FERRMED FREIGHT LOCOMOTIVE CONCEPT by

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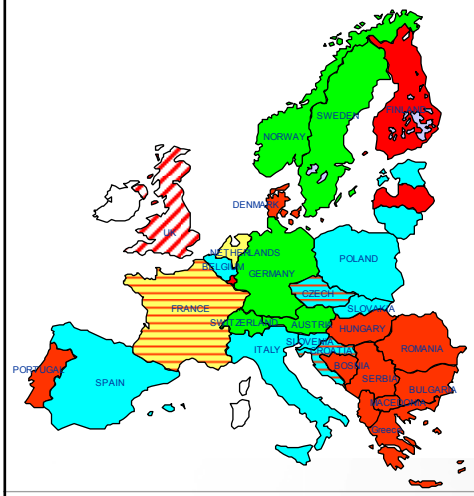
Objective of FERRMED Freight Locomotive Concept Study

To define the minimum parameters that the EU locomotives should have to fulfil 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



Single voltage :

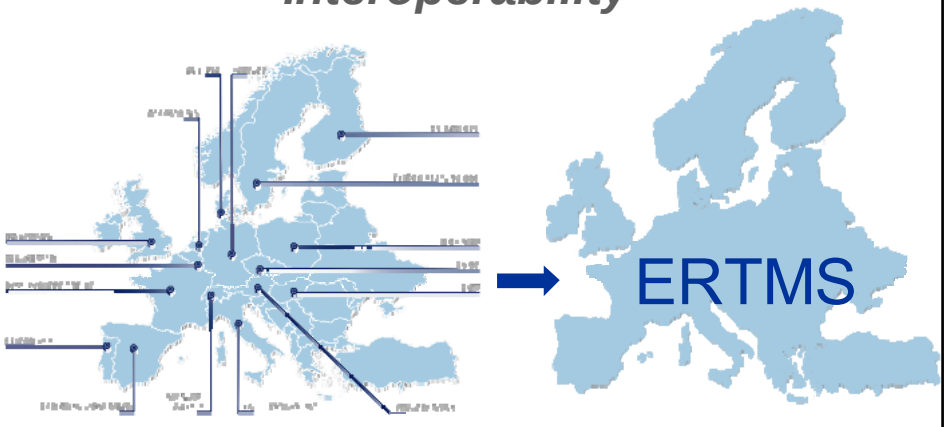
- 1 500 Vdc
- 3 000 Vdc
- 15 kVac 16Hz $^{2}/_{3}$
- 25 kVac 50Hz

Dual voltage :

- 1 500 V / 25 kV
- 3 000 V / 25 kV
- 750 V / 25 kV

FERRMED's scope
• 13 countries
• 4 voltages

Interoperability



A European initiative for a unique Train Control

Cross Acceptance

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

Agreement achieved:

F – D	13/03/06 locos
D – NL – I – CH – A	07/06/07 M. of U.
F – D	16/04/08 locos, trains
F – B – L – NL	22/12/08 locos, trains
F – CH	20/03/09 locos, trains
F – E	13/05/09 locos, trains

Agreement programmed:

D – B:	Dialog
D – PL:	Dialog
D – CZ:	Dialog
F – I:	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”	
Length	1500m
Load	3600 t ÷ 5000 t
Axle load	22,5 t/axle ÷ 25 t/axle (future)
Track gauge	1435 mm
Loading gauge	UIC C
Maximum speed	120 km/h

Maximum admissible train gross weight or load

It is calculated as the minimum of following value:

In the start

- 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**

During running

- Maximum admissible train gross weight depending on **running adhesion**
- Maximum admissible train gross weight depending on **continuous regime** (not applicable)

Maximum load that can be started

with current locomotives

				Depending on the starting tractive effort				Depending on the adhesion			
Locomotive type	Loco weight	Axle/load	Starting tractive effort	Slopes	Maximum load	Slopes	Maximum load	Slopes	Max. load	Slopes	Max. load
USA: GE ES44AC	188 t	31,3 t	880 kN	4 ‰	11.036 t	12 ‰	5.424 t	4 ‰	7.567 t	12 ‰	3.690 t
Europe: Co-Co	125 t	20,8 t	400 kN	4‰	4.977 t	12 ‰	2.426 t	4‰	5.031 t	12 ‰	2.453 t
Europe: Bo-Bo	85 t	21,25 t	300 kN	4‰	3.741 t	12 ‰	1.828 t	4‰	3.421 t	12 ‰	1.668 t

*$Q \leq [(Fs / 9{,}8 * 1000) / (rs + i)] - L$
Fs: starting tractive effort, I: slope, rs: starting resistance of the train

$Q \leq [(F\mu0 * 1000) / (rs + i)] - L$
$F\mu0 = \mu0 * La$; $\mu0$=33%, La: adherent weight

- American locomotives, with a higher starting tractive effort than European ones, can start more than 5.000t 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 **2.000t** 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 μ_o → depends on Infrastructure Managers
  FERRMED proposed a revision of μo 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

Load	Slope	Starting tractive effort in Co-Co locomotive	Starting tractive effort in Bo-Bo locomotive
3.600 t	0‰	146 kN	144,5 kN
	4‰	292 kN	289 kN
	12‰	584 kN	578 kN
	18‰	803 kN	794,5 kN
5.000 t	0‰	201 kN	199 kN
	4‰	402 kN	399 kN
	12‰	804 kN	797 kN
	18‰	1.105 kN	1.096 kN

- 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.

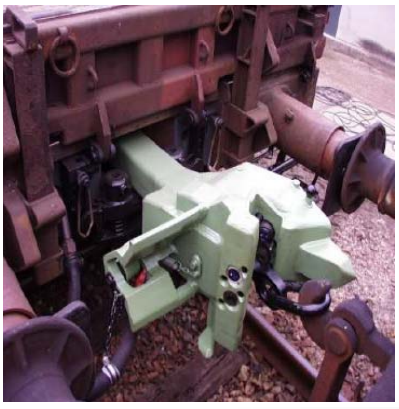
Maximum train gross weight that can be started
- depending on the coupling

Coupling type	Slope	Max. train gross weight
UIC coupling of 135 t	4 ‰	7.147 t
UIC coupling of 85 t	4‰	4.500 t
UIC coupling of 135 t	12 ‰	3.574 t
UIC coupling of 85 t	12 ‰	2.250 t

- With current European UIC coupling of 85 t 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 3.500t.
- Some automatic coupling can duplicate the load of the European ones.

- **Solution: Automatic coupling**

Automatic Coupler

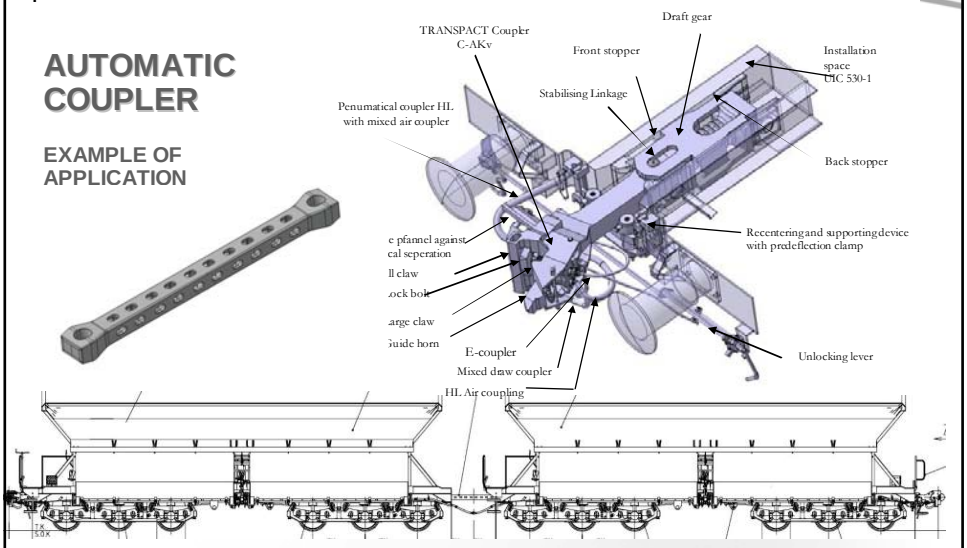


The proposed FERRMED coupler has the following main features and performances:

- 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

EXAMPLE OF APPLICATION



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

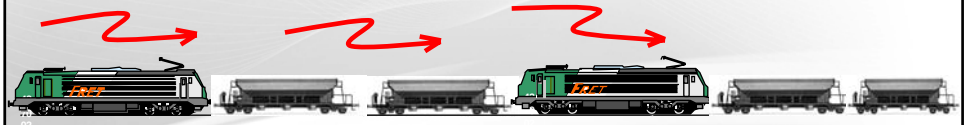
EXAMPLES OF APPLICATIONS

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**

Air Brake

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 loosing the radio transmission and so braking performance requested by a longer train (ex. : 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

Power required to haul "FERRMED Trains" at defined speed

Load	Slope	Speed	Power at wheel rim
3.600 t	0‰	40 km/h	1.178 kW
		60 km/h	2.075 kW
		100 km/h	5.093 kW
		120 km/h	7.215 kW
	4‰	40 km/h	2.800 kW
		60 km/h	4.509 kW
		100 km/h	9.149 kW
		120 km/h	12.324 kW
	12‰	40 km/h	6.045 kW
		60 km/h	9.379 kW
		100 km/h	17.261 kW
		120 km/h	22.058 kW
	18‰	40 km/h	8.479 kW
		60 km/h	13.027 kW
		100 km/h	23.346 kW
		120 km/h	29.360 kW

- 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".

Diesel locomotives

- Some modern current European Diesel locomotives achieve **3.500 kW and 400kN** and incorporate last innovations to reduce emissions and noise.
- They give **more flexibility** in the operations and interoperability.

Electrical locomotives

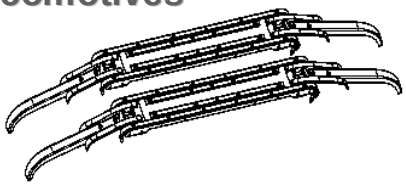
- New European **multi-tension** electrical locomotives solve interoperability problems.
- They have **more power** than diesel ones (up to 6.000kW) achieving higher speed but have lower starting tractive effort (300kN)

Power Supply

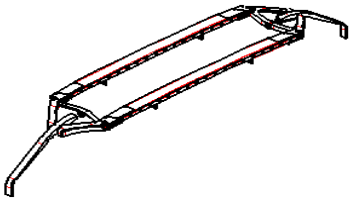
Electric locomotives

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

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Power Supply
Electric locomotives

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 .

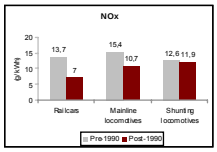
Each couple of pantos electronically controlled for the choice (driver's or automatic) of the main working parametres: speed , direction, n° of locos per train, front / rear panto , type of network , …

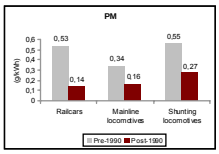
Power Supply
Diesel locomotives

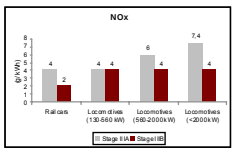
Main improvements → reduction of the exhaust emissions to comply EU Directives.

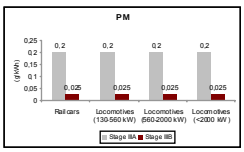
- **Combustion**: Internal engine design improvements
- **Exhaust after-treatment systems**
- **Combustibles:**
  - Better quality fuel (low sulfur...)
  - Biodiesel
  - Alternatives (H2)
  - Hybrid and dual locomotives

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









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

Conclusions of FERRMED Freight Locomotive Concept Study

Traction Characteristics "FERRMED Trains"	
Number of motorized axles	12 axles
Starting tractive effort of the train (12 ‰)	**600 kN** (3600t) ÷ **800 kN** (5000t)
Number of locomotives	More than one in multiple traction: 2 Co-Co or 3 Bo-Bo
Power of the train	7.000 kW ÷ 10.000 kW
Traction Characteristics FERRMED Freight Locomotive	
Starting tractive effort of the locomotive	300 kN ÷ 400 kN
Axle arrangement	Co-Co or Bo-Bo
Power of the locomotive	3.500 kW ÷ 5.000 kW
Type of traction	Diesel locomotive or electric multi-tension locomotive
Pantographs (for electric locos)	Two devices type C and two Type D

Conclusions of FERRMED Freight Locomotive Concept Study

Characteristics FERRMED Freight Locomotive	
Multiple traction	YES, distributed multiple traction. Communications options: wire / radio
Coupling	Automatic coupling compatible with current UIC screw couplers and Russian couplers
Brake	E-ECP Brake System (Enhanced-Electronically controlled pneumatic system)
Interoperability	YES. Fulfillment all applicable TSI and other European Directives
Safety and Signaling system	ERTMS
Train control system	ETCS
Radio system	GSM-R

Conclusions of FERRMED Freight Locomotive Concept Study

Characteristics FERRMED Freight Locomotive	
Cab	2 cabs with central desk ensuring safety and comfort of the driver
Noise	TSI CR Noise
Exhaust Emissions	EU 2004/26 Stage IIIB
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