The Högakusten Suspension Bridge - Corrosion Protection of Main Cables and Major Components

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Introduction

- Serious problems with main cable corrosion protection shortly after opening
- Main subject - retrofit of corrosion protect and operation experience
- Other major maintenance works carried out at same time: suspenders and cable bands
- Maintenance of end bearings
- Opinion on maintenance planning and the need for expertise

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Description

- Opened 1998
- Far north
- Main span 1,210 m
- Total 1,800 m
- Steel box girder - dehumidified
- Carriageway 17.8 m
- 2 x 2 traffic lanes
- Concrete pylons - 180 m

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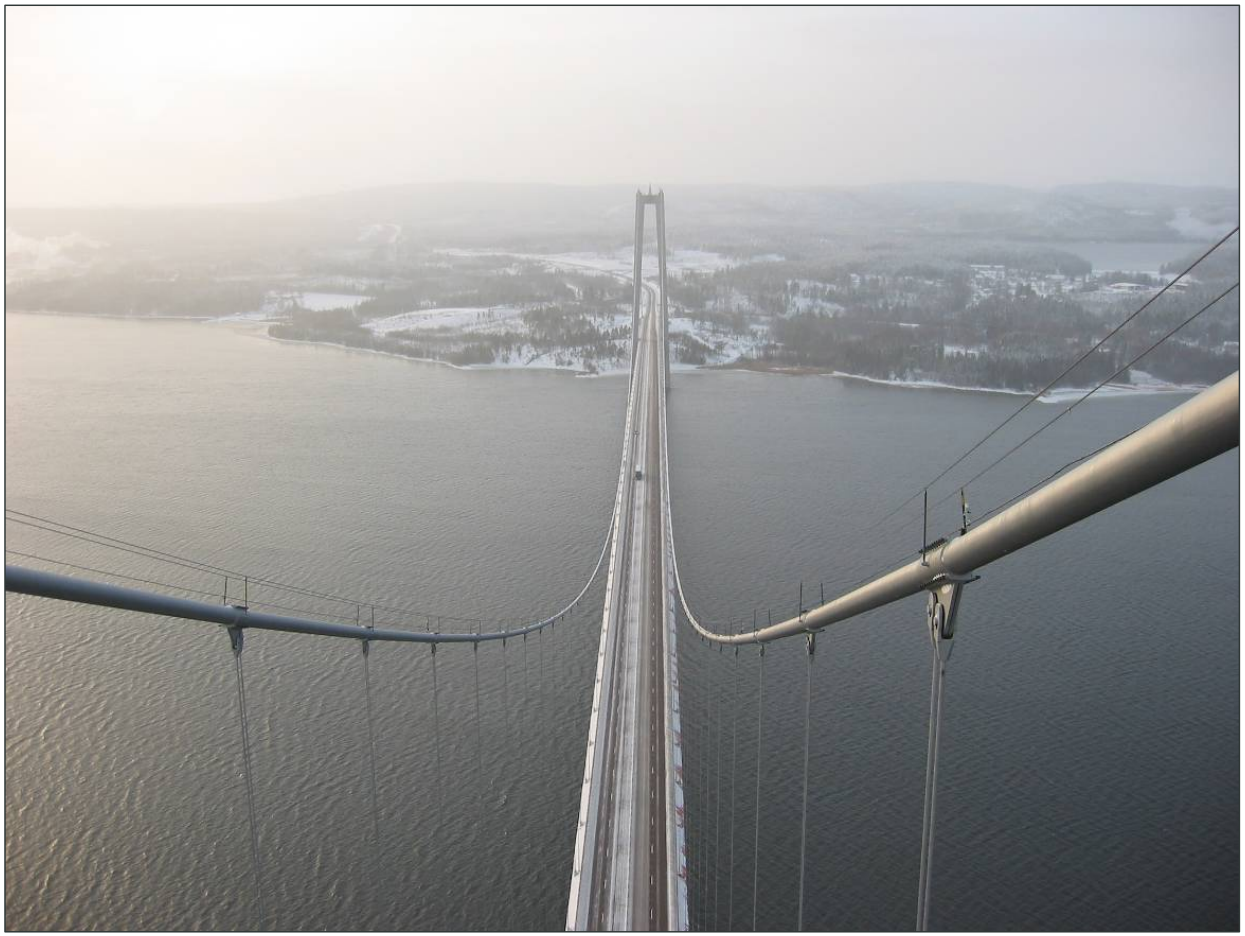
Cable system

Main cables

- Parallel wire
- Ø640 and 650 mm
- Each app. 1,900 m
- Galvanized wires, zinc paste, wrapping wire and paint

Suspenders

- Locked coil, nom. Ø55 mm, 63 and 92 mm near pylons
- 2 cables per suspender, sockets both ends
- Center distance 20 m



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Main cable condition

- Zinc paste omitted under construction
- Original protection defective
- Large amounts of water flowing in cables
- Forecast 2003 - depleted zinc within 10 years

Inspection 2004

- Depleted zinc on bottom wires
- Spots of ferrous corrosion
- Just 6 years after completion

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Retrofit of main cable corrosion protection

- Swedish Road Administration began investigations in 2003
- Dehumidification selected as best method
- Design work tendered 2004 and COWI awarded project
- Works tendered May 2004
- Works carried out 2005, just one season - 6 months

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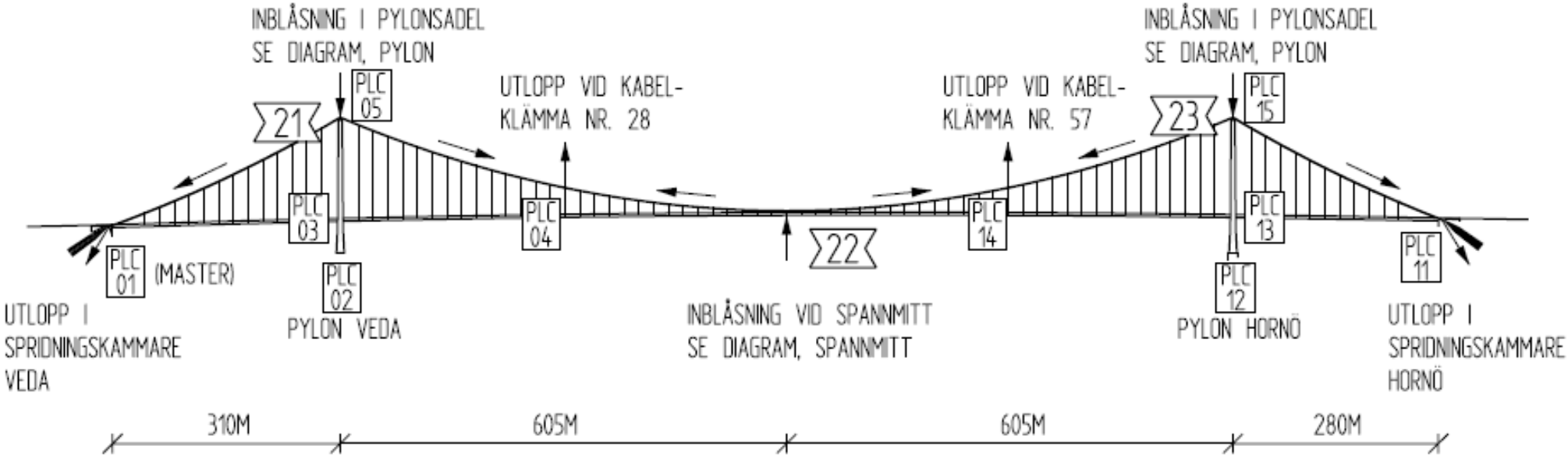
Dehumidification system

Three main components

- Sealing system - main cables, bands, saddles, etc.
- Dehumidification system - produces and blows dry air through main cables
- Control and monitoring system - controls and verifies effectiveness



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Sealing system

- Cableguard™ Wrap system
- Thickness 1.1 mm, width 200 mm
- Applied with 50% overlap for total thickness 2.2 mm
- Applied under tension with wrapping machine
- Two layers bonded with heat blanket
- Special details at bands to ensure tightness

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Sealing system

Advantages

- Lowest Life Cycle Cost
- Withstands overpressure
- Environmentally friendly - no paint
- Good working environment
- Available in many colors
- Execution less sensitive to weather
- Short construction period
- Virtually maintenance free
- Long lifetime, UV and weather resistant
- Easy to remove - does not bond to cable

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Dehumidification system - Main components

Dehumidification plants

- One in bridge girder at mid-span
- One in each pylon top
- Placed in buffer tanks:
  - Electrical consumption is minimized
  - Protected atmosphere for equipment
  - Good access for inspection and maintenance

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Dehumidification system - Main components

Injection points

- At mid-span
- At pylon saddles

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Dehumidification system - Main components

Exhaust points

- Intermediate points in main span
- In anchor houses

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Control and monitoring system

The system allows:

- Remote control
- Monitoring of functionality and performance

Following is monitored:

- In buffer tanks: relative humidity, temperature, absolute water content and functionality of the plant
- At injection points: air flow
- At exhaust points: relative humidity, temperature, absolute water content and air flow
- Ambient: relative humidity and temperature

Drying out process

- System started October 2005 with set value 40% RH
- Adjusted to 20% November to speed up process
- 2 year drying out period
- Confirmed by water content exhaust = water content injection
- Calculated water removed for 300 m cable: 500 liters, corresponds to 3% of cable void volume
- Set value adjusted to 40% RH November 2007

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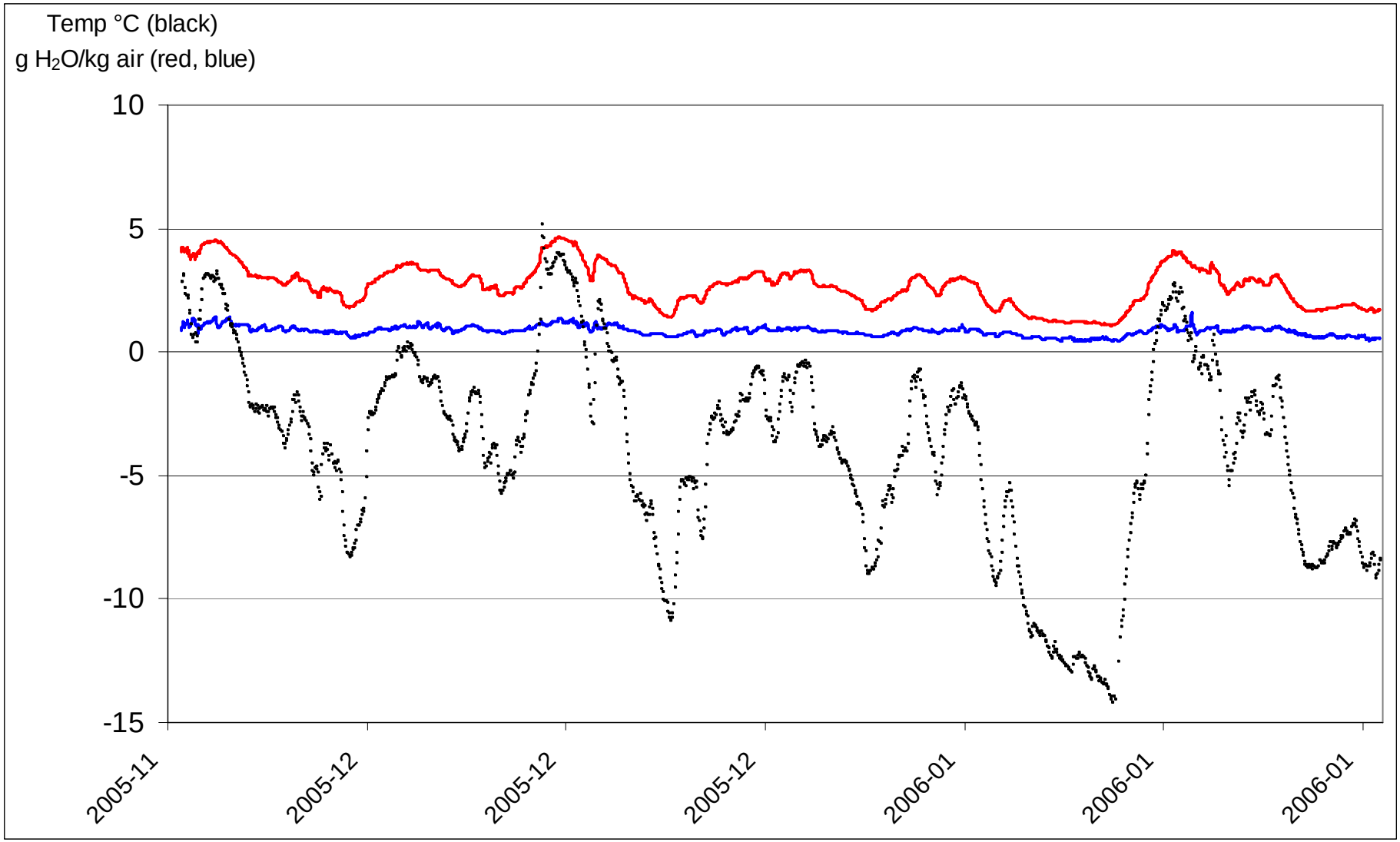
Drying out process
First winter: Nov. 2005 - Jan. 2006



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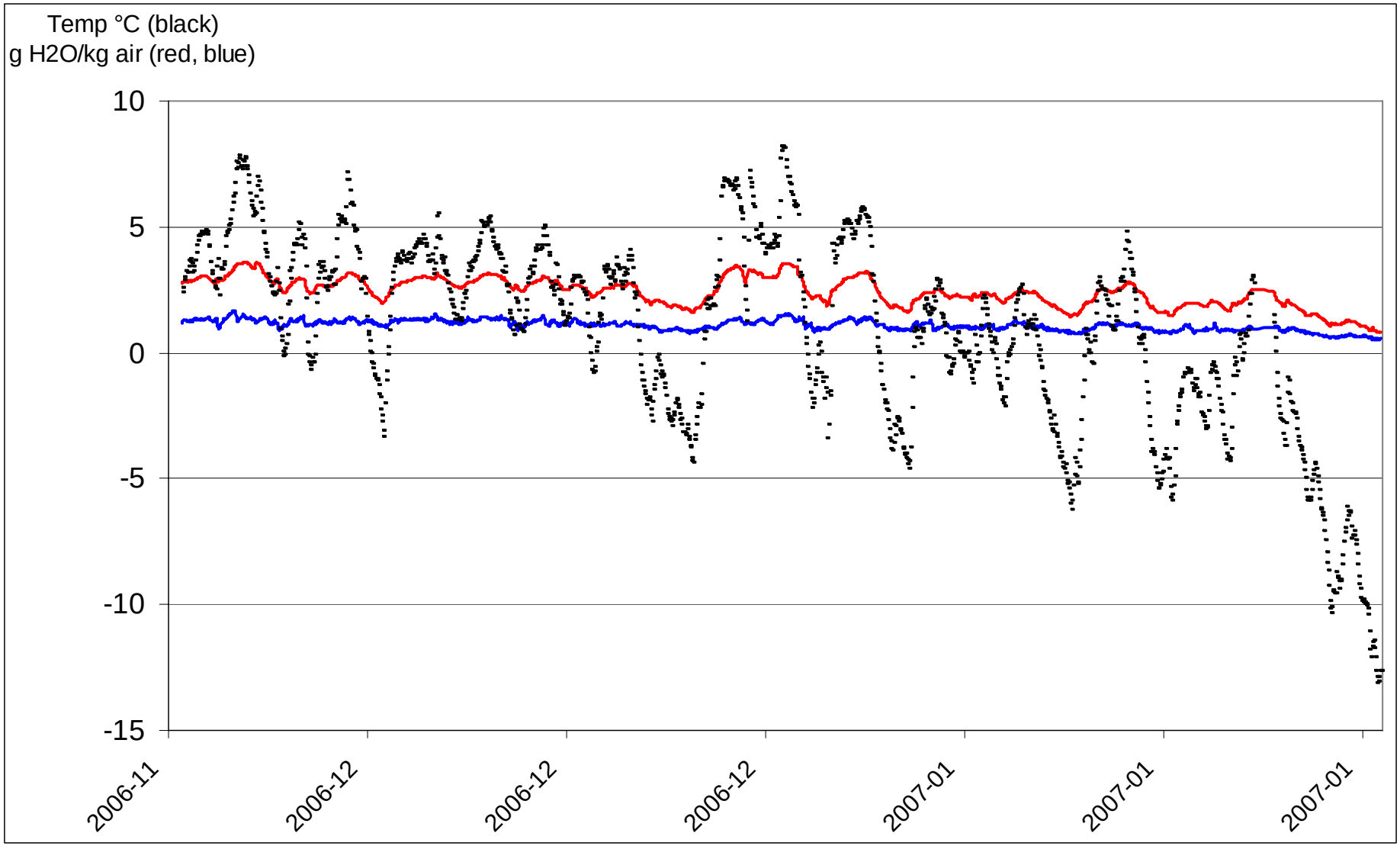
Drying out process
Second winter: Nov. 2006 - Jan. 2007



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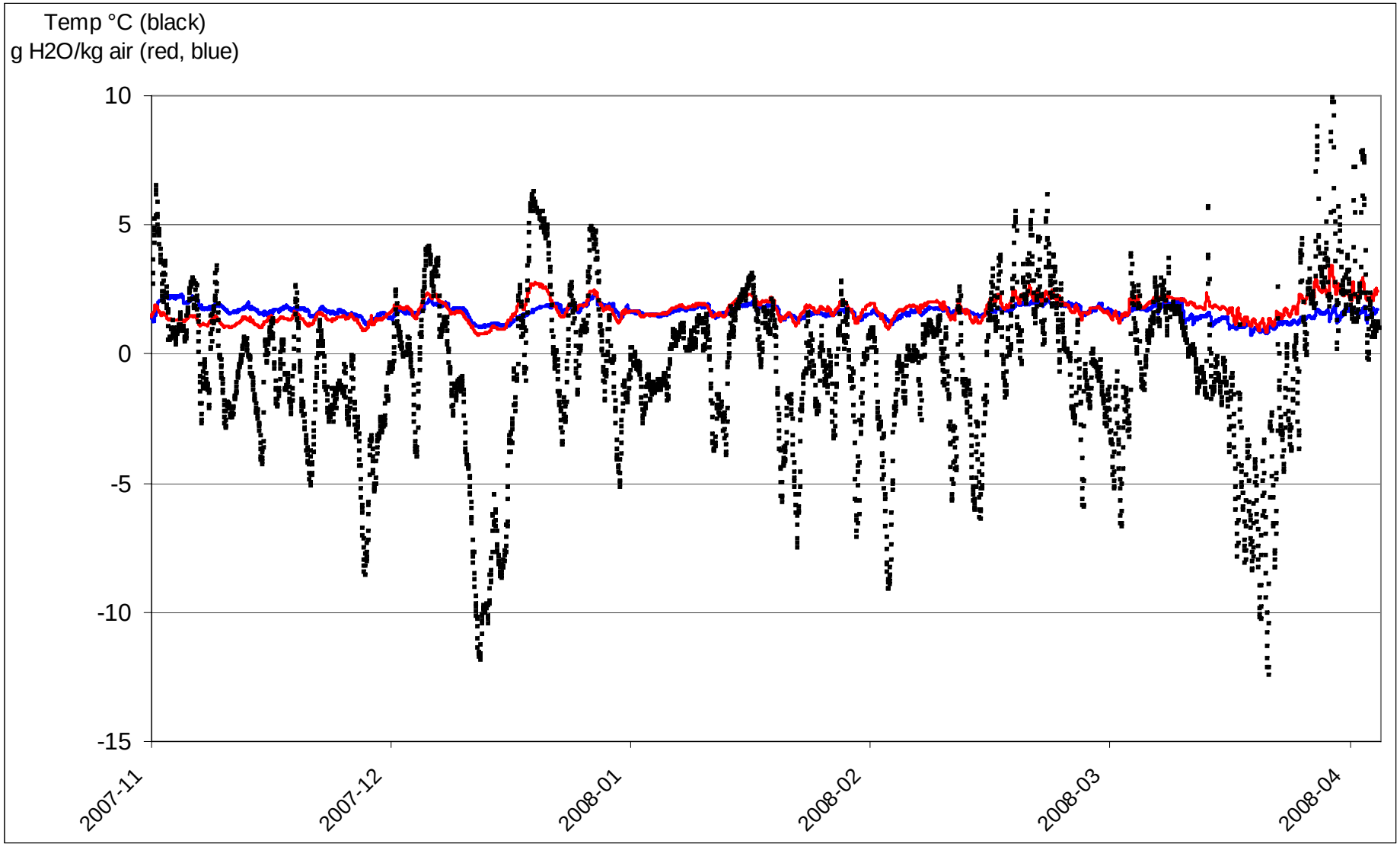
Drying out process
Third winter: Nov. 2007 - Jan. 2008



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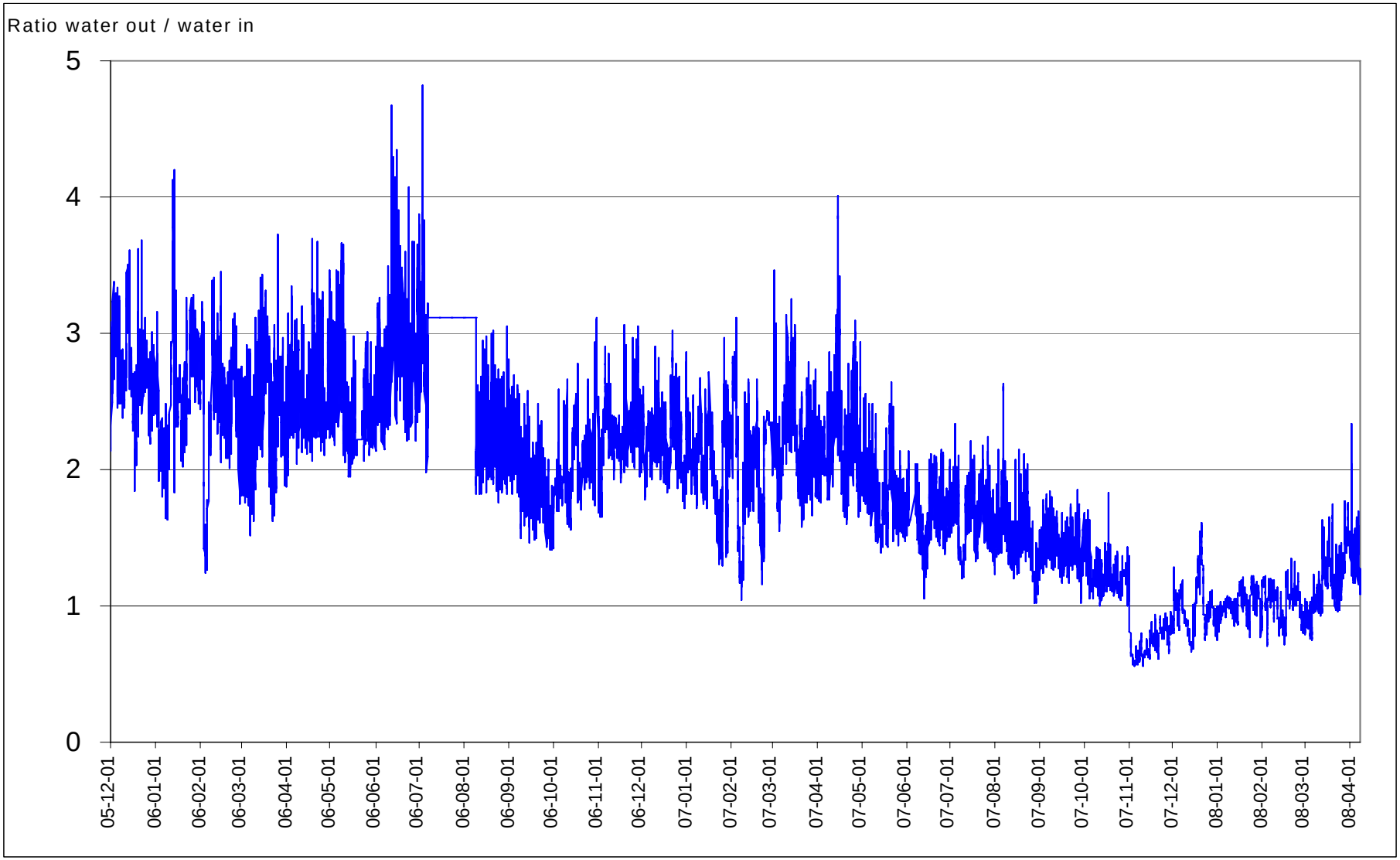
Drying out process
Overview Nov. 2005 - April 2008



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Dehumidification
Further operation experience

Durability of sealing system

- Ratio between exhaust flow and injection flow constant
- Indicates to leakage development

Low energy consumption

- Buffer tank solution is economical
- Running time varies over the year due to variation in ambient relative humidity
- Average running time first 2 years: 38%
- Consumption app. 40,000 kWh/year, savings of 60,000 kWh/year
- After adjustment of RH to 40% - expected consumption 25,000 kWh/year

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Other works
Access equipment

4 Elevator platforms, length 23 m

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Other works
Access equipment

4 Cable carriages

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Other works
Access equipment

2 Front loaders

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Other works
Suspender cables

- Total of 18 km cable
- Feared that filler was leaking through the paint
- Original paint not as recorded
- Actually Metalcoat from Bridon
- Insufficient thickness and contamination in grooves
- Cleaned with solvent and paint with sufficient thickness

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Other works
Upper sockets

- Sealing of upper sockets defective
- Material was brittle, lacked adhesion and cracked along edge
- Concave surface - water accumulation
- New solution with flexible material and plane surface

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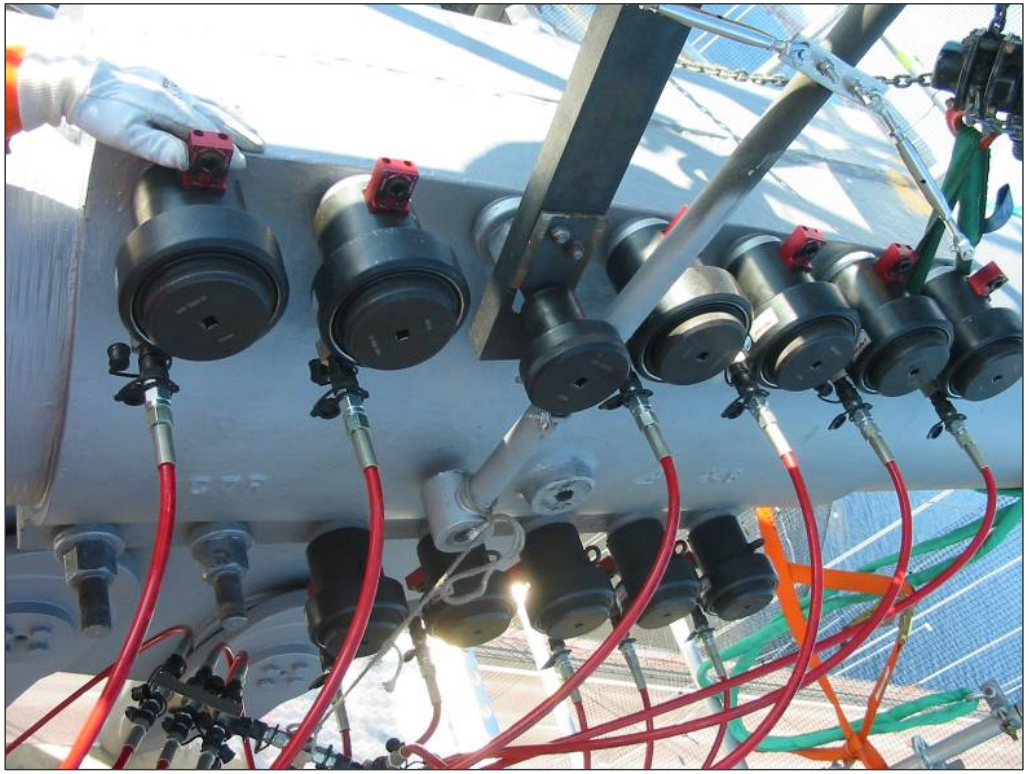
Other works
Cable band bolts

- Spot check of tension included
- Option for re-tensioning
- Reduction of forces generally app. 30% from 770 kN to 550 kN
- To fulfill design requirements bolts in 100 out of 164 cables band were re-tensioned



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Maintenance
End bearings

- The PTFE sliding surface of the end bearings was subject to excessive wear
- Investigations were carried to determine if vertical loads were larger than expected
- Vertical loads were within the expected range
- Causes determined to be low operation temperature (-20° C) and excessive friction
- Solution in 2007 - new sliding surface of MSM from Maurer
- Advantages of MSM
  - Less wear at low temperature
  - Larger load capacity
  - Less friction
  - Expected movement capacity of 50 km contra 10 km for PTFE

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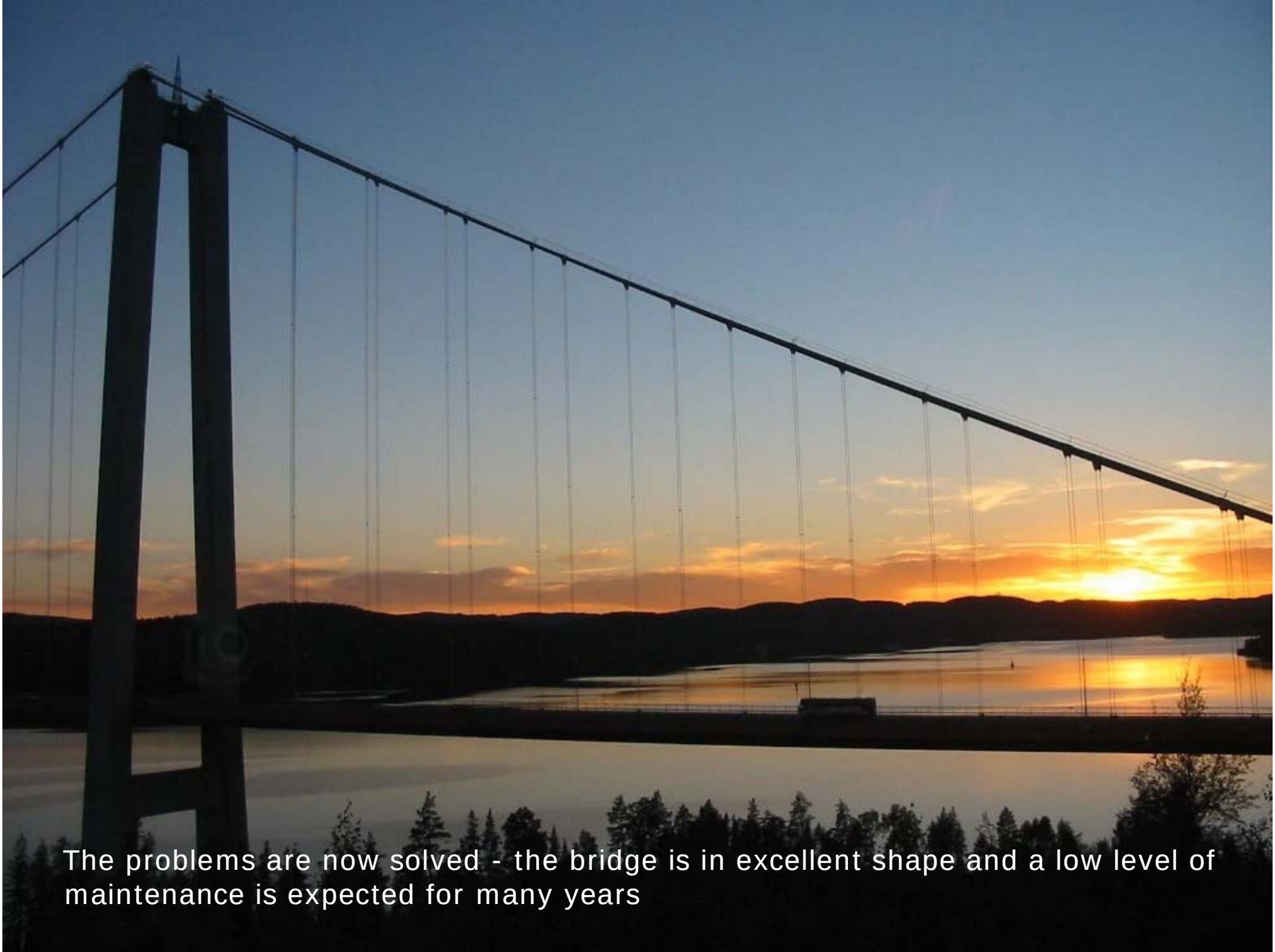
Conclusion

- Högakusten Bridge has a main span of 1,210 m - currently the 9th longest in the world
- It is one of only two major suspension bridges in Sweden
- It is essential for SRA to acquire assistance from specialist consultants and contractors, as in-house expertise is lacking
- A comprehensive report, including future maintenance, on the works was prepared. We recommend that such a report is prepared in connection with all major works
- If such a report had been prepared in connection with the original construction some problems may have been avoided
- Much more minor and major repairs have been carried out during the first 7 years than expected



The problems are now solved - the bridge is in excellent shape and a low level of maintenance is expected for many years