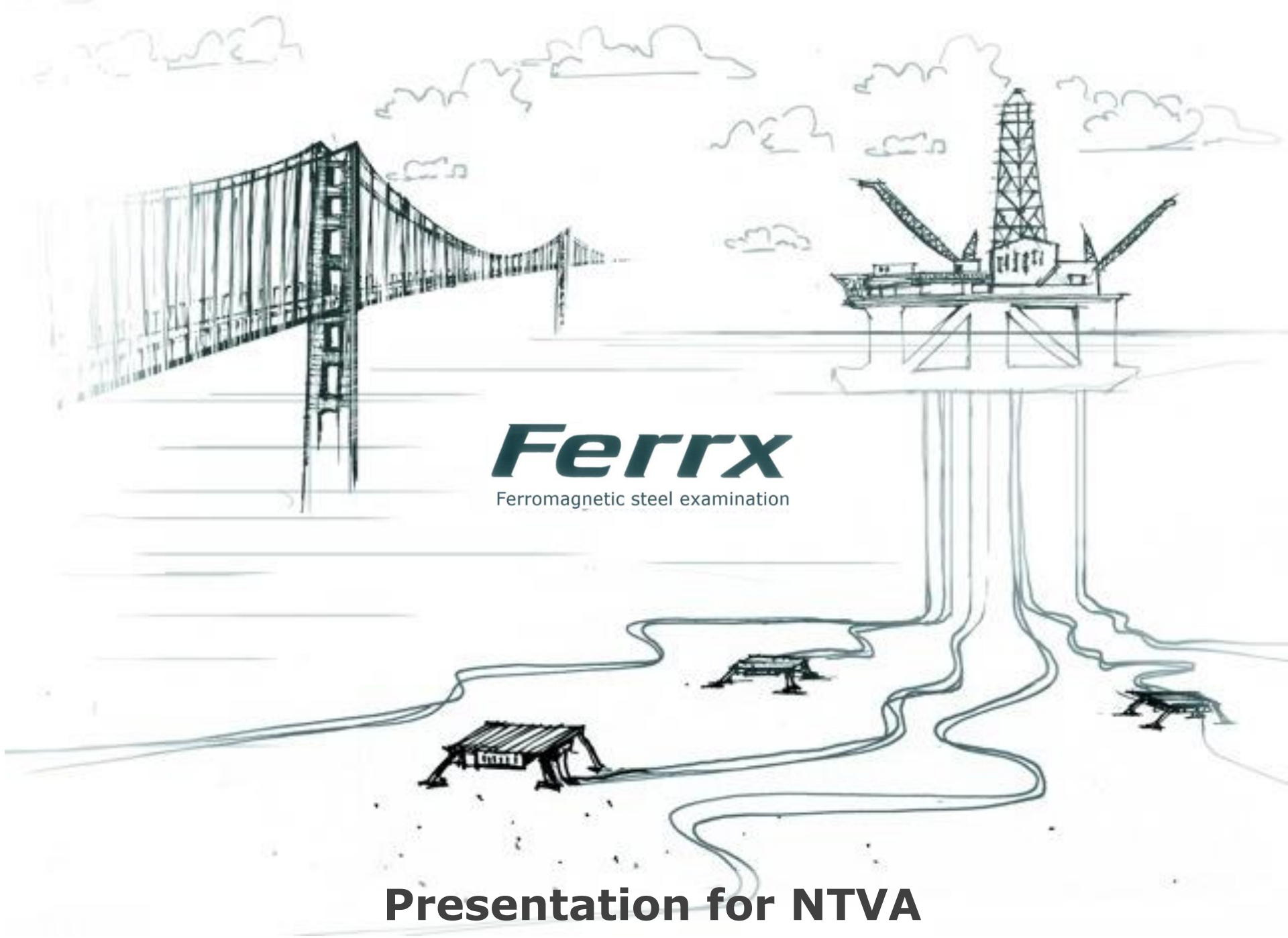


Ferrx

Ferromagnetic steel examination

Presentation for NTVA

Contents

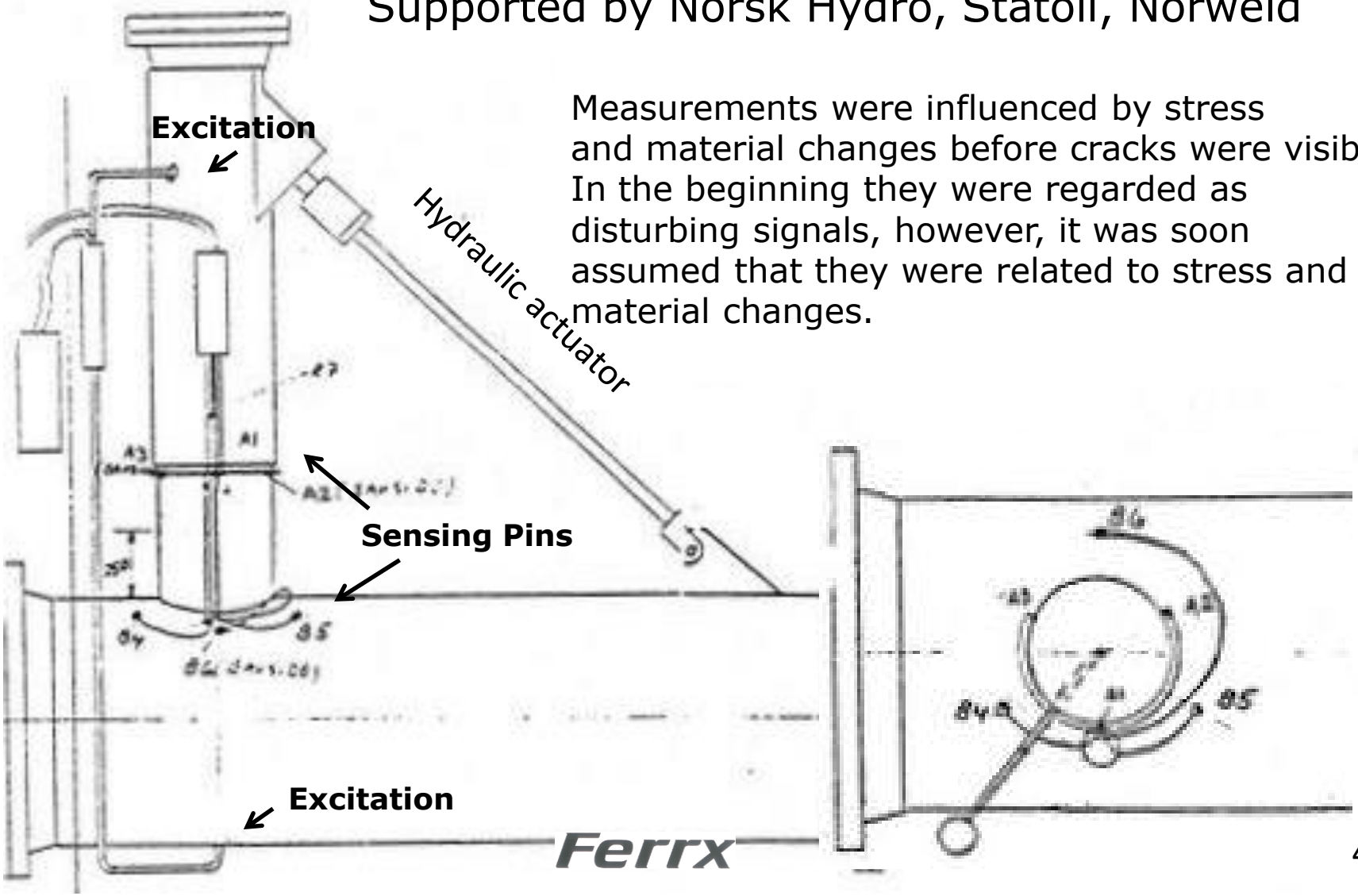
Background - Historical

- **SI (SINTEF) developed FSM**
  - After the Alexander Kielland accident in 1980 Hårek Hognestad at SI develops the Field Signature Method (FSM) for crack monitoring
  - CorrOcean got the rights to FSM in 1988
- **$SINTEF_{SI}$ develops transient potential drop method** (Transient Potential Drop)
  - Based on the FSM method
  - For determination of stress in steel
  - Tested for monitoring of stress in railway rail (neutral temperature in CWR (Continuous Welded Rail)
- **In 2005 Ferrx acquired rights and test equipment from $SINTEF_{SI}$**
  - Ferrx founded based on development and industrialization of this patented method.

SI's test in sea at Nutec 1986
Objective: Crack Detection in T-joint weld

Supported by Norsk Hydro, Statoil, Norweld

Measurements were influenced by stress and material changes before cracks were visible. In the beginning they were regarded as disturbing signals, however, it was soon assumed that they were related to stress and material changes.



Background – Market

Mostly defined by participating oil companies

- The aging and life extension of steel structures is a major challenge in many industry sectors.
- A safe permissible extension of structural life for continuing production and service will generate considerable savings for industry and society.
- FEMM provides accurate data for the assessment of structural integrity and improves prediction of remaining life of structures and life extension optimization.
- Application examples from the O&G market:
  - Monitoring of critical points of structure e.g. welds in steel risers or well head pipes.
  - Degree of strain damage for pipelines during pipe laying.
  - Verify correctness of formulas based on empirical data.

System monitoring railway rail

Field Trial 2009/2010.

To monitor Stress related to Rail's Neutral Temperature
and to demonstrate the reliability of the instrumentation system.

Main System Specification:

- Autonomous operation
- 1 - 4 measurements per day
- Communication via mobile network to Internet server
- Solar cell based power supply

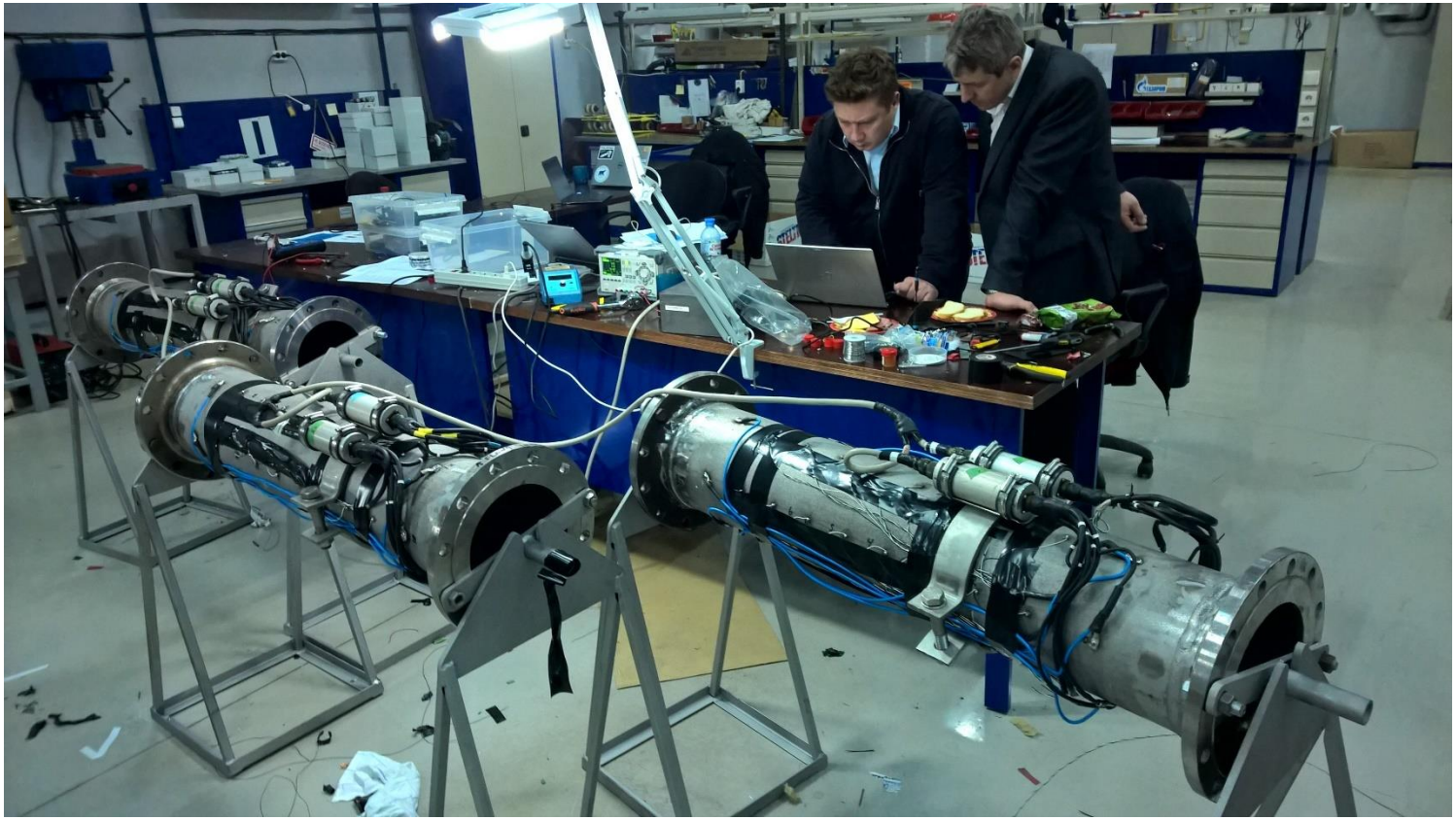
Monitoring of Subsea Pipes

DEMO2000 2010-2013 (RCN, Shell, Dong, Lundin)

System on work over riser.
Designed for water depth down to 1500m

Monitoring corrosion in pipes

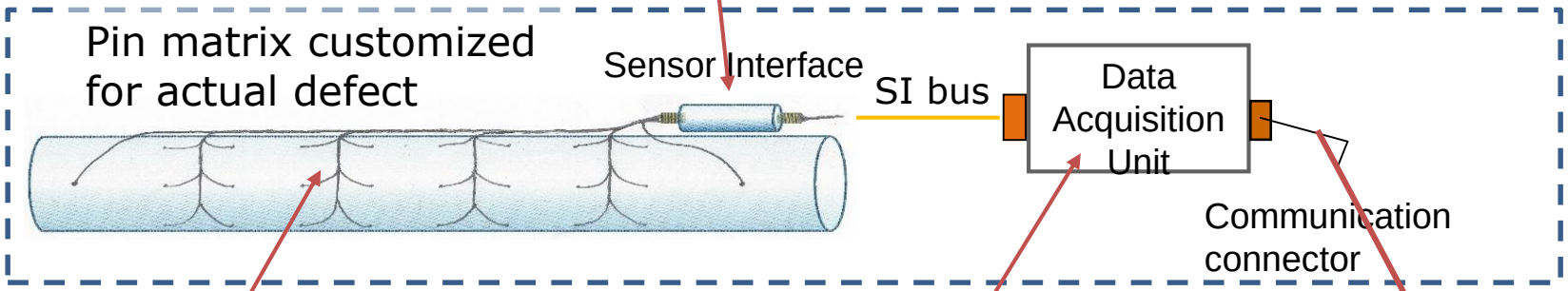
One system monitoring 3 pipes, GSM online to server.

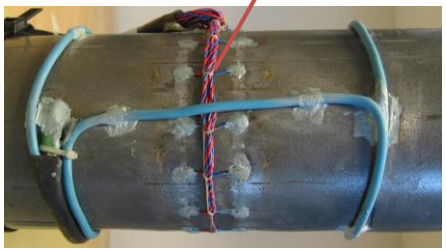


Installation of system in client’s workshop before sending to the field location

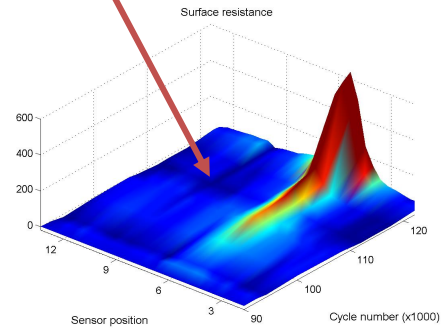
FEMM instrumentation

SI: 28 pin-pairs (4 sets of pins and excitation)
Up to 8 SIs on the SI Bus => 224 pairs/system.





Connection points protected
before encapsulation



Dedicated FEMM SW

Different encapsulation,
same electronics

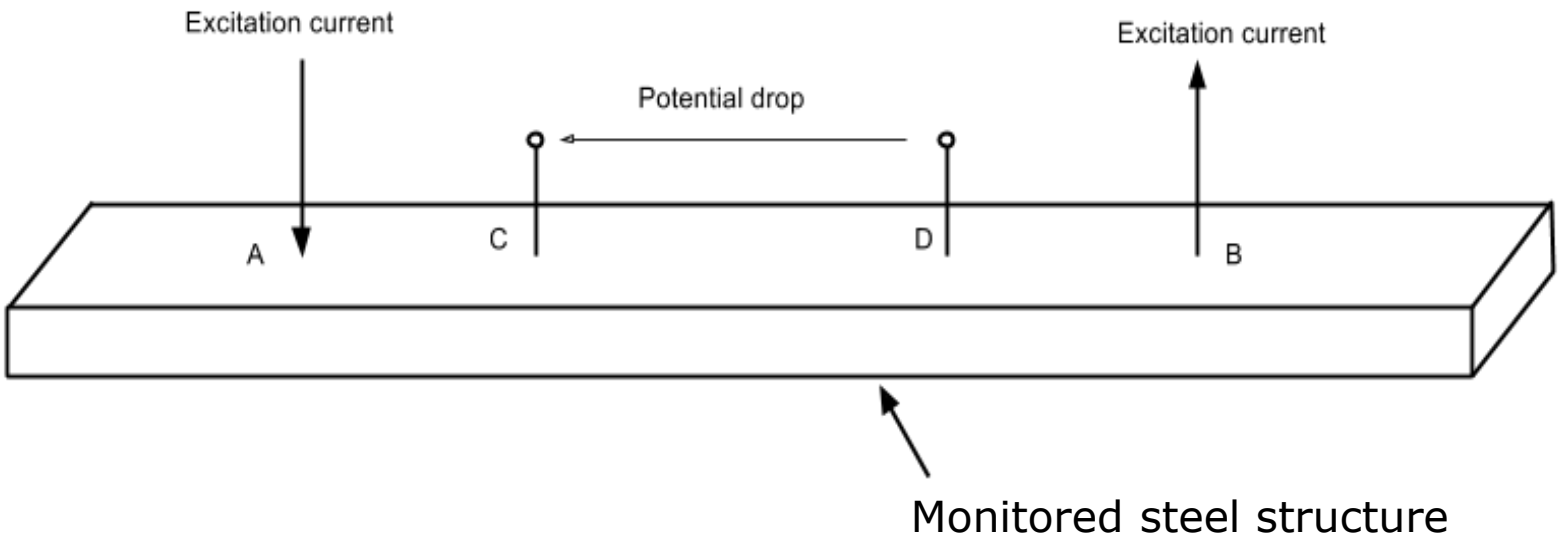
Prototype Subsea
datalogger
on 8” riser pipe

Ferrx

Monitoring Capabilities

- **Relative stresses**
  - Elastic stress
  - Detection of plasticity, stress exceeding yield
  - Changes of residual stresses
- **Remanent stress (max stress since last measurement)**
- **Fatigue development due to cyclic loads**
  - Material deterioration (dislocations and surface microcracks)
- **Crack initiation and growth/size estimation**
  - Distinguishes between internal and external cracks.
- **Non-intrusive monitoring of internal erosion and corrosion**
- **Monitoring of outer surface corrosion**

FEMM sensor on steel structure



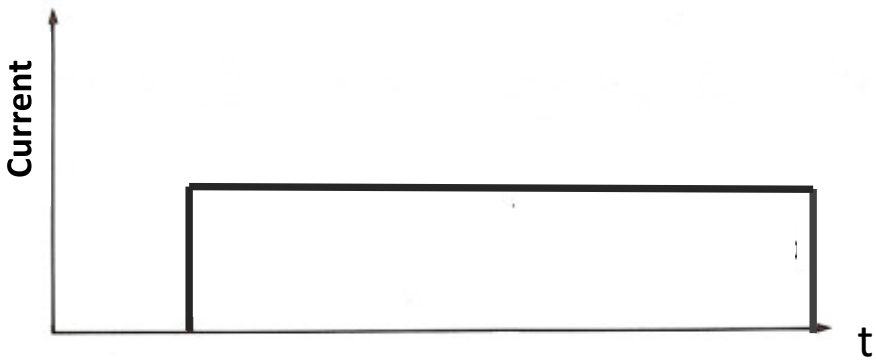
- A and B are current excitation connections
- C and D make a sensing pin-pair. Typically 28 pin-pairs on pipe's butt-weld
- Connections made by soldering, or stud-welding or spring-loaded sensing pins
- Sensors have same operational lifetime as monitored structures
- The area covered by sensing pins is monitored

Method description

Transient Potential Drop (patented)

Excitation Current and Voltage Response

Excitation current



Typ 0,5sec,

Response Signals

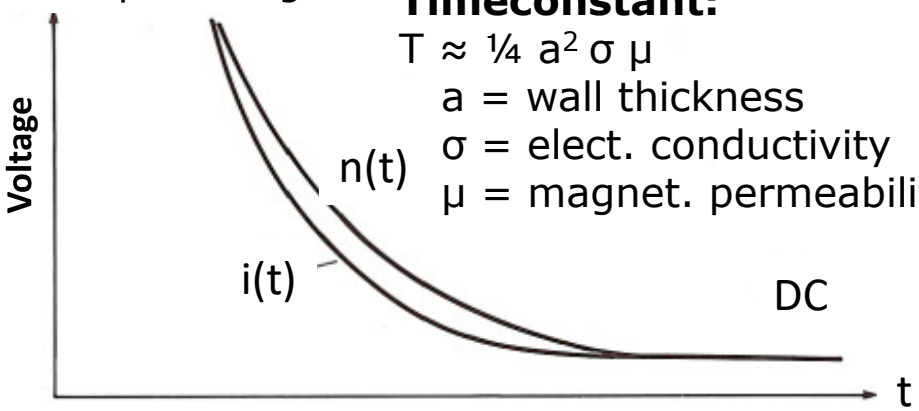
Timeconstant:

$T \approx \frac{1}{4} a^2 \sigma \mu$

a = wall thickness

σ = elect. conductivity

μ = magnet. permeability



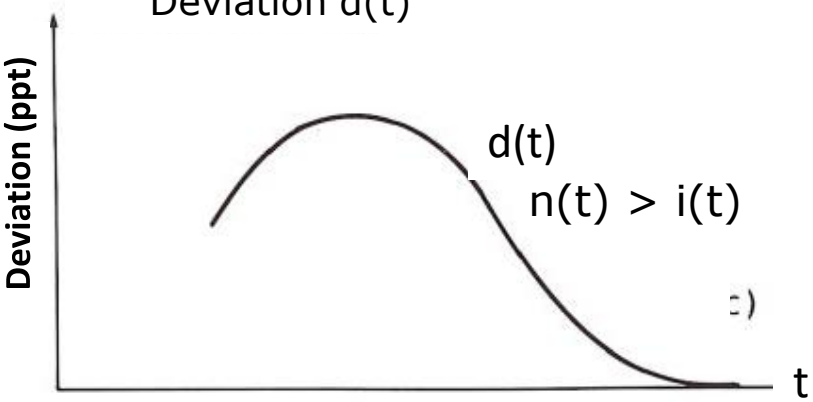
Response signals (transients)
for measurements i(t) and n(t)
DC ≡ DCPD (=FSM)

Relative measurements.

Deviation between two different response signals:

d(t) =[n(t) / i(t) - 1]1000 (ppt)

Deviation d(t)



Increased permeability due to tension stress

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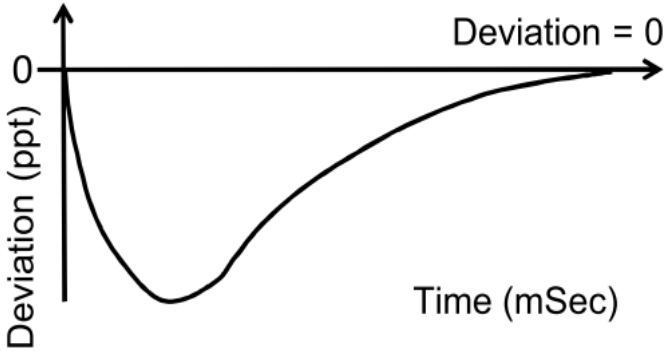
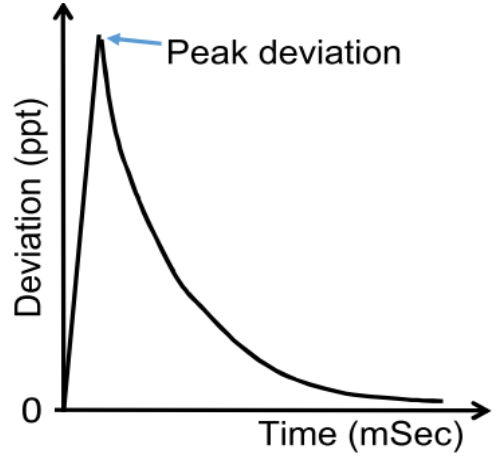
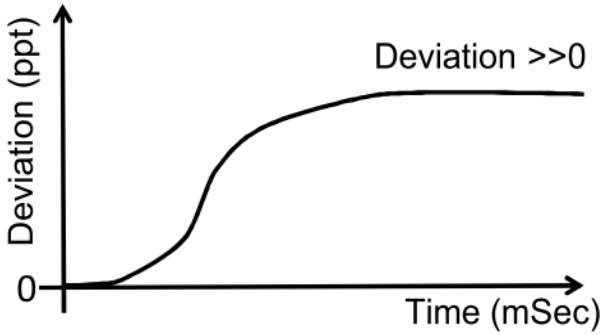
Typical deviation curves

Shape of curves influenced by μ, σ, depth and w.t.







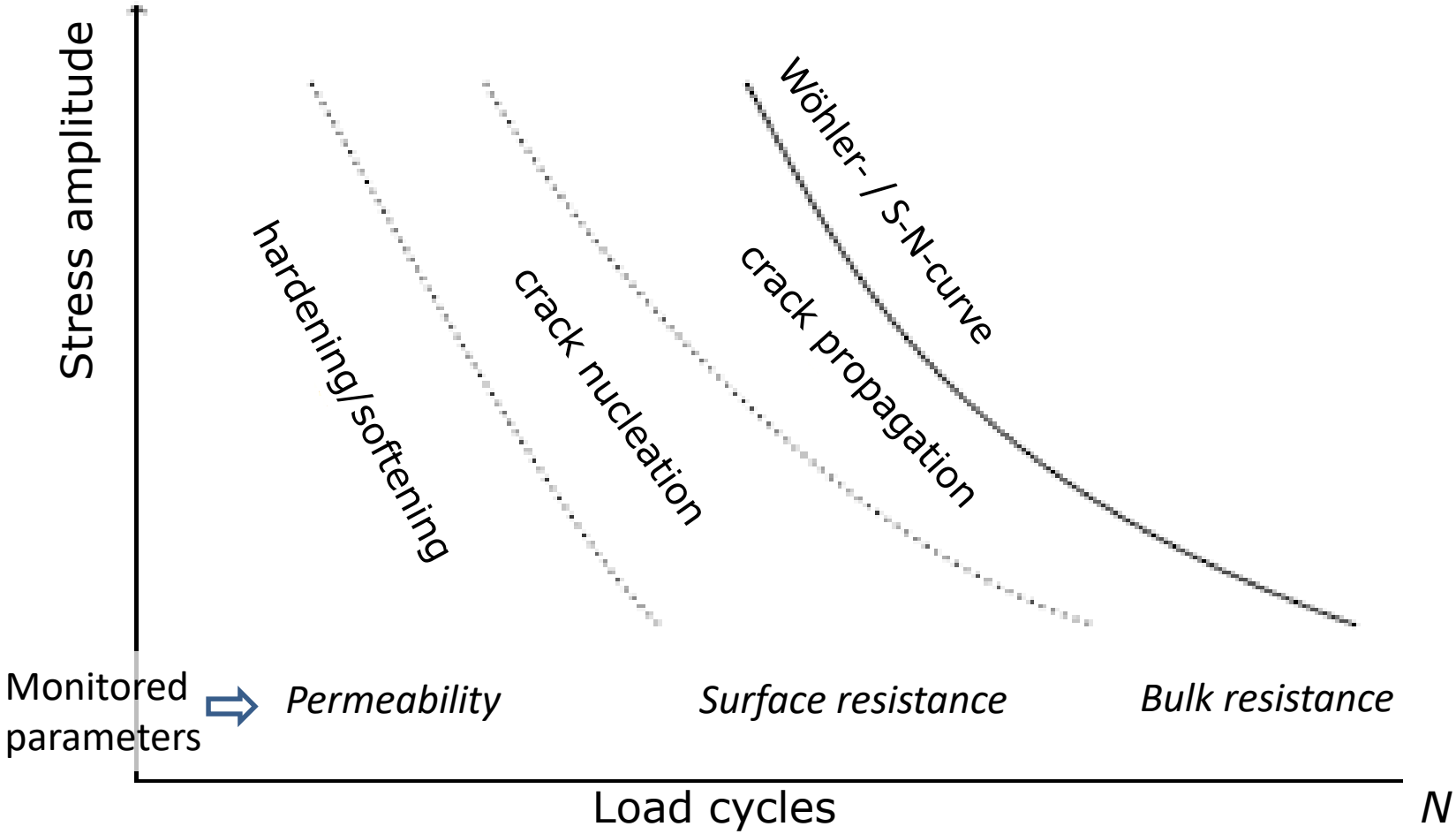
Increased compression stress.
=> Reduced permeability

Crack in the outer surface.
=> Mainly increased resistance

Crack or metal loss on the inside of pipe wall.
⇒ Increased resistance

(crack and corrosion are distinguished by data analysis)

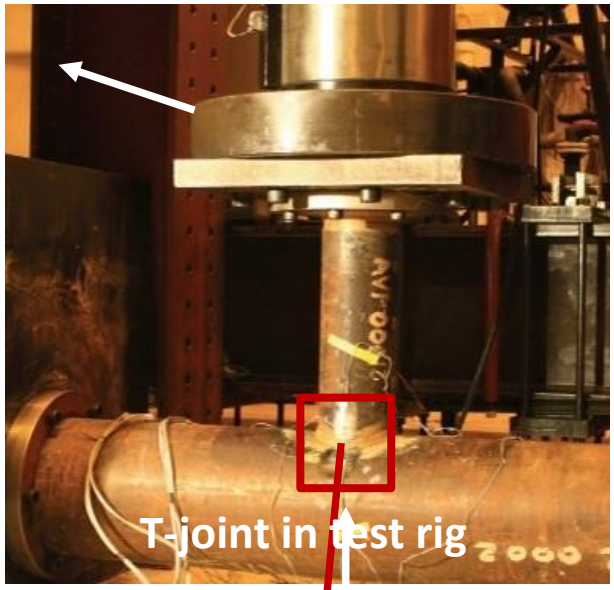
Fatigue of metals

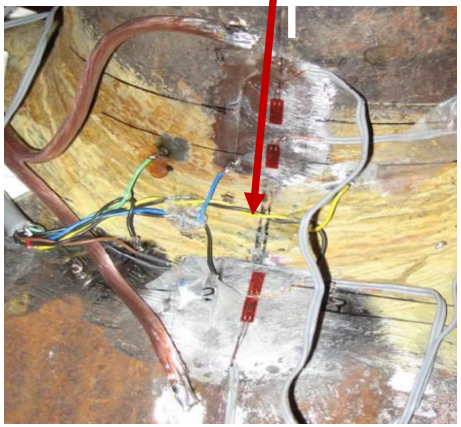


Fatigue process' 3 phases and changing parameters monitored by FEMM

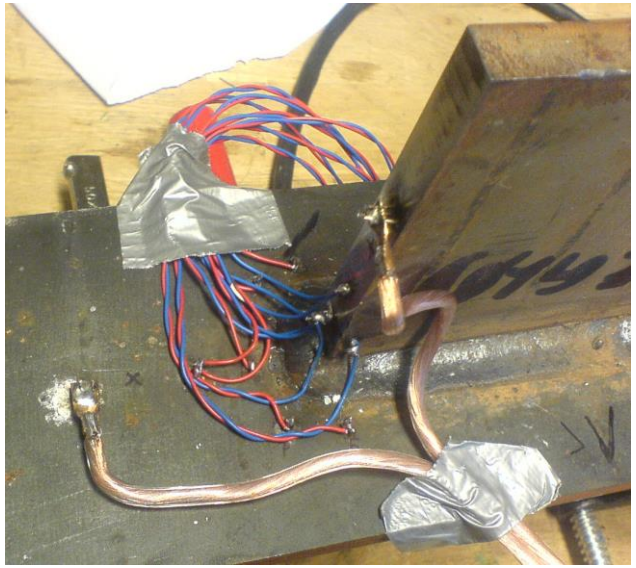
Example of fatigue testing

Run at Marintek in Trondheim

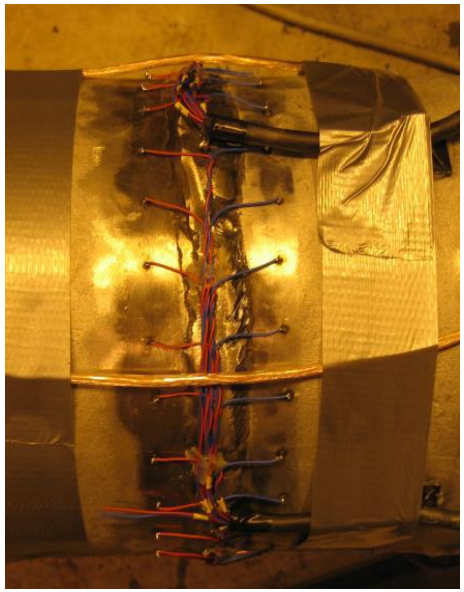




Zoom at the saddle point



Instrumentation on a single weld toe.



Monitoring weld in OD=8’’ WOR pipe

Ferrx

Monitoring Hi-Cycle Fatigue Tests of riser pipes at Marintek

(DEMO2000)

Test pipe (FMC WOR):

- Outer Diameter = 8’’
- Wall thickness = 15,5mm
- Yield ≥ 758MPa
- Weld monitored

Monitoring of:

- Changes in Residual stresses
- Material changes due to cyclic loads
- Crack initiation
- Crack growth

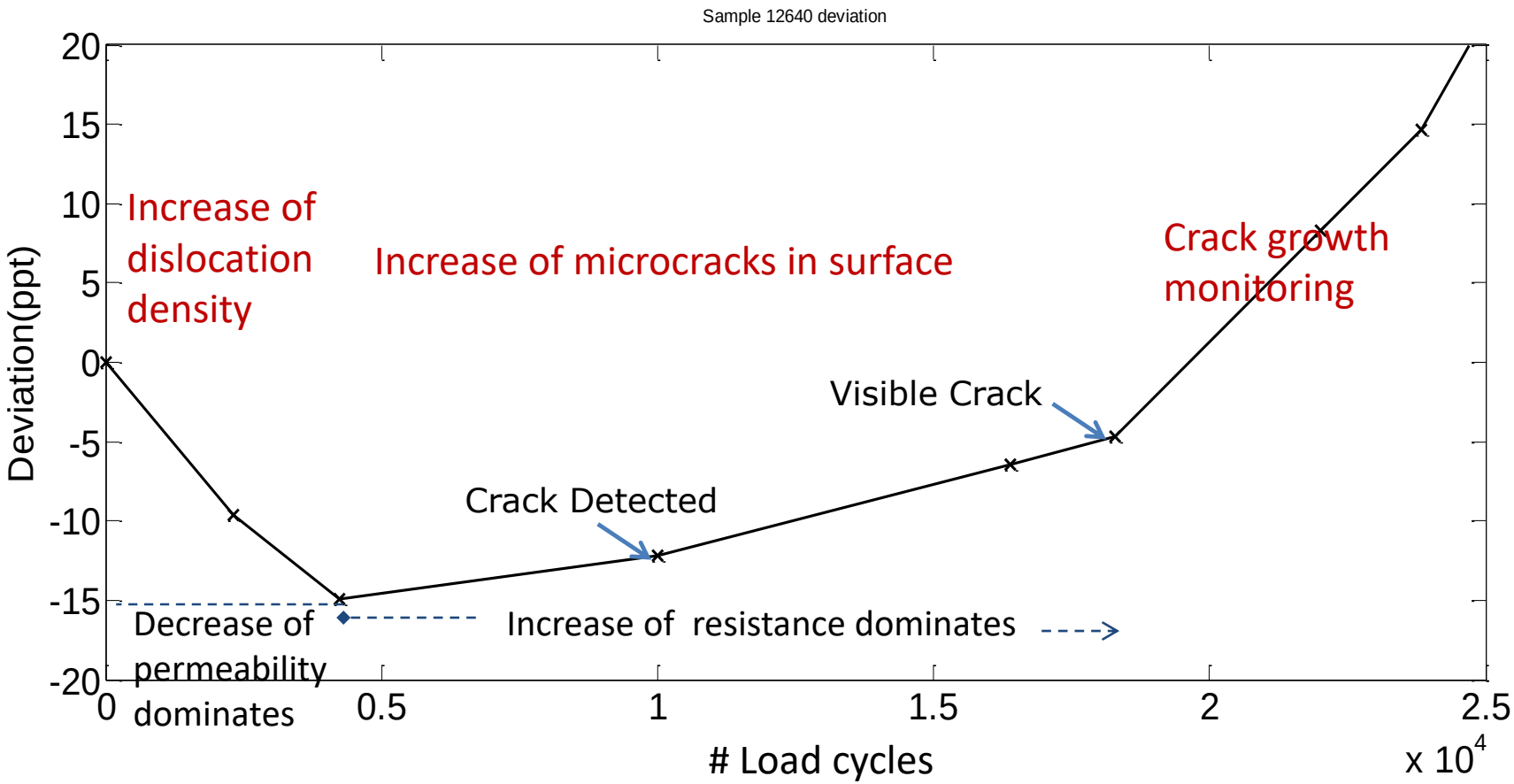
Pipe in test rig, one-sided loading.
Highest tension stress at 6 o’clock

Ferrx

Monitored riser pipe fatigue

Measured at 6 o'clock at the point of highest tension stress.

Typical change of electrical impedance in outer surface of weld during material deterioration and crack initiation.



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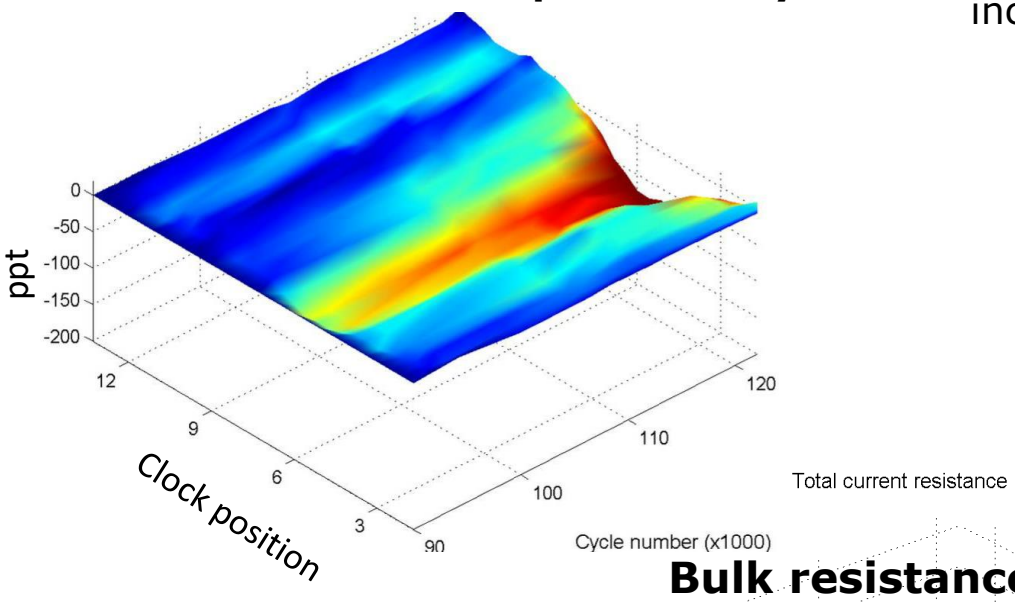
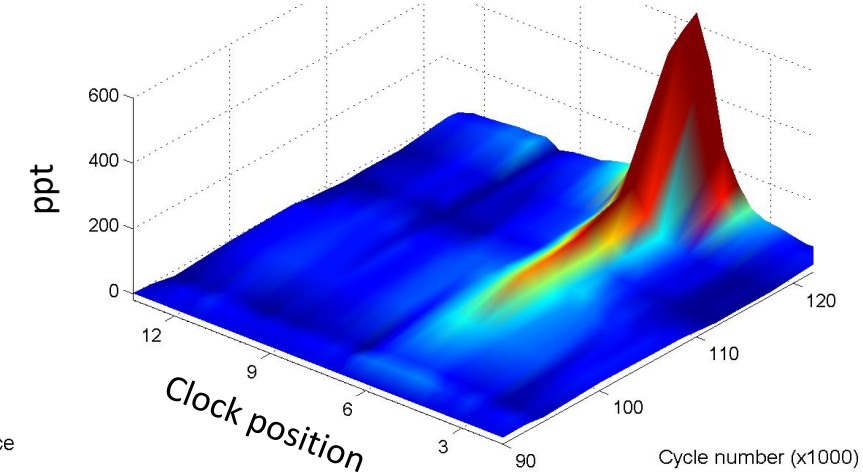
Pipe weld fatigue parameters.

All 28 sensing pin pairs on the complete circumference.

Estimated decrease of **permeability**.



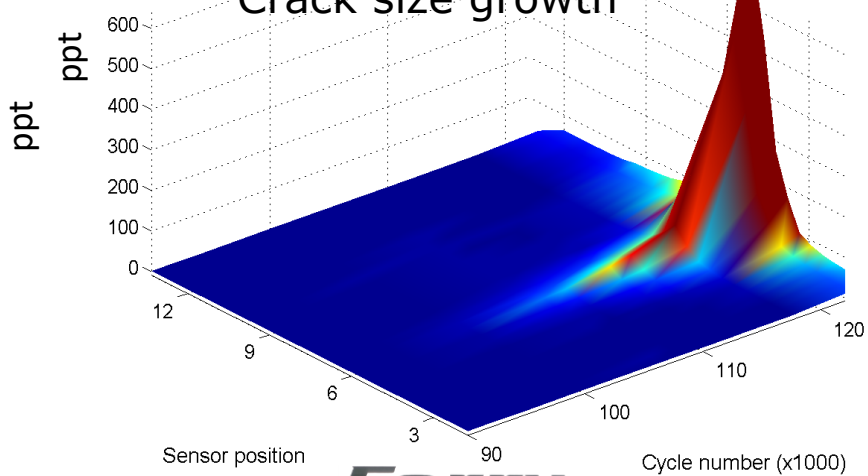
Surface material deterioration, estimated increase of **resistance in 1mm surface layer**



Total current resistance

Bulk resistance

Crack size growth



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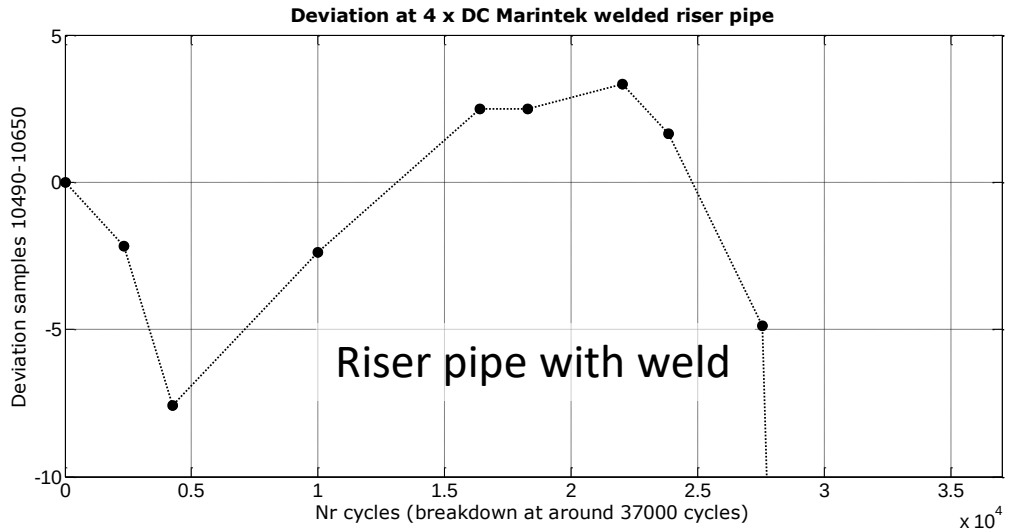
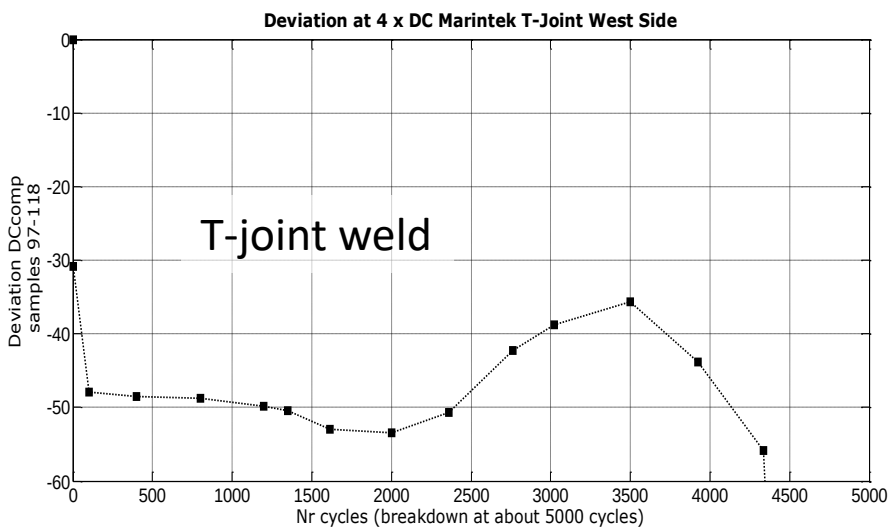
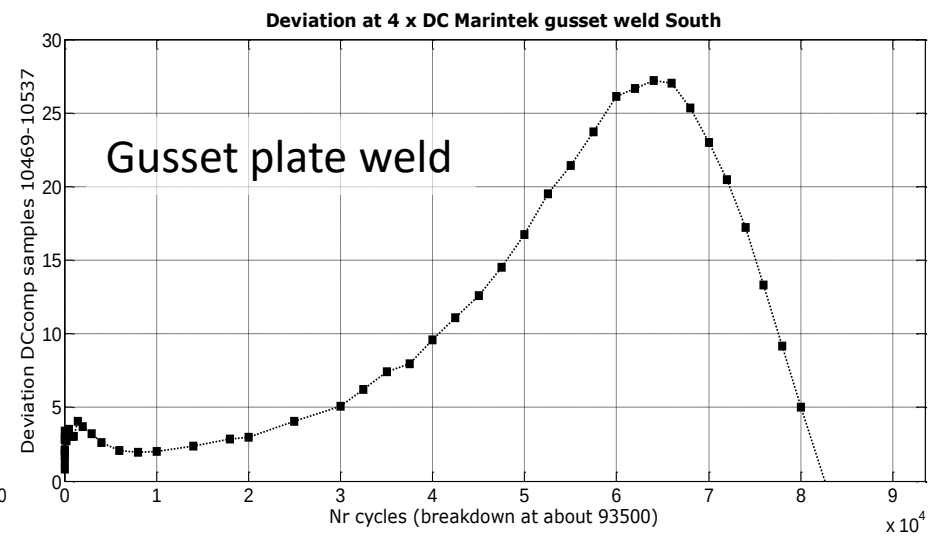
Recognizing 60 to 70 percent of total lifetime of welds



A fresh material will first go through shakedown/hardening effects, followed by a steady decrease as the dislocation density increases, then an increase as the crack forms and finally a notable decrease as the crack starts growing into the material. This final effect tends to occur at about 60-70% of lifetime.

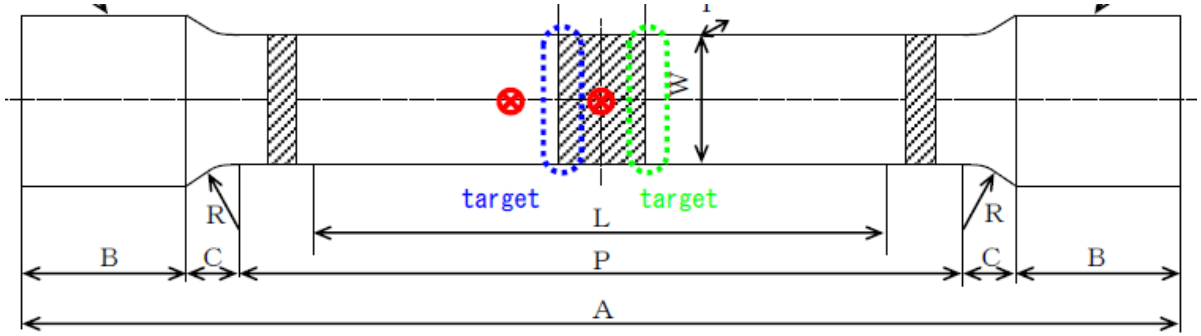


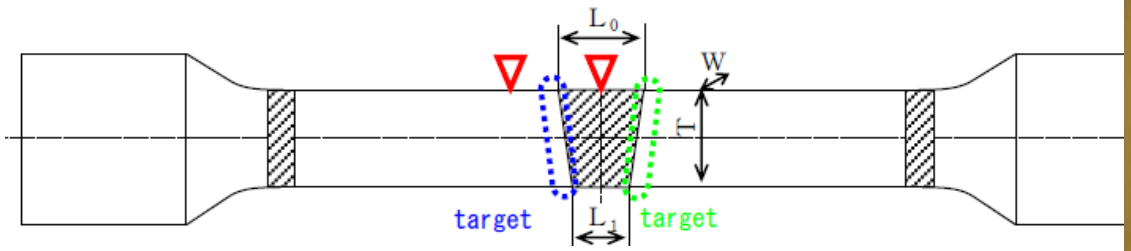


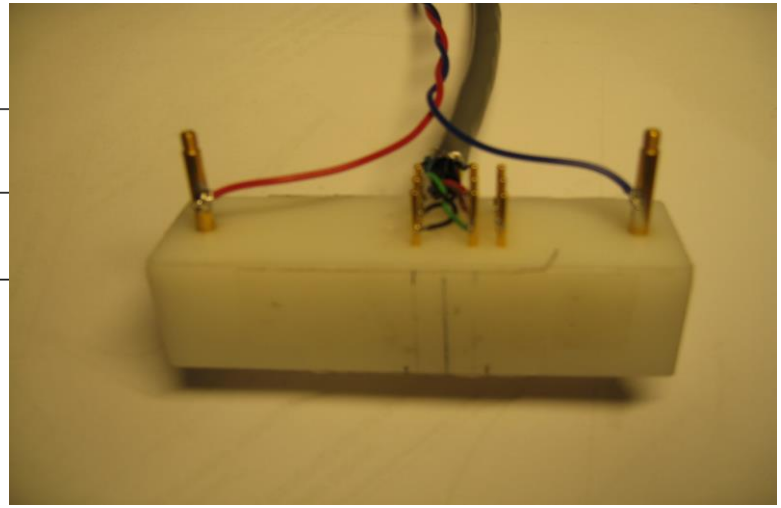
Ferrx

Detection of creep in HAZ for Tepco

Test in Ferrx lab 2010





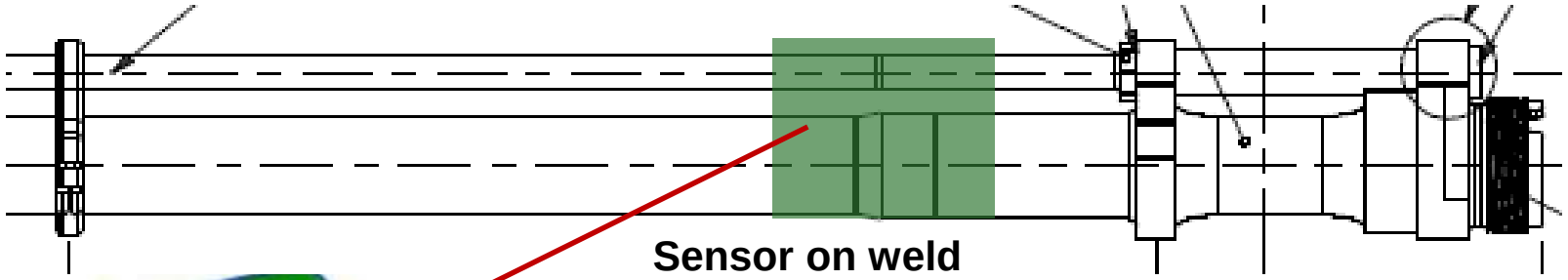


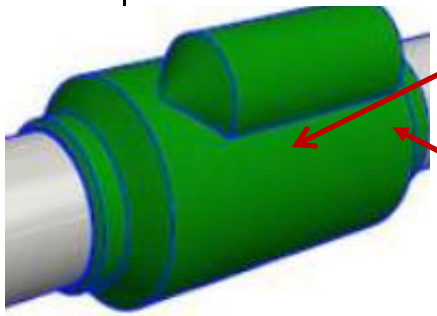
7 specimens, 6 with different degrees of creep
Creep area marked with blue dotted line
W=20, T=15

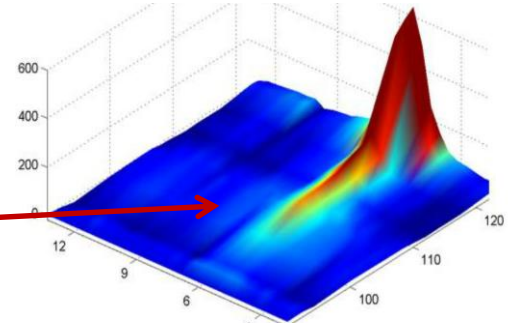
Pin holder:
3 pin pairs, 10mm spacing

FEMM IT for onsite riser inspection

Sensors installed on most exposed locations e.g. 3 riser joints.
Certified in 2016 by DNV GL according to DNV-RP-A203







Instrumented 8” pipe

- Pressure compensated
- Removeable
- Certified for Ex Zone 1

Portable Instrument

CE marked

FEMM PC SW for analyzing data

NDT of riser joint:

- Change of residual stress
- Material degradation
- Crack initiation and growth
- Internal metal loss

Ferrx

Prospect: ROV retrofit NDT clamp

ROV “pinholder” based on Deepwater’s Retroclamp

Specifications:

- Most pipe diameters
- Pins can penetrate coating
- Instantaneous measurement
- Deviation measurements using fixed autonomous system

Ferrx