

Environmental Challenges as an Opportunity in Steam Locomotive Operations on Museum and Tourist Railways in the 21st Century

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Mission Statement of FEDECRAIL's Environmental Working Group

FEDECRAIL's Environmental Working Group (EWG) was formed in 2009 to address all environmental issues concerning the operation of museum and tourist railways and the preservation of Europe's railway heritage. The EWG will assist FEDECRAIL's member railways to comply as closely as possible with current EU environmental regulations; however, whenever such compliance contradicts the primary mission of any museum – the preservation of artefactual historical sources – derogation will be sought.

Don'ts ...



... and do's!



The object under investigation



Specifications for environmentally friendly steam locomotive coal

- Type of coal Bituminous hard coal
- Lump size 80 – 120 mm or
(for hand-firing) 50 – 80 mm
- Water (in mass-% of the crude coal) $\leq 5 \%$
- Ash (in mass-% of the crude coal) $\leq 6 \%$
- Sulphur (in mass-% of the anhydrous substance) $\leq 1 \%$
- Volatile constituents 19 – 28 %
(in mass-% of the anhydrous and ash-free substance)
- Lower calorific value (of the crude coal) $> 28 \text{ MJ/kg}$
- Ash fusion temperature (T_B) $> 1300 \text{ }^\circ\text{C}$
- Iron (of the anhydrous substance) $\leq 5500 \text{ mg/kg}$
(when air is lacking, Fe_2SiO_4 and FeO are formed
and lower the melting point of the ash)
- Mercury (boiling point = $357 \text{ }^\circ\text{C}$) $\leq 0.2 \text{ mg/kg}$
(of the anhydrous substance)
- Cadmium (boiling point = $767 \text{ }^\circ\text{C}$) $\leq 0.6 \text{ mg/kg}$
(of the anhydrous substance)

Polish Locomotive Coal

(Lump size: 81.9 % 50 – 80 mm and larger)

Elemental analysis

• C	80.24 %
• H	4.84 %
• O	6.65 %
• N	1.27 %
• Cl	0.18 %
• S	0.40 %
• H ₂ O	2.70 %
• Ash	3.72 %

Other parameters

• Volatile constituents (anhydrous and ash-free)	32.02 %
• Lower calorific value (crude coal)	32.2 MJ/kg
• Ash fusion temperature (T _B)	1280 °C

Ash

• SiO ₂	23.00 %
• Al ₂ O ₃	12.65 %
• Fe ₂ O ₃	19.38 %
• CaO	14.03 %
• MgO	8.41 %
• Na ₂ O	1.57 %
• K ₂ O	0.94 %
• SO ₃	17.53 %
• TiO ₂	0.50 %
• P ₂ O ₅	0.13 %
• BaO	0.25 %
• Mn ₃ O ₄	0.28 %
• SrO	0.11 %
• ZnO	0.88 %

QJ Firing Instruction

- Shovels of coal should be placed in this order. The table symbolizes the firebox. The firehole is in the middle below.
- And this is the average relative amount of coal to be shovelled into each area per firing round. 100 = 100 % full shovel. The firehole is again in the middle below.

1	9	4
5	9	8
7	10	6
3	10	2

72	64	64	72
72	48	48	72
84	60	60	84
100	92	92	100

Average Emissions per kg of Polish Locomotive Coal

The values given below are average values over 10 single measurements at full load, ashpan air inlet fully open, right firing technique, $I_{\text{average}} = 1.55$ with a hole in the firebed once, otherwise $I_{\text{average}} = 1.32$ (8 measurements).

Compound	mol/kg	g/kg	(at $I = 1,5$) g/m³	German law 2002
CO ₂	66.867	2942.1	232.53	not regulated
CO	1.585	44.4	3.51	> 0.15
NO _x	0.113	5.2	0.41	< 0.50
HC	0.0035	0.15	0.01	not regulated
SO ₂	0.067	4.29	0.34	< 1.30

If all the sulphur in the coal were burnt, SO₂ emissions would be at 8.0 g/kg. This means that only 53.6 % of the sulphur is actually burnt; the remaining sulphur forms solid compounds thanks to the favourable ash composition.

Zero Carbon Footprint Project Zillertalbahn #5, 760 mm Gauge



Zero Carbon Footprint Project SePhys Burner during Trials in #5



Zero Carbon Footprint Project SePhys Burner in 52 8055



Zero Carbon Footprint Project SePhys Burner in 52 8055



Emissions in Stationary Tests

<u>Fuel</u>	<u>CO</u>	<u>NO₂</u>	<u>HC</u>
Diesel	0	226	0
FAME	92	236	0
Legal Limits	80	200/350	0

All values in mg/m³ (at STP and reference 3 % O₂)^A