Executive Summary Study of Lead-Acid Battery Systems for Peaking Power

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1.0 INTRODUCTION

A study of lead-acid batteries for peaking power applications and the auxiliaries required for an operable system has been completed. The results of the study are presented in a three-volume report as follows:

- Volume I - Executive Summary
- Volume II - Study of the Manufacturing Costs of Lead-Acid
 Batteries for Peaking Power
- Volume III - Study of the Auxiliaries for Lead-Acid
 Battery Systems for Peaking Power

The purpose of this volume is to summarize the salient points and conclusions derived from the study.

2.0 GENERAL

The technology presently exists for producing lead-acid batteries for peaking application in the existing industrial battery industry. But, because the industry is structured for producing these large batteries on a job shop basis, the potential economies of high-volume production are not being realized.

For purposes of this study, a cell design was specified and a typical plant size selected so that an in-depth cost analysis could be made of a manufacturing facility dedicated to the production of peaking batteries. In addition to state-of-the-art batteries, an advanced design based on technology developed by the Westinghouse Research Laboratories was also analyzed.

Another aspect of the study was to define and analyze the requirements for the balance of plant equipment. This includes the system auxiliaries -- all elements other than the battery cells or the power conversion equipment.

The peaking power application presents a potentially large market for a single type of battery. At an annual growth rate of 6% over today's installed capacity, and if 5% of all increases were met with battery installations, the extrapolated demand would be 185 battery systems (10 MW, 40 MWH each) per year by 1985. For a plant sized to produce 25 battery systems annually, this potential market represents demand for approximately seven manufacturing facilities.

The physical quantity of lead consumed by seven manufacturing plants would amount to 250,000 tons per year. This represents a 15% increase in lead demand over 1974 usage. The study indicates that there are adequate lead reserves to meet this demand; elimination of gasoline lead additives will alone satisfy the needs for peaking batteries.

Since lead materials account for 60% to 65% of the cost of lead-acid batteries, sensitivity of costs to changes in the lead market was analyzed; consideration also was given to the potential benefits of vertical integration in lead smelting and the resultant effective cost of lead materials. Exhibit 2-1 shows the results of this analysis. When the nominal market price of lead is at 25¢/lb, the benefits of vertical integration could potentially reduce the effective cost to 19¢/lb. Additionally, recognizing the benefits of recycling lead, the effective "out-of-pocket" cost of lead for replacement batteries would be 10¢/lb.

SECONDARY LEAD COST WITH VERTICAL INTEGRATION

(CENTS PER POUND)

EXHIBIT 2-1

3.0 MANUFACTURING COSTS - BATTERIES

Analysis of the product costs and business expenses associated with a lead-acid peaking battery manufacturing facility indicates that substantially lower selling prices can be realized compared to normal industrial battery pricing. The economies of a high-volume, single product operation result in greatly reduced business overhead expenses. Additionally, close integration of lead material supplies into the operation results in lowering the effective cost of lead, a large part of the product cost.

Discounted cash flow analysis techniques were used to evaluate the estimates of facilities costs, product costs, overhead, and working capital. Since the selling price of peaking batteries is an unknown factor, the approach taken was to evaluate the estimates to determine the approximate selling price that would yield a satisfactory return to an investor.

The curves in Exhibit 3-1 show the relationship of selling price to business risk. Since the price of lead has a significant influence on the analysis, a range of 10¢/lb to 25¢/lb is shown. The curves further reflect the potential benefits that could be derived from vertical integration in the manufacturing plant.

Similar curves for the Westinghouse advanced technology battery are shown in Exhibit 3-2. In this case, it was assumed that prior

EXHIBIT 3-1

State-of-the-Art Battery
Risk, Lead Cost, Selling Price Relationship
(with vertical integration)

development would have been externally funded and the technology advanced to the same level as the state-of-the-art battery. This approach permits analysis and comparison of both batteries on the same basis.

If a firm market demand for batteries is assumed, then an investor would be assured of a fully-loaded production facility and an existing technology. Thus, a low-risk situation would exist.

The study shows that under the assumed conditions (effective lead cost of 19¢/lb plus the potential benefits of vertical integration in the manufacturing plant), a direct product cost of \$29.73/KWH (4-hour rate) is realistic for the state-of-the-art battery. The corresponding selling price, assuming low business risk conditions, would be \$36.90/KWH. As scrap batteries of the same type become available for recycling (reducing the effective cost of lead to 10¢/lb), this price becomes \$29.87/KWH.

For the advanced technology battery, which holds promise of reduced lead material requirements coupled with a greater than 20-year service life, the analysis indicates (under the same assumptions as the state-of-the-art battery) a direct product cost of \$25.44/KWH and a corresponding selling price of \$31.62/KWH. A reduction in price to \$25.85/KWH would be possible with customer-provided scrap lead, which reduces the effective cost of lead to 10¢/lb. Of course, the total economic advantage of the advanced battery is realized by the combination of lower first cost and extended service life.

A summary of all the results is shown in Exhibit 3-3. This table shows the direct costs and projected selling prices under the various conditions of lead cost and vertical integration in the manufacturing plant.

EXHIBIT 3-2

Westinghouse Advanced Technology Battery
Risk, Lead Cost, Selling Price Relationship
(with vertical integration)

EXHIBIT 3-3

Summary of Results (\$/KWH @ 4-Hour Rate)

	<u>Direct Product Costs (\$/KWH)</u>	<u>Projected Selling Price (\$/KWH) with Moderate Risk</u>	<u>Projected Selling Price (\$/KWH) with Low Risk</u>
<u>STATE-OF-THE-ART</u>			
1) 25¢/lb, lead	\$36.81	\$48.25*	\$44.24*
2) Manufacturing plant vertical integration and 25¢/lb lead	34.30	45.48	41.68
3) Effective lead cost 19¢/lb with manufacturing plant vertical integration	29.73	40.50	36.90
4) Recycled batteries 10¢/lb lead	22.96*	32.65	29.87
<u>ADVANCED TECHNOLOGY</u>			
1) 25¢/lb, lead	32.36	41.77*	38.53*
2) Manufacturing plant vertical integration and 25¢/lb lead	34.30	38.80	35.50
3) Effective lead cost 19¢/lb with manufacturing plant vertical integration	25.44	34.50	31.62
4) Replacement batteries 10¢/lb lead	20.17*	28.75	25.85

*Determined during the study but not specifically identified elsewhere in this report.

4.0 AUXILIARIES

Various peaking battery systems were studied, incorporating the 10 MW, 40 MWH battery. Costs for the auxiliaries for each design were estimated in detail. The results indicate that the most economical choice consists of a 1620 VDC, 10-string design. The projected cost of installing a total system is \$3,071,000. This includes \$36.90/KWH for the battery (see Section 3.0); \$26.13/KWH for the auxiliaries; and \$55.00/KW for the power converter.

Each design studied includes the following features:

- Multi-Cell Module Design. The use of a seven- or nine-cell module provides ease of handling, superior floor space utilization, significant reduction in the number of field hook-ups and superior mechanical protection for the cells.
- Predictive Monitoring. By detecting incipient failures of individual cells before immediate action is required, corrective action can be scheduled so that system downtime and labor costs are minimized.
- Water Cooling. The use of a water cooling design to control electrolyte temperature has been shown to be cost effective in all regions of the continental United States, due to beneficial effects on cell life and floor space utilization.
- Manifold Ventilation. The use of manifolds in an induced-draft design provides positive control of the evolved gases, relieves some operational difficulties associated with cold weather operation, and is

compatible with methods of handling arsine and stibine gases, should the need arise.

The costs of the various designs are summarized in Exhibit 4-1. The minimum cost designs (\$307.11/KW) have the benefits of:

- Increased Voltage. Within the limits imposed by fuse design, increased voltage substantially improves power converter costs.
- Improved Monitoring Technology. Use of recent technological improvements in monitoring and control show a significant cost benefit.
- Shared Equipment. Sharing of a deionized water loop, monitoring, and protection equipment between the battery and power conversion gear shows some cost benefits.

In analyzing the effects of system rating, the cost per KW of the facility was found to be a steadily decreasing function of rating. In the range from 1 MW to 10 MW, total cost decreases from \$462/KW to \$325/KW. These costs are summarized in Exhibit 4-2. Note that within the range of ratings studied, the total cost per KW obeys a simple mathematical relationship.

The use of large capacity cells (49 KWH capacity) was also considered. Using conventional monitoring and protection devices in a 816 VDC, 2-string design, a total cost of \$3,309,500 was estimated. Applying advanced technology to the fusing and monitoring systems, and considering shared equipment between the battery and power conversion gears and increasing the nominal voltage to 1632 VDC for a single string design, the estimated cost is \$2,835,000. The costs are summarized in Exhibit 4-3.

EXHIBIT 4-1

10 MW, 40 MWH BATTERY COST SUMMARY

	<u>770 VDC</u>		<u>810 VDC</u>		<u>1620 VDC</u>		<u>1620 VDC*</u>	
	<u>Cost</u>	<u>\$/KWH</u>	<u>Cost</u>	<u>\$/KWH</u>	<u>Cost</u>	<u>\$/KWH</u>	<u>Cost</u>	<u>\$/KWH</u>
Building & Slab	350,000	8.75	335,400	8.39	309,000	7.73	309,000	7.73
Monitoring & Control	442,000	11.05	387,000	9.68	380,000	9.50	283,000	7.08
Ventilation	48,000	1.20	43,100	1.08	43,100	1.80	43,100	1.80
Acid Containment	110,000	2.75	110,000	2.75	110,000	2.75	110,000	2.75
Buswork & Protection	81,500	2.04	68,000	1.70	69,000	1.73	69,000	1.73
Water Cooling	117,000	2.93	117,000	2.93	117,000	2.93	107,000	2.68
Maintenance	49,000	1.23	49,000	1.23	49,000	1.23	49,000	1.23
Fire System	25,000	.63	24,000	.60	22,000	.55	22,000	.55
Water Addition	33,000	.83	33,000	.83	33,000	.83	33,000	.83
High Base Cost	-		6,000	.15	20,000	.50	20,000	.50
Auxiliaries Total	1,255,500	31.39	1,172,500	29.31	1,152,100	28.80	1,045,100	26.13
Battery	1,476,000	36.90	1,476,000	36.90	1,476,000	36.90	1,476,000	36.90
Energy Total	2,731,500	68.29/KWH	2,648,500	66.21/KWH	2,628,100	65.70/KWH	2,521,100	63.03/KWH
Power Converter	780,000	78/KW	780,000	78/KW	620,000	62/KW	550,000†	55/KW
TOTAL	3,511,500	351.15/KW	3,428,500	342.85/KW	3,248,100	324.81/KW	3,071,100	307.11/KW

*With optical monitoring system, shared deionized water loop.

†w/o high speed breaker, with shared monitoring system.

EXHIBIT 4-2

COST SUMMARY

1 MW to 10 MW @ 4-hr Rate

	<u>10 MW(1620 V)</u>		<u>5 MW(810 V)</u>		<u>1 MW(324 V)</u>	
	Total	\$/KWH	Total	\$/KWH	Total	\$/KWH
Auxiliaries	1,132,100	28.30	655,800	32.79	200,900	50.23
High Base Cost	20,000	.50	3,000	.15	600	.15
Battery	1,476,000	36.90	738,000	36.90	147,600	36.90
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Energy Total	2,628,100	65.70/KWH	1,396,800	69.84/KWH	349,100	87.28/KWH
Power Converter	620,000	62/KW	410,000	82/KW	113,000	113/KW
<hr/>						
TOTAL	3,248,100	324.81/KW	1,806,800	361.36/KW	462,100	462.10/KW

The total cost/KW of the peaking battery system, when plotted against system rating, obeys the relation:

$$\text{Total } \$/\text{KW @ 4-hr Rate} = \$462.10(\text{MW Rating})^{-.1531}$$

EXHIBIT 4-3

COST SUMMARY

10 MW, 40 MWH Battery Using Large Capacity Cells

	<u>816V</u>		<u>816 V*</u>		<u>1632 V*</u>	
	<u>Total</u>	<u>\$/KWH</u>	<u>Total</u>	<u>\$/KWH</u>	<u>Total</u>	<u>\$/KWH</u>
Auxiliaries	1,264,700	31.62	930,200	23.23	950,200	23.76
Battery	1,264,800	31.62	1,264,800	31.62	1,264,800	31.62
Energy Total	2,529,500	63.24/KWH	2,195,000	54.88/KWH	2,215,000	55.38/KWH
Power Converter	780,000	78/KW	780,000	78/KW	620,000	62/KW
TOTAL	3,309,500	330.95/KW	2,975,000	297.50/KW	2,835,000	283.50/KW

*Using Advanced Technology Monitoring and Protection Devices