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Photovoltaic Battery and Charge Controller Market and Applications Survey

Robert L. Hammond, Jane F. Turpin, Garth P. Corey, Thomas D. Hund, Steve R. Harrington

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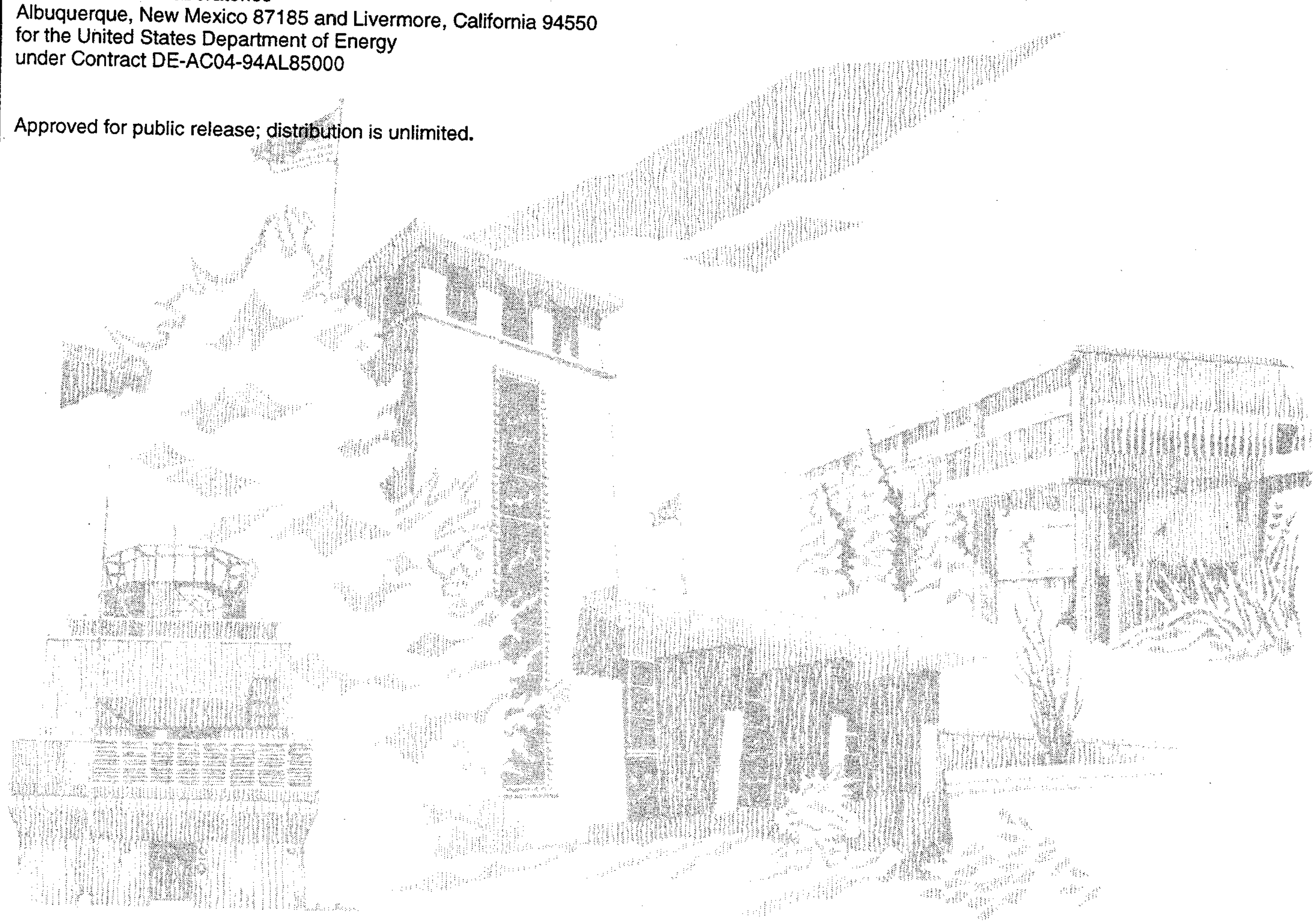

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PHOTOVOLTAIC BATTERY & CHARGE CONTROLLER MARKET & APPLICATIONS SURVEY

AN EVALUATION OF THE PHOTOVOLTAIC SYSTEM MARKET FOR 1995

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Abstract

Under the sponsorship of the Department of Energy, Office of Utility Technologies, the Battery Analysis and Evaluation Department and the Photovoltaic System Assistance Center of Sandia National Laboratories (SNL) initiated a U.S. industry-wide PV Energy Storage System Survey. Arizona State University (ASU) was contracted by SNL in June 1995 to conduct the survey. The survey included three separate segments tailored to: a) PV system integrators, b) battery manufacturers, and c) PV charge controller manufacturers.

The overall purpose of the survey was to: a) quantify the market for batteries shipped with (or for) PV systems in 1995, b) quantify the PV market segments by battery type and application for PV batteries, c) characterize and quantify the charge controllers used in PV systems, d) characterize the operating environment for energy storage components in PV systems, and e) estimate the PV battery market for the year 2000.

All three segments of the survey were mailed in January 1996. This report discusses the purpose, methodology, results, and conclusions of the survey.

ACKNOWLEDGMENTS

The authors wish to acknowledge and thank the Department of Energy, Office of Utility Technology, and Sandia National Laboratories management for their support, guidance, and funding of this work.

The time and patience of Sandra Gray and others who proofread and edited this report are greatly appreciated.

We also wish to thank the 38 individuals who responded to the survey. In some cases the individual who completed the survey was not the individual to whom the survey was addressed. Although we cannot thank those individuals by name, their time and effort in completing the survey is very much appreciated. Organizations and individuals that contributed are:

Large System Integrators

Name	Company
Tim Ball Chris Holz	Applied Power Corp.
Bruce Wilson	Atlantic Solar Products
Paul Garvison Helen Hatfield	Integrated Power Corp.
Robert Spotts	Photocomm, Inc.
Len Loomans	Remote Power Co., Inc.
Jim Padula Tim Lambarski	Solar Electric Specialties
Marshal Blalock	Southwest PV Inc.
David Kulik	Sunwize Energy Systems Inc.

Small System Integrators

Name	Company
Miles Russell	Ascension Technology Inc.
Steve Willey	Backwoods Cabin Electric Systems
Cedric Currin	Currin Corporation
Jeff Randall	Direct Water & Power Corp.
Abtaki Amir	GeoSolar
Dan Gilman	GSE Solar Systems
Gene Hitney	Hitney Solar Products
Bill Kaszeta	Photovoltaic Resources Int.
Allen Gunn, PE	Scientific Engineering
Al Simpler	Simpler Solar Systems, Inc.
Michael Collins	Solar Electric, Inc.
Steven Robbins	Solar Electric Power Co.
Alan Hurst	Solar Outdoor Lighting Inc.

Battery Manufacturers

Name	Company
Larry Meisner	C&D Charter Power Systems
Ed Mahoney	Concorde Battery Corp.
Mark Boram	Delco/Delphi Energy, GMC
Renwick Santangelo	East Penn Manufacturing Co. Inc.
Stephen Vechy	GNB
Bill Holmquist	Industrial Battery Engineering Inc.
Thomas Ruhlmann	Johnson Controls, Inc.
Jim Drizos	Trojan Battery Company
Don Wallace	U.S. Battery

Charge Controller Manufacturer

Name	Company
Jack Knowles	Ananda Power Technologies
Sam Dawson	Heliotrope General
Ken Gerkin	Morningstar Corp.
Arthur Sams	Polar Products
Terry Staler	Specialty Concepts, Inc.
Joe Wise	SunAmp Power
David Kulik	Sunwize Energy Systems Inc.
Sam Vanderhoof	Trace Engineering Company

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Section ES
EXECUTIVE SUMMARY

INTRODUCTION

In June 1995, the Battery Analysis and Evaluation Department and the Photovoltaic System Assistance Center of Sandia National Laboratories (SNL), initiated and sponsored a U.S. industry-wide PV Energy Storage System Survey. The Office of Utility Technology, Department of Energy , funded the project. Arizona State University (ASU) was contracted by SNL to conduct the survey. The survey included three separate segments tailored to the following groups:

A. PV system integrators
B. PV charge controller manufacturers
C. Battery manufacturers

The overall purpose of the survey was to:

1. quantify the market for batteries shipped with (or for) PV systems in 1995,
2. quantify the PV market segments by battery type and application for PV batteries,
3. characterize and quantify the charge controllers used in PV system,
4. characterize the operating environment for energy storage components in PV systems and
5. estimate the PV battery market for the year 2000.

In January 1996 Survey A was sent to PV System Integrators (11 large and 18 small); Survey B was sent to 10 Battery manufacturers; Survey C was sent to 10 Charge Controller manufacturers.

Responses to the three surveys were:

Survey A	Large System Integrators	8 responses from 11 inquiries (73%)
	Small System Integrators	13 responses from 18 inquiries (72%)
Survey B	Battery Manufacturers	9 responses from 10 inquiries (90%)
Survey C	Charge Controller Mfg.	8 responses from 10 inquiries (80%)

Responses for each survey (A, B, and C) were consolidated and highlights are presented below.

SURVEY A, SYSTEM INTEGRATORS

Survey A was segmented into four parts: 1) Battery Sales Data, 2) Battery Information Needed For PV System Design, 3) PV System Operating Conditions, and 4) Hybrid System Issues.

Part 1. Battery Sales Data.

Top-Down Market Analysis

The majority of results presented in Part 1 are based solely on summary results from the 21 System Integrators that responded to the survey. These summary results are, to a large extent, representative of the worldwide market and therefore can be extrapolated. However, the summary results do not provide a means to estimate total PV battery sales for either the U.S. market or the worldwide market. **In order to put the data from Part 1 in perspective, a Top-Down Market Analysis was developed to quantify the volume of batteries installed in PV systems.** The top down analysis is based on an industry consensus rule of thumb which states that for a typical PV system the equivalent of one 12V-100 amp-hour battery is used for each 50 watts (peak) of PV modules installed. Since the number of PV watts shipped each year (both U.S. and worldwide) is well known and published by recognized PV marketing experts[1], it is a straight forward process to estimate the total number of batteries installed in PV systems each year. Key conclusions from this analysis for 1995 are:

- **Worldwide sales of PV batteries = 2,961,000 kWh.**
- **Worldwide wholesale value for PV batteries shipped in 1995 was $302 million.**
- **Worldwide total installed capacity of PV batteries = 10,519,000 kWh**
- **U.S. sales of PV batteries in 1995 = 340,515 kWh**
- **U.S. sales of PV batteries in 1995 = $34.7 million**
- **the 21 System Integrators supplied about 14 percent of the U.S. PV battery market (in terms of dollar sales**

The approximations which went into these calculations limit the accuracy to about ← 25 percent.

Summary Of Results From The 21 System Integrators

All battery sales reported were for lead-acid batteries (there were no nickel-cadmium batteries reported). The total cost of batteries purchased by the 21 System Integrators in 1995 was $4.8 million at a unit volume of 26,308. A "top-down" market analysis showed the total worldwide PV battery shipments in 1995 to be approximately $302 million and 2,961 MWh. This is equivalent to about 2 million 12V-100 AH batteries. The U.S. share of this market was approximately 11.5 percent or 34.7 million dollars (340,515 kWh). The 21 System Integrators supplied about 14 percent of the 1995 U.S. PV battery market in terms of wholesale dollars and about 13.6 percent of the worldwide kWh sales. One conclusion that may be drawn from the analysis is that many U.S. end users buy their PV batteries directly from a battery supplier and not from a system integrator.

Seventy-one percent of the dollars were spent on valve-regulated batteries, and valve-regulated batteries cost 88 percent more than flooded-vented batteries per kWh ($128/kWh Vs $68/kWh). The use of valve regulated batteries increased by 145 percent from 1991 to 1995, while the use of flooded-vented batteries increased by 117 percent in units, but decreased by about 25 percent in dollars.

---

[1]based on averages of data from conversations with Bob Johnson of Strategies Unlimited (May 1996), and Paul Maycock of PV News, February 1996. Johnson and Maycock are two of the leading PV industry experts who have provided technology and market reports (including historical and forecasted PV sales data) for about two decades.

The eight Large System Integrators sold 78 percent of the total units (Large plus Small Integrators) and captured 88 percent of the total dollars (Large plus Small Integrators). Small System Integrators sold 16 percent of the valve-regulated units and 33 percent of the flooded-vented units.

The primary applications for valve-regulated lead-acid (VRLA) batteries were telecommunications (40 %[2]), telemetry (13%), and lighting (9%). Approximately 85 percent of all batteries reported in the categories of telecommunications, telemetry, and lighting used VRLA batteries. Thirty percent of all flooded-vented batteries were used in hybrid systems (as opposed to 89 percent of all hybrid applications used flooded-vented batteries), 31 percent in telecommunications, and 17 percent in remote homes. The preference for VRLA batteries or flooded-vented batteries depended to a large extent on the market segment that the battery serves.

Valve-regulated batteries are heavily skewed toward 12 V modules (60%); 35 percent were 6 V modules, and only 5 percent were 2 V cells. Flooded batteries were skewed toward 2 V cells (45%); 42 percent were 6 V modules, and 12 percent were 12 V modules.

In terms of amp-hour size, valve-regulated batteries were grouped in the 100-400 AH bin for 6 V modules and the 0-200 AH bin for the 12 V modules. Flooded batteries were more broadly distributed in the 600-3,000 AH range at 2 V, 200-400 AH at 6 V, and 1400-1800 AH at 12.

Part 2. Battery Information Needed For PV System Design

This part of the survey asked Integrators what information they needed from the battery manufacturer in order to properly design PV systems with optimum performance and minimum life-cycle cost. Integrators ranked 29 parameters in terms of importance (1=Essential, 2=Useful, 3=Not Important). The first 20 parameters were ranked between 1.0 and 2.0 (averages for all 21 Integrators). The parameter ranked most important was "Cost".

Part 3. PV System Operating Conditions

Part 3 profiles the Integrators' application of PV hardware, their approach to PV system design, and the environment into which PV systems are placed.

Integrators reported that 80 percent of their charge controllers use an ON-OFF algorithm. The ON-OFF algorithm is by far the most difficult charge management algorithm for which to define voltage set points; battery manufacturers rarely, if ever, specify voltage set points for ON-OFF algorithms. This difficulty was emphasized by a battery manufacturer:

> ...Listen to the battery industry when we tell you that we need constant voltage regulators, higher end voltage limits, and higher limits for low voltage disconnects.

About 60 percent of integrator respondents use temperature compensated voltage regulators in their charge controller systems. By comparison, 88 percent of charge controller respondents felt that temperature compensation was either vital or important.

---

[2] i.e., the percentage of kWh for all valve-regulated batteries.

Integrators reported that they get about 78 percent of the advertised battery cycle life, regardless of whether they were of the Flooded, Absorbed Glass Mat, or Gel technology.

Part 4. Hybrid System Issues

Hybrid systems are stand-alone systems with two or more types of power generating sources, one of which is photovoltaics. The purpose of Part 4 was to identify unique characteristics and requirements of hybrid systems.

Forty-eight percent of the Small Integrators' business was hybrid systems, compared to 16 percent for Large Integrators. This may be due to the fact that Small Integrators provide many PV systems for remote homes, which often use a backup generator.

The majority (52%) of hybrid systems batteries are flooded-vented lead-acid with antimony additive to the plates. None of the Integrators used flooded-vented batteries with calcium additive to the plates. Forty-eight percent of the batteries were VRLA.

SURVEY B. BATTERY MANUFACTURER SURVEY

This survey was designed to a) collect information regarding contacts and products that would be of interest to the PV industry and b) to determine what information that battery manufacturers needed from the PV industry. Nine of the ten battery manufacturers that received the three page questionnaire responded.

None of the nine respondents indicated that they had an "Application Guide for PV Customers" available at the time that the survey was submitted. However, four indicated that they will have an application guide available by the end of 1996.

SURVEY C. CHARGE CONTROLLER MANUFACTURERS

Two of the eight respondents had about 55 percent of the U.S. unit and dollar volume in 1995. On the other end of the scale, two manufacturers had less than 2 percent of the market. A 203 percent growth rate in unit volume was projected for 1996 by the respondents.

Manufacturers answered with one YES and seven NOs to the question "Do you receive adequate information from battery manufacturers regarding the performance of batteries in PV Systems?"

GENERAL CONCLUSIONS AND RECOMMENDATIONS

The Survey

This survey provides: a) quantification and characterization of batteries and charge controllers used in PV systems, b) characterization of the operating environment in which batteries and charge controllers are used, and c) feedback from PV System Integrators, battery manufacturers, and charge controller manufacturers defining what information each needs to optimize PV energy storage systems.

Sandia National Laboratories Assistance

Survey respondents identified areas of focus by each of the three industries (PV System Integrators, Battery Manufacturers, and Charge Controller Manufacturers) in which they would like Sandia National Laboratories' (SNL) assistance. The high priority areas identified were: a) assist in the development of application guides or notes, b) assist in the characterization of batteries for PV data sheet values, c) provide technical liaison between the PV and battery industries and, d) perform surveys to define the market.

Information Exchange

This Final Report will serve as an information exchange tool between the three elements of PV energy storage systems: PV System Integrators, battery manufacturers, and charge controller manufacturers. Names, companies, and phone/fax numbers identified in this report will allow direct communications between key participants in each of the three industries.

Survey respondents indicated an on-going need for data collection and dissemination. Information exchange and information dissemination is most effective when done on a regular basis. There is a significant benefit to SNL continue to serve as the focal point for PV Energy System information and generation, collection, and distribution by: a) expanding the contact list developed herein to all interested individuals, i.e., the LIST, b) creating an internet web site for easy access to existing battery storage information and as a means for industry to ask questions and contribute information, c) distribute a quarterly "news letter" of summary information to the LIST via e-mail, and d) distributing an *annual report* via e-mail to the LIST plus a hard copy to the Department of Energy and other selected individuals.

Responses to draft review copies of portions of the final report have been very positive. For example, Stephen Vechy, Photovoltaic Sales and Marketing Manager for GNB (the battery manufacturer respondent in this survey with the largest market share) said, "...the PV Survey [that] we have been working on is considered a very valuable tool for us at GNB. I do not know of any other medium that can provide the level of detail on the PV battery market."

Section 1
INTRODUCTION

BACKGROUND

In June 1995, the Sandia National Laboratories (SNL) Battery Analysis and Evaluation Department and the Photovoltaic System Assistance Center initiated and sponsored an industry-wide Photovoltaic Battery and Charge Controller Market and Applications Survey. This was an expanded version of the Photovoltaic Industry Battery Survey, published in April 1993[1]. Arizona State University (ASU) was contracted by SNL to conduct the survey. The expanded survey included three separate surveys tailored to the following industries:

A. PV system integrators
B. PV charge controller manufacturers
C. Battery manufacturers

PURPOSE

The purpose of this survey was to:

1. quantify the market for batteries shipped with (or for) PV systems in 1995,
2. quantify the PV market segments by battery type and application for PV batteries,
3. characterize and quantify the charge controllers used in PV systems,
4. characterize the operating environment for energy storage components in PV systems, and
5. estimate the PV battery market for the year 2000.

SCOPE

The scope of this survey included PV Energy Storage Systems rather than "battery" information. Surveys were developed to achieve the following:

- Establish estimates of U.S. sales of batteries in PV systems in 1995 and provide an estimate of sales in the year 2000.
- Provide information on how batteries are applied in PV systems to establish present use patterns and expectations.
- Determine how each of the PV and Battery sub-system organizations perceive the impact of charge controllers on their subsystem functionality and efficiency, and on battery life expectancy.
- Explore how the Charge Controller industry perceives their role within the PV industry and their contributions to the management of large and small PV/Battery systems.
- Develop a self sustaining communications link between battery manufacturers, PS system designers/users, and charge controller manufacturers.

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[1]Hammond, R., Harrington, S., Thomas, M., "Photovoltaic Industry Battery Survey, An Evaluation Of The Photovoltaic Battery Market, 1992", a Publication of the Photovoltaic Design Assistance Center, Sandia National Laboratories, April 1993.

METHODOLOGY

Three separate surveys were developed and tailored to the following industries:

A. PV system integrators
B. PV charge controller manufacturers
C. Battery manufacturers

Surveys were sent to 11 large PV System Integrators, 18 small PV System Integrators, 10 Battery manufacturers and 10 Charge Controller manufacturers (see Appendices A, B, and C for copies of Surveys A, B, and C, and Appendix D for the mailing list for each survey).

Some questions in each of the three surveys (A, B, and C) asked for pricing information and/or volume of sales. Since such information is considered sensitive and proprietary, the following statement was included in the cover letter which accompanied each survey:

> All survey materials related to individual respondents will be maintained Confidential and will not be disclosed to anyone outside of ASU (including SNL). Only the summary results for all respondents will be disclosed.

Responses to the three surveys were:

Survey A	Large System Integrators	8 responses from 11 recipients (73%)
	Small System Integrators	13 responses from 18 recipients (72%)
Survey B	Battery Manufacturers	9 responses from 10 recipients (90%)
Survey C	Charge Controller Mfg.	8 responses from 10 recipients (80%)
	Totals	38 responses from 49 recipients (78%)

Responses for each survey (A, B, and C) were consolidated and summary results are presented in Sections 2, 3, and 4 of this report. Conclusions are presented in Section 5.

Section 2
RESULTS: SURVEY A, SYSTEM INTEGRATORS

INTRODUCTION

In January 1996 a comprehensive survey was sent to 11 Large System Integrators and 18 Small System Integrators[1] (see Appendix D for the mailing list). The definition of a Large versus a Small System Integrator was subjective, but followed these guidelines:

- Large System Integrators are viewed as *distributors* of photovoltaic (PV) products and/or a minimum of 20 percent of sales are international.
- Small System Integrators are companies who are, in general, local *dealers* (i.e., serve a region of the U.S.) of PV products.
- Large System Integrators typically have higher annual gross sales than Small System Integrators.

A mix of large and small system integrators was included in the survey to determine if make, model, type, or size of batteries were substantially different for the two categories.

The survey (see Appendix A) was segmented into four parts:

Part 1. Battery sales data
Part 2. Battery information needed for PV system design
Part 3. Typical operating conditions for PV systems
Part 4. Hybrid system issues

The response to the survey was good (see Appendix D, pages D-2 and D-3 for respondents), with 72 percent of the total number of recipients responding:

Large System Integrators **8 responses from 11 recipients (73%)**

Applied Power Corporation	Remote Power Co.,
Atlantic Solar Products	Solar Electric Specialties
Integrated Power Corporation	Southwest PV Inc.
Photocomm, Inc.	Sunwize Energy Systems Inc.

Small System Integrators **13 responses from 18 recipients (72%)**

Ascension Technology Inc.	Photovoltaic Resources International
Backwoods Cabin Electric Systems	Scientific Engineering, Inc.
Currin Corp.	Simpler Solar Systems, Inc.
Direct Water & Power Corp.	Solar Electric, Inc.
GeoSolar	Solar Electric Power Co.
GSE Solar Systems	Solar Outdoor Lighting Inc.
Hitney Solar Products	

TOTAL **21 responses from 29 recipients (72%)**

[1]System Integrator is defined for the purpose of this report as a company whose primary business is the sale of PV systems (as opposed to the sale of modules or balance-of-system component sales).

PURPOSE

The primary purpose of Survey A was to:

1. quantify the market for batteries shipped with (or for) PV systems in 1995,
2. quantify the PV market segments by battery type and application for PV batteries,
3. and estimate the PV battery market for the year 2000.

The single most important purpose of Survey A was to document and quantify the PV battery market.

PART 1. BATTERY SALES DATA

Battery Shipments: Units, Dollars, and Kilowatt-hours

The 21 System Integrators who responded to the survey provided data for battery shipments in 1995, including manufacturer, model, voltage, amp-hour rating, technology, their cost, and the end-use application. Respondents supplied most of the data requested[2], with the exception of end-use applications data, which were left blank for about 15 percent of the batteries reported, and year 2000 projections, which were left blank by the majority of respondents.

Battery voltage, amp-hours, technology, and cost were cross-checked against manufacturer's literature and wholesale price list. Data were modified (or inserted if absent) where necessary to agree with the battery make and model reported. This process of verification ensured complete and accurate data.

There was concern when the survey was developed that some of the smaller dealers may purchase part of their balance-of-system hardware (e.g., batteries) from a large system house, which would result in the same hardware being counted twice. Question 1[3] in Survey A, Part 3, was designed to flag this situation, if it existed. Responses to that question showed that all 21 respondents essentially operated independently from each other and that little, if any, "double counting" existed.

Tables 2-1, 2-2 and 2-3, plus Charts 2-1 through 2-8, provide a summary of data collected in Part 1 from all 21 system integrators. The number of batteries shipped in 1995 are shown by technology (i.e., valve-regulated[4] or flooded-vented[5]) and battery manufacturer. Costs ($) shown are the price that the system house paid for the batteries (i.e., wholesale), not the cost to the end user (i.e., retail; about 20-60 percent higher than wholesale). Kilowatt-hours and $/kWh are also shown by manufacturer and technology.

The total cost of batteries purchased in 1995 by the 21 system integrators was approximately $4.8 million (see Table 2-3). The total volume (i.e., units[6]) of batteries was 26,308. Valve-regulated lead-acid (VRLA) batteries dominated the market with 64 percent of total units shipped (36 percent were flooded-vented)(Chart 2-1); 71 percent of dollar sales were for VRLA batteries vs. 29 percent for flooded-vented batteries (Chart 2-2).

There were no reported shipments of nickel-cadmium batteries (all were lead-acid batteries).

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[2]Two large system integrators supplied all information except pricing, indicating that company policy prohibited them from including pricing. Pricing for batteries reported by these two companies was estimated at 60 percent of the retail cost provided by the battery manufacturer.

[3]Question 1. What percentage of your balance of system is provided by another systems integrator?

[4]Valve-regulated battery: Often called valve-regulated lead-acid batteries (VRLA), these batteries are "sealed" (i.e., they have a spring tensioned self-sealing valve) and are designed for internal recombination of hydrogen and oxygen. These batteries can typically be operated in any position since the electrolyte cannot spill. VRLA batteries include AGM and GEL technologies:

a) AGM batteries use an absorbent glass mat (AGM) to immobilize the electrolyte. This technology is also called "starved electrolyte". Typical band names that use this technology are GNB, Concorde and Power Sonic.

b) GEL batteries immobilize the electrolyte in a thixotropic gel. Typical brand names that use this technology are Johnson Control, Deka, Sonnenschein, and Exide.

[5]Flooded-vented battery: A battery with an electrolyte that flows freely within each cell.

[6]Units: A unit battery is defined as one or more cells in a common case (not necessarily a monolithic case), which is assigned a part number by the manufacturer. For example, the GNB 3-100A33 is counted as one unit which consists of three cells in series; this module is rated at 6 volts, 2130 AH and weighs 920 pounds.

TABLE 2-1 VALVE-REGULATED BATTERIES [a]

MANUFACTURER	1995						
	# of Units	% of #	$ (Wholesale)	% of $	kWh	%-kWh	$/kWh
GNB	3,901	23%	$2,240,352	66%	14,234	54%	$157
DEKA	6,827	41%	$645,285	19%	6,746	25%	$96
JCI	2,704	16%	$245,191	7%	3,073	12%	$80
CONCORD	1,737	10%	$156,226	5%	1,661	6%	$94
SONNENSCEIN	1,223	7%	$73,846	2%	459	2%	$161
POWERSONIC	177	1%	$15,670	0%	98	0%	$160
MISC	277	2%	$14,212	0%	253	1%	$56
TOTAL	16,846	100%	$3,390,782	100%	26,524	100%	$128

TABLE 2-2 FLOODED-VENTED BATTERIES [a]

MANUFACTURER	1995						
	# of Units	% of #	$ (Wholesale)	% of $	kWh	%-kWh	$/kWh
CEAC (France) [1]	1,843	19%	$318,703	23%	4,182	21%	$76
C&D	768	8%	$271,872	20%	3,533	18%	$77
TROJAN	2,633	28%	$173,364	13%	4,174	21%	$42
GNB	182	2%	$168,119	12%	1,871	9%	$90
IBE	806	9%	$150,904	11%	1,641	8%	$92
EXIDE	1,685	18%	$116,950	9%	2,244	11%	$52
EAST PENN	628	7%	$80,448	6%	957	5%	$84
US BAT	800	8%	$71,740	5%	1,203	6%	$60
PACIFIC CHLORIDE	37	0%	$16,810	1%	187	1%	$90
MISC	80	1%	$1,150	0%	20	0%	$58
TOTAL	9,462	100%	$1,370,060	100%	20,012	100%	$68

Note 1. Compagnif Europeenne d'Accumulaturs (CEAC), France, was purchased by Exide in February 1996.

TABLE 2-3 TOTALS FOR ALL BATTERIES [a]

TECHNOLOGY	1995						
	# of Units	% of #	$ (Wholesale)	% of $	kWh	%-kWh	$/kWh
VALVE-REGULATED	16,846	64%	$3,390,782	71%	26,524	57%	$128
FLOODED-VENTED	9,462	36%	$1,370,060	29%	20,012	43%	$68
TOTAL	26,308	100%	$4,760,842	100%	46,536	100%	$102

Note a. Prices are for battery modules only, i.e., prices do not include balance of system hardware.
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Information in Table 2-1 is displayed in Charts 2-3 (units), 2-4 (dollar shipments), and 2-5 (kWh). While Deka batteries dominated the number of VRLA batteries shipped, GNB dollar shipments were nearly four times larger than Deka. The reason for this is that the Deka batteries are generally 20 to 62 amp-hours at 12 volts vs. the GNB batteries ranging from 145 to 855 amp-hours at 12 volts. Further, many of the GNB batteries were battery "modules', consisting of three or six individual, externally connected, 2-volt cells. Some of GNB's single 2-volt cells were 5100 amp-hours. Kilowatt-hours shipped by manufacturer are shown in Chart 2-5

CHART 2-1. % OF TOTAL UNITS SHIPPED, 1995

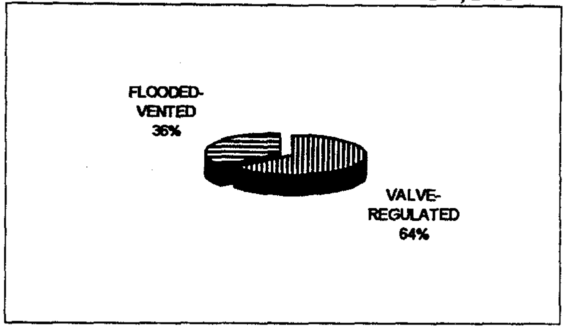


CHART 2-2. % OF TOTAL DOLLARS VALUE, 1995

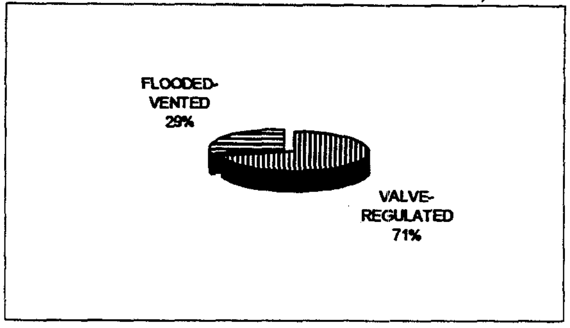


CHART 2-3. VALVE-REGULATED BATTERIES, # OF UNITS SHIPPED, 1995

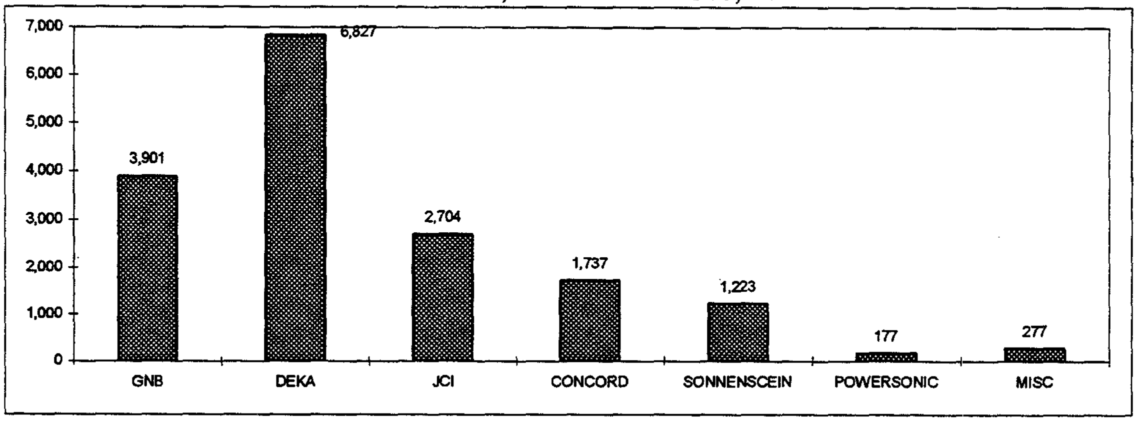


CHART 2-4. VALVE-REGULATED BATTERIES, DOLLAR VALUE SHIPPED, 1995

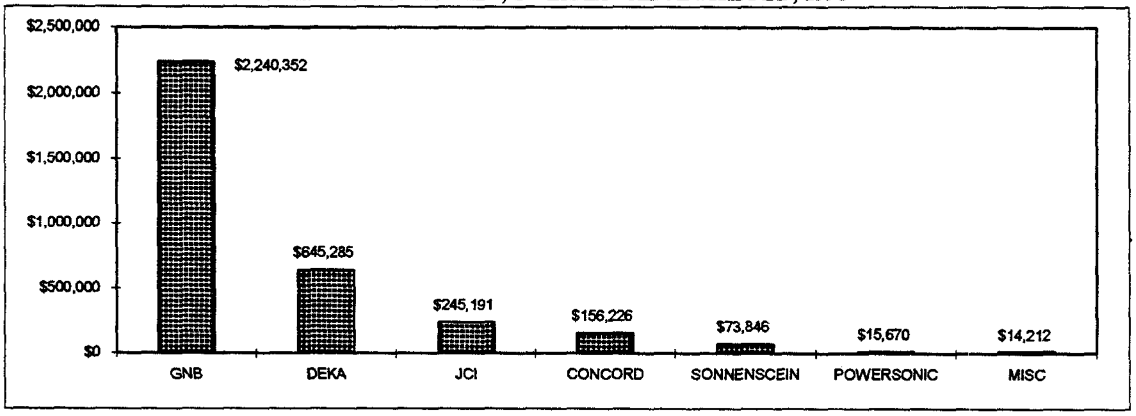
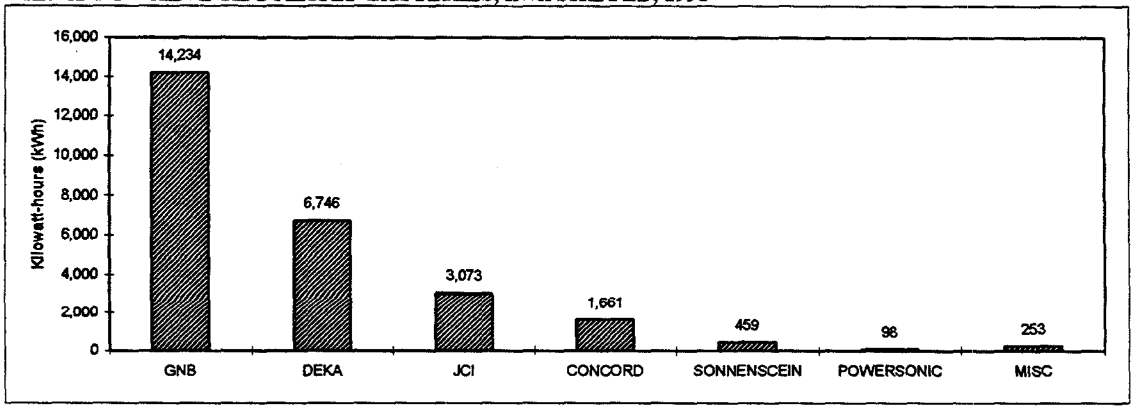


CHART 2-5 VALVE-REGULATED BATTERIES, kWh SHIPPED, 1995



Data for Flooded-vented batteries is plotted in Charts 2-6 (units), 2-7 (dollars) and 2-8 (kWh). Although more Trojan batteries were shipped than any other flooded-vented battery, the CEAC (French) battery accounted for the most dollars and the most kWh. The majority of Trojan batteries were the T-105 (6V, 220AH), and the CEAC batteries were primarily 2 volts at 210 AH to 2500 AH.

CHART 2-6. FLOODED-VENTED BATTERIES, # OF UNITS SHIPPED, 1995

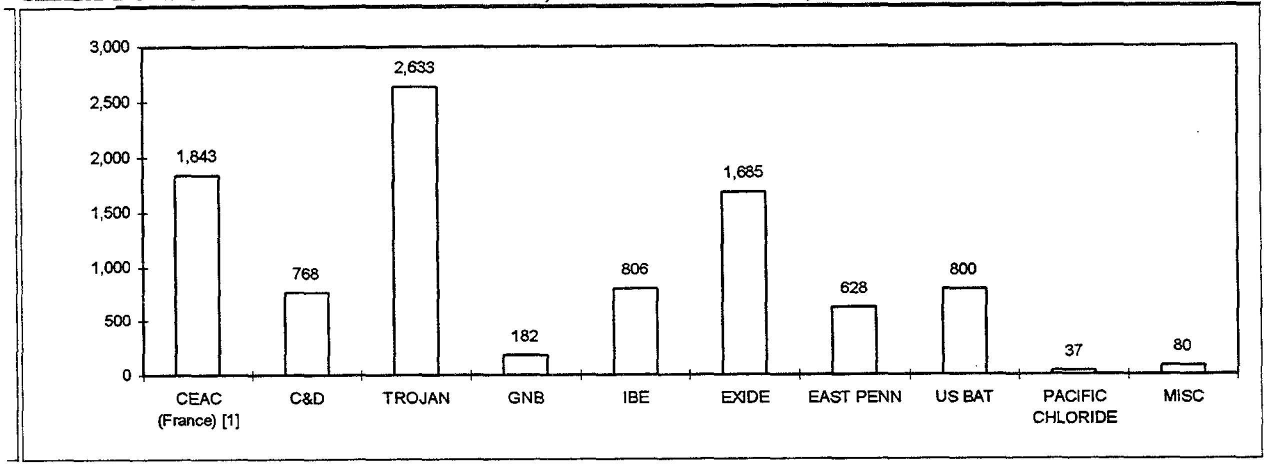


CHART 2-7. FLOODED-VENTED BATTERIES, DOLLAR VALUE SHIPPED, 1995

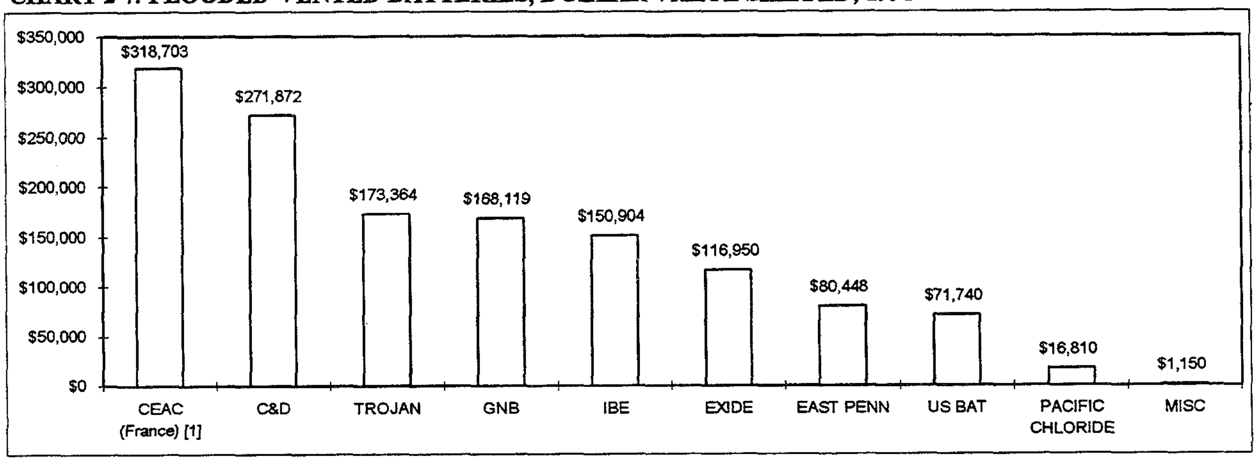
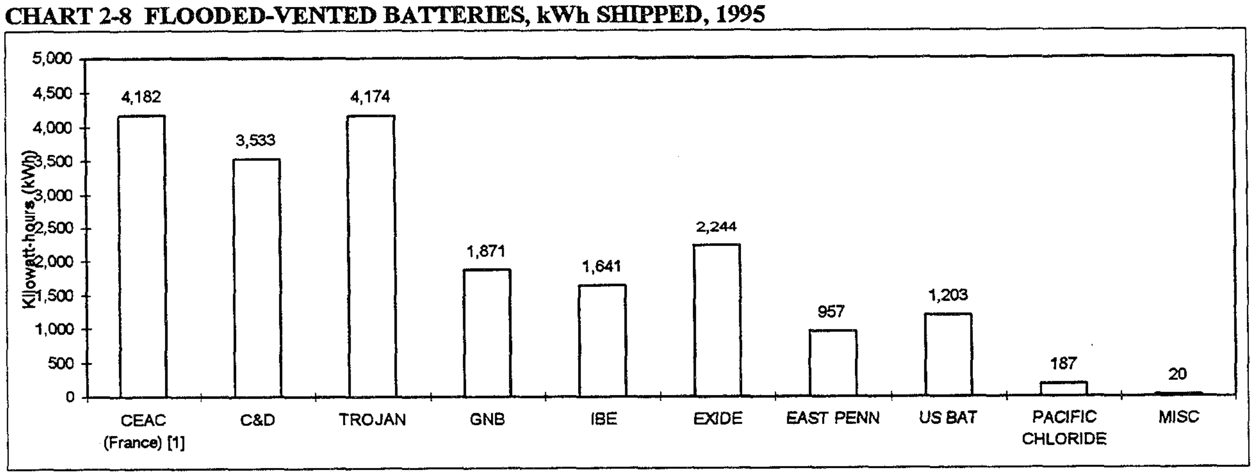


CHART 2-8 FLOODED-VENTED BATTERIES, kWh SHIPPED, 1995



Large Distributors vs. Small Distributors

Large distributors (defined on page 2-1) generally have a higher sales volume, a larger geographic territory, and spend more time on system design. Data in Tables 2-4, 2-5, and 2-6 show percentage of units and dollars of 1995 battery sales for the eight Large System Integrators and the 13 Small System Integrators. The Large System Integrators purchased 78 percent of the total units and 88 percent of the total dollars. These data indicate that the Small System Integrators purchased smaller batteries (since the unit cost is less). Data also show that the Small System Integrators use a higher ratio of flooded-vented batteries to valve-regulated batteries than the Large System Integrators. One reason for use of more VRLA batteries by Large System Integrators may be because there are less restrictions for shipping VRLA batteries than flooded-vented batteries.

1995 Survey Results vs. 1991 Survey Results

Results of the 1995 PV battery shipments are compared with the 1991 battery shipments in Tables 2-7, 2-8 and 2-9 (and charts 2-9 and 2-10). Kilowatt-hours were not available for 1991 to compare with 1995.

Note that this comparison of 1995 data with 1991 data provides a coarse approximation of market growth, since seven Large System Integrators responded in 1991 while in 1995 eight Large System Integrators and 13 Small System Integrators responded. The 13 Small System Integrators contributed 12 percent of the dollar sales in 1995, and it would be reasonable to assume that 13 Small System Integrators in 1991 would have also contributed 12 percent to the dollar sales. Another area of uncertainty in this comparison is the cost per kilowatt-hour of battery for the two years; it could have gone up or down in 1995 relative to 1991. With these cautions in mind, the following trends can be defined:

- The trend toward VRLA batteries has increased (144 percent in units and 145 percent in dollars[7]), with GNB dominating the market in dollars. The number of Flooded-Vented batteries has increased by 117 percent, while the dollar volume has decreased to 73 percent of the 1991 value. This decrease could be a result of smaller batteries (kWh) and/or a lower cost per kWh.

- A battery sales growth rate of 133 percent for units and 113 percent for dollars is considerably less than expected. It would be expected that this growth would track stand-alone PV module sales, which increased 145 percent (worldwide kW sales[8]) from 1991 to 1995. A possible reason for this was given by one of the respondents (a Large System Integrator). PV module prices have decreased about 20 percent from 1991 to 1995, resulting in system designs with larger PV arrays and correspondingly smaller kWh of batteries. This approach maintains the same margins of safety and reduces the total system cost. Another System Integrator, however, has maintained the same ratio of array PV watts to battery kWh from 1991 to 1995.

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[7]not adjusted for inflation

[8]based on discussions with Bob Johnson, Strategies Unlimited, May 1996

TABLE 2-4. VALVE-REGULATED BATTERIES; LARGE VS SMALL INTEGRATORS

	UNITS					DOLLAR VALUE, WHOLESALE				
MANUFACTURER	TOTAL	LARGE	% of Total	SMALL	% of Total	TOTAL	LARGE	% of Total	SMALL	% of Total
GNB	3,901	3,649	94%	252	6%	$ 2,240,352	$ 2,084,300	93%	$ 156,052	7%
DEKA	6,827	5,958	87%	869	13%	$ 645,285	$ 574,230	89%	$ 71,055	11%
JCI	2,704	2,532	94%	172	6%	$ 245,191	$ 230,165	94%	$ 15,026	6%
CONCORD	1,737	1,707	98%	30	2%	$ 156,226	$ 152,746	98%	$ 3,480	2%
SONNENSCEIN	1,223	137	11%	1,086	89%	$ 73,846	$ 8,374	11%	$ 65,472	89%
POWERSONIC	177	37	21%	140	79%	$ 15,670	$ 5,530	35%	$ 10,140	65%
MISC	277	193	70%	84	30%	$ 14,212	$ 5,398	38%	$ 8,814	62%
TOTAL	**16,846**	**14,213**	**84%**	**2,633**	**16%**	**$ 3,390,782**	**$ 3,060,743**	**90%**	**$ 330,039**	**10%**

TABLE 2-5. FLOODED-VENTED BATTERIES; LARGE VS SMALL INTEGRATORS

	UNITS					DOLLAR VALUE, WHOLESALE				
MANUFACTURER	TOTAL	LARGE	% of Total	SMALL	% of Total	TOTAL	LARGE	% of Total	SMALL	% of Total
CEAC (France) [1]	1,843	1,843	100%	0	0%	$ 318,703	$ 318,703	100%	$ -	0%
C&D	768	768	100%	0	0%	$ 271,872	$ 271,872	100%	$ -	0%
IBE	806	690	86%	116	14%	$ 150,904	$ 136,224	90%	$ 14,680	11%
TROJAN	2,633	1,112	42%	1,521	58%	$ 173,364	$ 84,063	48%	$ 89,301	106%
GNB	182	97	53%	85	47%	$ 168,119	$ 157,994	94%	$ 10,125	6%
EAST PENN	628	76	12%	552	88%	$ 80,448	$ 69,768	87%	$ 10,680	15%
EXIDE	1,685	1,635	97%	50	3%	$ 116,950	$ 114,450	98%	$ 2,500	2%
US BAT	800	128	16%	672	84%	$ 71,740	$ 17,980	25%	$ 53,760	299%
PACIFIC CHLORIDE	37	37	100%	0	0%	$ 16,810	$ 16,810	100%	$ -	0%
MISC	80	0	0%	80	100%	$ 1,150	$ 0	0%	$ 1,150	-
TOTAL	**9,462**	**6,386**	**67%**	**3,076**	**33%**	**$ 1,370,060**	**$ 1,187,864**	**87%**	**$ 182,196**	**13%**

TABLE 2-6. TOTALS FOR ALL BATTERIES; LARGE VS SMALL INTEGRATORS

	UNITS					DOLLAR VALUE, WHOLESALE				
TECHNOLOGY	TOTAL	LARGE	% of Total	SMALL	% of Total	TOTAL	LARGE	% of Total	SMALL	% of Total
VALVE-REGULATED	16,846	14,213	84%	2,633	16%	$ 3,390,782	$ 3,060,743	90%	$ 330,039	10%
FLOODED-VENTED	9,462	6,386	67%	3,076	33%	$ 1,370,060	$ 1,187,864	87%	$ 182,196	13%
TOTAL	**26,308**	**20,599**	**78%**	**5,709**	**22%**	**$ 4,760,842**	**$ 4,248,607**	**88%**	**$ 512,235**	**11%**

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TABLE 2-7. VALVE-REGULATED BATTERIES; 1991 VS. 1995

MANUFACTURER	UNITS		RATIO	$ (Wholesale)		RATIO
	1991	1995	95//91	1991	1995	95//91
GNB	5,242	3,901	74%	$1,684,455	$2,240,352	133%
DEKA	1,400	6,827	488%	$108,000	$645,285	597%
JCI	4,497	2,704	60%	$518,530	$245,191	47%
CONCORD	150	1,737	1158%	$12,000	$156,226	1302%
SONNENSCEIN	350	1,223	349%	$19,500	$73,846	379%
POWERSONIC	80	177	221%	$1,600	$15,670	979%
MISC	0	277		$0	$14,212	-
TOTAL	11,719	16,846	144%	$2,344,085	$3,390,782	145%

TABLE 2-8. FLOODED-VENTED BATTERIES; 1991 VS. 1995

MANUFACTURER	UNITS		RATIO	$ (Wholesale)		RATIO
	1991	1995	95//91	1991	1995	95//91
CEAC	0	1,843		$0	$318,703	-
C&D	0	768		$0	$271,872	-
TROJAN	1,658	2,633	159%	$122,540	$173,364	141%
GNB	1,176	182	15%	$367,465	$168,119	46%
IBE	1,052	806	77%	$260,908	$150,904	58%
EXIDE	1,428	1,685	118%	$499,800	$116,950	23%
EAST PENN	0	628		$0	$80,448	-
US BAT	1,200	800	67%	$48,000	$71,740	149%
PACIFIC C.	90	37	41%	$30,060	$16,810	56%
VARTA	1,500	0	5%	$525,000	$0	0%
MISC	10	80	800%	$25,000	$1,150	5%
TOTAL	8,114	9,462	117%	$1,878,773	$1,370,060	73%

TABLE 2-9. TOTALS FOR ALL BATTERIES; 1991 VS. 1995

TECHNOLOGY	UNITS		RATIO	$ (Wholesale)		RATIO
	1991	1995	95//91	1991	1995	95//91
VALVE-REGULATED	11,719	16,846	144%	$2,344,085	$3,390,782	145%
FLOODED-VENTED	8,114	9,462	117%	$1,878,773	$1,370,060	73%
TOTAL	19,833	26,308	133%	$4,222,858	$4,760,842	113%

A-PART1\SUM-DAT\1-TABLES 91-95

CHART 2-9. VALVE-REGULATED BATTERIES, 1991-1995 UNITS and DOLLARS

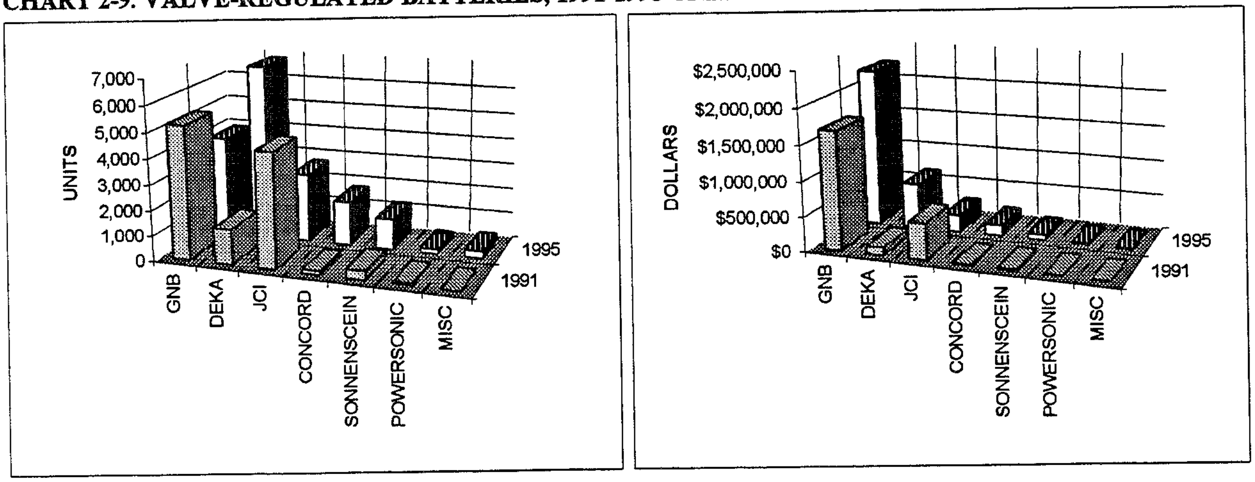
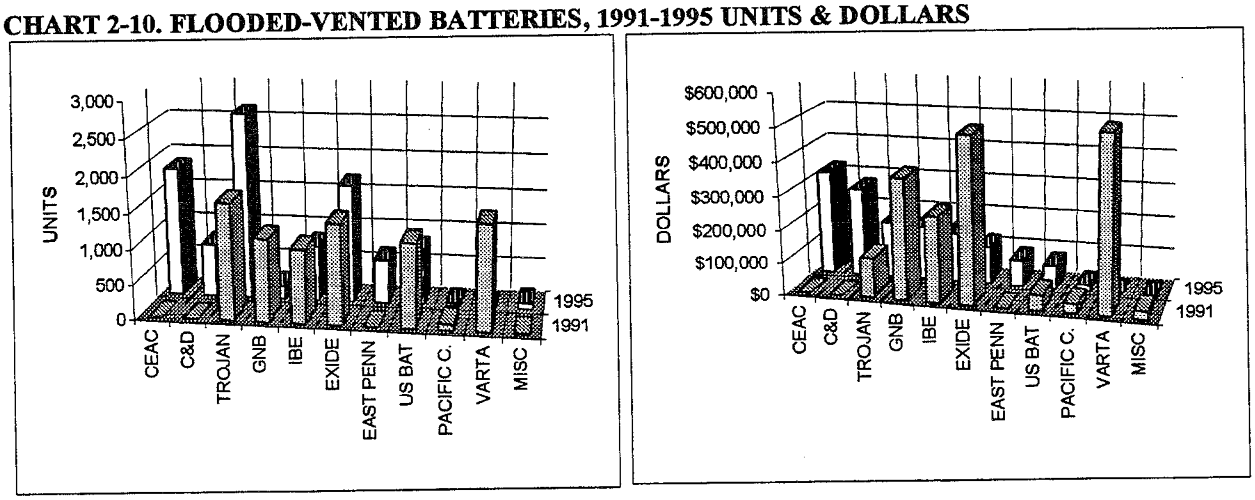


CHART 2-10. FLOODED-VENTED BATTERIES, 1991-1995 UNITS & DOLLARS



Application Specific Data

Each System Integrator was asked to indicate the percentage of batteries used in each of eight application categories[9] for each battery make and model reported. Results are shown in Tables 2-10 through 2-16 and Charts 2-11 and 2-12. Tables 2-10 through 2-12 show actual kWh of batteries reported in each application category while Tables 2-13 through 2-16 show percentage of kWh for each application category.

Cathodic protection was inadvertently left off the survey questionnaire, but one of the 21 respondents added this category. The quantity of batteries, however, was too small to warrant another category. The category "Unknown" was added primarily for the two Large System Integrators who did not include pricing or applications information, and for other integrators who did not know what the end application was. Table 2-13 shows the Unknown category to be significant (23 percent) for VRLA batteries, but only 5 percent for Flooded-vented batteries.

[9]Application categories: Hybrid, Lighting, Telecommunications less than 200 W-peak, Telecommunications greater than 200 Wp, Remote Home, Telemetry, Village Power and Water Pumping

TABLE 2-10. VALVE-REGULATED BATTERIES; kWh BY APPLICATION

MANUFACTURER	RH	TC<	TC>	TM	L	W	H	V	UKN	TOTALS
GNB	600	274	9,058	1,056	211	8	631	0	2,396	14,234
DEKA	806	418	43	1,759	1,026	297	0	361	2,037	6,746
JCI	420	615	0	568	554	207	0	308	400	3,073
CONCORD	6	137	12	119	156	0	72	126	1,033	1,661
SONNENSCEIN	0	13	0	0	401	0	0	0	46	459
POWERSONIC	42	3	0	0	10	0	0	0	43	98
MISC	0	0	0	13	68	0	23	0	149	253
TOTAL	1,874	1,459	9,112	3,516	2,425	512	725	795	6,105	26,524

TABLE 2-11. FLOODED-VENTED BATTERIES; kWh BY APPLICATION

MANUFACTURER	RH	TC<	TC>	TM	L	W	H	V	UKN	TOTALS
CEAC (France)	0	170	4,012	0	0	0	0	0	0	4,182
C&D	0	0	0	0	0	0	3,533	0	0	3,533
IBE	344	0	460	0	0	0	804	0	32	1,641
EAST PENN	487	0	220	128	0	0	116	0	6	957
TROJAN	2,442	163	132	108	326	225	66	463	250	4,174
GNB	26	0	972	0	80	75	719	0	0	1,871
EXIDE	67	0	0	0	0	0	0	2,157	21	2,244
US BAT	48	0	0	0	23	58	833	0	241	1,203
PACIFIC CHLORIDE	0	0	0	0	0	0	0	0	187	187
MISC	20	0	0	0	0	0	0	0	0	20
TOTAL, kWh	3,433	333	5,797	235	429	359	6,071	2,619	737	20,012

TABLE 2-12. TOTALS FOR ALL BATTERIES; kWh BY APPLICATION

TECHNOLOGY	RH	TC<	TC>	TM	L	W	H	V	UKN	TOTALS
VALVE-REGULATED	1,874	1,459	9,112	3,516	2,425	512	725	795	6,105	26,524
FLOODED-VENTED	3,433	333	5,797	235	429	359	6,071	2,619	737	20,012
TOTAL	5,307	1,792	14,909	3,752	2,854	870	6,796	3,414	6,842	46,535

A-PART1\SUM-DAT\1-TABLES kWh

H= Hybrid
RH = Remote Home
UKN = Unknown
L = Lighting
TM = Telemetry
V = Village Power
TC< = Telecommunications less than 200 W(peak) PV
TC> = Telecommunications greater than 200 W(peak) PV
W = Water Pumping

Forty percent of VRLA batteries were used in Telecommunications, while 29 percent of flooded-vented batteries were used in Telecommunications (Table 2-15 and Chart 2-11). Thirty-five percent of all batteries were used in Telecommunications. Flooded-vented batteries also show high usage in Remote Home (19 percent) and Hybrid (29 percent) applications.

The percentage of batteries by technology is presented in Table 2-16 and Chart 2-12. VRLA batteries dominate Telecommunications, Telemetry, Lighting and Water Pumping, while Flooded-vented batteries dominate Remote Home, Hybrid and Village Power systems.

TABLE 2-13. VALVE-REGULATED BATTERIES; kWh (IN %) BY APPLICATION

MANUFACTURER	RH	TC<	TC>	TM	L	W	H	V	UKN	TOTALS
GNB	4%	2%	64%	7%	1%	0%	4%	0%	17%	100%
DEKA	12%	6%	1%	26%	15%	4%	0%	5%	30%	100%
JCI	14%	20%	0%	18%	18%	7%	0%	10%	13%	100%
CONCORD	0%	8%	1%	7%	9%	0%	4%	8%	62%	100%
SONNENSCEIN	0%	3%	0%	0%	87%	0%	0%	0%	10%	100%
POWERSONIC	43%	3%	0%	0%	10%	0%	0%	0%	44%	100%
MISC	0%	0%	0%	5%	27%	0%	9%	0%	59%	100%
TOTAL	7%	6%	34%	13%	9%	2%	3%	3%	23%	100%

TABLE 2-14. FLOODED-VENTED BATTERIES; kWh (IN %) BY APPLICATION

MANUFACTURER	RH	TC<	TC>	TM	L	W	H	V	UKN	TOTALS
CEAC (France)	0%	4%	96%	0%	0%	0%	0%	0%	0%	100%
C&D	0%	0%	0%	0%	0%	0%	100%	0%	0%	100%
IBE	21%	0%	28%	0%	0%	0%	49%	0%	2%	100%
EAST PENN	51%	0%	23%	13%	0%	0%	12%	0%	1%	100%
TROJAN	58%	4%	3%	3%	8%	5%	2%	11%	6%	100%
GNB	1%	0%	52%	0%	4%	4%	38%	0%	0%	100%
EXIDE	3%	0%	0%	0%	0%	0%	0%	96%	1%	100%
US BAT	4%	0%	0%	0%	2%	5%	69%	0%	20%	100%
PACIFIC CHLORIDE	0%	0%	0%	0%	0%	0%	0%	0%	100%	100%
MISC	100%	0%	0%	0%	0%	0%	0%	0%	0%	100%
TOTAL, kWh	17%	2%	29%	1%	2%	2%	30%	13%	4%	100%

TABLE 2-15. TOTALS (100%) BY TECHNOLOGY; kWh (IN %)

TECHNOLOGY	RH	TC<	TC>	TM	L	W	H	V	UKN	TOTALS
VALVE-REGULATED	7%	6%	34%	13%	9%	2%	3%	3%	23%	100%
FLOODED-VENTED	17%	2%	29%	1%	2%	2%	30%	13%	4%	100%
TOTAL	11%	4%	32%	8%	6%	2%	15%	7%	15%	100%

TABLE 2-16. TOTALS (100%) BY APPLICATION; KWH (IN %)

TECHNOLOGY	RH	TC<	TC>	TM	L	W	H	V	UKN	TOTALS
VALVE-REGULATED	35%	81%	61%	94%	85%	59%	11%	23%	89%	57%
FLOODED-VENTED	65%	19%	39%	6%	15%	41%	89%	77%	11%	43%
TOTAL	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

H= Hybrid — L = Lighting — TC< = Telecommunications less than 200 W(peak) PV
RH = Remote Home — TM = Telemetry — TC> = Telecommunications greater than 200 W(peak) PV
UKN = Unknown — V = Village Power — W = Water Pumping

A-PART1\SUM-DAT\1-TABLES kWh

Tables 2-13 and 2-14 show the distribution of batteries by application for each battery manufacturer. It is clear from these data that the majority of batteries from each manufacturer fall into one or two application categories. For example, 66 percent of GNB VRLA batteries were used in Telecommunications applications. Fifty-eight percent of Trojan (Flooded-vented) batteries were used in Remote Home applications. All of the C&D (Flooded-vented) batteries were used in Hybrid systems and all of the CEAC batteries were used in Telecommunications applications.

CHART 2-11. TOTALS (100%) BY TECHNOLOGY; kWh (IN %)

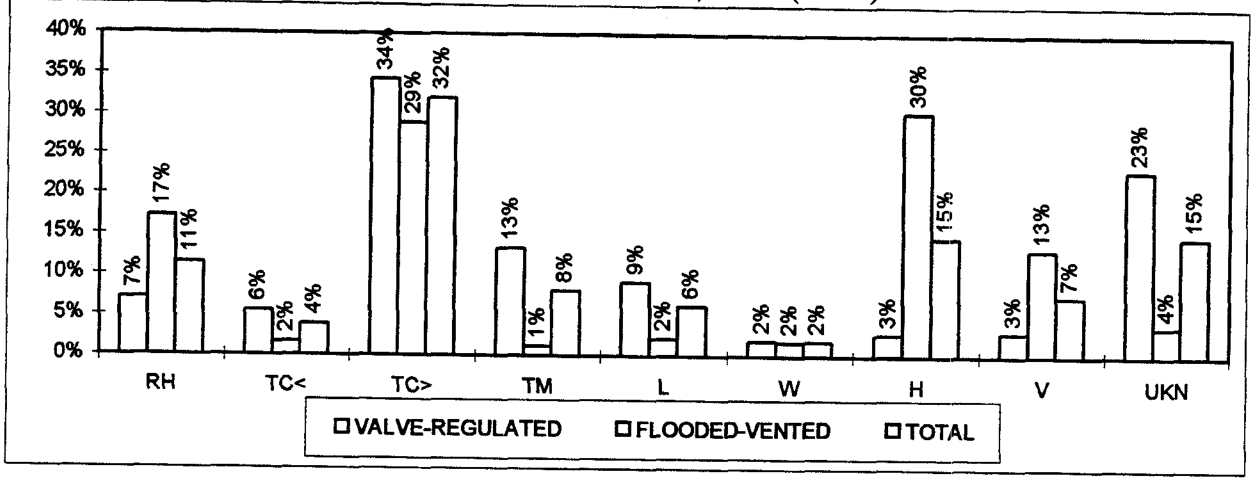
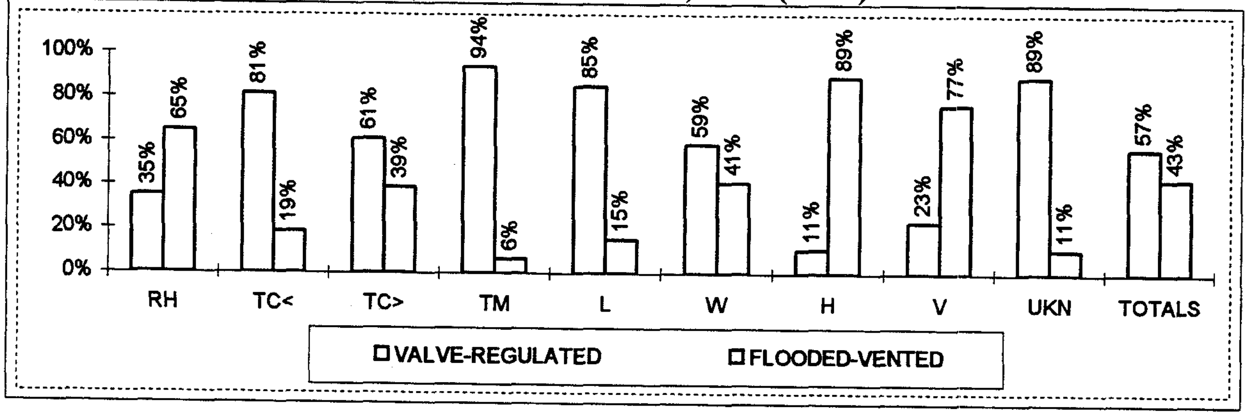


CHART 2-12. TOTALS (100%) BY APPLICATION; kWh (IN %)



Distribution of Batteries by Voltage and Amp-Hour Range

Data were sorted to determine how many 2-Volt batteries were used vs. 6-Volt batteries vs. 12-Volt batteries. Data were further sorted by amp-hour rating and placed in bins defined by amp-hour range (e.g., 0-100 AH). Instead of number of batteries, the "quantity" of batteries in each bin was kWh (i.e., V*AH*Units)[10]. This allows a direct comparison of the relative amount of lead, acid and dollars in a bin. These data are presented in Table 2-17 and Charts 2-13 through 2-18.

Data show that the predominate size of VRLA batteries is 12 Volts (59 percent) and less than 200 amp-hours. The predominant size of Flooded-vented batteries is 2 Volts (46 percent), mostly between 600 AH and 3,000 AH. Flooded-vented batteries are also common in the 6 Volt size, with all grouped 200 and 400 AH. Only 12 percent of flooded-vented batteries fall in the 12 Volt category, and one percent fell into the 24 Volt category.

A significant finding is that the single largest bin for VRLA and Flooded-vented batteries is 6,791 kWh for VRLA batteries between 0-100 AH. The next largest bin was 6-Volt Flooded-vented batteries between 200-300 AH (5,197 kWh).

[10]The convention of "*" for multiplication and "/" for division is used in this document.

TABLE 2-17. kWh BY BATTERY VOLTAGE AND AMP-HOUR RATING (RANGE)							
AH	VRLA			FLOODED			
RANGE	2 Volt	6 Volt	12 Volt	2 Volt	6 Volt	12 Volt	24 Volt
0-100		3	6,791			49	
100-200		602	5,079	35		166	
200-300		1,937	959	164	5,197	106	
300-400			57	9	3,121		
400-600			842	181			
600-800		73	1,374	768		255	
800-1K		363	646	158		30	20
1K-1.2K		321		361		168	
1.2K-1.4K		886		1,865			40
1.4K-1.6K		1,980		515		1,072	
1.6K-1.8K		2,401		281		571	20
1.8K-2.0K		371		292			
2.0K-2.5K				3,488			
2.5K-3.0K	418			1,080			
3K-4K	670						
4K-6K	318						
6K-10K		432					
SUBTOTALS	1,406	9,369	15,749	9,198	8,318	2,417	80
% of TOTAL	5.3%	35.3%	59.4%	46.0%	41.6%	12.1%	0.4%
TOTALS	26,524			20,012			
\A=PART1\SUM-DAT\KWH.XLS SUM-ALL							

CHART 2-13. VRLA, kWh BY AMP-HOUR RANGE; 2-Vdc BATTERIES

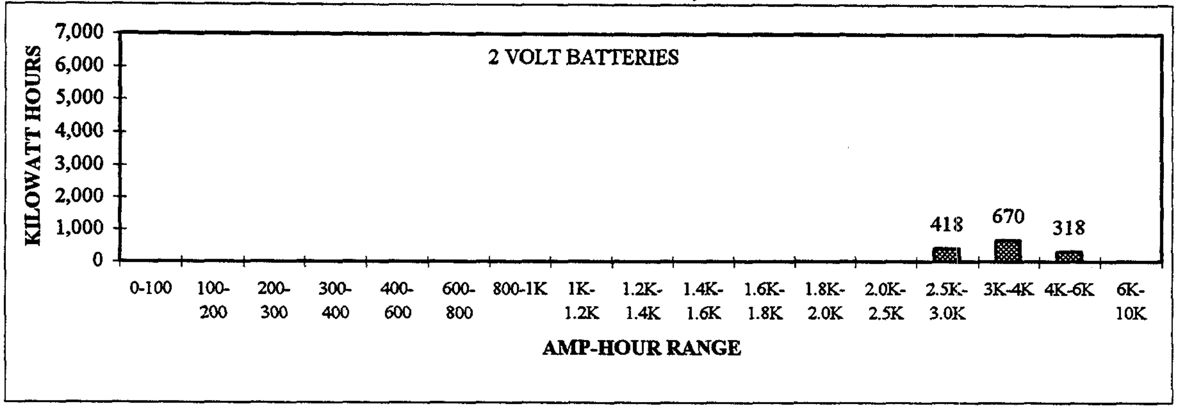


CHART 2-14. VRLA, kWh BY AMP-HOUR RANGE; 6-Vdc BATTERIES

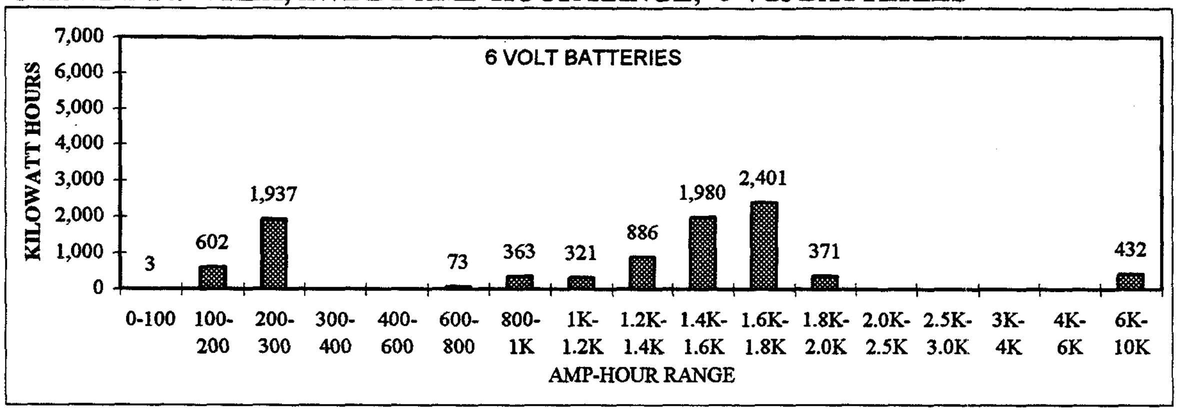
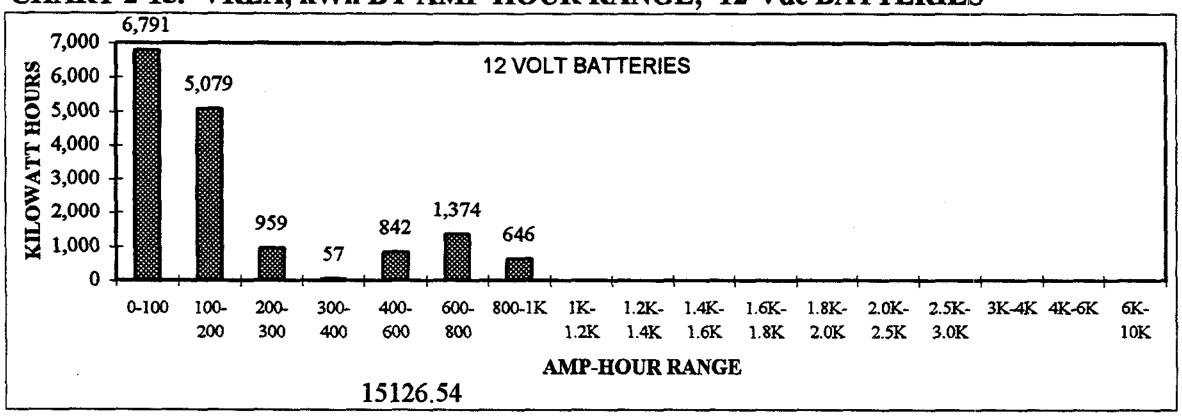


CHART 2-15. VRLA, kWh BY AMP-HOUR RANGE; 12-Vdc BATTERIES



\A-PART1\SUM-DAT\KWH.XLS SUM-ALL

CHART 2-16. FLOODED-VENTED, kWh BY AMP-HOUR RANGE; 2-Vdc BATTERIES

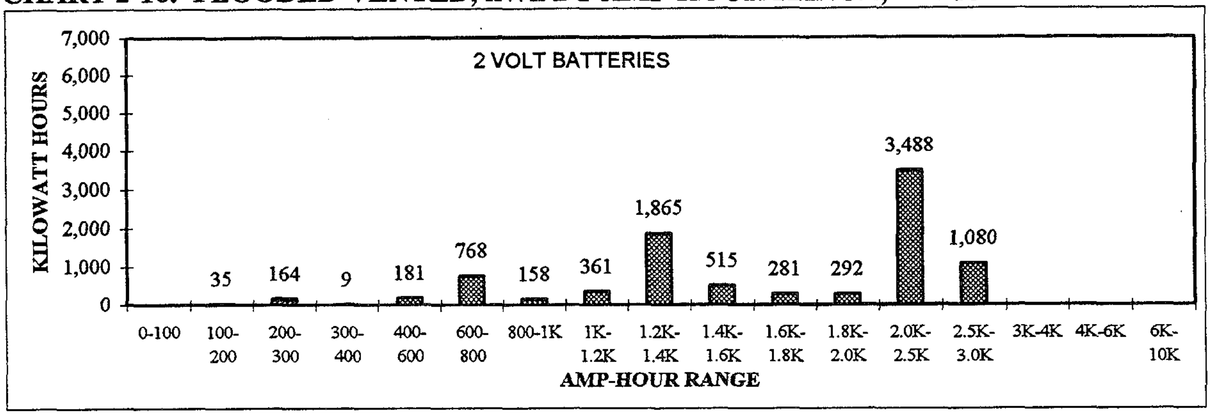


CHART 2-17. FLOODED-VENTED, kWh BY AMP-HOUR RANGE; 6-Vdc BATTERIES

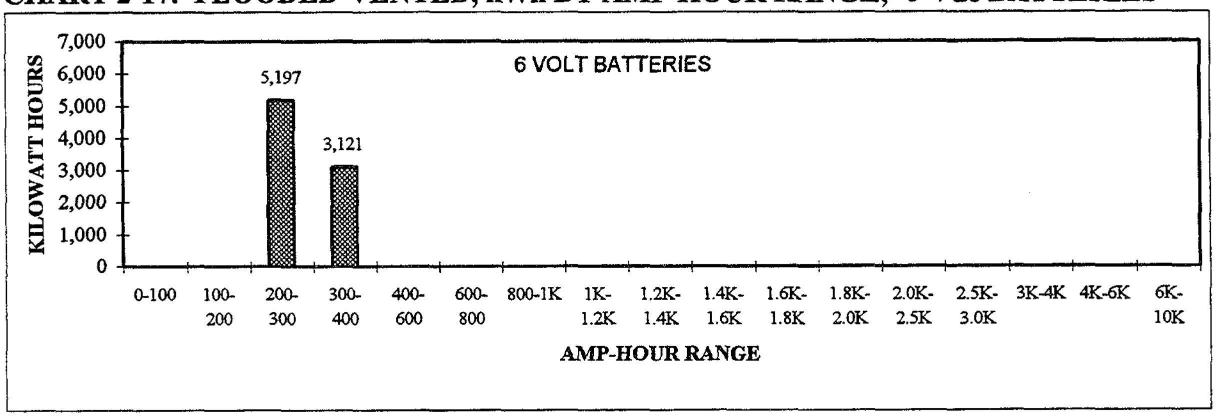
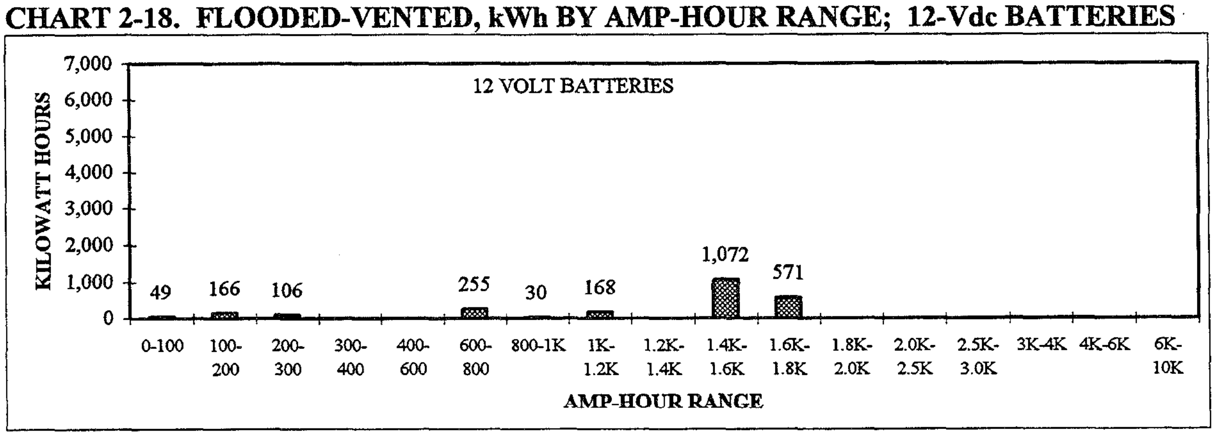


CHART 2-18. FLOODED-VENTED, kWh BY AMP-HOUR RANGE; 12-Vdc BATTERIES



\A-PART1\SUM-DAT\KWH.XLS SUM-ALL

Top-Down Market Analysis

Introduction

The preceding text and data presented in this section (Section 2, Part 1) are based solely on summary results from the 21 System Integrators that responded to the survey. These summary results are, to a large extent, representative of the worldwide market and therefore can be extrapolated. However, they do not provide a means to estimate total PV battery sales for either the U.S. market or the worldwide market. **The following Top-Down Market Analysis provides an estimate of total PV battery sales worldwide and in the U.S.** by all purchasers of PV batteries, not just system integrators[11].

Top Down Analysis

The top down analysis is based on a rule of thumb[12] which provides an estimate of the number of batteries used for each 50 watts (peak) of modules used. Since the number of PV watts shipped each year (both U.S. and worldwide) is well known and published by recognized PV marketing experts, it is a straight forward process to estimate the total number of batteries installed in PV systems each year.

Worldwide PV module shipments in 1995 were approximately 78 megawatts (MW) [13], with about 67 MW being used in stand-alone applications (about 11 MW were used in grid-connected and consumer[14] applications). Water pumping, a segment of the stand-alone market, often does not use batteries, so the 67 MW will be adjusted downward to **64 MW**, which represents PV module sales in systems that included batteries. As a rule of thumb, on average, one 12V-100 AH battery (i.e., 1.2 kWh) is used for each 50 watts of PV modules.

- **The total worldwide sales of PV batteries in 1995 was (64 MW/50W)*1.2 kWh = 1,536,000 kWh.**

Additional batteries were sold during 1995 to replace batteries that reached end-of-life in existing PV systems. Assuming a typical battery life of 5 years and that all PV system batteries installed in 1990, 1985, and 1980 were replaced (934,000+291,000+200,000 kWh), then a total of 1,425,000 kWh of batteries were replaced in 1995.

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[11]The 21 System Integrators that responded to this survey represent only a fraction (14%) of the U.S. PV battery market and a much smaller fraction of the worldwide PV battery market (1.6%). One reason why the 21 System Integrators have a small share of the total U.S. market is because the PV battery market is fragmented with many end users purchasing from local battery distributors. The end user may be, for example, an electric or gas utility, a telecommunications company, the Department of Defense, a recreational vehicle owner, or a remote home owner.
[12]The widely accepted rule of thumb is that for every 50 watts (peak) of PV modules used in a PV system, approximately 1.2 kWh of battery is used (e.g., one 12V, 100 Ah battery). This industry consensus rule of thumb is sometimes used to estimate the quantity of batteries for a "typical" PV system. The authors of this report estimated that the uncertainty of this rule is +/- 20 percent.
[13]Based on averages of data from conversations with Bob Johnson of Strategies Unlimited (May 1996), and Paul Maycock of PV News, February 1996. Johnson and Maycock are two of the leading PV industry experts who have provided technology and market reports (including historical and forecasted PV sales data) for about two decades.
[14]Consumer applications: small "expendable" products such as solar powered calculators, toys, and walk lights (< five watts peak).

The total of new-system batteries in 1995 (1,536,000 kWh) plus the replacement batteries (1,425,000 kWh) equals 2,961,000 kWh of PV system battery sales. From Table 2-3, the average cost per kWh in 1995 was $102 per kWh (wholesale).

- **The worldwide wholesale value for PV batteries shipped in 1995 was $302 million.**

The approximations which went into this calculation will limit the accuracy to about ± 25 percent, so that an appropriate range for wholesale dollar value would be $226 to $378 million.

It is estimated that about 11.5 percent[15] of the total 64 MW of stand-alone PV were installed in the U.S. in 1995. Therefore, total PV battery sales in the U.S. were 11.5%*2,961,000 kWh or 340,515 kWh (or about 11.5%*$302 million = $34.7 million).

- **This indicates that the 21 System Integrators control about $4.76 million[16]/34.7 million = 14 percent of the U.S. PV battery market (in terms of dollar sales).**

Using the same methodology to calculate the newly installed capacity each year (not counting replacement batteries, it is estimated that:

- **Approximately 10,519,000 kWh of batteries are currently installed in PV systems worldwide.**

Table 2-18a provides a summary of the worldwide top-down market data for 1995, while Table 2-18b provides a similar summary for the U.S. market. Data for years 1991 and 2000 are also included in these tables for comparison.

[15]Based on estimates of 12.8 percent by Paul Maycock (PV News) and 10.6 percent by Bob Johnson (Strategies Unlimited) during telephone conversations November 1, 1996.
[16]see Table 2-3 *Totals For All Batteries.*

TABLE 2-18a. WORLDWIDE TOP-DOWN PV BATTERY MARKET ESTIMATES

		Units	1991	1995	2000
a	Worldwide PV module shipments, stand-alone systems with batteries. [See note 1]	MW	44	64	134
b	50 watt (peak) of new PV module installation. [b=(a/50)*1.2*1000]	MWh	1,056	1,536	3,216
c	PV Replacement batteries based on average battery life of five years. [See note 1. See text for methodology.]	MWh	618	1,425	2,961
d	Total PV Batteries; new installations plus replacement batteries for the year indicated. [d=(b+c)]	MWh	1,674	2,961	6,177
e	Total PV Batteries (units) based on a "typical" size battery of 1.2 kWh (e.g., 12V-100AH). [e=d/(1.2*1000)]	No. Millions	1.40	2.47	5.15
f	Total dollar value of PV batteries based on $102/kWh (see Table 2-3). [f=d*102/1000]	$, Million	$ 171	$ 302	$ 630
g	1995, and 2000. [See note 1 for source of data and text for methodology.]	MWh	5,309	10,519	22,761
h	Total installed capacity of PV batteries from 1980 to: 1991, 1995, and 2000 (1.2 kWh "typical" size). [h=g*1000/1.2]	No. Millions	4.42	8.77	18.97
i	Total installed capacity of PV batteries from 1980 to: 1991, 1995, and 2000 ($102/kWh). [i=g*102/1000]	$, Million	$ 542	$ 1,073	$ 2,322

TABLE 2-18b. US TOP-DOWN PV BATTERY MARKET ESTIMATES

		Units	1991	1995	2000
a	US PV module shipments, stand-alone systems with batteries. [See note 1 and footnote 13][a=.115*(a of Table 2-18a)]	MW	5.06	7.36	15.41
b	PV batteries shipped, based on 1.2 kWh of batteries per each 50 watt (peak) of new PV module installation. [b=(a/50)*1.2*1000]	MWh	121	177	370
c	PV Replacement batteries based on average battery life of five years. [See note 1. See text for methodology.]	MWh	71	164	341
d	Total PV Batteries; new installations plus replacement batteries for the year indicated. [d=(b+c)]	MWh	193	341	710
e	Total PV Batteries (units) based on a "typical" size battery of 1.2 kWh (e.g., 12V-100AH). [e=d/(1.2*1000)]	No. Millions	0.16	0.28	0.59
f	Total dollar value of PV batteries based on $102/kWh (see Table 2-3). [f=d*102/1000]	$, Million	$ 20	$ 35	$ 72
g	Total installed capacity of PV batteries from 1980 to: 1991, 1995, and 2000. [See note 1 for source of data and text for methodology.]	MWh	611	1,210	2,618
h	Total installed capacity of PV batteries from 1980 to: 1991, 1995, and 2000 (1.2 kWh "typical" size). [h=g*1000/1.2]	No. Millions	0.51	1.01	2.18
i	Total installed capacity of PV batteries from 1980 to: 1991, 1995, and 2000 ($102/kWh). [i=g*102/1000]	$, Million	$ 62	$ 123	$ 267

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Note 1. These data are based on conversations with Bob Johnson, Strategies Unlimited (May 1996) and the publication PV News, February 1996, by Paul Maycock. Years 1991 and 1995 are based on historical data; data for the year 2000 are based on projections by Johnson and Maycock.
Johnson and Maycock are two of the leading PV industry experts who have provided technology and market reports (including historical and forecasted PV sales data) for about two decades.

PART 2. BATTERY INFORMATION NEEDED FOR PV SYSTEM DESIGN

The purpose of Part 2 of Survey A was to determine what information PV System Integrators needed from battery manufacturers in order to properly design PV systems with optimum performance and minimum life-cycle cost. The desired end result of Part 2 is that battery manufacturers will develop data sheets for the PV system designer that includes the information defined in Table 2-19. Each parameter was ranked as: 1 (Essential), 2 (Useful), or 3 (Not important) by each respondent

Table 2-19 includes the average rating from the Small System Integrators, Large System Integrators, and the average of the two rankings for each parameter. The parameters are listed in ascending order of the Large System Integrator for the following reasons:

- The Large System Integrators shipped 78 percent of the number of batteries and 88 percent of the dollar volume of batteries compared to the Small System Integrators (see Tables 2-4, 2-5 and 2-6)
- The Large System Integrators typically invest more resources than Small Integrators for research, development, and design of PV systems.
- The Large System Integrators have the most influence over the technical content of battery data sheets because of their sales volume and high level of system design expertise.

Responses from Small and Large Integrators track quite well for the 29 parameters listed, with the exception of "cost". Small Integrators ranked costs as 1.23, whereas the Large Integrators ranked it as 1.00. This implies that system sales and/or battery sales are less sensitive to cost for Small Integrators than Large Integrators. One reason for this may be that there is less competition for small local sales.

The responses from the 1991 survey are also shown in Table 2-19 for comparison with the 1995 results. While the rank order is very similar for 1991 and 1995 responses, the 1991 respondents rated nearly all parameters as essential or useful (very few responses were in the "not important" category).

TABLE 2-19. BATTERY INFORMATION NEEDED FOR PV SYSTEM DESIGN

1 = Essential, 2 = Useful, 3 = Not Important

	1991	1995			
	7 Large	Small	**Large**	Average	PARAMETER(S)
1	1.00	1.23	**1.00**	1.12	Cost
2	1.00	1.08	**1.00**	1.04	Nominal battery voltage
3	1.00	1.77	**1.14**	1.46	Amp-hour capacity at C/100
4	1.14	1.31	**1.14**	1.23	Recommended charging voltage vs. temperature vs. charge rate
5	1.14	1.15	**1.29**	1.22	Physical characteristics; dimensions, terminal size, weight
6	1.14	1.77	**1.29**	1.53	Shipping hazard code
7	1.29	1.54	**1.43**	1.48	Allowed and preferred orientations
8	NA	1.85	**1.43**	1.64	Amp-hour capacity at C/20
9	1.43	1.38	**1.43**	1.40	Battery life vs average daily DOD vs temperature
10	1.29	1.62	**1.43**	1.52	Recommended maintenance schedule
11	1.43	1.85	**1.43**	1.64	SOC as a function of battery voltage
12	1.14	1.31	**1.43**	1.37	Warranty (and warranty restrictions)
13	1.71	1.92	**1.57**	1.75	Maximum system voltage to ground
14	1.43	1.46	**1.57**	1.52	Recommended controller set points
15	1.43	1.69	**1.57**	1.63	State of Charge (SOC) vs Voc
16	1.43	1.67	**1.71**	1.69	SOC vs battery voltage at C/20
17	1.71	2.31	**1.86**	2.08	Available dry charged?
18	1.57	1.85	**1.86**	1.85	Electrolyte freezing point vs SOC
19	1.29	1.77	**1.86**	1.81	Maximum shelf life
20	1.71	2.00	**1.86**	1.93	Series/parallel recommendations
21	NA	2.00	**2.00**	2.00	Amp-hour capacity at C/8
22	1.57	2.00	**2.00**	2.00	Plate construction and additives
23	1.29	1.77	**2.00**	1.89	Recommended equalization procedure
24	1.71	1.54	**2.00**	1.77	Self-discharge rate vs temperature
25	1.71	2.23	**2.14**	2.19	Reserve electrolyte capacity
26	1.71	2.23	**2.14**	2.19	Special features such as extra electrolyte reserve
27	1.57	1.85	**2.29**	2.07	SOC as a function of specific gravity
28	1.43	2.00	**2.29**	2.14	Specific gravity typically shipped
29	1.57	2.31	**2.33**	2.32	Disposal/recycling instructions

Additional parameters (1995) not included in the survey (write-in, one time mention):

1 Absolute operating temperature limits
2 Allowable cell to cell voltage differences
3 Battery environmental areas; Battery Air Venting control;
4 Spill protection; Terminal & connection care; Sulfate controls.
5 Conductance
6 Fusing recommendations
7 Internal resistance values
8 Material Safety Sheet
9 Mounting Bolt Locations
10 Number of "conditioning" cycles (vs DOD) to reach full charge
11 Shipped capacity & chart showing full capacity gained after x cycles.
12 Short circuit current or internal resistance
13 Termination type, size, options

A-PART2.XLS TOTAL

PART 3. PV SYSTEM OPERATING CONDITIONS

The purpose of this part of the survey was to profile
1. System Integrators' application of PV hardware,
2. their design approach to PV systems, and
3. the environment into which PV systems are placed.

Respondents were asked to answer 20 questions (see Appendix A for the format of the actual questions). Many, if not most of the responses were subjective and represent the perception of the individual that completed the survey. Results are presented in Tables 2-20 through 2-29.

Where data from Small and Large System Integrators are averaged, a weighted average is used (Small Integrators have a weight of 12 and Large System Integrators have a weight of 88). This weighting is based on dollar sales per Table 2-3. Question 20 is an exception to this method of averaging, where equal weight is given to Small and Large System Integrators.

Answers to questions are tabulated in Tables 2-20 through 2-29. The following are highlights of answers to each question.

Question 1. *What percent of your balance of system is provided by another systems house?* This question was intended to determine to what degree the 21 respondents purchased hardware from each other and to determine the degree of "double counting" battery sales when compiling survey results. The results shown are somewhat deceiving since only two Small System Integrators showed any purchases from another System Integrator (dealers buying from distributors). These two integrators together reported <u>less than 0.1 percent of the total kWh</u> of batteries reported in 1995.

Question 2. *If battery manufacturers recommended specific set points for their batteries in PV systems, would you use them?* Responses indicate that 42 percent of the Small System Integrators and 71 percent of the Large System Integrators would verify battery manufacturer's charge controller set point recommendations before implementing the recommendations.

Question 3. *If battery manufacturers recommended specific charging algorithms for their batteries in PV systems, would you use them?* Like question 2, the majority of System Integrators want to verify battery manufacturer's recommendations (charging algorithms[1]) before using in field applications.

Question 4. *What percentage of the advertised battery cycle life do you estimate that you get?* Respondents believe that they get, on average, 78 percent of the advertised battery cycle life. The answers were about the same for Flooded-vented, AGM, or Gel technologies.

Question 5. *What percentage of your systems are designed for the following battery temperature extremes?*
Most system designs fall within the temperature range of -20F to +140F. System designs are distributed throughout this range, indicating that designs are highly temperature dependent.

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[1]Algorithm: a step-by-step procedure for solving a problem (frequently involving repetition of an operation) or accomplishing some end. In this application, an *algorithm* defines the process or technique used to prevent overcharging the battery.

Question 6. *What percentage of your system design use: (five part question)?* This question covers five broadly related topics concerning how the designer compensates for expected temperatures. Temperature compensation, for example, is used with 60 percent of voltage regulators (i.e., charge controllers).

Question 7. *What percentage of flooded-vented batteries use catalytic recombiner caps (i.e. Hydrocaps ^{tm})?* The survey shows that 31 percent of flooded-vented batteries use catalytic combiner caps, and that cost is the primary reason that the number is not higher than 31 percent.

Question 8. *Do you receive adequate information from the manufacturer regarding battery lifetime vs. depth of discharge?* Battery manufacturers received a score of 2.03 out of 5.00 for providing adequate information regarding lifetime vs. depth of discharge.

Question 9. *Do you feel that you have adequate information from the manufacturer regarding battery lifetime vs. temperature?* While 38 percent of the Small System Integrators reported that they have adequate information from the manufacturer regarding battery lifetime vs. temperature, none of the eight Large System Integrators received adequate information.

Question 10. *What percentage of your stand-alone systems use a maximum power tracker?* SSIs (Small System Integrators) reported that 14 percent of their systems use maximum power trackers while none of the LSIs (Large System Integrators) reported using maximum power trackers. It is unlikely that any of the SSIs used maximum power trackers, and that they interpreted the question as 2-axis tracker rather than a maximum power tracker.

Question 11. *What percentage of your systems use ni-cad batteries?* None of the System Integrators used Ni-Cad batteries in 1995.

Question 12. *What percentage of your systems operate at the following average amp-hour discharge rate?* Eighty-three percent of the systems were designed for a discharge rate between C/60 and C/200. SSIs typically design systems with <u>twice</u> the discharge rate of the LSIs.

Question 13. *When batteries are received, what do you estimate is the percentage of the rated amp-hour capacity they will deliver?* "As Received" batteries are typically at 83 percent of rated capacity and 81 percent of these batteries receive about 7.6 hours of charge before field installation. Less than 50 percent of the Small System Integrators charge the batteries before applying them in the application.

Question 14. *When designing a system and selecting a battery, what capacity value do you use the most?* Responses to this question again show a philosophical difference between Large and Small System Integrators. While Small System Integrators will have a tendency to match the discharge rate more closely to the application, Large System Integrators size the system more conservatively. Sixty-five percent of systems are designed using a C/100 capacity rating and about 24 percent use a C/20 rating.

Question 15. *What percentage of systems have a typical daily depth-of-discharge of: ( )?* This question asks for a profile of the battery depth of discharge (DOD). Ninety percent of the systems are designed for a DOD between 0-25 percent.

Question 16. *Low Voltage Disconnect (LVD):* This question consists of five questions, all related to Low Voltage Disconnect (LVD).

16a. *Where do you get the information for your LVD setting?* Seventy-one percent of LVDs settings are based on experience, not by literature from battery or charge controller literature.

16b. *Do you adjust the LVD set point(s) for low or high discharge rates?* Forty-six percent of the LVDs are adjusted for the expected discharge rate.

16c. *What LVD set point(s) do you use (based on a nominal 12 Vdc system)?* LVD set points are defined by discharge rate, and are fairly consistent for SSIs and LSIs.

16d. *When selecting an LVD set point, what is your single most important criteria in your decision?* Eighty-one percent of set points are selected to reduce the DOD in order to increase battery life.

16e. *What is the maximum depth-of-discharge (based on LVD settings) you typically design for?* Maximum DOD typically designed for is 70-80 percent for both Flooded-vented and VRLA batteries.

Question 17. *Charging Algorithms. For each controller type, indicate in Row 2 the percentage of systems that match the charge rate. Iin Row 3 indicate the typical system battery bank size (i.e., total amp hours).* Data regarding Charge Controller Algorithms vs. charge rate and battery bank size are summarized in Tables 23, 24, and 25. Responses to this question are organized by Small Integrators (17a), Large Integrators (17b) and Summary (17c). Table 2-25, Summary, shows that 79 percent of the Integrators use ON-OFF controllers, 7 percent use constant voltage controllers, 12 percent use pulse-width modulation controllers and 2 percent use no controller.

Although nearly 80 percent of the Integrators use charge controllers with the ON-OFF algorithm, this algorithm is the one most difficult for which to define voltage set points. Battery manufacturers rarely provide set point information for the ON-OFF controller and the optimum set points are a function of variables such as net charging current and battery state of charge. Verbal responses from Integrators indicate that they use this algorithm because: a) it is the lowest cost controller and/or b) when it is used with a mercury displacement relay, it is the least likely to be damaged by lightning.

Question 18. *Where do you get the information for your voltage regulation setting?* System Integrators obtain voltage regulator set points from battery manufacturer's literature (60%), charge controller manufacturers (32%), and prior experience (46%). The totals for Small and Large System Integrators (see Table 2-26) exceed 100 percent because many Integrators checked more than one source (i.e., they use more than one source of information).

Question 19. *What voltage regulation set points do you use for 12 V nominal batteries?* Voltage regulator set points are defined as a function of voltage regulator algorithm and battery charge rate for 12 volt batteries. Not all System Integrators use all types of charge controllers or all categories of charge rates. In numerous cases, the average values shown represent the response from only one systems house.

Responses to Question 19 are tabulated in Tables 2-27 and 2-28. These data are also presented graphically in Charts 2-19 through 2-26. These data show a wide range of set points used by the System Integrators, indicating that there is little consensus among the respondents as to the "correct" set points. This is particularly true for Flooded-vented (FLA) batteries. Set points for FLA batteries are dependent to some extent on the battery design. The factory recommended equalization set point for the Delco 2010, for example, is 16.5 Vdc. This stands out as an isolated point in Chart 2-19.

In general, set points for Valve-Regulated (VRLA) batteries are lower than for FLA batteries, and the set points are fairly consistent among all respondents.

Question 20. *If Sandia National Laboratories' Photovoltaic Design Assistance Center were able to expand the program to provide assistance in developing the market for batteries in PV systems, please indicate your areas of preference.* The responses clearly want the most help in the first category: Assist in the characterization of batteries for PV specifications (data sheet values), with 54 percent of Small Integrators showing this as the highest priority and 71 percent of the Large Integrators showing this as the highest priority.

Table 2-19 on page 2-20 is related to this question, since it defines the data sheet parameters of interest to the integrators.

TABLE 2-20. QUESTIONS 1-6

	SYSTEM INTEGRATORS		
	Small	**Large**	**Avg. [1]**
Question 1			
What percent of your balance of system is provided by another systems house?	20%	0	2%
Question 2			
If battery manufacturers recommended specific set points for their batteries in PV systems, would you use them?			
a) Yes	58%	29%	32%
b) No	0%	0%	0%
c) Evaluate before use	42%	71%	68%
Question 3			
If battery manufacturers recommended specific charging algorithms for their batteries in PV systems would you use them?			
a) Yes	42%	29%	30%
b) No	0%	0%	0%
c) Evaluate before use	58%	71%	70%
Question 4			
What percentage of the advertised battery cycle life do you estimate that you get?			
a) Flooded-vented	81%	78%	78%
b) VRLA/AGM	67%	78%	77%
c) VRLA /GEL	74%	78%	78%
Question 5			
What percentage of your systems are designed for the following battery temperature extremes?			
Low Temp; -60 to -40F	1%	1%	1%
Low Temp; -40 to -20F	9%	15%	14%
Low Temp; -20 to 0F	7%	22%	20%
Low Temp; 0 to 20F	21%	26%	26%
Low Temp; 20 to 40F	35%	22%	24%
Low Temp; 40 to 60F	23%	14%	15%
HighTemp; 60 to 80F	24%	9%	11%
HighTemp; 80 to 100F	33%	28%	29%
HighTemp; 100 to 120F	34%	37%	37%
HighTemp; 120 to 140F	6%	19%	18%
HighTemp; 140 to 160F	1%	6%	5%
Question 6			
What percentage of your system designs used:			
a) Temp compensated voltage regulators	54%	61%	60%
b) Battery AH capacity derated for expected low temps	57%	76%	74%
c) Load current compensated low voltage disconnect	45%	36%	37%
d) Battery specific gravity adjusted for expected low temps	3%	16%	14%
e) Insulated battery boxes (or cool cells)	35%	36%	36%

Note 1. Weighted average: Small=12; Large=88 (based on $ sales; see Table 2-6) A-PART3.XLS Q1-6

TABLE 2-21. QUESTIONS 7 THROUGH 14

	SYSTEM INTEGRATORS		
	Small	**Large**	**Avg. [1]**
Question 7			
What percentage of flooded-vented batteries use catalytic recombiner caps (i.e. Hydrocaps)?	16%	33%	31%
If you don't use, why:			
a: Cost	40%		40%
b: Lack of information on performance	10%	29%	26%
c: Didn't know they existed	0%		0%
d: Other	40%		40%
Question 8			
Do you receive adequate information from the manufacturer regarding battery lifetime vs depth of discharge? (1=poor; 5=excellent)	3.25	1.86	2.03
Question 9			
Do you feel that you have adequate information from the manufacturer regarding battery lifetime vs temperature? (YES)	38%	0%	4.6%
Question 10			
What percentage of your stand-alone systems use a maximum power tracker?	14%	0%	2%
Question 11			
What percentage of your systems use ni-cad batteries?	0%	0%	0%
Question 12			
What percentage of your systems operate at the following average amp-hour discharge rate:			
a) C/8-C/15	6%	1%	1%
b) C/15-C/30	25%	6%	8%
c) C/30-C/60	16%	8%	9%
d) C/60-C/100	35%	33%	34%
e) C/100-C/200	18%	54%	49%
Question 13			
When batteries are received:			
a. what is the percentage of the rated amp-hour capacity that they will deliver?	76%	84%	83%
b. Do you boost charge the batteries before installing them in the field? YES	46%	86%	81%
If yes - hours of charge (0, 2, 4, 8, 12, 16)	10.4	7.2	7.6
Question 14			
When designing a system and selecting a battery, what capacity value do you use the most? Indicate percent of batteries in each category:			
a) Manufacturer's C/20	53%	20%	24%
b) Manufacturer's C/100	38%	68%	65%
c) Other value	9%	12%	12%

A-PART3.XLS

Note 1. Weighted average: Small=12; Large=88 (based on $ sales; see Table 2-6)

A-PART3.XLS Q7-14

TABLE 2-22. QUESTIONS 15 AND 16

		SYSTEM INTEGRATORS								
		Small			Large			Total [1]		
		Min	Avg	Max	Min	Avg	Max	Min	Avg	Max
Question 15										
What percentage of systems have a typical daily depth-of-discharge of:										
a) Flooded Batteries	0-5% daily DOD		12%			18%			18%	
	5-10% daily DOD		14%			24%			22%	
	10-15% daily DOD		14%			26%			25%	
	15-25% daily DOD		36%			23%			24%	
	25-50% daily DOD		18%			4%			6%	
	50-100% daily DOD		6%			4%			4%	
b) VRLA Batteries	0-5% daily DOD		7%			19%			18%	
	5-10% daily DOD		17%			37%			35%	
	10-15% daily DOD		26%			19%			19%	
	15-25% daily DOD		47%			19%			22%	
	25-50% daily DOD		2%			2%			2%	
	50-100% daily DOD		0%			3%			3%	
Question 16										
Low Voltage Disconnect (LVD)										
a. Where do you get the information for your LVD setting?										
	Battery Mfg. Literature		23%			14%			15%	
	Charge controller Mfg.		8%			29%			26%	
	Experience		69%			71%			71%	
b. Do you adjust the LVD set point(s) for low or high discharge rates?										
	Yes		69%			43%			46%	
	No		31%			57%			54%	
c. What LVD set point(s) do you use? (based on a nominal 12 Vdc system)										
	C/8-C/15	10.5	11.1	11.6	11.0	11.3	11.7	10.9	11.3	11.7
	C/15-C/30	10.8	11.4	12.0	11.2	11.4	11.7	11.2	11.4	11.7
	C/30-C/60	10.5	11.2	11.8	11.3	11.5	11.7	11.2	11.5	11.7
	C/60-C/100	10.6	11.3	11.9	11.5	11.5	11.7	11.4	11.6	11.7
	C/100-C/200	11.0	11.5	12.0	11.0	11.5	11.8	11.0	11.4	11.8
d. When selecting an LVD set point, what is the single most important criteria in your decision:										
	Reduced dod for increased lifetime		50%			86%			81%	
	Maximum usable capacity		50%			29%			31%	
e. What is the maximum depth-of-discharge you typically design for (based on LVD setting)?										
Flooded-Vented Batteries	0-25% daily DOD		1%			1%			1%	
	25-50% daily DOD		1%			19%			17%	
	50-70% daily DOD		14%			9%			9%	
	70-80% daily DOD		56%			64%			63%	
	80-90% daily DOD		26%			8%			10%	
	90-100% daily DOD		1%			0%			0%	
VRLA Batteries	0-25% daily DOD		17%			1%			3%	
	25-50% daily DOD		8%			17%			16%	
	50-70% daily DOD		28%			13%			15%	
	70-80% daily DOD		19%			63%			58%	
	80-90% daily DOD		28%			6%			8%	
	90-100% daily DOD		1%			0%			0%	

Note 1. Weighted average: Small=12; Large=88 (based on $ sales; see Table 2-6)

A-PART3.XLS Q15-16

TABLE 2-23. QUESTION 17A; SMALL SYSTEM INTEGRATORS

Question 17. Charge Controller Algorithms	SMALL SYSTEM INTEGRATORS												
	#1	**#2**	**#3**	**#4**	**#5**	**#6**	**#7**	**#8**	**#9**	**#10**	**#11**	**#12**	**#13**
a) ON-OFF Controller													
% using this algorithm	40%	100%	100%	40%	30%	60%	40%	40%	10%	100%	0%	100%	52%
% using charge rate C/8-C/15	50	93		60		10				50		93	2
Battery Bank Size,AH	220	66		400		7				30		66	3000
% using charge rate C/15-C/30	50	7	10	30		30	50	90		50		7	15
Battery Bank Size,AH	660	132	250	600		300	90			270		132	1200
% using charge rate C/30-C/60			80	10		50	50	10	100				60
Battery Bank Size,AH			250	1000		1000	90		3100				1200
% using charge rate C/60-C/100			10			10							23
Battery Bank Size,AH			250			2000							800
% using charge rate C/100-C/200													
Battery Bank Size,AH													
b) Constant voltage													
% using this algorithm	40%	0%	0%	0%	25%	19%	0%	40%	89%	0%	100%	0%	4%
% using charge rate C/8-C/15	50										5		2
Battery Bank Size,AH	220										1000		3000
% using charge rate C/15-C/30	50		100			100		100			80		15
Battery Bank Size,AH	660		12			700		100			800		1200
% using charge rate C/30-C/60									100		10		60
Battery Bank Size,AH									270		400		1200
% using charge rate C/60-C/100											3		23
Battery Bank Size,AH											100		1200
% using charge rate C/100-C/200											2		
Battery Bank Size,AH											100		
c) Pulse width modulation													
% using this algorithm	20%	0%	0%	60%	40%	20%	60%	20%	0%	0%	0%	0%	44%
% using charge rate C/8-C/15	100			15			16						2
Battery Bank Size,AH	880			800			12						3000
% using charge rate C/15-C/30				75			26	100					15
Battery Bank Size,AH				1200			100	100					1200
% using charge rate C/30-C/60				10		100	58						60
Battery Bank Size,AH				1500		800	90						1200
% using charge rate C/60-C/100													23
Battery Bank Size,AH													1200
% using charge rate C/100-C/200													
Battery Bank Size,AH													
d) Other Charging Algorithms?	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
e) No charge controller	0%	0%	0%	0%	5%	1%	0%	0%	1%	0%	0%	0%	0%

A-PART3.XLS Q17A

TABLE 2-24. QUESTION 17B; LARGE SYSTEM INTEGRATORS

	LARGE SYSTEM INTEGRATORS							
	#1	#2	#3	#4	#5	#6	#7	#8
a) ON-OFF Controller								
% using this algorithm	95%	100%	60%	95%	85%	60%	80%	80%
% using charge rate C/8-C/15				0		0		
Battery Bank Size, AH								
% using charge rate C/15-C/30		100	10	60	8	80		
Battery Bank Size, AH			>100	100		100		
% using charge rate C/30-C/60			40	30	70	0	20	
Battery Bank Size, AH			>100	100			100	
% using charge rate C/60-C/100	100		40	5	20	20	20	
Battery Bank Size, AH	300		>100	36		100	200	
% using charge rate C/100-C/200			10	5	2	0	60	
Battery Bank Size, AH		100	>100	12			1000	
b) Constant voltage								
% using this algorithm	1%	0%	20%	2%	2%	20%	0%	0%
% using charge rate C/8-C/15				0		0		
Battery Bank Size, AH								
% using charge rate C/15-C/30			10	100		80		
Battery Bank Size, AH			>100	280		100		
% using charge rate C/30-C/60			40	0	90	0		
Battery Bank Size, AH			>100					
% using charge rate C/60-C/100	100		40	0	10	20		
Battery Bank Size, AH	300		>100			100		
% using charge rate C/100-C/200			10	0		0		
Battery Bank Size, AH			>100					
c) Pulse width modulation								
% using this algorithm	2%	0%	20%	2%	3%	20%	20%	20%
% using charge rate C/8-C/15			0	0		0		
Battery Bank Size, AH								
% using charge rate C/15-C/30			20	0	5	80		
Battery Bank Size, AH						100		
% using charge rate C/30-C/60			30	100	707	0	50	
Battery Bank Size, AH				3000			90	
% using charge rate C/60-C/100	100		30	0	20	20	50	
Battery Bank Size, AH	100					100	180	
% using charge rate C/100-C/200			0	0	5	0		
Battery Bank Size, AH								
d) Other Charging Algorithms?	0%	0%	0%	0%	0%	0%	0%	0%
e) No charge controller	2%	0%	0%	1%	10%	0%	0%	0%

A-PART3.XLS Q17B

TABLE 2-25. QUESTION 17C: WEIGHTED AVERAGES

Question 17C. Charge Controller Algorithms			
SUMMARY:	Averages, in Percent		
A-PART3.XLS Q17C	Small	Large	Avg. [1]
a) ON-OFF Controller	55%	82%	79%
b) Constant voltage	24%	5%	7%
c) Pulse width modulation	20%	11%	12%
d) Other algorithn	0%	0%	0%
e) No charge controller	1%	2%	2%

Note 1. Weighted average: Small=12; Large=88 (based on $ sales; see Table 2-6)

TABLE 2-26. QUESTION 18

Question 18			
Where do you get the information for your voltage regulation setting?	SYSTEM INTEGRATORS		
	Small	Large	Total [1]
Battery Mfg. Literature	85%	57%	60%
Charge controller Mfg.	54%	29%	32%
Prior experience	69%	43%	46%

Note 1. Weighted average: Small=12; Large=88 (based on $ sales; see Table 2-6) A-PART3.XLS Q18

TABLE 2-27. QUESTION 19 A & B

Question 19 a & b		SYSTEM INTEGRATORS								
What voltage regulation setpoints do you use for 12 V nominal batteries?		Small			Large			Total [1]		
		Min	Avg	Max	Min	Avg	Max	Min	Avg	Max
a. Series-interrupting & shunt-interrupting (i.e., on/off)										
Flooded lead antimony	C/8-C15	14.20	14.38	15.10	14.70	14.70	14.70	14.64	14.66	14.75
	C15-C30	14.20	14.69	16.50	14.50	14.60	14.80	14.46	14.61	15.00
	C30-C60	14.00	14.38	15.10	14.40	14.67	14.80	14.35	14.63	14.84
	C60-C100	14.20	14.50	15.10	14.10	14.40	14.80	14.11	14.41	14.84
	C100-C200	14.20	14.62	15.10	14.00	14.00	14.00	14.02	14.07	14.13
Flooded lead-calcium	C/8-C15	13.80	14.17	14.40				13.80	14.17	14.40
	C15-C30	13.80	14.30	14.70	14.50	14.65	14.80	14.42	14.61	14.79
	C30-C60	13.80	14.13	14.40	14.80	14.80	14.80	14.68	14.72	14.75
	C60-C100	13.80	14.23	14.60				13.80	14.23	14.60
	C100-C200	13.80	14.33	14.90				13.80	14.33	14.90
VRLA/Gel	C/8-C15	13.90	14.03	14.10				13.90	14.03	14.10
	C15-C30	13.90	14.05	14.20	14.10	14.23	14.30	14.08	14.21	14.29
	C30-C60	13.90	14.00	14.10	13.70	14.10	14.30	13.72	14.09	14.28
	C60-C100	14.10	14.10	14.10	13.70	14.08	14.30	13.75	14.08	14.28
	C100-C200	14.10	14.10	14.10	13.70	13.87	14.10	13.75	13.89	14.10
VRLA/AGM	C/8-C15	13.90	14.00	14.10	14.10	14.10	14.10	14.08	14.09	14.10
	C15-C30	13.90	14.10	14.30	14.10	14.23	14.30	14.08	14.22	14.30
	C30-C60	13.90	14.00	14.10	14.10	14.23	14.30	14.08	14.21	14.28
	C60-C100	14.10	14.10	14.10	13.80	14.18	14.30	13.84	14.17	14.28
	C100-C200	14.10	14.10	14.10	13.80	13.95	14.10	13.84	13.97	14.10
b. Constant voltage.										
Flooded lead antimony	C/8-C15	14.00	14.20	14.30	13.80	13.80	13.80	13.82	13.85	13.86
	C15-C30	14.00	14.26	14.50	13.80	13.80	13.80	13.82	13.85	13.88
	C30-C60	14.00	14.24	14.50	13.80	13.80	13.80	13.82	13.85	13.88
	C60-C100	14.00	14.18	14.30	13.80	14.05	14.05	13.82	14.07	14.08
	C100-C200	14.00	14.26	14.60	13.80	13.80	13.80	13.82	13.86	13.90
Flooded lead-calcium	C/8-C15	13.20	13.97	14.40				13.20	13.97	14.40
	C15-C30	13.20	13.97	14.40				13.20	13.97	14.40
	C30-C60	13.20	14.05	14.40				13.20	14.05	14.40
	C60-C100	13.20	14.03	14.60	14.30	14.30	14.30	14.17	14.27	14.34
	C100-C200	13.20	14.13	14.90				13.20	14.13	14.90
VRLA/Gel	C/8-C15	13.70	13.90	14.10	13.80	13.80	13.80	13.79	13.81	13.84
	C15-C30	13.70	14.03	14.40	13.80	13.80	13.80	13.79	13.83	13.87
	C30-C60	13.80	13.95	14.10	13.80	13.95	14.10	13.80	13.95	14.10
	C60-C100	13.80	14.00	14.10	13.80	14.07	14.10	13.80	14.06	14.10
	C100-C200	13.80	14.00	14.10	13.80	13.80	13.80	13.80	13.82	13.84
VRLA/AGM	C/8-C15	13.90	14.00	14.10	13.80	13.80	13.80	13.81	13.82	13.84
	C15-C30	13.90	14.07	14.20	13.80	13.80	13.80	13.81	13.83	13.85
	C30-C60	13.90	14.10	14.30	13.80	13.95	14.10	13.81	13.97	14.12
	C60-C100	14.10	14.10	14.10	13.80	14.07	14.10	13.84	14.07	14.10
	C100-C200	14.10	14.10	14.10	13.80	13.80	13.80	13.84	13.84	13.84

Note 1. Weighted average: Small=12; Large=88 (based on $ sales; see Table 2-6) A-PART3.XLS Q19 A-B

TABLE 2-28. QUESTION 19 C & D

Question 19 c & d			SYSTEM INTEGRATORS								
What voltage regulation set points do you use for 12 V nominal batteries?			Small			Large			Total [1]		
			Min	Avg	Max	Min	Avg	Max	Min	Avg	Max
c. Pulse width modulation.											
	Flooded lead antimony	C/8-C15	14.20	14.22	14.30	14.10	14.10	14.10	14.11	14.11	14.12
		C15-C30	14.20	14.25	14.40	14.00	14.00	14.00	14.02	14.03	14.05
		C30-C60	14.20	14.26	14.30	14.00	14.00	14.00	14.02	14.03	14.04
		C60-C100	14.20	14.25	14.30	13.90	14.10	14.10	13.94	14.12	14.12
		C100-C200	14.20	14.35	14.60	13.80	13.80	13.80	13.85	13.87	13.90
	Flooded lead-calcium	C/8-C15	13.10	13.93	14.40				13.10	13.93	14.40
		C15-C30	13.10	13.93	14.40				13.10	13.93	14.40
		C30-C60	13.10	14.03	14.40				13.10	14.03	14.40
		C60-C100	13.10	14.00	14.60	14.30	14.30	14.30	14.16	14.26	14.34
		C100-C200	13.10	14.10	14.90				13.10	14.10	14.90
	VRLA/Gel	C/8-C15	13.90	14.03	14.10	13.90	13.90	13.90	13.90	13.92	13.92
		C15-C30	13.90	14.03	14.10	13.90	13.90	13.90	13.90	13.92	13.92
		C30-C60	13.90	14.03	14.10	13.70	13.97	14.40	13.72	13.97	14.36
		C60-C100	14.10	14.10	14.10	13.70	14.05	14.40	13.75	14.06	14.36
		C100-C200	14.10	14.10	14.10	13.80	13.80	13.80	13.84	13.84	13.84
	VRLA/AGM	C/8-C15	13.90	14.00	14.10	13.90	13.90	13.90	13.90	13.91	13.92
		C15-C30	13.90	14.07	14.20	13.90	13.90	13.90	13.90	13.92	13.94
		C30-C60	13.90	14.00	14.10	13.80	14.03	14.40	13.81	14.03	14.36
		C60-C100	14.10	14.10	14.10	13.80	14.17	14.40	13.84	14.16	14.36
		C100-C200	14.10	14.10	14.10	13.80	13.80	13.80	13.84	13.84	13.84
d. Sub-Array control (controlling by sub-sections of the array)											
	Flooded lead antimony	C/8-C15	14.20	14.25	14.30	14.70	14.70	14.70	14.64	14.65	14.65
		C15-C30	14.20	14.33	14.50	14.50	14.50	14.50	14.46	14.48	14.50
		C30-C60	14.20	14.25	14.30	14.40	14.65	14.90	14.38	14.60	14.83
		C60-C100	14.20	14.25	14.30	14.10	14.20	14.30	14.11	14.21	14.30
		C100-C200	14.30	14.45	14.60	14.00	14.00	14.00	14.04	14.05	14.07
	Flooded lead-calcium	C/8-C15	14.30	14.30	14.30	0.00	0.00	0.00	1.72	1.72	1.72
		C15-C30	14.30	14.50	14.70	0.00	0.00	0.00	1.72	1.74	1.76
		C30-C60	14.30	14.30	14.30	0.00	0.00	0.00	1.72	1.72	1.72
		C60-C100	14.30	14.30	14.30	14.30	14.30	14.30	14.30	14.30	14.30
		C100-C200	14.30	14.30	14.30	0.00	0.00	0.00	1.72	1.72	1.72
	VRLA/Gel	C/8-C15	14.10	14.10	14.10	14.10	14.10	14.10	14.10	14.10	14.10
		C15-C30	14.10	14.10	14.10	14.10	14.10	14.10	14.10	14.10	14.10
		C30-C60	14.10	14.10	14.10	14.00	14.05	14.10	14.01	14.06	14.10
		C60-C100	14.10	14.10	14.10	13.90	14.10	14.30	13.92	14.10	14.28
		C100-C200	14.10	14.10	14.10	13.80	13.80	13.80	13.84	13.84	13.84
	VRLA/AGM	C/8-C15	14.10	14.10	14.10	14.10	14.10	14.10	14.10	14.10	14.10
		C15-C30	14.20	14.20	14.30	14.10	14.10	14.10	14.11	14.11	14.12
		C30-C60	14.10	14.10	14.10	14.00	14.17	14.40	14.01	14.16	14.36
		C60-C100	14.10	14.10	14.10	13.90	14.10	14.30	13.92	14.10	14.28
		C100-C200	14.10	14.10	14.10	13.80	13.80	13.80	13.84	13.84	13.84

Note 1. Weighted average: Small=12; Large=88 (based on $ sales; see Table 2-6)

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TABLE 2-29. QUESTION 20

Question 20

If Sandia National Laboratories' Photovoltaic Design Assistance Center were able to expand the program to provide assistance in developing the market for batteries in PV systems, please indicate your areas of preference.

	1 = **highest priority;** 5 = lowest priority														
	Averages for Small S.I.					Averages for Large S.I.					Averages for Sm. & Lg. [1]				
AREAS OF PREFERENCE	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
1. Assist in the characterization of batteries for PV specifications (data sheet values).	**54%**	15%	15%	0%	15%	**71%**	29%	0%	0%	0%	**63%**	22%	8%	0%	8%
2. Assist in the development of "application notes" or "application guides" for batteries.	38%	38%	15%	0%	8%	29%	57%	14%	0%	0%	34%	48%	15%	0%	4%
3. Provide technical assistance for charge controller manufacturers to characterize their newly developed controllers and algorithm.	0%	0%	46%	15%	38%	14%	0%	0%	29%	57%	7%	0%	23%	22%	48%
4. Act as technical liaison between the battery manufacturers and the charge controller industry.	38%	15%	23%	15%	8%	29%	29%	14%	0%	29%	34%	22%	19%	8%	18%

Note 1. Non-weighted average (i.e., equal weights for small and large)

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CHART 2-19. SERIES INTERRUPTING & SHUNT SET POINTS: SMALL INTEGRATORS

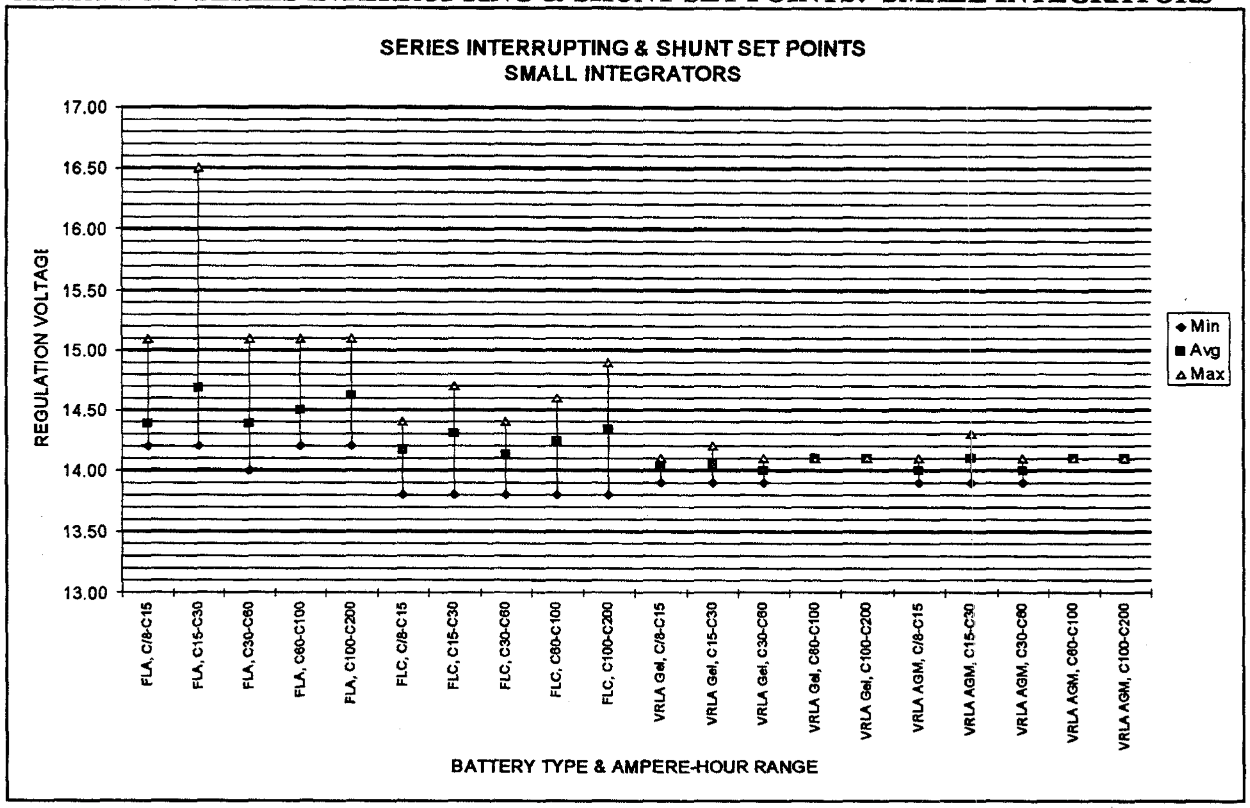


CHART 2-20. SERIES INTERRUPTING & SHUNT SET POINTS: LARGE INTEGRATORS

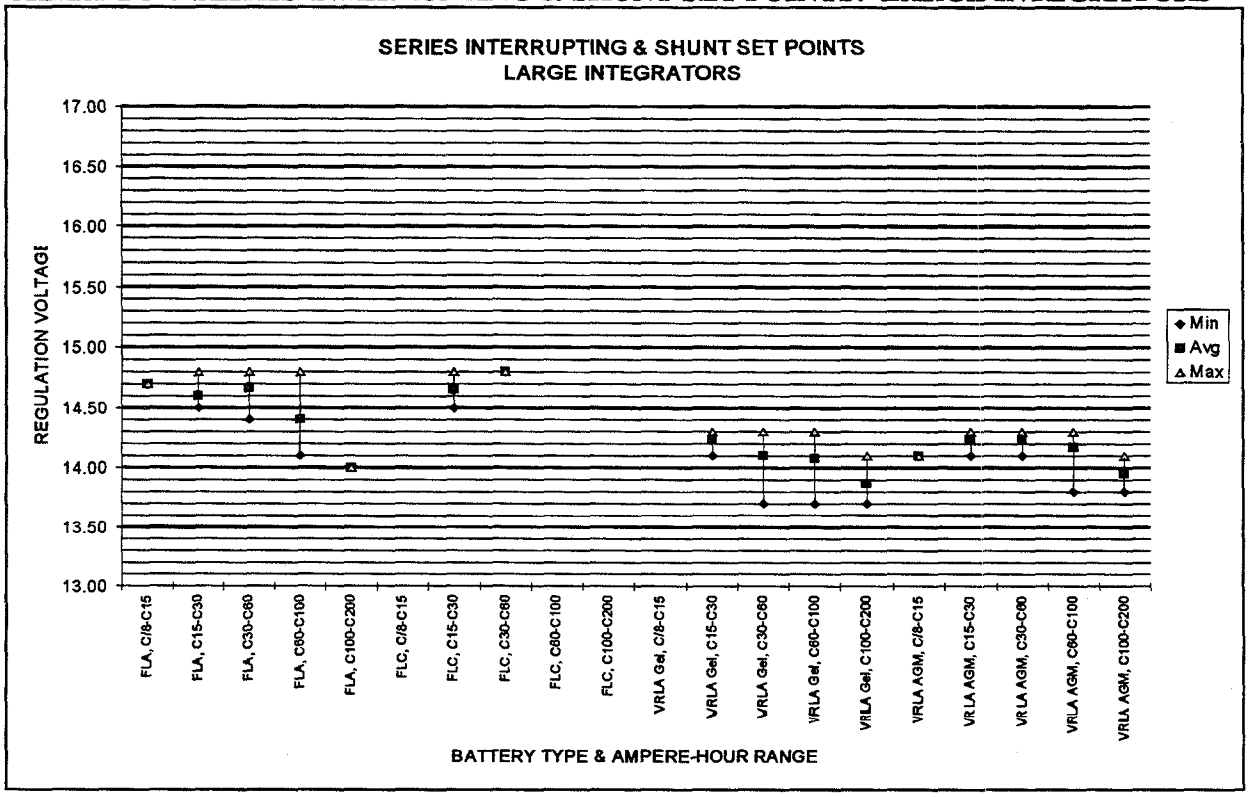


CHART 2-21. CONSTANT VOLTAGE SET POINTS: SMALL INTEGRATORS

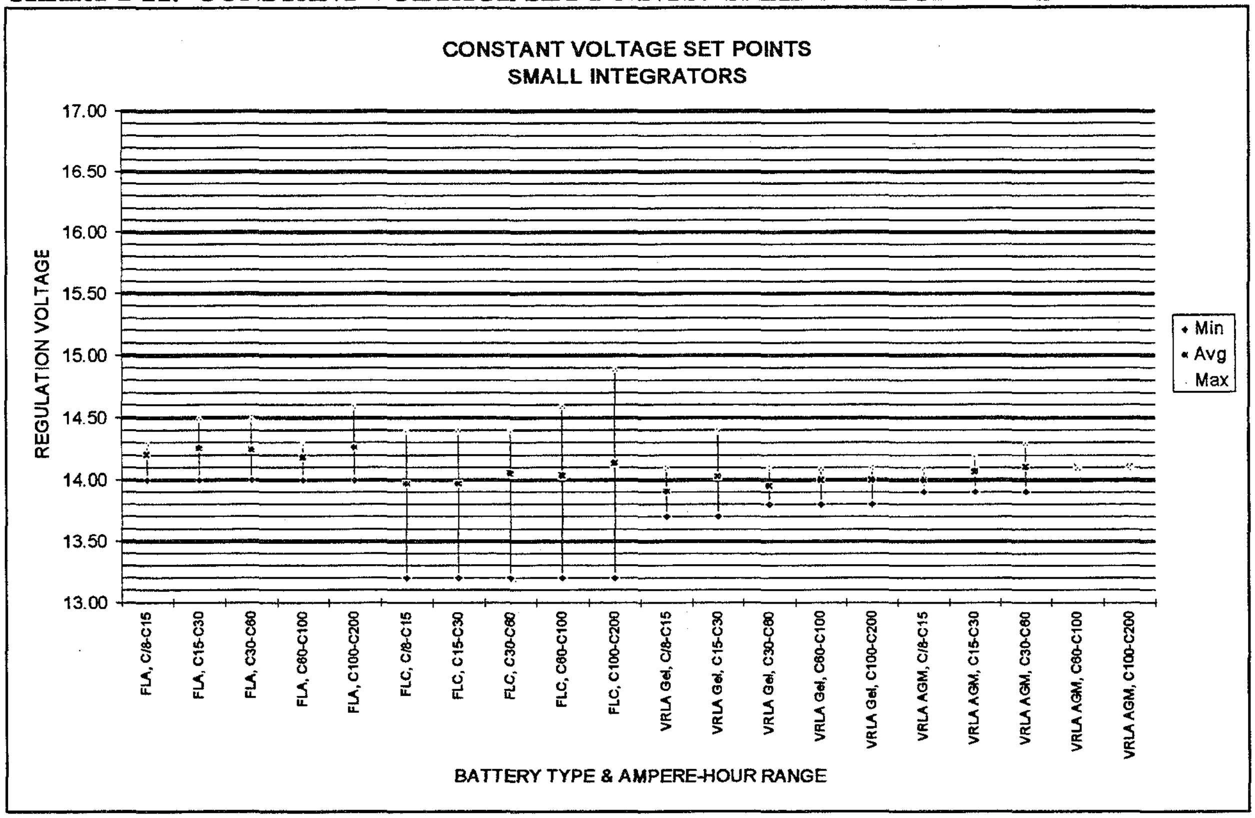


CHART 2-21. CONSTANT VOLTAGE SET POINTS: LARGE INTEGRATORS

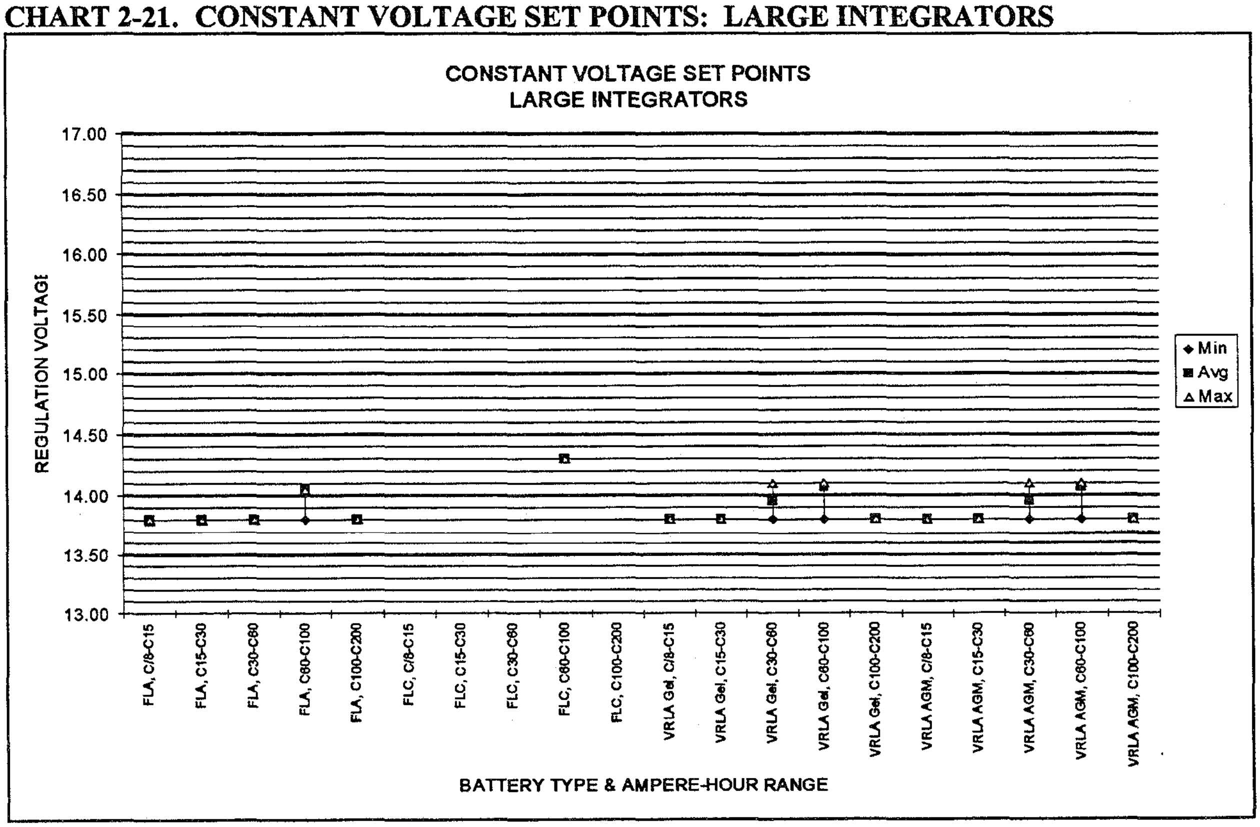


CHART 2-23. PULSE-WIDTH MODULATION SET POINTS: SMALL INTEGRATORS

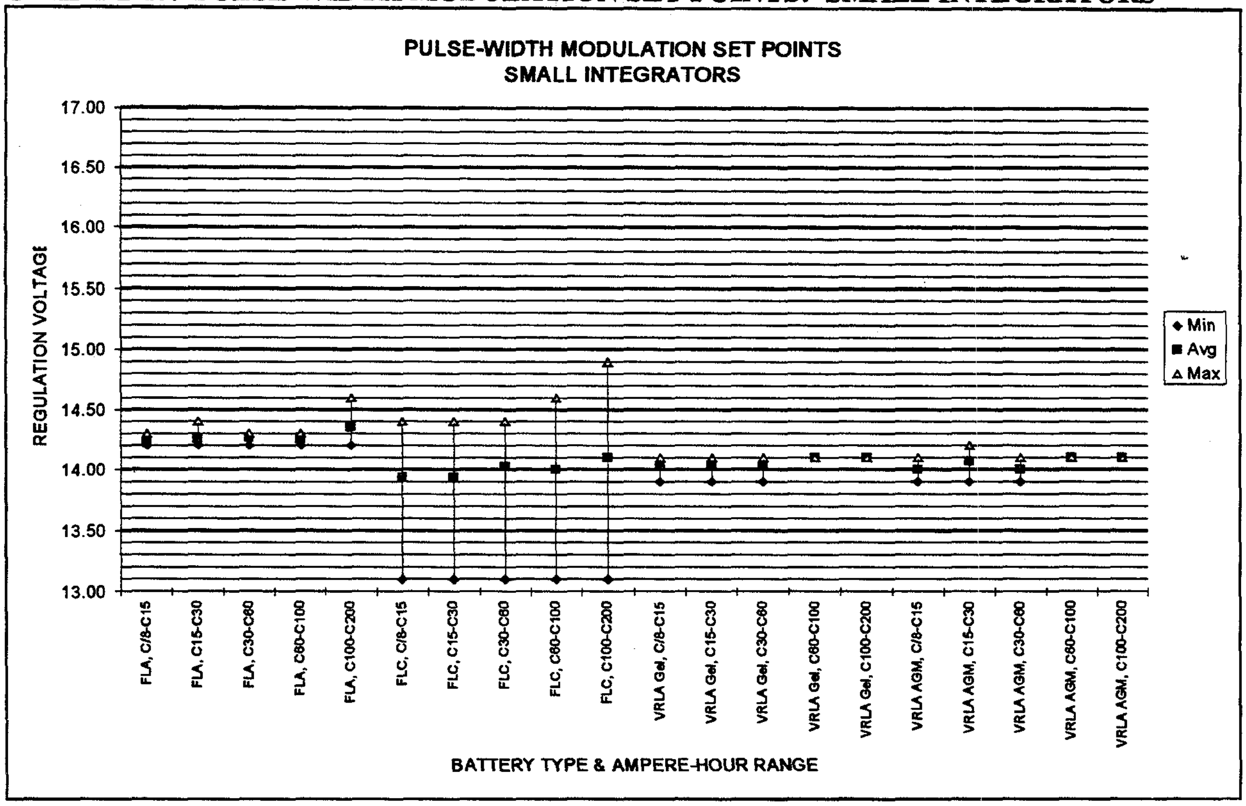


CHART 2-24. PULSE-WIDTH MODULATION SET POINTS: SMALL INTEGRATORS

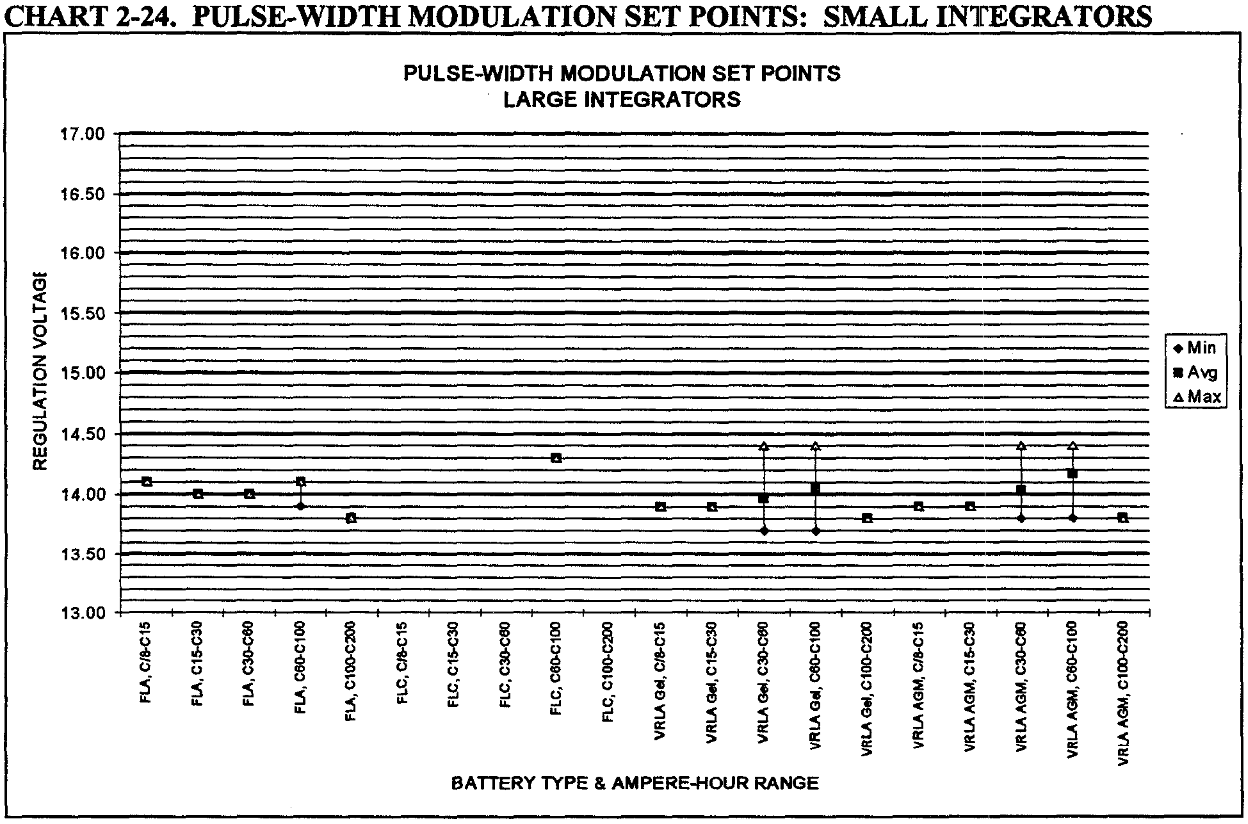


CHART 2-25. SUB-ARRAY SET POINTS: SMALL INTEGRATORS

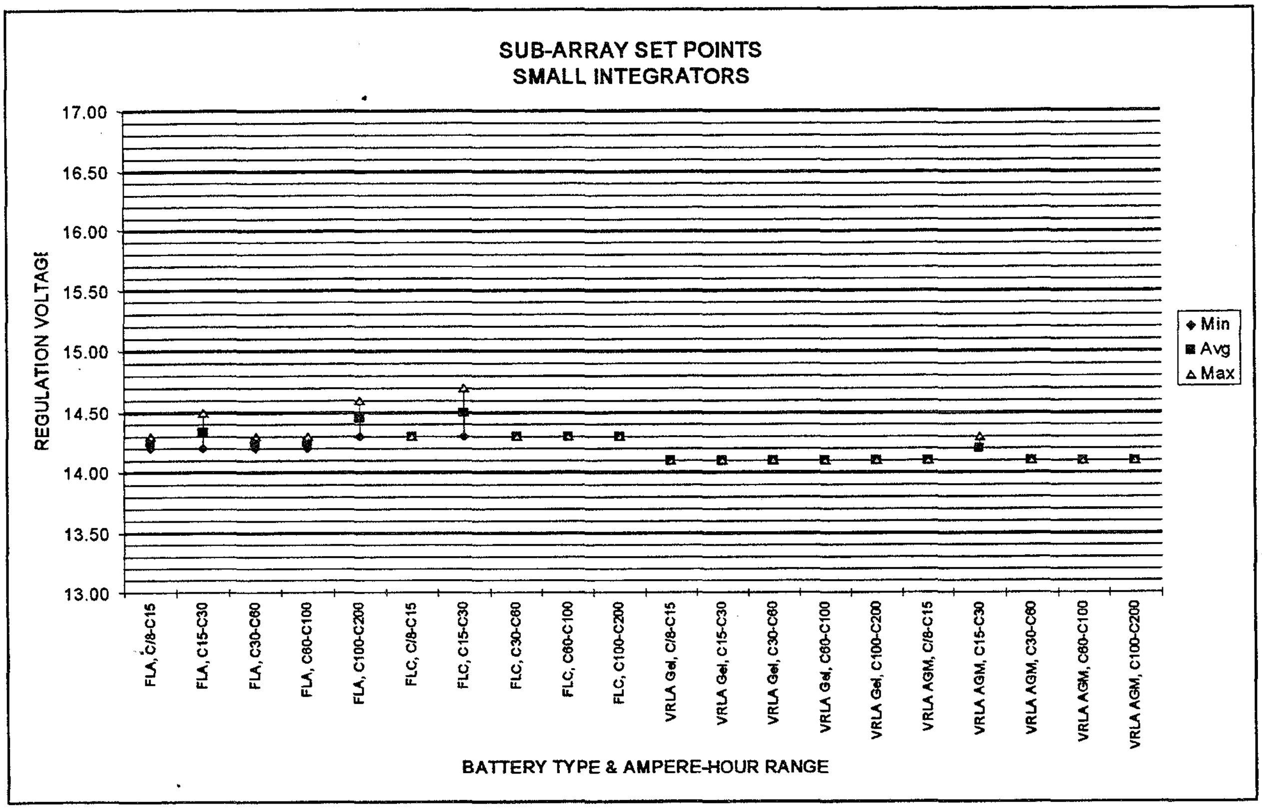
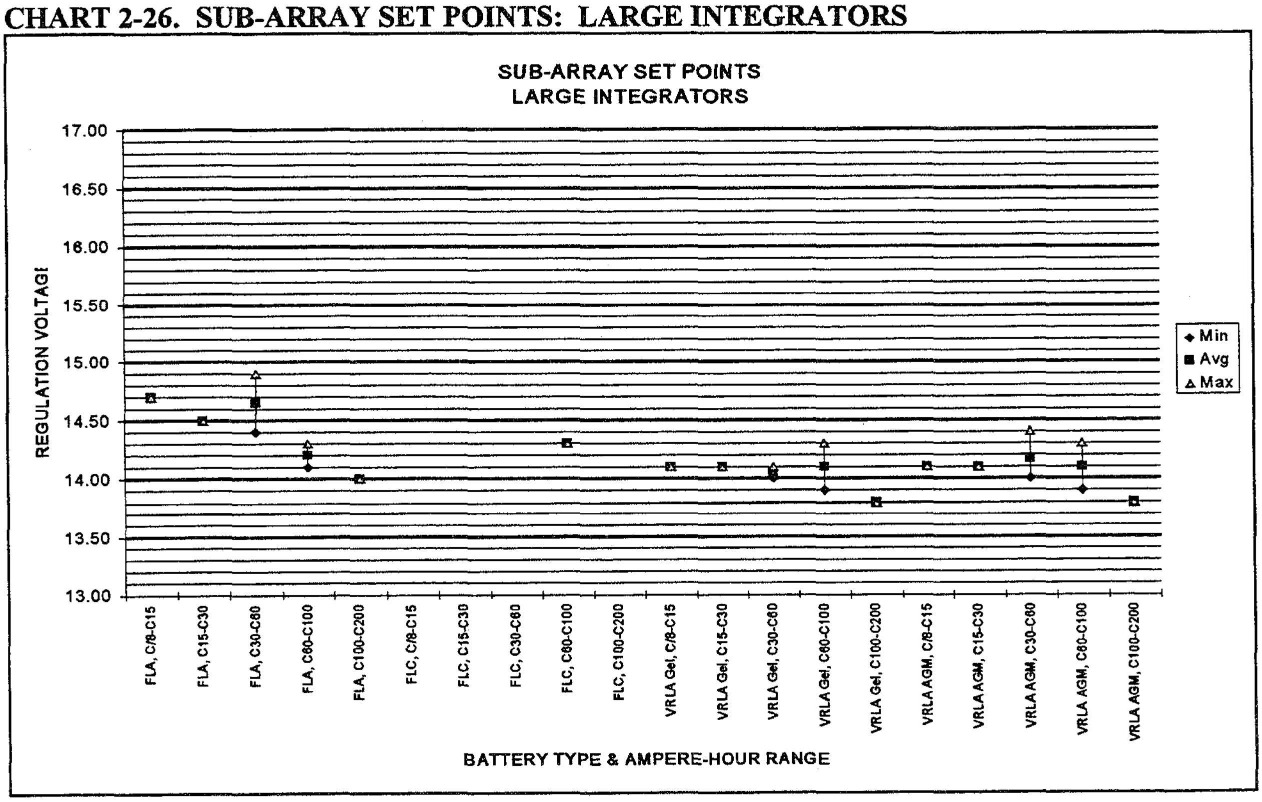


CHART 2-26. SUB-ARRAY SET POINTS: LARGE INTEGRATORS



PART 4. HYBRID SYSTEM ISSUES

Hybrid systems, as defined for the purpose of this survey, are stand-alone power generating systems with two or more types of power generating sources, one of the sources being photovoltaics. Other typical generating sources are diesel, gasoline or propane fueled generators (gensets), wind turbines, and thermal electric generators. Gensets are typically used as a backup source of power for the PV system during periods of extended cloudy weather and/or periods of unusually high energy consumption.

Part 4 is intended to identify the unique characteristics and requirements of hybrid systems. Results are displayed in Tables 2-29 (Questions 1 through 9) and 2-30 (Questions 10-16).

Where data from Small and Large System Integrators are averaged, a weighted average is used (Small Integrators have a weight of 12 and Large System Integrators have a weight of 88). This weighting is based on dollar sales per Table 2-6.

The following are highlights of answers to each question:

Question 1. *If you use parallel strings, what is the maximum number of parallel strings that you allow in a system?* When batteries are wired in parallel, a fault in a single cell can sink current from the parallel strings, creating an unsafe condition and causing a fire or explosion. Battery manufacturers generally do not specify the number of strings that can be paralleled. Forty-three percent of the system integrators limit paralleling to three or four strings. Surprisingly, two large system integrators (out of 7 that responded to this question) marked the category "9 or more".

Question 2. *At what battery size do you require battery grounding?* The majority of system integrators (65%) ground batteries, regardless of the size of the system.

Question 3. *Do you ground battery racks?* Eighty-four percent do not ground metal battery racks.

Question 4. *What do you use to determine the upper charge limit (state of charge) for a battery being charged by a mechanical charger (generator, wind, hydro, etc.)?* Nearly all system integrators (99%) limit the state of charge of batteries by measuring and limiting the battery bus voltage.

Question 5. *What percentage of your systems use integrated power centers vs. components mounted separately?* Seventy percent of system integrators mount components separately for power centers rather than placing all components in the same cabinet.

Question 6. *In systems with various power generation sources, how do you determine the battery charging set points?* The majority of integrators (83%) use different voltage set points for each power generating source. This may be due to different charging rates, or it may be due to generators being used to provide an equalizing charge.

Question 7. a) *What percentage of your business is hybrid systems?* The answers to this question were somewhat surprising, with 48% of systems by small integrators being hybrid, while only 16% are hybrid by large integrators. This may be due to the fact that small integrators provide PV systems for remote homes, which often use a backup generator.
b) *What is the typical maximum daily depth of discharge?* Typical daily battery depth of discharge is 20%.

Question 8. *What percentage of these systems [hybrid] do you design with an expected increase in seasonal depth of discharge?* Forty-five percent of small integrators plan on deeper cycle depths during seasons with low levels of sunlight vs. 27% for large system integrators.

Question 9. *What is the maximum seasonal depth of discharge that you allow?* Small system integrators allow deeper seasonal battery discharge (46%) than large system integrators (39%).

Question 10. *For hybrid systems, what battery technology do you recommend?* The majority (52%) of hybrid system batteries are flooded lead-acid with antimony additive to the plates. None of the integrators used flooded-vented batteries with calcium additive to the plates. Forty-eight percent of the batteries were VRLA.

Question 11. *What type of environmental control do you require for your battery area?* The majority of integrators (81%) used insulated battery boxes without active heating or cooling.

Question 12. *Do you use temperature compensation during battery charging operations?* Eighty-six percent of the integrators used temperature compensated charge controllers.

Question 13. *Do you directly monitor one or more battery temperatures during battery charging operation?* Eighty-four percent of the integrators measured battery temperature (vs. ambient temperature) for charge controller temperature compensation.

Question 14. *If you have had experience with thermal runaway in any of your battery systems, please indicate the NUMBER of events.* This question addresses the issue of thermal runaway, where the battery's internal resistance decreases as its temperature increases, which further increases its temperature, hence thermal runaway. Small integrators reported 5 systems with GEL batteries that experience thermal runaway and 12 cases of flooded-antimony batteries. Large integrators reported no cases of thermal runaway.

Question 15. *Has your company had any people injured due to battery explosions or electrolyte spillage?* Surprisingly, no cases of battery explosions or electrolyte spillage were reported.

Question 16. *Has your company been involved with any incident of a wiring or building fire that was a direct result of PV or system wiring or component failure?* No wiring or building fires due to PV component failure were reported.

TABLE 2-29. QUESTIONS 1-9

The following questions pertain to Hybrid Systems (more than one power source)	SYSTEM INTEGRATORS		
	Small	Large	Average [1]
Question 1			
If you use parallel strings, what are the maximum parallel strings you allow in a system?			
1	0%	0%	0%
2	36%	0%	4%
3 or 4	18%	43%	40%
5 or 6	45%	29%	31%
7 or 8	0%	0%	0%
9 or more	0%	29%	25%
Question 2			
At what battery size do you require battery grounding?			
All	55%	67%	65%
1 - 5 Kwh	18%	17%	17%
5 - 10 Kwh	27%	0%	3%
10 - 100Kwh	0%	17%	15%
> 100 Kwh	0%	0%	0%
Question 3			
Do you ground conductive battery racks?			
Yes	27%	14%	16%
No	73%	86%	84%
Question 4			
What do you use as the upper charge limit (state of charge) for a battery being charged by a mechanical charger (generator, wind, hydro, etc.)?			
Measured voltage	91%	100%	99%
Ampere-hours input	8%	0%	1%
Other	18%	0%	2%
Question 5			
What percentage of your systems use:			
Integrated power centers	21%	31%	30%
Components mounted separately	79%	69%	70%
Question 6			
In systems with various power generation sources, how do you determine the battery charging set points?			
Set them all the same irrespective of source	40%	14%	17%
Use different setpoints for different sources	60%	86%	83%
Question 7			
a) What percentage of your business is hybrid systems?	48%	16%	20%
b) What is the typical maximum daily depth of discharge?	22%	20%	20%
Question 8			
What percentage of these systems do you design with an expected increase in seasonal depth of discharge?	45%	27%	29%
Question 9			
What is the maximum seasonal depth of discharge you allowed?	46%	39%	40%

Note 1. Weighted average: Small=12; Large=88 (based on $ sales; see Table 2-6) A-PART4.XLS Q1-9

TABLE 2-30. QUESTIONS 10-16

The following questions pertain to Hybrid Systems (more than one power source)	SYSTEM INTEGRATORS		
	Small	Large	Average [1]
Question 10			
For hybrid systems, what battery technology do you recommend?			
VRLA, GEL	17%	25%	24%
VRLA, AGM	17%	25%	24%
Flooded Lead-antimony	66%	50%	52%
Flooded Lead-calcium	0%	0%	0%
Question 11			
What type of environmental control do you require for your battery area?			
Batteries installed in facility maintained at 70F nominal using HVAC	0%	0%	0%
Batteries installed in a thermally insulated area with no HVAX provision	67%	83%	81%
No environmental controls required for battery area	33%	17%	19%
Question 12			
Do you use temperature compensation during battery charging operations?			
Yes	91%	86%	86%
No	9%	14%	14%
Question 13			
Do you directly monitor one or more battery temperatures during battery charging operations?			
Yes	73%	86%	84%
No	27%	14%	16%
Question 14			
If you have had experiences with thermal runaway in any of your battery systems, please indicate the NUMBER of events:			TOTAL
VRLA, GEL	5	0	5
VRLA, AGM	0	0	0
Flooded Lead-antimony	12	0	12
Flooded Lead-calcium	0	0	0
Question 15			
Has your company had any people injured due to battery explosions or electrolyte spillage?			
Yes			
No	100%	100%	100%
Question 16			
Has your company been involved with any incidents of a wiring or building fire that were a direct result of PV or system wiring or component failure?			
Yes			
No	100%	100%	100%

Note 1. Weighted average: Small=12; Large=88 (based on $ sales; see Table 2-6)

A-PART4.XLS Q10-16

Section 3
RESULTS: SURVEY B
BATTERY MANUFACTURER

INTRODUCTION

In January 1996 a survey was sent to 10 battery manufacturers (see Appendix D, page 4) asking them to complete a three page questionnaire with seven questions (see Appendix B). Nine of the 10 manufacturers responded to the survey:

1. C&D Charter Power
2. Concorde Battery Corporation
3. Delco/Delphi Energy (GMC)
4. East Penn Manufacturing
5. GNB
6. Industrial Battery Engineering (IBE)
7. Johnson Control Inc. (JCI)
8. Trojan Battery Company
9. U.S. Battery

PURPOSE

There were two primary objectives of this part of the survey. First, it was to collect information regarding manufacturing contacts and products that would be of interest to the PV industry. And secondly, it was to determine what information that battery manufacturers needed from the PV industry.

RESULTS

Question 1. *Who is the primary contact in your company for photovoltaic batteries?* Contacts are listed in Table 3-1.

Question 2. *Have you participated or do you plan to participate in any of the following conferences?* Eight of the nine manufacturers responded to this question and their responses are listed in Table 3-2. Manufacturer's names were removed from the responses in Table 3-2 in order to maintain the potential proprietary nature of this information.

Question 3. *List products that you presently recommend for photovoltaic systems or feel would work well in PV systems.* Results are tabulated in Table 3-3.

Question 4. *Do you have a comprehensive "Application Guide" for your photovoltaic system customers?* An application guide tells a customer how to apply the battery in a specific application, whereas a "data sheet" deals primarily with specifications. Results are tabulated in Table 3-4. These results show that none of the nine respondents had an Application Guide, although four indicated that they would have such a guide by the end of 1996.

Question 5. *Which of the following parameters (i.e., data and specifications) do you provide?* This table was identical to the table sent to system integrators (see Table 2-18) so that information available from battery manufacturers could be compared with design information needed by integrators. While most battery manufacturers indicated that such data is available, it is usually neither available in the form of a data sheet nor readily available in any other form to the system integrator.

Question 6. *What could the PV industry do to stimulate your interest in developing "PV Battery Data Sheets" and "PV System Application Guides"?* This the only question in Survey B that asks for a response in form of text. Eight of the nine respondents provided comments (Table 3-6). Responses were very candid and provide significant insight into the battery manufacturer's point of view.

One response in particular provided a very important comment: **"Listen to the battery industry when we tell you we need constant voltage regulators, higher end voltage limits, and higher limits for low voltage disconnects".** This respondent knows what has been killing batteries in PV systems!

Question 7. *If Sandia National Laboratories' Photovoltaic Design Assistance Center were able to expand the program to provide assistance in developing the market for batteries in PV systems, please indicate your areas of preference (1 = highest priority, 2 = lowest priority).* Results are tabulated in Table 7. Respondents ranked the following two categories as Highest Priority:

1. Assist in the development of application guides or application notes (four 1s) and
2. Perform surveys to define the market (five 1s).

TABLE 3-1. CONTACT LIST

Company	Name/Title	Address	Telephone/Fax/e-mail
C&D Charter Power	Larry Meisner Product Manager	3043 Walton Road Plymouth Meeting, PA 19401	610-828-9000 x239 610-834-7334
Concorde Battery	Ed Mahoney Sales Manager	2009 San Barnardino Road W. Covina, CA 91790	818-813-1234 x502 818-338-3549
General Motors, Delphi Energy	Mark Boram Prod. Eng., Energy Storage	7601 E 88th Place Indianapolis, IN 46256	317-579-4952 317-579-3651
East Penn Mfg. Co	Clyde Elium Vice Pres., Stationary	Deka Road Lyon Station, PA 19536	610-682-6361 610-682-4781
GNB Technologies	Stephen Vechy PV Sales & Marketing Mgr.	829 Parkview Blvd. Lombard, IL 60148	708-691-7886 708-629-2635 SteveVechy@aol.com
Industrial Battery Engineering (IBE)	Gerald F. Russes Sales Manager	9121 DeGarmo Ave Sun Valley, CA 91352	818-767-7067 818-767-7173
Johnson Controls (JCI)	Tom Ruhlmann Technical Services Mgr.	900 E. Keefe Ave., PO Box 591 Milwaukee, WI 53201	414-967-6540 414-961-6506 Thomas.E.Ruhlmann @SCI.COM
Trojan Battery	Jim Drizos Product Manager	12380 Clark Street Santa Fe Springs, CA 90670	800-423-6569 x300 310-906-4033
U.S. Battery	Donald Wallace Vice President	1675 Sampson Ave Corona, CA 91719	909-371-8090 909-371-4671

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TABLE 3-2. TRADE SHOW PARTICIPATION

	Have you participated or do you plan on participating in any of the following conferences:?								
COMPANY		ASES	IEEE PVSC	SOLTECH	NREL	REDI SEER	UBG	UPVG	OTHER
A	1994						X		SCC-21
	1995						X		SCC-21
	1996			X			X		SCC-21
	1997								SCC-21
	1998								SCC-21
B	1994		X						SCC-21
	1995			X					SCC-21
	1996			X					SCC-21
	1997			X					SCC-21
	1998			X					SCC-21
C	1994						X		
	1995						X		
	1996						X		
	1997								
	1998								
D	1994						X		
	1995								
	1996								
	1997								
	1998								
E	1994						X		
	1995						X		
	1996						X		
	1997			X			X	X	
	1998						X		
F	1994								Trade Show
	1995								Trade Show
	1996								
	1997								
	1998								
G	1994								SCC-21
	1995								SCC-21
	1996								SCC-21
	1997								SCC-21
	1998								SCC-21
H	1994		X	X		X			SCC-21
	1995		X	X		X			SCC-21
	1996		X	X		X			SCC-21
	1997		X	X		X			SCC-21
	1998		X	X		X			SCC-21
I	1994								
	1995								
	1996								
	1997								
	1998								

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ASES American Solar Energy Society
IEEE PVSC Institute of Electrical & Electronic Engineers: PhotoVoltaic Specialists Conference
SOLTEC Solar Technology
NREL National Renewable Energy Laboratory
REDI/SEER Renewable Energy Development Institute and Solar Energy Expo & Rally
SCC-21 IEEE Standards Coordinating Committee 21
UBG Utility Battery Group
UPVG Utility PhotoVoltaic Group

TABLE 3-3a BATTERIES RECOMMENDED FOR PV SYSTEMS

Company	Model	Volts	AH, 20 hr rate	Plates [1]	Technology [2]	Typical app. [3]	Data sheet? (YES or NO)
C&D Charter Power	RHD-130	2	146	C	AGM	RH,TC>H	Yes
C&D Charter Power	RHD-190	2	218	C	AGM	RH,TC>H	Yes
C&D Charter Power	RHD-250	2	290	C	AGM	RH,TC>H	Yes
C&D Charter Power	RHD-315	2	364	C	AGM	RH,TC>H	Yes
C&D Charter Power	RHD-440	2	508	C	AGM	RH,TC>H	Yes
C&D Charter Power	RHD-600	2	654	C	AGM	RH,TC>H	Yes
C&D Charter Power	HD-300	2	360	C	AGM	RH,TC>H	Yes
C&D Charter Power	HD-400	2	480	C	AGM	RH,TC>H	Yes
C&D Charter Power	HD-500	2	600	C	AGM	RH,TC>H	Yes
C&D Charter Power	HD-700	2	840	C	AGM	RH,TC>H	Yes
C&D Charter Power	HD-900	2	1080	C	AGM	RH,TC>H	Yes
C&D Charter Power	HD-1100	2	1320	C	AGM	RH,TC>H	Yes
C&D Charter Power	HD-1300	2	1560	C	AGM	RH,TC>H	Yes
Concorde Battery	PVC-1234	12	33		AGM	TC,TM,L	Yes
Concorde Battery	PVC-1248	12	48		AGM	TC,TM,L	Yes
Concorde Battery	PVC-1260	12	60		AGM	TC,L	Yes
Concorde Battery	PVC-1272	12	72		AGM	TC,L,H	Yes
Concorde Battery	PVC-1280	12	80		AGM	TC,L,H	Yes
Concorde Battery	PVC-1285	12	85		AGM	TC,L,H	Yes
Concorde Battery	PVC-128695	12	95		AGM	TC,L,H	Yes
Concorde Battery	PVC-12105	12	105		AGM	TC,L,H	Yes
Concorde Battery	PVC-4D	12	210		AGM	RH,TC,L,H	Yes
Concorde Battery	PVC-8D	12	255		AGM	RH,TC,L,H	Yes
Concorde Battery	PVC-6180	6	180		AGM	RH,TC,L,H	Yes
Delphi Energy	D/S 2000	12	105	C	FL	All	Yes
East Penn Mfg.	S75	2 V/cell	100-2000	A	FL		No -1996
East Penn Mfg.	S85	3 V/cell	100-2001	A	FL		No -1996
East Penn Mfg.	S100	4 V/cell	100-2002	A	FL		No -1996
East Penn Mfg.	8GU1	12	see	C	GEL		Yes
East Penn Mfg.	8GU1H	12	data	C	GEL		Yes
East Penn Mfg.	8G22NF	12	sheet	C	GEL		Yes
East Penn Mfg.	8G24	12		C	GEL		Yes
East Penn Mfg.	8G27	12		C	GEL		Yes
East Penn Mfg.	8G30H	12		C	GEL		Yes
East Penn Mfg.	8GGC2	12		C	GEL		Yes
East Penn Mfg.	8G4D	12		C	GEL		Yes
East Penn Mfg.	8G8D	12		C	GEL		Yes
GNB	6-50A-05	12	120	H	AGM	All	Yes
GNB	6-50A-07	12	180	H	AGM	All	Yes
GNB	6-50A-9	12	240	H	AGM	All	Yes
GNB	6-50A-11	12	300	H	AGM	All	Yes
GNB	6-50A-13	12	360	H	AGM	All	Yes
GNB	6-50A-15	12	420	H	AGM	All	Yes
GNB	6-90A-05	12	200	H	AGM	All	Yes

NOTES:

1. *Plates:* **A** - Antimony, **C** - Calcium, **H** - hybrid
2. *Technology:* **FL** - Flooded Lead-Acid, **GEL** - VRLA gel, **AGM** - VRLA AGM, **N** - Ni-cad
3. *Most typical application:* **RH**-remote home, **TC<**-telecom <200W, **TC>**-telecom>200W, **TM**-telemetry, **L**-lighting, **W**-water pumping, **H**-hybrid

TABLE 3-3b. BATTERIES RECOMMENDED FOR PV SYSTEMS (Continued)

Company	Model	Volts	AH, 20 hr rate	Plates [1]	Technology [2]	Typical app. [3]	Data sheet? (YES or NO)
GNB	6-90A-07	12	300	H	AGM	All	Yes
GNB	90A-09S	2	400	H	AGM	All	Yes
GNB	6-90A-11	12	500	H	AGM	All	Yes
GNB	6-90A-13	12	600	H	AGM	All	Yes
GNB	6-90A-15	12	700	H	AGM	All	Yes
GNB	6-90A-17	6	800	H	AGM	All	Yes
GNB	3-90A-19	6	900	H	AGM	All	Yes
GNB	3-90A-21	6	1000	H	AGM	All	Yes
GNB	3-90A-23	6	1100	H	AGM	All	Yes
GNB	3-90A-25	6	1200	H	AGM	All	Yes
GNB	3-90A-27	6	1300	H	AGM	All	Yes
GNB	3-100A-13	6	680	H	AGM	All	Yes
GNB	3-100A-15	6	800	H	AGM	All	Yes
GNB	3-100A-17	6	900	H	AGM	All	Yes
GNB	3-100A-19	6	1020	H	AGM	All	Yes
GNB	3-100A-21	6	1140	H	AGM	All	Yes
GNB	3-100A-23	6	1260	H	AGM	All	Yes
GNB	3-100A-25	6	1360	H	AGM	All	Yes
GNB	3-100A-27	6	1480	H	AGM	All	Yes
GNB	3-100A-29	6	1600	H	AGM	All	Yes
GNB	3-100A-31	6	1700	H	AGM	All	Yes
GNB	3-100A-33	6	1820	H	AGM	All	Yes
GNB	1-100A-39	2	2040	H	AGM	All	Yes
GNB	1-100A-45	2	2400	H	AGM	All	Yes
GNB	1-100A-51	2	2700	H	AGM	All	Yes
GNB	1-100A-57	2	3060	H	AGM	All	Yes
GNB	1-100A-63	2	3420	H	AGM	All	Yes
GNB	1-100A-69	2	3780	H	AGM	All	Yes
GNB	1-100A-75	2	4080	H	AGM	All	Yes
GNB	1-100A-81	2	4440	H	AGM	All	Yes
GNB	1-100A-87	2	4800	H	AGM	All	Yes
GNB	1-100A-93	2	5100	H	AGM	All	Yes
GNB	1-100A-99	2	5460	H	AGM	All	Yes
Single Cell Modules:							
GNB	50A-05S	2	120	H	AGM	All	Yes
GNB	50A-07S	2	180	H	AGM	All	Yes
GNB	50A-09S	2	240	H	AGM	All	Yes
GNB	50A-11S	2	300	H	AGM	All	Yes
GNB	50A-13S	2	360	H	AGM	All	Yes
GNB	50A-15S	2	420	H	AGM	All	Yes
GNB	50A-17S	2	480	H	AGM	All	Yes
GNB	50A-19S	2	540	H	AGM	All	Yes
GNB	50A-21S	2	620	H	AGM	All	Yes
GNB	50A-23S	2	680	H	AGM	All	Yes

NOTES:
1. *Plates:* **A** - Antimony, **C** - Calcium, **H** - hybrid
2. *Technology:* **FL** - Flooded Lead-Acid, **GEL** - VRLA gel, **AGM** - VRLA AGM, **N** - Ni-cad
3. *Most typical application:* **RH**-remote home, **TC**<-telecom <200W, **TC**>-telecom>200W, **TM**-telemetry, **L**-lighting, **W**-water pumping, **H**-hybrid

TABLE 3-3c. BATTERIES RECOMMENDED FOR PV SYSTEMS (Continued)

Company	Model	Volts	AH, 20 hr rate	Plates [1]	Technology [2]	Typical app. [3]	Data sheet? (YES or NO)
GNB	50A-25S	2	740	H	AGM	All	Yes
GNB	50A-27S	2	800	H	AGM	All	Yes
GNB	90A-05S	2	200	H	AGM	All	Yes
GNB	90A-07S	2	300	H	AGM	All	Yes
GNB	90A-09S	2	400	H	AGM	All	Yes
GNB	90A-11S	2	500	H	AGM	All	Yes
GNB	90A-13S	2	600	H	AGM	All	Yes
GNB	90A-15S	2	700	H	AGM	All	Yes
GNB	90A-17S	2	800	H	AGM	All	Yes
GNB	90A-19S	2	900	H	AGM	All	Yes
GNB	90A-21S	2	1000	H	AGM	All	Yes
GNB	90A-23S	2	1100	H	AGM	All	Yes
GNB	90A-25S	2	1200	H	AGM	All	Yes
GNB	90A-27S	2	1300	H	AGM	All	Yes
GNB	100A-13S	2	680	H	AGM	All	Yes
GNB	100A-15S	2	800	H	AGM	All	Yes
GNB	100A-17S	2	900	H	AGM	All	Yes
GNB	100A-17S	2	900	H	AGM	All	Yes
GNB	100A-19S	2	1020	H	AGM	All	Yes
GNB	100A-21S	2	1140	H	AGM	All	Yes
GNB	100A-23S	2	1260	H	AGM	All	Yes
GNB	100A-25S	2	1360	H	AGM	All	Yes
GNB	100A-27S	2	1480	H	AGM	All	Yes
GNB	100A-29S	2	1600	H	AGM	All	Yes
GNB	100A-31S	2	1700	H	AGM	All	Yes
GNB	100A-33S	2	1820	H	AGM	All	Yes
Sunlyte:							
GNB	12-5000X	12	92	H	AGM	All	Yes
Resource Commander:							
GNB	6-85RC-0	12	180	A	FL	RH,L,W,H	Yes
GNB	6-85RC-0	12	255	A	FL	RH,L,W,H	Yes
GNB	6-85RC-9	12	350	A	FL	RH,L,W,H	Yes
GNB	6-85RC-1	12	440	A	FL	RH,L,W,H	Yes
GNB	6-85RC-1	12	535	A	FL	RH,L,W,H	Yes
GNB	6-85RC-1	12	630	A	FL	RH,L,W,H	Yes
GNB	6-85RC-1	12	720	A	FL	RH,L,W,H	Yes
GNB	6-85RC-1	12	815	A	FL	RH,L,W,H	Yes
GNB	6-85RC-2	12	910	A	FL	RH,L,W,H	Yes
GNB	6-85RC-2	12	1000	A	FL	RH,L,W,H	Yes
GNB	6-85RC-2	12	1095	A	FL	RH,L,W,H	Yes
GNB	6-85RC-2	12	1190	A	FL	RH,L,W,H	Yes
GNB	6-85RC-2	12	1280	A	FL	RH,L,W,H	Yes
GNB	6-85RC-3	12	1375	A	FL	RH,L,W,H	Yes
GNB	6-85RC-3	12	1470	A	FL	RH,L,W,H	Yes

NOTES:

1. *Plates:* **A** - Antimony, **C** - Calcium, **H** - hybrid
2. *Technology:* **FL** - Flooded Lead-Acid, **GEL** - VRLA gel, **AGM** - VRLA AGM, **N** - Ni-cad
3. *Most typical application:* **RH**-remote home, **TC<**-telecom <200W, **TC>**-telecom>200W, **TM**-telemetry, **L**-lighting, **W**-water pumping, **H**-hybrid

TABLE 3-3d. BATTERIES RECOMMENDED FOR PV SYSTEMS (Continued)

Company	Model	Volts	AH, 20 hr rate	Plates [1]	Technology [2]	Typical app. [3]	Data sheet? (YES or NO)
Industrial Battery En	3-SSN-9	6	270	A	FL	RH,L,W	Yes
Industrial Battery En	3-SSN-11	6	338	A	FL	RH,L,W	Yes
Industrial Battery En	3-SSN-13	6	406	A	FL	RH,L,W	Yes
Industrial Battery En	75N	2		A	FL	RH,L,W	Yes
Industrial Battery En	85N	2		A	FL	RH,L,W	Yes
Industrial Battery En	9 PL	2	389	A	FL	RH,L,W	Yes
Industrial Battery En	11PL	2	461	A	FL	RH,L,W	Yes
Industrial Battery En	13PL	2	554	A	FL	RH,L,W	Yes
Industrial Battery En	15PL	2	646	A	FL	RH,L,W	Yes
Industrial Battery En	17PL	2	738	A	FL	RH,L,W	Yes
Industrial Battery En	19PL	2	830	A	FL	RH,L,W	Yes
Industrial Battery En	21PL	2	923	A	FL	RH,L,W	Yes
Industrial Battery En	23PL	2	1015	A	FL	RH,L,W	Yes
Industrial Battery En	25PL	2	1107	A	FL	RH,L,W	Yes
Industrial Battery En	27PL	2	1199	A	FL	RH,L,W	Yes
Industrial Battery En	29PL	2	1292	A	FL	RH,L,W	Yes
Industrial Battery En	31PL	2	1384	A	FL	RH,L,W	Yes
Industrial Battery En	33PL	2	1476	A	FL	RH,L,W	Yes
Johnson Controls	U1-31 B		31	C	GEL	Varied	Yes
Johnson Controls	GC 12400 B		40	C	GEL	Varied	Yes
Johnson Controls	GC 12550 B		55	C	GEL	Varied	Yes
Johnson Controls	GC 12v75 B		75	C	GEL	Varied	Yes
Johnson Controls	GC12v100 B		90	C	GEL	Varied	Yes
Trojan Battery	T-105	6	225	A	FL	RH,L,H	Yes
Trojan Battery	T-145	6	244	A	FL	RH,L,H	Yes
Trojan Battery	L-16	6	350	A	FL	RH,H	Yes
Trojan Battery	J-305	6	305	A	FL	RH,H	Yes
Trojan Battery	J-250	6	250	A	FL	RH,H	Yes
Trojan Battery	27 TMH	12	115	A	FL	RH,L	Yes
Trojan Battery	27 TMX	12	105	A	FL	RH,L	Yes
Trojan Battery	SCS 150	12	100	A	FL	RH,L	Yes
Trojan Battery	SCS 200	12	115	A	FL	RH,L	Yes
Trojan Battery	SCS 225	12	130	A	FL	RH,L	Yes
Trojan Battery	30 XHS	12	130	A	FL	RH,L	Yes
U. S. Battery	US 250	6	250	A	FL	RH,L,W	Yes
U. S. Battery	US 305	6	305	A	FL	RH,L,W	Yes
U. S. Battery	L16	6	350	A	FL	RH,L,W	Yes
U. S. Battery	1-HC	6	95	A	FL	RH,L,W	Yes
U. S. Battery	US 185	12	195	A	FL	RH,L,W	Yes
U. S. Battery	EV-145	12	145	A	FL	RH,L,W	Yes
						BATT-BH.XLS Q3	

NOTES:

1. *Plates:* **A** - Antimony, **C** - Calcium, **H** - hybrid
2. *Technology:* **FL** - Flooded Lead-Acid, **GEL** - VRLA gel, **AGM** - VRLA AGM, **N** - Ni-cad
3. *Most typical application:* **RH**-remote home, **TC**<-telecom <200W, **TC**>-telecom>200W, **TM**-telemetry, **L**-lighting, **W**-water pumping, **H**-hybrid

TABLE 3-4. APPLICATION GUIDE AVAILABILITY

Question 4. Do you have a comprehensive "Application Guide" for your photovoltaic system customers? (Definition: An application guide tells a customer how to apply the battery in specific applications, whereas a "data sheet" deals primarily with specifications.)

MANUFACTURER	YES	NO	DATE AVAILABLE
C&D Charter Power		X	1996
Concorde Battery		X	1996
Delco/Delphi Energy		X	
East Penn Mfg.		X	
GNB		X	
Industrial Battery		X	
Johnson Controls			Sep-96
Trojan Battery			Sep-96
U S Battery		X	

BATT-BH.XLS Q4

TABLE 3-5a. DATA SHEET PARAMETERS

A	5. **Do you provide the following for your batteries used in PV systems:**	**C&d**			**Concorde**			**Delco/Delphi**		
	PARAMETER(S)	**YES**	**NO**	**Date Avail**	**YES**	**NO**	**Date Avail**	**YES**	**NO**	**Date Avail**
1	Nominal battery voltage	1			1			1		
2	Amp-hour capacity at C/8	1			1			*		
3	Amp-hour capacity at C/20	1			1			*		
4	Amp-hour capacity at C/100	1			1			1		
5	Specific gravity	1						*		
6	Self-discharge rate vs temperature vs lifetime		2		1			1		
7	Physical characteristics; dimensions, terminal size, weight; pkgd weight, size	1			1			1		
8	Recommended charging voltage vs temperature vs charge rate	1			1			1		
9	Recommended controller set points for on-off controllers vs charge rate	1						1		
10	Cost	1			1			1		
11	Electrolyte freezing point vs SOC		2		1			1		
12	Battery life vs average daily DOD, vs temperature	1			1			1		
13	Warranty (and warranty restrictions) If so, how long?	*			1			1		
14	General testing & charging requirements	*			1			1		
15	Recommended equalization voltage, frequency	1						1		
16	Series/parallel recommendations	*			1			1		
17	Plate construction and additives (% antimony, % calcium)	*				2		1		
18	Reserve electrolyte capacity	N/A				2		1		
19	Sustained overcharge rate (recombination rate)		2			2			2	
20	Allowed and preferred orientations (e.g., upside down)	1			1			1		
21	Available dry charged	N/A				2			2	
22	Amp-hour efficiency at 20% DOD vs lifetime vs other variables		2		1				2	
23	Disposal/recycling instructions	*			1			1		
24	Recommended maintenance schedule	*			1				2	
25	Maximum shelf life	*			1			1		
26	Shipping hazard code		2		1					
27	State of Charge (SOC) vs Voc		2					*		
28	SOC vs battery voltage at C/20		2		1			1		
29	SOC vs battery voltage		2		1			1		
30	SOC as a function of battery voltage atother various charge/discharge rates		2					1		
31	SOC as a function of specific gravity at various charge/discharge rates	N/A				2			2	
32	Maximum system voltage to ground		2						2	
	* Available on Request	BATT-BH.XLS Q5 a								

TABLE 3-5b. DATA SHEET PARAMETERS

B	5. Do you provide the following for your batteries used in PV systems:	East Penn Mfg.			GNB			IBE		
	PARAMETER(S)	**YES**	**NO**	**Date Avail**	**YES**	**NO**	**Date Avail**	**YES**	**NO**	**Date Avail**
1	Nominal battery voltage	1			1			1		
2	Amp-hour capacity at C/8	1			1				2	
3	Amp-hour capacity at C/20	1			1					
4	Amp-hour capacity at C/100	1			1			1		
5	Specific gravity	1			1			1		
6	Self-discharge rate vs temperature vs lifetime	1			1				2	
7	Physical characteristics; dimensions, terminal size, weight; pkgd weight, size	1			1			1		
8	Recommended charging voltage vs temperature vs charge rate	1			1			1		
9	Recommended controller set points for on-off controllers vs charge rate				1				2	
10	Cost				1			1		
11	Electrolyte freezing point vs SOC	1			1			1		
12	Battery life vs average daily DOD, vs temperature	1			1			1		
13	Warranty (and warranty restrictions) If so, how long?				1			1		
14	General testing & charging requirements	1			1				2	
15	Recommended equalization voltage, frequency	1			1				2	
16	Series/parallel recommendations				1			1		
17	Plate construction and additives (% antimony, % calcium)		2		1				2	
18	Reserve electrolyte capacity	1			1				2	
19	Sustained overcharge rate (recombination rate)		2		1				2	
20	Allowed and preferred orientations (e.g., upside down)	1			1				2	
21	Available dry charged	1			1			1		
22	Amp-hour efficiency at 20% DOD vs lifetime vs other variables	1			1			1		
23	Disposal/recycling instructions	1			1				2	
24	Recommended maintenance schedule	1			1			1		
25	Maximum shelf life	1			1				2	
26	Shipping hazard code	1			1			1		
27	State of Charge (SOC) vs Voc	1			1			1		
28	SOC vs battery voltage at C/20	1			1			1		
29	SOC vs battery voltage	1			1			1		
30	SOC as a function of battery voltage at other various charge/discharge rates	1			1				2	
31	SOC as a function of specific gravity at various charge/discharge rates	1			1			1		
32	Maximum system voltage to ground		2		1				2	
	* Available on Request	BATT-BH.XLS Q5 b								

TABLE 3-5c. DATA SHEET PARAMETERS

C	5. Do you provide the following for your batteries used in PV systems:	JCI			Trojan			U S Battery		
	PARAMETER(S)	YES	NO	Date Avail	YES	NO	Date Avail	YES	NO	Date Avail
1	Nominal battery voltage	1			1			1		
2	Amp-hour capacity at C/8	1			1				2	
3	Amp-hour capacity at C/20	1			1				2	
4	Amp-hour capacity at C/100	1			1				2	
5	Specific gravity	1			1			1		
6	Self-discharge rate vs temperature vs lifetime	1			1			1		
7	Physical characteristics; dimensions, terminal size, weight; pkgd weight, size	1			1			1		
8	Recommended charging voltage vs temperature vs charge rate	1			1			1		
9	Recommended controller set points for on-off controllers vs charge rate		2		1				2	
10	Cost	1				2		1		
11	Electrolyte freezing point vs SOC		2		1			1		
12	Battery life vs average daily DOD, vs temperature		2		1			1		
13	Warranty (and warranty restrictions) If so, how long?	1			1			1		
14	General testing & charging requirements	1			1			1		
15	Recommended equalization voltage, frequency	1			1			1		
16	Series/parallel recommendations	1			1			1		
17	Plate construction and additives (% antimony, % calcium)	1			1				2	
18	Reserve electrolyte capacity				1			1		
19	Sustained overcharge rate (recombination rate)	1				2		1		
20	Allowed and preferred orientations (e.g., upside down)	1				2			2	
21	Available dry charged		2			2		1		
22	Amp-hour efficiency at 20% DOD vs lifetime vs other variables		2			2		1		
23	Disposal/recycling instructions	1			1			1		
24	Recommended maintenance schedule		2		1			1		
25	Maximum shelf life	1			1			1		
26	Shipping hazard code	1			1			1		
27	State of Charge (SOC) vs Voc	1			1			1		
28	SOC vs battery voltage at C/20		2			2	9-96		2	
29	SOC vs battery voltage	1						1		
30	SOC as a function of battery voltage at other various charge/discharge rates		2			2		1		
31	SOC as a function of specific gravity at various charge/discharge rates		2			2		1		
32	Maximum system voltage to ground		2			2		1		
	*Available on Request	BATT-BH.XLS Q5 c								

TABLE 3-6. DEVELOPMENT OF DATA SHEETS & APPLICATION GUIDES

6. What could the PV industry do to stimulate your interest in developing PV Battery "Data Sheets" and "PV System Applications Guides"?	
C&D	System Integrators can provide typical data required or needed for sizing, installation, and maintenance of systems. List typical charge controllers used and typical specifications.
Concord	We have done much to provide information to this market, i.e., testing, data, temperature performance, and cycle life. The PV industry still needs to further supply battery information on real application requirements. Listen to the battery industry when we tell you we need constant voltage regulators, higher end voltage limits and higher limits for low voltage disconnects.
Delco / Delphi	Continue to show how much world-wide battery volume is available for sales.
East Penn	East Penn Manufacturing is interested in the PV market. As we proceed on a job-to-job basis we will develop data sheets. Any information is always helpful.
GNB	By completing the Absolyte IIP data sheet, GNB has complete PV data sheets for the products we actively market to the PV industry. A system application guide is our next priority. I feel it is very important to address PV from the systems standpoint because this is the only way to assure that the product meets customer expectations.
Industrial	Define any new applications that could utilize deep cycle lead acid batteries. Expand on how setting battery banks in parallel can provide the capacity needed.
JCI	This is already on our agenda and will be published in September 1966
Trojan	Trojan Battery Company is in the process of developing application specific literature for renewable energy. An Application Guide will follow.
U.S. Battery	No comments

[WORD TABLE]

TABLE 3-7 SNL ASSISTANCE IN MARKET DEVELOPMENT

Question 10. If Sandia National Laboratories' Photovoltaic Design Assistance Center were able to expand the program to provide assistance in developing the market for batteries in PV systems, please indicate your areas of preference. (1 = highest priority; 5 = lowest priority)

	Number of responses from nine manufacturers				
	#1s	**#2s**	**#3s**	**#4s**	**#5s**
Assist in the characterization of batteries or PV specifications	1	4	0	1	1
Assist in the development of "application notes or guides"	4	0	4	0	0
Perform surveys to define the market	5	2	1	0	0
Provide technical liaison between the PV & battery industries	1	1	1	4	5

[WORD TABLE]

Other (notes):

#6. What the needs would be for Power Companies to promote turn-key battery systems where they could lease, sell, or rent systems.

#7. Develop comparison of various charging schemes vs. Insolation, Life, and Application.

#8. It would be extremely valuable for Sandia to evaluate and publish studies relative the balance of systems needs, such as, controller set points relative to control charge technology and battery technology. For example, Sandia or IEEE should publish findings that on/off control set points optimize flooded batteries at (........), or VRLA (gel) batteries at (.......), or VRLA (AGM) batteries at (.......).

Section 4
RESULTS: SURVEY C
CHARGE CONTROLLER MANUFACTURER

INTRODUCTION

In January 1996 a survey was sent to 10 charge controller manufacturers (see Appendix D, page 5) asking them to complete a three page questionnaire with 10 questions (see Appendix C). Eight of the ten manufacturers completed the survey:

1. Ananda Power Technologies
2. Heliotrope General
3. Morningstar Corporation
4. Polar Products
5. Specialty Concepts Inc.
6. SunAmp Power
7. Sunwize Energy Systems Inc.
8. Trace Engineering

PURPOSE

The primary purpose was to characterize and quantify the type of charge controllers used in PV systems. In addition, the purpose was to collect information that would be of interest to the PV industry in utilizing the best controller for their application. A final objective was to determine what information that charge controller manufacturers needed from the PV industry and battery manufacturers to provide a better or more effective charge controller.

The charge controller is the "heart" of a PV system since the charging algorithm and set points determine how effectively and efficiently that the batteries charge -- or whether the batteries charge at all. Undercharging a flooded-vented battery will cause it to sulfate, greatly reducing battery life. Overcharging a valve-regulated lead acid battery will cause it to dry out, thereby greatly reducing its life. The charge controller has more influence on life cycle cost than any other component (since it can ruin a bank of batteries within a few months!) and it is the component in a system that should receive the most attention (e.g., appropriate set points and algorithm).

RESULTS

Note: All of the results presented in this section are based on the responses of the eight respondents. No attempt has been made to extrapolate these results to the total U.S. market or the total worldwide market.

The responses from the eight respondents are <u>not</u> weighted by sales volume. Two of the eight respondents have about 55% of the market in terms of volume and dollars (see Table 4-6). On the other end of the scale, two suppliers together have less than 2% of the market. Each individual response carried an equal weight when averaged or totaled.

Question 1. *Please assign a percentage to each market sector that you presently supply.*
Results are reported in Table 4-1. Individual responses varied significantly by market sector. The average percentages for each market sector was about equally distributed by sector, but with stand-alone homes and telecommunications each with about 24% market "share".

Question 2. *What is your company's position on temperature compensation of the regulation set points?*
Sixty-two percent of the respondents feel that temperature compensation is vital (required, not optional) while another 25% feel that it is important but optional. Those companies offering the temperature sensing element as "optional" may be doing so to reduce the apparent cost of the product.

Question 3. *How does the consumer select the charging settings for your charge controller products?*
Seventy-five percent provide field-adjustable settings. This is an important feature since batteries may be replaced with a type different than the original batteries. Only one of eight manufacturers supplies a fixed set point device.

Question 4. *Where do you get the information for selecting the recommended charge voltage settings?*
This question, buried in the middle of a dozen questions, may well be the most important question of the entire survey, since correct set points are essential for reasonable battery life (see Purpose on Page 4-1). Note that 62% of the manufacturers get the battery set points from experience, <u>not</u> from the battery manufacturer. **Only 25% use values recommended by battery manufacturers.** One reason may be that the majority of charge controllers use the ON/OFF algorithm, and battery manufacturers have characterized batteries with constant voltage limits. One manufacturer uses set points based on customer feedback -- probably because the customers are often system integrators who have years of experience charging batteries with PV. Another reason for these responses will be apparent from Question 5.

Question 5. *Do you receive adequate information from battery manufacturers regarding the performance of batteries in PV Systems?*
Only one of eight manufacturers responded with "yes". One of the goals of this survey is to identify the information needed by the charge controller manufacturers and to make battery manufacturers aware of the need.

Question 6. *If battery manufacturers publish data specifying appropriate charge algorithms and set points, would you pass those recommendations along to your customers?*
The answer was unanimous with eight "yes" responses. Charge controller manufacturers are clearly enthusiastic about implementing the proper algorithms and set points. Although changing algorithms would require development time and funds, there is no cost associated with using the optimum set points.

Question 7. *Would you adjust your product line to support those recommendations* [see Question 6].
All eight respondents checked "yes".

Question 8. *Do you have questions regarding the performance of any of your charge controllers?*
This question is subjective and open to interpretation. The responses, in general, indicate that manufacturers feel that they understand the requirements for charging flooded-vented batteries much better than VRLA batteries.

Question 9. *How may calls per month do you receive from distributors or users regarding the proper use of your product.*

Four manufacturers get from "1 to 20" calls per month. One manufacturer gets over 100 calls per month. Note that there is a wide difference in the volume of products by each manufacturer. There has been no attempt here to correlate the number of calls to the volume of product sold.

Question 10. *If Sandia National Laboratories' Photovoltaic Design Assistance Center were able to expand the program to provide assistance in developing the market for batteries, PV systems, please indicate your areas of preference.*

The highest priority was equally distributed among "Assist in the development of Application Notes or Guides", "Perform surveys to define the market", and "Provide technical liaison between the PV and battery industries". The number 2 priority was "Assist in the characterization of batteries or PV specifications".

Question 11. *Please fill in the chart on the next page with information regarding all products that you manufacture or plan to manufacture in the future.*

While this request was not phrased as a question, we will treat it as a question so as to maintain the above format. The complete product offerings of the eight respondents are listed in Table 4-5.

The number of units sold by make and model were also reported in the chart Question 11. These data are confidential and therefore were not included in Table 4-5. A summary of consolidated data are, however, presented in Table 4-6, but without manufacturers' names in order to maintain the confidential nature of the data. These data show that total sales for the eight manufacturers are 41,184 units and $5,207,127 for an average retail cost of $126.44 per unit.

Table 4-6 also shows moderate to very rapid growth rates (units) for each manufacturer, ranging from 118% to 528%! If all of the expectations in growth were to be realized, the growth rate for 1995 to 1996 for these eight manufacturers would be 203%. Given that PV module sales may grow 15-20% over this same period, it is unlikely that total charge controller unit sales would increase more than 20-25% (allowing for new sales and replacement sales), since there is a close correlation between the number of PV watts shipped per year and the number of charge controllers required. This means that for a supplier to increase market share faster than the industry growth rate, it must come from another suppliers market share. Discussions with some of the eight respondents indicate that much of the growth will occur due to exports, and the collective controller growth rate for the eight respondents could be 203% for 1996.

TABLE 4-1. QUESTIONS 1 - 7

Question 1 Please assign a percentage to each market sector you presently supply.

	Individual Responses, %								Ave.
Stand-Alone remote home systems	39%	52%	30%	0%	35%	10%	0%	30%	0%
Stand-Alone PV lighting systems	1%	0%	10%	10%	10%	5%	100%	3%	0%
Hybrid power systems	10%	2%	5%	20%	10%	65%	0%	20%	0%
Telecommunications	38%	5%	40%	70%	10%	15%	0%	2%	0%
Recreational vehicles	12%	41%	15%	0%	35%	15%	0%	15%	0%

Question 2 What is your company's position on temperature compensation of the regulation set point?

	Individual Responses								Total
Vital and Standard		X	X	X		X		X	5
Important but Optional	X				X				2
Not Important									0
Causes Problems									0
Not Enough Information							X		1

Question 3 How does the consumer select the charging settings for your charge controller products?

	Individual Responses								Total
Fixed						X			1
Adjustable	X	X		X	X		X	X	6
2 set points - Flooded & VRLA			X						1

Question 4 Where do you get the information for selecting the recommended charge voltage settings?

	Individual Responses								Total
Experience	X			X	X		X	X	5
Battery Manufacturers			X			X			2
Customer Feedback		X							1
Do Not Provide									0

Question 5 Do you receive adequate information from battery manufacturers regarding battery performance in PV Systems?

	Individual Responses								Total
Yes						X			1
No	X	X	X	X	X		X	X	7

Question 6 If battery manufacturers publish data specifying appropriate charge algorithms and set points, would you pass those recommendations along to your customers?

	Individual Responses								Total
Yes	X	X	X	X	X	X	X	X	8
No									0

Question 7 Would you adjust your product line to support those recommendations?

	Individual Responses								Total
Yes	X	X	X	X	X	X	X	X	8
No									0

SURVEY2\RLH\C-BH.XLS Q1-7

Note: none of the averages or totals in Questions 1 through 7 were weighted by sales volume for each manufacturer (two of the eight manufacturers have about 55% market share).

TABLE 4-2. QUESTION 8

Question 8. Do you have questions regarding the performance of any of your charge controllers?	Total number of responses from 8 manufacturers			
	No	Yes		
		Flooded [1]	AGM [2]	Gell [3]
Ability to fully charge batteries?	6	1	2	1
Appropriate regulation set points?	3	2	4	4
Appropriate LVD set points?	3	2	4	5
Product reliability?	7	0	1	1

C-BH.XLS Q8

Note 1. Flooded-vented batteries: Any battery with an electrolyte that flows freely within each cell.

Note 2. AGM: A battery in which the electrolyte is immobilized in a porous glass matte between the positive and negative plates. Sometimes referred to as a "starved electrolyte" battery due to the electrolyte being immobilized in the glass matte. Typical brand names, for example: GNB, Concorde, Power Sonic.

Note 3. (Gel Electrolyte) A VRLA battery in which the electrolyte is immobilized in a thixotropic gel. Typical brand names, for example: Johnson Controls, Deka, Sonnenschein, Exide.

TABLE 4-3. QUESTION 9

Question 9. How many calls per month do you receive from distributors or users regarding the proper use of your product?	Total number of responses from 8 manufacturers
1-20	4
21-50	2
51-100	1
More than 100	1

C-BH.XLS Q9

TABLE 4-4. QUESTION 10

Question 10. If Sandia National Laboratories' Photovoltaic Design Assistance Center were able to expand the program to provide assistance in developing the market for batteries in PV systems, please indicate your areas of preference. (1 = highest priority; 5 = lowest priority)

	Number of responses from eight manufacturers				
	#1s	#2s	#3s	#4s	#5s
Assist in the characterization of batteries or PV specifications	1	3	0	3	1
Assist in the development of "application notes or guides"	3	1	3	0	1
Perform surveys to define the market	3	2	2	0	1
Provide technical liaison between the PV & battery industries	3	1	0	2	2

Sec 4 Text Table

TABLE 4-5a. CHARGE CONTROLLER SPECIFICATIONS AND FEATURES

C-BH.XLS Q11a	Voltage				Current						Characteristics												Market		
MODEL	12	24	48	>48	<9	<21	<41	<61	<121	>121	Temp. comp. standard?	Temp. comp. optional?	UL Listed?	ETL Listed?	Includes low voltage disconnect?	Includes lighting control?	Expandable (master/slave)?	Battery amp meter?	Battery amp-hour meter?	Battery voltage meter?	Microprocessor based?	Max. power point tracker?	Now available?	Available in 1996?	Suggested retail cost, ea., '95
Ananda Power																									
SC 20	X	X				X						X		X							X		X		$ 69
PV60	X	X	X					X			X											X			$ 199
APT 1-4x	X	X	X	X				X	X			X		X	X	X	X	X		X			X		$ 595
APT 2-4x	X	X	X	X				X	X			X		X	X	X	X	X		X		X			$ 695
APT 3	X	X	X	X				X	X			X		X	X	X	X	X	X	X		X			$ 895
APT 5	X	X	X	X				X	X			X		X	X	X	X	X	X	X		X			$ 1,195
Heliotrope																									
CC-20B	X	X				X												X		X					$ 222
CC-30	X	X					X				X							X		X			X	X	$ 233
CC-60E	X	X						X			X			X	X			X		X			X	X	$ 453
CC-60E 48V			X					X			X			X	X			X		X			X	X	$ 507
CC-120E	X	X							X		X			X	X			X		X			X	X	$ 491
CC-120E 48V			X						X		X			X	X			X		X			X	X	$ 545
CC-60E 120V				X				X			X				X			X		X			X	X	$ 620
Morningstar																									
Prostar-12	X	X				X					X				X						X		X		$ 120
Prostar-20	X	X				X					X				X						X		X		$ 145
Prostar-30	X	X					X				X				X						X		X		$ 175
Prostar w/LCD	X	X				X	X				X				X			X		X	X		X		$ 195
Sunsaver 6	X				X						X													X	$ 53
SS 6 w/LVD	X				X						X				X									X	$ 65
Sunsaver 10	X					X					X													X	$ 62
SS-10 w/LVD	X					X					X				X									X	$ 78
Polar Products																									
SLC 92	X				X						X				X	X							X		$ 190
SLC 92 24/07		X			X																		X		$ 190
S1600/12	X					X					X				X			X		X				X	
S1600/24		X				X					X				X			X		X				X	
MICRO-2000	X	X					X				X				X	X	X	X	X	X	X	X		X	
Specialty Concepts Inc (SCI)																									
ASC	X	X				X						X	X		X	X							X		$ 55
SC	X	X	X					X				X			X	X		X		X			X		$ 200
PPC	X	X	X					X			X				X	X		X		X			X		$ 600
SCS	X	X	X						X		X				X	X		X		X			X		$ 900
MPC	X	X	X							X		X			X	X		X		X			X		$ 2,500
SC 3/15	X	X				X						X			X	X		X		X			X		$ 116

TABLE 4-5b. CHARGE CONTROLLER SPECIFICATIONS AND FEATURES

C-BH.XLS Q11b	Voltage				Current						Characteristics												Market		
MODEL	12	24	48	>48	<9	<21	<41	<61	<121	>121	Temp. comp. standard?	Temp. comp. optional?	UL Listed?	ETL Listed?	Includes low voltage disconnect?	Includes lighting control?	Expandable (master/slave)?	Battery amp meter?	Battery amp-hour meter?	Battery voltage meter?	Microprocessor based?	Max. power point tracker?	Now available?	Available in 1996?	Suggested retail cost, ea., '95
Sunamp																									
PBRS	X	X			X	X	X				X												X		$ 65
PVR	X	X				X	X				X												X		$ 95
PVI	X	X				X	X				X						X						X		$ 110
PBRT	X	X				X	X				X				X	X							X		$ 185
LSC	X	X				X	X				X				X	X							X		$ 195
SR-1220	X					X					X							X					X		$ 250
SunWise Energy Systems Inc.																									
SWSLC-12-15 LA	X					X					X				X	X							X		$ 179
SWSLC-24-8 LA		X			X						X				X	X							X		$ 199
Trace Engineering																									
C 30	X	X					X																X		$ 95
C 30A	X	X					X																X		$ 100
C 12	X					X								X	X	X				X	X		X		$ 110
C 40	X	X	X				X							X	X			X	X	X	X		X		$ 185
C 100	X	X	X						X					X	X			X	X	X	X				

TABLE 4-6. CHARGE CONTROLLER SALES AND PROJECTIONS

	Units, 1995		Dollar Sales, 1995		Projected Units	
Mfg.	**Units**	**% of Total**	**$**	**% of Total**	**1996**	**96/95**
A	75	0%	$13,925	0%	200	267%
B	285	1%	$54,150	1%	1,590	558%
C	1,054	3%	$330,362	6%	1,270	120%
D	5,375	13%	$512,250	10%	6,335	118%
E	7,000	17%	$717,500	14%	17,550	251%
F	4,734	11%	$800,790	15%	25,000	528%
G	1,230	3%	$1,019,850	20%	4,950	402%
H	21,431	52%	$1,758,300	34%	26,780	125%
TOTALS	**41,184**	**100%**	**$5,207,127**	**100%**	**83,675**	**203%**

C-BH.XLS Q11C

Section 5
SUMMARY AND CONCLUSIONS

INTRODUCTION

The overall purpose of the survey was achieved:

Purpose:
1. quantify the market for batteries shipped with (or for) PV systems in 1995,
2. quantify the PV market segments by battery type and application for PV batteries,
3. characterize and quantify the charge controllers used in PV systems,
4. characterize the operating environment for energy storage components in PV systems, and
5. estimate the PV battery market for the year 2000.

The estimate of the PV battery market for the year 2000, however, was not available from the survey responses since most respondents did not provide this information. This estimate was achieved by a "top-down analysis and presented in Section 2 of this report.

Conclusion from the three-part survey will be discussed individually for each of the three parts. Overall conclusions will follow discussions for the three parts.

SURVEY A. SYSTEM INTEGRATORS

The purpose of Survey A was to quantify the market for batteries shipped with (or for) PV systems in 1995, quantify the PV market segments by battery type and application for PV batteries, and estimate the PV battery market for the year 2000.

Eight of ten Large System Integrators responded to the survey and 13 of 18 Small System Integrators responded to the survey for an overall return of 72 percent.

Survey A was segmented into four parts: 1) Battery Sales Data, 2) Battery Information Needed For PV System Design, 3) PV System Operating Conditions, and 4) Hybrid System Issues.

Part 1. Battery Sales Data

Top-Down Market Analysis

The majority of results presented in Part 1 are based solely on summary results from the 21 System Integrators that responded to the survey. These summary results are, to a large extent, representative of the worldwide market and therefore can be extrapolated. However, the summary results do not provide a means to estimate total PV battery sales for either the U.S. market or the worldwide market. **In order to put the data from Part 1 in perspective, a Top-Down Market Analysis was developed to quantify the volume of batteries installed in PV systems.** The top down analysis is based on an industry consensus rule of thumb which states that for a typical PV system the equivalent of one 12V-100 amp-hour battery is used for each 50 watts (peak) of PV modules installed. Since the number of PV watts shipped each year (both U.S. and worldwide) is well known and published by recognized PV marketing experts[1], it is a straight forward process to estimate the total number of batteries installed in PV systems each year. Key conclusions from this analysis for 1995 are:

- Worldwide sales of PV batteries = 2,961,000 kWh
- Worldwide wholesale value for PV batteries shipped in 1995 was $302 million
- Worldwide total installed capacity of PV batteries = 10,519,000 kWh
- U.S. sales of PV batteries in 1995 = 340,515 kWh
- U.S. sales of PV batteries in 1995 = $34.7 million
- The 21 System Integrators supplied about 14 percent of the U.S. PV battery market (in terms of dollar sales)

The approximations which went into these calculations limit the accuracy to about ± 25 percent.

Summary Of Results From The 21 System Integrators

The total cost of batteries purchased by the 21 System Integrators in 1995 was $4.8 million at a unit volume of 26,308. The "top-down" market analysis showed the total worldwide PV battery market in 1995 to be approximately $302 million and 2,961 MWh of batteries shipped. This is equivalent to about 2 million 12V-100 AH batteries. The U.S. share of this market is approximately 11.5 percent or 34.7 million dollars (340,515 kWh). Therefore the 21 System Integrators supplied about 14 percent of the U.S. PV battery market in terms of wholesale dollars and about 13.6 percent of the worldwide kWh sales. These data indicate that many U.S. end users buy their PV batteries directly from a battery supplier and not from a system integrator.

A summary of 1995 sales for the System Integrators is shown in Table 5-1. Seventy-one percent of the dollars were spent on valve-regulated batteries, and valve-regulated batteries cost 88 percent more than flooded-vented batteries per kWh ($128/kWh Vs $68/kWh, respectively). The use of valve-regulated batteries increased by 145 percent from 1991 to 1995, while the use of flooded-vented batteries increased by 117 percent in units, but decreased by about 25 percent in dollars. One reason given by a large integrator for the trend toward VRLA batteries is that the risk of flooded-vented batteries not being watered properly is too high.

TABLE 5-1. TOTALS FOR ALL BATTERIES [a]

	1995						
TECHNOLOGY	**# of Units**	**% of #**	**$ (Wholesale)**	**% of $**	**kWh**	**%-kWh**	**$/kWh**
VALVE-REGULATED	16,846	64%	$3,390,782	71%	26,524	57%	$128
FLOODED-VENTED	9,462	36%	$1,370,060	29%	20,012	43%	$68
TOTAL	26,308	100%	$4,760,842	100%	46,536	100%	$102

Note a. Prices are for battery modules only, i.e., prices do not include balance of system hardware.

A-PART1\SUM-DAT\1-TABLES\95T&C

[1]based on averages of data from conversations with Bob Johnson of Strategies Unlimited (May 1996), and Paul Maycock of PV News, February 1996. Johnson and Maycock are two of the leading PV industry experts who have provided technology and market reports (including historical and forecasted PV sales data) for about two decades.

GNB was the dominant battery supplier in this survey with 47 percent of the dollars (30% of the kWh) of all batteries sold by the Integrators.

The eight Large System Integrators sold 78 percent of the units and captured 88 percent of the dollars, compared to the 13 Small System Integrators. These data verify that the eight Integrators identified before the survey as "large" were properly categorized. Small System Integrators sold 16 percent of the valve-regulated units and 33 percent of the flooded-vented units.

The primary applications for valve-regulated batteries were telecommunications (40%), telemetry (13%), and lighting (9%)(see Table 5-2). About 80 percent of all telecommunications, telemetry applications and lighting applications used VRLA batteries. Thirty percent of <u>all</u> flooded-vented batteries were used in hybrid systems, 31 percent in telecommunications, and 17 percent in remote homes. Note in Table 5-3 that hybrid systems, as a category, used 89 percent flooded-vented batteries. The preference for VRLA batteries or flooded-vented batteries depends to a large extent on the market segment that the battery serves.

TABLE 5-2. TOTALS (100%) BY TECHNOLOGY; kWh (EXPRESSED IN %)

TECHNOLOGY	RH	TC<	TC>	TM	L	W	H	V	UKN	TOTALS
VALVE-REGULATED	7%	6%	34%	13%	9%	2%	3%	3%	23%	100%
FLOODED-VENTED	17%	2%	29%	1%	2%	2%	30%	13%	4%	100%
TOTAL	11%	4%	32%	8%	6%	2%	15%	7%	15%	100%

TABLE 5-3. TOTALS (100%) BY APPLICATION; kWh (EXPRESSED IN %)

TECHNOLOGY	RH	TC<	TC>	TM	L	W	H	V	UKN	TOTALS
VALVE-REGULATED	35%	81%	61%	94%	85%	59%	11%	23%	89%	57%
FLOODED-VENTED	65%	19%	39%	6%	15%	41%	89%	77%	11%	43%
TOTAL	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

H= Hybrid L = Lighting TC< = Telecommunications less than 200 W(peak) PV
RH = Remote Home TM = Telemetry TC> = Telecommunications greater than 200 W(peak) PV
UKN = Unknown V = Village Power W = Water Pumping

A-PART1\SUM-DAT\1-TABLES kWh

Valve-regulated batteries are heavily skewed toward 12 Volt modules (60%); 35 percent were 6 Volt modules, and only five percent were 2 Volt modules. Flooded batteries were skewed toward 2 Volt modules (45 percent); 42 percent were 6 Volt modules, and 12 percent were 12 Volt modules (Table 5-4).

In terms of amp-hour size, valve-regulated batteries were grouped in the 100-400 AH bin for 6 Volt modules and the 0-200 AH bin for the 12 Volt modules. Flooded batteries were more broadly distributed in the 600-3,000 AH range at 2 Volts, 200-400 AH at 6 Volts, and 1400-1800 AH at 12 Volts (clearly modules, not individual monolithic units).

TABLE 5-4. kWh BY BATTERY VOLTAGE

AH	VRLA			FLOODED			
RANGE	2Volt	6 Volt	12 Volt	2 Volt	6 Volt	12 Volt	24 Volt
KWH TOTALS	1,406	9,369	15,749	9,198	8,318	2,417	80
% of TOTAL	5.3%	35.3%	59.4%	46.0%	41.6%	12.1%	0.4%
TOTALS	26,524			20,012			

\A=PART1\SUM-DAT\KWH.XLS SUM-ALL

Part 2. Battery Information Needed For PV System Design

This part of the survey asked Integrators what information they needed from the battery manufacturer in order to properly design PV systems with optimum performance and minimum life-cycle cost. Integrators ranked 29 parameters in terms of importance (1=Essential, 2=Useful, 3=Not Important). The first 20 parameters were ranked between 1.0 and 2.0 (average of all 21 Integrators). These data, presented in Table 2-19, page 2-20, are essential information for all battery manufacturers that serve the PV market. The parameter ranked most important was "Cost".

Part 3. PV System Operating Conditions

Part 3 profiles the Integrators' application of PV hardware, their approach to PV system design, and the environment into which PV systems are placed.

Integrators reported that 80 percent of their charge controllers use an ON-OFF algorithm. The ON-OFF algorithm is by far the most difficult charge management algorithm for which to define voltage set points; battery manufacturers rarely, if ever, specify voltage set points for ON-OFF algorithms. This difficulty was emphasized by a battery manufacturer:

> ...Listen to the battery industry when we tell you that we need constant voltage regulators, higher end voltage limits, and higher limits for low voltage disconnects.

There appears to be a trend toward the use of pulse-width modulated algorithm, temperature compensation, and more concern regarding the set point value. Only 25% of the Integrators reported that they used the battery manufacturer's recommended set points (probably because most battery manufacturers do not provide this information).

Integrators reported that they get about 78 percent of the advertised battery cycle life, regardless of whether they were of the Flooded, Absorbed Glass Mat, or Gel technology.

None of the 21 Integrators reported the use of nickel-cadmium batteries (i.e., all were lead-acid batteries).

Responses show that Large Integrators use larger safety margins in designing and sizing battery storage systems than do Small Integrators. For example, Small Integrators design systems with twice the discharge rate than do Large Integrators (twice the discharge rate means one half the number of "no sun days").

About 60 percent of integrator respondents use temperature compensated voltage regulators in their charge controller systems. In comparison, 88 percent of charge controller respondents (Section 4, page 4-4, Question 2) felt that temperature compensation was either vital or important.

The last question in Part 3 asked in what areas would the Integrators like assistance from SNL. The respondents clearly want assistance in the characterization of batteries for PV specifications (data sheet values), with 54 percent of Small Integrators showing this as the highest priority and 71 percent of the Large Integrators showing this as the highest priority.

Part 4. Hybrid System Issues

For the purposes of this report, hybrid systems are defined as stand-alone systems with two or more types of power generating sources, one of which is photovoltaics. The purpose of Part 4 was to identify unique characteristics and requirements of hybrid systems.

When batteries are wired in parallel, a fault in a single cell can sink current from the parallel strings, creating an unsafe condition and the potential for a fire or explosion. Battery manufacturers generally do not specify the number of strings that can be paralleled. Forty-three percent of the System Integrators limit paralleling to three or four strings. Surprisingly, two Large System Integrators (out of 7 that responded to this question) marked the category "9 or more".

Forty-eight percent of the Small Integrators' business was hybrid systems, compared to 16 percent for Large Integrators. This may be due to the fact that Small Integrators provide PV systems for remote homes, which often use a backup generator.

The majority (52%) of hybrid system batteries are flooded-vented lead-acid with antimony additive to the plates. None of the Integrators reported using flooded-vented batteries with lead-calcium plates. Forty-eight percent of the batteries were of the valve-regulated lead acid technology (both absorbent glass mat and gel).

SURVEY B. BATTERY MANUFACTURER

This survey was designed to: a) collect information regarding contacts and products that would be of interest to the PV industry and b) to determine what information that battery manufacturers needed from the PV industry. Nine of the ten battery manufacturers that received the three page questionnaire responded.

A list of contacts for the nine respondents was developed, which includes name, address, voice and facsimile numbers, and where available, an e-mail address (Table 3-1, page 3-3). In addition, a list of batteries suitable for PV systems is tabulated for each respondent. The table includes information regarding make, model, voltage and amp-hour rating, plates, technology, typical applications, and data sheet availability.

None of the nine respondents indicated that they had an "Application Guide for PV Customers" available at the time that the survey was submitted. However, four indicated that they will have an application guide available by the end of 1996.

Battery manufacturers received a table identical to the System Integrator form in Survey A, Part 2: *Battery Information Needed For PV System Design.* All nine battery manufacturer respondents indicated that they had most of the information defined by the 20 parameters that Integrators considered most important. Unfortunately, these data are typically not included in product literature and therefore they are not readily available to the Integrator.

Respondents were asked to identify what the PV industry could do to stimulate battery manufacturer interest in developing "PV Battery Data Sheets and PV System Application Guides". The response from Concord Battery was very specific:

We have done much to provide information to this market, i.e., testing, data, temperature performance, and cycle life. The PV industry still needs to further supply battery information on real application requirements. Listen to the battery industry when we tell you we need constant voltage regulators, higher end voltage limits, and higher limits for low voltage disconnects (e.g., 1.92 v/cell = 90% discharge).

This report will get the Concord message to the PV industry and provide the "battery information on real applications".

The last survey question asked in what areas would the Integrators like assistance from Sandia. Respondents ranked two categories as Highest Priority: 1) Assist in the development of application guides or application notes and 2) Perform surveys to define the market.

SURVEY C. CHARGE CONTROLLER MANUFACTURERS

Survey C was sent to 10 of the largest U.S. manufacturers of charge controllers. Eight manufacturers responded to the survey.

The purpose of Survey C was to: a) characterize and quantify the charge controllers manufactured in the U.S., b) collect information of interest to the PV industry, and c) determine what information that the charge controller manufacturers need from the PV industry and battery manufacturers.

Two of the eight respondents had about 55 percent of the U.S. units and dollars volume in 1995. On the other end of the scale, two manufacturers had less than 2 percent of the market. The total volume and sales for the eight manufacturers are shown in Table 5-5. A 203 percent growth rate in unit volume is very significant since worldwide growth of PV sales is on the order of 20 percent per year. Much of the growth shown in Table 5-5 will be due to exports of U.S. charge controllers.

TABLE 5-5. CHARGE CONTROLLER SALES AND PROJECTIONS

	Units, 1995		Dollar Sales, 1995		Projected Units	
Mfg.	Units	% of Total	$	% of Total	1996	96/95
TOTALS	41,184	100%	$5,207,127	100%	83,675	203%

C-BH.XLS Q11C

Charge controller manufacturers answered with one YES and seven NOs to the question "Do you receive adequate information from battery manufacturers regarding the performance of batteries in PV Systems?"

Respondents were asked to rank order areas that they would like assistance from Sandia. The highest priority was equally distributed among "Assist in the development of Application Notes or Guides", "Perform surveys to define the market", and "Provide technical liaison between the PV and battery industries". The number 2 priority was "Assist in the characterization of batteries (e.g., set points) for PV specifications".

GENERAL CONCLUSIONS AND RECOMMENDATIONS

The Survey

This survey provided: a) quantification and characterization of batteries and charge controllers used in PV systems, b) characterization of the operating environment in which batteries and charge controllers are used, and c) feedback from PV System Integrators, battery manufacturers, and charge controller manufacturers defining what information each needs to optimize PV energy storage systems.

Sandia National Laboratories Assistance

Survey respondents identified areas of focus by each of the three industries (PV System Integrators, Battery Manufacturers, and Charge Controller Manufacturers) in which they would like Sandia National Laboratories' assistance. The high priority areas identified were: a) assist in the development of application guides or notes, b) assist in the characterization of batteries for PV data sheet values, c) provide technical liaison between the PV and battery industries, and d) perform surveys to define the market.

Information Exchange

This Final Report will serve as an information exchange tool among the three elements of PV energy storage systems: PV System Integrators, battery manufacturers, and charge controller manufacturers. Names, companies, and phone/fax numbers identified in this report will allow direct communications among key participants in each of the three industries.

Respondents to the survey indicated a need for continued support by SNL in the collection and dissemination of information related to PV system energy management. Information exchange and information dissemination is most effective when done on a regular basis. There is a significant benefit to SNL continuing to serve as the focal point for PV Energy System information and generation, collection, and distribution by: a) expanding the contact list developed herein to all interested individuals, i.e., the LIST, b) creating an internet web site for easy access to existing battery storage information and as a means for industry to ask questions and contribute information, c) distribute a quarterly "news letter" of summary information to the LIST via e-mail, and d) distributing an *annual report* via e-mail to the LIST plus a hard copy to the Department of Energy and other selected individuals.

APPENDIX A

SURVEY FORMS

Survey A: System Integrator Survey

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SURVEY A:
SYSTEM INTEGRATOR SURVEY

Survey A is divided into four parts:

Part 1: Battery sales data
Part 2: Battery information needed for PV system design
Part 3: Typical operating conditions for PV systems
Part 4: Hybrid system issues

Please complete all four parts of the survey and mail by February 15 in the envelope provided to:

Bob Hammond
Center for Energy Systems Research, CEAS
Arizona State University
Box 875806
Tempe, AZ 85287-5806

Thank you for participating in this survey.

Sincerely,

Bob Hammond
Director, Alternative Energy Development

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SURVEY A:
SYSTEM INTEGRATOR SURVEY

PART 1: BATTERY SALES DATA

SURVEY A, PART 1A. SYSTEM INTEGRATOR SURVEY: FLOODED-VENTED BATTERIES

			Actual 1995		% of Total # of Batteries (1995) by Application									Projected 2000	
MFG	Model	V-AH	# of Batteries	Avg Unit Cost in $	RH	TC<	TC>	TM	L	W	H	V	UKN	# of Batteries	Avg Unit Cost in $
VARTA	VB	ALL													
EXIDE	E120	ALL													
GNB	CMDR	ALL													
	675RC-														
	13	12-474													
	17	12-632													
	19	12-711													
	23	12-869													
	27	12-1027													
	GNB TOTAL														
IBE	75N	2-184													
		2-1476													
		2-750													
		2-1000													
	IBE TOTAL														
TROJAN	L-16	6-350													
	L-16														
	L-16														
	T-105	6-220													
	T-105														
	TROJAN TOTAL														
PACIFIC C.	85A23	2-1160													
US BAT	2200	6-220													
MISC	ALL	ALL													
TOTALS															

** Application: RH: remote home; TC<: telecom < 200 watts; TC>: telecom > 200 watts; TM: telemetry; L: lighting; W: water pumping; H: hybrid; V: village power

CONFIDENTIAL SURVEY

SURVEY A, PART 1B. SYSTEM INTEGRATOR SURVEY: GNB BATTERIES

Series	Model	V-AH	Actual 1995 # of Batteries	Actual 1995 Avg Unit Cost in $	% of Total # of Batteries (1995) by Application: RH	TC<	TC>	TM	L	W	H	V	UKN	Projected 2000 # of Batteries	Projected 2000 Avg Unit Cost in $
12-5000		12-100													
12-5000															
6-45A		12-XX													
6-45A	7	140													
6-45A	11	230													
6-45A	15	320													
75A															
6-75A	7	12-235													
6-75A	15	12-545													
6-75A	15	12-545													
3-75A	17	6-625													
3-75A	19	6-700													
3-75A	21	6-780													
3-75A	23	6-860													
3-75A	27	6-1015													
3-75A	27	6-1015													
3-75A	27	6-1015													
3-75A	27	6-1015													
85A															
3-85A	25	6-1040													
3-85A	31	6-1295													
3-85A	31	6-1295													
3-85A	33	6-1385													
85A	39	2-1560													
85A	51	Feb-65													
ABSII	MISC	MISC													
TOTALS															

** Application: RH: remote home; TC<: telecom < 200 watts; TC>: telecom > 200 watts; TM: telemetry; L: lighting; W: water pumping; H: hybrid; V: village power

CONFIDENTIAL SURVEY

SURVEY A, PART 1C. SYSTEM INTEGRATOR SURVEY: JCI BATTERIES

Series	Model	V-AH	Actual 1995 # of Batteries	Actual 1995 Avg Unit Cost in $	% of Total # of Batteries (1995) by Application: RH	TC<	TC>	TM	L	W	H	V	UKN	Projected 2000 # of Batteries	Projected 2000 Avg Unit Cost in $
	GC12V100	12-90													
	GC12400	12-40													
	GC100B	12-100													
	GC6V200	6-200													
	UI-31	12-37													
	12120	12-12													
	1260	12-6													
	TXL21710	2-1710													
TOTALS															

** Application: RH: remote home; TC<: telecom < 200 watts; TC>: telecom > 200 watts;
TM: telemetry; L: lighting; W: water pumping; H: hybrid; V: village power

CONFIDENTIAL SURVEY

SURVEY A, PART 1D. SYSTEM INTEGRATOR SURVEY: MISC. VR BATTERIES

MFG	Model	V-AH	Actual 1995 # of Batteries	Actual 1995 Avg Unit Cost in $	% of Total # of Batteries (1995) by Application: RH	TC<	TC>	TM	L	W	H	V	UKN	Projected 2000 # of Batteries	Projected 2000 Avg Unit Cost in $
DEKA	86V	12-90													
	8624	12-66													
	8627	12-90													
	DEKA TOTALS														
SONNEN-	A21215	12-15													
SCEIN	A21224	12-24													
	SUNN TOTALS														
CONCORD	ALL	ALL													
POWER	ALL	ALL													
SONIC															
	OTHER TOTAL														

** Application: RH: remote home; TC<: telecom < 200 watts; TC>: telecom > 200 watts; TM: telemetry; L: lighting; W: water pumping; H: hybrid; V: village power

CONFIDENTIAL SURVEY

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SURVEY A:
SYSTEM INTEGRATOR SURVEY

PART 2: BATTERY INFORMATION NEEDED FOR PV SYSTEM DESIGN

SURVEY A, PART 2; SYSTEM INTEGRATOR
BATTERY INFORMATION NEEDED FOR PV SYSTEM DESIGN

RANK[1]			
1	2	3	PARAMETER(S)
			Nominal battery voltage
			Amp-hour capacity at C/8
			Amp-hour capacity at C/20
			Amp-hour capacity at C/100
			Specific gravity typically shipped
			Self-discharge rate vs temperature
			Physical characteristics; dimensions, terminal size, weight; packaged weight, size
			Recommended charging voltage vs temperature vs charge rate
			Recommended controller set points for on-off controllers
			Recommended controller set points for other charge controllers (constant voltage ,PWM)
			Cost
			Electrolyte freezing point vs SOC
			Battery life vs average daily DOD, vs temperature
			Warranty (and warranty restrictions)
			Recommended equalization procedure, voltage, frequency
			Series/parallel recommendations
			Plate construction and additives (% antimony, % calcium)
			Reserve electrolyte capacity
			Special features such as extra electrolyte reserve
			Allowed and preferred orientations (e.g., on its side, upside down)
			Available dry charged?
			Disposal/recycling instructions
			Recommended maintenance schedule
			Maximum shelf life
			Shipping hazard code
			State of Charge (SOC) vs Voc
			SOC vs battery voltage at C/20
			SOC as a function of battery voltage at other various charge/discharge rates
			SOC as a function of specific gravity at various charge/discharge rates
			Maximum system voltage to ground
			PLEASE NOTE ADDITIONAL PARAMETERS BELOW:

COMMENTS:

____

____

____

____

[1]* RANK; 1-essential, 2-useful, 3-not important

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SURVEY A:
SYSTEM INTEGRATOR SURVEY

PART 3: TYPICAL OPERATING CONDITIONS FOR PV SYSTEMS

SURVEY A, PART 3; SYSTEM INTEGRATOR

TYPICAL OPERATING CONDITIONS FOR PV SYSTEMS

1. What percent of your balance of system is provided by another systems house? ________

2. If battery manufacturers recommended specific setpoints for their batteries in PV systems, would you use them?
   a) Yes_____ b) No_____ c) I would evaluate the setpoints before deciding to use them______

3. If battery manufacturers recommended specific charging algorithms for their batteries in PV systems, would you use them?
   a) Yes_____ b) No_____ c) I would evaluate before deciding to use them______

4. What percentage of the advertised battery cycle life do you estimate that you get?

a) Flooded[2] batteries:
   ❐ 0-20% ❐ 20-40% ❐ 40-60% ❐ 60-80% ❐ 80-100%

b) VRLA[3]/AGM[4] batteries :
   ❐ 0-20% ❐ 20-40% ❐ 40-60% ❐ 60-80% ❐ 80-100%

c) GEL[5]/VRLA batteries:
   ❐ 0-20% ❐ 20-40% ❐ 40-60% ❐ 60-80% ❐ 80-100%

5. What percentage of your systems are designed for the following battery temperature extremes?

Low Temp	(-60)-(-40) F	(-40)-(-20) F	(-20)-0 F	0-20 F	20-40 F	40-60 F
%						

High Temp	60-80 F	80-100 F	100-120 F	120-140 F	140-160 F
%					

NOTE: The total % in each table should equal 100%

6. What percentage of your system designs use:

	0-20 %	20-40 %	40-60 %	60-80 %	80-100 %
a. Temperature compensated voltage regulators?					
b. Battery AH capacity derated for expected low temperature?					
c. Load current compensated low voltage disconnect?					
d. Battery specific gravity adjusted for expected low temperature?					
e. Insulated battery boxes (or Cool Cells$_{tm}$)?					

---

[2]Flooded batteries: Any battery with an electrolyte that flows freely within each cell.

[3]VRLA: Valve Regulated Lead-Acid, a term used for batteries designed for internal recombination of hydrogen and oxygen. The "sealed" valves on these batteries are spring loaded to release at internal pressures from 2-9 PSI. These batteries can typically operate in any position because the electrolyte cannot be spilled.

[4]AGM: A VRLA battery in which the electrolyte is immobilized in a porous glass matte between the positive and negative plates. Sometimes referred to as a "starved electrolyte" battery due to the electrolyte being immobilized in the glass matte. Typical brand names (does not include all): GNB, Concorde, Power Sonic.

[5]GEL: (Gel Electrolyte) A VRLA battery in which the electrolyte is immobilized in a thixotropic gel. Typical brand names (does not include all): Johnson Controls, Deka, Sonnenschein, Exide.

7. What percentage of flooded batteries use catalytic recombiner caps (i.e. Hydrocaps$_{tm}$)?
❐ 0-20% ❐ 20-40% ❐ 40-60% ❐ 60-80% ❐ 80-100%
_____ A: Cost _____ B: Lack of information on performance _____ C: Didn't know they existed
If you don't use hydrocaps - why?____

8. Do you receive adequate information from the manufacturer regarding battery lifetime vs depth of discharge?
❐ 1 (Poor) ❐ 2 ❐ 3 ❐ 4 ❐ 5 (Excellent)

9. Do you feel that you have adequate information from the manufacturer regarding battery lifetime vs temperature? Yes_____ No_____

10. What percentage of your stand-alone systems use a maximum power tracker?
❐ 0-20% ❐ 20-40% ❐ 40-60% ❐ 60-80% ❐ 80-100%

11. What percentage of your systems use ni-cad batteries?
❐ 0-20% ❐ 20-40% ❐ 40-60% ❐ 60-80% ❐ 80-100%

12. What percentage of your systems operate at the following average amp-hour discharge rate:

Discharge rate	C/8-C/15	C/15-C/30	C/30-C/60	C/60-C/100	C100-C/200
LVD					

NOTE: The total % in this table should equal 100%

13. a. When batteries are received, what do you estimate is the percentage of the rated amp-hour capacity they will deliver?
❐ 0-20% ❐ 20-40% ❐ 40-60% ❐ 60-80% ❐ 80-100%

b. Do you boost charge the batteries before installing them in the field?
Yes_____ No_____; If yes:

Hours of charge	0-2	2-4	4-8	8-12	12-16	16-24
(check box)						

14. When designing a system and selecting a battery, what capacity value do you use the most? (Indicate percentage of batteries that fall into each category):
a) Manufacturer's C/20 _______ b) Manufacturer's C/100 _______ c) Other value: _______

15. What percentage of systems have a typical daily depth-of-discharge of:

Flooded Batteries
________0-5% daily dod
________5-10% daily dod
________10-15% daily dod
________15-25% daily dod
________25-50% daily dod
________50-100% daily dod

VRLA Batteries
________0-5% daily dod
________5-10% daily dod
________10-15% daily dod
________15-25% daily dod
________25-50% daily dod
________50-100% daily dod

16. Low Voltage Disconnect (LVD)
   a. Where do you get the information for your LVD setting?
   Battery mfg. literature ______ Charge controller mfg. _______ Experience _______

   b. Do you adjust the LVD setpoint(s) for low or high discharge rates? Yes_____ No_____

   c. What LVD setpoint(s) do you use? (based on a nominal 12 Vdc system)

Discharge rate	C/8-C/15	C/15-C/30	C/30-C/60	C/60-C/100	C100-C/200
LVD					

   d. When selecting an LVD setpoint, what is your single most important criteria in your decision:
      a. Reduced depth-of-discharge for increased lifetime _______
      b. Maximum usable capacity ________

   e. What is the maximum depth-of-discharge (based on LVD setting) you typically design for?
   [Maximum percentage of amp-hours removed before the low voltage disconnect (LVD) is activated]

Flooded Batteries
_________0-25% maximum dod
_________25-50% maximum dod
_________50-70% maximum dod
_________70-80% maximum dod
_________80-90% maximum dod
_________90-100% maximum dod

VRLA Batteries
_________0-25% maximum dod
_________25-50% maximum dod
_________50-70% maximum dod
_________70-80% maximum dod
_________80-90% maximum dod
_________90-100% maximum dod

NOTE: Total in each column should equal 100%.

17. Charging Algorithms. For each controller type, indicate in Row 2 the percentage of systems that match the charge rate and in Row 3 the typical system battery bank size. (i.e., total amp hours)

   a. Series or shunt-interrupting charge controller(i.e., on/off).
   percent of total systems using this algorithm?

❒ 0-20% ❒ 20-40% ❒ 40-60% ❒ 60-80% ❒ 80-100%

1	Charge Rate	C/8-C/15	C/15-C/30	C/30-C/60	C/60-C/100	C100-C/200
2	%					
3	Battery Bank Size, AH					

   b. Constant voltage.
   % of total systems using this type algorithm?

❒ 0-20% ❒ 20-40% ❒ 40-60% ❒ 60-80% ❒ 80-100%

1	Charge Rate	C/8-C/15	C/15-C/30	C/30-C/60	C/60-C/100	C100-C/200
2	%					
3	Battery Bank Size, AH					

c. Pulse width modulation.
% of systems using this type algorithm?

❐ 0-20% ❐ 20-40% ❐ 40-60% ❐ 60-80% ❐ 80-100%

1	Charge Rate	C/8-C/15	C/15-C/30	C/30-C/60	C/60-C/100	C100-C/200
2	%					
3	Battery Bank Size, AH					

d: Other charging algorithm? ________. Define:____

e. What % of total systems do you install without charge controllers? (i.e., self-regulating modules) _____

18. Where do you get the information for your voltage regulation setting?
Battery mfg. literature _______ Charge controller mfg. _______ Prior experience _______
Astrologer _______ Mother-in-Law ________ My Dog ___________

19. What voltage regulation setpoints do you use for 12 V nominal batteries? (Note: Adjust for 24/48 V systems.)
Lead antimony = motive power batteries, Lead-Calcium = standby/shallow cycle batteries

a. Series-interrupting and shunt-interrupting (i.e., on/off).

Charge Rate	C/8-C/15	C/15-C/30	C/30-C/60	C/60-C/100	C100-C/200
Flooded lead-antimony					
Flooded lead-calcium					
VRLA/Gel					
VRLA/AGM					

b. Constant voltage.

Charge Rate	C/8-C/15	C/15-C/30	C/30-C/60	C/60-C/100	C100-C/200
Flooded lead-antimony					
Flooded lead-calcium					
VRLA/Gel					
VRLA/AGM					

c. Pulse width modulation.

Charge Rate	C/8-C/15	C/15-C/30	C/30-C/60	C/60-C/100	C100-C/200
Flooded lead-antimony					
Flooded lead-calcium					
VRLA/Gel					
VRLA/AGM					

d. Sub-Array control (controlling by sub-sections of the array)

Charge Rate	C/8-C/15	C/15-C/30	C/30-C/60	C/60-C/100	C100-C/200
Flooded lead-antimony					
Flooded lead-calcium					
VRLA/Gel					
VRLA/AGM					

20. If Sandia National Laboratories' *Photovoltaic Design Assistance Center* were able to expand the program to provide assistance in developing the market for batteries in PV systems, please indicate your areas of preference (1 = highest priority; 5 = lowest priority).

_______ Assist in the characterization of batteries for PV specifications (data sheet values)
_______ Assist in the development of "application notes" or "application guides"
_______ Perform surveys to define the market
_______ Provide technical liaison between the PV industry and the battery manufacturer

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SURVEY A:
SYSTEM INTEGRATOR SURVEY

PART 4: HYBRID SYSTEM ISSUES

HYBRID SURVEY

For the purposes of this survey, a hybrid system is considered to be any system with more than one power source that operates in an off-grid environment.

1. If you use parallel strings, hat are the maximum parallel strings you allow in a system?

____ Do not allow ____ 2 ____ 3-4 ____ 5-6 ____ 7-8 ____ 9 +

2. At what battery size do you start to require battery grounding?

____ All ____ 1-5 Kwh ____ 5-10 Kwh ____ 10-100 Kwh ____ >100 Kwh

3. Do you ground conductive battery racks? Yes______ No______

   If yes, what is the average amount of leakage current you experience? ______

   (Please express this as a fraction of the battery bank ampere hour size. For instance, a 2000Ah system with 2 amps of leakage current would be C/1000.)

4. What do you use as the upper charge limit (state of charge) for a battery being charged by a mechanical charger (generator, wind, hydro, etc.)?

   ______ Measured voltage
   ______ Ampere-hours input
   ______ Other, Explain: ____

5. What percentage of your systems use:

   ______ Integrated power centers (integrated charge controller, disconnects, etc.)
   ______ Components mounted separately (discrete charge controller, disconnects, inverter, etc.)

6. In systems with various power generation sources, how do you determine the battery charging setpoints?

   ______ Set them all the same irrespective of source.
   ______ Use different setpoints for different sources

7. With regards to hybrid systems, please give an estimate of the percentage of your business that is hybrid systems.

__ <10% __ 20% __ 30% __ 40% __ 50% __ 60% __ 70% __ 80% __ 90% __ 100%

and the typical expected maximum daily depth-of-discharge:

__ <10% __ 20% __ 30% __ 40% __ 50% __ 60% __ 70% __ 80% __ 90% __ 100%

8. What percentage of your systems do you design with an expected increase in seasonal depth-of-discharge?

__ 10% __ 20% __ 30% __ 40% __ 50% __ 60% __ 70% __ 80% __ 90% __ 100%

9. What is the maximum seasonal depth-of-discharge you allow in hybrid type systems? (check one)

__ 10% __ 20% __ 30% __ 40% __ 50% __ 60% __ 70% __ 80% __ 90% __ 100%

10. In a hybrid system, what type of battery technology do you recommend?

______ VRLA, Gel electrolyte
______ VRLA, AGM
______ Flooded Lead-Antimony
______ Flooded Lead Calcium
______ Whatever the customer will bear in cost (technology is not considered except for cost).

11. What type of environmental control do you require for your battery area?

______ Batteries installed in facility maintained at 70^{0}F nominal (or manufacturer recommended value) using HVAC.
______ Batteries installed in a thermally insulated area with no HVAC provision.
______ No environmental controls required for battery area.

12. Do you use temperature compensation during battery charging operations?

______ Yes ______ No

13. Do you directly monitor one or more battery temperatures during battery charging operations?

______ Yes ______ No

14. If you have had experiences with thermal runaway in any of your battery systems, please indicate the number of events for each battery type:

______ VRLA, Gel electrolyte
______ VRLA, AGM
______ Flooded Lead-Antimony
______ Flooded Lead Calcium

15. Has your company had any people injured due to battery explosions or electrolyte spillage?

______ Yes ______ No

______ Please indicate the number of incidents regardless of how insignificant they may be.

16. Has your company been involved with any incidents of a wiring or building fire that were a direct result of PV system wiring or component failure?

______ Yes ______ No

______ Please indicate the number of incidents regardless of how insignificant they may be.

APPENDIX B

SURVEY FORMS

Survey B: Battery Manufacturer Survey

SURVEY B
BATTERY MANUFACTURER SURVEY

1. Who in your company is the primary contact for the photovoltaic batteries?
   Name______________________ Title: ______________________
   Street, mail code______________________________________
   City, State, Zip Code__________________________________
   Telephone:______________ Fax:____________ e-mail:______________

2. Have you participated or do you plan on participating in any of the following conferences:?

CONFERENCE	1994	1995	1996	1997	1998
A) ASES					
B) IEEE PVSC					
C) SOLTECH					
D) NREL Reliability Workshop					
E) REDI/SEER					
F) UBG					
G) UPVG					
H) OTHER__________					

3. Please list the products you presently recommend for photovoltaic systems or feel would work well in PV systems.

#	Model	Volts	AH @ 20 hr rate	Plates [1]	Tech-nology [2]	Approx. Cost $/ea. Whsle	Retail	Typical applications [3]	Data sheet available? (YES or NO) [4]
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									

NOTES:
1. **A** - Antimony; **C** - Calcium, **H** - hybrid, other (state)
2. *Technology:* **FL** - Flooded Lead-Acid; **gel** - VRLA gel, **agm** - VRLA AGM, **N** - Nicad, other (state).
3. *Most typical application:* **RH**-remote home, **TC<**-telecom <200W, **TC>**-telecom>200W, **TM**-telemetry, **L**-lighting, **W**-water pumping, **H**-hybrid, other (state)
4. If **YES**, please attach data sheet. If **NO**, please state date when data sheet will be available.

4. Do you have a comprehensive "Application Guide" for your photovoltaic system customers? (Definition: An application guide tells a customer how to apply the battery in a specific application, whereas a "data sheet" deals primarily with specifications.)

A) Yes (please attach)
B) No
C) We plan on releasing one on __________(date).

5. Do you provide the following for your batteries used in PV systems:

#	Yes	No	Date Avail	PARAMETER(S)
1				Nominal battery voltage
2				Amp-hour capacity at C/8
3				Amp-hour capacity at C/20
4				Amp-hour capacity at C/100
5				Specific gravity
6				Self-discharge rate vs temperature vs lifetime
7				Physical characteristics; dimensions, terminal size, weight; packaged weight, size
8				Recommended charging voltage vs temperature vs charge rate
9				Recommended controller set points for on-off controllers vs charge rate
10				Cost
11				Electrolyte freezing point vs SOC
12				Battery life vs average daily DOD, vs temperature
13				Warranty (and warranty restrictions) If so, how long?
14				General testing & charging requirements
15				Recommended equalization voltage, frequency
16				Series/parallel recommendations
17				Plate construction and additives (% antimony, % calcium)
18				Reserve electrolyte capacity
19				Sustained overcharge rate (recombination rate)
20				Allowed and preferred orientations (e.g., upside down)
21				Available dry charged
22				Amp-hour efficiency at 20% DOD vs lifetime vs other variables
23				Disposal/recycling instructions
24				Recommended maintenance schedule
25				Maximum shelf life
26				Shipping hazard code
27				State of Charge (SOC) vs Voc
28				SOC vs battery voltage at C/20
29				SOC vs battery voltage
30				SOC as a function of battery voltage at other various charge/discharge rates
31				SOC as a function of specific gravity at various charge/discharge rates
32				Maximum system voltage to ground

6. What could the PV industry do to stimulate your interest in developing "PV Battery Data Sheets" and "PV System Application Guides"?

____
____
____
____
____
____
____
____
____

7. If the Sandia National Laboratories' *Photovoltaic Design Assistance Center* were able to expand the program to provide assistance in developing the market for batteries in PV systems, please indicate your areas of preference (1 = highest priority; 5 = lowest priority).

_______ Assist in the characterize batteries for PV specifications (data sheet values)
_______ Assist in the development of "application notes" or "application guides"
_______ Perform surveys to define the market
_______ Provide technical liaison between the PV industry and you (the battery manufacturer)
_______ Other, please specify____
____
____
____
____
____

APPENDIX C

SURVEY FORMS

Survey C: Charge Controller Manufacturer Survey

SURVEY C
CHARGE CONTROLLER MANUFACTURER SURVEY

1. Please assign a percentage to each market sector you presently supply.

Market type	Percentage of business
Stand-alone remote home systems	
Stand-alone PV lighting systems	
Hybrid power systems (multiple power source)	
Telecomm	
Recreational vehicles	

2. What is your company's position on temperature compensation of the regulation set point? (check one)
____ It is vital and is standard feature.
____ It is important but sold as an option.
____ It is not important.
____ It causes more problems that it is worth.
____ There is not enough information on the worth of this feature.

3. How does the consumer select the charging settings for your charge controller products. (check one)
____ They are fixed and must order according to battery type.
____ They are adjustable.
____ We have only two set points, one for flooded batteries and one for sealed (VRLA) batteries.

4. Where do you get the information for selecting the recommended charge voltage settings: (check one)
____ Experience
____ Battery manufacturers
____ Customer feedback
____ We do not provide suggested controller set points

5. Do you receive adequate information from battery manufacturers regarding the performance of batteries in PV systems?
____ Yes ____ No

6. If battery manufacturers publish data specifying appropriate charge algorithms and set points, would you pass those recommendations along to your customers?
____ Yes ____ No

7. Would you adjust your product line to support those recommendations?
____ Yes ____ No

8. Do you have questions regarding the performance of any of your charge controllers?

	No	If yes:	Flooded*	AGM**	Gell***
Ability to charge batteries fully					
Appropriate regulation set points					
Appropriate LVD set points					
Product reliability					

*Flooded batteries: Any battery with an electrolyte that flows freely within each cell.

**AGM: A battery in which the electrolyte is immobilized in a porous glass matte between the positive and negative plates. Sometimes referred to as a "starved electrolyte" battery due to the electrolyte being immobilized in the glass matte. Typical brand names (does not include all): GNB, Concorde, Power Sonic.

***GEL: (Gel Electrolyte) A VRLA battery in which the electrolyte is immobilized in a thixotropic gel. Typical brand names (does not include all): Johnson Controls, Deka, Sonnenschein, Exide.

9. How many calls per month (estimate) do you receive from distributors or users regarding the proper use of your product? (check one)

____ 1-20
____ 21-50
____ 51-100
____ >100

10. If Sandia National Laboratories' Photovoltaic Design Assistance Center were able to expand the program to provide assistance in developing better information for the use of charge controller manufacturers in PV applications, please indicate your areas of preference (1 = highest priority; 5 = lowest priority).

____ Assist in the characterization of batteries for PV specifications (data sheet values).
____ Assist in the development of "application notes" or Application guides" for batteries.
____ Provide technical assistance for charge controller manufacturers to characterize their newly developed charge controller products and algorithms.
____ Act as technical liaison between the battery manufacturers and the charge controller industry.
____ Other ______________________________

Please fill in the chart on the next page with information regarding all products you manufacture or plan to manufacture in the future.

CHARGE CONTROLLER MANUACTURER SURVEY

		Voltage				Current						Characteristics												Market				
#	CHARGE CONTROLLER MODEL	12	24	48	>48	<9	<21	<41	<61	<121	>121	Temp. comp. standard?	Temp. comp. optional?	UL Listed?	ETL Listed?	Includes low voltage disconnec	Includes lighting control?	Expandable (master/slave)?	Battery amp meter?	Battery amp-hour meter?	Battery voltage meter?	Microprocessor based?	Max. power point tracker?	Now available?	Available in 1996?	Units shipped '95	Suggested retail cost, ea., '95	Units Projections '96?
1																												
2																												
3																												
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APPENDIX D

Mailing Lists:

System Integrators - Large
System Inegrators - Small
Battery Manufacturers
Charge Controller Manufacturers

SYSTEM INTEGRATOR CONTACT LIST: Large System Integrators

		Last	First	Phone/FAX	Company	Address	City	State zip	Received
1	L S	Ball Holz	Tim Chris	360-438-2110 360-438-2115	Applied Power Corp.	1210 Homann Dr. SE	Lacey,	WA 98503	7/25/96
2	L S	Wilson	Bruce	410-686-2500 410-686-6221	Atlantic Solar Products	PO Box 70060	Baltimore,	MD 21702	2/7/96
3	L S	Garvison	Paul	301-663-8279 301-631-5199	Integrated Power Corp.	7618 Hayward Road	Frederick,	MD 21702	2/20/96
4	L S	Shugar	Dan	415-871-2275 415-871-2279	New World Power	150 Tehania Court	San Bruno,	CA 94066	
5	L S	Coleman	Clint	802-496-2955 802-496-2953	Northern Power Systems	1 North Wind Road	Moretown,	VT 05660	
6	L S	Spotts	Robert	602-948-8003 602-483-6431	Photocomm, Inc.	7681 East Gray Road	Scottsdale,	AZ 85260	3/22/96
7	L S	Loomans	Len	303-452-9383 303-452-9519	Remote Power Co., Inc.	12301 North Grant Street #230	Denver,	CO 80241-3130	2/15/96
8	L S	Padula	Jim	800-344-2003 707-459-5132	Solar Electric Specialties	P.O. Box 537	Willits,	CA 95490	3/11/96
9	L S	Blalock	Marshal	713-351-0031 713-351-8356	Southwest PV Inc.	212 East Main	Tomball,	TX 77375	2/14/96
10	L S	Brandborg	Dan	406-363-6924 406-363-6046	Sunelco	100 Skeels St.	Hamilton,	MT 59840-1499	
11	L S	Kulik	David	914-336-7700 914-336-7172	Sunwize Energy Systems Inc.	1151 Flatbrush Road	Kingston,	NY 12401	3/8/96

SYSTEM INTEGRATOR CONTACT LIST: Small System Integrators

		Last	First	Phone/FAX	Company	Address	City	State zip	Received
1	s	Katz	Dave	800-777-6609 707-923-3009	Alternative Energy Engineering	PO Box 339	Redway,	CA 95560	
2	s	Russell	Miles	617-890-8844 617-890-2050	Ascension Technology Inc.	POB 314	Lincoln Center,	MA 01773	2/7/96
3	s	Willey	Steve	208-263-4290 208-265-4788	Backwoods Cabin Electric Systems	8530 Rapid Lightning Creek Rd.	Sandpoint,	ID 83864	2/2/96
4	s	Currin	Cedric	517-835-7387 515-835-7395	Currin Corporation	5307 Sturgeon Ave	Midland,	MI 48641-1191	2/15/96
5	s	Randall	Jeff	505-889-3585 505-889-3548	Direct Water & Power Corp.	3455-A Princeton NE	Albuquerque,	NM 87107	2/14/96
6	s	Amir	Abtaki	407-393-7127 407-393-7165	GeoSolar	3401 N. Federal Hwy	Boca Raton,	FL 33431	3/15/96
7	s	Gilman	Dan	619-246-7733 619-246-5770	GSE Solar Systems	17451 Racoon Ave #12	Adelanto,	CA 92301	2/15/96
8	s	Heinz	Mark	619-251-6886	Heinz Solar	16575 Via Corto East	Desert Hot Springs,	CA 92240	
9	s	Hitney	Gene	520-636-2201 520-636-1664	Hitney Solar Products	PO Box 365	Chino Valley,	AZ 86323	2/19/96
10	s	Sagrillo	Mike	414-837-2267 414-837-7523	Lake Michigan Wind & Sun	3971 Bluebird Rd	Forestville,	WI 54213	
11	s	Lauzon	Pat	520-527-8017 520-527-0729	Northern Arizona Wind & Sun	2725 E Lakin Dr #2	Flagstaff,	AZ 86004	
12	s	Kaszeta	Bill	602-834-7778 602-835-8480	Photovoltaic Resources Int.	1902 N. Country Club Dr. #6	Mesa,	AZ 85201	2/16/96
13	s	Gunn, PE	Allen	800-345-2575 334-271-0818	Scientific Engineering	5960 E. Shirley Lane	Montgomery,	AL 36117	2/20/96
14	s	Simpler	Al	904-576-5271 904-576-5274	Simpler Solar Systems, Inc.	3118 W. Tharpe St.	Tallahassee,	FL 32303	2/14/96
15	s	Collins	Michael	619-581-0051 619-581-6440	Solar Electric, Inc.	5555 Santa Fe St., Ste. J	San Diego,	CA 92109-1602	2/7/96
16	s	Robbins	Steven	407-220-6615 407-220-8616	Solar Electric Power Co.	PO Box 2165	Palm City,	FL 34990	2/19/96
17	s	Hurst	Alan	407-286-9461 407-286-9616	Solar Outdoor Lighting Inc.	3131 Waaler Street	Stuart,	FL 34997	2/16/96
18	s	Slominski	Larry	800-397-2083 619-625-2083	United Solar Systems Corp.	5278 Eastgate mall	San Diego,	CA 92121	

BATTERY MANUFACTURER CONTACT LIST

		Last	First	Phone/FAX	Company	Address	City	State zip	Received
1	B	Meisner	Larry	610-828-9000 610-834-7334	C&D Charter Power Systems	3043 Walton Rd.	Plymouth Meeting,	PA 19462	2/20/96
2	B	Mahoney	Ed	818-813-1234 818-338-3549	Concorde Battery Corp.	2009 San Barnardino Road	West Covina,	CA 91790	2/28/96
3	B	Boram	Mark	317-646-3824 317-646-2628	Delco/Delphi Energy, GMC	PO Box 2439	Anderson,	IN 46018	2/19/96
4	B	Santangelo	Renwick	610-682-6361 610-682-4781	East Penn Manufacturing Co. Inc.	Deka Road	Lyon Station,	PA 19536	2/16/96
5	B	Vechy	Stephen	708-691-7886 708 629-2635	GNB	829 Parkview Blvd.	Lombard,	IL 60148-3249	3/22/96
6	B	Holmquist	Bill	818-767-7067 818-767-7173	Industrial Battery Engineering Inc.	9121 DeGarmo Ave	Sun Valley,	CA 91352	2/20/96
7	B	Ruhlmann	Thomas	414-967-6540 414-961-6506	Johnson Controls, Inc.	P.O. Box 591	Milwaukee,	WI 53201	2/15/96
8	B	Drizos	Jim	800-423-6569 310-906-4033	Trojan Battery Company	12380 Clark Street	Santa Fe Springs,	CA 90670	3/18/96
9	B	Wallace	Don	909-371-8090 909-371-4671	U.S. Battery	1675 Sampson Ave.	Corona,	CA 91719	2/2/96
10	B	Cook	Gene	215-345-5272 215-345-9241	Douglas Battery Co.	PO Box 91	Furlong,	PA 18925	

CHARGE CONTROLLER CONTACT LIST

		Last	First	Phone/FAX	Company	Address	City	State zip	Received
1	C	Knowles	Jack	916-292-3834 916-292-3330	Ananda Power Technologies	14618 Tyler Footee Road	Nevada City,	CA 95959	2/23/96
2	C	Bobier	Joe	304-485-7150 304-422-3931	Bobier Electronics, Inc.	37th & Murdoch Ave.	Parkersburg,	WV 26102	
3	C	Dawson	Sam	619-460-3930 619-460-9211	Heliotrope General	3733 Kenora Dr.	Spring Valley,	CA 91977	1/29/96
4	C	Gerkin	Ken	301-774-3107 301-774-3072	Morningstar Corp.	3414 Morningwood Dr Suite 200B.	Olney,	MD 20832	2/12/96
5	C	Jennings	Laurence	707-459-3211 707-459-2165	Photron	P.O. Box 578	Willits,	CA 95490	
6	C	Sams	Arthur	310-320-3114 310-320-3135	Polar Products	2808 Oregon Ct., Bldg. K-4	Torrance,	CA 90503	2/12/96
7	C	Staler	Terry	818-998-5238 818-998-5253	Specialty Concepts, Inc.	8954 Mason Ave.	Chatsworth,	CA 91311	2/19/96
8	C	Wise	Joe	602-833-1550 602-833-1711	SunAmp Power	1902 N. Country Club Dr. #8	Mesa,	AZ 85201	1/24/96
9	C	Kulik	David	914-336-7700 914-336-7172	Sunwize Energy Systems Inc.	1151 Flatbrush Road	Kingston,	NY 12401	1/30/96
10	C	Vanderhoof	Sam	360-435-8826 360-435-2229	Trace Engineering Company	5917-195th N.E.	Arlington,	WA 98223	2/20/96

DISTRIBUTION LIST

Last	First	Company	Address	City	State Zip
Hammond 50 COPIES	**Robert**	**ASU**	**1971 E. Huntington Dr.**	**Tempe**	**AZ 85282-2848**
Amir	Abtaki	GeoSolar	3401 N. Federal Hwy	Boca Raton	FL 33431
Ball	Tim	Applied Power Corp.	1210 Homann Dr. SE	Lacey	WA 98503
Blalock	Marshal	Southwest PV Inc.	212 East Main	Tomball	TX 77375
Bobier	Joe	Bobier Electronics, Inc.	37th & Murdoch Ave.	Parkersburg ,	WV 26102
Boram	Mark	Delco/Delphi Energy, GMC	PO Box 2439	Anderson	IN 46018
Brandborg	Dan	Sunelco	100 Skeels St.	Hamilton	MT 59840-1499
Coleman	Clint	Northern Power Systems	1 North Wind Road	Moretown	VT 05660
Collins	Michael	Solar Electric, Inc.	5555 Santa Fe St., Ste. J	San Diego	CA 92109-1602
Cook	Gene	Douglas Battery Co.	PO Box 91	Furlong	PA 18925
Currin	Cedric	Currin Corporation	5307 Sturgeon Ave	Midland,	MI 48641-1191
Dawson	Sam	Heliotrope General	3733 Kenora Dr.	Spring Valley,	CA 91977
Drizos	Jim	Trojan Battery Company	12380 Clark Street	Santa Fe Springs,	CA 90670
Garvison	Paul	Integrated Power Corp.	7618 Hayward Road	Frederick	MD 21702
Gerkin	Ken	Morningstar Corp.	3414 Morningwood Dr Suite 200B.	Olney	MD 20832
Gilman	Dan	GSE Solar Systems	17451 Racoon Ave #12	Adelanto	CA 92301
Gunn, PE	Allen	Scientific Engineering	5960 E. Shirley Lane	Montgomery ,	AL 36117
Heinz	Mark	Heinz Solar	16575 Via Corto East	Desert Hot Springs	CA 92240
Hitney	Gene	Hitney Solar Products	PO Box 365	Chino Valley,	AZ 86323
Holmquist	Bill	Industrial Battery Engineering Inc.	9121 DeGarmo Ave	Sun Valley	CA 91352
Hurst	Alan	Solar Outdoor Lighting Inc.	3131 Waaler Street	Stuart	FL 34997
Jennings	Laurence	Photron	P.O. Box 578	Willits,	CA 95490
Kaszeta	Bill	Photovoltaic Resources Int.	1902 N. Country Club Dr. #6	Mesa,	AZ 85201
Katz	Dave	Alternative Energy Engineering	PO Box 339	Redway	CA 95560
Knowles	Jack	Ananda Power Technologies	14618 Tyler Footee Road	Nevada City	CA 95959
Kulik	David	Sunwize Energy Systems Inc.	1151 Flatbrush Road	Kingston	NY 12401
Kulik	David	Sunwize Energy Systems Inc.	1151 Flatbrush Road	Kingston	NY 12401
Lauzon	Pat	Northern Arizona Wind & Sun	2725 E Lakin Dr #2	Flagstaff	AZ 86004

Loomans	Len	Remote Power Co., Inc.	12301 North Grant Street #230	Denver	CO 80241-3130
Mahoney	Ed	Concorde Battery Corp.	2009 San Barnardino Road	West Covina	CA 91790
Padula	Jim	Solar Electric Specialties	P.O. Box 537	Willits,	CA 95490
Randall	Jeff	Direct Water & Power Corp.	3455-A Princeton NE	Albuquerqu e	NM 87107
Robbins	Steven	Solar Electric Power Co.	PO Box 2165	Palm City	FL 34990
Ruhlmann	Thomas	Johnson Controls, Inc.	P.O. Box 591	Milwaukee,	WI 53201
Russell	Miles	Ascension Technology Inc.	POB 314	Lincoln Center	MA 01773
Sagrillo	Mike	Lake Michigan Wind & Sun	3971 Bluebird Rd	Forestville	WI 54213
Sams	Arthur	Polar Products	2808 Oregon Ct., Bldg. K-4	Torrance,	CA 90503
Santangelo	Renwick	East Penn Manufacturing Co. Inc.	Deka Road	Lyon Station	PA 19536
Shugar	Dan	New World Power	150 Tehania Court	San Bruno	CA 94066
Simpler	Al	Simpler Solar Systems, Inc.	3118 W. Tharpe St.	Tallahassee	FL 32303
Slominski	Larry	United Solar Systems Corp.	5278 Eastgate mall	San Diego,	CA 92121
Spotts	Robert	Photocomm, Inc.	7681 East Gray Road	Scottsdale	AZ 85260
Staler	Terry	Specialty Concepts, Inc.	8954 Mason Ave.	Chatsworth	CA 91311
Vanderhoof	Sam	Trace Engineering Company	5917-195th N.E.	Arlington,	WA 98223
Vechy	Stephen	GNB	829 Parkview Blvd.	Lombard,	IL 60148-3249
Wallace	Don	U.S. Battery	1675 Sampson Ave.	Corona,	CA 91719
Willey	Steve	Backwoods Cabin Electric Systems	8530 Rapid Lightning Creek Rd.	Sandpoint	ID 83864
Wilson	Bruce	Atlantic Solar Products	PO Box 70060	Baltimore	MD 21702
Wise	Joe	SunAmp Power	1902 N. Country Club Dr. #8	Mesa,	AZ 85201

ABB Power T&D Co., Inc.
Attn: P. Danfors
16250 West Glendale Drive
New Berlin, WI 53151

Argonne National Laboratories (2)
Attn: W. DeLuca
G. Henriksen
CTD, Building 205
9700 South Cass Avenue
Argonne, IL 60439

ABB Power T&D Co., Inc.
Attn: H. Weinrich
1100 Cornwall Road
Monmouth Junction, NJ 08852

Arizona Public Service (2)
Attn: R. Hobbs
Herb Hayden
P.O. Box 5399
Phoenix, AZ 85072

AC Battery Corporation
Attn: R. Flemming
2080 Energy Drive
P.O. Box 325
East Troy, WI 53120

Lucent Technologies
Attn: K. Bullock
3000 Skyline Drive
Mesquite, TX 75149

American Electric Power Service Corp.
Attn: C. Shih
1 Riverside Plaza
Columbus, OH 43215

AVO International
Attn: Gary Markle
510 Township Line Rd.
Blue Bell, PA 19422

Anchorage Municipal Light & Power
Attn: M. Aslam
1200 East 1st Avenue
Anchorage, AK 99501

Babcock & Wilcox
Attn: Glenn Campbell
P.O. Box 785
Lynchburg, VA 24505

Bechtel
Attn: W. Stolte
P.O. Box 193965
San Francisco, CA 94119-3965

California State Air Resources Board
Attn: J. Holmes
Research Division
P.O. Box 2815
Sacramento, CA 95812

Berliner Kraft und Licht (BEWAG)
Attn: K. Kramer
Stauffenbergstrasse 26
1000 Berlin 30
GERMANY

Calpine Corp.
Attn: R. Boucher
50 W. San Fernando, Ste. 550
San Jose, CA 95113

Bonneville Power Administration
Attn: J. Ray
Routing EO
P.O. Box 3621
Portland, OR 97208

Chugach Electric Association, Inc. (2)
Attn: T. Lovas
J. Cooley
P.O. Box 196300
Anchorage, AK 99519-6300

Business Management Consulting
Attn: S. Jabbour
24704 Voorhees Drive
Los Altos Hills, CA 94022

Consolidated Edison (2)
Attn: M. Lebow
N. Tai
4 Irving Place
New York, NY 10003

C&D Charter Power Systems, Inc. (2)
Attn: Dr. Sudhan S. Misra
Attn: Dr. L.Holden
Washington & Cherry Sts.
Conshohocken, PA 19428

Corn Belt Electric Cooperative
Attn: R. Stack
P.O. Box 816
Bloomington, IL 61702

Delphi Energy and Engine
Management Systems (2)
Attn: J. Michael Hinga
R. Rider
P.O. Box 502650
Indianapolis, IN 46250

East Penn Manufacturing Co., Inc.
Attn: M. Stanton
Deka Road
Lyon Station, PA 19536

International Energy Systems, Ltd.
Attn: G. Barker
Chester High Road
Nestor South-Wirral
Nestor, South Wirral
L64 UE UK
UNITED KINGDOM

Electric Power Research Institute (3)
Attn: S. Chapel
S. Eckroad
R. Schainker
P. O. Box 10412
Palo Alto, CA 94303-0813

EA Technology, Ltd.
Attn: J. Baker
Chester CH1 6ES
Capenhurst, England
UNITED KINGDOM

Electrochemical Engineering Consultants, Inc.
Attn: P. Symons
1295 Kelly Park Circle
Morgan Hill, CA 95037

Eagle-Picher Industries
Attn: J. DeGruson
C & Porter Street
Joplin, MO 64802

Electrochemical Energy Storage Systems, Inc.
Attn: D. Feder
35 Ridgedale Avenue
Madison, NJ 07940

Electrosources
Attn: Michael Dodge
P.O. Box 7115
Loveland, CO 80537

Electrosource, Inc.
Attn: B. Jay
3800-B Drossett Drive
Austin, TX 78744-1131

Eltech Research Corporation
Attn: Dr. E. Rudd
625 East Street
Fairport Harbor, OH 44077

Energy Systems Consulting
Attn: A. Pivec
41 Springbrook Road
Livingston, NJ 07039

Energetics, Inc. (4)
Attn: J. Badin
H. Lowitt
P. Taylor
L. Charles
7164 Columbia Gateway Drive
Columbia, MD 21046

Exxon Research Company
Attn: R. Bearden
P.O. Box 536
1900 East Linden Avenue
Linden, NJ 07036

Energetics, Inc. (2)
Attn: M. Farber
R. Scheer
501 School St. SW, Suite 501
Washington, DC 20024

Firing Circuits, Inc.
Attn: J. Mills
P.O. Box 2007
Norwalk, CT 06852-2007

Energy and Environmental Economics, Inc.
Attn: Greg J. Ball
353 Sacramento St., Suite 1540
San Francisco, CA 94111

General Electric Company
Attn: N. Miller
Building 2, Room 605
1 River Road
Schenectady, NY 12345

GE Industrial & Power Services
Attn: Bob Zrebiec
640 Freedom Business Center
King of Prussia, PA 19046

General Electric Drive Systems
Attn: D. Daly
1501 Roanoke Blvd.
Salem, VA 24153

Giner, Inc.
Attn: A. LaConti
14 Spring Street
Waltham, MA 02254-9147

GNB Technologies
World Headquarters
Attn: S. Deshpande'
375 Northridge Road
Atlanta, GA 30350

Golden Valley Electric Association, Inc.
Attn: S. Haagensen
Box 71249
758 Illinois Street
Fairbanks, AK 99701

Hawaii Electric Light Co.
Attn: C. Nagata
P.O. Box 1027
Hilo, HI 96720

GNB Technologies (3)
Industrial Battery Company
Attn: G. Hunt
J. Szymborski
R. Maresca
Woodlake Corporate Park
829 Parkview Blvd.
Lombard, IL 60148-3249

ILZRO (3)
Attn: J. Cole
P. Moseley
C. Parker
P.O. Box 12036
Research Triangle Park, NC 27709

Kenetech/Wind Power (2)
Attn: Michael Behnke
W. Erdman
6952 Preston Avenue
Livermore, CA 94550

Imperial Oil Resources, Ltd.
Attn: R. Myers
3535 Research Rd NW
Calgary, Alberta
CANADA T2L 2K8

Lawrence Berkeley Laboratory (3)
Attn: E. Cairns
K. Kinoshita
F. McLarnon
University of California
One Cyclotron Road
Berkeley, CA 94720

Innovative Power Sources
Attn: Ken Belfer
1419 Via Jon Jose Road
Alamo, CA 94507

Longitude 122 West
Attn: S. Schoenung
1241 Hobart St.
Menlo Park, CA 94025

J. Meglen
P.O. Box 3232
Oakton, VA 22124

Lucas Controls, Inc.
Attn: Donald J. Lucas
10925 Miller Rd., Ste. A
Dallas, TX 75355-1848

Metlakatla Power & Light
Attn: H. Achenbach
P.O. Box 359
Metlakatla, AK 99926

National Renewable Energy Laboratory (5)
Attn: R. McConnell
L. Flowers
J. Green
S. Hock
R. DeBlasio
1617 Cole Blvd.
Golden, CO 80401-3393

Micron Corporation
Attn: D. Nowack
158 Orchard Lane
Winchester, TN 37398

New York Power Authority
Attn: B. Chezar
1633 Broadway
New York, NY 10019

ZBB, LTD.
Attn: Robert J. Parry
P.O. Box 1410, West Perth
Western Australia 6872

Northern States Power
Attn: D. Zurn
414 Nicollet Mall
Minneapolis, MN 55401

Oglethorpe Power Company
Attn: C. Ward
2100 E. Exchange Place
P.O. Box 1349
Tucker, GA 30085-1349

NPA Technology
Attn: Jack Brown
Suite 700, Two University Place
Durham, NC 27707

Omnion Power Engineering Corporation
Attn: H. Meyer
2010 Energy Drive
P.O. Box 879
East Troy, WI 53120

Oak Ridge National Laboratory (3)
Attn: B. Hawsey, Bldg. 3025, MS-6040
J. Stoval, Bldg. 3147, MS-6070
J. VanCoevering, Bldg. 3147, MS-6070
P.O. Box 2008
Oak Ridge, TN 37831

Orion Energy Corp.
Attn: Doug Danley
18131 Metz Dr.
Germantown, MD 20874

PEPCO
Attn: John Young
1900 Pennsylvania NW, Room 842
Washington, DC 20068

Endecon Engineering
Attn: Rick Winter
Research Engineer
3160 Crow Canyon Rd., Suite 240
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