Hybrid Electric Utility Truck

- Class 6-7
- 24,000-33,000 GVW
- Engine DT466, 225 hp
- Automated Manual Transmission
- Battery-electric, 44 kW electric motor
- Engine-off PTO operations
- 25 kW / 5 kW export power

International-Eaton
North American Deployment & Assessment

24 Truck Deployment Locations

14 Fleets

AEP
Alabama Power
Baltimore Gas & Electric
Duke Energy
Entergy
Exelon
Florida Power and Light
Georgia Power
Hydro Quebec
Missouri Dept. of Trans.
PG&E
Pepco/PHI
Southern Calif Edison
TXU
Field Deployment Status

- All 24 trucks delivered to fleets
- 23 in field; 1 truck in fleet controlled testing
- Staggered deployment but 12 trucks have been in use over 1 year
- Standard comparison units in same locations
- 25 kW APG – installed in field; some units with 5 kW APG
Field Testing – Key Findings

Key Findings

• Reliability greatly improving
• Availability very high (99%)
• Users finding truck meets needs
• Fuel consumption improvements measured up to 54%
• Reduced noise
• Duty cycle is very important
• Best place in urban setting with high PTO use

• Reliability/Availability
• User acceptance
• Performance data
• Maintenance data

• 24 HEV
• 20 Baseline Trucks
• 12+ Months
• 14 Fleets
Utility Truck Operations

Daily Average Operation Parameters

<table>
<thead>
<tr>
<th></th>
<th>HEV</th>
<th>Base</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation Hrs</td>
<td>7 h</td>
<td>7 h</td>
</tr>
<tr>
<td>Boom, Hrs</td>
<td>0.5 h</td>
<td>1.8 h</td>
</tr>
<tr>
<td>Mileage</td>
<td>70 mi</td>
<td>80 mi</td>
</tr>
</tbody>
</table>

Application has lower boom hours than expected. Observing lots of idle time (measurement needs to be improved).
- Overall savings as high as 54%
- Total Gallons over Total Operation hours, capturing engine ON and OFF operation
- Dependant on duty cycle!

Decrease 2.1 to 1.4 gal/h totals fuel saving from 14.7 - 9.8 gallons, or 34%
Lab Testing savings from 12.5 – 7.5 gallons, or 40%
1. -27% driving MPG improvement of HEV

Testing data, 26%

The trucks drive daily ~70 miles and use 80% of fuel for driving.
Truck Availability

• What is Availability?
  – Industry measure of vehicle being available for revenue service
  – HEV Availability = Time vehicle is available for service. Hybrid system not preventing truck from being used.

• HEV Availability through August ’07: 99.26 %
• 23 of 24 units eligible for reporting – in full service for more than 1 month (1 in fleet controlled testing)
• 391 Truck Months (Aug ’07)
• 409,352 Miles Driven to date (Aug ’07)
Availability of HEV System
All Units

Majority of trucks show high availability!

Cumulative Availability (%)

Mission Ending Failures (MEFs): 4
Hybrid MEFs:
08/11/06 Unit 8 - Motor assembly issue (prototype process)
09/04/06 Unit 15 - Failed HCM analog input
10/02/06 Unit 13 - PEC, failed solder joint (prototype process)
10/16/06 Unit 2 - Poor 12V ground in hybrid system (prototype process)

Current HEV Availability is 99.26%
23 trucks reporting
No MEF for August

First three units placed in service 04-30-06
Availability HEV- Case A

HTUF Field Trial: 23 Truck Months (as of 8/31/07)

- Current HEV Availability: 95.5%
- Mission Ending Failures (MEFs): 1
  - 8/10/06 - Truck #8 - Motor Failure
  - Root Cause: Motor assembly issue (prototype process)
- Two units placed in service 07-19-06. Units 8 & 9.
Unit 12 was officially put into service 08/01/06. The truck was available for work 09/01/06.

Current HEV Availability 91.8%

Mission Ending Failures (MEFs): 0
What is Reliability?

- Component / System Reliability
- Failures result in reduced reliability
- Loss of Functionality results in reduced reliability
- Tracked for production
Service Issues by Type

130 Total Field Issues Logged (May ‘06 - August ‘07)

- 56 Chassis
- 47 Hybrid
- 27 Body

Courtesy Eaton & International
Issues Steadily Decreasing

- Pilot issues folded into learnings
- Improvements incorporated into production release
Vehicle Issues Per Truck

One issue per field test truck every two years!
Initial User Surveys (’06)

5 - much better
4 - somewhat better
3 - same
2 - somewhat worse
1 - much worse

• Comparative survey HEV to baselines
• 18 surveys collected
• Some baselines units have higher hp
• Most ratings better than baseline
• Goal was equal to or better than baseline
Surveys – Year Later (’07)

- Results from 8 operator surveys
- Operators not always same

5 - much better
4 - somewhat better
3 - same
2 - somewhat worse
1 - much worse

Chart showing mean values for various survey questions:
- Launch
- Braking
- Maneuver
- Acceleration
- Deceleration
- Grade Pull
- Shift Quality
- Boom
- Tool Circulation
- Noise in
- Noise out

Mean Value Scale: 0.0 to 5.0
New Hybrid Features Rated “Very Good”

Initial Survey ‘06
• 1 – 5 score
• New hybrid features rated “Very Good”

Year Later ‘07
Conclusions

- Number of issues decreased over time – great learning experience!
- HEV availability very high – 99%
- Truck are in applications which have lower than expected boom and PTO hours
- Majority of fuel used for driving ~80%
- HEV’s showed fuel savings up to 54%
- Benefits in MPG for driving only range from 1-27% likely varying with driving duty cycle (speed, terrain, etc)
- Noise reduction benefits rated high
Future Plans

- Continue data collection and validation
- Fleets considering placing trucks in service with higher boom and PTO hours & urban settings with lower mileage
- Duty cycle is very important – greater benefits when truck is in appropriate application
- Continue closer investigation of idle reduction opportunities
Team Effort!

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