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Mehr Wert.
Mehr Vertrauen.

Add value.
Inspire trust.

Risk-based Inspection and advanced NDT

Why do we want to go for RBI?

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Cesar Buque
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Dr. rer. nat. Cesar Buque

- Physicist and Materials Fatigue Specialist
- Master in Business Administration (MBA)
- Member of CEOC and ISO TC 135
- 25+ years experience in Mech. Integrity

Dr.-Ing. Robert Kauer

- Mech./Chem. Engineer since 1991
- ASME AIS and ASME Committee Member
- CEN Committee Member for RBI
- 20 years experience with RBI

Learning objectives

Learn about ...

- what is RBI?
- what are some advanced NDT techniques

See ...

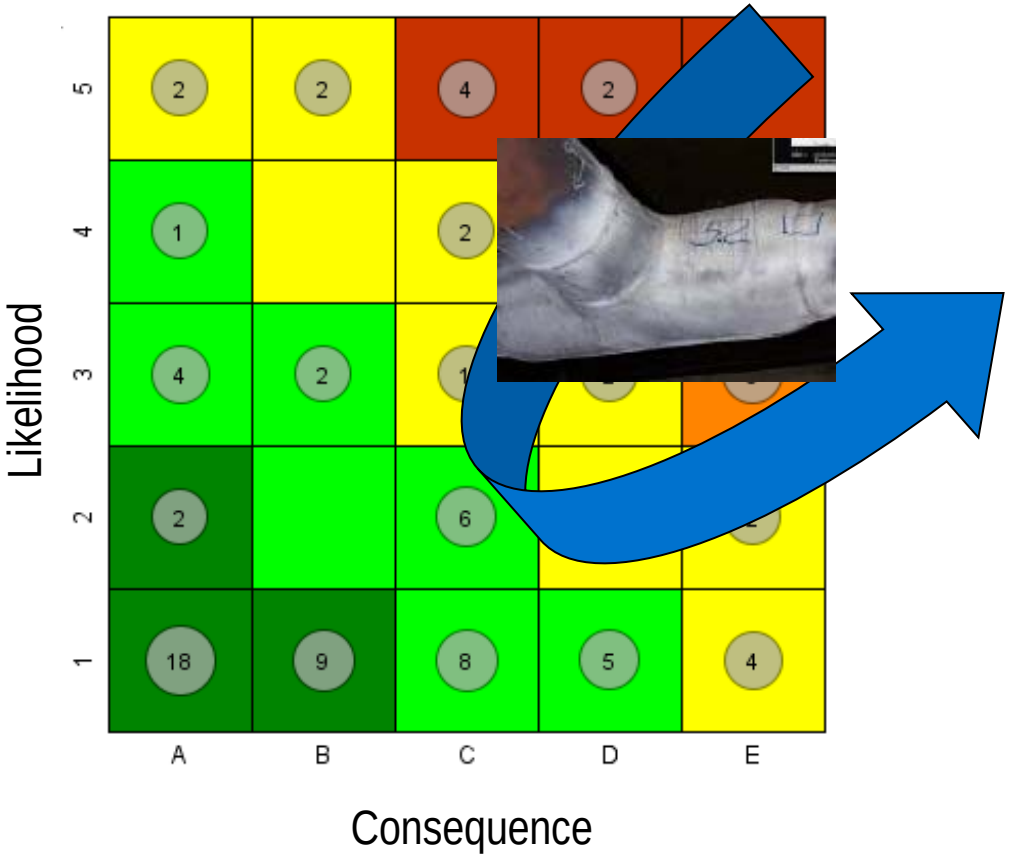
- how RBI is linked to inspection activities?

Agenda

- RBI – what is it and what are the benefits?
- The legal situation and RBI - a challenge?
- The main steps for RBI
- RBI and NDT
- Questions and summary

RBI – What is it?

A nice risk matrix?



No - RBI is a structured procedure to find OPTIMIZED answers for:

WHAT?

to inspect and analyze – where to focus on and where not

WHEN?

to inspect – what is a suitable interval or is a given interval ok?

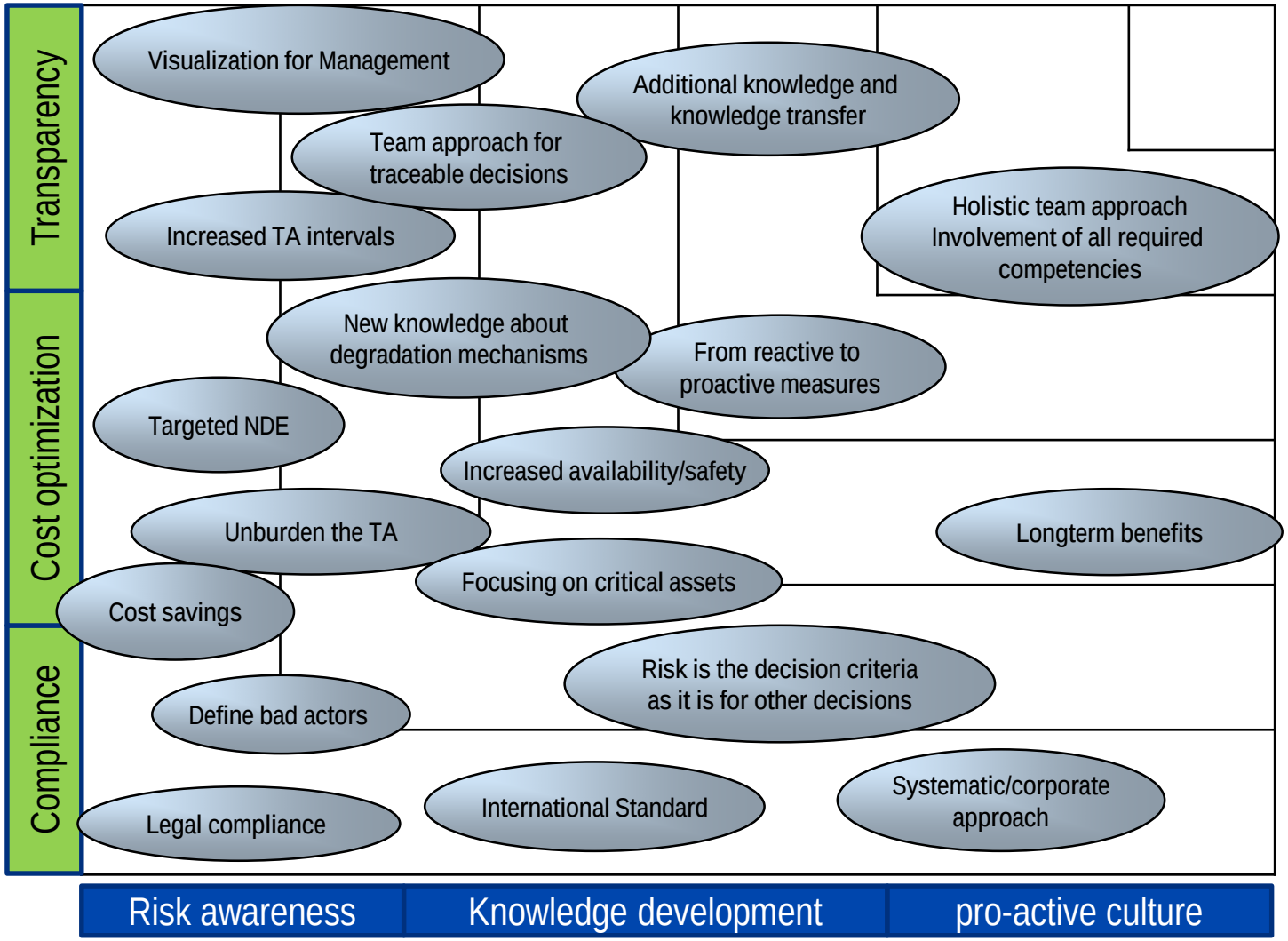
HOW?

to inspect – i.e. which method is most effective

EXTENT?

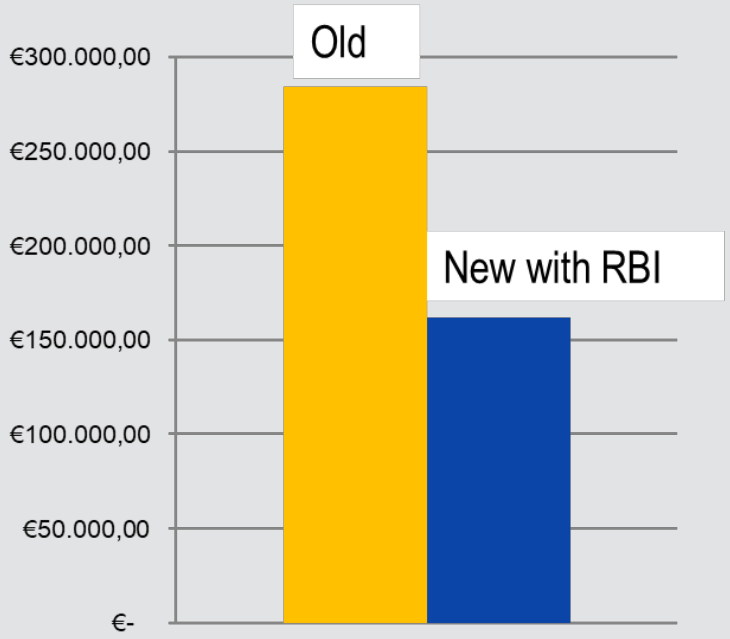
Spot or 100%?

RBI – Key benefits – Client's feedback



RBI – Some savings

- ✓ concentrate on critical equipment
- ✓ prolongate inspection/turnaround intervals
- ✓ switch from intrusive to non-intrusive inspection



Savings over a 10 year period:	
Costs	ca. 43 %
Production gain	21 days app. XX Mio €

Agenda

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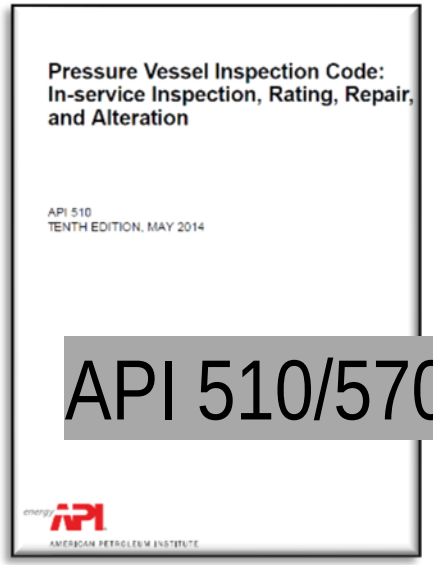
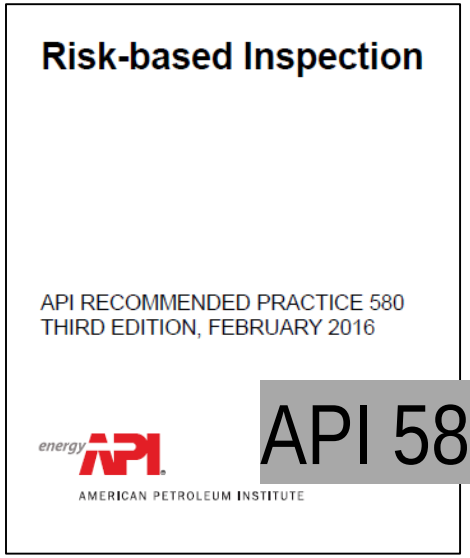
- Summary and conclusions

The legal situation for in-service activities

USA and many other countries in the world





some general rules
condition based
AND
reference to RBI

✓

Europe

different National Codes
mostly time-based

But ....

- Some European countries do <u>explicitly allow to make use of RBI</u>
- Some other countries <u>do accept RBI</u> though it is not directly mentioned, e.g. German Prüfkonzept acc. to EK-ZÜS paper (2015), which is now implemented in TRBS 1201-2 (2018)

in no country it is forbidden to go for RBI !!!

Agenda

- RBI – what is it and what are the benefits?
- The legal situation and RBI - a challenge?
- **The main steps for RBI**
- RBI and NDT
- Questions and summary

Introduction to Risk-based Inspection – RBI - what is it?

Definition (API 580/581)

RBI

A risk assessment and management process that is focused on loss of containment of pressurized equipment in processing facilities, due to material deterioration. These risks are managed primarily through equipment inspection.

RBI - what is it?

RBI

A risk assessment and management process that is **focused on loss of containment of pressurized equipment in processing facilities,** due to material deterioration. These risks are managed primarily through equipment inspection.

Consequence of Failure (CoF)

- Safety – Health – Environment
- Business interruption = € / $
- other consequences like reputation loss, repair costs, …

RBI - what is it?

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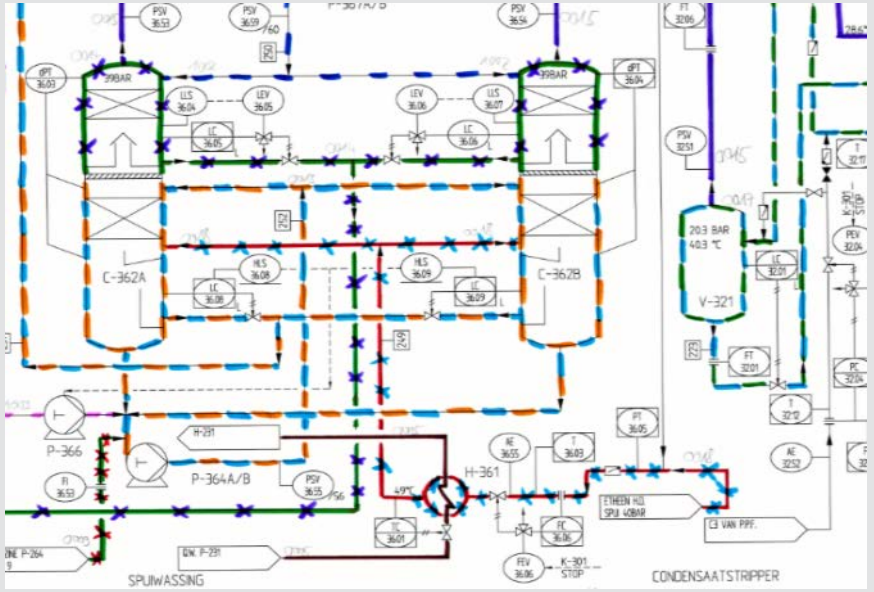
Degradation Loops (Corrosion Loops)



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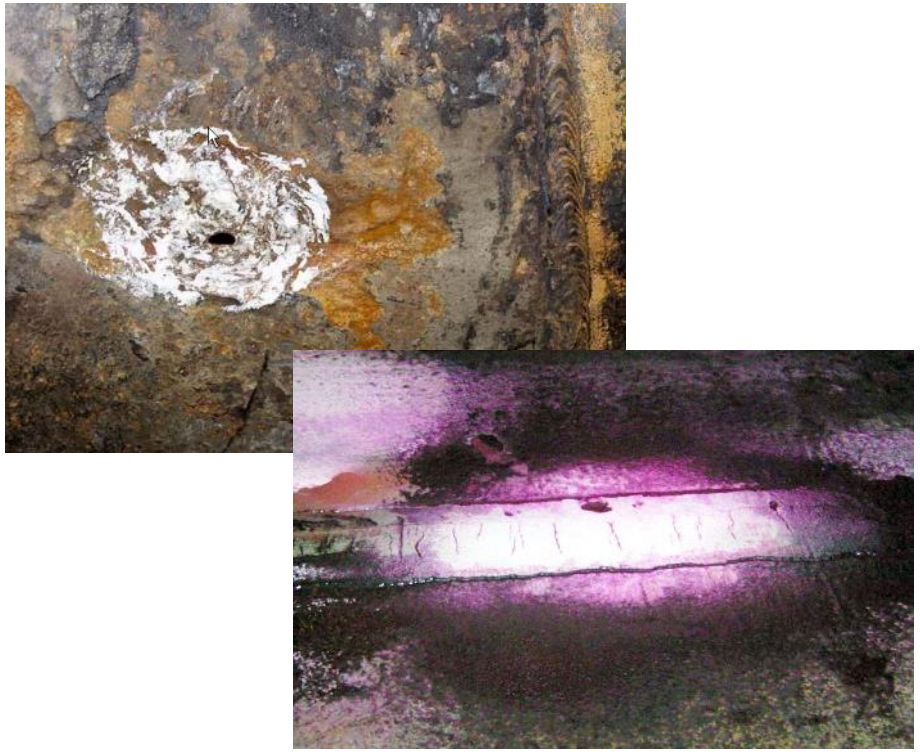
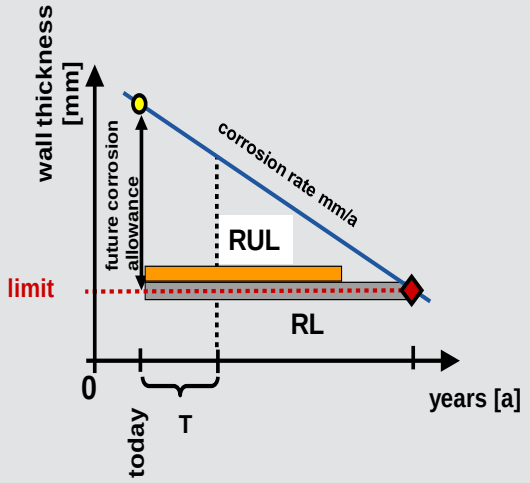
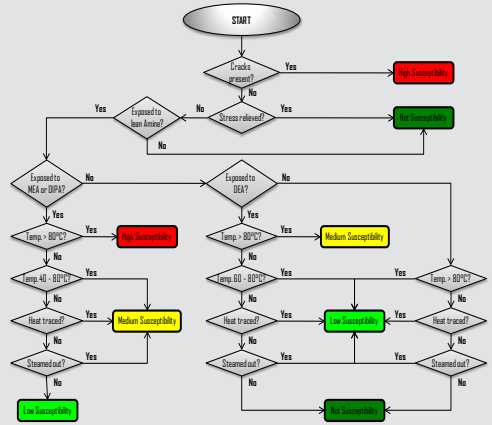


Probability of Failure (PoF)

trendable



non-trendable



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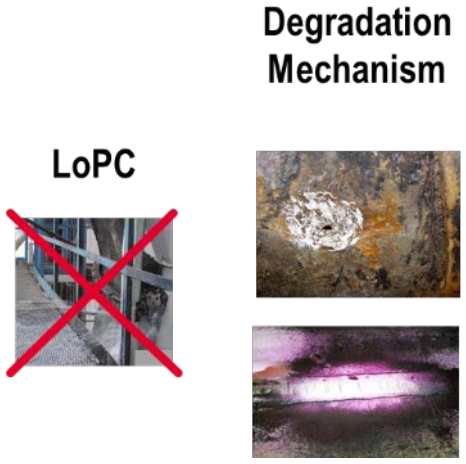

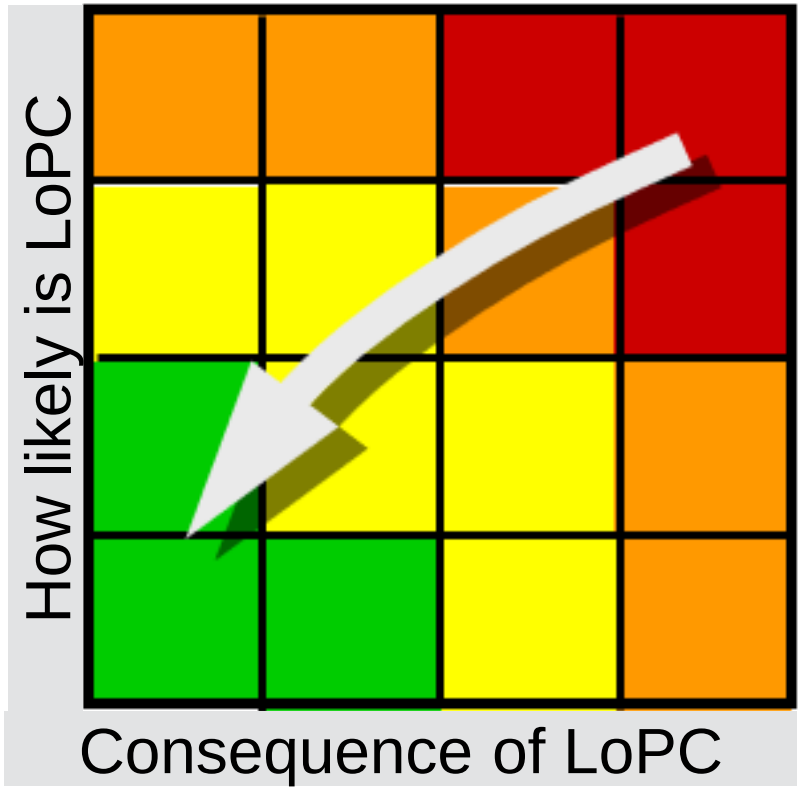

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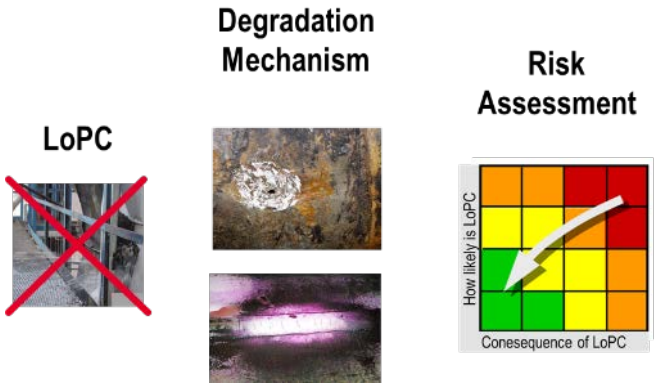
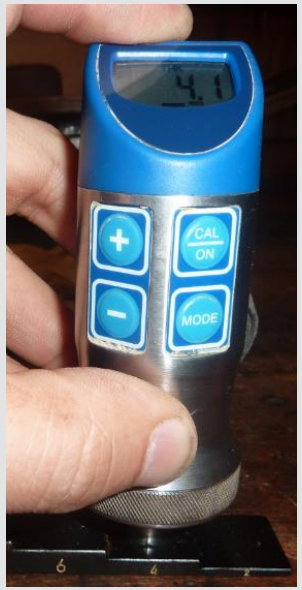
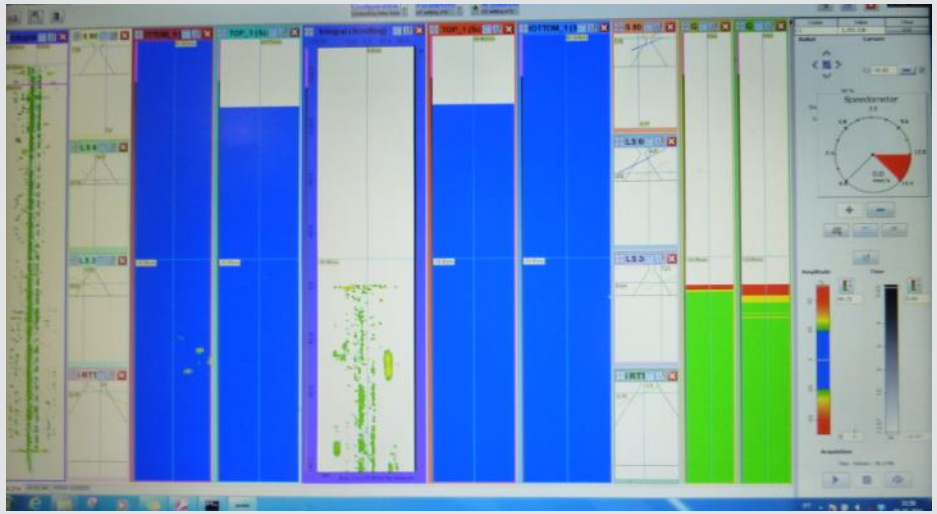


Inspection Methodologies

traditional



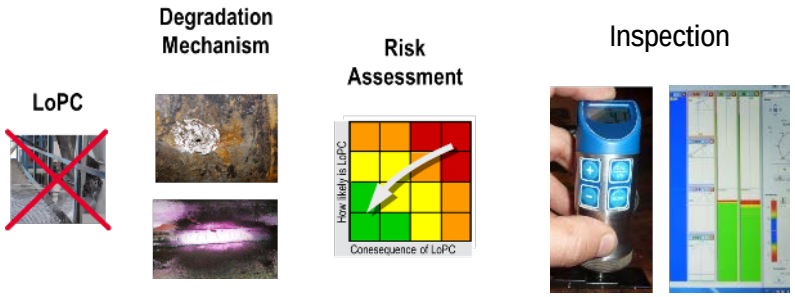
advanced



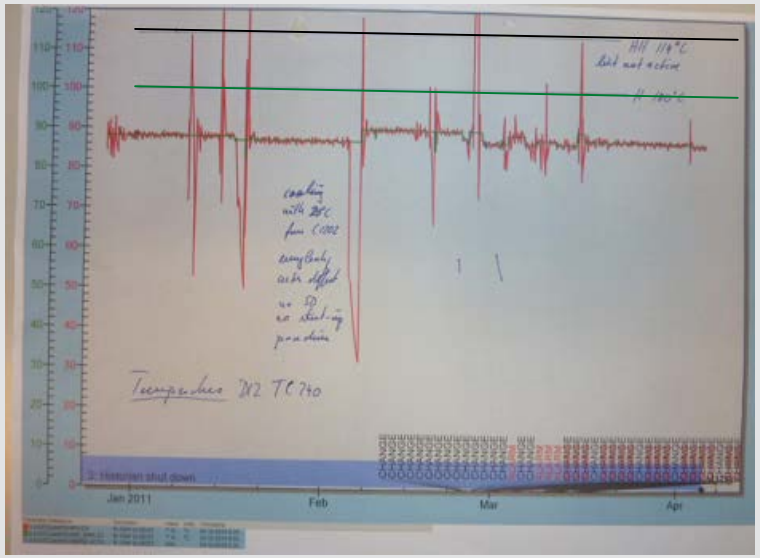
RBI - what is it?

RBI

A risk assessment and management process that is focused on loss of containment of pressurized equipment in processing facilities, due to material deterioration. These risks are managed primarily through equipment inspection **and monitoring.**



Monitoring of Critical Process Parameters
Integrity Operating Window



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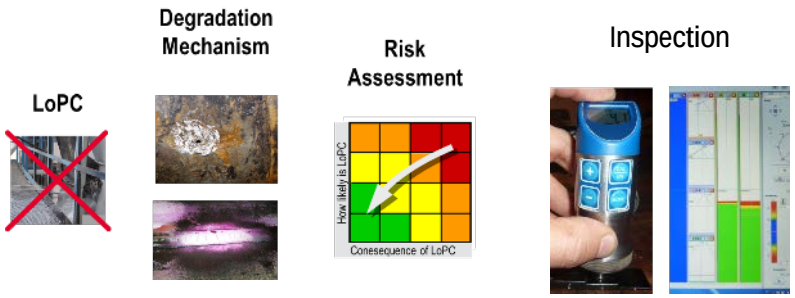

Monitoring of degradation progress

RBI - what is it?

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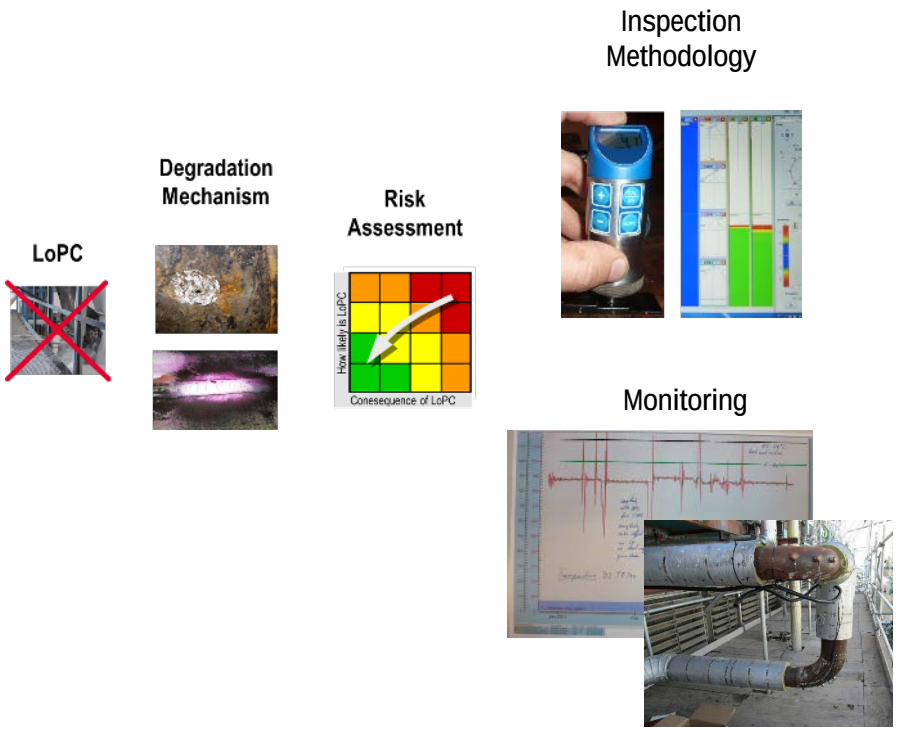
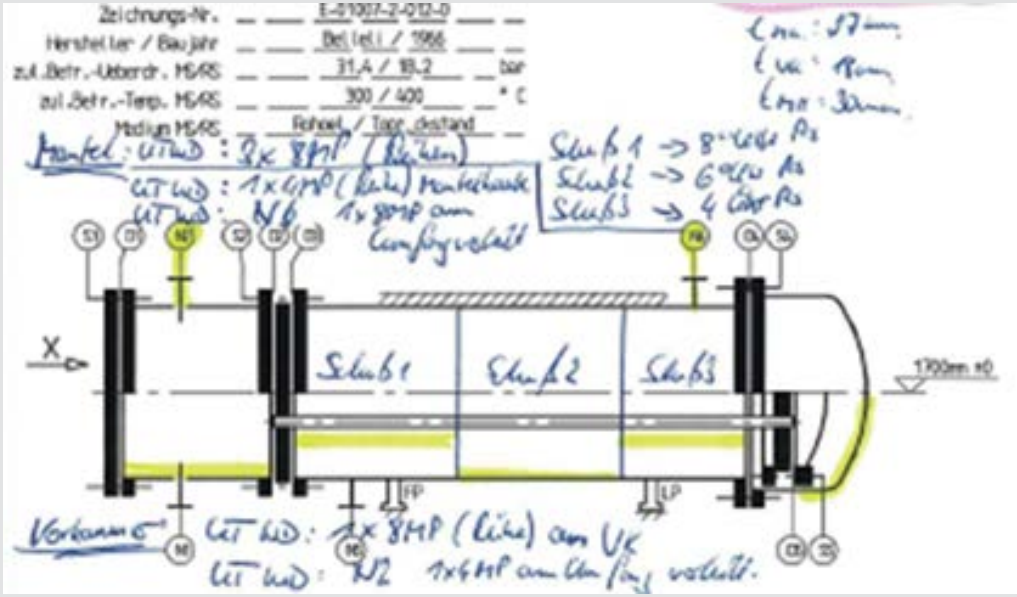


Susceptible locations



RBI - what is it?

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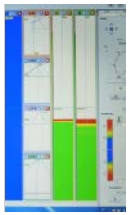
A risk assessment and management process that is focused on loss of containment of pressurized equipment in processing facilities, due to material deterioration. These risks are managed primarily through equipment inspection **and monitoring.**

LoPC

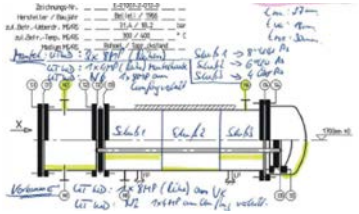
Degradation Mechanism

Risk Assessment

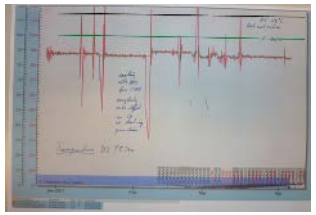
Inspection Methodology



Location



Monitoring



Timing

RBI - what is it?

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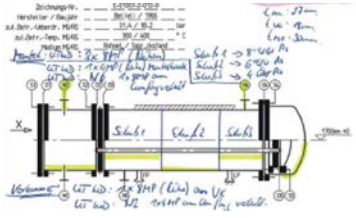
LoPC

Degradation Mechanism

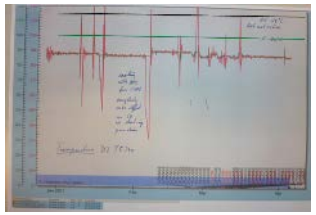
Risk Assessment

Inspection Methodology

Location

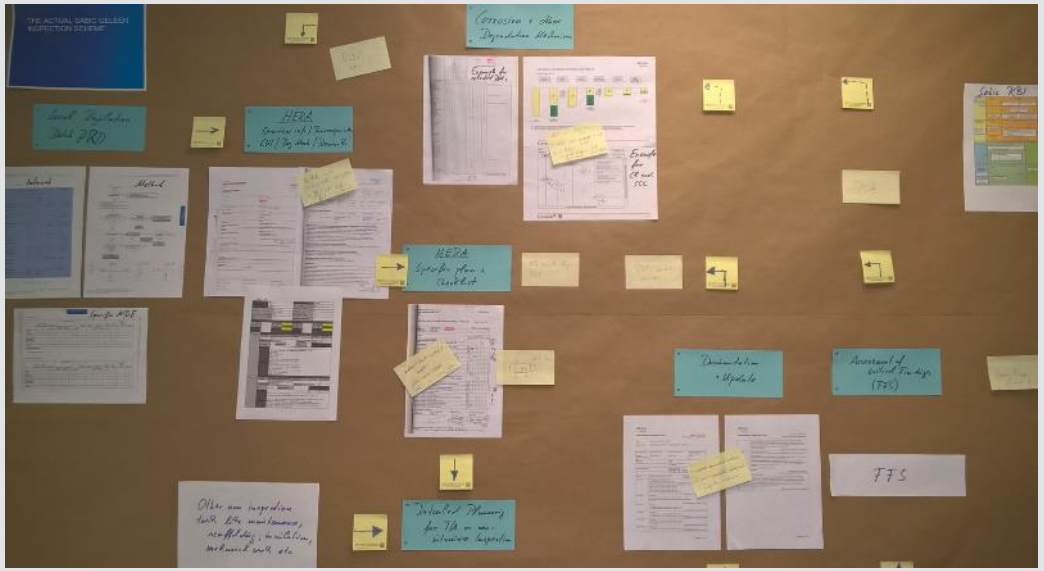


Monitoring



Timing

Management System



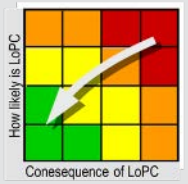
RBI - what is it?

Assessment & Strategy

LoPC

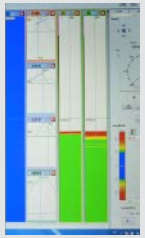
Degradation Mechanism

Risk Assessment

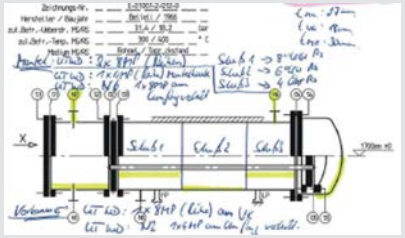


Detailed Planning

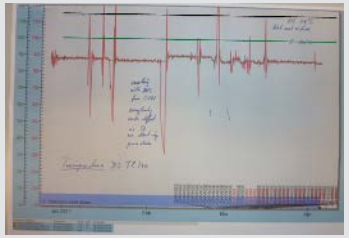
Inspection Methodology



Location



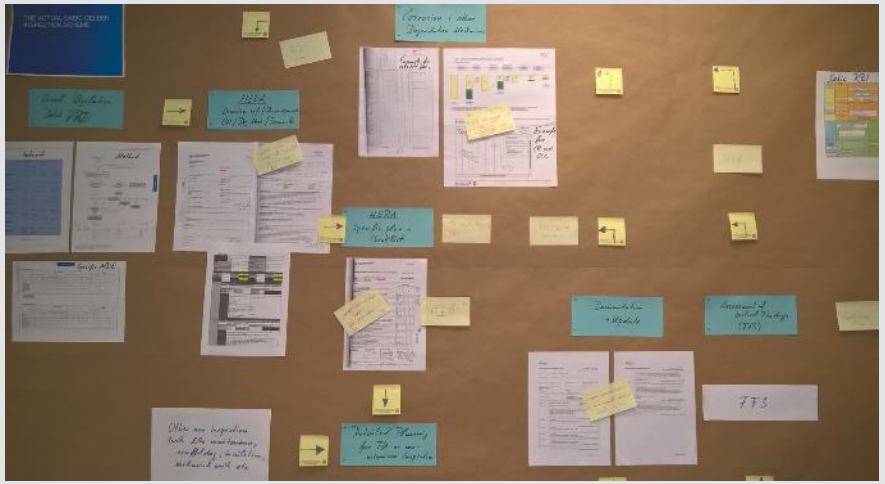
Monitoring



Timing

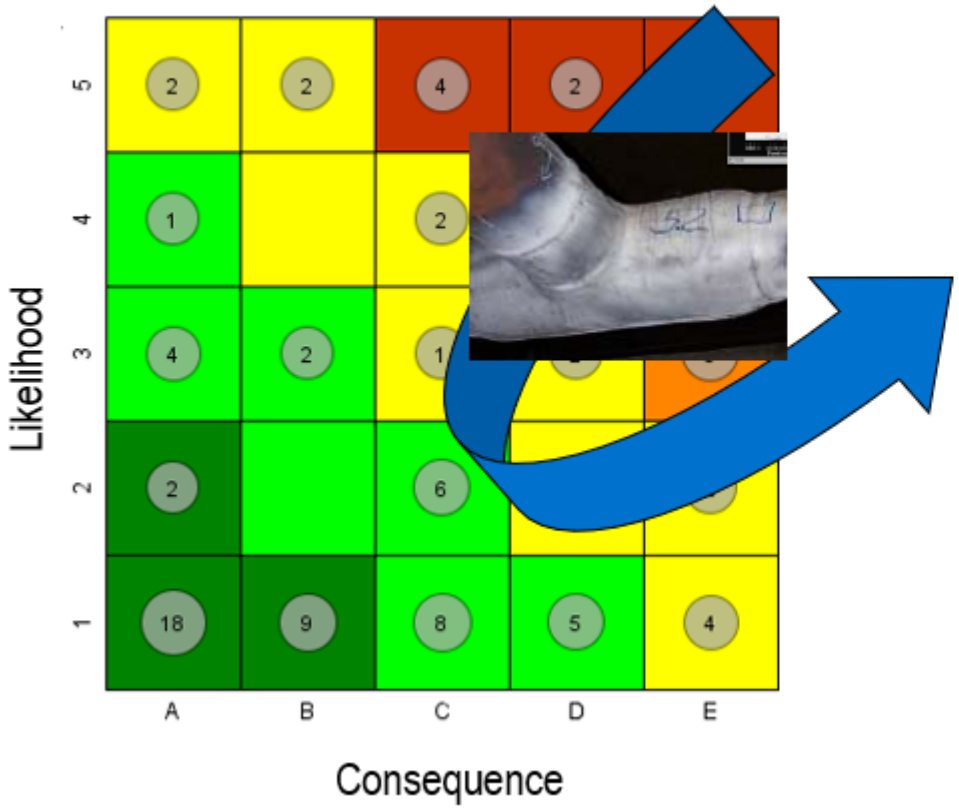
Implementation & Evergreening

Management System



With respect to NDT – what do we get from RBI?

A nice risk matrix?



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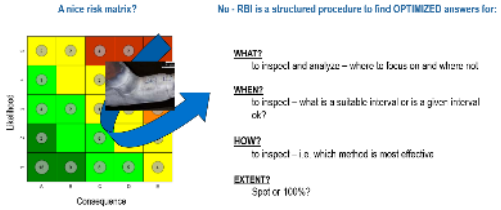
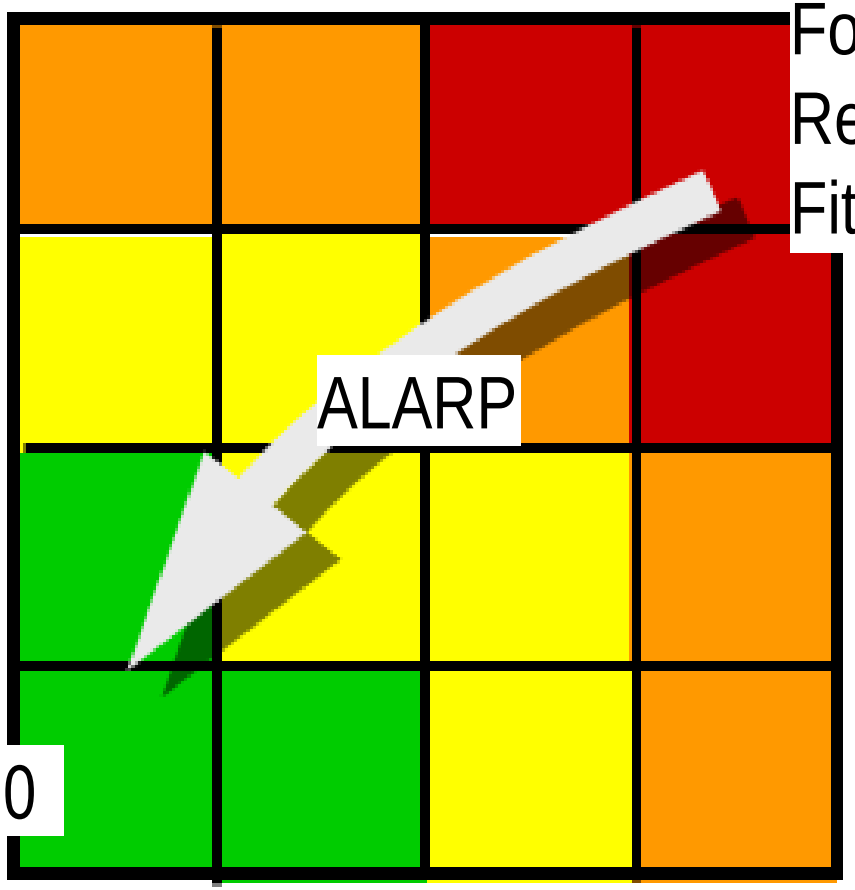
EXTENT?

Spot or 100%?

What to inspect?





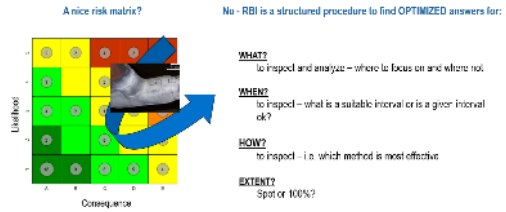
Focus

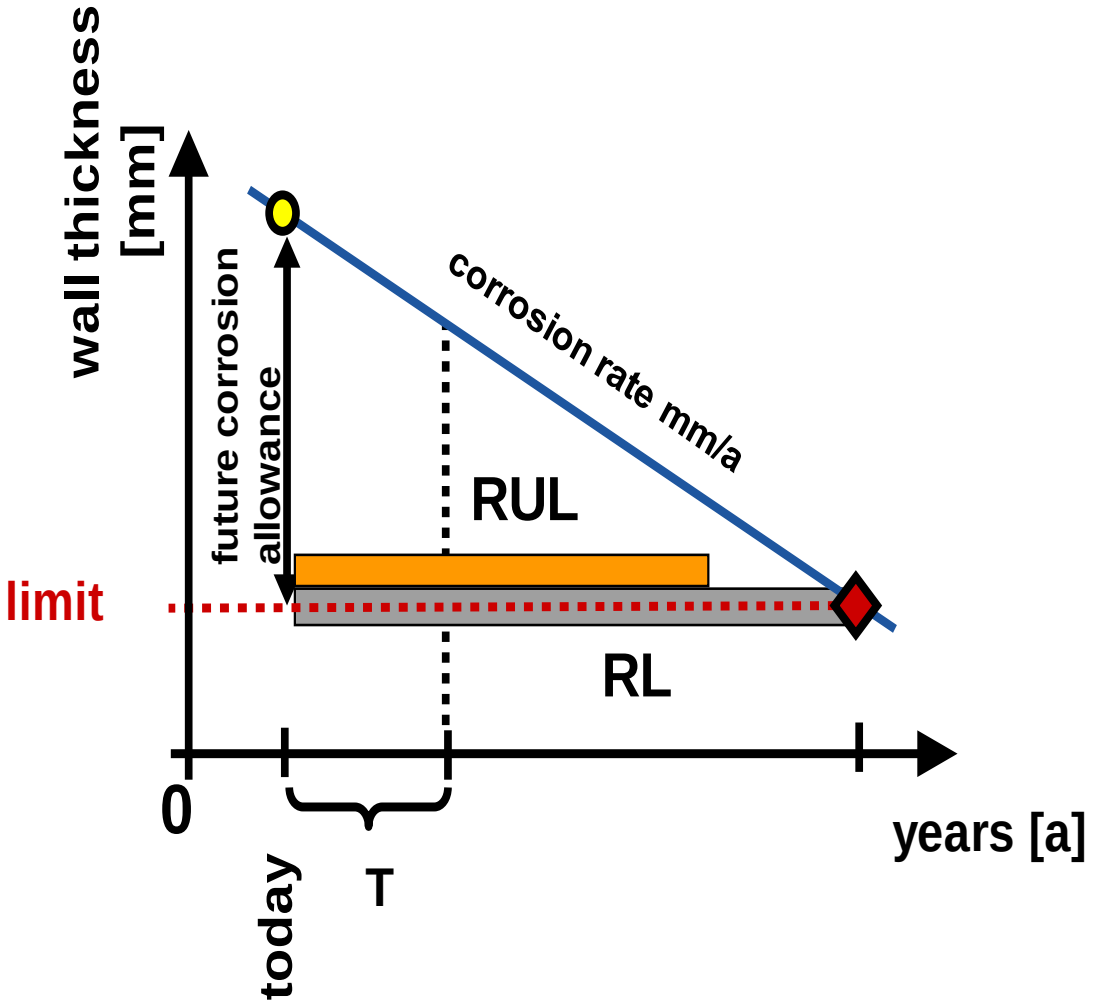
Repair, replacement or

Fitness for Service

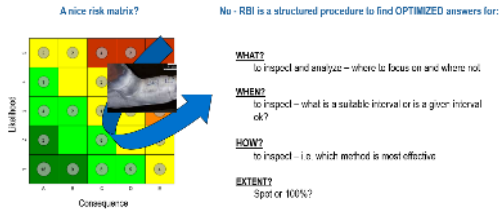
Minimize ≠ 0

When to inspect?





How to inspect?

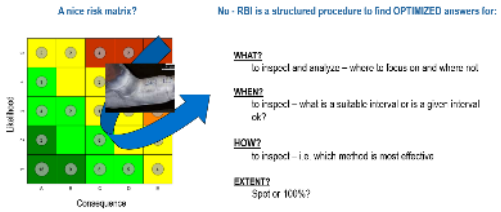


- General and localized metal loss, ➔ corrosion/ erosion
- Surface connected cracking ➔ fatigue, SCC
- Subsurface cracking ➔ wet H_2S, hydrogen induced cracking
- High-temperature microfissuring/microvoid formation and eventual macrocracking ➔ HTHA, creep
- Metallurgical changes ➔ hydrogen embrittlement, graphitization
- Blistering ➔ hydrogen blistering

How to inspect

The anomaly	The NDT method	comments
General corrosion	Corrosion Mapping using - Ultrasonics - Laser (3D Laser)	• Laser can scan and provide profilometry information of the corroded area. Remaining wall has to be assumed based on calculations (mind the nominal wall may vary by up to 10%) • Ultrasound can scan from the opposite site due to missing coupling in case immersion isn't allowed (PA or Burst probes are appropriate) Mind the following: • Within the corrosion area there maybe also pitting corrosion • Within the general corrosion area there may be also cracks
Localised corrosion (or pitting corrosion)	- Properly dimemsioned Ultrasonics - Phased Array - Somehow: potential drop - Hall sensor array /SLOFEC	• UT: Calibration blocks are required that have flat bottom holes of various depths and diameters are useful for identifying transducer limitations. Resolution 4 to 5 mm. Takes long time. PA is much faster. • Recommended use of A-Scan flaw detector or simply A-scan modus to scan the surface • Apply overlapping scans (PT may help to determine width of the scanning path) • Experienced technicians are needed
HIC and SOHIC	ToFD + PA combination Eddy currents Somehow: Potential drop	• Both are to be applied simultaneously • ToFD – Screening the weld region including HAZ to detect HIC and SOHIC • PA – Verification of Stepwise cracking and sizing extent of damage • Sometimes: Add TRL transducers to accurately determine stepwise cracking • Eddy currents (incl ACFM) are also a good alternative for the detection. Not appropriate for depth sizing.
High temperature Hydrogen Attack (HTHA)	Phased Array ToFD Ultrasonic Back scattering	• Phased Array is one of the primary methods to use when it comes to HTHA • ToFD is essential for analysing through-wall depth crack characteristics. It is the best for assessing and detecting all type of weld anomalies. • Ultrasonic backscattering. Makes use of the ultrasonic signal being scattered in the grain boundaries resulting from the presence of hydrogen damage. There is a direct correlation to affected material thickness. 10 Mhz and 5 MHz transducers are typically used in combination.

Location and extent of inspection

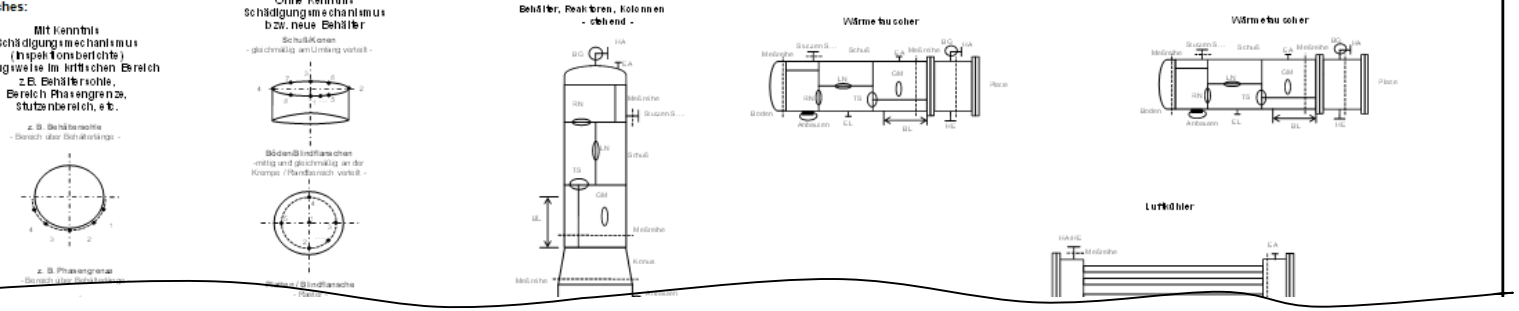


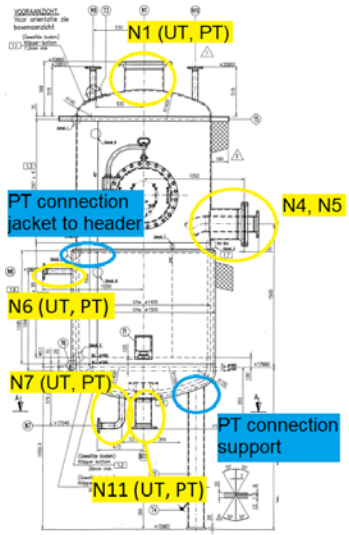
Mustermaßnahmenkatalog Ersatz innere Prüfungen - Guideline replacements internal inspections

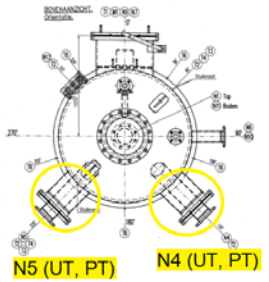
Schädigung - Damage Mechanism:	Flächiger Materialabtrag - General Thinning		
Standard:	API 581, table 5.2	Revision:	0.E
Komponenten - Components:	Behälter, Reaktoren, Kolonnen, Wärmetauscher und Luftkühler - Vessels, reaktors, columns, heat exchanger and air cooler	Datum - Date:	02.02.2010
Ergebnis - Result:	Ausgehend vom Schädigungsmechanismus und der Risikoeinstufung Festlegung von Meßmethoden/-orte und -umfänge als Ersatz für innere Prüfungen	Bearbeiter - Name:	Swoboda
	Based on defects and risk matrix determination of replacment approvals for internal inspection		

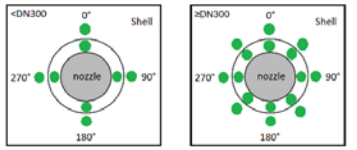
Inspektions Kategorie - Inspection Category	Meßvolumen gesamt - test scope total	Schuß / Konen - shell / cone: Meß-methode - test methode	Bezugslänge - relevant length (BL)	Meßvolumen - test scope [N] in Abhängigkeit von - depends on Durchmesser - diameter: <500	500 bis <1000	1000 bis <2000	2000 bis <3000	3000 bis <4000	≥4000 bis <5000	Einheit - unit	Böden / Blindflansche - heads / blind flanges: Meß-methode - test methode	Meßvolumen - test scope [N] in Abhängigkeit von - depends on Durchmesser - diameter: <500	500 bis <1000	1000 bis <2000	2000 bis <3000	3000 bis <4000	≥4000 bis <5000	Einheit - unit	Bemerkungen - Remarks	Stutzen - nozzles: Meß-methode - test methode	Meßvolumen - test scope [N]: Haupteintritt/ Hauptaustritt/ Entlüftung/ Entwässerung - Main inlet / main outlet / drain / vent (HE/HA/EA/EL)	Bögen bends (BG)	verbl. Stutzen remaining nozzles (S....)	Bemerkungen - Remarks	Platten - plates: Meß-methode - test methode	Meßvolumen - test scope [N] Raster [a x b]	Einheit - unit	Bemerkungen - Remarks	Bemerkungen - remarks
E	SP	UT-WD	pro 10m	4	4	4	4	8	8	[Stk/pcs]	UT-WD	5	5	5	5	9	9	[Stk/pcs]	*)	UT-WD alt. RÖ-SCH	2 von 4 2 von 4			*), Ø wie Schuß - like shell	UT-WD	300x1000	[-]	*)	
D	SP	UT-WD	pro 10m	4	4	4	4	8	8	[Stk/pcs]	UT-WD	5	5	5	5	9	9	[Stk/pcs]	*)	UT-WD alt. RÖ-SCH	2 von 4 2 von 4			*), Ø wie Schuß - like shell	UT-WD	300x1000	[-]	*)	
C	SP	UT-WD	pro 10m	4	4	8	8	16	16	[Stk/pcs]	UT-WD	5	5	5	5	17	17	[Stk/pcs]	*)	UT-WD alt. RÖ-SCH	2 von 4 2 von 4			Ø wie Schuß - like shell	UT-WD	300x1000	[-]	*)	
B	SP bzw. 20% (Ut[m])	UT-WD alt. Ut[m]	pro2m pro2m	4 20	8 20	8 20	16 20	32 20	32 20	[Stk/pcs] [%]	UT-WD alt. Ut[m]	5 20	5 20	5 20	5 20	17 20	33 20	[Stk/pcs] [%]		UT-WD alt. RÖ-SCH alt. Ut[m]	4 von 4 4 von 4 4 von 4	20% 20% 20%	20% 20% 20%	Ø wie Schuß - like shell	UT-WD alt. Ut[m]	300x700 20%	[-] [%]		
A	spezifisches Prüfprogramm, muß detailliert erarbeitet werden / specific inspection program, have to be defined in case																												

Skizzen - sketches:









Agenda

- RBI – what is it and what are the benefits?
- The legal situation and RBI - a a challenge?
- The main steps for RBI
- RBI and NDT
- Questions and summary

Classic way to select an inspection technique

Proper inspection planning requires:

- consideration of material issues → what is possible?
- susceptible degradation mechanisms and failure modes → what do we need to find?
- what needs to be reported → sizing accuracy
- process knowledge and plant specifics → process, accessability, ...

with a thorough RBI all these issues are addressed

Good practice is a combination of techniques …..

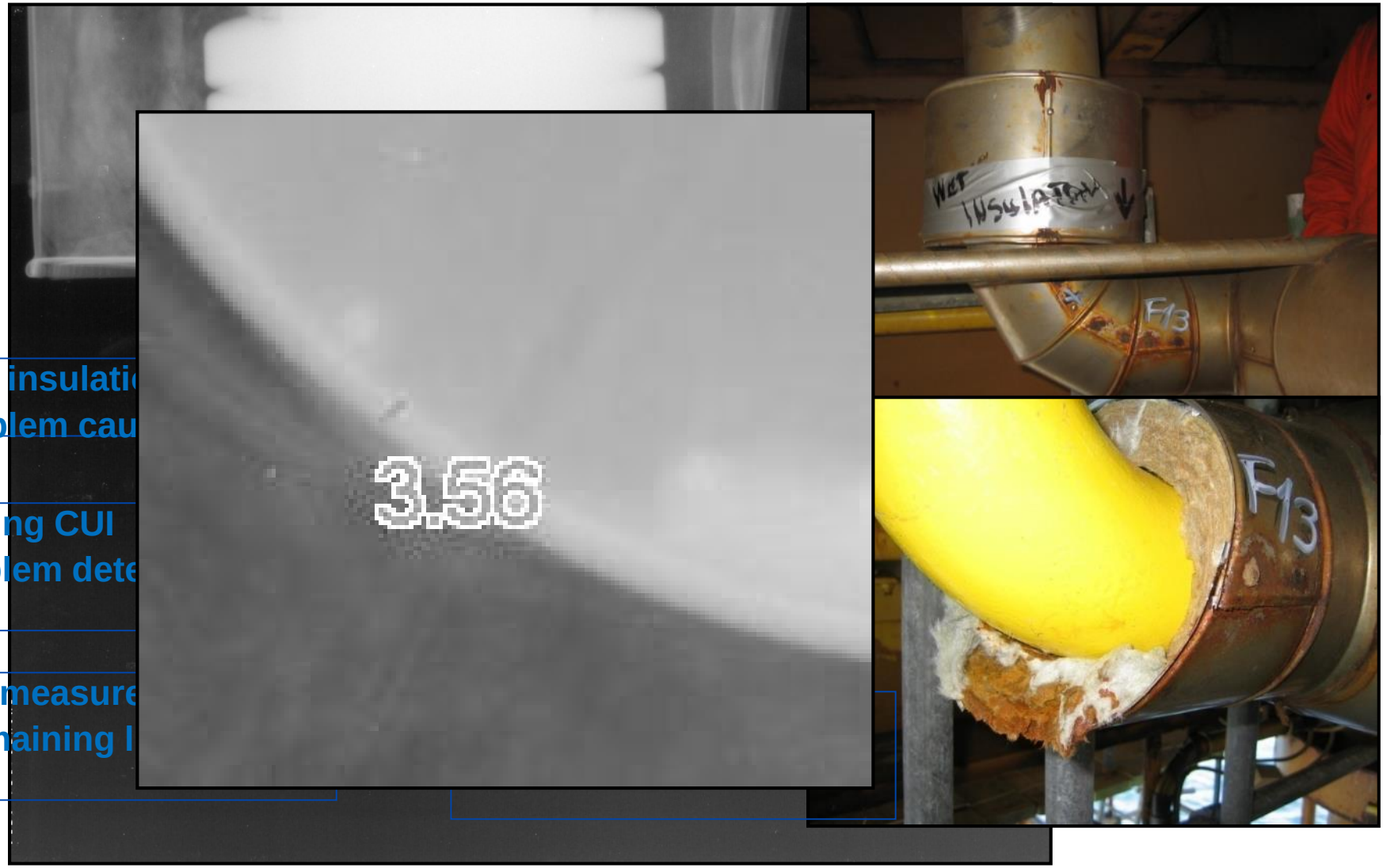
- Standard and well establised techniques (VT, UT, RT, MT, PT, ...)

- Guided long ultrasonic waves
- ToFD
- Phased Array
- Digital radiography
- Acoustic Emmission testing

- Permanent Monitoring (predictive analytics)
- .....

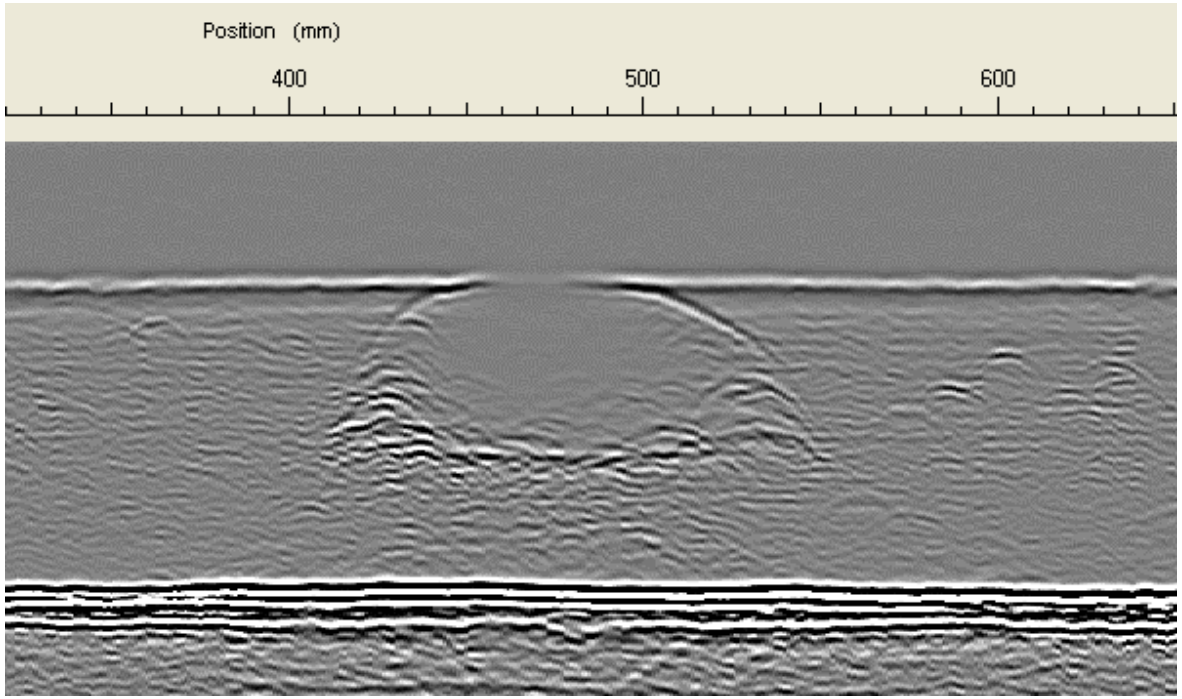
…. to get a good overview (screening) plus quantitative results for the assessment

Digital radiography



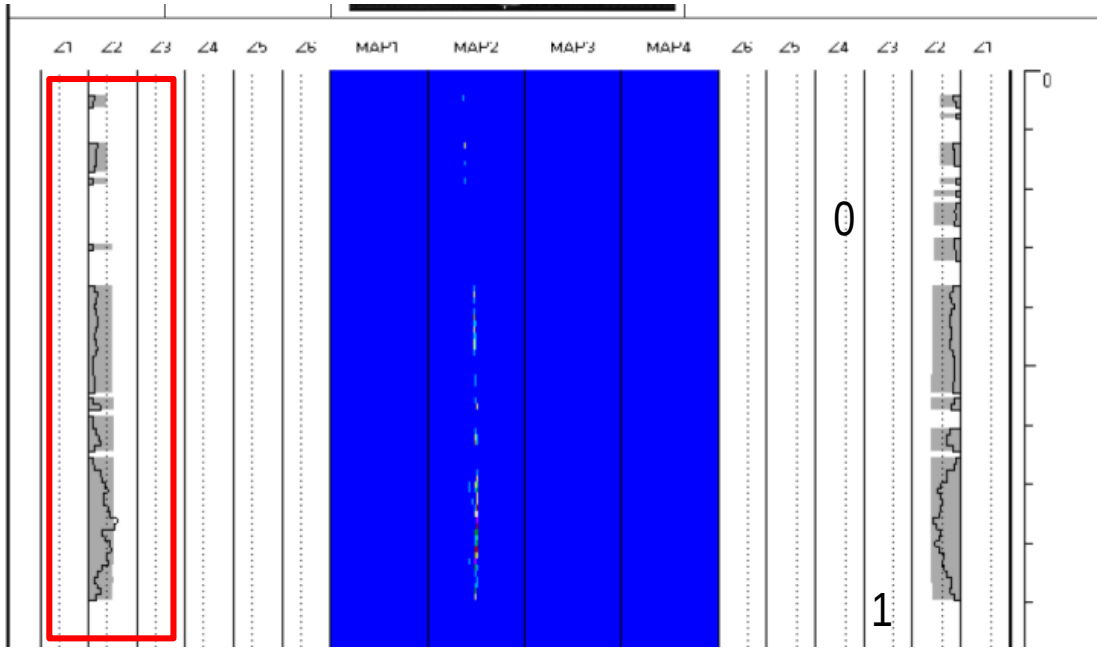
Advanced UT (ToFD and Phased Array) to characterize cracks

ToFD



Mid wall crack

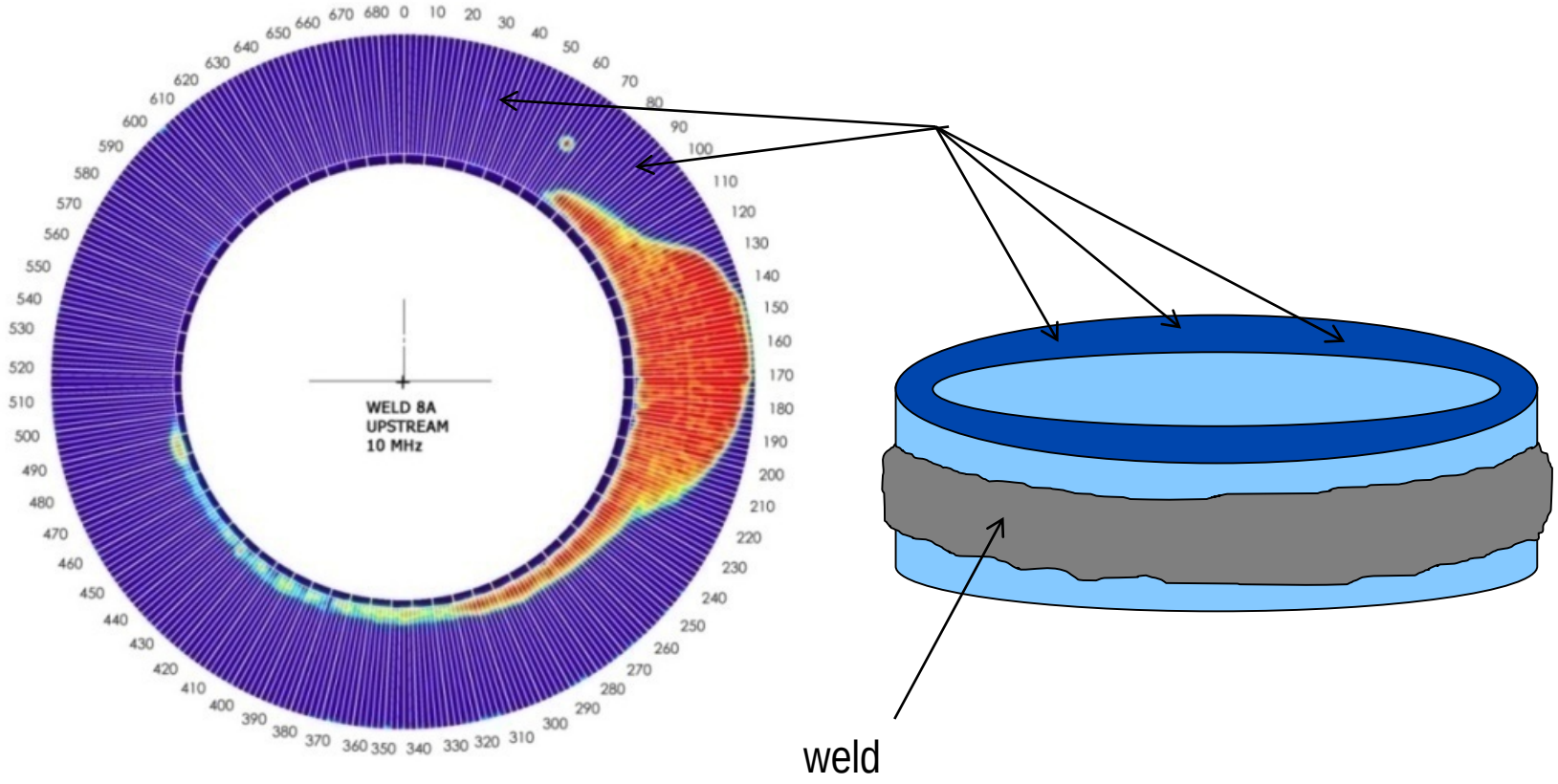
Phased Array Tandem



Through wall crack

Question: What is correct?

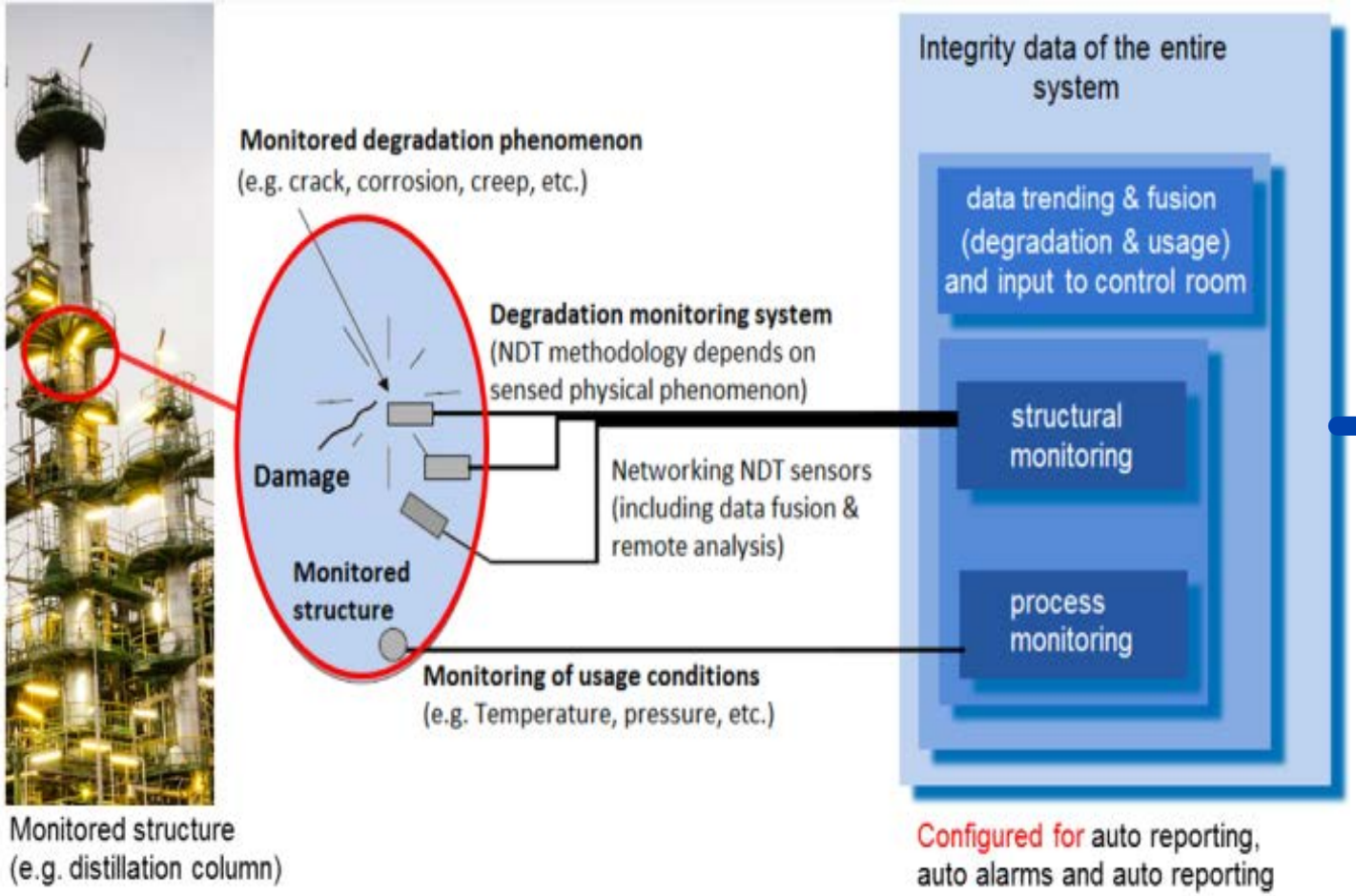
Advanced UT (ToFD and Phased Array) to characterize cracks



Ultrasonic Immersion test: Through wall crack

conclusion: ToFD failed in this particular case

Permanent monitoring



Automated Computation

FFS and RLA

Digital dashboard

Key Outcome

- wall thickness deterioration over time
- real time FFS
- real time RLA

Prediction:
- when to repair
- when to order new parts

…. keeping an eye on corrosion – best way for predictive analytics

Summary NDT

- Anomalies like Cracking, Corrosion, Blistering, HIC, SOHIC damage can occur throughout the production facility especially whenever there is a wet H2S environment present.
- Ultrasonic methodologies are the most prominent answer to those challenges.
- Corresponding technologies (TofD, Phased Array, TofR, UT Backscattering, etc.) are to be properly selected by experience Level III NDT specialists in close cooperation with the RBI engineers
- Our Level III services are specifically designed to support plant operators to best comply with the RBI assessments and recommendations
- Permanent monitoring of critical assets represent the most modern and advanced way to access damage and to predict the future and so save significant costs and increase plant availability

Agenda

- RBI – what is it and what are the benefits?
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Summary

- RBI is intended to give a structured procedure to answer the relevant questions around inspection planning

- There are many cost-saving opportunities when going for RBI, which are related to interval prolongation, non-intrusive instead of intrusive inspections, long-term plannability

- Systematic selection of effective and efficient NDT techniques

Feedback and new topics

	So so			Quite good				Very good		
	1	2	3	4	5	6	7	8	9	10
How did you like this webinar ?										
Were the speakers understandable?										
Did the webinar match your expectations?										
Any comment?										

Our next Webinar will be focussing on a concrete case study. We will demonstrate in detail how RBI was applied in an industrial facility and how NDT and RBI came together to save significant costs and to increase plant availability	
Interested in attending?	
Email Address: (We will contact you using this address)	
Company:	