Main surveillance and control methodologies

European Working Group Penstocks & pressure shafts & pressure tunnels
Workshop on 3rd November 2022 - Armin Kager

HYDRO SAFETY ENGINEERING

CIGB ICOLD

ITCOLD

RSE Ricerca Sistema Energetico

HYDRO SAFETY ENGINEERING

1) General aspects
2) Historical evolution
3) Visual controls
4) Non-destructive material testing
5) Destructive material testing
6) Tests on structural elements (concrete)
7) Other controls
8) Conclusions

General aspects

Why do we carry out examinations and inspections of steel pipelines?

- To get a comprehensive survey of the **maintenance condition**.
- To get a **basis** for the assumptions of the **calculated assessments**.
- To get information about the **remaining service life** of the infrastructure.
- To get important information with regard to **condition-oriented maintenance**.

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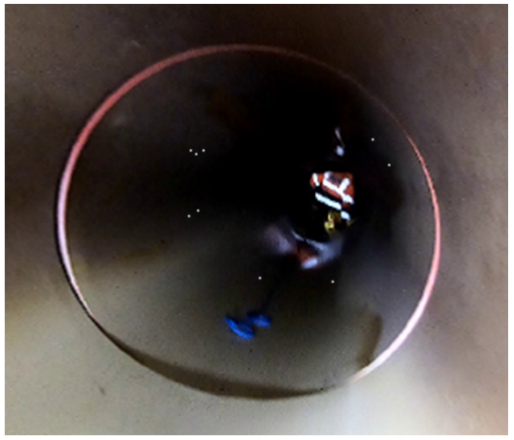
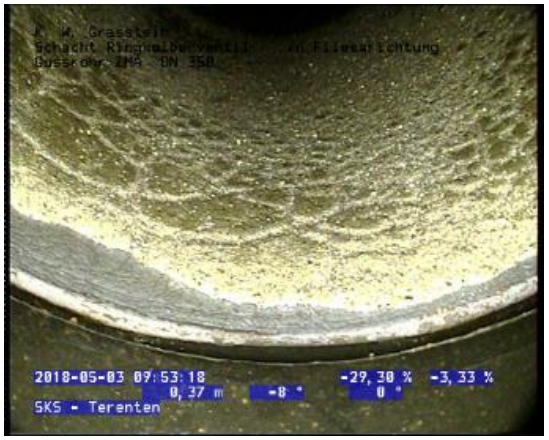
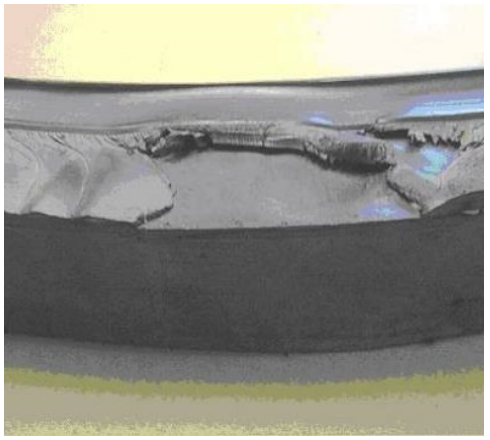
General aspects

Essentially, the following statements apply to both metallic and non-metallic pipelines (e.g. GRP, concrete or plastic).







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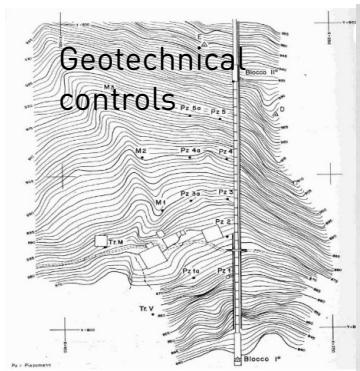
Historical evolution

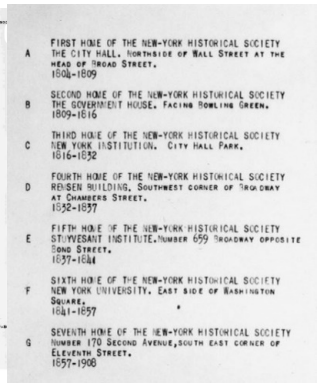
Useful documents can be:

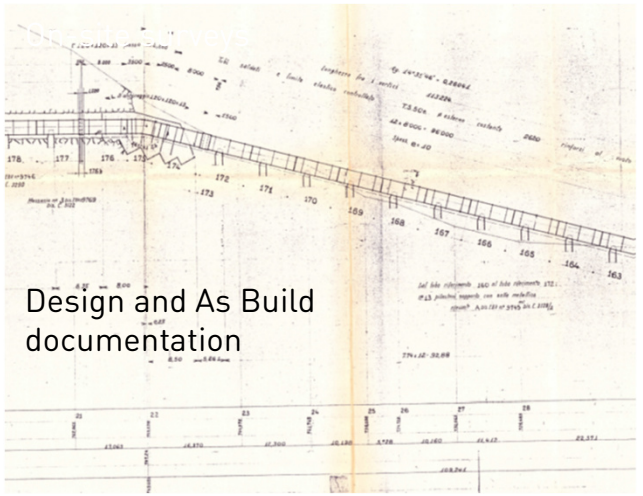
..... also:

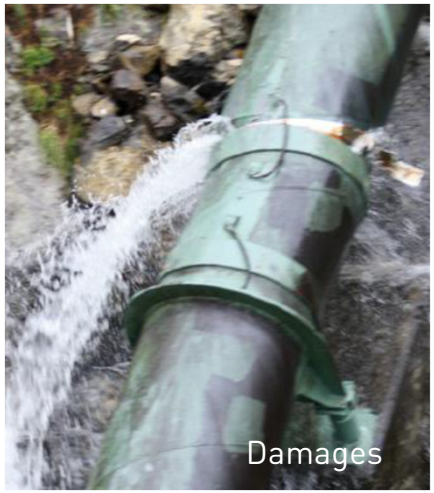
- Delivery notes.
- Information about changes during construction and refurbishments/repairs.
- Inspection reports.
- Construction details.
- Information on terrain movements, seismic events, etc.



Construction diaries







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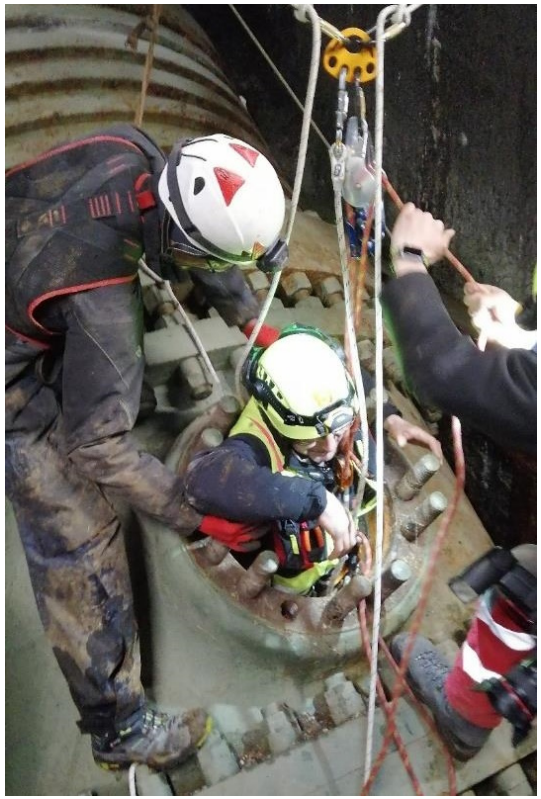
Visual controls

Activities to carry out:

- Inspection from the **inside** by walk-through with operators, robots and drones
- Inspection from the **outside** (for freely laid pipelines)
- Diggings and controls from **outside** (for buried pipelines - at greater intervals).



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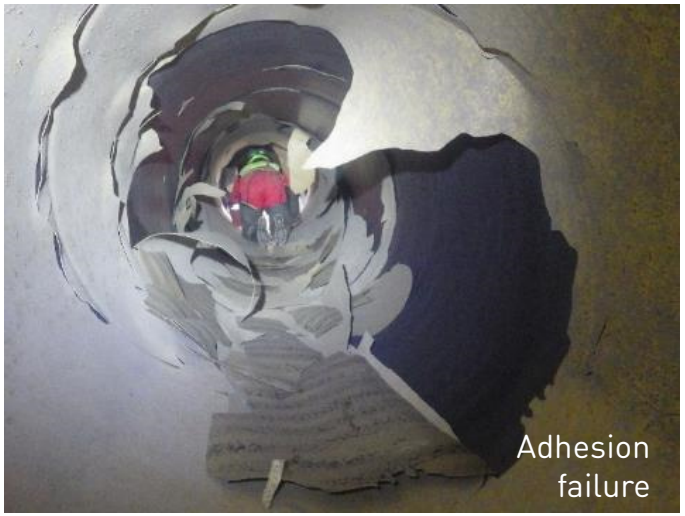
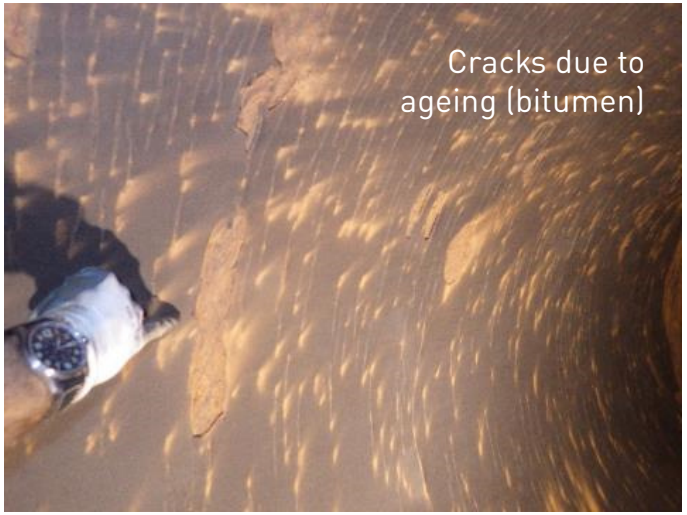
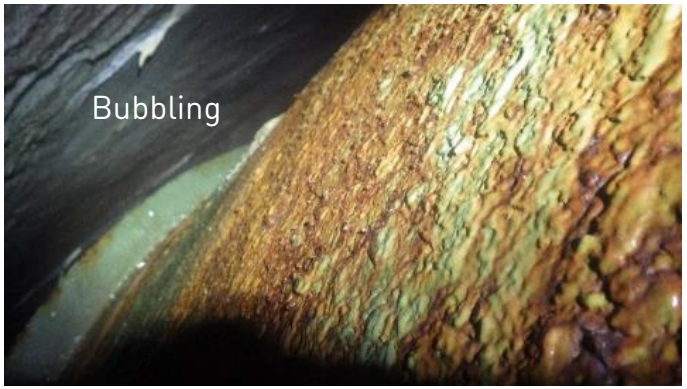
Visual controls

What needs to be checked?

- **Condition of the passive corrosion protection**
- **Corrosion**
- Abrasion
- Deformation/ovalisation
- Joints
- Special parts







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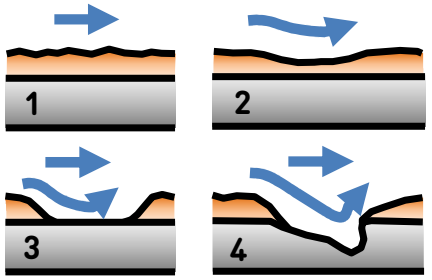

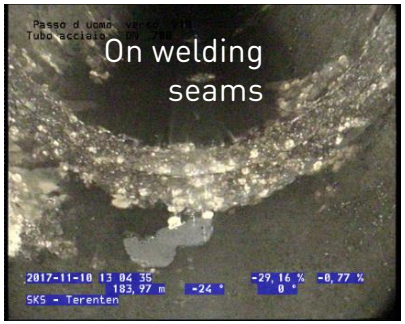

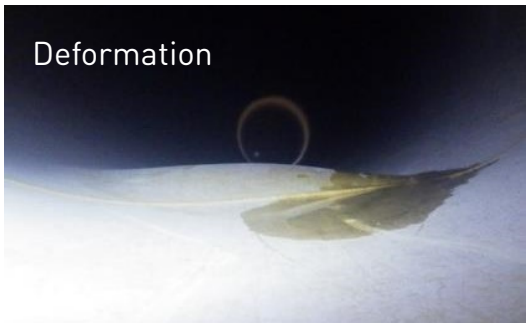

HYDRO SAFETY ENGINEERING

Visual controls

What needs to be checked?

- Condition of the passive corrosion protection
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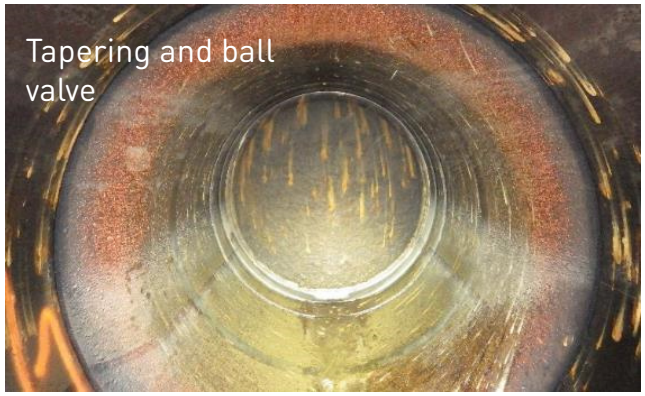
- Deformation/ovalisation
- Joints
- **Special parts**

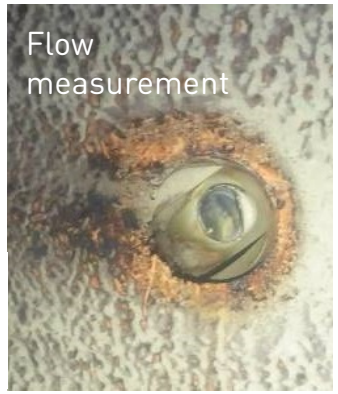

Manholes


Inlet area


Saddle plate


Tapering and ball valve


Inspection openings

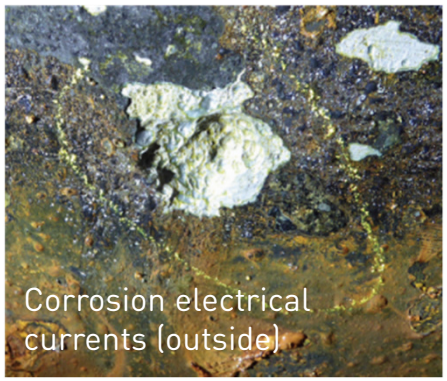

Flow measurement

Visual controls

What needs to be checked?

- Particular attention on areas with **intensive hydraulic stress** (inside)
- Sensitive areas like **bearing saddles** and **anchoring blocks** (outside)
- **Environment above buried penstocks** (heavy traffic, power lines, especially DC, vegetation, groundwater conditions, etc.)


Erosion-corrosion


Corrosion electrical currents (outside)

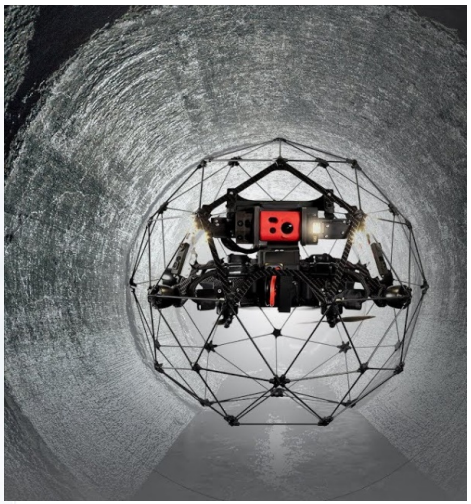

Saddle

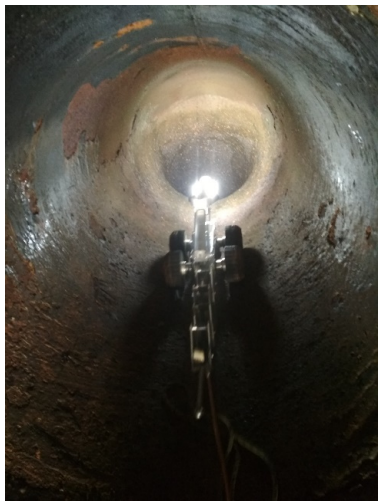

Anchoring block

Visual controls

What are the main things to pay attention to?

- Good **planning**
- **Qualified** personnel with a lot of experience
- A **high level of safety** in the execution of the work
- Best possible **equipment**
- Good **ventilation**
- Good **lighting** conditions
- Best possible **cleaning** of the pipes (flushing)





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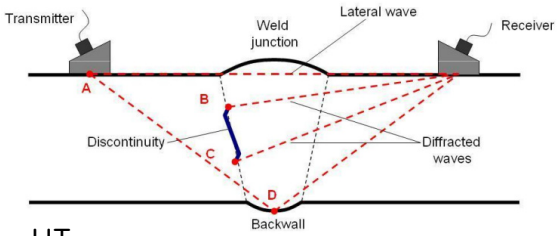
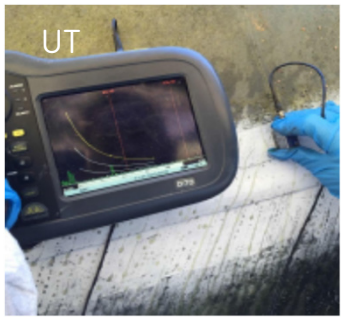
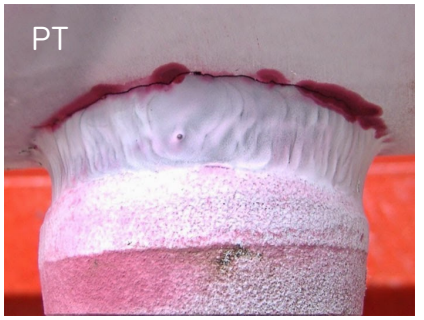
Non-destr. material testing

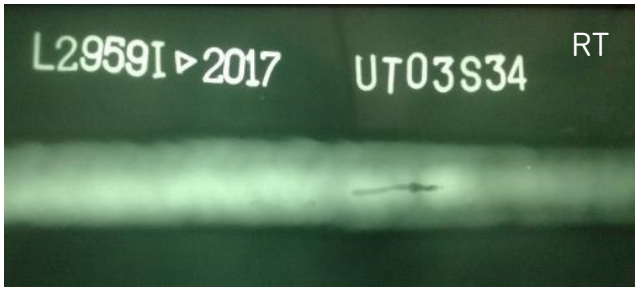
- **Wall thickness measurements** using ultrasound for **statistical evaluations** of residual wall thickness.
- **Raster and B-Scan measurements** to determine corrosion and abrasion in areas subject to particular stresses.
- Detection of **defects on the surfaces** of weld seams and pipe walls (penetrant testing PT, magnetic particle testing MT).
- Detection of **defects in weld seams** and pipe walls (ultrasonic testing UT, radiographic testing RT).



UT

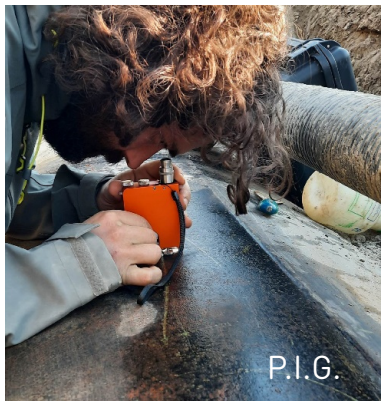




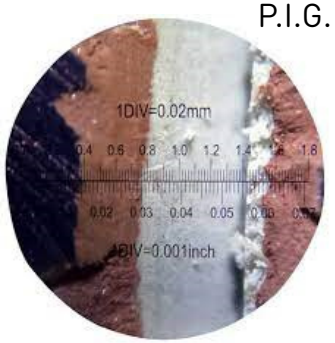


Non-destrucive material testing

- Measurement of **coating thickness** (magnetic inductive measurement)
- Detection and estimation of the **individual layer thicknesses** (of base, intermediate and top coatings) with **P.I.G.**
- **Adhesion testing** (pull-off, X-cut, cross-cut)
- Determination of corrosion grade (LaserScan)
- Deformations and ovalisation (LaserScan)
- Hardness testing to estimate the mechanical properties



P.I.G.



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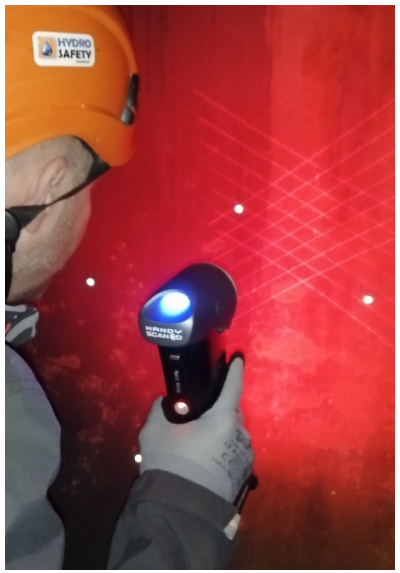

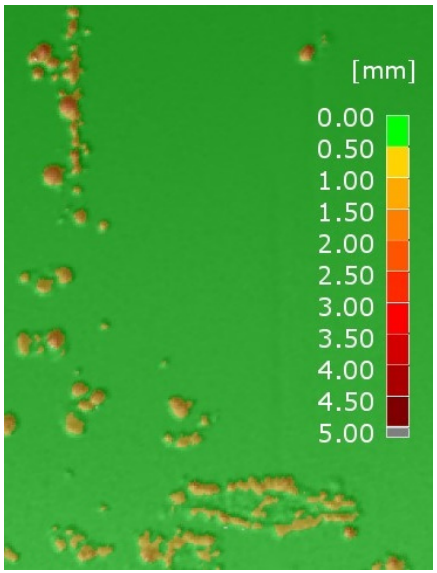

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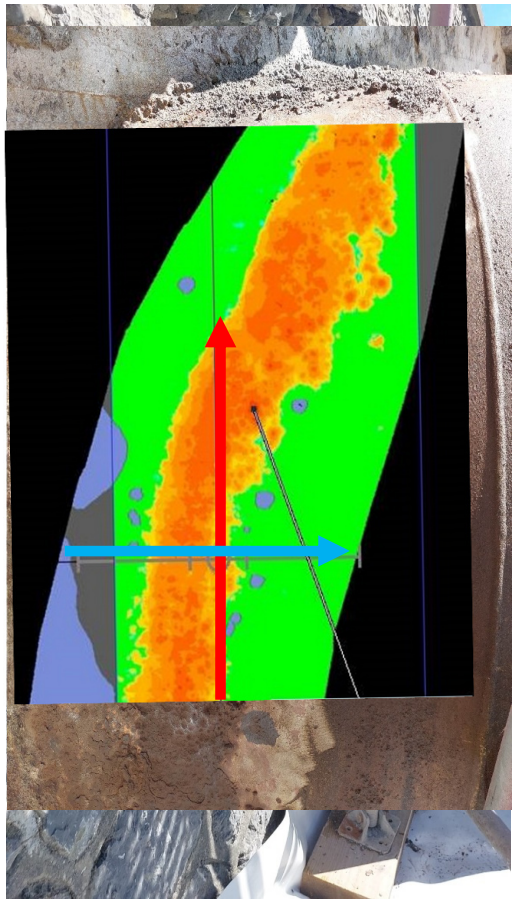
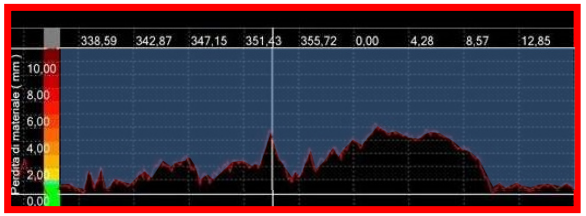
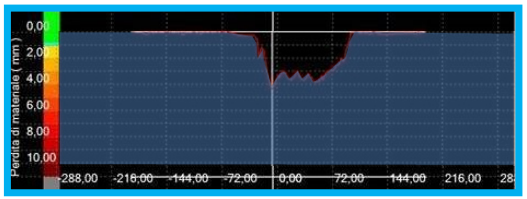
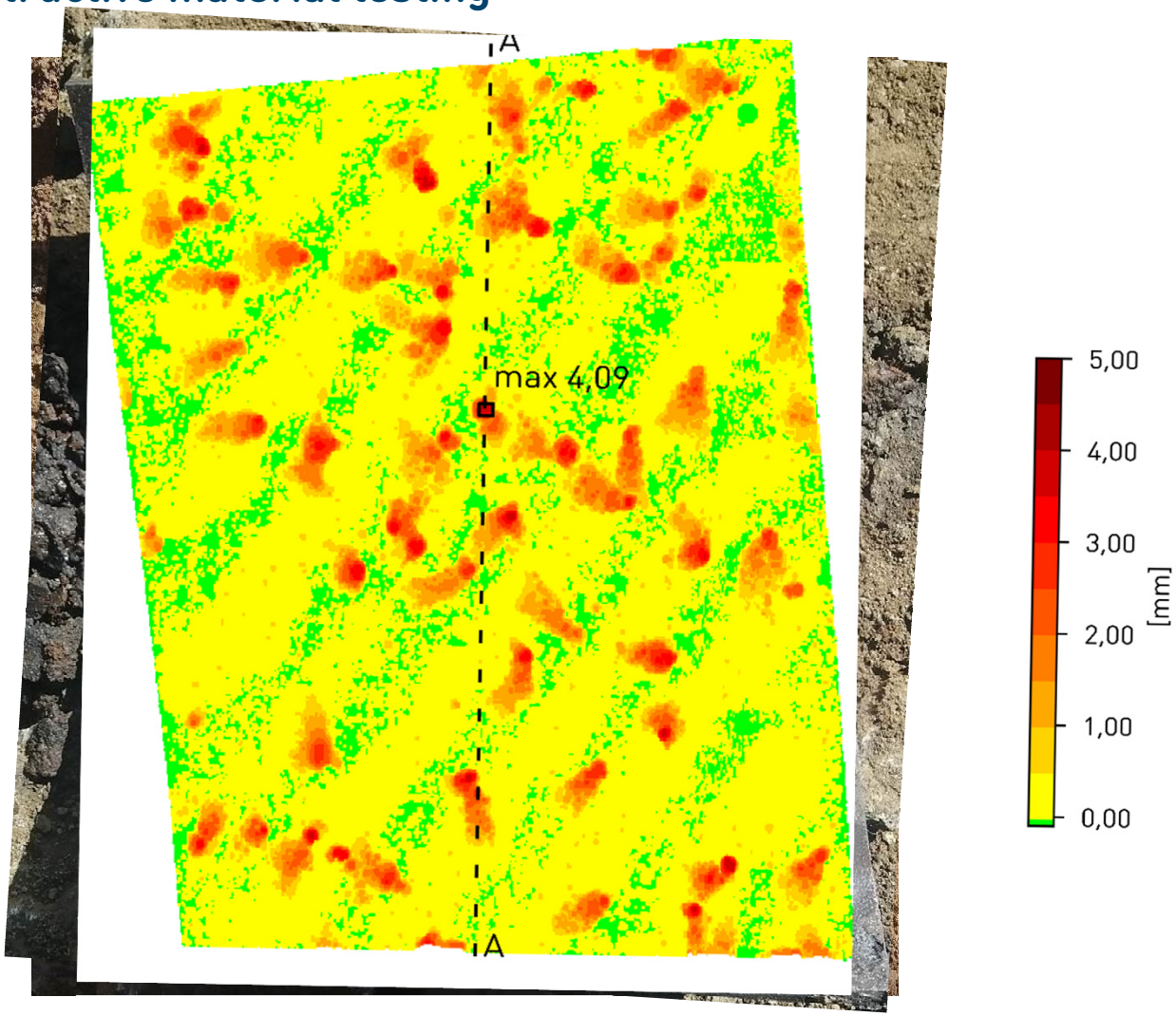


Laserscan





Non-destructive material testing



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Destructive material testing

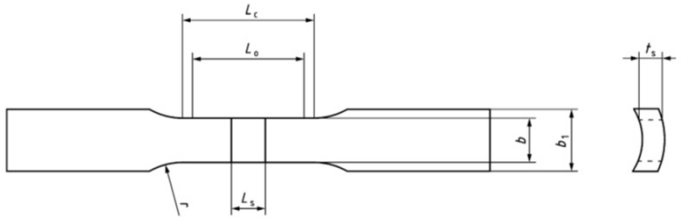
Determination of metallurgical parameters on samples

- **Tensile strength** in longitudinal and transverse direction
- **Flexural strength**
- **Notched impact strength**
- Hardness
- Chemical composition
- Metallurgical structure
- Calculation of the nil-ductility temperature (NDT)

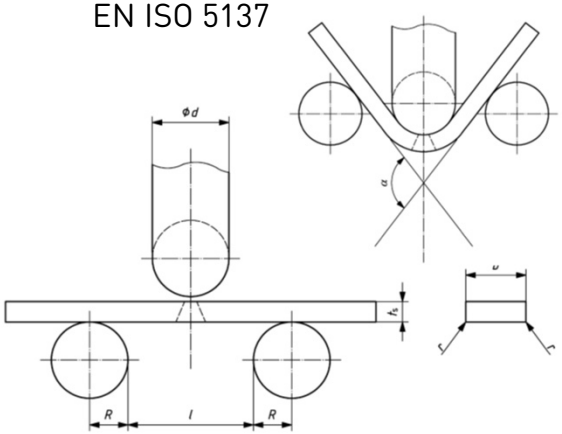
Examination of welds

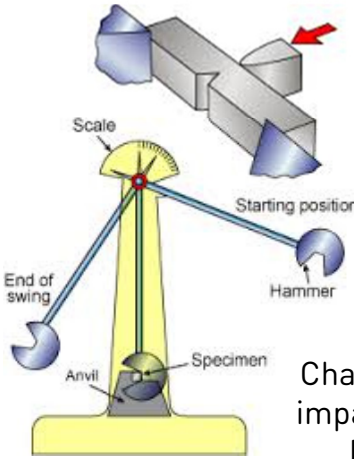
- Micrographs

Tensile strength test
EN ISO 4136



Flexural strength test
EN ISO 5137





Charpy notched impact strength
EN ISO 9016

Destructive material testing

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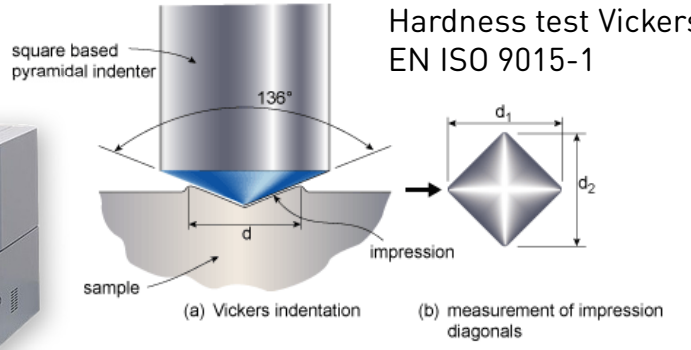
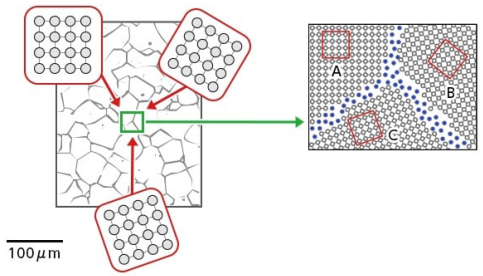
Chemical analysis of metal samples

Hardness test Vickers EN ISO 9015-1



Analysis of metallurgical structure – EN ISO 17369



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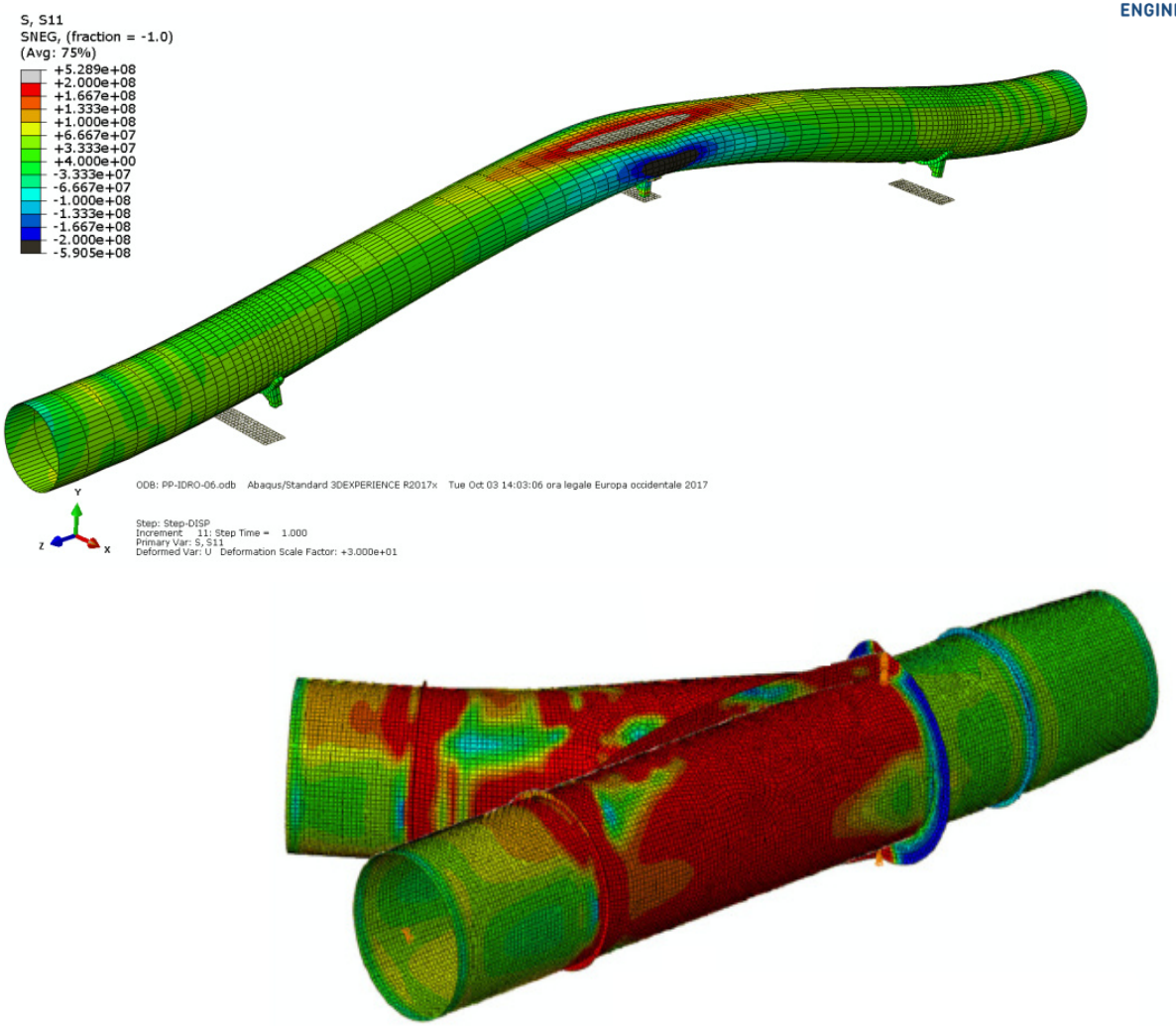

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Tests on structural elements

- Determination of **carbonation** depth EN 14630
- Determination of **density** EN 12390-7
- Determination of **real density and apparent density** EN 1936
- Determination of **ultrasonic pulse velocity** EN 12504-4
- Determination of the **compressive strength** of test specimens EN 12390-3
- Determination of **secant modulus of elasticity** in compression EN 12390-13
- **Tensile splitting strength** of test specimens EN 12390-6
- **Petrographic** examination ASTM C856–04
- **Diffractometric** and **chemical analysis**

Phenolphthalein test

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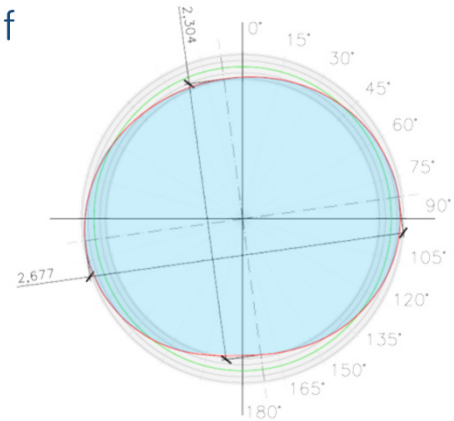
Other controls

- **Deformations and ovalisation** (LaserScan)
- Use of pigs for holistic control
- Extensometer for the determination of local deformations
- Attachment of strain gauge rosettes for measuring multi-axial strains/stresses



Laserscan-Vermessung

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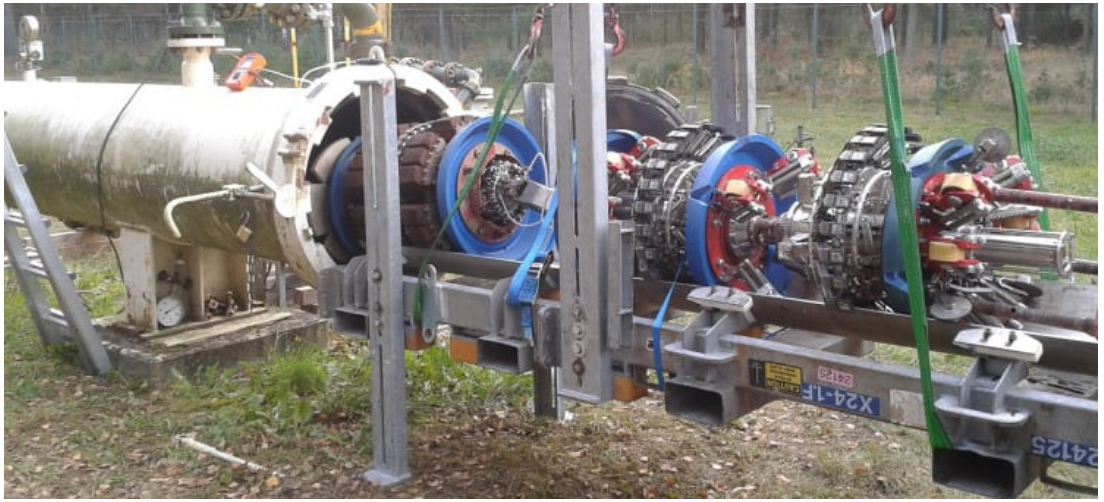

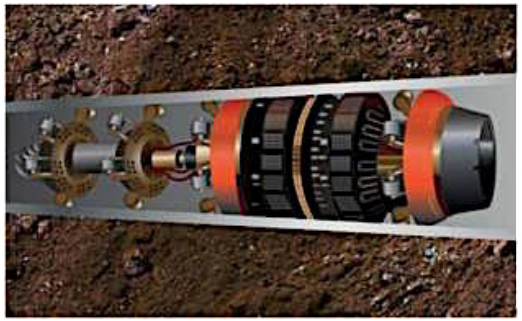

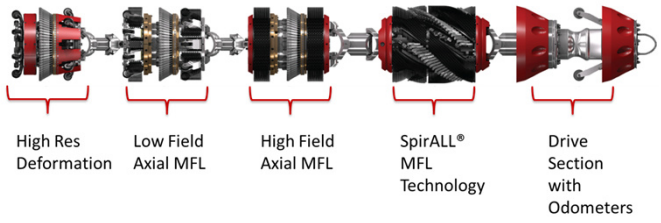

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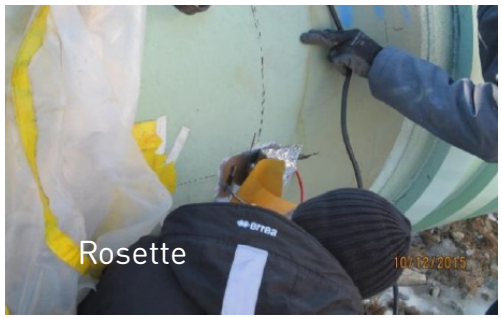
Extensometer on pipe


Rosette


Extensometer on expansion joint

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What to pay attention to?

- Accurate storage of **documentation**
- Target oriented **tendering**
- Visual inspection of the pipeline by **qualified and experienced personnel**
- Checking the functional capability of **emergency devices**, **air valves** and outlets
- Measurement program must be **flexibly** adapted to the condition of the pipeline
- No compromises on **safety**


Thank you for your attention!
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CIGB ICOLD
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RSE Ricerca Sistema Energetico
EWG Penstocks & Pressure Shafts - Meeting on 27th April 2021

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Ing. Armin Kager

- Civil engineer
- "Hydraulic and Environmental Engineering" at the University of Innsbruck
- From 1998 to 2005 own engineering office and professional experience in Italy and Germany
- Between 2005 and 2014, leading employee at SEL AG (company active in the hydro-power sector), responsible for engineering and control of numerous infrastructures of the company's own hydropower plants.
- Since 2014 own engineering office with specialisation in control of infrastructures, especially HP penstocks and galleries.
- Up to now inspected penstocks:
  - ✓ DN 800 to DN 5.000 mm
  - ✓ 40 km
  - ✓ 0 -130 %
- FROSIO International Coating Inspector