JOHNSON CONTROLS, INCORPORATED

Johnson Controls, Inc
$6 Billion in Sales
FY 1993

- Automotive Systems Group
- Battery Group
  $670 Million
- Controls Group
- Plastics Technology Group
TRUE BIPOLAR BATTERY DEVELOPMENT
WPAFB CONTRACT

• GOALS:

Develop a Composite Bipolar Substrate Material with the Following Characteristics:

Resistivity: < 2Ω -cm
Thicknes: < 0.064 cm
Weight: < 150 mg/cm
Area: > 400 cm²

The 270 Volt Battery will be Designed to be used in the More Electric Aircraft Program
TRUE BIPOLAR BATTERY DEVELOPMENT
WPAFB CONTRACT

- VALUE:

  Contract Total 1,013.4M
  Spending To Date 636.4M
  Funding For FY'94 377.0M

10% Cost Share to JCBGI
TRUE BIPOLAR BATTERY DEVELOPMENT
WPAFB CONTRACT

• APPROACHES:

Compound Stable Conductive Filler(s) into Plastic or Thermosets to Produce Non-Porous Highly Conductive, Lightweight Substrate Material

Use Compounding Additives Which Enhance Conductivity, and Manufacturability While Eliminating Porosity
TRUE BIPOLAR BATTERY DEVELOPMENT
WPAFB CONTRACT

- PROGRESS:

Conductive Filler Stability Proven
Conductive Filler Supplier Qualified
Composition of Substrate Identified
Project Substrate Thickness of 0.010-0.015"
Numerous Batteries Tested To Date
TRUE BIPOLAR BATTERY DEVELOPMENT

WPAFB CONTRACT

NEXT STEPS:

- Improved Containment Design Trial
- Improve Present Manufacturing Techniques - Mass Production
- Produce Lighter, Thinner, More Conductive Substrate
- Test for SLI, EV Applications
## JCBGI LABBM
### 300 Volt Bipolar Battery System
#### ELA Program

<table>
<thead>
<tr>
<th>Battery Parameter</th>
<th>Design Specs</th>
<th>WPAFB Goals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Substrate Thickness</td>
<td>0.015&quot;</td>
<td>0.025&quot;</td>
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<tr>
<td>Substrate Resistivity</td>
<td>2Ω -cm</td>
<td>2Ω -cm</td>
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<tr>
<td>Substrate Weight/Area</td>
<td>150 mg/cm²</td>
<td>150 mg/cm²</td>
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<tr>
<td>Substrate Area</td>
<td>1200 cm²</td>
<td>400 cm²</td>
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</tbody>
</table>
ELA Current Profile
30 amp Base Load, 200 amp Pulse for 0.2 Seconds
ELA Current Profile

20 amp Background, 310 amp 1.5 second Spikes

Discharge Current (amps)

Time (seconds)

1993 NASA Aerospace Battery Workshop
Advanced Technologies Session
<table>
<thead>
<tr>
<th>Battery System 1 Parameters</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Battery Size</td>
<td>15&quot; x 15&quot; x 9&quot;</td>
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<tr>
<td>Weight</td>
<td>228 pounds</td>
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<tr>
<td>Number of Cells</td>
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</tr>
<tr>
<td>OCV</td>
<td>300 Volts</td>
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<tr>
<td>Cell Thickness</td>
<td>0.063&quot;</td>
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</table>
JCBGI Bipolar Lead/Acid
300 Volt Battery System 1
ELA Program

TOP VIEW

END BLOCKS

VENTS/PORTS

15.0"

END VIEW

TERMINAL PAD

15.0"

SIDE VIEW

ENCASEMENT

15.0"

9.0"

1993 NASA Aerospace Battery Workshop -767- Advanced Technologies Session
ELA Current Profile

30 amp Base Load, 400 amp Pulse for 0.2 Seconds

Current (amps)

Time (seconds)

0 0 60 120 180 240 300 360 420 480 540 600

450 400 350 300 250 200 150 100 50 0
**JCBGI LABBM**  
**300 Volt Bipolar Battery System**  
**ELA Program**

**Battery System 2 Parameters**

<table>
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<tr>
<th>Parameter</th>
<th>Value</th>
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<tr>
<td>Battery Size</td>
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<td>Number of Cells</td>
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<tr>
<td>OCV</td>
<td>300 Volts</td>
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<tr>
<td>Cell Thickness</td>
<td>0.061&quot;</td>
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</table>
JCBGI Bipolar Lead/Acid
300 Volt Battery System 2
ELA Program

TOP VIEW

END BLOCKS

VENTS/PORTS

16.8"

END VIEW

TERMINAL PAD

16.8"

SIDE VIEW

ENCASEMENT

8.7"

1993 NASA Aerospace Battery Workshop -771- Advanced Technologies Session