NORTH AMERICAN SOCIETY FOR TRENCHLESS TECHNOLOGY

Fiber Optic Cure Verification (FCV) Ensures Quality, Longevity of CIPP Liner Installations

Nashville, TN
March 11-15, 2012

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Paper ID # C-6-05

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1. Introduction of OSSCAD

- OSSCAD GmbH & Co. KG, founded in 2007 is an high tech company with location in the Technology Centre of Bergisch Gladbach – near Cologne – in Germany.
- OSSCAD is an abbreviation for
  Optical Sensor Systems Consulting And Development.
- OSSCAD provides consulting and engineering in the field of optical sensor technologies with focus on
  - cable monitoring,
  - sewer renovation and
  - special applications in optical sensor technology.
- According to customer requirements OSSCAD offers consulting for
  - system integration / system development,
  - local installation and
  - service & support to end customer.
- Additional information under www.osscad.de

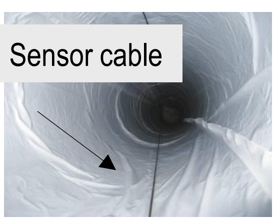
Studies and sensor developments

- Nov. 2007 — Circle profile DN 300
- April 2008 — Circle profile DN 500
- Nov. 2008 — Egg profile B/H 1000/1500
- June 2009 — Manufactory test (steam curing)
- August 2009 — Manufactory test (UV curing)
- Liner projects in Germany, Austria and France (2009-2010)00
- August 2010 — Feasibility study
- January 2011 — System test (UV curing)

Feasibility study

- First projects with optical temperature sensor
- Type of liner: glass-fiber reinforcement (GRF) and needle-felt liner

R&D Project “Inspection of pipe lining“
Project responsibility:
IKT - Institute for Underground Infrastructure

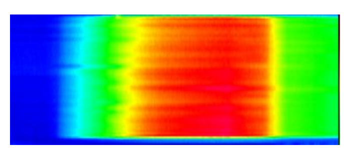


Drawing the sensor cable into the sewer.

Development A

- Temperature sensor cable for the liner integration
- Curing Monitoring software

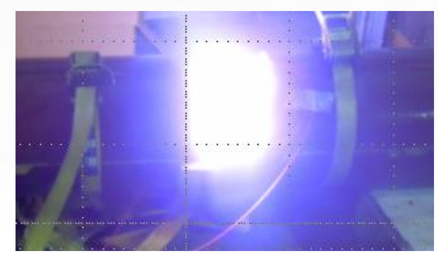
Temperature sensor fitted into the liner during the manufacturing.



3D Plot

Development B

- Feasibility study
- UV sensor cable
- UV sensor system



2. Process control of the lining curing during the sewer renovation

2.1 Expected temperature values during the liner curing - State-of-the-art

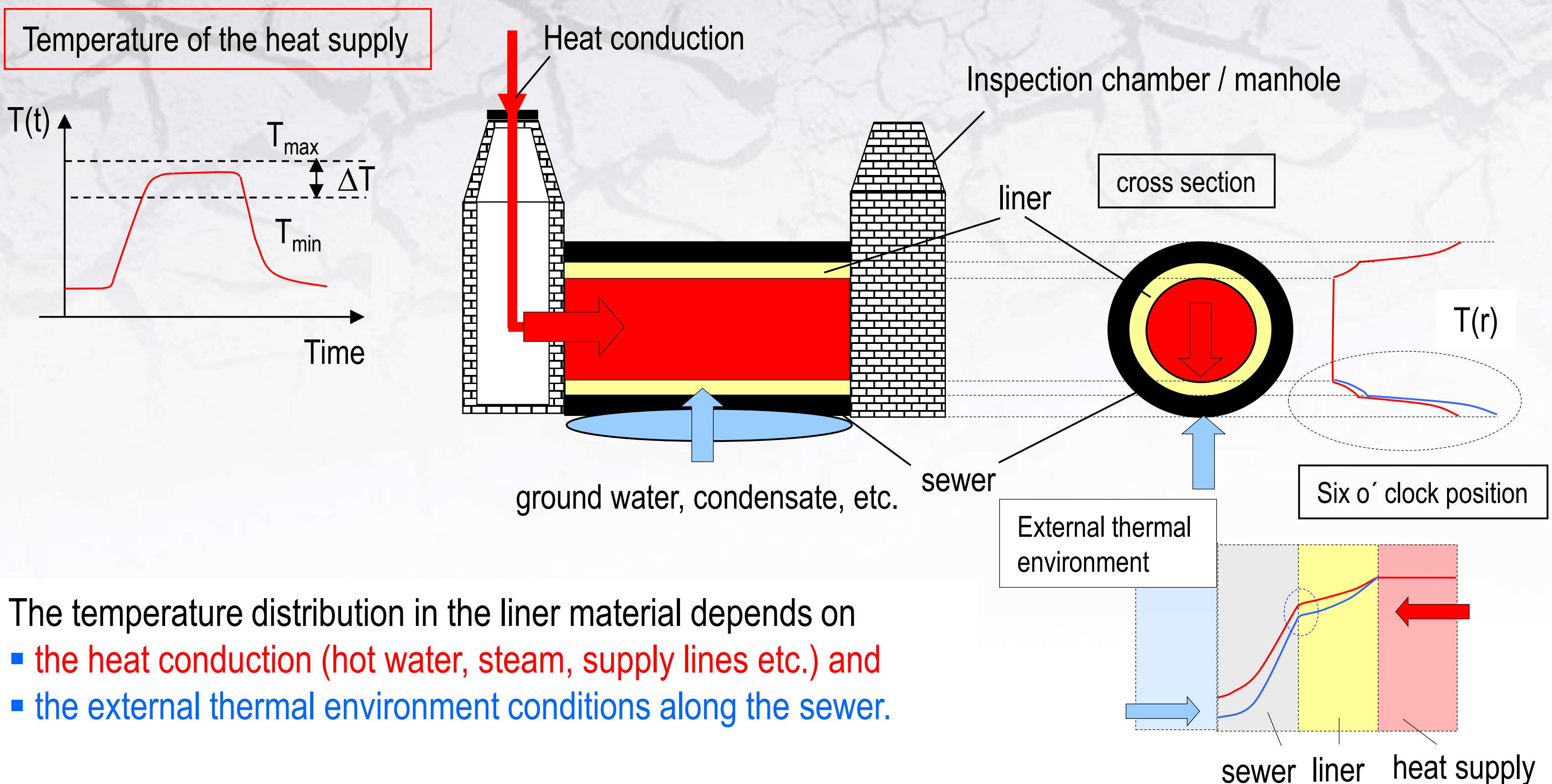
2.2 Discrete (point) temperature measuring

2.2.1 Case study: Inhomogeneous temperature distribution along the sewer

2.3 Technical consequence, motivation & mission

2. Process control of the lining curing during the sewer renovation

2.1 Expected temperature values - State-of-the-art



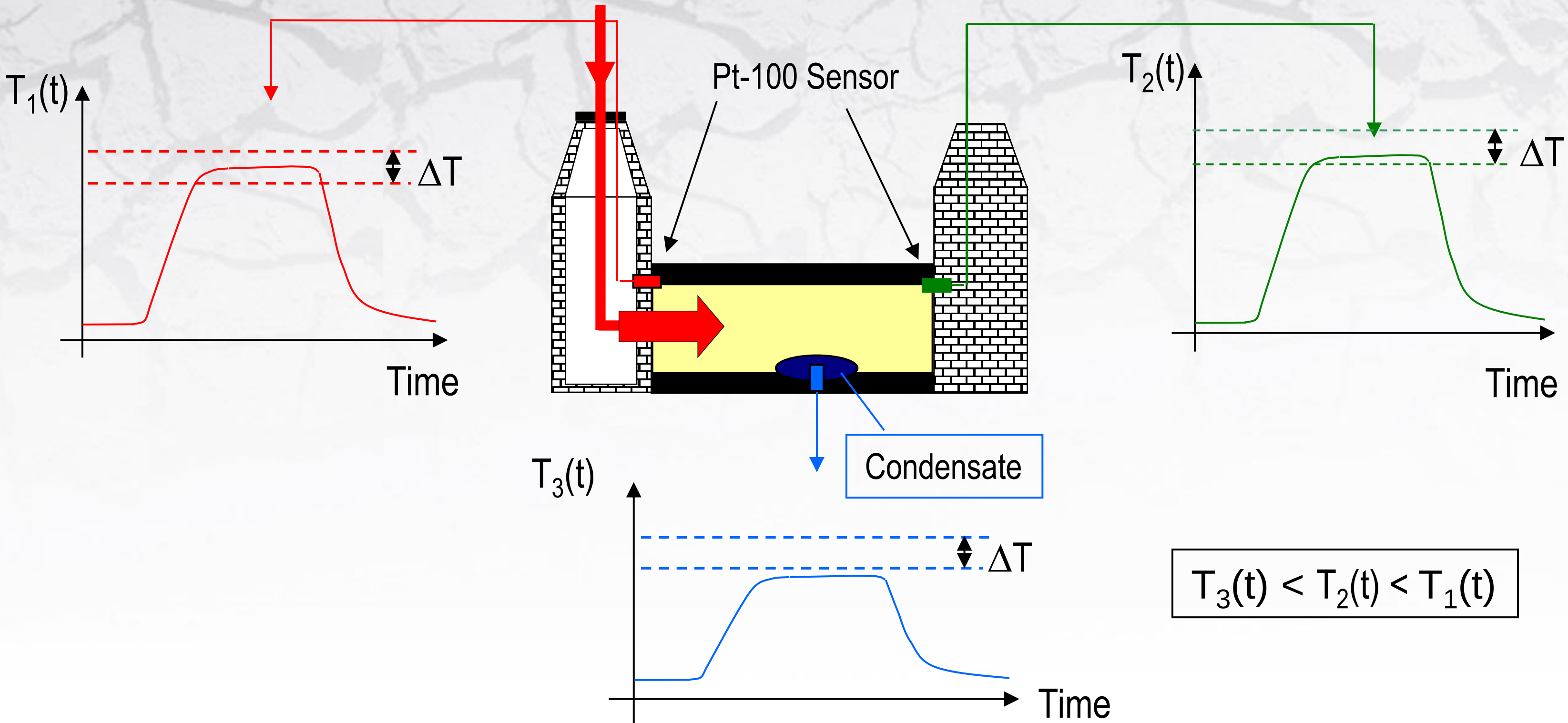
The temperature distribution in the liner material depends on

- the heat conduction (hot water, steam, supply lines etc.) and
- the external thermal environment conditions along the sewer.

The external thermal environment conditions have a strong impact on the liner curing.

2. Process control of the lining curing during the sewer renovation

2.2. Discrete (point) temperature measuring
2.2.1 Case study: Inhomogeneous temperature distribution along the sewer



$T_3(t) < T_2(t) < T_1(t)$

Note:
The point sensor in the inspection chambers cannot measure this thermal behaviour.
Installation of further point sensors between the inspection chambers is not possible.

2.3 Technical consequence, motivation & mission

Technical consequence:

Extension of the period of the heat input (safety premium) in order to achieve the minimal temperature value ($T>T_{min}$) for the right liner curing.

Note: This safety premium does not work in all cases.
This safety premium produces

- higher operating time,
- higher energy costs and
- higher inspection effort in cases of quality problems.

Our motivation:

Optimize the process control by using a fiber optical curing monitoring system in order to

- optimize the process guiding for a homogeneous curing and quality,
- reduce the risk for nonconforming curing by difficult field conditions,
- reduce the costs of renovation (energy costs and site operation expenses),
- improve the consumer's acceptance for liner renovation.

Our technical mission:

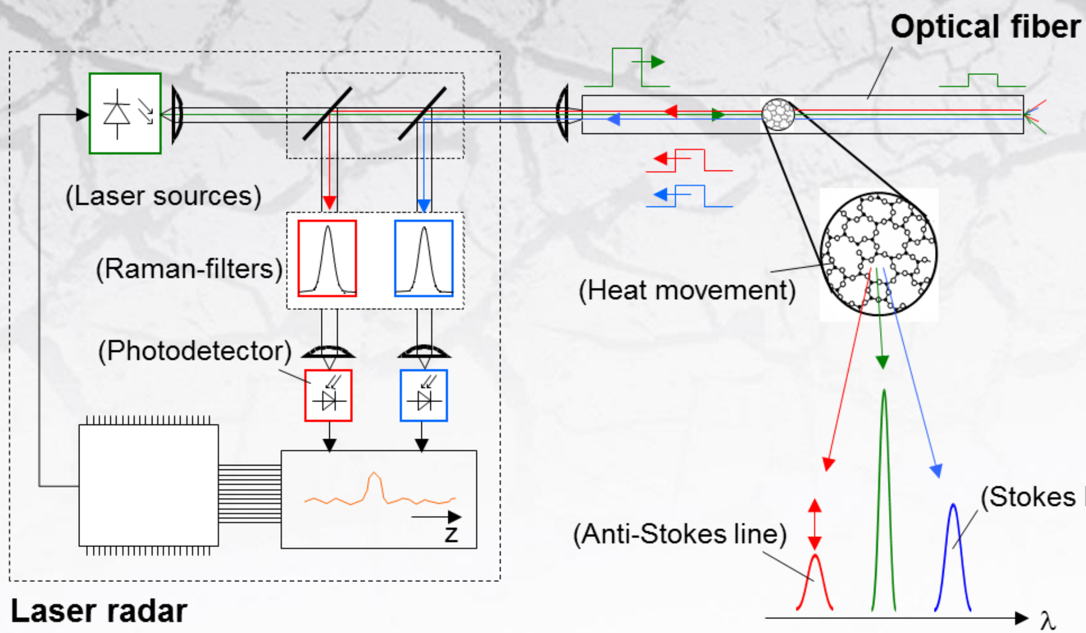
- temperature measuring without gaps along the liner
- development of a sensor cable design for the liner integration
- to develop an easy evaluation software for the operator

3. Optical Fiber Curing Monitoring System (CMS)
3.1 Principle of the optical method
3.2 Optical temperature sensor cable
3.3 Evaluation and visualisation of the liner curing
3.3.1 Case study A: Homogeneous curing distribution
3.3.2 Case study B: Inhomogeneous curing distribution
3.4 Software tools of the curing monitoring system
3.4.1 Schematic Curing View (Operator view)
3.4.2 3D-Plot (Curing analyse view)
3.4.3 Demonstration of a curing monitoring 3D-Plot
3.5 Manufacturing test

4. Pilot and reference projects of the Curing Monitoring System (CMS)
4.1 Needle felt liner - Hot water curing
4.2 GFR liner - Steam curing

3. Optical Fiber Curing Monitoring System (CMS)

3.1 Principle of the optical method



Typical measurement parameters:

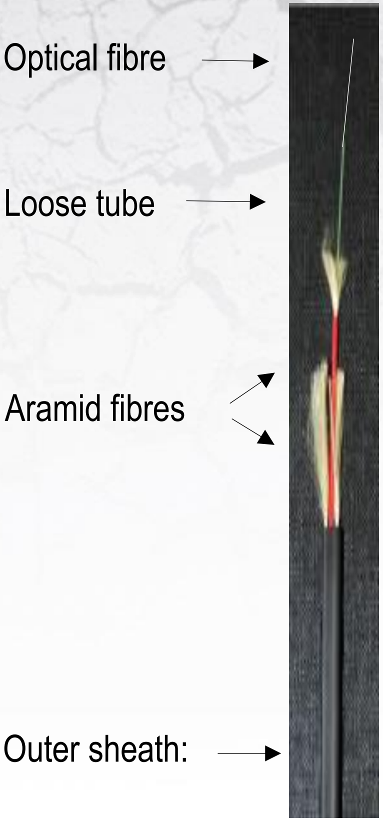
Measurement time: 30s
Spatial resolution 1 to 2 feet
Range: 1500 feet (max. 6550 feet)
Temperature resolution: ±1°C

The **main advantages** of the optical fiber technology compared to point sensors

- to measure the temperature without gaps
- to measure the temperature as a function of time and location
- the possibility to integrate the sensor into the liner (enables an easy installation)
- the immunity against electromagnetic fields and
- the low prices of the optical fibre sensor

3.2 Optical temperature sensor cable

Optical fibre connector mounted on the sensor cable



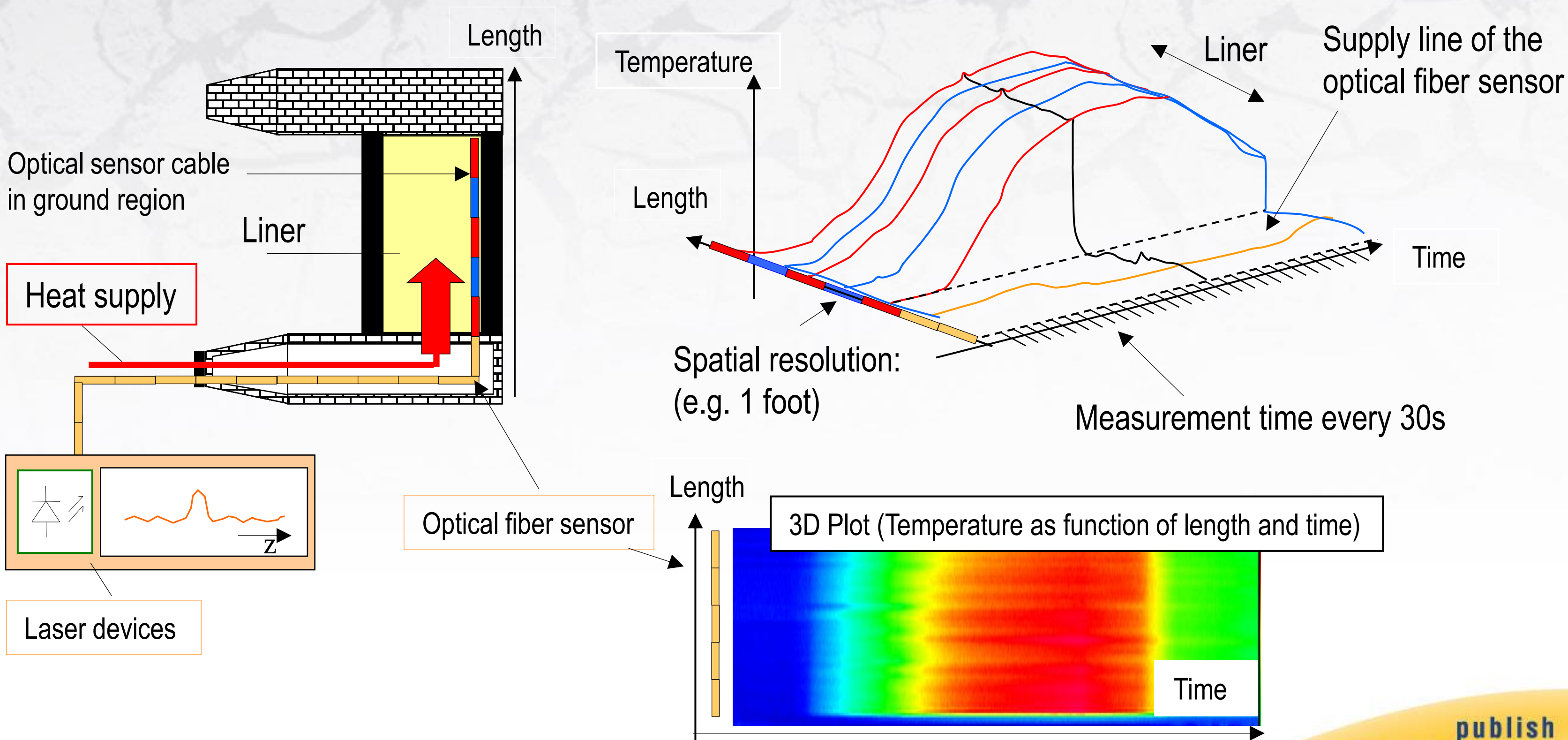
Sensor cable suitable for sewer drawing and for liner integration

Temperature Sensor Cable

Optical fibre:	Quartz glass fibre
Coating:	Acrylate coated
Fibre protection:	Loose tube
Strain-relief:	Aramid fibres
Outer sheath:	Plastic
Cable dimension:	Rectangle profile

3.3 Evaluation and visualisation of the liner curing
3.3.1: Case study A: Homogeneous curing distribution

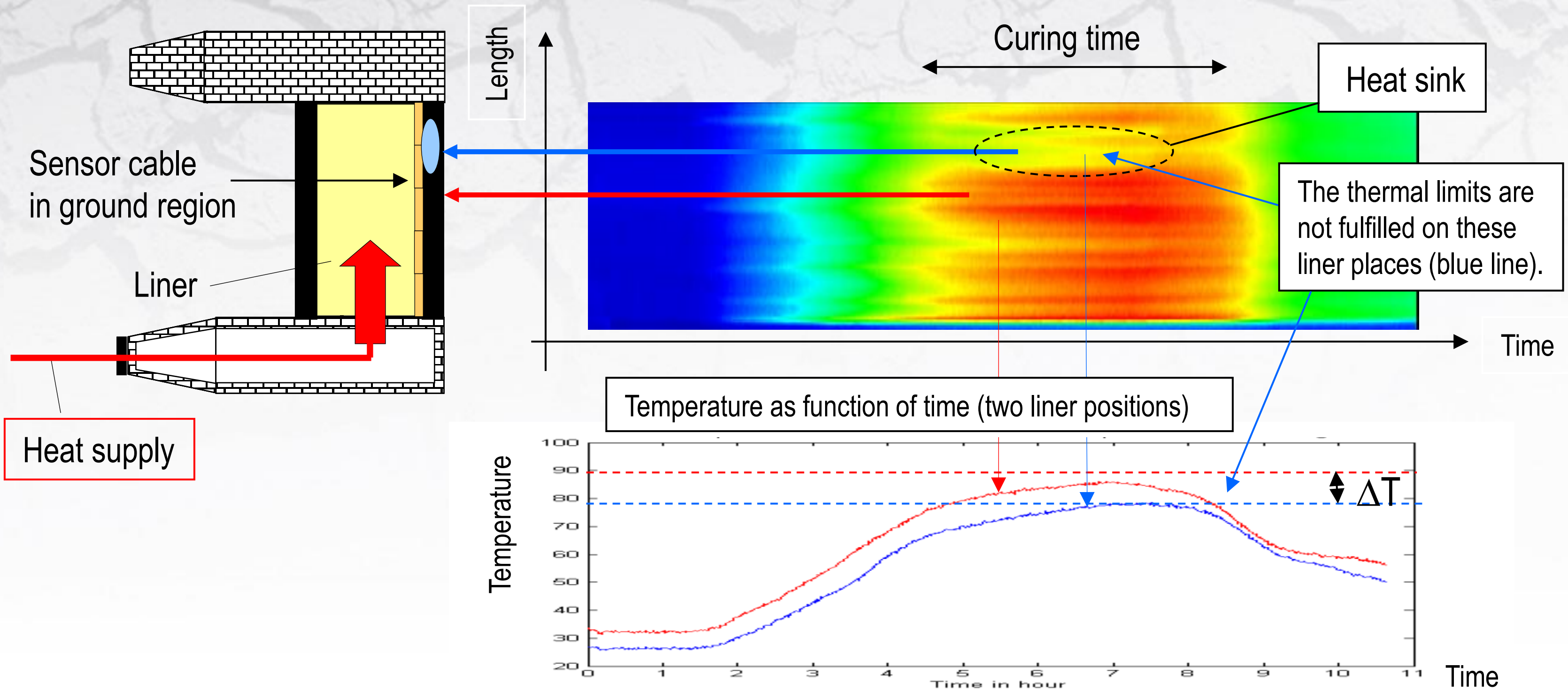
Measuring the temperature along the liner with a homogeneous external thermal environment conditions.



3. Optical Fiber Curing Monitoring System (CMS)

3.3 Evaluation and visualisation of the liner curing

3.3.2: Case study B: Inhomogeneous curing distribution (cold area at the liner end)

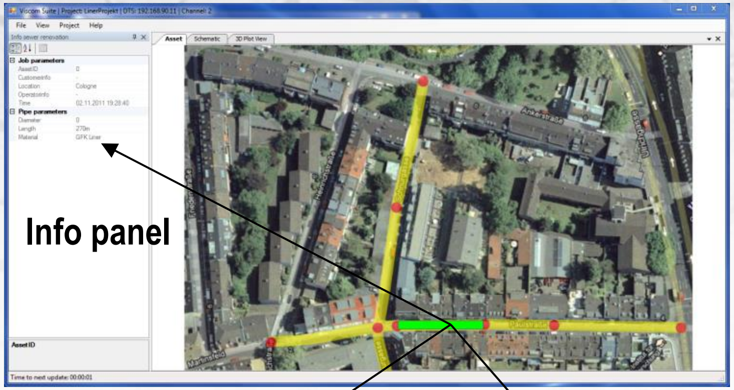


The optical fiber curing monitoring systems enable

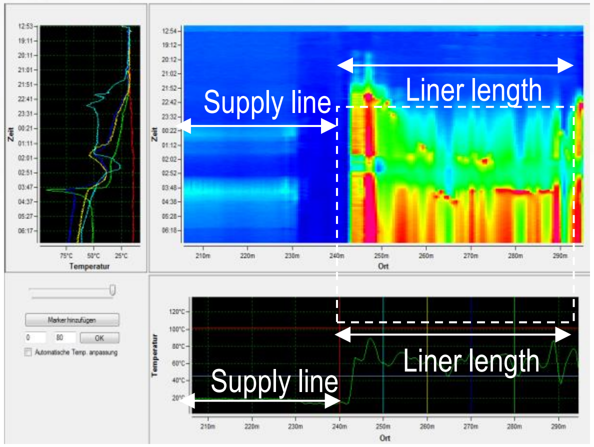
- to measure the liner temperature at every position along the liner and
- to monitor the curing to pass the thermal limits.

3.4 Software tools of the CMS

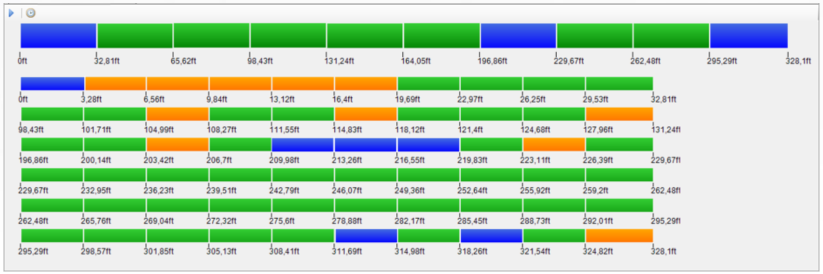
Liner Information View of the renovation project



3D View (Thermo graphic image)

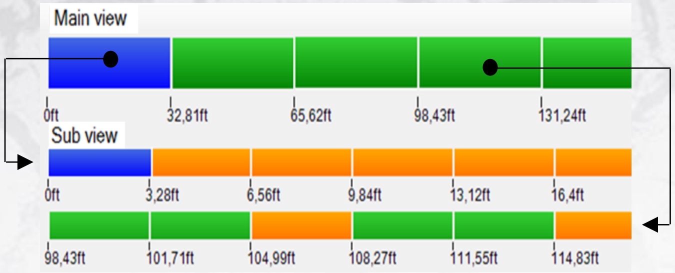


Schematic Curing View



3.4 Software tools of the CMS
3.4.1 Schematic Curing View (Operator view)

Schematic Curing View



The main and sub views (zone view) of the schematic curing view represent **the temperature value or heat input** per distance along the liner.

The threshold for the temperature value and the heat input, the length of the main and sub view and the colour of the zones can be freely configured.

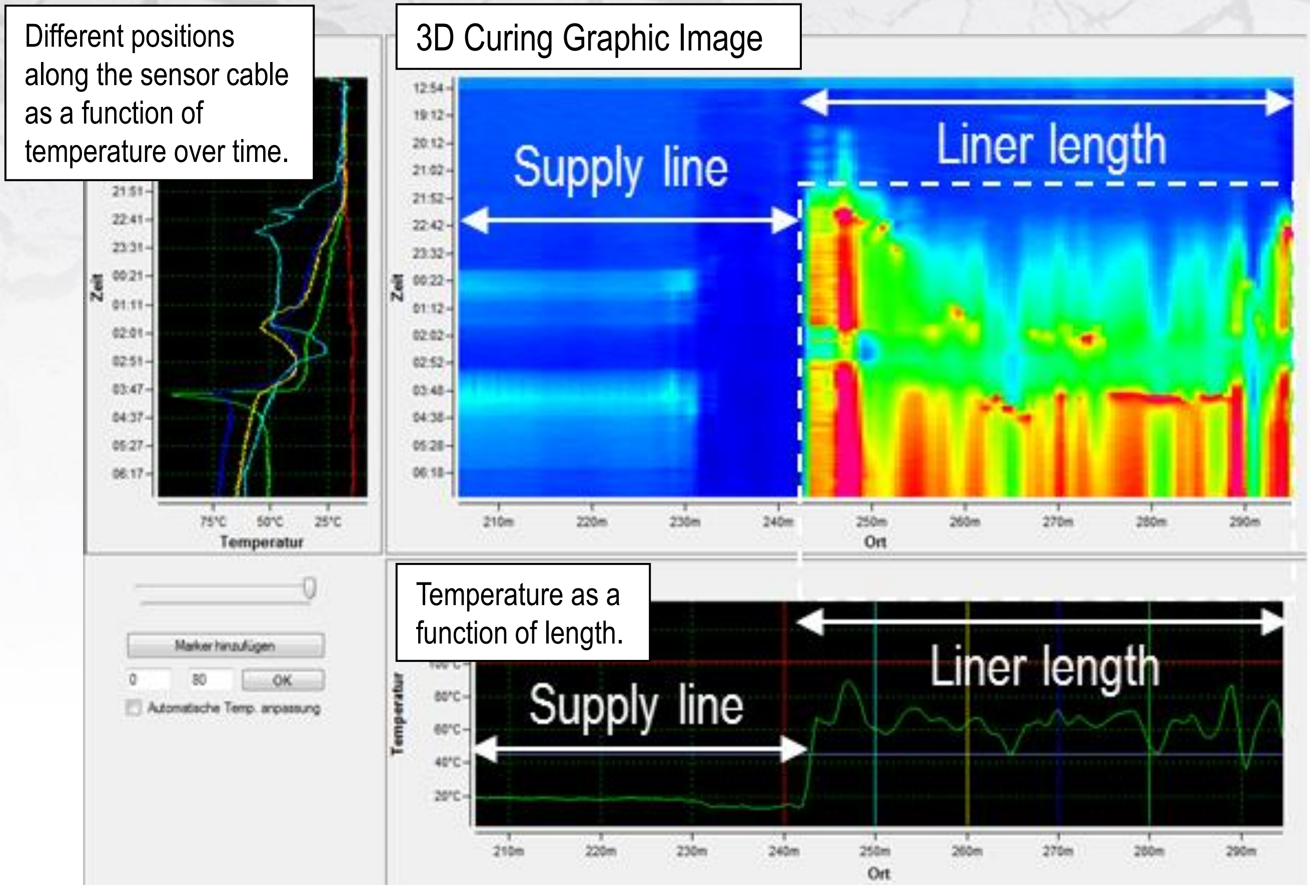
Example:

Main distance:	e.g. 32.8 feet	
Sub distance:	e.g. 3,28 feet	
Colour of the zones:	red:	T > 248F (120°C)
	orange:	248F (120°C) ≥ T > 176F (80°C)
	green:	176F (80°C) ≥ T ≥ 140F (60°C)
	blue:	140F < T

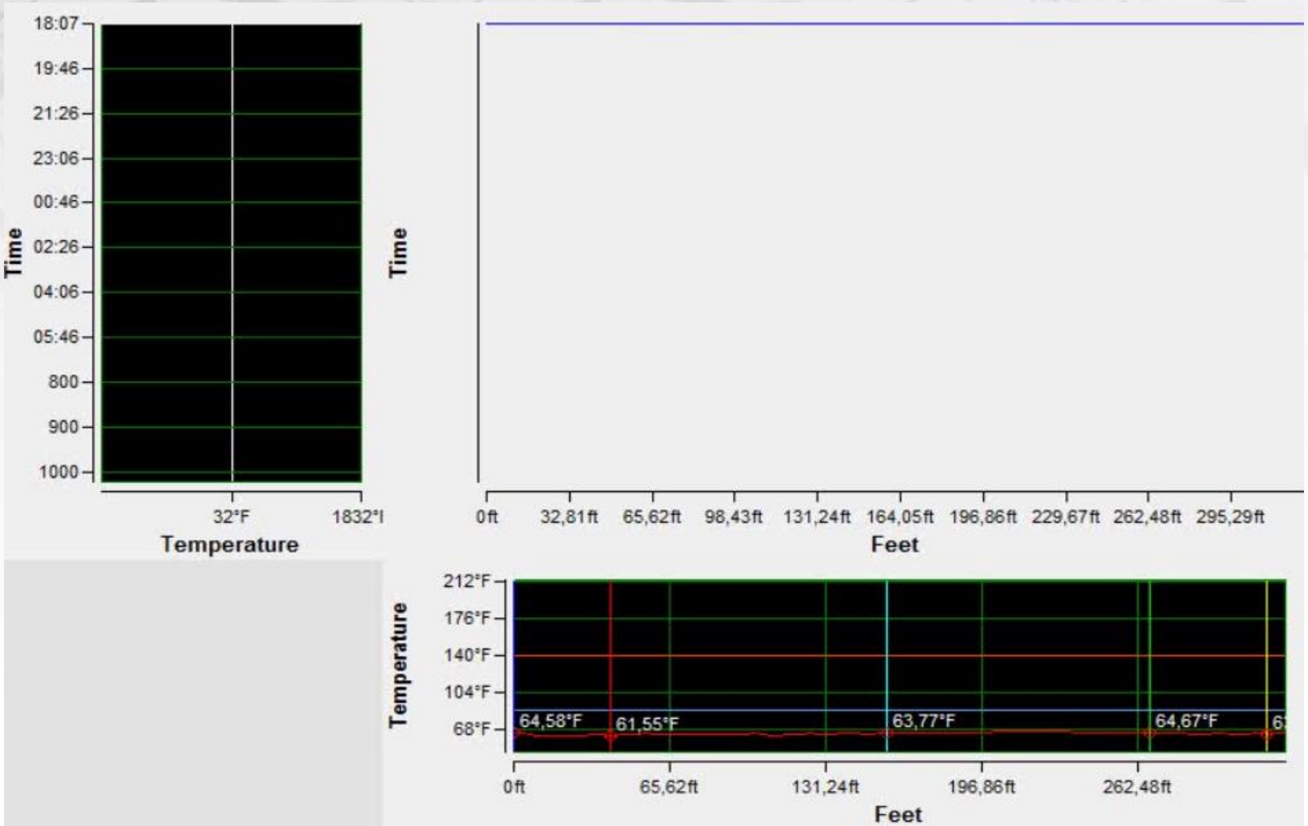
The afford of the zone view is the evaluation per computer.
The operator gets the temperature values of the zones in different colours along the sewer.
The operator can optimize the energy supply very easy:

- blue colour means to increase or to extended the heat input and
- green colour means the curing temperature meets the thermal limits or the heat input.

3.4 Software tools of the CMS
3.4.2 3D-Plot (Curing analyse view)

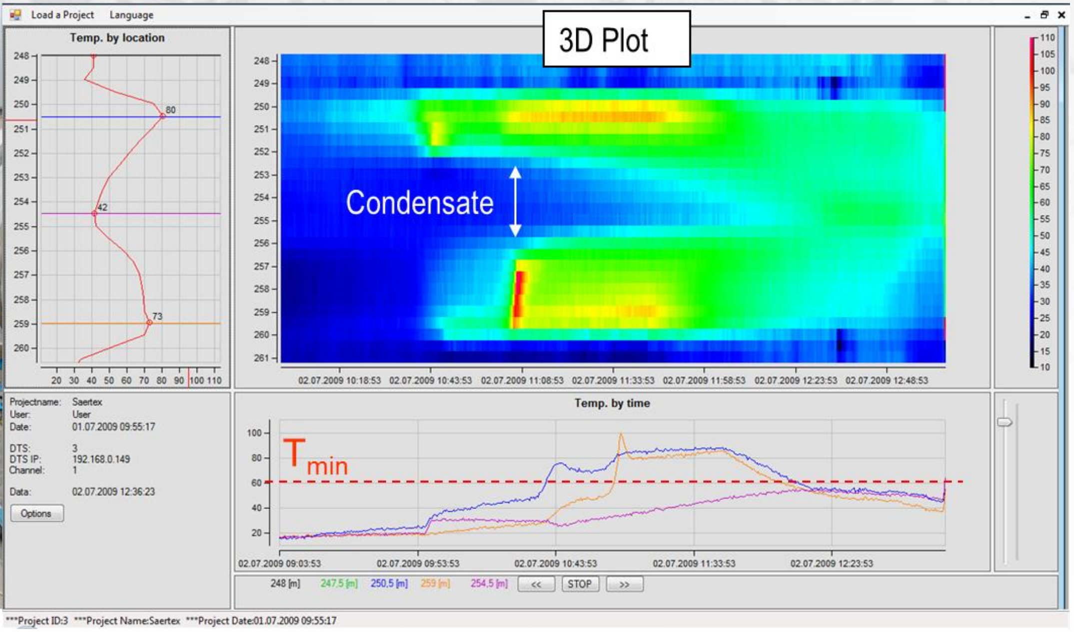


3. Optical Fiber Curing Monitoring System (CMS)



3.5 Manufacturing test: GFR liner - Steam curing

Integration of the sensor cable at the outer film (skin) of the liner.



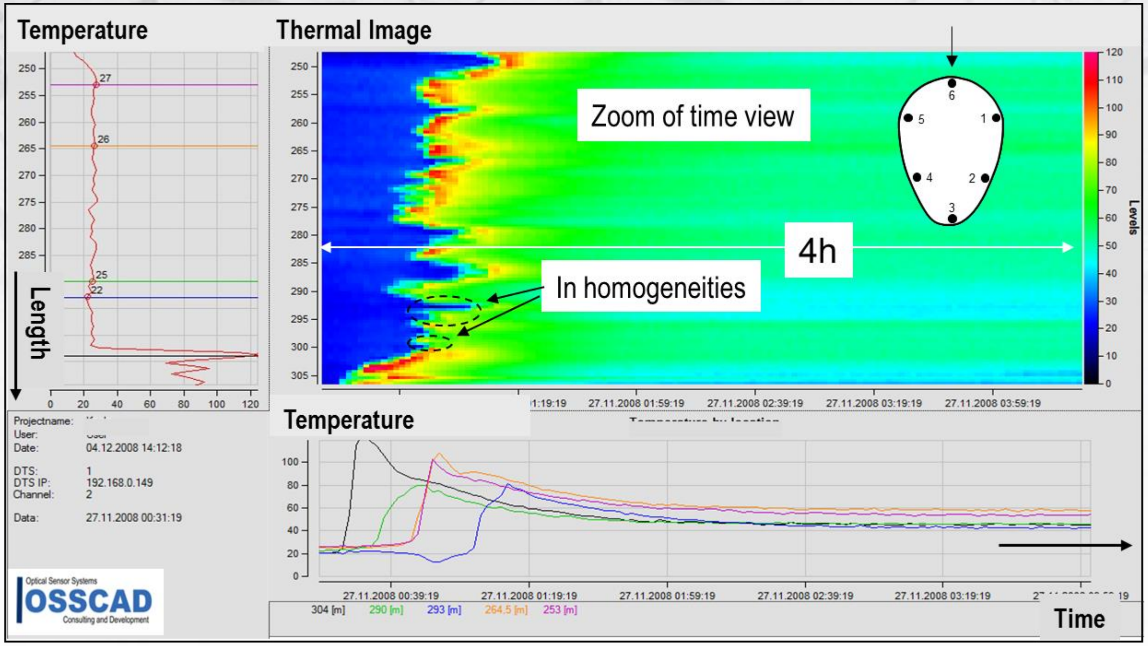
Results:

- Precise location of the low thermal area due to the condensate.
- The liner at the condensate does not achieve the minimal temperature limits.
- The elasticity E-Modulus (DIN EN ISO) does not fulfil the required limits.

4. Pilot and reference projects

4.1 Needle felt liner - Hot water curing

Drawing the sensor cable into the sewer (peak region), egg profile, nominal diameter: DN 1000/1500



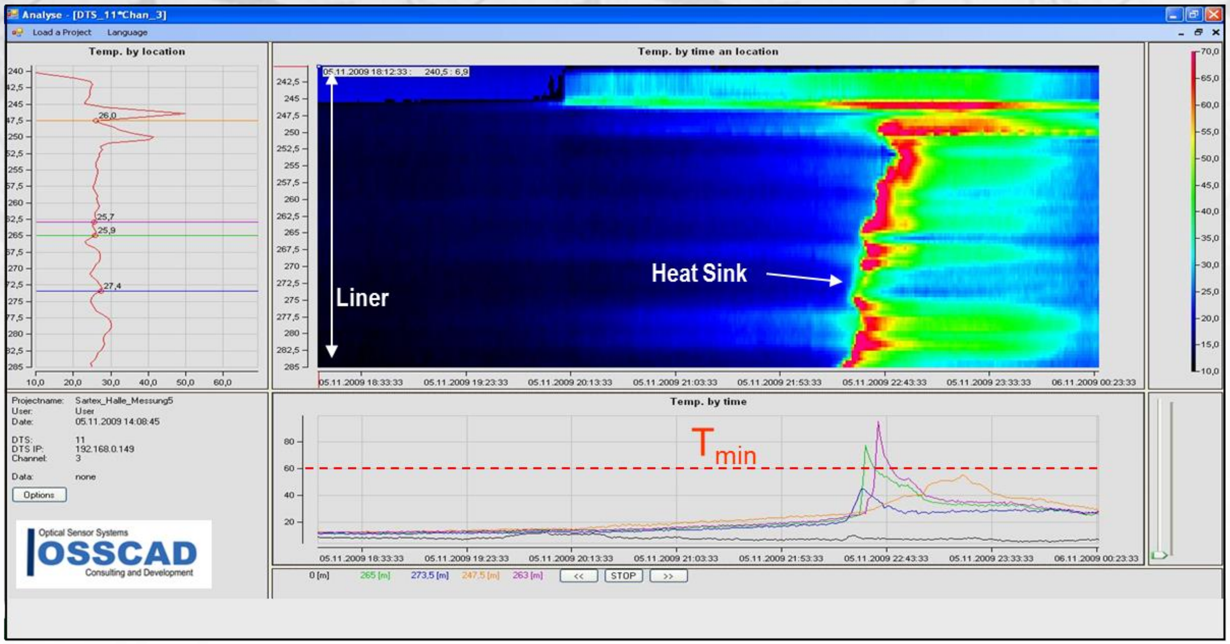
Results:

- Measuring of exothermic reactions along the liner profile.
- The temperature distribution is not homogeneous by using a hot water curing.
- Due to an extended curing time, the liner achieves the required stability and quality.

4. Pilot and reference projects

4.2 GFR liner - Steam curing

Integration of the sensor cable at the outer film (skin) of a glass-fiber reinforcement (GRF) liner.



Results:

- The temperature limit of 60°C is not reached all along the liner.
- By extending the curing time to 24 hours, the liner achieves the required mechanical strength.

5. Summary and Outlook

Summary:

- The temperature measuring system has been successfully used for curing processes using hot water and steam.
- The sensor cable can be fitted in the liner during manufacturing.
- The temperature measuring system in combination with a powerful software allows the optimization of the process guiding:
  - If the <u>minimum temperature is not achieved along the sewer reach</u>, the operator can extend the heat input to pass the required curing quality particularly by difficult field conditions.
  - If the <u>minimum temperature is reached earlier than expected,</u> then the safety premium can be avoided and the duration of the heat input can be reduced as well as the energy costs and the operation expenses.
- Process guiding with optical sensors is an indication for a better liner quality of the liner curing.

Outlook:

- Adaptation of the evaluation setup in the process control of the test vehicle to monitor the lining curing automatically by using the fiber optic temperature systems.

Thank you for your attention.

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