Hybrid-Electric Drive Systems for Heavy Duty Vehicles

ISE Corporation

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CARB CONFIRMS ISE DRIVE SYSTEM’S LOW EMISSIONS

TRANSPORTATION FOR A CLEAN PLANET

NOx Emissions

PM Emissions

Standard diesel bus

LPG hybrid bus

Standard CNG bus

Leading diesel hybrids

ISE gasoline hybrid bus

Standard CNG bus

Leading diesel hybrids

ISE gasoline hybrid bus

LPG hybrid bus
ENERGY FLOW
TRANSPORTATION FOR A CLEAN PLANET
VEHICLE SUBSYSTEMS AND COMPONENTS

TRANSPORTATION FOR A CLEAN PLANET

Motive Drive System

Vehicle Control
(SAE CAN J1939)

Energy Storage

Accessory Systems

Vehicle APU
Gasoline Hybrid Cradle Assembly
### ENERGY STORAGE SUBSYSTEM

#### ZEBRA Battery Pack
- 20kWh Usable Energy
- 34kW Charge and Discharge Power/Module
- Integrated BMS, GFI, Contactors
- 100 WH/kg
- -40°C to 50°C with only fan cooling
- Expected life 2.5-5 years
- Weight 200kg/pack
- Recycling Program in place

#### ThunderVolt II™ Ultracapacitor Pack
- 200 kW Usage/Discharge Current
- Total Energy Stored: 0.407kWh
- Peak Voltage: 403V
- Rated Current: 400A
- -35°C to 65°C Operating Temperature
- Optional Fire System
REMOTE DIAGNOSTIC UNIT (RDU) & VEHICLE OPERATIONS CENTER

TRANSPORTATION FOR A CLEAN PLANET

• **RDU**
  - Wireless link from vehicle allows real time data access via internet
  - Customer can monitor operation and troubleshoot issues remotely
  - Component suppliers can have their experts help troubleshoot remotely
  - 80211 (Wireless Ethernet) allows high data rate transmission upon return to yard
  - ISE will keep database of all vehicle data which customer can access as required

• **Vehicle Operations Center**
  - First two to be installed at AC Transit and SunLine Transit
ISE HYBRIDS ARE DESIGNED TO REDUCE EMISSIONS

TRANSPORTATION FOR A CLEAN PLANET

- Ford ULEV-rated engine
- Runs on standard gasoline
- Siemens electric drive
- 40’ New Flyer bus
- In service at Omnitrans
- Fleet Model Bus in Altoona Test
HIGH EFFICIENCY, ZERO EMISSION FUEL CELL BUS

ThunderPower Joint Venture with Thor Industries
Equipped with UTC Fuel Cells 60kW PEM fuel cell
Fuel Cell Subsystem Operates at Over 50% Net Efficiency
Battery Hybrid Drive System Improves Efficiency ~25%
Achieves 7-11 MPG (9.8MPEG Average in Palm Springs Service)
First Fuel Cell Bus in Revenue Service in California
AC TRANSIT & SUNLINE TRANSIT FUEL CELL BUSES

- Custom Fuel Cell Bus Chassis Produced by Van Hool
- Powered by 120kW UTC PEM Fuel Cell
- Uses ISE-Siemens Hybrid Drive System
  - Siemens 170kW Motors and Inverters, DC-DC Converter
  - Three Zebra NaNiCl Battery Packs
  - Fab Industries/SCI Hydrogen Fuel System
  - ISE Controls, Accessories, Thermal Control Systems
- Demonstration of Three Buses at AC Transit and One at SunLine Transit Scheduled to Begin in Early 05
HYDROGEN ICE HYBRID BUS CONFIGURATION

- Ford V10 H2 Engine
- Control System
- Energy Storage
- Accessories
- Inverter
- Drive Motor
- Generator
# Comparing Emissions from Conventional and Hybrid Buses

<table>
<thead>
<tr>
<th>DRIVE / EMISSIONS</th>
<th>NOx (g/mi)</th>
<th>PM (g/mi)</th>
<th>CO2 (g/mi)</th>
<th>EFFICIENCY</th>
<th>AVERAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional Diesel</td>
<td>30</td>
<td>0.25</td>
<td>2500</td>
<td>33-35%</td>
<td>Poor</td>
</tr>
<tr>
<td>Conventional CNG</td>
<td>15</td>
<td>0.02</td>
<td>2400</td>
<td>26-28%</td>
<td>Poor</td>
</tr>
<tr>
<td>Hybrid Diesel</td>
<td>15</td>
<td>0.02</td>
<td>2400</td>
<td>40-42%</td>
<td>Good</td>
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<tr>
<td>Hybrid CNG</td>
<td>1</td>
<td>0.001</td>
<td>2300</td>
<td>31-33%</td>
<td>Very Good</td>
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<tr>
<td>Hybrid Gasoline</td>
<td>0.5</td>
<td>0</td>
<td>2300</td>
<td>33-35%</td>
<td>Very Good</td>
</tr>
<tr>
<td>Hybrid Hydrogen ICE</td>
<td>0.5</td>
<td>0</td>
<td>0</td>
<td>40-42%</td>
<td>Excellent</td>
</tr>
<tr>
<td>Conventional Fuel Cell</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>45-55%</td>
<td>Excellent</td>
</tr>
<tr>
<td>Hybrid Fuel Cell</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>50-60%</td>
<td>Excellent</td>
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</tbody>
</table>
HYDROGEN FUELED GOAL:

ZERO EMISSIONS
TRANSPORTATION
POWERED BY CLEAN
RENEWABLE ENERGY