

**Bombardier Transportation Sweden**

Refurbishment of the class 11E locomotive for Spoornet South Africa

The 11E locomotive designed for operation on the coalline between Ermelo and Richards Bay in South Africa


- History
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- General main data 11E locomotive
- Background of the problems
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Ref: Bombardier picture

**The 11E History**


- 1985-87 30+15 class 11E locomotives were built, delivered and commissioned by GM EMD and ASEA Sweden.
- 1987-93 UN sanctions against South Africa. No Trading.
- 1994 Official contacts and visits commence with Spoornet
- 1995 Swedish technical support discussions starts up.
- 1996 Investigation and report regarding the present 11E locomotive status done by Swedish engineers.
- 1997 Refurbishment price indication presented to Spoornet.
- 2000 (Oct) Contract signed between Spoornet and Bombardier SA (Adtranz SA) for a basic upgrade alternative.
- 2002 -2004 Delivery of the rebuilt 11E



Ref: Bombardier picture

**The Objective of the 11E refurbishment.**

- After the sanctions, investigations and discussions took place between Spoornet and Bombardier Transportation Sweden (Adtranz Sweden), to improve the locomotive performance.
- The Spoornet goal was to improve:
  - - Fleet availability from 80% to 90%.
  - - Fleet reliability from 55 to 25 fpmkm.
  - - Reduce maintenance hours by 1/3.
- The Bombardier offered solution was a complete overhaul and modernisation of the 11E fleet.
- The work managed by BT S.A.
- Technical support by BT Sweden
- The refurbishment to be done at Transwerk in Durban.



Ref: Bombardier picture

**The 11E Locomotive Main data.**

- **Line data:** 25 kV 50 Hz
- **Gauge:** 1067 mm
- **Locomotive Weight:** 168 (6 x 28) tonnes
- **Stall Tractive effort:** 580 kN
- **Cont. Tractive effort:** 400 kN at 34 km/h
- **Max. Dyn. Brake Effort:** 360 kN at 15 to 45 km/h
- **Traction motor control:** AC to DC Thyristor converters
- **Power Factor Correction:** 4 step thyristor switched PFC filter 4 x 342 kVAR
- **Traction Motors:** 650 kW sep. ex. DC
- **Aux power:** 200 kW static inverter 3x400V 50Hz

**The first 11E at Richards Bay, August 2002.**



Ref: Bombardier picture

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### The Coal line operation

- General train data.
  - Train configuration: 4 locos (in the front) + 200 coal wagons
  - Loco & wagon mass:  $4 \times 168 + 200 \times 104 \Rightarrow 672 + 20800\text{ton}$

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### 11E loaded train at Vryheid



Ref: Bombardier picture

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### Loaded trainset on its way to the harbour



Ref: Bombardier picture

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### Loaded trainset on its way to the harbour



End of train.  
Photo from drivers cab

Ref: Bombardier picture

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### The Coal line operation

- Coal operation
  - Coal is railed from 49 mines
  - Furthest mines are approximately 650-850km from Richards Bay
  - Average of 13 train units of 200 trucks per day
  - Coal are tipped at the harbour storage of a rate of 5 500tons/hour
  - Coal export from Richards Bay is approx 92Mt/a

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### Coal terminal Richards Bay



Ref: RBCT

**Background of the cooler problems**

The heat exchangers are subject to extreme conditions in service:



- 1) Clogging inside pipes and pollution on the fins
- 2) Shock and vibration has taken the coolers to the end of its lifetime.
- 3) High air humidity and salt water brake down aluminium material in the old coolers.
- 4) Dirt from the many sugar fields that the train passes in its journey

**The old soft soldered copper/brass heat exchangers**




Ref: Bombardier picture

**The old soft soldered copper/brass heat exchangers**


Ref: Bombardier picture

**Pollutions between radiators**



Ref: Bombardier picture

**Flat fin construction**



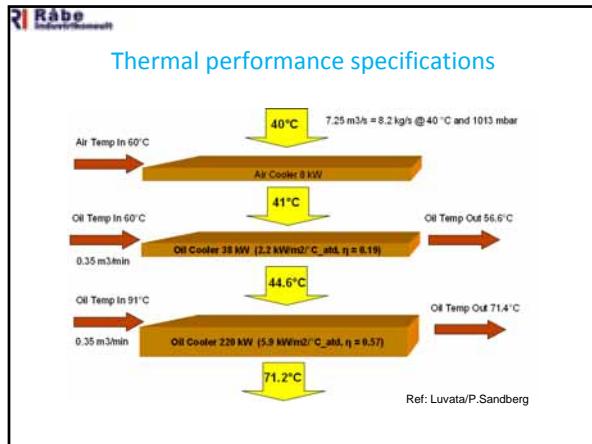
Ref: Bombardier picture

**Technical requirement**

- **Short description of cooling system**  
The radiators are equipped with two blowers forcing locomotive ambient air from the roof section down through the heatexchangers and out of a hole in the locomotive underframe. The airflow is from top to bottom.

The heatexchangers consists of three different systems.

- An air to air radiator for cooling the convertor internal air-kept
- An oil to air radiator for convertor oilsystem
- An oil to air radiator for the main transformer



### Cooler main data

- Convertor oil cooler**

Cooling capacity(min)	2,0 kW/°C
Cooling power	38 kW
- Transformer oil cooler**

Cooling capacity(min)	4,74 kW/°C
Cooling power	220kW

- ### Mechanical data
- Unit size L= 1654 mm (64.75"), H= 350 mm (13.77"), W= 762 mm (30")
  - Fins: The old flat fin construction was converted to corrugated fin type of construction with 8 fins per inch (easy to wash with high pressure water)
  - Brass tubes and copper fins
  - Tubes: The converter cooler has 7 row of tubes, the transformer cooler 15 rows. Tube size 19 mm (¾"), wall thickness 0.406 mm (0.016"). Internal turbulators.
  - Frame in steel
  - Surface primer painted
  - Shock and vibration must fulfill IEC 61373, Class 1B

- ### Liquid and air
- Air - The stated data is calculated with 10% margin to consider pollution on the air inside of the cooler
 

Air flow	8,2 kg/s
Max pressure drop	86 Pa
Max air inlet temp	+41°C
  - Liquid(Convetor oil) Properties at +50°C
 

Type: Transformer oil	
Spec: Heat capacity	3,4 kJ/kg K
Density:	853kg/m <sup>3</sup>
Viscosity:	5,75cst
Max inlet oil temp.	+60°C
Liquid flow	250dm <sup>3</sup> /min
Max working pressure	2 Bar
Pressure drop max	0,85Bar

- ### Liquid and air
- Transformer
 

Air flow	8,2 kg/s
Max pressure drop	86 Pa
Max air inlet temp	+44,6°C
  - Liquid(Transformer oil) Properties at +85°C
 

Type: Transformer oil	
Spec: Heat capacity	2,26 kJ/kg K
Density:	831kg/m <sup>3</sup>
Viscosity:	2,53cst
Max inlet oil temp.	+90°C
Liquid flow	1200dm <sup>3</sup> /min
Max working pressure	2 Bar
Pressure loss max	0,55Bar

- ### Enviromental conditions
- Operation ambient temperature**

Normal condition:	+25°C
Extreme conditions:	-40°C to +40°C
  - Good protection against atmosphere with high salt mist and humidity.
  - Change of temperature -35°C to +85°C according to IEC 60068-2-14
  - Corrosion: typical corrosion resistance of copper, brass and steel
  - Humidity 0 – 100%HR Condensing
  - Altitude 1700m

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### Reliability

- Failure rate  $\lambda > 0,3 \times 10^{-6}$  failure/hour
- Expected lifetime 15-20 Years

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### Test

- Typetest- equal or better than existing coolers
  - Leaking proof test
  - Strength calculation to fulfill IEC 61373, class 1B
  - Performance test

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### Oilcooler



Ref: Young Touchstone Wabtec

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### CuproBraze cooler



Ref: Bombardier picture

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### Analysis on oilcooler PN 421469

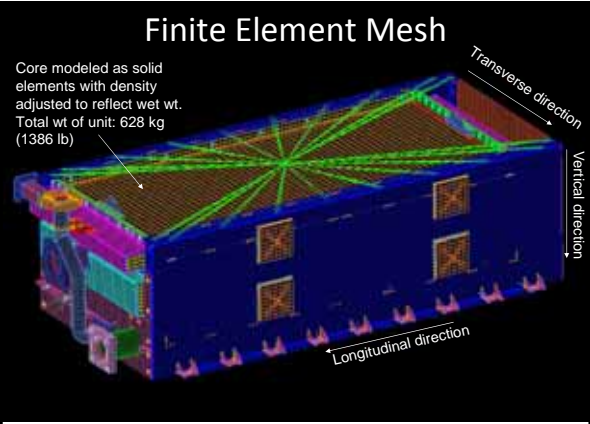
- Evaluate PN421469 for possible failure areas under vibration and shock load.
- Use test levels for shock and random vibration specified in IEC 61373 for Class 1B product. Shock levels should be either the values specified in IEC 61373 or at least 5g in longitudinal direction & shocks of at least 2g and 3g in the lateral and vertical direction respectively, whichever is higher.
- In addition to response analysis, include static analysis with max acceleration applied in each direction
- Failure criteria: structural components must be below yield (assumed to be 248 MPa/ 36 ksi)
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Ref: Young Touchstone Wabtec

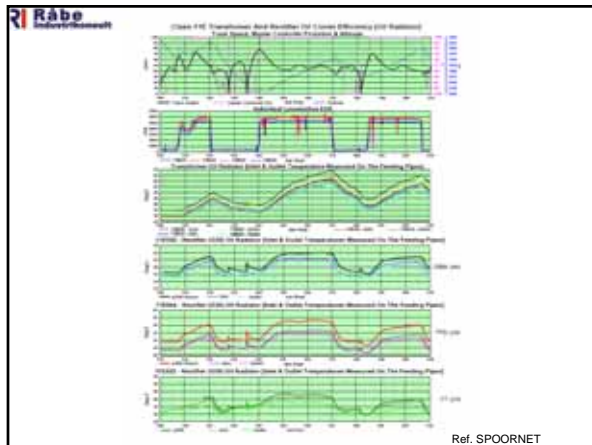
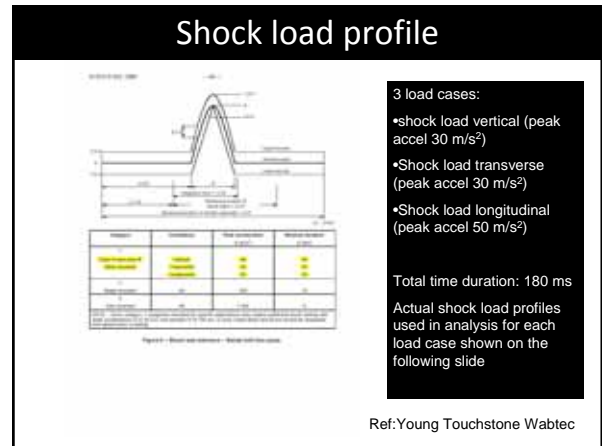
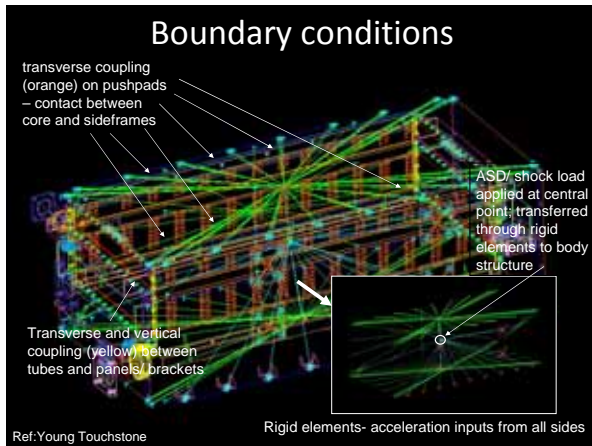
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### Finite Element Mesh

Core modeled as solid elements with density adjusted to reflect wet wt.  
Total wt of unit: 628 kg (1386 lb)



Ref: Young Touchstone Wabtec



- ### Key benefits for customer
- New technical cost effective solution meaning lower cost for refurbishment and new production of rail vehicles.
  - Cooling capacity
  - Size and weight reduction – less material used, more efficiently coolers.
  - Environmental friendly material used, less use of energy during the production process
  - Less noise because of lower pressure drop over the cooler. Meet EN noise targets
  - Less pollution between the coolers because use the same fin distance in the different coolers.
  - Designed for minimum of maintaince cost.
  - Plug and play – Reduce cost for replacement of old coolers when use the same interfaces.

- ### Next step possible futures
- **“Customer needs”**  
- Cost effective oilcoolers for new applications, includes whole spectra from new built vehicles and refurbishment projects or just replacement when coolers start to brake or cooling efficiency are reduced.  
Improved cooling supervision on same space when replace old coolers.

- ### References
- Luvata
  - Young Touchstone a Wabtec Company
  - Bombardier Transportation Sweden AB
  - Spoornet
  - Richards Bay Coal Terminal
- Standards to be considered
- |                |  |
|----------------|--|
| ASTM D 1384-80 | Railway applications-Electronic power converter for rolling stock.                         |
| EN 50207       | Environmental Testing  |
| IEC 60068-2    | Rules for electric traction equipment  |
| IEC 60077      | Railway applications - Rolling stock equipment - Shock and Vibration test.                 |
| IEC 61373      | Railway rolling stock – Fire behaviour, Choice of material                                 |
| NF F 16-101    | Railway rolling stock – Fire behaviour, Material choosing, application for electric system |
| NF F 16-102    | Mechanical screw joint   |
| 2120 097-A     |  |

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**Thank you for your attention**

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