955187

PHASE I OF THE NEAR TERM
HYBRID PASSENGER VEHICLE DEVELOPMENT
PROGRAM

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FINAL REPORT

APPENDIX B: TRADE-OFF STUDIES

Volume II: Appendices

Prepared for
JET PROPULSION LABORATORY
by
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The research described in this publication represents the second of the several Tasks of the "Phase I of the Near Term Hybrid Passenger Vehicle Development Program" being carried-on Centro Ricerche FIAT (CRF) on Contract No. 955187 from the Jet Propulsion Laboratory, California Institute of Technology.

Turin, June 15, 1979

This Report, prepared by:

M. Traversi and R. Piccolo of CRF

has been issued in conformance to the following specifications:

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Exhibit No. II, Dec. 1, 77

Contract Documentation – Phase 1

Data Requirement Description No. 2

LIST OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDIX A.3-1 – "SPEC 78" Computer Simulation Model

The mathematic model in the object (SPEC '78) was implemented in 1978 to provide a powerful design tool for the evaluation of performance consumption and emissions of any type of vehicle using any combination of components in the propulsion system.

The model can now simulate the most common propulsion systems but was designed in such a way that the simulation of any new propulsion system can be easily added to the basic program.

The program consists of mathematic simulations of any vehicle component and external environment effects: internal combustion engine, transmission, automatic transmission, differential, rear-axle ratio, electric motors and controls, batteries performances, aerodynamic drag, rolling resistance etc. An appropriate code is used to identify any specific propulsion system consisting of a given configuration made of specific components. A second identification code is used to label the system control logic.

The model, on the basis of input design parameters, calculates the vehicle performance parameters on a time base related to given initial operating condition.

The time base is made of a sequence of discrete time steps cycle points of the simulated mission which can be varied from 1 ms to 1 s.

The traveled distance is then obtained as the integral of the speed vs/ time function.

The program input data consists of vehicle code, propulsion system code and mission parameters. The program output data consists of performance, consumptions and emissions achieved in the mission. The program is also able to show the efficiency breakdown at component level.

The values of any variables under evaluation, if required, can also be given at intervals not longer than 1 second.

The mathematic simulation used by CRF was validated by other calculation methods and experimental data for conventional propulsion, hybrid (1) and electric vehicles.

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(1) See Ref. [1], Subsection 1.2, Vol. I.

SPEC 78 - Program Index Table

1 Heading
2 Configuration block diagram
3 Main vehicle parameters
4 Lead-Acid batteries map
5 Overall batteries data
6 Electric motor maximum power characteristics
7 Paramaters for electric motor simulation
8 Current maximum values
9 Magnetization curves map
10 Parameters for the internal combustion engine simulation
11 Power and torque force characteristics of the internal combustion engine
12 Rear-axle ratio
13 Minimum values for emissions in different measurement units
14 Internal combustion engine consumptions and emissions map
15 Torque converter characteristics
16 Continuously variable ratio transmission efficency map
17 Continuously variable ratio transmission setting data
18 Internal combustion engine utilization diagram
19 Maximum CVRT input power and torque
20 ICE and electric motor reduction gear velocity ratio
21 Table of Vehicle performance
22 Table of Consumptions on the selected run
23 Table of Emissions during a cycle
24 Table of Total energy necessary in one cycle
25 Table of Electric energy
26 Vehicle acceleration capability instantaneous data
27 Instantaneous data for single cycle consumptions
28 Instantaneous data for single cycle emissions.

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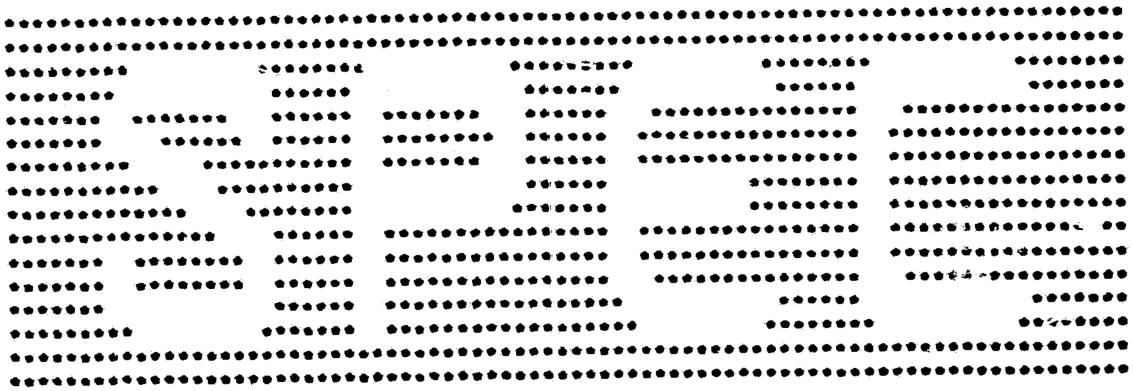

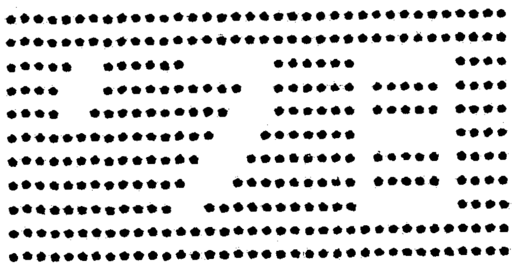

S I M U L A Z I O N E

P R E S T A Z I O N I

E M I S S I O N I

C O N S U M I

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*****************************************************************

              *** DEFINED  CONFIGURATION ***

*****************************************************************


                                                           WHEEL
                                                             I
                                                             I
                                                             I
                                                             I
  I.C.E.----CVRT+CONV.----CLUTCH------RATIO------------------I
                                        I                    I
                                        I                    I
                                        I                    I
                                        I                    I
       -BATT.------EL.MOT.-----CLUTCH                      WHEEL


*****************************************************************

                    ***CODE =33101***

*****************************************************************


VETTURA JPL 'GAMMA IBRIDA'

*****************************************************************
```

DATI DEL VEICOLO

PESO TOTALE	1710.000	(KG)
PESO ANTERIORE	.902	(T)
PESO POSTERIORE	.808	(T)
AREA FRONTALE	2.200	(M**2)
COEFFICIENTE DI RESISTENZA AERODINAMICA	.300	
PRESSIONE DI GONFIAGGIO ANT	2.200	(KG/CM*CM)
" " " POST	2.000	(KG/CM*CM)
COEFFICIENTE DI MAGGIOR.RESIST.ROTOL.*ANT*	.450	
" " " " " *POST*	.450	
RAGGIO DI ROTOLAMENTO	.381	(M)
MOMENTO DI INERZIA DI MASSA DELLE RUOTE	.240	(K*M*S*S)
COEFFICIENTE DI ATTRITO	.030	
ALTEZZA DEL BARICENTRO	.572	(M)
PASSO DEL VEICOLO	2.710	(M)
CODICE DI TRAZIONE	1	

PIANO QUOTATO BATTERIE

AL PIOMBO

STATO DI CARICA = 100.00(%)

CORRENTE	TENSIONE
.000000	147.840000
25.000000	145.440001
50.000000	143.040001
75.000000	140.639999
100.000000	138.719999
125.000000	136.799999
150.000000	134.879999
175.000000	132.959999
225.000000	128.639999
250.000000	126.000000

STATO DI CARICA = 83.30(%)

CORRENTE	TENSIONE
.000000	146.400000
25.000000	144.000000
50.000000	141.840000
75.000000	139.559999
100.000000	137.280001
125.000000	134.879999
150.000000	132.480000
175.000000	130.080000
225.000000	124.320000
250.000000	121.440000

STATO DI CARICA = 66.60(%)

CORRENTE	TENSIONE
.000000	145.440001
25.000000	143.040001
50.000000	140.160000
75.000000	137.760000
100.000000	134.879999

```
RENDIMENTO AGGIUNTIVO DI SCARICA.......... =      1.00

RENDIMENTO AGGIUNTIVO DI RICARICA......... =      1.00


CAPACITA' NOMINALE DELLA BATTERIA.......... =   -180.00   (AH)

VALORE INIZIALE      *      *   ........ =   -180.00   (AH)
```

DATI MOTORE ELETTRICO

CODICE TIPO MOTORE.. = 1

NUMERO PUNTI DELLA CURVA DI POTENZA MAX.............................. = 15

GIRI MOTORE(G/M)	POTENZA MAX(CV)
.000	.000
250.000	7.820
500.000	15.000
750.000	23.900
1000.000	31.960
1250.000	34.600
1500.000	34.500
2000.000	34.500
2500.000	34.000
3000.000	32.600
3500.000	28.800
4000.000	25.160
4500.000	21.760
5000.000	19.720
5500.000	17.600

DATI COSTRUTTIVI

NUMERO COPPIE POLARI	2
NUMERO CAVE DI ROTORE	55
COSTANTE DI MACCHINA	3.6570
RESISTENZA DI MACCHINA (OHM)	.0209
CADUTA DI TENSIONE SPAZZOLE SU COLLETTORE (V)	2.6000
NUMERO SPIRE ECCITAZIONE SERIE	2.5000
RESISTENZA TOTALE ECCITAZIONE DERIVATA (OHM)	35.9000
NUMERO SPIRE ECCITAZIONE DERIVATA DI UN POLO	365.0000
SEZ. DENTI ROT. SOTTO IL POLO PR. (M**2)	.0172
SEZIONE GIOGO ROTORE (M**2)	.0053
PESO DENTI ROTORE (KG)	16.7200
PESO GIOGO ROTORE (KG)	14.5800
SIGMA I PERDITE NEL FERRO	1.2000
SIGMA P PERDITE NEL FERRO	19.6000
FATTORE PERDITE PER ISTERESI	1.0500
FATTORE PERDITE PER CORRENTI PARASSITE	1.1000
COEFFICIENTE MAGGIORATIVO PER FORMA ONDA	2.0000
SPESSORE LAMIERINO PACCO INDOTTO (MM)	.3500
RAGGIO COLLETTORE (M)	.0560
RAGGIO ROTORE (M)	.0875
POTENZA NOMINALE (W)	20000.0000
COEFF. PERDITE ATTRITO SPAZZOLE (W/(M/SEC))	15.4000
SEZIONE DI UNA ESPANSIONE POLARE (M**2)	.0169
FATTORE BETA PERDITE SUPERF. DEI POLI	.3000
FATTORE DI CARTER	1.4000
COEFFIC. PERDITE SUPERF. DEI POLI	2.0000
PASSO TRA LE CAVE (M)	.0100
RESISTENZA DI INDOTTO (OHM)	.0172
GRADO MINIMO	.0000
TENSIONE NOMINALE (V)	144.0000
CADUTA DI TENSIONE SU CHOPPER (V)	2.0000
GRADO MAX	1.0000

LIMITI DI CORRENTE E COPPIA

CORRENTE MAX IN TRAZIONE (A)	250.0000
CORRENTE MAX IN FRENATURA (A)	-150.0000
TENSIONE DI ECCITAZIONE(V)	144.0000
COPPIA ALLO SPUNTO (KGM)	23.0000
MOMENTO DI INERZIA (K*M*S*S)	.0140
GIRI MINIMI IN FRENATURA (G/M)	500.0000
GIRI LIMITE PER LA REGOLAZIONE DELL'EVENTUALE CAMBIO CONTINUO IN FRENATURA	2500.0000

ORIGINAL PAGE IS
OF POOR QUALITY

CURVE DI MAGNETIZZAZIONE

CORRENTE = .00(A)

AMPERSPIRE	FLUSSO
.0	.002000
200.0	.003400
300.0	.005300
400.0	.007400
500.0	.009200
600.0	.010800
700.0	.012000
800.0	.012600
1000.0	.014200
1200.0	.015000
1400.0	.015600
1600.0	.016000
1800.0	.016300
2000.0	.016500
2500.0	.016900
3000.0	.017100
3500.0	.017200
4000.0	.017300
4500.0	.017400

CORRENTE = 50.00(A)

AMPERSPIRE	FLUSSO
.0	.000000
200.0	.003400
300.0	.005300
400.0	.007400
500.0	.009200
600.0	.010800
700.0	.012000
800.0	.012600
1000.0	.014200
1200.0	.015000
1400.0	.015600
1600.0	.016000
1800.0	.016300
2000.0	.016500
2500.0	.016900

ALTRI DATI RELATIVI AL MOTORE TERMICO

GIRI MINIMI....................................	=	800.0000	(G/M)
CONSUMO MINIMO..................................	=	.1700	(GR/S)
SOGLIA..	=	7000.0000	
CILINDRATA......................................	=	1.0000	(LITRI)
PESO SPECIFICO COMBUSTIBILE.....................	=	.7400	(KG/LITRO)
MOMENTO DI INERZIA..............................	=	.0054	(KG*M*S*S)

DATI DI POTENZA E COPPIA

NUMERO PUNTI DELLE CURVE.. = 10

GIRI(G/M)	COPPIA(KG*M)	POTENZA(CV)
1000.0000	6.80	9.50
1500.0000	6.17	12.91
2000.0000	6.45	18.00
2500.0000	7.08	24.72
3000.0000	7.35	30.80
3500.0000	7.50	36.63
4000.0000	7.56	42.36
4500.0000	7.48	47.00
5000.0000	7.03	49.10
5500.0000	6.46	49.62

COPPIA ALLO SPUNTO.................................... = 10.50 KG*M

DATI DIFFERENZIALE

```
RAPPORTO DEL PONTE.................... =        5.8000

RENDIMENTO .  .  ..................... =         .9500
```

VALORI MINIMI DELLE EMISSIONI

CO MINIMO	=	37168.672	PPM
HC MINIMO	=	9268.718	PPM
NOX MINIMO	=	17.288	PPM
RAPPORTO ARIA BENZINA	=	13.858	
RAPPORTO H/C	=	1.658	
PORTATA ARIA+BENZINA	=	8.632	KG/H

VALORI MINIMI DELLE EMISSIONI

CO MINIMO	=	317.468	G/H
HC MINIMO	=	39.223	G/H
NOX MINIMO	=	.248	G/H
RAPPORTO H/C	=	1.858	

*** TAPELLE ***

GIRI RPM	POTENZA CV	CONSUMO (KG/H)	CO PPM	HC PPM	NOX PPM
1000.00	9.50	2.05	59558.15	1905.06	209.96
1000.00	8.90	1.58	2559.64	1151.04	1048.24
1000.00	7.00	1.40	2948.22	1061.36	1513.87
1000.00	6.00	1.23	3390.56	1017.17	1221.33
1000.00	4.00	.95	6117.43	1101.14	536.41
1000.00	3.00	.83	9303.61	1116.43	342.49
1000.00	1.50	.66	34549.74	1013.06	28.30
1000.00	.00	.61	37288.11	1937.60	17.16

GIRI RPM	POTENZA CV	CONSUMO (KG/H)	CO PPM	HC PPM	NOX PPM
1500.00	12.91	3.10	64601.34	1965.41	214.97
1500.00	11.88	2.39	2804.50	1184.27	1996.49
1500.00	9.75	2.07	3156.78	1131.18	159.04
1500.00	8.45	1.89	3764.06	1313.04	1435.15
1500.00	5.93	1.54	6535.83	1699.31	768.68
1500.00	4.35	1.29	11458.17	1770.81	386.25
1500.00	2.15	1.64	35430.23	1170.16	64.78
1500.00	.00	1.00	34360.75	2142.59	34.96

GIRI RPM	POTENZA CV	CONSUMO (KG/H)	CO PPM	HC PPM	NOX PPM
2000.00	18.00	4.41	72338.79	2046.06	153.05
2000.00	16.71	3.24	3498.33	1338.11	1815.65
2000.00	14.00	2.88	6200.13	1178.90	1478.19
2000.00	11.04	2.46	5940.42	1009.00	1164.71
2000.00	8.62	2.12	7324.47	994.04	832.75
2000.00	6.26	1.76	9061.04	1254.61	538.71
2000.00	3.55	1.40	19258.59	1502.69	211.36
2000.00	.00	1.20	18897.44	1478.93	146.43

GIRI RPM	POTENZA CV	CONSUMO (KG/H)	CO PPM	HC PPM	NOX PPM
2500.00	24.72	5.57	62112.77	1798.44	389.27
2500.00	22.50	4.18	4025.01	1260.25	2032.53
2500.00	18.83	3.64	3673.88	1102.16	1832.08
2500.00	15.15	3.15	6107.41	1046.98	1523.99
2500.00	11.58	2.66	7497.23	993.02	1189.29
2500.00	8.36	2.21	9916.95	1252.67	774.75
2500.00	4.64	1.67	12238.24	1327.98	331.03
2500.00	.00	1.20	12390.08	1361.24	317.55

DATI CONVERTITORE DI COPPIA

PUNTI DELLA CARATTERISTICA DEL CONVERTITORE =..... 18

INDICE LOCK-UP = 1 CONVERTITORE CON LOCK-UP

SCORRIMENTI	CARATT.CONVERTITORE	RAPP. AMPLIFICATI DI COPPIA
.000	635.00	2.1400
.100	645.00	1.9700
.200	660.00	1.8400
.300	675.00	1.6750
.400	700.00	1.5550
.500	730.00	1.4300
.600	765.00	1.2800
.700	810.00	1.1300
.810	915.00	1.0000
.890	1135.00	.9850
.920	1230.00	.9850
.930	1330.00	.9850
.940	1510.00	.9850
.950	1860.00	.9850
.960	2450.00	.9850
.970	2950.00	.9850
.980	3500.00	.9850
.990	4000.00	.9850

VALORE SCORRIMENTO CORRISP. INS. LOK-UP........ .910

DATI CAMPIO CONTINUO

CURVE DELLE PERDITE

TAU = .4000

GIRI	PERDITE
.0	.0000
500.0	.1500
1000.0	.5000
2000.0	1.5500
3000.0	3.0000
4000.0	4.0000
5000.0	7.2500
5500.0	8.5000

TAU = 2.0000

GIRI	PERDITE
.0	.0000
500.0	.1500
1000.0	.5000
2000.0	1.5500
3000.0	3.0000
4000.0	4.8000
5000.0	7.2500
5500.0	8.5000

TAU = 4.0000

GIRI	PERDITE
.0	.0000
500.0	.1500
1000.0	.5000
2000.0	1.5500
3000.0	3.0000
4000.0	4.8000
5000.0	7.2500
5500.0	8.5000

```
RAPPORTO MAX.............................. =        2.[illegible]
RAPPORTO MIN.............................. =        .[illegible]


CAMPO DI REGOLAZIONE
DEL MOTORE TERMICO


GIRI MINIMI =      2[illegible].  (G/MIN)
GIRI MAX    =      2[illegible].  (G/MIN)
```

CURVA DI FUNZIONAMENTO

DEL MOTORE TERMICO

NUMERO DI PUNTI = 10

POTENZA(CV)	COPPIA(KGM)	GIRI(G/M)
5.25	4.45	1005.00
10.50	5.01	1500.00
15.30	5.49	2000.00
20.75	5.94	2500.00
26.52	6.33	3000.00
32.50	6.65	3500.00
38.25	6.85	4000.00
44.25	7.04	4500.00
49.12	7.03	5000.00
49.62	6.46	5500.00

CURVE DI COPPIA E POTENZA IN USCITA DAL CONVERTITORE

GIRI (G/MIN)	COPPIA (KGM)	POTENZA (CV)	RENDIMENTO	SCORRIMENTO
0.	10.50	.00	.000	[illegible]
77.	10.09	1.08	.111	.054
155.	9.66	2.10	.212	.108
235.	9.38	3.09	.306	.152
322.	9.05	4.04	.392	.216
405.	8.65	4.69	.466	.272
495.	8.30	5.74	.533	.324
591.	8.02	6.62	.556	.378
693.	7.74	7.49	.654	.432
830.	7.45	8.33	.703	.486
916.	7.12	9.10	.740	.542
1030.	6.76	9.79	.766	.594
1174.	6.41	10.50	.783	.648
1321.	6.05	11.16	.792	.702
1531.	5.85	12.51	.804	.756
1762.	5.64	13.66	.812	.810
2175.	5.64	17.14	1.000	1.000
2531.	5.21	21.76	1.020	1.002
3007.	6.33	26.58	1.008	1.000
3422.	6.56	31.54	1.006	1.002
3838.	6.78	36.35	1.030	1.008
4253.	6.05	41.26	1.020	1.000
4560.	7.04	45.69	1.008	1.000
5054.	5.94	49.24	1.000	1.002
5530.	6.46	49.62	1.000	1.003

DATI SOTTOSISTEMA • 2 •

RAPPORTO MOTORE ELETTRICO-TERMICO.......... = 1.0002

RENDIMENTO • • • .... = .9500

RISULTATI DELLE PRESTAZIONI

VELOCITA' MAX RAGGIUNTA.................................	=	137,1658	KM/H
RAPPORTO CAMBIO ALLA VMAX...............................	=	,0188	
GIRI MOTORE TERMICO ALLA VELOCITA' MAX..................	=	5499,9999	GIRI/MIN
PENDENZA MAX. SUPERABILE ALLO SPUNTO....................	=	36,2184	%
TEMPO NECESSARIO PER RAGGIUNGERE I 400 METRI............	=	21,8527	SEC
VELOCITA' RAGGIUNTA AI 400 METRI........................	=	101,4138	KM/H
TEMPO NECESSARIO PER RAGGIUNGERE I 1000 METRI...........	=	48,8838	SEC
VELOCITA' RAGGIUNTA AI 1000 METRI.......................	=	[illegible]	KM/H

LIMITI DI SLITTAMENTO

ACCELERAZIONE...	=	3,5417	M*S*S
PENDENZA..	=	36,1027	%

RISULTATI RIASSUNTIVI — PERCORSO SAE/A

SPAZIO PERCORSO	.2939	(KM)
TEMPO IMPIEGATO	0 ORE 1 MIN 12 SEC	
CONSUMO TOTALE DI CARBURANTE	18.0766	(GR)
" " " "	6.1559	(KG/100KM)
" " " "	8.3237	(LT/100KM)
" " " "	12.0139	(KM/L)
" " " "	25.2324	(MPG)
CONSUMO CON POTENZA POSITIVA	12.2966	(GR)
CONSUMO CON POTENZA NEGATIVA	1.5320	(GR)
CONSUMO IN SOSTA	4.25[illegible]	(GR)

EMISSION RESULTS

CO	=	6.6480	(GR)
CO	=	33.2512	(GR/ML)
HC	=	.4972	(GR)
HC	=	2.6758	(GR/ML)
NOX	=	.2237	(GR)
NOX	=	1.1166	(GR/ML)

IMPEGNO ENERGETICO

FASI CON POTENZA POSITIVA

ENERGIA TOTALE RICHIESTA ALLE RUOTE	12337.5394	(KGM)
ENERGIA TOTALE FORNITA DAL MOTORE TERMICO	13125.4967	(KGM)
ENERGIA RICHIESTA PER ACCELERARE IL VEICOLO	7237.3497	(KGM)
ENERGIA RICHIESTA PER ROTOLAMENTO	2371.5754	(KGM)
ENERGIA RICHIESTA PER RESISTENZA AERODINAMICA	698.2159	(KGM)

FASI CON POTENZA NEGATIVA

ENERGIA CINETICA DISPONIBILE	6991.9487	(KGM)
ENERGIA SPESA PER ROTOLAMENTO	377.5516	(KGM)
ENERGIA SPESA PER AERODINAMICA	66.4250	(KGM)
ENERGIA SPESA IN FRENATURA	6554.0914	(KGM)

ENERGIE ELETTRICHE

ENERGIA ELETTRICA UTILIZZATA	=	[illegible]	[illegible]
ENERGIA ELETTRICA SCARICATA	=	[illegible]	[illegible]
ENERGIA ELETTRICA FORNITA ALLE BATTERIE	=	[illegible]	[illegible]
ENERGIA ELETTRICA RICARICATA	=	[illegible]	[illegible]
LIVELLO DI CARICA DELLE BATTERIE (SEGNO-=CARICA)	=	[illegible]	(A*H)

V	T	SPAZIO	ACC	PEND	PAR	PRCT	PDISP	PES	CIPIA	TAUC
(KM/H)	(S)	(M)	(M/S/S)	(%)	(CV)	(CV)	(CV)	(CV)	(G/M)	
.62	.05	.00	3.1937	38.60	.00	.02	1.57	1.42	55.00	2.00
1.25	.11	.02	3.1517	38.02	.00	.04	3.10	2.81	110.00	2.00
1.87	.16	.04	3.1141	37.50	.00	.06	4.59	4.18	165.00	2.00
2.50	.22	.08	3.0776	37.00	.00	.08	6.06	5.49	220.00	2.00
3.12	.28	.12	3.0385	36.47	.00	.10	7.49	6.77	275.00	2.00
3.74	.33	.18	3.0011	35.96	.00	.12	8.89	8.03	330.00	2.00
4.37	.39	.24	2.9553	35.34	.00	.15	10.23	9.22	385.00	2.00
4.99	.45	.32	2.9147	34.80	.00	.17	11.55	10.39	440.00	2.00
5.62	.51	.41	2.8796	34.33	.00	.19	12.66	11.55	495.00	2.00
6.24	.57	.51	2.8492	33.92	.00	.21	14.16	12.78	550.00	2.00
6.87	.63	.62	2.8220	33.56	.00	.23	15.45	13.83	605.00	2.00
7.49	.69	.74	2.7937	33.19	.00	.25	16.71	14.94	660.00	2.00
8.11	.76	.88	2.7669	32.84	.01	.27	17.96	16.03	715.00	2.00
8.74	.82	1.02	2.7400	32.48	.01	.29	19.18	17.10	770.00	2.00
9.36	.88	1.18	2.7122	32.12	.01	.31	20.37	18.13	825.00	2.00
9.99	.95	1.36	2.6828	31.74	.01	.33	21.53	19.13	880.00	2.00
10.61	1.01	1.54	2.6542	31.36	.01	.36	22.67	20.11	935.00	2.00
11.23	1.08	1.74	2.6241	30.97	.02	.38	23.78	21.05	990.00	2.00
11.86	1.14	1.95	2.5970	30.62	.02	.40	24.88	21.99	1045.00	2.00
12.48	1.21	2.18	2.5701	30.28	.02	.42	25.96	22.91	1100.00	2.00
13.11	1.28	2.42	2.5455	29.96	.03	.44	27.[illegible]	23.82	1155.00	2.00
13.73	1.35	2.68	2.5206	29.64	.03	.46	28.09	24.72	1210.00	2.00
14.35	1.42	2.95	2.4965	29.34	.03	.48	29.13	25.59	1265.00	2.00
14.98	1.49	3.23	2.4743	29.05	.04	.50	30.17	26.47	1320.00	2.00
15.60	1.56	3.53	2.4625	28.90	.04	.53	31.31	27.44	1375.00	2.00

V	T	ACC	POT. AER.	POT. POT.	POT. RUOTE	POT. FLET.	GIRI FLET.	GIRI RUOTE	RAPP. CAMBIO	POT. TERM.	GIRI TERM.	CORRENTE BATTERIA	ENER. ELT.	CONSUMO IST.	PRESA CAMBIO	RENDIM POT.EL.
(M/S)	(S)	(M*S*S)	(CV)	(CV)	(CV)	(CV)	(G/MIN)	(G/MIN)		(CV)	(G/MIN)	(AMPERE)	(A*H)	(GR)	(CV)	
.23	1.	.47	.00	.03	.31	.00	59.	7.	2.00000	2.24	1000.	.00	-85.0002	.287	.01	.82
.70	2.	.47	.00	.08	.93	.00	179.	22.	2.00000	2.55	1000.	.00	-85.0000	.216	.04	.82
1.17	3.	.47	.00	.14	1.54	.00	297.	37.	2.00000	2.91	1001.	.00	-85.0000	.231	.09	.80
1.54	4.	.47	.00	.20	2.18	.00	416.	52.	2.00000	3.54	1098.	.00	-85.0000	.266	.16	.80
2.11	5.	.47	.01	.25	2.78	.00	534.	67.	2.00000	4.24	1107.	.00	-85.0000	.312	.25	.82
2.57	6.	.47	.01	.31	3.41	.00	653.	82.	2.00000	5.06	1302.	.00	-85.0000	.354	.35	.80
3.04	7.	.47	.02	.37	4.00	.00	772.	96.	2.00000	6.03	1408.	.00	-85.0000	.415	.47	.80
3.51	8.	.47	.02	.42	4.60	.00	892.	111.	1.80257	5.44	1005.	.02	-85.0000	.321	.50	.80
3.97	9.	.44	.03	.48	5.00	.00	1008.	125.	1.59475	5.77	1005.	.02	-85.0000	.342	.50	.80
4.43	10.	.47	.05	.54	5.92	.00	1124.	141.	1.51500	6.76	1065.	.00	-85.0000	.389	.56	.78
4.90	11.	.47	.07	.60	6.53	.00	1244.	156.	1.48113	7.51	1152.	.00	-85.0000	.422	.63	.82
5.37	12.	.47	.09	.66	7.17	.00	1364.	171.	1.45444	8.27	1240.	.00	-85.0000	.464	.72	.82
5.85	13.	.47	.11	.72	7.82	.00	1484.	186.	1.43333	9.04	1329.	.00	-85.0000	.550	.80	.80
6.32	14.	.47	.14	.78	8.47	.00	1604.	200.	1.41657	9.81	1420.	.00	-85.0000	.579	.90	.80
6.79	15.	.47	.17	.84	9.13	.00	1724.	215.	1.40136	10.59	1510.	.00	-85.0006	.612	.99	.80
7.25	16.	.44	.21	.90	9.25	.00	1840.	230.	1.32579	10.74	1525.	.00	-85.0000	.619	1.00	.80
7.71	17.	.47	.25	.96	10.42	.00	1956.	245.	1.36484	12.12	1669.	.00	-85.0000	.781	1.16	.82
8.18	18.	.47	.30	1.02	11.09	.00	2078.	260.	1.35109	12.93	1753.	.02	-85.0000	.828	1.26	.80
8.65	19.	.47	.36	1.09	11.77	.00	2196.	275.	1.34117	13.77	1841.	.00	-85.0200	.832	1.38	.82
8.89	20.	.00	.39	1.12	1.50	.00	2255.	282.	.71182	2.09	1804.	.00	-85.0000	.283	.50	.80
8.89	21.	.00	.39	1.12	1.50	.00	2255.	282.	.71182	2.09	1804.	.02	-85.0000	.283	.50	.80
8.89	22.	.00	.39	1.12	1.50	.00	2256.	282.	.71182	2.09	1804.	.02	-85.0000	.283	.50	.80
8.89	23.	.00	.39	1.12	1.50	.00	2256.	282.	.71182	2.09	1804.	.00	-85.0000	.283	.50	.82
8.89	24.	.00	.39	1.12	1.50	.00	2256.	282.	.71182	2.09	1804.	.00	-85.0000	.283	.50	.80
8.89	25.	.00	.39	1.12	1.50	.00	2256.	282.	.71182	2.09	1804.	.00	-85.0000	.283	.50	.80
8.89	26.	.00	.39	1.12	1.50	.00	2256.	282.	.71182	2.09	1804.	.00	-85.0000	.283	.50	.80
8.89	27.	.00	.39	1.12	1.50	.00	2256.	282.	.71182	2.09	1804.	.02	-85.0200	.283	.50	.80
8.89	28.	.00	.39	1.12	1.50	.00	2256.	282.	.71182	2.09	1804.	.00	-85.0000	.283	.50	.83
8.89	29.	.00	.39	1.12	1.50	.00	2256.	282.	.71182	2.09	1804.	.00	-85.0000	.283	.50	.80
8.89	30.	.00	.39	1.12	1.50	.00	2256.	282.	.71182	2.09	1804.	.00	-85.0000	.283	.50	.80
8.89	31.	.00	.39	1.12	1.50	.00	2256.	282.	.71182	2.09	1804.	.00	-85.0000	.283	.50	.82
8.89	32.	.00	.39	1.12	1.50	.00	2256.	282.	.71182	2.09	1804.	.00	-85.0000	.283	.50	.80
8.89	33.	.00	.39	1.12	1.50	.00	2256.	282.	.71182	2.09	1804.	.00	-85.0000	.283	.50	.80
8.89	34.	.00	.39	1.12	1.50	.00	2256.	282.	.71182	2.09	1804.	.00	-85.0000	.283	.50	.80
8.89	35.	.00	.39	1.12	1.50	.00	2256.	282.	.71182	2.09	1804.	.00	-85.0000	.283	.50	.80
8.89	36.	.00	.39	1.12	1.50	.00	2256.	282.	.71182	2.09	1804.	.00	-85.0000	.283	.50	.80
8.89	37.	.00	.39	1.12	1.50	.00	2256.	282.	.71182	2.09	1804.	.00	-85.0000	.283	.50	.80
8.89	38.	.00	.39	1.12	1.50	.00	2256.	282.	.71182	2.09	1804.	.00	-85.0000	.283	.50	.80
8.40	39.	-.97	.33	1.05	-17.89	-16.15	2133.	267.	.50000	.00********		-56.19	-85.0156	.178**********		.81
7.42	40.	-1.00	.23	.92	-16.35	-14.75	1882.	235.	.50000	.00********		-50.83	-85.0297	.178**********		.80
6.43	41.	-.97	.15	.79	-13.81	-12.46	1632.	204.	.50000	.00********		-42.54	-85.0415	.178**********		.80
5.46	42.	-.97	.09	.67	-11.76	-10.62	1385.	173.	.50000	.00********		-35.04	-85.0513	.178**********		.78
4.47	43.	-1.00	.05	.54	-9.96	-8.99	1135.	142.	.50000	.00********		-28.33	-85.0591	.178**********		.75
3.49	44.	-.97	.02	.42	-7.55	-6.81	885.	111.	.50000	.00********		-19.50	-85.0646	.178**********		.70
2.50	45.	-1.00	.01	.30	-5.59	-5.04	635.	79.	.50000	.00********		-12.12	-85.0679	.178**********		.63
1.51	46.	-.99	.00	.18	-3.32	-3.00	382.	48.	.50000	.00********		.00	-85.0679	.178**********		.82
.51	47.	-1.01	.00	.06	-1.15	-1.04	129.	16.	.50000	.00********		.00	-85.0679	.178**********		.82

TEMPO (S)	HC (GR)	CO (GR)	NOX (GR)	RAPPORTO ARIA BENZINA	CONSUMO (GR)
1.	.00206	.06248	.00097	12.798682	.207
2.	.00191	.04917	.00125	12.472960	.216
3.	.00187	.03257	.00173	11.996000	.231
4.	.00217	.04757	.00321	14.016060	.266
5.	.00229	.06917	.00490	12.644747	.312
6.	.00364	.04041	.00604	13.279919	.354
7.	.00477	.03615	.00881	13.940025	.415
8.	.00228	.01846	.00760	12.047640	.321
9.	.00228	.01535	.00908	12.142300	.342
10.	.00291	.01704	.01177	12.118806	.399
11.	.00376	.02268	.01392	12.923013	.422
12.	.00430	.02416	.01700	13.604164	.464
13.	.00556	.17159	.00986	12.877009	.550
14.	.00532	.10409	.00361	14.057047	.579
15.	.00528	.02952	.01440	14.991522	.612
16.	.00531	.03077	.01731	14.969393	.619
17.	.00786	.67991	.01421	12.768336	.781
18.	.00847	.38942	.01462	12.740025	.820
19.	.00838	.29207	.02203	13.398144	.832
20.	.00213	.06832	.00084	12.913120	.203
21.	.00213	.06832	.00084	12.913120	.203
22.	.00213	.06832	.00084	12.913120	.203
23.	.00213	.06832	.00084	12.913120	.203
24.	.00213	.06832	.00084	12.913120	.203
25.	.00213	.06832	.00084	12.913120	.203
26.	.00213	.06832	.00084	12.913120	.203
27.	.00213	.06832	.00084	12.913120	.203
28.	.00213	.06832	.00084	12.913120	.203
29.	.00213	.06832	.00084	12.913120	.203
30.	.00213	.06832	.00084	12.913120	.203
31.	.00213	.06832	.00084	12.913120	.203
32.	.00213	.06832	.00084	12.913120	.203
33.	.00213	.06832	.00084	12.913120	.203
34.	.00213	.06832	.00084	12.913120	.203
35.	.00213	.06832	.00084	12.913120	.203
36.	.00213	.06832	.00084	12.913120	.203
37.	.00213	.06832	.00084	12.913120	.203
38.	.00213	.06832	.00084	12.913120	.203
39.	.01090	.08818	.00007	13.050000	.170
40.	.01090	.08818	.00007	13.050000	.170
41.	.01090	.08818	.00007	13.050000	.170
42.	.01090	.08818	.00007	13.050000	.170
43.	.01090	.08818	.00007	13.050000	.170
44.	.01090	.08818	.00007	13.050000	.170
45.	.01090	.08818	.00007	13.050000	.170
46.	.01090	.08818	.00007	13.050000	.170
47.	.01090	.08818	.00007	13.050000	.170

APPENDIX A.3-2 – Propulsion System Alternatives

This Appendix provides a description of the Configuration alternatives as presented in our Proposal with the exclusion of the series configuration not even taken into consideration during the Trade-off Studies because of its less fuel-efficient operation.

In all parallel configurations the engine power is applied directly to the drive wheels and the power handled by the reversible electric machine (electric motor-generator) can be added or subtracted as appropriate.

The interconnection between the two machines can be accomplished using various mechanical configurations which have the function of uncoupling or altering the speed ratios with respect to one another and relative to the wheels and can always be represented in the block diagram shown on Figure A.3-2.1, as Subsystems No. 1, 2 and 3.

The simplest layout is shown on Figure A.3-2.2; Subsystem No. 1 merely consists of a clutch, Subsystem No. 2 includes a reduction gear unit between motor and engine, while Subsystem No. 3 is not required.

An improvement of the previous system is shown in Figures A.3-2.3 and A.3-2.4 where a Continuously Variable Ratio Transmission (CVRT) is introduced in Subsystems No. 3 and No. 1 respectively.

Obviously, the introduction of a more complex mechanical component such as the CVRT increases the vehicle cost but significantly improves system performance and efficiency.

The Trade-off Studies must therefore determine whether the cost increase is justified by a significant improvement.

The choice between the two configurations using a CVRT is not significantly tied to economic constraints as much as to the following technical considerations.

In the case of the CVRT placed immediately upstream of the rear axle (Configuration No. 2), all the power supplied to the wheels, which is the sum of thermal and electric power, is handled by the transmission under optimal conditions. The same applies to the braking energy which, thanks to the stepless transmission, may be recovered at rotational speeds corresponding to high motor efficiency. The CVRT, on the other hand, must be capable of handling a higher torque being this requirement associated with a more difficult coupling between the engine and the motor owing to fixed ratio

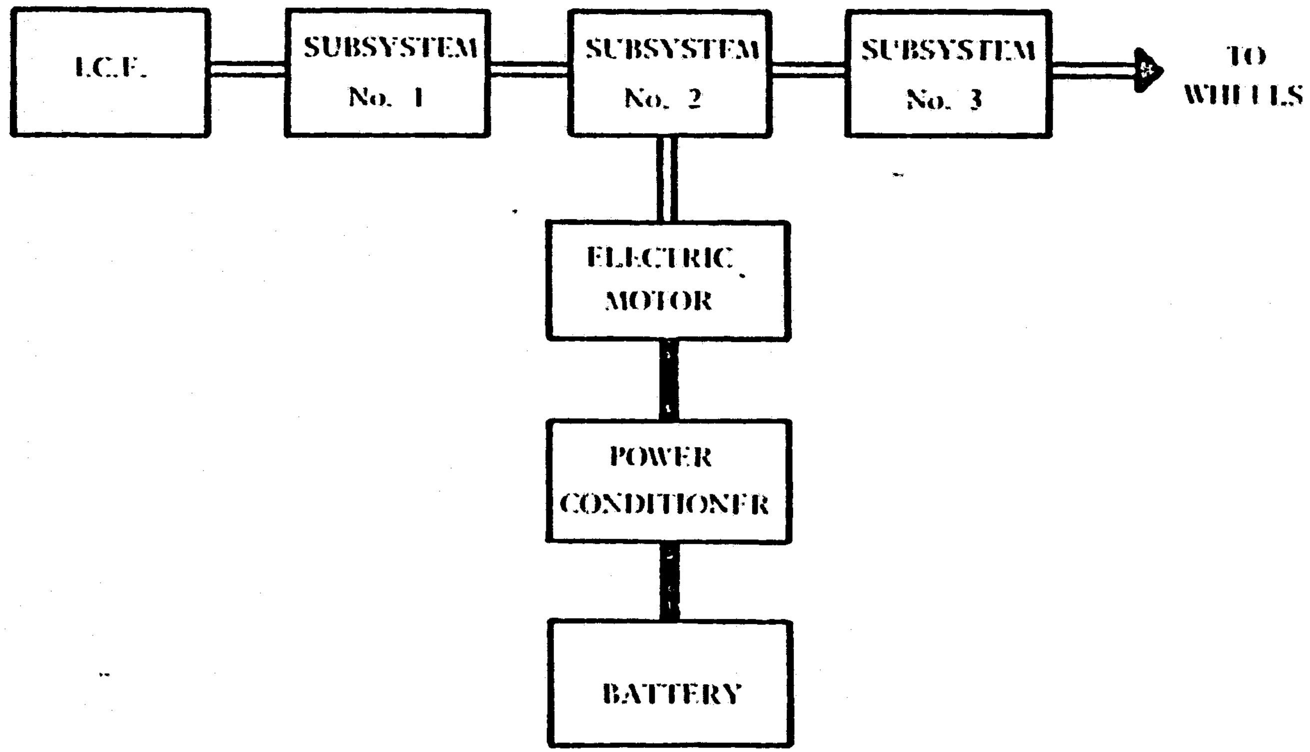

FIG. A.3-2.1 – HYBRID VEHICLE POWERTRAIN: PARALLEL CONFIGURATION

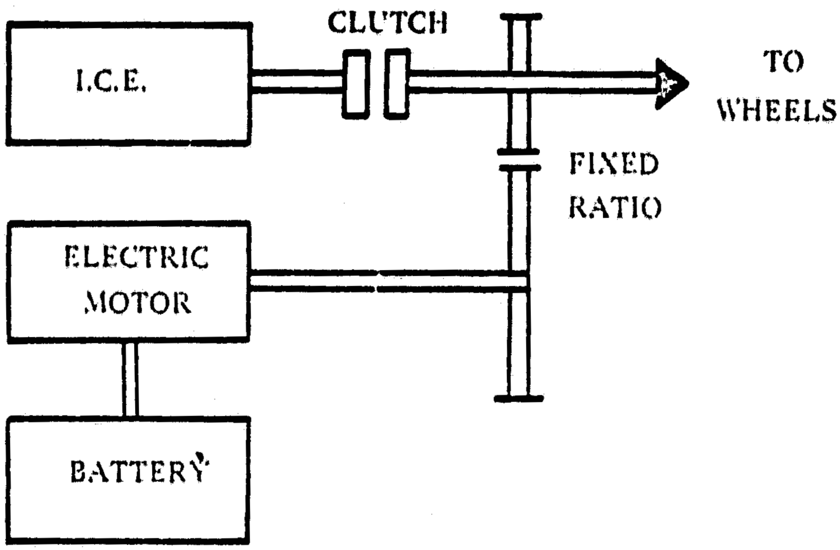

FIG. A.3-2.2 – HYBRID VEHICLE: PARALLEL CONFIGURATION No. 1

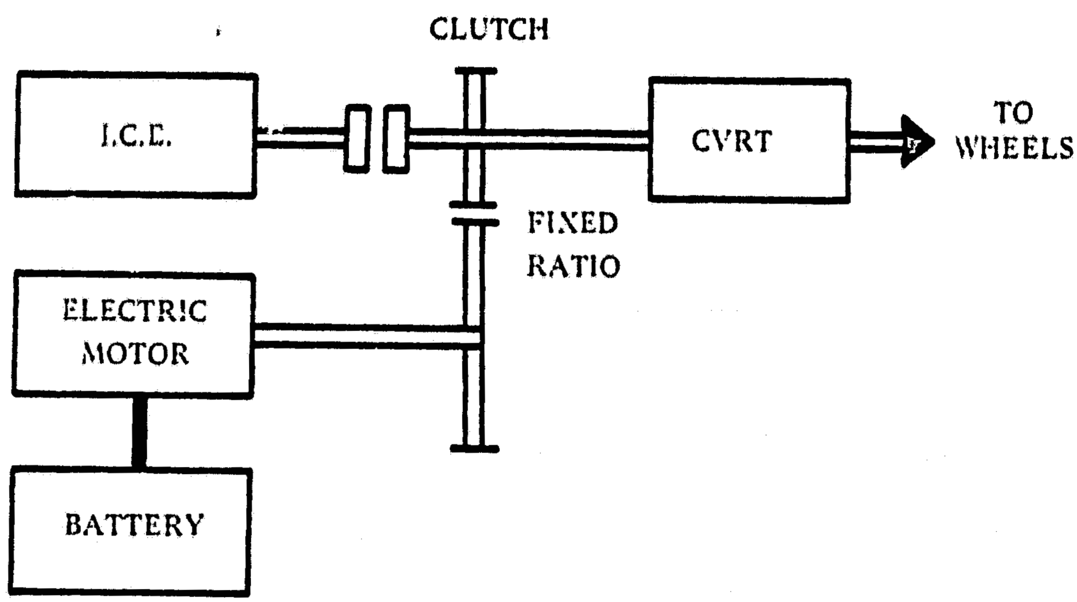

FIG. A.3-2.3 – HYBRID VEHICLE: PARALLEL CONFIGURATION No. 2

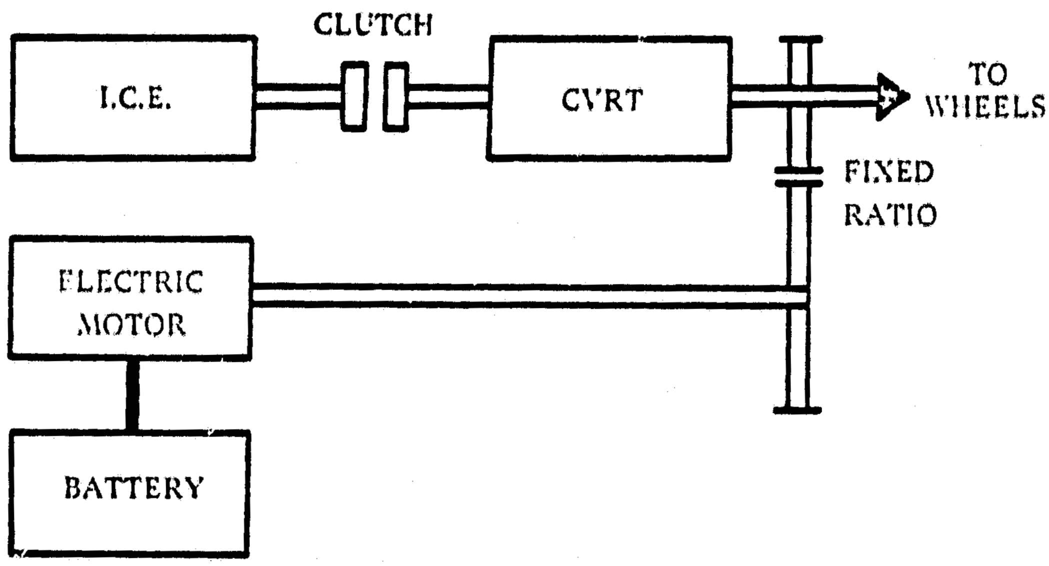

FIG. A.3-2.4 – HYBRID VEHICLE: PARALLEL CONFIGURATION No. 3

existing between the two.

In the case of Configuration No. 3, where the CVRT is placed on the engine output shaft upstream of the fixed ratio, less severe operating conditions and ratings are required for the CVRT while the coupling between the motor and the engine becomes much more flexible and provides therefore the possibility of a wider choice of components. In this case however only the engine power is delivered to the wheels in optimum conditions and the recovery of the braking energy is less efficient occurring at motor rotational speeds imposed by the wheel speed and by the selected fixed ratio.

A variant may be introduced on the three above configurations by introducing a clutch between the motor and the fixed ratio. For the sake of simplicity, since the same clutch could be used in any configuration, only the case where the clutch is introduced in Configuration No. 3 will be considered as shown on Figure A.3-2.5.

The function of this clutch is to isolate the motor from the drive train when only the engine thermal power is used or required so that the energy corresponding to the mechanical loading effect of the electric motor can be saved.

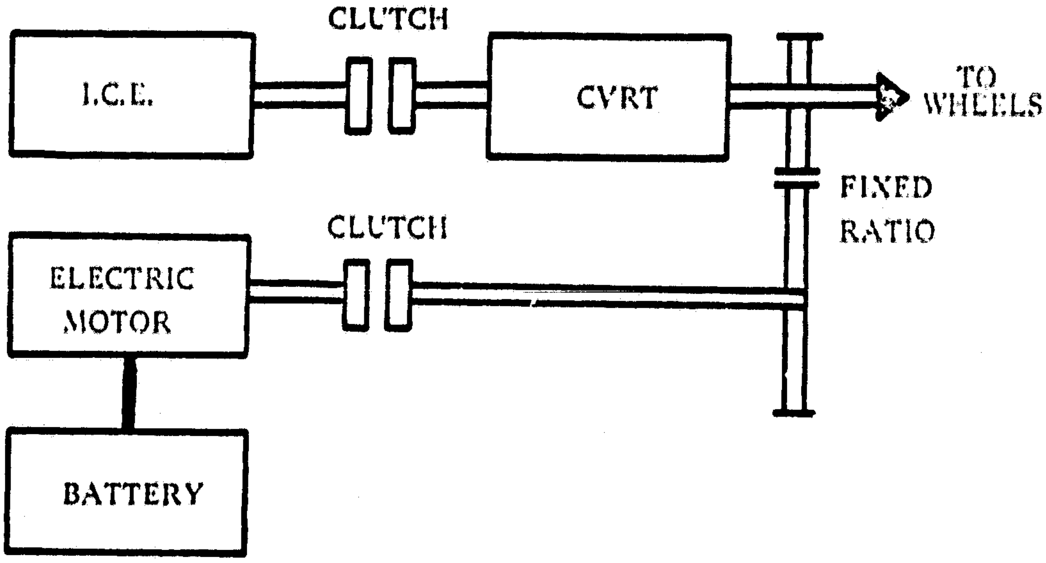

FIG. A.3-2.5 – HYBRID VEHICLE: PARALLEL CONFIGURATION No. 4

APPENDIX A.3-3 — Lead-Acid and Na-S Traction Batteries

The battery and the electric propulsion system of the H.V. will be analyzed in greater details during the preliminary design. This Appendix provides some preliminary assessments on the fundamental characteristics of the only two types of traction batteries that have been evaluated during the Trade-off Studies: Lead-Acid and Sodium-Sulphur. The Lead-Acid type is characterized by a low initial cost, is already available on the market and is susceptable of some technological improvements. The Sodium-Sulphur type offers much higher specific energy but, as a product, it is still under development and therefore, while susceptable of significant technological improvement, its product availability by 1985 has yet to be validated. The main characteristics of the selected batteries are shown in Table A.3-3.1: they can be assumed as representative of the foreseable performance range.

A.3-3.1 Lead-Acid Batteries

The maximum available power at a given time is function of the average discharge power and of the total energy supplied to the load as shown in Fig. A.3-3.1 Assuming vehicle operation in the electric mode only, the vehicle range capability can be calculated as follows. The battery average discharge power is given by

$$\overline{W} = \frac{q \cdot v}{M_b}$$

where:

q is the vehicle average energy consumption

v is the vehicle average speed

M_b is the battery weight

The selected maximum power allows to determine, for a given $\overline{W}$, the specific energy (E) supplied by the battery. The vehicle range is then calculated by means of

$$R = \frac{E \cdot M_b}{q}$$

TABLE A.3-3.1

TRACTION BATTERIES CHARACTERISTICS

PARAMETER	LEAD-ACID	SODIUM-SULPHUR
OPEN CIRCUIT VOLTAGE, V	144	144
DISCHARGING VOLTAGE, V	144-110	144-72
CAPACITY (5 h), Ah	100	315
MAX DISCHARGING CURRENT, A	250	450
RECHARGING CURRENT (4 h), A	25	78
CURRENT EFFICIENCY: Ah_{out}/Ah_{in}	> 0.9	1
POWER EFFICIENCY Wh_{out}/Wh_{in}	⩾ 0.7	Function of operating conditions
NUMBER OF ELEMENTS	12	432 (12 x 36)
SIZE, mm	775 x 830 x 300	794 x 976 x 400
WEIGHT, kg	300	300
OPERATING TEMPERATURE	ambient	300 - 350 °C
LIFE CYCLES	400 to 800	300 to 900
MAINTENANCE FREQUENCY, mounths	6	6
COST, $	1,000	3,000
COST OF MAINTENANCE, $/year	80	50

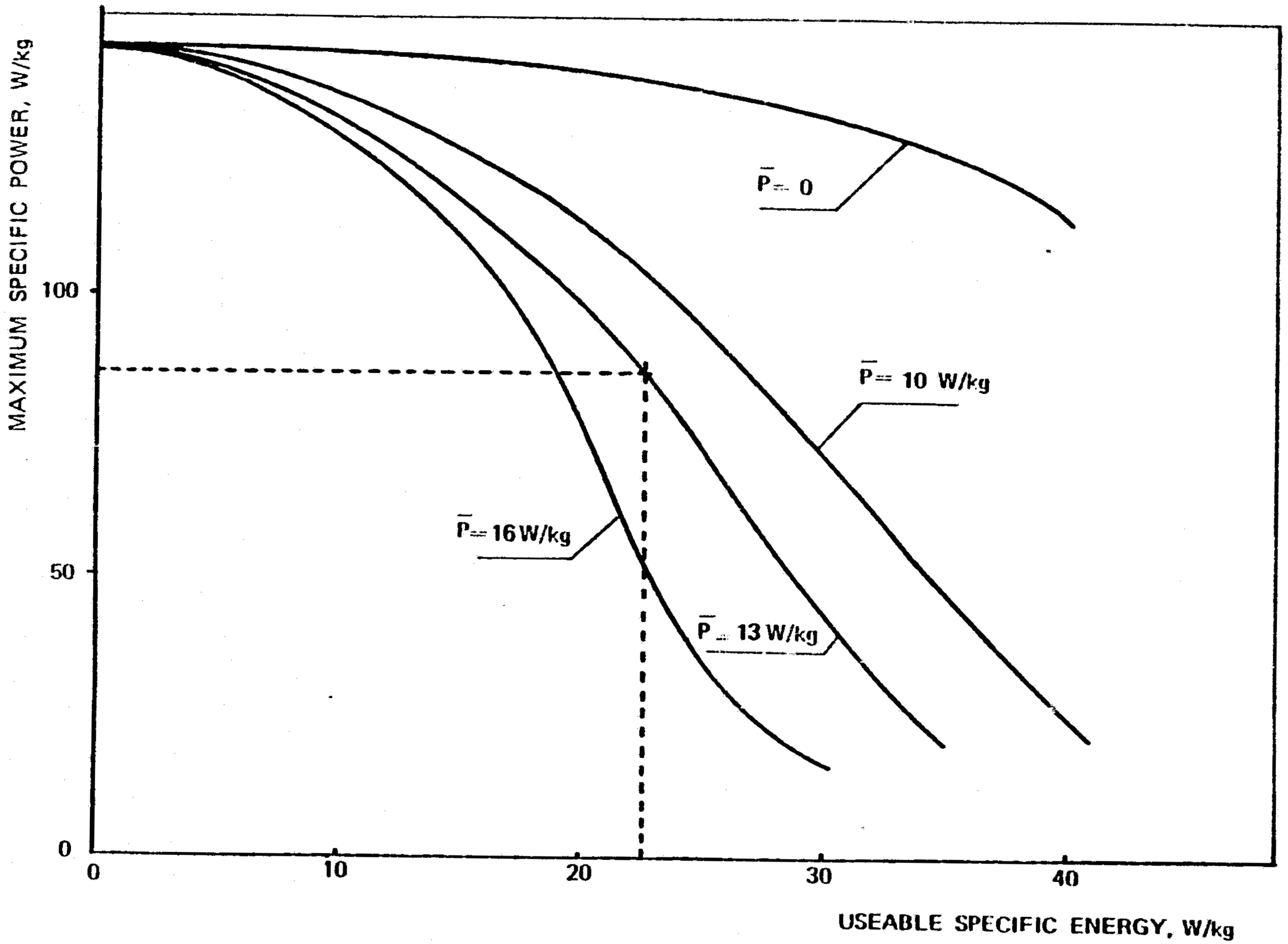

FIG. A.3-3.1 — MAXIMUM POWER VS USEABLE SPECIFIC ENERGY AS A FUNCTION OF AVERAGE POWER

Considering a 5 hour discharge time in a hybrid propulsion system, the maximum energy that can be drawn from the battery corresponds to 80% of the stored energy. For the 1985 Lead-Acid batteries the expected specific energy is about 40 Wh/Kg which, for a 300 Kg. battery, corresponds to a total energy availability of 12 KWh. However, at 80% discharge the available power is much lower than the power at full charge and therefore, to guarantee vehicle performance over the entire operating range, the maximum discharge must be limited to about 50% of the available Ah and the initial maximum power accordingly derated. The 1985 model batteries shall guarantee 400 discharge cycles but, if the specific energy is kept in the 33 - 36 Wh/Kg, a life-cycle above 800 can be expected.

On the other hand Lead-Acid batteries, at discharge levels below 80% have a rather small internal resistance and provide therefore reasonably high efficiency operation.

A.3-3.2 Sodium-Sulphur Batteries

The power that can be supplied to the load is a simple function of the discharge current (I):

$$W = (V_o - RI) \cdot I$$

The maximum power available is then:

$$W_{max} = \left(\frac{V_o}{2}\right)^2 \cdot \frac{1}{R}$$

The total energy available from the batteries can be calculated as a function of the instantaneous discharge current as follows:

$$E = \int (V_o - RI) \cdot I \cdot dt$$

and is therefore dependent on the vehicle speed vs/ time pattern. Considering a discharge at constant power the total available energy is given by:

$$E = C \cdot V = C \cdot (V_o - RI)$$

where C is the battery capacity given by $C = \int I \cdot dt$. The power and energy of the battery as a function of the discharge current are shown in Figures A.3-3.2 and A.3-3.3 Assuming a discharge depth of 80%, a life of 300 cycles is expected for Sodium-Sulphur batteries

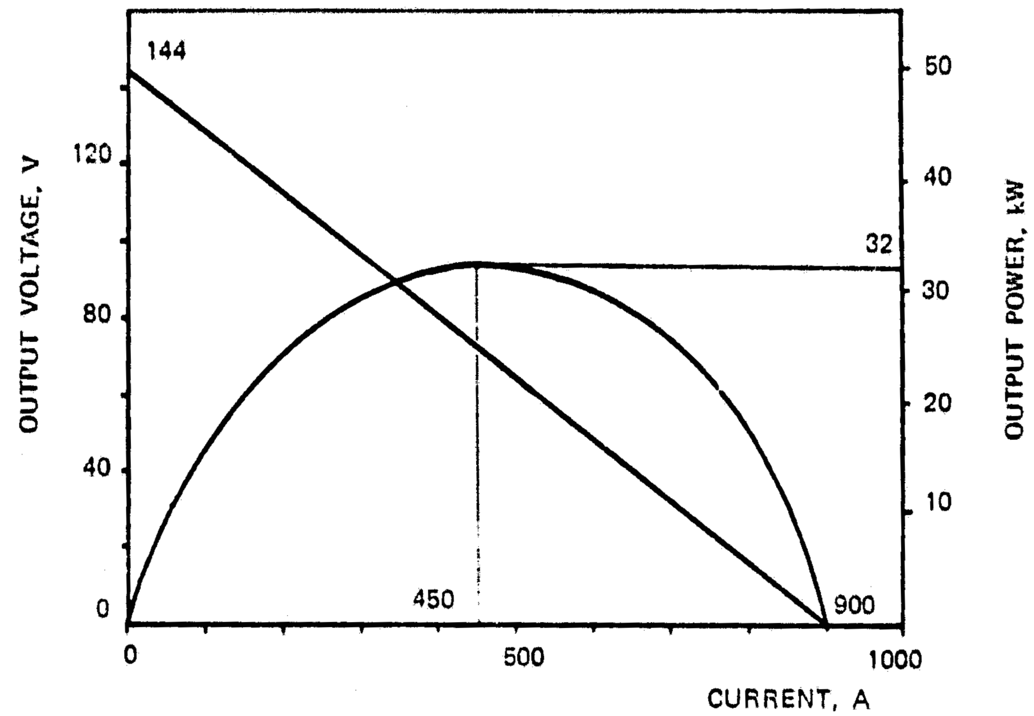

FIG. A.3-3.2 — POWER AND VOLTAGE AS A FUNCTION OF DISCHARGE CURRENT

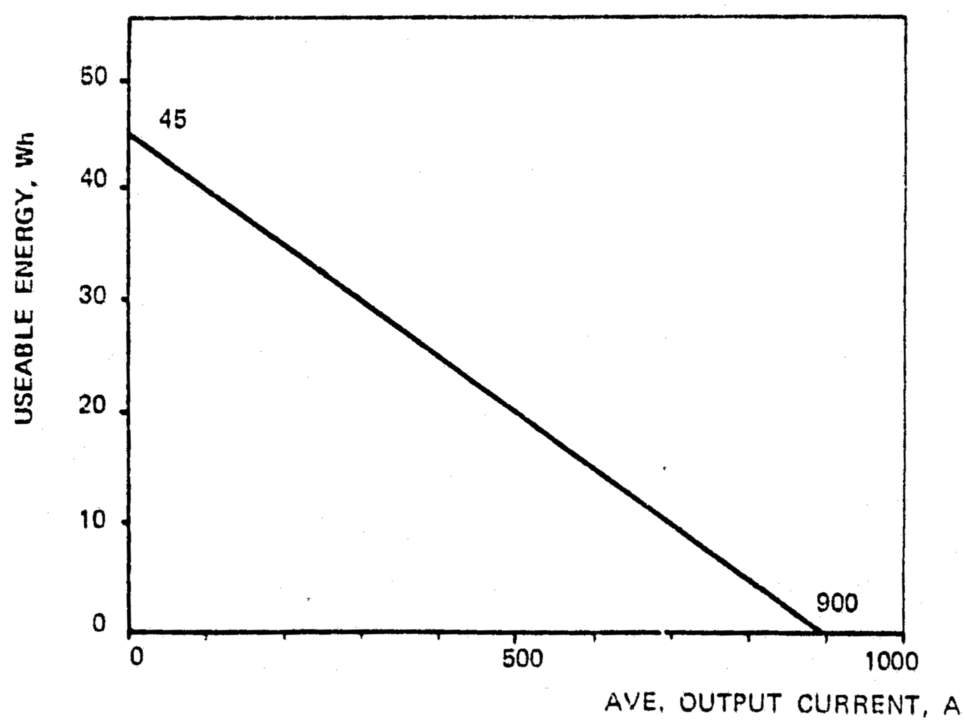

FIG. A.3-3.3 — ENERGY AS A FUNCTION OF DISCHARGE CURRENT presently produced is small series by the Brown Boveri Company. The technology is expected to improve significantly and a 600 cycle life is expected by 1985 which could reach 900 cycles by 1990.

The Sodium-Sulphur battery operates at a temperature between 300 and 350°C. If the temperature falls below the operating range, the β-allumina conductivity drops and all the reagents and reaction by-products solidify. For a 300 kg battery, 10 kWh per day are required to keep the battery at operational temperature, assuming that presently available insulation techniques are used. The battery heating energy is normally provided by the energy dissipated in the battery internal resistance during the charge/discharge cycles. In addition to the charge/discharge life, the Sodium-Sulphur battery also has a limited life in terms of cycles of thermal cooling below the normal operating range. The negative impact of thermal cooling on battery life is much more pronounced if cooling occurs at low charge levels because of damages induced to the ceramic component (β-allumina).

APPENDIX A.3-4 – FIAT Procedures and Regulation for mass production Cost estimates.

This Appendix provides a summary of the FIAT Procedures and Regulations as used by CRF to evaluate the production cost of a new vehicle which a mass production of above 1,000 - 1,500 units/day is planned for. This procedure could not be thoroughly used during the Trade-off Studies due to the limited design definition of the various vehicle components: the actual cost analysis was therefore based on the production cost of actual vehicle parts and components similiar to those itemized but not defined at the manufacturing level for the hybrid vehicle conceptual design to be further developed during the Preliminary Design task.

A.3-4-1 Vehicle Breakdown

As a first step all the vehicle parts and components are broken down into four main categories or "assemblies":

- Engine and Transmission
- Chassis
- Body Frame
- Electrical equipment.

For each assembly the vehicle breakdown is further developed throughout the "GROUPS" and "SUBGROUPS" level down to the "COMPONENT" level as shown on Figure 4.3-4.1.

A.3-4.2 Component Cost Analysis

The manufacturing drawings of the various parts, components and subassemblies are analyzed to identify materials characteristics and quality, dimensions, tolerances etc.

The production cost of the UNFINISHED PARTS is first calculated in kL/kg (or $/kg): the additional costs for FIRST PROCESSING and PARTS FINISHING are then added as appropriate together with the current cost of standard parts from EXTERNAL SUPPLIERS.

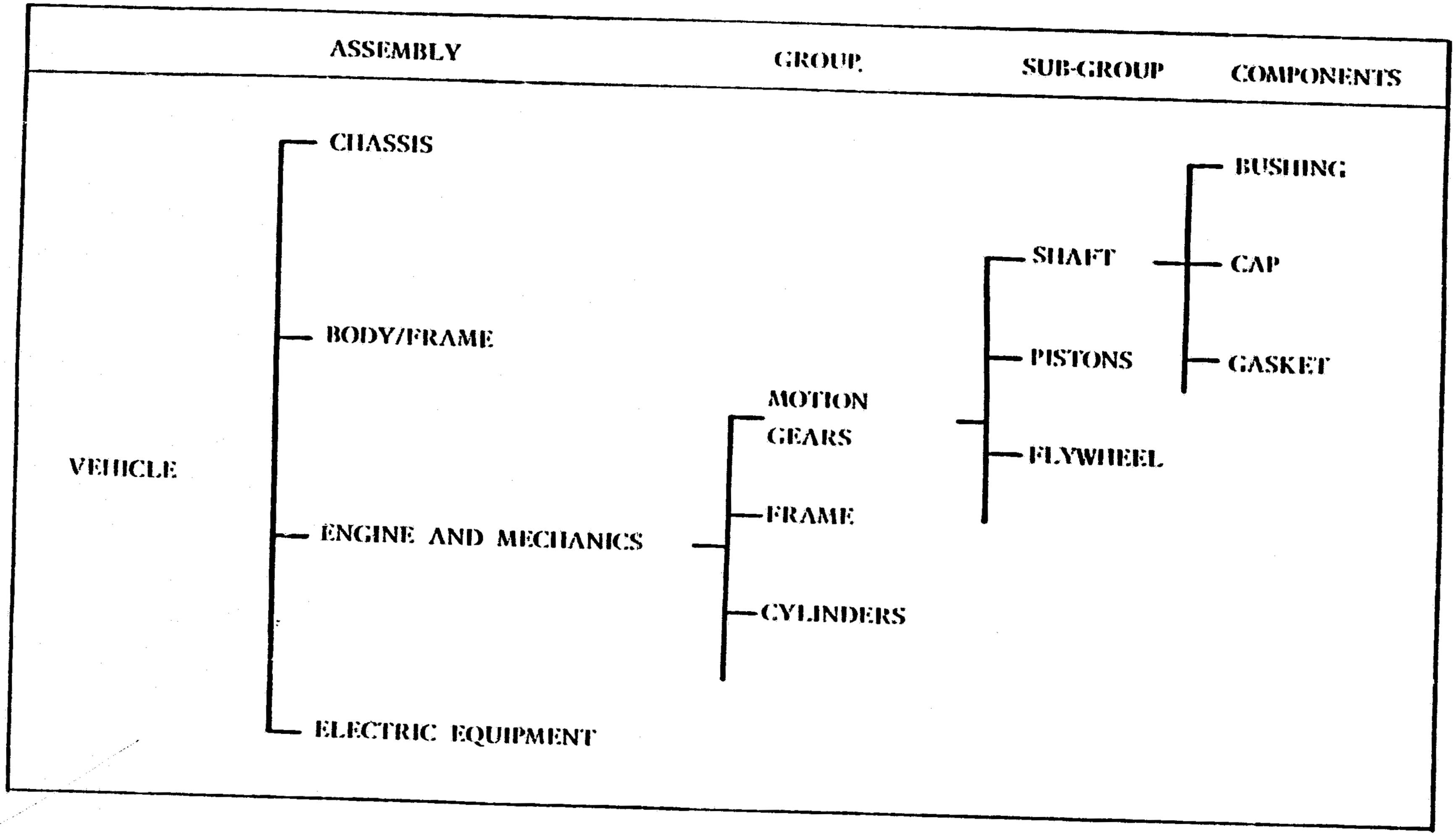

FIG. A.3-4.1 — VEHICLE COMPONENTS BREAKDOWN

A.3-4.3 Labor Cost Analysis

The manufacturing drawings are then analyzed to identify the appropriate production cycles and define the cost effectiveness of production organization to optimize the mix of the following objectives:

- Short manufacturing time
- Minimum manpower
- Simple production and tooling equipment

Based upon the existing production requirements a processing cycle is defined for the various components which includes a list of the machinery and tooling to be used. Processing cycle and assembling times, as well as machine set-up time where appropriate, are identified step by step, so that optimal work sequence and timing could be obtained.

Where small batch productions are appropriate an assessment of the incidence of machine set-up on the total process cycle is made to determine the optimal batch size.

A.3-4.4 Investments

On the basis of the expected cycle times upon evaluation of the effects of machine set-up, rejects, replacement and machinery efficiency, the actual machine load is evaluated for the various parts. As a result the amount of equipment necessary to achieve the required production level and the corresponding value of the investment for assembly lines, machinery, fixtures, gauges and tools can be defined.

The plant size, number of workers and plant related services can therefore be identified leading to the total investment value. The projected construction and tooling machinery cost must be continuously updated using the established relationships with the various contractors and suppliers.

A.3-4.5 Manufacturing Costs

The projected manufacturing times are converted into manufacturing costs according to the projected average hourly labor rates including both direct and overhead manhours.

The expenses resulting from general and specific investments are expressed as appropriate in yearly depreciation costs taking into account expected interest rates.

The total production cost is obtained by adding the total cost of parts materials previously identified.

Based upon the number of vehicles to be produced on a yearly basis the total vehicle cost can be accordingly defined including an estimated additional cost to account for the improvements and design changes to be experienced during or after the first year of production.