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HYBRID VEHICLE POTENTIAL ASSESSMENT

Volume 7: Hybrid Vehicle Review

By
K. O. Leschly

September 30, 1979

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Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

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ELECTRIC AND HYBRID VEHICLE SYSTEM RESEARCH AND DEVELOPMENT PROJECT

HYBRID VEHICLE POTENTIAL ASSESSMENT VOLUME VII. HYBRID VEHICLE REVIEW

September 30, 1979

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Prepared for
U.S. Department of Energy

by
Jet Propulsion Laboratory
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Pasadena, California

PREFACE

In 1976, Congress passed the Electric and Hybrid Vehicle (EHV) Research, Development, and Demonstration Act of 1976, Public Law 94-413, later amended by Public Law 95-238. The Department of Energy is conducting an EHV development program in compliance with that Law. The EHV System Research and Development Project, one element of this Program, is being conducted by the Jet Propulsion Laboratory (JPL) of the California Institute of Technology through an agreement with the National Aeronautics and Space Administration. This report presents the results of the investigations conducted under the Hybrid Vehicle Potential Assessment Task which is a part of the EHV Systems R&D Project.

Early results of this study were used as the technical basis for the Near Term Hybrid Vehicle Development Program now being carried out by the JPL Electric and Hybrid Vehicle System Research and Development Project.

This report is in ten volumes. Volume I contains an overview of the study and the major findings. Volumes II through X are of technical supplementary reports that describe the details of the study and present the most important data generated by the study elements.

STUDY TEAM MEMBERS

Principal Investigator	F. T. Surber
Hybrid Vehicle Review	K. O. Leschly
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Power Train Analysis	S. P. DeGrey S. G. Liddle Z. Popinski
Cost Analysis	K. S. Hardy R. C. Heft
Impacts Analysis	K. O. Leschly

Volumes Comprising the Hybrid Vehicle Potential Assessment

Report No.	Subject	Author(s)
5030-345, Vol. I	Summary	F. T. Surber et al.
5030-345, Vol. II	Mission Analysis	F. T. Surber G. K. Deshpande
5030-345, Vol. III	Parallel Systems	S. P. DeGrey
5030-345, Vol. IV	Series Systems	Z. Popinski
5030-345, Vol. V	Flywheel Systems	S. G. Liddle
5030-345, Vol. VI	Cost Analysis	K. S. Hardy
5030-345, Vol. VII	Hybrid Vehicle Review	K. O. Leschly
5030-345, Vol. VIII	Scenario Generation	K. O. Leschly
5030-345, Vol. IX	Power Train Summary, Component Descriptions, HYVEC Vehicle Simulator	S. G. Liddle S. P. DeGrey
5030-345, Vol. X	Electric and Hybrid Vehicle Cost Handbook	R. C. Heft S. C. Heller

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HYBRID VEHICLE REVIEW

A review of hybrid vehicles (HVs) built during the past ten years or planned to be built in the near future has been conducted in support of the Hybrid Vehicle Potential Assessment. The primary purpose for this review was to generate an updated and more extensive data base on the state-of-the-art of hybrid vehicles, than reported in previous studies (1, 2, 3, 4, 5, 6). Furthermore, an attempt has been made to classify and analyze these vehicles to get an overall picture of their key characteristics.

1. APPROACH

The review included on-road hybrid passenger cars, trucks, vans and busses. It has been structured as a four step process:

1. Identify (INVENTORY) actually built and planned hybrid vehicles and their builders and owners. This activity included: a) literature search of bibliographies, reference listings, and recent study reports; b) scanning of relevant professional journals and conference proceedings; and c) follow up on hints and rumors from people involved with electric and hybrid vehicle related work ("ears to the ground").

2. Complete a 1-page SUMMARY VEHICLE DESCRIPTION (see pg. 30) for each vehicle, based on the literature and/or phone conversation with the particular builder. Foreign builders were approached through their embassies or business representatives here in the U.S.A.

3. Mail a 6-page DETAILED VEHICLE SPECIFICATION QUESTIONNAIRE (see pgs. 31-36) to each builder in an attempt to get a more detailed description of their vehicle.

4. TABULATE, CLASSIFY, and ANALYZE the data collected during steps 1 to 3.

In support of the initial phase of the data collection activities, visits were made to seven different sites in the U.S.A., covering 8 hybrid passenger cars, 1 hybrid van, and 1 hybrid bus.

2. GENERAL FINDINGS AND ANALYSIS

All of the vehicles identified in the hybrid vehicle review are experimental and basically proof-of-concept vehicles. While a few of these vehicles are meant to be preproduction prototypes, none of them have actually led to any volume production larger than two-of-a-kind.

A total of 81 hybrid vehicles were identified worldwide. Twelve of them are still at the design stage planned to be built in the near future, while the rest (69) have been built within the last ten years.

Most of these vehicles have been operated with only one particular hybrid powertrain configuration (i.e., a specific arrangement of a specific set of major powertrain components). Only three vehicles (all passenger cars) have at one time or another been modified so dramatically that they each can be said to represent more than one hybrid configuration:

- GMC's Stir-Lec (2 configurations)
- Kordesch's Austin (2 configurations)
- Univ. of Florida's Urban Car (3 configurations)

The 81 vehicles identified represent, in other words, a total of 85 hybrid vehicle configurations. It should be noted that existing hybrid vehicle designs which are not presently intended to be implemented in an actual vehicle have been excluded.

A more detailed count of the reviewed hybrid vehicles in terms of their present status, national origin, and type of vehicle is given below in Table 1.

TABLE 1: HYBRID VEHICLE STATUS

Present Status	Passenger Cars USA	Passenger Cars Foreign	Trucks and Vans USA	Trucks and Vans Foreign	Busses USA	Busses Foreign	Total
Running Condition	19	6	2	6	2	2	37
Out of Order	1	0	0	0	0	0	1
Disassembled	2	0	1	0	1	0	4
Status Unknown	14	8	3	1	0	1	27
Subtotal Built to date	36*	14	6	7	3	3	69
Planned for the near future	9	1	2	0	0	0	12
Total	60		15		6		81

* Representing 40 configurations.

Most of the 85 reviewed hybrid vehicle configurations are conversions of conventional production vehicles. Of the 64 configurations where chassis and body style are known, there are 45 (or 70%) such conversions and 6 (or 10%) with modified production chassis and/or custom made fiberglass bodies. Only 13 (or 20%) are specially built from the ground up.

The historical distribution of the hybrid vehicle configurations is shown in Figure 1, in terms of the first year of operation. Most of the earlier hybrid vehicles were built in an attempt to make low pollution vehicles, while the later hybrids predominantly have been designed with a higher fuel economy in mind.

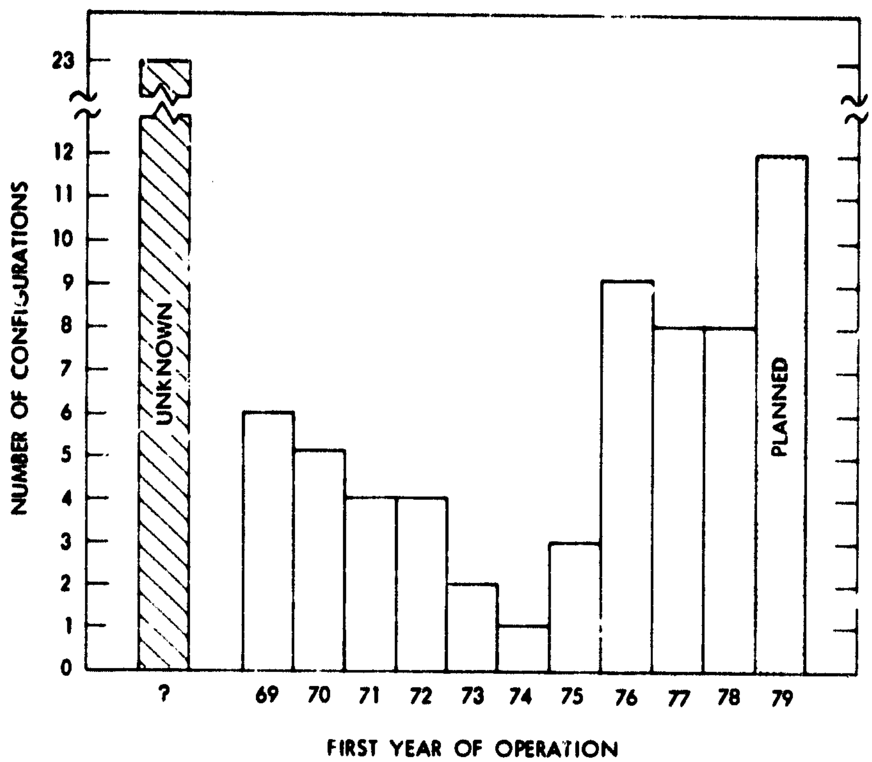


FIGURE 1: HISTORICAL DISTRIBUTION OF HV CONFIGURATIONS

Fuel. Almost 70% (59 configurations) of the reviewed configurations have been identified as "multiple fuel electric hybrids" (the present DOE definition of a hybrid vehicle) while only 18% (15 configurations) have been identified as single fuel hybrids (Figure 2).

Storage. All of the 74 configurations with known type(s) of fuel and energy storage are "multiple storage hybrids", including dual battery systems for the 4 configurations with batteries only (Figure 3). It should be noted that the "multiple storage" term was initially used to identify the hybrid vehicles in this review.

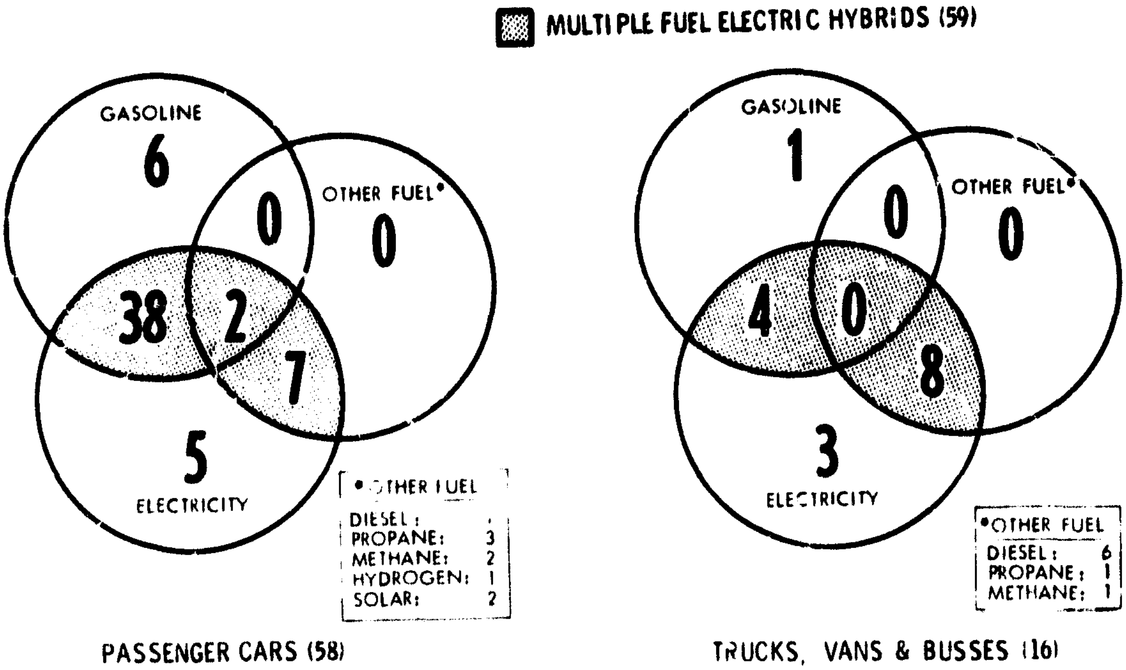


FIGURE 2: DISTRIBUTION OF HV CONFIGURATIONS VS. FUEL

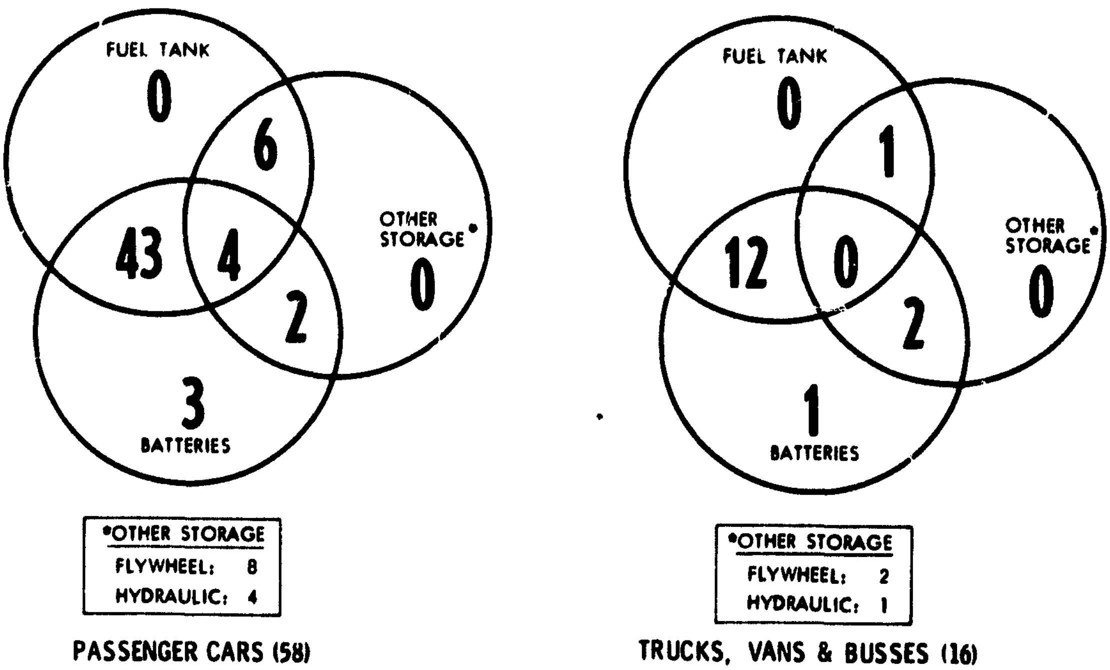


FIGURE 3: DISTRIBUTION OF HV CONFIGURATIONS VS. STORAGE

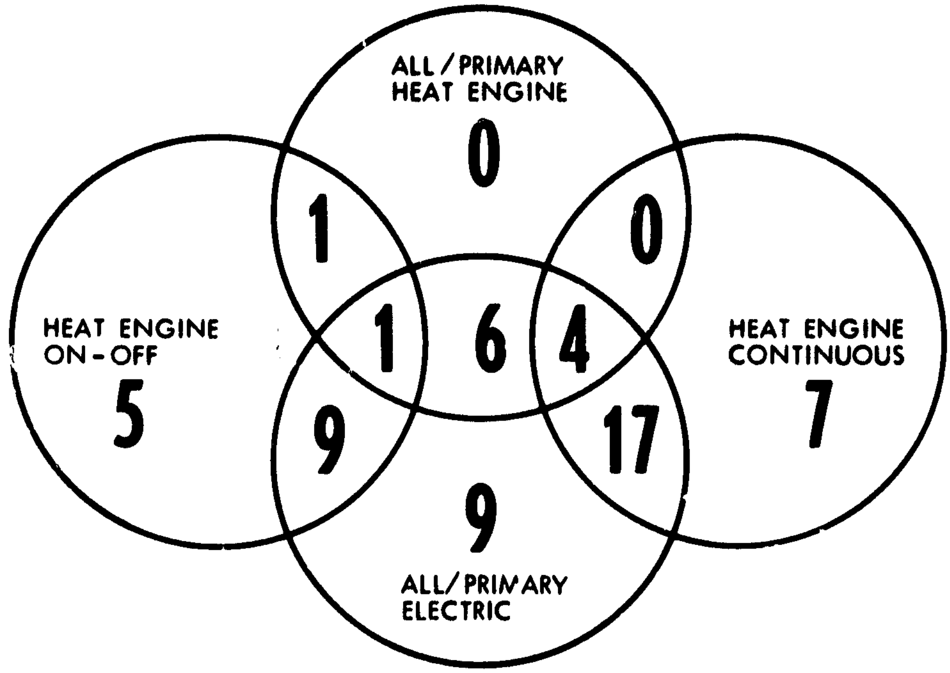
Operating Modes. The operating modes of 59 of the reviewed configurations have been identified at the present. All of these configurations are designed to be operated in one or more of the following four operating modes exclusively:

- Heat Engine On-Off. The heat engine will automatically be turned on or off depending on the need for power and/or energy or at certain vehicles speeds.
- Heat Engine Continuous. The heat engine will run continuously either at a constant rpm or a variable rpm depending on the need for power and/or energy.
- All/Primary Heat Engine. The heat engine will deliver most or all of the needed power and energy to drive the vehicle, and in some cases even to recharge batteries (or other energy storage devices). In cases of extreme power demands, the batteries (or other energy storage devices) might be utilized as a supplementary power source.
- All/Primary Electric. The batteries will deliver most or all of the needed power and energy to drive the vehicle. In cases of extreme power demands the heat engine (or other energy storage devices) might be utilized as a supplementary power source.

The distribution of hybrid vehicle configurations on these four operating modes is shown in Figure 4. Regenerative braking is employed in a little more than half (or 34) of these 59 configurations. About 35% (21 configurations) of them have been designed with only one operating mode in mind. Most of these also happen to be single fuel hybrids which correspond closely to the general trend of equivalence between the number of fuels and operating modes (Table 2).

Power Plants. The distribution of the 59 "multiple fuel electric hybrids" (identified above) in terms of their type of electric and non-electrical power plants is shown in Figure 5. It is seen that about 75% of them (or 44) are using a conventional Otto cycle engine combined with some kind of a DC motor.

Most often the parallel hybrids (i.e., hybrids with direct drive from the heat engine to the driveshaft) do not have a separate generator as opposed to the series hybrid which requires a separate generator. But four configurations, or about 20% of the parallel hybrids violate this general trend by having a separate generator (Table 3).



PASSENGER CARS (44)
& TRUCKS, VANS & BUSSES (15)

FIGURE 4: DISTRIBUTION OF HV CONFIGURATIONS VS. OPERATING MODES

TABLE 2: DISTRIBUTION OF HV CONFIGURATIONS VS. FUELS AND OPERATING MODES

Type of HV Configuration	Single Fuel	Dual Fuel	Triple Fuel	Unkown Fuel	Total
Single Mode	14	7	0	0	21
Dual Mode	1	30	2	0	33
Triple Mode	0	5	0	0	5
Unknown Mode	0	15	0	11	26
Total	15	57	2	11	85

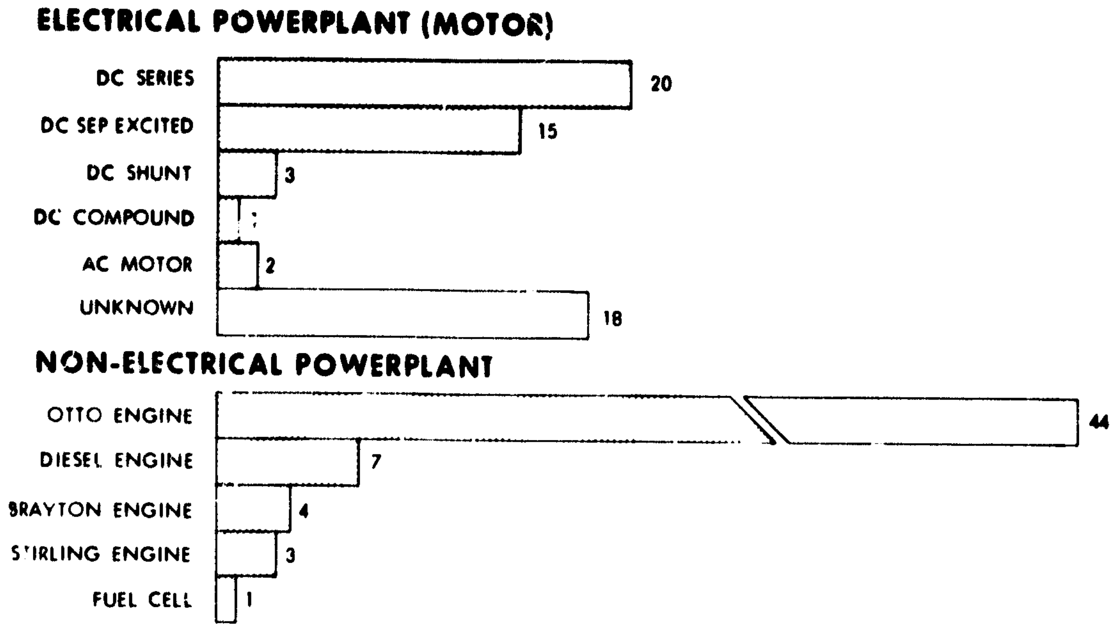


FIGURE 5: POWER PLANTS (MULTIPLE FUEL ELECTRIC HVs ONLY)

TABLE 3: DISTRIBUTION OF HV CONFIGURATIONS VS. HV TYPE WITH AND WITHOUT SEPARATE GENERATOR

Type of HV Configuration	Separate Generator	No Separate Generator	Unknown	Total
Series	30	0	0	30
Parallel	4	14	2	20
Other	0	17	0	17
Unknown	0	0	18	18
Total	34	31	20	85

Powertrain Schemes. A classification of the hybrid vehicle configurations was attempted in terms of their particular powertrain scheme (Figure 7). The powertrain schemes for the conventional ICE and the conventional electric vehicles are shown in Figure 6 for reference. A total of 20 hybrid vehicles powertrain schemes, distributed on five major configuration classes, were required to cover all of the 61 hybrids with known powertrain scheme:

CLASS S:	SERIES HYBRIDS	(3 VARIATIONS/28 HVs)
CLASS P:	PARALLEL HYBRIDS	(6 VARIATIONS/16 HVs)
CLASS F:	FLYWHEEL HYBRIDS	(6 VARIATIONS/9 HVs)
CLASS D:	DUAL BATTERY HYBRIDS	(1 VARIATION/4 HVs)
CLASS O:	OTHER HYBRIDS	(4 VARIATION/4 HVs)

Even though this classification indicates that on the average no more than three hybrid configurations are alike, there is a strong tendency to clustering around a few typical powertrain schemes (like "Sa" and "Pa").

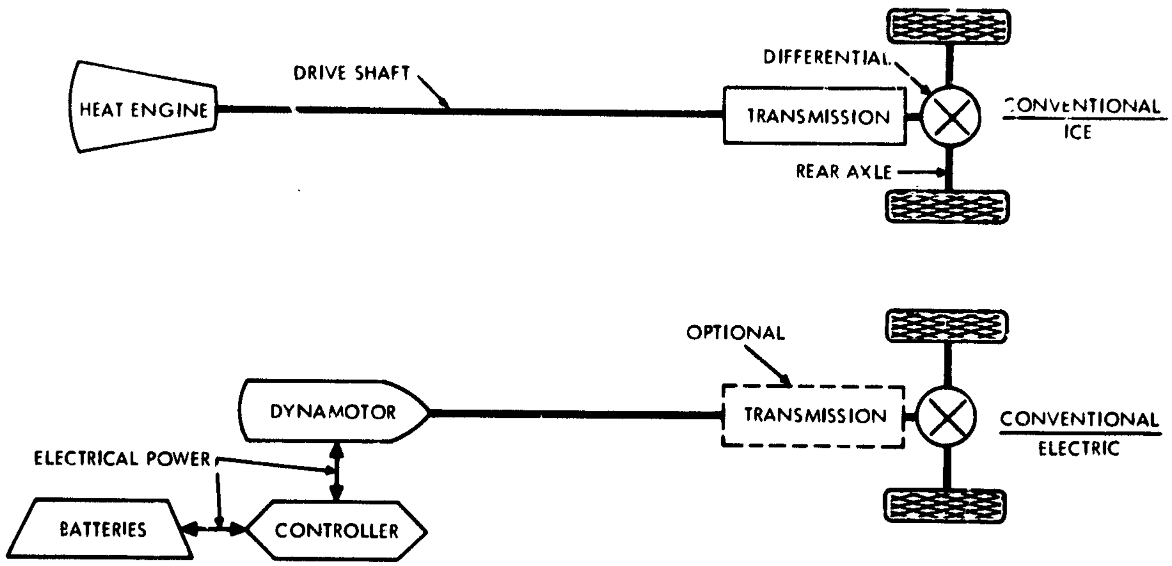


FIGURE 6: CONVENTIONAL POWERTRAIN SCHEMES

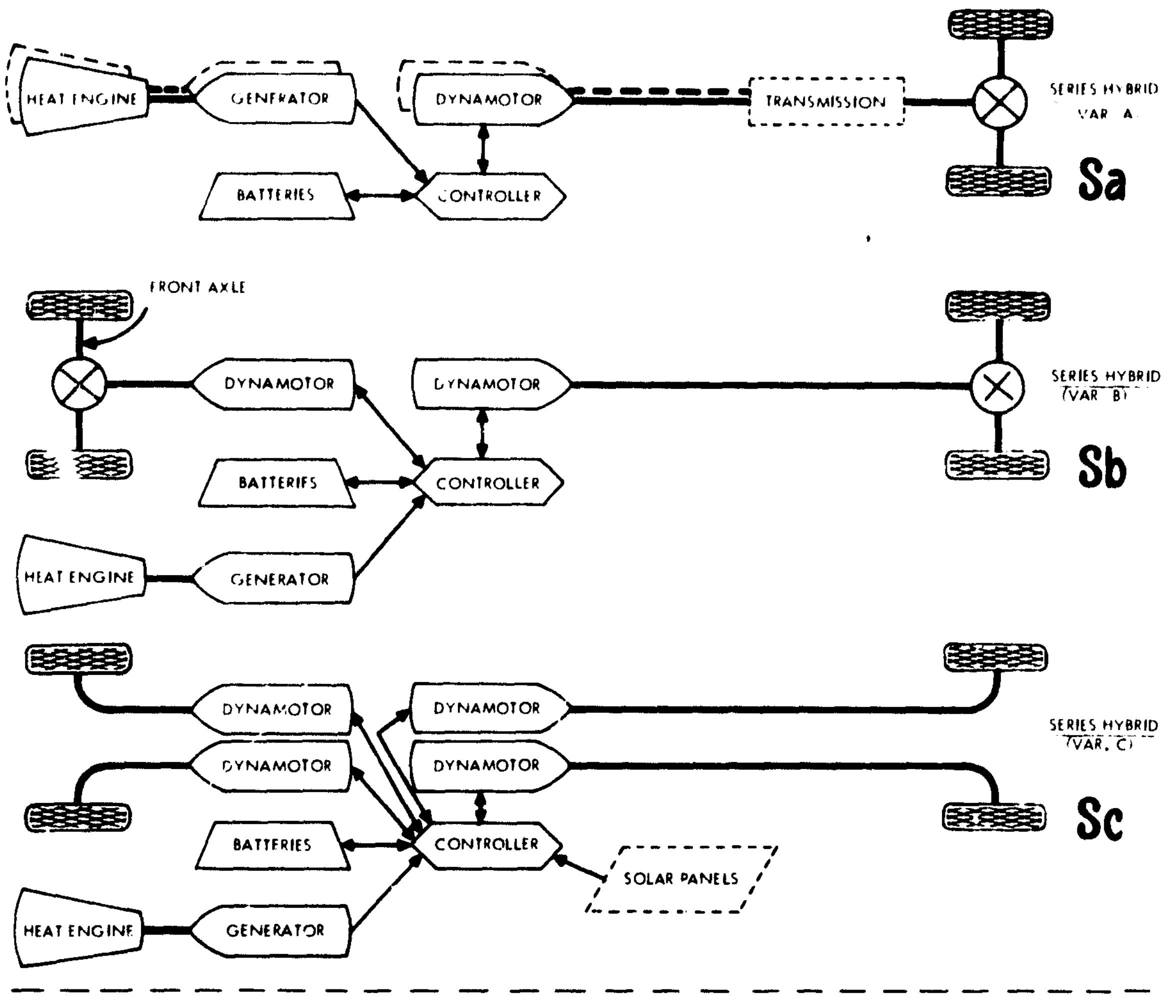


FIGURE 7: HV POWERTRAIN SCHEMES /Page 1

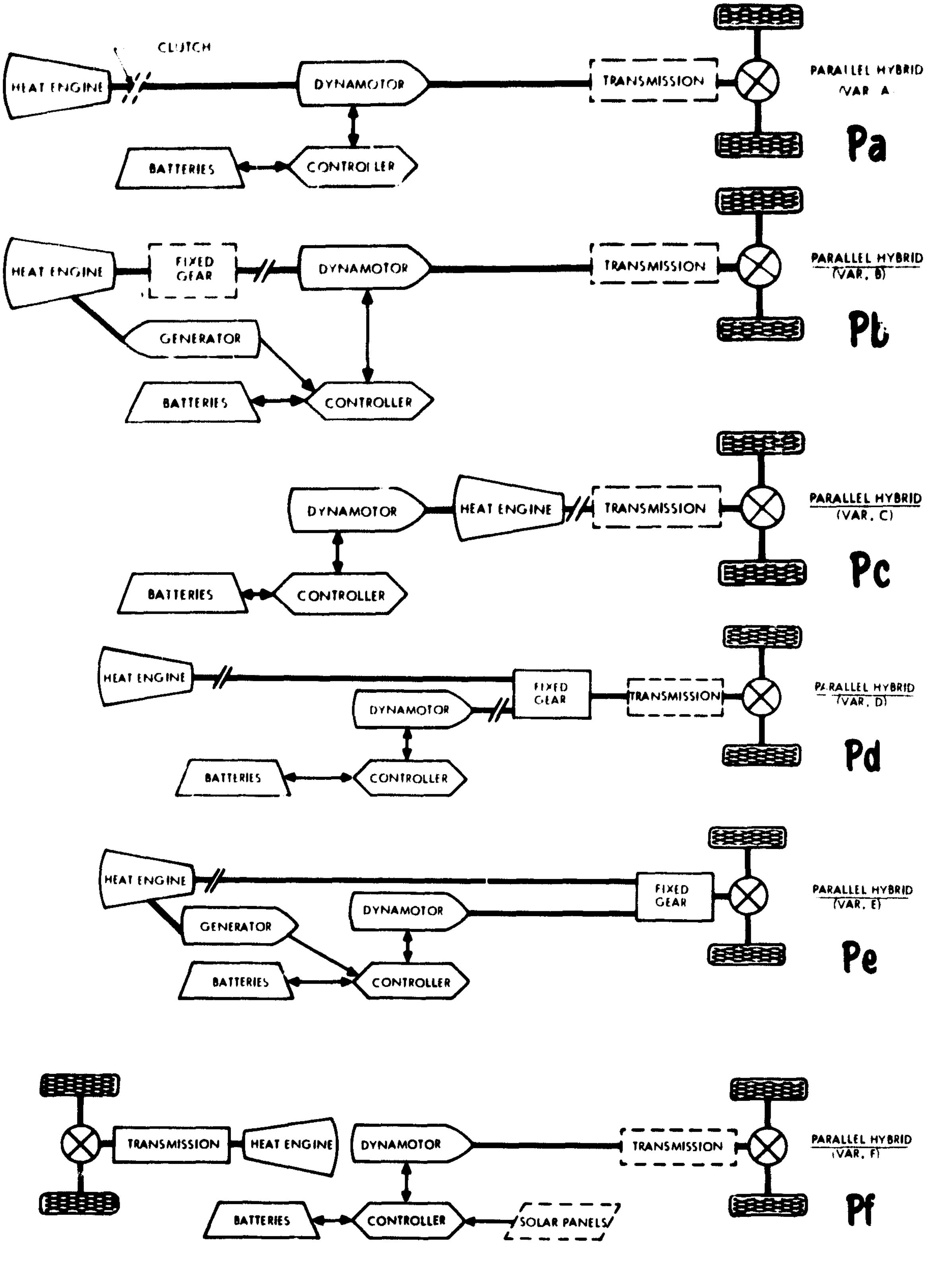


FIGURE 7 (cont): HV POWERTRAIN SCHEMES /Page 2

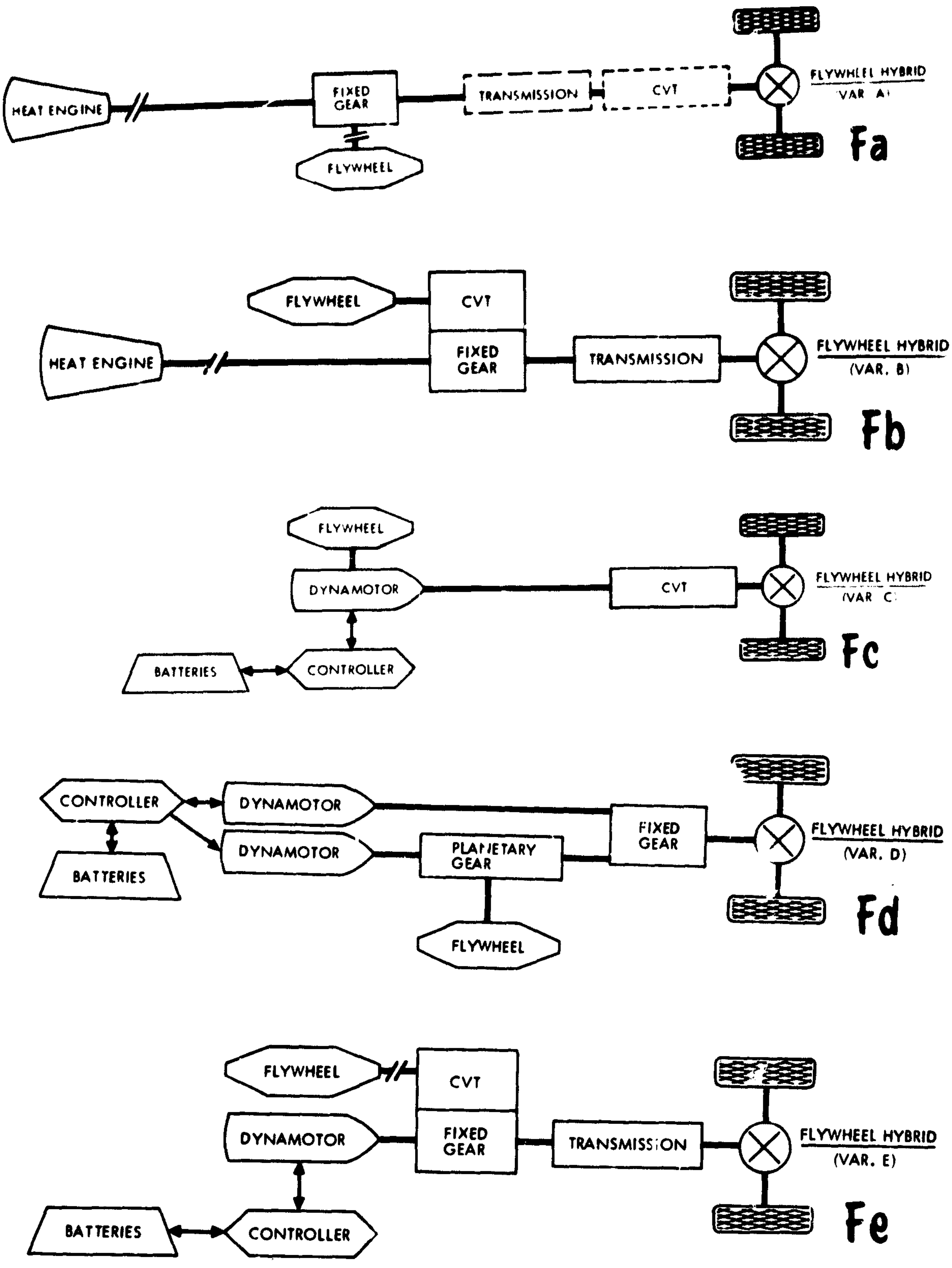


FIGURE 7 (cont): HV POWERTRAIN SCHEMES /Page 3

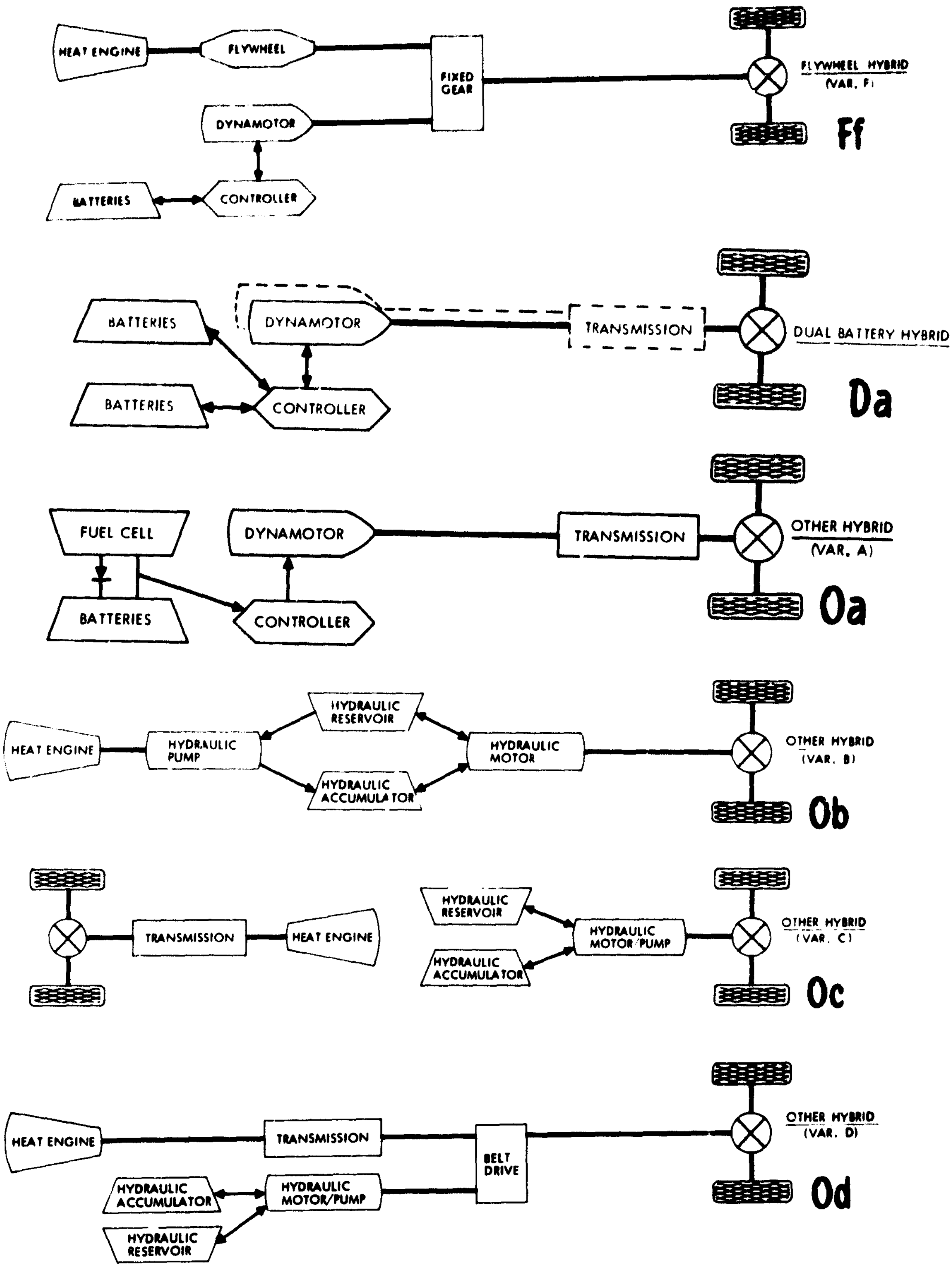


FIGURE 7 (cont): HV POWERTRAIN SCHEMES /Page 4

3. HYBRID VEHICLE DATA BASE

The data base presented on the following pages consists of three sets of tables:

- KEY CHARACTERISTICS (Tables 4, 5).
  Lists the major component types, operating modes, and present status. Includes all 85 configurations.

- SUMMARY VEHICLE DESCRIPTIONS (Tables 6, 7, 8).
  Lists the general vehicle specification data, with emphasis on the sizes of the major power train component. Includes all 85 configurations.

- PERFORMANCE (Tables 9, 10).
  Lists test results and manufacturers estimates of the vehicle performance. Includes only 30 configurations.

This data base is furthermore subdivided according to the following vehicle types: passenger cars (64 configurations), trucks and vans (15 configurations), and busses (6 configurations).

TABLE 4

KEY CHARACTERISTICS OF HYBRID PASSENGER CARS /Page 1

LEGEND

- RC Running Condition
- OR Out of order (repair)
- DA Disassembled
- PL Planned
- SU Status Unknown
- \- Unknown/Undecided

	PASSENGER CARS	FUELS				STORAGE					POWER PLANTS								TRANSMISSION						OPERATING MODES					PT	PS
		Gasoline	Diesel	Electricity	Other	Lead-Acid Batteries	Other Batteries	Fuel Tank	Flywheel	Other	Otto Engine	Diesel Engine	Other Heat Engine	AC Motor	DC Series Motor	DC Sep Ex Motor	Other DC Motor	Separate Generator	3-speed Manual	4-speed Manual	Automatic	Torque Converter	CVT	Other	Regenerative Braking	HE On-Off	HE Continuous	All/Primary Electric	All/Primary HE	Powertrain Scheme	Present Status
P-1	Worchester Polytech. Inst.	●		●		●		●			●				●			●								●		●		Sa	SU
P-2	Univ. of New Hampshire			●	●	●		●			●					●		●									●	●		Sb	SU
P-3	Univ. of Wisconsin (Pinto)	●						●	●		●									●			●		●	●			●	Fa	RC
P-4	Univ. of Wisconsin (Urban)			●	●	●		●			●				●					●					●		●	●		Pd	RC
P-5	Mass. Inst. of Technology	●		●		●		●			●					●		●		●							●	●		Sa	DA
P-6	Univ. of Colorado	●		●			●	●			●						●	●		●					●	●		●		Sa	OR
P-7	National Motors	●		●		●		●			●					●		●			●	●					●	●	●	Pb	SU
P-8	General Motors (512C Urban)	●		●		●		●			●				●			●						●		●		●		Pe	SU
P-9	General Motors (XEP-1A)			●		●	●								●									●				●		Da	SU
P-10	General Motors (Stir-Lec I)	●		●		●		●					●	●				●									●	●		Sa	DA
P-11	General Motors (Stir-Lec II)	●		●		●		●					●		●			●						●			●	●		Sa	SU
P-12	Minicars (Hybrid C-1)	●		●		●		●			●						●				●						●			Pa	SU
P-13	Elmo Long	●		●		●		●		●			●		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	--	PL
P-14	Andell Motors			●	●	●		●			●				●			●			●				●		●	●		Sc	PL
P-15	Daihatsu (EV1-H)/Japan			●		●	●							●										●	●			●		Da	RC
P-16	Toyota (EV2-H)/Japan			●		●	●									●					●				●			●		Da	RC
P-17	Univ. of Toronto/Canada			●	●	●		●			●					●		●		●				●	-	-	-	-	-	Pb	SU
P-18	New Jersey Inst. of Tech.	-	-	-	-	-	-	-	-	-	-	-	-				●	-	-	-	-	-	-	-	-	-	-	-	-	--	SU
P-19	Bradshaw & Westwood/Australia	●		●	●	●		●			●			●				●						-	●		●	●		Sc	PL
P-20	Stitts R&D (Fairlane)	●		●		●		●			●				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	--	PL
P-21	Stitts R&D (VW Beetle)	●		●		●		●			●				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	--	PL
P-22	Karl Kordesch (1st Conv.)			●	●	●		●							●					●								●		Oe	DA
P-23	Karl Kordesch (2nd Conv.)	●		●		●		●			●				●			●		●							●	●		Sa	RC
P-24	Earl Osborn	●		●		●		●			●				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	P-	DA
P-25	Roy Kaylor	●		●		●		●			●					●		●		●							●	●	●	Sa	RC
P-26	TurElec	●		●		●		●					●		●			●		●					●	●		●		Sa	RC
P-27	Petro-Electric Motors	●		●		●		●			●					●			●						●		●			Pc	RC
P-28	CAR (Dodge)			●	●	●		●			●					●			●						●	●		●		Pa	RC
P-29	CAR/SCE (Hornet)	●		●		●		●			●				●			●									●	●		Sa	RC
P-30	Univ. of Florida (1st Conv.)	●		●		●		●			●					●		●								●		●		Sa	DA

TABLE 4 (contd)

KEY CHARACTERISTICS OF HYBRID PASSENGER CARS /Page 2

LEGEND

RC Running condition
OR Out of order (repair)
DA Disassembled
PL Planned
SU Status Unknown

\- Unknown/Undecided

	FUELS				STORAGE					POWER PLANTS								TRANSMISSION						OPERATING MODES					PT	PS
PASSENGER CARS	Gasoline	Diesel	Electricity	Other	Lead-Acid Batteries	Other Batteries	Fuel Tank	Flywheel	Other	Otto Engine	Diesel Engine	Other Heat Engine	AC Motor	DC Series Motor	DC Sep Ex Motor	Other DC Motor	Separate Generator	3-speed Manual	4-speed Manual	Automatic	Torque Converter	CVT	Other	Regenerative Braking	HE On-Off	HE Continuous	All/Primary Electric	All/Primary HE	Powertrain Scheme	Present Status
P-31 Univ. of Florida (2nd Conv.)	●		●		●		●			●				●			●		●							●	●		Sa	DA
P-32 Univ. of Florida (3rd Conv.)		●	●		●		●				●			●			●		●				●			●	●		Sa	RC
P-33 Robert Bosch/W. Germany	●		●			●	●			●					●									●	●		●		Pa	SU
P-34 Volkswagen/W. Germany	●		●		●		●			●					●				●		●			●	●		●	●	Pa	RC
P-35 Aachen Univ./W. Germany	●		●		●		●	●		●				-	-	-		-	-	-	-	-	-	●		●			Ff	SU
P-36 National Park Service	●		●		●		●			●			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	--	PL
P-37 Structural Plastics	●		●		●		●		●	●			-	-	-	-	-	-	-	-	-	●	-	-	-	-	-	-	P-	PL
P-38 Alterdyne	●		●		●		●					●		-	-	-	●	-	-	-	-	-	-	-	-	-	-	-	S-	PL
P-39 William Towns/England	●		●		●		●			●				●			●									●	●		Sa	RC
P-40 Kinergy R&D (Camaro)	●						●	●		●										●				●	●				Fa	RC
P-41 Kinergy R&D (Cadillac)	●						●	●		●										●		●		●	●				Fb	RC
P-42 Kinergy R&D (Volvo 343DL)	●						●	●		●												●		●	●				Fa	RC
P-43 Kinergy R&D (VW Beetle)			●		●			●						-	-	-								●			●		Fe	RC
P-44 Global Scien Engrs (VW Rabbit)	●						●		●	●									●				●	●	●				Oc	SU
P-45 Global Scien Engrs (Granada)	●						●		●	●													●	●	●				Ob	SU
P-46 J. R. Williams	●		●		●		●			●			-	-	-	-	●	-	-	-	-	-	-	-	-	-	-	-	Sa	SU
2-47 Clifford Deane	●		●		●		●			●			-	-	-	-	●	-	-	-	-	-	-			●	●		Sa	SU
P-48 Garrett			●		●			●							●								●	●			●		Fd	PL
P-49 Wallace Moore	●		●	●	●		●			●				●				●									●	●	Pf	RC
P-50 PGE (taxi)/Italy	●		●		●		●			●					●					●				●			●	●	Pd	RC
P-51 Henry Knauper	●		●		●		●			●				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	--	PL
P-52 Daihatsu (Fellow Max)/Japan	●		●		●		●			●				●				-	-	-	-	-	-	●		●	●	●	Pf	SU
P-53 Toyo Kogyo (EX005)/Japan	●		●		●		●			●			-	-	-	-	●	-	-	-	-	-	-	-	-	-	-	-	S-	SU
P-54 John DeGruchy/England	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	--	SU
P-55 F. W. Hughes/England	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	--	SU
P-56 A. T. Freeman/England	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	--	SU
P-57 M. Skeels/England	●		●		●		●			●				●				-	-	-	-	-	-				●	●	P-	RC
P-58 Mechanical United Association	●		●		●		●			●					●		-							-	-	-	-	-	--	RC
P-59 JMJ Electronics	●		●		●		●			●			-	-	-	-	●	-	-	-	-	-	-	-	-	-	-	-	Sa	RC
P-60 Edwards Electronics	●		●		●		●	●		●			-	-	-	-	-	-	-	-	-	●	-	-	-	-	-	-	--	RC
P-61 Electric Fuel Propulsion	●		●			●	●			●				-	-	-	●			●						●	●		Sa	RC
P-62 Electric Passenger Car	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	--	SU
P-63 General Engine	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	--	SU
P-64 Hybricon	●		●		●		●			●				-	-	-		-	-	-	-	-	-	●			●	●	Pf	RC

TABLE 5

KEY CHARACTERISTICS OF HYBRID TRUCKS, VANS, AND BUSSES

LEGEND

- RC Running condition
- OR Out of order (repair)
- DA Disassembled
- PL Planned
- SU Status Unknown
- – Unknown/Undecided

		FUELS				STORAGE					POWER PLANTS								TRANSMISSION						OPERATING MODES					PT	PS
		Gasoline	Diesel	Electricity	Other	Lead-Acid Batteries	Other Batteries	Fuel Tank	Flywheel	Other	Otto Engine	Diesel Engine	Other Heat Engine	AC Motor	DC Series Motor	DC Sep Ex Motor	Other DC Motor	Separate Generator	3-speed Manual	4-speed Manual	Automatic	Torque Converter	CVT	Other	Regenerative Braking	HE On-Off	HE Continuous	All/Primary Electric	All/Primary HE	Powertrain Scheme	Present Status
TRUCKS AND VANS																															
T-1	Lead Industries Association			●	●	●		●					●		●			●						●			●	●		Sa	PL
T-2	Energy R&D	●		●		●		●			●				●			●		●						●	●	●		Sa	RC
T-3	Nissan (EV4-H)/Japan			●		●	●										●								●			●		Da	RC
T-4	U.S. Army Meradcom	●		●			●	●					●		●			●									●	●	●	Sc	SU
T-5	Gould	●		●		●		●			●					●							●		●		●	●		Pc	DA
T-6	Garrett			●		●			●								●						●		●			●		Fc	RC
T-7	Southern Illinois Univ.			●	●	●		●			●						●	●		●					●		●			Sa	PL
T-8	SRF/Israel			●		●			●							●							●		●			●		Fc	RC
T-9	PGE (IM3 Pick-Up)/Italy	●		●		●		●			●					●				●					●			●	●	Pd	RC
T-10	Fiat/Italy	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	--	SU
T-11	Tech. Univ./Denmark	●						●		●										●					●		●			Od	RC
T-12	Daihatsu (DV26T-HB)/Japan		●	●		●		●				●					●			●					●		●	●		Pa	RC
T-13	Toyo Kogyo (Titan)/Japan		●	●		●		●				●			-	-	-	●	-	-	-	-	-	-				●	●	P-	RC
T-14	ITT Research Institute	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	--	SU
T-15	Power Train	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	--	SU
BUSSES																															
B-1	Billings Energy	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	--	RC
B-2	Fiat/Italy	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	--	SU
B-3	General Motors		●	●		●		●				●			-	-	-	●	-	-	-	-	-	-	-	-	-	-	-	Sa	DA
B-4	Univ. of Florida		●	●		●		●				●			●			●									●	●		Sa	RC
B-5	Daimler-Benz/W. Germany		●	●		●		●				●				●		●							●		●	●		Sa	RC
B-6	Kawasaki/Japan		●	●		●		●				●			●			●							●	●		●		Sa	RC

TABLE 6

SUMMARY VEHICLE DESCRIPTION OF HYBRID PASSENGER CARS /Page 1

Manufacturer and Owner	Chassis & Years of Operation	Wheelbase Curb Weight Passengers	Hybrid Type	Heat Eng. Fuel and kW-Max	Generator Type and kW-Rated	El-Motor Type and kW-Rated	Batteries Voltage & Weight	Flywheel Weight & kWh-Max	Electric Power Conditioning	Transmision and Regen. Braking	Notes & Status
Worchester Polytech. Institute	AMC Gremlin 1970-	2-pass	HE-Battery Series On-Off	UC Otto gasoline	AC 3phase 25 kw	DC Series 19 kW	Lead-Acid 16x6V	N/A	SCR Chop	No transm	P-1 SU
Univ. of New Hampshire	1970-		HE-Battery Series Continuous	UC Otto propane 22.5 kW		DC Sep Ex 2x20 kW	Lead-Acid 10x12V	N/A	SCR Chop		P-2 SU
Univ. of Wisconsin	Ford Pinto 1976-	240 cm 1800 kg 2-pass	HE-Flyw On-Off	UC Otto gasoline 56 kW	N/A	N/A	N/A	Steel .50 kWh @10,000rpm	N/A	4s manual & CVT Reg Braking	P-3 RC
Univ. of Wisconsin	Spec built 1972-	234 cm 1270 kg 2-pass	HE-Battery Parallel Continuous	Rotary propane 37 kW	(motor)	DC Series 13.5 kW @4000 rpm	Lead-Acid 3x12V 204 kg	N/A	Transistor Chopper	4s manual & Spec gear Reg Braking	P-4 RC
Mass. Inst. of Technology	68 GMC Corvair 1970-72	1800 kg 2-pass	HE-Battery Series Continuous	UC Otto gasoline 34 kW	AC 3phase 12 kW	DC Sep Ex 15 kW	Lead-Acid 14x12V	N/A	SCR Chop	4s manual No Reg Br	P-5 DA
Univ. of Colorado	68 Renault R10 1975-	226 cm 1150 kg 5-pass	HE-Battery Series On-Off	UC Otto gasoline 19 kW	AC 3phase 4 kW	DC Comp 7.5 kW	Lead-Cobalt 6x6V	N/A	Contactors & resistors	4s manual Reg Braking	P-6 OR
National Motors (Gemini II)	78 Olds Delta 88 1978	195 cm 2450 kg 5-pass	HE-Battery Parallel Continuous	UC Otto gasoline		DC Sep Ex 14 kW @2400 rpm	Lead-Acid 18x6V 490 kg	N/A		Automatic Reg Braking	P-7 SU
General Motors (512C Urban)	Spec built 1969-	132 cm 570 kg 2-pass	HE-Battery Parallel On-Off	UC Otto gasoline 4 kW	DC 1.3 kW	DC Series 7.5 kW @2400 rpm	Lead-Acid 6x12V 60 kg	N/A	SCR Chop	Spec gear No Reg Br	P-8 SU
General Motors (XEP-1A)	68 Opel Kadett 1969-	242 cm 1340 kg 4-pass	Dual Battery	N/A	N/A	DC Series 2x10.5 kW	Zn-Air/ Lead-Acid 135V/8x14V	N/A	SCR Chop	Spec gear No Reg Br	P-9 SU
General Motors (Stir-Lec I)	68 Opel Kadett 1969-	242 cm 1450 kg 4-pass	HE-Battery Series Continuous	Stirling gasoline 6 kW	AC 3phase 18.6 kW	AC Induc 15 kW	Lead-Acid 14x12V 225 kg	N/A	SCR Chop	Spec gear No Reg Br	P-10 DA
General Motors (Stir-Lec II)	Same as Stir-Lec I 1969-	242 cm 1475 kg 4-pass	HE-Battery Series Continuous	Stirling gasoline 6 kW	AC 3phase 18.6 kW	DC Series 15 kW	Lead-Acid 14x12V 225 kg	N/A	SCR Chop	Spec gear No Reg Br	P-11 SU

TABLE 6 (contd)

SUMMARY VEHICLE DESCRIPTION OF HYBRID PASSENGER CARS /Page 2

Manufacturer and Owner	Chassis & Years of Operation	Wheelbase Curb Weight Passengers	Hybrid Type	Heat Eng. Fuel and kW-Max	Generator Type and kW-Rated	El-Motor Type and kW-Rated	Batteries Voltage & Weight	Flywheel Weight & kWh-Max	Electric Power Conditioning	Transmision and Regen. Braking	Notes & Status
Minicars (Hybrid C-1)	Spec built 1971-	152 cm 1360 kg 3-pass	HE-Battery Parallel Continuous	UC Otto gasoline 30 kW	(motor)	DC Shunt 7 kW	Lead-Acid 8x12V + 4x6V 290 kg	N/A	Contactors	2s automatic No Reg Br	P-12 SU
Elmo M. Long	Cadillac Eldorado	2500 kg 6-pass	HE-B-Hydr[1]	Brayton gasoline			Lead-Acid	N/A			P-13 PL
Andell Motors			HE-Battery Series	Special[2] Methane 37 kW	DC	DC Series 4x3.7 kW	Lead-Acid 12x12V	N/A		No transm Reg Braking	P-14 PL
Daihatsu/MITI Japan (EV1-H)	Spec built 197[illegible]-	219 cm 1250 kg 4-pass	Dual Battery	N/A	N/A	AC Asyn[3] 12.6 kW	Iron-Air/ Lead-Acid 96V/2x/2V	N/A	Transistor Chopper	2s manual Reg Braking	P-15 RC
Toyota/MITI Japan (EV2-H)	Spec built 1976-	240 cm 1255 kg 4-pass	Dual Battery	N/A	N/A	DC-Sep Ex 20 kW	Zn-Air/ Lead-Acid 166V/2x72V	N/A	Thyristor Chopper	2s automatic	P-16 RC
Univ. of Toronto. Canada	Chevelle (modified) 1971-	2-pass	HE-Battery Parallel	UC Otto propane	DC Shunt 12 kW	DC Sep Ex 12 kW	Lead-Acid 10x12V	N/A	SCR Chop		P-17 SU
New Jersey Inst. of Tech.						DC Shunt 20 kW					P-18 SU
Bradshaw & Westwood, Australia		4-pass	HE-B-Solar Series	UC Otto gasoline			Lead-Acid 16x	N/A			P-19 PL
Stitts R&D	65 Ford Fairlane	305 cm 5-pass	HE-Battery	UC Otto gasoline 34 kW		DC 11 kW	Lead-Acid 10x12V	N/A			Former EV P-20 PI
Stitts R&D	62 VW Beetle	240 cm 4-pass	HE-Battery	UC Otto gasoline 11 kW		DC 3 kW	Lead-Acid 8x6V	N/A			Former EV P-21 PL
Karl Kordesch (1st conv)	61 Austin 1971-75	1200 kg 4-pass	Fuel Cell Battery	N/A	N/A	DC Series 7.5 kW	Lead-Acid 7x12V 175 kg	N/A	Contactors	4s manual No Reg Br	Former EV P-22 DA

1. With Hydraulic Accumulator.
2. A special designed combined rotary and steam turbine engine.
3. With Thyristor Inverter.

TABLE 6 (contd)

SUMMARY VEHICLE DESCRIPTION OF HYBRID PASSENGER CARS /Page 3

Manufacturer and Owner	Chassis & Years of Operation	Wheelbase Curb Weight Passengers	Hybrid Type	Heat Eng. Fuel and kW-Max	Generator Type and kW-Rated	El-Motor Type and kW-Rated	Batteries Voltage & Weight	Flywheel Weight & kWh-Max	Electric Power Conditioning	Transmission and Regen. Braking	Notes & Status
Karl Kordesch (2nd conv.)	61 Austin 1976-	1220 kg 4-pass	HE-Battery Series Continuous	UC Otto gasoline 12 kW	AC 3phase 7 kW	DC Series 7.5 kW	Lead-Acid 8x12V	N/A	Contactors	4s manual No Reg Br	P-23 RC
Earl Osborn	-1977	950 kg	HE-Battery Parallel	UC Otto gasoline		DC	Lead-Acid	N/A	SCR Chop		P-24 DA
Kaylor Energy Products	55 VW Beetle 1977-	240 cm 920 kg 2-pass	HE-Battery Series On-Off	UC Otto gasoline 11 kW	DC Shunt 6 kW	DC Sep Ex 14.5 kW	Lead-Acid 12x6V	N/A	Contactors & SCR Chop	4s manual No Reg Br	P-25 RC
TurElec	Spec built 1973-	305 cm 1800 kg 5-pass	HE-Battery Series On-Off	Brayton gasoline 38 kW	AC 3phase 30 kW	DC Series 15 kW @4500 rpm	Lead-Acid 8x12V	N/A	SCR Chop	4s manual Reg Braking	P-26 RC
Petro-Electric Motors	72 Buick Skylark 1972-	295 cm 1875 kg 6-pass	HE-Battery Parallel Continuous	Rotary gasoline 97 kW	(motor)	DC Sep Ex 15 kW	Lead-Acid 8x12V 135 kg	N/A	Contactors Transistor	3s manual Reg Braking	P-27 RC
Creative Automotive Research (CAR)	66 Dodge Charger 1966-	282 cm 1980 kg 4-pass	HE-Battery Parallel On-Off	UC Otto gas/meth 18.5 kW	(motor)	DC Sep Ex 12 kW	Lead-Acid 9x12V 205 kg	N/A	Contactors Rheostat	4s manual Reg Braking	P-28 RC
CAR/Southern Cal. Edison	71 AMC Hornet Wagon 1976-	278 cm 1930 kg 4-pass	HE-Battery Series Continuous	UC Otto gasoline 7.5 kW	DC Shunt 7.5 kW	DC Series 15 kW	Lead-Acid 16x12V 270 kg	N/A	Contactors Resistors	No transm No Reg Br	P-29 RC
Univ. of Florida (1st conv)	Datsun 510 (modified) 1972-73	206 cm 1375 kg 2-pass	HE-Battery Series On-Off	UC Otto gasoline 10.5 kW	AC 3phase 6.5 kW	DC Sep Ex 2x19 kW	Lead-Acid 8x12V 135 kg	N/A	Contactors	No transm No Reg Br	P-30 DA
Univ. of Florida (2nd conv)	Datsun 510 (modified) 1973-74	206 cm 1270 kg 2-pass	HE-Battery Series Continuous	UC Otto gasoline 10.5 kW	AC 3phase 6.5 kW	DC Series 15 kW @4000 rpm	Lead-Acid 8x12V 190/145 kg	N/A	SCR Chop	4s manual No Reg Br	P-31 DA
Univ. of Florida (3rd conv)	Datsun 510 (modified) 1978-	206 cm kg 2-pass	HE-Battery Series	Diesel Diesel	AC 3phase	DC Series 15 kW @4000 rpm	Lead-Acid 8x12V 192 kg	N/A	SCR Chop	4s manual w/freewheel No Reg Br	P-32 RC
Robert Bosch W. Germany	Ford Escort 1974-	- 1500 kg 2-pass	HE-Battery Parallel On-Off	UC Otto gasoline 33 kW	(motor)	DC Sep Ex 16 kW @2400 rpm	Ni-Cd 144V 205 kg	N/A	SCR Chop	No transm Reg Braking	P-33 SU

TABLE 6 (contd)

SUMMARY VEHICLE DESCRIPTION OF HYBRID PASSENGER CARS /Page 4

Manufacturer and Owner	Chassis & Years of Operation	Wheelbase Curb Weight Passengers	Hybrid Type	Heat Eng. Fuel and kW-Max	Generator Type and kW-Rated	El-Motor Type and kW-Rated	Batteries Voltage & Weight	Flywheel Weight & kWh-Max	Electric Power Conditioning	Transmision and Regen. Braking	Notes & Status
Volkswagen W. Germany	VW Minibus 1975-	240 cm 1775 kg 5-pass	HE-Battery Parallel On-Off	UC Otto gasoline 26 kW[1]	(motor)	DC Sep Ex 16 kW @2400rpm	Lead-Acid 11x12V 285 kg	N/A	SCR Chop	Fixed in 3rd gear Reg Braking	P-34 RC
Aachen Univ. IKA W. Germany	VW Minibus	240 cm 2100 kg 5-pass	HE-B-Flyw	Rotary gasoline 15 kW	(motor)	DC 8 kW	Lead-Acid 12x12V	Steel 1 kWh @18,000rpm			P-35 SU
National Park Service	Marathon		HE-Battery	Rotary gasoline 15 kW			Lead-Acid	N/A			P-36 PL
Structural Plastics			HE-B-Hydr[2] Parallel	UC Otto gasoline				N/A			P-37 PL
Alterdyne			HE-Battery Series On-Off	Brayton gasoline 5 kW		DC		N/A			P-38 PL
William Towns England	Spec built 1977-	153 cm 500 kg 2-pass	HE-Battery Series Continuous	UC Otto gasoline	DC Shunt 2.2 kW	DC Series 6 kW	Lead-Acid 4x12V	N/A	Transistor Chopper	Chain drive No Reg Br	P-39 RC
Kinergy R&D	71 GMC Camaro 1976-	274 cm 1600 kg 2-pass	HE-Flywheel On-Off	UC Otto gasoline 45 kW	N/A	N/A	N/A	Steel 45 kg .25 kWh	N/A	4s manual Reg Braking	P-40 RC
Kinergy R&D	73 Cadillac Sedan 1977-	330 cm 2500 kg 5-pass	HE-Flywheel On-Off	UC Otto gasoline 45 kW	N/A	N/A	N/A	Steel 90 kg .25 kWh	N/A	4s manual CVT Reg Braking	P-41 RC
Kinergy R&D	77 Volvo 343DL 1977-	980 kg 2-pass	HE-Flywheel On-Off	UC Otto gasoline 45 kW	N/A	N/A	N/A	Steel 75 kg .25 kWh	N/A	CVT Reg Braking	P-42 RC
Kinergy R&D	71 VW Beetle 1978-	240 cm 1180 kg 4-pass	Battery-Flywheel	N/A	N/A	DC 8 kW	Lead-Acid 12x6V	Steel 60 kg .25 kWh		CVT Reg Braking	P-43 RC
Global Scientific Engineers	VW Rabbit 1978-		HE-Hydraulic[2] On-Off	UC Otto gasoline	N/A	N/A	N/A	N/A	N/A	Hydraulic accumulator Reg Braking	P-44 SU

1. A 38 kW-max engine limited to 26 kW-max.
2. With Hydraulic Accumulator.

TABLE 6 (contd)

SUMMARY VEHICLE DESCRIPTION OF HYBRID PASSENGER CARS /Page 5

Manufacturer and Owner	Chassis & Years of Operation	Wheelbase Curb Weight Passengers	Hybrid Type	Heat Eng. Fuel and kW-Max	Generator Type and kW-Rated	El-Motor Type and kW-Rated	Batteries Voltage & Weight	Flywheel Weight & kWh-Max	Electric Power Conditioning	Transmision and Regen. Braking	Notes & Status
Global Scientific Engineers	Ford Granada 1978-		HE-Hydraulic[1] On-Off	UC Otto gasoline	N/A	N/A	N/A	N/A	N/A	Hydraulic accumulator Reg Braking	P-45 SU
J.R. Williams			HE-Battery Series					N/A			P-46 SU
Clifford Deane		240 cm 1400 kg 2-pass	HE-Battery Series Continuous	UC Otto gasoline	DC 7.5 kW		Lead-Acid	N/A			P-47 SU
Garrett/DOE	Spec built	241 cm 1300 kg 4-pass	Battery-Flywheel	N/A	(motor)	DC Sep Ex 21 kW	Lead-Acid 18x6V	Composite 1.0 kWh	Transistor Chopper	Spec gear Reg Braking	P-48 PL
Wallace Moore	Honda CVCC Wagon 1977-	228 cm - 4-pass	HE-B-Solar Parallel[1]	SC Otto gasoline	none	DC Series 2x2.5 kW	Lead-Acid 6x6 kW	N/A	Contactors Resistors	3s manual No Reg Br	P-49 RC
PGE, Italy (taxi)	Spec built	223 cm 1450 kg 5-pass	HE-Battery Parallel On-Off	UC Otto gasoline	none	DC Sep Ex 9 kW	Lead-ACid 12x6V	N/A	Transistors Thyristors	4s manual Reg Braking	P-50 RC
Henry Knauper	68 VW Beetle	240 cm	HE-Battery	UC Otto gasoline 7.5 kW		DC 9 kW	Lead-Acid 12x6V	N/A	Contactors		P-51 PL
Daihatsu, Japan (Fellow Max)	1970-	209 cm 850 kg 2-pass	HE-Battery Parallel[1]	UC Otto gasoline	(motor)	DC Series 5.3 kW	Lead-Acid 72V	N/A	SCR Chop	4s manual Reg Braking	P-52 SU
Toyo Kogyo, Japan (EX 005)	Spec built 1970-	450 kg 4-pass	HE-Battery Series	Rotary gasoline	DC 3 kW	DC 2x1 kW	Lead-Acid 8x12V	N/A			P-53 SU
Degruchy, England											P-54 SU
Hughes, England											P-55 SU

1. Heat engine front wheel drive and electric motor rear wheel drive.

TABLE 6 (contd)

SUMMARY VEHICLE DESCRIPTION OF HYBRID PASSENGER CARS /Page 6

Manufacturer and Owner	Chassis & Years of Operation	Wheelbase Curb Weight Passengers	Hybrid Type	Heat Eng. Fuel and kW-Max	Generator Type and kW-Rated	El-Motor Type and kW-Rated	Batteries Voltage & Weight	Flywheel Weight & kWh-Max	Electric Power Conditioning	Transmision and Regen. Braking	Notes & Status
Freeman, England											P-56 SU
Skeels, England	Leyland Minivan		HE-Battery Parallel[1]	UC Otto	none	DC Series 5.3 kW	Lead-Acid 6x12V	N/A	Thyristor Chopper	No Reg Br	P-57 RC
Mechanical United Assoc.	Mercedes		HE-Battery	UC Otto gasoline		DC SepEx	Lead-Acid 4x12V	N/A	SCR Chop	No transm P-58	RC
JMJ Electronics	78 Dodge Omni 1978-		HE-Battery Series On-Off	UC Otto gasoline 7.5 kW				N/A			P-59 RC
Edwards Electronics											P-60 RC
Electric Fuel Propulsion			HE-Battery Series On-Off					N/A			P-61 RC
Electric Passenger Car											P-62 SU
General Engine											P-63 SU
Hybricon	78 Honda 600 1978-	4-pass	HE-Battery Parallel[1]	SC Otto Gasoline 24 kW	None	DC 2x	Lead-Acid 7x6V	N/A		Reg Braking	P-64 RC

1. Heat Engine front wheel drive and electric motor rear wheel drive

TABLE 7

SUMMARY VEHICLE DESCRIPTION OF HYBRID TRUCKS AND VANS /Page 1

Manufacturer and Owner	Chassis & Years of Operation	Wheelbase Curb Weight Passengers	Hybrid Type	Heat Eng. Fuel and kW-Max	Generator Type and kW-Rated	El-Motor Type and kW-Rated	Batteries Voltage & Weight	Flywheel Weight & kWh-Max	Electric Power Conditioning	Transmision and Regen. Braking	Notes & Status
Lead Industries Association	Battronic Minivan	240 cm - 2-pass	HE-Battery Series Continuous	Stirling propane 2.5 kW		DC Series 31.5 kW	Lead-Acid 2x56V	N/A	SCR Chop & contac-tors	2s manual No Reg Br	Former EV T-1 PL
Energy R&D	Spec built 1977-	240 cm 1705 kg 2-pass	HE-Battery Series On-Off	UC Otto gasoline 12 kW	DC Shunt 7.5 kW	DC Series 18.5 kW	Lead-Acid 16x6V	N/A	SCR Chop w/bypass	4s manual No Reg Br	T-2 RC
Nissan Motor Japan (EV4-H)	Spec built 1977-	244 cm 3595 kg 2-pass	Dual Battery		none	DC Shunt 27 kW	Zn-Air 165 V Lead-Acid	N/A	SCR Chop	No transm Reg Braking	T-3 SU
U. S. Army MERADCOM	1971-	4300 lb	HE-Battery Series	Brayton 2x30 kW		DC Series 4x30 kW	Ni-Cad 96V	N/A			T-4 SU
Gould	AMG Jeep 1976-77	206 cm 1500 kg 2-pass	HE-Battery Parallel Continuous	UC Otto gasoline 19 kW	(motor)	DC Sep Ex	Lead-Acid 12x12V 196 kg	N/A	SCR Chop	CVT Reg Braking	T-5 SU
Garrett Corp.	AMG Jeep DJ-5E 1978-	206 cm 1485 kg 2-pass	Battery-Flywheel	N/A	N/A	DC 15 kW	Lead-Acid 54V		SCR Chop	CVT Reg Braking	T-6 RC
S. Illinois University	VW Beetle (modified)	240 cm 1270 kg 2-pass	HE-Battery Series Continuous	UC Otto Methanol 2x7.5 kW	3.3 kW	DC Shunt 12 kW	Lead-Acid 12x6V	N/A	Transistors	4s manual	T-7 PL
SRF, Israel	Bedford Van	2800 kg 2-pass	Battery-Flywheel	N/A	N/A	DC Sep Ex 19 kW @4500 rpm	Lead-Acid 144V			CVT Reg Braking	T-8 RC
PGE, Italy (M3 pick-up van)	Spec built	160 cm 970 kg 2-pass	HE-Battery Parallel On-Off	UC Otto gasoline	none	DC Sep Ex 5 kW	Lead-Acid	N/A	Transistors Thyristor Chopper	4s manual Reg Braking	T-9 RC
Fiat, Italy											T-10 SU
Tech Univ. Denmark			HE-Hydraulic	UC Otto gasoline	N/A	N/A	N/A	N/A			T-11 RC

TABLE 7 (contd)

SUMMARY VEHICLE DESCRIPTION OF HYBRID TRUCKS AND VANS /Page 2

Manufacturer and Owner	Chassis & Years of Operation	Wheelbase Curb Weight Passengers	Hybrid Type	Heat Eng. Fuel and kW-Max	Generator Type and kW-Rated	El-Motor Type and kW-Rated	Batteries Voltage & Weight	Flywheel Weight & kWh-Max	Electric Power Conditioning	Transmision and Regen. Braking	Notes & Status
Daihatsu, Japan (DV26T-HB)	Daihatsu Truck 1977-	300 cm 2695 kg 3-pass	HE-Battery Parallel	Diesel diesel	(motor)	DC Shunt 8 kW @2600 rpm	Lead-Acid 6x12V 260 kg	N/A	SCR Chop	4s manual Reg Braking	T-12 RC
Toyo Kogyo Japan (Titan)	Mazda Titan 1976-	250 cm 2320 kg 3-pass	HE-Battery Parallei	Diesel diesel	AC	DC 7.5 kW	Lead-Acid 4x12V 175 kg	N/A	Contactors		T-13 RC
ITT Research Institute											T-14 SU
Power Train											T-15 SU

TABLE 8

SUMMARY VEHICLE DESCRIPTION OF HYBRID BUSSES

Manufacturer and Owner	Chassis & Years of Operation	Wheelbase Curb Weight Passengers	Hybrid Type	Heat Eng. Fuel and kW-Max	Generator Type and kW-Rated	El-Motor Type and kW-Rated	Batteries Voltage & Weight	Flywheel Weight & kWh-Max	Electric Power Conditioning	Transmision and Regen. Braking	Notes & Status
Billings Energy											B-1 RC
Fiat Italy											B-2 SU
General Motors	GM Coach (19) 1969-70	9000 kg	HE-Battery Series	Diesel 32 kW	AC 3phase 15 kW	DC 15 kW	Lead-Acid 84V	N/A			B-3 SU
Univ. of Florida	Otis Electrobus 1975-	412 cm 6800 kg 14-pass	HE-Battery Series Continuous	Diesel 45 kW	AC 3phase 2x15 kW	DC Series 37 kW	Lead-Acid 2x42V	N/A	Contactors & resistors	No transm No Reg Br	B-4 RC
Daimler-Benz W. Germany (OE 305)	1976-	560 cm 12800kg 88-pass	HE-Battery Series On-Off	Diesel 92 kW	AC 3phase 60 kW	DC Sep Ex 108 kW	Lead-Acid 360V	N/A	SCR Chop	Fixed ratio gear Reg Braking	B-5 RC
Kawasaki, Japan	1972-	480 cm 10150kg 79-pass	HE-Battery Series On-Off	Diesel	AC 3phase 27 kW	DC Series 67 kW @2400 rpm	Lead-Acid 420V	N/A	Thyristor Chopper	No Transm Reg Braking	B-6 RC

TABLE 9

PERFORMANCE OF HYBRID PASSENGER CARS /Page 1

Curb/Test Weight (kg)	P-3 Univ of Wisconsin 1800/1360		P-4 Univ of Wisconsin 1270/ -		P-6 Univ of Colorado 1150/ -		P-9 GMC (XEP-1A) 1340/1545	P-11 GMC (Stir-Lec II) 1475/ -	P-12 Minicars (C-1) 1360/ -	P-22 Kordesch (1st conv) 1000/1100	P-73 Kordesch (2nd conv) 1000/1360		
Operating Mode	HE On-Off	Flyw Only	HE Cont	Elec Only	HE On-Off	Elec Only	Elec Only	HE Cont	HE Cont	Elec Only	HE Cont[b]	HE Cont[c]	Elec Only
Maximum Speed:													
a. Continuous @ .... (kph)	115	na	80	50	64	56	90	100	-	65	-	65	-
b. For 10 seconds @ .... (kph)	130	130	95	-	73	-	-	-	120	100	-	100	90
Acceleration:													
a. 0-30 kph in .... (sec)	-	na	-	-	13	-	-			6	-	6	-
b. 0-50 kph in .... (sec)	4	na	10	-	30	-	9			14	-	15	-
c. 0-90 kph in .... (sec)	8	na	20	na	na	na	60			-	-	-	-
d. 30-60 kph in .... (sec)	2	na	-	na	-	na	9			12	-	12	-
e. 80-120 kph in .... (sec)	4	na	na	na	na	na	na			na	-	na	na
Gradeability:													
a. 5% grade @ .... (kph)	-	na	-	-	-	-	-			40	-	-	-
b. 10% grade @ .... (kph)	-	na	-	-	-	-	-			20	-	-	-
c. Maximum grade .... (%)	20	na	10	-	-	-	-			20	20	20	-
Range:													
w/Regenerative Braking?	yes	yes	yes	yes	yes	yes	no			no	no	no	no
a. EPA City for .... (km)	-	na	-	-	-	-	-			-	-	-	-
b. EPA Hyw for .... (km)	-	na	-	-	-	-	-			-	-	-	-
c. SAE J227a-D for ...... (km)	-	na	-	-	-	-	-			-	-	-	-
d. SAE J227a-C for ...... (km)	-	na	-	-	-	-	-			-	24	56	
e. Spec Cycle for .... (km)	-	na	-	-	-	-	-			-	-	-	-
f. Const Speed for ...... (km)	-	na	-	-	-	-	250[a]			225[a]	56[a]	121[a]	37[a]
Fuel Economy (gas only):													
w/Regenerative Braking?	yes	yes	yes	yes	yes	yes	yes			no	no	no	no
a. EPA City @ .... (mpg)	26.4	na	-	na	-	na	na			na	-	-	na
b. EPA Hyw @ .... (mpg)	-	na	12.0	na	-	na	na			na	-		na
c. SAE J227a-D @ .... (mpg)	-	na	-	na	-	na	na			na	-	-	na
d. SAE J227a-C @ .... (mpg)	-	na	-	na	-	na	na			na	35	15	na
e. Spec Cycle @ .... (mpg)	-	na	-	na	25	na	na			na	-	-	na
f. Const Speed @ .... (mpg)	-	na	-	na	-	na	na			na	80[a]	30[a]	na
Source:													
a. Manufacturer	●	●	●	●	●	●				●	●	●	●
b. NASA testing											●	●	●
c. SAE Paper							●						
d. Other Open Literature										●			

Legend: na (not applicable)
 \- (not available)

Notes: a. @55 kph
b. Low alternator speed (2800 rpm)
c. High alternator speed (3200 rpm)

TABLE 9 (contd)

PERFORMANCE OF HYBRID PASSENGER CARS /Page 2

Curb/Test Weight (kg)	P-27 Petro-Electric Motors 1875/1810	P-28 CAR (Dodge) 1980/ -		P-29 CAR/SCE (Hornet) 1930/2040		P-31 Univ of Florida 1270/ -		P-34 Volkswagen (Taxi) 1775/1800			P-40 Kinergy (Camaro) 1600/ -	P-41 Kinergy (Cadillac) 2500/ -	P-42 Kinergy (Volvo) 980/1140
Operating Mode	HE Cont	HE On-Off	Elec Only	HE Cont	Elec Only	HE Cont	Elec Only	HE On-Off	HE Only	Elec Only	HE On-Off	HE On-Off	HE On-Off
Maximum Speed:													
a. Continuous @ .... (kph)	95	65	20	65	-	100	-	105	105	70	120	90	150
b. For 10 seconds @ .... (kph)	135	-	-	70	70	-	-	-	-	-	140	105	150
Acceleration:													
a. 0-30 kph in .... (sec)	-	-	na	-	-	-	-	-	-	-	-	-	-
b. 0-50 kph in .... (sec)	-	30	na	9	-	9	-	9	9	-	[illegible]	13	4
c. 0-90 kph in .... (sec)	-	na	na	na	na	-	-	-	28	-	7	50	11
d. 30-60 kph in .... (sec)	-	30	na	-	-	-	-	-	-	-	2	15	3
e. 80-120 kph in .... (sec)	-	na	na	na	na	na	na	na	na	na	14	na	18
Gradeability:													
a. 5% grade @ .... (kph)	-	40	-	-	-	-	-	-	-	-	90	80	-
b. 10% grade @ .... (kph)	-	-	-	-	-	-	-	-	-	-	60	50	60
c. Maximum grade .... (%)	-	15	-	23	-	-	-	23	23	-	35	20	35
Range:													
w/Regenerative Braking?	yes	yes	yes	no	no	no	no	yes	yes	yes	yes	yes	yes
a. EPA City for .... (km)	-	-	-	-	-			-	-	-	-	-	-
b. EPA Hyw for .... (km)	-	-	-	-	-	-	-	-	-	-	-	-	-
c. SAE J227a-D for ...... (km)	-	-	-	-	-	-	-	-	-	-	-	-	-
d. SAE J227a-C for ...... (km)	-	-	-	-	-	-	-	-	-	-	-	-	-
e. Spec Cycle for .... (km)	-	-	-	-	-	-	-	-	-	-	-	-	-
f. Const Speed for ...... (km)	-	-	-	-	-	290[a]	16[a]	-	-	-	-	-	-
Fuel Economy (gas only):													
w/Regenerative Braking?	yes	yes	no	no	no	no	no	yes	yes	yes	yes	yes	yes
a. EPA City @ .... (mpg)	-	40	na	-	na	-	na	-	-	na	-	-	-
b. EPA Hyw @ .... (mpg)	-	-	na	-	na	-	na	-	-	na	-	-	-
c. SAE J227a-D @ .... (mpg)	-	-	na	-	na	-	na	-	-	na	-	-	-
d. SAE J227a-C @ .... (mpg)	-	-	na	-	na	-	na	-	-	na	-	-	-
e. Spec Cycle @ .... (mpg)	-	-	na	-	na		na	-	-	na	29[b]	-	38[d]
f. Const Speed @ .... (mpg)	-	-	na	-	na	23[a]	na	-		na	-	25[c]	-
Source:													
a. Manufacturer		●	●	●	●	●	●				●	●	●
b. NASA testing								●	●	●			
c. SAE Paper													
d. Other Open Literature		●	●			●	●						

Legend: na (not applicable)
- (not available)

Notes:
a. @ 50 kph
b. On road test: 487 km, average speed 74 kph
c. @ 80 kph
d. Suburban driving condition

TABLE 10

PERFORMANCE OF HYBRID TRUCKS AND BUSSES

	T-2 Energy R&D (HEVAN)		T-5 Gould (AMC Jeep)		T-12 Daihatsu (DV26T-HB)		B-4 Univ of Florida	
Curb/Test Weight (kg)								
Operating Mode	HE Cont	Elec Only	HE Cont	Elec Only	HE Cont	Elec Only	HE On-Off	Elec Only
Maximum Speed:								
a. Continuous @ .... (kph)					60	-		
b. For 10 seconds @ .... (kph)					80	25		
Acceleration:								
a. 0-30 kph in .... (sec)					-	na		
b. 0-50 kph in .... (sec)					-	na		
c. 0-90 kph in .... (sec)					na	na		
d. 30-60 kph in .... (sec)					-	na		
e. 80-120 kph in .... (sec)					na	na		
Gradeability:								
a. 5% grade @ .... (kph)					-	-		
b. 10% grade @ .... (kph)					-	-		
c. Maximum grade .... (%)					20	10		
Range:								
w/Regenerative Braking?					yes	yes		
a. EPA City for .... (km)					-	-		
b. EPA Hyw for .... (km)					-	-		
c. SAE J227a-D for ...... (km)					-	-		
d. SAE J227a-C for ...... (km)					-	-		
e. Spec Cycle for .... (km)					-	-		
f. Const Speed for ...... (km)					-	-		
Fuel Economy (gas only):								
w/Regenerative Braking?					yes	yes		
a. EPA City @ .... (mpg)					-	-		
b. EPA Hyw @ .... (mpg)					-	-		
c. SAE J227a-D @ .... (mpg)					-	-		
d. SAE J227a-C @ .... (mpg)					-	-		
e. Spec Cycle @ .... (mpg)					-	-		
f. Const Speed @ .... (mpg)					-	-		
Source:								
a. Manufacturer					●	●		
b. NASA testing								
c. SAE Paper								
Other Open Literature								

4. REFERENCES

The following literature was used in the initial step of identifying the hybrid vehicles built to date:

1. Current Status of Alternative Automotive Power Systems and Fuels, Volume IV: Electric and Hybrid Power Systems. The Aerospace Corporation, prepared for EPA, July, 1974.

2. Should We Have a New Engine? An Automotive Power Systems Evaluation, Volume II: Technical Reports. Jet Propulsion Laboratory, August, 1975.

3. Data Book: Electric and Hybrid Heat Engine/Electric Vehicles (working drafts). The Aerospace Corporation, prepared for ERDA (now DOE), October, 1976, and March, 1977.

4. A Pictorial Characterization of Worldwide Electric and Hybrid Vehicles. Robert Kirk and Kenneth Barber, prepared for ERDA (now DOE), August, 1977.

5. Recommended Performance Standards for Electric and Hybrid Vehicles. Arthur D. Little, Inc., prepared for ERDA (now DOE), October, 1977.

6. State-of-the-Art Assessment of Electric and Hybrid Vehicles. NASA Lewis Research Center, prepared for ERDA (now DOE), January, 1978.

7. Electric Vehicle Research, Development and Demonstration Act of 1975 (H.R. 5470), Hearings. 94th Congress, June, 1975.

8. Bibliography on Electric Vehicles, 1967-76. GM Research Laboratories Library, April, 1977.

9. Fourth International Electric Vehicle Symposium, Volumes 1 and 2, Dusseldorf. Electric Vehicle Council, 1976.

10. Electric Vehicle News, Volumes 1 through 6. 1972-77.

5. REVIEW FORMS

The following pages show the two review forms utilized in this hybrid vehicle review:

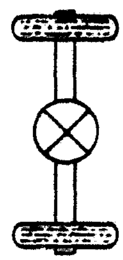
- The Summary Vehicle Description Form (Page 29)

- The Detailed Vehicle Specification Form (Pages 30-35) jpl

SUMMARY VEHICLE DESCRIPTION

- Veh. No.
- Status
- Date

Drive train schematic:



Controls: — — —

Electrical Power: ———

Mechanical Power: ———

Manufacturer: ____________

Contact: ____________ Wheelbase: ________ cm

Chassis: ____________ ; Years of operation: ________

Curb weight: ________ kg; Payload: ________ kg; GVW: ________ kg

Cargo capacity: ________ m^3 No. of passengers: ________

Fuels: Gasoline ☐ ; Diesel ☐ ; Electricity ☐ ; Other(s): ________

Storages: Fuel tank ☐ ; Batteries ☐ ; Flywheel ☐ ; Other(s): ________

Hybrid type: Heat-engine ☐ ; Battery ☐ ; Flywheel ☐ ; Other(s): ________

Heat-engine: UC Otto ☐ ; SC Otto ☐ ; Diesel ☐ ; Other: ______ ; kW-max: ______

El-motor: DC Series ☐ ; DC Sep. Excited ☐ ; Other: ______ ; kW-rated: ______

Battery: Lead Acid ☐ ; Other: ________ Voltage: ______ V(x V)

Flywheel: Steel ☐ ; Composite ☐ ; Storage Cap.: ____ kwh; Weight: ____ kg

Controller: SCR Chopper ☐ ; Transistors ☐ ; Other: ____________

Transmission: Manual __ -speed ☐ ; Automatic ☐ ; CVT ☐ ; Other: ________

Regenerative braking: yes ☐ ; no ☐

Generator: 3 phase AC ☐ ; Other: ________ ; Rated: ________

Purpose of this particular hybrid design (conversion):

lower emissions ☐ ; better fuel economy ☐ ; fuel substitution ☐ ;

range extension ☐ ; better acceleration/gradeability ☐ ;

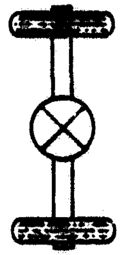
Other: ____________

Veh. no.
Status
Date

DETAILED VEHICLE SPECIFICATIONS

Vehicle: ____________________

Drive train schematic:



Controls: — — —

Electric Power: ———

Mechanical Power: ▬▬▬

General Description

Length	cm	Wheelbase	cm	Seating Capacity	pass.
Width	cm	Curb Weight	kg	Cargo Capacity	m^3
Height	cm	Gross V.W.	kg	Fuel Capacity	ℓ
		Frontal Area	m^2	Drag Coefficient	

	Type	Model	Weight	Manufacturer
Transmission				
Differential				
Clutches				
Suspension				
Brakes				
Tires				
Accessories				

Converted		
Present status		Date:

Page 1

DETAILED VEHICLE SPECIFICATIONS (Continued)

Veh. no.

Major Drive Train Components

Engine

Manufacturer:	
Type:	Model & year:
Max. Hp: @ rpm (abs. maximum) Eff. Hp: @ rpm (most fuel efficient) Opr. Hp: @ rpm (operating level)	

Displacement vol.: cc	Compr. ratio:
No. of cylinders:	Net weight: kg
Fuel:	Optional fuels:
Fuel consumption @ operating level: 1/hour	
BSFC Map attached: ☐ yes ☐ no	
Engine modified: ☐ yes ☐ no	
Fuel system:	
Lubrication system:	
Starting system:	
Cooling system:	
Supplementary notes:	

Generator

Manufacturer:	
Type:	Model & year:
Rated: KVA @ rpm @ volt)	
Cooling system:	
Operating output:	
Net weight: kg	Modified: ☐ yes ☐ no

Rectifier

Manufacturer:
Type:

Page 2

Veh. No.

Major Drive Train Components (Continued)

Motor

Manufacturer:			
Type:	Model & year:		
Rated: kW (Hp) @ rpm			
Max.: kW (Hp) @ rpm for mins			

Modified: ☐ yes ☐ no	Net weight: kg
No. of motors:	Volume: m^3
Torque vs. speed map attached ☐ yes ☐ no	
Efficiency vs. speed map attached ☐ yes ☐ no	
Cooling system:	
Supplementary notes:	

Batteries

Manufacturer:		
Type:	Model & year:	
Voltage: volt (x V)	Weight: kg	
Operating voltage(s):	Volume: m^3	
Peak Power: kW	Watering system:	

	2 hrs.	3 hrs.	4 hrs.	hrs.
Amp.-hours at var. discharge rates:				
Watt-hours/kg:				
Cycle life claim: cycles @ % discharge				
Supplementary notes:				

Charger

Manufacturer:	
Type:	Model & year:
Volume: m^3	Weight: kg

Page 3

Veh. No.

Major Drive Train Components (Continued)

Flywheel

Manufacturer:				
Type:	Model & year:			
Weight: kg (net); kg (w/housing & vac pump)				
Thickness: mm	Diameter: cm			
Housing material:	Housing pressure: psi			
Vacuum pump manufacturer:				
Vacuum pump type & model:				
Max. speed: rpm	Peak power: kw @ max. rpm			
Energy map attached (kwh vs. rpm) ☐ yes ☐ no				
	rpm	rpm	rpm	rpm
Charging time from 0 rpm to var. speeds:	sec.	sec.	sec.	sec.
Energy used (kwh):				
Energy available (kwh):				
Operating range: to rpm				
Supplementary notes:				

Power Conditioning (Controller)

Manufacturer:	
Type:	Model & year:
Volume: m^3	Weight: kg
Cooling system:	
Block circuit diagram attached:	
Efficiency map attached:	
Max. capacity (power):	
Supplementary notes:	

Page 4

DETAILED VEHICLE SPECIFICATIONS (Continued)

Veh. No.

Other Characteristics

Accessory Battery

Manufacturer:	
Type:	Model & year:
Voltage: volt (x V)	Weight: kg

Other Drive Train Comp.

Type:	Detailed descr. attached:
Type:	Detailed descr. attached:
Type:	Detailed descr. attached:

Safety Considerations

Tests, rating, compliance with Fed. Safety Std:

Control Strategy

Special Characteristics

Information Sources

1.
2.
3.
4.

DETAILED VEHICLE SPECIFICATIONS (Continued)

Veh. No.

Vehicle Performance

Data source

Manufacturers spec's: ☐ ;	Test data: ☐
Test weight: kg	Test date:
Source document:	

Speed

Cruise (continuous):	km/hr (	mph)
Maximum (10 secs):	km/hr (	mph)
Max. (electric only):	km/hr (	mph)

Acceleration

0 - 50 km/hr:	sec	30 - 60 km/hr:	sec
0 - 90 km/hr:	sec	80 - 130 km/hr:	sec
- km/hr:	sec	- km/hr:	sec

Gradeability

Distance at various grades and speeds		%	%	%
	km/hr.	km	km	km
	km/hr.	km	km	km
	km/hr.	km	km	km
Max. grade: %				

Range and fuel economy

Driving cycles	Hybrid mode			Electric mode		
	km	km/MJ	mpg	km	km/MJ	mpg
EPA Highway						
EPA City						
J227a B						
J227a C						
J227a D						
Fuel economy map attached: ☐ yes ☐ no						

Supplementary notes

Page 6

END

DATE FILMED

05/07/80