

Lead-Acid Batteries For Use In Submarine Applications

Joseph Szymborski

GNB Industrial Power

A Division of Exide Technologies



Los Angeles Class



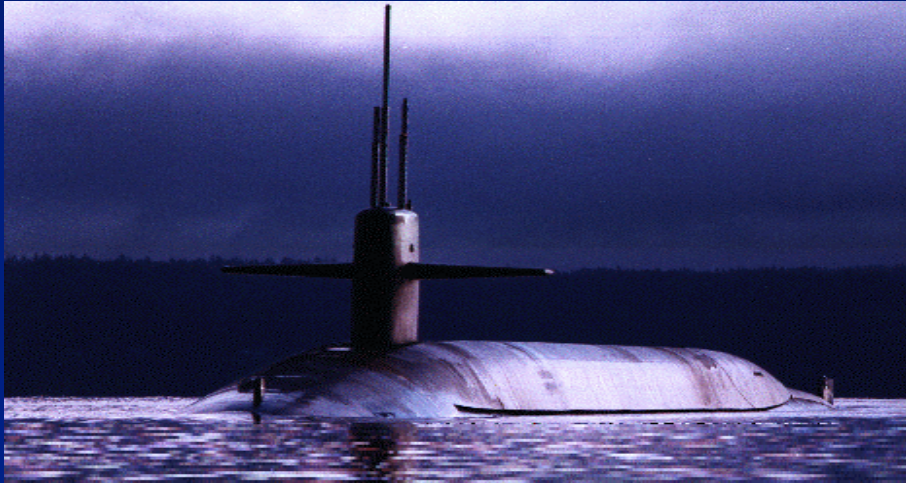
Ship Characteristics

Dimensions	Length - 362 ft
	Beam - 33 ft
Displacement	7,147 tons
Crew	13 Officers
	125 Enlisted

ASB Cell Characteristics

Size	55x14x14"
Mass	1,310 lbs
C/3 rate	2,400A
# Cells	126

Ohio Class



Ship Characteristics

Dimensions	Length - 560 ft
	Beam - 42 ft
Displacement	8,750 tons
Crew	15 Officers
	148 Enlisted

PDX Cell Characteristics

Size	45x20x23"
Mass	2,100 lbs
C/3 rate	3,450A
# Cells	128

Seawolf



Ship Characteristics

Dimensions	Length - 353 ft
	Beam - 40 ft
Displacement	9,150 tons
Crew	13 Officers 121 Enlisted



LLL Cell Characteristics

Size	41x19 x19"
Mass	1,515 lbs
C/3 rate	2,700A
# Cells	126

Virginia



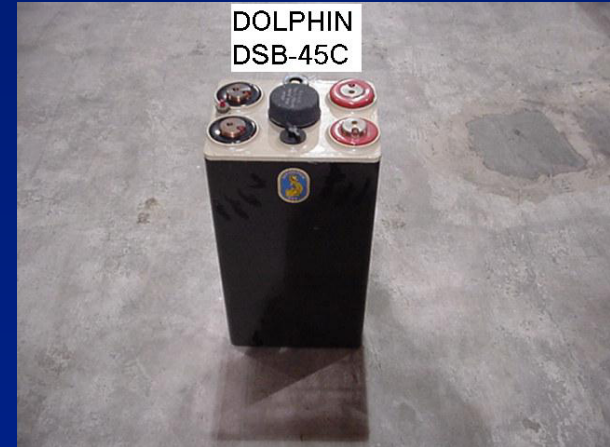
Ship Characteristics

Dimensions	Length - 377 ft
	Beam - 34 ft
Displacement	7,800 tons
Crew	14 Officers
	120 Enlisted

ASB Cell Characteristics

Size	55 x 14 x 14"
Mass	1,310 lbs
C/3 rate	2,400A
# Cells	126

Dolphin



Ship Characteristics

Dimensions	Length - 165 ft Beam - 18 ft
Displacement	950 tons
Crew	5 Officers 46 Enlisted 5 Scientists

DSB Cell Characteristics

Size	26 x 13 x 10"
Mass	339 lbs
C/3 rate	740A
# Cells	252 / 2 strings

Anatomy of the Submarine Battery

- Lead-Acid Electrochemistry
 - ⇒ Same As Automotive SLI, Fork Lifts and UPS
 - ⇒ Optimized For Standby (Float) Operation
- Flooded Electrolyte Designs
 - ⇒ Excess Free Liquid Sulfuric Acid
 - ⇒ Requires Air Agitation / D.I. Water Additions
 - ⇒ Maintenance: Cell Cleaning / S.G. Measurements
 - ⇒ Complicated Charge Procedures / Ventilation
- Constructed To Survive Severe Shock Conditions

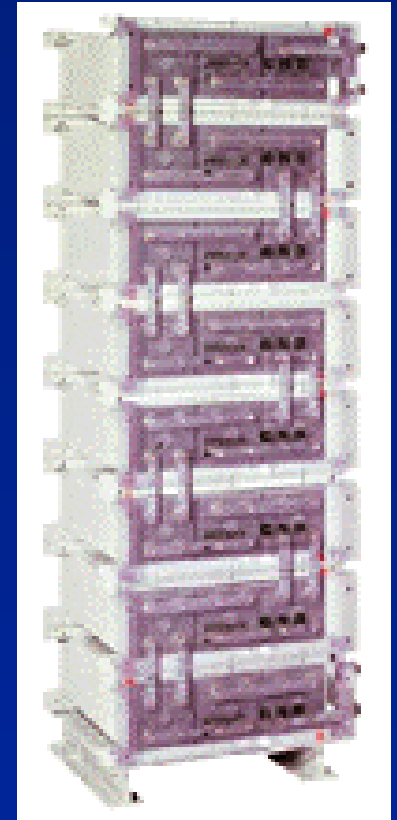
Commercial Direction



Flooded

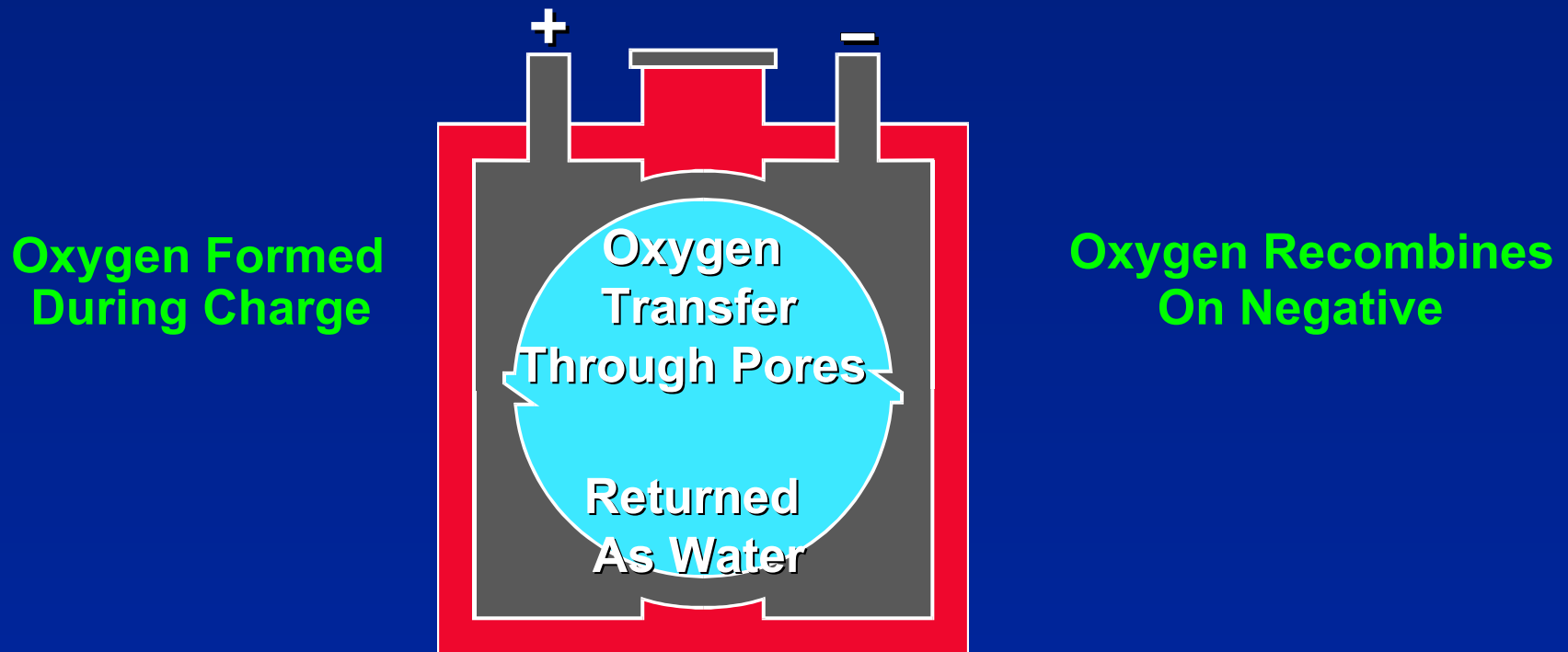


VRLA



VRLA – The Oxygen Cycle

Valve Regulated Lead-Acid Battery

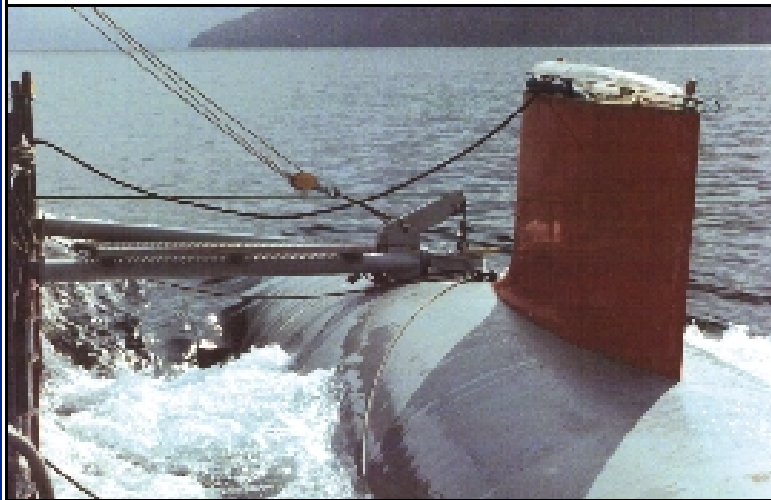


VRLA In A Submarine

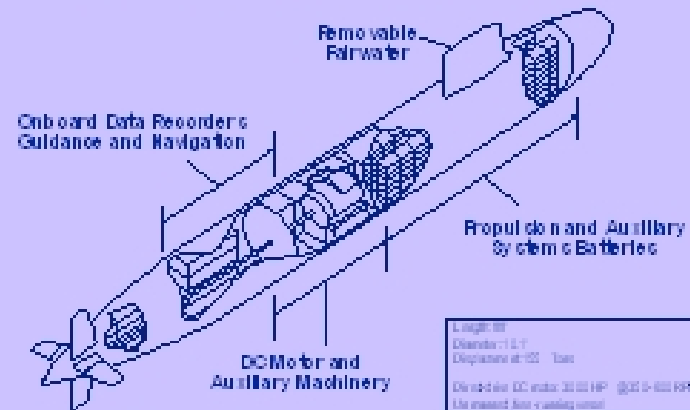


LSV1 - Kokanee

- **Quarter-scale R&D platform for:**
 - Propulsor acoustics
 - Hull appendages
 - Sail
 - Powering
 - Maneuvering
- **Full-scale speeds, depths**
- **Accurate, reproducible results**
- **Instrumented test range**



Large Scale Vehicle (KOKANEE)



VRLA On The LSV1



First Generation - LSV-153

Single Container with 153 Plates

2-Volts / 750Ah at 150A Rate

5 Kw / Cell - 7 Minutes Continuous

Cell: 22 x 6.5 x 9" / 130 lbs



Second Generation - 3LSV-1140

Adapted From Commercial Product

Three 2-V Modules In Parallel

Each = 225Ah at C/5 Rate

Module: 7.8 x 6.6 x 7" / 36 lbs

The Kokanee's Battery



Battery Compartment

- 480Cells In Series
- Tapped In Segments
- Max Power - 2.4MW
- 8-Hour Recharge
- 4-Year Lifetime
- > 400 Cycles (80% DOD)
- Minimal Maintenance
- Virtually No Hydrogen
- Easy Cell Replacement

LSV2 - Cutthroat



- LSV2 Cell - Enhanced LSV-1140
- 2-Volt / 250Ah at C/5 Rate
- Configuration: 4 Parallel Strings
- 420 Cells In Series - 840 Volts
- Total Battery 1,680 Cells
- 19 Minutes Run Time at 1kW / Cell
- 4 Year Lifetime
- > 400 Cycles To 80% DOD
- < 8-Hour Recharge
- Minimal Maintenance
- Virtually No Hydrogen Emissions

Navy ASDS



- GNB Champion VRLA Battery - Installed on new Advanced Seal Delivery System (ASDS) for use as the ASDS training battery
- Silver-zinc recently installed with plans for lithium ion polymer in the future



Cell Characteristics:

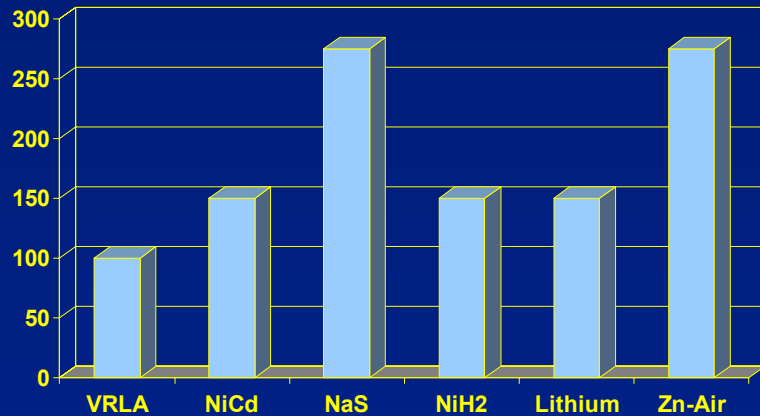
Ships Characteristics:

- Dimensions Length - 65 ft. / Beam - 6.75 ft.
- Displacement 55 tons
- Crew 2 + up to 16 passengers

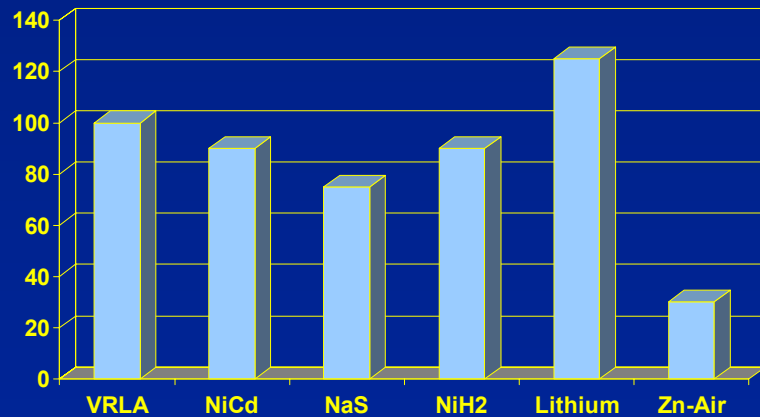
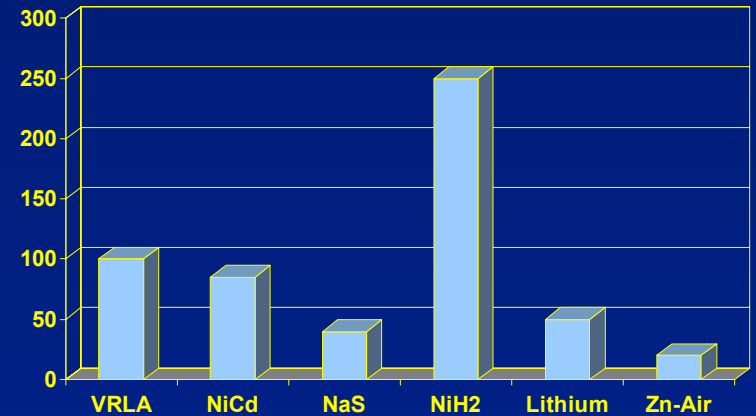
Type	Champion 12V / Group 27
Mass	65 lbs
C/3 rate	27A
Configuration	7 parallel strings; 22 cells/string

VRLA vs “Advanced” Technologies

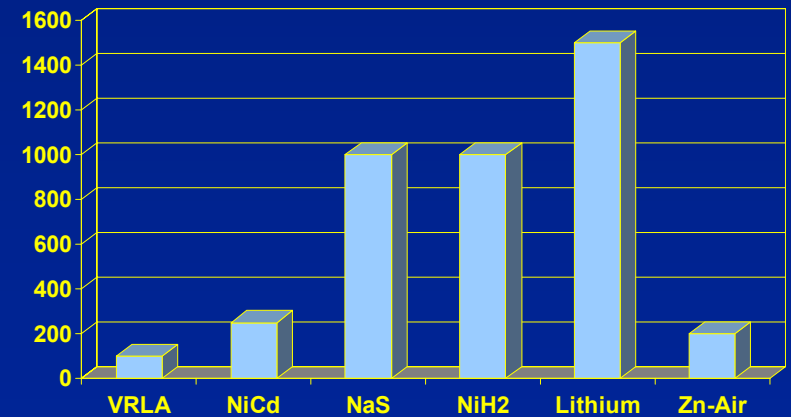
Energy Density



Cycle Life

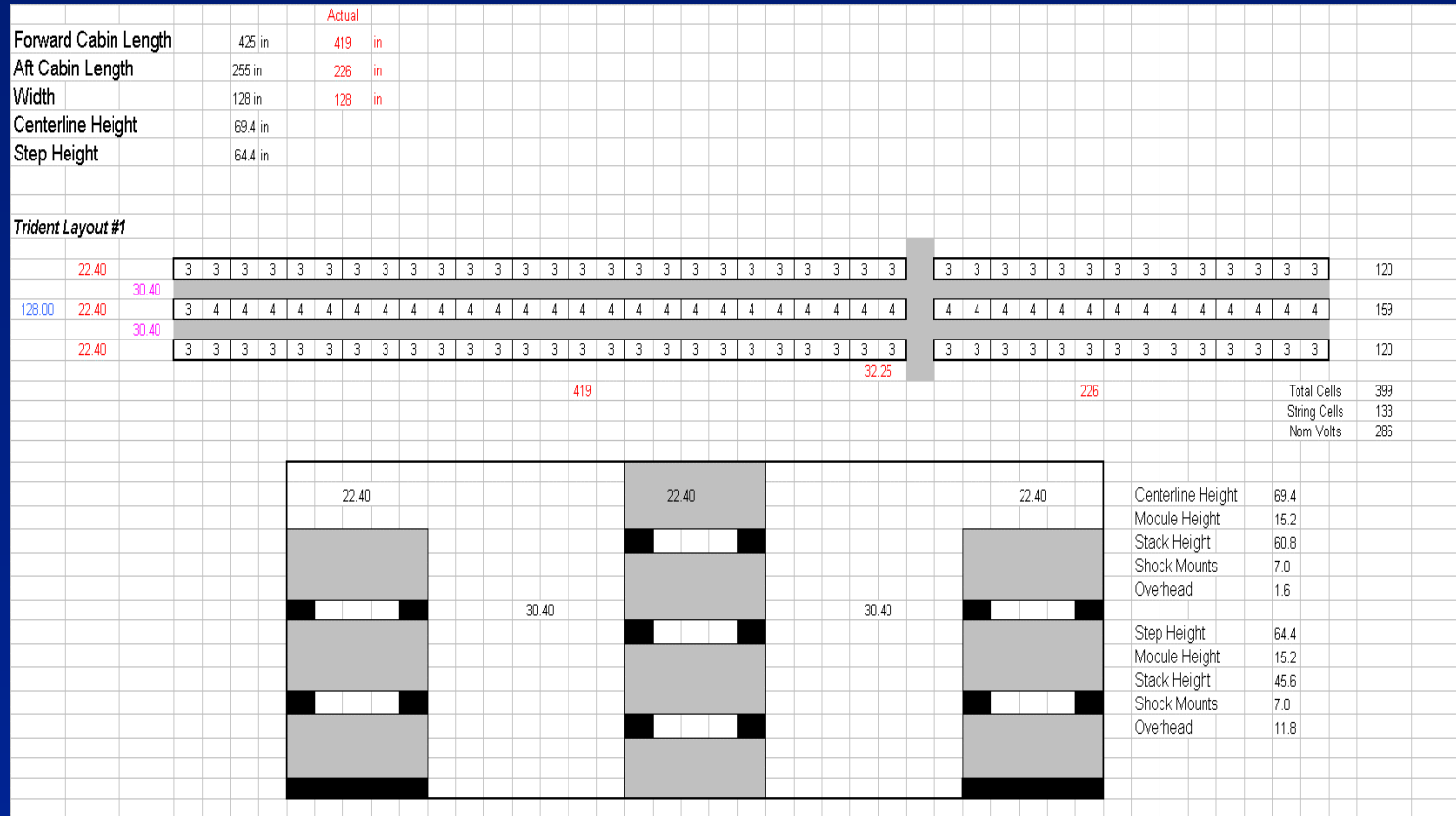


Power Density



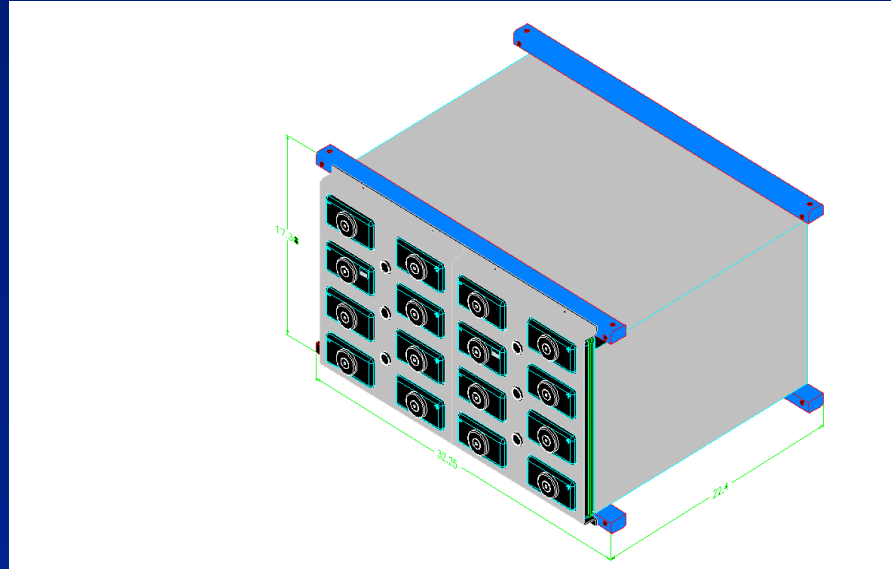
Cost

VRLA In Submarine's Future



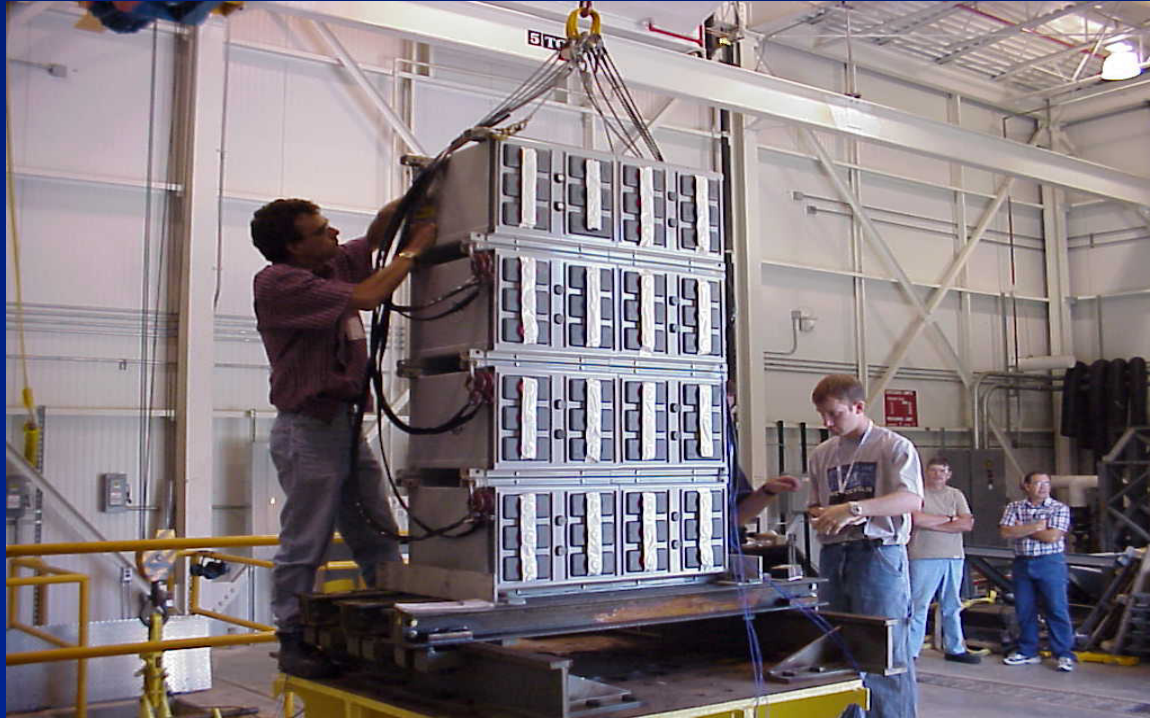
Fitment Analyses Completed

VRLA In Submarine's Future



Cell Designs Have Been Proposed
Prototypes Being Fabricated

VRLA In Submarine's Future



Commercial VRLA Cells Have
Been Shock Tested

VRLA In Submarine's Future



VRLA Installed At
Submarine Nuclear
Training Schools

VRLA and Submarines

- VRLA Engineering Program Underway
- VRLA Will Be Qualified For Submarines
- Fleet Will Be Converted To VRLA
- VRLA Will Serve The Fleet For Many Years Into The Future
- Advanced Technologies Need To Be Proven
 - ⇒ Scale-Up / Operation / Shock / Safety / Life

Acknowledgements

