CONS/2114-2

Study of the Manufacturing Costs of Lead-Acid Batteries for Peaking Power

Final Report for the Period Ending Oct. 1976

Westinghouse Electric Corporation
Pittsburgh, Pennsylvania

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DISCLAIMER

VOLUME II

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1.0 EXECUTIVE SUMMARY

The industrial lead-acid battery business is characterized by the manufacture to customer order of a multiplicity of battery sizes and configurations which may reach the consumer through several levels of distribution.

A detailed study has been made of a postulated 1,000 MWH per year (4-hour rate) lead-acid battery business dedicated to supplying a single design of 40-MWH peaking power batteries to electric utilities. State-of-the-art industrial lead-acid battery technology is assumed but the manufacturing facility and business organization is specifically tailored to the one product. Analysis of the product costs and business expenses associated with such an operation indicates that substantially lower selling prices can be realized compared to normal industrial battery pricing.

Independent of business risk consideration, the two factors which contribute significantly to the difference are:

1. Greatly reduced business overhead expenses
2. Close integration of lead material supply (and recycling) into the operation

Because the cost of lead represnets a large part of the product cost, the second factor is of particular importance.

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 is realistic. The corresponding selling price, assuming low business risk conditions, would be $36.90/KWH at the 4-hour rate ($29.89 at the 10-hour rate).

Under moderate risk conditions, with lead at the full market price of 25¢/lb, and without any improvement from vertical integration, the selling price would be $48.25/KWH.

As scrap batteries of the same type become available for recycling, the $36.90/KWH price is reduced to $29.87/KWH. This assumes that the purchaser, in need of a replacement battery, provides an identical battery for salvage. The scrap value of the trade-in reduces the effective cost of lead to 10¢/lb.

A similar study was carried out incorporating the advanced lead-acid battery technology under development at the Westinghouse Research Laboratories. This technology holds promise of reduced lead material requirements coupled with a 20-year service life.

The analysis indicates an estimated direct product cost of $25.44/KWH, based on an effective lead cost of 19¢/lb plus the potential benefits of vertical integral. Assuming low business risk conditions, the corresponding selling price would be $31.62/KWH at the 4-hour rate ($25.61/KWH at the 10-hour rate). 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 the results is shown in Exhibit 1-1. 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 1-1

Summary of Results

	Direct Product Costs ($/KWH)	Projected Selling Price ($/KWH) with Moderate Risk	Projected Selling Price ($/KWH) with Low Risk
STATE-OF-THE-ART			
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
ADVANCED TECHNOLOGY			
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.

2.0 INTRODUCTION

Electric utilities are searching for ways to make more effective use of installed base load generation capacity for intermediate and peaking demand loads. Since the base load generation equipment is not fully utilized during off-peak periods, it would be attractive if an economical, environmentally acceptable method were found to store excess generation capacity available at low demand periods for use at peak demand periods. Several possibilities are available for this purpose, one being the use of lead-acid batteries.

The technology now exists for producing lead-acid batteries for this application in the existing industrial lead-acid industry. Cells large enough for the purpose have been made for railroad, mining, and submarine use. The industry, however, is structured for producing these batteries on essentially a job shop basis, not on an efficient assembly line basis as is used in the SLI (starting, lighting, ignition) lead-acid battery industry. Because of this situation, cost per KWH of industrial batteries is high compared to SLI batteries.

If industrial size batteries were produced for a peaking application, there would be an extremely large market for a given size product; therefore, a peaking battery industry could be structured like the SLI industry. The purpose of this study is to determine the cost of state-of-the-art lead-acid batteries produced under this condition. To this end a product has been designed and a typical plant size selected so that an in-depth cost study could be made. The design is such that components can be produced on equipment now in existence in the industry.

Since lead itself accounts for roughly 60% of the cost of present lead-acid batteries, and battery life affects the annual cost of use, the most effective way of reducing battery cost is to develop long life batteries which reduce the amount of lead required per KWH. The Westinghouse Research Laboratory has such a battery under development. A second purpose of this report is to project the cost per KWH of this advanced technology battery.

Since selling price, not necessarily cost, is of prime importance to the user, the report also studies the impact of various factors on selling price. The total cost of the peaking battery installation ready for use is also of extreme interest to the user. The study examines the sensitivity of cost to the electric utility as a function of parameters that affect the cost to manufacture state-of-the-art and advanced technology lead-acid battery systems.

3.0 MARKET CHARACTERISTICS

The pertinent market characteristics for peaking battery systems were established by examining power demand growth projections by Regional National Reliability Council reports for the Federal Power Commission.

The installed generating capacity for 1976 is estimated at 519 gigawatts. The equivalent peak capacity is considered to be 75% of installed capacity, or 389 gigawatts in 1976. Two load growth factors were used: 2% and 6%. Additionally, 10% to 20% of the increase in load growth was assumed to be applied as peaking power systems. Finally, 25% of the growth in peaking power systems was assumed to be installed as lead-acid peaking power battery systems. Thus, the range of expected peaking battery systems required was bounded by a 2-10-25 factor (2% load growth; 10% peaking systems; of which 25% are peaking battery systems) and a 6-20-25 factor (6% load growth; 20% peaking systems; of which 25% are peaking battery systems).

These growth requirements were extrapolated to the year 2000; Exhibit 3-1 lists the number of peaking battery systems required annually. At the low growth factor (2-10-25), 22 battery systems (10 megawatts each) are required to be installed in 1985 and 30 systems to be installed in the year 2000. Similarly, at the higher growth rate (6-20-25), the number of systems required annually for 1985 and 2000 is 180 and 445, respectively. The 1976 figures (in parentheses) indicate the number of battery systems that could be in place in 1976 based upon the system composition and assuming lead-acid peaking battery systems were economically viable with industry in a position to manufacture.

EXHIBIT 3-1

Numbers of 10-MW Battery Systems per Year

Growth Factor	1976	1985	2000
2-10-25	(975)	22	30
6-20-25	(1950)	185	445

4.0 LEAD

The situation with lead--its cost and availability to manufacturing plants producing lead-acid peaking battery systems--resides as one of the most significant factors in assessing the viability of lead-acid batteries for peaking power applications. Present usage and projected trends will be examined from several sources in evaluating the availability of lead for peaking battery applications.

Costs and pricing of lead sources to, through, and from secondary smelters from sources of scrap were studied along with the pricing relationships between primary and secondary lead to establish levels of costs for lead. Operators of secondary and primary smelters were contacted and were cooperative in efforts to establish cost benefits from lead for use in high volume production of lead-acid peaking batteries.

4.1 USES AND AVAILABILITY OF LEAD

The world lead resource is estimated at 330 million tons; approximately 50% is estimated as economically recoverable reserves. The North American continent is estimated to contain 170 million tons of the lead resource, with the United States having 119 million tons, or 70% of the North American reserves for lead (see Exhibit 4-1).

In 1973, the U. S. demand for lead was 1,598,000 tons. The major uses of lead (Exhibit 4-2) are transportation (batteries) and gasoline (anti-knock additives) totalling 61% of consumption, i.e., 44% and 17%, respectively. The consumption of lead for anti-knock additives is projected to reduce

EXHIBIT 4-1

World Lead Resources
(Millions Short Tons)

	Measured Reserves	Estimated Undiscovered Economical Reserves	Total
North America	84	86	170
United States	(59)	(60)	(119)
Other	(25)	(26)	(51)
South America	6	6	12
Europe	25	25	50
Africa	5	9	14
Asia	27	27	54
Australia	18	12	30
Total World	165	165	330

Source: Mineral Facts & Problems, 1975 Edition, U. S. Department of Interior

LEAD

SUPPLY-DEMAND RELATIONSHIPS-1973

(thousands of short tons)

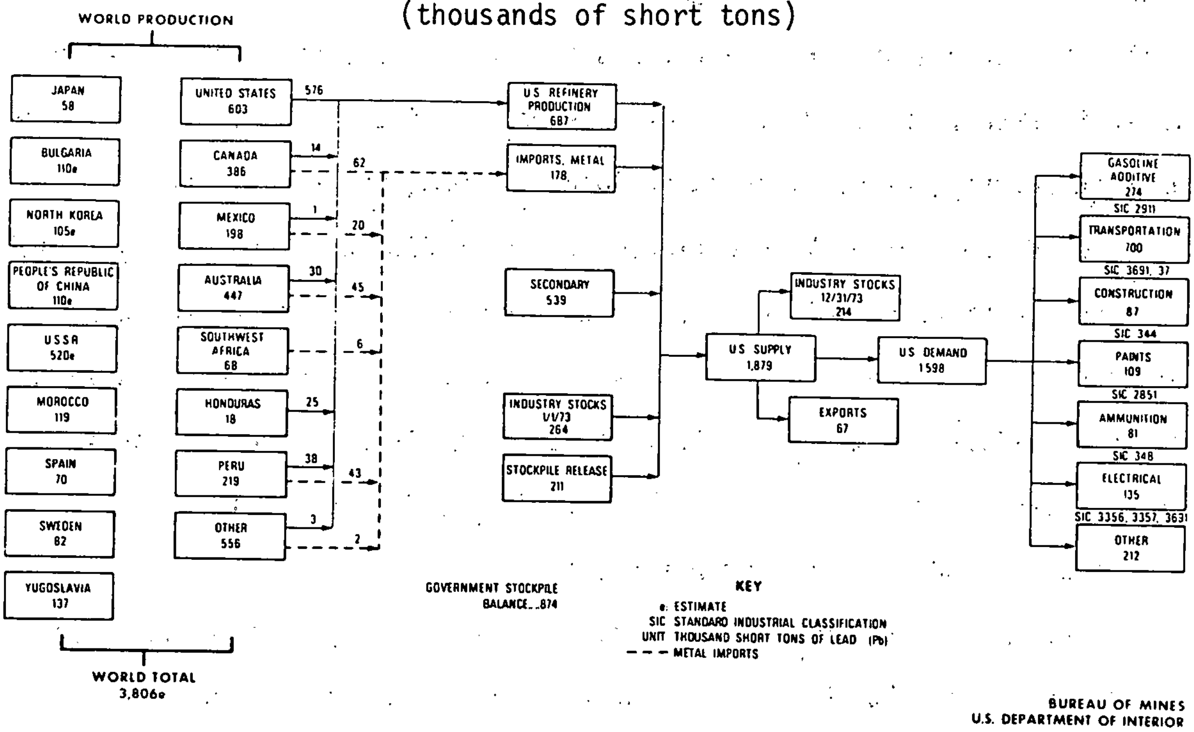


EXHIBIT 4-2

Lead Supply-Demand Relationships

Source: Mineral Facts & Problems, 1975 Edition, U. S. Department of Interior drastically as a result of efforts by the Environmental Protection Agency to eliminate its eventual use in gasoline.

The estimated usage of lead for peaking battery systems for the state-of-the-art battery is 35,600 tons per year per manufacturing plant. Assuming seven manufacturing plants were operational in 1985, the annual lead consumption demand for peaking batteries would be 250,000 tons per year. This requirement to produce 7,000 megawatt-hours per year from these projected manufacturing facilities would demand less lead than what was consumed in gasoline additives for the year 1973. Assuming the use of lead for anti-knock additives is eliminated, this lead could be diverted to the manufacture of lead-acid peaking battery systems.

Furthermore, this diversion of lead resources from gasoline additives to peaking batteries can be looked upon as a conservation of natural resources. When lead is used in the manufacture of batteries, it is not consumed, but remains as a lead form and at the end of the battery's useful life can be readily and economically converted into new batteries. On the other hand, lead consumed in anti-knock gasoline additives is totally consumed and also creates an undesirable environmental side effect.

In considering the demand for lead in the advanced technology battery, an estimated 28,700 tons per year per manufacturing plant would be required. This substantial reduction for the requirement for lead would result in a demand of 200,000 tons in 1985 and 400,000 tons by the year 2000, producing 7,000 and 14,000 megawatt-hours of battery systems per year, respectively.

From this consideration, it can be concluded that the lead requirements for lead-acid peaking battery systems do not pose a supply/demand barrier to their viability. The availability of lead for lead-acid batteries for peaking applications for 1985 represents a 15% increase in lead demand based upon 1974 usage. Furthermore, this demand can be readily met by the substitution of lead in gasoline anti-knock additives for peaking batteries and could even be evaluated as a conservation of lead resources.

4.2 LEAD COSTS FOR PEAKING BATTERIES

There are two sources of lead available to consumers of lead: 1) primary and 2) secondary. Primary lead is lead derived from lead-bearing ores and won to its metallic form by smelting and refining; this is the source of new, virgin lead to the supply/demand stream. Secondary lead, on the other hand, is lead that comes from several sources of lead-bearing scrap that is subsequently melted and refined in secondary smelters.

Thirty-five to forty percent of world lead usage depends on secondary lead. Over the ten-year period from 1964 to 1974, 37% of lead consumption in the United States was from scrap lead sources. Furthermore, 80% of the lead used in lead-acid storage batteries in the United States comes from secondary or recycled lead. Secondary lead, its sources, costs, and relationship to primary lead are key factors to be considered in establishing levels of cost for lead for lead-acid peaking batteries.

There are two specific cases of lead costs to be considered for the manufacture of peaking batteries. Case I is for lead made available to the manufacturing plant fabricating batteries through the purchase of lead from operators of secondary smelters. Case II considers potential lead cost benefits by vertical integration into secondary lead smelting by the battery manufacturer.

In Case I the purchase of lead from secondary smelters recognizes that secondary lead prices are equivalent to prices quoted for primary lead. In the marketplace a pound of lead of equivalent specification has the same value or worth independent of its source whether it be from primary or secondary lead smelter operations. When a change occurs in primary lead, the quoted price of secondary lead is adjusted principally by the upward or downward movement of the cost of lead scrap to the secondary smelter.

A further examination of lead costs from secondary smelters can be made by attempting to build up the cost of lead by considering the various components of the cost buildup. Exhibit 4-3 considers lead costs for new lead-acid peaking battery systems and out-of-pocket cost for lead to build a replacement battery system as a result of recycling lead from a peaking battery at the end of its useful life.

At an established lead price of 25 cents per pound, cost of scrap from whole batteries ranges from 11 to 12 cents per pound; battery breaking costs are estimated at 2 to 3 cents per pound; smelting and refining costs at 6.5 to 7.5 cents per pound. This leaves a remainder of 2.5 to 4.5 cents for smelter overhead, lead transportation to the smelter, and profit. Practically, however, for the situation of lead cost to a manufacturing plant building lead-acid peaking battery systems for new applications, it may be reasonable to assume that actual lead prices could be reduced as much as 15% to 21.25 cents per pound.

This range of price sensitivity from 21.25 to 25.00 cents per pound can be supported as follows:

(1) The investors of the secondary smelter recognize that a planned level of lead throughput is essential to the business decision to establish a secondary smelter. The lead throughput can only exist if there is a desired level of scrap lead, as an input, and a desired level of demand for lead, as an output. The existence of a high volume manufacturing plant building lead-acid peaking batteries may assure a base output load for

SECONDARY LEAD PRICE/COST ESTIMATES
(CENTS PER POUND)

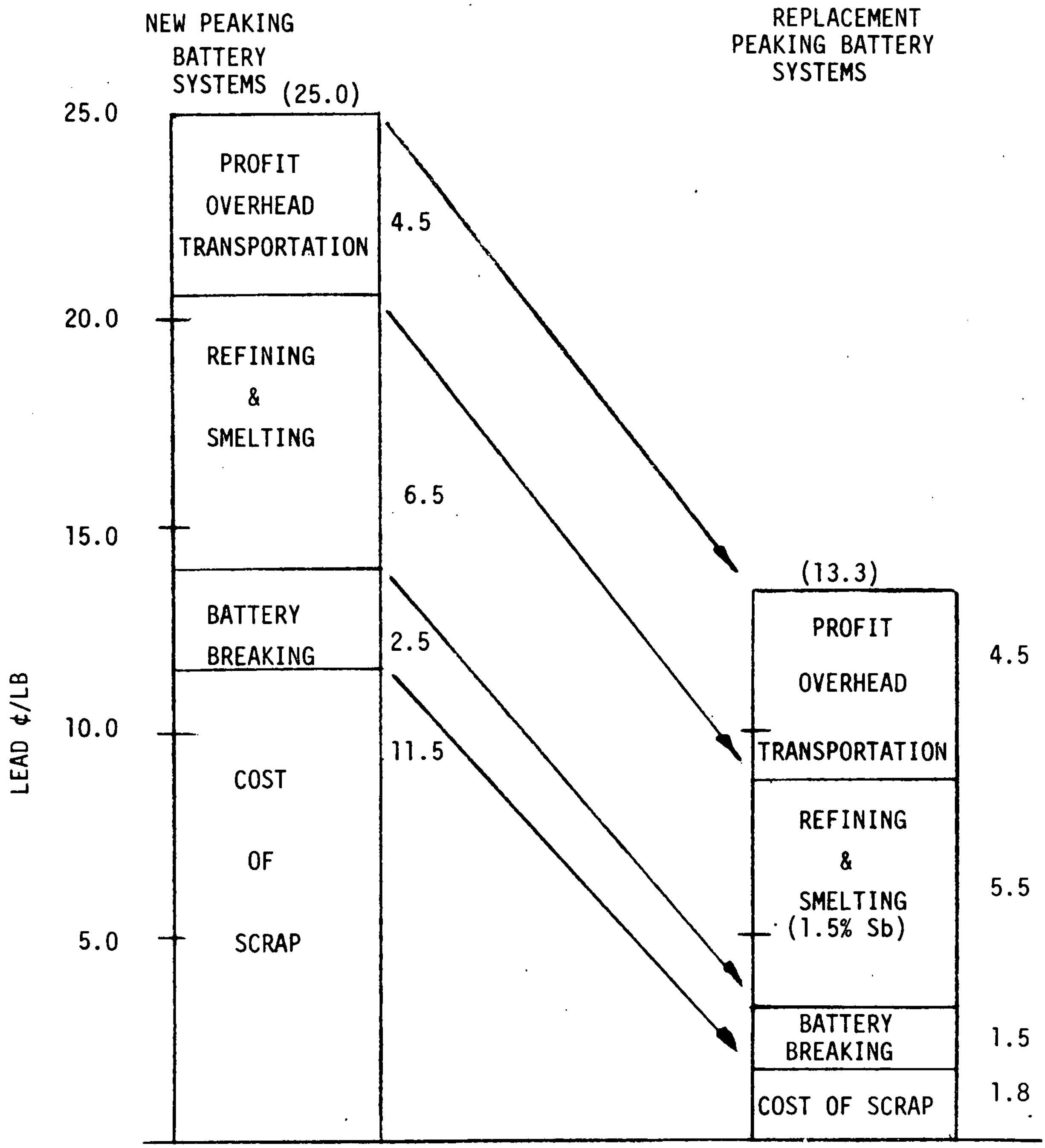


EXHIBIT 4-3

the smelter; integrating backward into sources of lead scrap would insure a source of scrap and may result in lower cost of scrap to the smelter.

(2) The second factor relates to inherent economies within the smelter operation due to a large demand base of the total output dedicated to peaking battery lead specifications that may be passed along in part to the battery manufacturer in the form of lower lead costs.

(3) These factors tied together with prudent business contractual arrangements offer a promise of lead prices available to the battery manufacturer in a range of 21 to 25 cents per pound when secondary lead prices are quoted at 25 cents per pound.

The second category of lead costs for peaking battery systems is related to replacement batteries at the end of the useful life of a battery system. In Exhibit 4-3, a 13.3 cents per pound lead cost is estimated when secondary lead is quoted at 25 cents per pound. This cost estimate recognizes that the lead in the used battery would be recycled, at an 85% recovery level. This cost per pound of lead, at 13.3 cents, must be considered as an out-of-pocket cost since the recycled lead has an inherent scrap value. In addition, lower costs per pound have been estimated for battery breaking and smelting-refining costs because lead scrap from the peaking battery to be recycled would have a known geometry and alloy/contaminate content and thus yield a favorable cost benefit. Furthermore, a price sensitivity as explained earlier for new battery systems lead to a potential price/cost range of 12 to 13.3 cents per pound for lead to the manufacturer of replacement lead-acid peaking battery systems.

In Case II, the situation for lead price represents a further improvement in economies of manufacturing by vertical integration into secondary lead smelting. Key benefits result from: the favorable benefits discussed in Case I; the value of antimony recovery that is inherent in secondary smelting; energy savings; and reduced remelt cost that result from pumping liquid lead from the smelter directly to grid casting and oxide manufacturing.

An effective lead cost of 19 cents per pound, when the quoted market price is 25 cents per pound, can be supported as follows:

(1) If the favorable cost factors described in Case I were to result in 10% to 15% reduction in the quoted price of lead, the impact would be approximately 3 cents per pound (~ 12% x 25¢).

(2) Examination of the lead and antimony content of a cell (see Exhibit 6-2 in a subsequent section of this report) indicates that 1.8% of the combined amount is antimony. At $1.67 per pound, this antimony contributes a value of 3 cents per pound of the scrap, which can be considered as a direct offset to the cost of lead.

The elements of cost for vertical integration of secondary lead for new and replacement lead-acid batteries are illustrated in Exhibit 4-4 at 19 and 10 cents per pound for secondary lead from commercial smelters quoted at 25 cents per pound.

SECONDARY LEAD COST WITH VERTICAL INTEGRATION

(CENTS PER POUND)

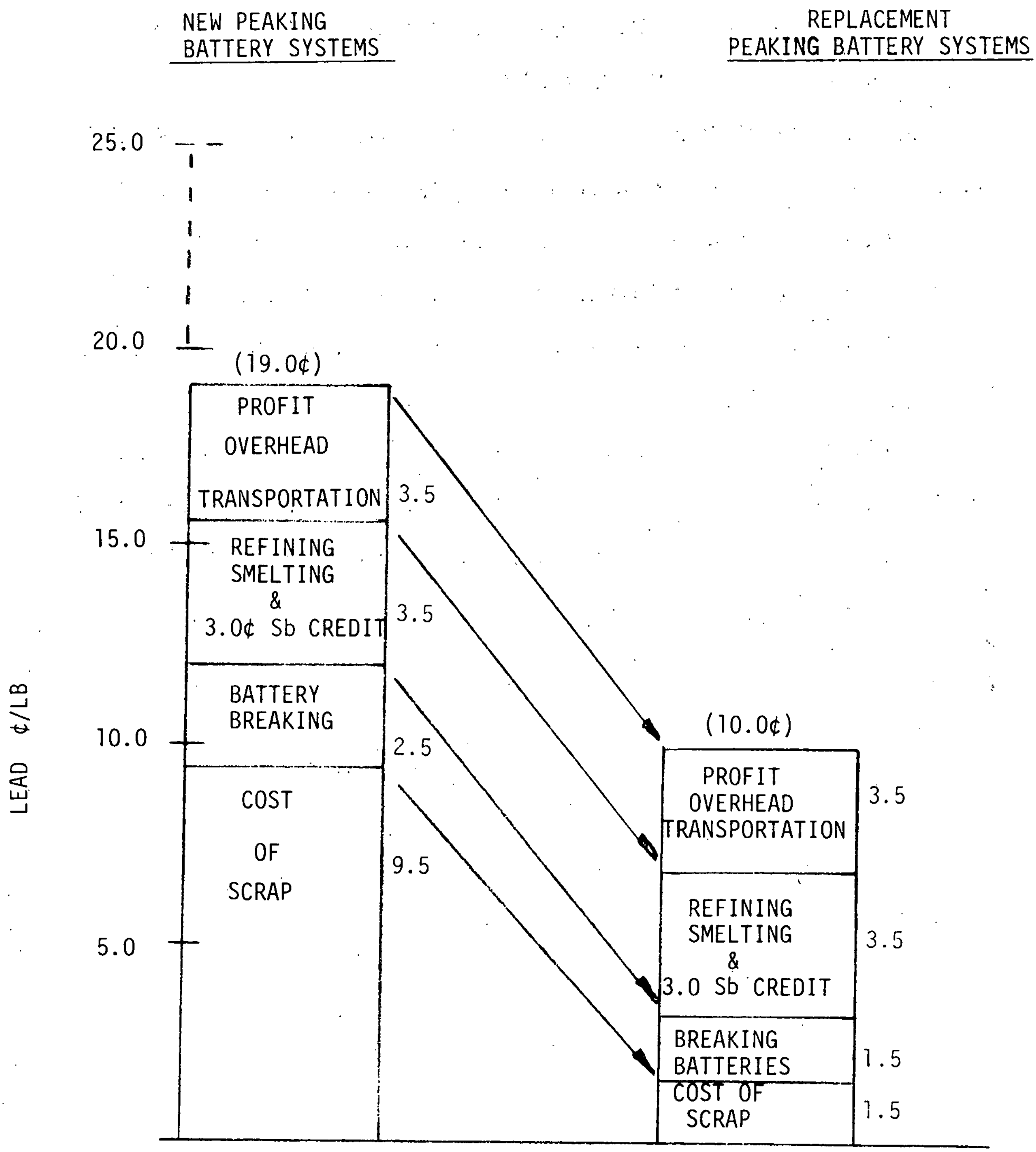


EXHIBIT 4-4

4.3 CONCLUSIONS

There appear to be adequate lead resources for lead-acid peaking battery systems through the year 2000.

Prices/cost of lead available for new installation of lead-acid peaking battery systems at quoted secondary lead prices of 25 cents per pound could range from 21 to 25 cents per pound. Vertical integration by the battery manufacturer may result in lead costs as attractive as 19 cents per pound when commercial secondary lead prices are at 25 cents per pound.

Similarly, costs to recycle lead from end-of-life lead-acid peaking battery systems into replacement battery systems would involve out-of-pocket costs of 12 to 13.3 cents per pound and with vertical integration, 10 cents per pound.

5.0 BASIC ASSUMPTIONS

The assumptions that were made to establish the base for the study relate to the technical requirements of a peaking battery system; the capacity of the manufacturing plant; and the elements of cost that were studied to arrive at the manufacturing cost and, hence, projected selling prices for lead-acid peaking battery systems.

5.1 TECHNICAL REQUIREMENTS

The power rating of the peaking battery system has been set at 10 megawatts with a 770-volt nominal system and 1000 volts, maximum. The discharge times for peaking power batteries range from three to five hours. An average discharge time of four hours was selected for the study defining a 40 megawatt-hour battery system. The relationship of battery system rating from the three- to the ten-hour rate is shown in Exhibit 5-1.

The time to recharge the battery system has been set at ten hours. Two hundred fifty charge discharge cycles per year has been established for the application based upon a five-day operational week and one cycle per day.

EXHIBIT 5-1

Discharge Time vs Battery System Capacity

Discharge Time (Hours)	Battery System Capacity, KWH (Percent)
10	100%
8	96%
5	85%
4	81%
3	74%

5.2 MANUFACTURING PLANT CAPACITY

The manufacturing plant was sized to generate sufficient sales volume on an annual basis to cover overhead costs so that an individual manufacturing plant could be self-sufficient, i.e., "stand alone." Consequently, a manufacturing plant was sized for a capability to produce twenty-five 40 megawatt-hour lead-acid battery systems per year, or an annual capacity of 1000 megawatt-hours. The plant would have a manufacturing process concept and have facilities tailored for the high volume production of a single cell, sized for peaking battery systems. Plants are planned to be operated at full production. The number of manufacturing plants producing twenty-five, 40-MWH peaking battery systems per year for the years 1985, and 2000, for the assumed growth rates, are shown in Exhibit 5-2.

EXHIBIT 5-2

Number of Manufacturing Plants
Producing 25, 40-MWH Peaking Battery Systems
Per Year

Growth Rate	1985	2000
2-10-25	1	2
6-20-25	7	18

5.3 ELEMENTS OF COST

The elements of cost studied to arrive at the manufacturing cost and to use as a basis for projecting selling prices for peaking batteries are listed in Exhibit 5-3. These costs can be categorized as direct product costs, manufacturing facilities costs, and overhead costs. Basic lead cost was assumed to be twenty-five cents per pound, although the sensitivity to lower lead cost was reflected in the analysis. Additional assumptions are included with the discussions of the cost elements.

EXHIBIT 5-3

Cost Elements

- Lead Cost @ 25¢ per pound
- Direct Product Costs
  - Materials
  - Labors
  - Expense
- Manufacturing Facilities
  - Plant Floor Space
  - Process Equipment
  - Land & Building
- Overhead Costs

6.0 STATE-OF-THE-ART BATTERY

6.1 DESIGN SPECIFICATION

The cell chosen for this study is shown in Exhibit 6-1 and will be identified as the KW 160-45 state-of-the-art cell. Specifications for the cell are listed in Exhibit 6-2. It is rated at essentially 5 KWH; thus, a 40 megawatt-hour peaking installation will require 8085 cells arranged in 21 parallel strings of 385 cells connected in series.

The cell design is such that seven cells will be combined at the factory into a module as shown in Exhibit 6-3. The cells will be mounted on a base molded of polypropylene structural foam and covered with a single cover after the cell interconnections have been made. The cover will have attached water cooling coils, an automatic water addition mechanism, and vent plugs for each cell. The water addition devices and vents will be connected to the manifolds. (The functioning of these devices is described in detail in Volume III of this report.) The cover will interlock each cell and be held in place by the terminals of the end cells.

This module design serves several important functions. Ninety percent of the cell interconnections will be made at the factory leaving only 10% to be made at the installation site. The base is designed to be strong enough to serve as a four-way shipping pallet as well as a platform to provide proper isolation distance of the cells from the floor at the installation. If a cell failure is detected, the module it is in will be replaced. The defective cell can then be replaced in the module allowing it to be used as a future replacement module. Venting and water addition manifolds are also added at the factory.

The module will be completely assembled at the factory and shipped to the installation site without electrolyte, which will be added at the site. Cells will be formed after the installation is complete using the power conversion equipment of the site. Factory representatives will oversee the installation, formation, and startup.

STATE - OF - THE - ART CELL

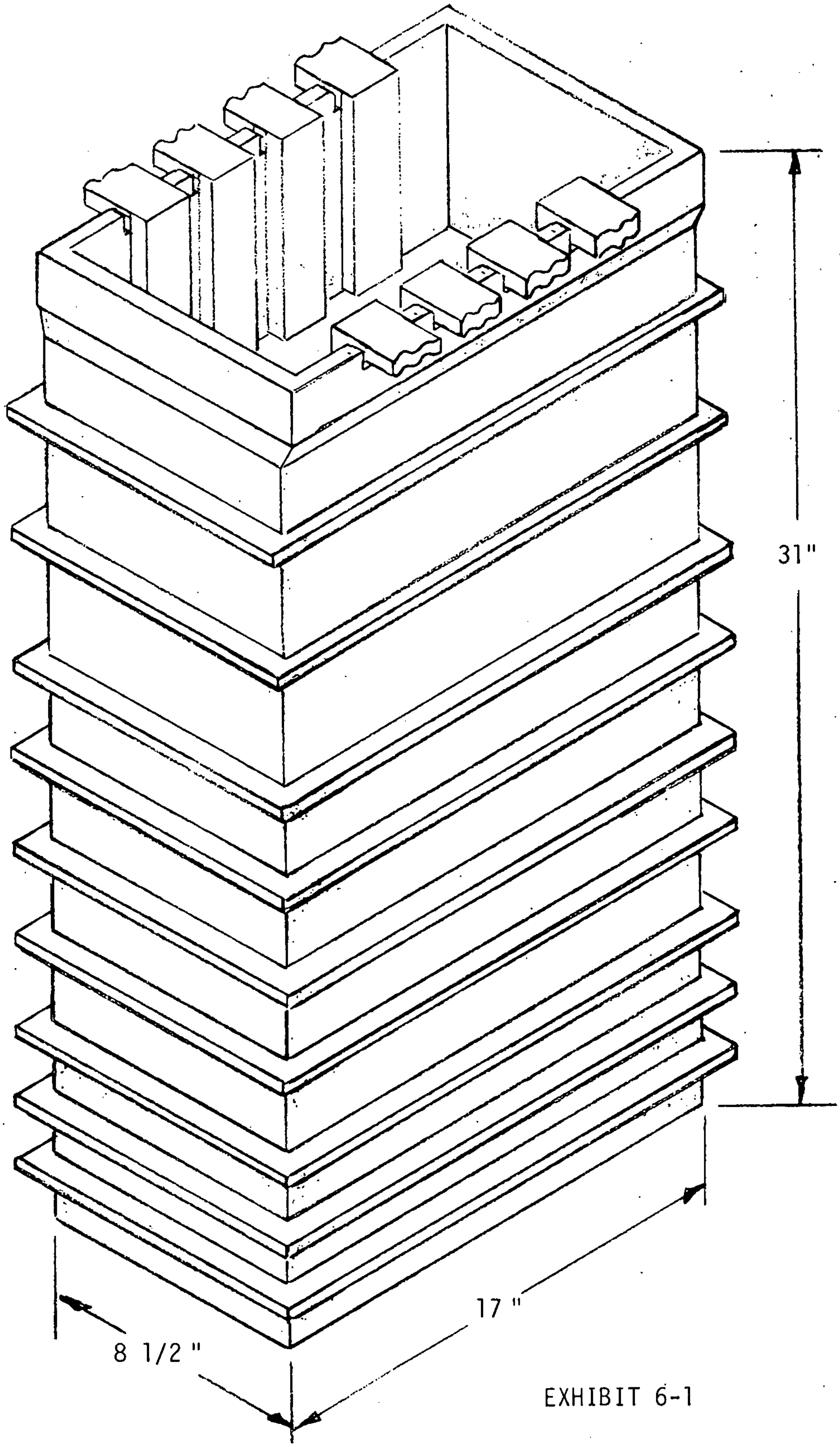


EXHIBIT 6-1

EXHIBIT 6-2

Product Design Spec

1. CELL IDENTIFICATION NUMBER KW 160-45

2. CELL CAPACITY

	4 hr rate	10 hr rate
Nominal		
AH	3220	3880
WH	6171	7570
End of Life (80% nom.)		
AH	2578	3104
WH	4937	6052

3. PHYSICAL DIMENSIONS

a. Size: L 17.75" W 9.31" H 33"

b. Outline Drawing Exhibit 6-1

e. Module Drawing If Considered Exhibit 6-3

4. COMPONENT WEIGHTS (lbs)

	Total	Lead Content	Sb Content
Grids	140.11	134.03	5.60
Oxide	217.4	197.67	
Straps	6.8	6.5	.30

4. COMPONENT WEIGHTS (contd)

	Total	Lead Content	Sb Content
Posts (8)	10.65	10.23	0.42
Cell Interconnects (8)	2.61	2.51	0.10
Separators	12.06	--	
Jar, Cover Vent	10.0	--	
Electrolyte	101.0	--	
Totals	500.0	350.94	6.36

5. COMPOSITION OF PLATES

	Positive	Negative
Active Material	25% Pb_2O_3, 75% PbO	96.7% PbO, 2.9% Ba SO_4 4 fillers
Grids	96.0 Pb, 4.0% Sb	Same

6. ELECTRICAL PARAMETERS - 4 HR RATE

Capacity	3223	Ahrs
Capacity End of Life (Rated)	2578	Ahrs
Energy Cap. End of Life (Rated)	4937	Whrs
Energy Efficiency	76	%
Life - Number of Cycles	1750	
Cell Voltages		
Start of Discharge (@ 80 °F)	1.98	V
Discharge Cut-Off (@ 85 °F)	1.81	V
Start of Charge (@ 80 °F)	2.10	V
Charge Cut-Off (@ 89 °F)	2.45	V
Equalizing Charge (@ 89 °F)	2.35	V
Equalizing Charge Initial Current	150	A
Equalizing Charge Final Current	100	A
Maximum Short Circuit Current	20,000	A
Internal Resistance	0.1	mΩ

STATE - OF - THE - ART
MODULE

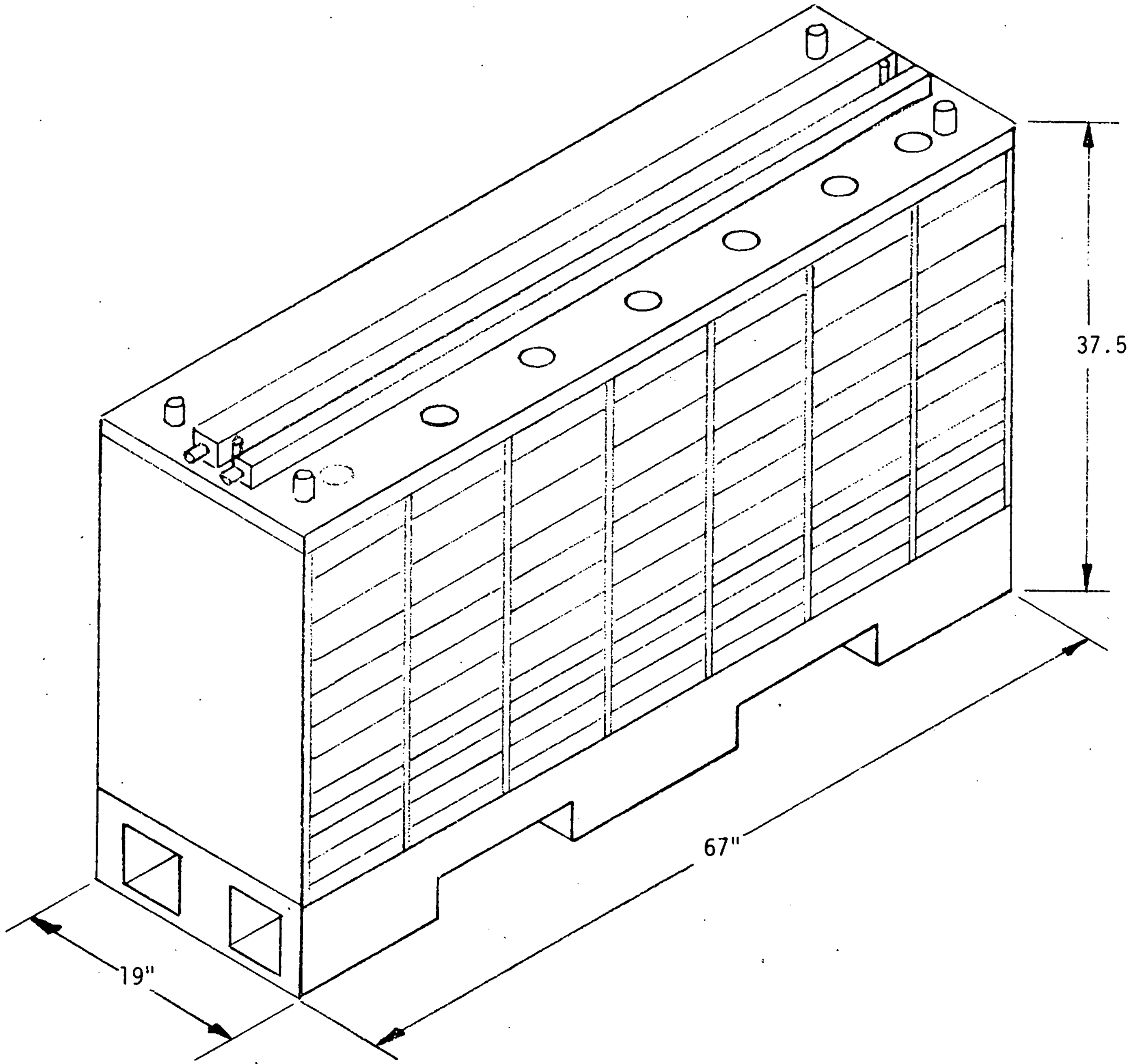
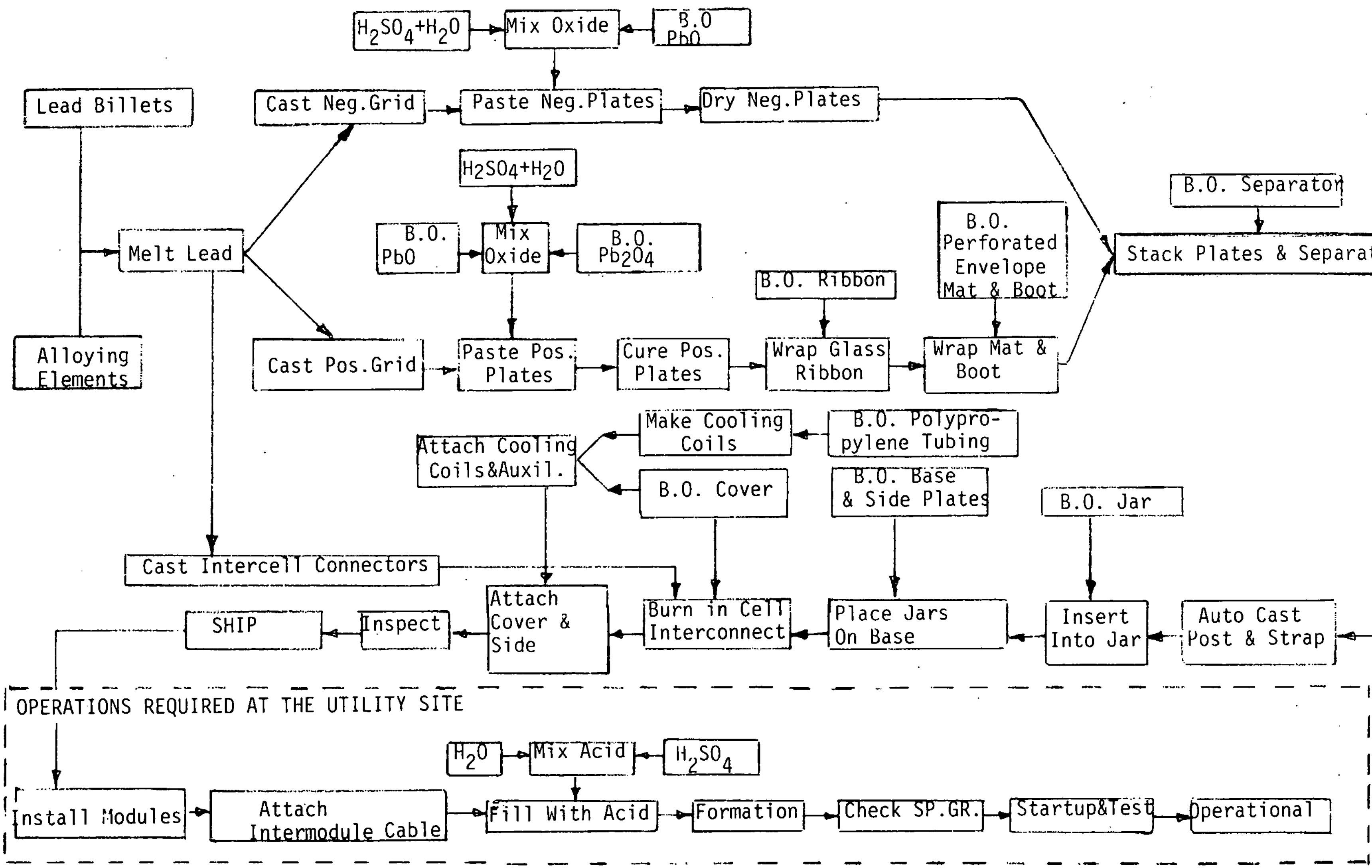


EXHIBIT 6-3

6.2 MANUFACTURING PROCESS

The Process Flow Diagram for the KW 160-45 is illustrated in Exhibit 6-4. This represents the case where both lead and oxides are bought outside; the process starts with alloying lead and mixing oxides and acid into paste. The modules are completed and shipped out of the factory without electrolyte. The electrolyte and intermodule connectors are added at the installation site after which the cells are formed.



PROCESS FLOW CHART

EXHIBIT 6-4

6.3 COST ESTIMATES

6.3.1 Material Cost

The determination of material costs required that several assumptions be made in view of the fact that a projected design precludes obtaining exact quantitative cost information on all elements. The assumptions made in this case are as follows:

(1) Lead purchasable at 25 cents per pound and present market prices for antimony, arsenic, and tin.

Grid lead cost determined as follows:

.96# Pb @ 25¢/# =	$.24
.04# Sb @ $1.67/# =	.067
.0015# Sn @ $3.50/# =	.005
.0015# As @ $2.00/# =	.003
	$.315/lb grid alloy

Lead content per KWH is given in Exhibit 6-5.

(2) Cost of standard purchased items and raw materials determined by present prices paid. These are separator material items.

(3) Cost of purchased items designed especially for this battery was developed from tentative quotes obtained from vendors. These items are the case, cover, base, and side plates.

(4) Cost of in-house fabricated parts determined by use of present unit costs of materials required. These are the cooling, watering, and ventilating items.

EXHIBIT 6-5
Lead Content/KWH (State-of-the-Art)

	lbs/KWH (4-hour rate)
Grids	27.14
Active Materials	39.70
Conductors, Posts & Seal Nuts	3.84
TOTAL	70.68

(5) A process yield for producing plates of 97.5%. Recovery of 85% of the loss to be sold in the scrap market at 10 cents per pound was assumed.

Based on these assumptions a comprehensive material cost list is presented in Exhibit 6-6. As the summation of the table indicates, the total material cost is $157.78 per cell or $31.96/KWH at the 4-hour rate. This breaks down into $113.56 ($23.00/KWH) for lead-related materials and $44.22 ($8.96/KWH) for non-lead costs. Note that lead-related materials account for 72% of the direct materials cost. A summary of materials cost per KWH is shown in Exhibit 6-7.

6.3.2 Machinery and Equipment

The manufacturing facilities, tooling, auxiliary equipment, factory floor space, and labor requirements were determined by the Westinghouse Production Technology Center. To accomplish this, plant visits were made to KW Battery in Skokie, Illinois, and General Battery in Reading, Pennsylvania, to study both industrial and SLI manufacturing facilities and procedures. Comprehensive discussions were held with KW Battery

EXHIBIT 6-6

KW 160-45

Material Cost Estimate

ASSUMPTIONS

1. At $.25/lb lead
   a. 4% antimonial grid lead costs $.315/lb
   b. Negative oxide cost (litharge) $.276/lb
   c. Positive oxide (red lead) $.286/lb

2. Plate yield = 97.5% (80% of bss recoverable)

Item	Qty. Per Cell	Cost Per Cell	Cost per KWH (4-hour rate)
Negative & Positive Grids	143.70 lbs	$ 45.26	$ 9.17
Negative & Positive Oxide	222.96 lbs	62.71	12.70
Straps & Cell Connector	20.97 lbs	6.32	1.28
Reclaimed Lead	7.33 lbs	-.73	-.15
Positive Plate Wrap	5.00 lbs	14.83	3.00
Separator & Protectors	44 pcs	14.94	3.03
Case	1 pc	4.33	.88
Cover	1/7 pc	1.01	.21
Base	1/7 pc	5.14	1.04
Side Plates	2/7 pc	1.47	.30
Auxiliaries		1.39	.28
Electrolyte	101 lbs	1.11	.22
		$157.78	$31.96

	Per Cell	Per KWH
Lead Costs	$113.56	$ 23.00
Non-Lead	44.22	8.96
Total	$157.78	$ 31.96

EXHIBIT 6-7

Summary Of Material Costs

	Cost Per KWH (4-hour rate)
GRIDS	$ 9.11
OXIDE	12.62
POSTS, STRAPS INTERCELL CONN.	1.26
SEPARATORS	6.05
JAR & COVER	2.42
AUXILIARIES	.28
ELECTROLYTE	.22
TOTAL	$31.96

manufacturing personnel to aid in the selection and sizing of the most appropriate equipment available for the various operations to minimize labor costs and operational difficulties. Discussions with equipment manufacturers were also held and quotations for selected equipment obtained. Floor space was determined by the equipment size and KW Battery experience.

The results of this study are presented in Exhibit 6-8 which includes auxiliary equipment and floor space requirements. The total equipment cost estimate amounts to $2,879,000, including installation; 130,000 square feet of floor space is required. Both estimates include office equipment and space.

6.3.3 Labor Cost

Labor requirements were determined from the operational speed of the equipment. Exhibit 6-8 shows the number of operators required, by equipment. For operations not machine-dependent, actual time values obtained from KW Battery were used with modifications required by specific design features of the proposed battery and considering also that this is a one-product operation.

The total number of operating personnel on a three-shift basis came to 150 including 6 operators to fill in for absenteeism. At an average rate of $5.25 per hour for 260 paid days per year, this amounts to a direct labor cost of $1,650,000 per year. Per unit labor costs are:

$66,000 per battery
$8.16 per cell
$1.65 per KWH

EXHIBIT 6-8

State-Of-Art

Plant, Equipment & Labor Estimates

KW 160-45 40 Megawatt Hr. Battery

25 Batteries/Year
Three Shift Operation

	No. Of Pieces Of Equipment	Estimated Total Cost Of Equipment	Oper. Req'd	Floor Space Req'd Ft^2
OXIDE HANDLING & MIXING	18	$ 224,000	6	11,000
ALLOYING FURNACES	3	90,000	6	750
GRID & PARTS CASTING	11	471,000	27	12,500
PLATE PASTING	3	136,000	27	2,250
PLATE DRYING & CURING	11	600,000	7.5	6,300
POS. PLATE WRAPPING	17	200,000	24	3,400
ASSBL. PLATES & CAST STRAPS	1	200,000	15	1,250
PLACE CELLS IN JAR, PLACE ON BASE	3	145,000	6	3,250
JAR, COVER & BASE MOLDS	3	112,000		
BURN INTERCELL CONN.	MISC	20,000	4.5	3,100
CONT. TEST & REPAIR	MISC	45,000	3	2,250
PREPARE COVER	MISC	50,000	4.5	1,000
ATTACH COVER & COMPLETE MODULE	MISC	20,000	1.5	2,250
SHIPPING & REC.	MISC	120,000	12	20,000
MACH. SHOP & LABS	MISC	195,000	O.H.	1,750
SPARE PARTS INV.	MISC	160,000	O.H.	500
WASTE & STACK				
GAS TREATMENT		In Bldg Cost	O.H.	4,000
MED. HEALTH	MISC	20,000		200
AISLE & LAYDOWN SPACE				40,250
PLANT SERVICE				4,000
OFFICE		71,000		10,000
TOTAL		$2,879,000	144	130,000
			+ 6 Relief	
			150	

6.3.4 Land and Building

Based on a factory site of 50 acres in size, and assuming $5,000 per acre, land acquisition would cost $250,000.

The cost of a building of the size required for this operation was estimated by the Westinghouse Construction Technology Center at $3,800,000, using the St. Louis area as a representative geographical location. This estimate is for a 130,000 ft^2 building and includes site work, services, architect/engineering fees, air compressor, propane stand-by, bag house, waste treatment, 135-car parking lot, and 1000 feet of railroad siding.

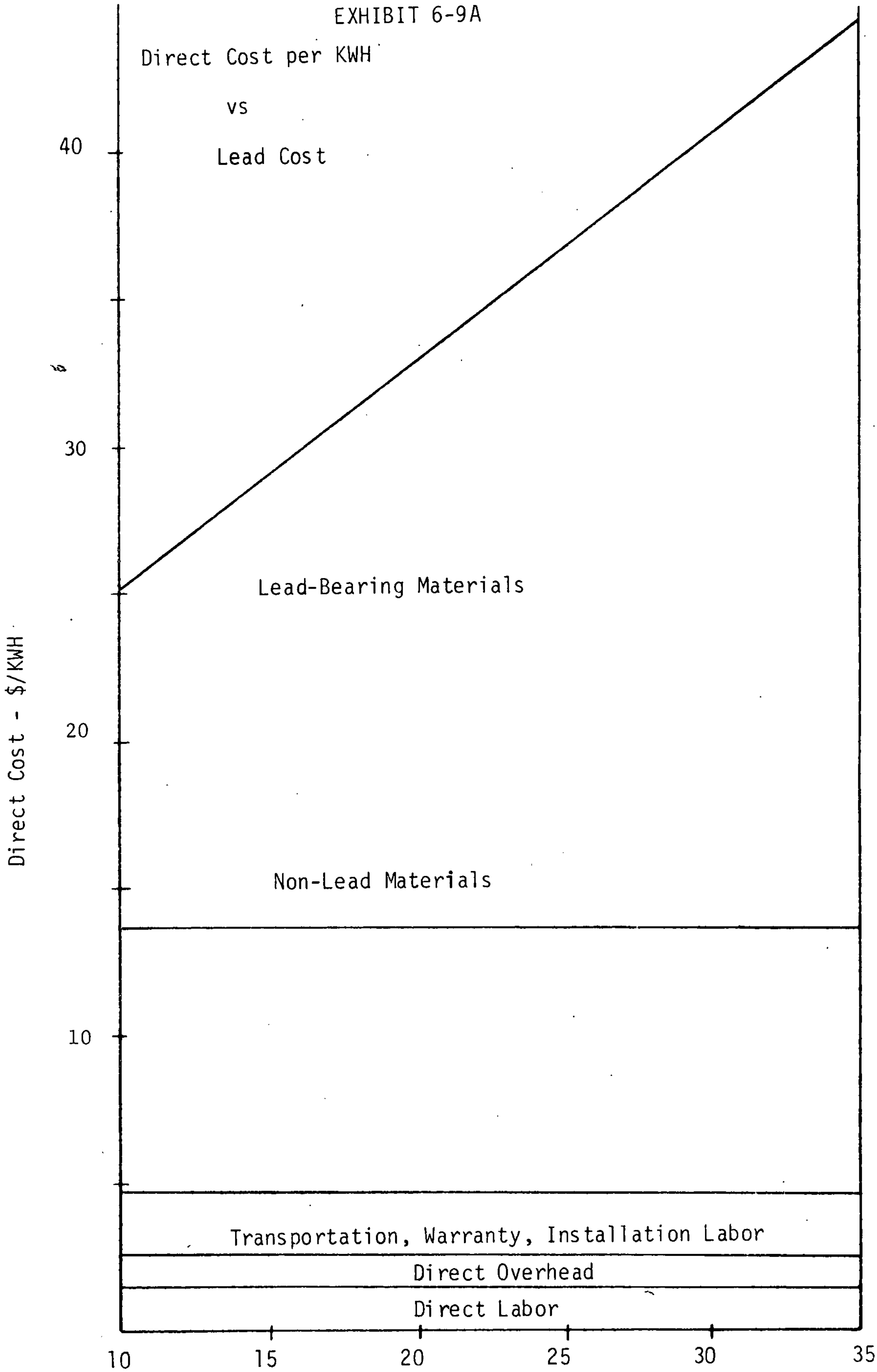
6.3.5 Direct Cost Summary

A summary of the direct costs, dollars per KWH, is shown in the table in Exhibit 6-9 and graphically in Exhibit 6-9A. The graph illustrates the large proportion of cost attributable to lead materials and the resultant effects in direct cost of changes in lead cost. A complete discussion of the overhead items is included in Section 6.5 of this report.

EXHIBIT 6-9
Cost Summary
(@ 25¢ Pb)

		$/KWH (4-hour rate)
Material		$ 31.96
Labor		1.65
Direct Overhead	1.03	
Other Direct Costs:		
Transportation	1.60	
Warranty	.35	
Installation Labor	.22	3.20
Total Direct Cost		$ 36.81

EXHIBIT 6-9A


Direct Cost per KWH
vs
Lead Cost
Lead-Bearing Materials
Non-Lead Materials
Transportation, Warranty, Installation Labor
Direct Overhead
Direct Labor
Direct Cost - $/KWH
40
30
20
10
10
15
20
25
30
35

6.4 VERTICAL INTEGRATION (Excluding Smelting)

Several possibilities for cost improvement through vertical integration were studied to determine their potential effect on the cost. One such opportunity is for the plant to produce its own oxides from metallic lead. The direct product cost as determined in Exhibit 6-10 in this case is \$35.24 per KWH. Compared to a direct cost of \$36.81/KWH from Exhibit 6-9, a net savings of \$1.57/KWH can be realized.

Another opportunity for more vertical integration is in the packaging area. For this study, the case, cover, module base, and sides are obtained from vendors specializing in injection molding. The total cost for these items is \$2.42 per KWH. If they were to be molded in-house, the cost would be as follows:

$$\text{Material} - 3.5\#/\text{KWH} \times 35 \text{ cents}/\# = \$1.23$$

$$\text{Labor} - \frac{10 \text{ oper.} \times \$5.25/\text{hr} \times 40 \times 52}{1{,}000{,}000 \text{ KWHr/yr}} = .11$$

$$\text{Overhead (est)} = .04$$

$$\text{Depreciation} - \frac{\$1{,}000{,}000 \text{ est.} \times .10}{1{,}000{,}000} = \underline{.10}$$

$$\$1.48$$

Thus, a possible savings of 94 cents/KWH is available in this area.

The two promising areas for vertical integration then are oxide making and package molding. Savings of \$1.57/KWH for oxide and 94 cents/KWH for molding result in a total of \$2.51/KWH or 7% of the base direct cost. The resulting direct cost will be \$34.30 instead of \$36.81.

EXHIBIT 6-10

Effect of In-House Oxide Manufacture
on Direct Product Cost
(25¢/lb Lead)

I. Cost of Oxidizing Lead to Litharge

A. Material Cost = lead cost x Pb content in oxide — $ .232/#
.25 x .928 = $.232/#

B. Labor Cost @ 4 operators/shift:

$$\frac{12 \times 5.25 \times 40 \times 52}{39{,}100{,}000\#/yr} = \$.003/\#$$ — .003/#

C. Overhead — .001/#

D. Equipment Depreciation @ $100,000 Cost:

$$\frac{\$100{,}000 \div 10}{39{,}100{,}000} = \$.0002$$ — .0002

TOTAL — $ .2362

II. Unit Costs of Oxides

A. Neg oxide @ 100% Litharge = .2362 — $ .2362

B. Pos oxide @ 75% Litharge, 25% Red Lead:

.75 x .2362 = .177 — .177
.25 x .316 = .079 — .079 — .256

III. Direct Product Cost Calculation

	Qty/Cell	Unit Cost	Cost/Cell
Neg & Pos Grid	143.70#	.315	$ 45.26
Pos Oxide	117.94	.256	30.19
Neg Oxide	105.02	.236	24.78
Straps & Conn.	20.07	.315	6.32
Reclaimed Pb	7.33	.10	.73
			$105.82

New Cost of Lead Materials (with Vertical Integration)	$105.82
Non-Lead Material Costs (Exhibit 6-6)	44.22
Labor Costs (Section 6.3.3)	8.16
Direct Overhead and Other Direct Costs (Exhibit 6-9, $3.20/KWH)	15.79
Costs per Cell	$173.99
Cost per KWH	$ 35.24

6.5 OVERHEAD EXPENSES

In determining the estimate of overhead expense necessary to support a battery manufacturing facility, consideration was given to the size of the plant, the number of production workers requiring support and supervision, the machinery, equipment, and manufacturing processes, and all known conditions associated with the state-of-the-art peaking battery. Where possible, existing data and experience factors were applied to arrive at a realistic estimate.

Base conditions include a 130,000 ft^2 plant producing at an annual rate of 25 batteries per year on a 3-shift, 5-day week. Only one style of battery would be manufactured and there would be a low number of individual orders per year. Thus, a very minimum level of overhead would be required for traditional functions such as order entry, cost accounting, customer engineering, product development, manufacturing information and scheduling, inventory planning and control, and purchasing.

The overhead staff of the plant and associated expenses were estimated at a level required to operate the plant and keep processes under control at steady-state conditions of 25 batteries per year. These expenses are shown in Exhibits 6-11 through 6-14; they include only on-going operating expenses. (Startup, new plant planning, and strategic expenses are discussed in Section 6.6.2.) Exhibit 6-11 lists the Administrative General Expenses for managing the plant; Exhibit 6-12 lists Engineering and Services Expenses for general engineering and installation. The manufacturing expenses in Exhibit 6-13 are listed in two groups: managed overhead and direct overhead.

Those expenses in the direct overhead group are directly related to the production of batteries and are considered to be proportionately variable with production levels; they are considered to be a part of direct cost. The managed overhead consists of expenses that are relatively fixed over slight changes in volume and do not vary automatically. Exhibit 6-14 lists the remaining expenses that are overhead in nature. Transportation cost was estimated on the basis of $1.00/cwt for 300-400 miles each way (i.e., weight of incoming material $\simeq$ weight of shipped product). At approximately 3,200,000 lb/battery, this amounts to $1,600,000 per year.

EXHIBIT 6-11

A&G Functions

	Salary Rate	Quantity	Total Cost
Plant Manager	45K	1	$ 45K
Secretary	12K	1	12K
Controller	30K	1	30K
Payroll Clerk	10K	1	10K
A/P, A/R & Gen'l Acctg. Clerks	10K	2	20K
Cost Accountant	12K	1	12K
Materials Mgr.	25K	1	25K
Buyers	15K	1	15K
Purchasing Clerk	10K	1	10K
Personnel Relations Mgr.	30K	1	30K
Benefits Clerk	10K	1	10K
Medical	15K	1	15K
Total A&G Salaries		13	$234K
Benefits			47K
Computer Costs			50K
Telephone Costs			10K
Travel Costs			10K
Supplies, Copies & Misc.			24K
Total A&G Mgd. Cost			$375K

EXHIBIT 6-12

Engineering and Service Functions

	Salary Rate	Quantity	Total Cost
Engrg. & Service Mgr.	30K	1	$ 30K
Customer Service Engr.	18K	2	36K
Drafters	13K	1	13K
Installation Engineers	18K	2	36K
Order Correspondent	15K	1	15K
Secretary	8K	1	8K
Total E&S Salaries		8	$138K
Benefits			27K
Telephone Costs			15K
Travel Costs			55K
Supplies Copies & Misc.			25K
Total E&S Mgd. Costs			$260K

EXHIBIT 6-13

Manufacturing Functions

	Salary Rate	Quantity	Total Cost
Mfg. Mgr.	35K	1	$ 35K
Scheduler & Planners	12K	2	24K
Secretary	10K	1	10K
First Line Supv.	17K	6	102K
Receiving Clerks	10K	2	20K
Mfg. Services Mgr.	25K	1	25K
Factory Engineers	18K	2	36K
Plant & Tool Maint.	15K	12	180K
Janitors	8K	2	16K
QA Mgr.	25K	1	25K
Qual. Engrs.	18K	1	18K
Inspectors	12K	3	36K
Lab Technicians	15K	2	30K
Waste Treatment Operator	8K	1	8K
Total Mfg. Overhead Salaries		37	$ 565K
Benefits			113K
Telephone Costs			5K
Travel Costs			10K
Total plant fuel costs			285K
Medical Supplies & Exams			25K
Water & Sewage costs			80K
Waste treatment supplies			40K
Office Supplies etc.			20K
Total Mfg. Managed Overhead			$1143K
Misc. Shop Supplies Excl. Waste Treatment			50K
Electric Power Costs			300K
Unapplied Materials			200K
Employe benefits on direct hourly personnel			326K
Maintenance Materials			150K
Total Direct Overhead	($1.03/KWH, Exhibit 6-9)		$1026K

EXHIBIT 6-14

Other Costs

Transportation Costs - Truck	($1.60/KWH)	$1,600K*
Product Warranty Costs	($.35/KWH)	350K*
Selling Costs		700K
Insurance and Taxes		175K
Total Other Costs		$2,825K

*These items included with direct cost; see Exhibit 6-9.

6.6 ECONOMIC ANALYSIS

6.6.1 General

The economic analysis for the peaking battery was made from the viewpoint of a private investor with capital resources that he could apply to any number of investment opportunities. Given several alternatives, such an investor would certainly choose the one that represents the greatest, most certain opportunity for a high return. This choice depends upon the amount of investment required; the time it takes to start realizing a cash return on that investment; the amount of the cash return; and the attendant risks involved with actually attaining that level of return.

There are several types of risks that must be considered in an investment evaluation including technical, financial, and market risk. Technical risks are those dealing with the product itself (whether or not it can actually be manufactured as planned and whether or not it will actually perform as required), and those dealing with the machinery, equipment, and processes required to manufacture the product. Financial risks are those involving cost (whether the estimates are accurate and complete), and those involving time (whether the project will be completed on time, the timing of cash outlays and cash returns, etc.). Another significant risk is in the market (demand and selling price for the product). This risk is greater, of course, when there is no existing, proven market for the proposed product.

The degree of risk for a given situation can be established on the basis of three criteria: new or existing technology; new or existing facilities; and new or existing market. When only one of these is new, the risk is considered low. If two are new, the risk is moderate. If all three are new, it is a high risk situation.

The discounted cash flow method of analysis was used for this study. With this method, all the cash outflows are determined over a number of years. These include capital investment, start-up expense, working capital, and the yearly operating costs of the business. Then, the cash inflows are determined, including receipts from sales and the tax benefits associated with strategic expense, investment credit, and accelerated depreciation of plant and equipment. Finally, the net cash flows over the life of the plant are converted to present value at various discount rates until that rate is found that results in the present value of all cash inflows being equal to the present value of the cash outflows. Because of the numerous iterations involved, the computations are done on a computer.

6.6.2 Cost Estimates

For the peaking battery project, an in-depth analysis was performed to obtain the best possible estimates for costs. These costs are summarized in Exhibit 6-15. Details of capital investment, direct costs, and indirect overhead can be found in other sections of this report. The potential improvement from vertical integration was also reflected in this analysis.

Strategic expenses include tooling and initial miscellaneous factory expenses, the manufacturing planning effort during construction and installation of plant and equipment, and the start-up expenses associated with training an initial work force and debugging equipment and processes.

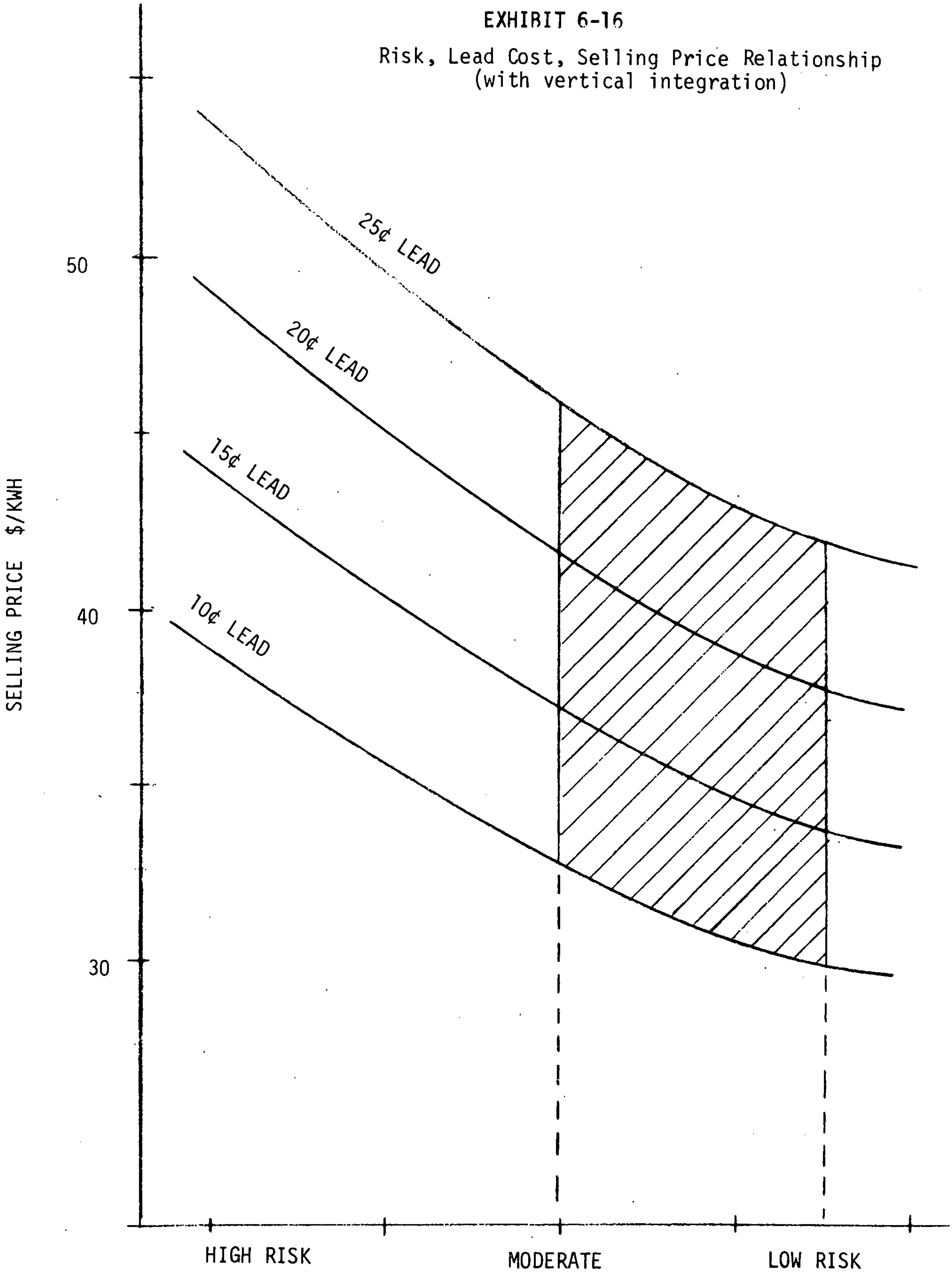
EXHIBIT 6-15

Summary of Cost Data
(Lead @ 25¢/lb)

Land (50 acres) (Section 6.3.4)	$ 250K
Building (130,000 sq. ft.) (Section 6.3.4)	3,800
Machinery & Equipment (Exhibit 6-8, $2879K less $679K tooling)	2,200
Total Capital Investment	$ 6,250K
Factory Tooling	$ 679
Initial Stock of Factory Supplies & Expense Items for Start-up	51
Manufacturing Planning (135 man-months)	270
Training & Start-up Costs	2,000
Total Strategic Expense	$ 3,000K
Accounts Receivable (45 days)	$ 5,210K
Inventories	4,637
Less: Accounts Payable & Warranty Reserve	- 3,056
Total Working Capital	$ 6,791K
Direct Labor (Exhibit 6-9 $1.65/KWH)	$ 1,650K/year
Direct Material (Exhibit 6-9 $31.96/KWH)	31,960
Transportation (Exhibit 6-14)	1,600
Direct Overhead (Exhibits 6-13 and 6-9)	1,026
Warranty (Exhibit 6-14)	350
Installation Labor (22¢/KWH)	225
Subtotal Direct Cost	36,811K/year
Less: Potential Improvement from Vertical Integration (Section 6.4 $2.51/KWH)	2,510
Total Direct Cost	$34,301K/year
Administrative & General (Exhibit 6-11)	$ 375K/year
Engineering & Service (Exhibit 6-12)	260
Manufacturing Managed Overhead (Exhibit 6-13)	1,143
Marketing (Exhibit 6-14)	700
Insurance & Taxes (Exhibit 6-14)	175
Total Indirect Overhead	$ 2,653K/year

EXHIBIT 6-16

Risk, Lead Cost, Selling Price Relationship
(with vertical integration)



An estimate was also made for a level of working capital consistent with a normal business investment, including accounts receivable; raw material, work-in-process, and finished goods inventories; accounts payable; and warranty reserves.

An output of 25 batteries per year was assumed, based on a 3-shift, 5-day week, with a 60% level achieved by the fourth year and full output from the fifth year on.

6.6.3 Analysis

Since the market for peaking batteries is untested, the selling price was not a known factor. Therefore, the approach taken was to evaluate a range of conditions of investment, cost, and risk to determine the approximate selling prices that would yield a satisfactory return to the investor under the various conditions. This approach gives recognition to the alternatives that are available and shows the sensitivity of the selling price to risk, lead cost, investment, and volume.

The curves in Exhibit 6-16 show the relationship of selling price to risk under conditions of a normal business investment. Since the price of lead has significant influence on the analysis, a range of 10¢/lb to 25¢/lb is shown. This recognizes not only the variation in the lead market but also the potential impact of buying policies, volume influences, or vertical integration within lead smelting operations. It was assumed that assurances of a certain market would be made to the potential investor. Thus, on the basis of new facilities, existing technology, and a certain (existing) market, a low-risk situation would exist.

EXHIBIT 6-17

Risk, Lead Cost, Selling Price Relationship with No Investment in Working Capital (with vertical integration)

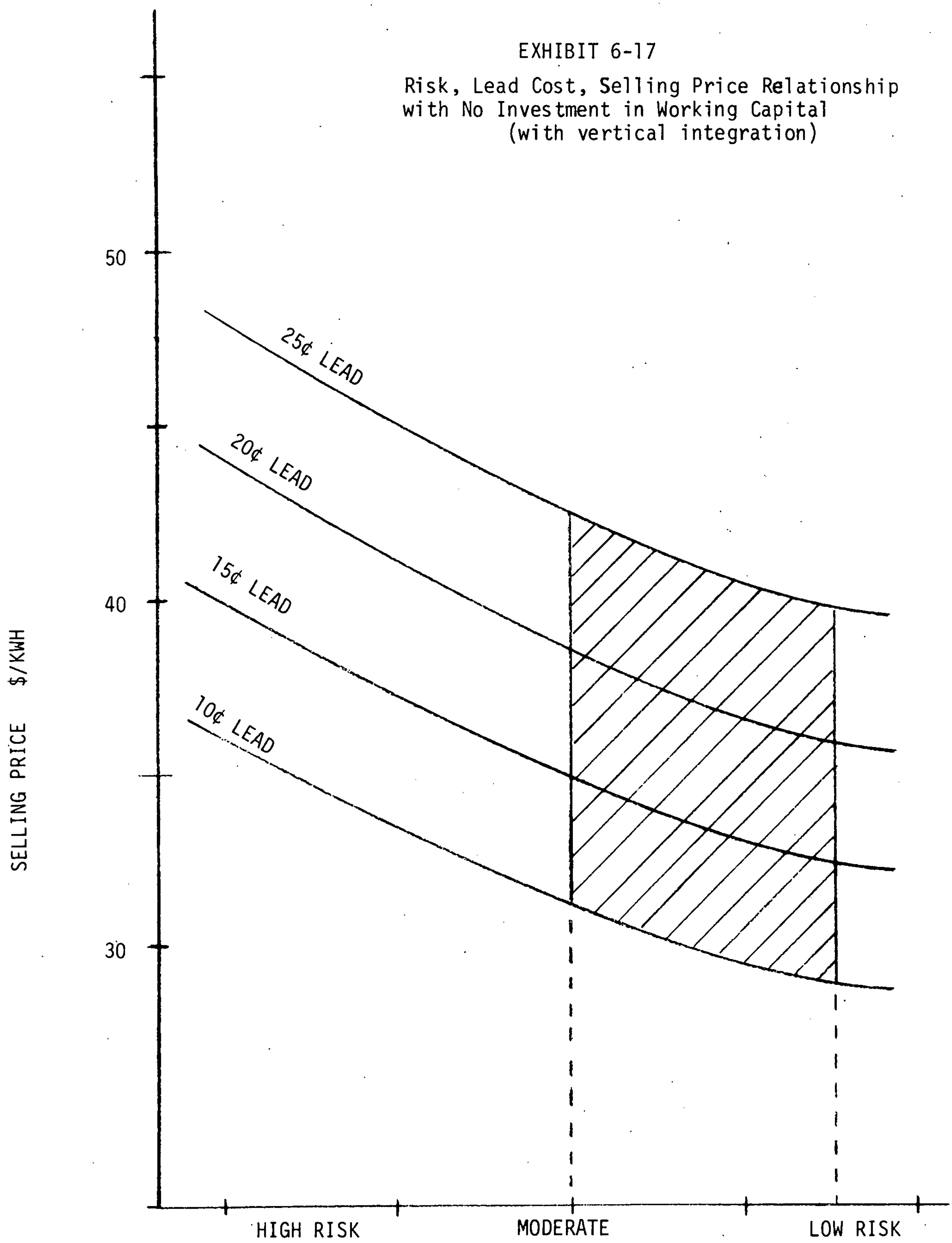


Exhibit 6-17 shows price curves that would result if no working capital were required. Although this is different from normal business situations, it could be accomplished through advance or partial payments on orders which would eliminate accounts receivable and would support inventories.

Exhibit 6-18 illustrates what happens when there is external support to finance the investment in land, buildings, machinery and equipment ($6,250K), and also the initial planning, training, and start-up expense ($3,000K); see Exhibit 6-15.

When the effects of external investment and no working capital are combined, the curve becomes essentially flat as shown in Exhibit 6-19. There is a small amount of start-up cost that is assumed to be borne by the plant, and hence a slight slope remains. In this situation, the most significant factor to have an impact on selling price would be the price of lead, and this impact is essentially linear.

Since the preceding analyses were based on a 3-shift, 5-day week, the potential exists for operating at a higher volume without increasing the size of the facility or the amount of equipment. The result of more volume would be to decrease the average overhead cost per battery, and thus the selling price, whereas a drop in volume would have the opposite effect. In analyzing the effects of volume, it was assumed that direct product costs and working capital would vary directly with volume and managed costs would vary at one-fifth the rate. The resultant relationship is shown by the curves in Exhibit 6-20.

EXHIBIT 6-18

Risk, Lead Cost, Selling Price Relationship
with No Capital Investment or Strategic Expens
(with vertical integration)

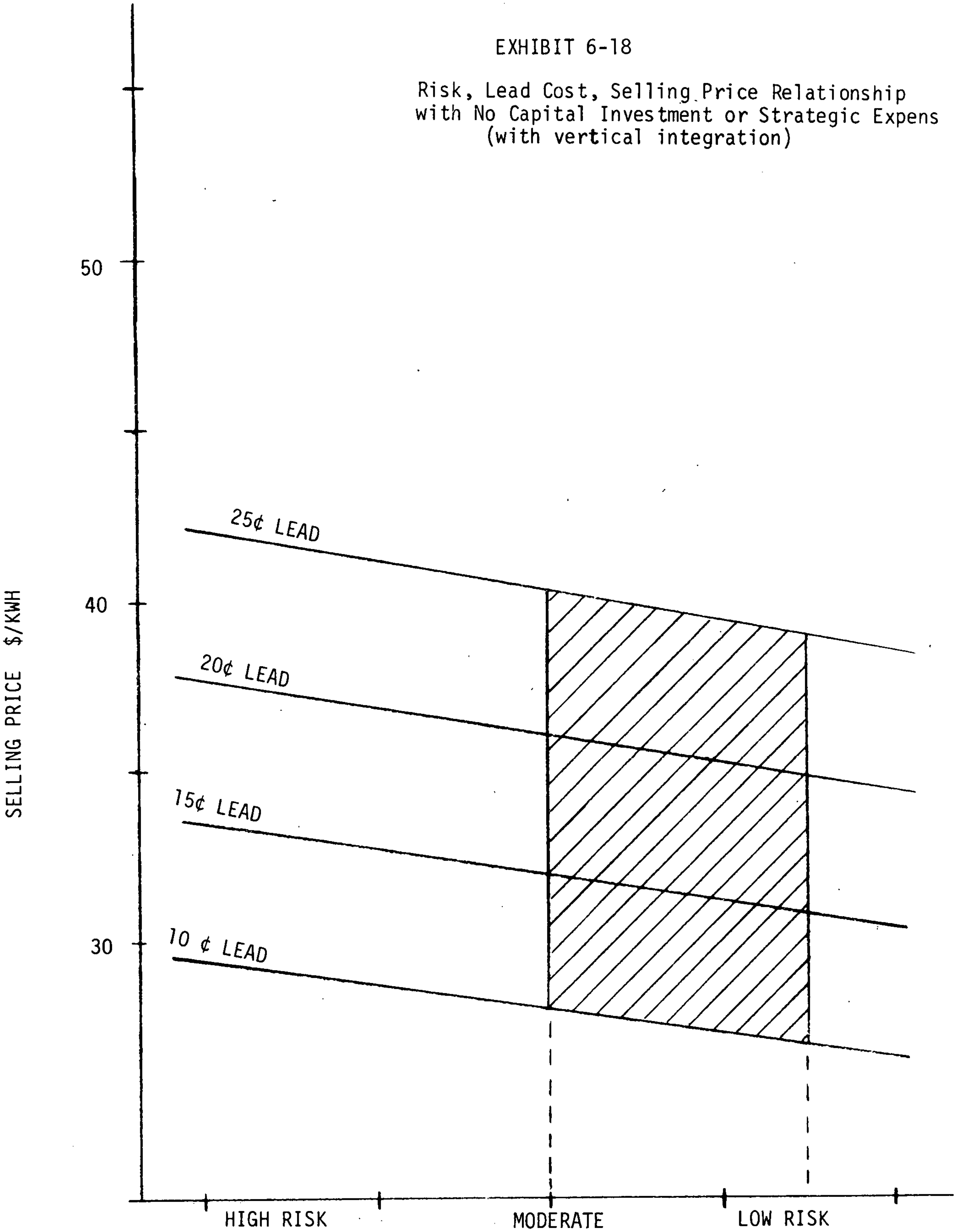


EXHIBIT 6-19

Risk, Lead Cost, Selling Price Relationship with No Capital Investment, No Strategic Expense, and No Investment in Working Capital
(with vertical integration)

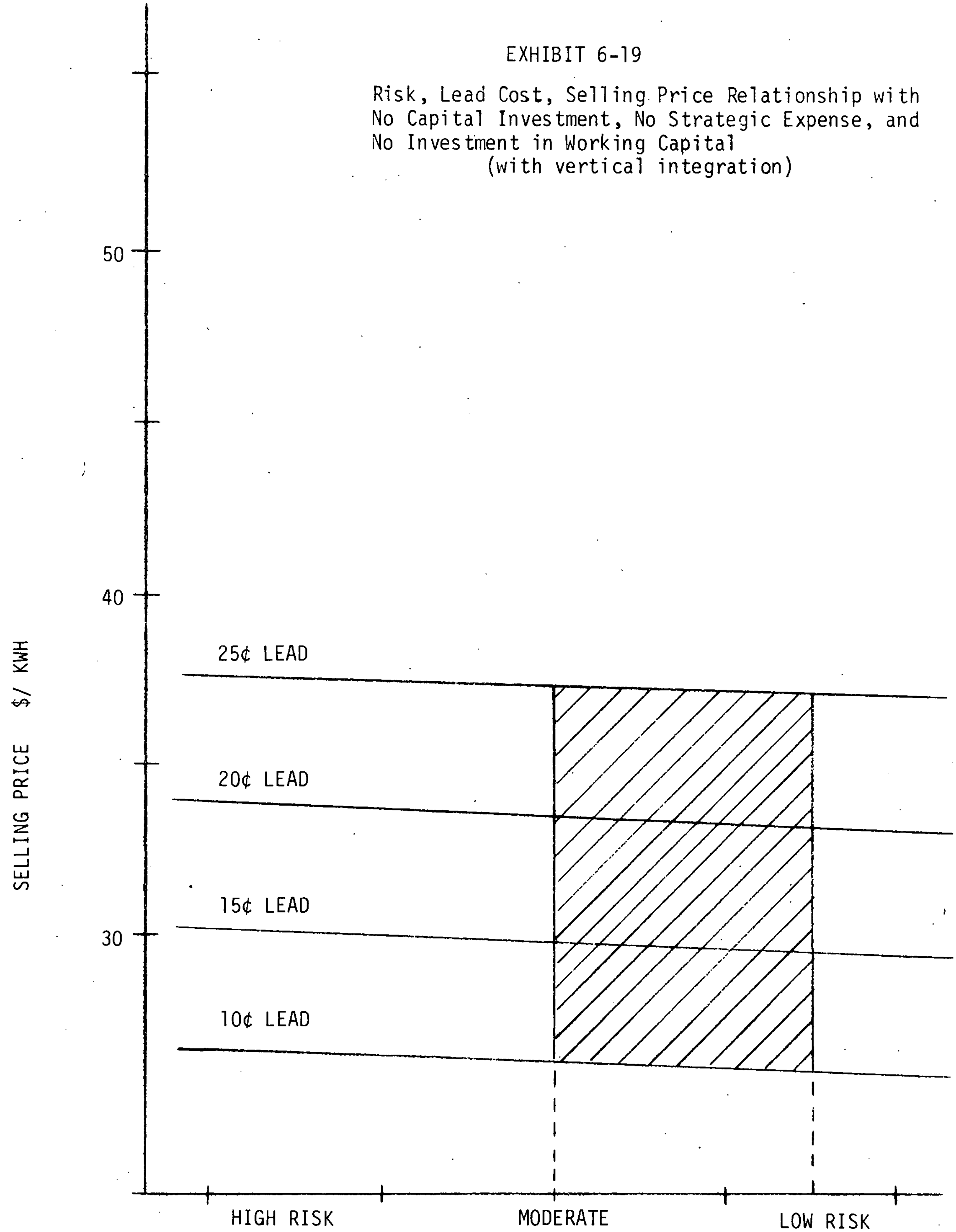
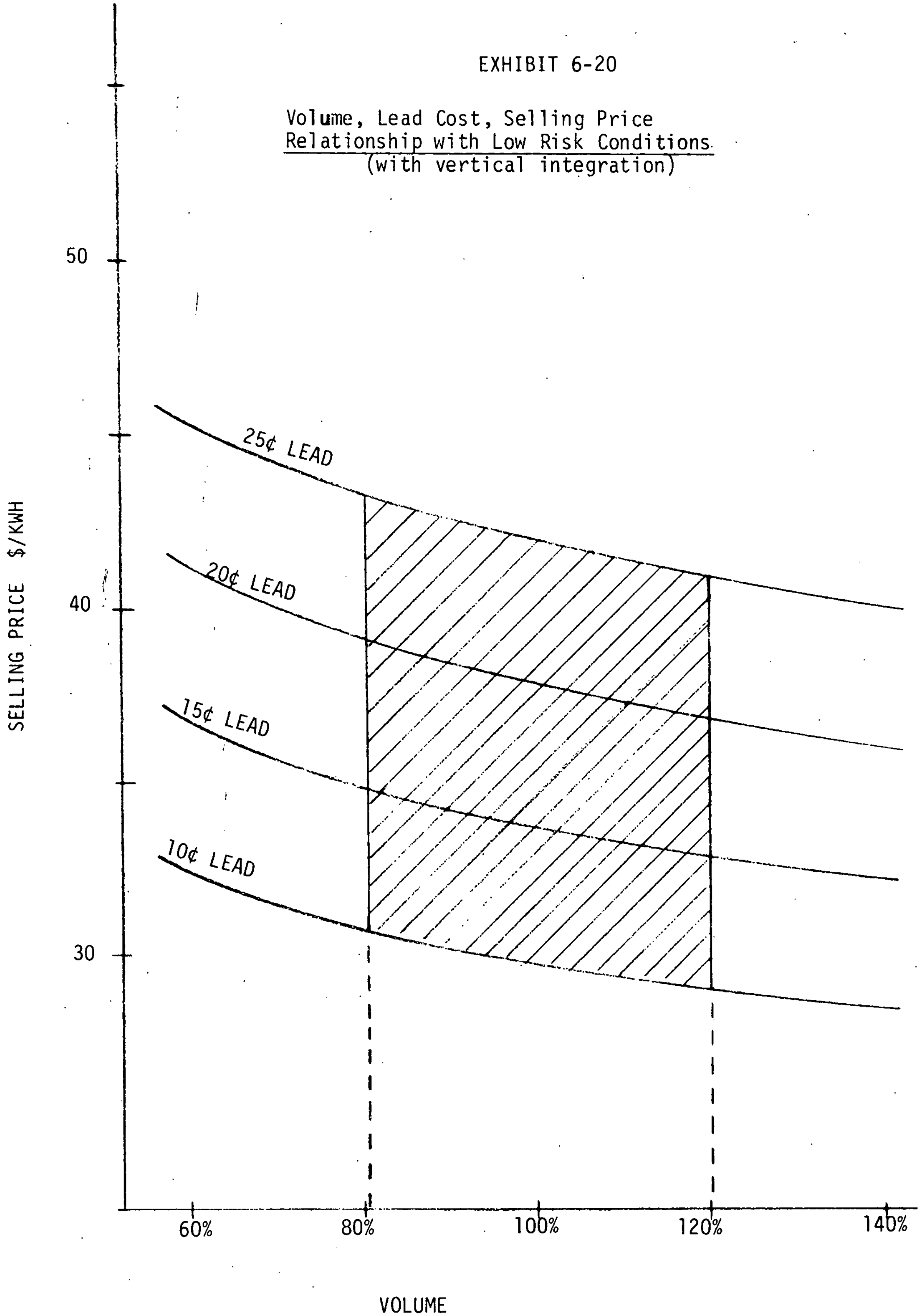


EXHIBIT 6-20

Volume, Lead Cost, Selling Price
Relationship with Low Risk Conditions
(with vertical integration)



6.7 CONCLUSIONS

A detailed study has been made of a postulated 1,000 MWH per year (4-hour rate) lead-acid battery business dedicated to supplying a single design of 40-MWH peaking power batteries to electric utilities. State-of-the-art industrial lead-acid battery technology is assumed but the manufacturing facility and business organization is specifically tailored to the one product. Analysis of the product costs and business expenses associated with such an operation indicates that substantially lower selling prices can be realized compared to normal industrial battery pricing.

Two factors which contribute significantly to the difference are:

1. Greatly reduced business overhead expenses
2. Close integration of lead material supply (and recycling) into the operation

Because the cost of lead represents a large part of the product cost, the second factor is of particular importance.

The results of the study of lead supply indicate that vertical integration by the battery manufacturer into secondary smelting can result in an effective lead cost of 19 cents per pound based on a 25-cent-per-pound primary lead market. If it is assumed that the customer supplies a comparable scrap battery for lead salvage, the effective out-of-pocket cost of lead to the battery fabrication activity becomes 10 cents per pound.

On the basis of an effective lead cost of 19 cents per pound, and applying the potential improvements of vertical integration, the analysis indicates that a direct cost of $29.73/KWH (4-hour rate) could be attained. Further, it seems consistent to project an outlook of firm market demand that would assure an investor of a fully-loaded production facility and little risk in the venture. Thus, at a low business risk, the selling price corresponding to the above direct cost would be $36.90/KWH. (This equates to $29.89/KWH at the 10-hour rate.)

To put these results in perspective with earlier studies, it was determined that under moderate risk conditions, with lead at an effective cost of 25¢/lb, and without any improvement from vertical integration, the selling price would be $48.25/KWH.

The curves in Exhibit 6-21 illustrate the impact of external investment on the selling price for the case representing an effective lead cost of 19¢/lb with vertical integration in the manufacturing plant.

A pro forma operating statement for the projected sales price of $36.90/KWH is shown in Exhibit 6-22. This statement reflects, in summary form, the annual operating statement of the business at a future point in time when steady-state operations are achieved.

Further conclusions can be drawn from an analysis of the curves presented. For example, if working capital requirements were reduced through the use of advance payments on orders, the price would be $35.27/KWH.

As scrap batteries of the same type become available for recycling, the effective cost of lead drops to 10¢/lb and the $36.90/KWH price is reduced to $29.87/KWH, assuming the purchaser trades in an identical battery for salvage.

EXHIBIT 6-21

Relationship of Risk, Selling Price, and Investment

(19¢/lb lead, with vertical integration in manufacturing plant)

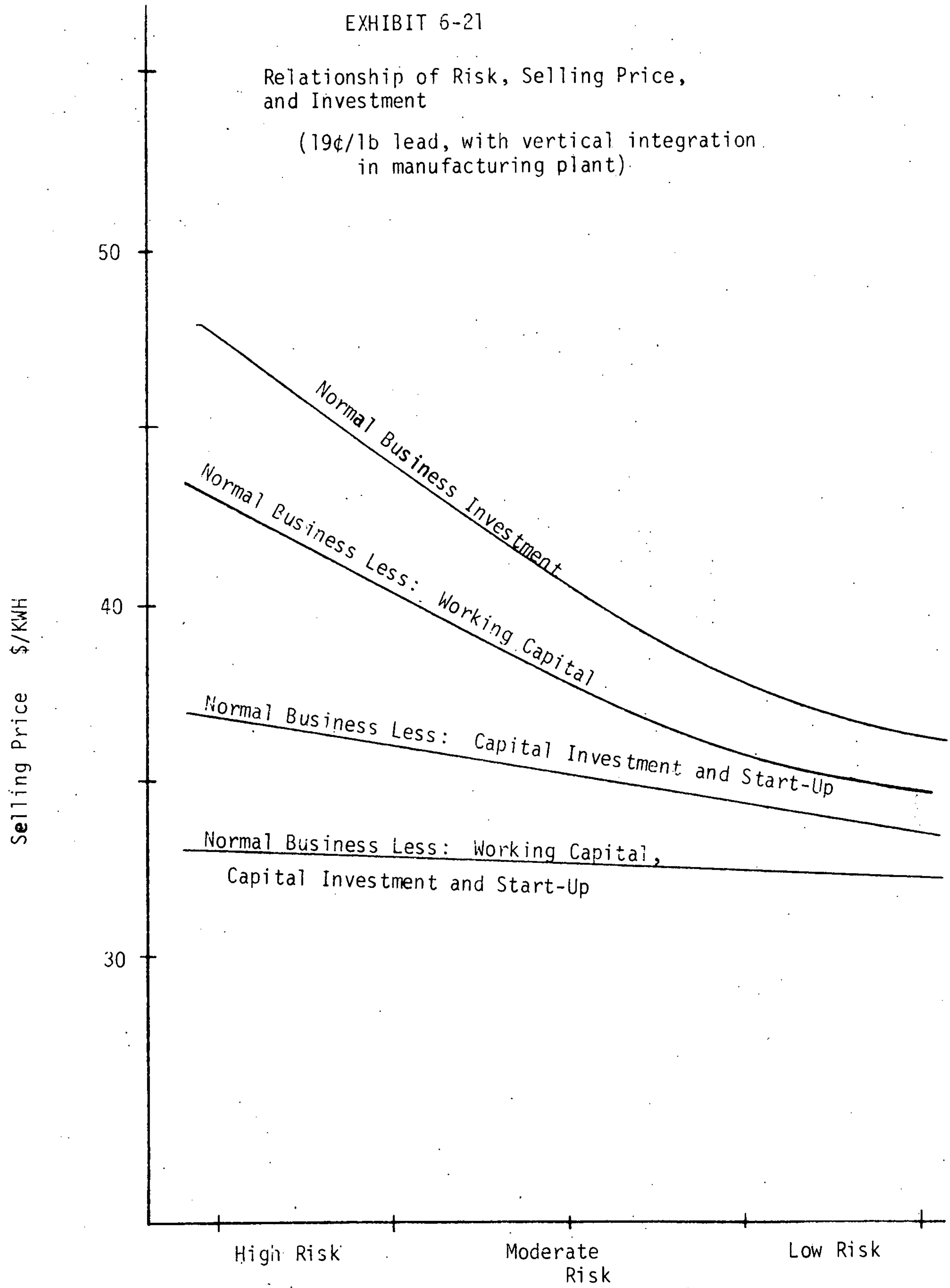


EXHIBIT 6-22

Pro Forma Operating Statement

Sales (25 Batteries)	$36,902
Direct Cost	29,730
Margin Over Direct	7,172
Managed Costs	2,478
Committed Costs	443
Total Cost	$32,651
Income Before Taxes	$ 4,251

7.0 WESTINGHOUSE ADVANCED TECHNOLOGY BATTERY

7.1 DESIGN SPECIFICATION

The advanced technology cell for peaking battery application is based on technology developed by the Westinghouse Research Laboratories. The cell is shown in Exhibit 7-1 and is known as the WE67. Its specifications are listed in Exhibit 7-2. Note that its capacity is 49 KWH, ten times larger than the KW160-45, requiring 816 cells for the peaking battery installation.

Because of its size, these cells will not be combined into modules but will be shipped to the site and installed individually. However, some of the same concepts used for the module of the KW160-45 are applicable. The cell will rest on a base molded of structural polypropylene foam which will serve both as a handling and shipping pallet as well as a platform for electrical isolation purposes at the installation site. Structural end plates molded of the same material are used to maintain restraining pressure on the plates. Attached to the cover are cooling coil, vent plug, automatic watering device, and air pumps for electrolyte mixing.

The cells will be installed so that the end plates are on the aisle providing cell case protection and allowing for restraining pressure adjustment. The cooling coils will be interconnected and ventilation and water addition manifolds added.

The intent of the design is to reduce the amount of lead required and to triple the life by reducing the major life-limiting factor--grid corrosion. Development progress so far indicates that both goals are achievable. Cells produced have the required capacity and are performing as expected on accelerated life tests.

ADVANCED TECHNOLOGY CELL

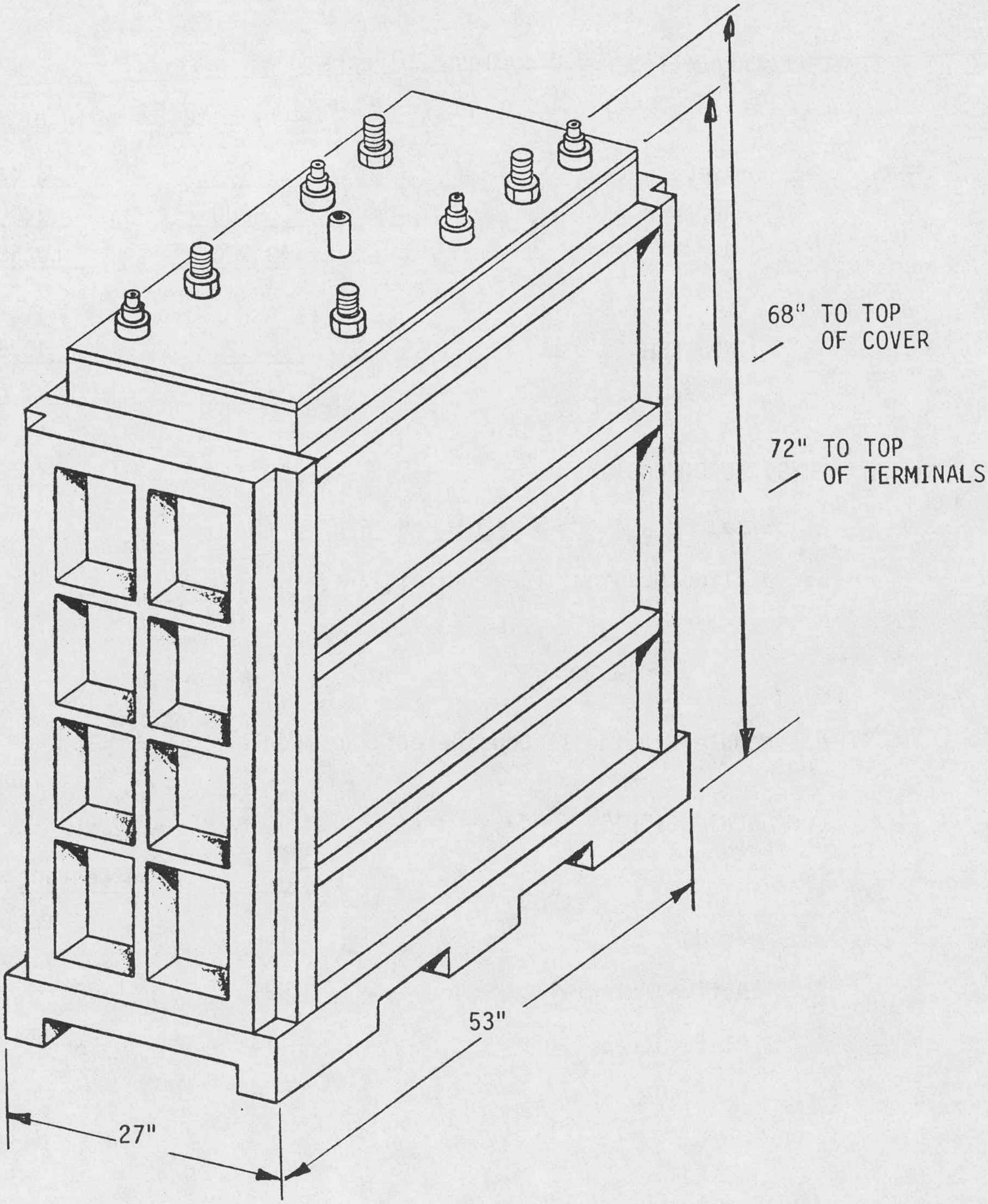


EXHIBIT 7-1

EXHIBIT 7-2

PRODUCT DESIGN SPEC

1. CELL IDENTIFICATION NUMBER WE 67 Design II

2. CELL CAPACITY 5000 cycles, 20 years

	4 hr rate	10 hr rate
Ave. Voltage	1.96	2 oz
AH	25,000	30,000
WH	49,000	60,500
#Pb/KWH	57.2	46.5
WH/#Pb	17.5	21.6

3. PHYSICAL DIMENSIONS

a. Size: L 3.75' W 2.0' H 5.0' ID

b. Outline Drawing (See Exhibit 7-1)

e. Module Drawing If Considered: No module

4. COMPONENT WEIGHTS

	Total	Lead Content
Grids	1164	1142
Active Material	1629	1483
Plate Straps	114	76

EXHIBIT 7-2 (continued)

4. COMPONENT WEIGHTS (contd)

	Total	Lead Content
Posts 4/cell	103	54
Seal Nuts 4/cell	10	10
Separators	195	--
Jar, Cover Vent	150	--
Electrolyte	1350	--
Totals	4715	2765

5. ELECTRICAL PARAMETERS - 4 HR RATE

Capacity	25,000	Ahrs
Average Discharge Voltage	1.96V	
Energy Cap.	49,000	Whrs
Energy Efficiency	78	%
Life - Number of Cycles	5,000	
Cell Voltages		
Start of Discharge (@ 77 °F)	2.02	V
Discharge Cut-Off (@ " °F)	1.9	V
Start of Charge (@ " °F)	2.3	V
Charge Cut-Off (@ " °F)	2.6	V
Equalizing Charge (@ " °F)	2.3	V
Equalizing Charge Initial Current	500	A
Equalizing Charge Final Current	100	A
Maximum Short Circuit Current	25,000	A
Internal Resistance	0.012	mΩ

7.2 COST ESTIMATES

7.2.1 Material Cost

The determination of materials cost for the advanced technology cell uses the same assumptions as those used for the state-of-the-art battery. Exhibit 7-3 presents the lead content per kilowatt-hour, which can be compared to Exhibit 6-5 for the state-of-the-art cell.

EXHIBIT 7-3

Lead Content/KWH (WE-67)

	lbs/KWH (4-hour rate)
Grids	23.3
Active Materials	30.3
Conductors, Posts, & Seal Nuts	4.6
TOTAL	58.2

Exhibit 7-4 is a comprehensive list of the materials cost. Total material costs are $1,384.23 per cell or $28.25 per kilowatt-hour at the four-hour rate. Lead cost is $939.06 per cell or $19.16 per KWH and non-lead costs are $445.17 per cell or $9.09 per KWH. Thus, lead accounts for 68% of the material cost. Exhibit 7-5 is a summary of material costs/KWH.

EXHIBIT 7-4
WE 67
Material Cost Estimate

ASSUMPTIONS

1. At $.25/lb lead
    a. Grid lead costs $.292/lb
    b. Negative oxide costs $.275/lb
    c. Positive oxide costs $.286/lb
2. Plate yield = 97.5% (80% of loss recoverable)

Item	Qty. Per Cell	Cost Per Cell	Cost per KWH (4-hour rate)
Negative & Positive Grids	1194 lbs	$ 420.29	$ 8.57
Negative & Positive Oxide	1671 lbs	470.28	9.59
Straps & Posts	227 lbs	70.99	1.45
Reclaimed Lead	60 lbs	-6.00	-.12
Glass Mats	1068 ft^2	39.52	.81
Pos. Plate Wrap	1000 ft^2	59.39	1.21
Separators	528 ft^2	129.36	2.64
Case	1 pc	36.52	.75
Cover	1 pc	7.20	.15
Base	1 pc	28.20	.58
Side Plates	2 pcs	53.28	1.09
Tensioning Device	6 pcs	30.00	.61
Auxiliaries		30.36	.62
Electrolyte	1350 lbs	14.84	.30
		$1384.23	$28.25

	Per Cell	Per KWH
Lead Costs	$ 939.06	$ 19.16
Non-Lead Costs	445.17	9.09
Total	$1384.23	$ 28.25

EXHIBIT 7-5
Summary of Material Costs

	Cost per KWH (4-hour rate)
Grids	$ 8.50
Oxide	9.54
Posts, Straps	1.45
Separators	4.66
Case & Cover	3.18
Auxiliaries	.62
Electrolyte	.30
TOTAL	$28.25

7.2.2 Machinery and Equipment

Some operations of the advanced technology process require specialized equipment that is not commercially available. The Westinghouse Production Technology Center's advanced equipment design personnel made estimates of concept and cost for these items.

The results of the equipment study are presented in Exhibit 7-6 along with labor, floor space, auxiliaries, and office requirements. Total equipment comes to $2,599.000 including installation, with 90,000 square feet of floor space required.

7.2.3 Labor Cost

Labor costs were based on the state-of-the-art estimates making proper adjustments for the different processes involved. The total number of operating personnel is 109 on a three-shift basis, including four operators to fill in for absenteeism. At an average rate of $5.25 per hour and 260 paid days a year, this amounts to a direct labor cost of $1,200,000 per year. Per unit labor costs are:

$48,000 per battery
$58.16 per cell
$1.20 per KWH

EXHIBIT 7-6

Advanced Technology
Plant, Equipment & Labor Estimates
WE-67 40 Megawatt-Hour Battery
25 Batteries/Year
Three-Shift Operation

Operation	No. of Pieces of Equipment	Estimated Total Cost of Equipment	Oper. Req'd	Floor Space Req'd ft²
Oxide Mixing & Handling	16	$ 196,000	18	9,000
Plate Processing	3	340,000	7	2,300
Small Parts Casting	1	71,000	1	500
Plate Wrapping	3	111,000	9	550
Terminal Welding	1	170,000	9	500
Automatic Stacking	1	140,000	6	2,000
Cast on Posts & Straps	1	250,000	12	1,500
Mold Jar	1	91,000	6	2,000
Assemble Cell in Jar	1	185,000	6	700
Base Cover & Side Plate Molds	3	109,000	-	-
Attach Side Plates & Base to Cell & Place on Conveyor	1	100,000	3	3,000
Continuity Test & Repair	1	75,000	4	2,000
Prepare Cover & Attach to Cell	2	130,000	12	3,500
Shipping & Receiving	Misc	220,000	12	20,000
Mach. Shop & Labs	Misc	195,000	O.H.	1,750
Spare Parts Inventory	Misc	120,000	-	500
Medical Health	Misc	20,000	O.H.	200
Aisle & Laydown Space				26,000
Plant Service	Misc	5,000	O.H.	4,000
Office	Misc	71,000	O.H.	10,000
		$2,599,000	105	90,000
			+ 4 relief	
			109	

7.2.4 Land and Building

The estimates for land and building were based upon those made for the state-of-the-art battery. At approximately $30 per square foot, a building of 90,000 ft.^{2} would cost $2,700,000. A site of 50 acres would cost $250,000, assuming acquisition at $5,000 per acre.

7.2.5 Direct Cost Summary

A summary of the direct costs, dollars per KWH, is shown in the table in Exhibit 7-7 and graphically in Exhibit 7-7A. The graph illustrates the large proportion of cost attributable to lead materials and the resultant effects in direct cost of changes in lead cost. A complete discussion of the overhead items is included in Section 7.4 of this report.

EXHIBIT 7-7
Cost Summary
(25¢ lead)

		\$/KWH (4-hour rate)
Material		\$ 28.25
Labor		1.20
Direct Overhead	.94	
Other Direct Costs:		
Transportation	1.40	
Warranty	.35	
Installation Labor	.22	2.91
Total Direct Cost		\$32.36

7.3 VERTICAL INTEGRATION (Excluding Smelting)

As with the state-of-the-art battery, possibilities for cost improvement through vertical integration were studied to determine their potential effect on the cost.

If the plant produced its own oxides, a reduction of $1.21 per KWH in the DPC could be realized. The cell jars are planned to be manufactured in-house. The base, cover, and side plates could be manufactured in-house with a maximum savings of about $.75 per KWH.

Further improvements to the manufacturing processes unique to the Westinghouse advanced technology battery are projected to save $.98/KWH, bringing the total savings to $2.94/KWH. Thus, the direct cost could potentially be reduced from $32.36/KWH to $29.42/KWH by vertical integration within the battery manufacturing plant.

7.4 OVERHEAD EXPENSES

The overhead expenses for the advanced technology battery are listed in Exhibits 7-8 through 7-11. Essentially the same types of expenses were estimated as for the state-of-the-art battery, with consideration given to differences in plant size, numbers of people, and the type of equipment and manufacturing processes involved.

EXHIBIT 7-7A

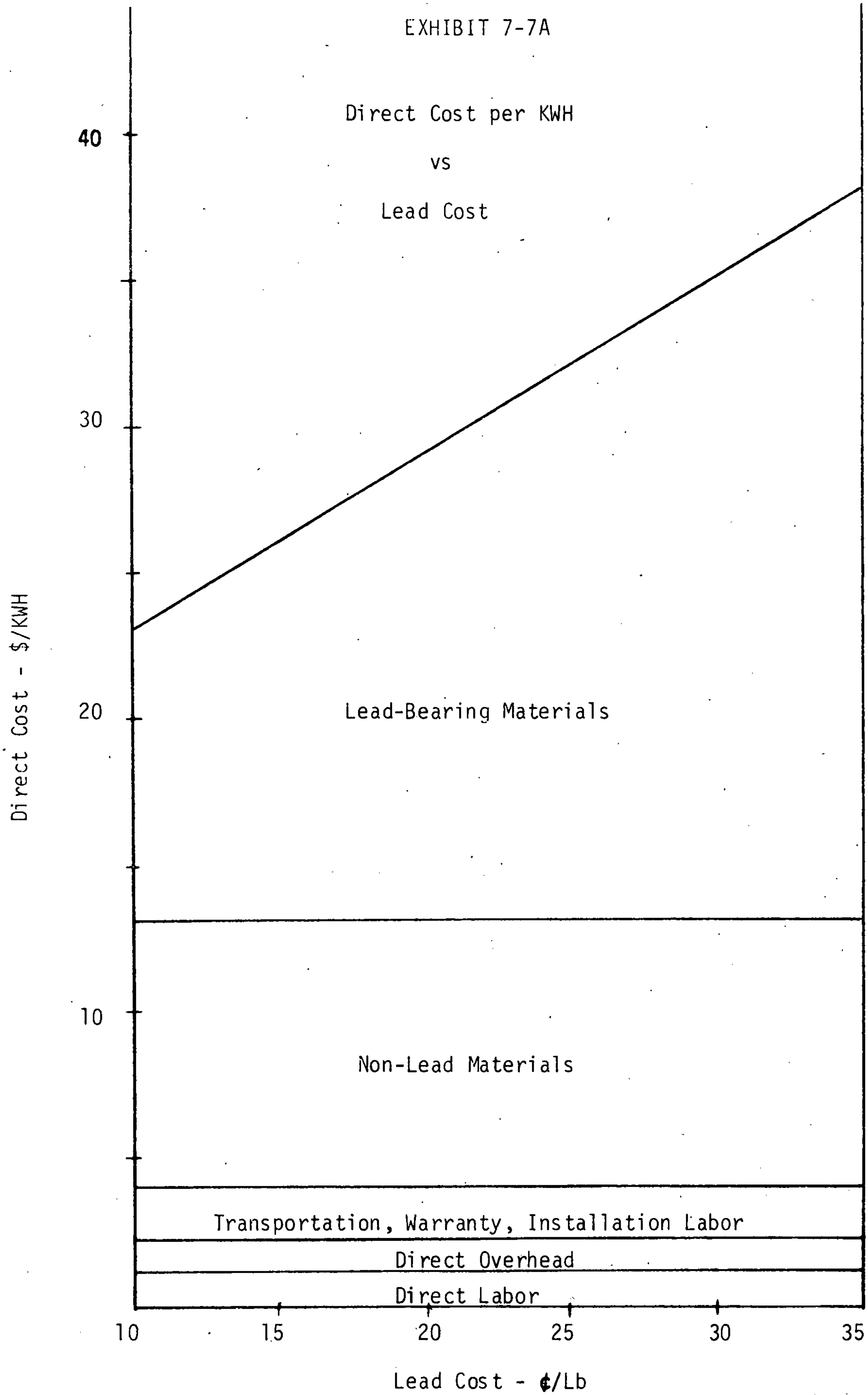

Direct Cost per KWH
vs
Lead Cost
40
30
20
10
Direct Cost - $/KWH
Lead-Bearing Materials
Non-Lead Materials
Transportation, Warranty, Installation Labor
Direct Overhead
Direct Labor
10
15
20
25
30
35
Lead Cost - ¢/Lb

EXHIBIT 7-8

A&G FUNCTIONS

	Salary Rate	Quantity	Total Cost
Plant Manager	45K	1	$ 45K
Secretary	12K	1	12K
Controller	30K	1	30K
Payroll Clerk	10K	1	10K
A/P, A/R & Gen'l Acctg. Clerks	10K	2	20K
Cost Accountant	12K	1	12K
Materials Mgr.	25K	1	25K
Buyers	15K	1	15K
Purchasing Clerk	10K	1	10K
Personnel Relations Mgr.	30K	1	30K
Benefits Clerk	10K	1	10K
Medical	15K	1	15K
Total A&G Salaries		13	$234K
Benefits			47K
Computer Costs			50K
Telephone Costs			10K
Travel Costs			10K
Supplies, Copies & Misc.			24K
Total A&G Mgd. Cost			$375K

EXHIBIT 7-9

Engineering and Service Functions

	Salary Rate	Quantity	Total Cost
Engrg. & Service Mgr.	30K	1	$ 30K
Customer Service Engr.	18K	2	36K
Drafters	13K	1	13K
Installation Engineers	18K	2	36K
Order Correspondent	15K	1	15K
Secretary	8K	1	8K
Total E&S Salaries		8	$138K
Benefits			27K
Telephone Costs			15K
Travel Costs			55K
Supplies Copies & Misc.			25K
Total E&S Mgd. Costs			$260K

EXHIBIT 7-10

Manufacturing Functions

	Salary Rate	Quantity	Total Cost
Mfg. Mgr.	35K	1	$ 35K
Scheduler & Planners	12K	2	24K
Secretary	10K	1	10K
First Line Supv.	17K	6	102K
Receiving Clerks	10K	2	20K
Mfg. Services Mgr.	25K	1	25K
Factory Engineers	18K	2	36K
Plant & Tool Maint.	15K	12	180K
Janitors	8K	2	16K
QA Mgr.	25K	1	25K
Qual. Engrs.	18K	1	18K
Inspectors	12K	3	36K
Lab Technicians	15K	2	30K
Waste Treatment Operator	8K	1	8K
Total Mfg. Overhead Salaries		37	$565K
Benefits			113K
Telephone Costs			5K
Travel Costs			10K
Total plant fuel costs			50K
Medical Supplies & Exams			25K
Water & Sewage costs			80K
Waste treatment supplies			40K
Office Supplies etc.			20K
Total Mfg. Managed Overhead			$908K
Misc. Shop Supplies Excl. Waste Treatment			50K
Electric Power Costs			250K
Unapplied Materials			200K
Employe benefits on direct hourly personnel			238K
Maintenance Materials			200K
Total Direct Overhead	($.94 /KWH, Exhibit 7-7)		$ 938K

EXHIBIT 7-11

Other Costs

Transportation Costs - Truck	($1.40/KWH)	$1400K*
Product Warranty Costs	($.35/KWH)	350K*
Selling Costs		700K
Insurance and Taxes		150K
Total Other Costs		$2600K

*These items included with direct cost; see Exhibit 7-7.

7.5 ECONOMIC ANALYSIS

7.5.1 General

The advanced technology battery was given the same type of economic analysis as the state-of-the-art battery. The same considerations were given to investment, time, cash return, and risk. The discounted cash flow method of analysis was used, employing computer techniques, to evaluate the various investment factors.

In this case, it was assumed that prior development would have been externally funded and the technology advanced to the same level as the state-of-the-art. This approach permits analysis and comparison of both batteries on the same basis.

7.5.2 Cost Estimates

The cost estimates summarized in Exhibit 7-12 are the result of the in-depth analysis that was done. Note that no provision was made for any additional development expense, which would, in fact, be required to bring the battery to the technical state-of-the-art that was assumed.

7.5.3 Analysis

The approach taken for the analysis was to evaluate a range of conditions to determine the approximate selling prices that would yield a satisfactory return to the investor under the various conditions. As with the state-of-the-art battery, a number of alternatives were analyzed to show the sensitivity of the selling price to risk, lead cost, investment, and volume. These results are illustrated in the curves in Exhibits 7-13 through 7-17.

EXHIBIT 7-12

Summary of Cost Data
(Lead @ 25¢/lb)

Land (50 acres) (Section 7.2.4)	$ 250K
Building (90,000 sq. ft.) (Section 7.2.4)	2,700
Machinery & Equipment (Exhibit 7-6; $2599K Less $559K Tooling)	2,040
Total Capital Investment	$ 4,990K
Factory Tooling	559K
Initial Stock of Factory Supplies & Expense Items for Start-up	46
Manufacturing Planning (135 man-months)	270
Training & Start-up Costs	1,855
Total Strategic Expense	$ 2,730K
Accounts Receivable (45 days)	$ 4,410K
Inventories	4,010
Less: Accounts Payable & Warranty Reserve	-2,710
Total Working Capital	$ 5,710K
Direct Labor (Exhibit 7-7 $1.20/KWH)	$ 1,200K/year
Direct Material (Exhibit 7-7 $28.25/KWH)	28,250
Transportation (Exhibit 7-11)	1,400
Direct Overhead (Exhibits 7-10 and 7-7)	938
Warranty (Exhibit 7-11)	350
Installation Labor (Exhibit 7-7 $.22/KWH)	225
Subtotal Direct Cost	$32,363K/year
Less: Potential Improvement from Vertical Integration (Section 7.3 $2.94/KWH)	2,940
Total Direct Cost	$29,423K/year
Administrative & General (Exhibit 7-8)	$375K
Engineering & Service (Exhibit 7-9)	260
Manufacturing Operations (Exhibit 7-10)	908
Marketing (Exhibit 7-11)	700
Insurance & Taxes (Exhibit 7-11)	150
Total Indirect Overhead	$ 2,393K/year

EXHIBIT 7-13

Risk, Lead Cost, Selling Price Relationship
(with vertical integration)

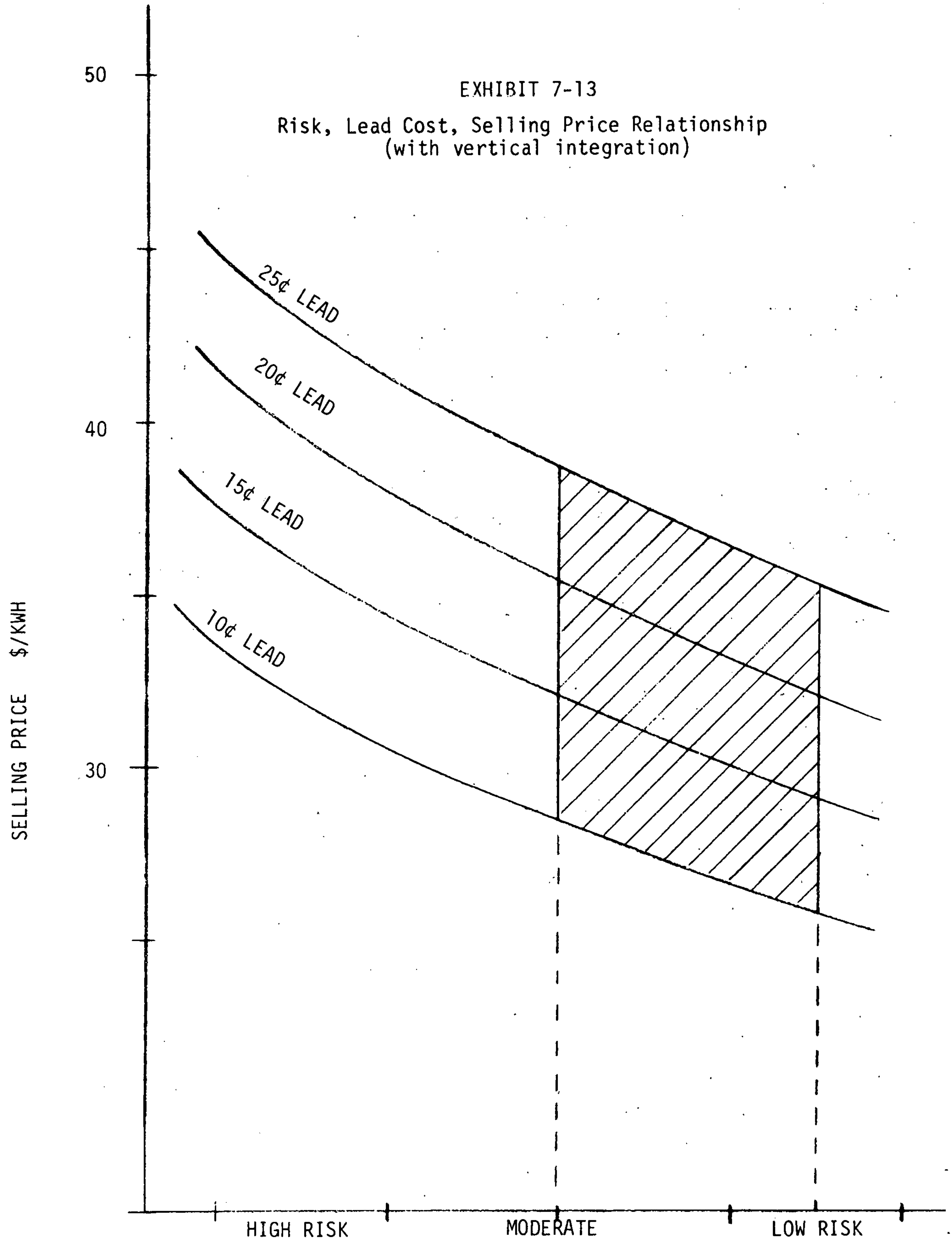


EXHIBIT 7-14

Risk, Lead Cost, Selling Price Relationship with No Investment in Working Capital

(with vertical integration)

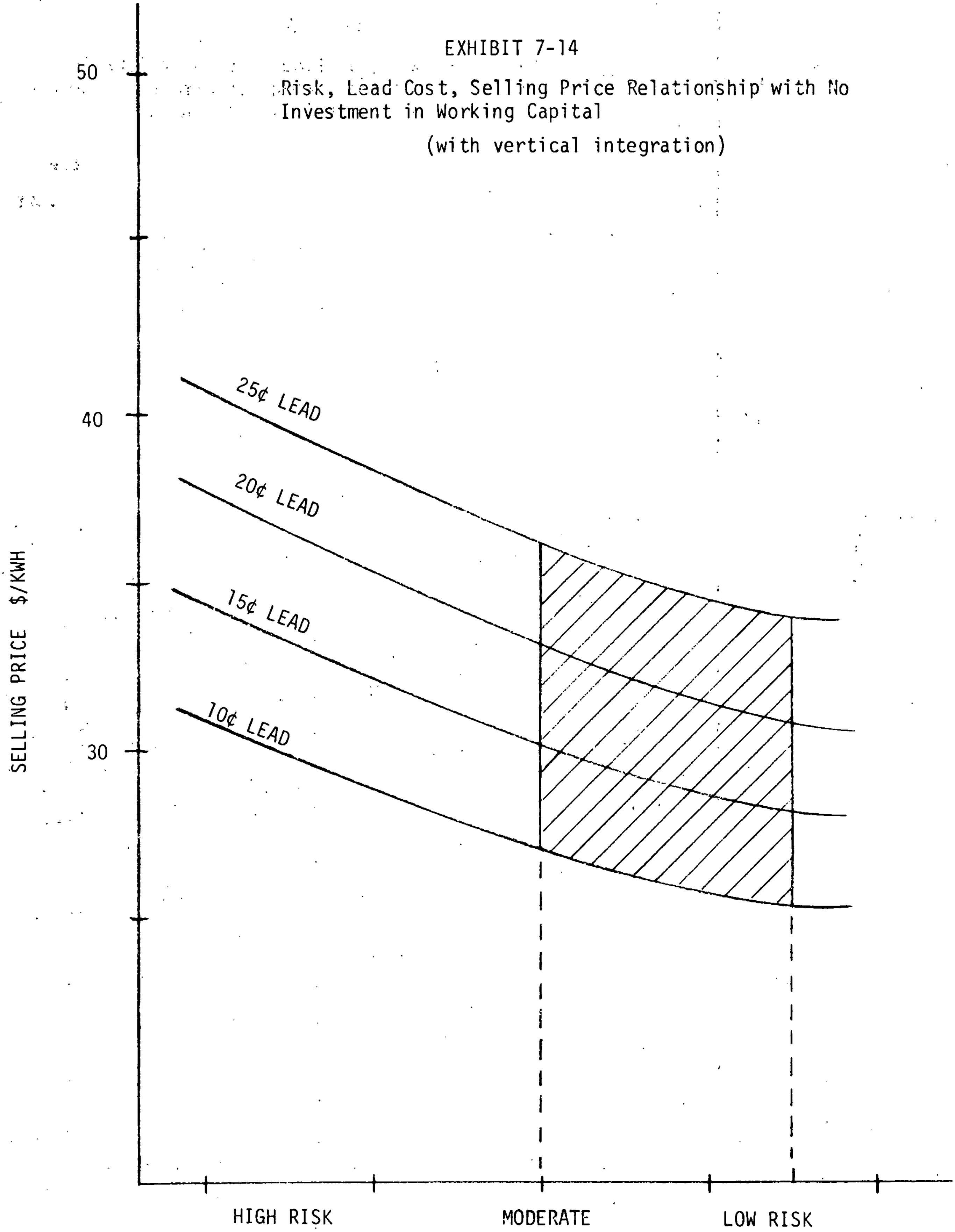


EXHIBIT 7-15

Risk, Lead Cost, Selling Price Relationship
with No Capital Investment or Strategic Expense
(with vertical integration)

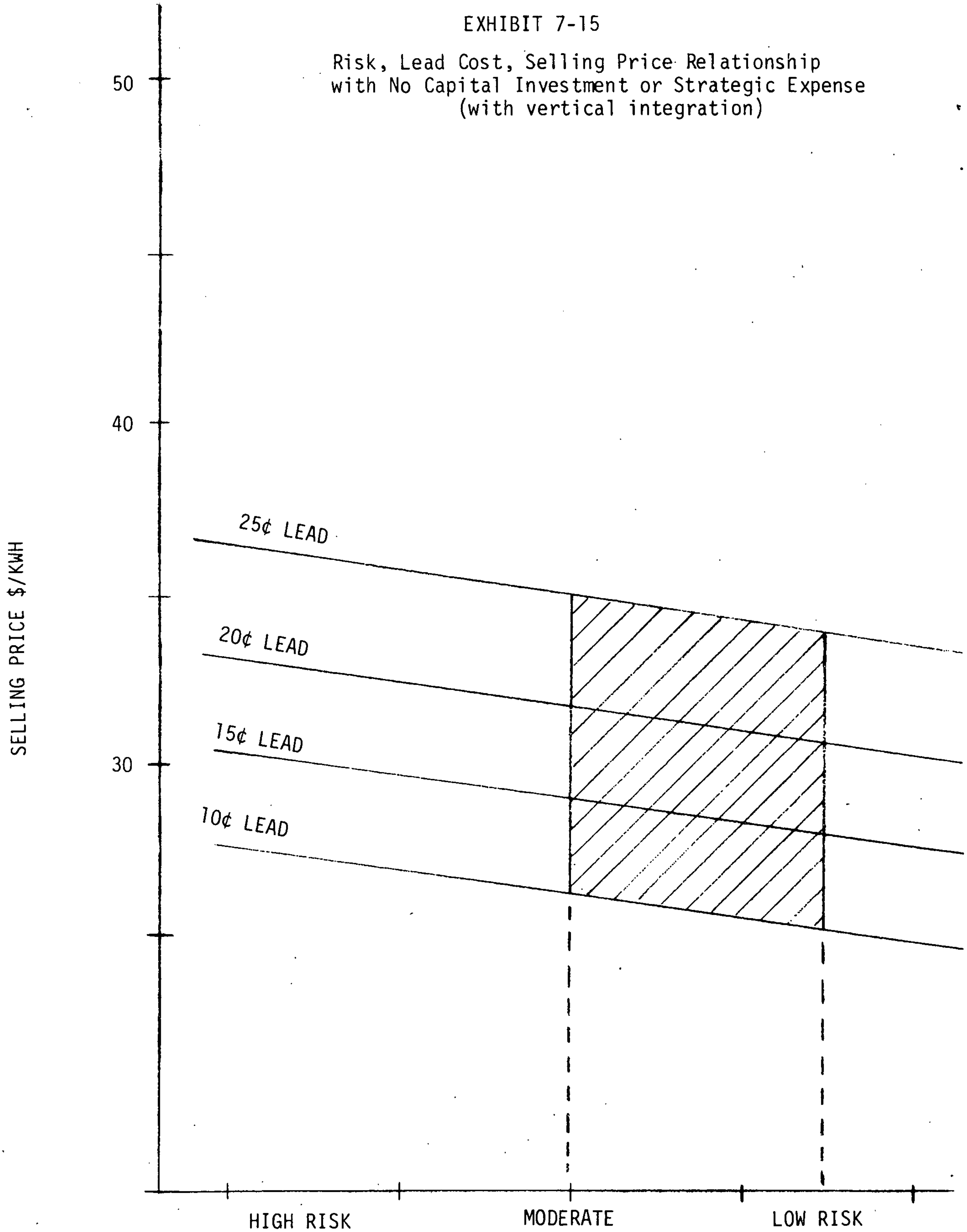


EXHIBIT 7-16

Risk, Lead Cost, Selling Price Relationship with No Capital Investment, No Strategic Expense, and No Investment in Working Capital
(with vertical integration)

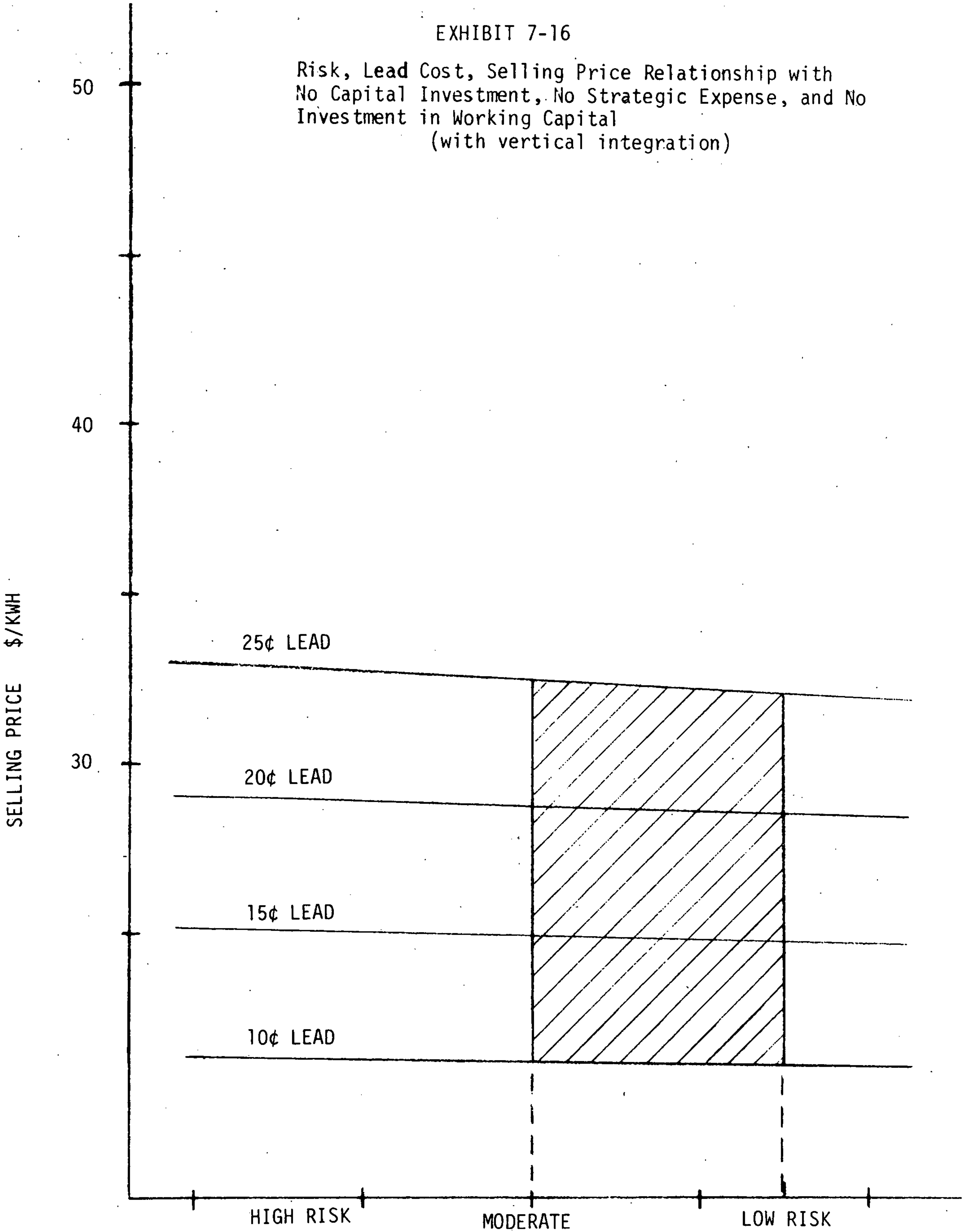
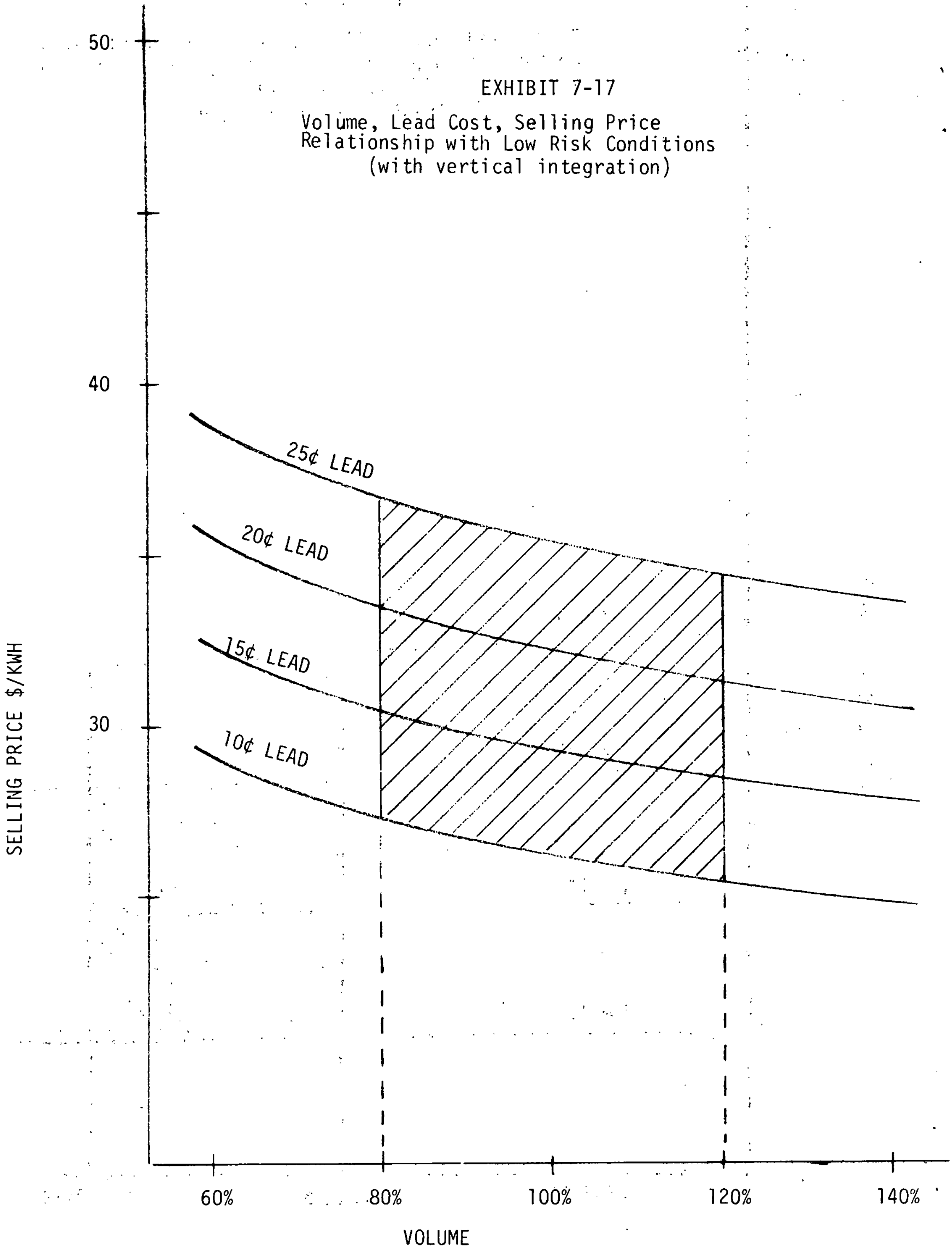


EXHIBIT 7-17

Volume, Lead Cost, Selling Price Relationship with Low Risk Conditions (with vertical integration)



7.6 CONCLUSIONS

This portion of the study was carried out incorporating the advanced lead-acid battery technology under development at the Westinghouse Research Laboratories. This technology holds promise of reduced lead material requirements coupled with a 20-year service life.

Assumptions as to the manufacturing facility and business organization were similar to the state-of-the-art business situation. In order to permit comparison of both batteries on the same basis, it was further assumed that sufficient development would have been previously done to advance the technology to the same level as the state-of-the-art.

On the basis of lead cost at 19 cents per pound, and including the potential improvements from vertical integration, the analysis indicates that a direct cost of $25.44/KWH (4-hour rate) could be achieved. Assuming a low business risk, which is consistent with assurances of a steady market demand and a fully-loaded production facility, the corresponding selling price would be $31.62/KWH.

The curves in Exhibit 7-18 illustrate the impact of external investment on the selling price for the case representing an effective lead cost of 19¢/lb with vertical integration in the manufacturing plant.

A pro forma operating statement for this situation is schown in Exhibit 7-18 reflecting the annual operations of a steady-state business at a point in the future.

By eliminating working capital requirements through advance payments, the price would be $30.22/KWH.

With customer-provided scrap lead, the effective cost of lead would be 10¢/lb and the price would become $25.85/KWH. This scrap lead might be from state-of-the-art batteries that are traded in for replacement by advanced technology batteries.

EXHIBIT 7-18

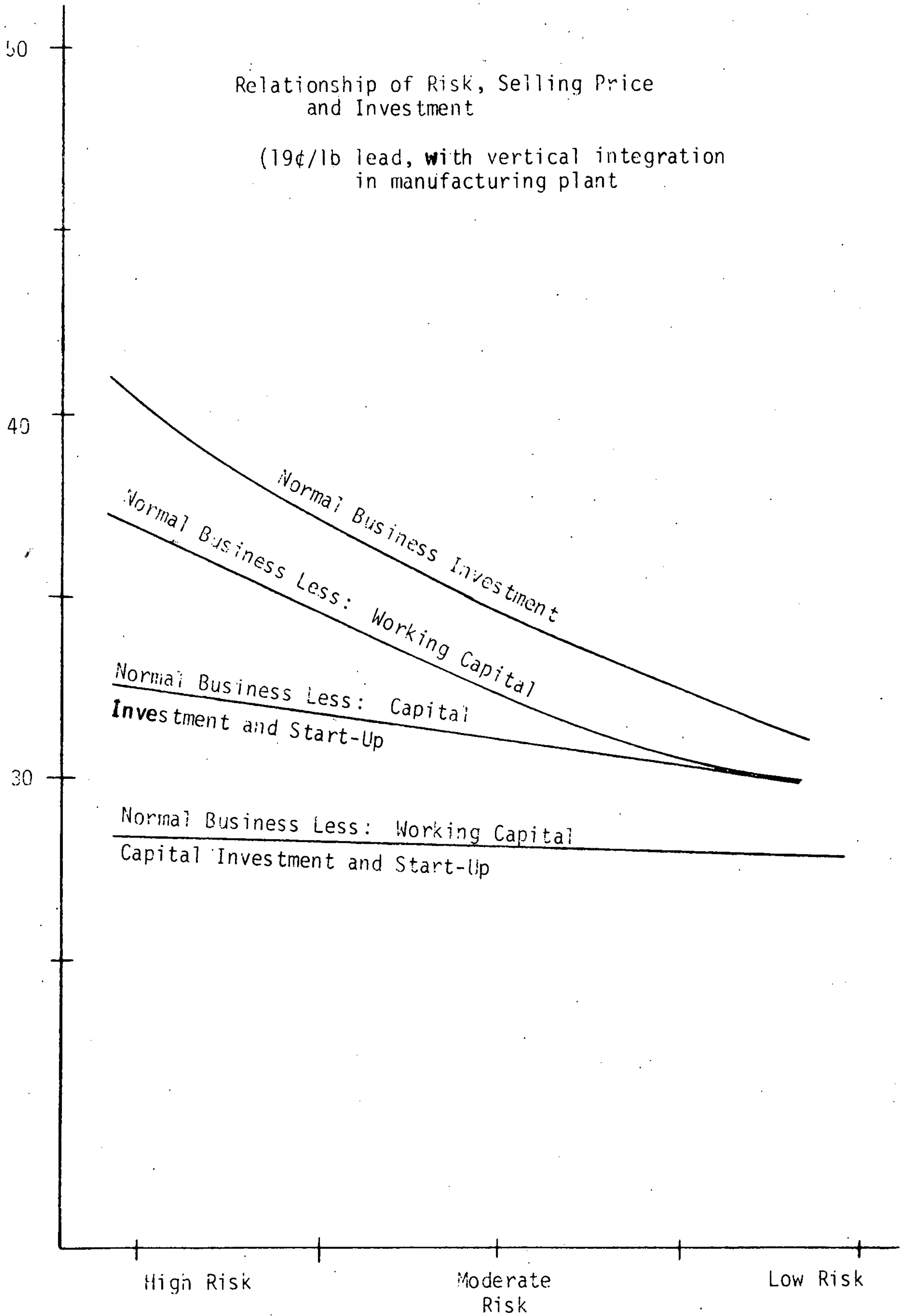

50
40
30
Relationship of Risk, Selling Price
and Investment
(19¢/lb lead, with vertical integration
in manufacturing plant
Normal Business Investment
Normal Business Less: Working Capital
Normal Business Less: Capital
Investment and Start-Up
Normal Business Less: Working Capital
Capital Investment and Start-Up
High Risk
Moderate
Risk
Low Risk

EXHIBIT 7-19

Pro Forma Income Statement

Sales (25 Batteries)	$31,615
Direct Cost	25,435
Margin Over Direct	6,180
Managed Costs	2,243
Committed Costs	380
Total Cost	$28,058
Income Before Taxes	$ 3,557

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