Super Batteries

Final Presentation

Presentation Outline

- Project Goal
- The basics of batteries
- How a battery works
- Why use super batteries
- Market Analysis
- Battery synthesis
- Plant Location
- Transportation
- Environmental Impact
- Life Cycle Analysis
- Economic Analysis
- Conclusions

Project Goal

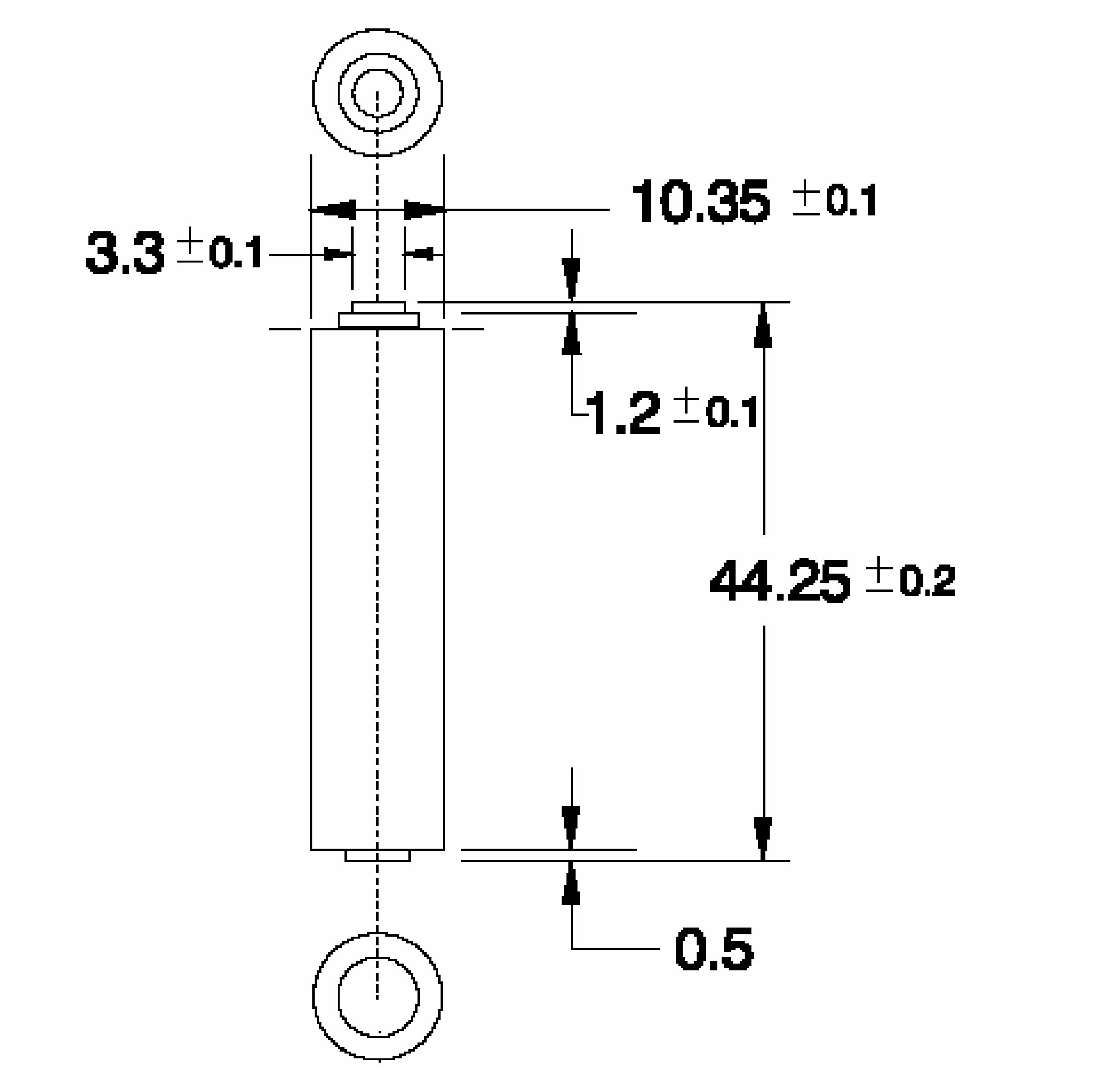
- Design a plant to make ingredients for super iron batteries

The Basics of Batteries

Definition:

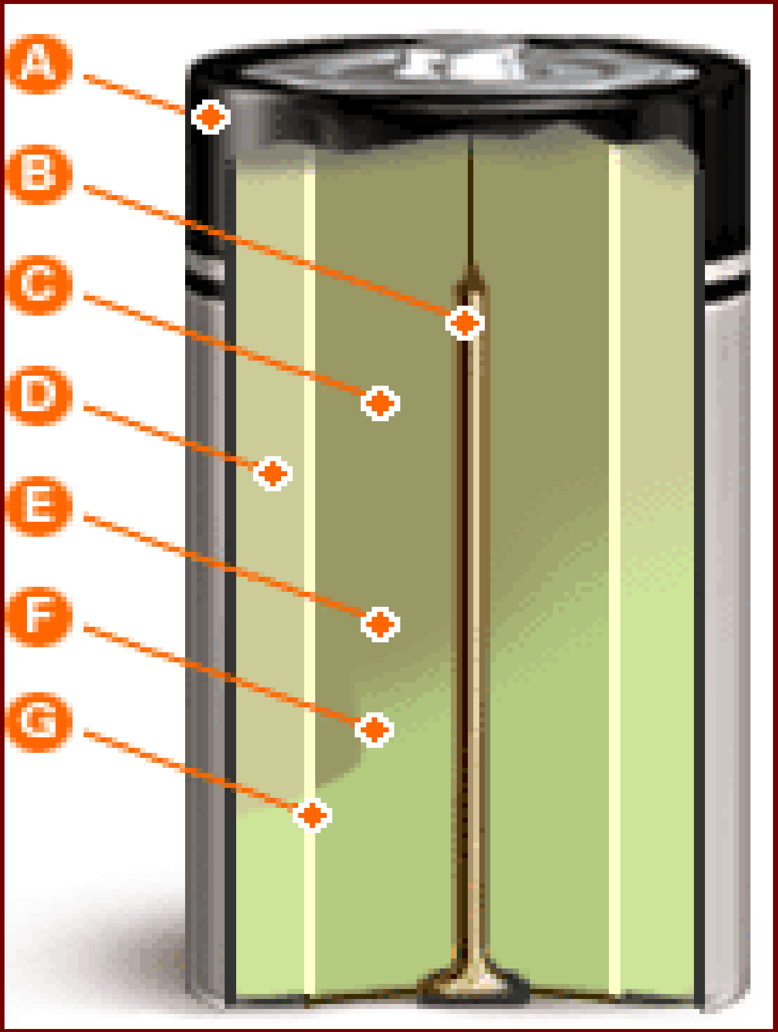
Batteries are devices that translate chemical energy into electrical energy

Standard AAA Dimensions



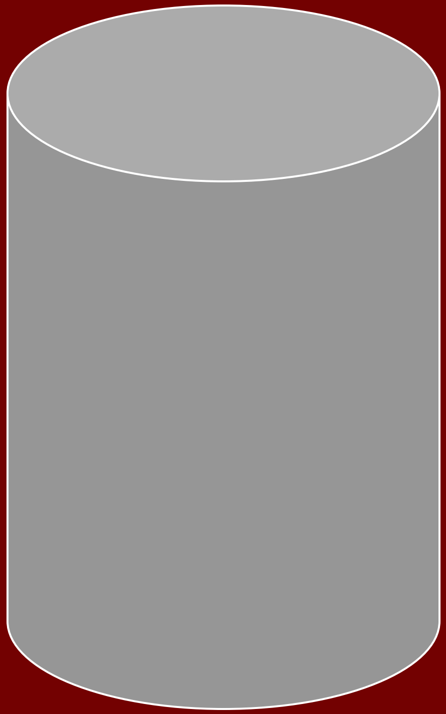
Battery Basics

- **<u>The 7 basic parts</u>**
  - A) Container
  - B) Collector
  - C) Electrodes
  - D) Cathode
  - E) Anode
  - F) Electrolyte
  - G) Separator



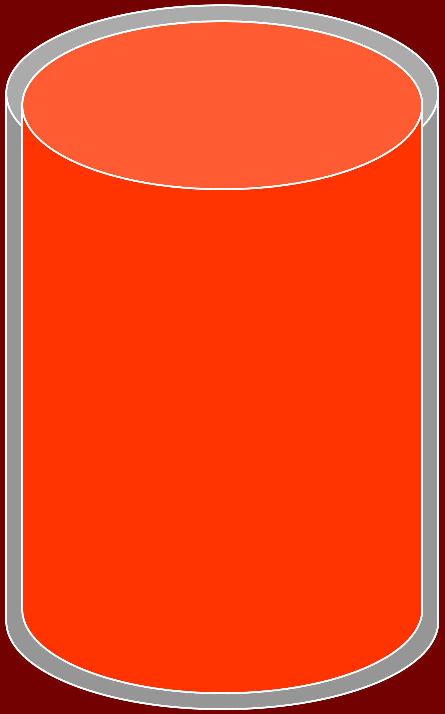
Constructing the Battery

- Start with an empty steel can – the battery container.



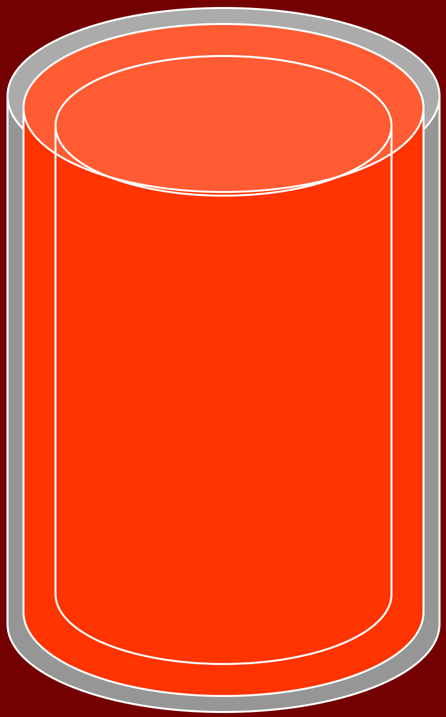
Constructing the Battery

- A cathode mix of Super-Iron carrying a naturally occurring positive electrical charge is molded to the inside wall of the empty container.



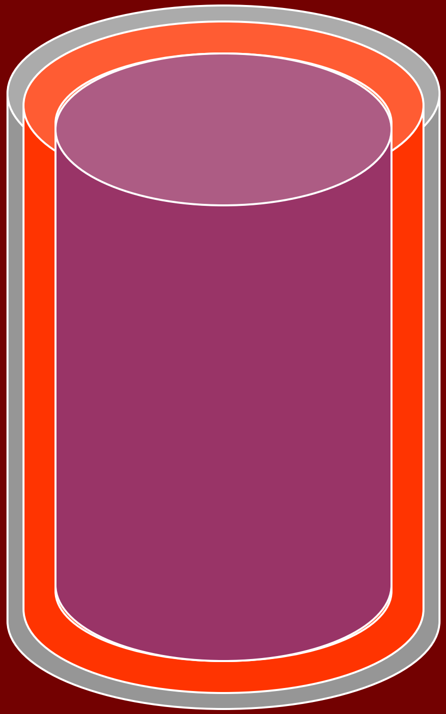
Constructing the Battery

- A separator paper is inserted to keep the cathode from touching the anode.



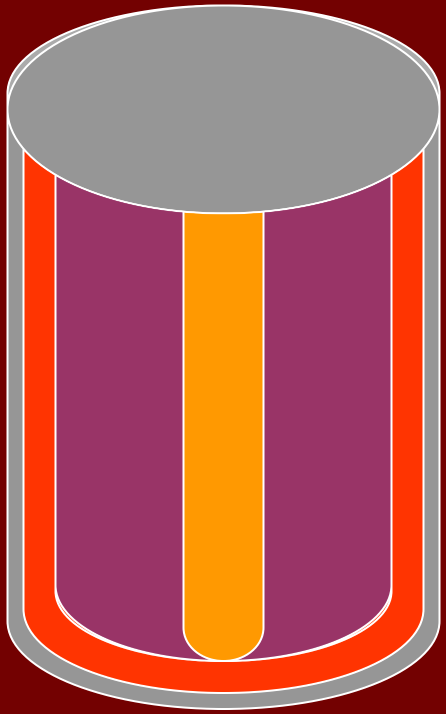
Constructing the Battery

- The anode, which carries a negative electrical charge, and potassium hydroxide electrolyte are then pumped into each container.

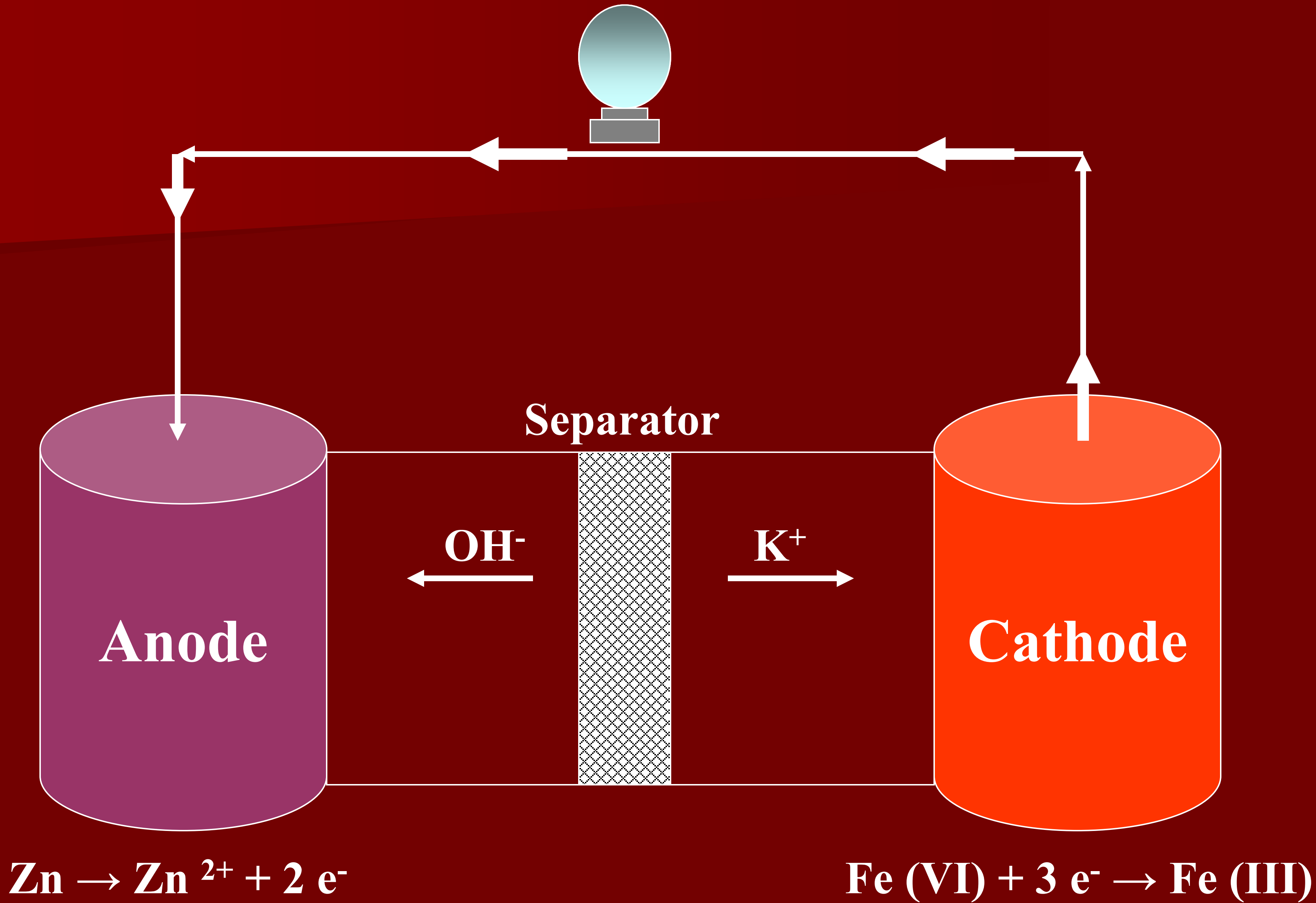


Constructing the Battery

- The brass pin, which forms the negative current collector, is inserted into the battery, which is then sealed and capped.



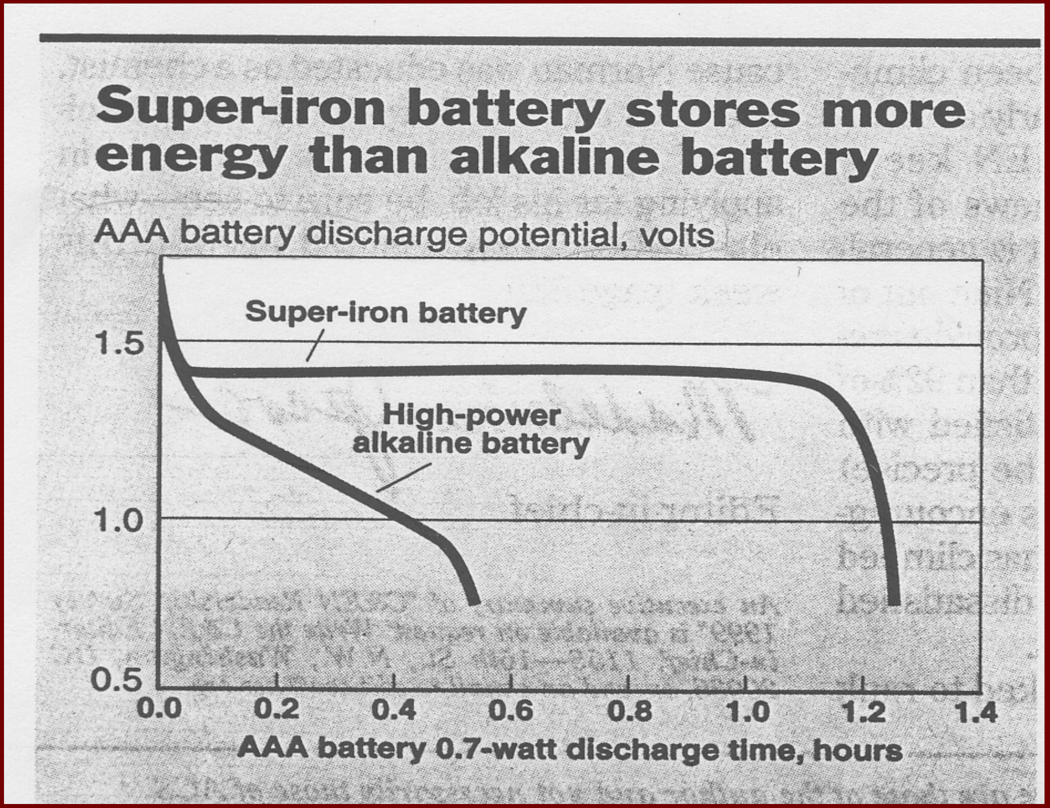
How a battery works


Separator
OH-
K+
Anode
Cathode
Zn → Zn 2+ + 2 e-
Fe (VI) + 3 e- → Fe (III)

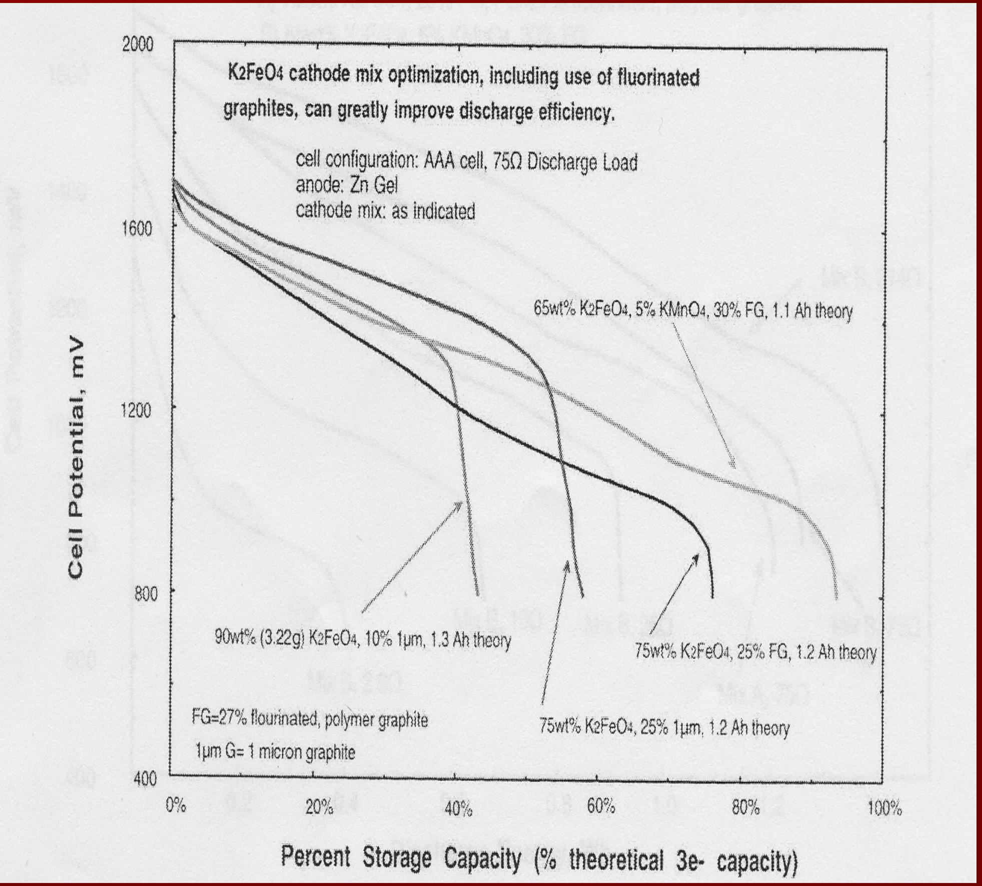
Advantages of Iron (VI)

Advantages: Energy Storage

- Including a iron (VI) cathode in a standard battery increases the energy storage capacity by 50%.



Our Choice of Cathode



- Our choice of cathode material is based on cost and performance.
- 65 wt % Na_2FeO_4
- 5 wt % $KMnO_4$
- 30 wt % CF_x

Advantages: Environmental

- Standard Alkaline Battery :

$$2MnO_2 + Zn \rightarrow ZnO + Mn_2O_3$$

$$2Mn^- + 2e^- \rightarrow 2Mn^{2-}$$

$$Zn \rightarrow Zn^{2+} + 2e^-$$

- Super Battery Discharge Reaction:

$$Na_2Fe(VI)O_4 + Zn \rightarrow Fe(III)_2O_3 + ZnO + Na_2ZnO_2$$

$$Fe(VI)^{6+} + 3e^- \rightarrow Fe(III)^{3+}$$

$$Zn \rightarrow Zn^{2+} + 2e^-$$

Market analysis

Market Analysis

The most important objective of a company:

To make profit

The most important person in a company:

The consumer

A strategic plan defines a company's overall mission and objectives. The goal is to build strong and profitable connections with consumers.

Points of Sale

- Provides enough power to last 50% longer than traditional AAA batteries and 200% longer in high drain applications (Licht)
- Contains fewer toxic metals than traditional batteries and its super iron cathode degenerates into environmentally friendly rust
- Will sell for a competitive price to the AAA batteries already on the market

Competitors?

SuperBattery's total capital investment: $472,000

Energizer's total capital investment: $3 billion

Conclusion:

SuperBattery's market is 0.01% the size of Energizer's market

Market Analysis

Segmentation of Market

The process of niching offers smaller companies the opportunity to compete by focusing their limited resources on serving niches overlooked by larger competitors.

Market Analysis

- Consumers are grouped and served in various ways based on the following factors:
  - Geographic
  - Demographic
  - Psychographic
  - Behavioral
  - Social-Cultural
    - Special Interest Groups

Market Analysis

- Geographic Segmentation

A profitable company must pay attention to geographical differences in needs and wants.

- Demographic Segmentation

Demographic segmentation divides the markets into groups based on variables such as age, gender, family size, family life cycle, income, occupation, education, religion, race, and nationality

Segmentation Variables

Geographic

- World region or country: US
- Country region: Pacific, East South Central, East North Central, New England, Middle Atlantic
- City or Metro size: 500,000-1,000,000; 1,000,000-4,000,000; 4,000,000 or over
- Density: Urban
- Climate: Northern, Southern

Segmentation Variables

Demographic

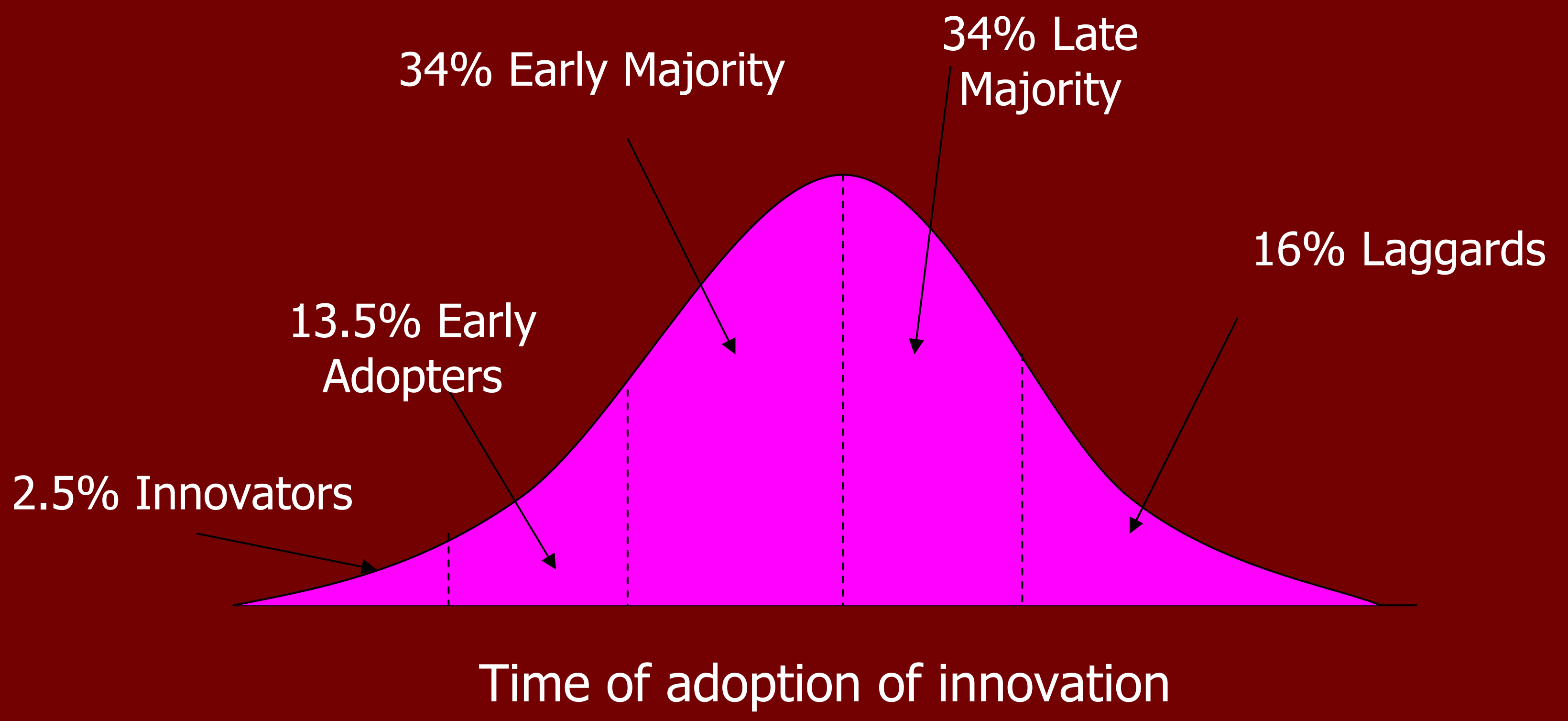
- Age: Under 6, 6-11, 20-34, 35-49
- Gender: Male, Female
- Family Size: 1-2, 3-4, 5+
- Family Life Cycle: Young, single; young, married, no children; young, married, children; older, married, children; older, married, no children; older, single
- Income: $50,000-over
- Occupation: Professional and technical; managers; officials, and proprietors; clerical, and sales; supervisors, students, homemakers; volunteer workers
- Education: High school graduate, some college, college graduate
- Generation: Generations X,Y,Z, echo boomer
- Race: N/A

Market Analysis

Demographics come into play here because different ideas appeal to different groups consisting of different characteristics.

Market Analysis

ADOPTER CHARACTERIZATION BREAKDOWN



Adopter Characterization

- Innovators – young, better educated, higher income; venturesome
- Early Adopters – leaders in the community; adopt new ideas early but carefully; trendsetters
- Early Majority – deliberate; adopt new ideas before the average person
- Late Majority – skeptical; older in age and wait until the reviews are massively published
- Laggards – tradition bound and brand loyal; won’t change until the new trend becomes tradition

Market Analysis

- Large market appeals to the idea of

  MORE POWER FOR YOUR MONEY

- Segmentation for a small new company leads to

THE ENVIRONMENTALLY FRIENDLY BATTERY

Population Characteristics

City	Population
National Average	52,000
Austin, TX	587,900
Seattle, WA	537,200
Portland, OR	503,600
San Francisco, CA	746,800
Charlotte, NC	520,800
NYC, NY	7,428,200
Washington, DC	519,000

Economical Demographics

City	Cost of Living Index	Median Income ($)	Per Capita Income($)
National Average	100	53,475	20,710
Austin, TX	102.9	50,179	20,118
Seattle, WA	135.7	50,993	26,516
Portland, OR	127	51,156	20,030
San Francisco, CA	**209.5**	**74,773**	**27,727**
Charlotte, NC	108.3	58,713	21,862
NYC, NY	189.1	60,765	24,877
Washington, DC	120.9	65,083	26,855

SF Demographics

- 8.2% children ages 5-14
- 48% ages 20-45
- 44.3% of all families having children
- 45.6% of all families young and single
- 1.7% unemployment rate
- 56.8% making $50,000 and over per household

Cost Comparison

BATTERY PRICES ACCORDING TO CVS PHARMACIES			
City	**Sales Tax (%)**	**AAA Duracell 4pk ($)**	**AAA Duracell 8pk ($)**
National Average	5.42	N/A	N/A
Austin, TX	8.05	3.17	5.89
Seattle, WA	8.35	3.39	6.09
Portland, OR	0.00	2.99	5.89
San Francisco, CA	**8.25**	**4.99**	**8.79**
Charlotte, NC	6.15	3.19	5.89
NYC, NY	8.25	4.59	8.69
Washington, DC	5.75	3.79	6.49

Cost Comparison

- CVS Pharmacy has a standard markup for all batteries – about 25%
- According to the price list above, San Francisco has the highest cost of batteries
- Duracell sells their batteries to CVS Pharmacy for about $1.00/battery

CAN SUPER BATTERY COMPARE?

Cost Comparison

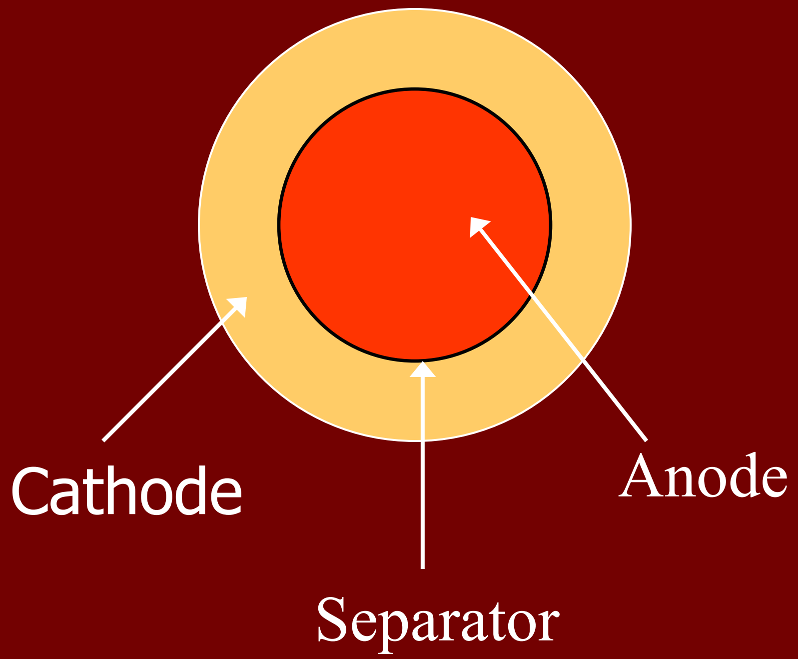
- For Super Battery to be cost competitive, a battery must be sold for $1.00/battery
- The cost per battery for production is $0.86
- $0.14 profit per battery is about 16%
- If a higher profit margin is needed, extra investment would have to be dumped into advertisements and promotions stressing the environmental aspect of the battery
- Economics will discuss this in further detail

Battery Synthesis

Cathode Synthesis

Battery Design: Cathode

Top Cross-Sectional View of Battery:

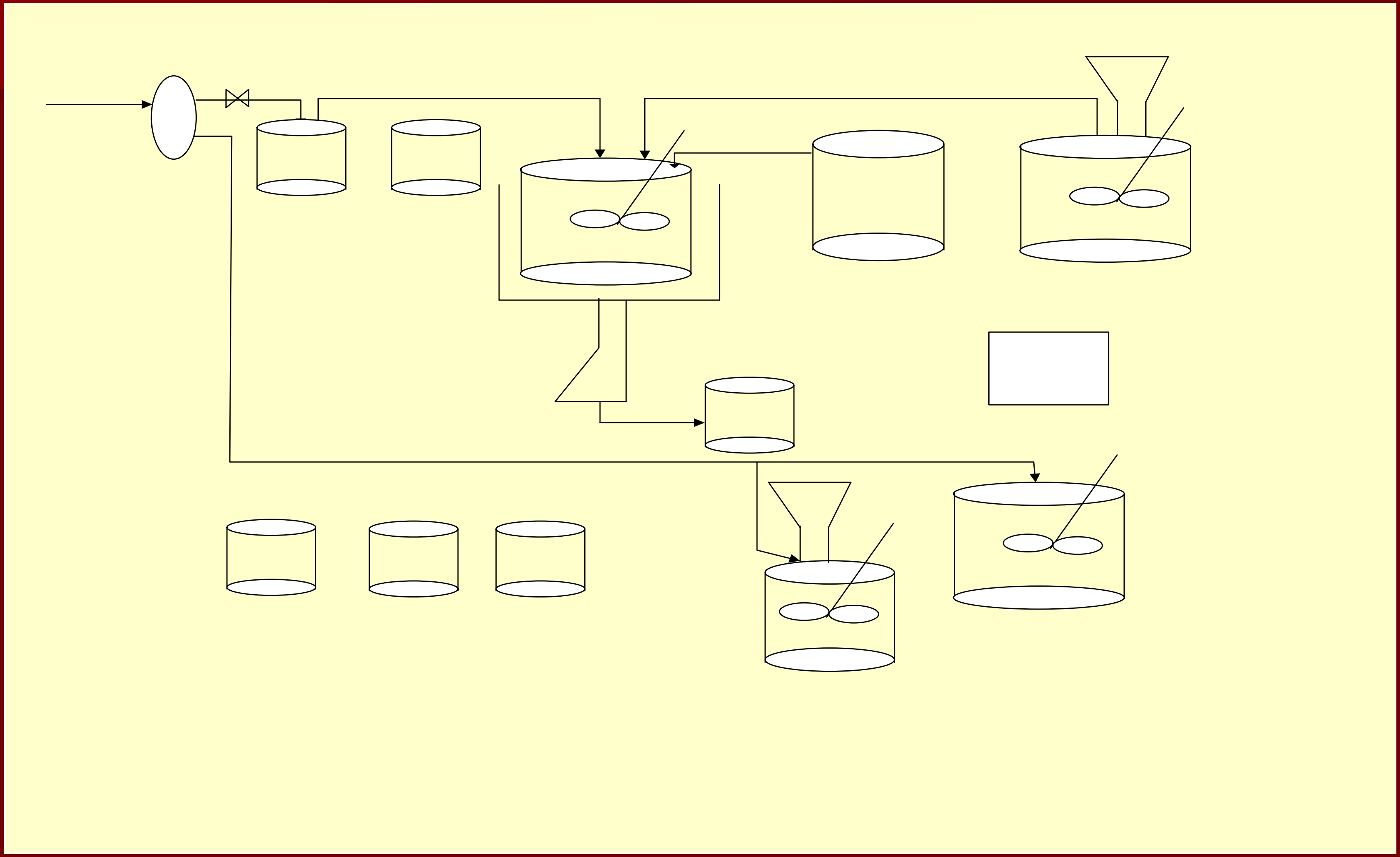


- The cathode is the material between the casing and the separator.
- The volume of the cathode is an estimated 49 % of the battery interior.

Cathode Challenge

- To create a cathode based on Iron (VI).
- This process has never been completed on an industrial scale.
- Very little information exists concerning the chemical characteristics of Iron (VI) and its different compounds.

Chemists vs. Engineers



City water

City water

Chemists vs. Engineers

- Chemists: Cathode synthesis scaled-up directly from laboratory work:

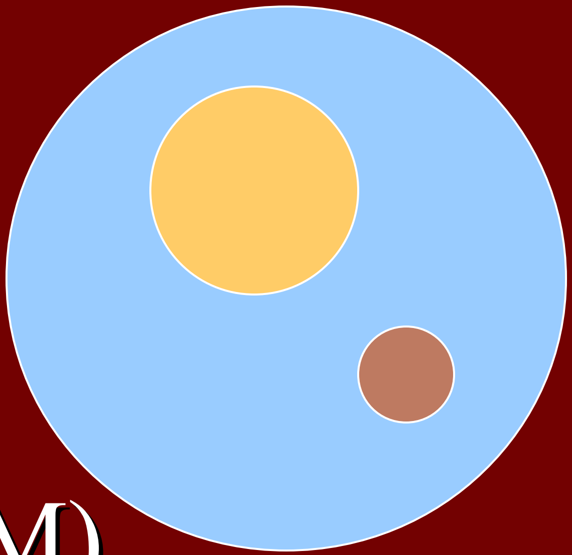
  Weekly Cost: $4,889,000

- Engineers: Modifications throughout cathode synthesis:

  Weekly Cost: $39,600

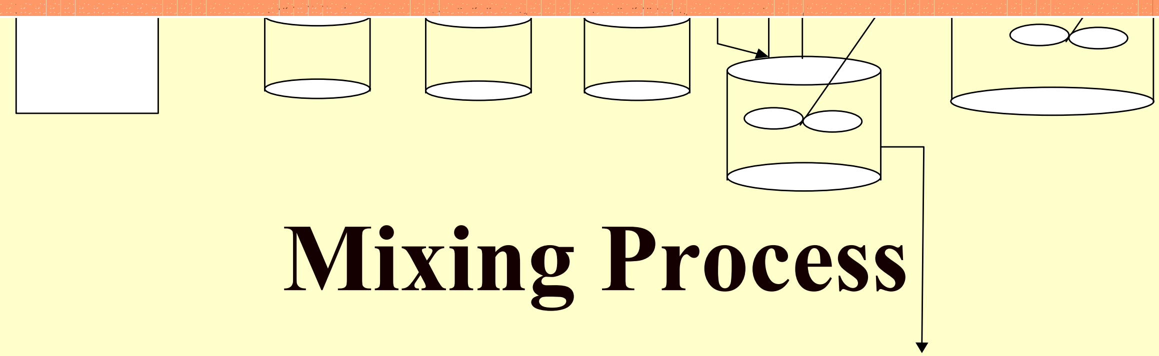
Iron (VI) Super Battery Cathode

- Mass Breakdown of Cathode Components:
  – 2.38 g Na_2FeO_4
  – 0.183 g $KMnO_4$
  – 1.098 g CF_x
  – 3.66 mL KOH (13.5 M)



Cathode Synthesis PFD

$Fe(NO_3)_3 \cdot 9H_2O + 3/2 NaClO + 5NaOH \rightarrow$
$Na_2FeO_4 + 3/2 NaCl + 3NaNO_3 + 23/2\ H_2O$



Mixing Process

City water

Anode Synthesis

Anode Synthesis: Why?

- Provide low cost negative electrodes at a high voltage
- Low weight addition to battery
- Lowest possible oxidation state for anode material
- High discharge capability
- Not susceptible to corrosion in saturated KOH to stabilize iron (VI)
- The alternative cadmium or mercury additives may be cheaper, but not environmentally friendly

Common Methods

- Using pure zinc metallic powder mixed with electrolyte

  Problem: hydrogen is generated by the zinc and causes a corrosion reaction – leads to increased pressure inside the battery and electrolyte leak

- Kneading zinc powder, gel forming materials and magnesium with a small amount of water

  Problem: Too much time for electrolyte to penetrate into the zinc electrode paste

Common Method

- Using a mixture of pure zinc and either indium, aluminum, or lead to prevent corrosion

  Problem: Inability of the zinc paste to hold it’s shape in the battery which lead to leakage and early loss of charge capability

Zinc History

- 1982 Jones US Patent 4358517 explains the effectiveness of using carbon hydroxide mixed with potassium hydroxide as the electrolyte solution
- 1990 JP 227729/89 discussed the role of a gelling agent such as carboxymethyl cellulose

  Problem: With time, the electrode falls out of gel state due to its large specific gravity or contact between zinc particles become unstable
- Ten years ago the method involved an addition of mercury in order to prevent corrosion

  Problem: Environmentally Unacceptable

Zinc History

- 1996 Charkey US Patent 4084047 discusses beneficial oxide additives that enhance electrode conductivity, particularly Bi_2O_3

Goals

– Minimize the shape change
– Provide a stable construction to achieve prolonged cycle life
– Improved capacity under heavy current discharge loads and low temperature
– Improved stability during storage
– Maximum energy density
– Avoid toxicity to the environment
– To provide the highest utilization of the iron (VI) electrode as possible in order to be cost effective

Anode Synthesis

Mass Breakdown per Battery:

- 0.554 g of calcium oxide
- 1.4674 g of zinc oxide (volume fraction 0.51 ZnO:0.32 CaO)
- 0.1523 g of bismuth oxide
- 0.2547 g of hydroxy-et cellulose (10%wt)
- 0.1247 g PTFE (known as the binder, 5%wt)
- 2.5472 mL KOH

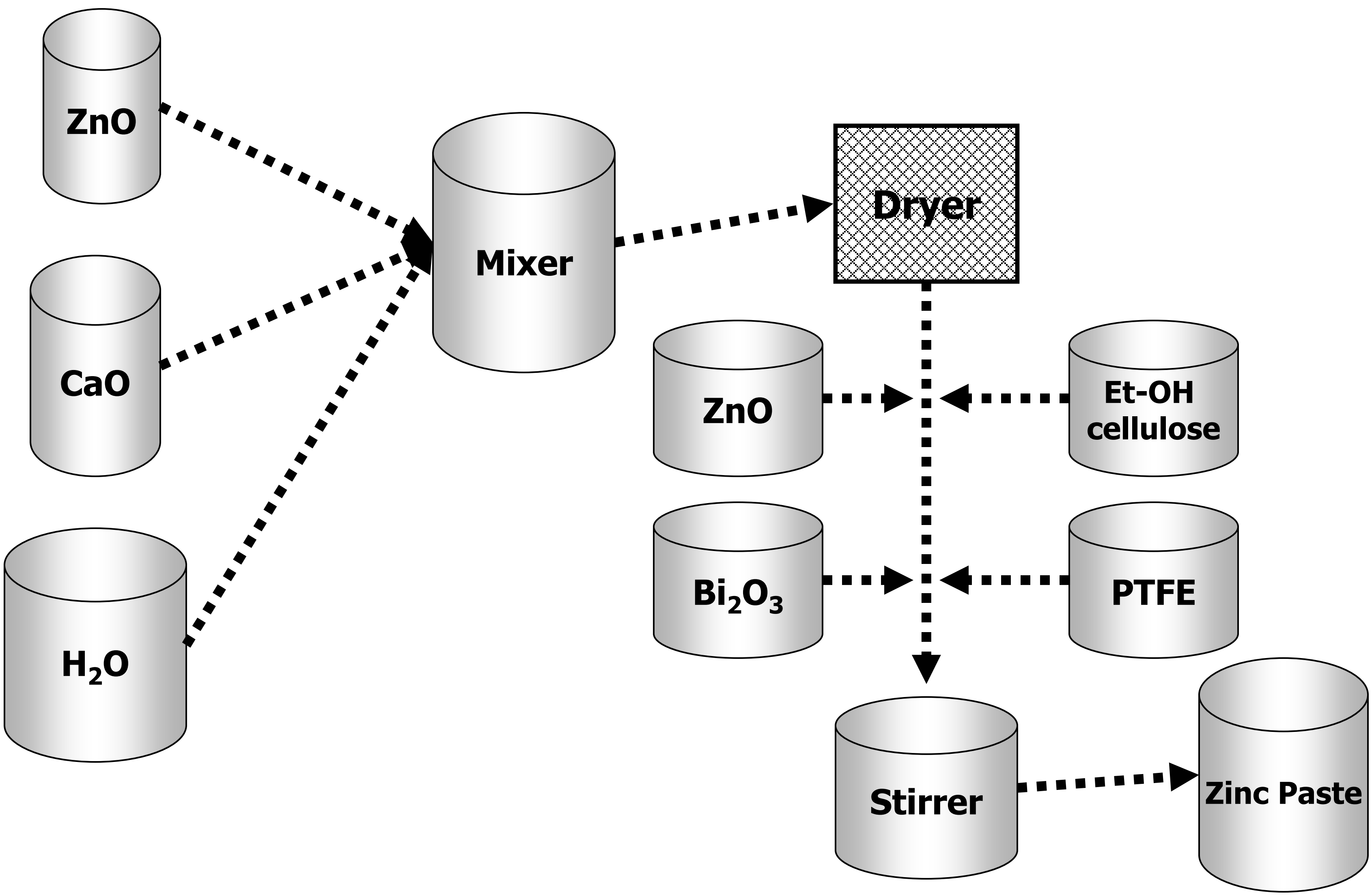
Components

- Zinc Oxide
  - important material for obtaining good dispersion in a short time
  - Ability to absorb large quantities of electrolyte solution between particles
  - Has high capability to combine the particles of the zinc electrode material with electrolyte
- Calcium Oxide
  - Shown to significantly improve performance by maintaining stability (preventing migration) in order to hold the capacity of the battery longer
  - Reduce the solubility of active material through formation of $CaZn_2(OH)_6$

Components

- Bismuth Oxide
  - Provides a conductive matrix which is more electropositive than zinc
  - Easily reduced to metal
  - Considered an inorganic inhibitor
- PTFE
  - Binder aids in connecting all the elements
  - Enhances oxygen recombination with the formation of calcium zincates at the zinc electrode
  - Affinity for reacting with oxygen
  - Aids in rapid oxygen recombination during discharge

Anode Synthesis



Reasoning

1. Metallic oxide (calcium oxide) adds stability without altering other components of the battery
2. Capable of keeping the low oxidation level necessary
3. High life cycle
4. Good rate capability
5. Excellent mechanical characteristics
6. Capable of mass production

Components

Casing Material

- **304 Cold Rolled Stainless Steel**

  - manufactured in a variety of shapes and sizes cheaply

  - Durable with high corrosion resistance

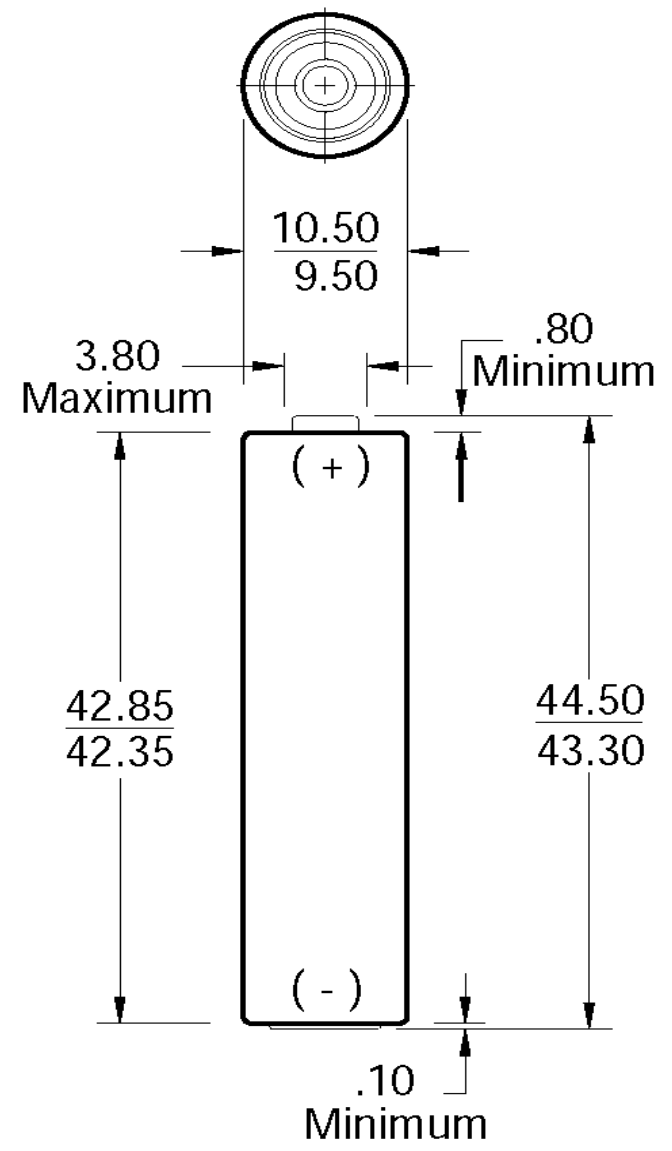
Circular cylindrical fabricated as a deep drawn can

- Reduces the number of fabrication processes
- Enhances the case integrity
- Allows for less variation in the diameter
- Produces better quality welds increasing shelf-life

Casing Material

Battery Dimensions (AAA)

- Wall thickness-.635 mm
- Length – 44.5 mm
- Diameter – 10. 5mm



Header Material

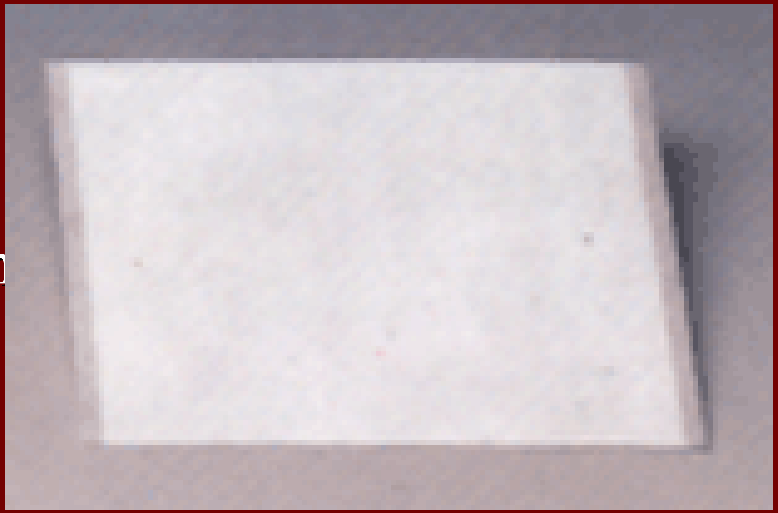
- Glass-to-metal sealed electric terminal
- Fit is important to obtain high quality welding
- Thickness – 3.175 mm

Ultrasonic Metal Welding

- Cold-phase friction welding technique
- Surfaces subjected to high frequency oscillations while being rubbed together under pressure
- Molecules on the surfaces mix with one another, creating a firm bond
- Weld cycles typically under one-half seconds allowing high productivity rates

Separator

- Microporous membrane
- Prevents contact between the positive and negative electrode
- Allows ions to move freely between the anode and the cathode without internal shorts
- Insulator
- Permeablility, strength, ability to maximize ionic conductivity



Collector

- Electrical connection between the porous cathode and the positive terminal of the battery

- Brass pin

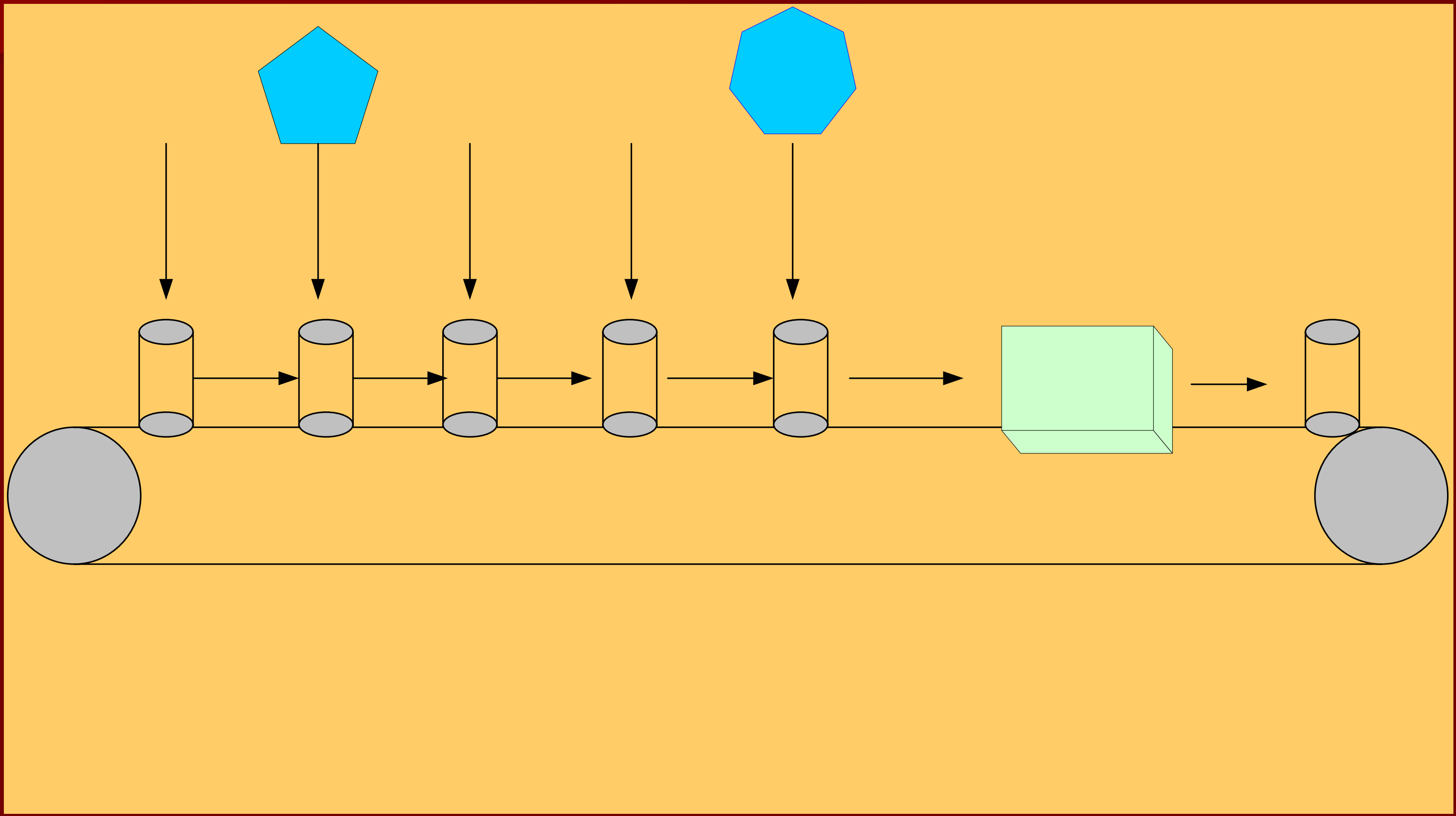
  - 20 mm long, 1.5 mm diameter

  - Brass is a high purity homogeneous alloy

  - good corrosion resistance

  - high surface quality that minimizes the formation of hydrogen inside the battery

Construction Process



Separator

Packaging

- Ensure product quality
- Important role in the marketing strategy
- Sleek plastic cylinders made from ecologically friendly recyclable and reusable materials
- Self-contained shipper that doubles as a floor display
- Uses 40 percent less shelf space than that of other battery suppliers

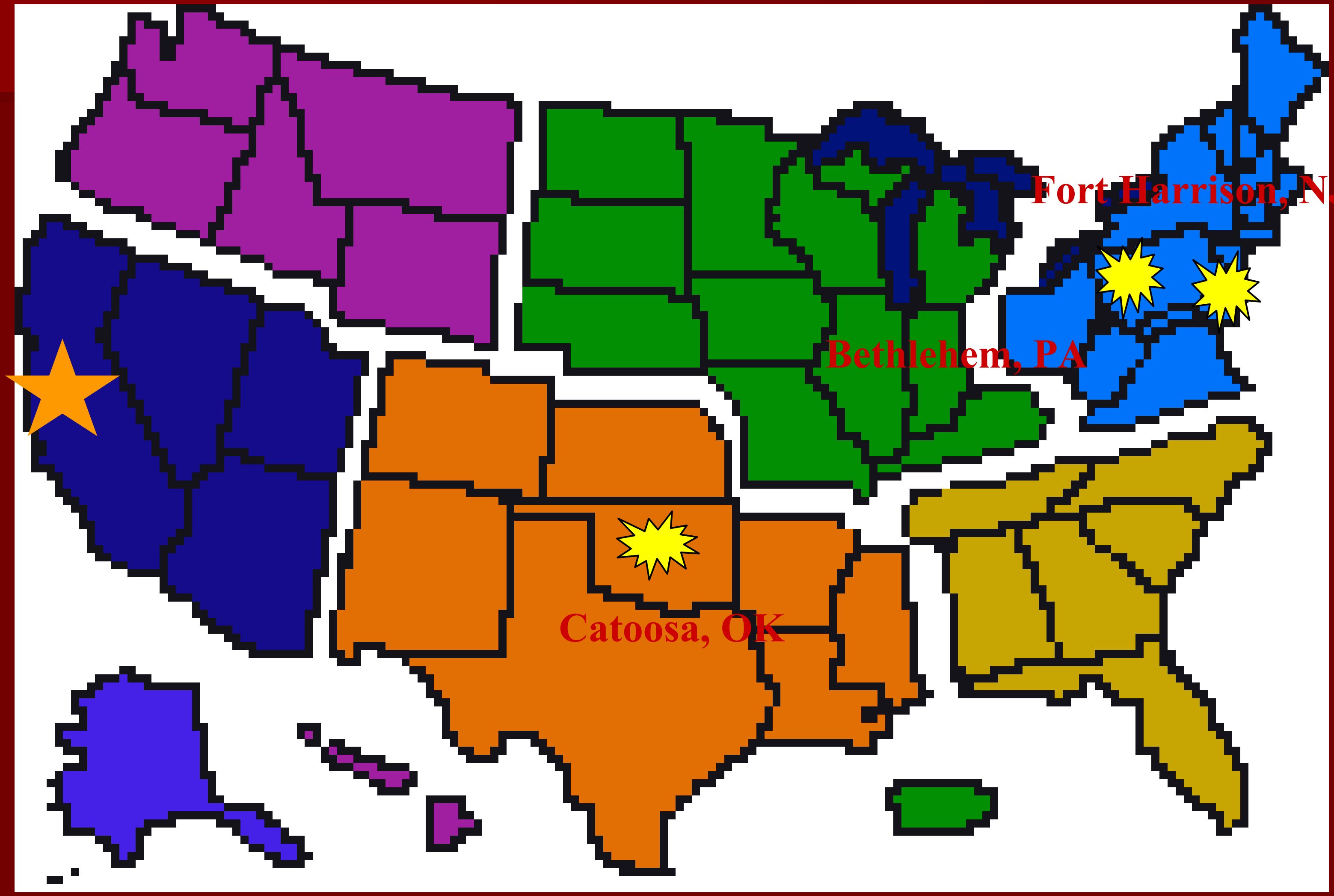
Plant Location

Plant Location

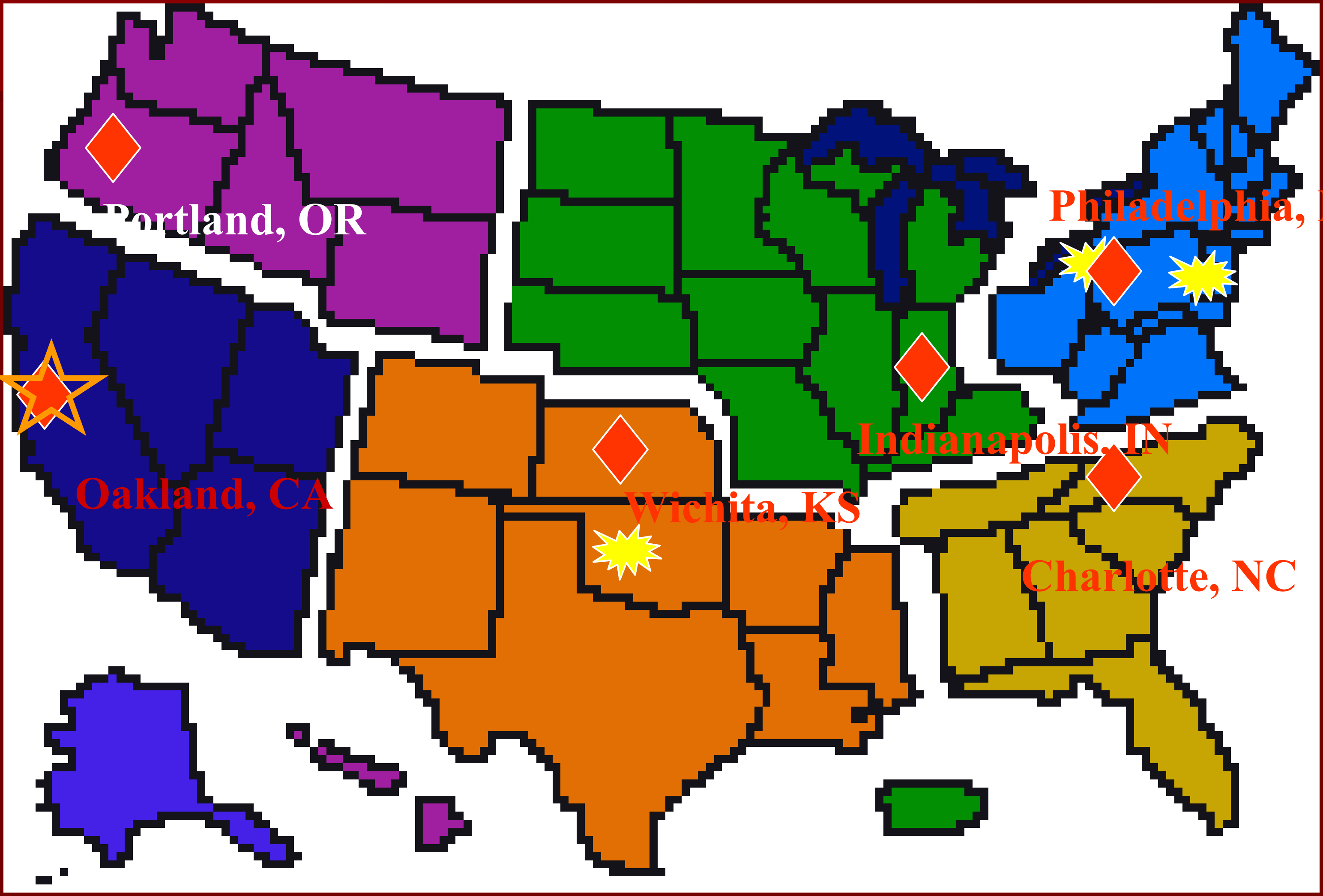
Shipping Cost

-Import Raw Materials
- Export Complete Super Battery

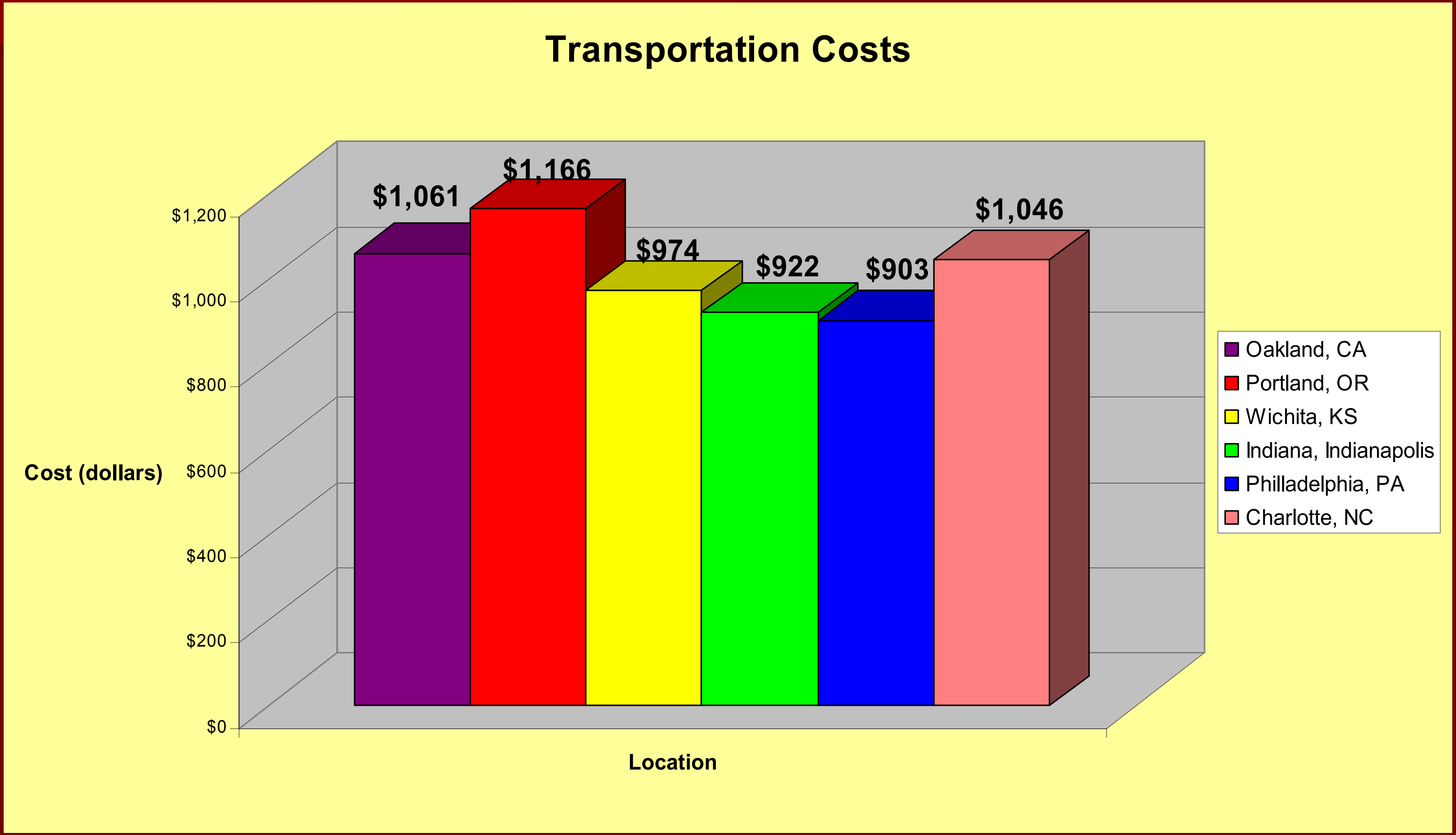
Raw Materials



Locations Considered



Shipping Costs



Factors Considered

	Utilities	Property Tax	Sales Tax
Wichita, KS	105.4	11.5%	5.30%
Indianapolis, IN	98.9	13.8%	6%
Philadelphia, PA	144.5	25.4%	6%
Charlotte, NC	97.2	12.4%	4.50%

The plant will be located in Charlotte, NC.

Transportation

Different Modes of Transportation

- **Rail**

- 20, 50, or even 100 carload movements
- lacks flexibility to service all markets
- deliveries can vary by a number of days

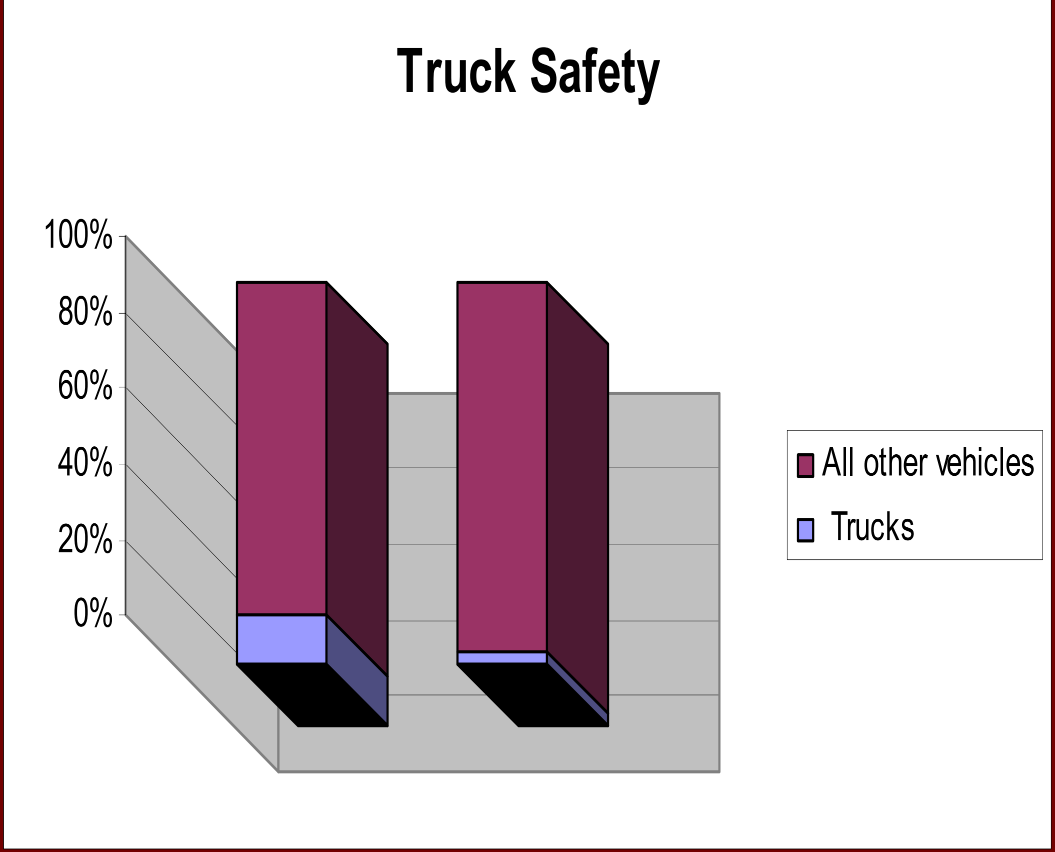
- ability to move large quantities
- long distances
- relatively low cost

Different Modes of Transportation

- **Trucking**
  - High-speed intercity movement
  - Smaller shipments
  - More-frequent deliveries

Trucking

- Trucking makes up 15% of all vehicles on US roadways.
- Trucking involved in only 3% of accidents.



Environment

Method to Protect Environment

- The most effective measure in preserving our environment is not to react to environmental accidents, but to prevent accidents and spills.

Sources of Environmental Harm

- Point Source Pollution (PS)
  - Spills or disposal into local sewer.
- Non-Point Source Pollution (NPS)
  - Uncontrolled spills or disposal into surrounding environment.

Preventing Environmental Harm

- Prevention during…..
  - Receiving hazardous materials.
  - Fabrication
  - Plant transportation
  - Storage
  - Disposal

Non-Point Source Spill (NPS) Prevention

- Preventing truck incidents with Camel Fiberglass Drive-Thru Systems
  – Contain a 500 gallon spill

Non-Point Spill (NPS) Prevention

- Preventing rail incidents with the “Star Track” system
- Contain a 500 gallon spill.

Non-Point Spill (NPS) Prevention

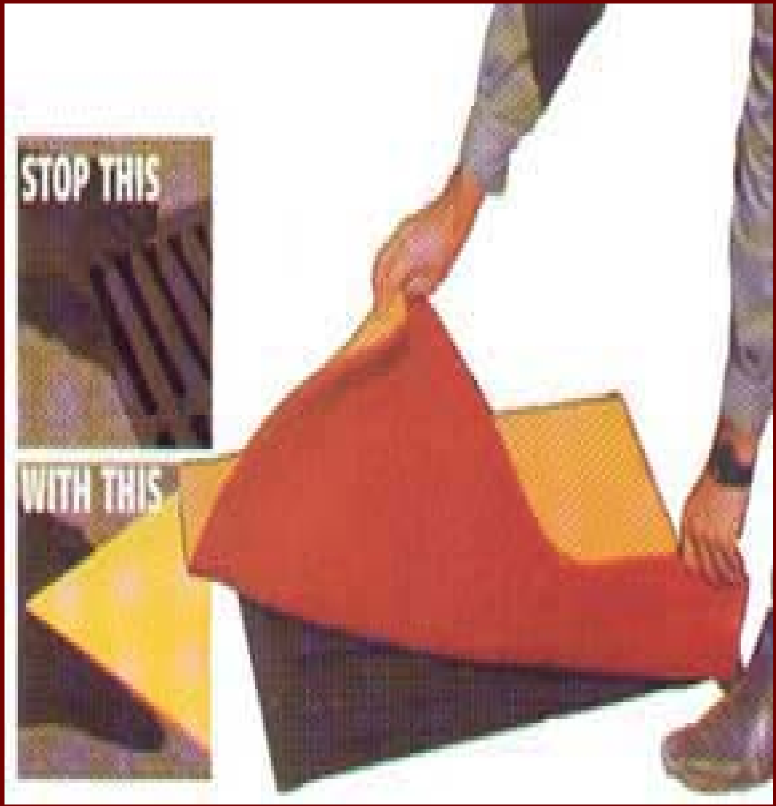
- Chemically resistant polyurethane box curds are installed around the parameter

Non-Point Source Spill (NPS) Prevention

- Transportation within the plant

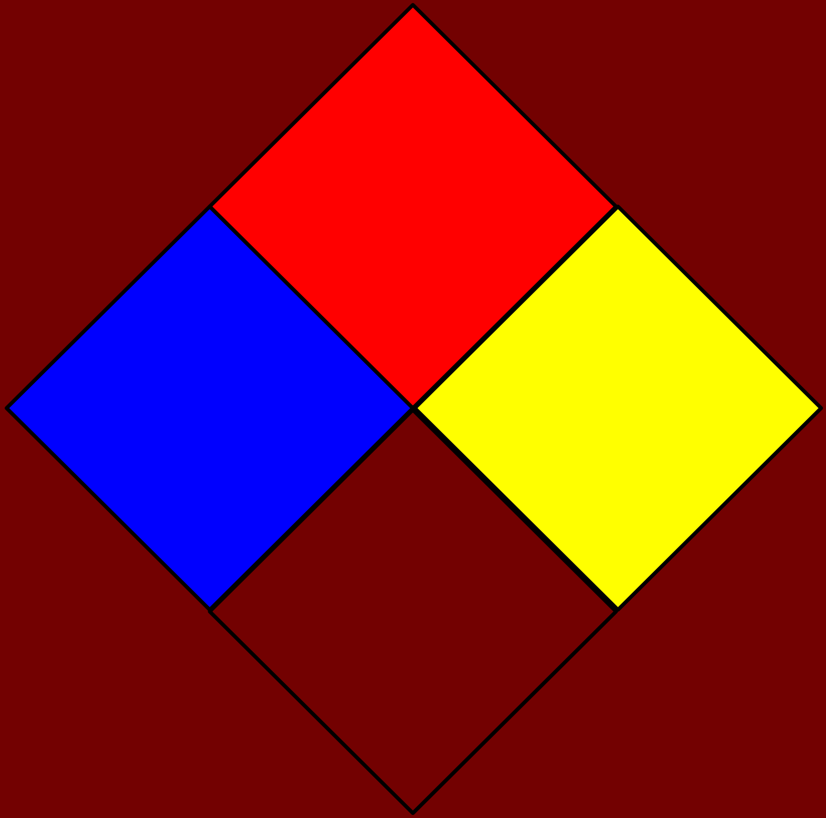
Point source (PS) pollution prevention

Conical plug drain seal and drain protector safety seal



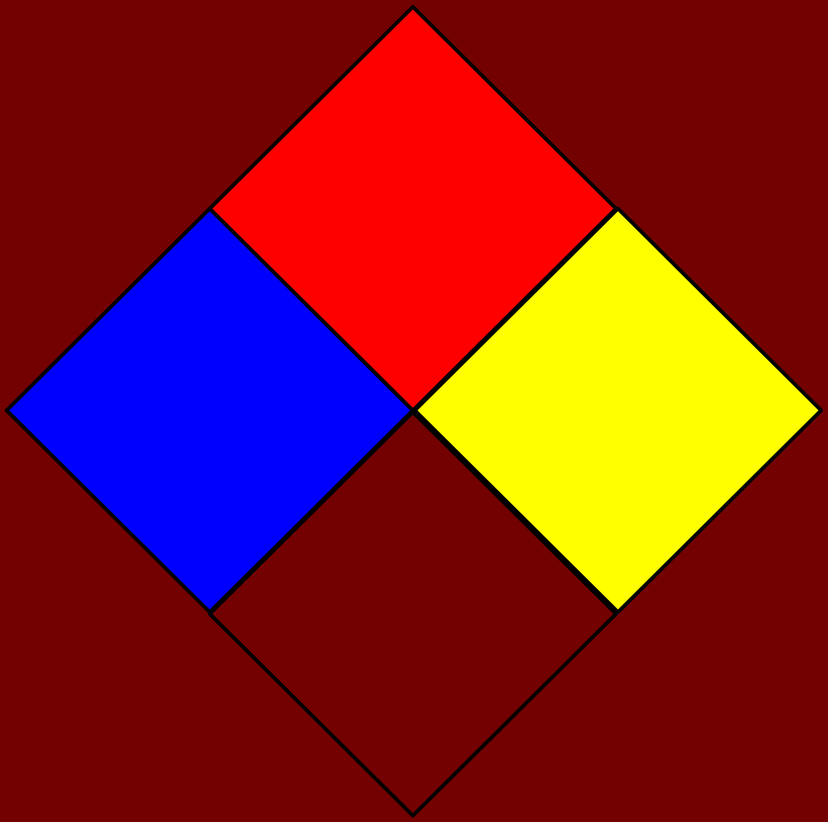
Storage Color Code

- Blue: Poison
- Red: Flammable liquid
- Yellow: Store away from flammable or combustible materials (oxidizers)
- White: Store in a corrosion-proof area
- Orange: General chemical storage
- Striped: Store individually. Material is incompatible with other materials in the same color class.



Dangers Inside Plant

- Potassium Hydroxide, KOH
  - POISON! DANGER! CORROSIVE!
  - Special spill and leak measures inside and outside of plant
- Occupational Exposure Limits and Health Hazards



Battery Plant Waste

- Sodium Chloride
  - Stable salt that dissolves in water.
  - No special clean up standards.
- Sodium Nitrate
  - Strong oxidizer
  - Minor health hazards

- Disposed of by EcoMat system.

Plant Waste Disposal

- **EcoMat Inc.**
- Based in San Francisco Bay Area
- Environmentally friendly
- Recycles nitrates to nitrogen gas and CO_2

EcoMat Inc.

- Environmentally friendly
- Economical
- Very light maintenance
- Lower chance of Non point source pollution

Battery Disposal Waste

- Potassium Hydroxide KOH
  - *Same precautions*
- Zinc
  - One of the most common elements in the earth's crust.
  - Most does not dissolve in water.
  - Minor health hazards

Battery Disposal Waste

- Iron Oxide Fe_2O_3
- Minor health hazards
- Environmental Effects
  - Can make drinking water taste bad, and can stain plumbing fixtures and laundry.
  - U.S. Environmental Protection Agency (EPA) has established secondary drinking-water standards.

Battery Disposal Waste

- Stainless Steel & Brass
  - – No threat to soil or ground water.
  - – Life Cycle well over 100 years.

Life Cycle Analysis

Cathode Raw Materials

$NaOH$

$NaClO$

$Fe(NO_3)_3\ 9H_2O$

$KMnO_4$

CF_x

KOH

$Fe(NO_3)\cdot 9H_2O +$
$NaClO + 5NaOH$
$\rightarrow Na_2FeO_4 +$
$NaCl + H_2O$

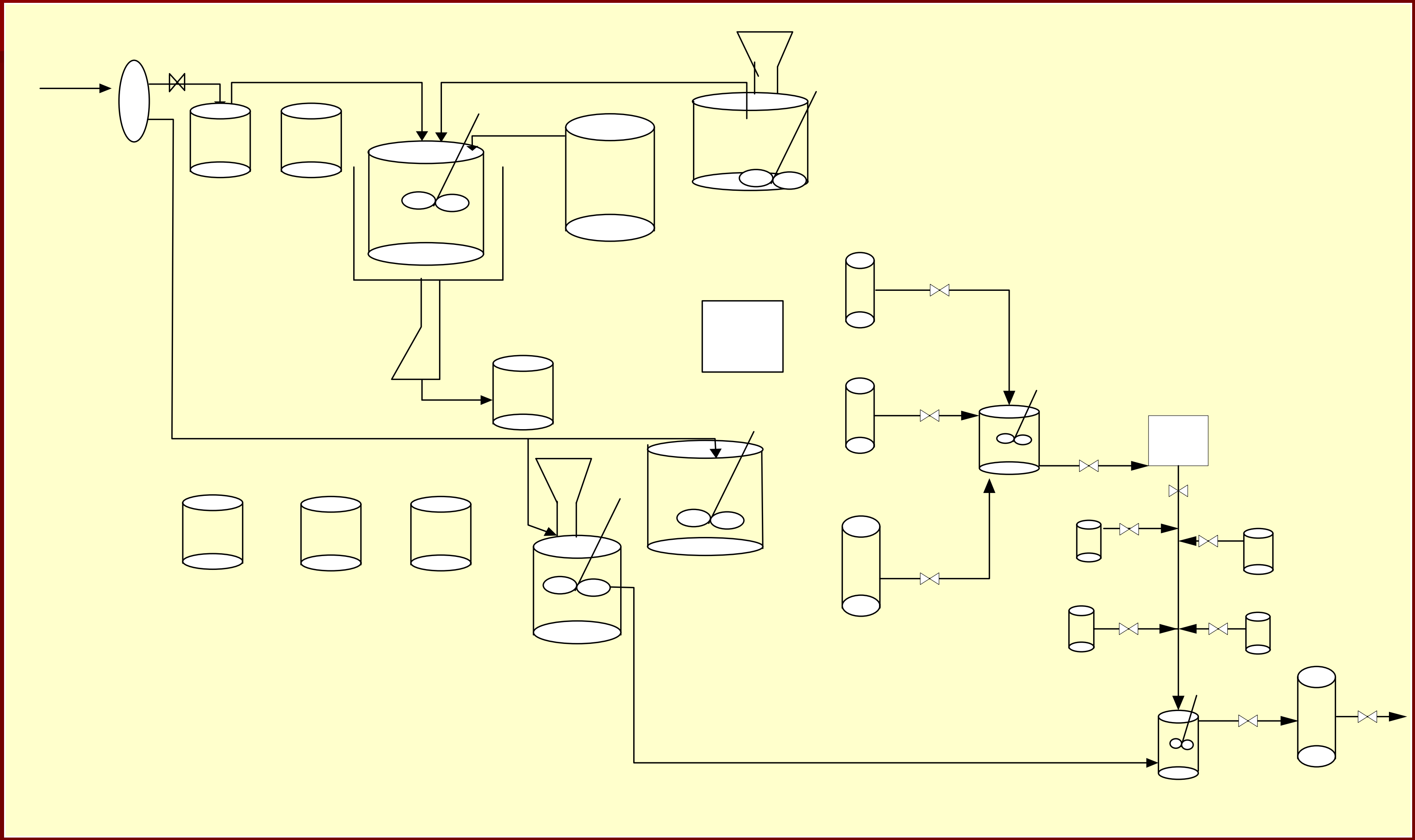
Anode Raw Materials

- ZnO
- CaO
- Bi_2O_3
- Et-hydroxy cellulose
- PTFE
- KOH

Additional Raw Materials

- 304 stainless steel header equipped with a glass-to-metal sealed electric terminal
- Brass Current Collector
- NFWA Membrane Battery Separator

Battery Production



Battery Production

- Water Usage: 10.8 mL/battery
- Energy: 0.105 kWhr/battery

Transportation

- All raw materials and product batteries are transported using:

LTL Trucking and Cargo Company

Battery Usage

- Standard sized AAA batteries are purchased by consumer.
- The iron (VI) super-batteries are used in electronic devices, where the following reaction occurs during cell discharge:

$$Na_2Fe(VI)O_4 + Zn \rightarrow$$
$$Fe(III)_2O_3 + ZnO + Na_2ZnO_2$$

Disposal

- The consumer discards the battery in the trash.
- Eventually, the discarded super-batteries will be placed into landfills.

Economic Analysis

Economic Analysis Outline

- Economic Background
- Chemists vs. Engineers
- Equipment, FCI, TCI
- Profitability
- Effect of Capacity on Economics
- FCI vs. Capacity
- Risk Analysis

Economic Background

- Economic life of 10 years
- Operating rate of 40 hrs / week
- Inflation rate of 4%

Chemists vs. Engineers

- FCI: $978,000
- TCI $1,125,000
- Weekly Cost: $4,889,000
- NPW $-147,000,000
- ROI: -227%

- FCI: $411,000
- TCI $472,000
- Weekly Cost: $43,200
- NPW $2,750,000
- ROI: 79%

Purchased equipment, FCI, TCI

- Capacity ~ 50,000 batteries / week
- Total Purchased Equipment ~ $82,000
- Fixed Capital Investment (FCI) ~ $411,000
- Total Capital Investment (TCI) ~ $472,000

Equipment Cost

Cathode Equipment	Volume (gal)	Cost ($)
Deionizer		$2,526
Tank-1 Carbon Steel (Distilled H_2O)	5.28	$20
Tank-2 Carbon Steel (NaClO)	16.09	$25
Tank-3 Carbon Steel ($Fe(NO_3)_3$ $9H_20$)	36.60	$30
Tank-4 Carbon Steel (NaOH pellets)	16.58	$25
Tank-5 Carbon Steel (Na_2FeO_4)	11.64	$20
Tank-6 Carbon Steel ($KMnO_4$)	0.90	$20
Tank-7 Carbon Steel (CFx)	5.58	$20
Tank-8 Carbon Steel (KOH pellets)	17.95	$25
Tank-9 Carbon Steel (Waste Storage)	74.21	$1,426
Reactor-1	69.27	$5,048
Filter-1 Cast iron	69.27	$87
Mixer-1 Steel bhp=2.7 (NaOH)	2.22	$2,259
Mixer-2 Steel bhp=2.7 (KOH)	2.40	$2,259
Mixer-3 Steel bhp=2.7 (Cathode)	4.82	$2,259
Vacuum Dryer-1		$12,000

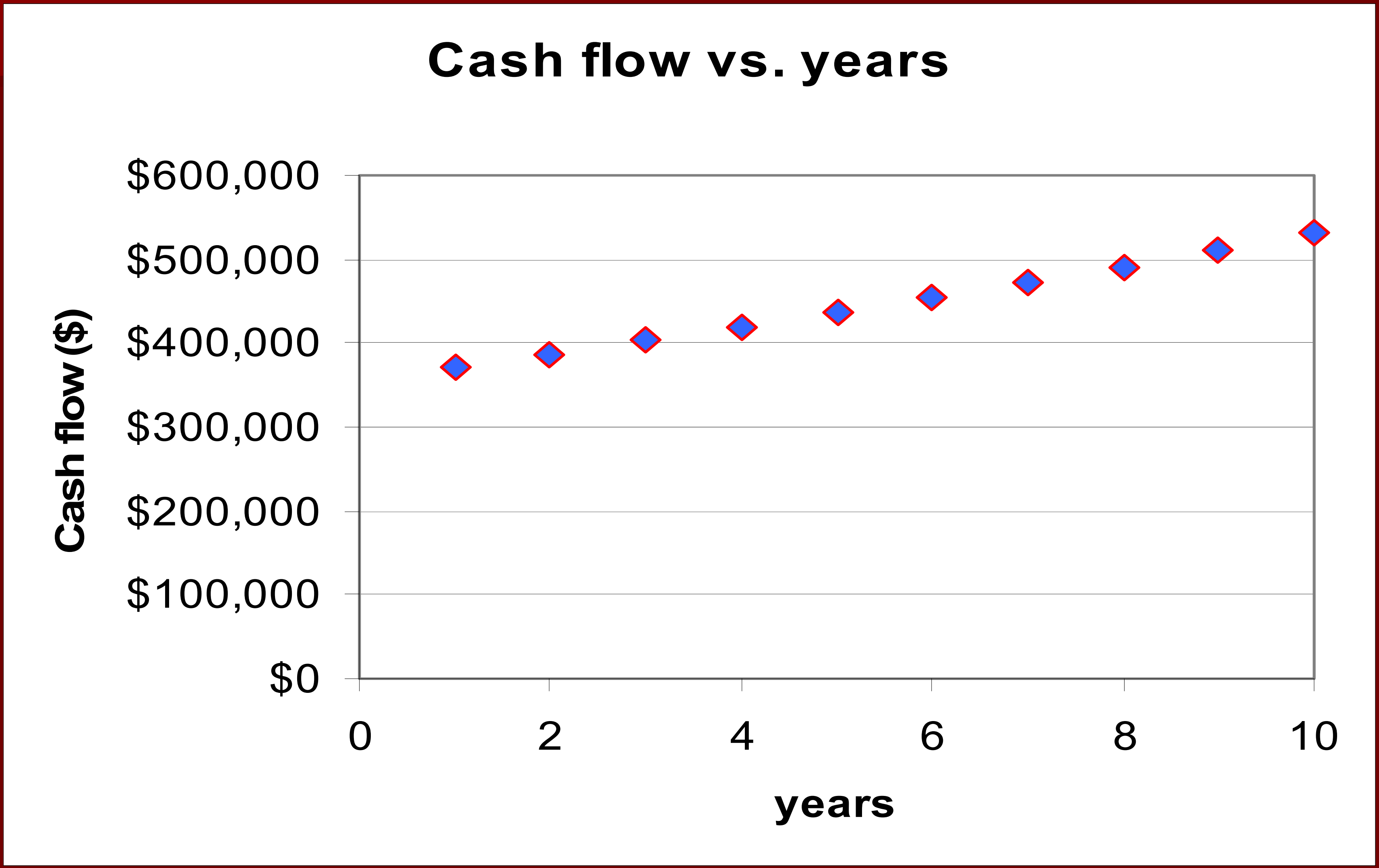
Equipment Cost

Anode Equipment	Volume (gal)	Cost ($)
Mixer-4 stainless steel – 6 hp	24.95	$3,312
Stirrer-1 stainless steel – 2 hp	10.82	$2,259
Tank-10 Carbon Steel (ZnO)	3.59	$20
Tank-11 Carbon Steel (CaO)	2.15	$20
Tank-12 Carbon Steel (Et-hydroxy)	3.74	$20
Tank-13 Carbon Steel (Bi_2O_3)	0.23	$20
Tank-14 Carbon Steel (PTFE)	1.12	$20
Tank-15 Carbon Steel	10.83	$20
Vacuum Dryer-4 carbon steel		$12,000

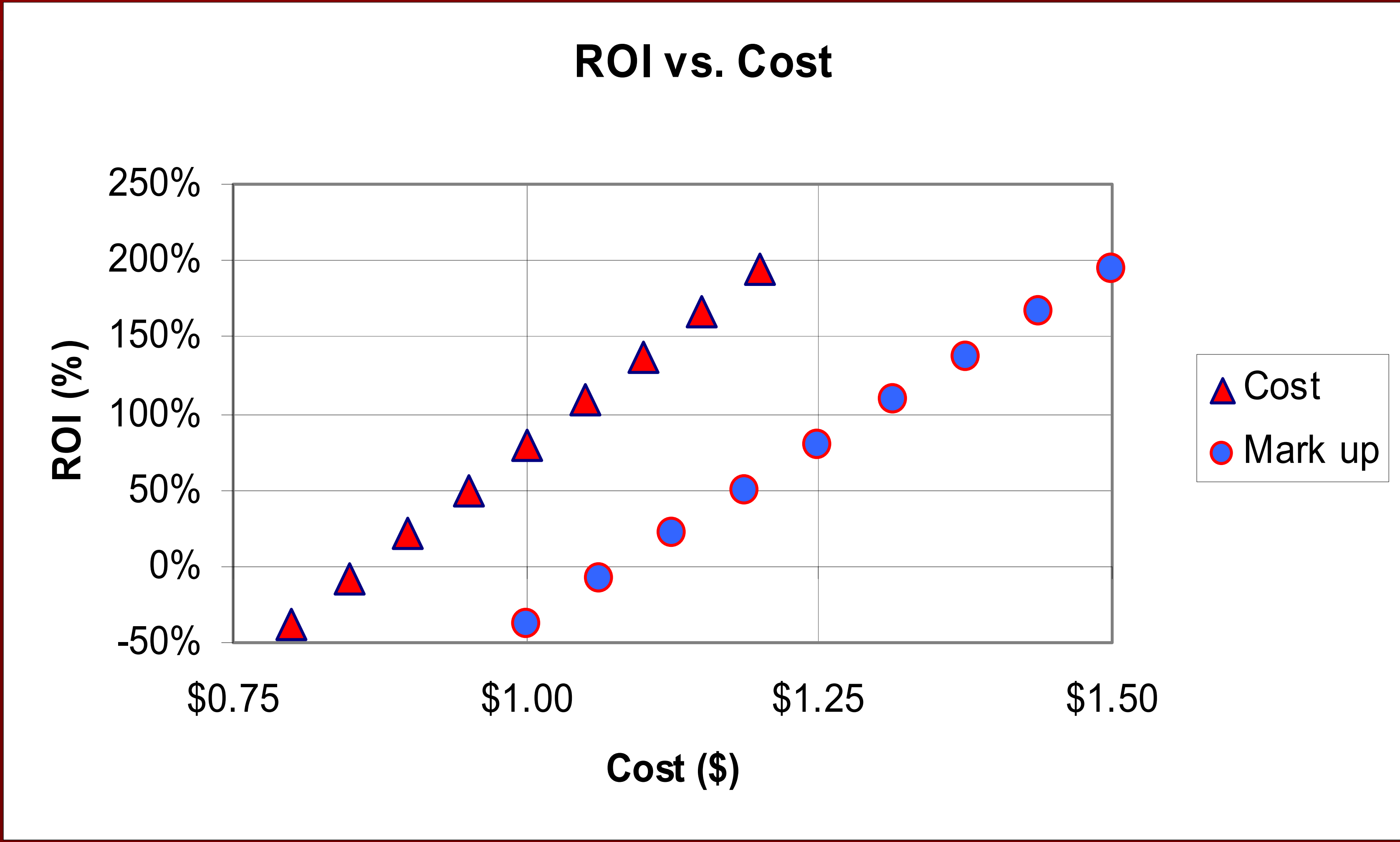
Profitability

- Total Weekly Cost ~ $43,200
- Total Weekly Sales ~ $50,000
- Yearly Cash Flow ~ $373,000
- Net Present Worth (NPW) ~ $2,750,000
- Return of Investment (ROI) ~ 79%
- Pay Out Time ~ 1 yr and 3 months

Economic Analysis



ROI vs. Cost

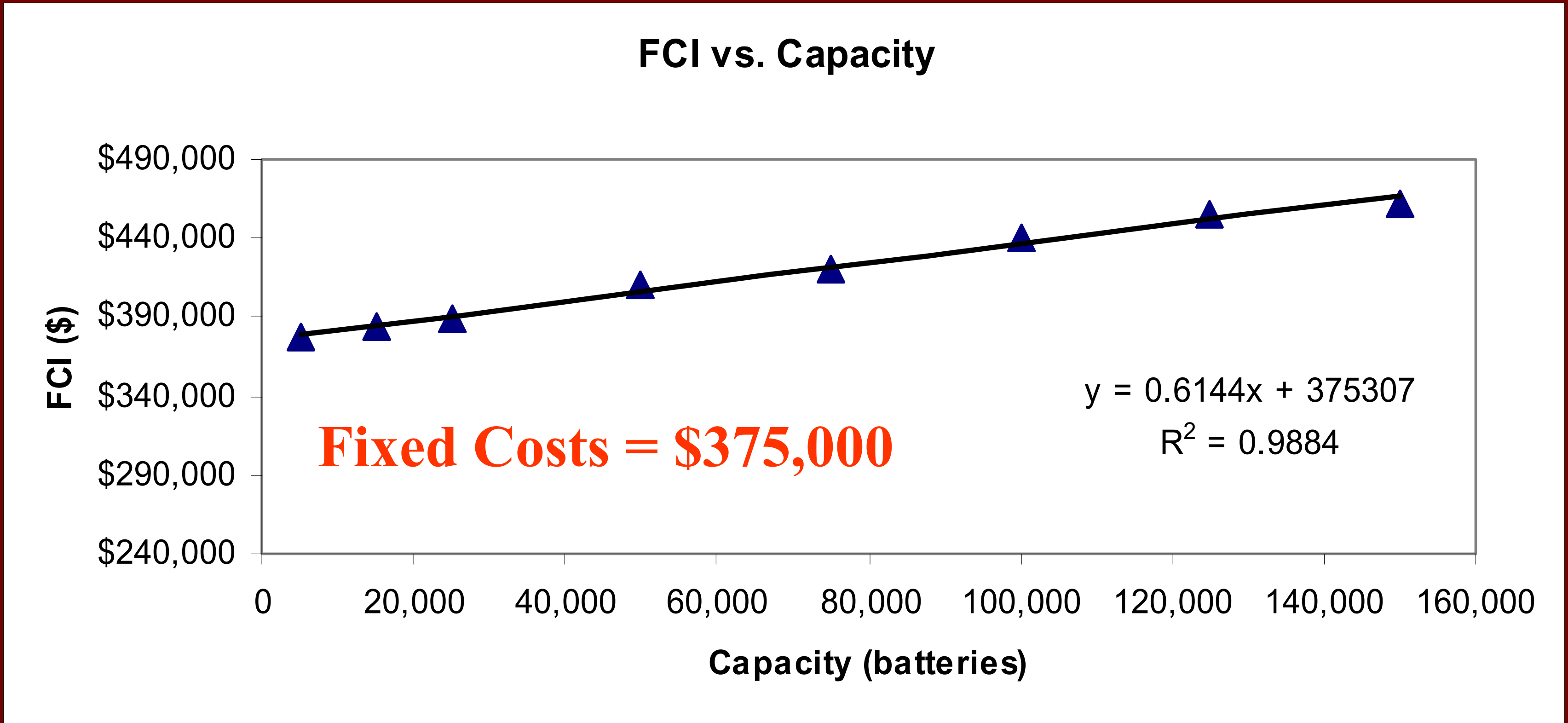


ROI vs. Cost
250%
200%
150%
100%
50%
0%
-50%
ROI (%)
$0.75
$1.00
$1.25
$1.50
Cost ($)
Cost
Mark up

Capacity Effects

EXCEL

FCI vs. Capacity

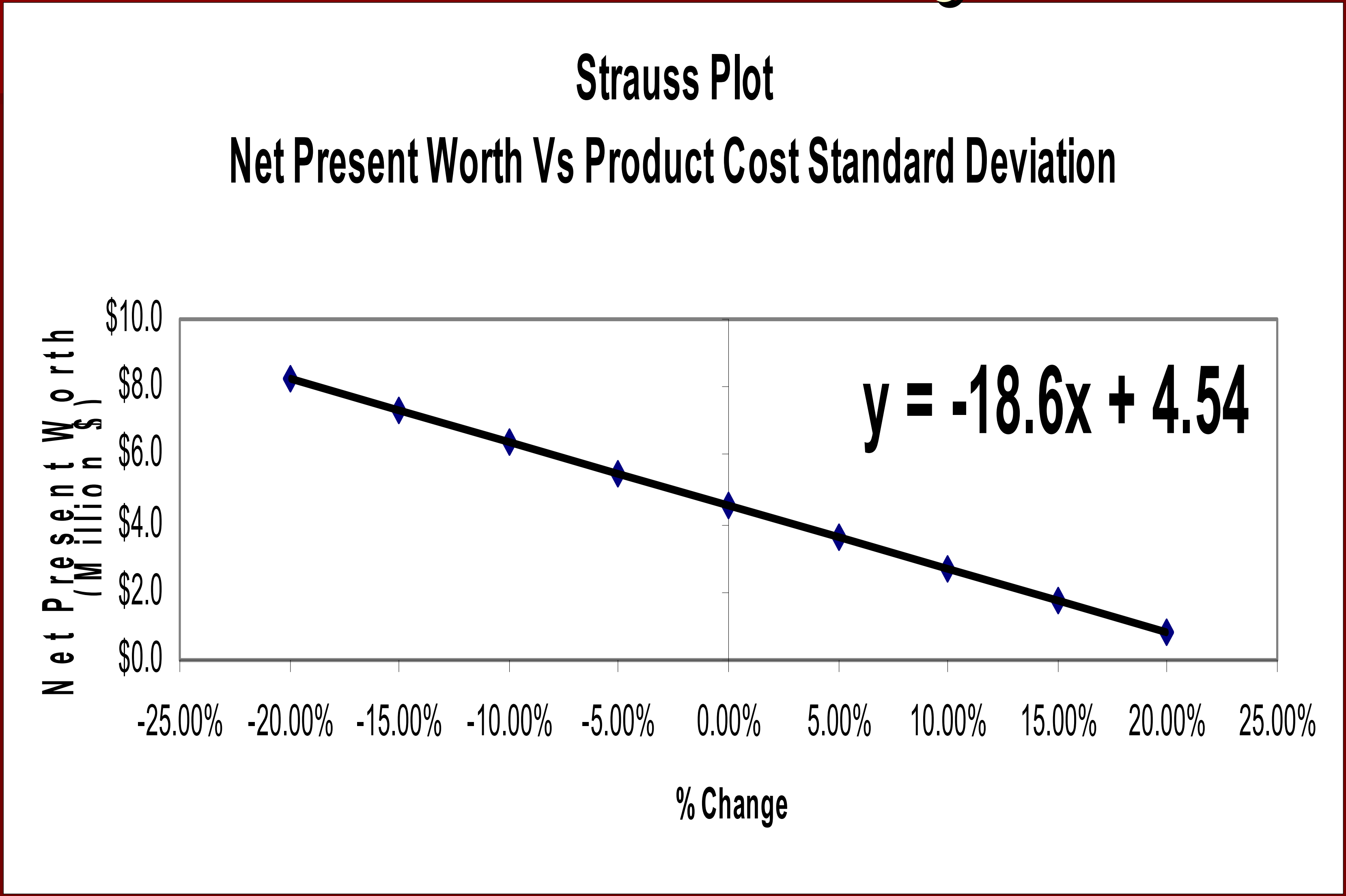


Risk Analysis

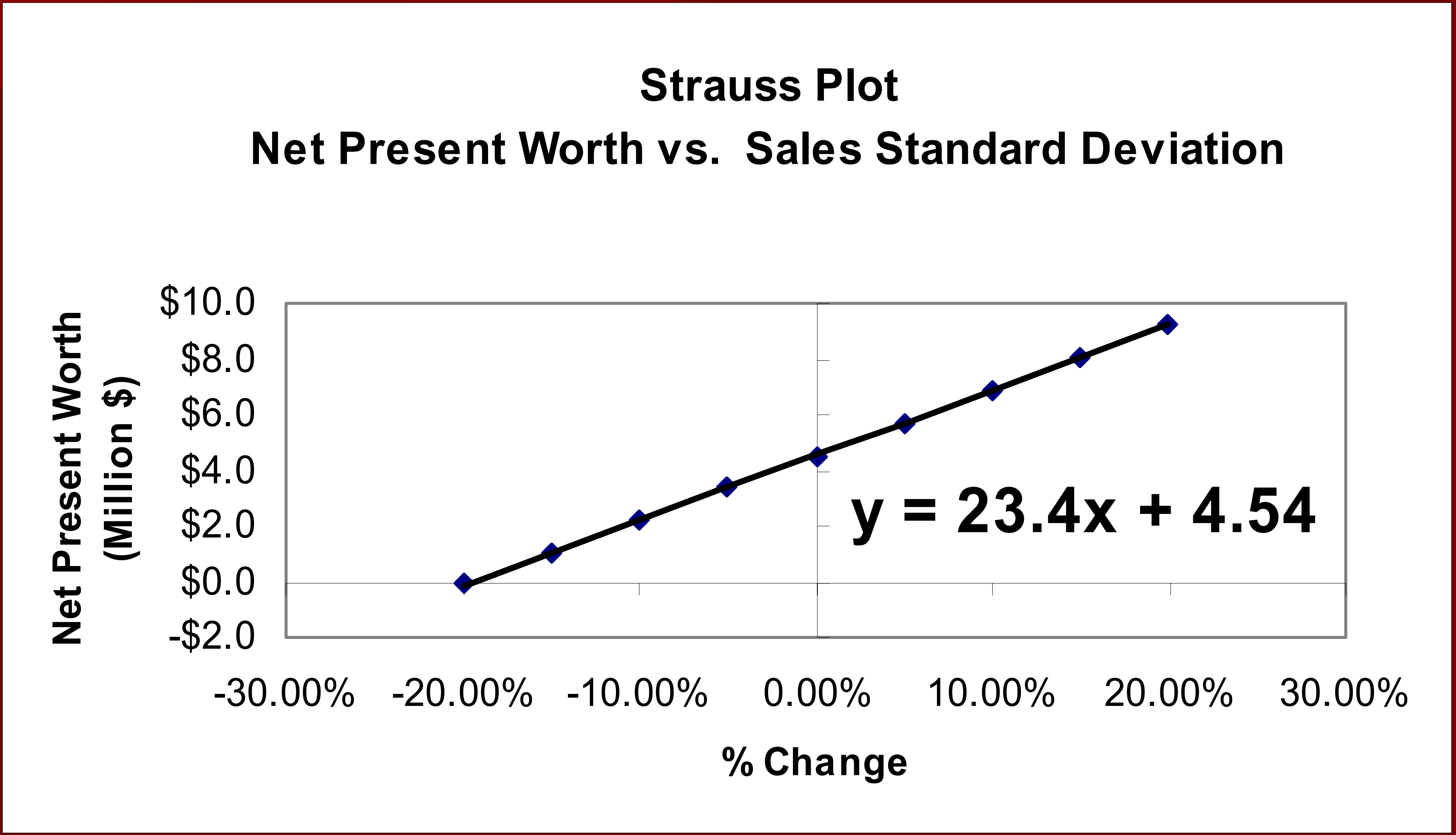
Risk Analysis

- Based on NPW
- Sensitivity Strauss Plots
- Product cost, product sales, FCI
- NPW Histogram

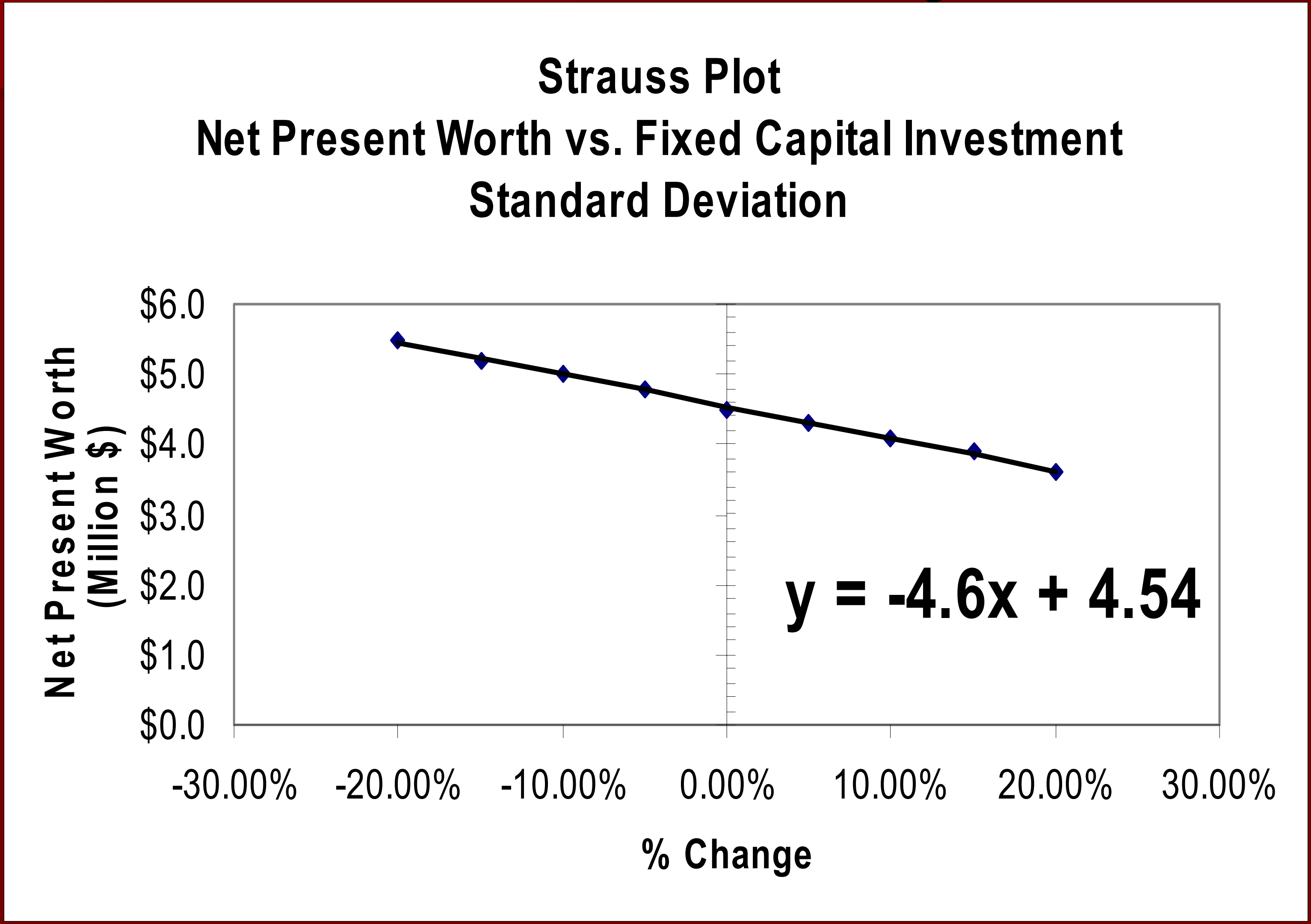
Sensitivity



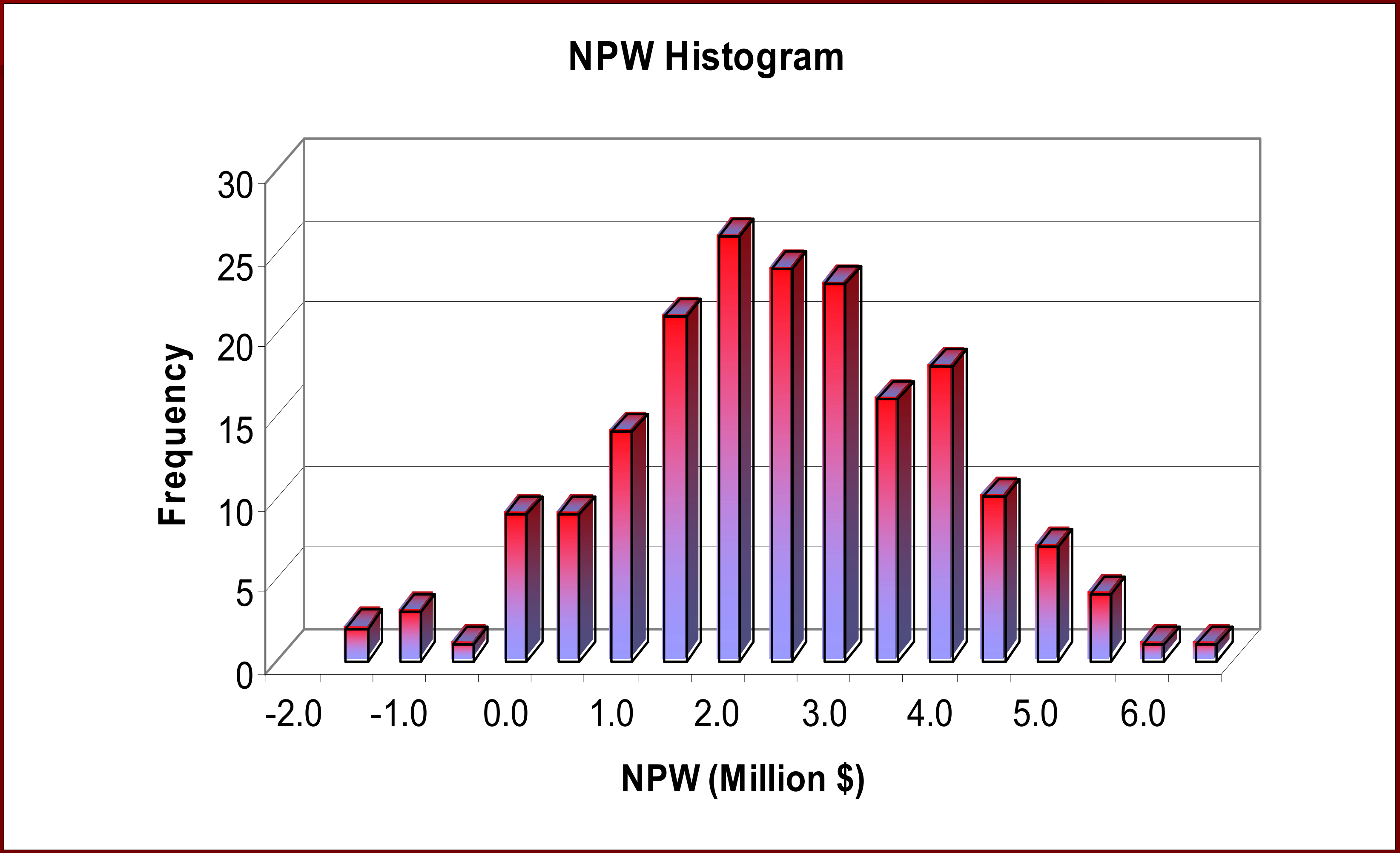
Sensitivity



Sensitivity



NPW Histogram



Conclusions

Conclusions

- Lots of potential!
- Batteries last longer and are more environmentally friendly
- Process is profitable

Challenges & Improvements

- Chemists vs. Engineers
- Make process profitable
- Very little information about Iron (VI) compounds

- Use mathematical model to optimize capacity, plant location, and market
- Research more on Iron (VI) compounds to optimize process

Any Questions???