Objective of FERRMED Freight Locomotive Concept Study

To define the minimum parameters that the EU locomotives should have to fulfill the FERRMED Standards, particularly for hauling long and heavy trains along Europe.

The items analyzed are:
- interoperability, signalling
- starting tractive effort,
- adherent weight and adhesion,
- power required and power supply,
- coupling, multiple traction and brake system,
- comfort and safety of the driver
- environmental aspects: noise, emissions and energy efficiency
Interoperability

FERRMED’s scope:
• 13 countries
• 4 voltages

A European initiative for a unique Train Control
Cross Acceptance

Cross Acceptance – The „Pillars“ creating the European „Web“

Agreement achieved:

- F - C: 13,03,05 locos
- D - NL - I - CH - A: 67,06,07 M. of U
- I - U: 16,04,05 locos, trains
- F - B - L - NL: 22,12,05 locos, trains
- F - CH: 28,03,05 locos, trains
- F - E: 13,05,05 locos, trains

Agreement programmed:

- D - B: Dialog
- D - PL: Dialog
- D - CZ: Dialog
- F - E: Dialog

Others (following ERA proposal):
Trains ≥ trains and multiple units

Ideal case: Locomotive certified in only one European country and which could operate in all European countries (like truck)

“FERRMED TRAINS”

Characteristics “FERRMED Trains”

<table>
<thead>
<tr>
<th>Length</th>
<th>1500m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load</td>
<td>3600 t - 5000 t</td>
</tr>
<tr>
<td>Axle load</td>
<td>22,5 t/axle – 25 t/axle (future)</td>
</tr>
<tr>
<td>Track gauge</td>
<td>1435 mm</td>
</tr>
<tr>
<td>Loading gauge</td>
<td>UIC C</td>
</tr>
<tr>
<td>Maximum speed</td>
<td>120 km/h</td>
</tr>
</tbody>
</table>
Maximum admissible train gross weight or load

It is calculated as the minimum of following value:

- Maximum admissible train gross weight depending on locomotive characteristics (starting tractive effort)
- Maximum admissible train gross weight depending on starting adhesion
- Maximum admissible train gross weight depending on coupling

<table>
<thead>
<tr>
<th>Locomotive Type</th>
<th>Loco weight (t)</th>
<th>Axle/load</th>
<th>Starting tractive effort (kN)</th>
<th>Slopes</th>
<th>Maximum load (t)</th>
<th>Slopes</th>
<th>Maximum load (t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA: GE ES44AC</td>
<td>188 t</td>
<td>31.3 t</td>
<td>880 kN</td>
<td>4 %</td>
<td>11.036 t</td>
<td>12 %</td>
<td>5.424 t</td>
</tr>
<tr>
<td>Europe: Co-Co</td>
<td>125 t</td>
<td>20.8 t</td>
<td>400 kN</td>
<td>4 %</td>
<td>4.977 t</td>
<td>12 %</td>
<td>2.426 t</td>
</tr>
<tr>
<td>Europe: Bo-Bo</td>
<td>85 t</td>
<td>21.25 t</td>
<td>300 kN</td>
<td>4 %</td>
<td>3.741 t</td>
<td>12 %</td>
<td>1.828 t</td>
</tr>
</tbody>
</table>

- American locomotives, with a higher starting tractive effort than European ones, can start more than 5,000 t in slopes of 12%.
- Starting tractive efforts of European locomotives are enough to haul “FERRMED trains” in low slopes but not in high slopes where maximum load is lower than 2,000 t or even less depending on the slopes.
Maximum load that can be started
- depending on the starting adhesion

The adhesion can be increased:
- Increasing the starting adhesion $\mu_0$ depends on Infrastructure Managers
  FERRMED proposed a revision of $\mu_0$ values
  • Increasing the adherent weight (weight of motorized axles):
    - Higher axle-load limited to 22.5 t/axle in Europe
    - more number of motorized axles ➔ SOLUTION

Conclusion: To start “FERRMED trains” in slopes of 12mm/m (22.5 t/axle), 2 Co-Co locomotives or 3 Bo-Bo locomotives in multiple traction are required, that is, **12 motorized axles**

### Starting tractive effort

<table>
<thead>
<tr>
<th>Load</th>
<th>Slope</th>
<th>Starting tractive effort in Co-Co locomotive</th>
<th>Starting tractive effort in Bo-Bo locomotive</th>
</tr>
</thead>
<tbody>
<tr>
<td>3,600 t</td>
<td>0%</td>
<td>146 kN</td>
<td>144.5 kN</td>
</tr>
<tr>
<td></td>
<td>4%</td>
<td>292 kN</td>
<td>289 kN</td>
</tr>
<tr>
<td></td>
<td>12%</td>
<td>584 kN</td>
<td>578 kN</td>
</tr>
<tr>
<td></td>
<td>18%</td>
<td>803 kN</td>
<td>794.5 kN</td>
</tr>
<tr>
<td>5,000 t</td>
<td>0%</td>
<td>201 kN</td>
<td>199 kN</td>
</tr>
<tr>
<td></td>
<td>4%</td>
<td>402 kN</td>
<td>399 kN</td>
</tr>
<tr>
<td></td>
<td>12%</td>
<td>804 kN</td>
<td>797 kN</td>
</tr>
<tr>
<td></td>
<td>18%</td>
<td>1,105 kN</td>
<td>1,096 kN</td>
</tr>
</tbody>
</table>

- In low slopes, the current European locomotives can haul "FERRMED trains", but not in high slopes.
- **Required starting tractive effort 600kN - 800kN to start in slopes of 12%**
- More than 1 European locomotive is required.
Maximum train gross weight that can be started
- depending on the coupling

<table>
<thead>
<tr>
<th>Coupling type</th>
<th>Slope</th>
<th>Max. train gross weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>UIC coupling of 135 t</td>
<td>4 ‰</td>
<td>7.147 t</td>
</tr>
<tr>
<td>UIC coupling of 85 t</td>
<td>4 ‰</td>
<td>4.500 t</td>
</tr>
<tr>
<td>UIC coupling of 135 t</td>
<td>12 ‰</td>
<td>3.574 t</td>
</tr>
<tr>
<td>UIC coupling of 85 t</td>
<td>12 ‰</td>
<td>2.250 t</td>
</tr>
</tbody>
</table>

- With current European UIC coupling of 85 t it is not possible to haul “FERRMED trains” of 5.000 t without breaking the hook.
- With European reinforced UIC coupling of 135 t, the maximum train gross weight that can be started in slopes of 12mm/m is 3.500 t.
- Some automatic coupling can duplicate the load of the European ones.

Solution: Automatic coupling

Automatic Coupler

The proposed FERRMED coupler has the following main features and performances:

- compliant Fiche UIC n° 522, 523, 524, 530-1, 567-3 829 and certified EBA and German MoT + TSI
- Working in any rough service conditions (shocks, dust, winter)
- Automatic coupling and centering with fully integrated air + electric connections.
- Max effort: 1000kN traction; 2000 kN compression
- Mechanically compatible with Russian coupler SA-3 and with traditional UIC hook and side buffers
- Uncoupling with an external lateral lever, with a very low effort (25 dN)
Automatic Coupler

**PROS:**
- Safe, reliable handling of long trains and automatic marshalling operations.
- Reduced wear of wheels and rails and derailments (+ stability)
- Transmission of electrical signals (ECP)
- Coupling of traditional and new wagons and removal of side buffers after the period of transition

**CONS:**
- Higher Complexity and Cost
- Transition period needs coupler + side buffers
EXAMPLES OF APPLICATIONS

Service proven in Germany, France, Norway

Multiple Traction

High constraints on the UIC coupling

Reduced constraints on the UIC coupling
But necessity to have a radio control, two drivers or a wire connection
Air Brake

The Air Brake is the ultimate safety system allowing to slow down and to stop the trains.

According to the UIC regulations, the maximum length of trains allowed in service is 750 metres. Longer trains could become dangerous during braking operations, mainly on steep slopes and curved lines (mountains).

The UIC Air Brake is a full service proven system with over than one century of experience. The air for braking is stored on each vehicle and every decrease of pressure in the Brake Pipe causes a brake application.

ADVANTAGE: safety

DISADVANTAGE: long reaction times

FERRMED Proposals for performance improvements:

A) Synchronization of multiple Traction / Braking operations via radio equipments on board locomotives

or

B) Train wired Control and Command System (ECP)
a) Multiple traction and braking via radio

The possibility to synchronize via radio the traction and braking efforts between two or more locomotives allows to compose longer and heavier trains, still conserving or even improving the running performances and safety.

**PROS:**
- Allows lower longitudinal pulling effort during traction
- Allows lower longitudinal compression efforts during braking (risk of derailment)
- Allows longer and heavier trains to be handled, also on "difficult" lines (mountains and curves)

**CONS:**
- Risks of losing the radio transmission and so braking performance requested by a longer train (e.g.: trains partially inside a tunnel)
- The train is still braked starting from two or more locomotives, with wagons brake depending from the propagation of the pneumatic signal.

b) ECP Brake* and Communication System

The system is based on a wired communication system, running all along the train for lengths over 1500 m.

The wires, two pairs for redundancy, are used to transmit either the power and the signals. In case of loss of one line, the second one is able to deliver the same performances.

**Main advantages:** Brake application and release in real time (lower longitudinal efforts). Auxiliary reservoirs totally full all time (increased safety)

**Main disadvantages:** Need for wiring all the wagons; no traditional wagon without wiring is acceptable in between the train

* Electronically Controlled Pneumatic Brake
Multiple Traction and braking

**FERRMED Standards**

- **Automatic coupling** which accepts higher efforts than UIC coupling and makes able the wired connection
- **Multiple traction required**: more than 1 locomotive
- **Radio control for distributed locomotives** (MARATHON)
  - Compatible with European and TSI norms
  - Manage the discontinuity of communications without endangering the safety of the train
- **ECP Brake and Communication system for long trains** (longer than 750m)

**NOTE: MARATHON program**
- European Program
- Sponsored by European Commission
- Consortium of 16 companies
- Pilot train: 1500 m train up to 120 kph (2 locomotives)
- Tests planned in 2013

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### Power required to haul “FERRMED Trains” at defined speed

<table>
<thead>
<tr>
<th>Load</th>
<th>Slope</th>
<th>Speed (km/h)</th>
<th>Power at wheel rim (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3600 t</td>
<td>0%</td>
<td>40</td>
<td>1.178</td>
</tr>
<tr>
<td></td>
<td></td>
<td>60</td>
<td>2.075</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100</td>
<td>5.093</td>
</tr>
<tr>
<td></td>
<td>4%</td>
<td>40</td>
<td>2.800</td>
</tr>
<tr>
<td></td>
<td></td>
<td>60</td>
<td>4.509</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100</td>
<td>9.149</td>
</tr>
<tr>
<td></td>
<td>12%</td>
<td>40</td>
<td>6.045</td>
</tr>
<tr>
<td></td>
<td></td>
<td>60</td>
<td>9.379</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100</td>
<td>17.261</td>
</tr>
<tr>
<td></td>
<td>18%</td>
<td>40</td>
<td>8.479</td>
</tr>
<tr>
<td></td>
<td></td>
<td>60</td>
<td>13.027</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100</td>
<td>23.346</td>
</tr>
<tr>
<td></td>
<td></td>
<td>120</td>
<td>29.360</td>
</tr>
</tbody>
</table>

- **Power** does not influence the maximum load that can be hauled but powerful locomotives allow higher speed and better acceleration
- Required power increases with the slopes and with the speed
- **Power of the train between 7.000 kW and 10.000 kW → power or individual locomotives: 3.500 kW – 5.000kW**
Power Supply

- Both type of traction, diesel or electrical, solve already now the power requirements to haul “FERRMED trains”.

<table>
<thead>
<tr>
<th>Diesel locomotives</th>
<th>Electrical locomotives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Some modern current European Diesel locomotives achieve <strong>3,500 kW and 400kN</strong> and incorporate last innovations to reduce emissions and noise.</td>
<td>New European multi-tension electrical locomotives solve interoperability problems.</td>
</tr>
<tr>
<td>They give <strong>more flexibility</strong> in the operations and interoperability.</td>
<td>They have <strong>more power</strong> than diesel ones (up to 6,000kW) achieving higher speed but have lower starting tractive effort (300kN).</td>
</tr>
</tbody>
</table>

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**Types of Pantographs**

- **Fiche UIC 608**

- **Type C** for DC catenary 1500 and 3000 V
- **Type D** for AC catenary 15,000 and 25,000 V
THE PANTOGRAPH - Installation solutions for FERRMED locomotives

- 2 pantos for DC and 2 pantos for AC catenary

This configuration, with the correct profiles of the collector strips, allows the accessibility to the majority of railway lines in Europe.

Each couple of pantos electronically controlled for the choice (driver’s or automatic) of the main working parameters: speed, direction, number of locos per train, front/rear pantos, type of network, ...

Power Supply
Electric locomotives

Main improvements → reduction of the exhaust emissions to comply EU Directives.

- **Combustion**: Internal engine design improvements
- **Exhaust after-treatment systems**
- **Combustibles**:
  - Better quality fuel (low sulfur...)
  - Biodiesel
  - Alternatives (H2)
  - Hybrid and dual locomotives

Operational measures like idling reduction or energy efficiency improvements can be also apply to reduce the emissions.

Power Supply
Diesel locomotives

<table>
<thead>
<tr>
<th>Stage</th>
<th>PM</th>
<th>PM</th>
<th>PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>IA</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>IIA</td>
<td>0.025</td>
<td>0.025</td>
<td>0.025</td>
</tr>
<tr>
<td>IIIA</td>
<td>0</td>
<td>0.05</td>
<td>0.1</td>
</tr>
<tr>
<td>IIIB</td>
<td>0.15</td>
<td>0.2</td>
<td>0.25</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Stage</th>
<th>PM</th>
<th>PM</th>
<th>PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>IA</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>IIA</td>
<td>0.025</td>
<td>0.025</td>
<td>0.025</td>
</tr>
<tr>
<td>IIIA</td>
<td>0</td>
<td>0.05</td>
<td>0.1</td>
</tr>
<tr>
<td>IIIB</td>
<td>0.15</td>
<td>0.2</td>
<td>0.25</td>
</tr>
</tbody>
</table>
Other Environmental improvements

**Energy efficiency:**
- By operational measures:
  - Optimizing routes, traffic flows and fleet performance
- By innovations in the rolling stock
  - Driver assistance systems (DAS)
  - Recovery energy brake
  - Improve the performance of the traction system but also of the auxiliary equipment
  - Aerodynamic design
  - Devices that reduce the idle in diesel locomotives: AESS, APU,…

**Noise:** TSI CR Noise
- Acoustic insulation of the cabin
- New materials for the braking system
- Use of brake discs instead brake shoes
- New materials and new designs of bogies and wheels to reduce the impact of track irregularities
- Acoustic improvements in engines, compressors, brake, fans…
- Suspension technologies of the critical
- Aerodynamic design

**Comfort**

- **2 cabs with central desk**
- **Driver Desk**: European Driver’s Desk (EUDD+) which will facilitate the interoperability in Europe
- **Ergonomic design** of the cabin (noise, vibration)
- Air conditioning, refrigerator, oven, toilets, bed
- **Driving Advice System**: management of energy consumption
Transition period

Many of required innovations are already developed but still not implemented

- Cross - Acceptance \(\rightarrow\) Interoperability in the European Rail Freight Core Network
- Several on-board safety systems \(\rightarrow\) just ETCS when full implementation ERTMS
- Automatic coupling compatible with current ones
- Unify the length of the train in all Europe to 750m \(\rightarrow\) 1500m
- Multiple traction with 2 locomotives in the head \(\rightarrow\) distributed multiple traction with communication between locomotives by wire or by radio

Conclusions of FERRMED Freight Locomotive Concept Study

<table>
<thead>
<tr>
<th>Traction Characteristics “FERRMED Trains”</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of motorized axles</td>
<td>12 axles</td>
</tr>
<tr>
<td>Starting tractive effort of the train (12 ‰)</td>
<td>600 kN (3600t) - 800 kN (5000t)</td>
</tr>
<tr>
<td>Number of locomotives</td>
<td>More than one in multiple traction: 2 Co-Co or 3 Bo-Bo</td>
</tr>
<tr>
<td>Power of the train</td>
<td>7,000 kW - 10,000 kW</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Traction Characteristics FERRMED Freight Locomotive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Starting tractive effort of the locomotive</td>
</tr>
<tr>
<td>Axle arrangement</td>
</tr>
<tr>
<td>Power of the locomotive</td>
</tr>
<tr>
<td>Type of traction</td>
</tr>
<tr>
<td>Pantographs (for electric locos)</td>
</tr>
</tbody>
</table>
## Conclusions of FERRMED Freight Locomotive Concept Study

### Characteristics FERRMED Freight Locomotive

<table>
<thead>
<tr>
<th>Feature</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multiple traction</td>
<td>YES, distributed multiple traction. Communications options: wire / radio</td>
</tr>
<tr>
<td>Coupling</td>
<td>Automatic coupling compatible with current UIC screw couplers and Russian couplers</td>
</tr>
<tr>
<td>Brake</td>
<td>E-ECP Brake System (Enhanced-Electronically controlled pneumatic system)</td>
</tr>
<tr>
<td>Interoperability</td>
<td>YES. Fulfillment all applicable TSI and other European Directives</td>
</tr>
<tr>
<td>Safety and Signaling system</td>
<td>ERTMS</td>
</tr>
<tr>
<td>Train control system</td>
<td>ETCS</td>
</tr>
<tr>
<td>Radio system</td>
<td>GSM-R</td>
</tr>
</tbody>
</table>

**Cab**: 2 cabs with central desk ensuring safety and comfort of the driver.

**Noise**

| Exhaust Emissions | EU 2004/26 Stage III B |

**Others**

- Incorporation of state-of-the-art technologies to improve energy efficiency
- Incorporation of state-of-the-art driving advice systems and operations assistance systems

**Materials**

About 95% recyclable materials