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New appraoch for X-ray weld inspection of pipeline segments

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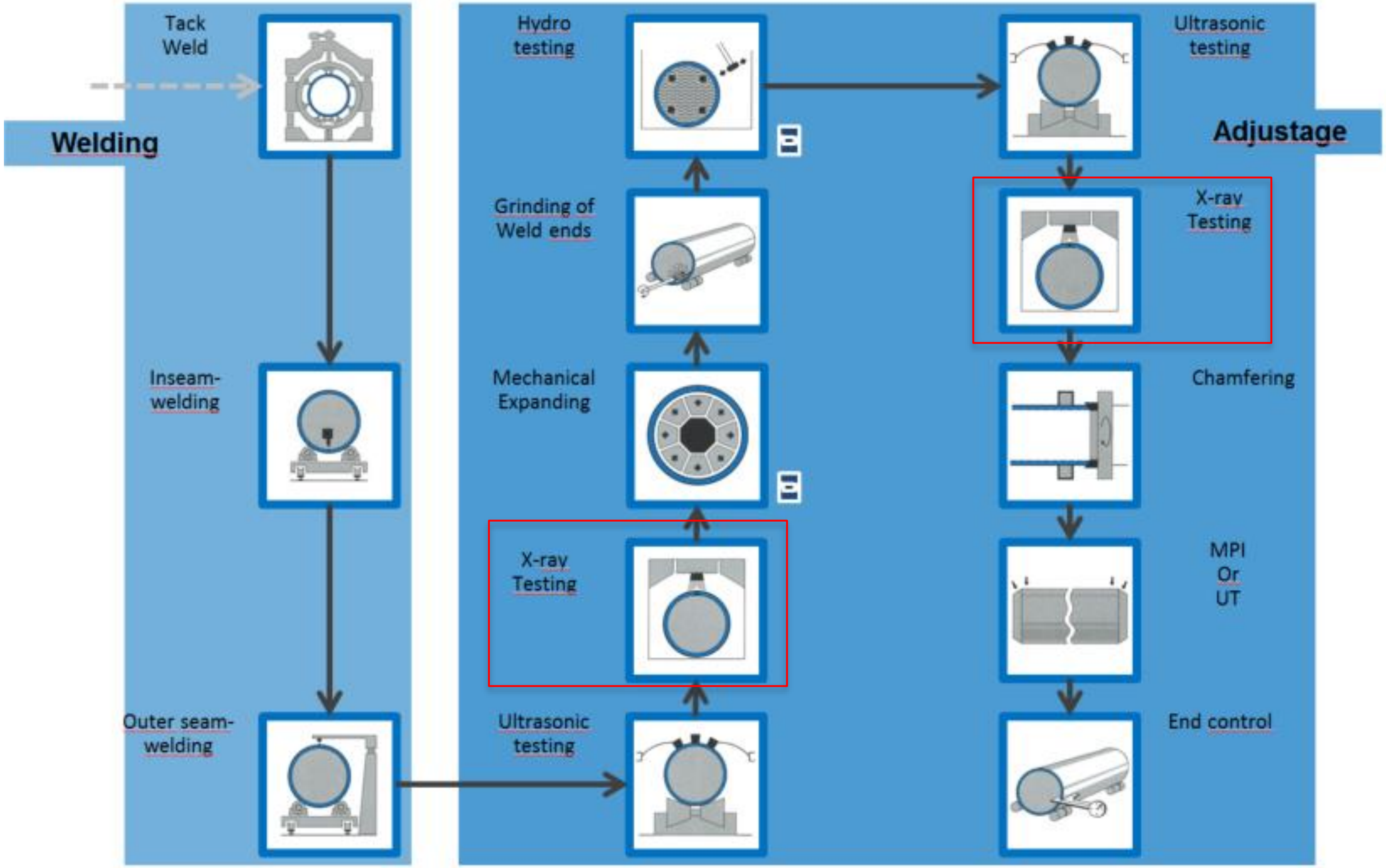
Overview

- Weld inspection in heavy industries (Pipe and Tank)
- Analogue Film – “The old approach”
- Transition to digital Radiography
  - The international standards
  - Detectors (DDA) – Form factor and Read Out Speed
- New setup with DDA’s
- The next automation level – Feed-thru system
- Commercial Analysis and comparison
- Conclusion

Pipe Manufacturing

Material flow SAW Pipes



Material flow SAW Pipes

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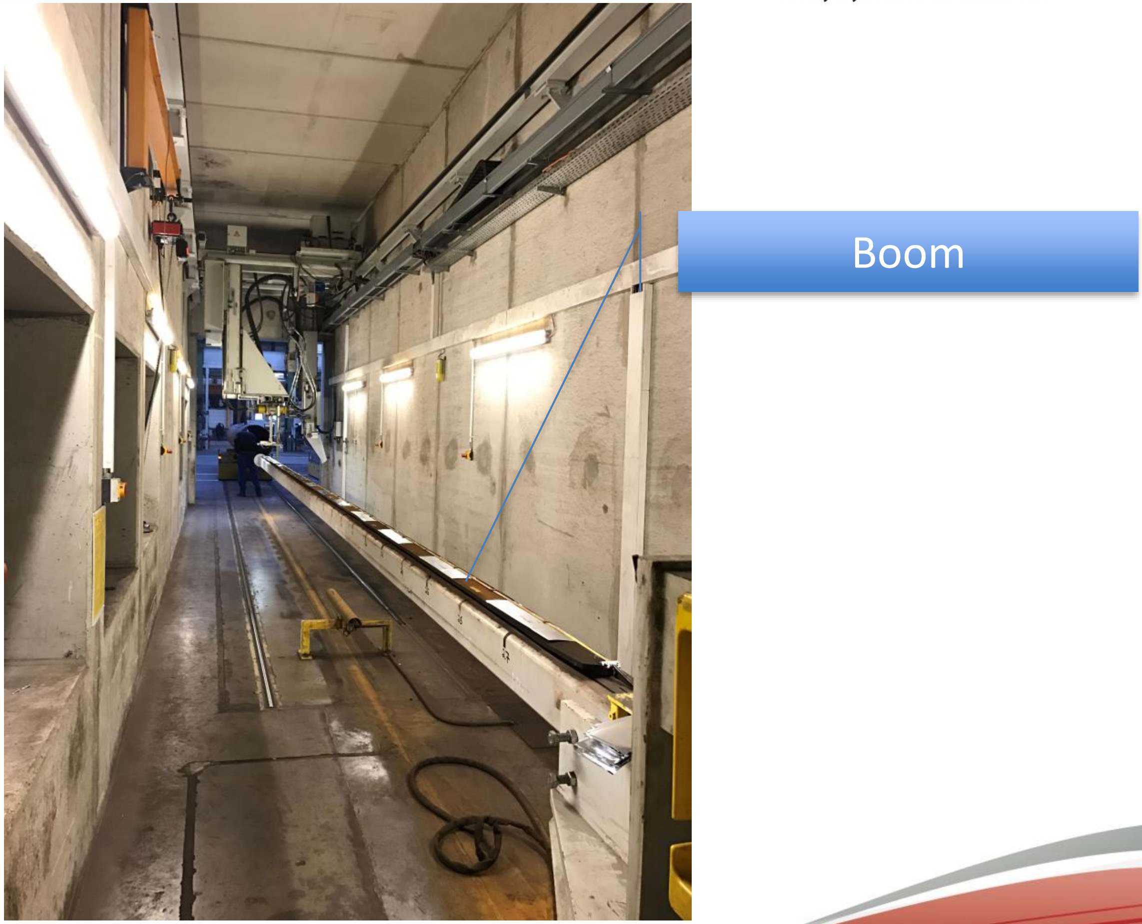
- Ultrasonic testing as an upstream method for weld inspection

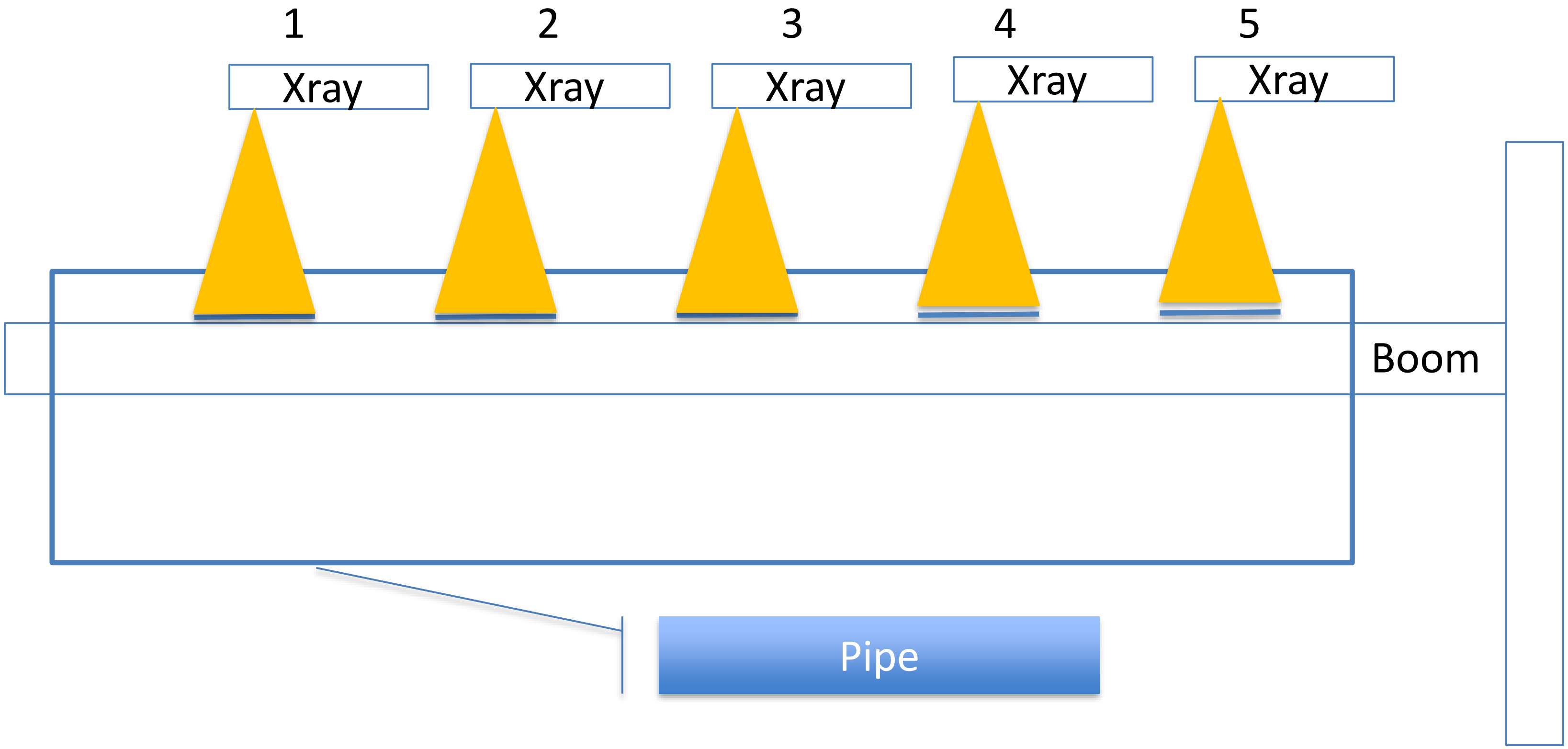
- Depending on standards or customer request X-ray test

    - Only at UT indications
    - Inspection of both ends of the welding line
    - Random inspection of a certain percentage of the welding line
    - Inspection of the complete welding line

Setup in reality



Pipe inspection with Film – 1. Setup



Classic X-ray setup: Film

Classic X-ray setup: Film

Pro

- Easy to handle
- Less startup investments

Contra

- Continous cost
- Offline development
- Needs chemicals (environment, storage)
- Quality depends on the quality of developing chemicals and human factor
- Long exposure time

Digital Detector Array (DDA)

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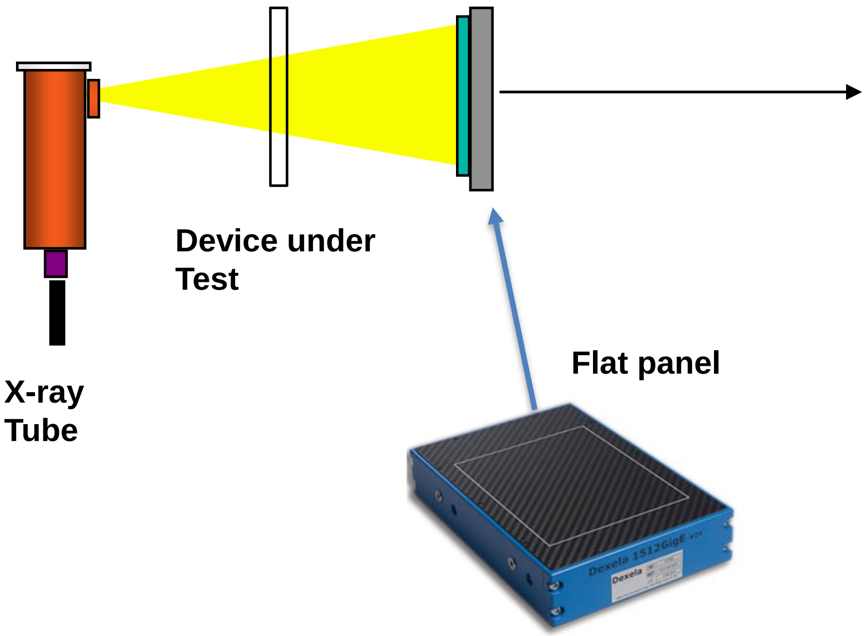
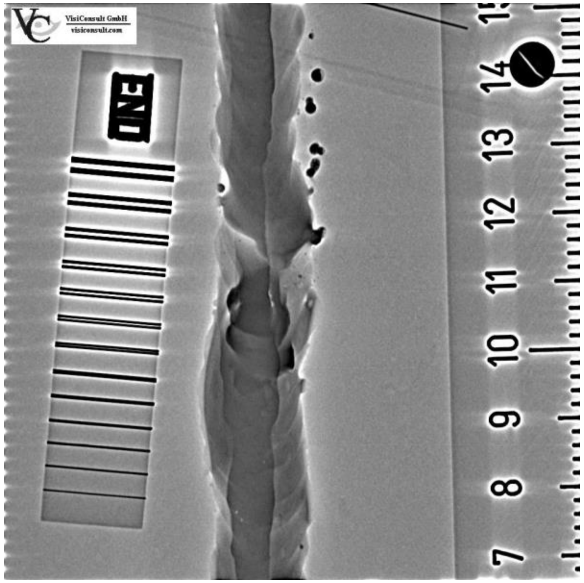
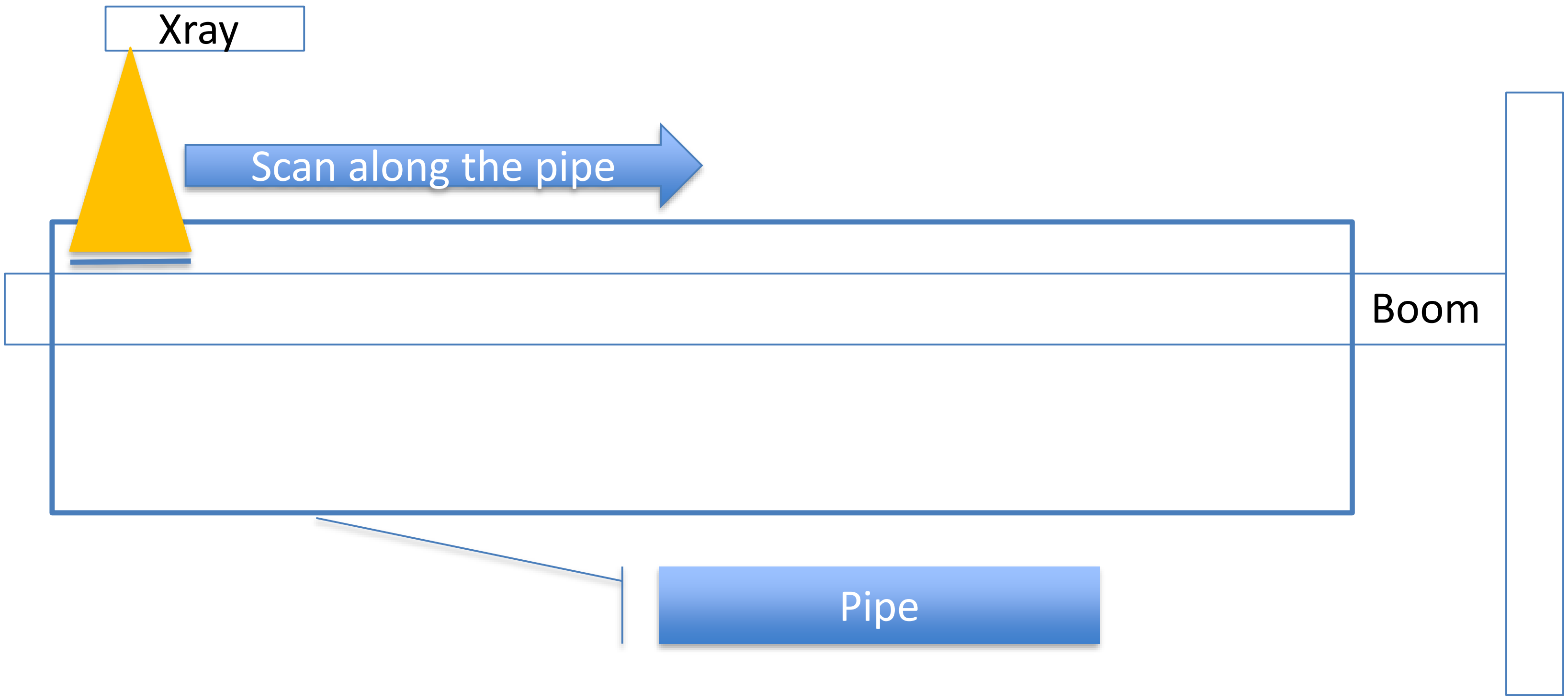
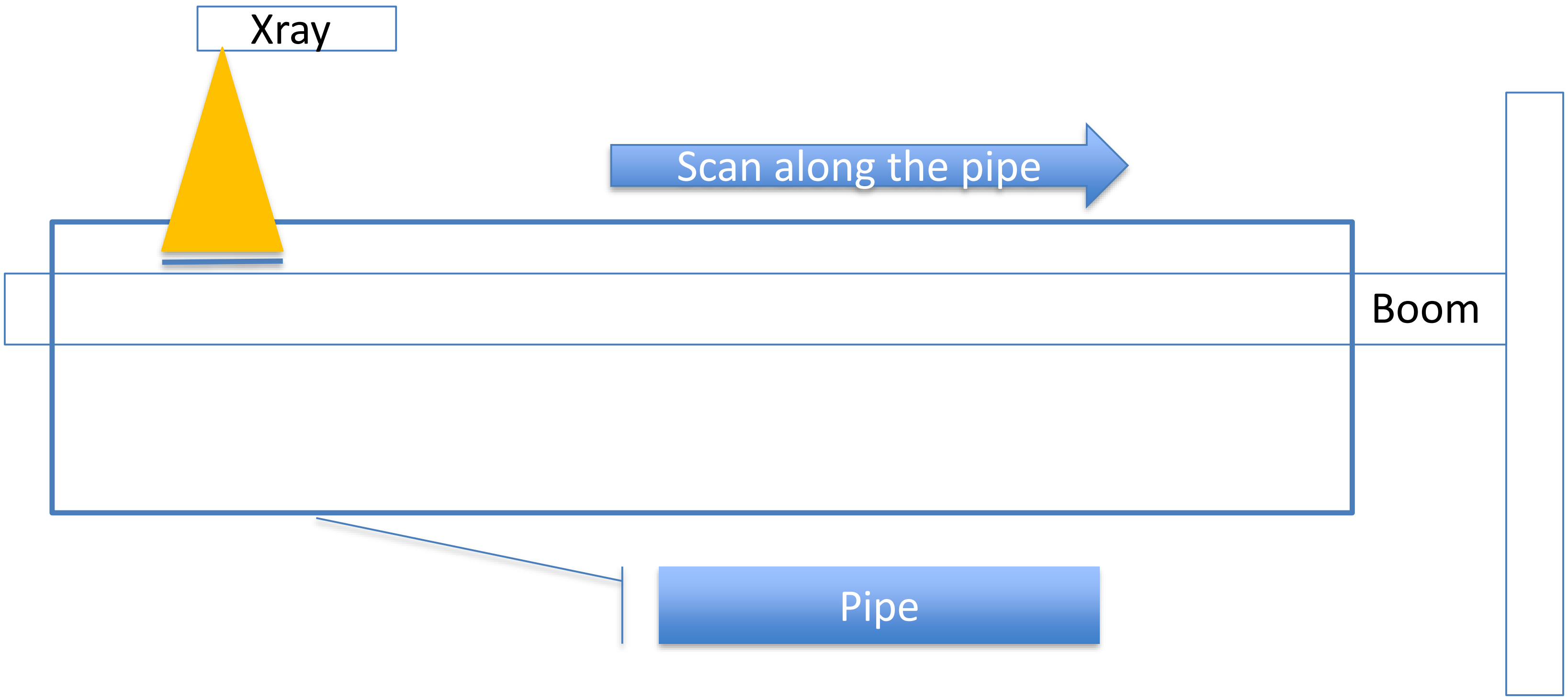




Pipe inspection with DDA



Pipe inspection with DDA



Pipe inspection with DDA (flat panel)

Pro

- Easy to handle
- Low continuous costs
- No consumables
- Immediate results of the X-ray test
- Live investigations at the weld
- No chemicals
- Short exposure time

Contra

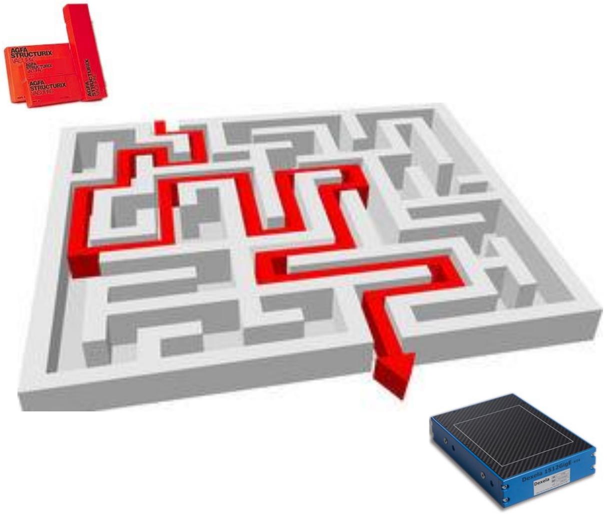
- Trained operators are necessary (Digital Radiography qualification)
- X-ray equipment is different to film exposure (focal spot must be smaller)

Transition strategy

The transition from analog to digital is straight forward

BUT

you must take a lot of things in consideration to be successful



Standards for pipe inspection (API 5L/Shell/DNV)

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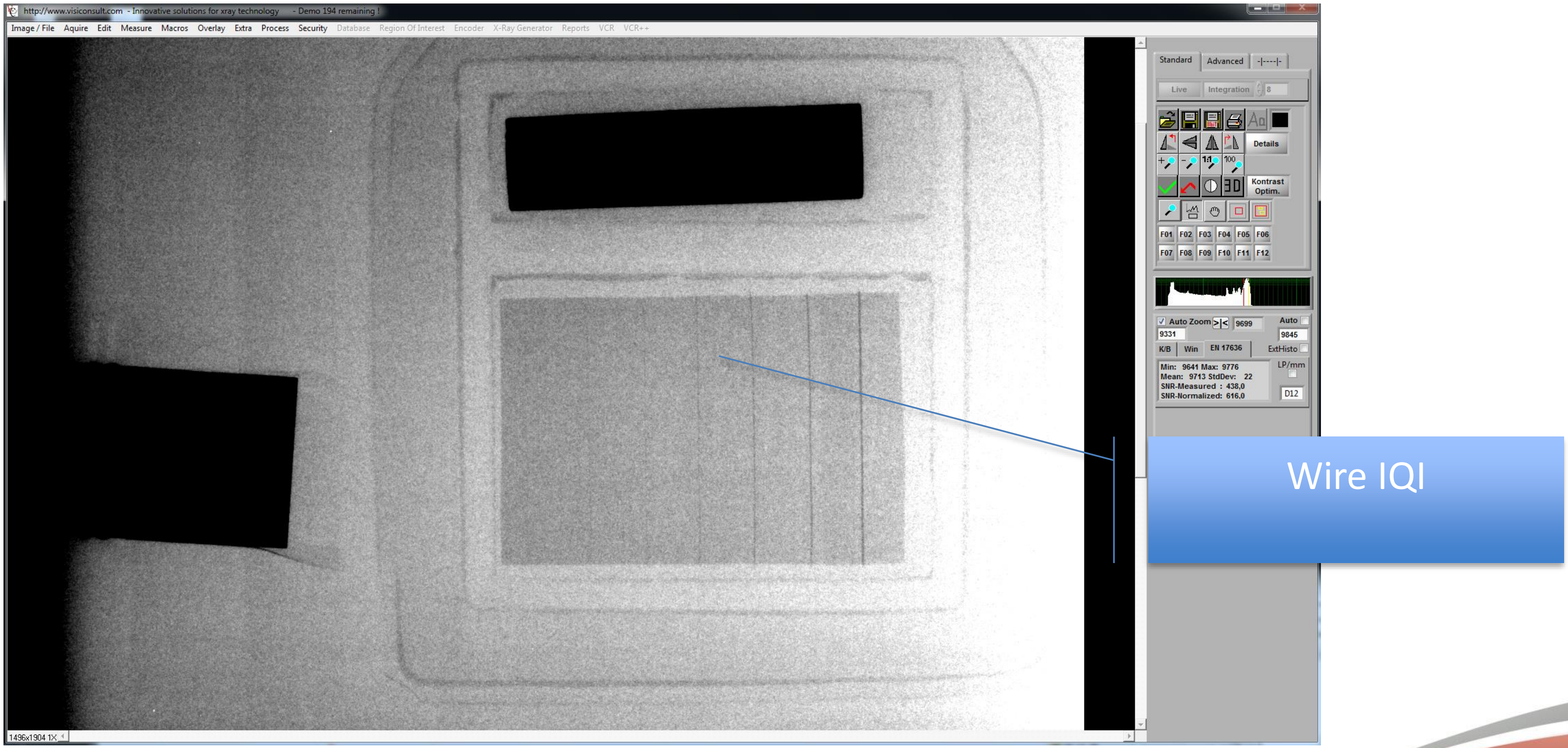
Table E.3 — ISO wire-type IQI for radiographic inspection

Weld thickness [a] mm (in)	Essential wire diameter mm (in)	FE wire set	Wire number
≤ 8 (0.3)	0,16 (0.006)	W 10 to W 16	14
> 8 (0.3) to ≤ 11 (0.4)	0,20 (0.008)	W 10 to W 16	13
> 11 (0.4) to ≤ 14 (0.6)	0,25 (0.010)	W 10 to W 16 or W 6 to W 12	12
> 14 (0.6) to ≤ 18 (0.7)	0,32 (0.013)	W 10 to W 16 or W 6 to W 12	11
> 18 (0.7) to ≤ 25 (1.0)	0,40 (0.016)	W 10 to W 16 or W 6 to W 12	10
> 25 (1.0) to ≤ 32 (1.2)	0,50 (0.020)	W 6 to W 12	9
> 32 (1.2) to ≤ 41 (1.6)	0,63 (0,025)	W 6 to W 12	8
> 41 (1.6) to ≤ 50 (2.0)	0,80 (0.032)	W 6 to W 12	7
> 50 (2.0)	1,00 (0.039)	W 6 to W 12	6

[a] The weld thickness is the sum of the specified wall thickness and the estimated thickness of the weld reinforcement.

- API 5L takes only the contrast into consideration !
- The so called Wire IQI's are used to show that you fulfill the standard

Standards for pipe inspection (API 5L/Shell/DNV)

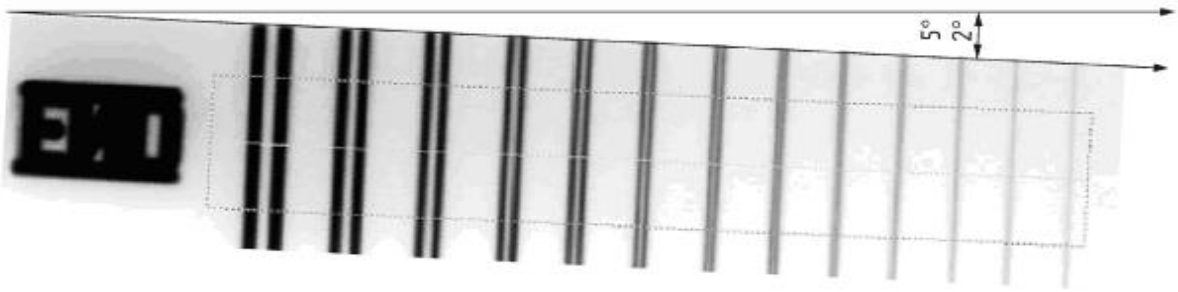


API5L – 45th revision

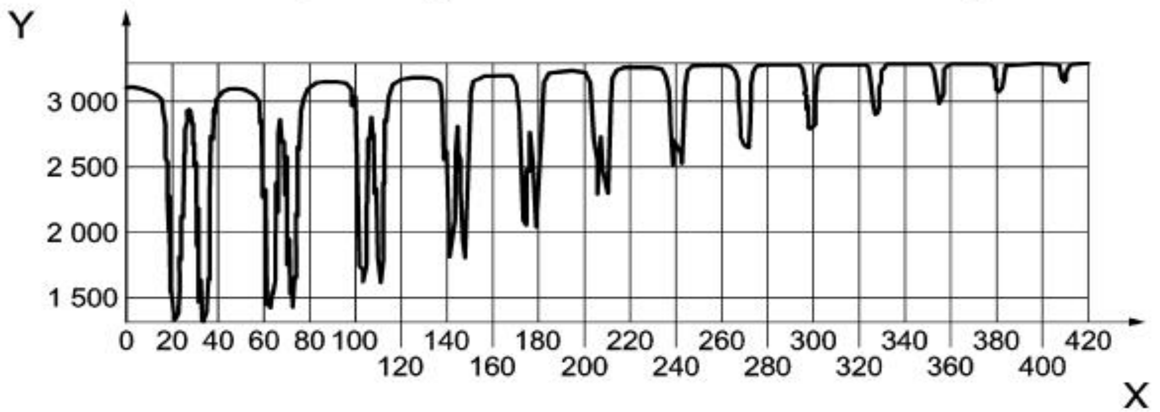
The newest release of API5L takes DDA´s in consideration:

- Relation to the ISO standard **ISO 10893-7:2011**
- This standard is now referring to contrast resolution and geometrical resolution
- This standard has 2 different weld classes
  - API5L is classical the lower class A
  - **BUT** most high-end manufacturers are testing according the higher Class B

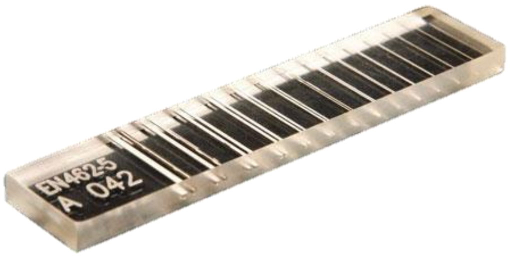
Geometrical resolution with Double Wire IQI



a) Abbildung des Doppeldraht-BPK in einem Durchstrahlungsbild



b) Aus mindestens 21 Zeilen gemitteltes Profil des Doppeldraht-BPK



Geometrical resolution with Double Wire IQI

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Table B.14 — Maximum image unsharpness for all techniques Class B

Image Quality Class B Duplex wire ISO 19232-5		
Penetrated thickness w^{a} mm	Minimum IQI value and maximum unsharpness (ISO 19232-5)[b] mm	Maximum basic spatial resolution in mm (equivalent to wire thickness and spacing) [b]
$w \leq 1{,}5$	D 13+ 0,08	0,04
$1{,}5 < w \leq 4$	D 13 0,10	0,050
$4 < w \leq 8$	D 12 0,125	0,063
$8 < w \leq 12$	D 11 0,16	0,08
$12 < w \leq 40$	D 10 0,20	0,10
$40 < w \leq 120$	D 9 0,26	0,13
$120 < w \leq 200$	D 8 0,32	0,16
$w > 200$	D 7 0,40	0,20

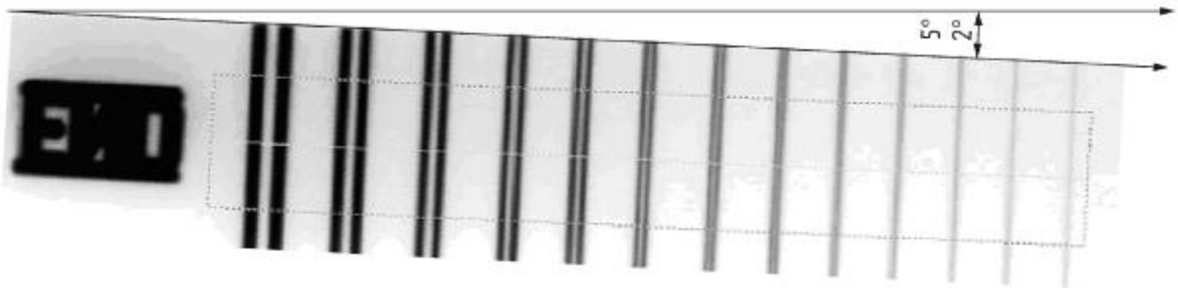
[a] For double wall technique, single image, the nominal thickness t shall be used instead of the penetrated thickness w.

[b] The IQI reading for system selection (see Annex C) applies for contact radiography. If geometric magnification technique (see 7.7) is used the IQI reading shall be performed in the corresponding reference radiographs.

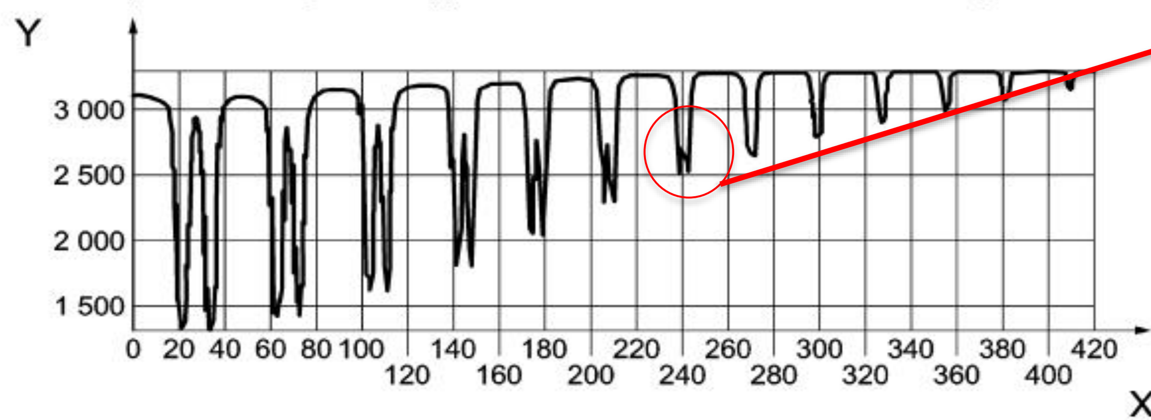
ISO 10893-7
defines the
maximum
unsharpness of the system

Be aware
that the critical question is
the minimum thickness of the
Material !

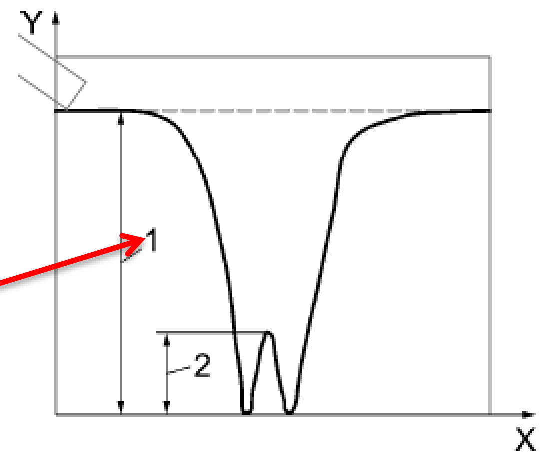
Geometrical resolution with Double Wire IQI



a) Abbildung des Doppeldraht-BPK in einem Durchstrahlungsbild

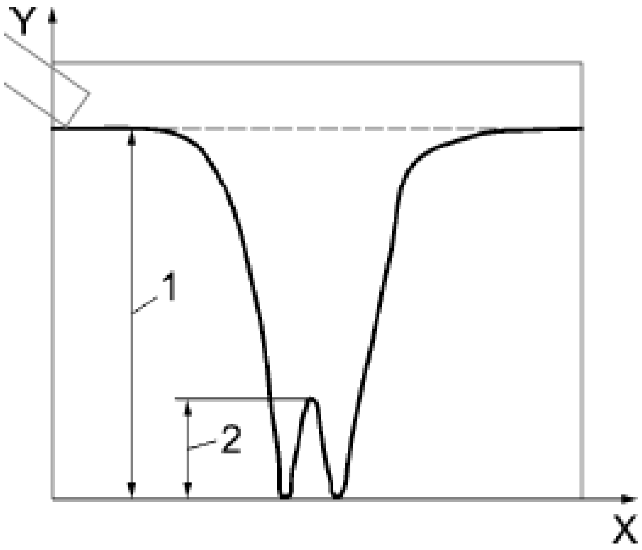


b) Aus mindestens 21 Zeilen gemitteltes Profil des Doppeldraht-BPK



d) Calculation of the dip (in %) by: dip = 100 x dip amplitude/background amplitude

Geometrical resolution with Double Wire IQI



d) Calculation of the dip (in %) by: dip = 100 x dip amplitude/background amplitude

Be aware
The dip (2) must be a minimum of 20% of the maximum (1)

This calculation has to be done by Software and not by human eyes

API5L – With ISO 10893-7:2011

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	API 5L		ISO 10893-7:2011					
	IQI on source side on weld z		IQI on source side beside the weld on nominal thickness t					
	According to ISO 10893-7		Single wall class A			Single wall class B		
z and t (mm)	Single wire (ASMT E 4 747-04)	Single wire (ISO 19232-1:2004)	Single wire	Hole number	Double wire	Single wire	Hole number	Double wire
≤ 1,0	**A4**	**W14**	**W18**	**H3**	**D11**	**W19**	**H2**	**D13+**
≤ 1,2	A4	W14	W18	H3	D11	W19	H2	D13+
≤ 1,5	A4	W14	**W17**	H3	D11	W19	H2	D13+
≤ 2,0	A4	W14	W17	H3	D11	**W18**	H2	**D13**
≤ 2,5	A4	W14	**W16**	**H4**	**D10**	W18	H2	D13
≤ 3,0	A4	W14	W16	H4	D10	**W17**	**H3**	D13
≤ 3,5	A4	W14	W16	H4	D10	W17	H3	D13
≤ 4,0	A4	W14	**W15**	**H5**	D10	W17	H3	D13
≤ 4,5	A4	W14	W15	H5	D10	**W16**	**H4**	**D12**
≤ 5,0	A4	W14	W15	H5	D10	W16	H4	D12
≤ 5,5	A4	W14	**W14**	H5	**D9**	W16	H4	D12
≤ 6,0	A4	W14	W14	H5	D9	W16	H4	D12
≤ 7,0	A4	W14	W14	**H6**	D9	**W15**	H4	D12
≤ 8,0	A4	W14	**W13**	H6	D9	W15	H4	D12
≤ 9,0	**A5**	**W13**	W13	H6	D9	**W14**	**H5**	**D11**
≤ 9,5	A5	W13	W13	H6	D9	W14	H5	D11
≤ 10	A5	W13	W13	H6	D9	W14	H5	D11
≤ 11	A5	W13	**W12**	**H7**	**D8**	W14	H5	D11
≤ 12	**A6**	**W12**	W12	H7	D8	W14	H5	D11
≤ 13	A6	W12	W12	H7	D8	**W13**	**H6**	**D10**

ISO 10893-7:2011 – Flat panel

Sample 10 mm Steel – Weld Class B

API 5L

Asks for:
Wire : W13
Double wire : Not defined

Is OK!

ISO 10893-7

Asks for:
Wire : W14
Double wire : D11

Is NOK!

Perkin Elmer XRD822
200 µm Pixelsize

Wire : W15
Doublewire IQI : D7

ISO 10893-7:2011 – Flat panel

Sample 10 mm Steel – Weld Class B

API 5L

Asks for:
Wire : W13
Double wire : Not defined

Is OK!

ISO 10893-7

Asks for:
Wire : W14
Double wire : D11

Is OK!

Varian Panel
127 µm Pixelsize

Wire : W16
Doublewire IQI : D9

ISO 10893-7:2011 – Flat panel

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Sample 10 mm Steel – Weld Class B

API 5L

Asks for:
Wire : W13
Double wire : Not defined

Is OK!

ISO 10893-7

Asks for:
Wire : W14
Double wire : D11

Is OK!

Why it is ok ?

Varian Panel
127 µm Pixelsize

Wire : W16
Doublewire IQI : D9

ISO 10893-7:2011 — Compensation

Varian Panel 127 µm Pixelsize			**ISO 10893-7**	
			Asks for:	
Wire	: W16	→	Wire	: W14
Doublewire IQI	: D9	←	Double wire	: D11

Compensation:

When you have too less resolution you can compensate with higher contrast sensitivity !

D9 is two stages too low (D11 required)
W16 are two stages too high (W14 required)

ISO 10893-7:2011– SNR

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Signal to Noise Ratio

Beside the visibility of defects you must guarantee that you're your noise level is low enough – Or your signal has a minimum ratio compared to the noise

Tabelle 3 — Mindest-SNR_N-Werte (CR und DDA) und Vorderfolien aus Metall (Aufnahmefolien nur für CR) für die digitale Durchstrahlungsprüfung von Stahl, Kupfer und Nickel-Basis-Legierungen

Strahlenquelle	Durchstrahlte Werkstoffdicke w mm	Mindest-SNR_N [c] Klasse A	Klasse B
Spannung des Röntgenstrahlers ≤ 50 kV		100	150
Spannung des Röntgenstrahlers [d] > 50 kV bis 150 kV		70	120
Spannung des Röntgenstrahlers [d] > 150 kV bis 250 kV		70	100
Spannung des Röntgenstrahlers [d] > 250 kV bis 350 kV	≤ 50	70	100
	> 50	70	70
Spannung des Röntgenstrahlers [d] > 350 kV bis 1 000 kV	≤ 50	70	100
	> 50	70	70

Min SNR required

ISO 10893-7:2011– SNR

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Tabelle D.1 — Erforderliche $SNR_{measured}$-Werte für ausgewählte CR-Systeme mit unterschiedlichen SR_b, die den jeweiligen SNR_N-Werten äquivalent sind

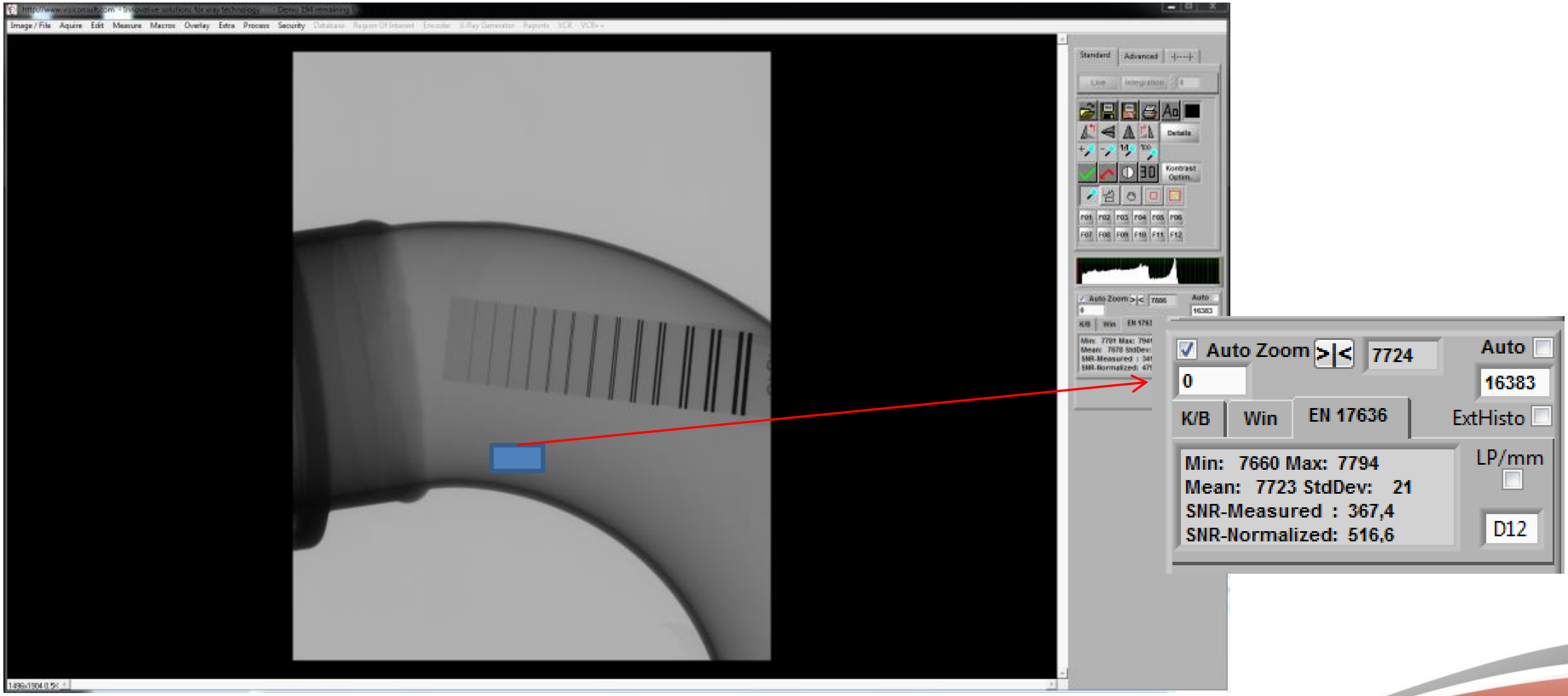
System-parameter	Hochauflösendes System			Standardsystem					
Doppeldraht-BPK-Qualifizierung	13+	13	12	11	10	9	8	7	6
Basis-Ortsauflösung SR_b	40 µm	50 µm	63 µm	80 µm	100 µm	130 µm	160 µm	200 µm	250 µm

$$SNR_N = SNR_{measured} \cdot \frac{88{,}6\mu m}{SR_b}$$

From the image

SNR-measured = Meanvalue / Standard deviation

ISO 10893-7:2011– SNR



Choice of the detector

Which DDA for which wall thickness and Class B ?

Min. Wallthickness	Pixelsize	DDA
2 mm	75µm	Dexela (CsI) 1512
10 mm (Comp)	127 µm	Varex Imaging PaxScan 2520DX
60 mm	200 µm	Perkin Elmer XRD822

Besides the choice of the detector the system design plays a big factor

Old design

A heavy boom is carrying the film or DDA (1000 kg)

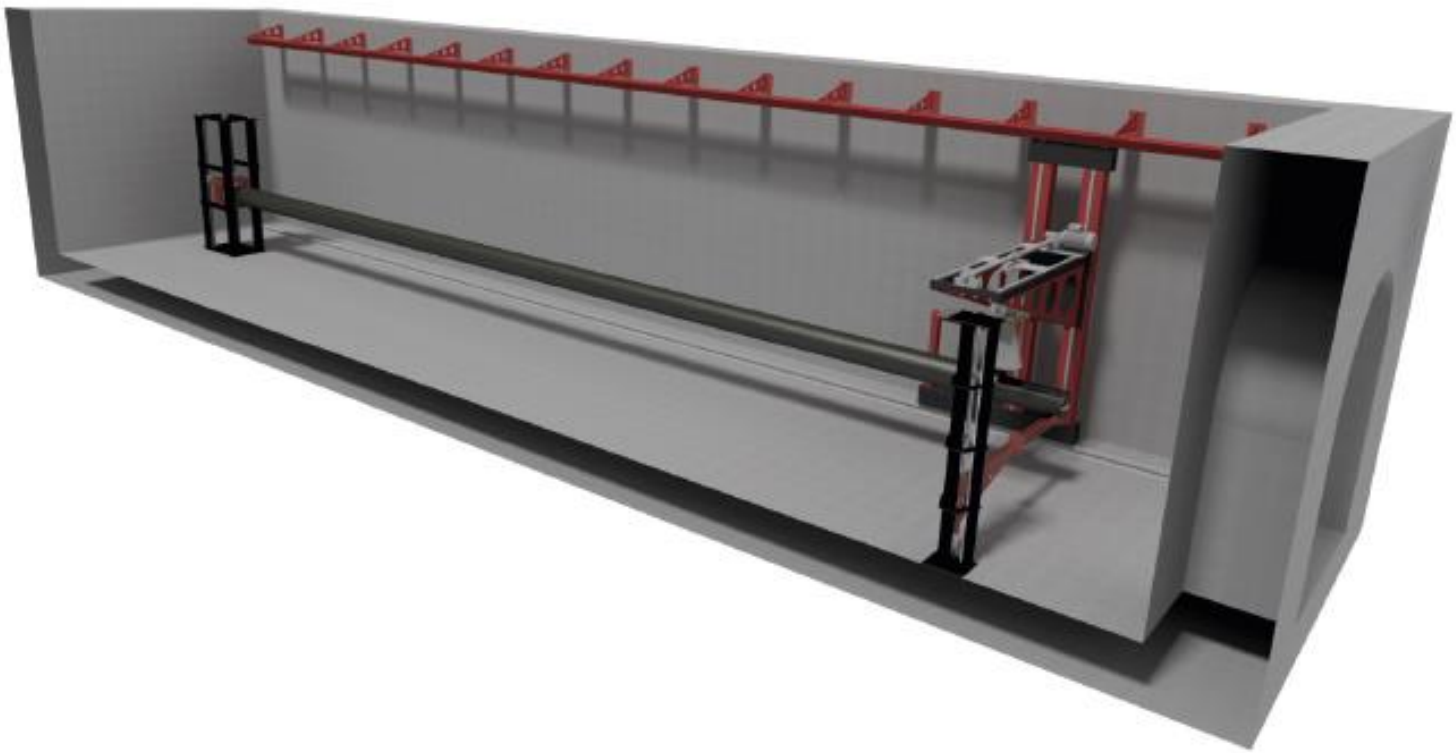
Pipes feed in and out is always in the same direction

New design – The boom

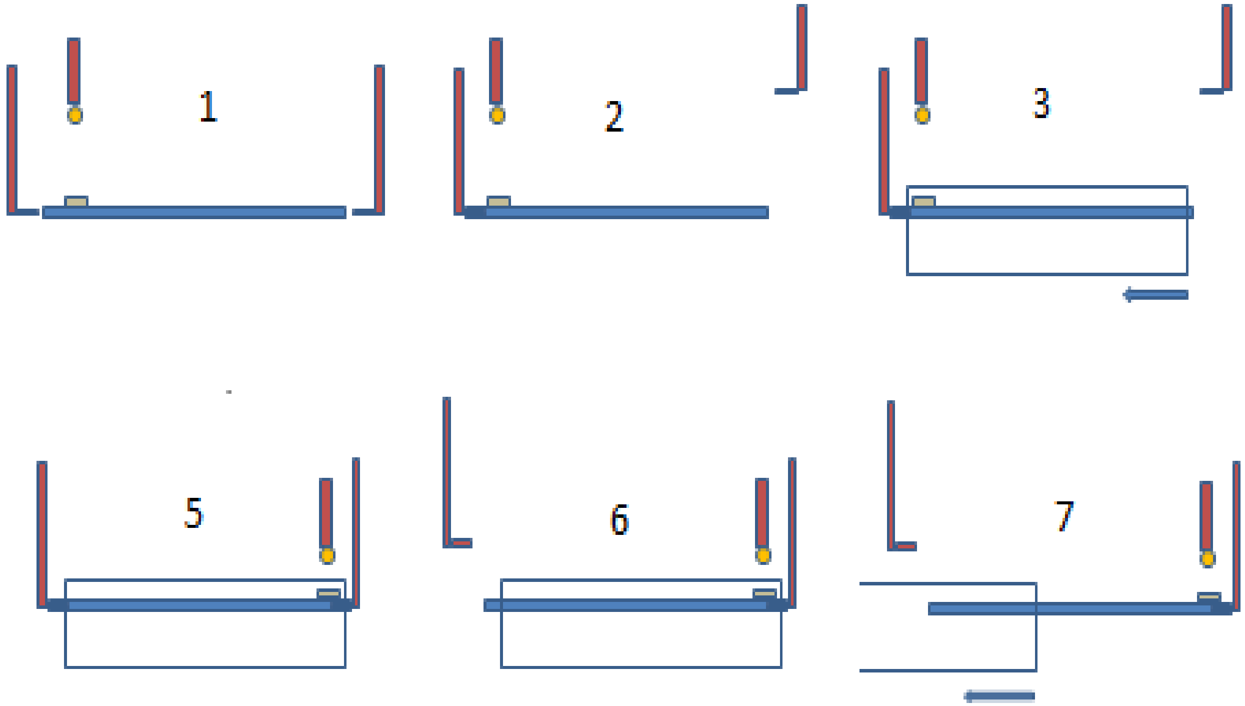
- Carbon
- Less than 100 kg
- Panel is inside the boom
- Panel is protected
- Easy cooling

- Min. inner diameter : 190 mm

New design – Termination type



New design – Feed thru type



Costs

The change from film to digital technique is mainly driven by reducing the cycle time, eliminating the film with its wet development area and at least also human resources.

Sample calculation with 3 different setups:

We assume that we have 12m LSAW pipe with 15 mm wall thickness.
The gate is opened.
The bunker is empty.
100% test of the weld.
300 working days per year.
50 € per hour labour costs per employee
5 € per 48 cm film incl. development.

Costs

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Step	Film 6* 48 cm	2520 panel – terminus mode	2520 panel feed thru mode
Move pipe in	60 sec	60 sec	60 sec
Close Gate	25 sec	25 sec	25 sec
Placing the film	120 sec	-	-
X-ray On	3 sec	3 sec	3 sec
Expose	(1200/40) * 30 sec	(1200/23) * 4 sec	(1200/23) * 4 sec
Move to Position	((1200/40)-1) * 3 sec	((1200/23)-1) * 2 sec	((1200/23)-1) * 2 sec
X-ray Off	3 sec	3 sec	3 sec
Open Gate	25 sec	25 sec	25 sec
Move pipe Out	60 sec	60 sec	60 sec
Move pipe to Wait position	60	60 sec	
Sum	22 min 2.5 pipes/ hour 20 pipes/ shift	9 min 6 pipes/hour 48 pipes/ shift	8 min 7-8 pipes / hour 60 pipes / shift
Cost´s of Material Costs HR Per shift	(1200/40)*20*5 €= 3000 € 2* 8 * 50 € = 800 €	0 € 1* 8 * 50 € = 400 €	0 € 1* 8 * 50 € = 400 €
Cost´s per year with one shift	1.140.000 € per year	120.000 € Per year	120.000 € Per year
Cost´s per year with 2 shifts	2.280.000 € per year	120.000 € Per year	120.000 € Per year

Conclusion

Change over from an existing film setup to a brand new digital bunker will bring a Return on Invest in less than 2 years !

Beside the commercial facts there are several soft facts:

- Higher test quality
- Faster feedback of identified defect inside the weld
- Protection of the environment
- Better reputation on the market because of better results.
- Access to other “high-end demanding” customers, because of improved inspection quality
- Higher prices for sold products.

Thanks for your attention

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Any questions or feedback?

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