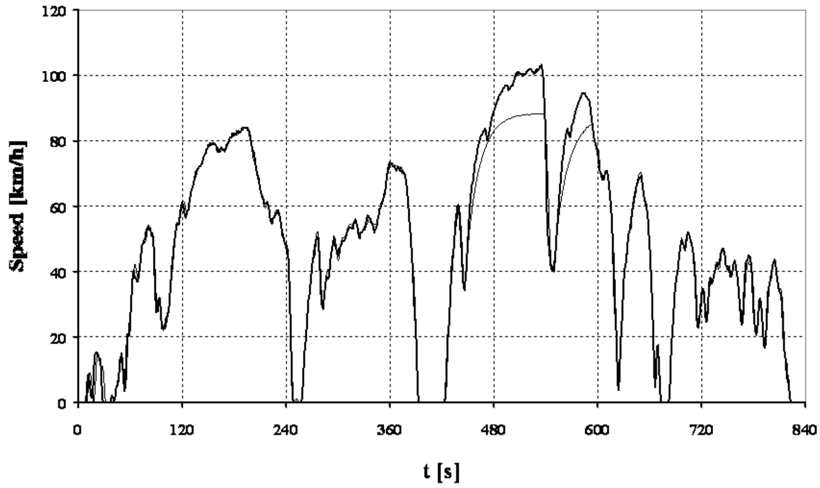


Figure i.1 Nominal and Actual speed profile

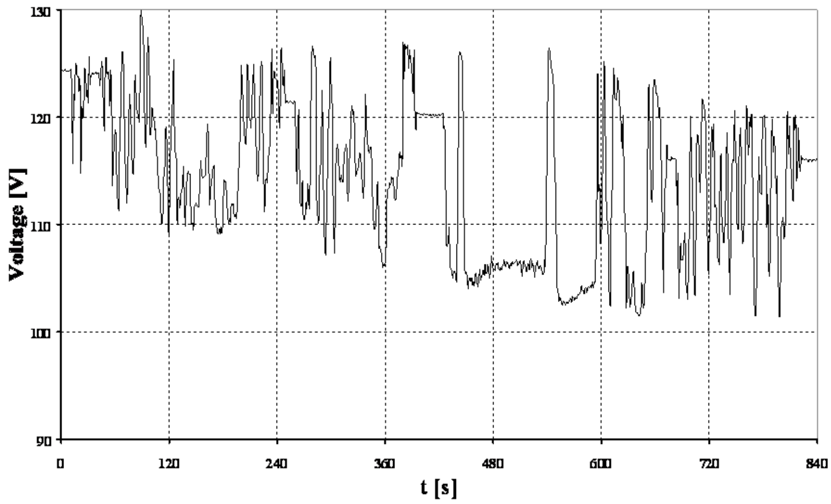


Figure i.2 Vehicle battery voltage

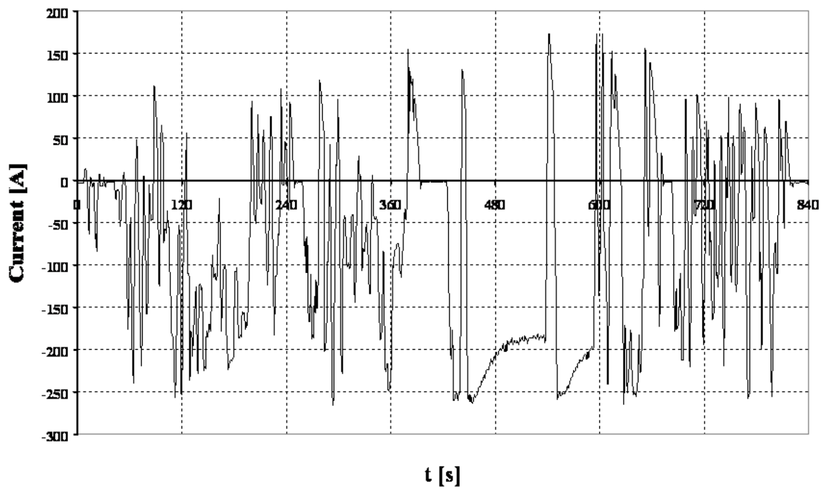


Figure i.3 Vehicle battery current; battery out

Appendix ii Test results of the Hyzem Urban cycle

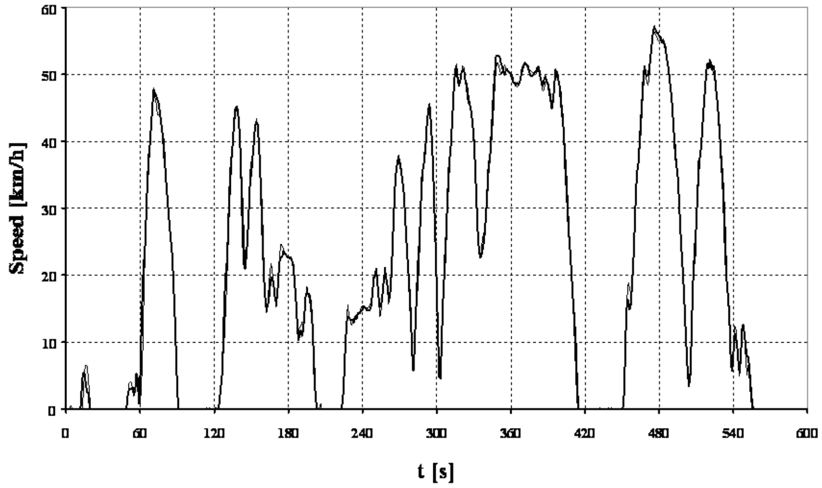


Figure i.1 Nominal and Actual speed profile

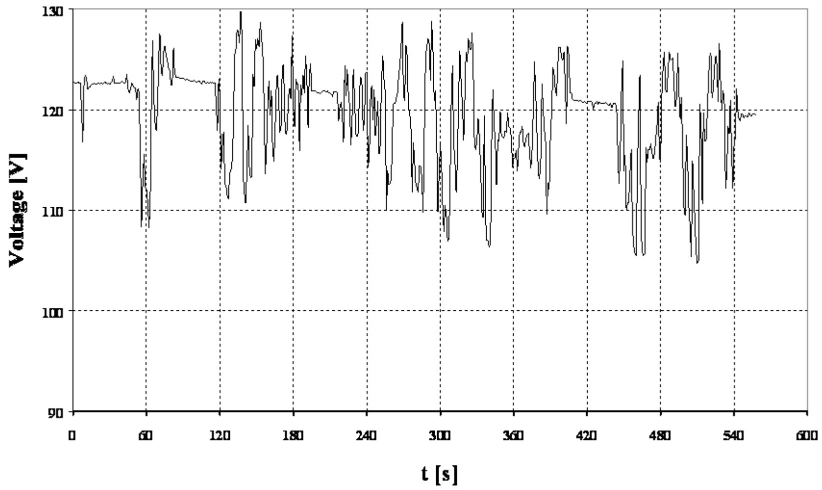


Figure i.2 Vehicle battery voltage

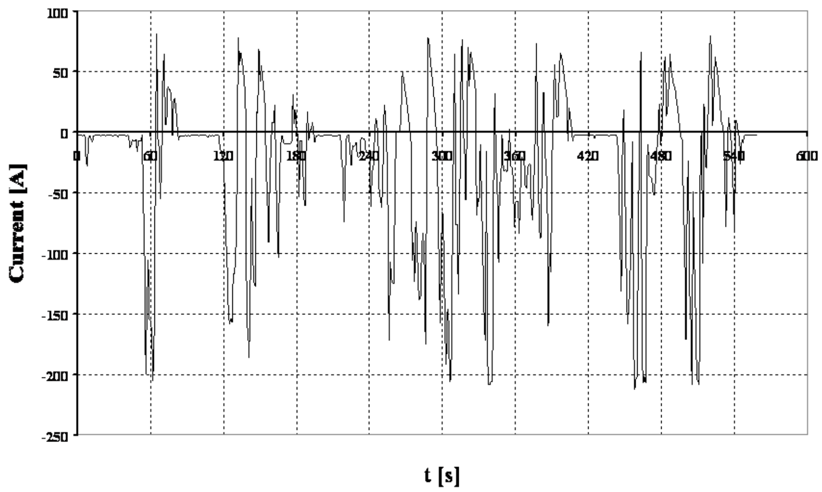


Figure i.3 Vehicle battery current; battery out

Appendix iii Test results of the Hyzem High Way cycle

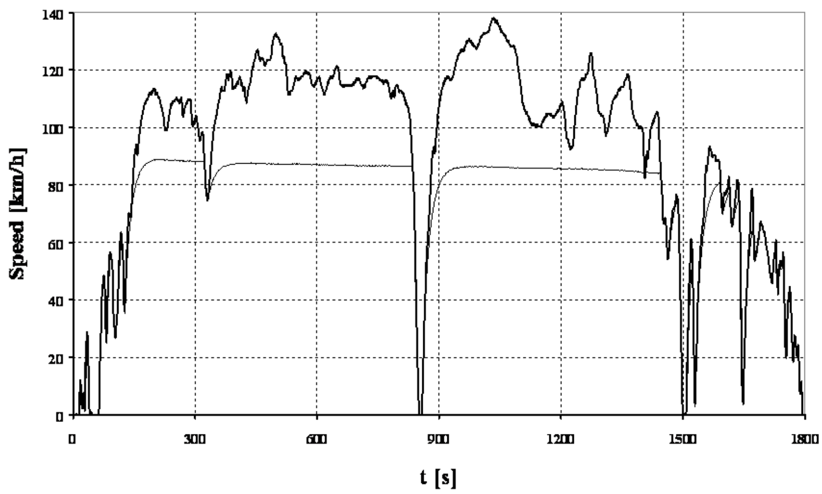


Figure i.1 Nominal and Actual speed profile

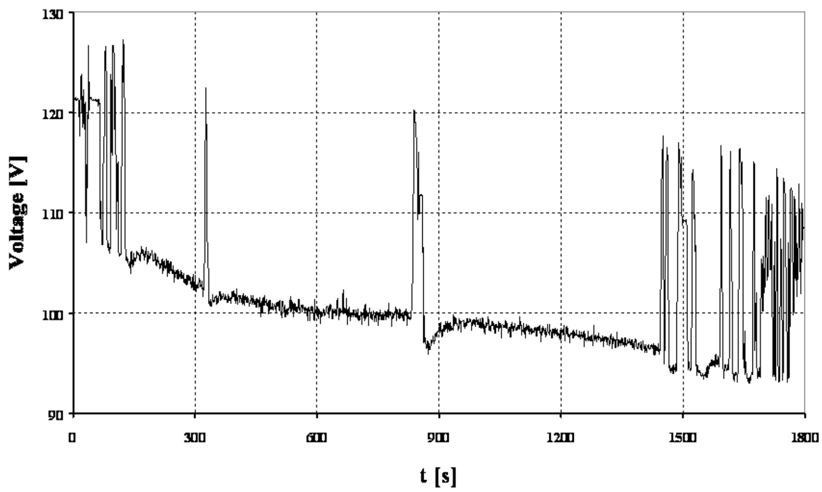


Figure i.2 Vehicle battery voltage

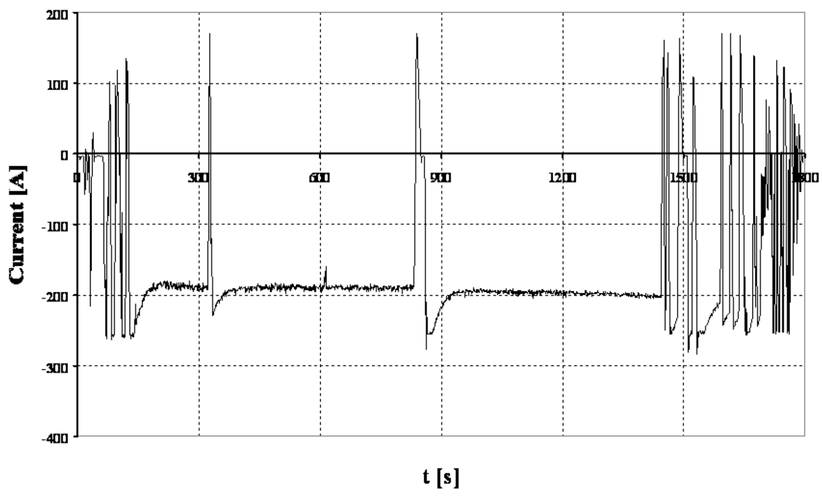


Figure i.3 Vehicle battery current; battery out

Appendix iv Test results of the New European Drive Cycle

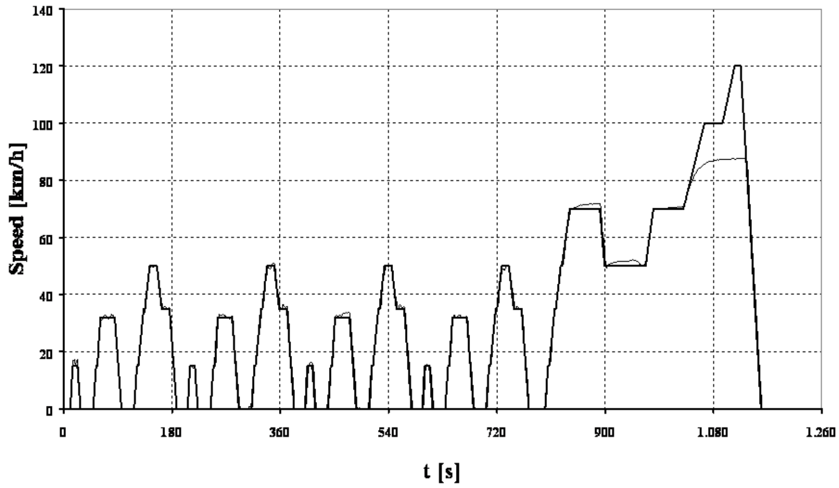


Figure i.1 Nominal and Actual speed profile

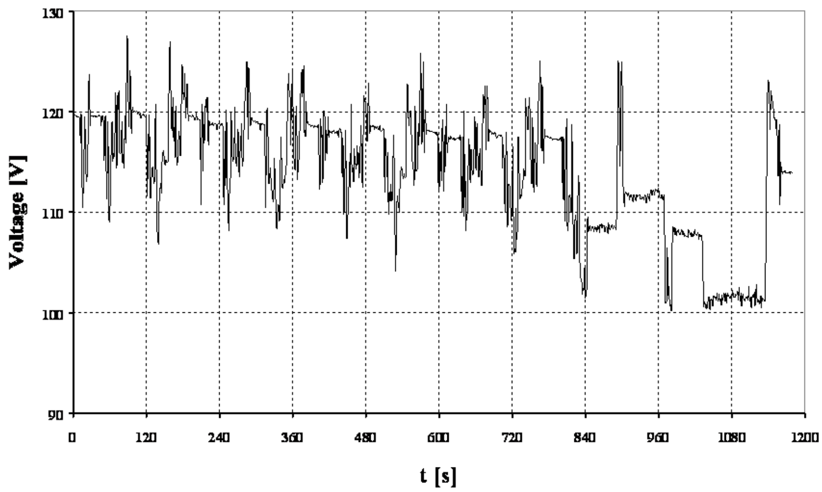


Figure i.2 Vehicle battery voltage

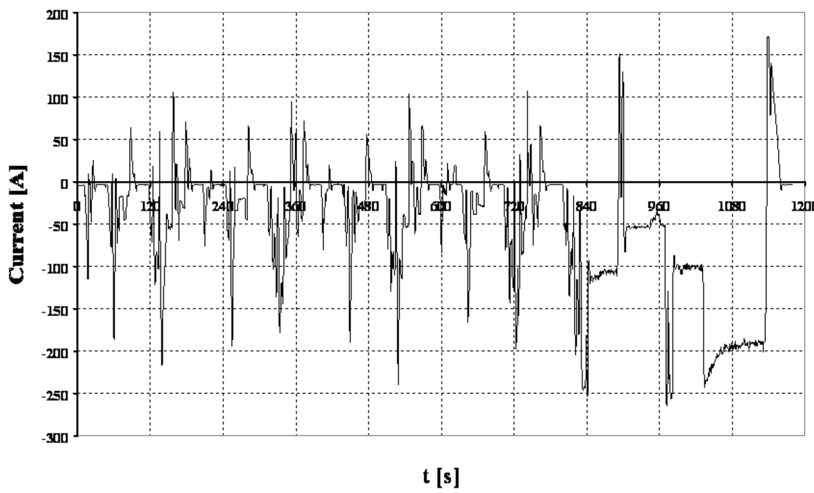


Figure i.3 Vehicle battery current; battery out

Appendix v Test results of the US FTP cycle

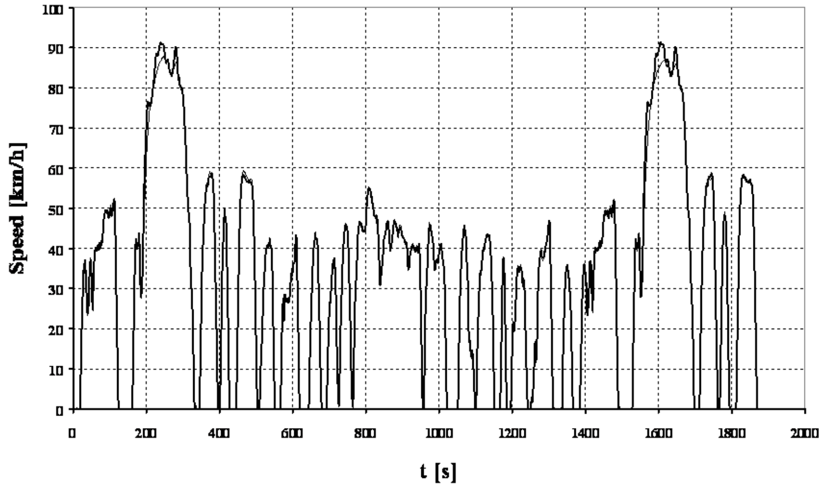


Figure i.1 Nominal and Actual speed profile

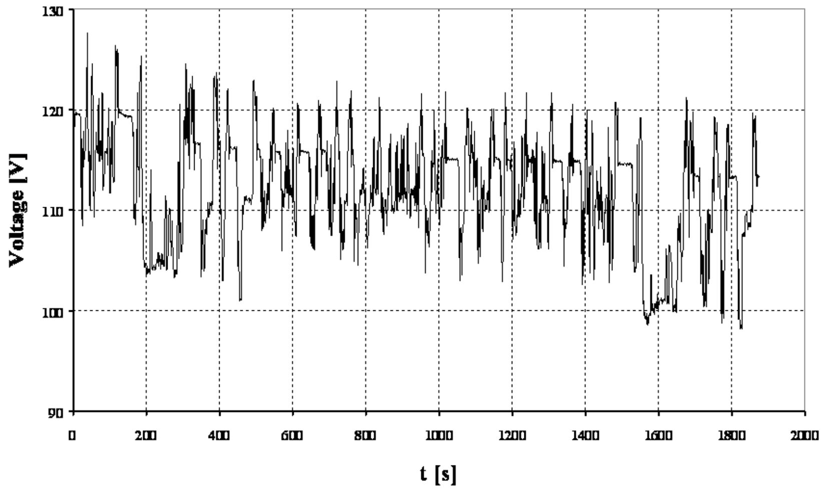


Figure i.2 Vehicle battery voltage

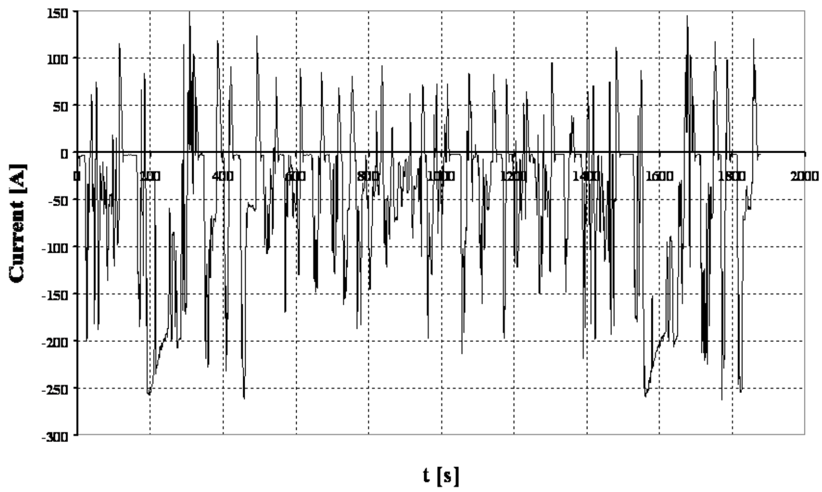


Figure i.3 Vehicle battery current; battery out

Appendix vi Test results of the Japanese 10-15 cycle

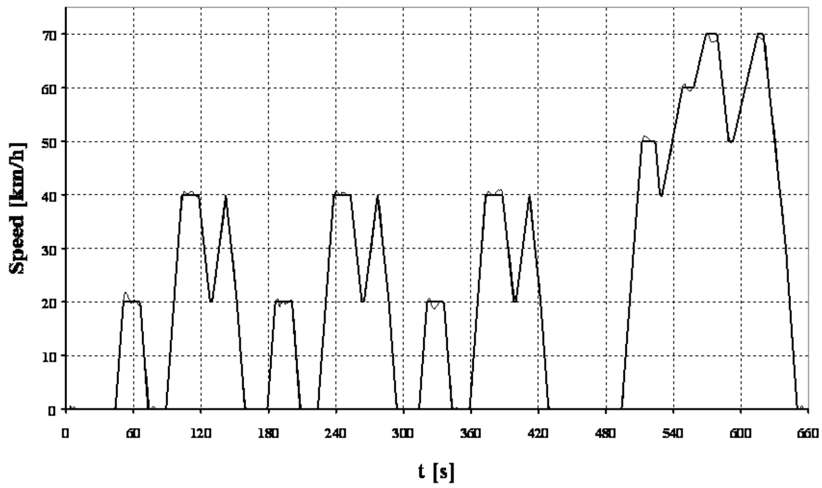


Figure i.1 Nominal and Actual speed profile

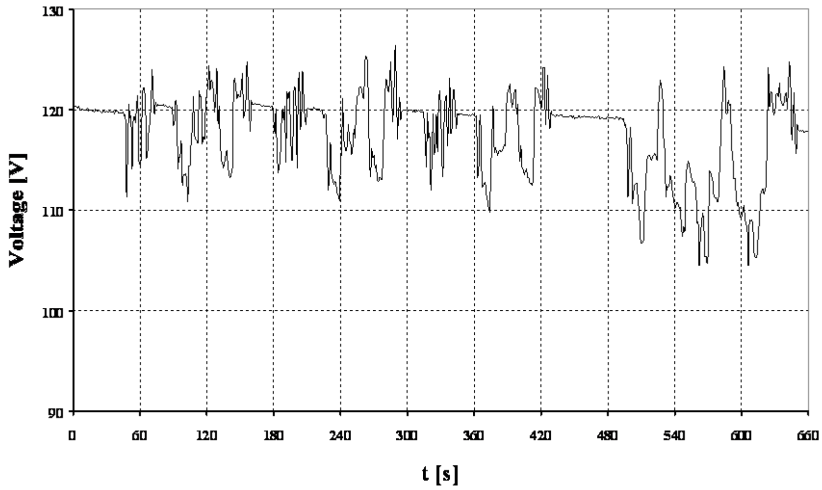


Figure i.2 Vehicle battery voltage

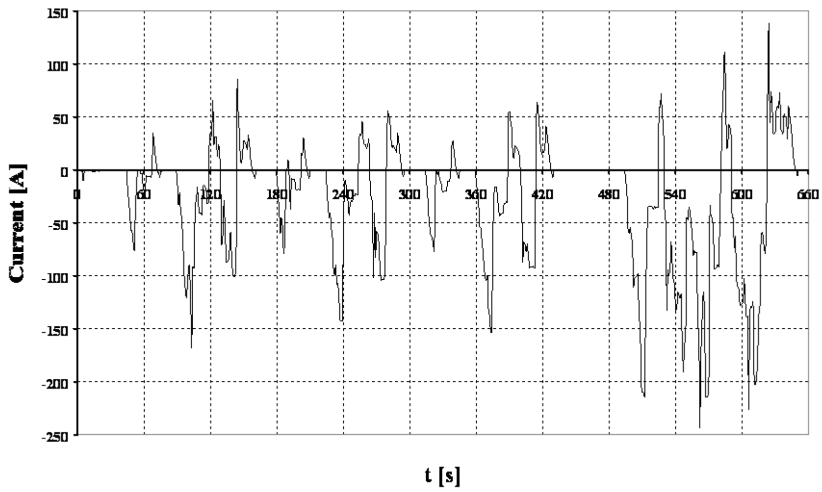


Figure i.3 Vehicle battery current; battery out

Appendix vii Nomenclature

a	acceleration	m/s²
t_{TOTAL}	Total cycle time	s
U_A	Average voltage	V
I	Current	A
E_G	Energy from the grid	kWh
$E_{B,C}$	Energy stored in the vehicle batteries, during charging	kWh
$E_{B,DC}$	Energy from the vehicle batteries, during cycle driving	kWh
$E_{I,C}$	Energy stored in the vehicle batteries in AmpereHoures, during charging	Ah
S_{DC}	Distance covered, during cycle drive	km
E_I	Energy from the vehicle batteries in AmpereHoures, during cycle driving	Ah
EC_G	Energy Consumption, relative to the Grid	kWh/km
R_E	Energy Consumption Ratio, EC relative to NEDC	-
EC_B	Energy Consumption, relative to the vehicle batteries	kWh/km
$EC_{B,I}$	Energy Consumption in AmpereHoures, relative to the vehicle batteries	Ah/10km
f_T	Failure time	%
η	Charger efficiency	-