ELECTRIC & HYBRID VEHICLE TECHNOLOGY

TOPTEC

SEPTEMBER 14-15, 1992

DEARBORN, MI

A FOCUSED TOPICAL TECHNICAL WORKSHOP SPONSORED

BY

SAE's CONTINUING PROFESSIONAL DEVELOPMENT GROUP

AND

THE U.S. DEPARTMENT OF ENERGY

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FOREWORD

At the turn of the century, there were more electric vehicles on the road than gasoline-powered vehicles. It was difficult for the electric vehicle and its battery system to compete with the superior energy density, power and inexpensive price of petroleum-based fuels, however, and the electric vehicle became an oddity as petroleum-powered vehicles took over the vehicle population. Today, growing awareness of environmental and energy issues associated with the automobile has resulted in renewed interest in the electric vehicle. In recognition of this, the Society of Automotive Engineers has added a TOPTEC on electric vehicles to the series of technical symposia focused on key issues currently facing industry and government.

This workshop on the Electric and Hybrid Vehicle provides an opportunity to learn about recent progress in these rapidly changing technologies. Research and development of both the vehicle and battery system has accelerated sharply and in fact, the improved technologies of the powertrain system make the performance of today's electric vehicle quite comparable to the equivalent gasoline vehicle, with the exception of driving range between "refueling" stops. Also, since there is no tailpipe emission, the electric vehicle meets the definition of "Zero Emission Vehicle: embodied in recent air quality regulations.

The discussion forum will include a review of the advantages and limitations of electric vehicles, where the technologies are today and where they need to be in order to get to production level vehicles, and the service and maintenance requirements once they get to the road.

There will be a major focus on the status of battery technologies, the various approaches to recharge of the battery system, and the activities currently underway for developing standards throughout the vehicle and infrastructure system.

Intermingled in all of this technology discussion will be a view of the new relationships emerging between the auto industry, the utilities, and government. Since the electric vehicle and its support system will be the most radical change ever introduced into the private vehicle sector of the transportation system, success in the market requires an understanding of the role of all of the partners, as well as the new technologies involved.

Your feedback on these workshops, including both the technical content and arrangements, is needed in order to ensure continuous improvement of their value to the professional community, so please do not hesitate to ask questions or offer critiques. The organizers and SAE Staff look forward to your comments.

ACKNOWLEDGMENTS

The Society of Automotive Engineers expresses its sincere appreciation to the workshop organizers:

Mr. A. Scott Keller
Senior Test Engineer
Electrotek Concepts, Inc.

Dr. Roberta J. Nichols
Manager, Electric Vehicle Strategy & Planning Department
Electric Vehicle Planning & Program Office
Ford Motor Company

and to the following sponsor:

U.S. Department of Energy

Organizer Biography - Electric & Hybrid Vehicle Technology TOPTEC

A. Scott Keller
Senior Test Engineer
Electrotek Concepts Inc.

Mr. Keller is Senior Test Engineer in charge of electric vehicle component evaluation for Electrotek. His work includes the testing of battery chargers, battery management/monitoring systems, battery thermal management systems, and vehicle subsystems such as air conditioners and power steering.

With over 12 years in electric and hybrid vehicle research and testing, Mr. Keller has written over 25 publications on the topic. He is a registered professional engineer with a BEE from Georgia Tech and will receive his MSEE in December from the University of Tennessee. His credentials also include being a senior member of IEEE, a session organizer and chairman for the 1991 Society of Automotive Engineers Passenger Car Meeting Electric Vehicle Session and a member of Eta Kappa Nu.

Organizer Biography - Electric & Hybrid Vehicle Technology TOPTEC

Roberta J. Nichols
Manager, Electric Vehicle Strategy & Planning Department
Electric Vehicle Planning & Program Office
Ford Motor Company

Robert J. Nichols is Manager of the Electric Vehicle Strategy and Planning Department in the Electric Vehicle Planning and Program Office, Technical Staffs, Ford Motor Company.

Dr. Nichols has been responsible for providing technical leadership in alternative fuels to Ford's worldwide operations.

Dr. Nichols joined Ford in 1979 and assumed a lead role in the company's propane, natural gas, and alcohol fuel vehicle programs. Ford's current emphasis is on Flexible Fuel Vehicles, which can burn alcohol, gasoline, or any combination of these, from the same tank. Dr. Nichols is named on three United States patents for control systems for engine operation using two fuels of different octane, volatility, and volumetric energy content.

Prior to joining Ford, she was a Member of the Technical Staff of The Aerospace Corporation, El Segundo, California for 19 years. She also served as a consultant to the State of California's Synthetic Fuels Program in 1978-79.

A native of Los Angeles, Dr. Nichols received a B.S. degree in Physics in 1968 from the University of California at Los Angeles. She earned an M.S. in Environmental Engineering in 1975 and a Ph.D. in Engineering in 1979, both from the University of Southern California.

She is the recipient of many professional honors, including the Outstanding Engineer Merit Award from the Institute for the Advancement of Engineering (1974), The Woman of the Year Award from The Aerospace Corporation (1975), the National Achievement Award from the Society of Women Engineers (1988), a Clear Air Award for Advancing Air Pollution Technology from the South Coast Air Quality Management District (1989), election to Fellow grade membership in the Society of Automotive Engineers (1990), and selection as the engineering profession representative in the Clairol Corporation Mentor Program (1991). She is listed in several publications such as the World Who's Who of Women, and American Men and Women in Science.

ELECTRIC & HYBRID VEHICLE TECHNOLOGY
TOPTEC
September 14 & 15, 1992

FINAL AGENDA:

DAY ONE

Section 1

AGENDA

Monday, September 14, 1992

7:00 am - 5:00 pm	Registration - The Dearborn Inn
8:00 am - 8:15 am	Welcome & Introduction - A. Scott Keller, Sr. Test Engineer, Electrotek Concepts Inc.
8:15 am - 8:45 am	Electric Vehicles: Introduction and Overview - Geoff Harding, Sr. Exec. Special Vehicles, International Automotive Design
8:45 am - 9:30 am	Vehicle Characteristics - Robert McKee, President, McKee Engineering
9:30 am - 10:00 am	Break
10:00 am - 10:30 am	Battery System Technologies I (Overview) - Andrew Burke, Principal Program Specialist, Idaho National Engineering Lab
10:30 am - 11:00 am	Battery System Technologies II (Present & Near-Term) - Michael Andrew, Mgr., Advanced Lead-Acid, Johnson Controls, Inc.
11:00 am - 11:30 am	Battery System Technologies III (Advanced/Future & Fuel Cells) - Paul Butler, Dept. Manager, Sandia National Lab
11:30 am - 12:00 pm	Questions & Answers
12:00 pm - 1:30 pm	Lunch with Invited Keynote Speaker, Alan Lloyd, Chief Scientist, South Coast Air Quality Management District
1:30 pm - 2:00 pm	Battery Support Systems - Kenneth Winter, Manager, Power Control, Chrysler Corp.
2:00 pm - 2:30 pm	Battery Charger Principles - Grover Wilson, Engineering Manager, Hobart Brothers Co.
2:30 pm - 3:00 pm	Break

3:00 pm - 4:00 pm	Vehicle Powertrain Technologies - Wally Rippel, President, AC Propulsion, Inc.
4:00 pm - 4:30 pm	Infrastructure Requirements - James Janasik, Project Manager, Electric Power Research Inst.
4:30 pm - 5:00 pm	Questions & Answers

Revised 8/25/92

ELECTRIC & HYBRID VEHICLE TECHNOLOGY
TOPTEC
September 14, 1992

ABSTRACTS, BIOGRAPHIES

& PRESENTATIONS

Section 2

ELECTRIC & HYBRID VEHICLE TECHNOLOGY
TOPTEC
SEPTEMBER 14, 1992

Welcome & Introduction

A. Scott Keller, Electrotek Concepts, Inc.

Abstract-Electric & Hybrid Vehicle Technology TOPTEC
Monday, September 14, 1992

Electric Vehicles: Introduction & Overview

Geoffrey Harding
Sr. Executive - Special Vehicles
International Automotive Design U.K. Ltd.

To introduce this TOPTEC Discussion and initially present an overview of the current and future electric vehicle scene, it is necessary to group vehicles in some way and then consider only certain factors common to all (or at least most) of the vehicles within each group.

Undoubtedly, the worldwide interest in the environment has provided a stimulus to EV and hybrid development such that, for a variety of reasons, most of the world's major vehicle manufacturers have invested significant sums in their respective EV programs. Without such investment, it is difficult to see how electric and hybrid vehicle producers could ever have available the essential supplier vase they require and, without such investment, it is not possible to see any real chance of the cost of drive system equipment being substantially reduced. This is absolutely necessary if at least some of the economic problems surrounding EV's are to be eliminated.

It will be suggested that lead acid battery powered vehicles will for a long time continue to a attractive for some EV applications and one major factor which will restrict the attraction of the advanced batteries with higher and higher energy densities will be the problem of replacing the energy after it has been consumed. Another will be that even if a relatively low cost per kWh for high capacity batteries can be achieved such batteries are likely to be economically unattractive for applications other than those where high DOD's are required very frequently.

As a possible solution to the problems of energy storage, the concepts of various hybrid systems will be explored. The hybrid is the most likely vehicle to stimulate market penetration but comments will be made on emission test procedure that could inhibit development of vehicles that would, overall, have the most significant benefit in reducing mobile pollution.

Electric vehicles are regarded today as the only zero emission vehicles available. Certainly, in large numbers, they have the ability to improve the environment around them but even more work is necessary to convince skeptics that their introduction is a good way to assist in the preservation of world energy resources and reduce atmospheric pollution.

The implications of attempting to match what customers expect from today's excellent ICE automobiles using cleaner vehicles which can only store very small amounts of energy on board will also be addressed.

Biography-Electric & Hybrid Vehicle Technology TOPTEC

Geoffrey Harding
Sr. Executive - Special Vehicles
International Automotive Design U.K. Ltd.

Mr. Geoffrey Harding is currently Senior Executive - Special Vehicles, IAD UK Ltd. The responsibilities of his position include heading up IAD Electric Vehicle Systems in Redditch, UK which contains all of IAD's expert personnel involved with Electric and Hybrid Vehicles and their systems.

For the past 19 years, Mr. Harding has been responsible for Electric and Hybrid Vehicle development in Lucas, UK and, subsequently, IAD. Prior to this, he spent 25 years in public transport engineering operations with buses, trucks, trains, ships and hovercraft.

Mr. Harding became a chartered engineer, a member of the Institution of Mechanical Engineers and of several other institutes and institutions by examination. He has been a senior research fellow of Birmingham (UK) University. He is a fellow of the Society of Automotive Engineers and was named "Man of the Year" in 1983 by the Electric Vehicle Council (of the USA). Mr. Harding has had published many papers on variety of electric and hybrid vehicle matters and on public transport topics including the design of hovercraft.

SAE INTERNATIONAL

** NOTES **

ALTERNATIVE FUEL SERIES

SAE in the 90s

Abstract-Electric & Hybrid Vehicle Technology TOPTEC
Monday, September 14, 1992

Vehicle Characteristics: Vehicle Mechanical Design

Robert S. McKee
President
McKee Engineering Corporation

Topics discussed will be size, weight, aerodynamics, rolling resistance, suspension geometry and mechnical drive train. Also covered will be the packaging of batteries so they can be removed for service or exchange.

Biography-Electric & Hybrid Vehicle Technology TOPTEC

Robert S. McKee
President
McKee Engineering Corporation

Mr. Robert McKee has been President of McKee Engineering Corporation for 30 years. He is actively involved in the design and fabrication of prototype electric vehicles and component parts, including battery handling systems, frames, suspension systems and drive trains.

Mr. McKee attended Michigan Tech and the University of Nebraska.

SAE INTERNATIONAL

** NOTES **

ALTERNATIVE FUEL SERIES

SAE in the 90s

Abstract-Electric & Hybrid Vehicle Technology TOPTEC
Monday, September 14, 1992

Battery System Technologies I - Overview

Andrew F. Burke
Principal Program Specialist, Energy Programs Group
EG&G Idaho, Inc., Idaho National Engineering Laboratory

Battery system (pack) requirements for each of the vehicles considered in the study are given in Table 2 of the following material. These requirements apply to all battery types. Battery cell and module characteristics must be compatible with the pack requirements of the vehicle if a particular battery is to be used in that vehicle. In other words, it must be possible to configure a battery pack of the required voltage and planform and height dimensions using available cells/modules of the particular battery before that battery can be used in the vehicle. Since space and voltage requirements vary significantly for the various vehicles, no single cell or module can be expected to be suitable for all vehicles. Hence, for each battery type and technology, a family of batteries is needed to meet electric vehicle requirements. Fortunately, in may cases, battery companies market a family of designs for each of their battery technologies. Additional module sizes using the same technology would likely be mad available if required by particular vehicle designs.

Biography-Electric & Hybrid Vehicle Technology TOPTEC

Andrew F. Burke
Principal Program Specialist, Energy Programs Group
EG&G Idaho, Inc., Idaho National Engineering Laboratory

Dr. Burke received a B.S. and M.S. in applied mathematics from Carnegie Tech and a M.S. and Ph.D. in mechanical and aerospace engineering from Princeton University. He has taught engineering at Clarkson College and Union College.

Dr. Burke has worked on electric and hybrid vehicles at the Jet Propulsion Laboratory and General Electric. he is presently a Principal Program Specialist in the Electric/Hybrid Vehicle Program at the Idaho National Engineering Laboratory in Idaho Falls, Idaho. He has published numerous papers and reports on electric vehicles and batteries and is currently involved with the evaluation of Supercapacitors for electric vehicle applications.

Table 2. Battery Requirements and Constraints

Name	Max Weight (kg)	System Voltage	Peak Power (kW)	Max. Volume (ℓ)	Max. Pack Dimensions (cm) (L)	(W)	(H)
1998 Vehicles							
Car A	350	340-360	45	265	85	96.5	32
Van A	450	340-360	65	365	117	96.5	32
Van B	700	340-360	98	525	170	96.5	32
ETX-II	600	340-360	65	444	185	75	32
Impact	380	340-360	65	185	185	25	40
ETV-I	450	340-360	45	260	190 [a] 76	28 53	28 28
1990 Vehicles							
TEVan	900	208	65	397	210	70	27
DSEP	900	195	65	365	187	75	26
ETX-II	600	200	65	360	185	75	26
GVan	1170	216	55	535	187	110	26

(a) T-shaped battery box; center tunnel and rear-box

Table 3. Characteristics of Johnson Controls, Inc. Sealed Lead-Acid Batteries

Module[a]	Voltage	(Ah)C/3	Weight(kg)	Dimensions (mm) L	W	H	Volume (ℓ)	Wh/kg C/3	Wh/ℓ C/3
GC6V200	6	130	32.7	321	178	259	14.8	23.7	52
U-1-31	12	23	10.9	198	133	185	4.9	25.1	56
GC12400	12	27	15.0	228	139	205	6.5	21.4	49
GC12550	12	37	18.6	261	173	226	10.2	23.7	43
GC12800	12	57	24.5	331	174	214	12.3	27.7	55
GC12V100[b]	12	66	30.9	331	174	241	13.9	25.4	56

(a) This is the Dynasty series of batteries

(b) Tested at INEL (Reference 5): C/3 - 68 Ah, 26.9 Wh/kg

Table 4. Characteristics of Sonnenschein Sealed Lead-Acid Batteries

Module[a]	Voltage	(Ah)C/3	Weight(kg)	Dimensions (mm) L	W	H	Volume(ℓ)	Wh/kg C/3	Wh/ℓ C/3
DF 6V180[b]	6	150	30.2	245	190	276	12.8	29.3	70
DF 45	12	25	10.4	196	132	180	4.7	28.4	63
DF 75	12	35	12.3	210	175	175	6.4	33.5	65
DF 115	12	50	17.8	278	175	175	8.5	33.1	69
DF 150	12	65	23.1	381	175	190	12.7	32.7	60
DF 180	12	75	30.0	330	170	240	13.6	29.5	65
DF 4DLT	12	90	39.0	514	190	222	21.7	27.2	50

(a) This is the Dryfit Prevailer Marine and RV series of batteries

(b) Tested at INEL (Reference 7): C/3 - 150 Ah, 28.0 Wh/kg

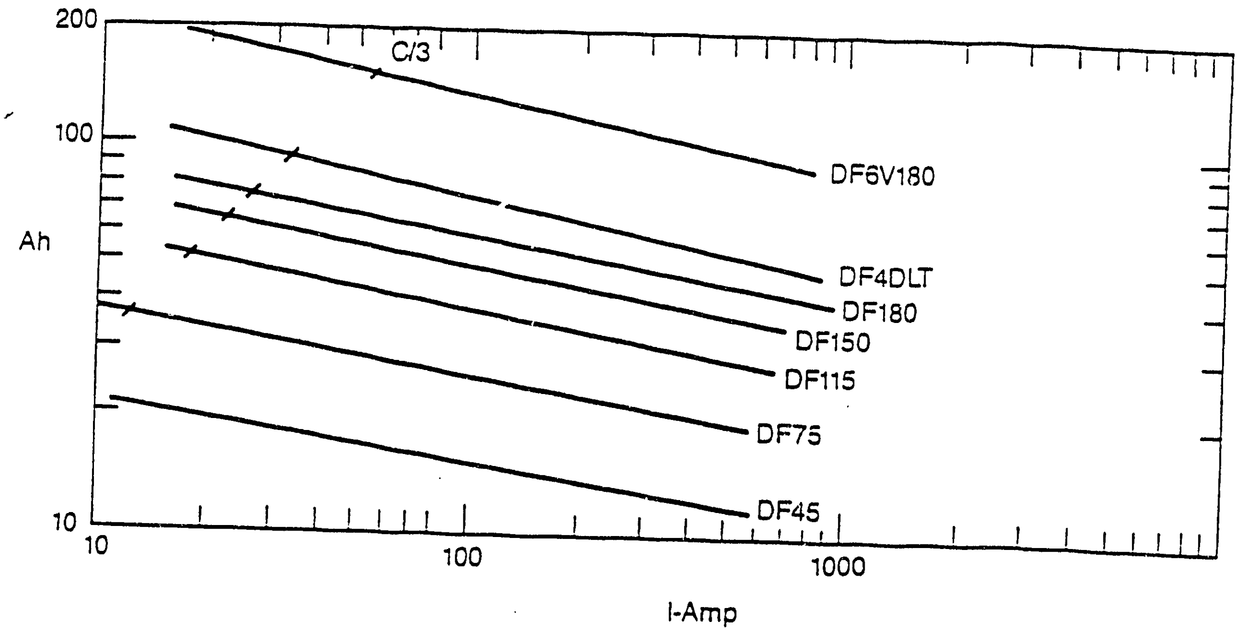


Figure 2: Peukert Curves for the Sonnenschein sealed lead-acid batteries.

1-6632

Table 7. Characteristics of Sealed Nickel-Cadmium Batteries

Module[a]	Voltage[b]	(Ah) C/3	Weight (kg)	Dimensions (mm) L	W	H	Volume (ℓ)	Wh/kg C/3	Wh/ℓ C/3
H 40	6.5	42	6.5	140	115	165	2.66	39.4	96
H 50	6.5	53	7.5	180	115	165	3.41	43.2	95
H 60	6.5	63	8.5	200	115	165	3.79	44.5	100
H 70	6.5	72	9.5	230	115	165	4.36	46.2	101
H 80	6.5	84	10.5	265	115	165	5.03	48.8	102
H 90	6.5	95	11.5	295	115	165	5.60	50.4	103
H 100	6.5	106	12.5	325	115	165	6.16	51.0	105

(a) Hoppecke sealed nickel-cadmium batteries under development - engineering estimates of cell performance

(b) 5 cells per module

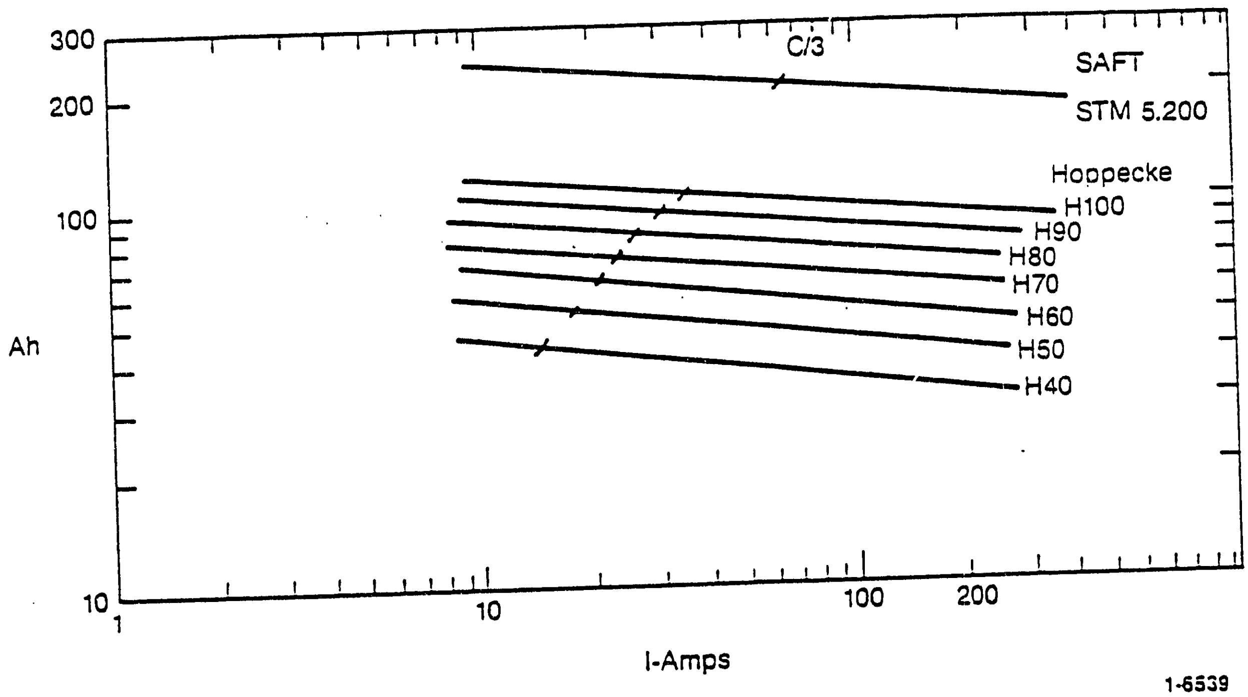


Figure 5: Peukert Curves for sealed nickel-cadmium batteries.

NEWS
National/Panasonic
Technics / Quasar
7 May 1992
MEP-92-10

World's First Sealed Nickel Metal Hydride Battery for Electric Vehicle Developed by Matsushita

1. HIGH ENERGY DENSITY

   Energy density of 70 Wh/Kg was achieved through increasing the charge ability of the nickel electrode under high temperatures, and improving the composition of the hydrogen absorbing alloy ($MmNi_5$). With this high storage efficiency --twice that of lead storage batteries -- the battery component of an electric vehicle can be made smaller and lighter.

2. HIGH OUTPUT POWER

   Through a new composition of electrodes, the battery can generate power of up to 180 W/Kg, with 170 W/Kg even at the end of the discharge.

3. LONG LIFE SPAN

   Through increased durability of the positive and negative materials and a dual pocket construction with a thin, heat-resistant separator for extra protection, the life span of the battery has been extended to 1500 charges. This eliminates the need for replacing the battery every two to three years, as required by lead storage batteries.

4. MAINTENANCE-FREE

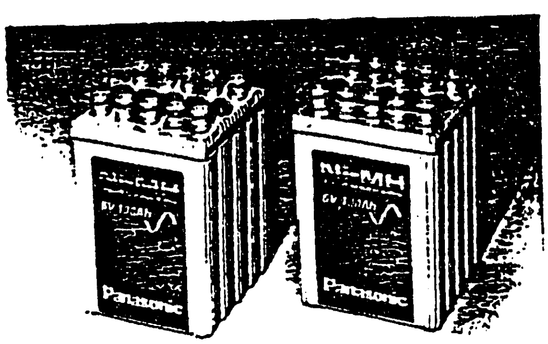
   The application of pressure resistant materials and special seal technology enabled Matsushita to fully close the battery, eliminating the maintenance.

5. RECYCLABILITY

   Not only is the battery itself friendly to the environment, the nickel and hydride substrates and the casing have been designed for recyclability.

SPECIFICATIONS

Voltage:	6 volts
Capacity:	130 ampere-hours
Dimensions (W x D x H):	162 mm x 162 mm x 210 mm
Weight:	11 Kg
Energy Capacity:	70 Wh/Kg (goal: 80 Wh/Kg) 140 Wh/l
Output Capacity:	170 W/Kg
Recharge Cycles:	1500 times
Temperature Range:	-20C to +60C



Prototype of Nickel Metal Hydride Storage Battery for Electric Vehicle (Matsushita Electric, May, 1992)

Table 9. Cost and cycle life information on various batteries

Battery Type	Manufacturer/ Module	Capacity (Wh) C/3	Module (a) Cost $	$/kWh	Cycle Life (b)
Lead-Acid Flooded	Lucas Chloride 3ET205	1050	275	262	N.A.V.
	Japan Storage				
	E75P	810	330	407	600
	ED150P	1610	590	366	1000
Lead-Acid Sealed	Sonnenschein				
	DF6V180	895	160	179	700(c)
	DF 150	775	110	142	700
	DF 75	420	73	174	700
	DF 45	298	50	168	700
	Johnson Controls				
	GC6V200	775	232	299	500(d)
	GC12V100	785	233	297	500
	GC12550	440	167	380	500
	GC12400	320	131	410	500
	U1 - 31	275	95	345	500
Nickel-Cadmium Flooded	SAFT				
	STM 5-200	1220	752	616	2000(d)
	STM 5-140	825	592	718	2000
	STM 1.130	140	103	735	2000
	STM 1.60	75	58	773	2000
	STM 1.40B	43	35	814	2000

(a) List Price
(b) Cycle life claimed in brochures from manufacturer
(c) C/5. 60% DOD
(d) C/5. 80% DOD

Table 11. Battery configurations for 1998 vehicles using sealed nickel-cadmium batteries

1998 Vehicles		Battery Module [b]						Battery Pack [c]			
					Dimensions						
Name	Type	Model [a]	(Ah)C/3	Wgt (kg)	L	W	H	Volts	Wgt (kg)	Volume (ℓ)	Capacity kWh
Car A	2-pass	H 40	45	5.8	140	115	177	345	325	160	15.0
Van A	Microvan	H 60	60	7.8	200	115	160	345	434	206	20.0
Van B	lg. Van	H 90	100	12.9	295	115	175	345	723	335	34.0
ETX-II	Minivan	H 80	85	11.0	265	115	170	345	614	290	29.0
Impact	2-pass. Sports	H 40	45	5.8	140	115	177	345	325	160	15.0
ETV-I	4-pass compact	H 60	60	7.8	200	115	160	345	434	206	20.0

(a) Hoppecke sealed cells (Table 7)

(b) 5-cell modules - nominal voltage 6.1 V

(c) 56 modules in each pack

SUMMARY OF BATTERY EFFICIENCY CHARACTERISTICS		
Battery/Type	Charge/Discharge Efficiency (%)	Ah % overcharge
Sonnenschein 6V180 Sealed lead-acid	77-84 (7-10 hr charging)	3-8
Chloride ET205 Tubular lead-acid	65-70	16-18
Chloride ETX-I Tubular lead-acid	60-70	20-25
SAFT SEH-5-200 Nickel-Cadmium	65-70	18-21
CSPL ETX-II Sodium-sulfur	85-92	<1
Eagle-Picher NiF-170 Nickel-iron	55-61	30-35
Westinghouse NiF-200 Nickel-iron cells	61-65	18-22
Electrosource 4 V modules Sealed lead-acid	75-80 (1 hr charging)	5-7

CHARGING CHARACTERISTICS OF THE SONNENSCHEIN 6V180 BATTERY
(Sealed Lead-Acid)

Tests with the Sonnenschein Charger (Ref. 1)

		Battery			Charger	
(Ah) Out	(kWh) Out	(kWh) In	% Ah ov. ch	Effic. (%)	(kWh) In	Effic. (%)
105 (C/2, 100%)	12.31	16.4	13	75.0	19.86	83
113 (C/2, 100%)	13.41	16.87	8	79.5	20.29	83
60 (C/2, 57%)	7.28	8.64	5	84.2	10.37	83
80 (C/2, 73%)	9.69	11.57	5	83.8	13.85	83

INEL Battery Laboratory Characterization Tests (Ref. 2)

Discharge Rate	(Ah) Out	(kWh) Out	(kWh) In	% Ah ov. Ch	Effic. (%)	Charge Time (hr)
C/3	136	4.05	4.82	4	84.0	9
C/3	145	4.34	5.18	4	83.8	9.5
10 W/kg (2.5 hr)	141	4.21	4.95	3	85.0	10.3
20 W/kg (1.0 hr)	114	3.31	3.99	2	83.0	8
42 W/kg (.5 hr)	99	2.65	3.49	3	75.9	5
60 W/kg (.21 hr)	83	2.10	2.91	2	72.1	4.7

CHARGING CHARACTERISTICS OF THE SAFT SEH-5-200 BATTERY (Ref. 5)
(Nickel-Cadmium)

Discharge Rate	(Ah) Out	(kWh) Out	(kWh) In	% Ah ov. ch	Effic. (%)	Charge Time (hr)
C/3	206	7.51	10.92	19	68.8	7
C/3	205	7.44	10.9	20	68.2	7
C/2	198	7.16	10.66	21	67.2	7
C/1	193	6.64	10.28	20	64.6	6.6
7 W/kg (8 hr)	205	7.62	10.96	21	69.5	7
21 W/kg (2.3 hr)	198	7.21	10.6	21	68.0	7
42 W/kg (1.0 hr)	191	6.67	10.3	21	64.8	7
60 W/kg (.7 hr)	188	6.35	9.95	18	63.8	7
SFUDS (5 hr)	191	N/A	9.85	18	---	6.5

CHARGING CHARACTERISTICS OF THE CSPL ETX-II BATTERY
(Sodium-Sulfur)

Discharge Rate	(Ah) Out	(kWh) Out	(kWh) In **	% Ah ov. ch	Effic. (%)	Charge Time (hr)
C/2.7	266	48.5	53.4	0	90.8	8
C/2.6	260	47.4	53.3	.5	88.9	8.25
C/1.6	248	43.5	51.0	.9	86.3	7.7
C/1.6	240	42.2	49.4	.7	85.4	8
C/.5*	143	22.1	29.4	.6	75.2	4.7
14 W/kg (5.5 hr)	270	51.0	55.5	1	91.9	8.8

* Discharge terminated on battery temperature limit

** All charging terminated by battery watchdog unit

CHARGING CHARACTERISTICS OF THE ELECTROSOURCE BATTERY
(Sealed Lead-Acid, 4 V Module)

Discharge Rate	(Ah) Out	(Wh) Out	(Wh) In	% Ah ov. ch	Effic. (%)	Charge Time (hr)
C/3	35.4	.13	.17	7	76.5	1.3
C/3	35.7	.14	.17	6	82.3	1.15
C/2	34.2	.13	.17	6	76.5	1.25
C/2	32.7	.12	.16	6	75.0	1.15
C/1	29.5	.11	.14	6	78.6	1.15
C/1	29.2	.11	.14	6	78.6	1.05
7 W/kg (5 hr)	35.2	.13	.17	7	76.4	1.33
21 W/kg (1.4 hr)	30.2	.11	.14	5	78.6	1.0
21 W/kg (1.4 hr)	30.9	.12	.15	6	80.0	1.05
60 W/kg (.78 hr)	24.7	.09	.12	4	75.0	.8

BATTERIES

Lead-Acid

Flooded
Sealed

Alkaline

Nickel-Iron (NiFe)
Nickel-Cadmium (NiCd)
(Nickel-Zinc (NiZn))

High Temperature

Sodium-Sulfur (NaS)
Lithium Aluminum Iron Sulfide (LiALFeS)

Metal-Air

Iron-Air
(Zinc-Air)

Flow

Zinc-Bromide (ZnBr)

Battery Characteristics

- Energy Density - Wh/kg
- Peak Power Density - W/kg
- Cycle Life
- Cost - $/kWh
- Energy Efficiency (%)
- Maintenance

Table 4. Summary of the Characteristics of Various Battery Systems

Battery Type	1976 Wh/(1) kg	1976 W/kg(2) (peak)	1976 Cycle(3) Life	1990 Wh/ kg	1990 W/kg (peak)	1990 Cycle Life	1995 Wh/ kg	1995 W/kg (peak)	1995 Cycle Life
Lead-Acid									
Flooded-flat	30	80	200	37	150	300	40	150	300
Flooded-tubular	---	---	---	34	80	500	35	100	600
Sealed-starved	---	---	---	30	130	200	38	200	300
Alkaline									
NiFe	38	90	500	52	110	800	55	130	1200
NiCd	---	---	---	47	130	300	50	200	500
High Temperature									
NaS	---	---	---	85	90	200	110	125	500
LiAL/FeS	---	---	---	75	95	---	90	120	200
Metal Air									
Fe-Air	---	---	---	55	50	100	70	60	300
Zn-Air	---	---	---	---	---	---	100	90	200
Flow									
ZnBr	---	---	---	70	150	100	80	150	500

(1) energy density at 10 W/kg

(2) peak power density at 50% DOD

(3) discharged on the SFUDS (80% DOD)

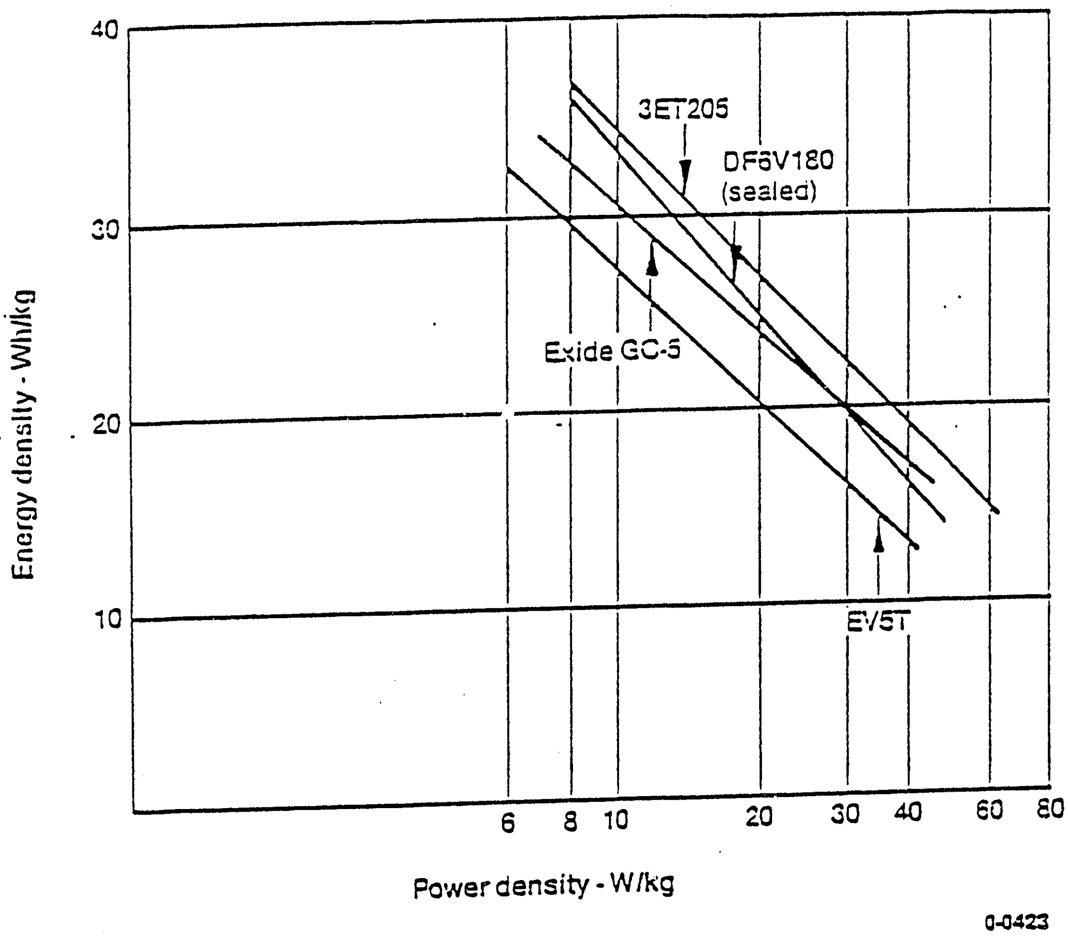


Figure 1a. Ragone curves for commercially available lead-acid batteries.

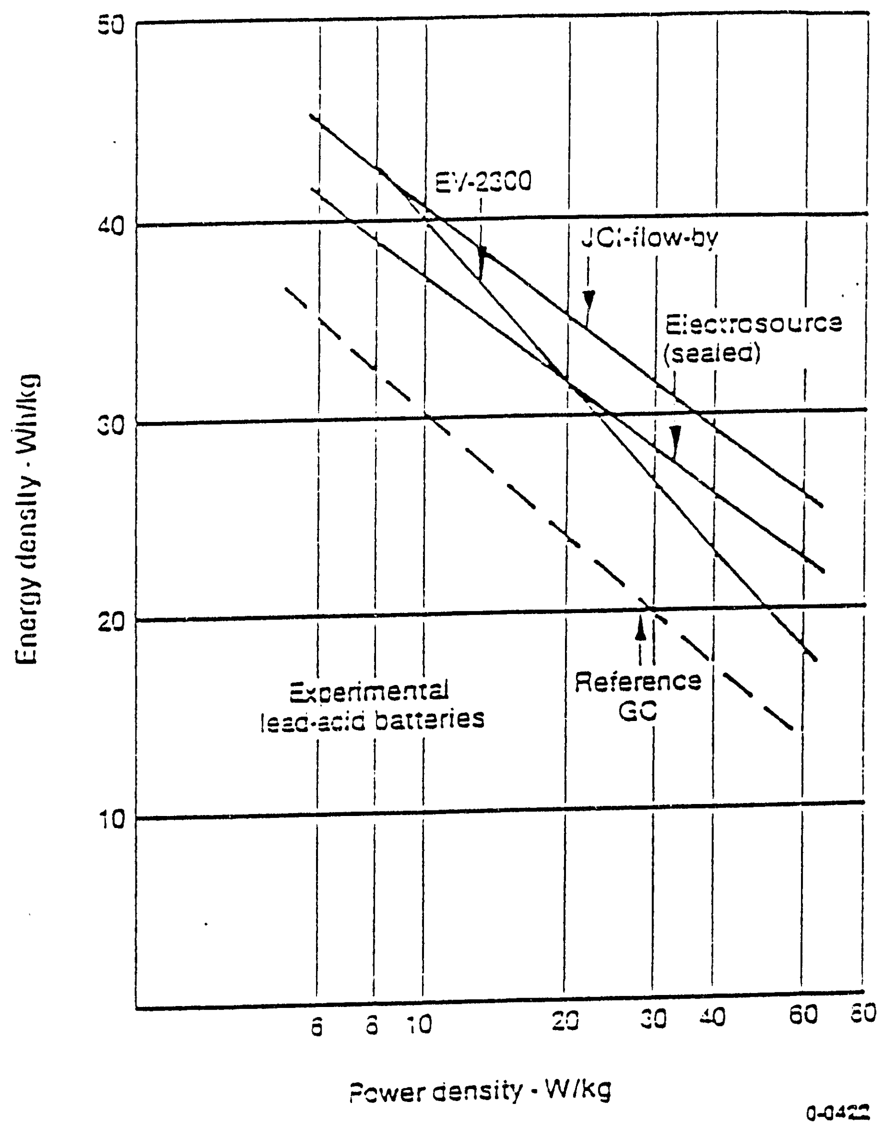


Figure 1b. Ragone curves for experimental lead-acid batteries.

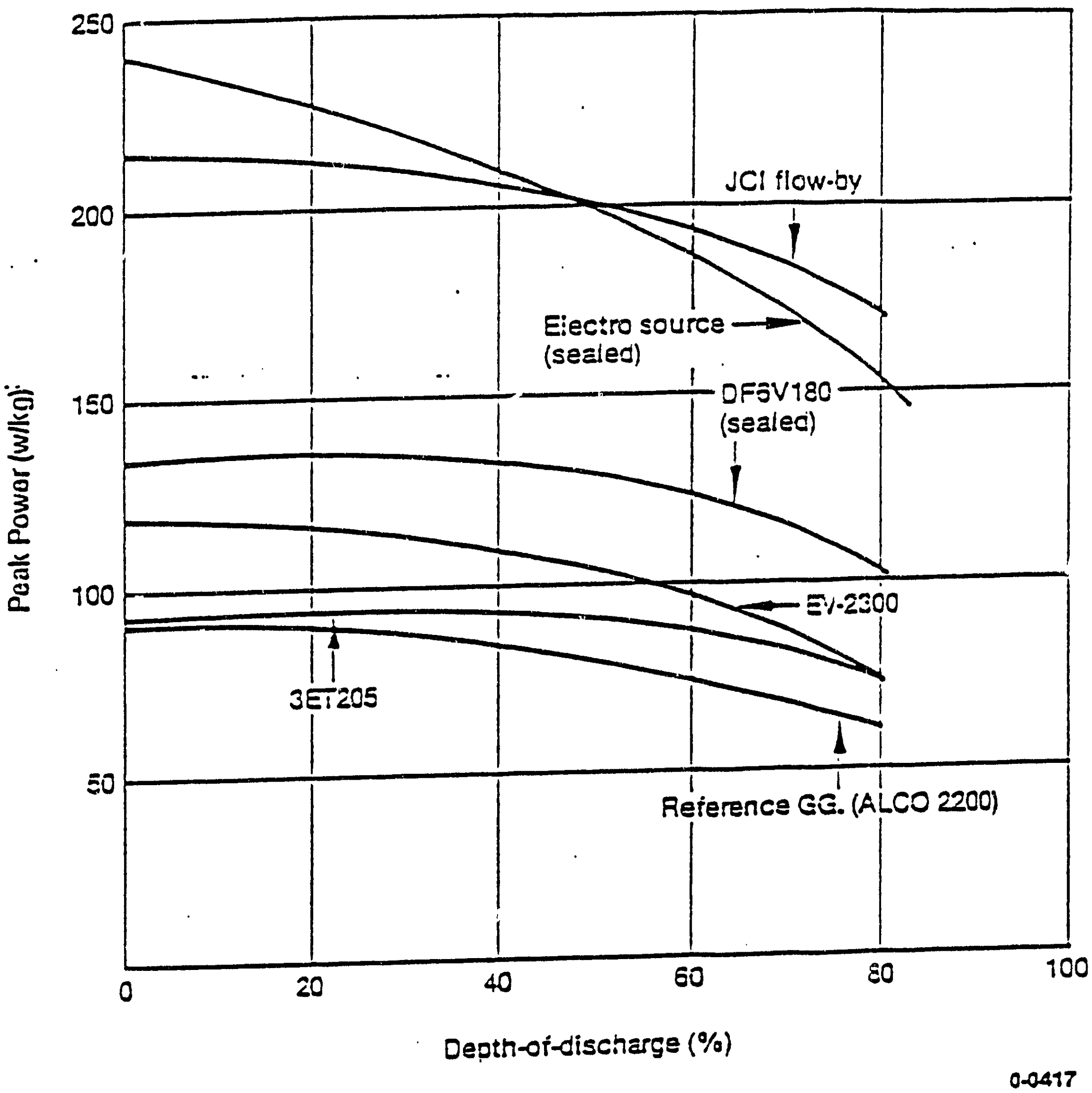


Figure 2. Peak Power as a function of depth-of-discharge for various lead-acid batteries

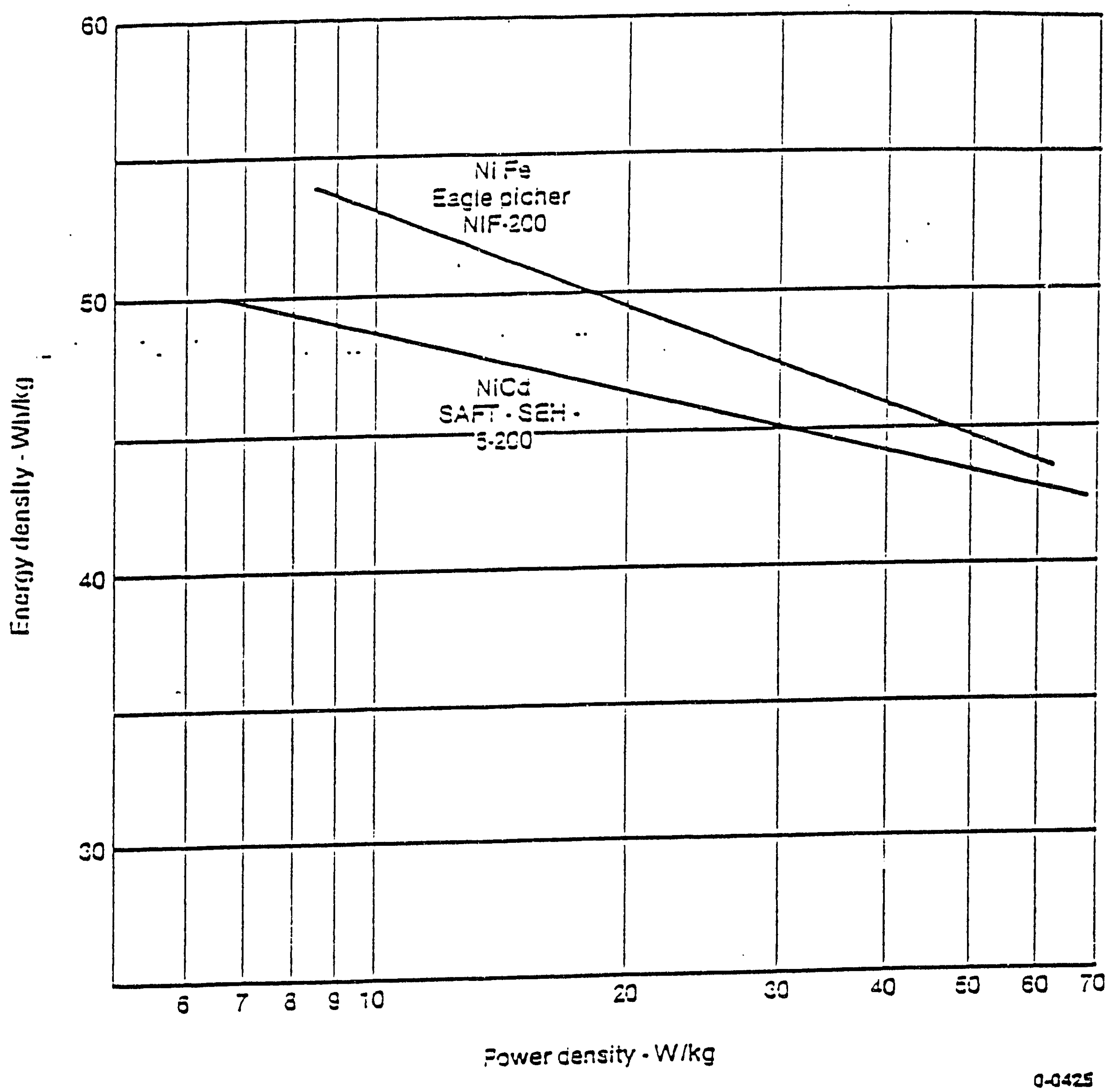


Figure 3. Ragone curves for NiFe and NiCd batteries.

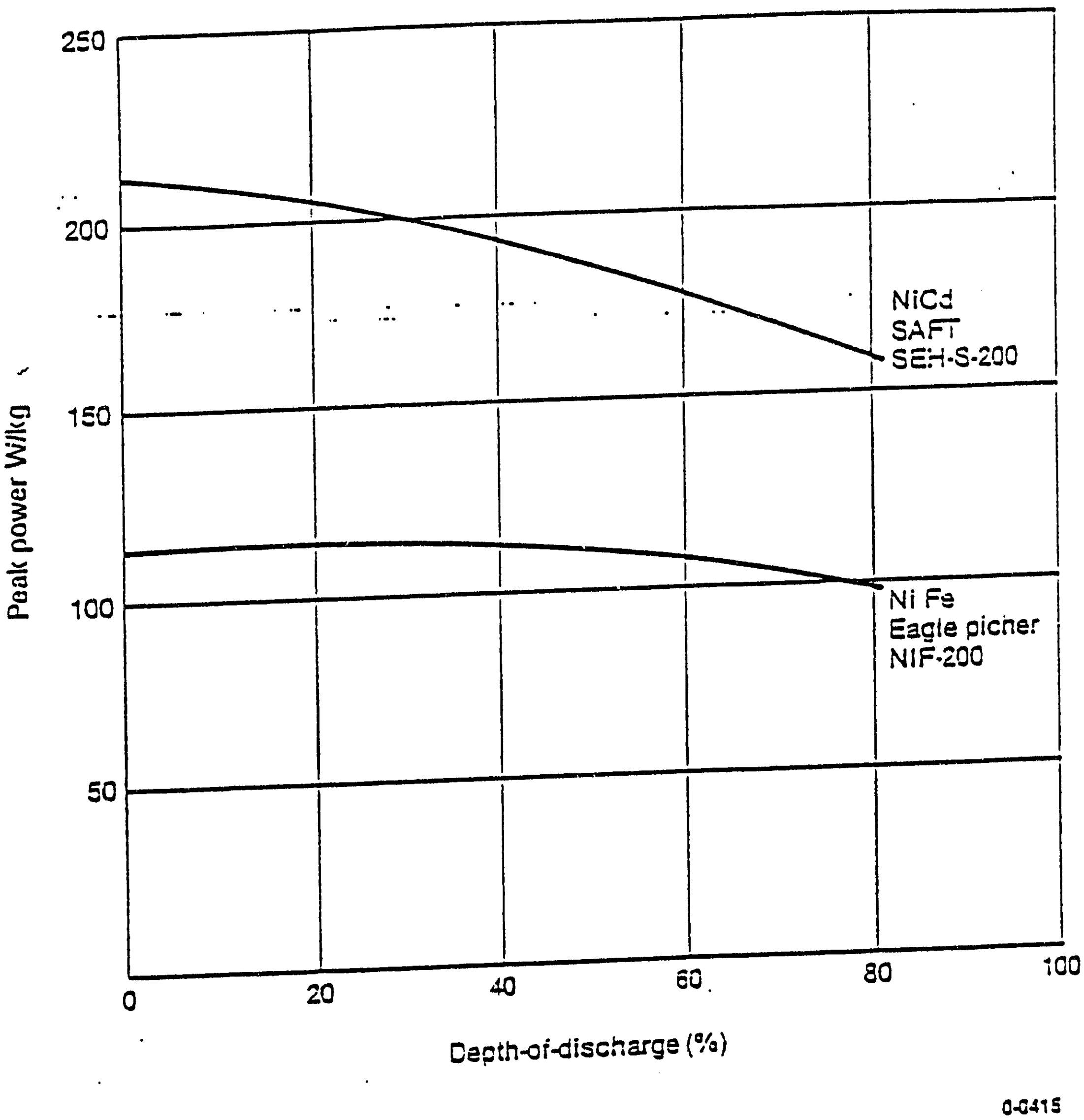


Figure 4. Peak power as a function of depth-of-discharge for NiCd and NiFe batteries.

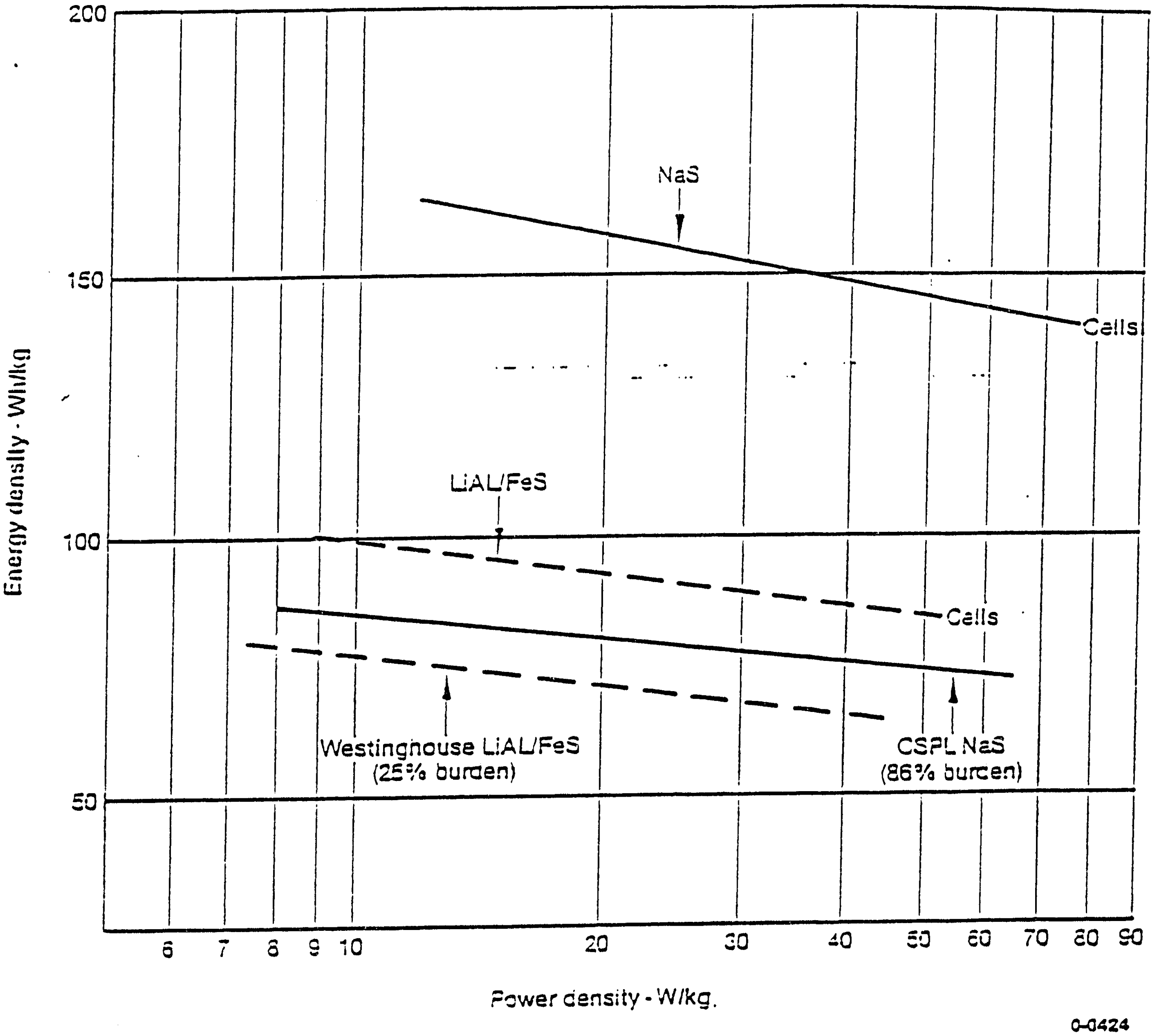


Figure 5. Ragone Curves for NaS and LiAL/FeS Batteries and cells

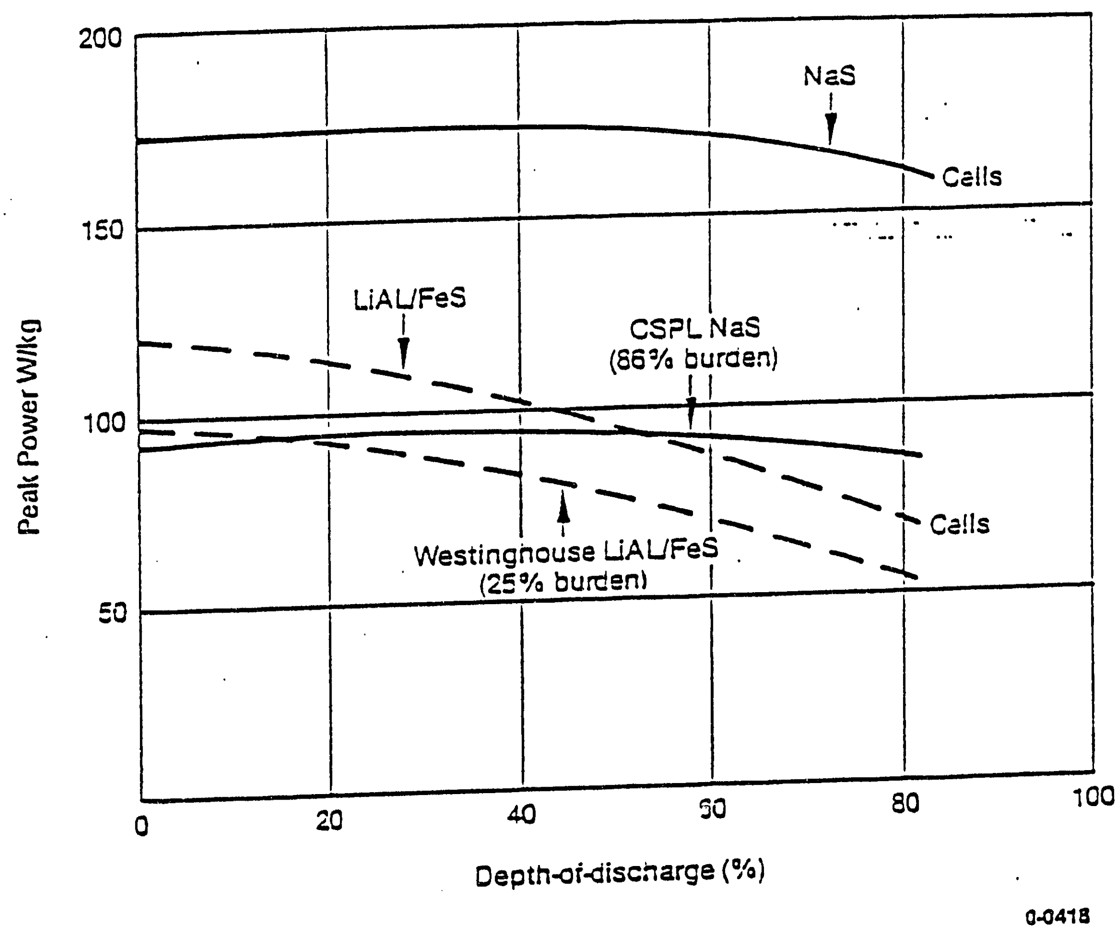


Figure 6. Peak Power as a function of depth-of-discharge for NaS and LiAL/FeS batteries and cells.

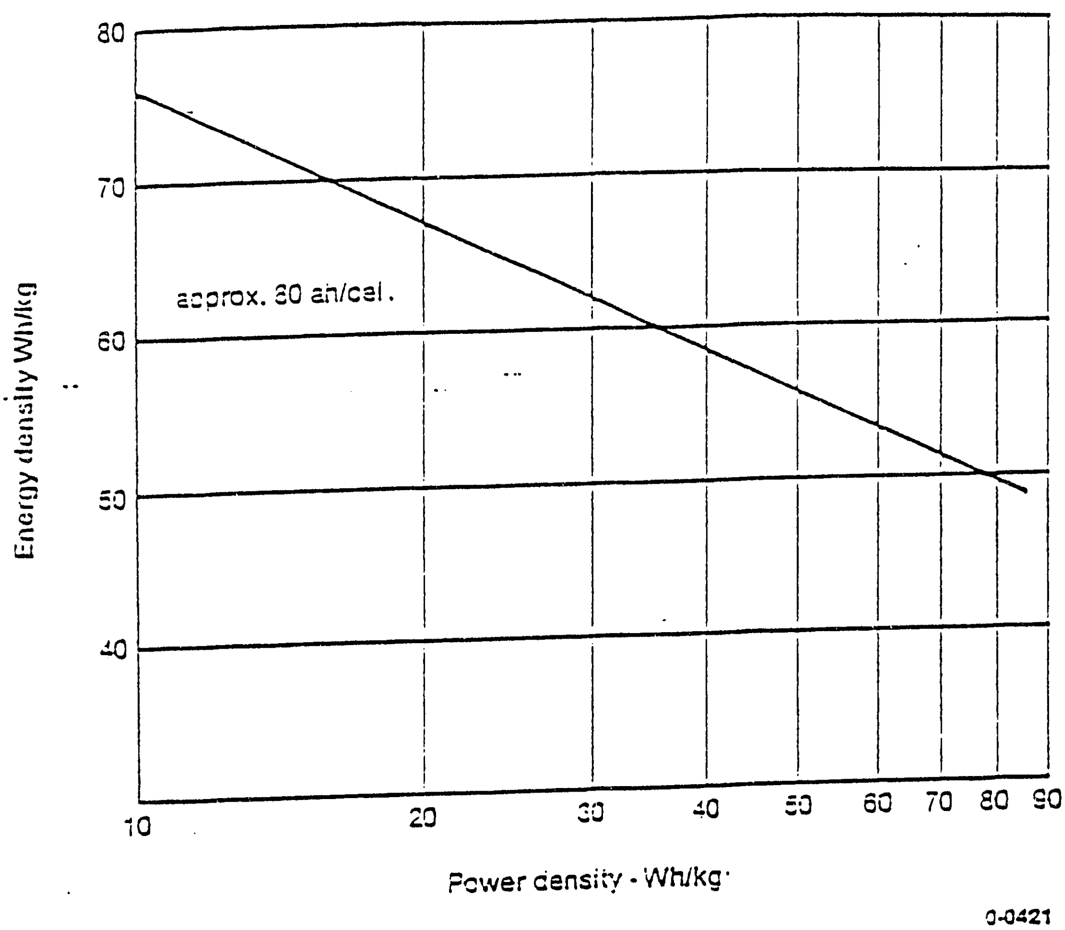


Figure 8. Ragone curve for the JCI ZnBr battery.

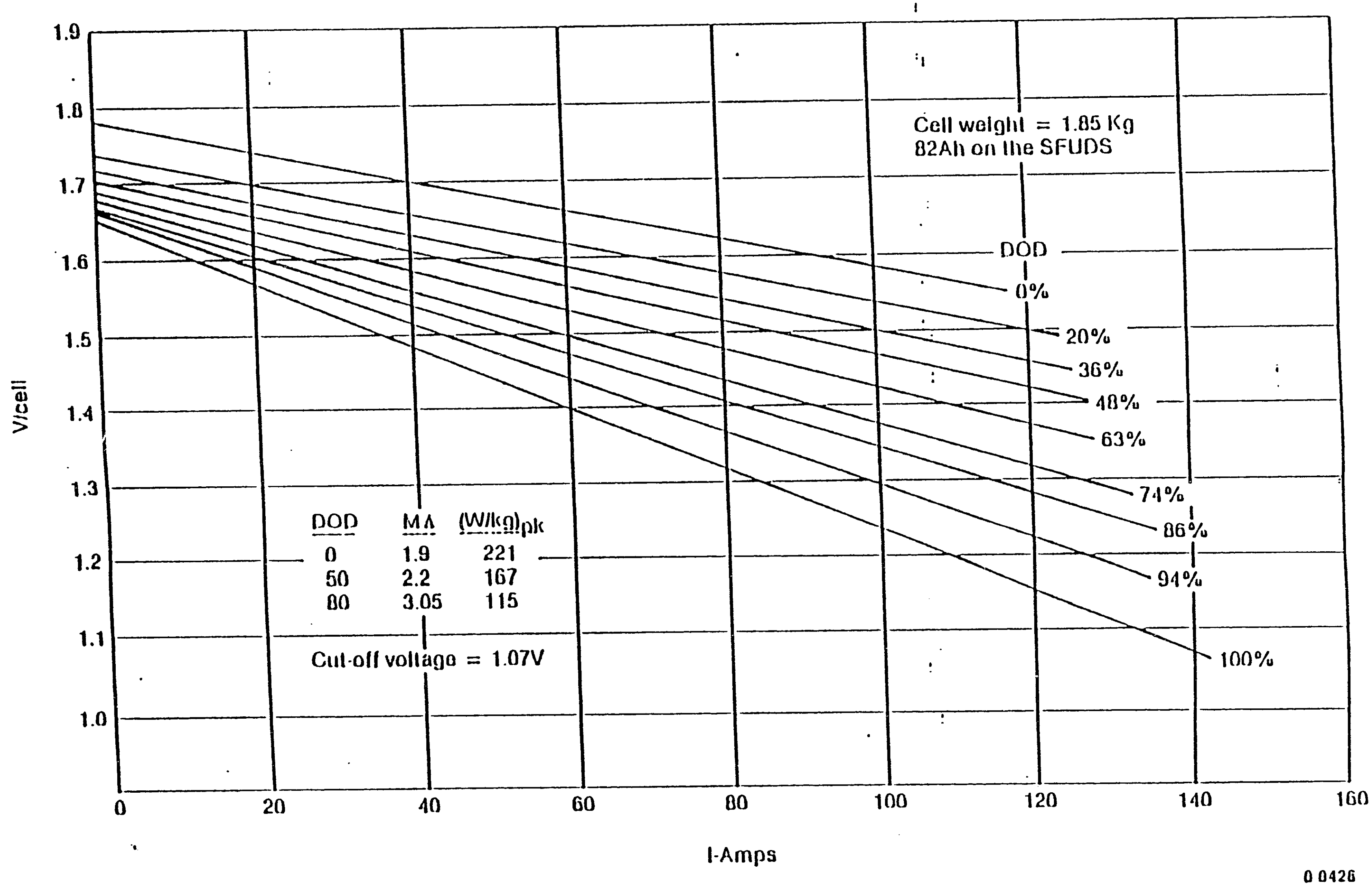


Figure 9. Voltage-current characteristics for the JCI ZnBr cell.

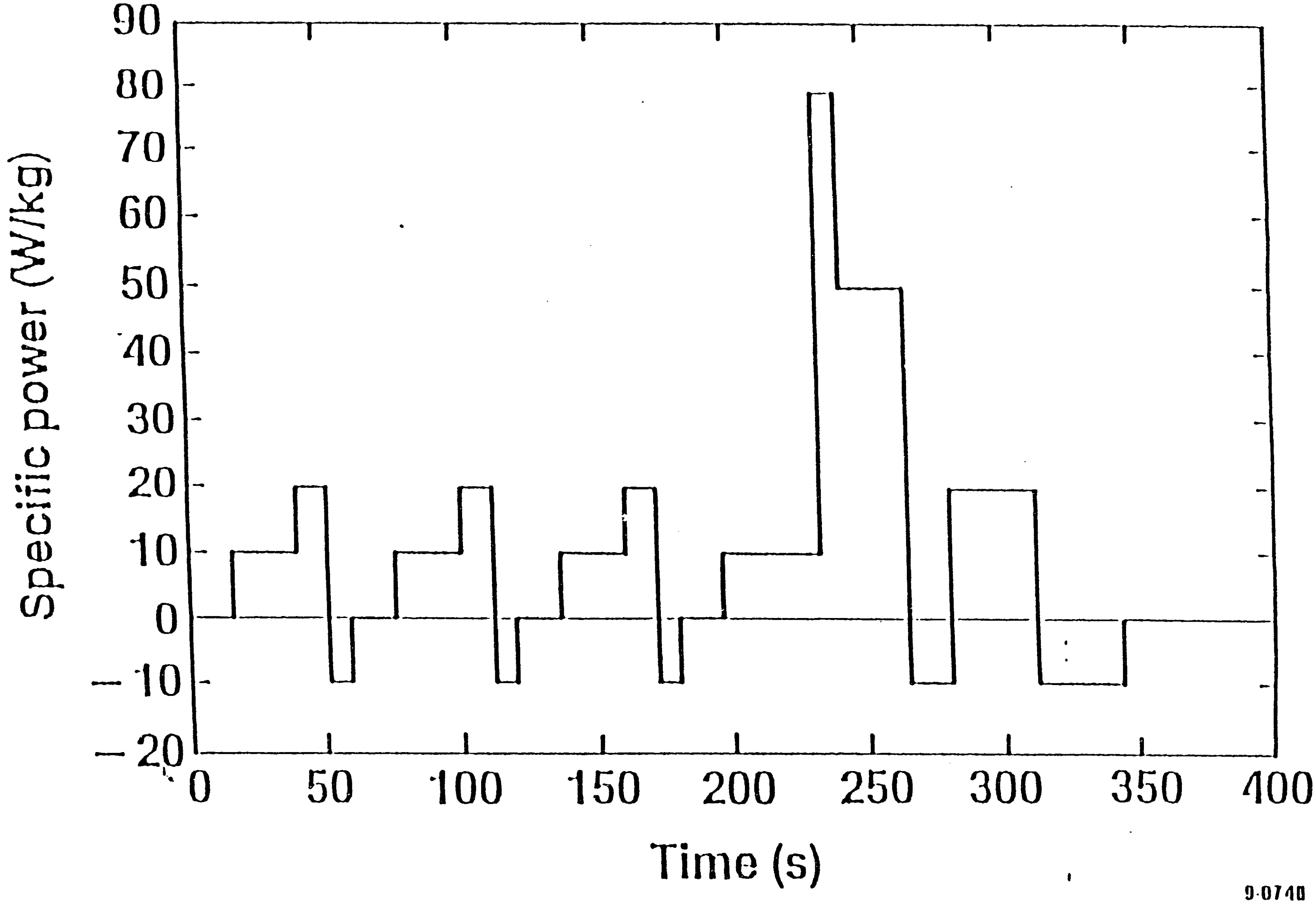
BATTERY TESTING

- Performance Characterization
- Cycle Life

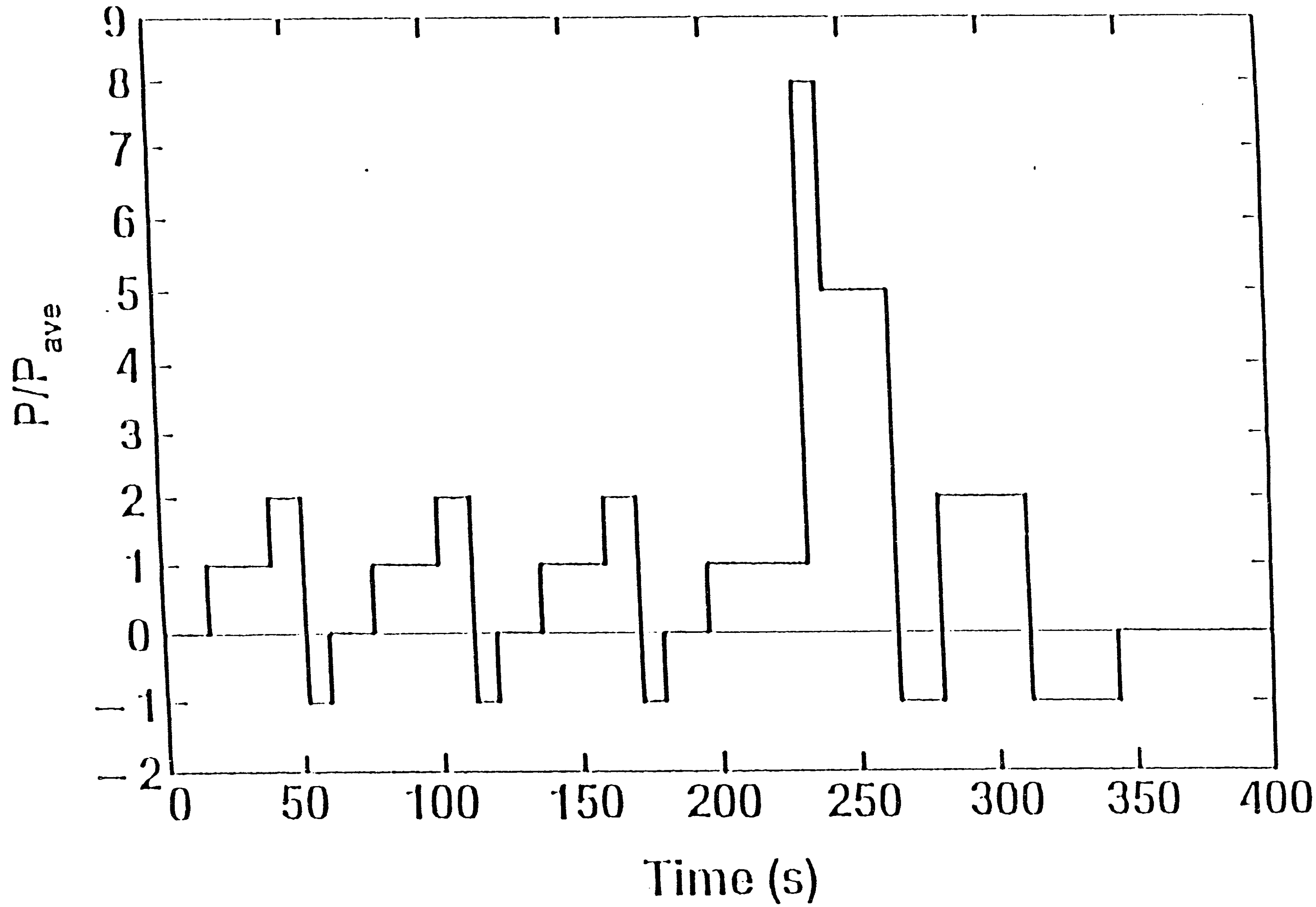
DISCHARGE POWER PROFILES

- Constant Power
- FUDS (Federal Urban Driving Schedule)
- SFUDS (Simple FUDS)
- GSFUDS (Generic SFUDS)

SFUDS Battery Discharge Profile



GSFUDS Battery Discharge Profile



SFUDS	GSFUDS	
10 W/kg	Pav	(W/kg)av
20 W/kg	2 Pav	2 (W/kg)av
50 W/kg	5 Pav	5 (W/kg)av
79 W/kg	(Rmax) Pav	(Rmax)(W/kg)av
-10 W/kg	- Pav	- (W/kg)av

Calculation Procedure for the GSFUDS

W_V - weight of vehicle (loaded)
W_B - weight of the battery
$\frac{Wh}{km}$ - energy consumption of the vehicle on the FUDS cycle

---

$$\left(\frac{P_{BAT}}{W_V}\right) FUDS$$

Maximum power requirement to follow the FUDS cycle

$$PAV = \left(\frac{Wh}{km}\right) V_{av};\ V_{av} = 32\,km/h$$

$$P_{BAT}, max = W_V \left(\frac{P_{BAT}}{W_V}\right) FUDS$$

$$(W/kg)\,av = Pav/W_B$$

$$(W/kg)\,peak = P_{BAT}, Max/W_B$$

$$Rmax = \frac{P_{BAT}, Max}{PAV} = \frac{(W/kg)\,peak}{(W/kg)\,av}$$

Idaho National Engineering Laboratory

Managed by the U.S. Department of Energy

EGG-EP-9688
DECEMBER 1991

LABORATORY TESTING OF THE CSPL SODIUM SULFUR TRACTION BATTERY FOR THE ETX-II VEHICLE

A. F. BURKE

EG&G Idaho

Work performed under DOE Contract No. DE-AC07-76ID01570

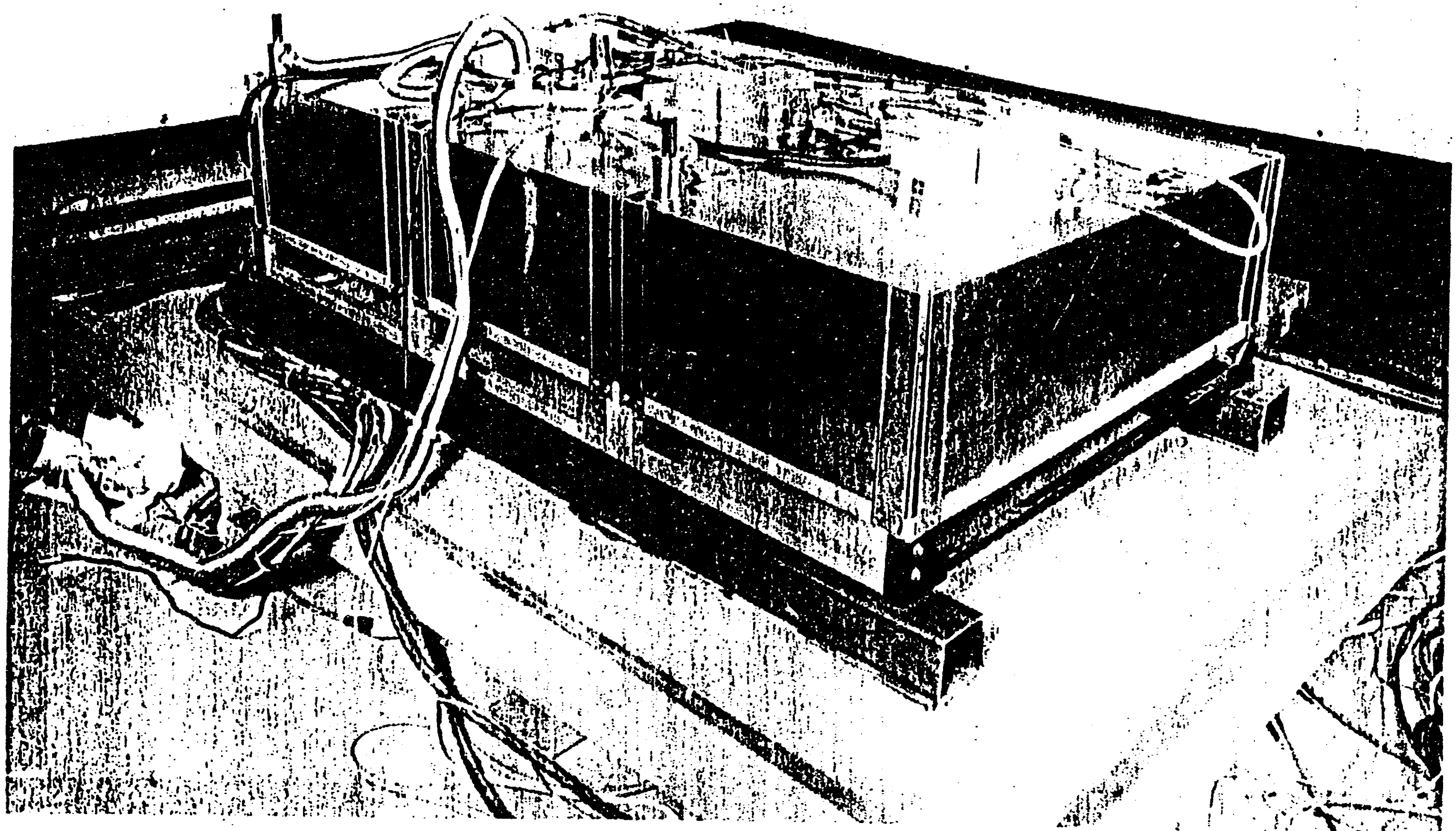


Figure 2. Photograph of the CSPL ETX-II sodium-sulfur battery.

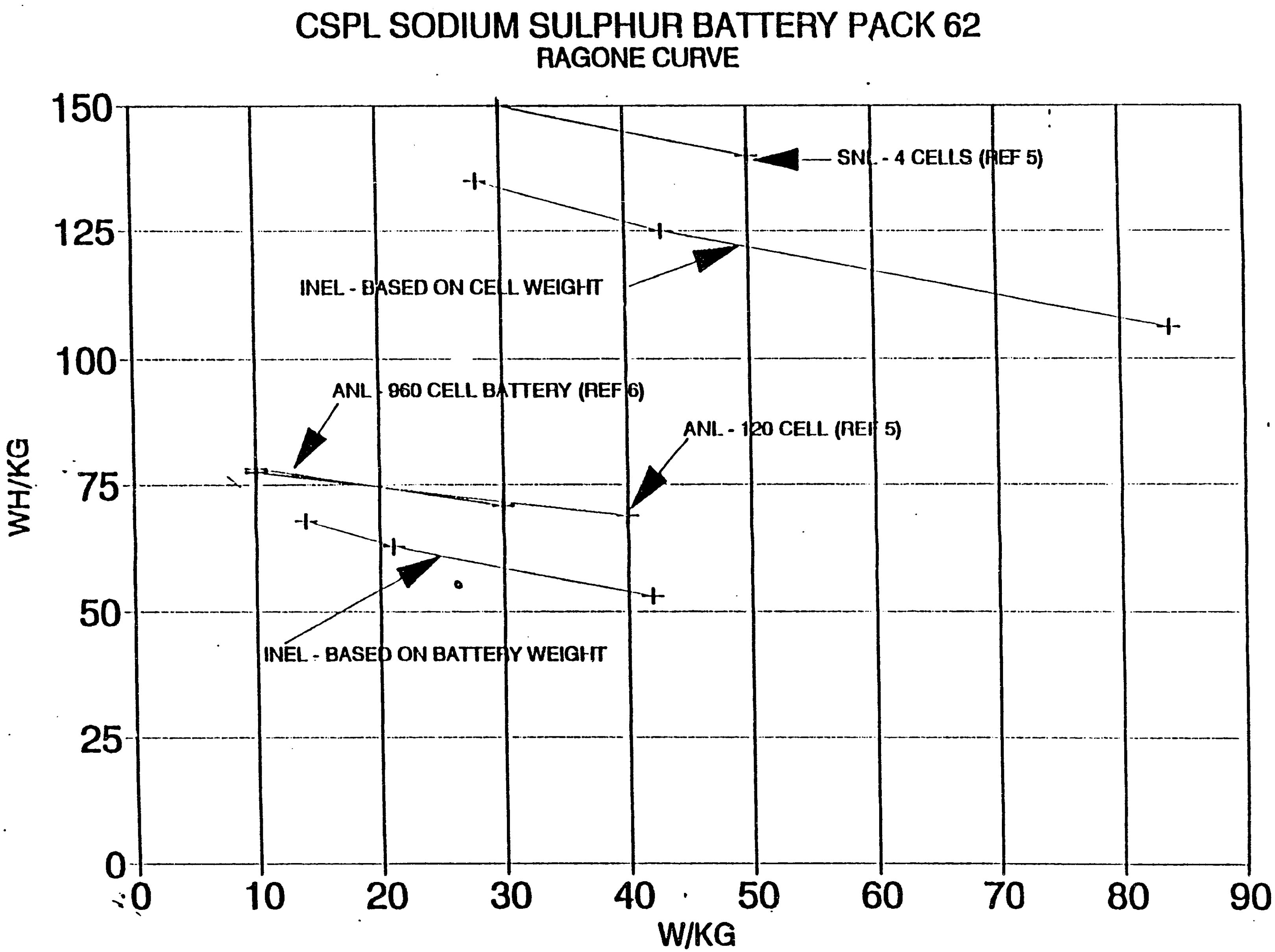


Figure 7. The Ragone curve for the sodium-sulfur battery.

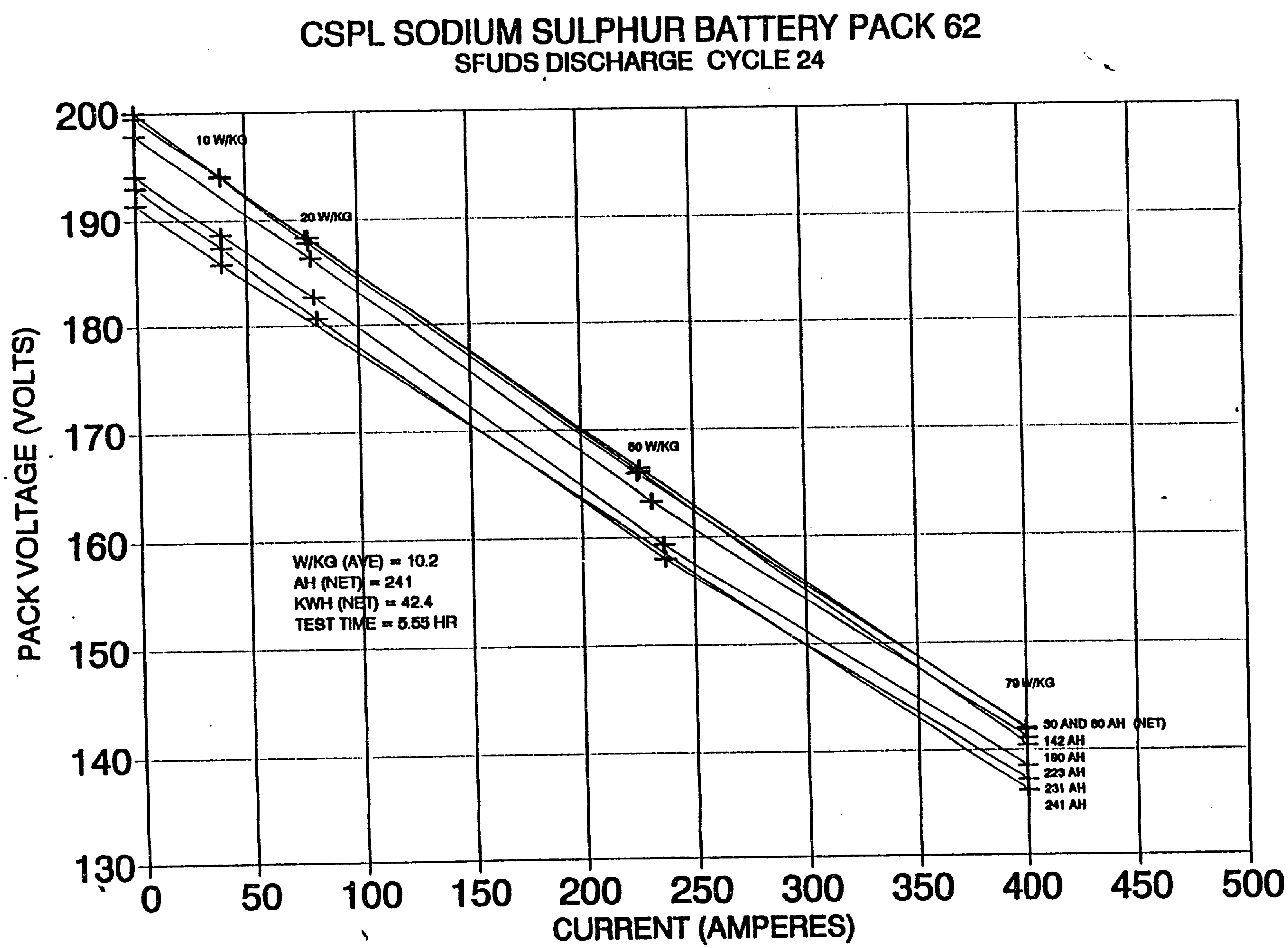


Figure 10. Voltage versus current, Ah plot from SFUDS data.

** NOTES **

Abstract-Electric & Hybrid Vehicle Technology TOPTEC
Monday, September 14, 1992

Battery System Technologies II - Present & Near-Term

Michael G. Andrew
Manager, Advanced Lead-Acid
Johnson Controls Battery Group, Inc.

Resurgent interest in the commercialization of electric vehicles has catalyzed efforts to develop battery technologies with optimized electrical performance and economic characteristics. Advanced lead-acid battery technology is well positioned to satisfy the near to mi-term needs of this environmentally sensitive propulsion technology. Lead-acid batteries have demonstrated capable EV performance,, the critical manufacturing and recycling infrastructures already exist, and battery production costs are projected to be in compliance with ASABC goals.

Advanced valve-regulated, also described as sealed, lead-acid batteries are attractive based on their maintenance-free nature and recent as well as planned improvements in specific power (acceleration) and specific energy (range). Cycle life remains a key issue, but the development of integrated battery subsystems, in particular thermal management, offers the potential for significant advanced in this area. Thermal management is also critical to the feasibility of rapid recharging, where the ability to remove the heat generated during charging is essential to good battery life. With this capability, the vehicle range is no longer limited by the technology of the power source, but by the availability of recharging stations. An alternative design, the bipolar lead-acid battery, offers substantially higher specific power than advanced conventional technology. Currently, quasi-bipolar designs are being evaluated in the prototype stage while true bipolar substrate technology is being actively pursued. Both approached hold significant promise for hybrid electric vehicles whose drive systems' options include the need for an ultra-high specific power rechargeable battery.

Biography-Electric & Hybrid Vehicle Technology TOPTEC

Michael G. Andrew
Manager, Advanced Lead-Acid
Johnson Controls Battery Group, Inc.

Mr. Andrew is Manager of Advanced Monopolar and Bipolar Lead-Acid at Johnson Control Battery Group, Inc. He is a member of the Technical Committee - ALABC and was program manager for 5 U.S. government sponsored lead-acid battery developed programs.

Mr. Andrew specializes in the design, engineering and production of advanced lead-acid batteries for electric vehicles and pulse power applications, with 14 years experience.
He has a B.S. in chemical process engineering from the University of Wisconsin-Milwaukee, graduating with honors in 1979.

SAE INTERNATIONAL

** NOTES **

ALTERNATIVE FUEL SERIES

SAE in the 90s

Abstract-Electric & Hybrid Vehicle Technology TOPTEC
Monday, September 14, 1992

Battery System Technologies-Advanced/Future & Fuel Cells

Paul C. Butler
Department Manager
Sandia National Labs

Advanced batteries and fuel cells have been under development by industry and government agencies for many years. The need for improved power sources has long been recognized as critical for viable electric vehicles (EV). Other applications which would likely develop if high performance energy storage devices were available include utility energy storage, demand-side management, and remote stand-alone uses. The need is critical for EVs because currently available batteries are too expensive, have inadequate lifetimes, or do not perform with sufficient power or energy capability.

The energy storage devices being developed can be characterized as high temperature batteries, ambient temperature batteries, fuel cells, and very high energy density capacitors (double layer capacitors). This presentation will review the background and status of each of these technology areas. High temperature batteries include sodium/sulfur, lithium/iron disulfide, and sodium/nickel chloride. Ambient temperature systems presently under development include zinc/air, nickel/zinc, nickel/metal hydride and lithium/polymer electrolyte. Fuel cells being developed include phosphoric acid, molten carbonate, solid oxide, and proton exchange membrane types. High energy density capacitors include carbon-sulfuric acid and mixed metal oxide designs. Each of these technology areas will be reviewed with respect to EV applications.

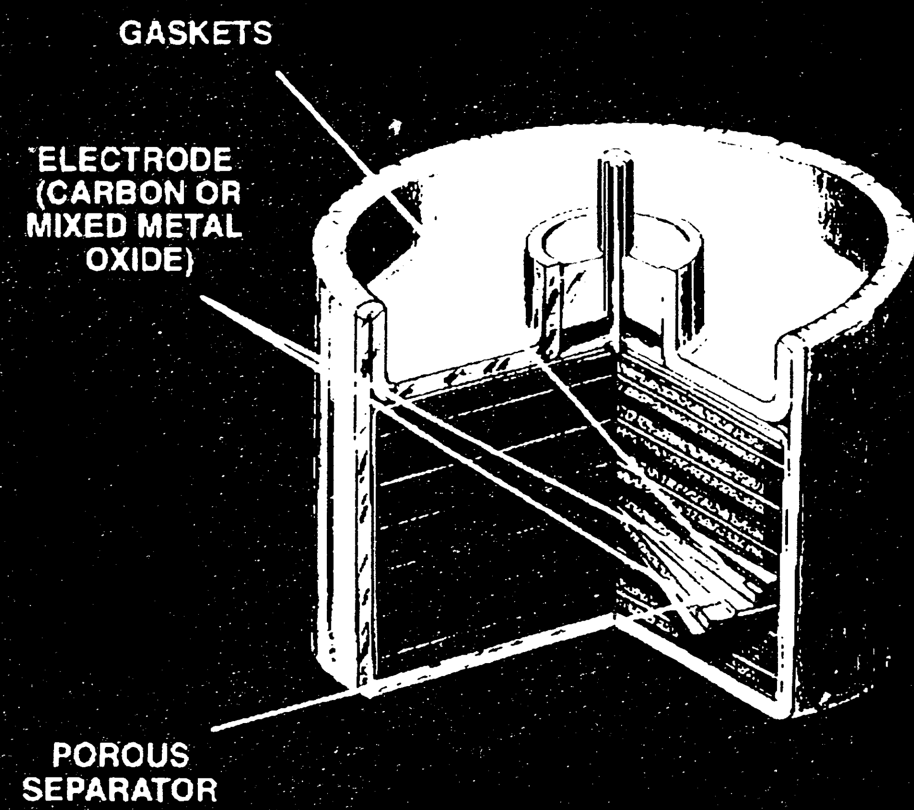
Biography-Electric & Hybrid Vehicle Technology TOPTEC

Paul C. Butler
Department Manager
Sandia National Labs

Mr. Paul Butler is Manager of the Storage Batteries Department of Sandia National Laboratories. He has been involved with Battery Engineering and Testing for 12 years.

Mr. Butler is responsible for engineering development of several advanced batteries for electric vehicle and utility applications. he has pbulished more than 20 publications in this field. He received a M.S. in ChE from UCLA, and a B.S. in Chemistry from Idaho State University.

DOUBLE-LAYER CAPACITOR



- HIGH CAPACITANCE/ENERGY/POWER DENSITY IN SMALL WEIGHTS AND VOLUMES $2F/cm^3$, 3 Wh/kg, 50 W/kg
- MECHANICALLY RUGGED
- OPERATING TEMPERATURE RANGE -55° C TO 85° C
- >100,000 CYCLES LIFETIME
- CAN BE CONNECTED IN SERIES

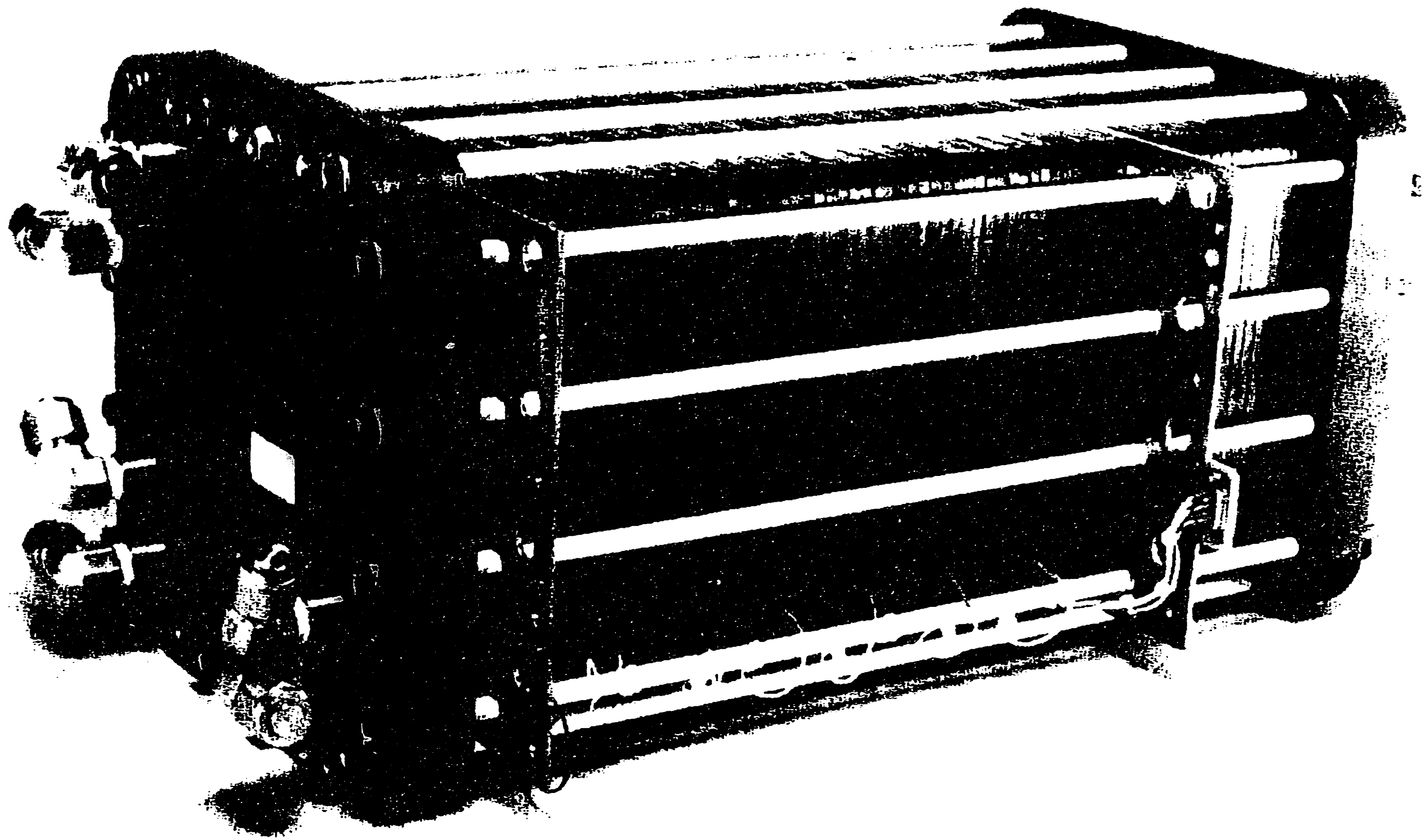
- WEAPON COMPONENT IN PRODUCTION
- PROJECTS UNDER WAY
  - RAIL GUN VEHICLE
  - EARTH PENETRATOR
  - ELECTRIC
- PROJECTED CHARACTERISTICS
  - > 5 Wh/kg
  - > 50 kw at 200-300 V

- USES VERY LARGE SURFACE AREAS OF C OR MMO AND IONS TO CHARGE INTERFACE

ESR-0476

DIGITAL PHOTO by SIII Photo 3153-1

PROTOTYPE FUEL CELL STACK

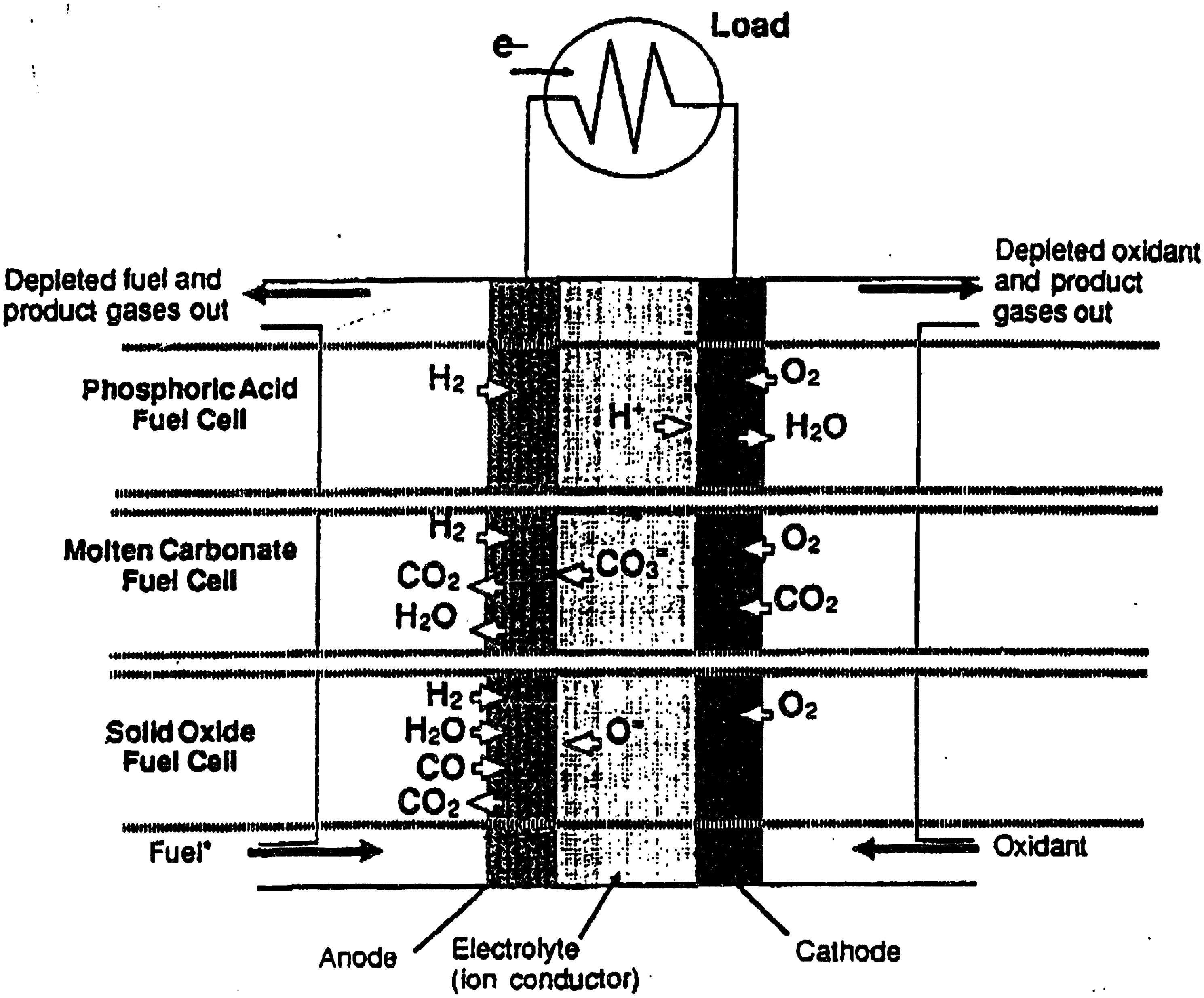


FUEL CELL CHARACTERISTICS

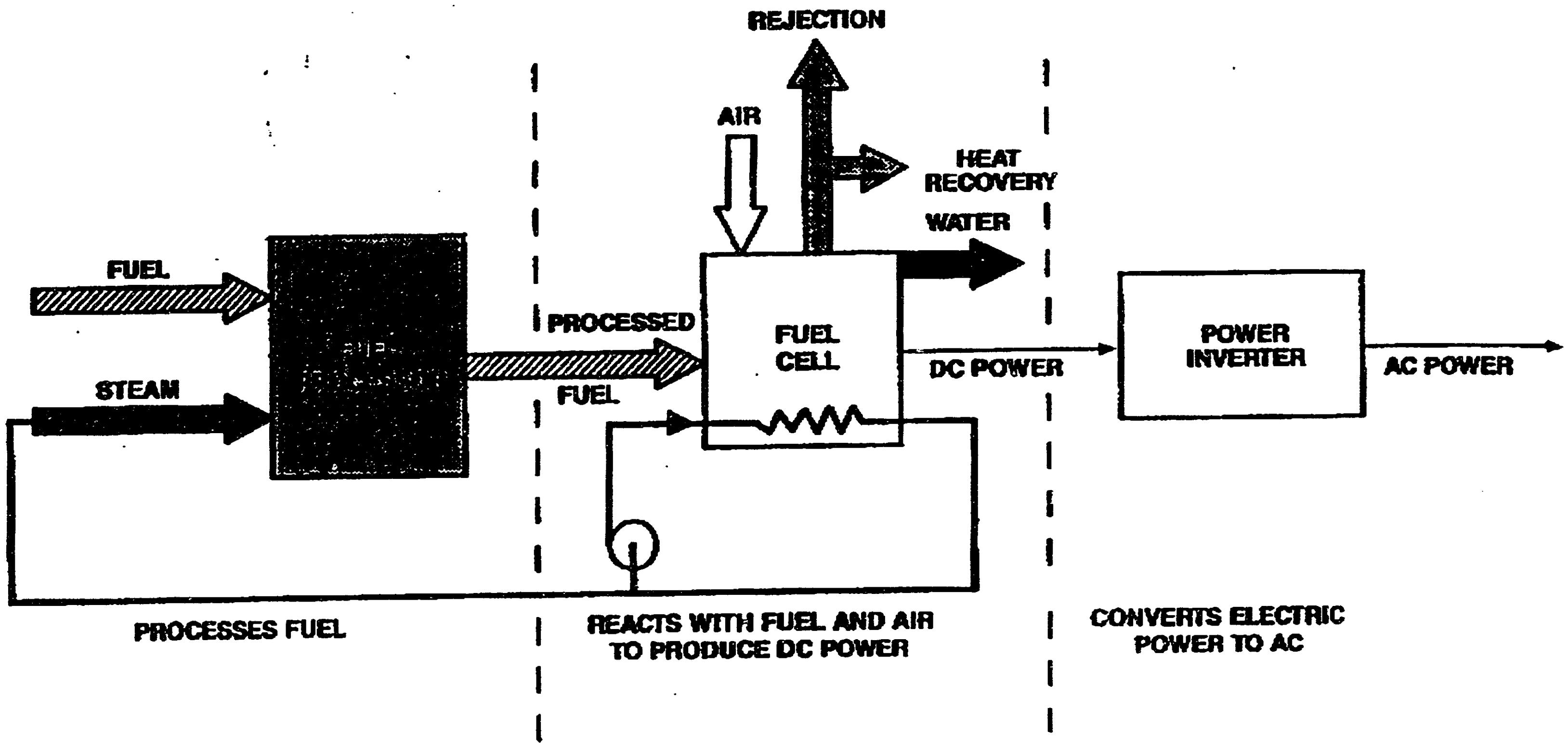
Fuel Cell Systems for Vehicle Applications

System	Electrolyte	Anode and Reaction	Cathode and Reaction	Temperature
Phosphoric acid	90% H_3PO_4	C (Pt catalyst) $H_2 \rightarrow 2H^+ + 2e^-$	C (Pt-alloy catalyst) $O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$	190°C
Alkaline	> 4M KOH	C (Pt catalyst) $H_2 + 2OH^- \rightarrow 2H_2O + 2e^-$	C (Pt or macrocyclinc) $O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$	60-200°C
Solid polymer electrolyte	SPE	Pt $H_2 \rightarrow 2H^+ + 2e^-$	Pt $O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$	80-100°C
Molten carbonate	Li_2CO_3/K_2CO_3 + β-alumina	Ni-alloys $H_2 + CO_3^{=} \rightarrow H_2O + CO_2 + 2e^-$	NiO + other oxides $O_2 + 2CO_2 + 4e^- \rightarrow 2CO_3^{=}$	650°C
High-temperature solid oxide	Doped zirconia	Ni(Co) cermet $H_2 + O^{=} \rightarrow H_2O + 2e^-$	Oxides $O_2 + 4e^- \rightarrow 2O^{=}$	1000°C

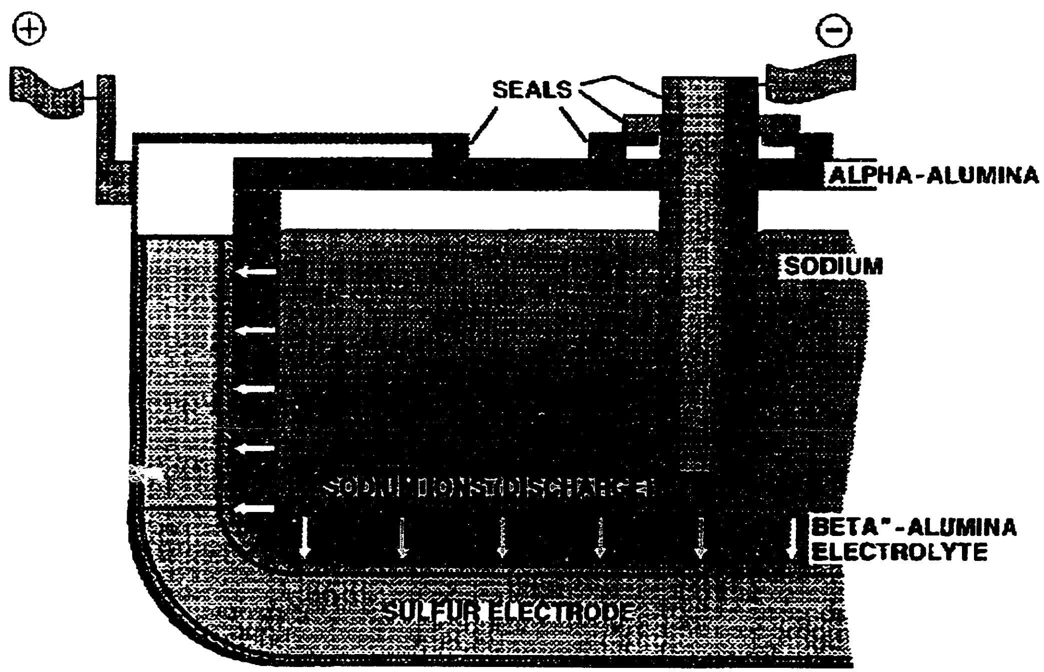
FUEL CELL SCHEMATIC



FUEL CELL SYSTEMS BLOCK DIAGRAM



RECHARGEABLE SODIUM / SULFUR BATTERY



REACTIONS

$$Na + S \underset{\text{CHARGE}}{\overset{\text{DISCHARGE}}{\rightleftharpoons}} Na_2S_5$$

92A2000.01

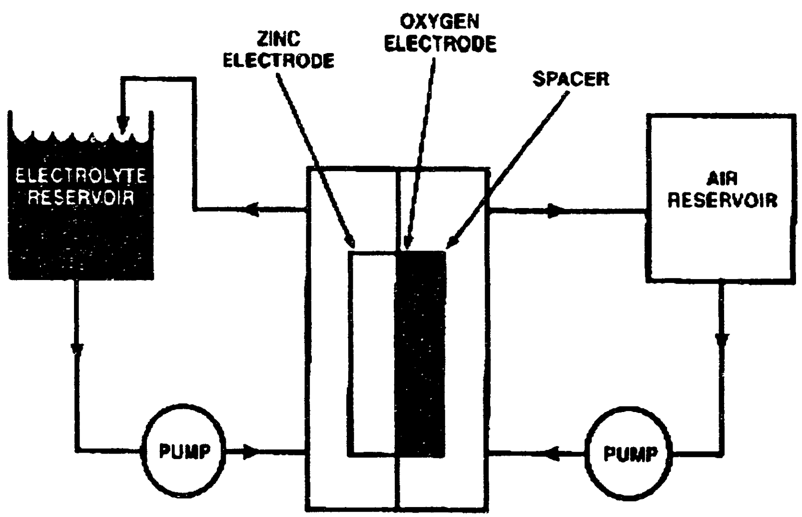
CHARACTERISTICS

- HIGH TEMPERATURE SYSTEM (350°C)
- SOLID ELECTROLYTE AND LIQUID ELECTRODES
- HIGH SPECIFIC ENERGY AND POWER
- LONG LIFETIME (5 - 10 YR)
- EXTENDED CYCLE CAPABILITY (2000 CYCLES)
- LOW MAINTENANCE

PROGRAM STATUS

- CELLS DEVELOPED
- PROTOTYPE EV BATTERIES DESIGNED AND BUILT
- *CONCEPTUAL UTILITY LOAD-LEVELING* SYSTEM DESIGNED

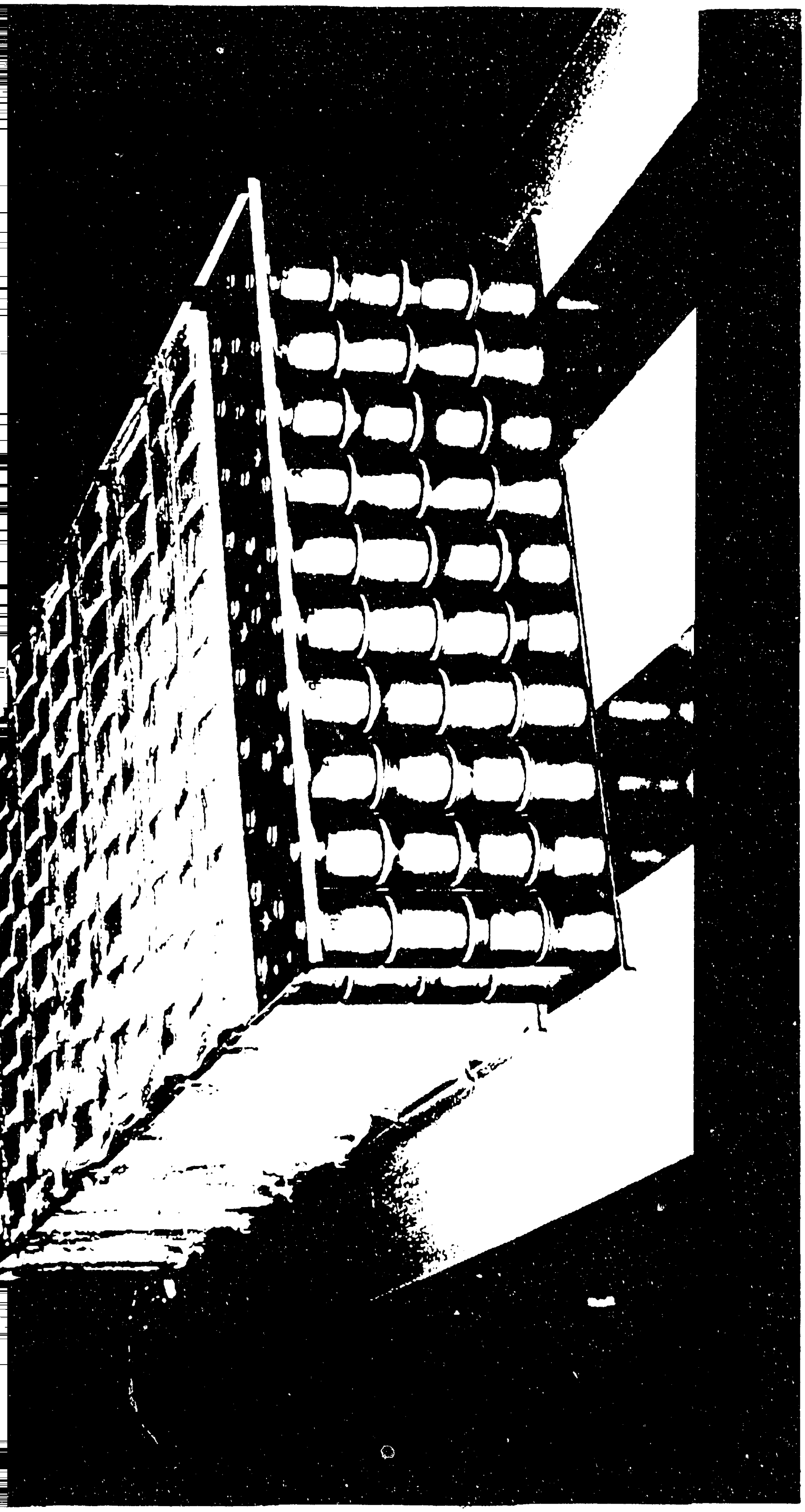
RECHARGEABLE ZINC/AIR BATTERY

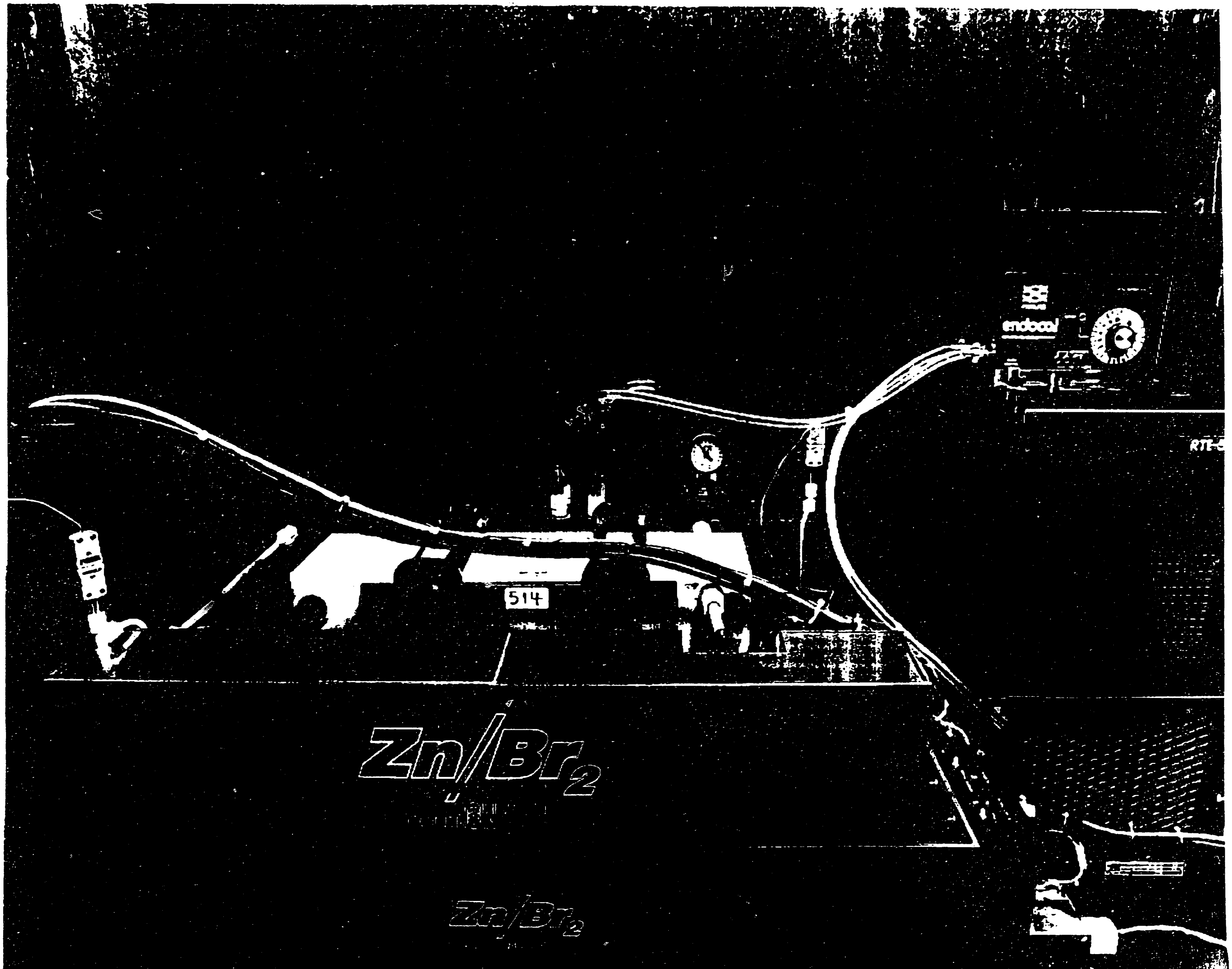


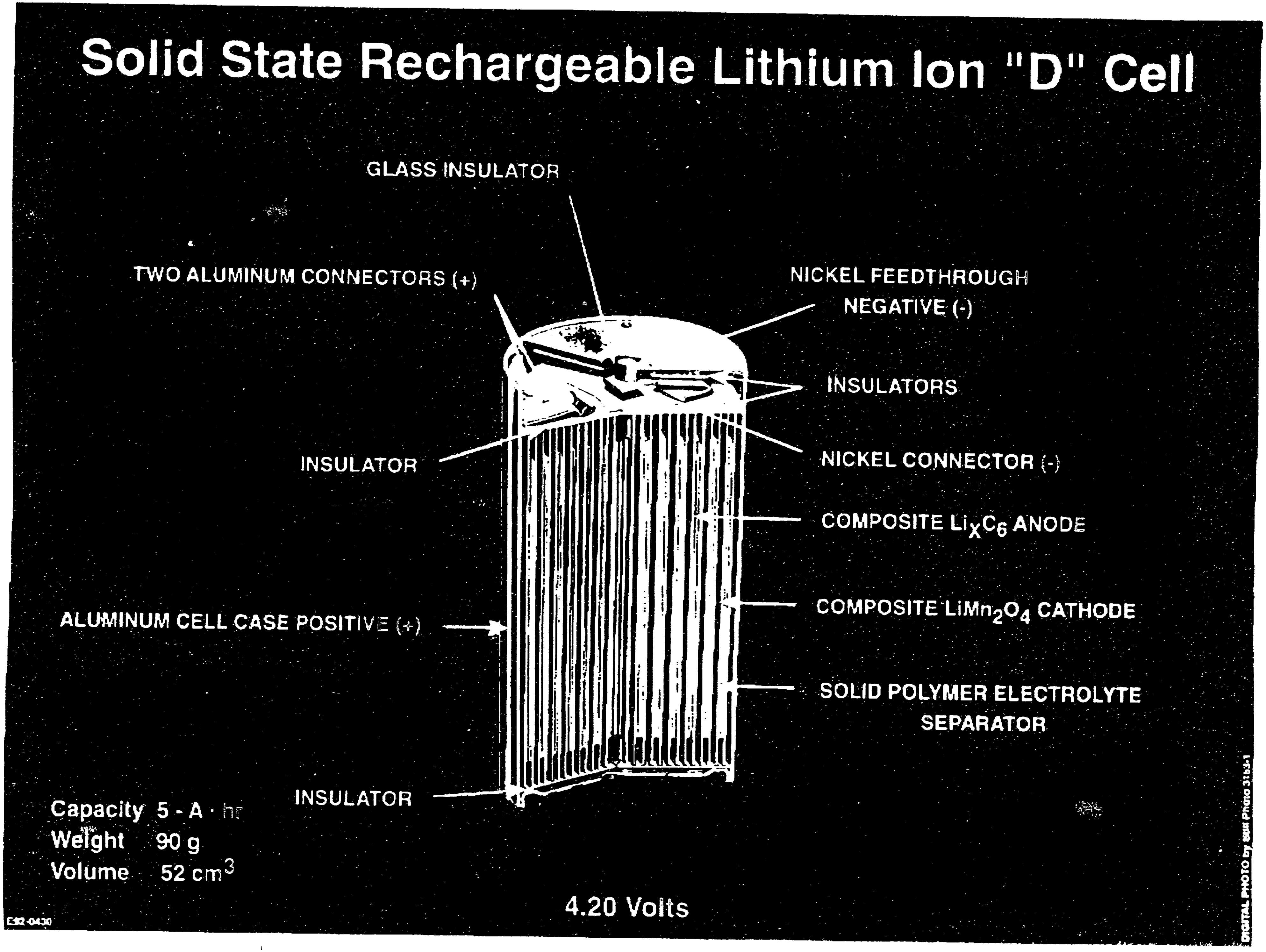
$$Zn + O_2 + 2OH^- + H_2O \underset{\text{charge}}{\overset{\text{discharge}}{\rightleftharpoons}} Zn(OH)_4^{2-}$$

- AMBIENT TEMPERATURE OPERATION
- BENIGN ACTIVE MATERIALS
- HIGH SPECIFIC ENERGY
- LOW COST MATERIALS
- CAN BE ELECTRICALLY RECHARGED
- AIR ELECTRODE LIMITS LIFE

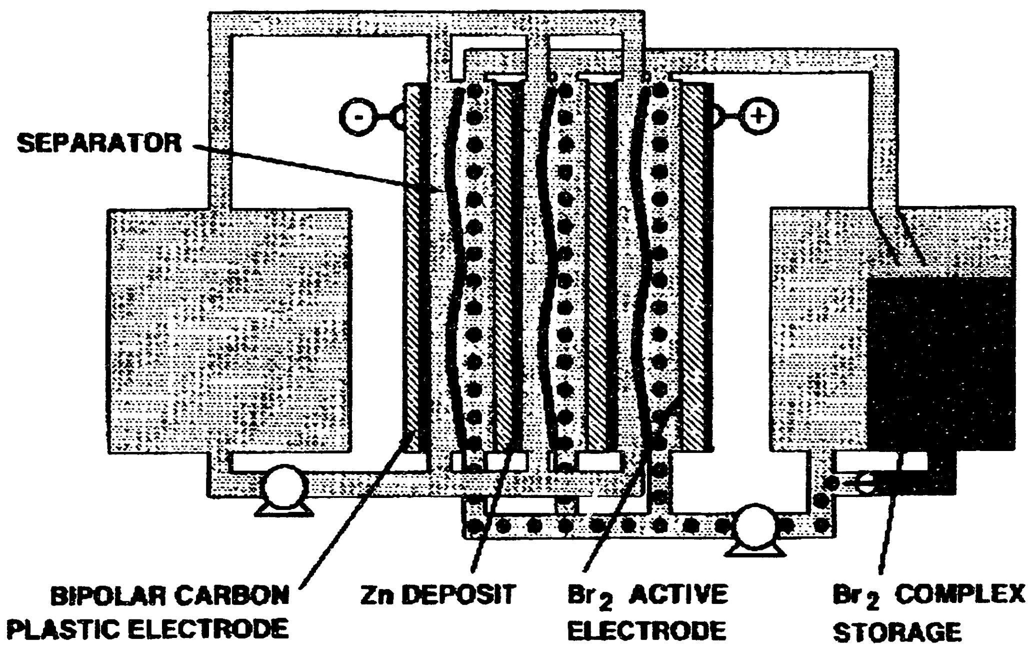
- SINGLE CELLS DESIGNED AND ON TEST
- CONCEPTUAL SYSTEM DESIGNS BEING DEVELOPED
- NEW AIR ELECTRODE CATALYSTS IDENTIFIED




endocal
514
Zn/Br2
Zn/Br2


Solid State Rechargeable Lithium Ion "D" Cell
GLASS INSULATOR
TWO ALUMINUM CONNECTORS (+)
NICKEL FEEDTHROUGH NEGATIVE (-)
INSULATORS
INSULATOR
NICKEL CONNECTOR (-)
COMPOSITE Li_xC_6 ANODE
ALUMINUM CELL CASE POSITIVE (+)
COMPOSITE $LiMn_2O_4$ CATHODE
SOLID POLYMER ELECTROLYTE SEPARATOR
INSULATOR
Capacity 5 - A · hr
Weight 90 g
Volume 52 cm^3
4.20 Volts
E92-0430
DIGITAL PHOTO by Bell Photo 3163-1

RECHARGEABLE ZINC/BROMINE BATTERY



CHARACTERISTICS

- FLOWING ELECTROLYTE SYSTEM
- BIPOLAR CONSTRUCTION
- MODERATE SPECIFIC POWER AND ENERGY
- POTENTIALLY LOW COST SYSTEM

PROGRAM STATUS

- IN ADVANCED DEVELOPMENT
- PROTOTYPE EV BATTERY BUILT
- PROTOTYPE LOAD-LEVELING BATTERY MODULE BUILT

REACTIONS

$$Zn + Br_2 \underset{\text{CHARGE}}{\overset{\text{DISCHARGE}}{\rightleftharpoons}} ZnBr_2$$

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FUEL CELL AND CAPACITOR TECHNOLOGIES

FUEL CELLS

* PHOSPHORIC ACID
* MOLTEN CARBONATE
* SOLID OXIDE
* PROTON EXCHANGE MEMBRANE

HIGH ENERGY DENSITY CAPACITORS

* CARBON–SULFURIC ACID
* MIXED METAL OXIDE

ADVANCED BATTERY TECHNOLOGIES

AMBIENT TEMPERATURE BATTERIES

* ZINC/AIR
* ZINC/BROMINE
* NICKEL/METAL HYDRIDE
* NICKEL/ZINC
* LITHIUM/POLYMER ELECTROLYTE

HIGH TEMPERATURE BATTERIES

* SODIUM/SULFUR
* SODIUM/NICKEL CHLORIDE
* LITHIUM/IRON DISULFIDE

SAE INTERNATIONAL

** NOTES **

ALTERNATIVE FUEL SERIES

SAE in the 90s

Electric & Hybrid Vehicle Technology TOPTEC

LUNCHEON

12:00p.m.- 1:30p.m., September 14, 1992

Invited Keynote Speaker - Alan Lloyd, Chief Scientist, SCAQMD

Alan C. Lloyd
Chief Scientist
South Coast Air Quality Management District

Significant amounts of activity are occurring in California both to develop electric vehicles and their components, as well as to provide plans to create the infrastructure to support a viable electric vehicle program. This talk will focus on these recent events and will provide an update on the current plans for the introduction of electric vehicles. The contrast will also be made between information on current vehicles and their implication for the introduction of electric vehicles.

Alan C. Lloyd
Chief Scientist
South Coast Air Quality Management District

Mr. Lloyd has been with SCAQMD, Diamond Bar, California since 1988. As Chief Scientist, he is in charge of the Technology Advancement Office and advises Executive Management on applications of technical and scientific research and development to improve air quality; formulate research development proposals which advance technology, and provide scientific input to the Executive Officer for public policies including technology which affects the Los Angeles Basin.

From 1984 to 1988, Mr. Lloyd served as General Manager of ENSR (formerly ERT, Westlake) in Camarillo, California. There, he was responsible for the management of all financial, technical and personnel aspects of the california office of ENSR. While still ERT, Westlake, California, Mr. Lloyd held the positions of Manager with the Air Quality Division, Environmental Research and Technology, Inc.; Deputy Manager of the Environmental Analysis Division; Manager, Environmental Modeling Section; and Senior Staff Scientist. He had worked as a Research Chemist starting in 1967.

Mr. Lloyd is a member of the Air & Waste Management Association and has teaching credits dating back to 1971. A member of numerous committees, he currently serves on the Research Screening Committee of the CA Air Resources Board; the Safe New Alternatives Program (SNAP) of the United States Environmental Protection Agency; the Atmospheric Science Advisory Council of UCLA; the Ad Hoc Technical Panel to provide technical expertise to DOE for preparation of a National Program Plan for Fuel Cells in Transportation; the STAPPA and ALAPCO Air Toxics Committee; and the Advisory Committee for the CA Museum of Science and Industry on "Our Urban Environment".

Abstract-Electric & Hybrid Vehicle Technology TOPTEC
Monday, September 14, 1992

Battery Support Systems

Kenneth Winters
Manager, Power Systems
Industrial Division - Pentastar Electronics, Inc.

The development of commercially acceptable battery systems for today's budding electric vehicle market requires intensive design efforts to minimize operator intervention of frequent maintenance tasks and to provide maximum vehicle performance and battery life. Meeting the demanding performance requirements of electric vehicles aimed at near term production requires the use of not only advanced techniques but concepts which fit within the current logistical framework of today's automotive arena and within the sometimes very critical customer acceptance profile.

This presentation deals with possible techniques which are suitable for solving some of the support problems associated with the "less than perfect" characteristics of today's batteries. A summary of techniques related to automated battery watering, module voltage monitoring, state-of-charge calculation, thermal management, battery gas management and long term logging and archiving of data for service diagnostics and warranty protection are presented.

After the technical review, these techniques and hardware system will be evaluated in light of current production, field support and market requirements.

Kenneth Winters
Manager, Power Systems
Industrial Division - Pentastar Electronics, Inc.

Mr. Winters is currently the manager of Power Systems Development at Pentastar Electric. He specializes in integrated Electric Vehicle Systems and EV component development for the past 15 years. He also has over 20 years of design experience in power electronics components and systems.

Mr. Winters originated the Chrysler TEVan electric vehicle concept; developed 5 military products related to electric traction systems now being used aboard U.S. submarines; and is experienced in the design of large scale data acquisition and system control (SCADA) equipment. He received a BSEE from the University of Florida.

ALTERNATIVE FUEL SERIES

SAE in the 90s

** NOTES **

Abstract-Electric & Hybrid Vehicle Technology TOPTEC
Monday, September 14, 1992

Off-Board Lead Acid Battery Charger Principles

Grover Wilson
Application Engineering Manager
Hobart Brothers - Battery Charger Division

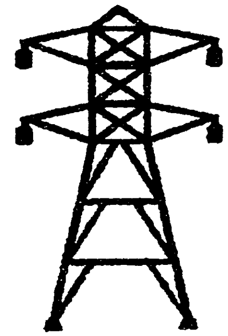
Not only must the charger profile (its output voltage-current-time relationship) be correctly matched to the requirements of the battery, but proper charge termination techniques are also extremely important for optimum life and performance from lead acid batteries. This presentation will describe the various charge profiles in use today for charging lead acid batteries. Also discussed will be the most common charge termination techniques presently used in the industry.

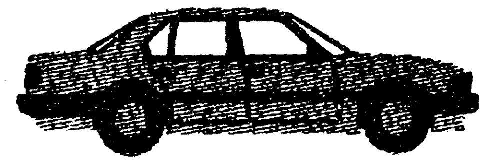
Biography-Electric & Hybrid Vehicle Technology TOPTEC

Grover Wilson
Application Engineering Manager
Hobart Brothers - Battery Charger Division

Mr. Wilson's current activities include research into the next generation battery charger for electric vehicles and also the development of portable propane/natural gas DC generators for emergency charging of EV batteries. He has 27 years experience in the power conversion field and has spent the past 15 years working in the Battery Charger Group designing both constant current-constant voltage and taper type chargers.

A graduate of the University of Dayton with a degree in Engineering, Mr. Wilson is a member of BCI (Battery Council International) Battery Charger Technical Committee. He is also a member of UL's Industry Advisory Conference for industrial battery chargers, SAE and IEEE.





LEAD-ACID BATTERY CHARGER PRINCIPLES

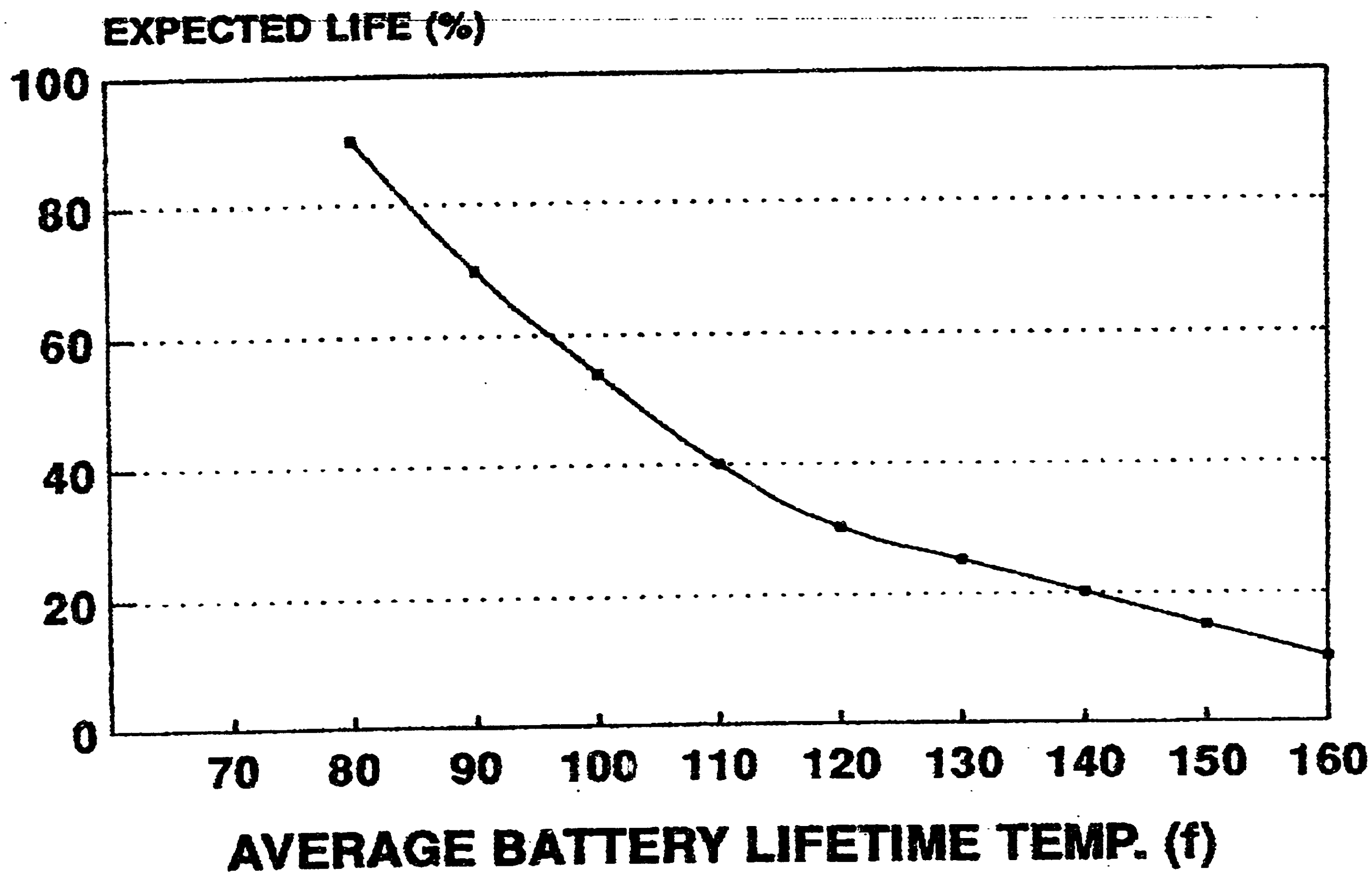
SAE
ELECTRIC & HYBRID VEHICLE TECHNOLOGY TOPTEC
SEPTEMBER 14, 1992
DEARBORN, MI.

PRESENTED BY:
GROVER WILSON
HOBART BROTHERS
TROY, OH.

BATTERY LIFE

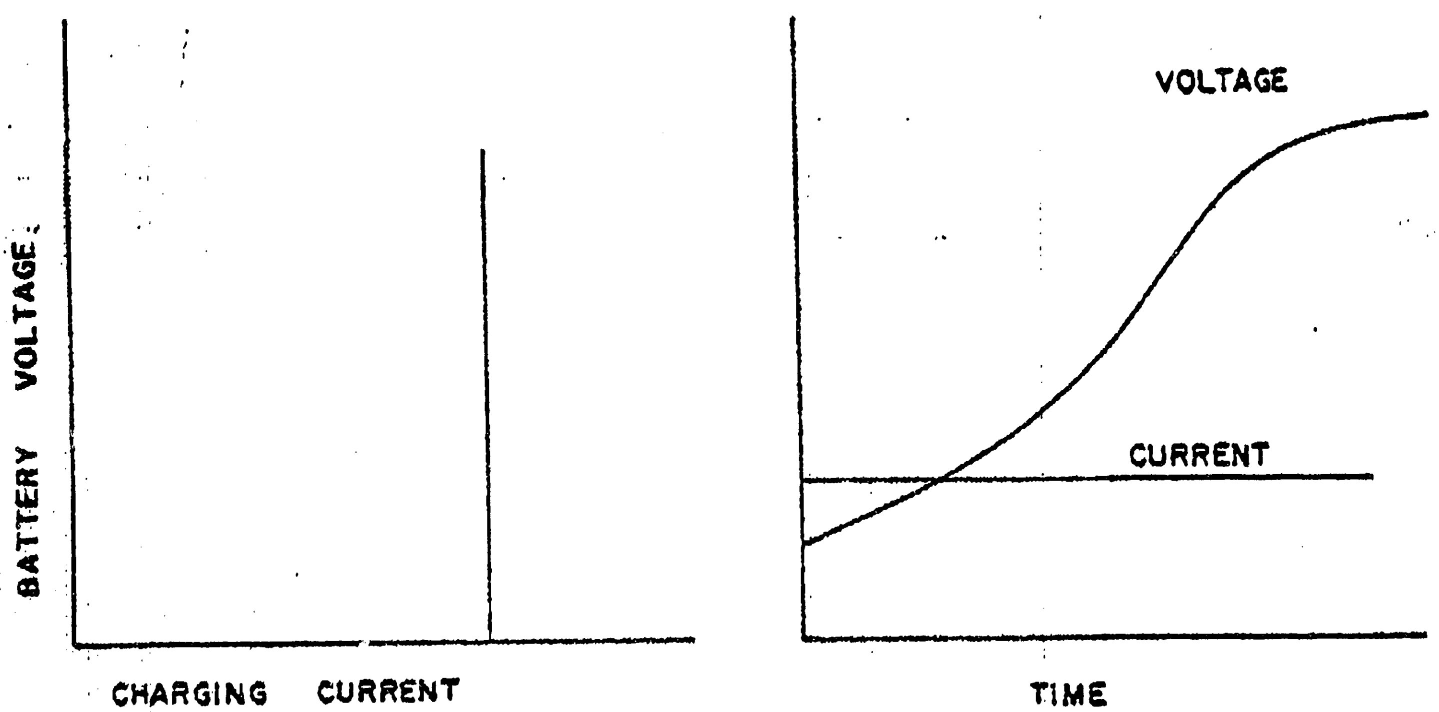
- TEMPERATURE RELATED
- DEPTH OF DISCHARGE RELATED
- TOO LITTLE GASSING
- EXCESSIVE GASSING

TEMPERATURE EFFECT
LEAD ACID BATTERY LIFE

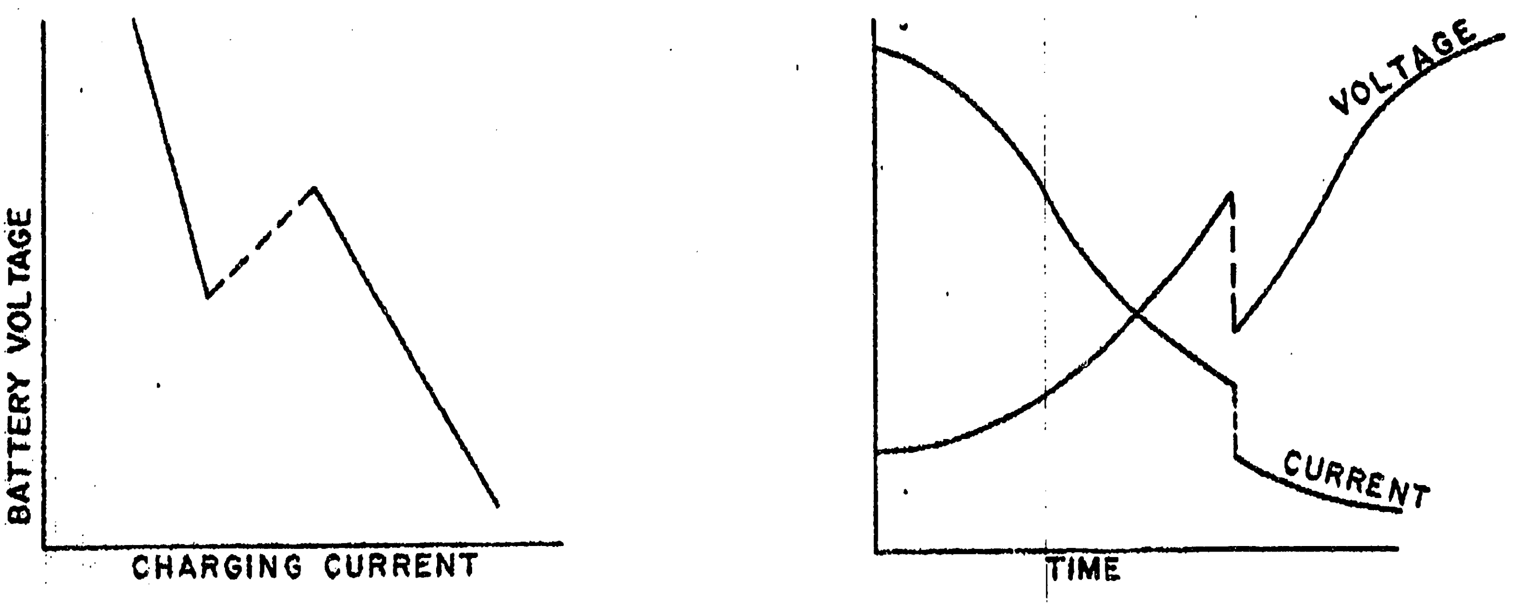


VOLTAGE TIME RELATIONSHIPS

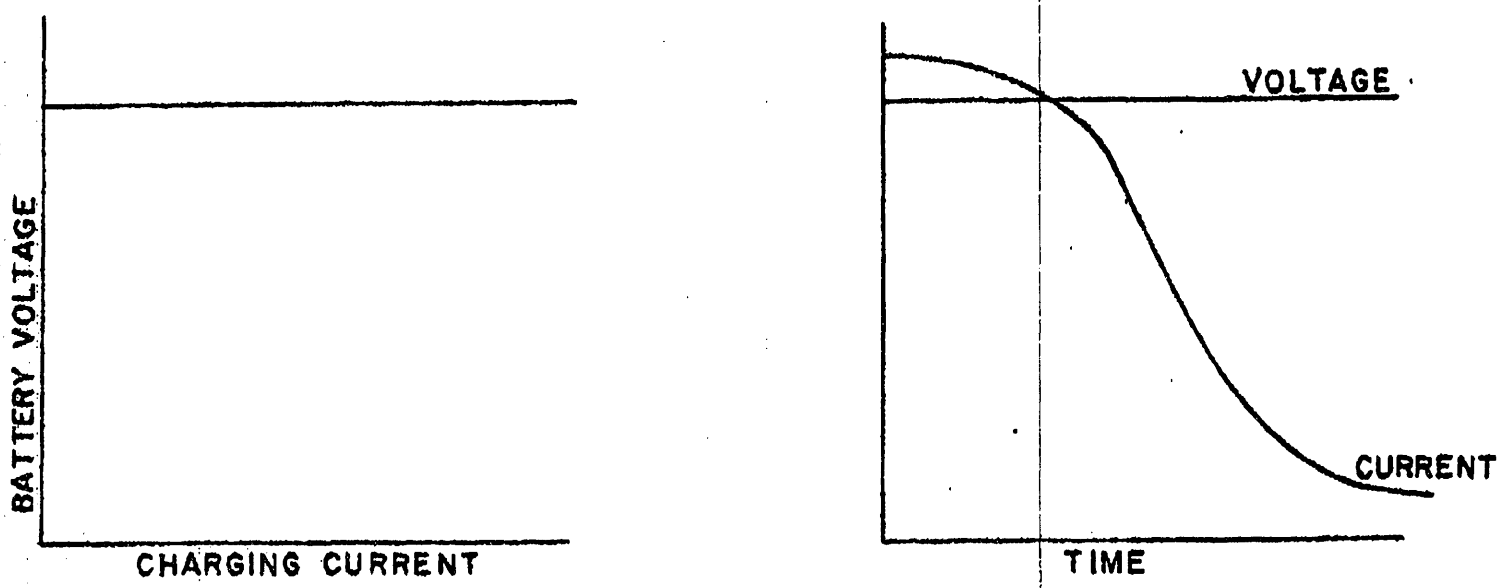
- CONSTANT CURRENT
- TWO RATE (MODIFIED CONSTANT CURRENT)
- CONSTANT VOLTAGE
- TAPER (MODIFIED CONSTANT VOLTAGE)
- CONSTANT CURRENT – TAPER
- CONSTANT CURRENT – TAPER – CONSTANT CURRENT
- OTHERS



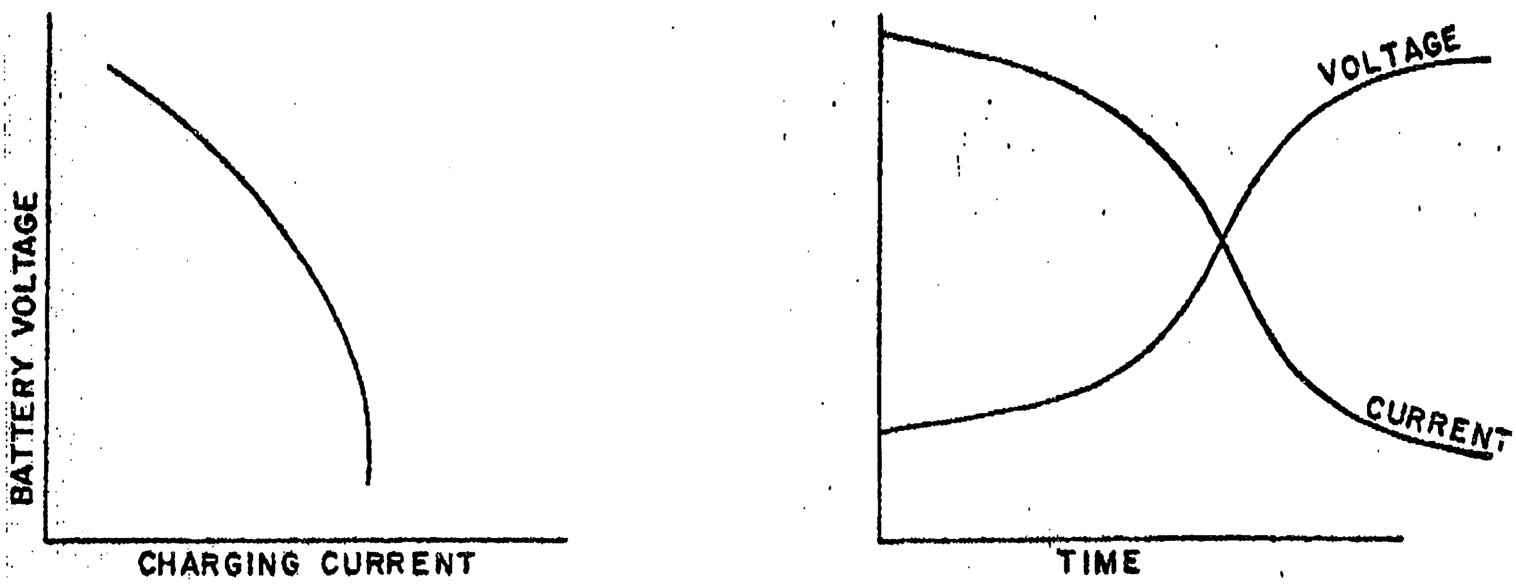
<u>Constant Current Charging</u>



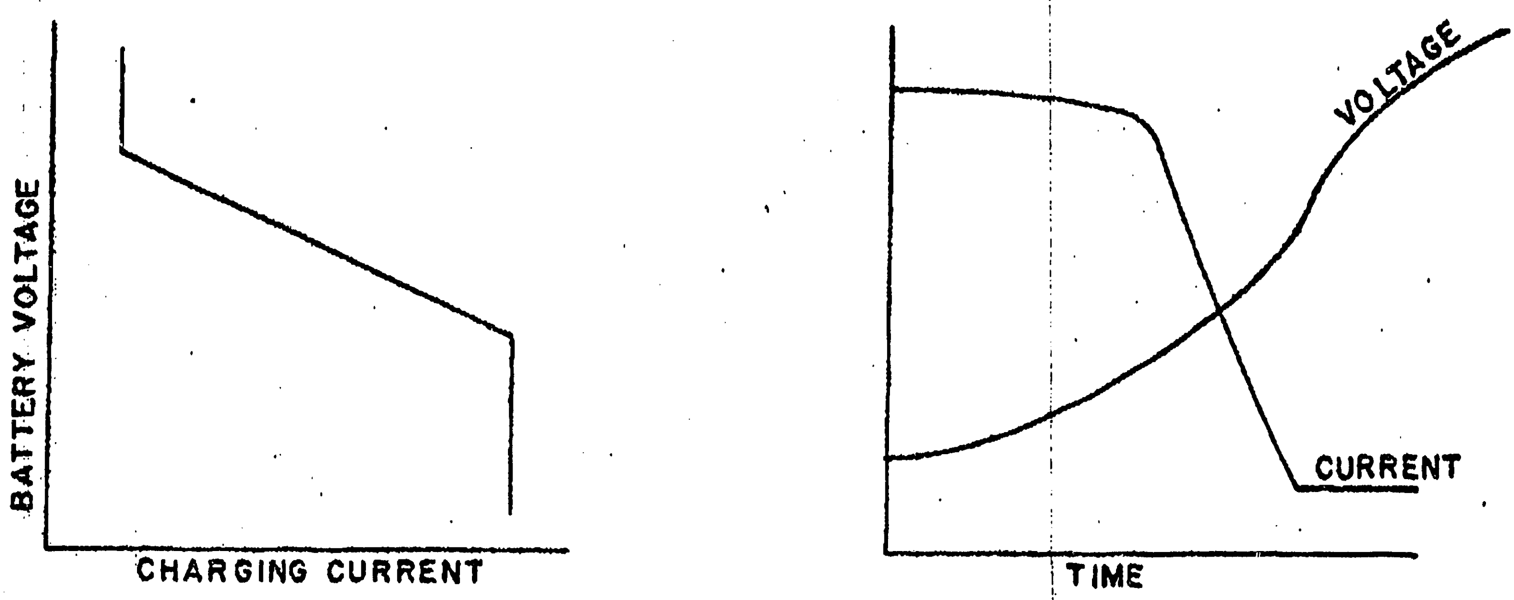
2-rate (Modified Constant Current) Charging



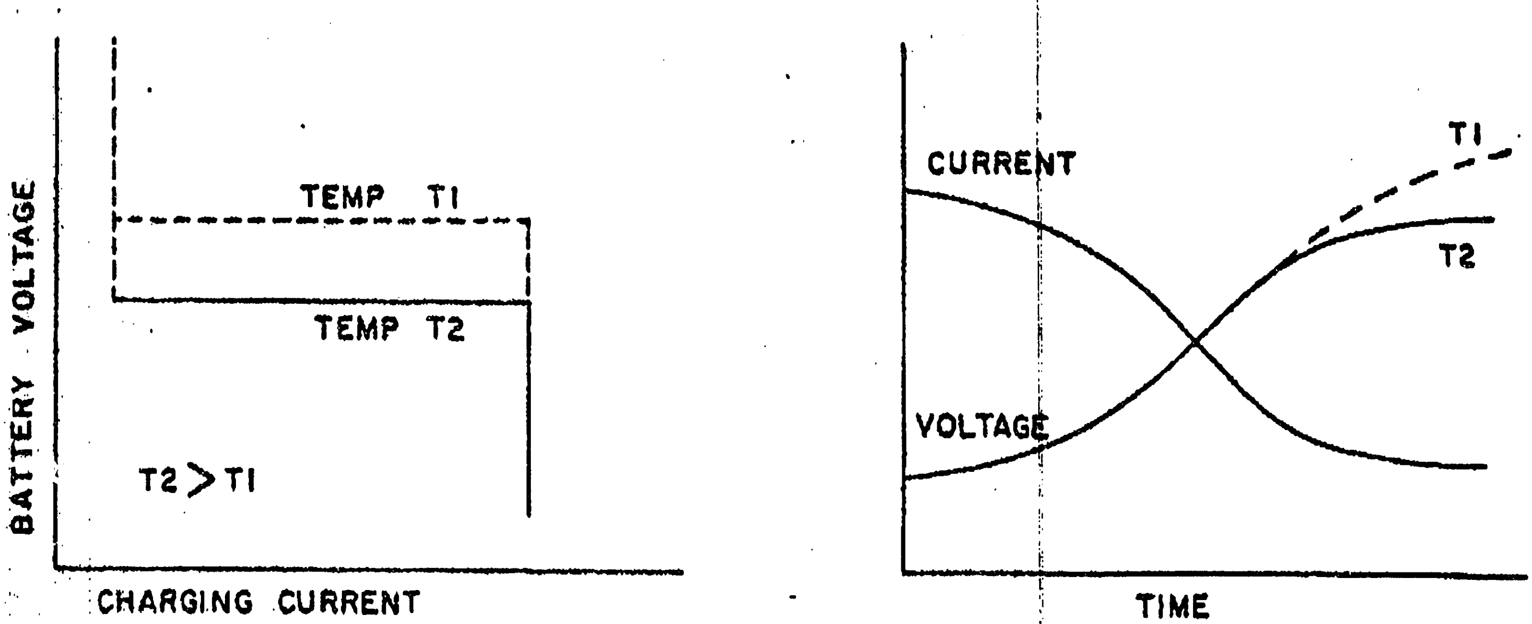
<u>Constant Voltage Charging</u>



Taper (Modified Constant Voltage) Charging

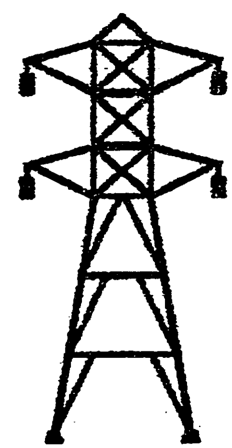


Constant Current - Taper - Constant Current Charging



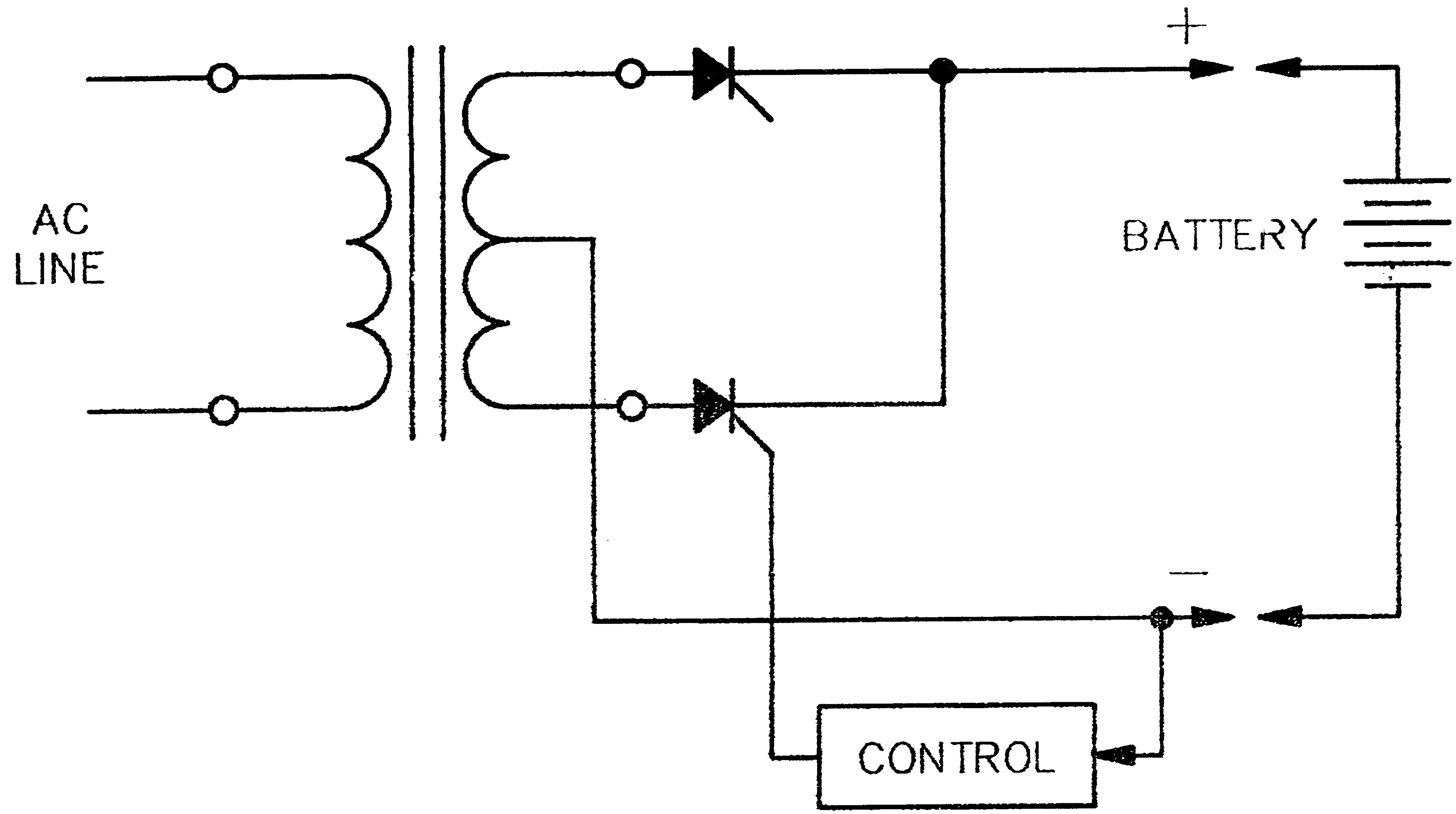
Constant Current - Constant Voltage (Temperature Compensated)

PROCESSING ENERGY

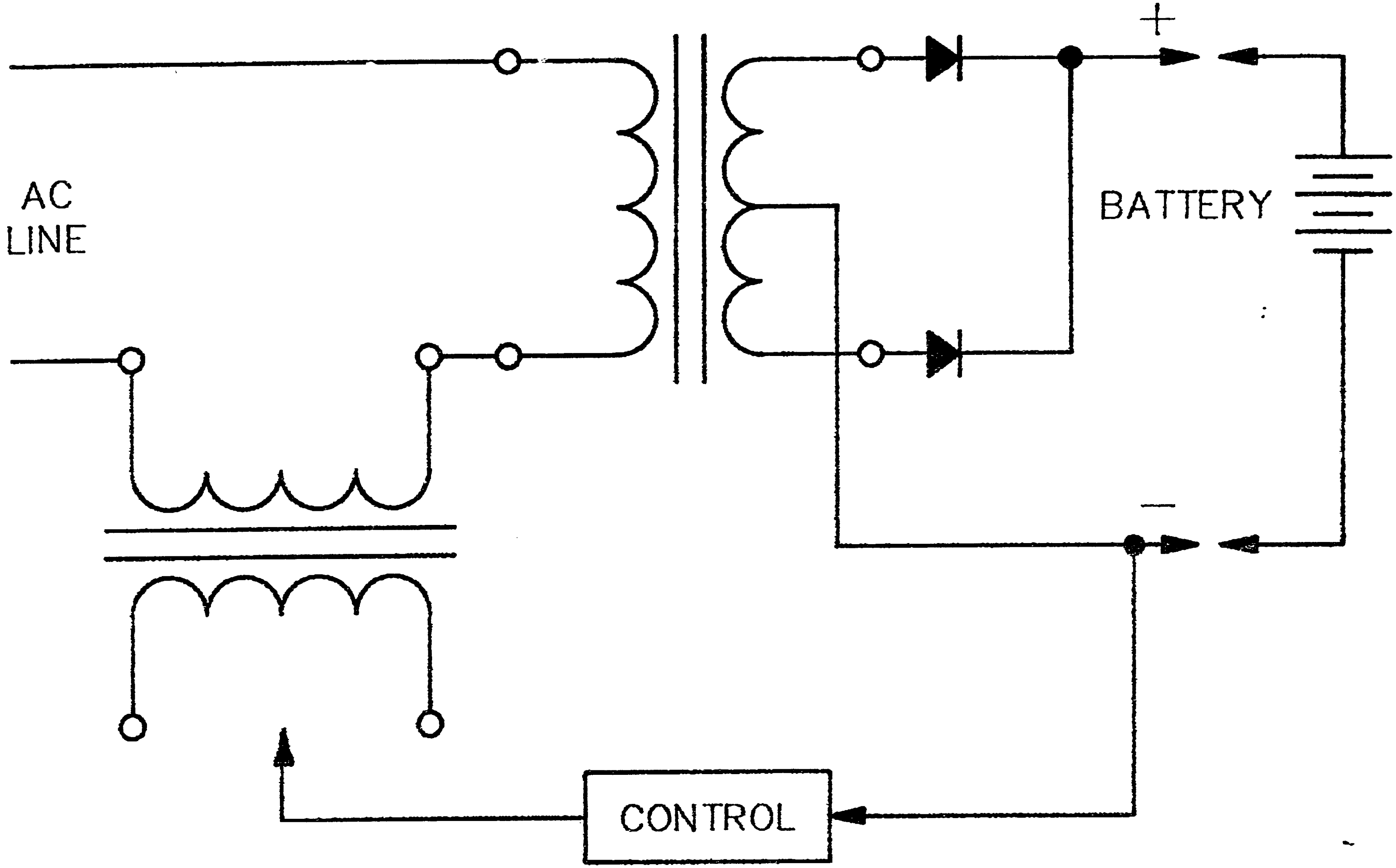


TOPOLOGIES

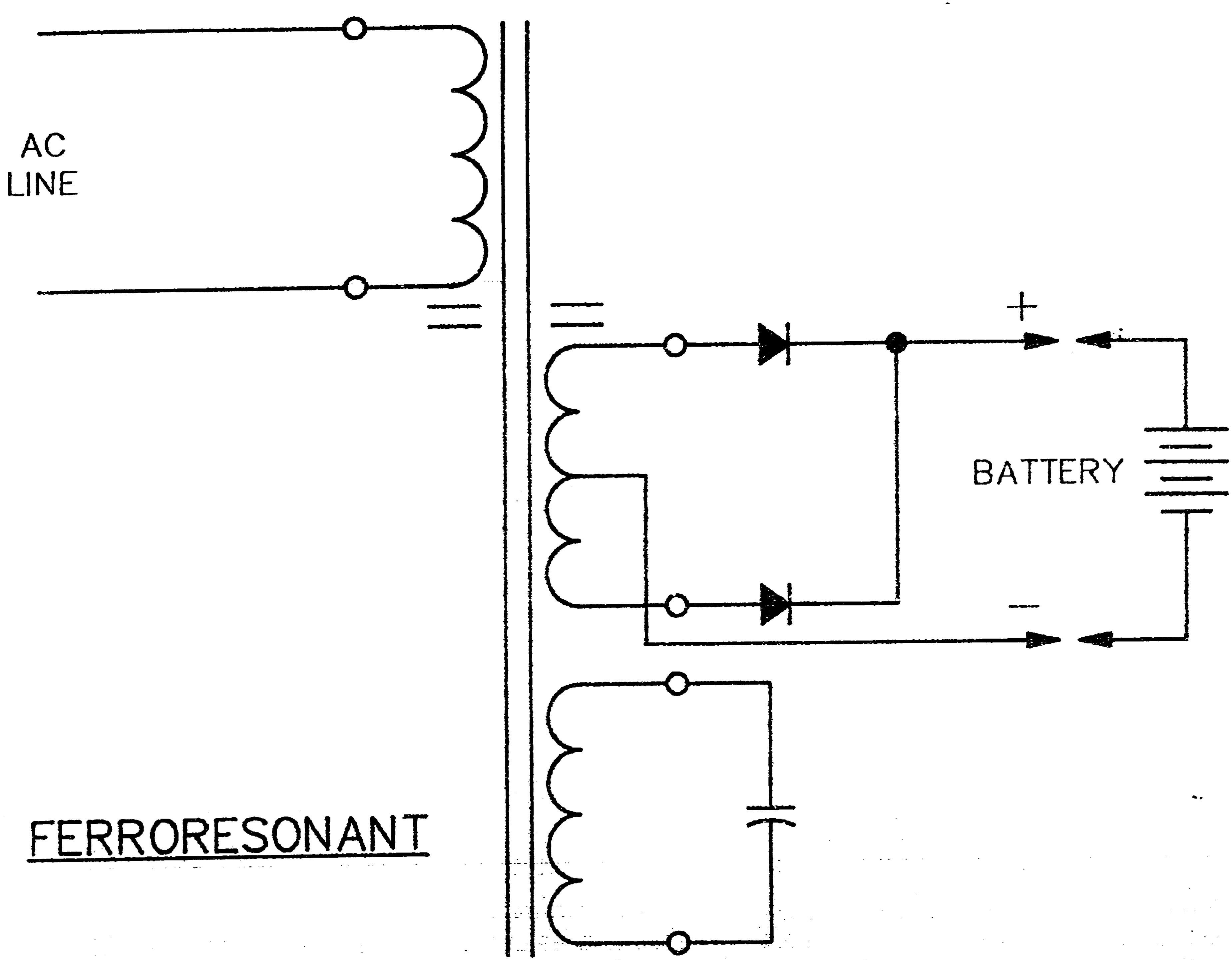
- THYRISTOR (SCR)
- MAGNETIC AMPLIFIER
- FERRORESONANT
- LINEAR
- CONTROLLED FERRORESONANT
- CONVERTER



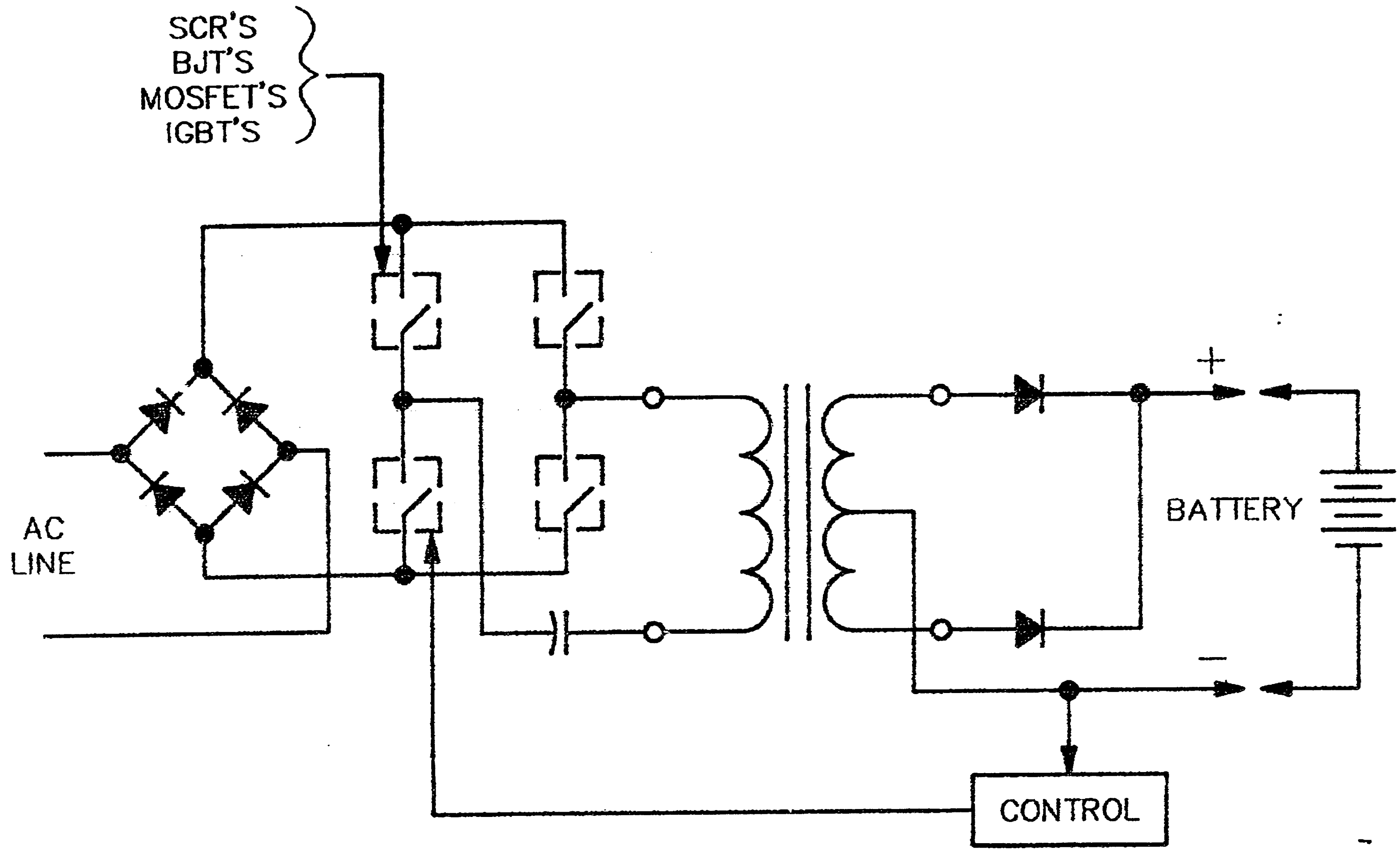
SCR



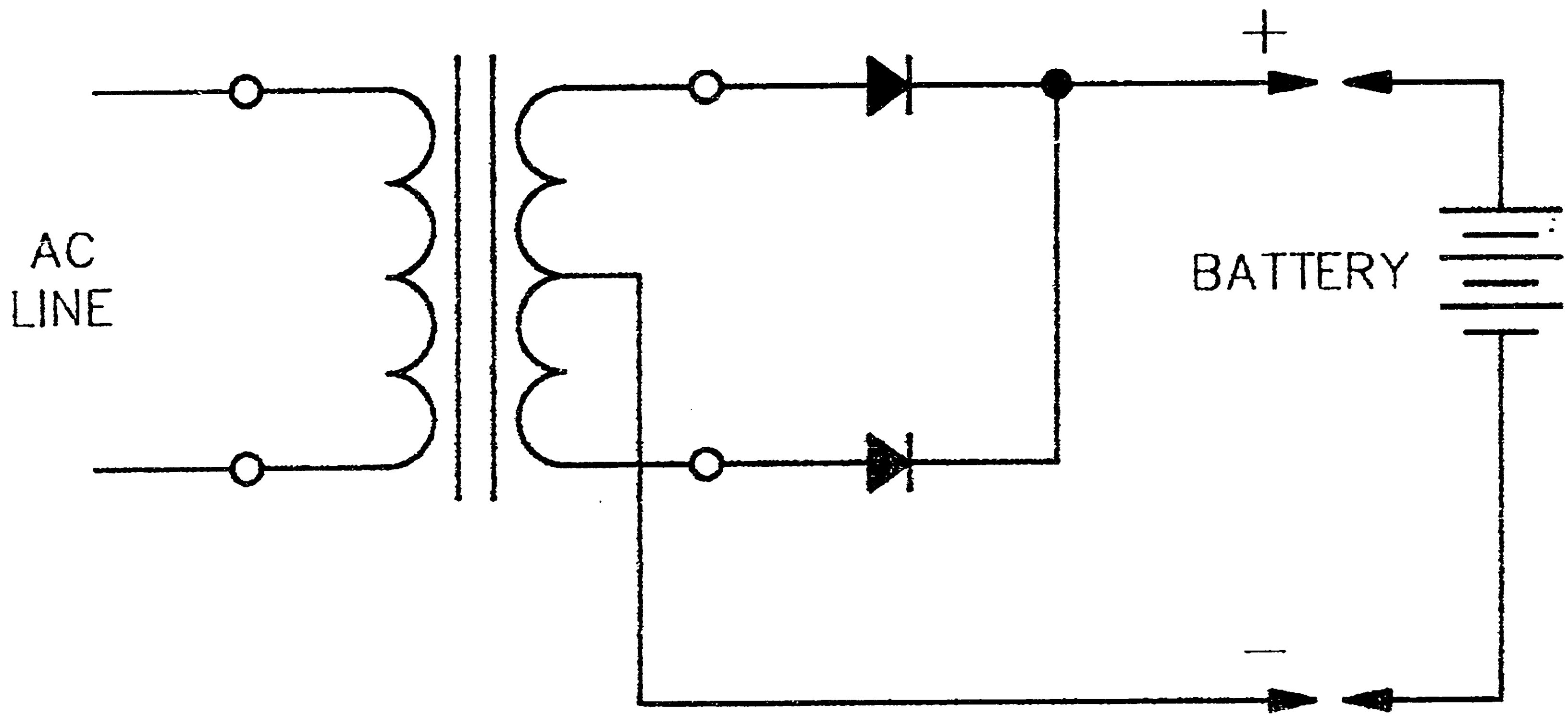
MAG AMP



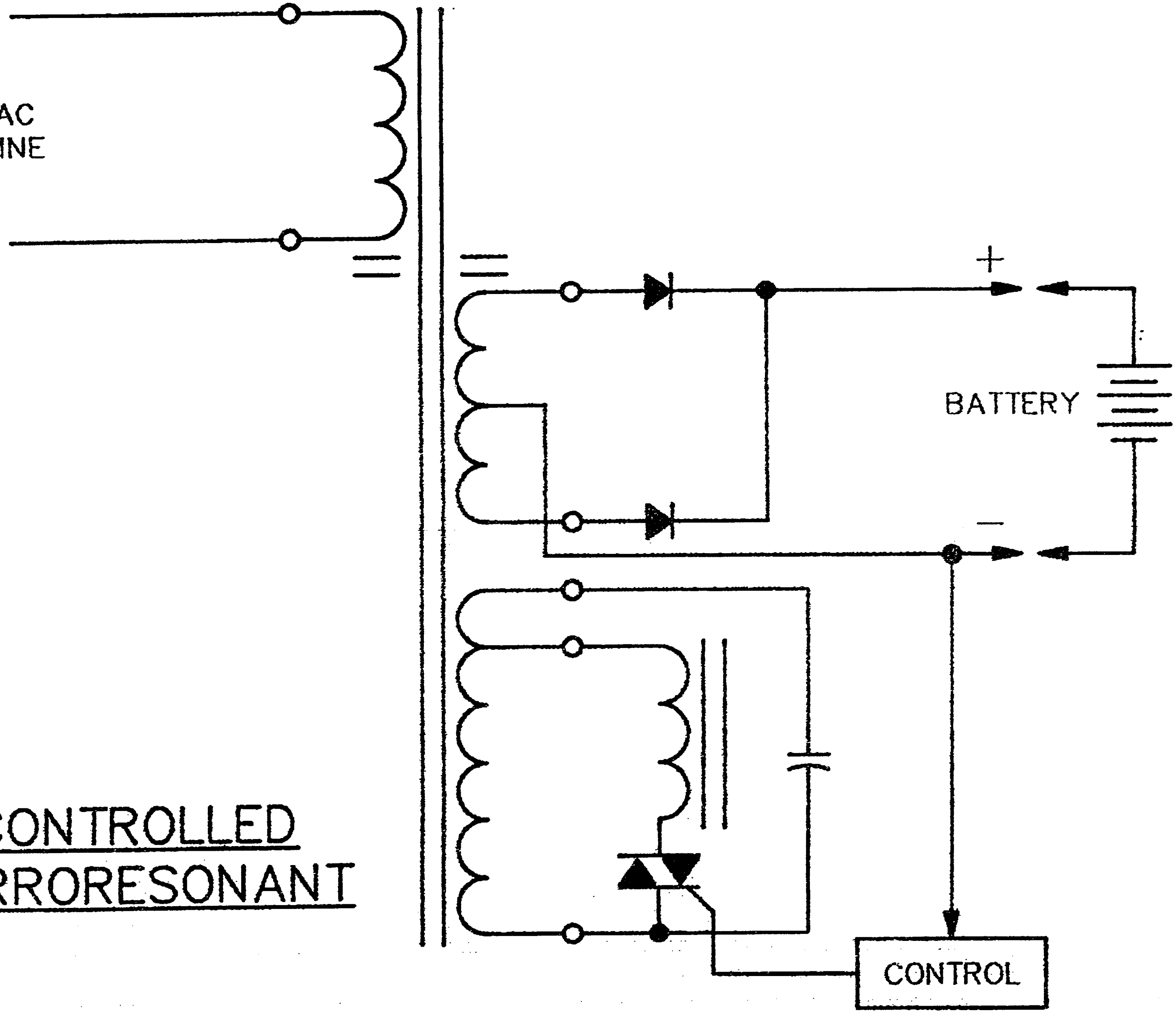
FERRORESONANT



CONVERTER



LINEAR

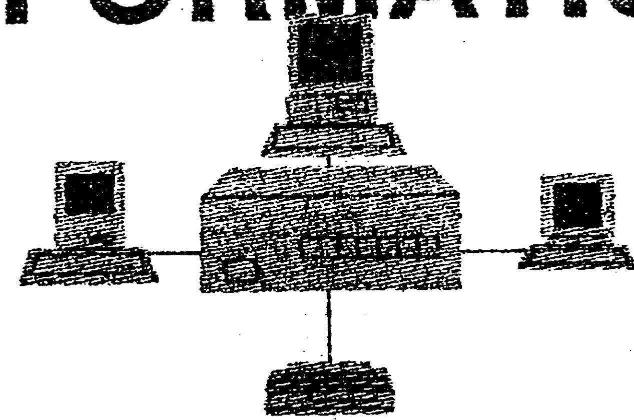


CONTROLLED
FERRORESONANT

POWER CONVERSION CIRCUIT

	MAG-AMP SCR	FERRO	CONTROLLED FERRO	CONVERTER
EFFICIENCY	MED/HIGH	HIGH	HIGH	HIGH
POWER FACTOR	LOW	HIGH	HIGH	MEDIUM
HARMONIC LINE CURRENT	HIGH	LOW	LOW	LOW
SIZE/WEIGHT	MEDIUM-HEAVY	MEDIUM-HEAVY	LARGE-HEAVY	SMALL-LIGHT
ELECTRICAL NOISE	MEDIUM	LOW	LOW	MEDIUM
AUDIBLE NOISE	MEDIUM	LOW	LOW	LOW
COST	MEDIUM	LOW	MEDIUM	HIGH
CHARGE PROFILE FLEXIBILITY	GOOD	MEDIUM	GOOD	GOOD

PROCESSING INFORMATION



CHARGE TERMINATION

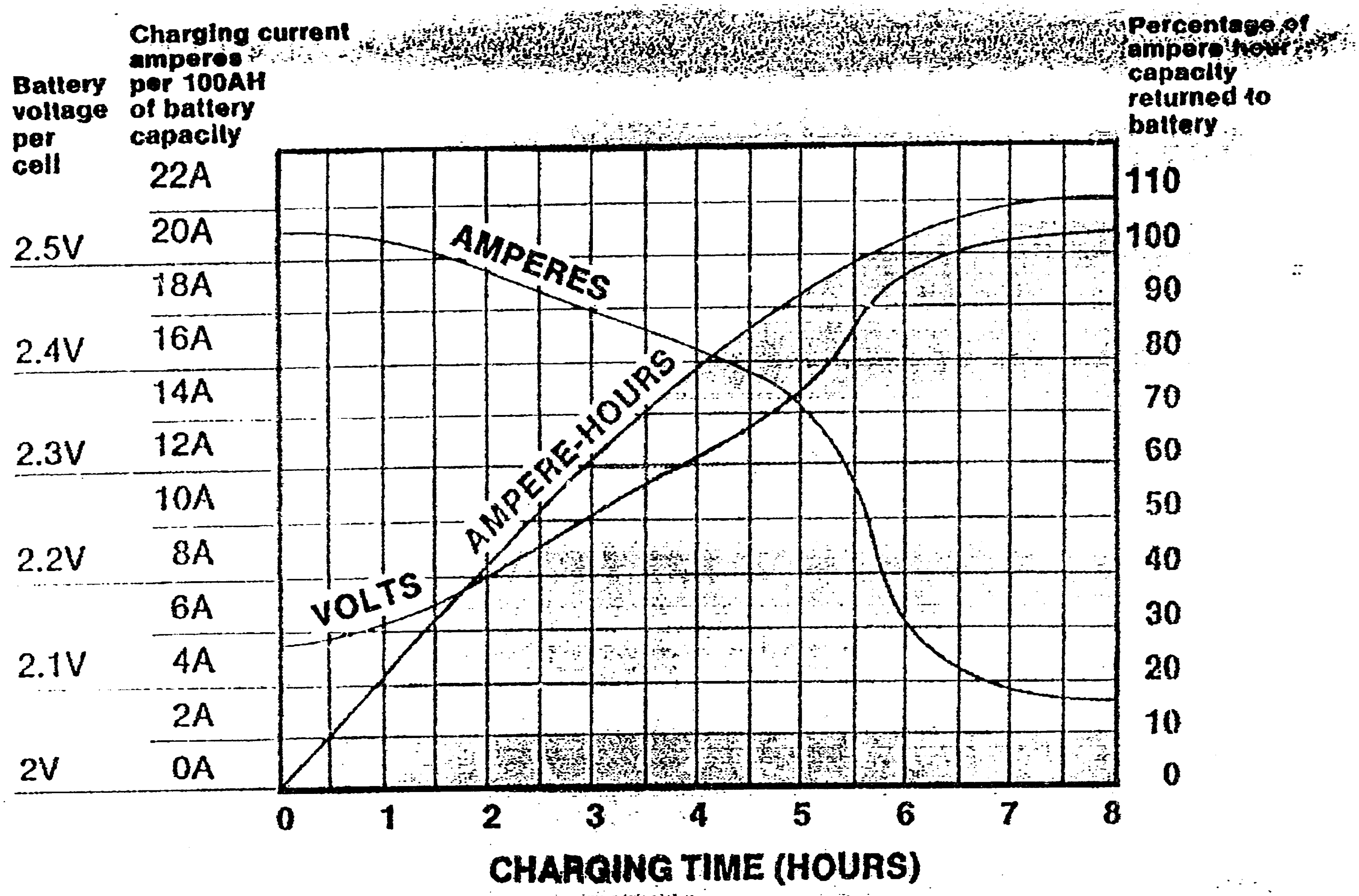
TYPES

- STRAIGHT TIME
- VOLTAGE TIME
- PROPORTIONAL VOLTAGE TIME
- dv/dt
- OTHERS

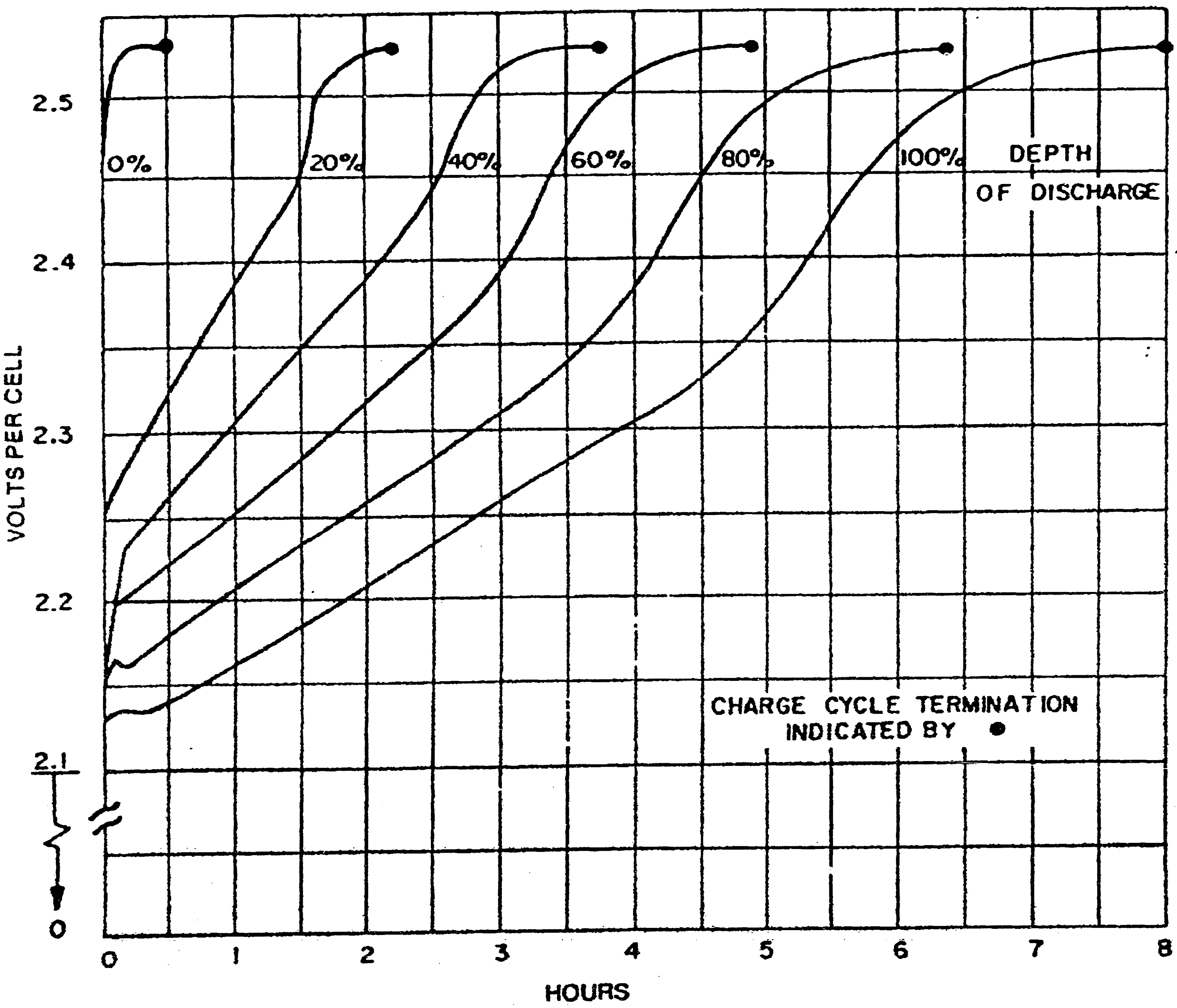
CHARGING CHART

CHARGE TIME VERSUS SPECIFIC GRAVITY

SPECIFIC GRAVITY	CHARGE TIME
1280	0
1270	.5
1260	1.0
1250	1.5
1240	2.0
1230	2.5
1220	3.0
1210	3.5
1200	4.0
1190	4.5
1180	5.0
1170	5.5
1160	6.0
1150	6.5
1140	7.0
1130	7.5
1120	8.0
1110	8.5
1100	9.0



Battery voltage per cell
Charging current amperes per 100AH of battery capacity
Percentage of ampere hour capacity returned to battery
2.5V
2.4V
2.3V
2.2V
2.1V
2V
22A
20A
18A
16A
14A
12A
10A
8A
6A
4A
2A
0A
110
100
90
80
70
60
50
40
30
20
10
0
AMPERES
AMPERE-HOURS
VOLTS
0
1
2
3
4
5
6
7
8
CHARGING TIME (HOURS)



VOLTS PER CELL
2.5
2.4
2.3
2.2
2.1
0
0%
20%
40%
60%
80%
100%
DEPTH
OF DISCHARGE
CHARGE CYCLE TERMINATION
INDICATED BY ●
0
1
2
3
4
5
6
7
8
HOURS

108 CELL 100 AH BATTERY CHARGER

ENERGY SAVINGS-dv/dt VS. STRAIGHT TIME

DOD %	AVG. AC INPUT POPWER BEYOND FULLY CHARGED POINT	EXCESS RUNNING TIME (TIMER VS. dv/dt TERMINATION	KWH LOSS
100	1.25 KW	0.00 Hr.	0.0
80	1.25 KW	1.60 Hr.	2.0
60	1.25 KW	3.10 Hr.	3.9
40	1.25 KW	4.25 Hr.	5.3
20	1.25 KW	5.75 Hr.	7.2

MODERN CONTROL FEATURES

- COMPUTER INTERFACE CAPABILITIES
- PROGRAMMABLE
- INTERROGATION OF CHARGE CYCLE
  - AMP HOURS RETURNED
  - OPEN CIRCUIT VOLTAGE
  - START AND FINISH AMPS
  - START AND FINISH VOLTS
- ENERGY SAVING CAPABILITIES
  - TIME OF DAY START
  - DELAYED START
  - TIME OF DAY BLOCKOUT
- BATTERY/CHARGER MISMATCH PROTECTION
- AUTOMATIC START/STOP
- INTERFACE WITH POWER SOURCE AND ADJUST OUTPUT
- OTHER
- AUTOMATIC EQUALIZE

** NOTES **

Abstract-Electric & Hybrid Vehicle Technology TOPTEC
Monday, September 14, 1992

Vehicle Powertrain Technologies

Wally E. Rippel
President
AC Propulsion, Inc.

Recent developments have elevated EVs from golf cart-type vehicles to performance machines. The key technologies behind this revolution are the AC induction motor drive and the sealed recombinant lead acid battery. Aspects and trends for these two technologies will be discussed and it will be shown that such vehicles have a surprising potential for simultaneously realizing high-performance, more than adequate range and good economics. It will also be shown that these are the key technologies for a future mass-market hybrid EV.

Biography-Electric & Hybrid Vehicle Technology TOPTEC

Wally E. Rippel
President
AC Propulsion, Inc.

Mr. Rippel is the President of AC Propulsion, Inc., a company which has developed and is now producing the AC-100 Electric Vehicle drive system. This is a high performance (120 hp), high efficiency induction motor drive system which includes an integrated 20 kW recharge system. He specializes in Power Electronics development and manufacturing including 22 years experience in research and development.

Mr. Rippel's education includes a MSEE from Cornell University in 1970 and a BS in Physics from Caltech in 1968. His recognitions include 19 US patents and one pending, 17 publications and 13 technology awards from NASA. He served as a consultant to the GM Sunraycer effort in 1987 and to the GM Impact effort from 1988-1990.

VEHICLE POWERTRAIN TECHNOLOGIES

by

Wally E. Rippel

AC Propulsion, Inc.

September 14, 1992

Presentation to SAE TOPTEC

Dearborn, Michigan

A NEW EV PHILOSOPHY

- Better to achieve range through efficiency than energy storage
- Both batteries and drive systems allow high power at low cost
  (Therefore capitalize on performance as well as lack of pollution)
- Range extension is better achieved via hydrocarbons than electrons
- Develop pure EV for "niche market"
- Develop series hybrid for mass market

TECHNICAL BACKGROUND

- Propulsion elements for pure EV
  - Battery Charger
  - Battery
  - Power Conditioning and Controls for Motor
  - Auxiliary Power Conditioning
  - Motor
- Drive System Figures of Merit
  - System Energy Efficiency
    - Wall Plug to wheels
    - Battery to Wheels
  - System Power / Weight
  - System Energy / Weight
  - System Energy Storage / Cost

MOTOR CANDIDATES

- Motor Candidates
  - DC Brush Type, Wound Field
  - DC Brush Type, Permanent Field
  - DC Brushless, Wound Field
  - DC Brushless, Permanent Field
  - AC Induction
  - Switched Reluctance
- Induction Motor Selected
  - High Torque / Weight and Power / Weight
    (> 1.5 ft-lb/lb, rpm up to 15,000)
  - High Efficiency Over Wide Speed and Torque Range if Properly Excited
  - Low Cost
  - Rugged

POWER ELECTRONICS DESIGN

- Philosophy
  - Give the Motor Exactly What it Wants
  - Minimize Weight, Size and Power Loss
- Parameters Selected for AC-100
  - 120 hp Peak
  - 336 V bus
  - High Speed Switching
  - Low Inductance Packaging
  - Forced-air Cooling
  - Fixed Ratio Drive

- Parameters Selected for AC-100 (Continued)

  - Optimal Slip Control
  - 18 kHz Switching
  - Sine Modulation for all Conditions
  - Integrated, Unity Power - Factor Recharge
  - Isolated Instrumentation Port
  - Protection Circuitry
  - Safety Interlocks

BATTERY

- Candidates
  - Ni-Cad
  - Ni-Metal-H
  - High Energy
  - Flooded Lead Acid
  - Gel-Cell Lead Acid
  - Recombiant Lead Acid
- Recombiant Lead Acid Selected
- Future Battery Options

SUMMARY

- High-Performance EV for Niche Market
  - Light-Weight, Efficient Drive System Enabled by Power Electronic Technology
  - Acceptable Range and Good Battery Economics Enabled by High System Efficiency
- High-Performance Hybrid EV for Mass-Market
  - Emissions 10 X Lower Than Pure Combustion
  - Oil Use 10 X Lower Than Pure Combustion
  - High Performance
  - Low Cost
  - Technology at Hand

SAE INTERNATIONAL

** NOTES **

ALTERNATIVE FUEL SERIES

SAE in the 90s

Abstract-Electric & Hybrid Vehicle Technology TOPTEC
Monday, September 14, 1992

Safe, Convenient Electric: Building the EV Infrastructure

James Janasik
Project Manager, Transportation Program
Electric Power Research Institute

The U.S reliance on petroleum-based fuels for transportation continues to grow. Traffic congestion and air pollution continue to plague most urban areas. Recent legislation such as the Clean Air Act and the revamped Highway Bill call for increased use of alternate fuel vehicles and mass transit programs. Zero emission legislation in California, New York and Massachusetts direct automakers to begin selling 2% zero emission vehicles in 1998 and 10% by 2003 (or 350,000 vehicles).

Consumer acceptance of EVs will depend on vehicle cost, safety and ease of use. Automakers and electric utilities are preparing now to ensure that EVs satisfy consumer requirements. Electric utilities have decades of experience in providing electrical service for a variety of needs. And, EPRI hopes to smooth the way for utilities by creating standards, identifying and eliminating potential safety issues, and coordinate research activities as appropriate across the U.S.

EPRI manages the National Infrastructure Working Committee, and inter industry group that plans and implements research activities. EV owners need the assurance that any EV, regardless of manufacturer, can be easily charged at any site. EPRI is involved in all aspects of this effort.

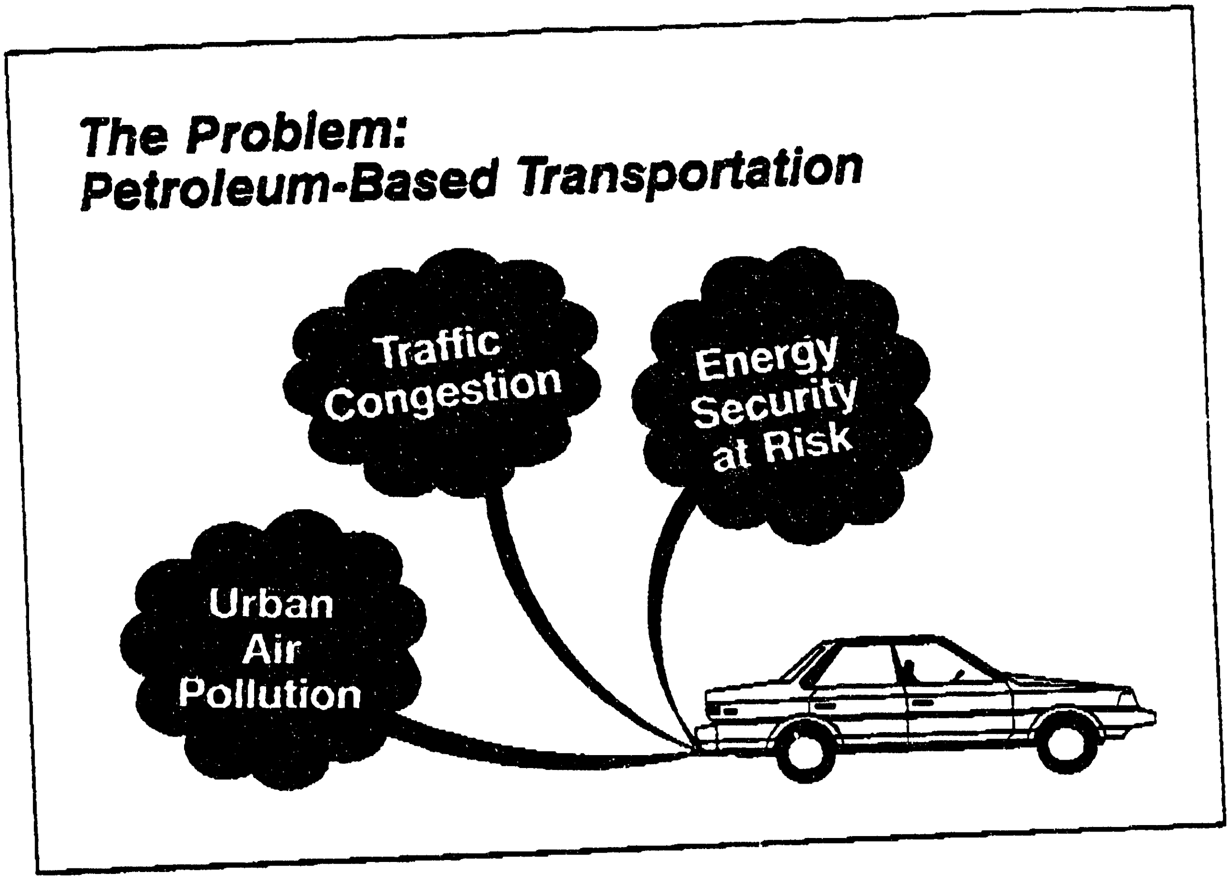
Although critical to EV commercialization, Infrastructure Development is not expected to entail any real problems for the utility industry. The utility industry is confident that safe and convenient charging options will be ready when EVs hit the market.

Biography-Electric & Hybrid Vehicle Technology TOPTEC

James Janasik
Project Manager, Transportation Program
Electric Power Research Institute

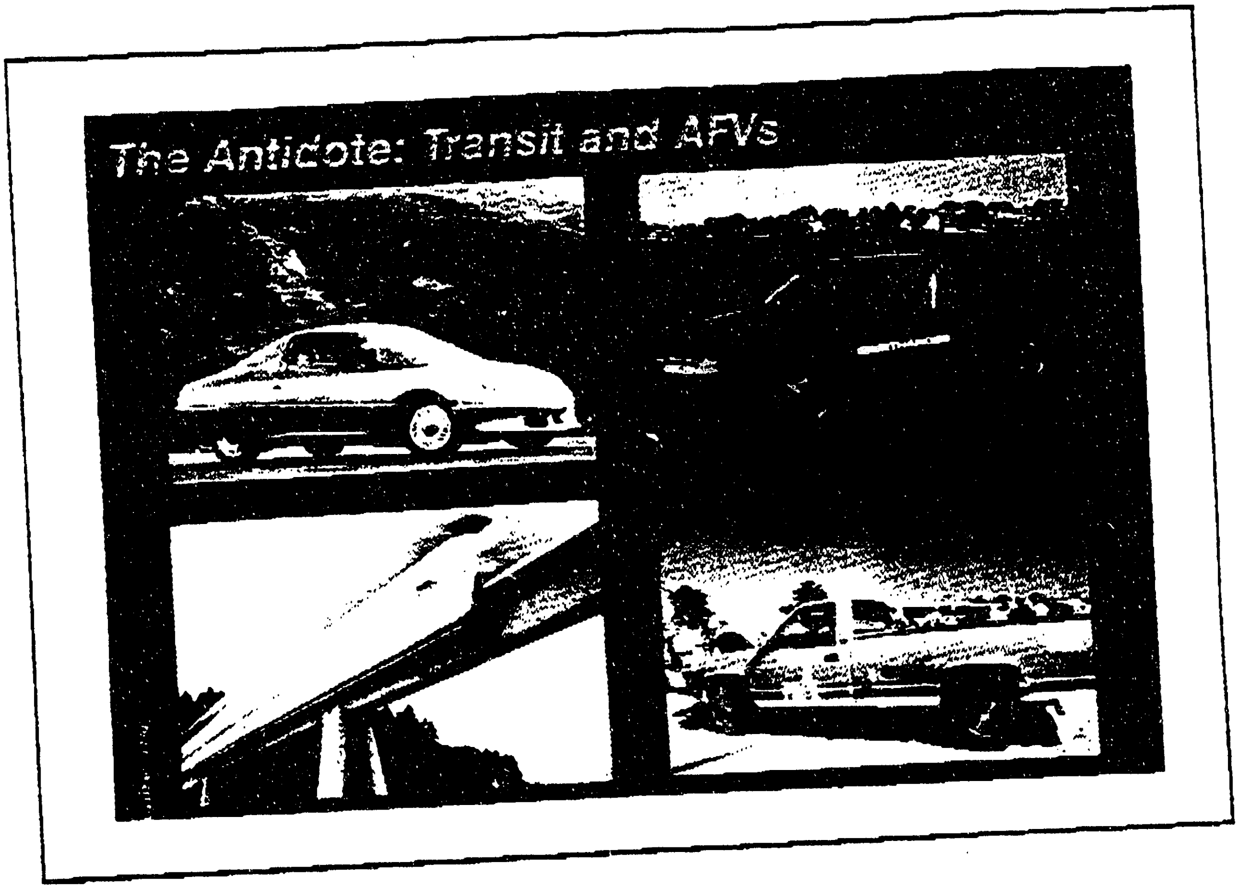
Mr. Janasik is Project Manager in the Transportation Program at the Electric Power Research Institute, and is responsible for developing infrastructure deployment to support national commercialization of electric vehicles.

Over the past 15 years, Mr. Janasik developed strong linkages with senior electric utility industry management in the areas of business planning, marketing and technology transfer. He has a Bachelor's Degree in business administration from Marquette University and a Graduate Degree in business administration from San Jose State.



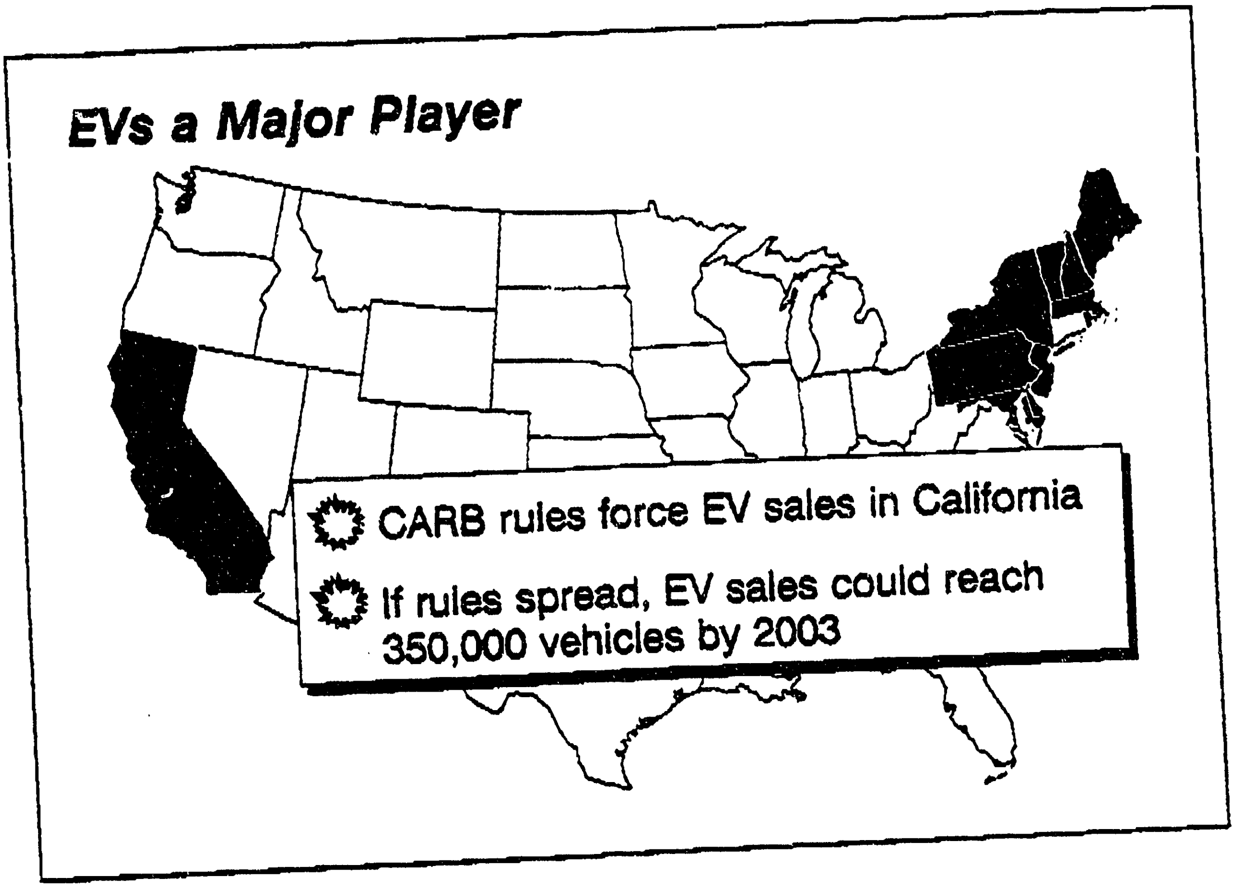
The Problem: Petroleum-Based Transportation

As our reliance on petroleum-based fuels for transportation grows, so do the resulting problems. Because much of the petroleum we use is imported, national security and the balance of payments are at risk. Further, urban air pollution remains critically high--despite increasingly tough tailpipe standards. And traffic congestion continues to plague most urban areas, draining the time, money, and patience of millions of people.



The Antidote: Transit and AFVs

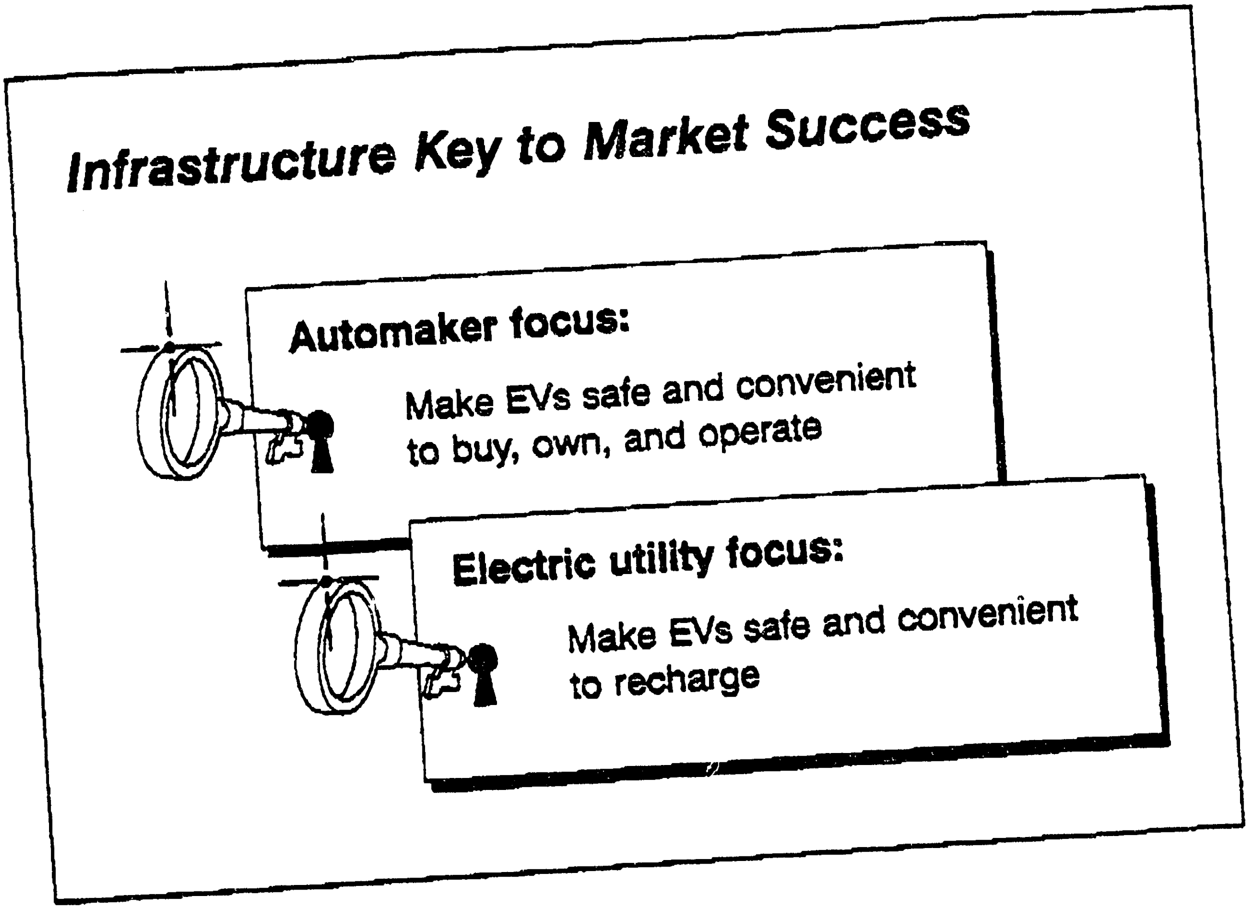
Policymakers are rising to the challenges presented by these problems with innovative measures. The recently passed Clean Air Act Amendments call for increased use of alternative fuels–such as methanol, natural gas, propane, and electricity--in many fleet and transit vehicles. Another milestone piece of legislation, the revamped highway bill, diverts dollars traditionally slated for highways to mass transit projects, creates special funds for projects that promise to clean up the air and decrease traffic congestion, and establishes programs to develop electric trains and vehicles. As these measures go into effect, alternative fuel vehicles (AFVs) and new transit solutions may become familiar transportation options.



EVs a Major Player

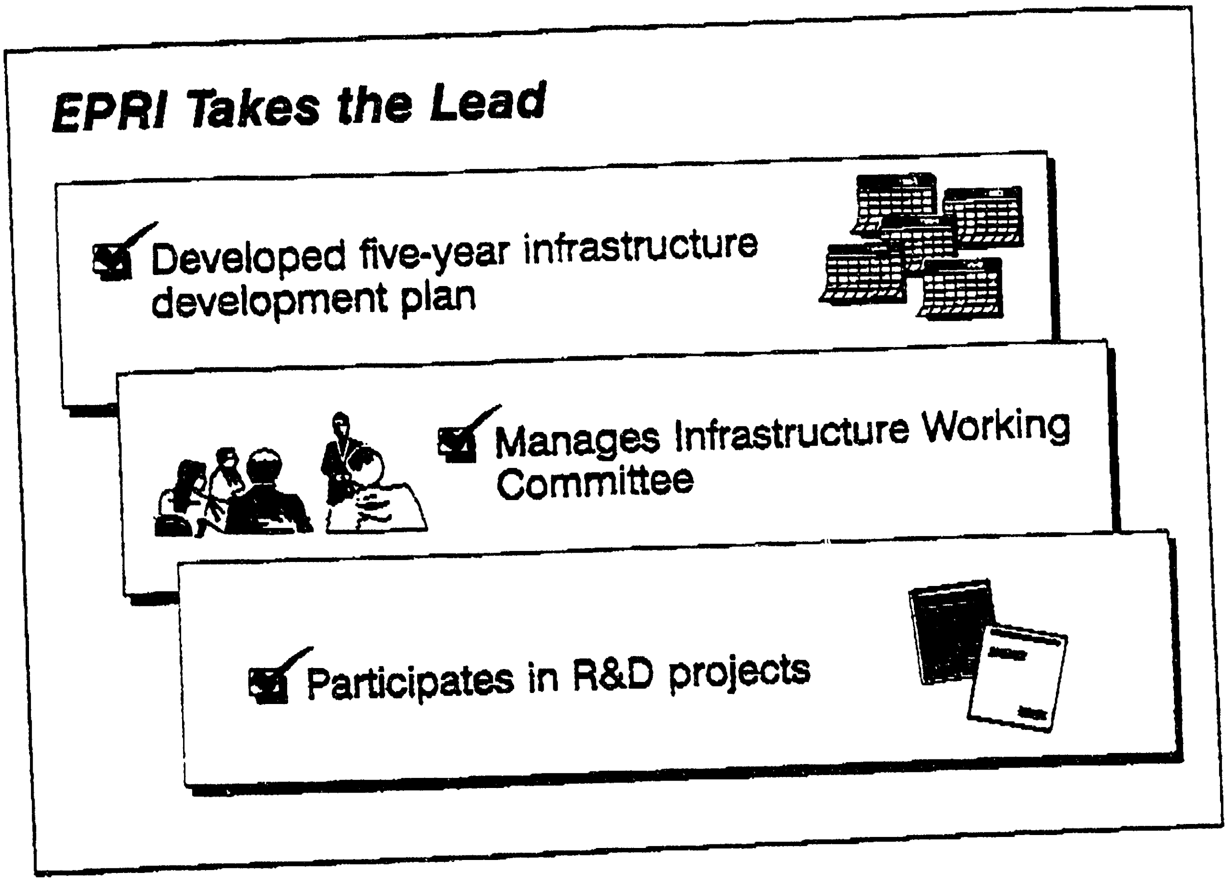
Valued for their ability to significantly reduce vehicle pollution, electric vehicles (EVs) will play a major role in the transportation revolution. Already, the California Air Resources Board (CARB) has adopted rules that direct automakers to begin selling vehicles that produce zero emissions--a requirement that only EVs currently meet. Starting in 1998, 2% of all light-duty vehicles sold must have zero emissions, and by 2003, the percentage rises to 10%.

Massachusetts and New York have adopted similar rules, and other states are seriously considering following suit. Successful implementation of a zero-emission vehicle requirement in all these states could create an impressive market for EVs: about 350,000 vehicles per year by 2003.



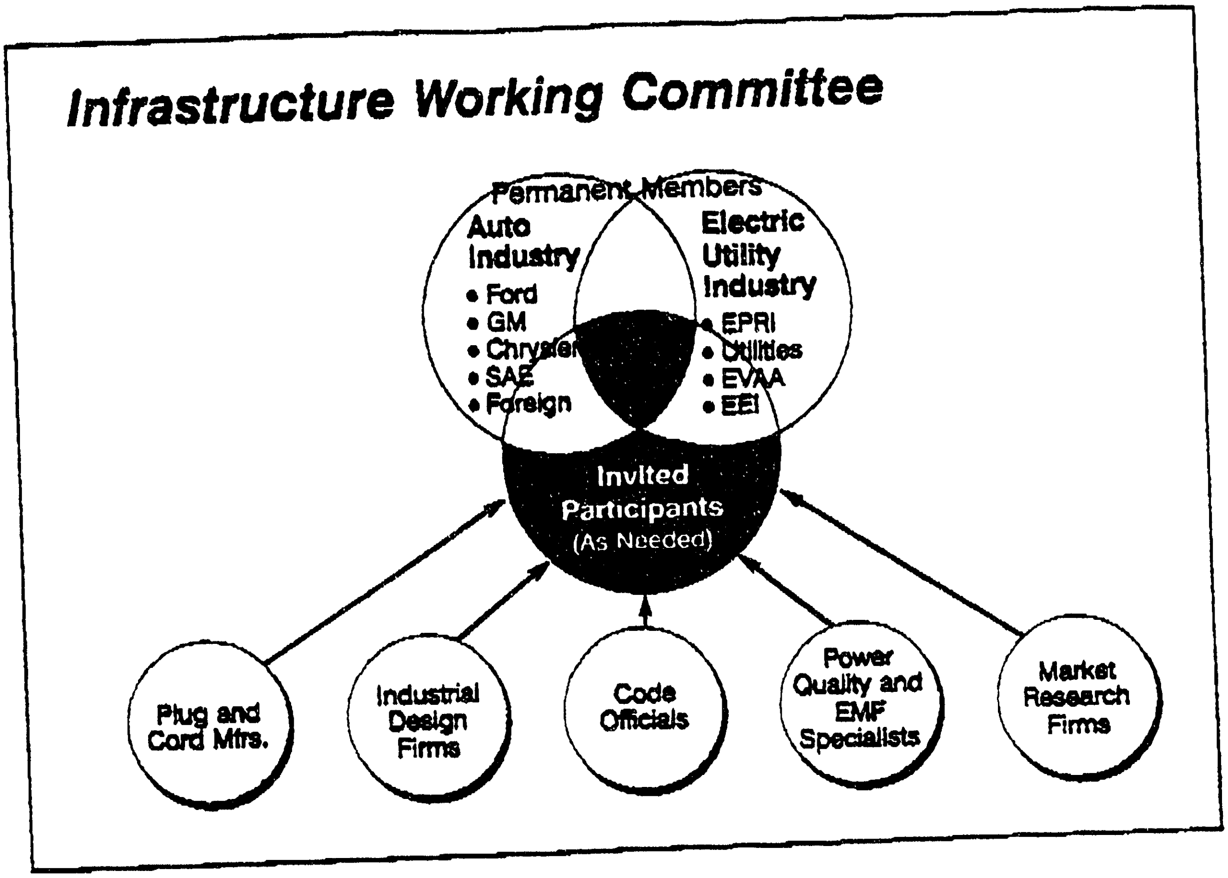
Infrastructure Key to Market Success

Although legislation can force an initial market for EVs, creating a self sustaining, long-term market for these vehicles requires widespread consumer acceptance. Ultimately, this acceptance will depend on vehicle performance, cost, safety, and ease of use. With large stakes in the future of EVs, automakers and electric utilities are preparing now to ensure that EVs satisfy consumer requirements. Automakers are focused on vehicle development and building the service and sales infrastrucutre, and electric utilities are developing the refueling infrastructure.



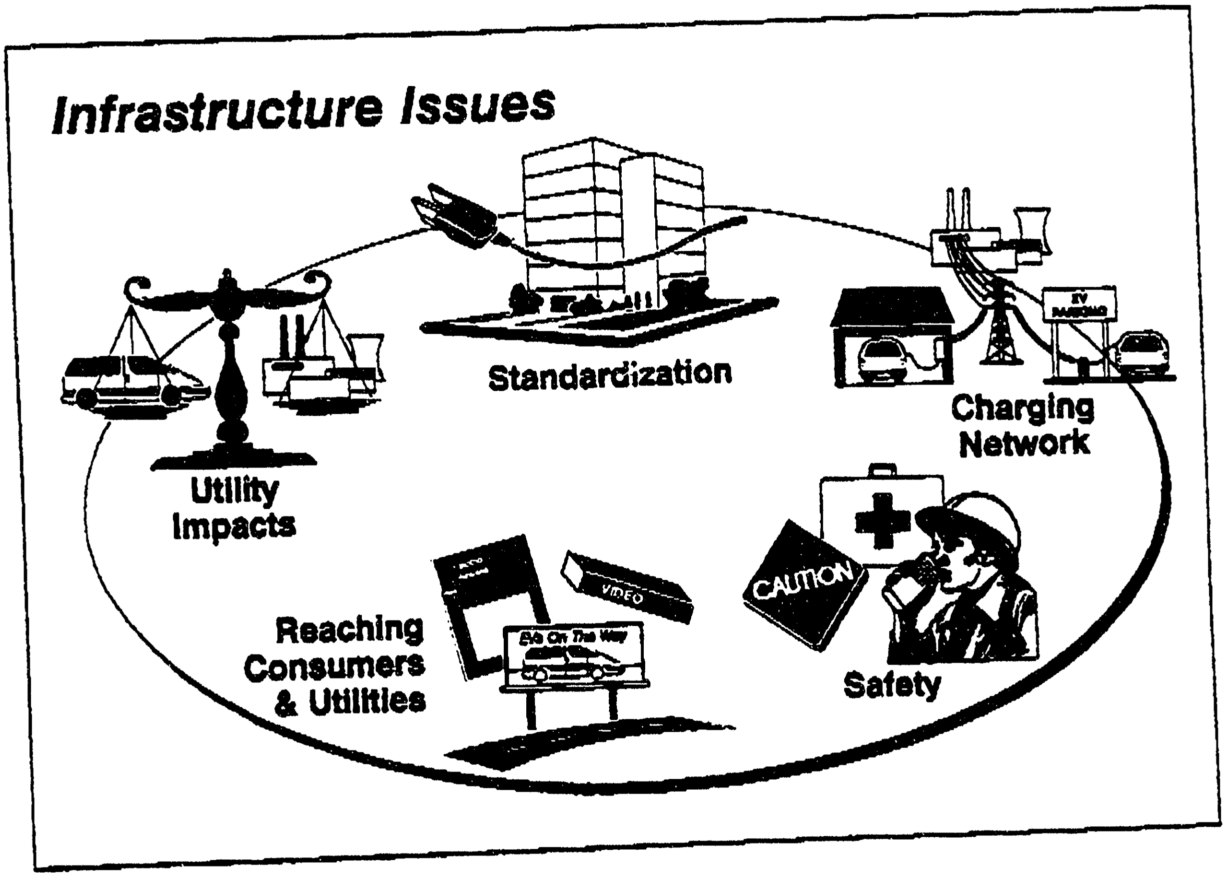
EPRI Takes the Lead

With decades of experience in providing electrical service for a variety of needs, the utility industry is able and qualified to prepare the EV refueling infrastructure. Leading a unified utility effort, the Electric Power Research Institute hopes to smooth the way by creating standards, identifying and eliminating potential safety issues, and coordinating research activities as appropriate across the United States. To guide this work, EPRI has developed a comprehensive plan that outlines research and development projects to take place between 1992 and 1996.



The Infrastructure Working Committee

EPRI also manages the Infrastructure Working Committee (IWC), an interindustry group that plans and implements research activities. The IWC brings together permanent members from the auto and electric utility industries, as well as invited members from other fields that can contribute to the development effort. Permanent members include Ford, General Motors, Chrysler, overseas automakers, the Society of Automotive Engineers (SAE), EPRI, utilities, the Electric Vehicle Association of the Americas, the U.S. Department of Energy (DOE), and the Edison Electric Institute. Invited members include the National Electric Manufacturers Association (NEMA), plug and cord manufacturers, industrial design firms, Underwriters Laboratories, code officials, power quality and EMF specialists, and market research firms.

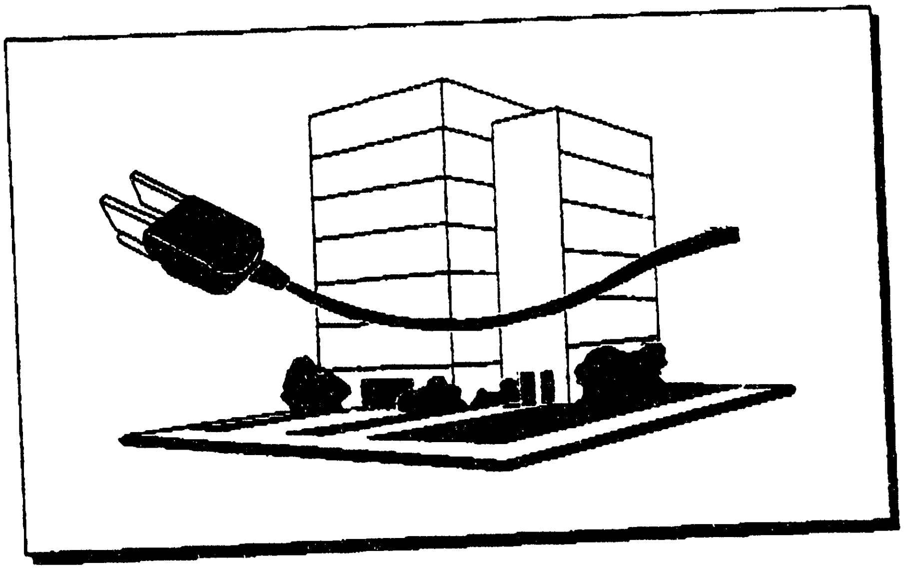


Infrastructure Issues

EPRI's infrastructure activities are divided into five general areas:

- Standardizing connecting hardware and electrical service for EVs
- Building charging stations and a charging network
- Identifying and eliminating potential safety risks
- Optimizing the load management benefits of EVs
- Reaching consumers and utilities

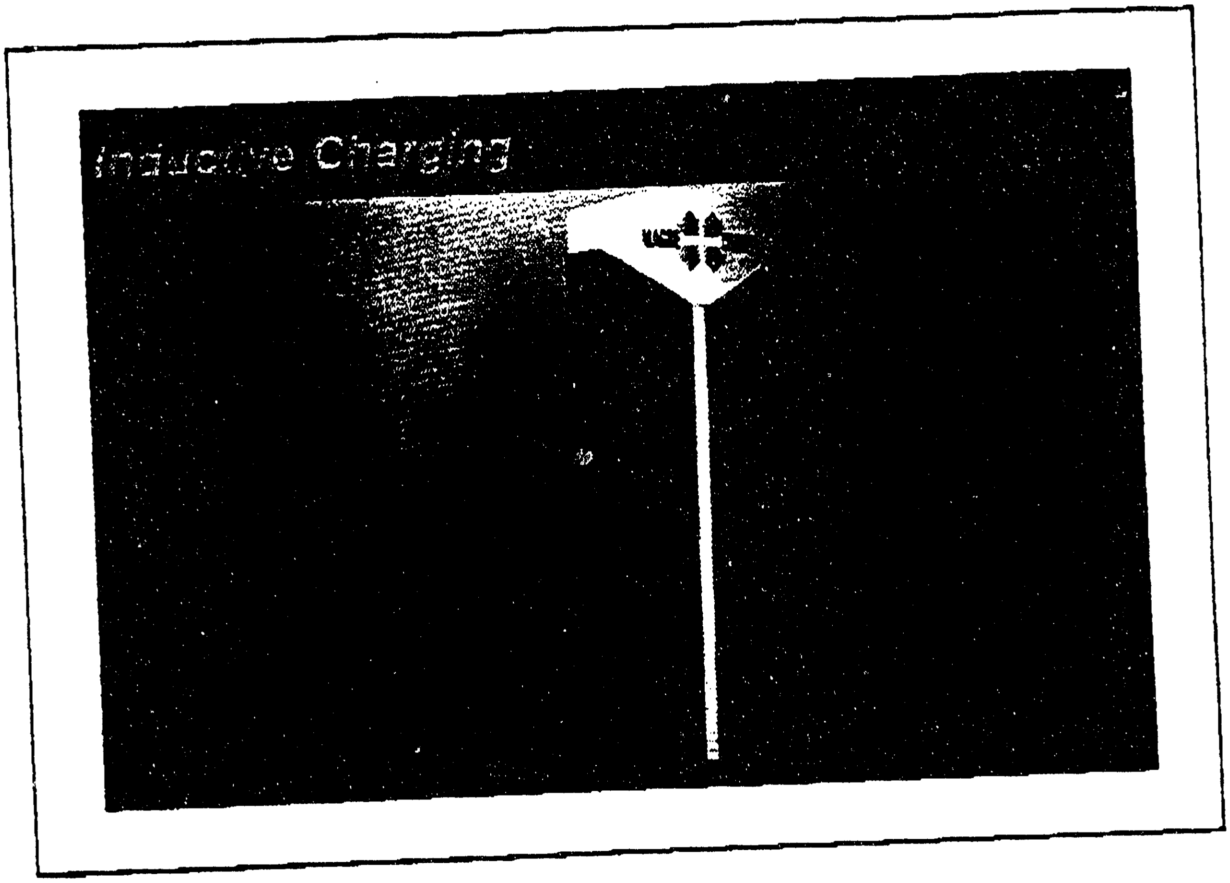
Ensuring a Smooth Connection



Ensuring a Smooth Connection

EV owners need the assurance that any EV—regardless of manufacturer—can be easily charged at any site. Meeting this need requires standardizing EV connecting hardware, such as plugs and cords, and electrical service in buildings. Performing this work before EVs are widely commercialized will ensure that standardization will never be a consumer issue.

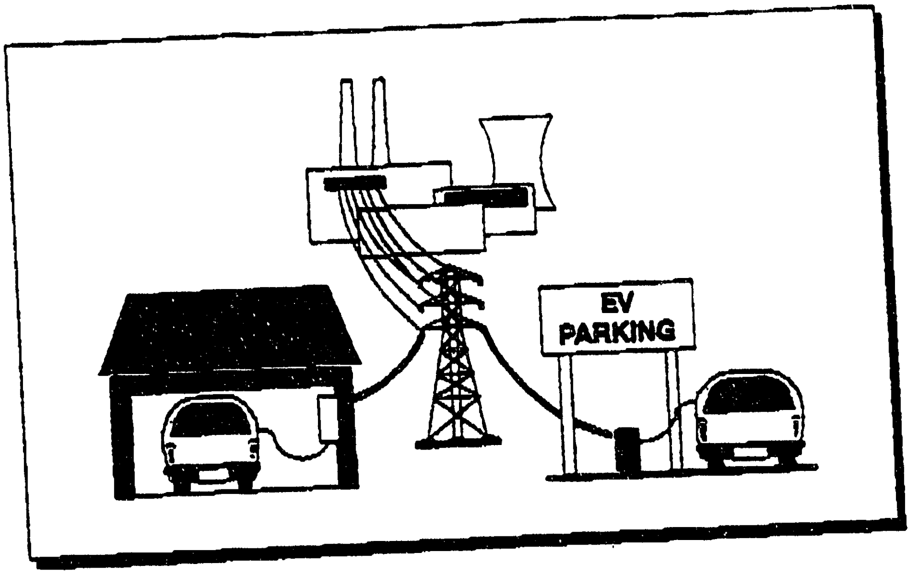
EPRI is involved in all aspects of this effort. Through the Infrastructure Working Committee (IWC), the Institute will propose connecting standards to the SAE. EPRI is also working with NEMA to create specifications for EV charging hardware. Another EPRI project is reviewing building codes and standards in all 50 states, and will recommend any necessary revisions to facilitate EV charging. EPRI is also coordinating the development of the hardware and layout of public charging systems.



Inductive Charging

To prepare for long-range charging needs, EPRI, automakers, and others are studying the efficiency, cost, safety, and operational characteristics of inductive charging concepts. This emerging technology transfers electricity from a power source to a vehicle battery using a magnetic field, rather than standard electric cords and plugs. Inductive charging is particularly appealing as it avoids some standardization problems. Because inductive charging can accommodate differences in battery size, required voltage, and charging algorithms on-board the vehicle, any EV equipped with inductive charging would be able to charge at any standard inductive charging station.

Building the Charging Network

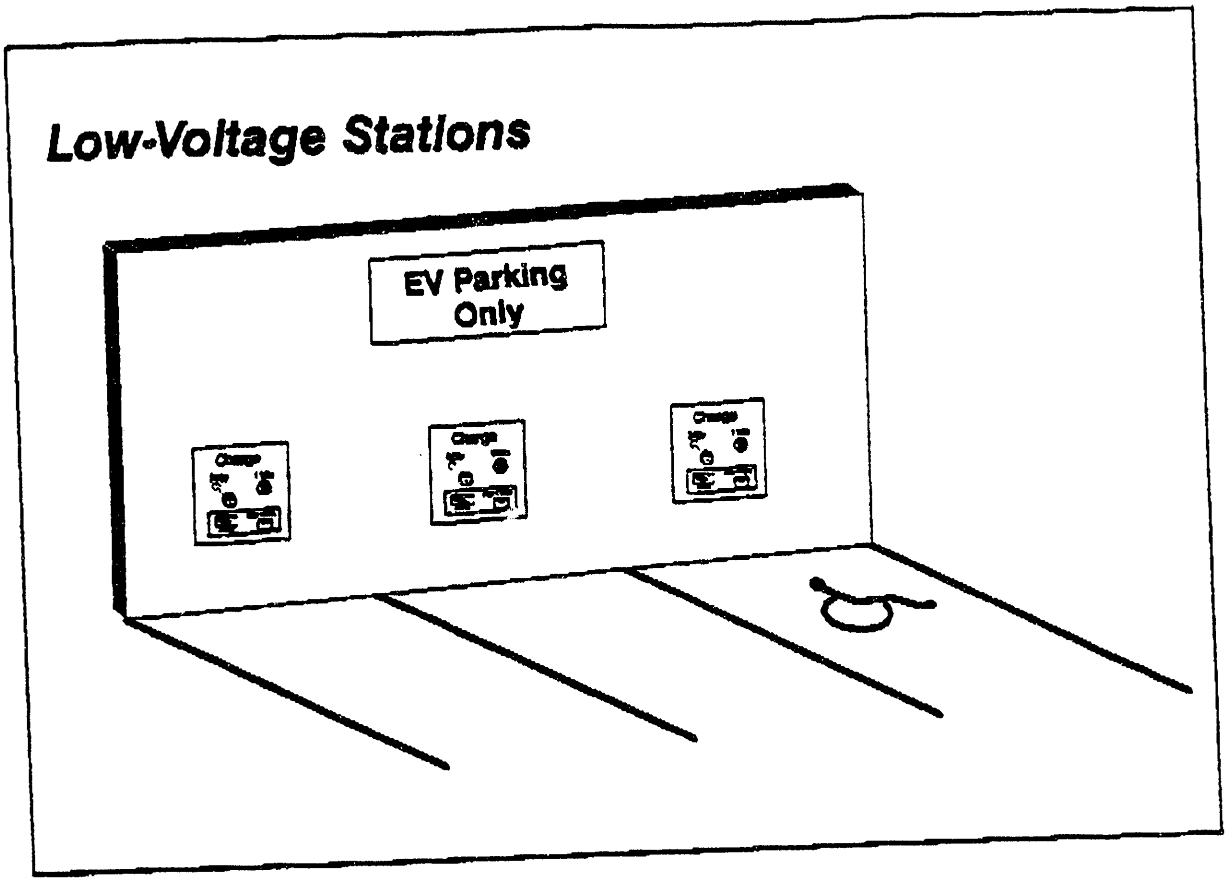


Building the Charging Network

Most EV charging is expected to take place at night, while the vehicles are parked at home. Charging an EV at home, using the standard 120/208V or 240V electrical service, will probably be similar to plugging in any mid-sized electrical appliance. Because supplying this type of service is not expected to pose any serious or unusual problems, infrastructure development activities are focusing more on public charging.

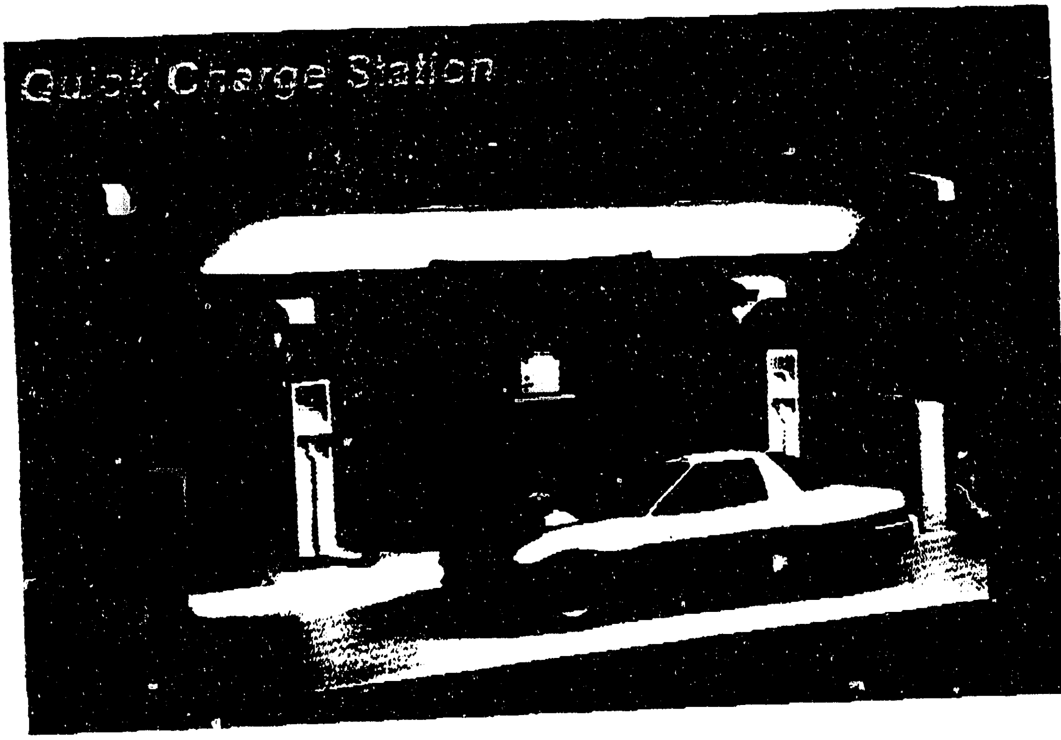
Charging stations at work sites, shopping malls, curbside, and public parking lots may someday be a common means of recharging and range extension away from home. The electrical system that will serve these stations is already well established, but utilities may need to examine the transmission and distribution (T&D) grid to ensure the supply of appropriate electrical service in a few key areas. EPRI is also studying some issues--such as safety, reliability, convenience and load management--to help guarantee the future network meets EV owners' needs efficiently and safely.

Safe, Convenient, Electric:
Building the EV Infrastructure



Low-Voltage Stations

As a first step, EPRI plans to design, test, and demonstrate prototype low-voltage charging stations. Such stations will probably use standard voltage and a combination of on- and off-board battery charging equipment. EPRI will also examine automatic billing methods for such charging.



The Quick-Charge Concept

Further, EPRI is looking at the quick-charging station concept, which could offer partial recharge in about the same amount of time needed to fill a gas tank. Quick charging will require 480V, or higher, three-phase power and the use of off-board battery power electronics. Quick-charging issues include safety, convenience, high-voltage charging electronics, facilities configuration, electrical service/systems, and effects on the local distribution network. Economics--cost feasibility and cost recovery through electricity rates--are also very important. EPRI will conduct parallel R&D activities with auto companies, industrial designers, battery and electrical equipment manufacturers, and facilities developers to help develop prototype quick-recharge facilities and guidelines.

Safety First

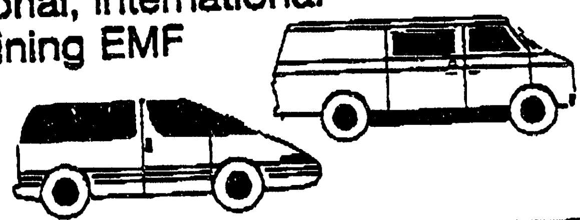
Safety First

Consumers will only use EVs if they believe that vehicle operation and charging are safe under all types of operating conditions. The two main types of health and safety risks are electrical shock from EV charging and potential EMF exposure from both vehicle charging and operation.

EPRI is working to eliminate the risk of electrical shock by studying connector designs and making recommendations for improvement, reviewing building codes and suggesting revisions where necessary. The Institute would also propose electric code revisions, if necessary. EPRI's research on inductive charging--which is inherently safe because it does not require the EV user to plug anything into the power source--may also help mitigate shock-related safety concerns.

The EMF Question

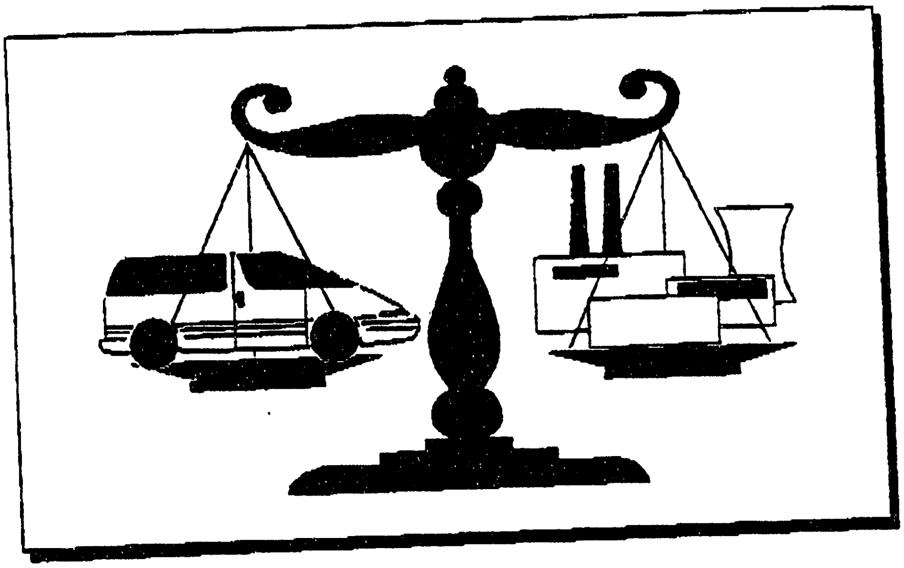
- EMF measured for TEVan and G-Van
- Ongoing national, international studies examining EMF



The EMF Question

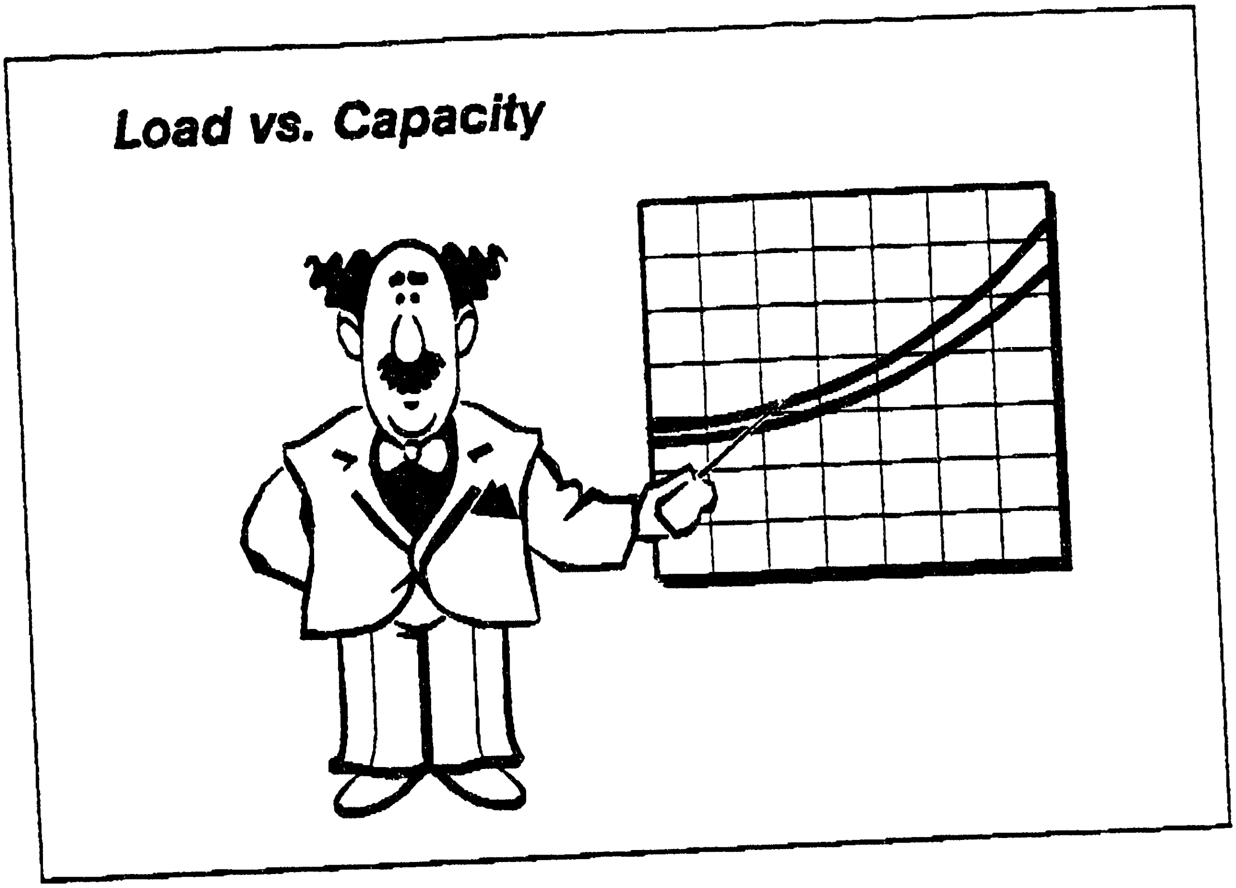
The Institute is also gathering data on electromagnetic fields (EMF). Testing for EMF, and for power quality, was conducted on the G-Van and the TEVan at the Electric Vehicle Testing Facility in Chattanooga, Tennessee. However, a more thorough understanding of EMF fields is required before any conclusion about health risks can be reached. EMF implications are being addressed through ongoing EPRI work and many international studies.

Addressing Utility Impacts



Addressing Utility Impacts

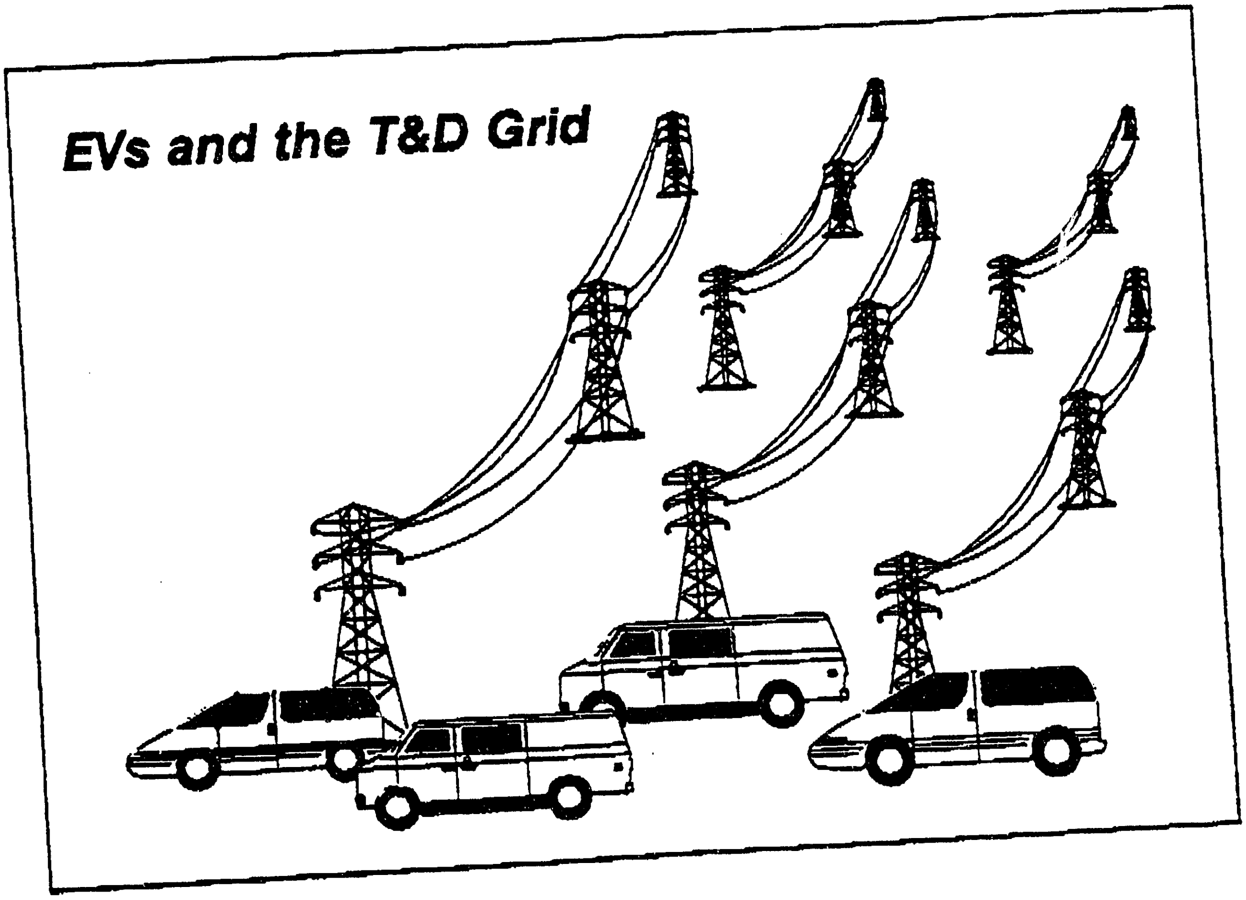
For the most part, EVs are expected to benefit the electric utility industry. EVs could become a large new off-peak load that would increase electricity sales while making more efficient use of generation capacity. To maximize these benefits, EPRI is working with the utility industry to identify and mitigate any possible negative impacts of EVs on the utility system.



Load vs. Capacity

In most instances, EVs will not present capacity problems for utilities until sometime in the next century--if ever. However, to offset any concerns, EPRI is supporting utility work to determine the size and shape of the EV load, looking at generating mix, reserve margin, and projected EV market penetration. The results will provide utilities with the basis for making strategic planning decisions about EVs. In addition, EPRI will help utilities develop incentives and other load management strategies to encourage customers to charge their vehicles during off-peak hours.

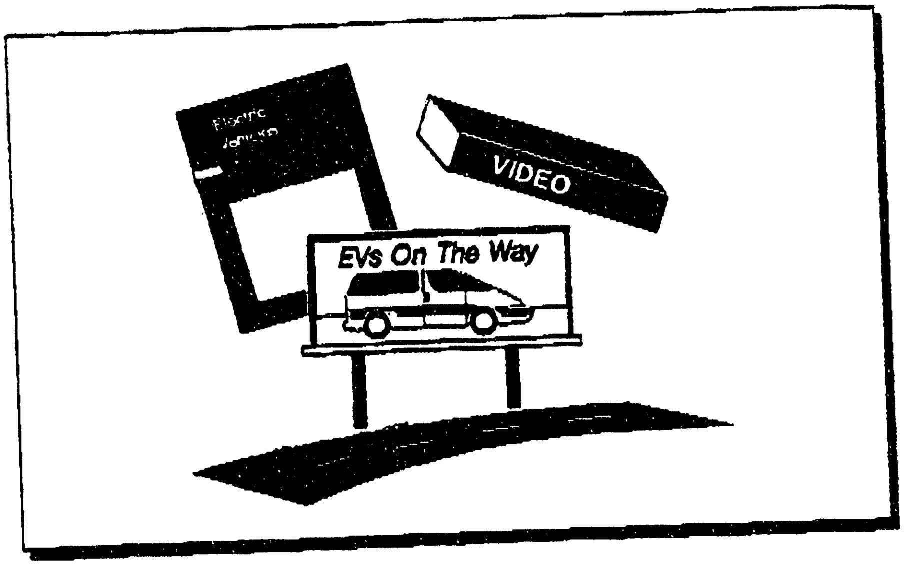
EPRI is addressing the potential load management problems of daytime charging--which tends to shift EV load from off-peak to on-peak--by studying the impacts of nonresidential charging facilities and examining mitigating strategies such as wayside storage.



EVs and the T&D Grid

Another long-term concern is the impact of EV charging on local T&D networks. Although some localized problems may occur, the effect of nighttime residential charging will probably be minimal. The effect of quick charging, however, could be consequential. Studying such issues as the nature of load diversity, network upgrade needs, and total utility peak power requirements can help determine the magnitude of quick-charging effects. The utility industry could then examine mitigating actions.

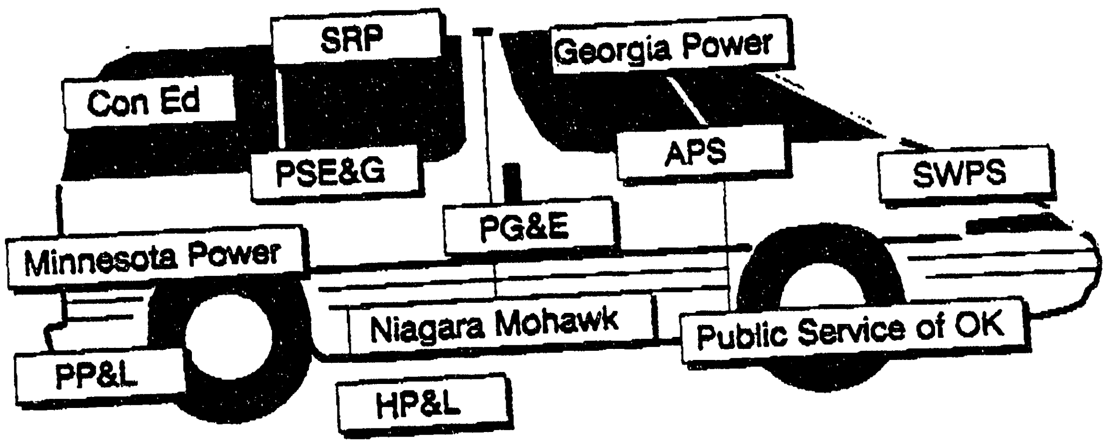
Reaching Consumers and Utilities



Reaching Customers and Utilities

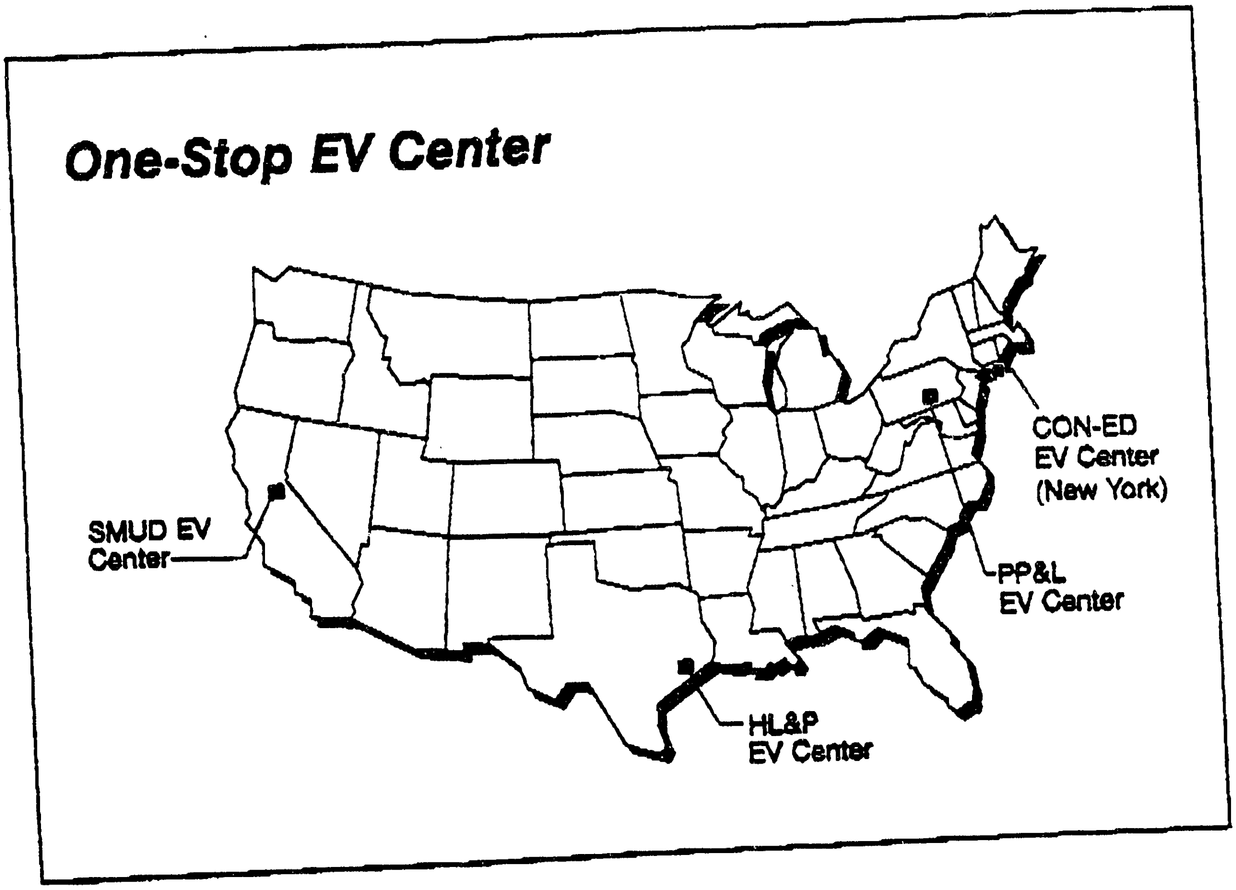
A well-developed campaign to make more people aware of EVs' special characteristics can greatly enhance public acceptance of these vehicles. EPRI will support utilities and automakers in this effort by developing a comprehensive education plan that could include educational materials, handouts, videos, information centers at utilities, displays in regions of heavy traffic, and, possibly, mobile education units.

Bringing Utilities on Board



Bringing Utilities On-Board

Because utilities are an essential partner in developing a working EV infrastructure, EPRI is looking at ways to increase utility involvement in EVs. For example, EPRI is conducting a survey to determine the type and scope of current EV activities at selected utilities. EPRI will then encourage utilities in regions with air quality problems to develop EV programs and commercialization strategies.



One-Stop EV Center

EPRI is also looking for utilities to host regional EV centers. Such centers will bolster EVs by providing demonstrations, technical workshops, hardware field testing, and customer education. Currently, four utilities have agreed to host and operate a center, and EPRI has plans to open others in regions across the United States.

Infrastructure: What Utilities Do Best

Although critical to EV commercialization, infrastructure development is not expected to entail any real problems for the utility industry. Providing electrical service for diverse needs is what utilities do best. Nevertheless, commercialization strategies must be developed to ensure the ultimate success of these clean vehicles. Having identified the crucial issues and begun the necessary work, the utility industry is confident that safe and convenient charging options will be ready when EVs hit the market.

** NOTES **

Electric & Hybrid Vehicle Technology TOPTEC
September 15, 1992

FINAL AGENDA:

DAY TWO

Section 3

AGENDA

Tuesday, September 15, 1992

7:00 am - Noon	Registration - The Dearborn Inn
8:00 am - 8:15 am	Introduction - Roberta Nichols, Mgr., EV External Assoc., Ford Motor Co.
8:15 am - 8:45 am	State-of-the-Art Vehicle Test Results - Kenneth Tenure, Sr. Consultant, Bevilacqua-Knight, Inc.
8:45 am - 9:15 am	Electric Vehicle Servicing/Maintenance Requirements - Randy Stone, Engineer I, Southern California Edison
9:15 am - 9:45 am	Break
9:45 am - 10:15 am	Vehicle Standardization Areas I - Willie Harney, Program Manager, Conceptor Industries, Inc.
10:15 am - 10:45 am	SAE Standards Committee for EV - Ronald Sims, Systems Engineer, Ford Motor Co.
10:45 am - 11:30 am	Hybrid Vehicles and Range Extenders - Andrew Burke, Principal Program Specialist, Idaho National Engineering Lab
11:30 am - 12:00 pm	Questions & Answers
12:00 pm - 1:30 pm	Lunch/Invited Keynote Speaker - Stanford Ovshinsky, President, Energy Conversion Devices, Inc.
1:30 pm - 2:00 pm	Charger/Utility Interface Concerns - A. Scott Keller, Senior Test Engineer, Electrotek Concepts, Inc.
2:00 pm - 2:30 pm	Utility Load Management Strategies - Ernest Morales, Research Engineer, Southern California Edison
2:30 pm - 3:00 pm	Questions & Answers/Closing

Run:8/25/92

ELECTRIC & HYBRID VEHICLE TECHNOLOGY
TOPTEC
September 15, 1992

ABSTRACTS, BIOGRAPHIES

& PRESENTATIONS

Section 4

ELECTRIC & HYBRID VEHICLE TECHNOLOGY
TOPTEC
SEPTEMBER 15, 1992

Introduction

Roberta Nichols, Ford Motor Co.

Abstract-Electric & Hybrid Vehicle Technology TOPTEC
Tuesday, September 15, 1992

State-Of-The-Art Vehicle Test Results - Electric G-Van Field Evaluation

Kenneth Tenure
Senior Consultant
Bevilacqua-Knight, Incorporated

Today, there are over 95 Conceptor electric G-Vans in operation throughout the United States and Canada. Twenty-two organizations using 48 G-Vans are participating in an ongoing field evaluation of the G-Van.

The field evaluation is comprised of three components: a monthly vehicle log, a user response questionnaire and user group. These three data collection methods obtain objective and subjective information pertaining to vehicle performance, reliability, maintenance and user acceptance. Specific criteria measured and analyzed include vehicle mileage, energy efficiency, vehicle maintenance, and user assessments of vehicle performance and attributes. Vehicle applicability to fleet applications are evaluated through user group activities. The user group focuses on operational as well as maintenance issues.

Field evaluation results are currently being used to identify product improvement requirements, define and improve maintenance procedures, assess electric G-Van product readiness, and electric van market expansion opportunities.

Biography-Electric & Hybrid Vehicle Technology TOPTEC

Kenneth W. Tenure
Senior Consultant
Bevilacqua-Knight, Incorporated

Ken Tenure is a senior consultant for Bevilacqua-Knight Inc. (BKI). At BKI, Mr Tenure manages alternative fuel vehicle evaluation and commercialization programs. he is involved in the performance monitoring of natural gas vehicle fleets and electric vehicles. Under contract to the Electric Power Research Institute, Mr. Tenure assisted in developing the field evaluation procedures for the electric G-Van demonstration, the largest ongoing electric vehicle demonstration program in the United States. Today, Mr. Tenure continues to monitor and evaluate G-Van field performance and serves as chair to the National G-Van User Group.

Before joining BKI, Mr. Tenure directed vehicle evaluation and program development for the Electric Vehicle Association of the Americas (EVAA). Activities at EVAA included participation in EPRI's electric vehicle Infrastructure Working Committee and co-chair of EVAA's Product Introduction Committee.

Mr. Tenure gained extensive automotive experience during his eight years with Toyota Motor Sales, USA, Inc. His responsibilities at Toyota included managing new business development, creating and directing Toyota's new vehicle and service surveys, analyzing warranty service, and sales planning.

Earlier work experience included developing commercialization strategies for advanced energy-saving automotive technologies for the U.S. Department of Energy.

Mr. Tenure holds a M.A. in economics from the University of Maryland and a B.A. in economics and international relations from the American University, Washington, D.C.

G-Van Field Evaluation

Objectives:

- Assess vehicle performance
- Determine vehicle reliability/maintenance requirements
- Examine vehicle use and determine commercial readiness
- Expand EV visibility and utility industry involvement


EPRI 9

G-Van Specifications

Area	Description
Motor	216-volt DC, 42 kW (52 hp)
Battery	216-volt, 205 ampere-hours (5-hour rate), tubular lead-acid
Transmission	Chain and sprocket
Off-board charger	200/250-volt, 35 amps, 60 Hz

Methodology

- In-field data collection - driver logs/ monthly summary reports
- User response questionnaires
- User groups

In-Field Data Collection
Driver Logs/Monthly Summaries

- ✓ Mileage
- ✓ Energy use
- ✓ Vehicle maintenance

User Response Questionnaires

- Uses
- Applicability
- Attribute assessments
- Improvements

User Group

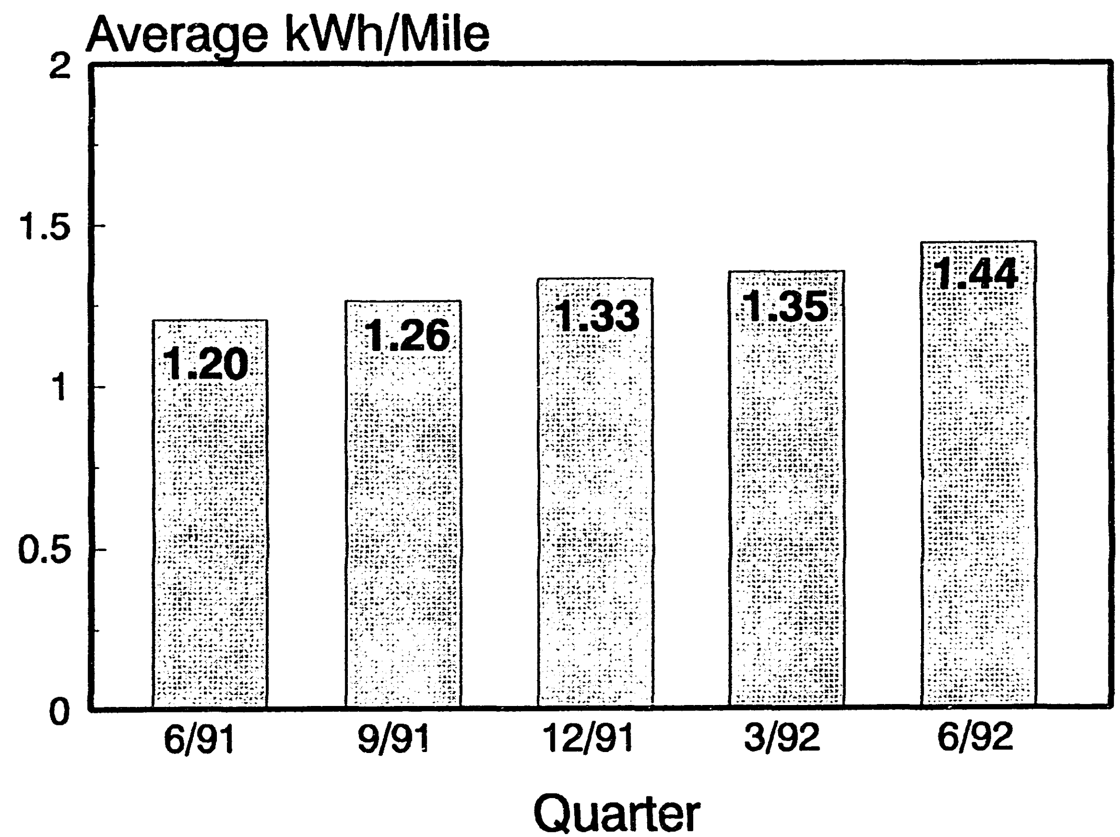
- Product performance
- Maintenance
- Vehicle uses/applicability

Evaluation Overview

- Ongoing since January 1991
- 26 organizations
- 60 G-Vans
- Over 235,000 miles accumulated

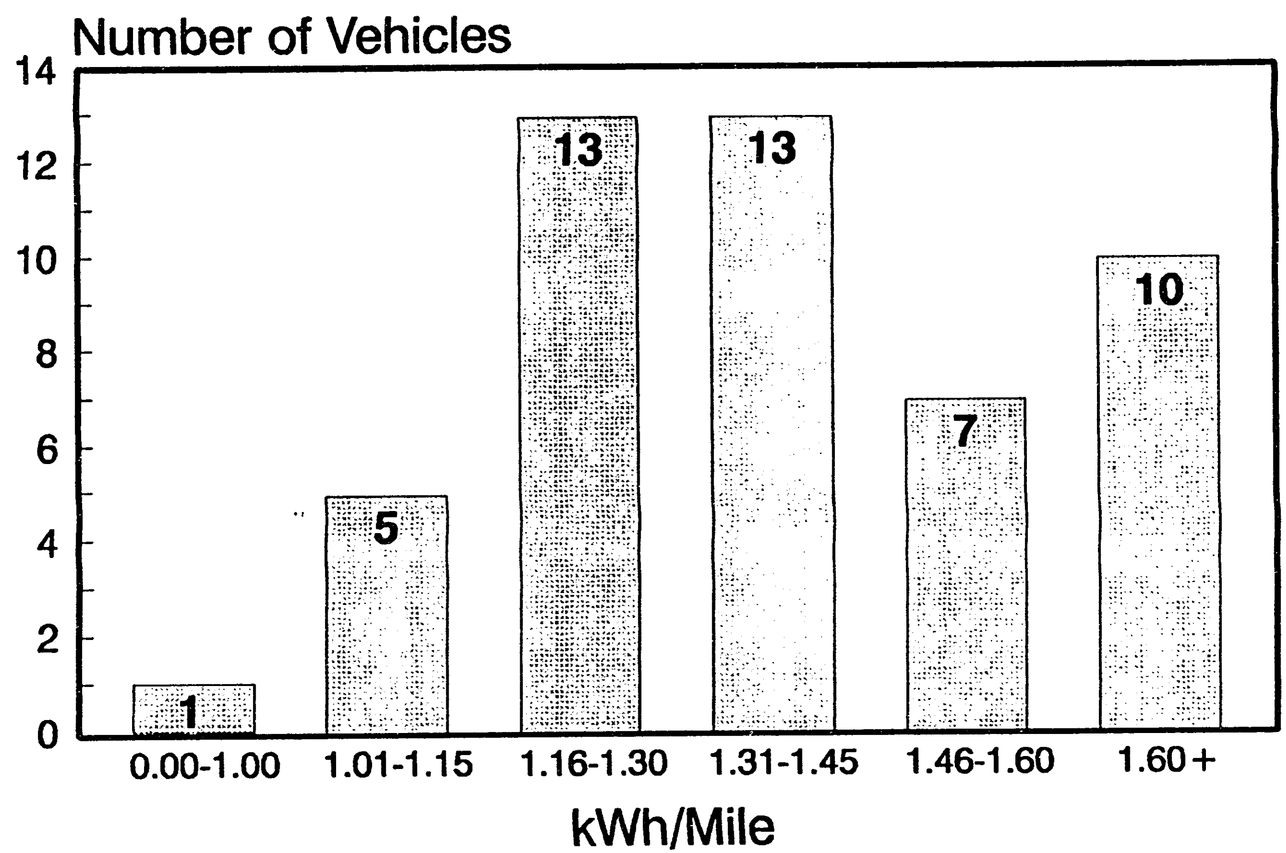
EVALUATION RESULTS

Energy Efficiency



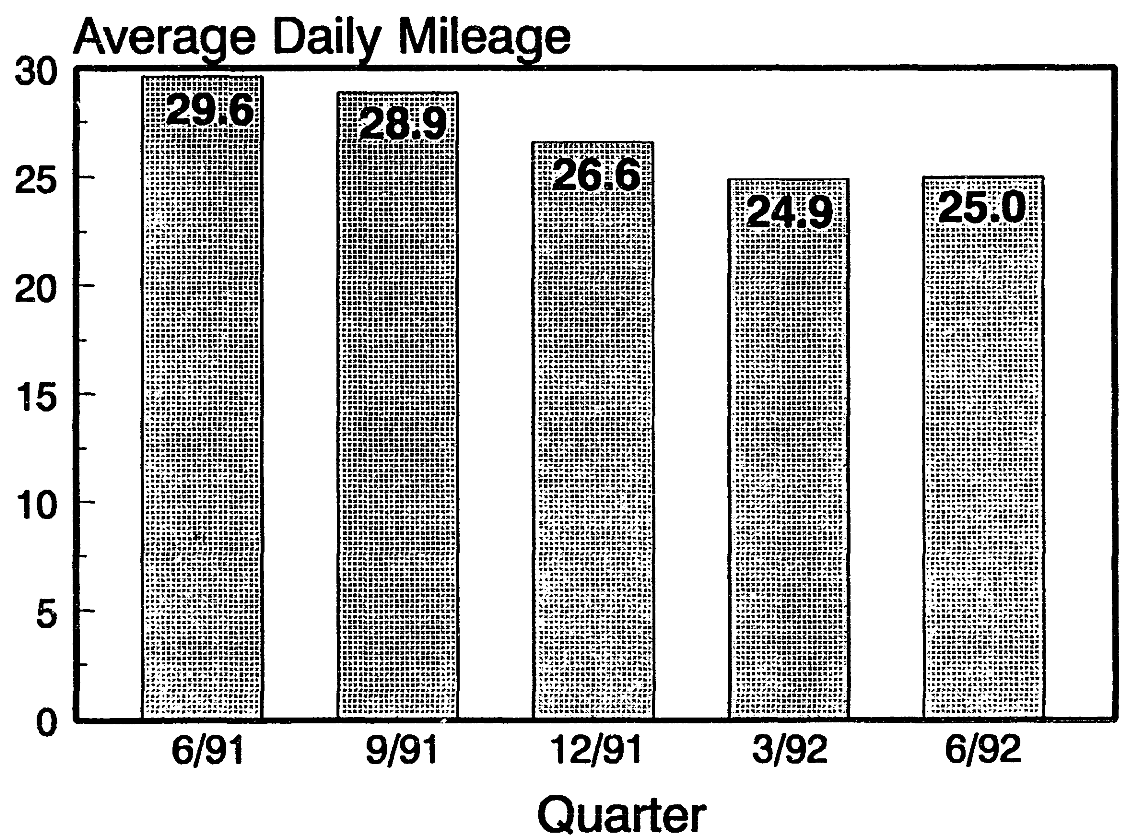
CSKT2103-08 8/92

Distribution of kWh/mile
June 1992 Life-to-Date



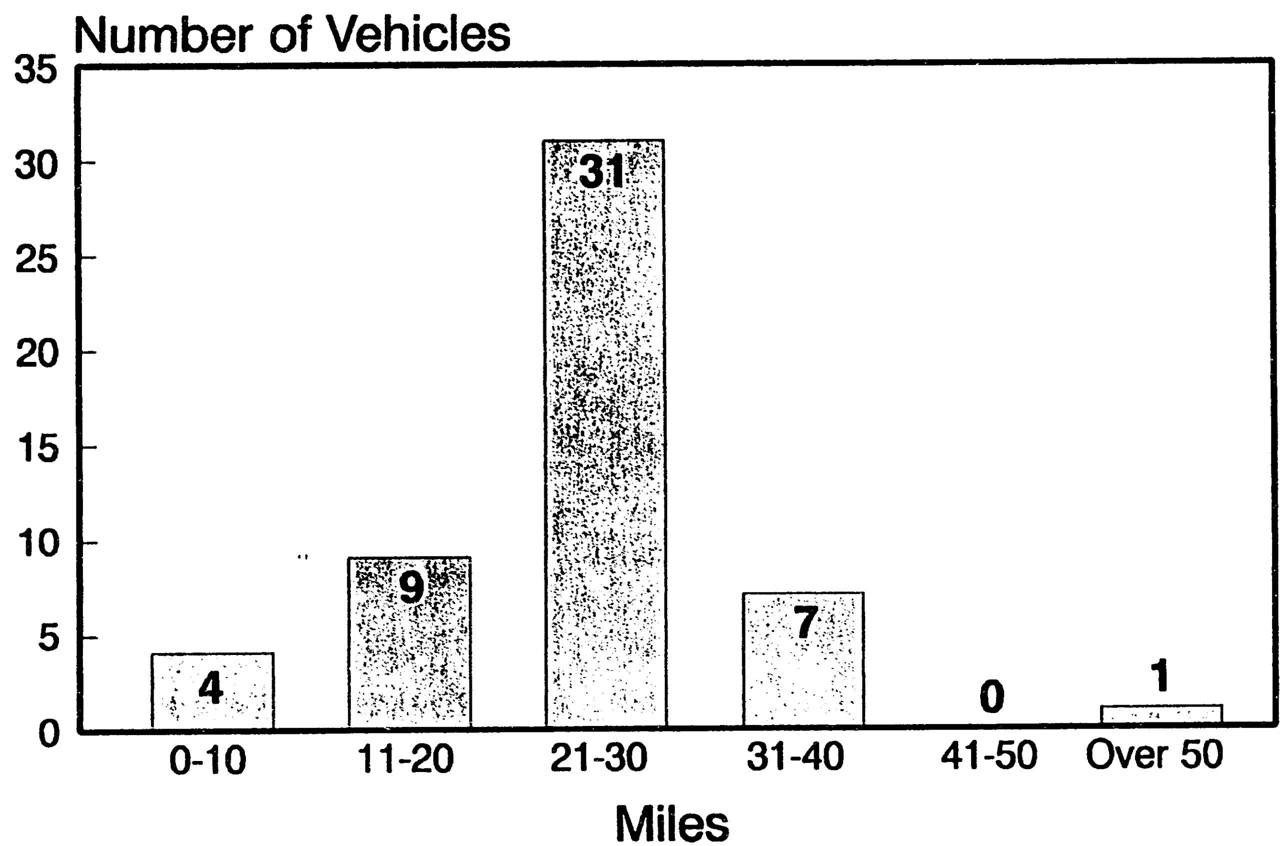
CSKT2103-09 8/92

Daily Mileage



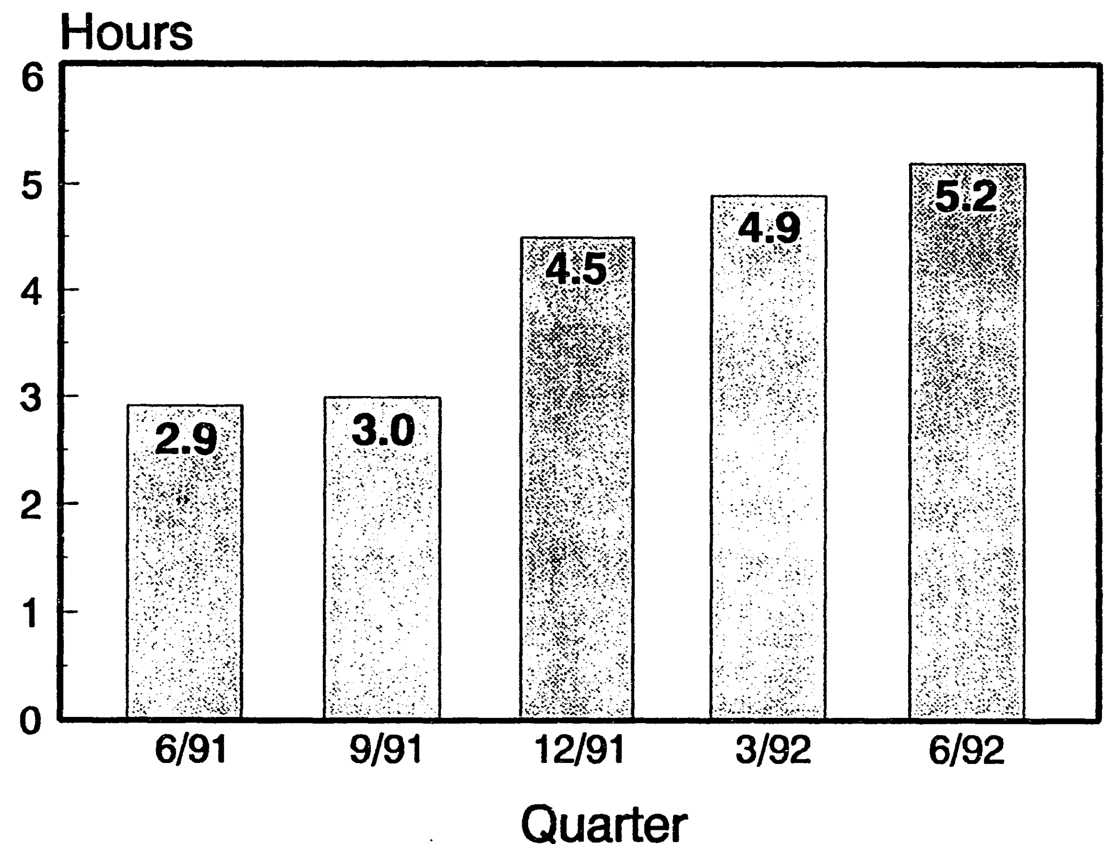
CSKT2103-10 8/14/92

Distribution of Daily Mileage



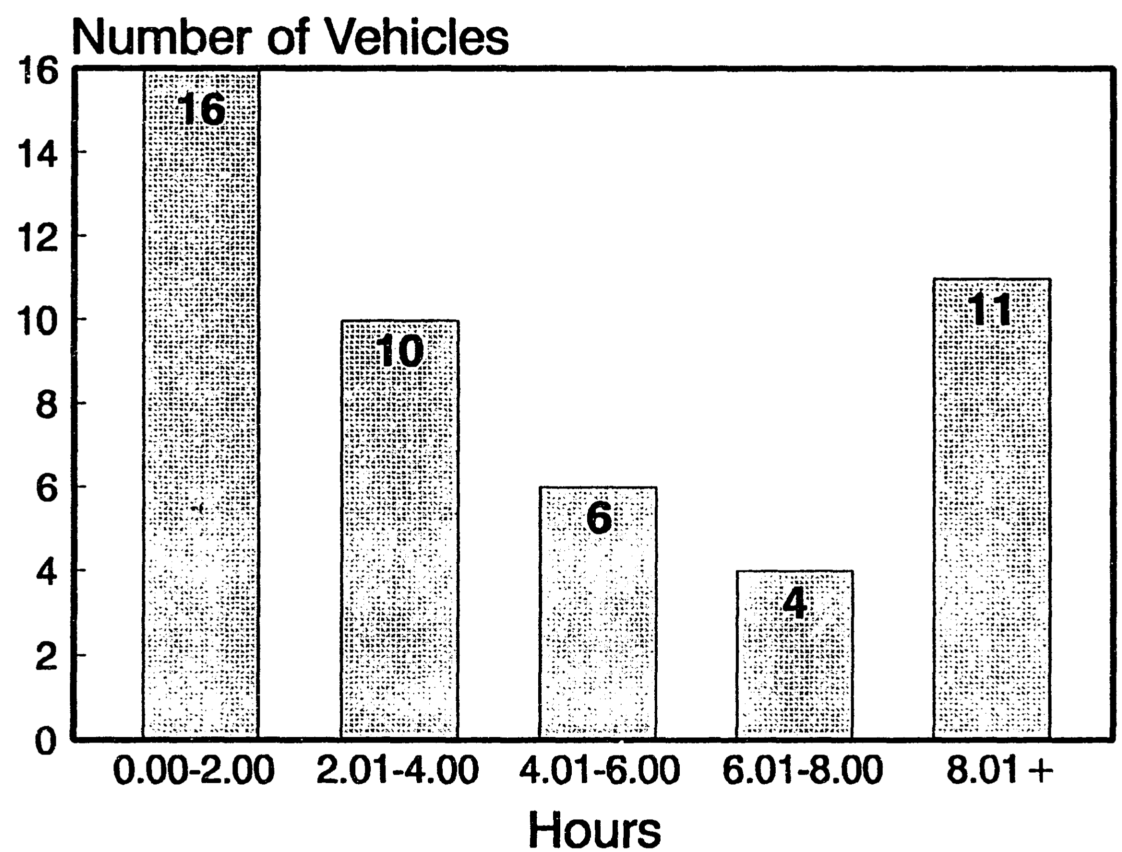
CSKT2103-11 8/12/92

Maintenance
Average Unscheduled Maintenance/1000 miles



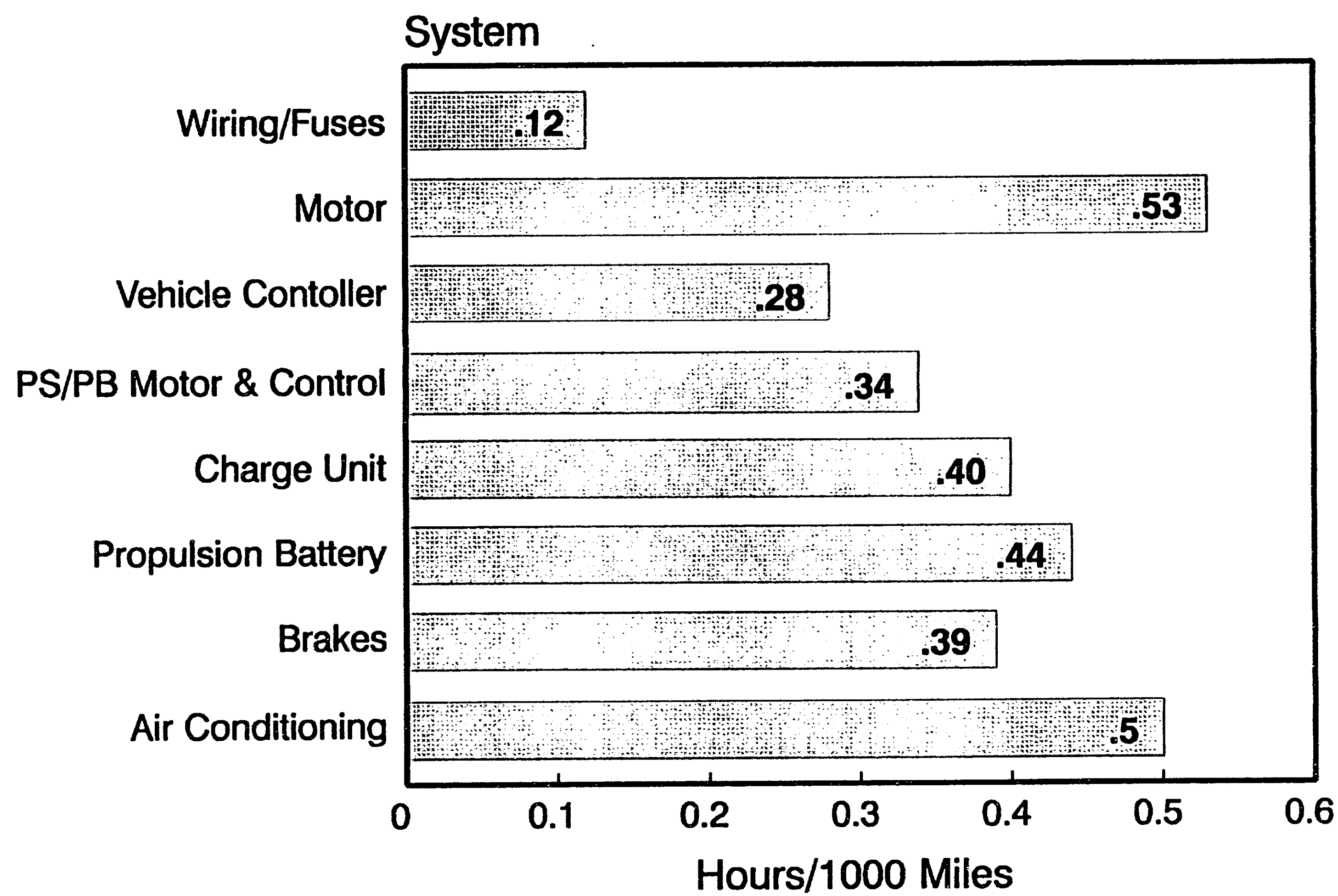
CSKT2103-12 8/92

Distribution of Unscheduled Maintenance Hours



CSKT2103-20 8/92

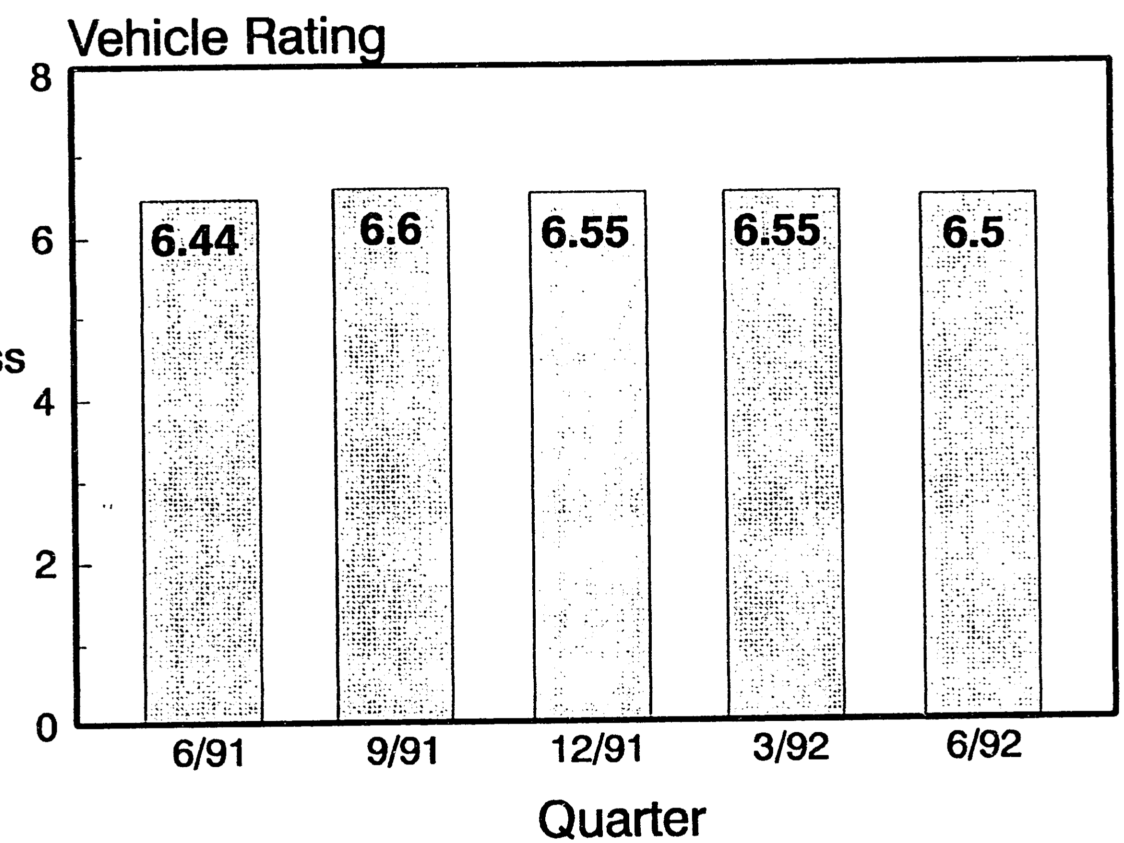
Unscheduled Maintenance by System



CSKT2103-13 8/12/92

User Response
Overall Vehicle Rating

0 = Worthless
10 = Ideal



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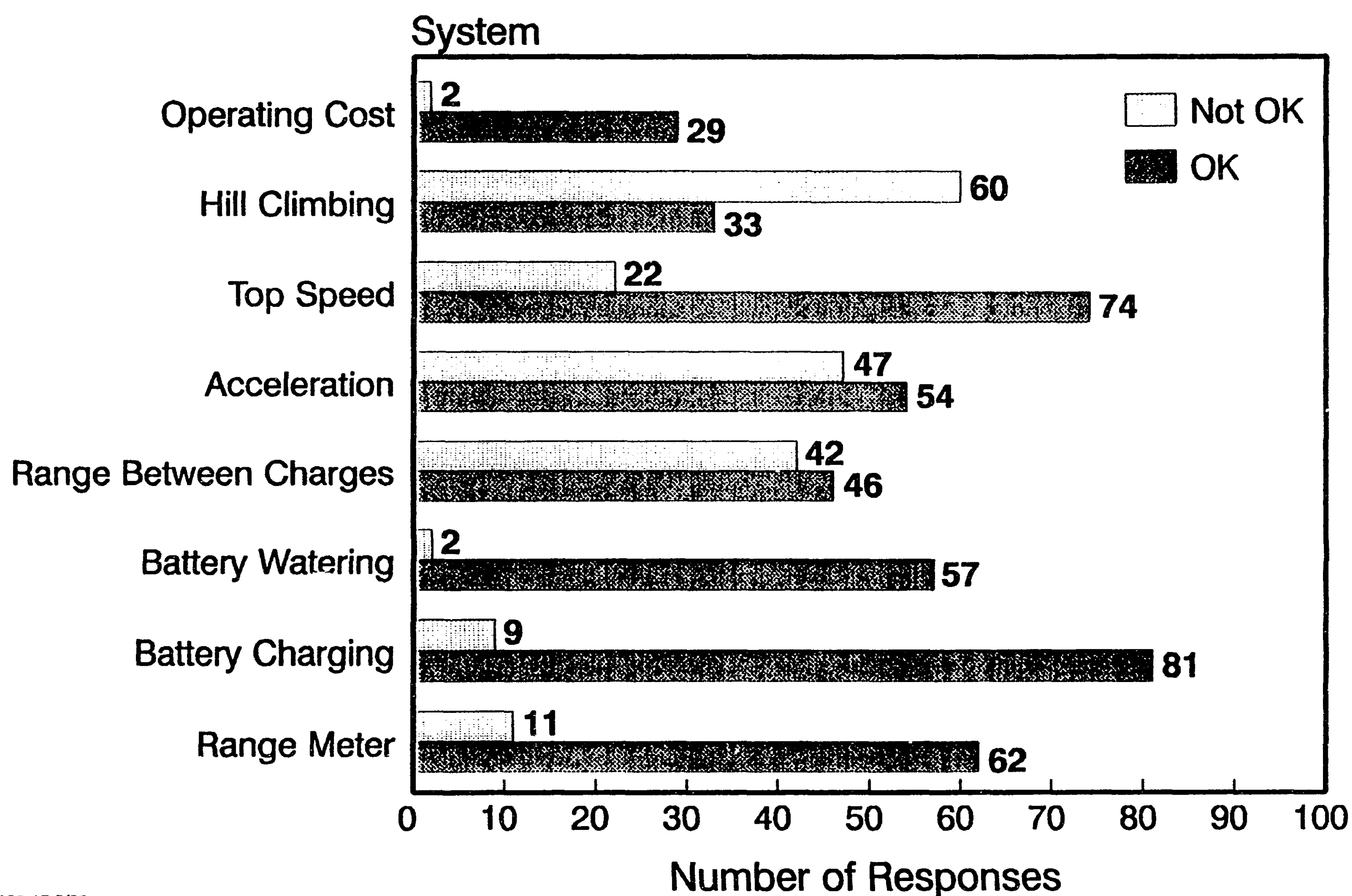
User Response By System



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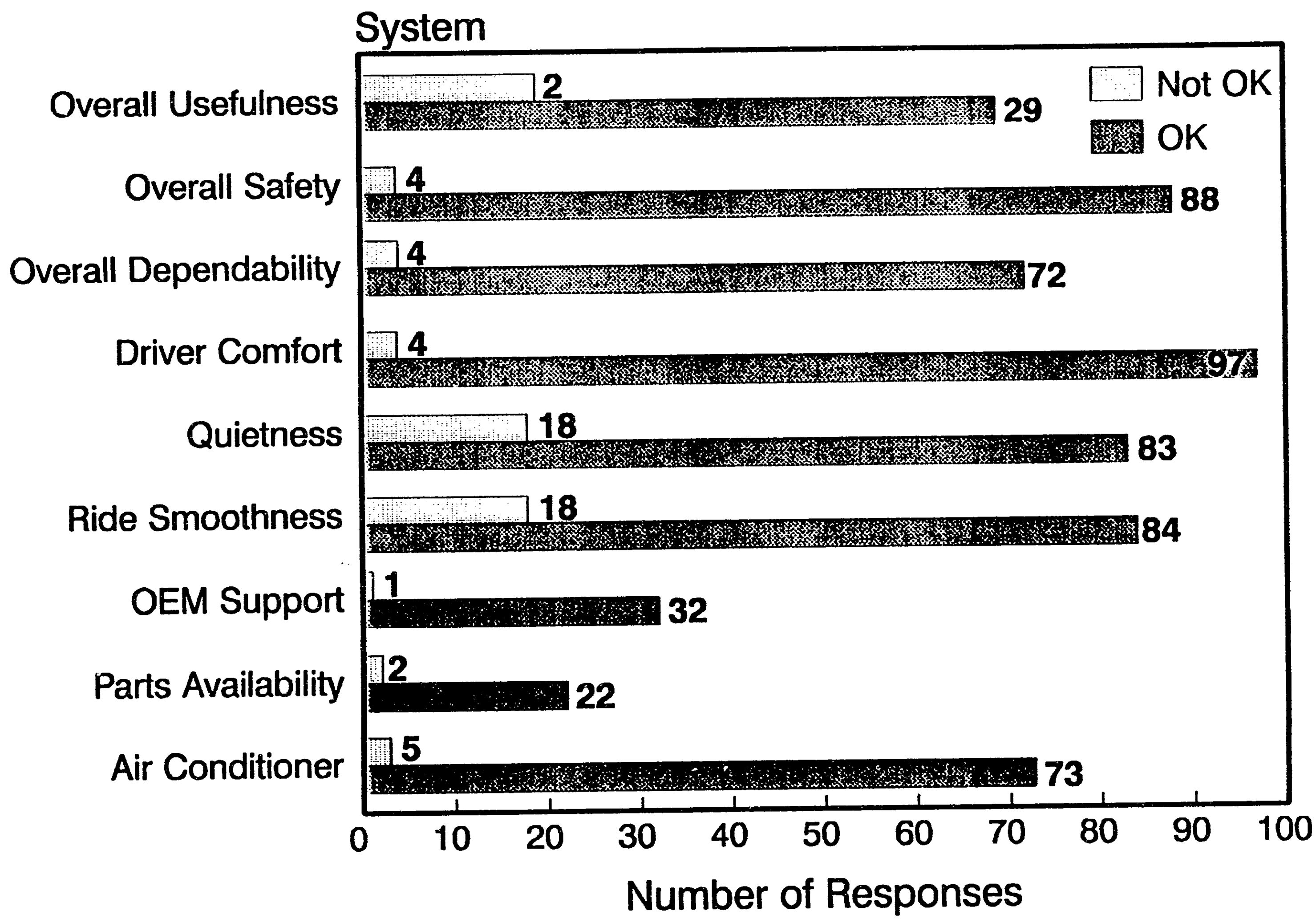
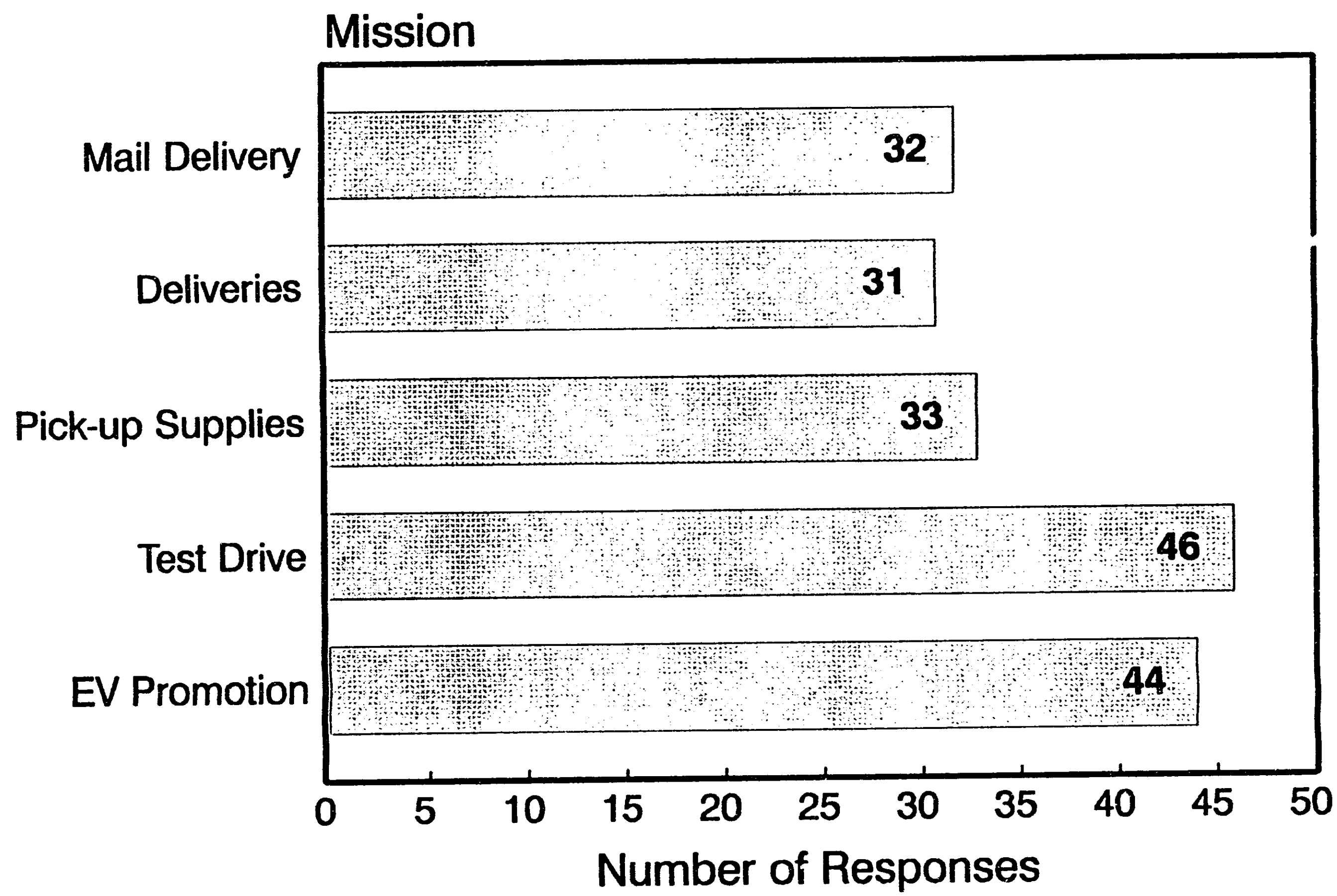
User Response By System (Cont'd)



CSKT2103-15a 8/92

G-Van Uses



CSKT2103-16 8/92

Qualitative Information from User Group

G-Van is extremely popular with the public

G-Van best suited for mid-range fixed applications

Performance uncertainty is a major barrier to greater acceptance

Conclusion

- Combination of quantitive, qualitative and anecdotal information is an effective evaluation tool
- Performance uncertainty and reduced range is a major concern
- The G-Van is appropriate for limited-range applications
- However. . .The vehicle is not ready for commercial acceptance until performance is consistent

** NOTES **

Abstract-Electric & Hybrid Vehicle Technology TOPTEC
Tuesday, September 15, 1992

Electric Vehicle Servicing/Maintenance Requirements

Randy Stone
Engineer I - Transportation Services Department
Southern California Edison

Electric vehicle maintenance and repair requires trained personnel, specialized testing and repair equipment, and a facility.

The personnel who maintain electric vehicles must have a general automotive mechanic knowledge and skills. In addition, the maintenance personnel must be knowledgeable and skilled in the area of low and high voltage electrical systems and battery testing and repair.

The specialized equipment required to maintain electric vehicles starts with a good multimeter with a DC high amp probe for general electrical testing. A battery watering device, load bank and specific gravity meter are required for maintaining batteries. A megger is required to check the electrical integrity of electric motors. Ultimately, custom diagnostic equipment is used to test the controller and vehicle power train circuitry for a specific model of vehicle.

The facility required to maintain electric vehicles differs from the conventional garage in several ways. The lifting and handling of batteries requires lifts and trolleys with the proper capacities and lifting styles to accommodate electric vehicles. An area for battery charging, discharging, storage and maintenance is also required.

Biography-Electric & Hybrid Vehicle Technology TOPTEC

Randy Stone
Engineer I - Transportation Services Department
Souther California Edison

In his current position, Mr. Stone supervises the maintenance and repair of a diverse fleet of electric-powered vehicles. He has 4 years experience in the research and development of electric vehicles from the fleet operators perspective.

Mr. Stone has a B.S. in Mechanical Engineering from the University of Kansas and is registered as a Professional Engineer in Mechanical Engineering in the state of California.

** NOTES **

Abstract-Electric & Hybrid Vehicle Technology TOPTEC
Tuesday, September 15, 1992

SAE Standards Forum for Electric Vehicles

Ron Sims
EV Battery Systems Engineer - EV Powertrain Engineering, NAAO
Ford Motor Company

This presentation will cover:

- Role & Membership of SAE EV Standards Forum
- Infrastructure of EV Standards deriving agencies - from SAE to ISO
- Standardization Areas identified by SAE EV Forum
- NHTSA proposed EV rules and emerging standards
- Status of current EV Standards activities
- Participation in Standards process

Biography-Electric & Hybrid Vehicle Technology TOPTEC

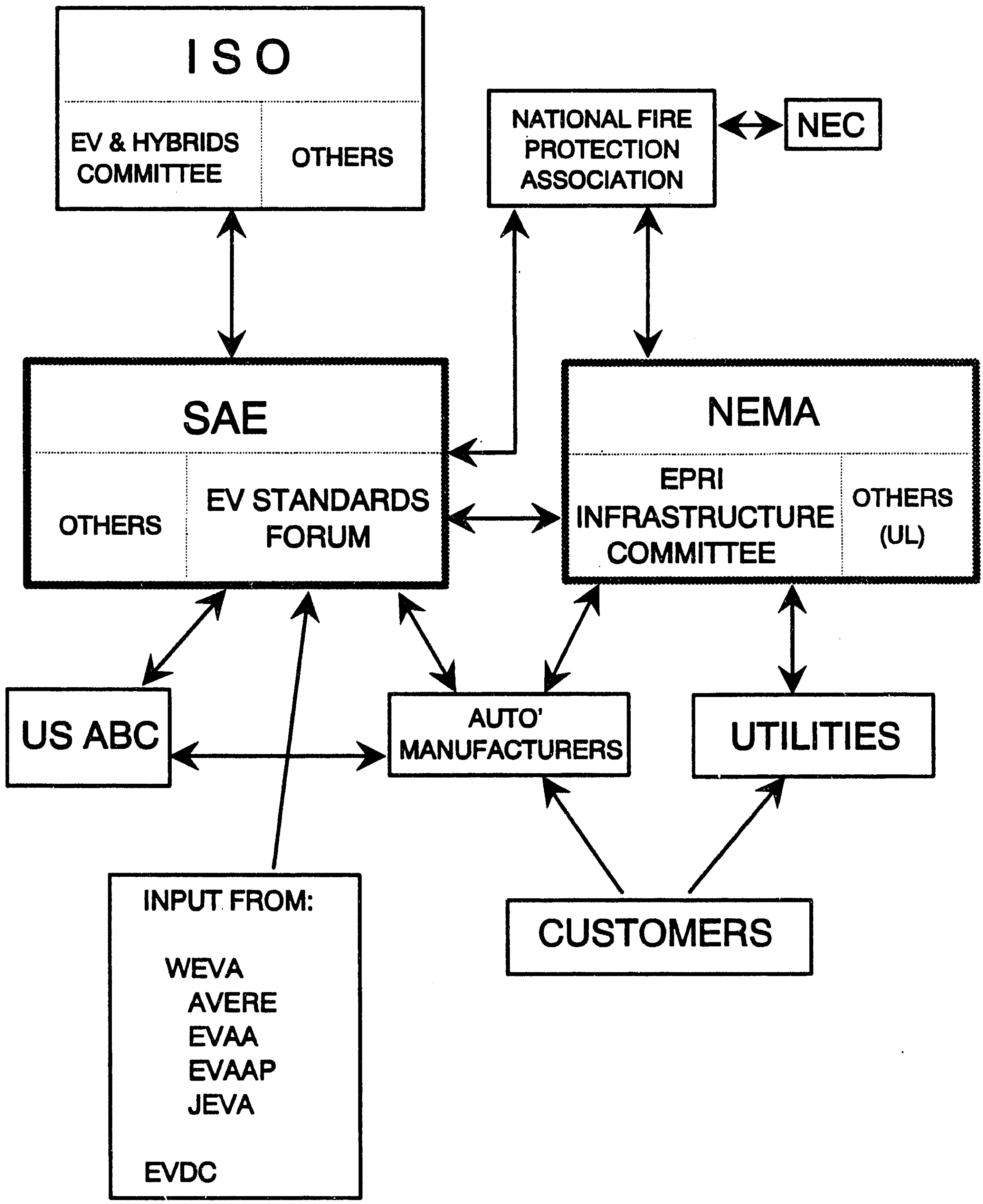
Ron Sims
EV Battery Systems Engineer - EV Powertrain Engineering, NAAO
Ford Motor Company

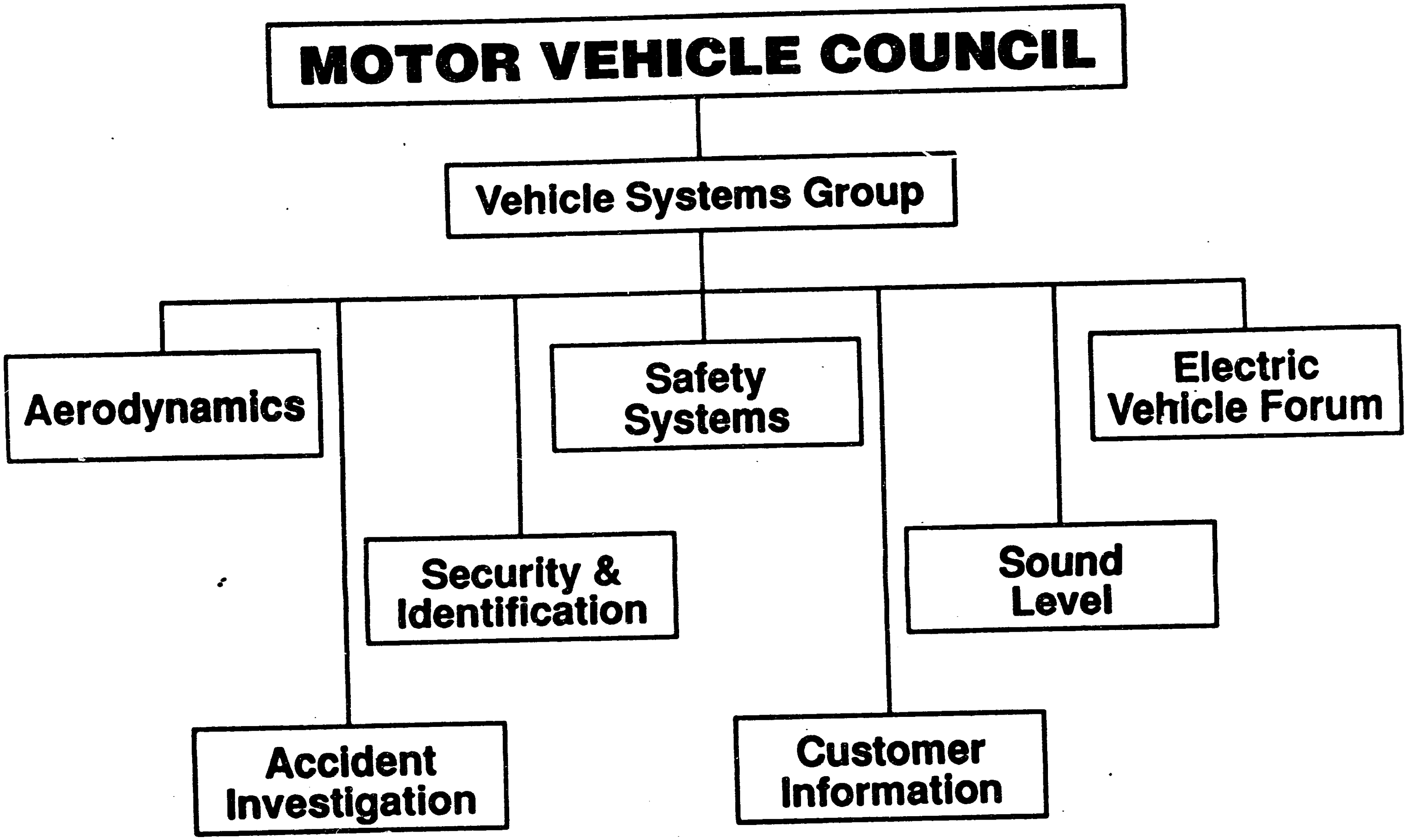
In his current position, Mr. Sims is Project Leader overseeing EV Battery Systems Engineering activities for Ford Ecostar EV Program. He is also Chairman of the SAE EV Standards Forum.

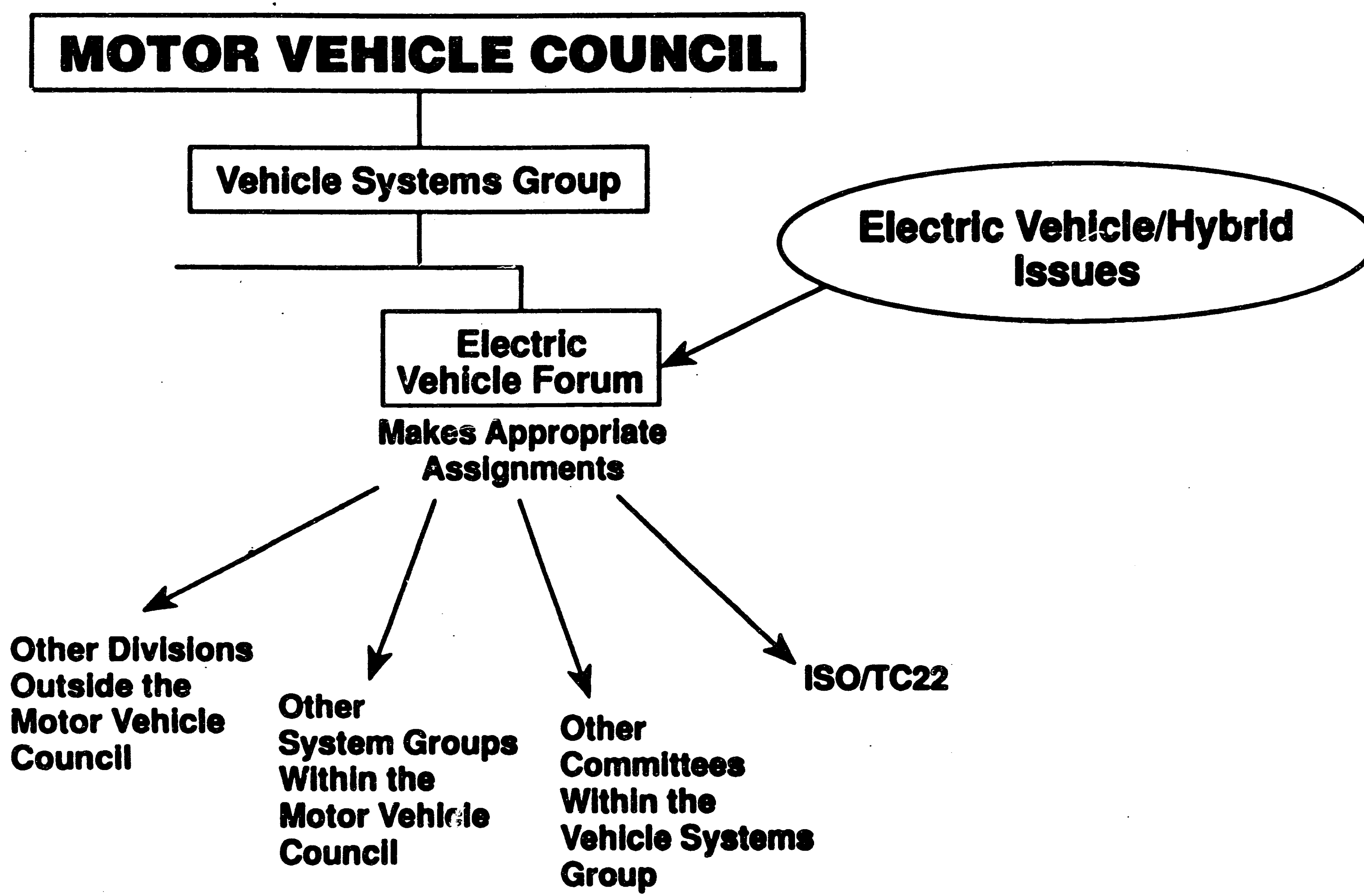
Mr. Sims' fields of specialization include 12 years in advanced coatings research for automotive materials and 14 years of EV Battery Systems research and development.

Receiving a B.Sc. in Metallurgy from Aston University, Birmingham, U.K., Mr. Sims is a Professional Engineer Member of British Engineering Council. He has presented numerous technical papers at International Conferences on metal coating processes and electric vehicle battery systems.

THE EV STANDARDS INTERFACE




MOTOR VEHICLE COUNCIL
Vehicle Systems Group
Aerodynamics
Accident Investigation
Security & Identification
Safety Systems
Customer Information
Sound Level
Electric Vehicle Forum


MOTOR VEHICLE COUNCIL
Vehicle Systems Group
Electric Vehicle/Hybrid Issues
Electric Vehicle Forum
Makes Appropriate Assignments
Other Divisions Outside the Motor Vehicle Council
Other System Groups Within the Motor Vehicle Council
Other Committees Within the Vehicle Systems Group
ISO/TC22

ELECTRICAL SYSTEMS

- Storage Battery Std. Comm.
- Dual/Higher Voltage Study Comm.
- Electrical Distribution System Std. Comm.
- EMI & EMR Std. Comm.
- Vehicle Systems Diagnostics Std. Comm.

POSSIBLE ASSIGNMENT OF THE ISSUES

MOTOR VEHICLE COUNCIL

Maintenance Division

- Service Guidelines

Powertrain Systems

- Drive Cycle Standards
- Transmissions
- Emission Controls

Electrical Systems

- Diagnostics
- Electrical System Safety
- Battery Testing
- Recycling - Battery
- Motor Testing
- Electromagnetic Compatibility
- Disposal
- Electrical Distribution System
- Linkage to USABC Consortium

Vehicle System

- Vehicle Safety
  - Crash-worthiness
  - Garage, Enclosed Space
  - Storage
  - Charging Interface
  - Define Where UL Approval Required

SAE EV STANDARDS FORUM

MISSION STATEMENT:

To specify standards, or variations of existing ones, which support industry-wide practices for uniform testing, operational flexibility, cost minimization, and consumer safety in EVs and hybrids.

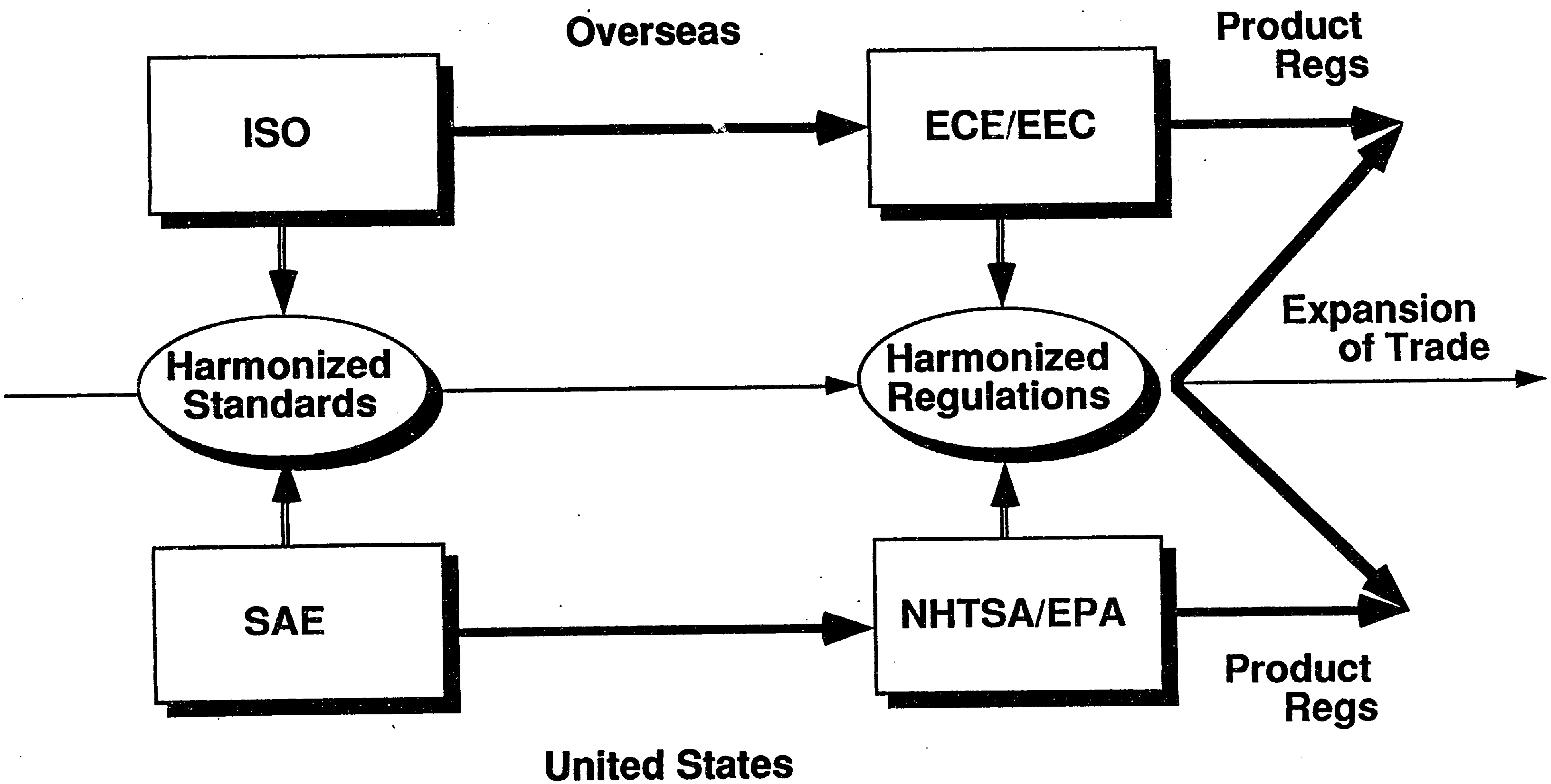
MEMBERS:

Chrysler
Electrotek EVTF (Secretary)
SAE
General Motors
Ford (Chair)
EPRI EV Consultant

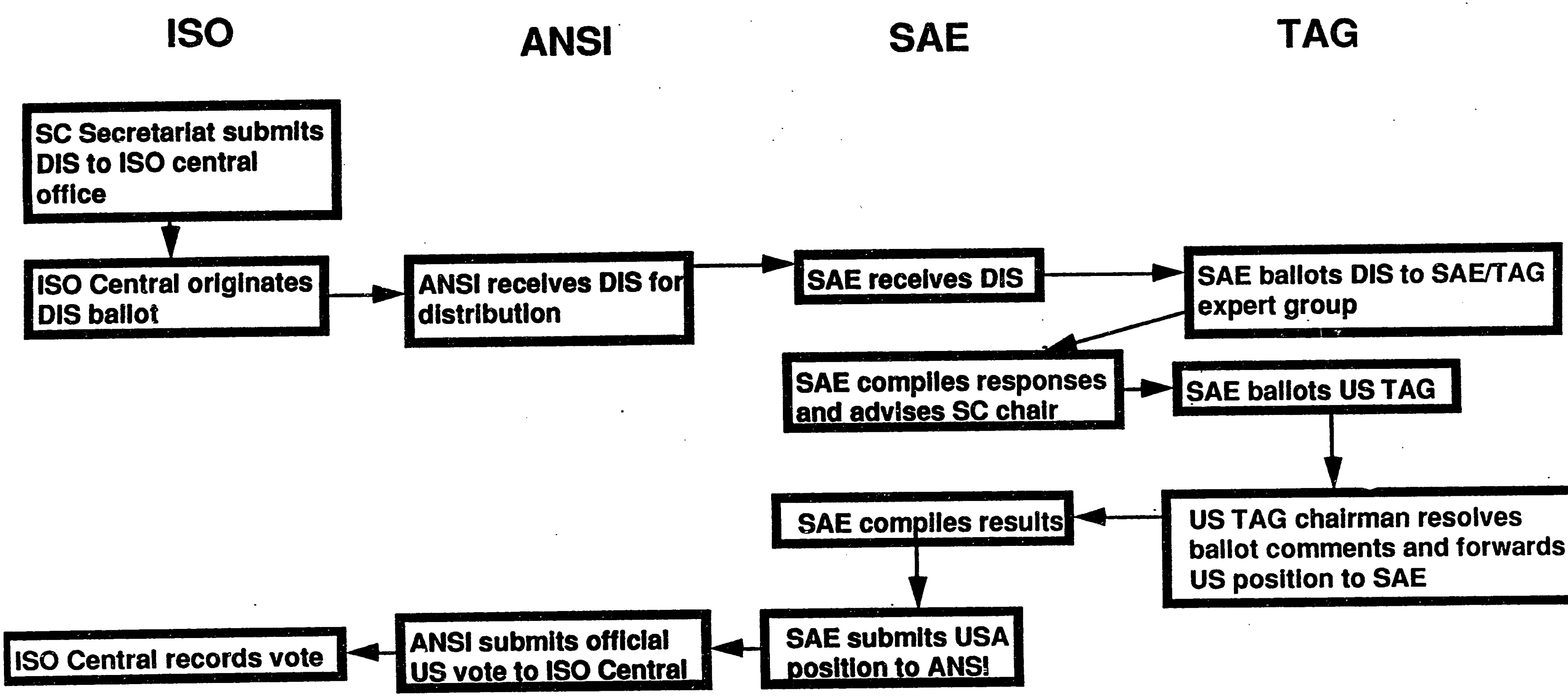
STANDARDIZATION AREAS (Prioritized):

- Battery Charging System:
  - Vehicle Cord & Plug
  - Charger Construction & Operation
  - Battery Watering & Monitoring Systems
- EV Safety
- EV Wiring Practices
- EV Test Standards
- Vehicle Diagnotics
- Service Guidelines & Battery Disposal
- Electromagnetic Compatibility
  - Susceptibilty
  - Emissions

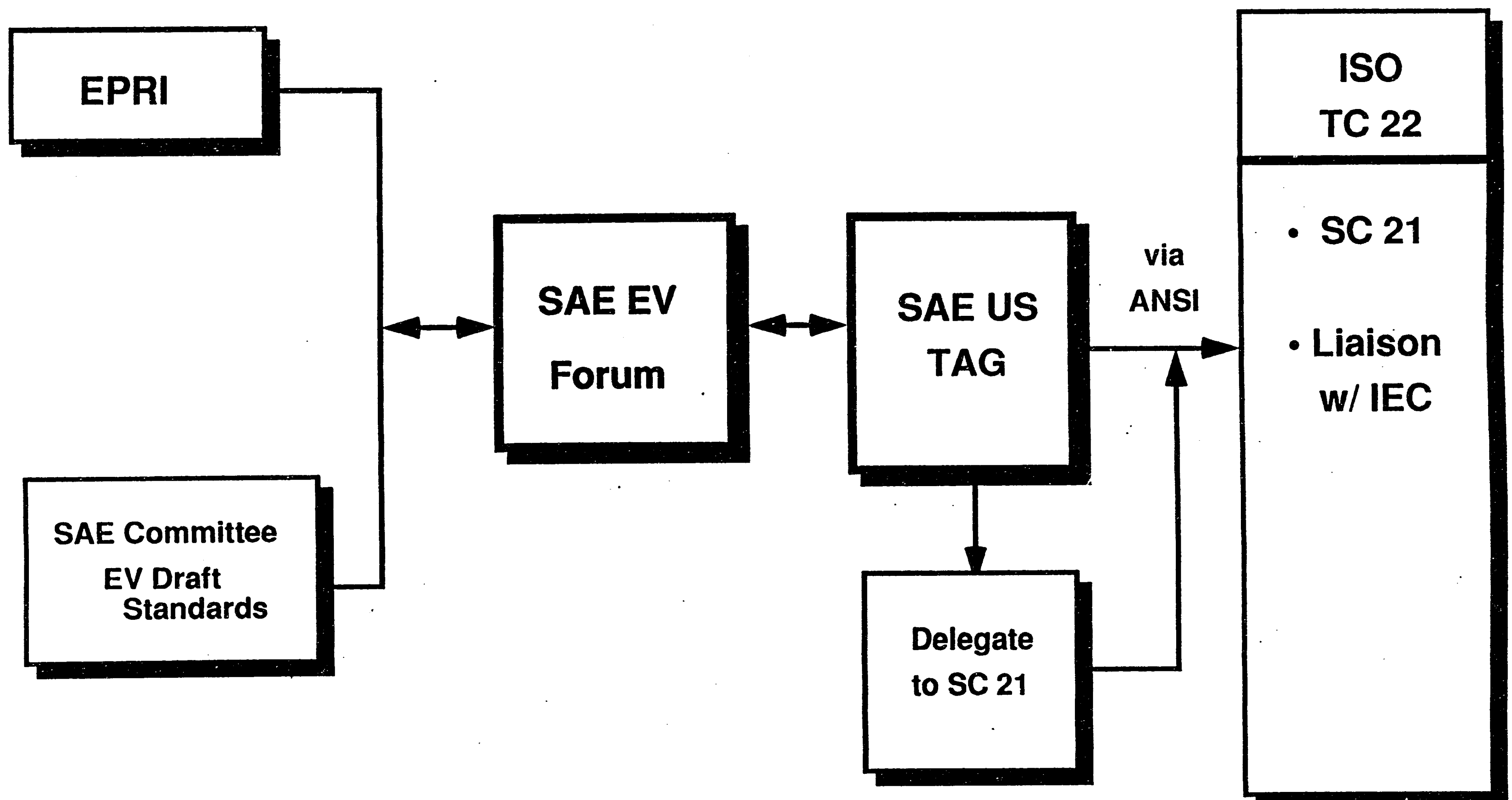
ISO standards often become the basis for product regulations in overseas markets



Standards are developed through several stages



Suggested route for coordinating US and international electric vehicle standards development



PROPOSED SPECIFICATIONS
FOR ELECTRIC VEHICLE PLUG & CORD SETS

VOLTAGE AND AMPERAGE

120V/15A

- Typically used for lighter vehicles with smaller battery packs.
- May be used for convenience charging on any vehicle away from home.
- Suitable for connecting to any common garage circuit.
- Vehicle may carry 10-30ft of cord on board. Some sort of retractable mechanism may be used.
- The "lowest common denominator."

240V/30A

- Popular configurations for residential use.
- Typically used for lighter vehicles with smaller battery packs.
- Allows more rapid charging.
- Will likely require new circuit to garage -- but at reasonable cost.
- Cord likely not carried on vehicle.

240V/50A

- Typically used for charging heavier vehicles or vans with larger battery packs.
- More likely a commercial or fleet application; but could be special residential application.
- Cord almost surely not carried on vehicle.

GROUND FAULT PROTECTION

- GFI sensitivity at 5 milliamps
- In the plug for 120V line carried on vehicle
- In the cord or plug for cord left at home base

COMMUNICATIONS

- Required:
  - Confirm charge circuit is complete and charging can occur
  - Confirm at plug connection (not inside vehicle)
  - Communication in single cord preferred
- Signaling from utility to charger (for purpose of loud shedding)
- Diagnostics
- Programming (communicate with house, or utility company)

CORD LIFE

- Durable to match estimated 10-year auto life
- Reasonable replacement cost at service shop

ENVIRONMENT

- Outdoor
- Watertight
- Temperature - 40°C to 105°C
- Abrasion/Oil/Chemical Resistant
  - Sulfuric Acid & Potassium Hydroxide
  - Brake Fluid
  - Road Salt
  - Anti-Freeze
  - Windshield Washer Fluid
  - Others
- Flame/Flammability Resistant

CRUSH AND IMPACT RESISTANT

- Withstand drop onto concrete at 1.5 meters
- Withstand drive-over (up to 8,000 pound van)
- Non-trained user can assess damage
- Severe damage renders unusable

SAFETY INTERLOCK

- Prevent driving when power is on
- Prevent driving when plugged in and power is off
- May require adaptation of plug or cord to work with feature on vehicle

SAFETY BREAKAWAY

- When vehicle is moved by outside force (e.g. hit by other vehicle while parked)
- Sealed and water tight within cable
- One time only occurrence - replace cord after failure
- Electrically dead at failure
- Center cord location (insures straight pull regardless of connections to vehicle or structure)

MECHANICAL LOCKING/RETENTION

- Locking/retention required (minimum force retention)
- Make/break under load (U.L. requirements)

OSHA

- Some provision for lock or tag out (to meet OSHA requirement at service shops)

CORD LENGTH

- 50-foot maximum as set by code
- No limitation on ability to combine cords

CAR INLET COVER

- Part of car body
- Responsibility of auto company

** NOTES **

Abstract-Electric & Hybrid Vehicle Technology TOPTEC
Tuesday, September 15, 1992

Hybrid Vehicles & Range Extenders

Andrew F. Burke
Principal Program Specialist, Energy Programs Group
EG&G Idaho, Inc., Idaho National Engineering Laboratory

Various aspects of the design and evaluation of hybrid/electric vehicles are considered with emphasis on the consequences of utilizing advanced electric driveline components such as AC motors/electronics and ultracapacitors. Special attention is given to series hybrid drivelines, because they benefit much more directly than parallel hybrid drivelines from the recent large improvements in the specific weight and volume of electric drive motors/electronics. The results of the present study indicate that series hybrid vehicles with an electric range of 90-100 km and good acceleration performance (0-88 km/h acceleration times of less than 12 seconds) can be designed with a powertrain weight and volume comparable to that of a parallel hybrid of the same performance. The driveline efficiencies of the series and parallel designs for both city and highway driving differ by less than 15 percentage points. The control of the series hybrid driveline is expected to be significantly simpler than that of the parallel hybrid system and in addition, meeting the California ULEV emission standards should be less difficult for the series hybrid design, because the start of its engine can be delayed until the catalyst is warm without affecting vehicle driveability.

Simulation results for series hybrid vehicles on the FUDS and the Federal Highway cycles indicate that their fuel economy (miles per gallon) operating in the conventional ICE vehicles of comparable interior size. Hybrid/electric vehicles using ultracapacitors to load level the greater potential improvement in fuel economy. Load leveled operation of the engine may make it less difficult to use high specific power engines, such as two-duty vehicles having stringent emission control requirements.

Biography-Electric & Hybrid Vehicle Technology TOPTEC

Andrew F. Burke
Principal Program Specialist, Energy Programs Group
EG&G Idaho, Inc., Idaho National Engineering Laboratory

Dr. Burke received a B.S. and M.S. in applied mathematics from Carnegie Tech and a M.S. and Ph.D. in mechanical and aerospace engineering from Princeton University. He has taught engineering at Clarkson College and Union College.

Dr. Burke has worked on electric and hybrid vehicles at the Jet Propulsion Laboratory and General Electric. he is presently a Principal Program Specialist in the Electric/Hybrid Vehicle Program at the Idaho National Engineering Laboratory in Idaho Falls, Idaho. He has published numerous papers and reports on electric vehicles and batteries and is currently involved with the evaluation of Supercapacitors for electric vehicle applications.

SUMMARY

This report is concerned with the development of procedures for testing of hybrid/electric vehicles to determine their energy consumption and emissions characteristics. Special emphasis is given to hybrid vehicles, which can be operated above some minimum battery state-of-charge in an all-electric mode for all types of driving (city and highway). When the all-electric range of these vehicles is exceeded, the vehicles are operated in the hybrid mode, in which an engine/generator is turned on to generate electricity on-board the vehicle. Key issues in testing hybrid vehicles are identified and discussed. These issues include the test cycles to be used, the instrumentation required, the effect of battery state-of-charge and control strategy in the hybrid mode on the need for repeated test cycles, and the data to be collected and how that data from repeated cycles is interpreted to determine the vehicle energy consumption and emissions characteristics.

The test procedures presented are based, to the maximum degree possible, on existing procedures for testing conventional ICE vehicles (40-CFR Parts 85 and 86). Hence, the testing of hybrid/electric vehicles utilizes the Federal Urban Driving Schedule (FUDS) and Federal Highway Test Schedule (FHTS) driving cycles and the constant volume sampling technique and associated instrumentation for emissions measurements. The battery state-of-charge during the test and vehicle electrical energy consumption for the cycles is determined from the Ah and Wh in and out of the battery. These quantities would be obtained from the measured battery voltage and current using a multi-channel instrument, which integrates the battery current and power. It would not be necessary to record, as a function of time, the battery current and time, because only the integrated quantities (Ah and Wh) are needed to evaluate the vehicle energy consumption. The hybrid vehicles would be tested in both the all-electric and hybrid modes on the FUDS and FHTS cycles. The testing could be done on a single day with the all-electric tests being done first to discharge the battery to an appropriate level to begin hybrid mode testing. The all-electric energy consumption (Wh/km) and range could be determined from single passes through the FUDS and FHTS cycles if the battery energy capacity characteristic (Ragone curve) is known.

The test procedures in the hybrid mode depend on whether the vehicle is a range-extended or an all-purpose hybrid. The energy consumption (miles per gallon and Wh/km) and emissions of range-extended hybrid vehicles can be determined from single passes through the FUDS and FHTS cycles, because for those vehicles, the engine/generator operates continuously at a constant power output in the hybrid mode. This results in the battery state-of-charge decreasing by the same amount for each pass through the driving cycle with repeated cycles yielding the same energy consumption and emissions data. All-purpose hybrid vehicles, which have the engine/generator unit sized to permit unlimited vehicle range in all types of driving, up to a specified maximum highway speed, would likely have a hybrid control strategy, which involves on/off engine operation. This results in the battery being charged when the engine is on and the battery being discharged when the engine is off. For these vehicles, testing on the FUDS or FHTS cycles should be done such that the battery state-of-charge is the same at the beginning and end of the test. This type of cycle has been termed the hybrid charge/discharge cycle, which can extend over more than one FUDS or FHTS cycle. Simulations of all-purpose vehicles using the SIMPLEV simulation program have shown that if the hybrid battery charge/discharge cycle is used, the fuel consumption and emissions are essentially the same for repeated cycles and tests involving a long series of FUDS and FHTS cycles are not needed. The application of the hybrid vehicle test data for the calculation of the energy consumption (electricity and liquid fuels) and emissions for generic daily use-patterns is discussed. Both the energy consumption and emissions values can be expressed in terms of vehicle characteristics available from the suggested hybrid vehicle tests.

The study has shown that testing series hybrid vehicles, both range-extended and all-purpose designs, is relatively straight-forward and should not require several days of testing to obtain their energy consumption and emissions characteristics. Since the vehicles utilize a second energy source (electricity), it is necessary to measure the Ah and Wh in and out of the battery, but that can be done using a single instrument, which is much simpler and less costly than the instrumentation currently used to determine the emissions. The FUDS and FHTS driving cycles can be used in the hybrid testing, but in testing all-purpose hybrid vehicles, the tests should be terminated based on battery state-of-charge rather than at a fixed mileage on one of the driving cycles as is done for conventional ICE vehicles.

Table 1. Review of completed and current hybrid vehicle projects.

Developer	Vehicle Type	Year	Parallel/ Series (P/S)	Motor (kW)	Engine/[1] Generator (kW)	Battery Type	Battery Weight (kg)	Electric Range (km)	Ref
COMPLETED PROJECTS									
DOE/JPL/GE	Full-size Car	1980	P	33 (DC)	55	lead-acid	340	48	8
VW	Sub-Compact	1988	P	6 (AC)	55	lead-acid	215	35	16
Ellers	Sub-Compact	1985	P (split)	30 (DC)	55	lead-acid	480	70	18
Lucas	Compact	1983	S	50 (DC)	30	lead-acid	550	72	15
CURRENT PROJECTS									
Clean Air Technology (LA 301)	Sub-Compact	1992	P	43 (DC)	25	lead-acid	540	80	19
VW (Chico)	Mini-Compact	1992	P	6 (AC)	25	lead-acid	205	35	23
GVan (XREV)	Large Van	1991	S	45 (DC)	7	lead-acid	1170	110	21
GM (HX3)	Concept Car	1990	S	90 (AC)	40	lead-acid	380	7	22
Stanford (XA-100)	Compact	1991	S	33 (DC)	25 (Rotary)	lead-acid	300	32	20

(1) All engines are 4-stroke gasoline engines unless noted otherwise

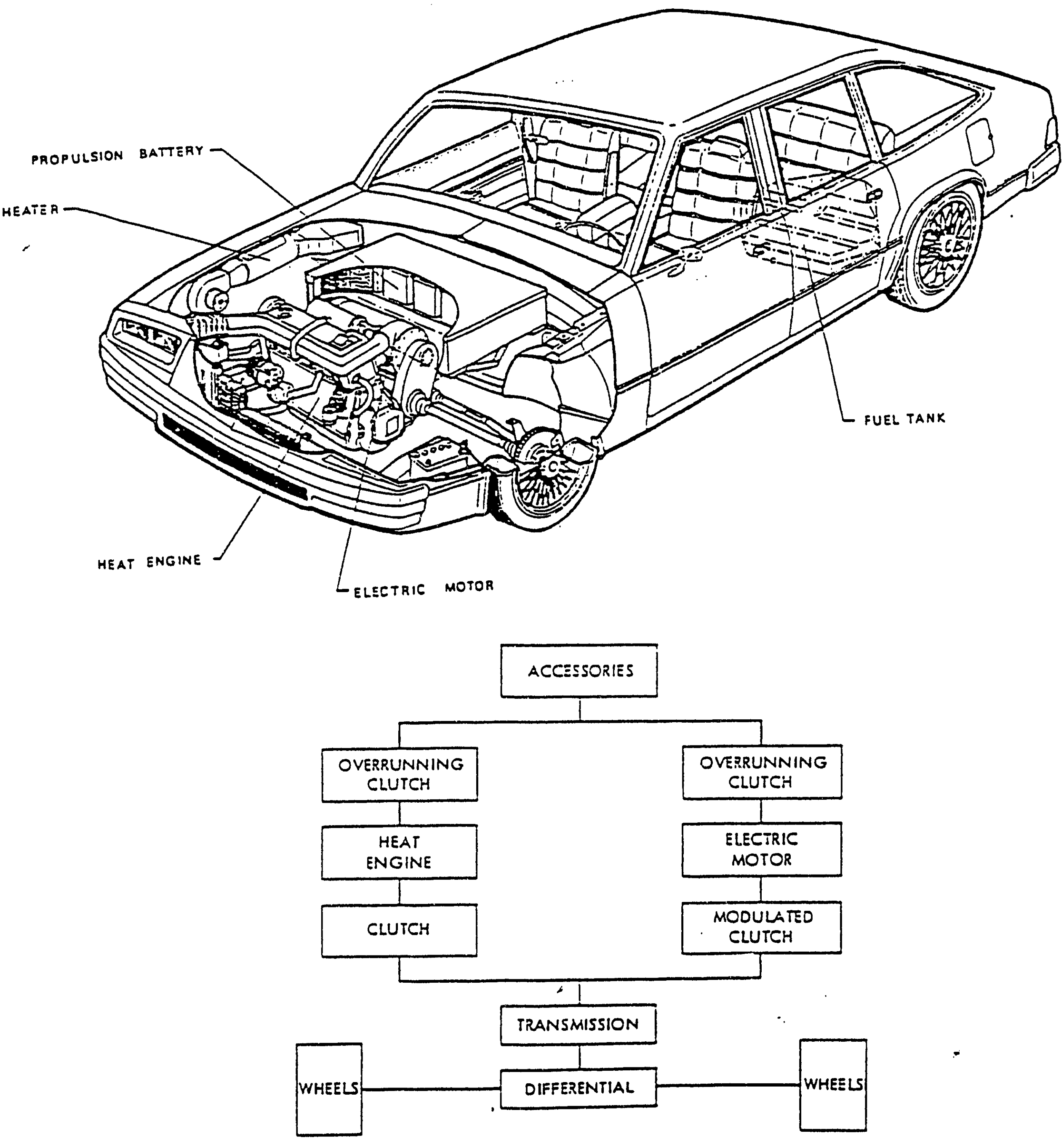


Figure 1. The near-term hybrid vehicle (HTV) driveline schematic.

Table 2. Motor and electronics characteristics for DC and AC systems.

Developer/Type	Motor		Voltage	Electronics		Transmission	System Peak Power
	kg/kW[1]	ℓ/kW	V	kg/kW[1]	ℓ/kW	Y or N	kW
General Electric D.C. Sep. Exc. (ETV-1)	3.0	0.97	108	1.5	1.7	N	30
General Electric A.C. Induction (ETX-1)	1.2	0.13	192	1.3	1.4	Y	40
General Electric A.C. PM Sychr. (ETX-II)	0.98	0.15	192	0.69	0.91	Y	52
General Electric A.C. Induction (MEVP)	0.60	0.14	340	0.55	0.45	N	56
Cocconi Eng. A.C. Induction (Impact)	0.5	0.17	320	0.35	0.66[2]	N	90-100
Pentastar D.C. Sep. Exc. (TEVan)	1.5	0.45	176	0.80	1.8[2]	Y	50

(1) All specific power and volume values based on maximum motor power

(2) Includes DC-DC converter and battery charger

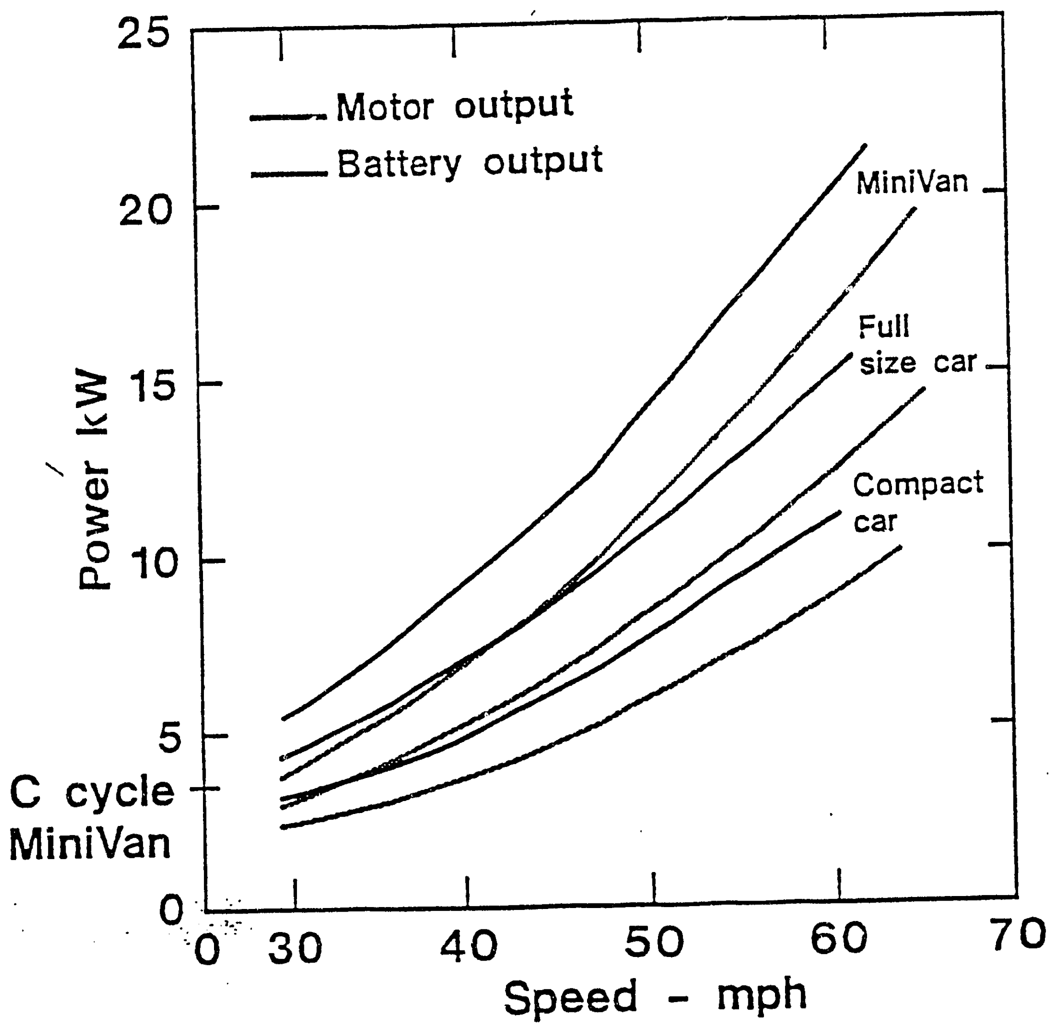
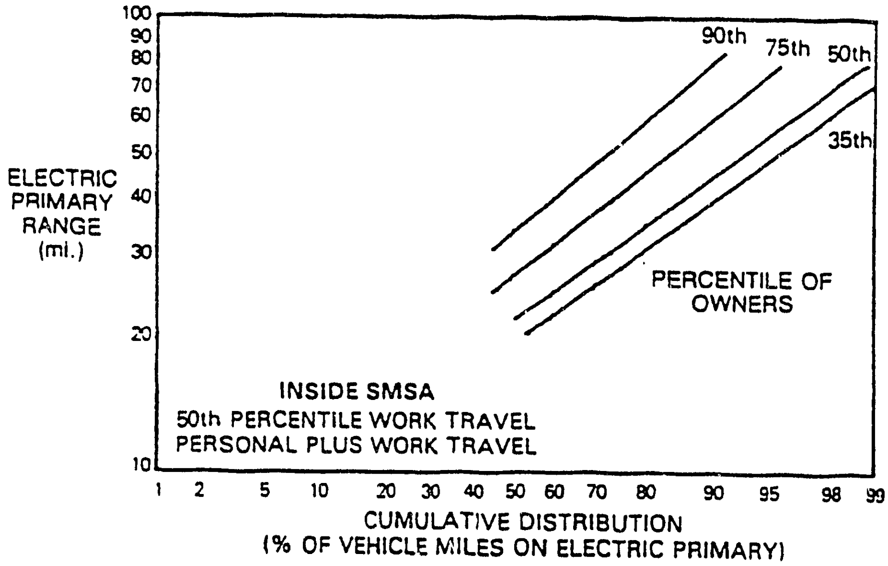
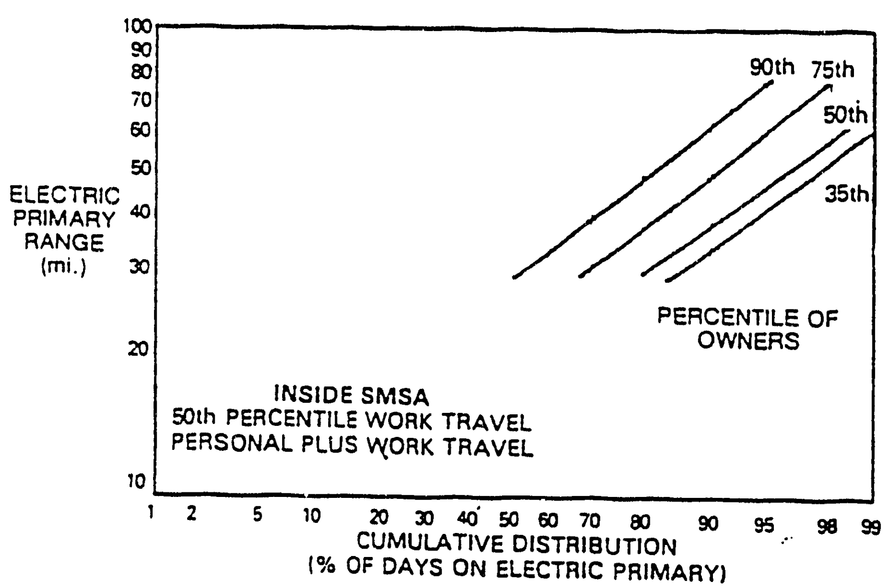


Figure 2. Motor and battery power requirements for various constant speeds.



Effect of vehicle range on vehicle use - inside SMSA.



Effect of vehicle range on vehicle use - inside SMSA.

Figure 3. Electric range requirements for various percentile owners.

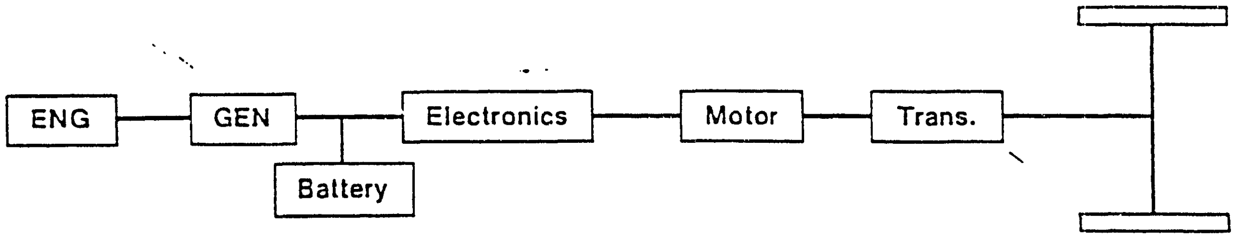
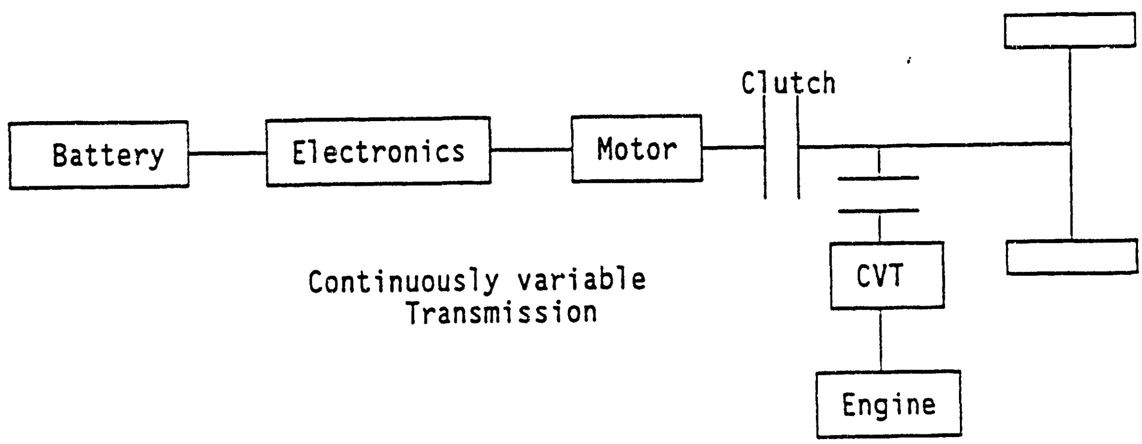


Figure 4. Series hybrid driveline schematic.

Dual-Shaft Configuration



Single-Shaft Configuration

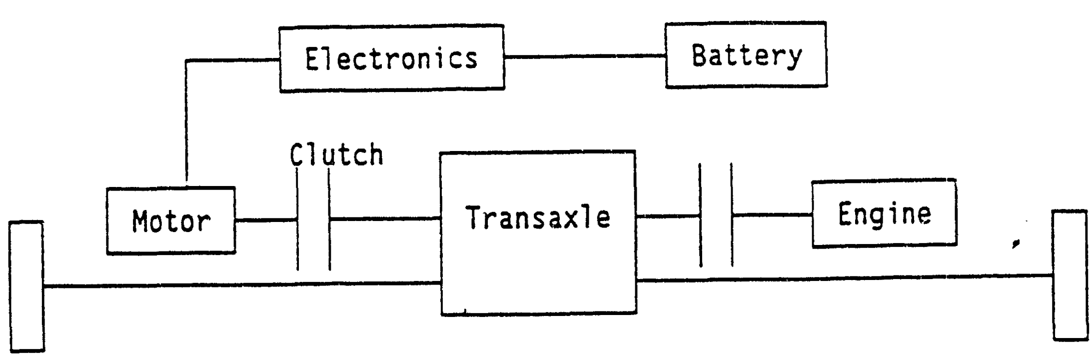


Figure 5. Parallel hybrid driveline schematics.

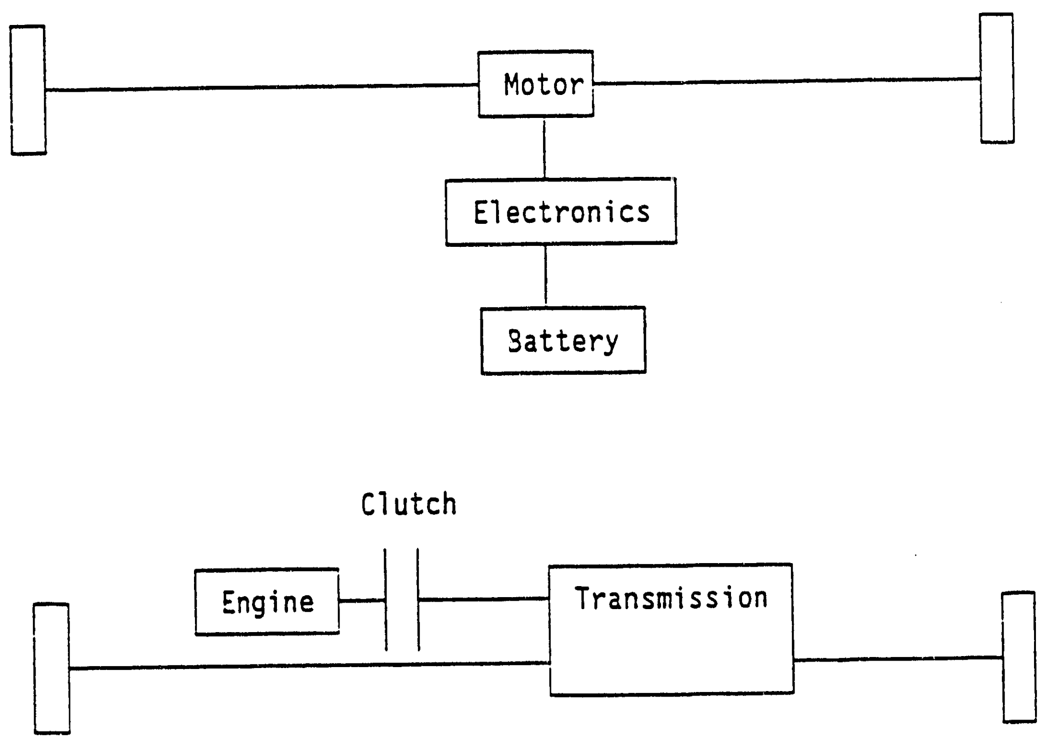


Figure 6. Split hybrid driveline schematic.

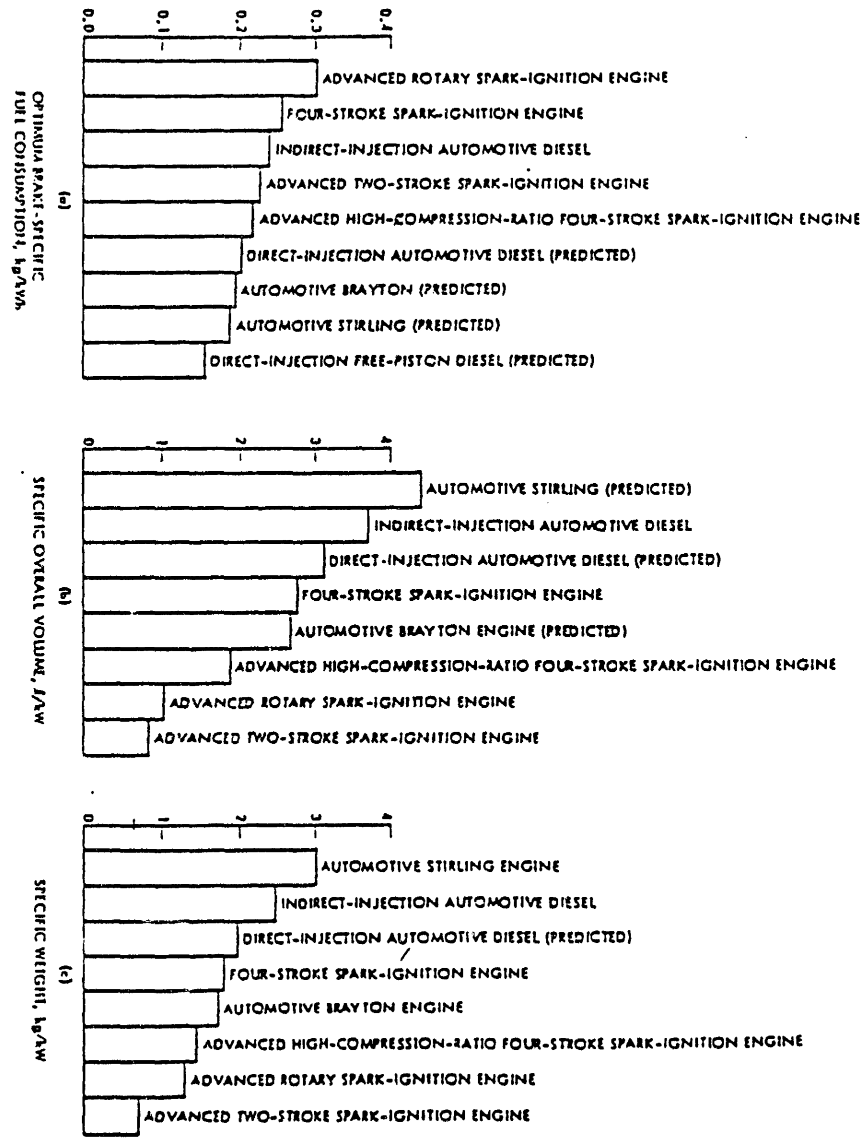


Figure 7. Characteristics of various engine types for hybrid vehicles.

Table 3. Characteristics of recent specialty engines.

Engine Developer/Type	Max. Power (kW)	kg/kW	ℓ/kW	min bsfc gm/kWh	Reference
Norton/Rotary	30	0.7	1.4	300	31
Rotec/Rotary	26	1.1	1.2	360	32
NoMac/Gas Turbine	25	1.3	2.2	270	34
VW/Direct Injection, Ignition Compression, Supercharged	29	3.5	4.1	240	33

Table 4. Weight and volume of 30kW engines of various types.

Engine Type	Weight (kg)	Volume (liter)	min bsfc (gm/kWh)	Reference
Rotary	35	38$^{(1)}$	300	31 and 32
Two-Stroke	25	30$^{(1)}$	250	30
Gas Turbine	33	56$^{(2)}$	270	34
2 Cylinder 4-valve, Spark Ignition	50	100	280	44
(1) Does not include the radiator				
(2) Includes space for the generator				

Table 5. Series hybrid vehicle and powertrain characteristics

	Vehicle			Motor/Generator			Battery			
Type	Weight (kg)	C_DA (m^2)	fr (%)	Motor (kW)[1]	Generator (kW)	Weight (kg)	Max Power (kW)	(W/kg)	kWh[2]	Wh/kg
Minivan	1760	1.16	0.85	56	25	350	60	171	20	58
Microvan	1360	0.759	0.85	37.5	20	225	46	204	14	64
Compact Car	1260	0.495	0.85	37.5	17.5	200	42	210	10	50

(1) Motor and electronics were MEVP components

(2) All vehicles had a range of 90-100 km

Table 6. Series hybrid electric range, fuel economy, and acceleration characteristics.

Vehicle Type	Electric				Series Hybrid				Acceleration Times (sec)	
	FUDS		FHWC		FUDS		FHWC			
	Wh/km	Range[1] (km)	Wh/km	Range (km)	mpg[2]	Effic. (%)[3]	mpg	Effic. (%)	0-48 km/h	0-80 km/h
Minivan	185	93	188	86	26.1	0.85	26.4	0.88	4.7	12.1
Microvan	136	96	132	93	35.6	0.85	37.5	0.88	4.7	12.5
Compact Car	116	99	103	107	41.8	0.86	47.8	0.87	4.3	11.0

(1) Useable range to DOD = 80%

(2) Gasoline fuel and min bsfc = 300 gm/kWh

(3) Average efficiency from engine output to inverter input

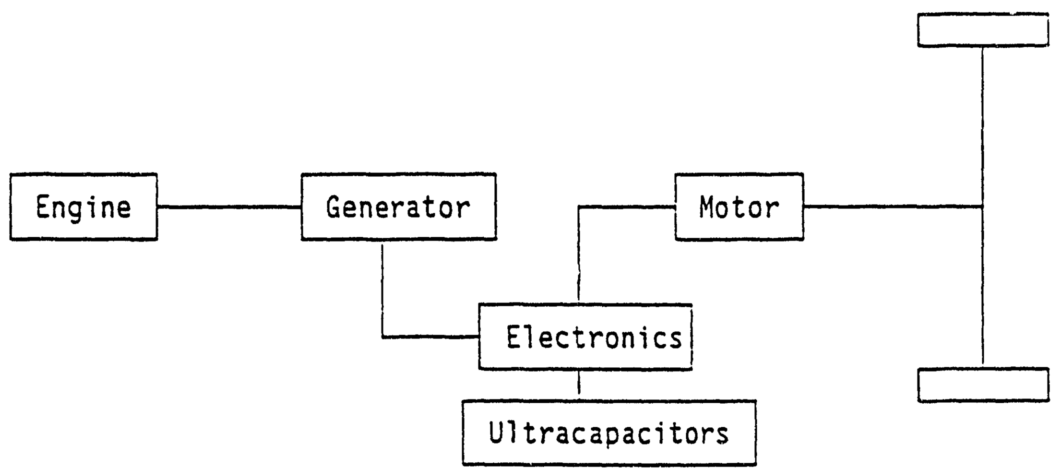


Figure 8. Engine-electric driveline schematic using ultracapacitors.

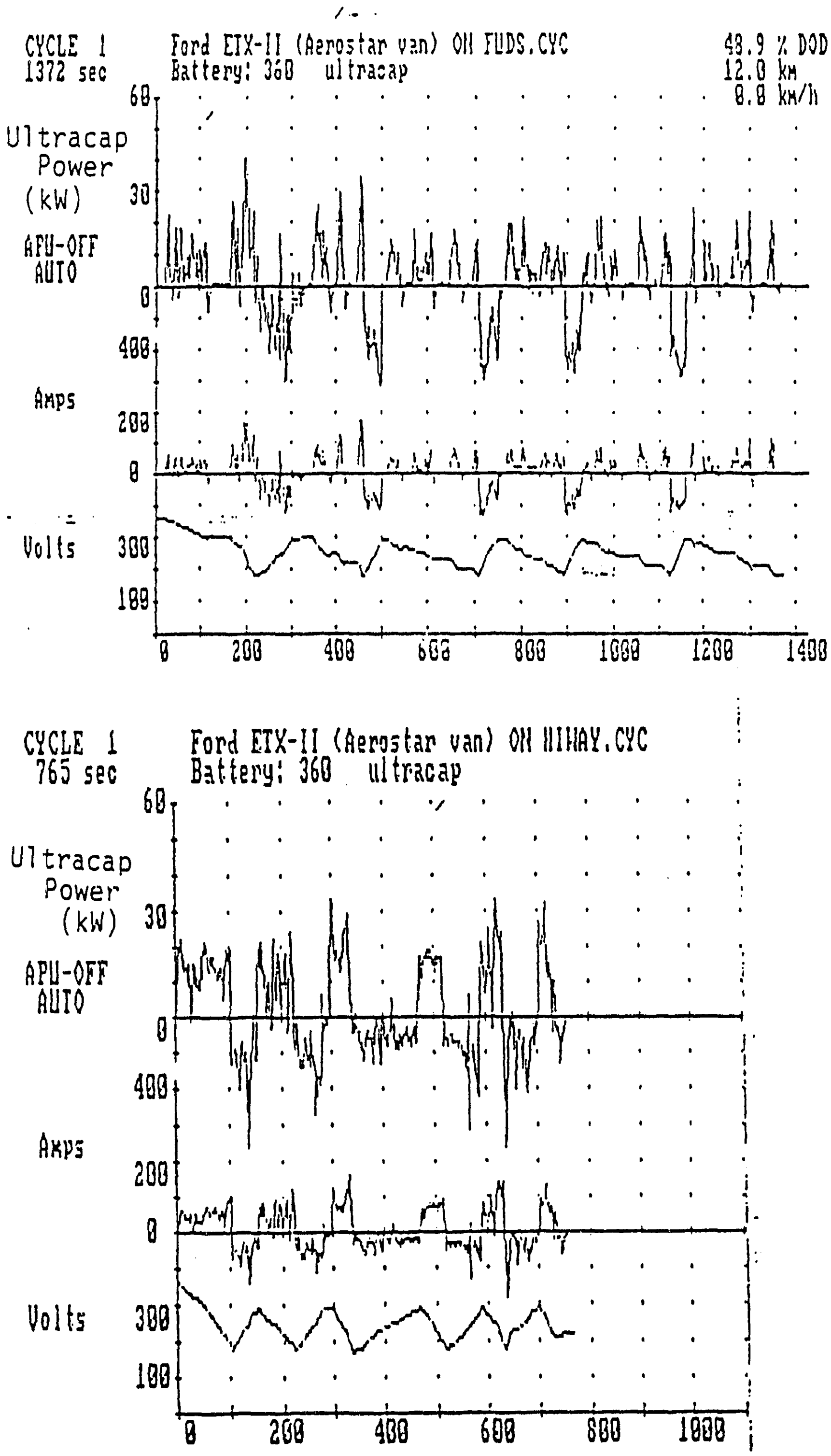


Figure 9. Ultracapacitor charge/discharge on the FUDS and FHWC cycles wth an APU.

Table 7. Engine-electric vehicle characteristics using ultracapacitors.

Vehicle				Motor/Generator			Ultracapacitors		
Type	Weight (kg)	C_DA (m^2)	fr (%)	Motor (kW)	Generator (kW)	Weight (kg)	Wh	(Wh/kg)	Max Power (kW)
Minivan	1501	1.16	0.85	56	25	85	500	5.9	60
Microvan	1200	0.759	0.85	37.5	20	68	400	5.9	46
Compact Car	1150	0.495	0.85	37.5	20	68	400	5.9	42

Table 8. Fuel economy of the engine-electric vehicles using ultracapacitors.

Vehicle Type	Fuel Economy (mpg)			
	FUDS		FHWC	
	Engine-Electric	Conventional ICE [1]	Engine-Electric	Conventional ICE
Minivan	33.1	18	30.5	22
Microvan	45.3	---	44.3	---
Compact Car	51.5	27	56.1	36

(1) 1992 EPA fuel economy rating for cars in this class

Table 9. The weight breakdown for hybrid minivans.

		Parallels		
	1992 Series	1992 Parallel	1980 Parallel (HTV)	1992 Engine-Electric
Chassis + payload	1220	1220	1250	1220
Driveline Components				
Motor/electronics[(1)]	65 kg/56 kW	32 kg/25 kW	158 kg/33 kW	65 kg/56 kW
Transaxle	37	37	62	37
Ultracapacitors	0	0	0	85/500 Wh
Engine[(1)]	35 kg/30 kW	50 kg/40 kW	150 kg/55 kW	35 kg/30 kW
Generator/electronics	20 kg/30 kW	0	0	20 kg/30 kW
Transmission/gearing	0	30	56	0
Total Driveline Weight (w/o batteries)	157	149	426	242
Total Driveline Weight (including batteries)	507	499	801	242
Total Vehicle Weight	1727	1719	2051	1462

(1) Weight (kg)/maximum power (kW)

Table 10. The weight breakdown for hybrid compact passenger cars.

		Parallels		
	1992 Series	1992 Parallel	1980 Parallel (ETV-1)	1992 Engine-Electric
Chassis + payload	865	865	980	865
Driveline Components				
Motor/electronics[(1)]	45 kg/37 kW	22 kg/15 kW	134 kg/30 kW	45 kg/37 kW
Transaxle	37	37	51	37
Ultracapacitors	0	0	0	68/400 Wh
Engine[(1)]	23 kg/20 kW	30 kg/25 kW	0	23 kg/20 kW
Generator/electronics[(1)]	15 kg/20 kW	0	0	15 kg/20 kW
Transmission/gearing	0	20	0	0
Total Driveline Weight (w/o batteries)	120	109	185	188
Total Driveline Weight (including batteries)	345	334	680	188
Total Vehicle Weight	1210	1199	1660	1053

(1) Weight (kg)/maximum power (kW)

Table 2. Summary of hybrid vehicle test procedures.

PROCEDURE	SPECIFICATIONS
Dynamometer Setup	Set vehicle inertia weight and match the coast-down curve.
Instrumentation	Constant volume sampling system and exhaust gas analyzers for emissions measurement. Ah and Wh integrating unit - battery voltage and current as inputs.
Driving Cycles	FUDS and FHTS
All-Electric Tests	
Vehicle Warm-ups	Constant speed (55-60 mph) for 10 miles.
FUDS	One cycle
FHTS	One cycle
Data	Wh and Ah in and out of battery for each cycle.
Calculations	Wh/km, gross and net for each cycle Δ SOC for each cycle range (km) each cycle to DOD = .80
Hybrid Mode Testing Range-Extended	
Battery SOC at beginning of test	SOC < 50%
FUDS	One cycle for electrically heated catalyst; two cycles for unheated catalyst.
FHTS	Same as above.
Data	Wh and Ah in and out of the battery for each cycle emissions (HC, CO, NO_x, CO_2) from one bag per cycle.
Calculations	Wh/km, gross and net for each cycle Δ SOC for each cycle range (km) - maximum for each cycle (Δ DOD = .8). Emissions: gm/mi HC, CO, NO_x for each cycle MPG for each cycle
All-Purpose	
Battery SOC at beginning of test	SOC < 50%
FUDS	One hybrid charge/discharge cycle with SOC same at beginning and end of cycle with electrically heated catalyst; two cycles for unheated catalyst.
FHTS	Same as above.
Data	Wh and Ah in and out of battery for each hybrid battery cycle. Emissions (HC, CO, NO_x, CO_2) one bag for each battery hybrid cycle.
Calculations	Wh/km, gross and net for each battery hybrid cycle. Emissions: gm/mi HC, CO, NO_x for each battery hybrid cycle. MPG for each battery hybrid cycle Ah net for each battery hybrid cycle (should be zero)
Battery recharge after test	
Data	Net Ah from battery during test. kWh into battery during recharge. Ah into battery during recharge. kWh into the charger from the wall plug.
Calculations	Charger efficiency. Battery charge/discharge efficiency.

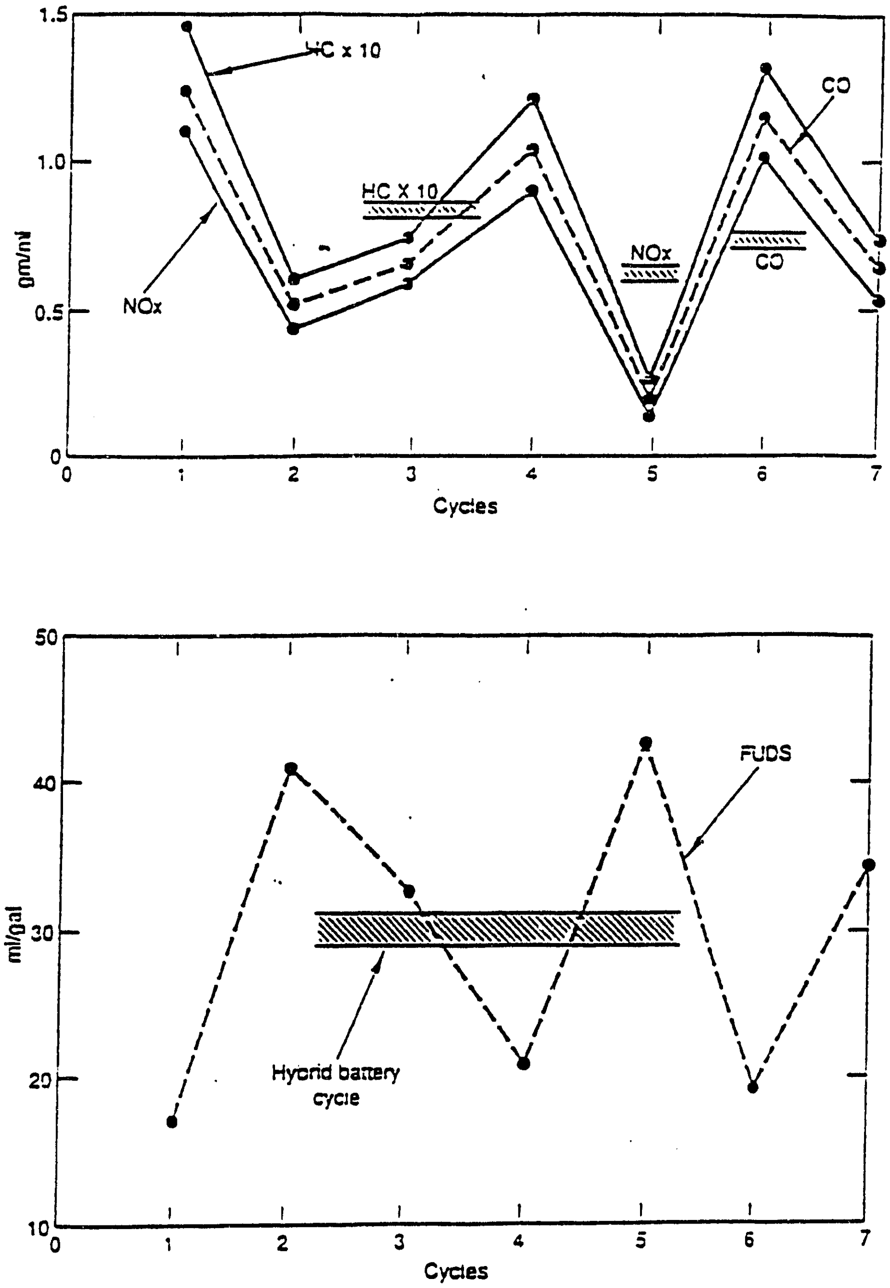
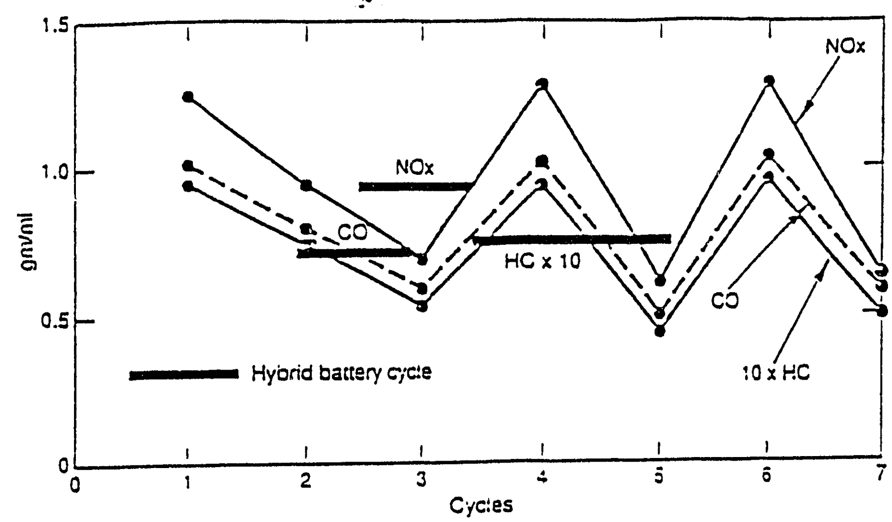


Figure 7. Emissions and fuel economy of the minivan on the FUDS and hybrid charge/discharge cycles (electrically heated catalyst, ΔDOD = .1).



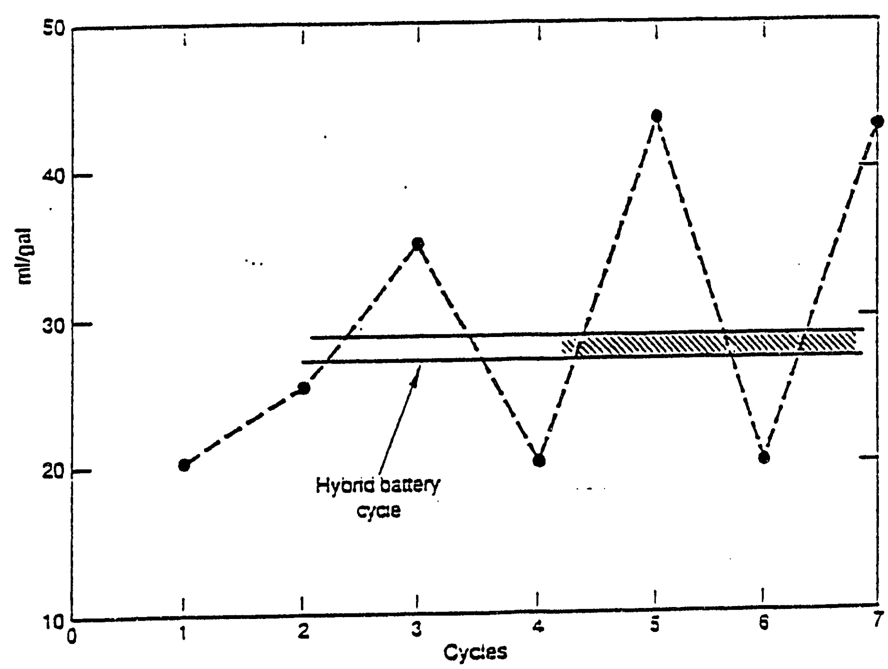


Figure 8. Emissions and fuel economy of the minivan on the FHTS and hybrid charge/discharge cycles (electrically heated catalyst, ΔDOD = .1).

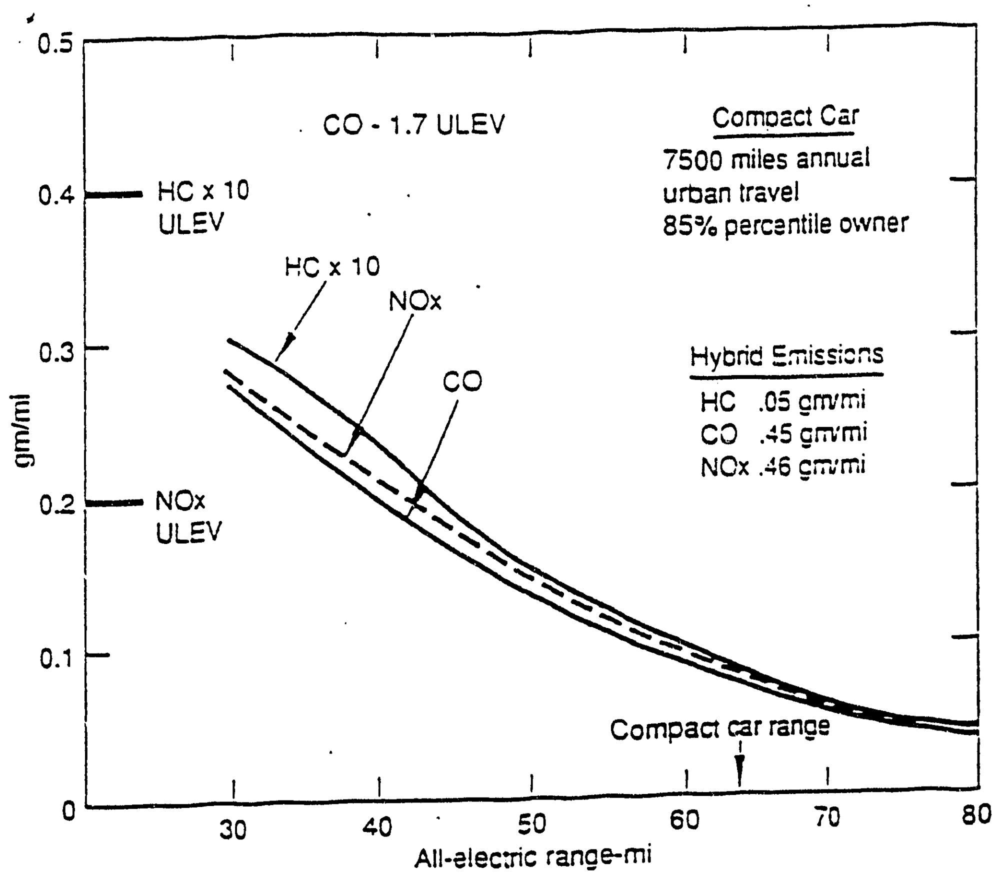


Figure 9. The effect of all-electric range on the annual average emissions of the hybrid compact car in urban driving.

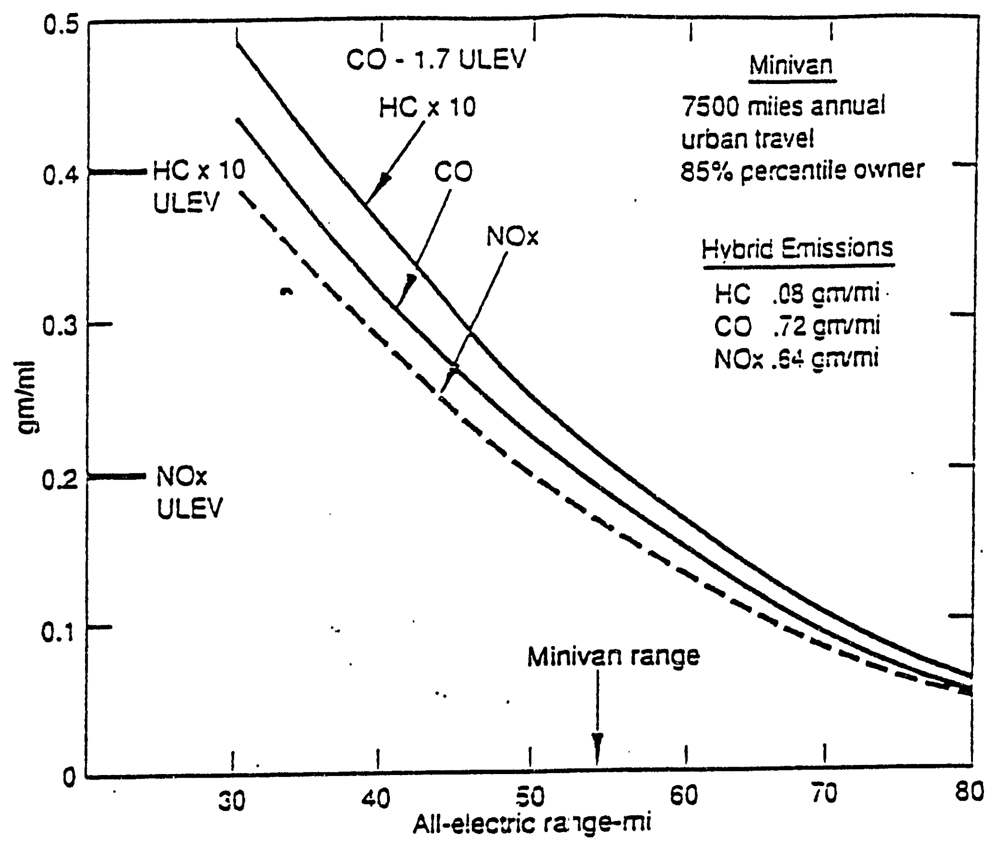


Figure 10. The effect of all-electric range on the annual average emissions of the hybrid minivan in urban driving.

Table 8. Characteristics of the minivan as a range-extended vehicle (generator - 8 kW).

Driving Cycle	MPG	Wh/km	Emissions (gm/mi)			Max. Range (km)	
			HC	CO	NO_X	Electric[1]	Hybrid[1]
FUDS[2]	29.5	—	.071.100	.676	.877	87	unlimtd
FHTS	52.0	84	.041	.385	.50	77	169
50 mph	54.0	81	.039	.369	.479	84	182
60 mph	65.0	137	.032	.308	.399	64	101

(1) DOD = .8
(2) electrically heated catalyst, Δ DOD = .075

Table 9. Fuel economy and emissions for the minivan on the urban cycle for $P_{gen} = P_{av}$ (electrically heated catalyst).

Cycle No.	Distance* (mi)	DOD	MPG	Emissions (gm/mi)		
				HC	CO	NO_X
1	7.5	.193	28.3	.091	.791	.616
2	7.5	.194	28.2	.091	.794	.623
3	7.5	.191	28.0	.092	.803	.632
4	7.5	.200	29.5	.091	.797	.631

* incremental distance on the urban cycle

Table 10. Fuel economy and emissions of the minivan on the urban cycle (electrically heated catalyst).
(Δ DOD = .1)

Cycle No.	Distance (mi)	DOD	MPG	Emissions (gm/mi)		
				HC	CO	NO_X
0	0	.648	—	0	0	0
1	7.4	.559	17.0	.145	.127	1.13
2	14.9	.591	24.1	.102	.894	.791
3	22.4	.600	26.6	.093	.812	.722
4	29.7	.548	24.7	.010	.874	.773
5	37.3	.637	29.5	.084	.732	.647
6	44.7	.567	27.0	.091	.801	.709
7	52.2	.581	27.8	.089	.777	.687

Table 11. Fuel economy and emissions for the minivan on the urban cycle from the hybrid battery cycle (electrically heated catalyst).

(Δ DOD = .1)

Cycle No.	Distance* (mi)	MPG	Emissions (gm/mi)		
			HC	CO	NO_X
1	12.9	29.5	.083	.731	.650
2	12.2	29.9	.082	.722	.642
3	11.9	30.7	.081	.706	.617
4	12.4	29.0	.085	.745	.662

* incremental distance for the hybrid battery cycle

Table 12. Fuel economy and emissions of the minivan on the highway cycle (electrifcally heated catalyst).

(Δ DOD = .1)

Cycle No.	Distance (mi)	DOD	MPG	Emissions (gm/mi)		
				HC	CO	NO_X
0	0	.655	—	0	0	0
1	10.3	.595	20.9	.100	.957	1.24
2	20.5	.593	23.8	.088	.840	1.10
3	30.8	.630	26.7	.079	.748	.975
4	41.0	.568	24.9	.084	.80	1.05
5	51.3	.633	27.3	.077	.731	.95
6	61.5	.571	25.9	.0809	.770	1.01
7	71.8	.632	27.4	.076	.728	.951

Table 13. Fuel economy and emissions of the minivan on the highway cycle based on the hybrid battery cycle (electrically heated catalyst).

(Δ DOD = .1)

Cycle No.	Distance (mi)	MPG	Emissions (gm/mi)		
			HC	CO	NO_X
1	24.4	28.2	.074	.710	.926
2	24.0	27.4	.076	.727	.951
3	20.5	27.8	.075	.718	.940

Table 5. Summary of ultracapacitor technology (1992 Design, Performance, Status).

	Construction			Performance						Status				
Name	Config.	Electrode Mat'l	Electrolyte	Wh/kg	Wh/l	Resistance ohm-cm²	(W/kg)pk (1)	Effic (2) (%)	Cost	Size (cm²)	Voltage	Cap. (F)	Basis for Projection	Ref.
NEC Supercap														
FY	prismatic	carbon	sulfuric acid	.33	.55	45	---	---	low	4	5	2.2	Mfg Spec Sheet	---
FE	prismatic	carbon	sulfuric acid	.01	.18	1.9	---	---	low	4	5	1.5	Mfg Spec Sheet	1
Experimental	prismatic	carbon/phenol composite	sulfuric acid	4-5	8-12	$<10^{-1}$	>1000	>90	low	100	5	1000	Literature	1
Panasonic	spiral wound, single cell	carbon	organic	2.2	2.5	7	400	80-90	low	single cell	3 V	600	INEL Testing	---
Evans	prismatic	carbon	sulfuric acid	.2	.5	1	---	---	low	6	11	.5	Mfg Spec Sheet	---
Seiko Instruments	button cell	polyacene polymer	organic	1.9	4.9	12	---	---	---	3	5	2.5	Mfg Spec Sheet	---
Pinnacle Research Institute	bipolar	mixed oxides (Ru, Ta)	sulfuric acid	5	14	$<10^{-2}$	>10,000	>95	high	2	100 V	.01	Mfg Testing	2
		(Advanced	Design)	>20	>60	$<10^{-2}$	>10,000	>95	med	---	---	---	Press Release	2
Maxwell/Auburn	bipolar	carbon/metal fiber composite	KOH	5	11	$<10^{-1}$	>1000	>90	low	under development			DOE Program Goals	
CDE Labs	bipolar	aerogel carbon	KOH	4-10	8-20 (under development)	$<10^{-1}$	>1000	>90	med	2	1	24	Lab. tests	3
Giner, Inc.	bipolar	carbon/Ru-oxides	solid polymer	1.4	2	.3	---	---	high	25	5	4	Literature	4
DOE Advanced Ultracap.	bipolar	open	open	10-15	20-30	$<10^{-1}$	>2000	>95	low	>50 (To be	>100 developed)	---	DOE Program Goals	

(1) Maximum power at which the energy recoverable from capacitor is at least 80% of that recoverable at 100 W/kg.

(2) Efficiency on the PSFUDS cycle for the peak power step at (W/kg)pk.

References:

1. Tabuchi, J., etals, Activated Carbon/Carbon Composite Fro 1000 F Electric Double Layer Capacitor, Abstract at the Fall Meeting of the Electrochemical Society, Phoenix, Arizona, October 13-17, 1991. (NEC Corp.).
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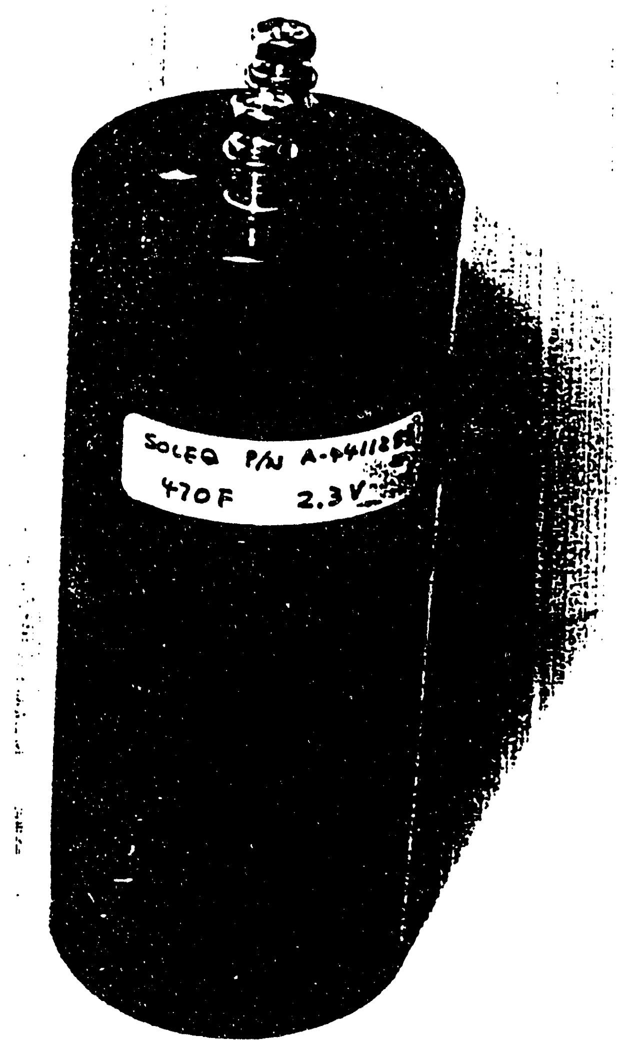
3. Mayer, S.T., etals, The Aerocapacitor: An Electrochemical Double Layer Energy Storage Device, Paper to be published in the Journal of the electrochemical Society. (Lawrence Livermore Laboratory).
4. Sarangapani, S., etals, Proton Exchange Membrance Electrochemical Capacitors, Paper presented at the IECEC Meeting in Reno, Nevada, August 1990.

Table 1. Near-term and advanced goals for the DOE ultracapacitor development programs.

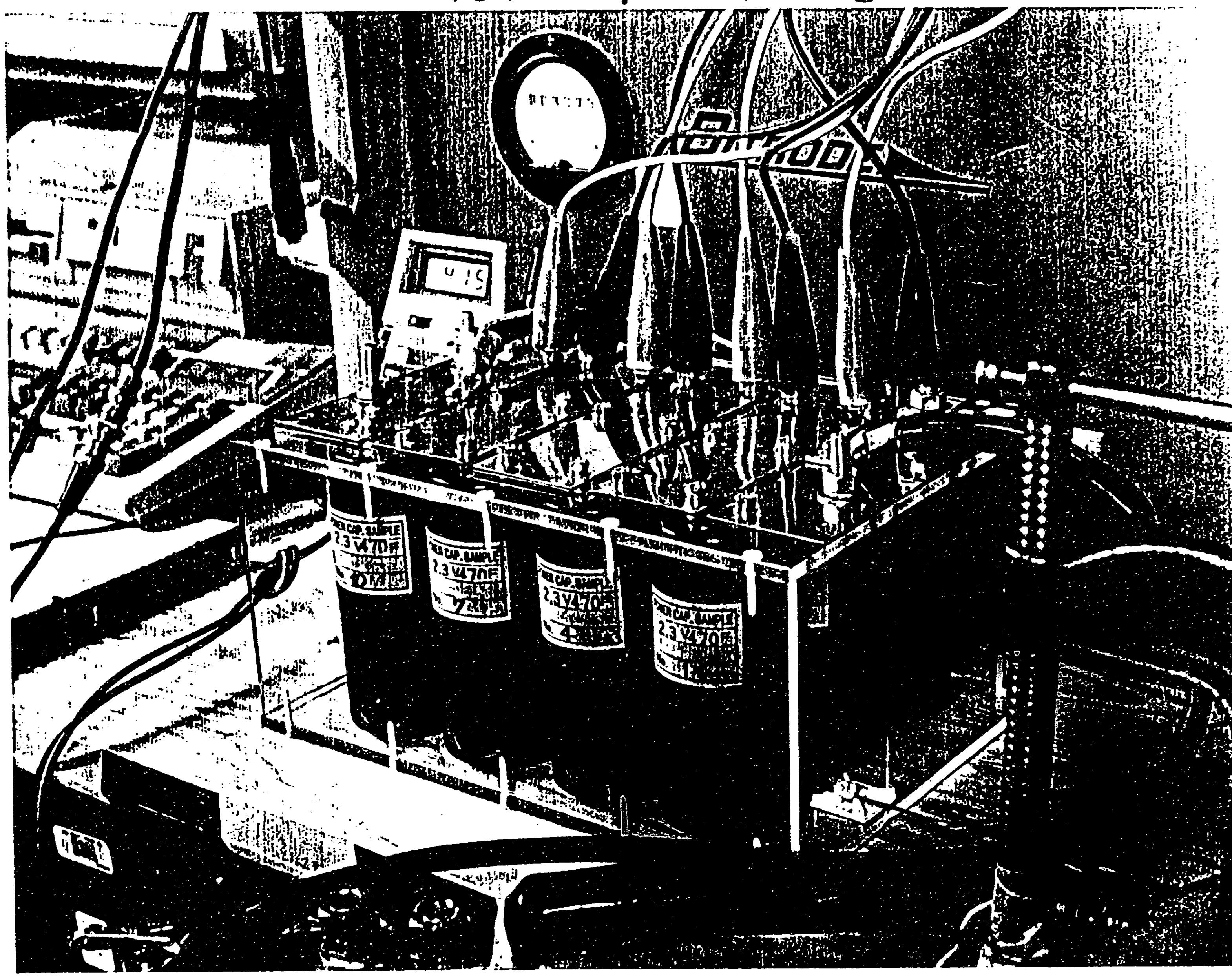
Battery w/o Capacitor	Near-Term	Advanced
Weight (kg)	500-600	200-300
Power Density (W/kg) Average Gradeability Peak (accel)	 10 30-50 80	 20 110-160 375-550
Ultracapacitor Unit		
Energy stored (Wh)	500	750
Maximum Power (kW)	50	80
Weight (kg)	<100	<50
Volume (ℓ)	<40	<20
Energy density (Wh/kg)	>5	>15
Maximum useable power density (W/kg)	>500	>1600
Round trip efficiency (%)	>90	>90
Vehicle Acceleration		
0-88 km/h (sec)	<20	<8

Table 2. Physical characteristics of the 3 V, 600 F capacitor

Rating	3.0 V, 600 Farads
Technology	Single cell, spiral wound, carbon-based, non-aqueous electrolyte
Energy Stored	2700 W sec
Size Diameter Length Volume	 5.12 cm 12.4 cm 255 cm^3
Weight	330 gm
Energy Density	2.27 Wh/kg (8.18 J/gm) 2.94 Wh/ℓ (10.6 kJ/ℓ)


SOLEQ P/N
470F 2.3V

12V Cap. Module



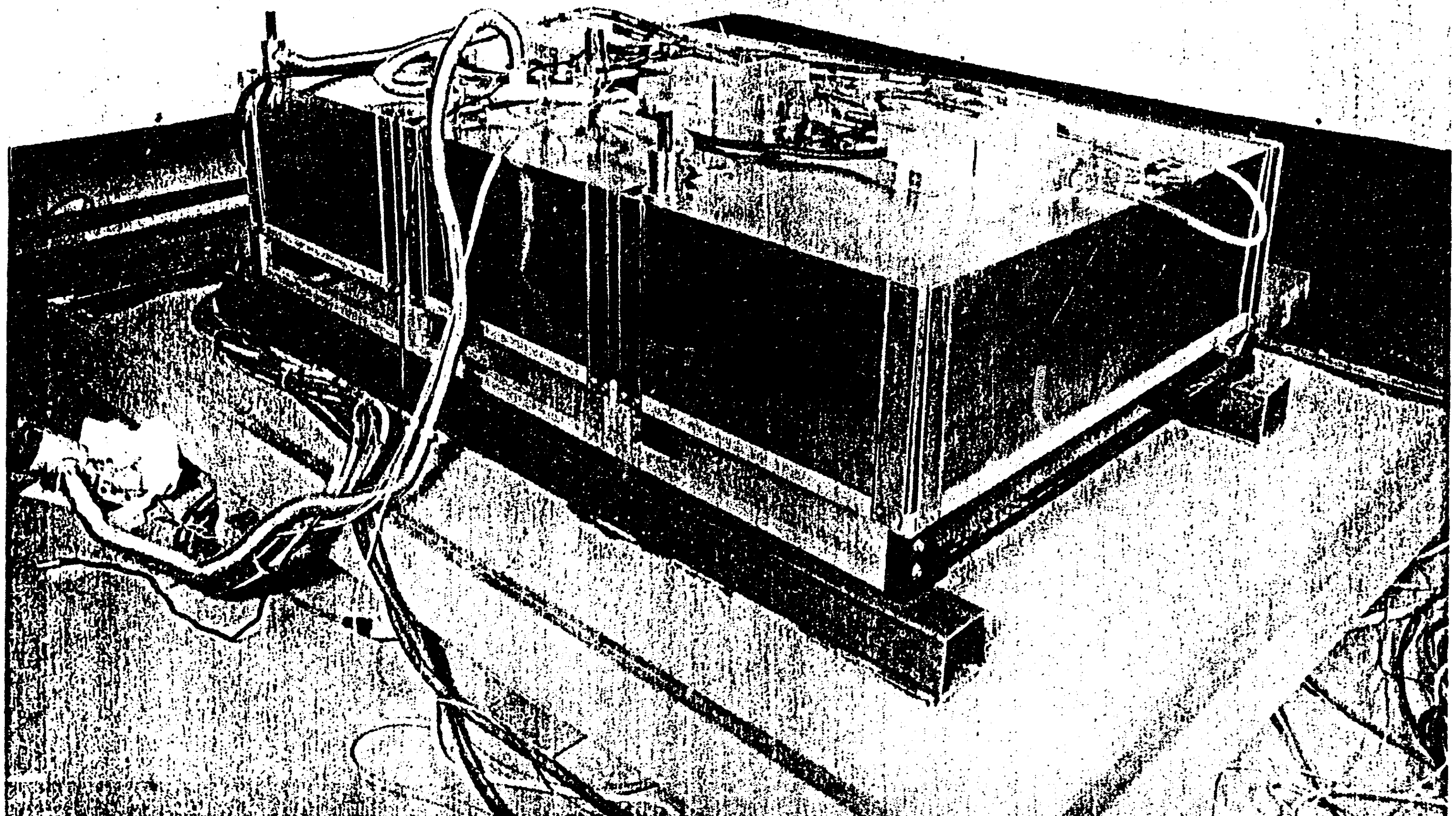


Figure 2. Photograph of the CSPL ETX-II sodium-sulfur battery.

** NOTES **

Electric & Hybrid Vehicle Technology TOPTEC

LUNCHEON

12:00p.m.- 1:30p.m., September 15, 1992

Invited Keynote Speaker - Stanford R. Ovshinsky, President & CEO,
Energy Conversion Devices, Inc.

Keynote Speaker Abstract - Electric & Hybrid Vehicle Technology TOPTEC

Nickel Metal Hydrides -- The Basis for Viable Electric Vehicles

Stanford R. Ovshinsky
President and Chief Executive Officer
Energy Conversion Devices, Inc.

In order to understand the importance of the new emerging electric vehicle industry, we must put into perspective the unusual events which have converged to make the electric car not only possible but imperative.

There were electric vehicles in 1900. The missing ingredient to their becoming an important factor in the automotive industry has been the battery.

Mr. Ovshinsky will discuss how pollution, the dependence on oil and the need for the rebuilding of the industrial base of the United States all provided the impetus for the formation of the U.S. Battery Consortium.

Mr. Ovshinsky will describe how he developed new materials that utilize concepts related to short range chemical order that have transformed the field of nickel metal hydrides, positively affecting the design of electric automobiles and allowing the Ovonic battery to be chosen by the Consortium.

Keynote Speaker Biography - Electric & Hybrid Vehicle Technology TOPTEC

Stanford R. Ovshinsky
President and Chief Executive Officer
Energy Conversion Devices, Inc.

Mr. Ovshinsky has worked in the field of amorphous films since 1955. In 1960, with his wife, Iris, he founded Energy Conversion Devices, Inc. to continue research and development in amorphous materials for use in various phases of information storage and control combined with the concepts of energy conversion. He is president and chief executive office of the company and is chairman of the Institute for Amorphous Studies. His work in synthetic materials emphasizes applications in three major areas -- energy conversion, including photovoltaics and energy storage such as batteries; information systems, including switching, memories, 3-dimensional intelligent computers and amorphous circuits; and engineered materials for a wide variety of uses such as high temperature applications and corrosion and abrasion resistance. He has worked in the field of superconductivity since the 60's.

He has well over 100 U.S. patents, is the author of numerous scientific papers ranging from neurophysiology to amorphous semiconductors, and in 1968 was the recipient of the Diesel Gold Medal for Invention presented by the German Inventors Association. He was awarded a Doctor of Science degree from Lawrence Technological University, an honorary Doctor of Engineering degree from Bowling Green State University, and an honorary Doctorate of Science from Jordan College. He is an honorary advisor for science and technology at the Beijing University of Aeronautics and Astronautics, Beijing, China; a member of the advisory council for the College of Arts and Science of Lawrence Technological University; a member of the Board of Governors at Cranbrook Institute of Science, and an adjunct professor of Engineering at Wayne State University. He was inducted into the Michigan Chemical Engineering Hall of Fame and named 1987 Michigan Scientist of the Year by Impression 5 Science Museum. In October 1987, he was profiled on NOVA, public television's science series. In August 1988, he was presented with the Coors American Ingenuity Award, becoming the third recipient of this award which had previously honored the inventor of the digital computer and the integrated circuit. He received the Toyota Award for Advancement in May 1991 for his development of Ovonic nickel-metal hydride batteries for electric vehicles.

He is a fellow of the American Physical Society, a Fellow of the American Association for the Advancement of Science, a Senior Member of the Institute of Electrical and Electronic Engineers, and a member of Sigma Xi.

Abstract-Electric & Hybrid Vehicle Technology TOPTEC
Tuesday, September 14, 1992

Charger/Utility Interface Concerns

A. Scott Keller
Senior Test Engineer
Electrotek Concepts Inc.

The battery charger is the connecting link between the electric utility and the electric vehicle (EV). Its operation is therefore of interest to both the utility industry and the EV suppliers and users. In particular, chargers may cause considerable problems for the utilities if they become a significant portion of the electrical load. Aside from the electrical power requirements of the chargers, their *power quality* characteristics must be taken into consideration. As chargers take energy from the utility, the harmonics they generate are injected into the distribution system. These harmonics may affect motors, transformers, and rotating-disk kilowatthour meters. They may also alter relay coordination and shorten the life of electrical equipment. Further, these harmonics and the electromagnetic fields generated by chargers can interfere with communications systems. In addition to concerns over harmonics, chargers may appear to the electrical system as inductive loads. That is, the non-resistive load posed by the chargers will affect the phase relationship of the input voltage and current (the displacement factor and the power factor). Large numbers of chargers in the utility service area would therefore affect the utility's capabilities and strategies of power factor correction.

This presentation will discuss the potential problems of chargers as they relate to the electric utility. Different charger technologies and their associated power quality characteristics will be covered. Next, the effects of high-power rapid chargers will be reviewed. Finally, a modelling study will be covered which estimates the harmonic distortion caused by different numbers of chargers to an electrical distribution system.

Biography-Electric & Hybrid Vehicle Technology TOPTEC

A. Scott Keller
Senior Test Engineer
Electrotek Concepts Inc.

Mr. Keller is Senior Test Engineer in charge of electric vehicle component evaluation for Electrotek. His work includes the testing of battery chargers, battery management/monitoring systems, battery thermal management systems, and vehicle subsystems such as air conditioners and power steering.

With over 12 years in electric and hybrid vehicle research and testing, Mr. Keller has written over 25 publications on the topic. He is a registered professional engineer with a BEE from Georgia Tech and will receive his MSEE in December from the University of Tennessee. His credentials also include being a senior member of IEEE, a session organizer and chairman for the 1991 Society of Automotive Engineers Passenger Car Meeting Electric Vehicle Session and a member of Eta Kappa Nu.

Overview

- Terminology and issues
- Comparison of charger technologies
- Rapid charging concerns
- Effects of chargers on utility distribution system

Terminology

- **Power Quality - a qualitative measure of the voltage, current, and frequency condition, where a deviation can cause an adverse effect to the end user**

- **Harmonic - a sinusoidal component of a wave having a frequency that is an integral multiple of the fundamental frequency**

- **Total Harmonic Distortion (Harmonic Factor)**

$$THD(Voltage) = \frac{\sqrt{V_3^2 + V_5^2 + V_7^2 \ldots}}{V_1}$$

$$THD(Current) = \frac{\sqrt{I_3^2 + I_5^2 + I_7^2 \ldots}}{I_1}$$

Terminology (Continued)

- **Total Demand Distortion - the total current distortion in percent of maximum demand current, not fundamental current**
- **Power Factor - ratio of real power to apparent power (volt-amps)**
- **Displacement Factor - cosine of angle between fundamental voltage and current**

EV Charger Issues

- Harmonic Generation
  - Magnitude/frequency of harmonics
  - Additive effects of harmonics in distribution system
  - Problems created by harmonics
  - Neutral current overloading

- Power Factor
  - Increase in utility's inductive load (system losses)
  - Affects power factor correction capabilities and strategies

EV Charger Issues (Continued)

- **Power Demand**
  - Magnitude (conventional vs rapid charging)
  - Time of day (overnight vs opportunity charging)

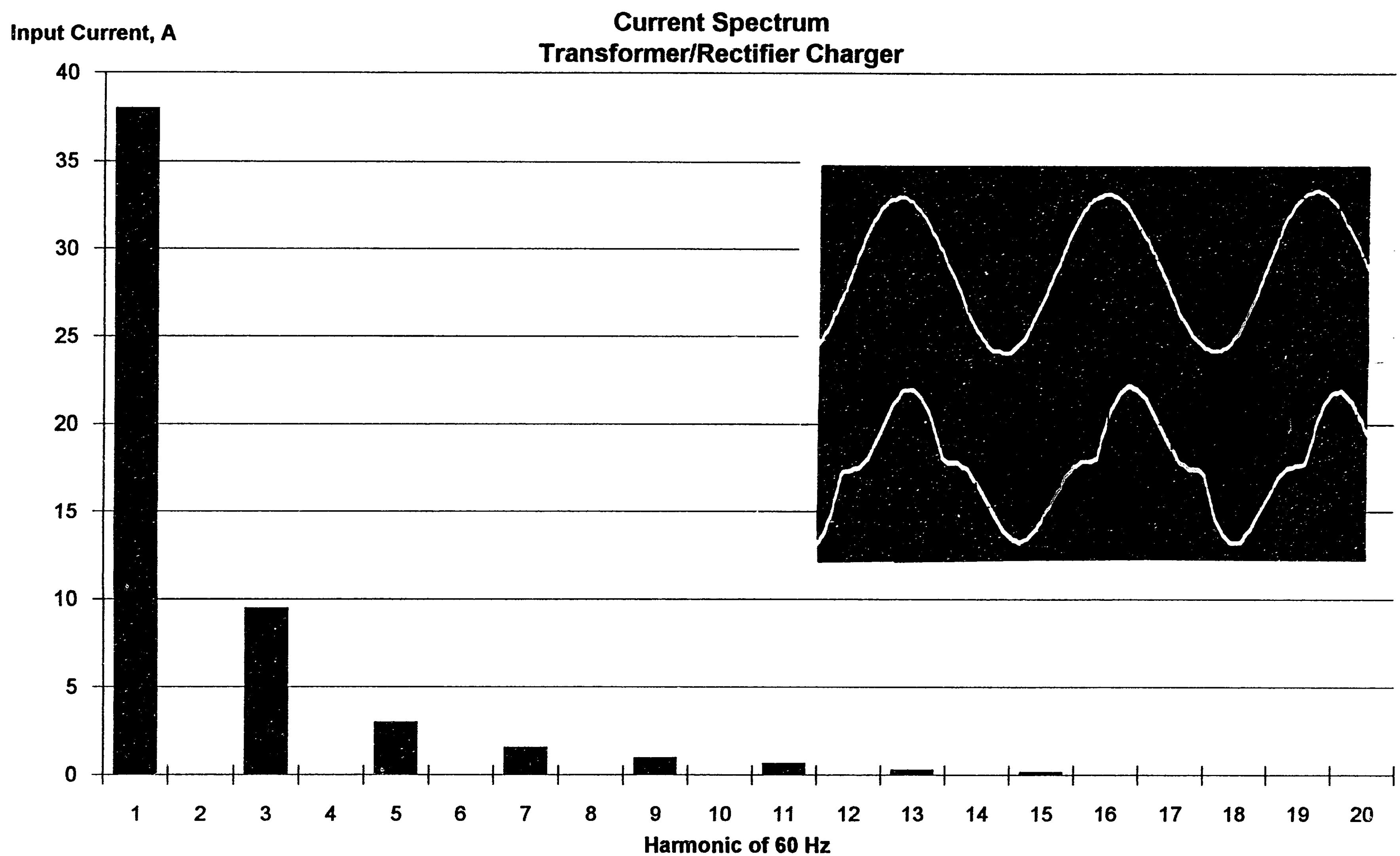
- **Load Management**
  - Off-peak vs on-peak charging
  - Dedicated charger feed with remote control
  - "Smart" charger capability

Problems Caused by Harmonics

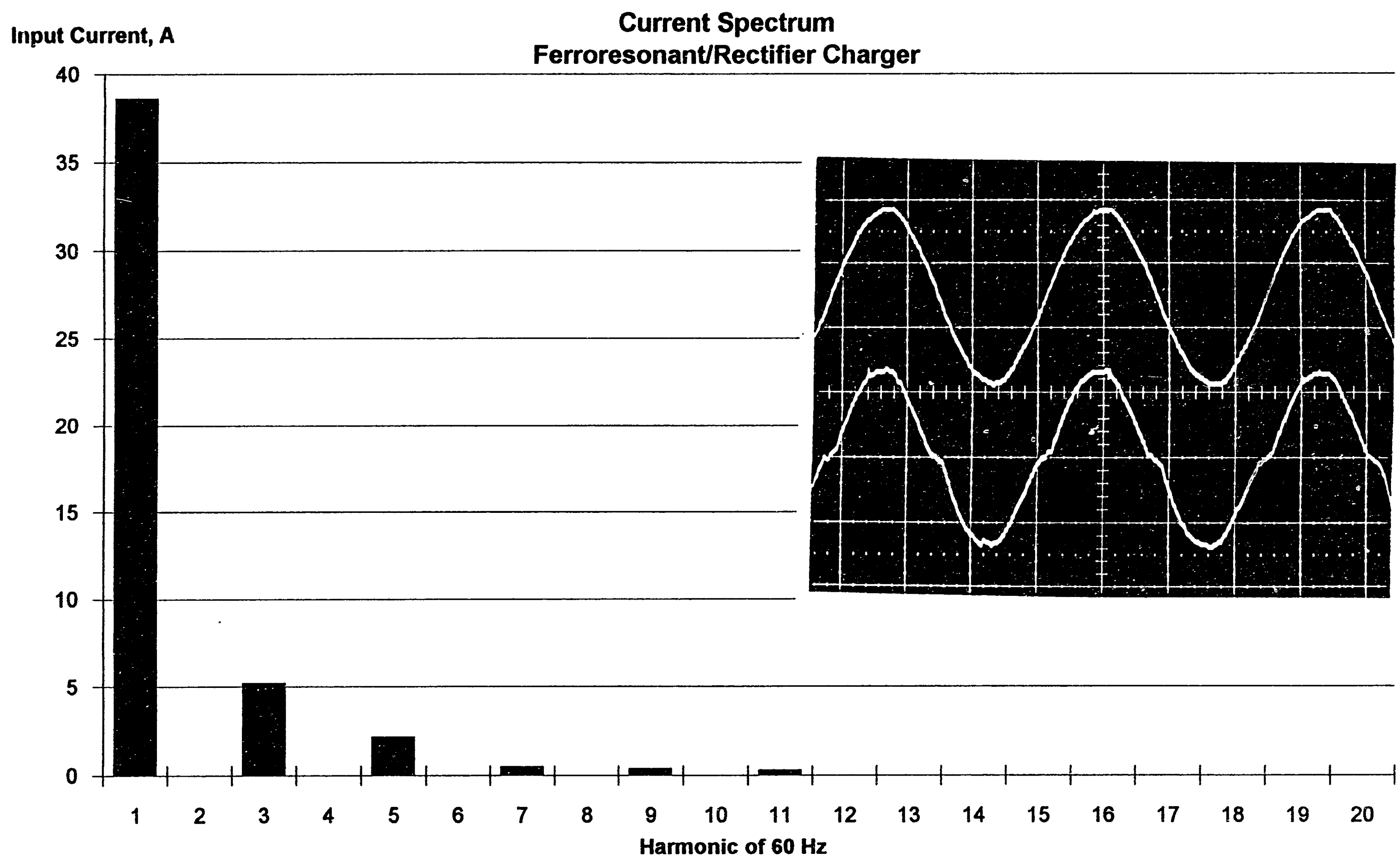
- Overheat motors and transformers (reduction in life)
- Affect accuracy of rotating-disk kWh meters
- Alter utility relay coordination
- Overload power factor correction capacitors
- Cause resonance between capacitors and transformers (creates voltage distortion)
- Generate noise in communications systems (telephone circuits, etc.)

COMPARISON OF CHARGER TECHNOLOGIES

Charger	AC/DC Eff	THD (Current)	Power Factor
Transformer/rectifier	90%	15-35%	0.75
Ferroresonant/rectifier	90%	15-30%	0.95
Transformer/SCR	85%	50-100%	0.70
Switched-mode	85%	5-20%	0.95



Current Spectrum
Transformer/Rectifier Charger
Input Current, A
40
35
30
25
20
15
10
5
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Harmonic of 60 Hz



Current Spectrum
Ferroresonant/Rectifier Charger
Input Current, A
40
35
30
25
20
15
10
5
0
1
2
3
4
5
6
7
8
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10
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12
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16
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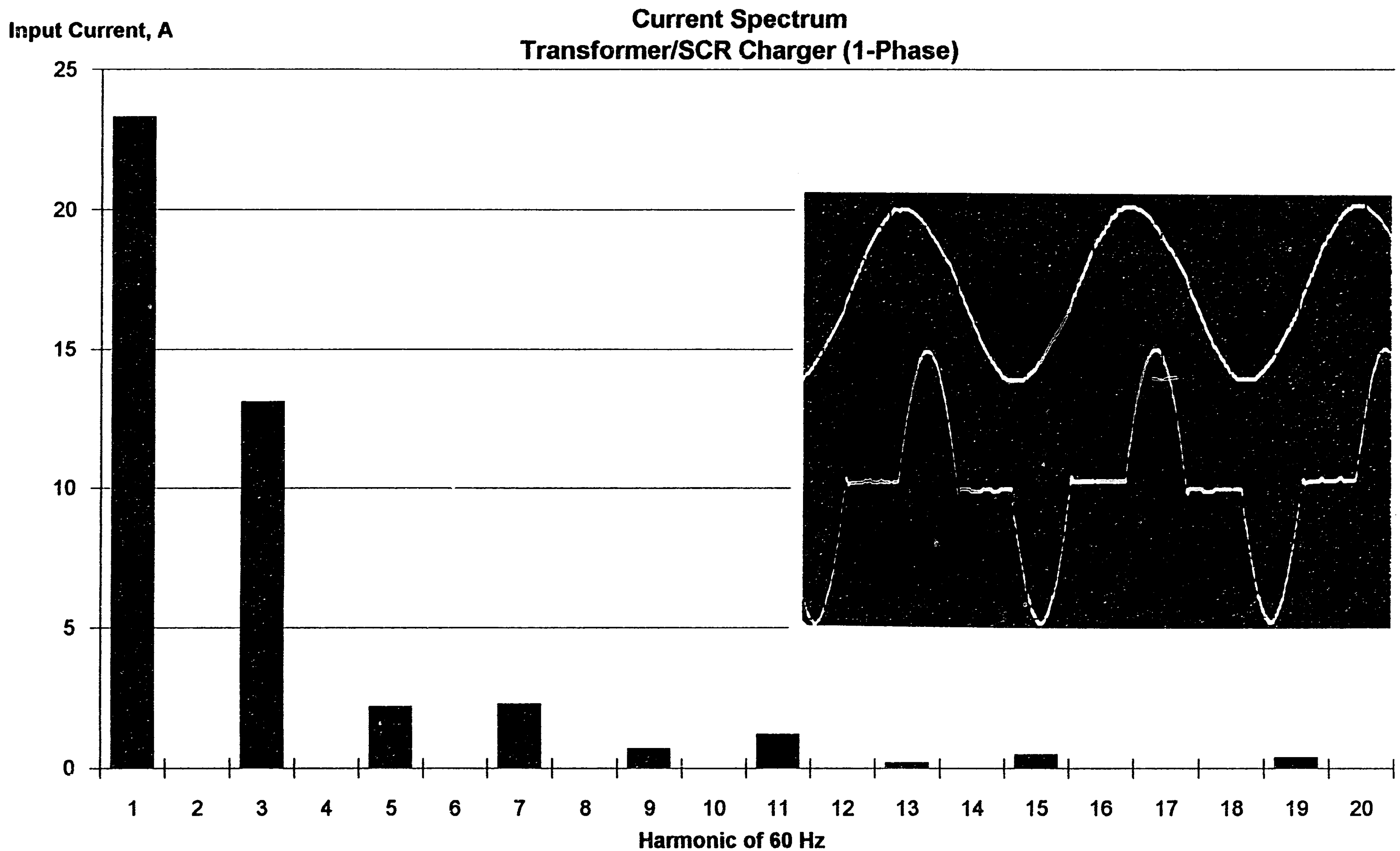
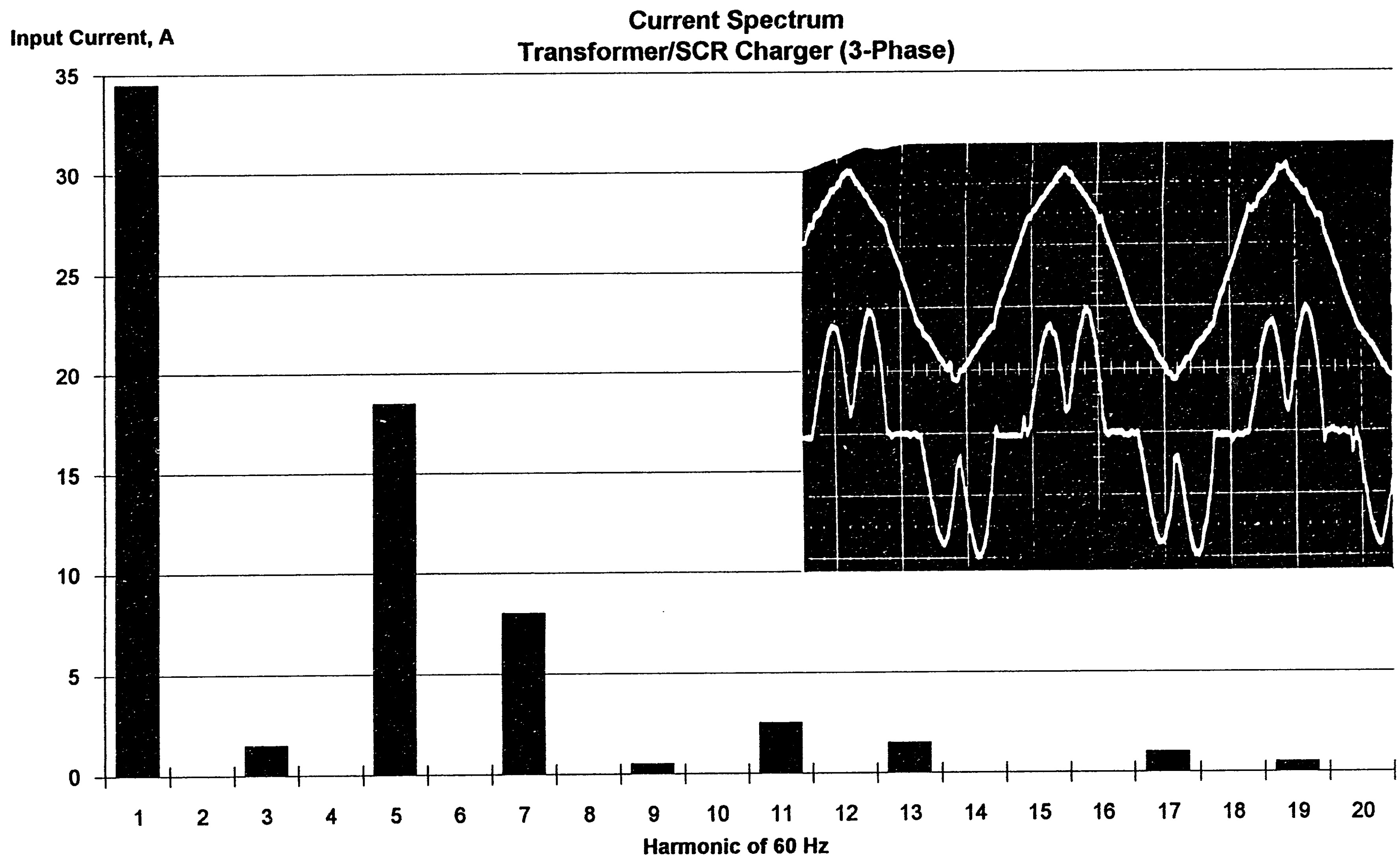
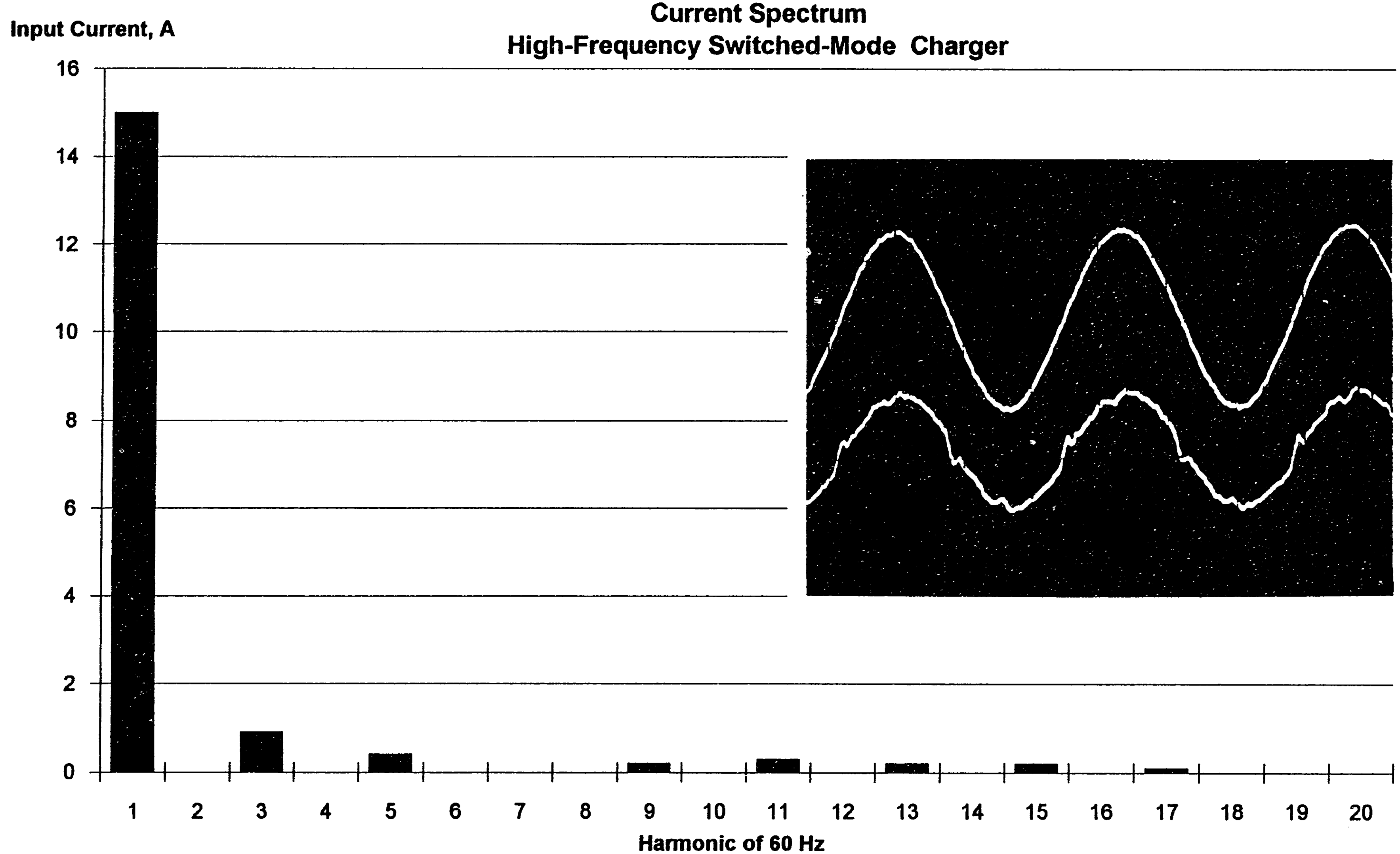
18
19
20
Harmonic of 60 Hz


Input Current, A
Current Spectrum
Transformer/SCR Charger (1-Phase)
25
20
15
10
5
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Harmonic of 60 Hz


Current Spectrum
Transformer/SCR Charger (3-Phase)
Input Current, A
35
30
25
20
15
10
5
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Harmonic of 60 Hz

Current Spectrum
High-Frequency Switched-Mode Charger



IEEE 519

IEEE 519 is recommended practices and requirements for harmonic control in electric power systems

- **Applies to an entire electrical distribution system**
- **Sets guidelines for a given mix of linear and non-linear loads**
- **Allowable harmonic generation is based on user size relative to the system short-circuit capacity at point of common coupling (short circuit ratio)**
- **Intended for large customers and the overall system rather than single load devices**

IEEE 519

Proposed Harmonic Current Injection Limits
for Individual Customers on the Power System

SCR	Individual Harmonic Limits					TDD
	<11	11-18	18-23	24-35	>35	Limit
<20	4.0%	2.0%	1.5%	0.6%	0.3%	5.0%
20-50	7.0%	3.5%	2.5%	1.0%	0.5%	8.0%
50-100	10.0%	4.5%	4.0%	1.5%	0.7%	12.0%
100-1000	12.0%	5.5%	5.0%	2.0%	1.0%	15.0%
>1000	15.0%	7.0%	6.0%	2.5%	1.4%	20.0%

Harmonic current limits at the ***point of common coupling*** *between the utility and customer:*

SCR = Short Circuit Ratio - the ratio of the short circuit current at the point of common coupling to the maximum customer demand current

TDD = Total Demand Distortion, total (RMS) current distortion in percent of ***maximum demand current (not fundamental current)***

Proposed Harmonic Voltage Distortion Limits
for General Power Systems

Bus Voltage kV	Individual Harmonic Limit	THD Limit
<69	3.00%	5.00%
69 -138	1.50%	2.50%
>138	1.00%	1.50%

IEC 555-2

IEC 555-2 sets limits for harmonic generation at the source

- **Applies to individual electronic/electrical equipment with input currents of 16 A (220-240 V 1-phase and 380-415 V 3-phase)**

- **Specifies absolute and relative limits for particular classes of equipment such as power tools and lighting**

EV Chargers vs Other Residential Loads

Color TV	0.08 kW
Refrigerator	0.3 kW
Microwave Oven	1.3 kW
Heat Pump	4.2 kW
Conventional EV Charger	7.5 kW
Rapid EV Charger	>100 kW

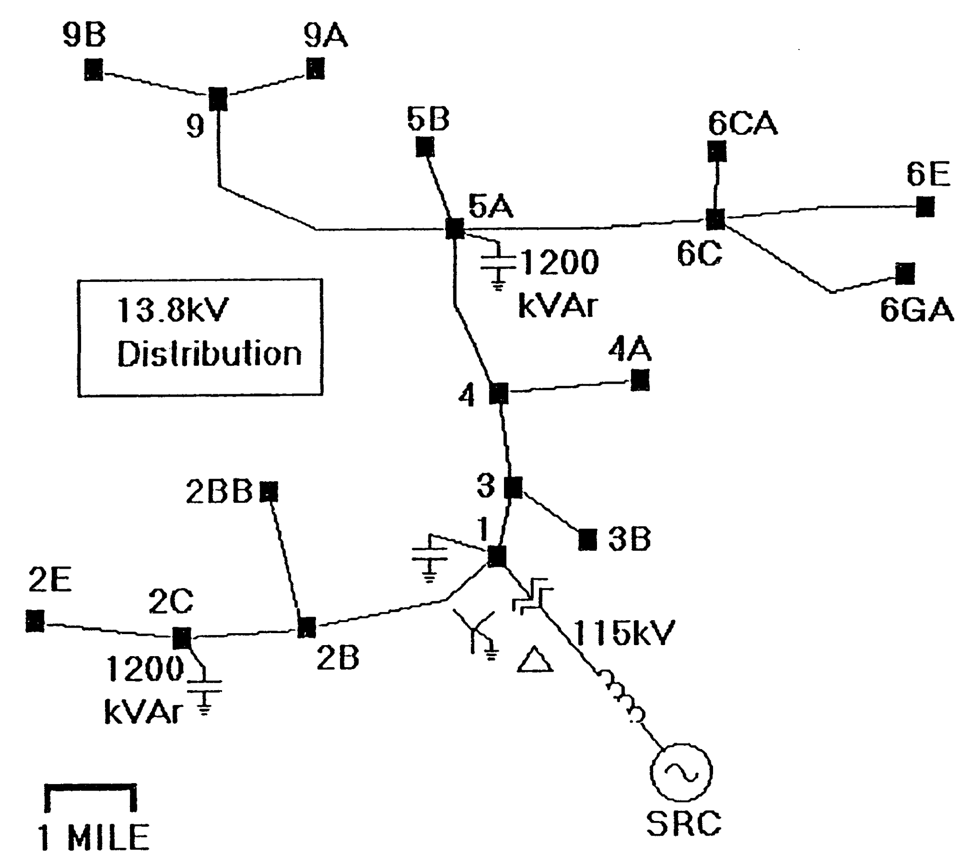
High-Power Rapid Charging

- Used primarily on-peak
- Requires short-duration, high power demand
- 15 kWh dc charge in 5 minutes requires over 200 kW ac real power (assumes fully-discharged battery, 85% charger eff)
- New and/or upgraded distribution feeders needed
- New load management and power-factor-correction strategies needed
- Possible need for wayside storage (batteries)
- Concern for power quality and electromagnetic fields

Computer Simulation of Distribution Network

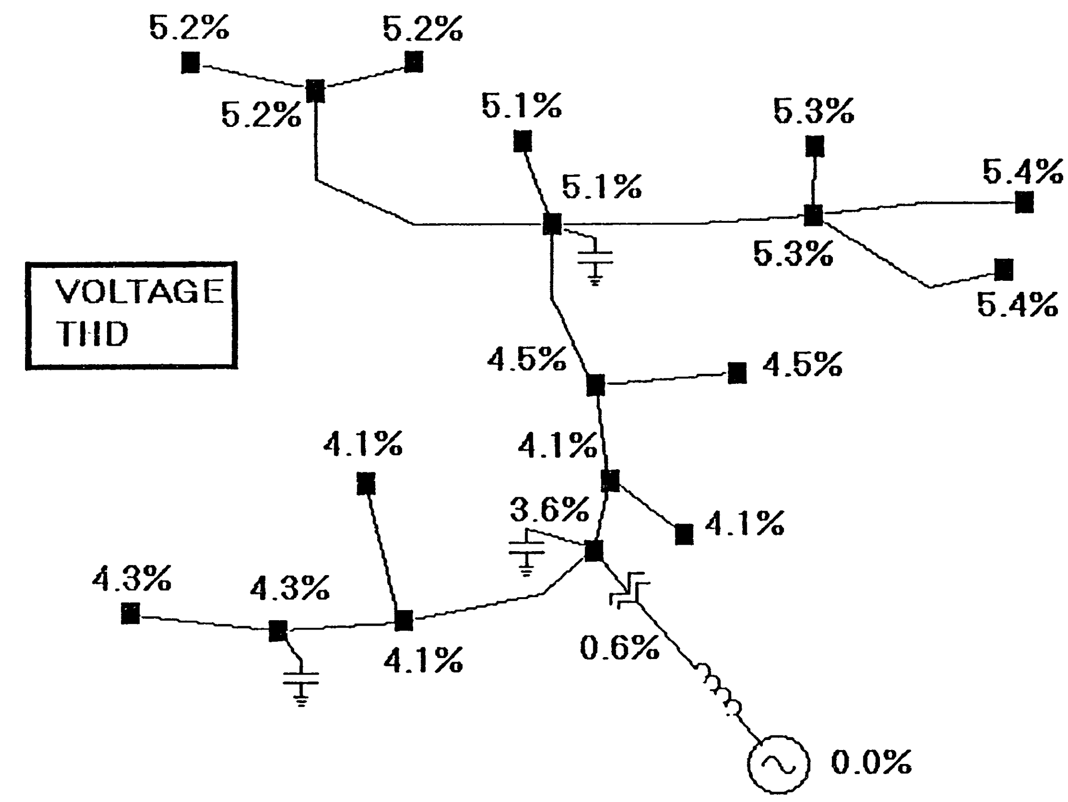
- Based on actual network in northeast U.S.
- This network serves 800 homes, is loaded to less than 33% capacity
- Calculations used a 1-phase transformer/SCR charger (57 A rms current, 77% current THD)
- Simulation and analysis performed by Dave Mueller of Electrotek

One-Line Diagram of Modelled Feeders



Harmonics with 200 Chargers Online

Buss	THDv
Source	0.0%
115kV	0.6%
1	3.6%
2B	4.1%
2BB	4.1%
2C	4.3%
2E	4.3%
3	4.1%
3B	4.1%
4	4.5%
4A	4.5%
5A	5.1%
5B	5.1%
6C	5.3%
6CA	5.3%
6E	5.4%
6GA	5.4%
9	5.2%
9A	5.2%
9B	5.2%

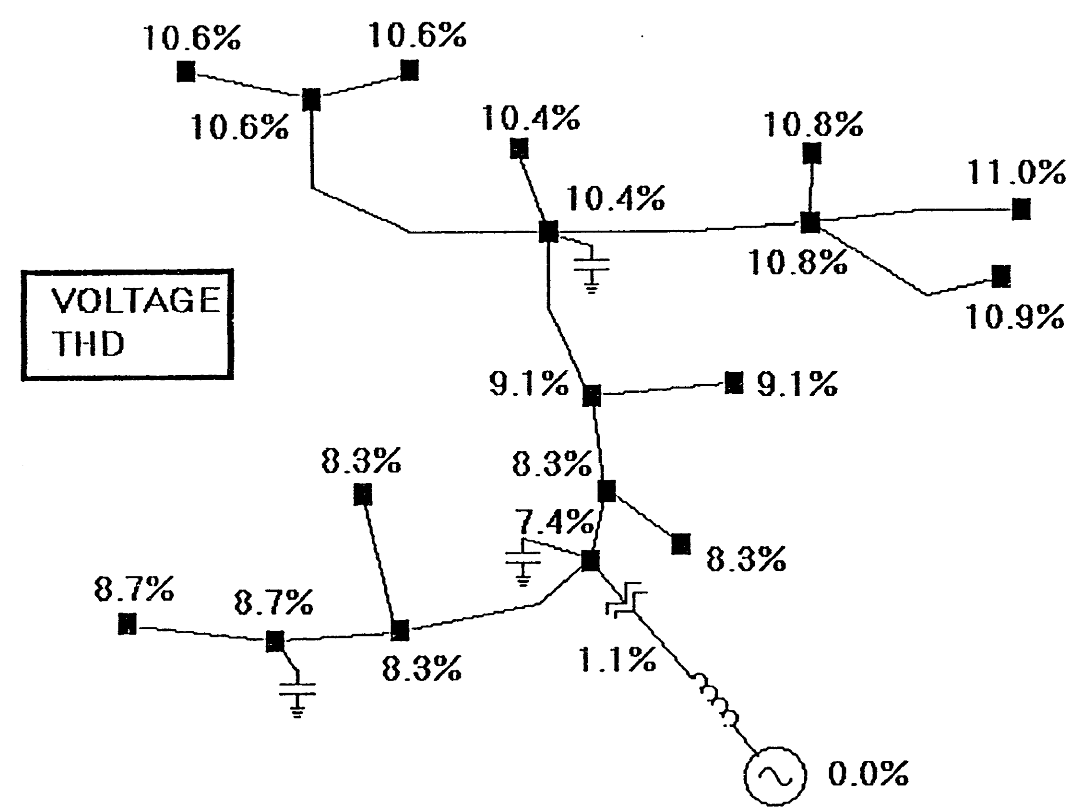


Bus 5B Waveform
With 200 Chargers Online

5.1% Voltage THD

Harmonics with 400 Chargers Online

Buss	THDv
SRC	0.0%
115kV	1.1%
1	7.4%
2B	8.3%
2BB	8.3%
2C	8.7%
2E	8.7%
3	8.3%
3B	8.3%
4	9.1%
4A	9.1%
5A	10.4%
5B	10.4%
6C	10.8%
6CA	10.8%
6E	11.0%
6GA	10.9%
9	10.6%
9A	10.6%
9B	10.6%

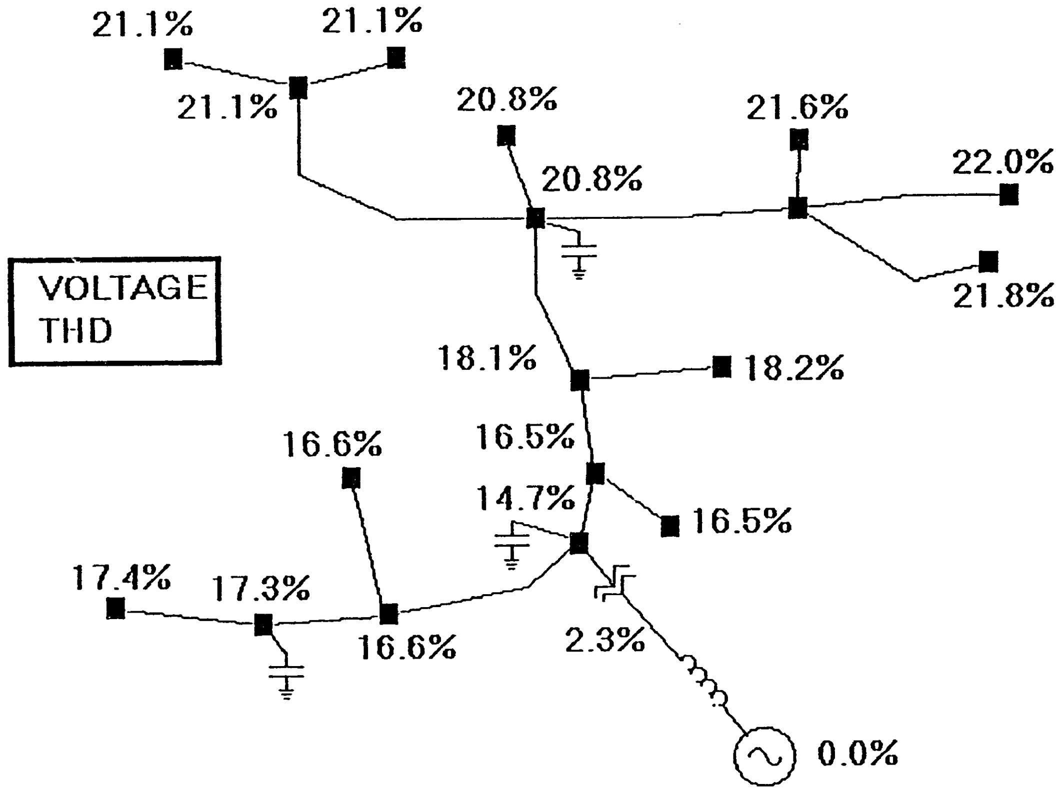


Bus 5B Voltage Waveform With 400 Chargers Online

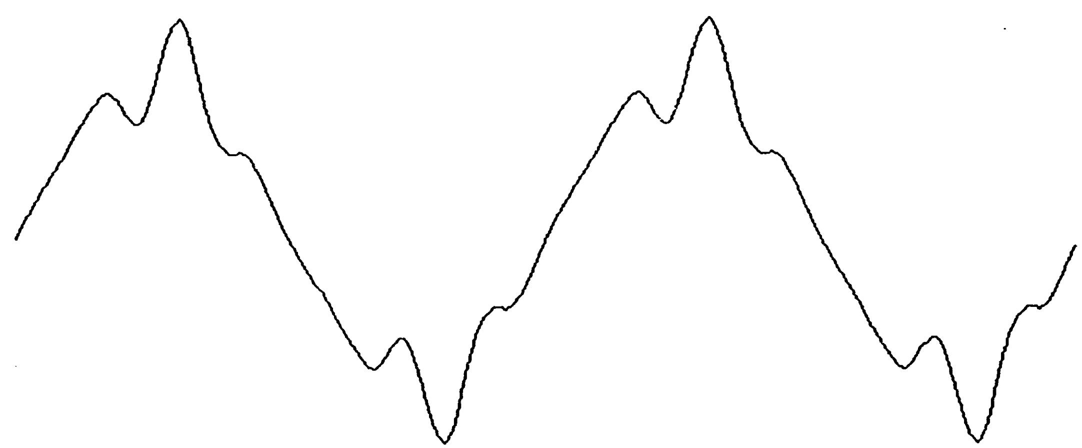
10.4% Voltage THD

Harmonics with 800 Chargers Online

Buss	THDv
SRC	0.0%
115	2.3%
1A	14.7%
2B	16.6%
2BB	16.6%
2C	17.3%
2E	17.4%
3	16.5%
3B	16.5%
4	18.1%
4A	18.2%
5A	20.8%
5B	20.8%
6CA	21.6%
6E	22.0%
6GA	21.8%
9	21.1%
9A	21.1%
9B	21.1%



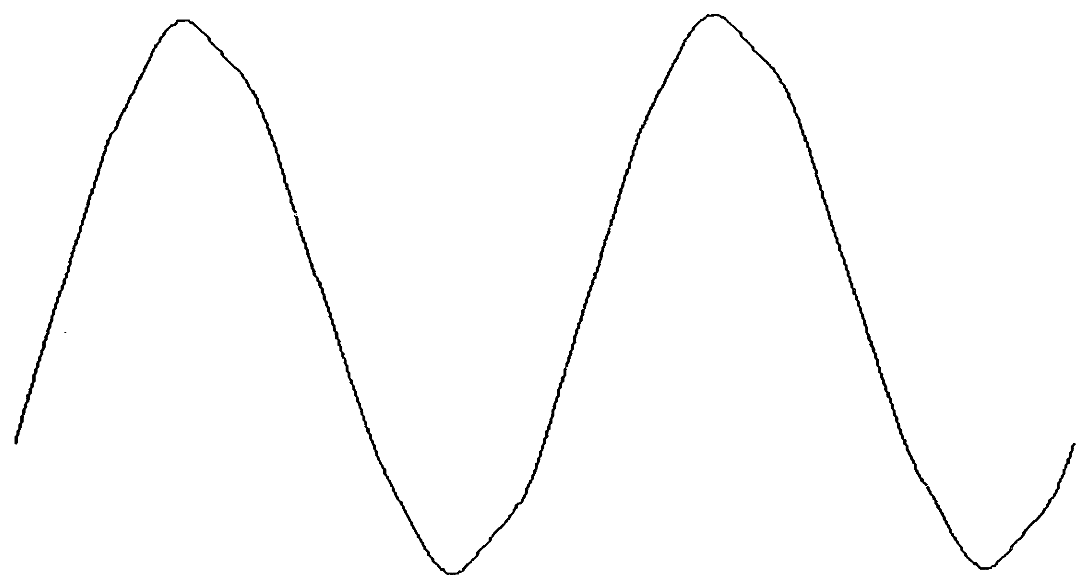
Voltage Waveform at 5B
With 800 Chargers Online



21% Voltage THD

Voltage at 115kV Transmission

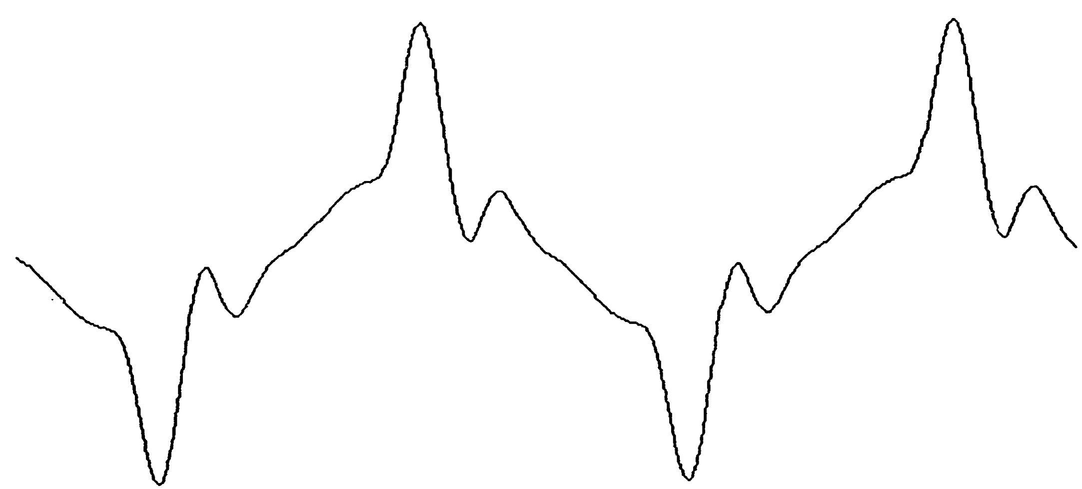
With 800 Chargers Online:



2.3% Voltage THD

Transformer Secondary Current

With 800 Chargers Online:



51.7% Current THD

Transformer Primary Current

With 800 Chargers Online:

40.4% Current THD

Summary of Harmonic Effects

- With 200 chargers online, the harmonic voltage distortion exceeds IEEE-519 recommended levels.

- With 400 chargers online, the harmonic voltage distortion is at a level known to decrease life of motors.

- With 800 chargers online, greater than 20% voltage THD can result; even the transmission system harmonics approach IEEE-519 recommended levels.

- Note that feeder was loaded to only 50% of its capacity with 800 chargers online.

Potential Solutions to Harmonics Concerns

- Harmonic filtering on the distribution system
- Harmonics cancellation using active power line conditioners
- PWM or other nearly-sinusoidal technologies for the rectifier front end of chargers
- Limit the penetration of chargers on the distribution feeder

Load Management Strategies

- **Opportunities for off-peak charging**

- **Dedicated charger feed with remote control could allow utilities to optimize load**

- **"Smart" charger could operate according to programmed strategy based on charge time, time available, and utility rate structures**

Summary

- Chargers must be designed for low-harmonic, high power factor operation
- Large numbers of chargers on individual electrical feeders can create power quality disturbances throughout the feeder
- Particular attention must be given to rapid chargers regarding power quality, utility generation/distribution capabilities, and load management

** NOTES **

Abstract-Electric & Hybrid Vehicle Technology TOPTEC
Tuesday, September 15, 1992

Utility Load Management Strategies

Ernest T. Morales, Jr.
Research Engineer, Electric Transportation
Southern California Edison Co.

Southern California Edison's current Demand Side Management Electric Vehicle evaluation program is being developed jointly by Edison, the California Public Utilities Commission and the California Energy Commission, and is in final draft stages. The three principle objectives of the program are: 1) to evaluate the potential impact of EV's on the Edison system by assessing customer user segments within the Edison service territory; 2) to analyze the vehicle usage patterns of various market segments to better understand recharging patterns and likely impacts of various load management strategies; and 3) to forecast load growth and ensure that Edison will meet its role as the fuel supplier for EV's as inexpensively as possible and in a manner that does not impede development of the EV market, or compromise the reliability of electrical service to other customers.

Biography-Electric & Hybrid Vehicle Technology TOPTEC

Ernest T. Morales, Jr.
Research Engineer, Electric Transportation
Southern California Edison Co.

Mr. Morales is Project Manager for SCE's Demand Side Management Electric Vehicle Evaluation Program. He has 4 years experience in urban planning, 2 years in transportation planning and 13 years in utility service planning, operations and distribution engineering.

Mr. Morales' educational background includes a B.Arch. from Cal Poly San Luis Obispo in 1968, a M.A. in urban planning from UCLA in 1972 and a M.S. in transportation systems analysis from M.I.T. in 1974.

** NOTES **

Electric & Hybrid Vehicle Technology TOPTEC
September 14-15, 1992

ORGANIZATIONS REPRESENTED

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BEVILACQUA-KNIGHT INC
BRIGGS & STRATTON
BRISTLELITE WIRE CORP
CERAMATEC
CHRSYLER CORP
COLORADO SCHOOL OF MINES
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UNITED TECHNOLOGIES

UNIV OF TENNESSEE

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VOLKSWAGEN OF AMERICA INC

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WASHINGTON UNIV

WASHTENAW COMM COLLEGE

WAYNE STATE UNIV

WEST VIRGINIA UNIV

WILLIAMS INTERNATIONAL

Electric & Hybrid Vehicle Technology TOPTEC
September 14-15, 1992

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VEHICLE SYS ENGRG

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ESSEX GROUP INC
ENGRD PRODS DIV

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IDAHO NATIONAL ENGRG LAB

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DEPT MGR
SANDIA NATIONAL LABS

CANTONI, UZI
PROG TECH MGR
DIAL CORP
TRANSPORTATION MFG CORP

CEASAR, GERALD
RES MGR
B P OIL
B P AMERICA

COMFORT, WILLIAM
SR MECH ENGR
LAWRENCE LIVERMORE LAB

CULBERTSON, DON
SR PROJ ENGR
GENERAL MOTORS CORP
EMIS & FUEL ECON COMPL

DOUTY, DON
CONSULTANT
U S STEEL
PROD APPL

EGLESTON, BRENT
CAR STRATEGY/PROD PLNG MGR
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H POWER CORP

FITZ, FRANK
ENGR
EPILOGICS INC

GEER, JAMES
PROG MGR
FORD MOTOR CO
ELECTRONICS DIV

GLINTER, JEFF
PROJ ENGR
GENERAL MOTORS CORP
INLAND FISHER GUIDE

GUNN, RICHARD
PROJ MGR
ONTARIO BUS INDUSTRIES

HARDING, GEOFF
SR EXEC-SPEC VEH
INTL AUTOMOTIVE DESIGN

HARNEY, WILLIAM
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MAGNA INTERNATIONAL
CONCEPTOR INDS INC

HARRIS, TIM
TECHNICAL DEVL MGR
POWER WHEELS
RES & DEV

HARTMAN, BETTY R G
TRANSP SALES MGR
IMI TECH CORP

HASLAM, MARK
CERAMATEC

HATTERSCHIDE, THOMAS
ENGRG VP
GNB INC
ENGRG/ABD

HEITNER, KEN
ADV BATTERY SYS MGR
U S DEPT OF ENERGY
ELEC & HYBRID PROP DIV

HIRANO, SHINICHI
SR RES ENGR
MAZDA MOTOR CORP
MAZDA R&D OF N AMERICA

ISAAC, MAURICE
TECH PROG MGR
GE COMPANY
GE AUTOMOTIVE

JANASIK, JAMES
PROJ MGR
ELECTRIC POWER RES INST
TRANS PROG

JOHNSON, STUART
SR PROD ENGR
VOLKSWAGEN OF AMERICA INC
EMISSIONS REG

KELLER, A SCOTT
SR TEST ENGR
ELECTROTEK CONCEPTS INC

KINNEY, RAYMOND
PROG MGR REVENUE
ENHANCEMENT
NY STATE ELECTRIC & GAS

KIZER, THOMAS
EXEC ENGR
CHRSYLER CORP
POWERTRAIN/ELEC ENGRG

KNAUER, DAVIS
AUTO BATTERY ENGRG DIR
EAST PENN MFG
ENGRG DEPT

KOHLER, RICHARD
PROG DEV MGR
EATON CORP
CORP R & D

KONRATH, PAUL A
AUTO PRODS MGR
TEXAS INSTRUMENTS
METALLURGICAL MTLS DIV

KOTANIDES JR, JOHN
STAFF DES ENGR
GOODYEAR TIRE & RUBBER CO
PASSENGER TIRE

KURTZ, WILLIAM
EMISS CTRL MGR
MERCEDES BENZ OF N A
EMISSIONS CTRL DEPT

LANCIANO, CLAUDE
ELECT DES SUPV
FORD MOTOR COMPANY
OPEO/ELEC VEH ENGRG

LARKIN, SEAN
SR ENGR
NORTHROP CORP
AIRCRAFT DIV

LEMAJEUR, SCOTT
PRODUCT ENGR
COOPER INDUSTRIES
BELDEN AUTO WIRE & CABLE

SCAPTURA, CHRISTOPHER
RESEARCH STAFF
NATIONAL GEOGRAPHIC SOCIETY
MAGAZINE

SHERMAN, JAMES
STAFF PROJ ENGR
GENERAL MOTORS CORP
POWERTRAIN M/C 719

SHI, LIE
RES ENGR
HOECHST CELANESE
NEW BUSINESS TECH

SHIPINSKI, JOHN
MGR POWERTRAIN
TOYOTA MOTOR CORP
TOYOTA TECH CTR USA

SIEGLE, GORDON
PROD DES ENGR
FORD MOTOR CO
TAPME

SIMS, RON
EV BATTERY SYS ENGR
FORD MOTOR CO
EV POWERTRAIN ENGRG, NAAO

SPOONER, EDWARD
MGR
TUV RHEINLAND OF N AMER INC

STEGERT, SCOTT
PROJ ENGR
ELECTRO WIRE PRODS INC

STILES, ROBERT W
NATURAL GAS SLS MGR
NY STATE ELEC & GAS CORP
GAS BUSINESS

STONE, RANDY
ENGR I
SOUTHERN CALIFORNIA EDISON
TRANS SVCS DEPT

STREHLOW, WOLFGANG
DIR OF BUSI DEV
3M CO
NEW PROD DEPT

SUMINSKI, STEVEN
ACCT EXEC
TDK ELECTRONICS CORP
SALES

SUZUKI, YORIKATSU
CHIEF ENGR
MEIDENSHA CORP

SZUDAREK, ROBERT
PRIN ENGR
UNITED TECHNOLOGIES
PROD ENGRG-WIRING SYS

TAMURA, MINORU
SR STAFF ENGR
NISSAN MOTOR CO
NISSAN RES & DEV

TATEND, AKIO
GEN MGR
MEIDENSHA CORP

LI, ED
STAFF ENGR
MOTOROLA INC
AUTO TECH

LICHTNER, ROLF
HOMOLOGATION ENGR
TUV RHEINLAND
AUTO TECH

LIEBBE, ROB
TRANS SYS ENGR
ARGONNE NATIONAL LAB
ENERGY SYS

LIIEVA, PETER
MECH ENGR
TEXACO INC
RES & DEV

LLOYD, DR ALAN
CHIEF SCIENTIST
SOUTH COAST AIR QUAL MGMT
PLNG & TECH ADV OFC

MALMO, JOANNE
GEN ENGR
DEPT OF ENERGY
TECH TRANSFER

MATHEUS, GERARDO
PROD ENGR
BRISTLELITE WIRE CORP
NOGALES DIV

MCCOY, GILBERT
ENERGY SYS ENGR
WASHINGTON STATE ENERGY
OFFICE

MCGIBBON, AVELAINO
VEH SYS ENGR
TASC
AUTO SYS ENGRG

MCKEE, ROBERT
PRES
MCKEE ENGRG CORP

MICEK, DENNIS
PROD DES ENGR
FORD MOTOR CO
ENGINE DIV

MILLER, DANIEL R
AUTO SALES ENGR
TEXAS INSTRUMENTS
METALLURGICAL MATERIALS

MITCHELL, ROBERT K
MGR ADV RES
BRIGGS & STRATTON
R & D

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NICHOLS, ROBERTA JEAN
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OVSHINSKY, STANFORD
PRES
ENERGY CONVERSION DEVICES

PAMPREEN, RONALD
ADV TECH MGR
WILLIAMS INTERNATIONAL
BUSINESS DEV

PARKER, DAVID A
PRODUCT DESIGN ENGR
FORD MOTOR CO
ELECTRONICS DIV

PENFOLD, G
SR ENGR
DEERE & COMPANY
TECH CENTER

PIKE, J A
TECH SPEC
FORD MOTOR CO
CAR PROD DEV

PUTT, RON
VP
MATSI INC

QUIL, BRIAN
MECH ENGR
DEPT OF THE NAVY
NESA

QUINTY, KENNETH
PROJ ENGR
PENNA POWER & LIGHT
TRANSP SVCS

RAMIREZ, JOSE
ENGR
LONG MFG LTD
ADV ENGRG DEPT

REEBER, THOMAS C
MFG PROC ENGR
FORD MOTOR CO
TRANS & CHASSIS/ ELEC VEH

RIMKUS, WILLIAM
MECH ENGR
ARGONNE NATL LABS
CTR FOR TRANSP RES

RIPPEL, WALLY
PRES
AC PROPULSION INC

ROTHMAN, JOSH
PROD DES ENGR
ISUZU TECH CTR OF AMER
PROD PLNG & ENGRG

SADLER, GREG
ENGINEER
MAZDA MOTOR CORP
MAZDA RESCH & DEVEL OF N A

SAIKALIS, GEORGE
RESEARCH ENGR
HITACHI AMERICA LTD
R & D

TENURE, KENNETH
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BEVILACQUA-KNIGHT INC

THEISEN, PETER
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LIVERNOIS ENGRG CO

WEINBERGER, BERNARD
SR RES SCIENTIST
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RESEARCH CTR

WILSON, GROVER
APPLICATION ENGRG MGR
HOBART BROS CO
BATTERY CHARGER

WINTERS, KENNETH
MGR POWER SYSTEMS
PENTASTAR ELECTRONICS INC
INDUSTRIAL DIV

YUNG, ROBERT W
DEV STAFF MBR
MARTIN MARIETTA CORP
ENERGY SYS

ZAMMIT, MICHAEL G
TECH SVSC MGR
JOHNSON MATTHEY INC
CATALYTIC SYS DIV

ZIEGLER, RICHARD
PROJ DEV MGR
MARTIN MARIETTA SYS INC
APPLIED TECH

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FUTURE TOPTECS & DATES

Section 8

END

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