IET Evening Lecture:
Battery trains and fast charging
Trial of Battery Electric Trains on Greenford Branch
16th April 2024
Julian Fletcher, Technology Development Manager (Fast Charge Battery Train Trial)
Agenda

- Personal background and project history
- The train
- The Fast Charge project
- Where are we now?
- What next?
- Q&A
Some personal background
Brief history of the Class 230 project
Brief history of the Class 230 project

D78 stock
London Underground

Diesel electric
Prototype

Diesel electric
West Midlands Trains

Diesel battery hybrid
Transport for Wales

Battery (2nd gen + Fast Charge)
GWR Greenford branch trial

Battery (2nd gen)
COP26 / GWR

Battery (1st gen)
USA export

3rd rail electric
Isle of Wight
The key ingredients

Train

People

Charging system
# The Train: mass

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tare mass</td>
<td>95 t</td>
<td>COP26 configuration – any changes considered negligible. Approx 8 tonnes (8.5%) more than diesel</td>
</tr>
<tr>
<td>Fully seated mass</td>
<td>105 t</td>
<td>138 seats.</td>
</tr>
<tr>
<td>Crush loaded mass</td>
<td>135 t</td>
<td>138 seats + 62 m² standing area.</td>
</tr>
</tbody>
</table>
The train: interior

![Train exterior](image1)

![Train interior](image2)

![Passengers](image3)

![Train interior](image4)
The Train: under its own power at COP26
Greenford branch Fast Charge Battery Train trial
Fast Charge: system overview

DNO connection
3 phase, 400V, 63A

Fast Charge Battery Bank (FCBB)
430kWh, 760V

Battery train

Shoegear
700kW trial
1.8MW max (per train)

GWR
Fast Charge: How it works

“station confirmation”

“lower the shoes”

“initiate fast charge”
Automatic charging a.k.a. “Fast Charging”

- Innovative cooling concept
- Air - cooling inside container
- Water cooling / heating on system level
- Highest power and energy density
Fire safety: traction batteries

External abuse conditions
- External heating
- Over-charging
- Over-discharging
- High current charging
- Structural damage
- Crush
- External short circuit

Causing or energizing internal events or exothermic reactions
- Lithium plating
- Internal short circuit
- Electrode-electrolyte reactions
- Decomposition
- Electrochemical reactions

If heating rate exceeds dissipation rate

Thermal runaway
- Leak
- Smoke
- Gas venting
- Flames
- Explosion

Data source: National Renewable Energy Laboratory and Warwick Manufacturing Group
Fast Charge system - Fast Charge Battery Banks
Fire safety: Fast Charge Battery Banks

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Fast Charge system – shoegear
Fast Charge system - shoegeear /charge rails
Fast Charge system - shoegeear /charge rails
Energy simulations
Energy simulations – typical outputs
Energy simulation: round trip consumption (typical)

Greenford branch

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Round trip distance</td>
<td>7.8 km</td>
</tr>
<tr>
<td>Round trip energy consumption</td>
<td>40 kWh</td>
</tr>
<tr>
<td>Fast Charging time required</td>
<td>3:56</td>
</tr>
<tr>
<td></td>
<td>(of 4:00)</td>
</tr>
</tbody>
</table>
Energy simulation – getting to Reading depot (ECS), typical

<table>
<thead>
<tr>
<th>West Ealing FCBB to Reading TMD</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Single trip distance</td>
<td>49 km</td>
</tr>
<tr>
<td>Single trip energy consumption</td>
<td>125 kWh</td>
</tr>
<tr>
<td>Depot charging time required</td>
<td>3 – 4 hours</td>
</tr>
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</table>
How far will it go?

Class 230 running non-stop at 60 mph on a flat route with no passengers or heating

...with heating on full
...limited to 40 mph
...stopping every 20 km
...stopping every 5 km
...up a 1:150 gradient
...stopping every 20 km up a 1:150 gradient
...stopping every 5 km up a 1:150 gradient
...up a 1:70 gradient
...stopping every 20 km up a 1:70 gradient
...stopping every 5 km up a 1:70 gradient

Greenford branch range

Range (Crush Loaded) [km]  Range [km]
Where are we now: main line testing
Where are we now: Routine Fast Charging
Full timetable operation, passenger carrying
Ongoing evaluation
Data – based deliverables
Cost of ownership


Battery case added by GWR Fast Charge Battery Train Team.

- Diesel
- Fuel cell hydrogen (FCH)
- Catenary electrified
- Battery electrified with Fast Charge
Embodied carbon: COP26 configuration

COP26 config: 255 tonnes total embodied carbon

Total Embedded Carbon COP26 Class 230.

- Gas: 25%
- Aluminium: General: 14%
- Materials: 52%
- Steel: Stainless: 3%
- Steel: General - UK (EU) Average Recycled Content: 4%
- Copper: Reused copper: 1%
- Li-On Battery: 28%
- Plastics: general: 2%
- Electricity: 2%
- Fleet Vehicles: 7%
- Travel: 10%
- Waste: 1%
Cumulative emissions

Year          | DMU tonnes CO2e cumulative | BEMU CO2e tonnes cumulative
---            |----------------------------|-----------------------------
2025          | 300                        | 200                         |
2026          | 500                        | 300                         |
2027          | 1000                       | 500                         |
2028          | 1500                       | 1000                        |
2029          | 2000                       | 1500                        |
2030          | 2500                       | 2000                        |
2031          | 3000                       | 2500                        |
2032          | 3500                       | 3000                        |
2033          | 4000                       | 3500                        |
2034          | 4500                       | 4000                        |

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Year       | CO2e/kWh  | JF projection
---         |-----------|----------------
2005       | 600       |                
2010       | 500       |                
2015       | 400       |                
2020       | 300       |                
2025       | 200       |                
2030       | 100       |                
2035       | 50        |                
2040       | 10        |                
2045       | 0         |                

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GWR
FAQs

“Everything you always wanted to know about Fast Charge battery trains*

*But were afraid to ask”
Thank you