STATUS OF NICKEL-HYDROGEN CELL TECHNOLOGY

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Nickel-hydrogen cell technology has been developed which solves the problems of thermal management, oxygen management, electrolyte management, and electrical and mechanical design peculiar to this new type of battery. This technology has been weight optimized for low orbit operation using computer modeling programs but is near optimum for other orbits. Cells ranging in capacity up to about 70 ampere-hours can be made from components of a single standard size and are available from two manufacturers. The knowledge gained is now being applied to the development of two extensions to the basic design: (1) a second set of larger standard components that will cover the capacity range up to 150 ampere-hours, and (2) the development of multicell common pressure vessel modules to reduce volume, cost and weight. A manufacturing technology program is planned to optimize the producibility of the cell design and reduce cost. Collectively these programs bring nickel-hydrogen cell technology to the point of diminishing returns with respect to improvements in weight and volume energy density and cost reduction obtainable from manipulation of the cell configuration. The most important areas for further improvement are life and reliability which are governed by electrode and separator technology.

AF NI/H2 BATTERY DEVELOPMENT APPROACH

EMPHASIS

- CELL DESIGN
- CELL TEST
- SPACE EXPERIMENT
- MANUFACTURING TECHNOLOGY
- STANDARD COMPONENTS SYSTEM

MODERATE EFFORT

- ELECTRODES
- SEPARATORS

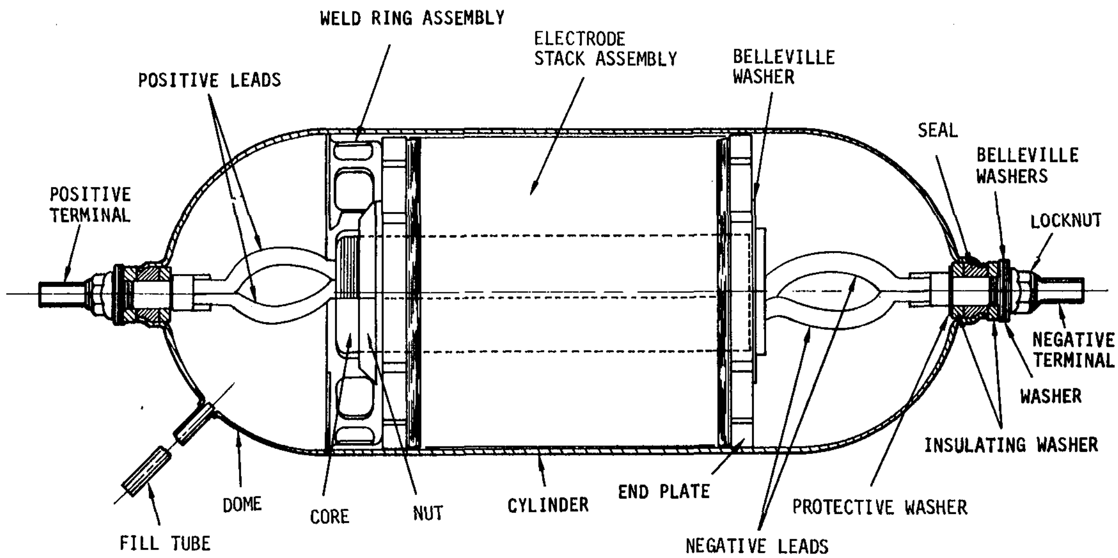
LITTLE EFFORT

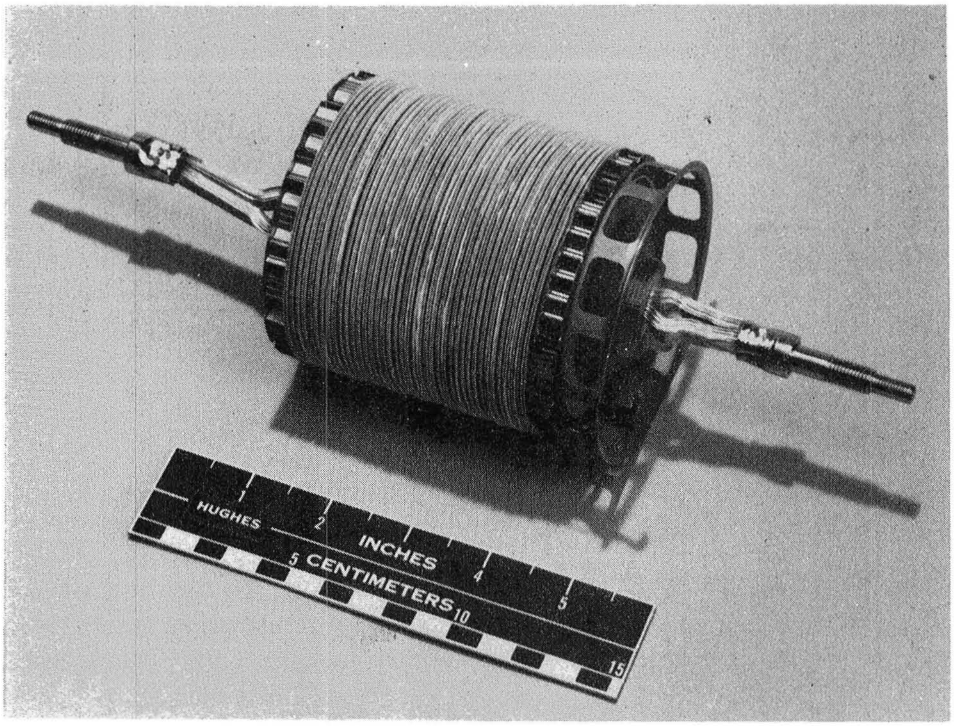
- BATTERY DESIGN
- CHARGE CONTROL

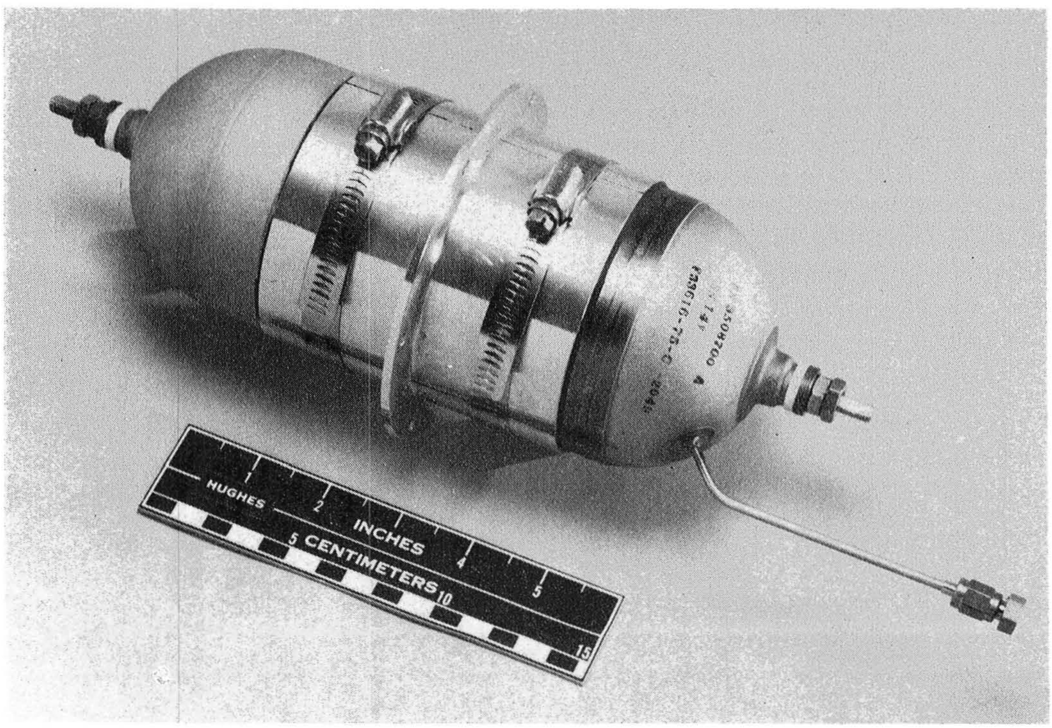
AF NI/H2 BATTERY DEVELOPMENT FEATURES

• ALL ORBIT CAPABILITY	- UP TO 80% DOD IN LOW ORBIT
• GOOD HEAT REJECTION IN ALL SIZES	- ANNULAR STACK GEOMETRY
• 0-150 AMPERE-HOURS	- TWO DIAMETERS, VARIABLE LENGTH
• OXYGEN MANAGEMENT	- OXYGEN RECIRCULATION STACK DESIGN
• ELECTROLYTE MANAGEMENT	- WICK RETURN TO STACK
• NO ELECTRODE SWELLING	- ELECTROCHEMICAL IMPREGNATION
• SHORT PROTECTION	- ETCHED FOIL NEGATIVE SUBSTRATE
• CHEMICAL & THERMAL STABILITY	- ZIRCONIUM-OXIDE CLOTH SEPARATOR
• SINGLE PRESSURE VESSEL WELD	- HYDROFORMED SHELLS, HYDRAULIC SEAL
• STANDARD COMPONENTS SYSTEM	- TWO CELL DIAMETERS, TWO CONFIGURATIONS

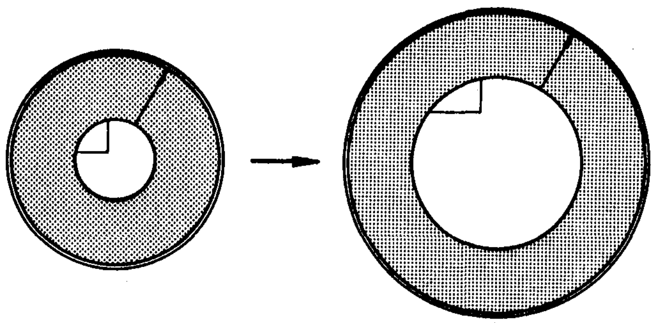
NI/H2 CELL SCHEMATIC




HUGHES
INCHES
CENTIMETERS

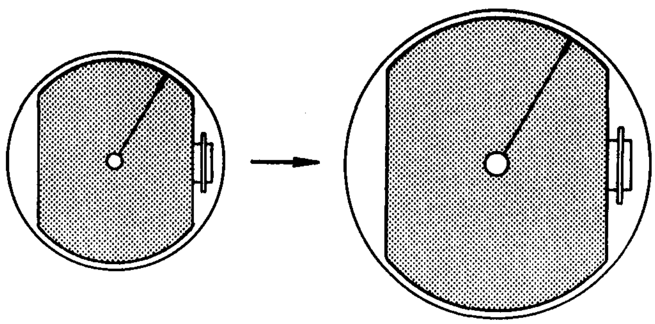

HUGHES
INCHES
CENTIMETERS

GOOD HEAT REJECTION IN ALL SIZES



ANNULAR ELECTRODE (CHOSEN)

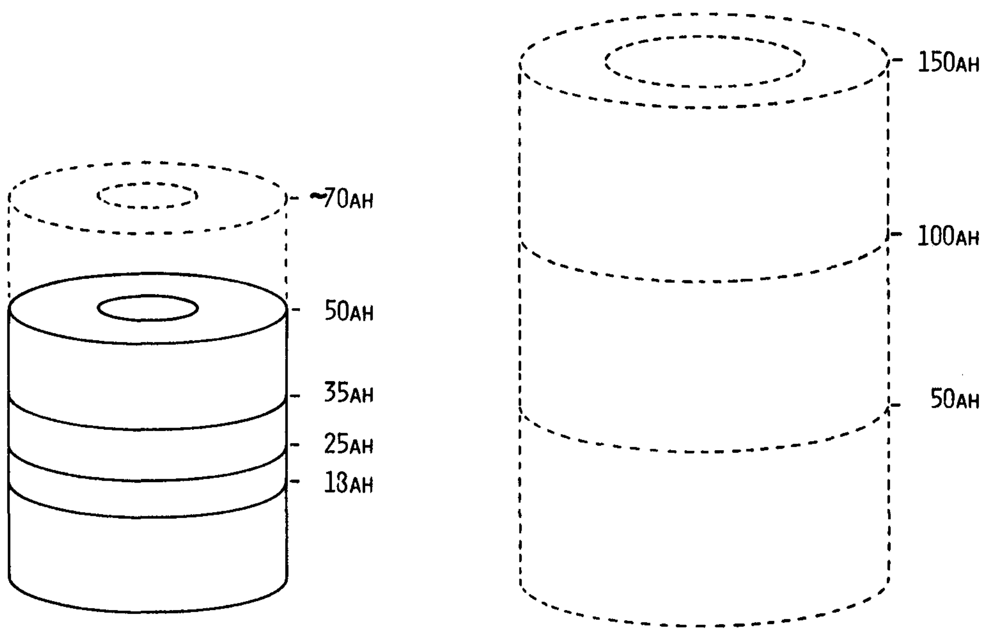
- SHORT HEAT TRANSFER PATH
- UNIFORM GAP TO PRESSURE VESSEL
- LARGER SIZES:
  - HEAT TRANSFER DISTANCE ~SAME
  - $\left[\frac{\text{WASTE HEAT}}{\text{HEAT TRANSFER AREA}}\right]$ STAYS SAME



TRUNCATED DISC ELECTRODE

- LONGER HEAT TRANSFER PATH
- CUTOUTS FOR TABS AND LEADS REDUCE HEAT TRANSFER
- LARGER SIZES:
  - HEAT TRANSFER DISTANCE INCREASES
  - $\left[\frac{\text{WASTE HEAT}}{\text{HEAT TRANSFER AREA}}\right]$ INCREASES

TWO STANDARD DIAMETERS - TWO CAPACITY RANGES



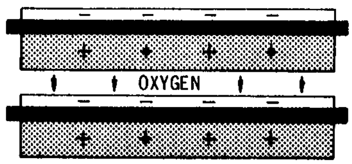
3.5 INCH DIAMETER

ALL CAPACITIES USE SAME COMPONENTS

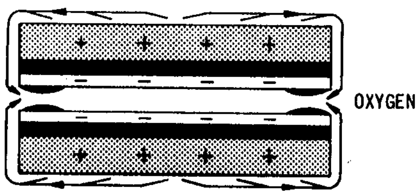
4.5 INCH DIAMETER

ALL CAPACITIES USE SAME COMPONENTS

OXYGEN MANAGEMENT



RECIRCULATION STACK



BACK-TO-BACK STACK

RECIRCULATION STACK (CHOSEN)

- SHORT OXYGEN PATH
- LARGE OXYGEN RECOMBINATION AREA
- RECOMBINATION HEAT AND WATER EVENLY DISTRIBUTED OVER NEGATIVE ELECTRODE

NEGATIVE ELECTRODE

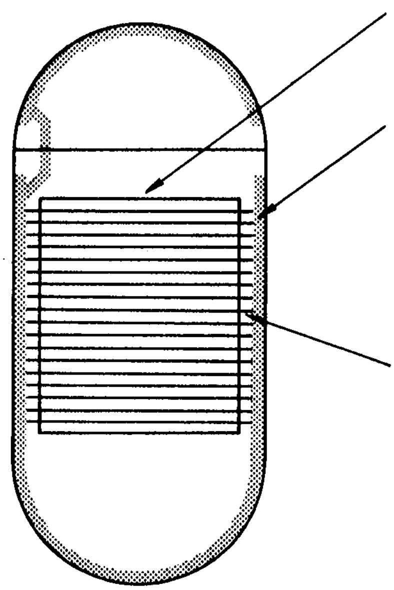
- TEFLON BACKING HIGHLY PERMEABLE TO OXYGEN

RELATED FACTORS

- RECIRCULATION STACK REQUIRES RECIRCULATION SYSTEM
- RECIRCULATION SYSTEM CONTRIBUTES TO ELECTROLYTE AND THERMAL MANAGEMENT

ELECTROLYTE MANAGEMENT SYSTEM

RECIRCULATION SYSTEM



RECIRCULATION STACK

- REQUIRES RECIRCULATION SYSTEM

WALL WICK

- ZIRCONIUM-OXIDE COATING ON INSIDE OF PRESSURE VESSEL
- EXCESS ELECTROLYTE PROVIDED
- MAINTAINS ELECTROLYTE BALANCE WITHIN STACK
- RETURNS ELECTROLYTE TO STACK

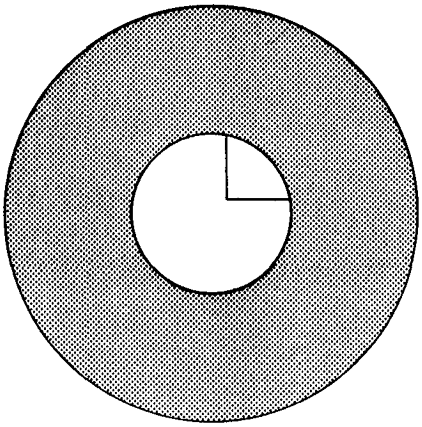
SEPARATORS

- DISTRIBUTE ELECTROLYTE BETWEEN WALL WICK AND ELECTRODES

RELATED FACTORS

- RECIRCULATION SYSTEM CONTRIBUTES TO THERMAL MANAGEMENT

POSITIVE ELECTRODE



ELECTROCHEMICAL IMPREGNATION

- DIMENSIONAL STABILITY
- BETTER UTILIZATION OF ACTIVE MATERIAL
- LONGER LIFE
- LOWER COST WHEN PRODUCTION IS ESTABLISHED

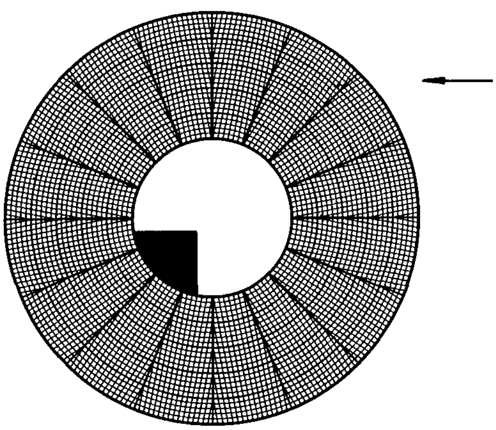
NICKEL SCREEN SUBSTRATE

- COLD WELDED TO ELIMINATE LOOSE WIRES

EDGE PROTECTION

- COINED BOTH SIDES
- POLYSULFONE COATED

NEGATIVE ELECTRODE



TYPE

- TEFLON BONDED - PLATINUM CATALYST

PHOTOCHEMICALLY ETCHED NICKEL FOIL SUBSTRATE

- DIMENSIONALLY STABLE
- NO LOOSE WIRES TO CAUSE SHORT CIRCUITS
- LOWER VOLTAGE DROP
- BETTER TAB WELDS

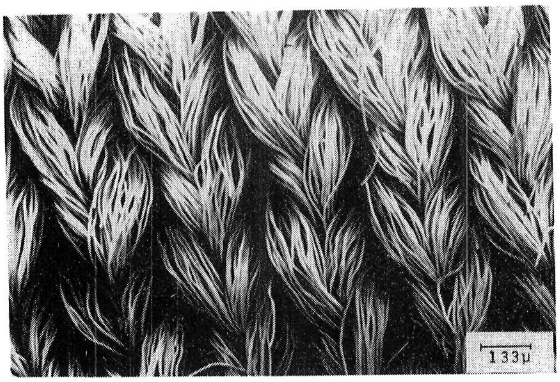
PROBLEM

- OCCASIONAL FLOODING

POTENTIAL SOLUTIONS

- WASH OUT RESIDUAL WETTING AGENTS
- CHANGE SINTERING TEMPERATURE
- CHANGE TEFLON CONTENT
- CHANGE PORE SIZE OF TEFLON BACKING

SEPARATOR



ZIRCONIUM-OXIDE CLOTH

- THERMALLY STABLE
- CHEMICALLY STABLE
- INTRINSICALLY WETTABLE
- DUAL POROSITY AIDS ELECTROLYTE MANAGEMENT
  - FIBER BUNDLES HOLD ELECTROLYTE TIGHTLY
  - VOIDS PROVIDE RESERVOIR ACTION

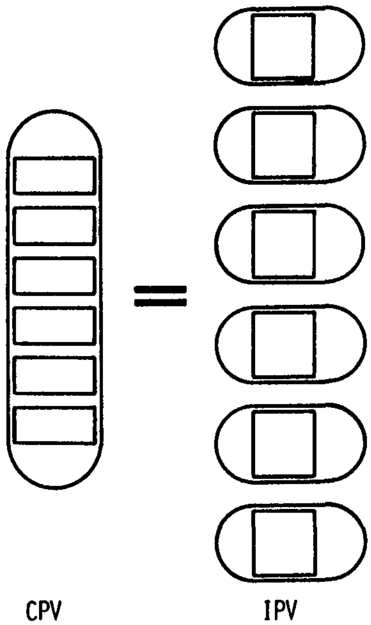
PROBLEM

- ON OVERCHARGE - OXYGEN PASSING THROUGH SEPARATOR AND RECOMBINING ON NEGATIVE CAN CAUSE LOCAL HOTSPOTS THAT CAN MELT PINHOLES IN NEGATIVE

POTENTIAL SOLUTION

- REDUCE OXYGEN PERMEABILITY WITH COATING

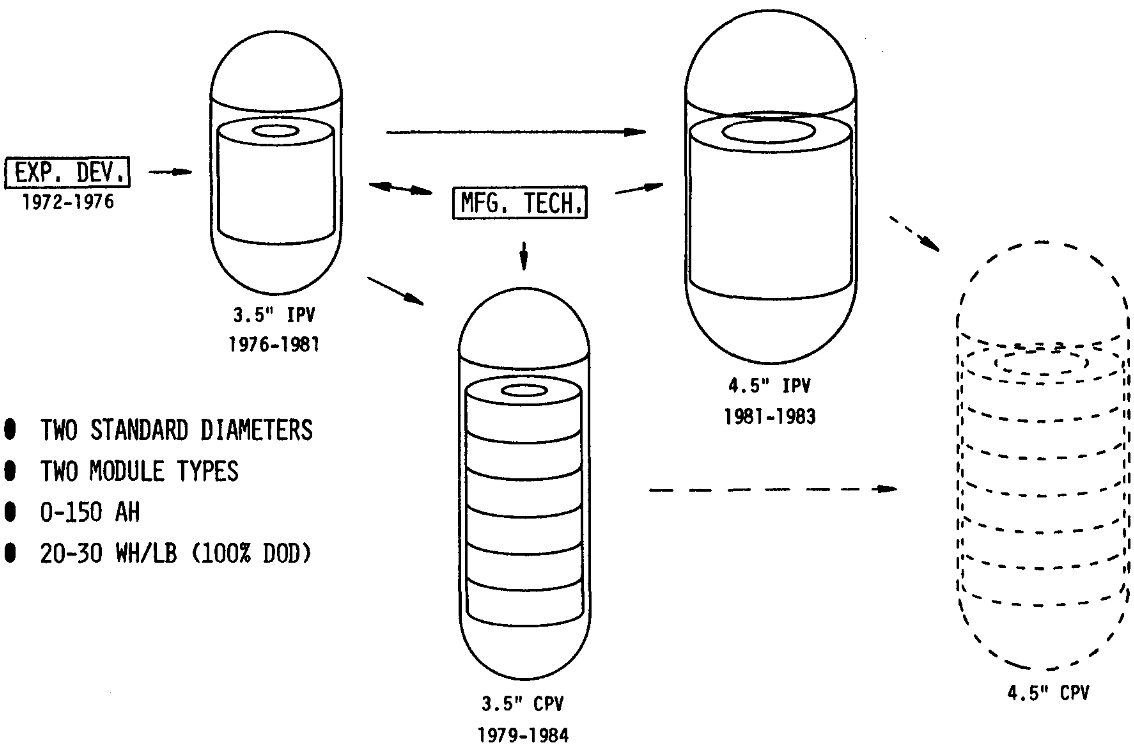
COMMON PRESSURE VESSEL NI/H2 BATTERY



ADVANTAGES:
- 40% VOLUME REDUCTION
- 30% COST REDUCTION
- 20% WEIGHT REDUCTION

PROBLEMS:
- ELECTROLYTE BRIDGING BETWEEN CELLS
- INTERCELL CONNECTIONS
- INTERCELL VAPOR TRANSFER

NI/H2 BATTERY STANDARD COMPONENTS SYSTEM



- TWO STANDARD DIAMETERS
- TWO MODULE TYPES
- 0-150 AH
- 20-30 WH/LB (100% DOD)

FURTHER DEVELOPMENT REQUIRED

SEPARATOR

- REDUCE OXYGEN PERMEABILITY

NEGATIVE ELECTRODE

- ELIMINATE FLOODING
- REDUCE PLATINUM CONTENT

POSITIVE ELECTRODE

- TECHNOLOGY IMPROVEMENT
- DEVELOP ACCELERATED SCREENING TESTS

PRESSURE VESSEL

- RELOCATE TERMINALS TO REDUCE VOLUME 30%
- REDUCE COST OF GIRTH WELD

BATTERY DESIGN (WITH CELL REDUNDANCY)

CHARGE CONTROL

CELL AND BATTERY LIFE TESTING