Pipeline In-line Inspection
管道内检测技术

- Bill Gu
- March 9th, 2020

Who am I?

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Ph.D , Registered professional Engineer in Canada. Over 20 years experience in pipeline integrity management, specialising in ILI technology, defect assessment methodologies, risk and reliability assessment, corrosion growth studies and advanced data management

Is PPS commercial leader for China and a Principal Consultant in the Integrity Services Division at Bakerhughes. He is a member of APEGGA, ASME, ISO, PRCI and NACE.

提纲

1. 内检测的发展历史
2. 常规内检测技术
3. 如何选择适合的检测技术
4. 超声波与漏磁检测的区别
5. 最新内检测发展趋势

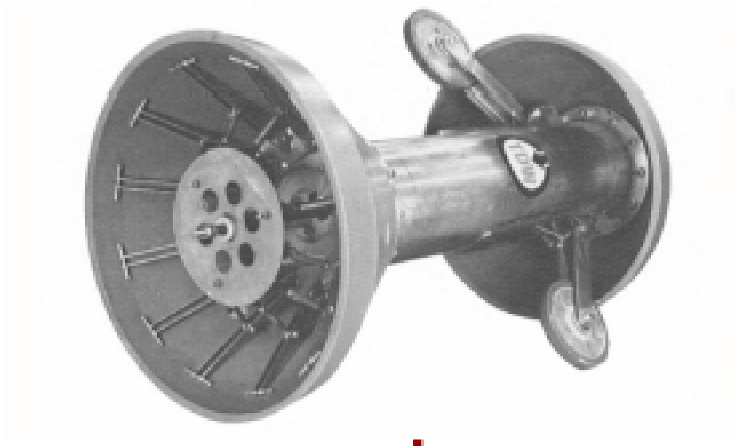
- 内检测的发展历史

History of ILI -1960s

- **Magnetic Flux Leakage (MFL) tool**: Developed in 1965 by Tuboscope to detect areas of metal loss
  - First tool had 12 sensors, with 90° arc on bottom of pipe (low resolution)
  - Detected internal corrosion on crude oil pipelines
  - Tape Recorder used as data storage

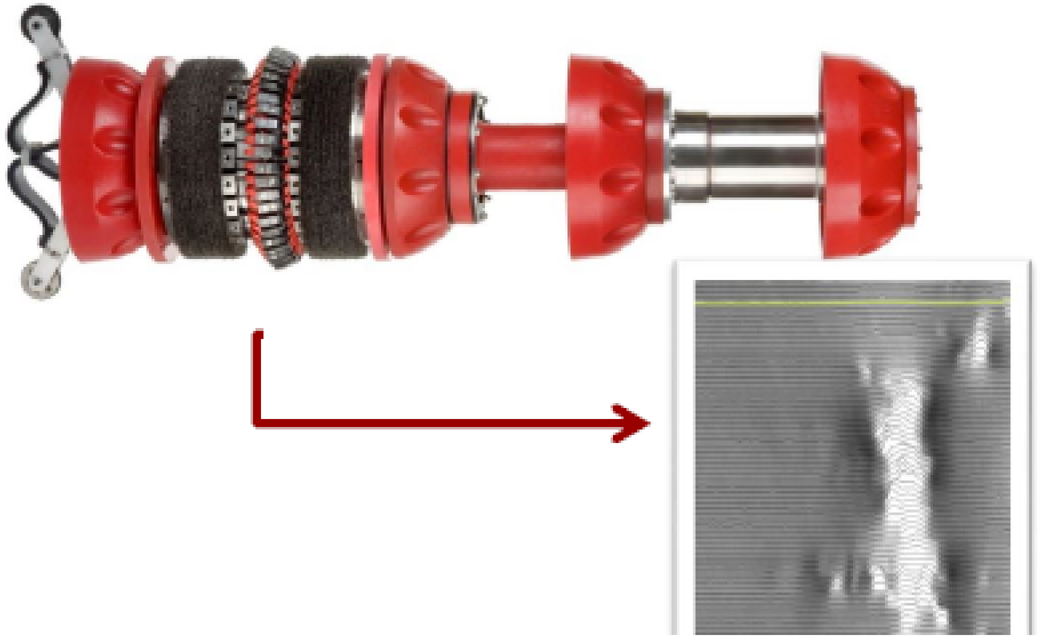
History of ILI – 1960s

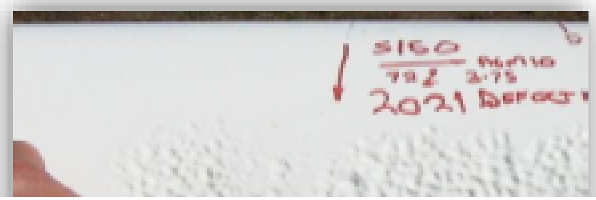
- **Kaliper** tool first developed by TDW in late 1960s
- Provided course measurements of dents and out-of-roundness pipe
- Single channel recorder with sensors mounted on inside of rear cups
- Data recorded on pressure sensitive paper inside the tool



History of ILI – 1970s and 1980s

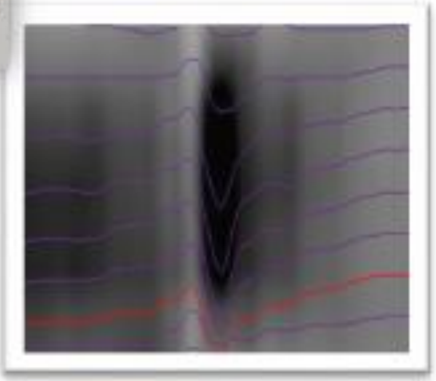
- 1970s - British Gas (BG) invests in their own high-resolution MFL inspection tool. Vetco and Tuboscope succeed in developing new MFL tools.
- Instead of 12 sensors per tool, these new tools had approximately 1.27 cm (0.5 in) spacing, permanent magnets, and inner diameter/outer diameter (ID/OD) discrimination.
- Inspection tools could detect and size anomalies





History of ILI – 1970s and 1980s

- **Deformation (DEF)** tools improve from single channel sensors to 6-12 channel sensors
- Nearly every vendor develops DEF tool with various levels of resolution.



History of ILI – 1990s and 2000s

- **Ultrasonic Crack Detection (UTCD):** Pipeline Integrity International (PII) develops first tool in 1994 for axial cracks.

Photo: geoilandgas.com

- **Circumferential MFL (CMFL)** - developed for axial metal loss and crack-like defects

Photo: geoilandgas.com

- **Combo-tools** are introduced using multiple technologies on a single tool – DEF + MFL

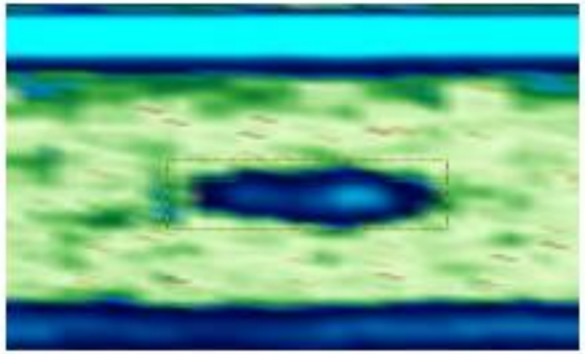
History of ILI – 1990s and 2000s

- **Electromagnetic Acoustic Transducer (EMAT):**
  - Rosen and GE-PII develop first EMAT tools - crack inspections on gas transmission pipelines

Photo: geoilandgas.com

Photo: rosen-group.com

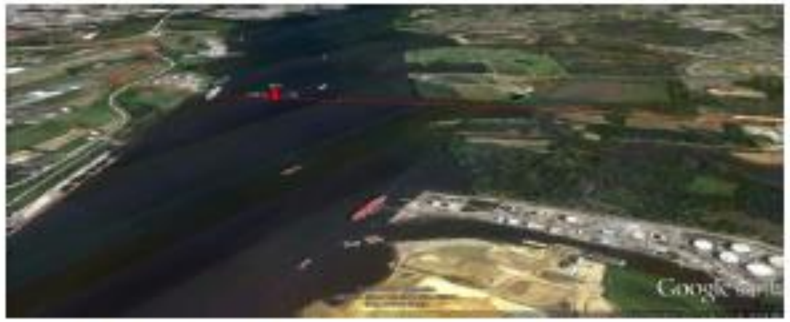
  - TDW develops first EMAT tool in late 2000s



History of ILI – 1990s and 2000s

- **Speed Control tools** – allows pipelines to operate at full rate while ILI tool travels at a slower rate.

- **Mapping (XYZ) tools** – provides GPS coordinates of pipeline



- **Robotic tools** – difficult to pig pipelines
  - Unbarred tees, low/no-flow, diameter changes, mitre bends

Photo: diakont.com

BakerHughes内检测器系列研发历史

1977年开发高分辨率漏磁检测器，
1998年增加GIS定位测绘功能。

1985年研制超声波壁厚腐蚀检测器。

1992年研制用于输气管线的弹性波裂纹检测器。

1994年开发出高分辨率超声波裂纹检测器，用于液体管线。

1999年研制出环向漏磁检测器，用于轴向狭长腐蚀和严重的直焊缝裂纹缺陷。

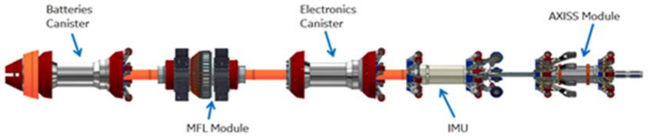
2002年开发出高分辨率EMAT裂纹检测器，用于输气管线。

2005多变径可伸缩检测器

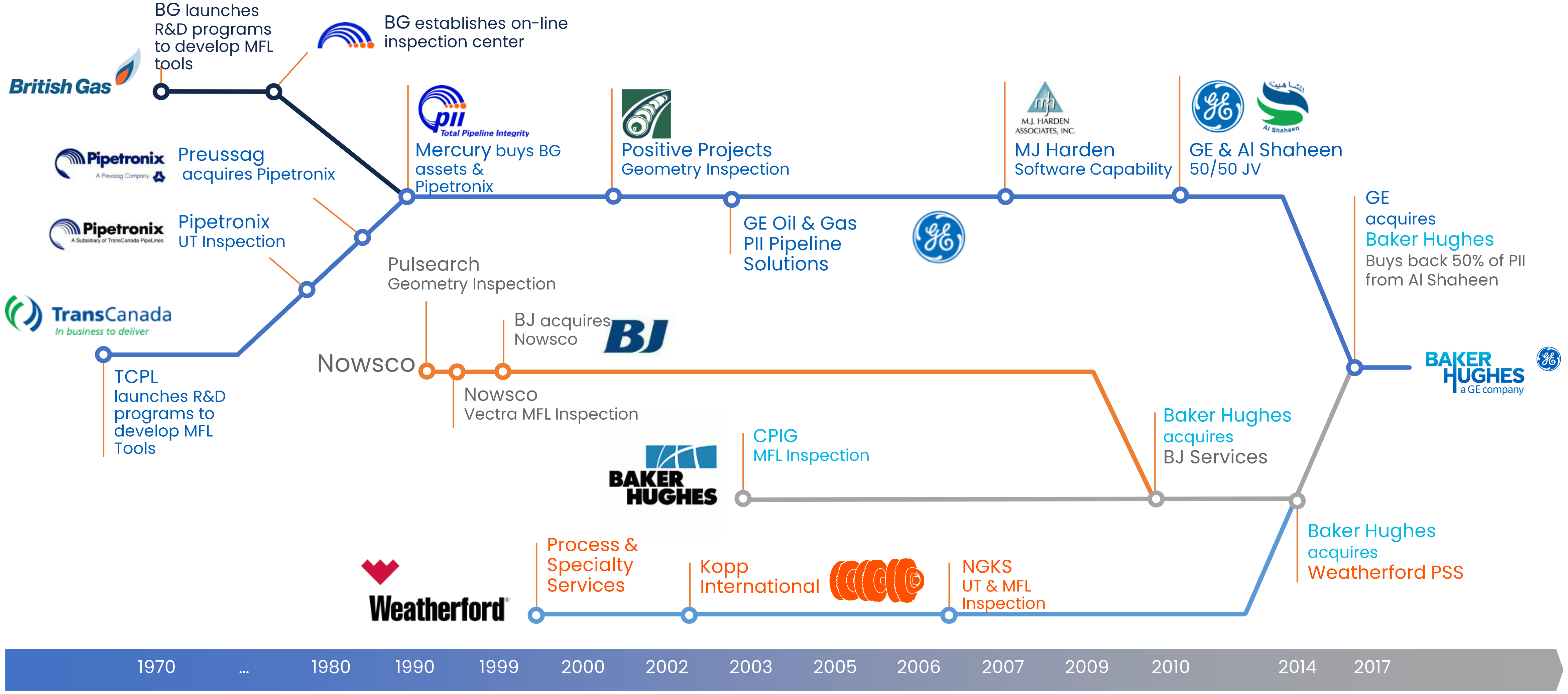
2005 Ultra ScanDuo 相控阵检测器

2008第四代漏磁检测器开发

2012 轴向应变检测器 AXISS



内检测公司的发展历史- ILI



- 常规内检测技术


MagneScan

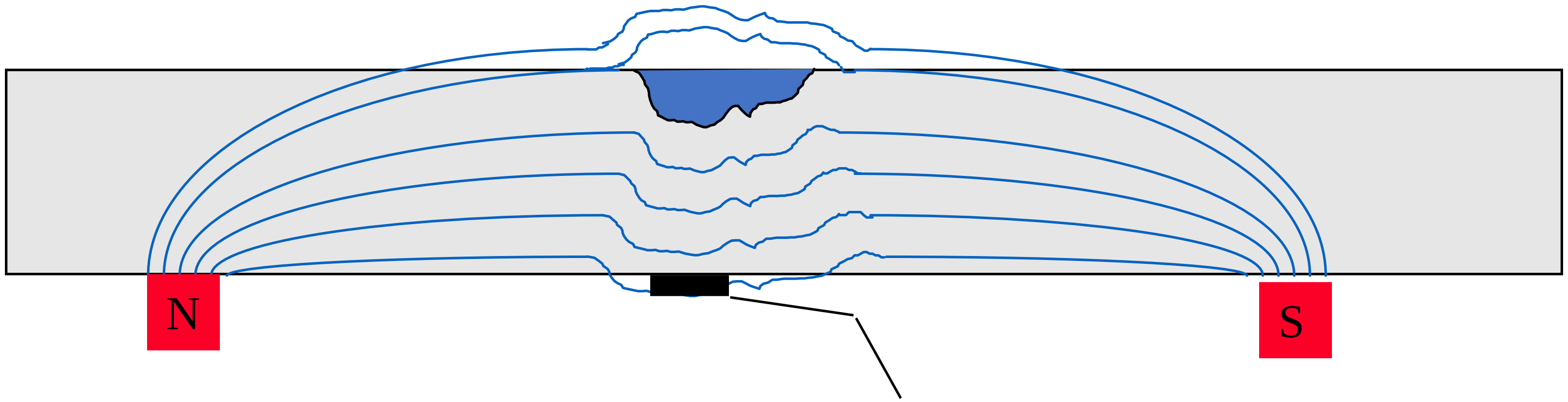
MagneScan 漏磁检测器

- *Magnetic Flux Leakage*

- *主要适用于:*
- 金属损失探测——管道内外腐蚀等
- 油气管道都适用

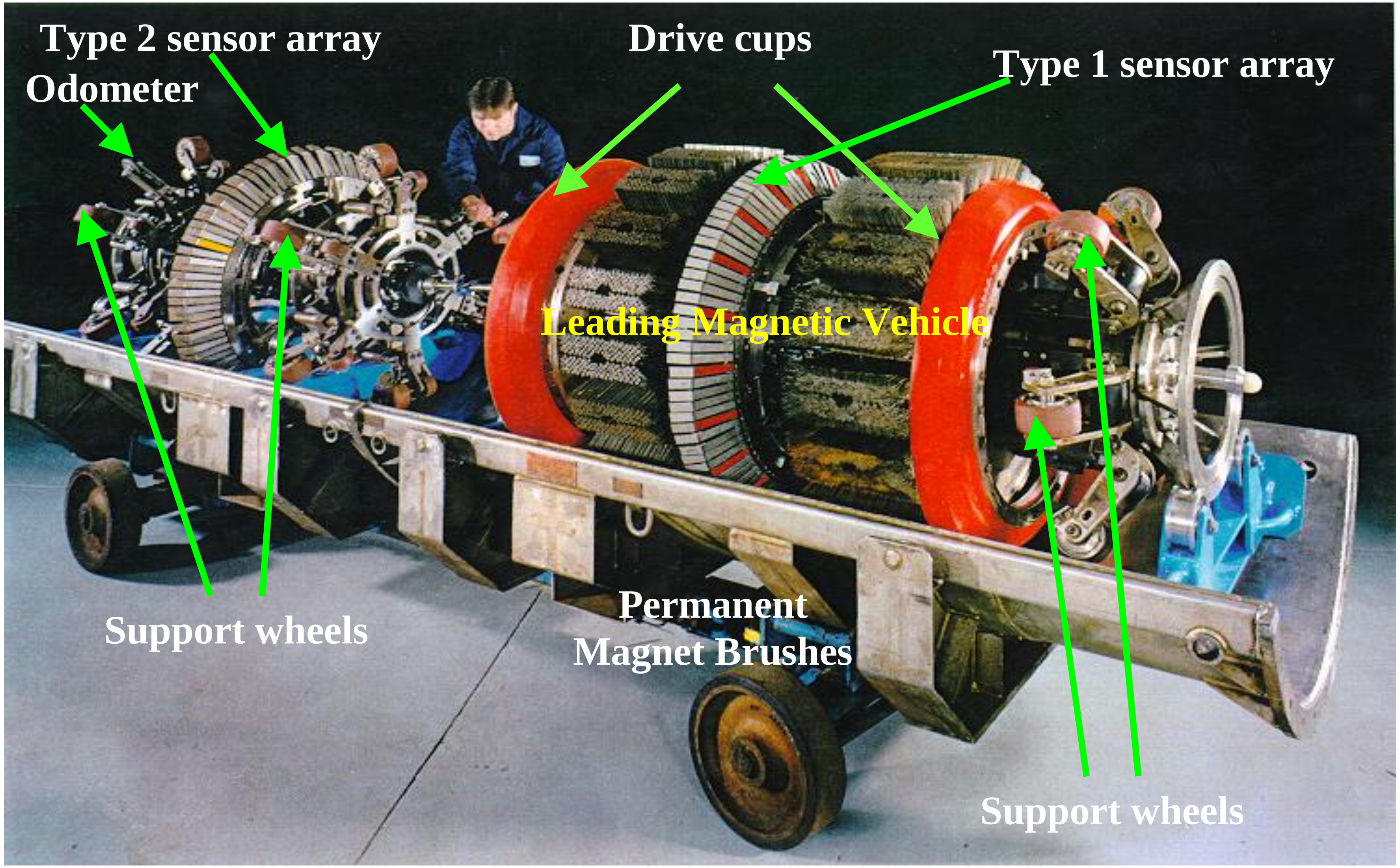
- 其次还可以探测
- 环焊缝缺陷
- 管道金属外接物
- 管道材质硬疤

漏磁检测器原理



- 强磁铁产生高磁通量通过管壁
- 如下情况会使磁力线产生扭曲：
    - 管壁中有金属损失点
    - 如果有金属接近管壁
    - 材质变化
- 传感器会接受到磁通量的变化

MagneScan 漏磁检测器



3" - 56" 英寸

56” MFL Tool

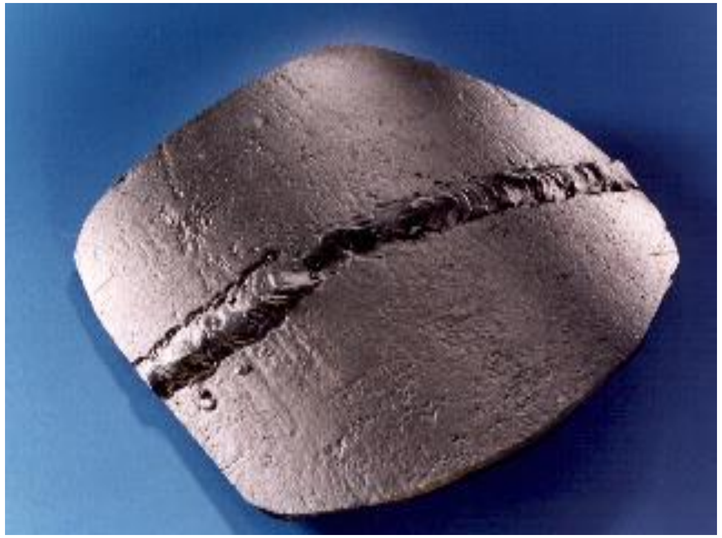
36/48 英寸双径检测器

ENBRIDGE

漏磁检测器可以探测到的缺陷

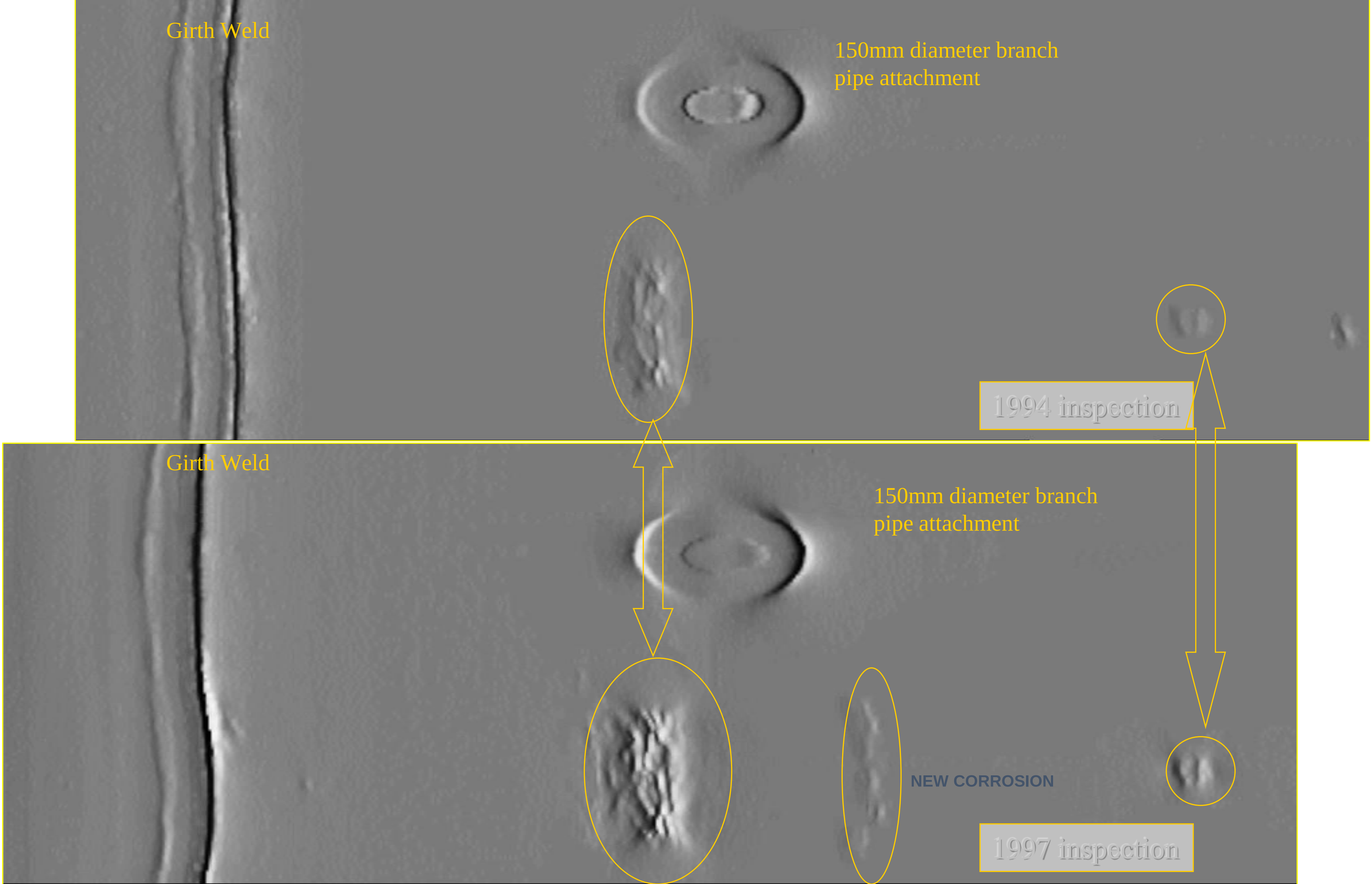
Corrosion

Contacting Metal Objects



Weld defects

Dents & Gouging


Girth Weld
150mm diameter branch pipe attachment
1994 inspection
Girth Weld
150mm diameter branch pipe attachment
NEW CORROSION
1997 inspection


UltraScan WM

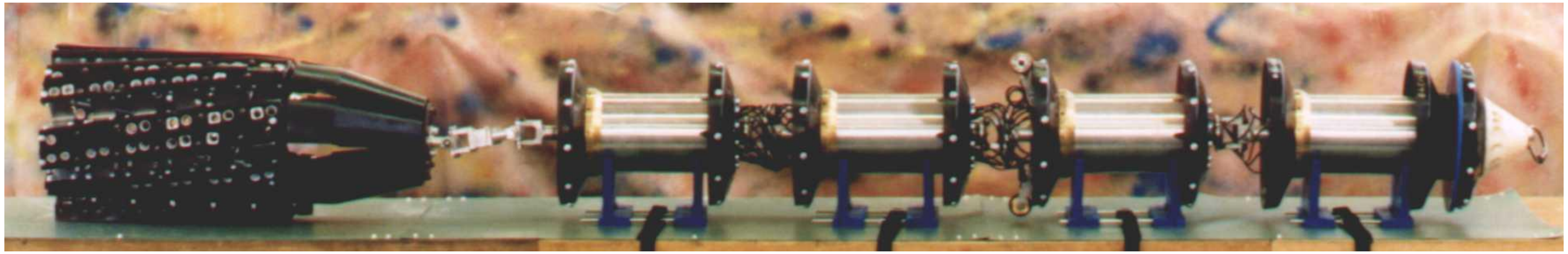
超声波壁厚检测器USWM

- *Ultrasound - Time of Flight*

- *主要适用于*
- 金属损失探测——管道内外腐蚀
- 输油或液体管线

- *其次还可以探测*
- 夹层缺陷
- 氢鼓泡

UltraScan WM



10“ UltraScan WM

金属损失的直接测量

精度较高±0.4mm

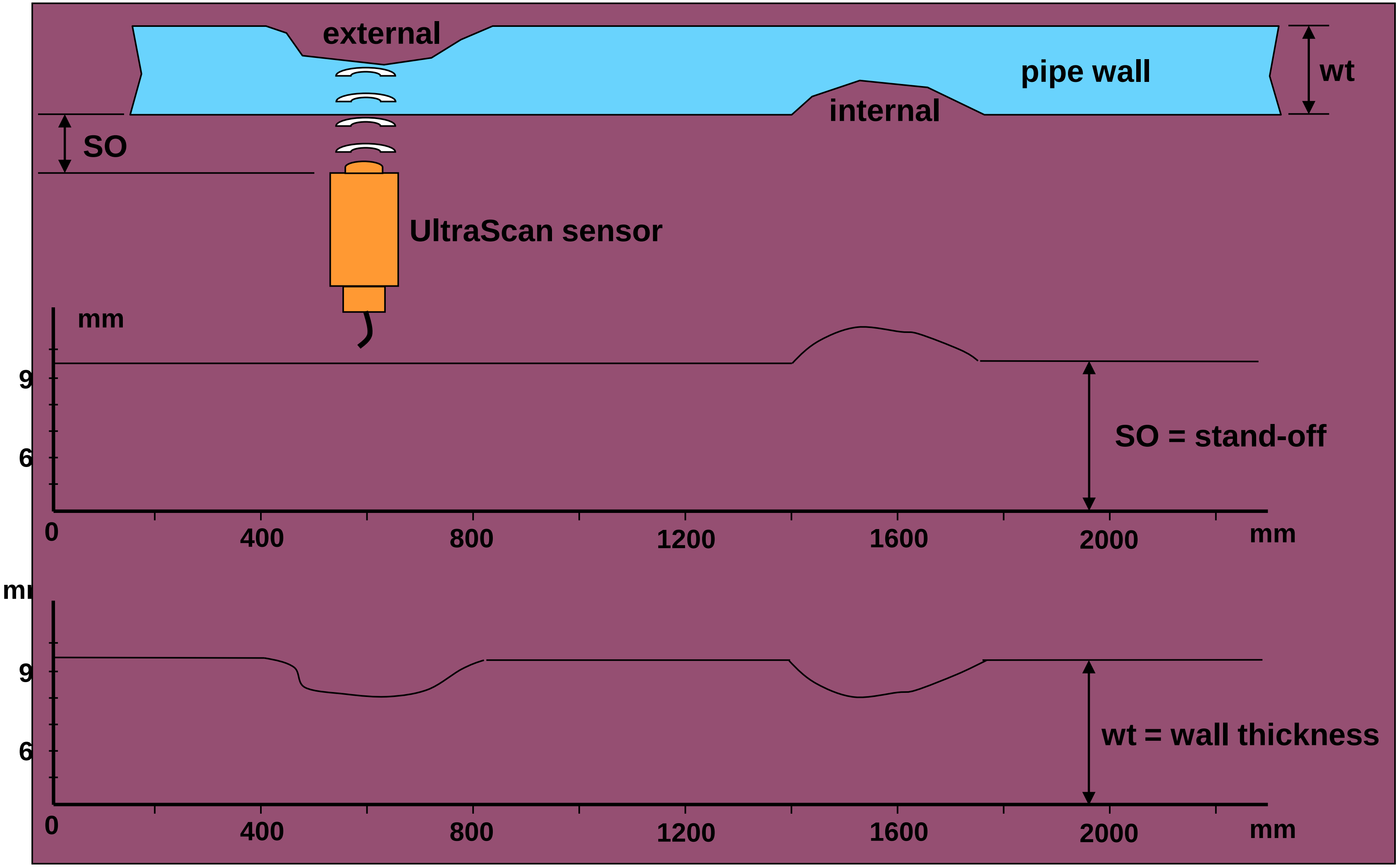
有效区分内外腐蚀

可探测除腐蚀外的管体加工缺陷如夹层等

只适用于输油管线

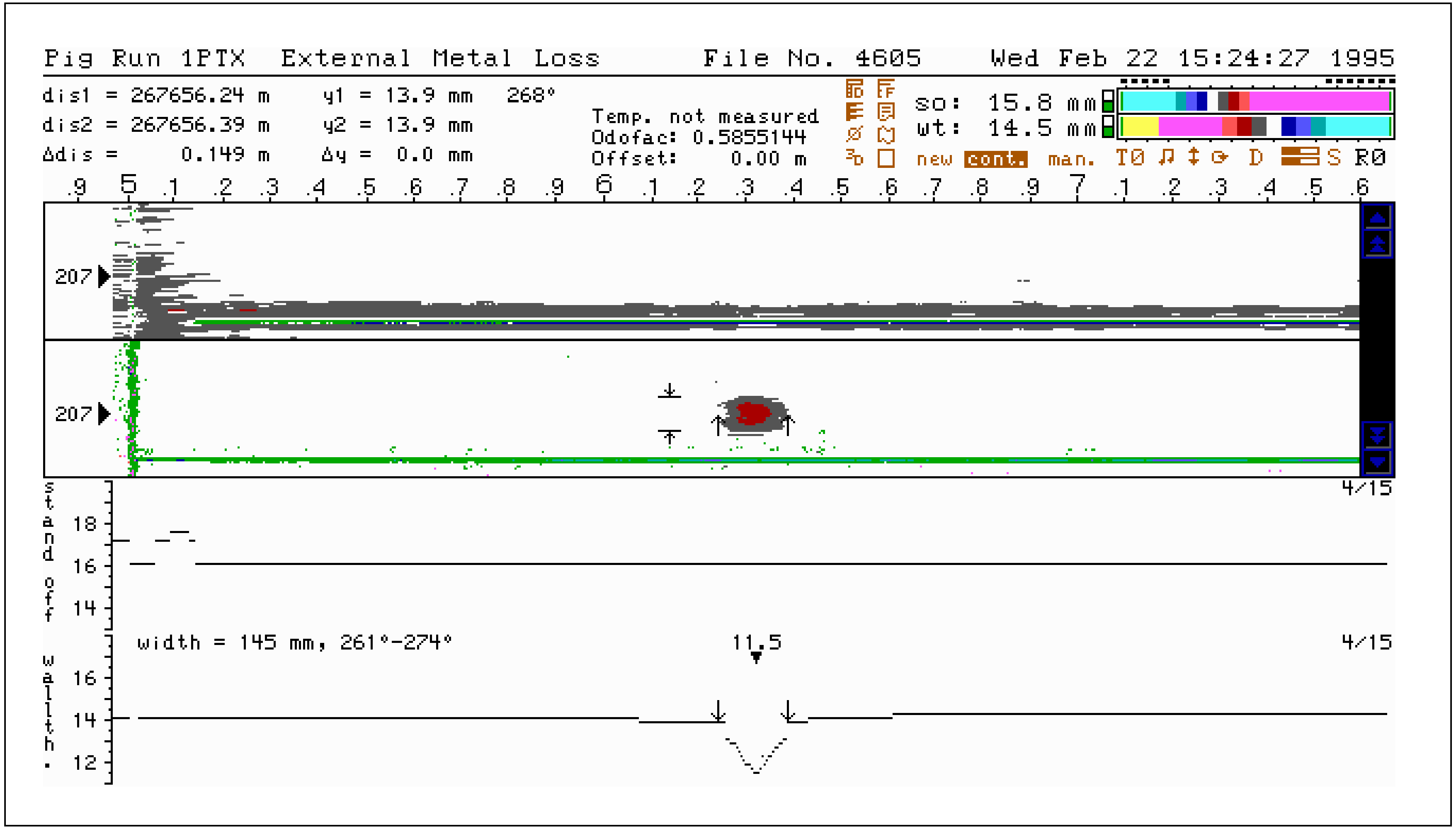
费用较漏磁检测器昂贵约20%

超声波原理

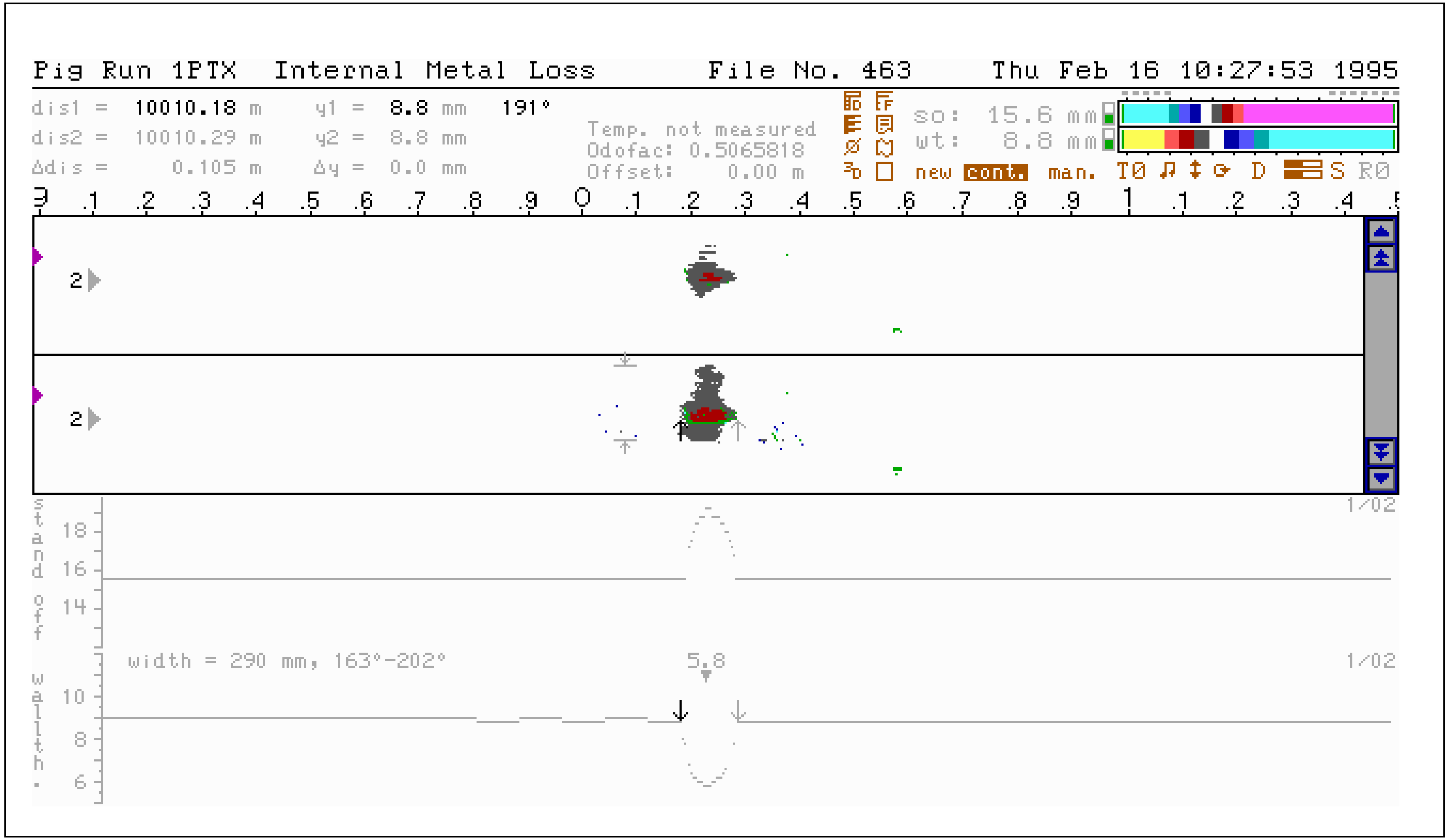


external
pipe wall
wt
internal
SO
UltraScan sensor
mm
9
6
0
400
800
1200
1600
2000
mm
SO = stand-off
mm
9
6
0
400
800
1200
1600
2000
mm
wt = wall thickness

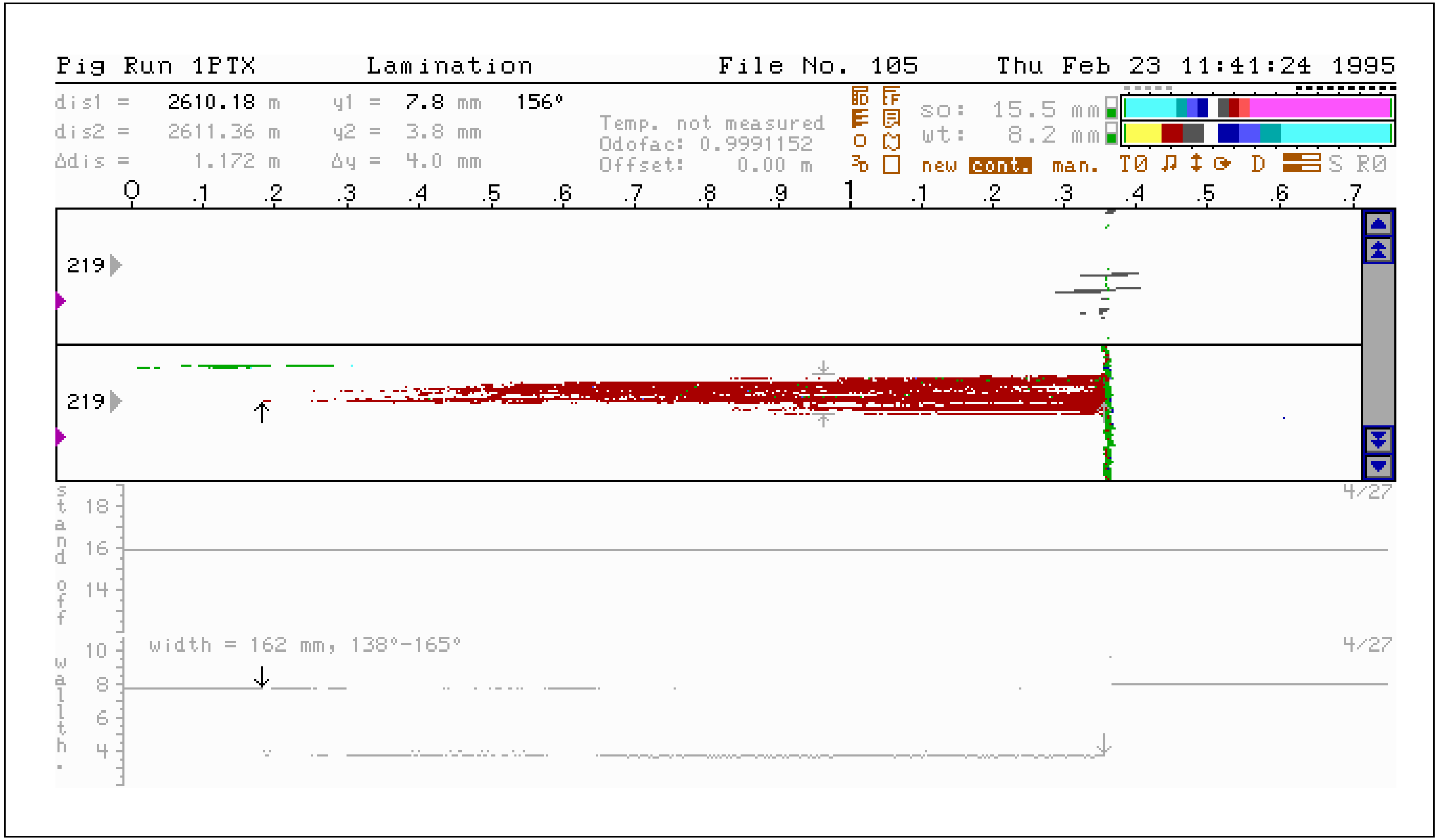
外腐蚀信号


Pig Run 1PTX External Metal Loss File No. 4605 Wed Feb 22 15:24:27 1995
dis1 = 267656.24 m y1 = 13.9 mm 268°
dis2 = 267656.39 m y2 = 13.9 mm
Δdis = 0.149 m Δy = 0.0 mm
Temp. not measured
Odofac: 0.5855144
Offset: 0.00 m
so: 15.8 mm
wt: 14.5 mm
new cont. man.
207
207
4/15
stand off
18
16
14
width = 145 mm, 261°-274°
11.5
4/15
wallth.
16
14
12

内腐蚀信号


Pig Run 1PTX Internal Metal Loss File No. 463 Thu Feb 16 10:27:53 1995
dis1 = 10010.18 m y1 = 8.8 mm 191°
dis2 = 10010.29 m y2 = 8.8 mm
Δdis = 0.105 m Δy = 0.0 mm
Temp. not measured
Odofac: 0.5065818
Offset: 0.00 m
so: 15.6 mm
wt: 8.8 mm
new cont. man.
width = 290 mm, 163°-202°
5.8
1/02
stand off
wall th.

夹层缺陷信号


Pig Run 1PTX
Lamination
File No. 105
Thu Feb 23 11:41:24 1995
dis1 = 2610.18 m
dis2 = 2611.36 m
Δdis = 1.172 m
y1 = 7.8 mm
y2 = 3.8 mm
Δy = 4.0 mm
156°
Temp. not measured
Odofac: 0.9991152
Offset: 0.00 m
so: 15.5 mm
wt: 8.2 mm
new cont. man.
219
219
stand off
wall th.
width = 162 mm, 138°-165°
4/27
4/27


UltraScan CD

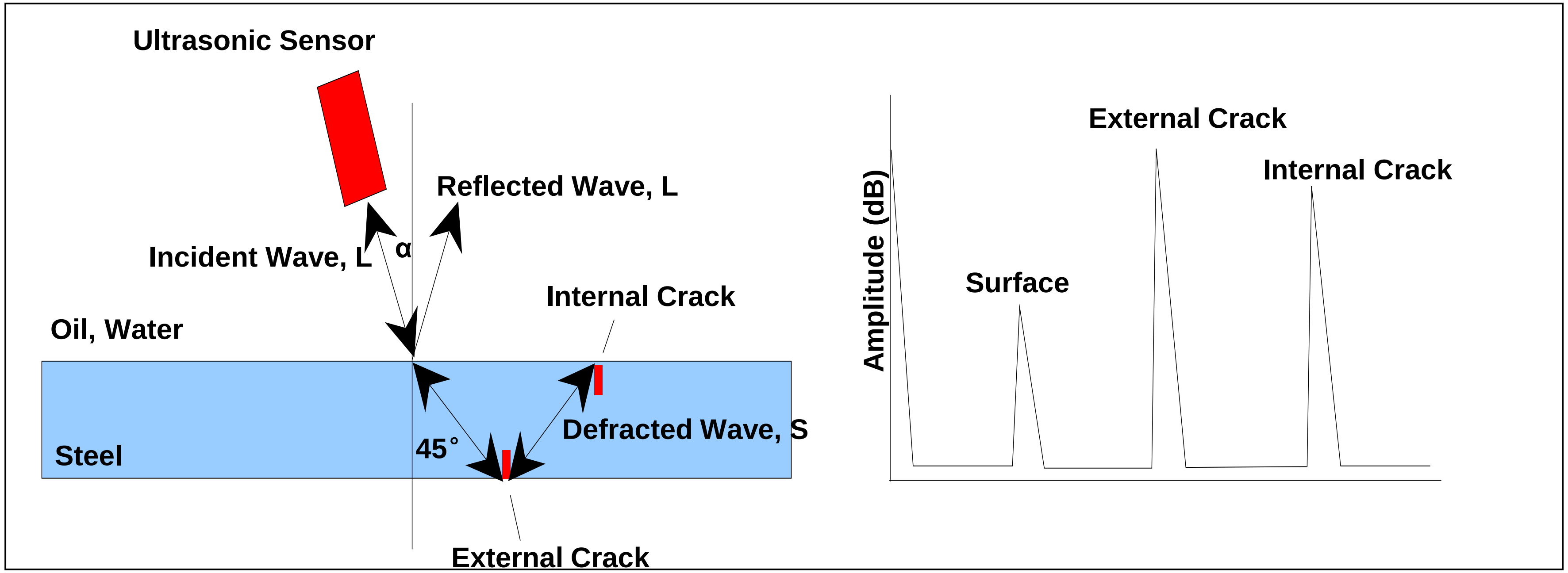
Ultrascan CD-超声波裂纹探测器

- *Ultrasound - 45º Shear Wave*
- *主要适用于*

- 管体应力腐蚀裂纹

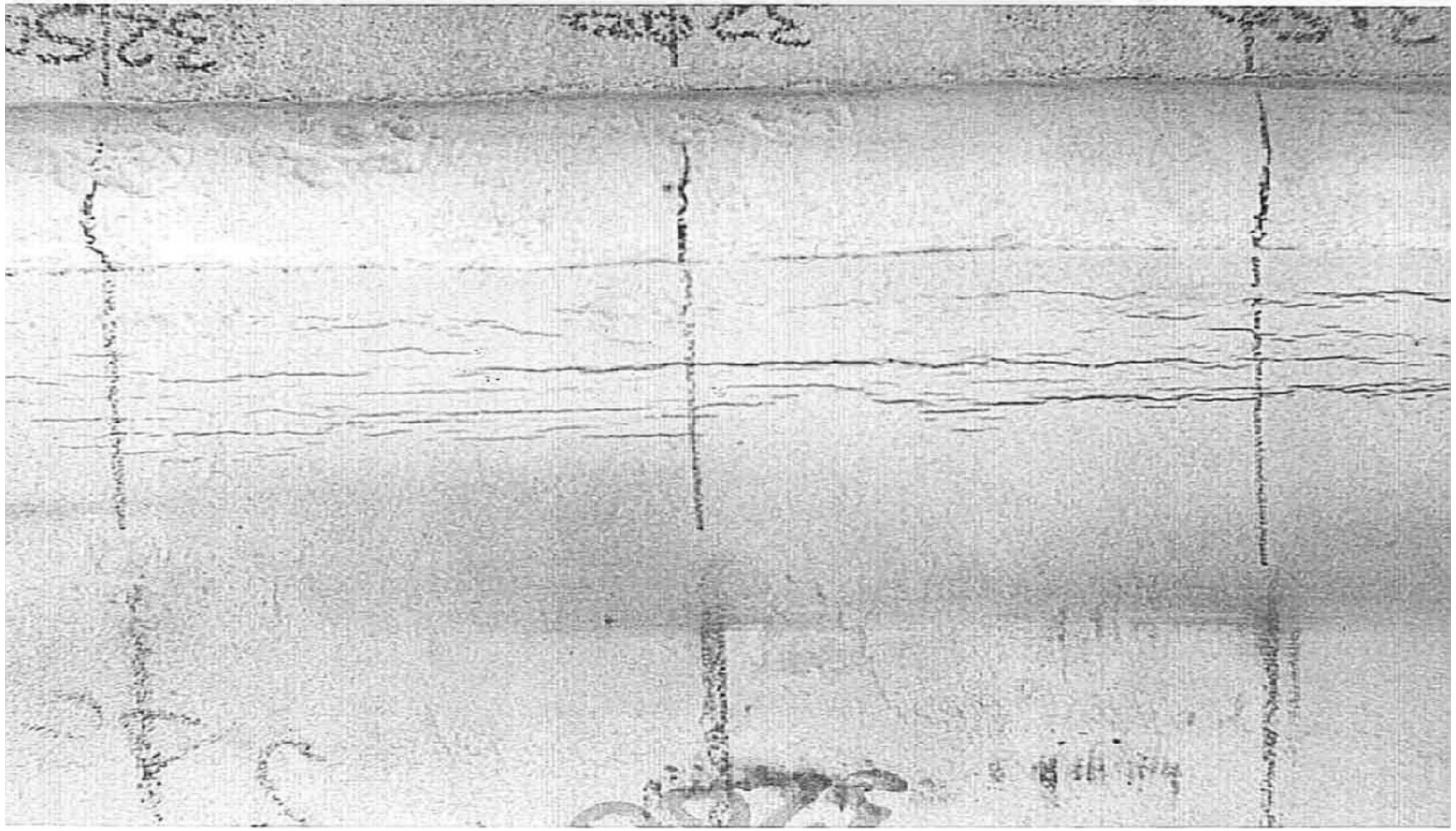
- *还可探测到*
- 焊缝的疲劳和收缩裂纹

超声波裂纹检测器原理



Ultrasonic Sensor
Reflected Wave, L
Incident Wave, L
α
Internal Crack
Oil, Water
Steel
45°
Defracted Wave, S
External Crack
Amplitude (dB)
Surface
External Crack
Internal Crack

SCC 焊缝附近的应力腐蚀裂纹



检测器发射

环向漏磁检测器

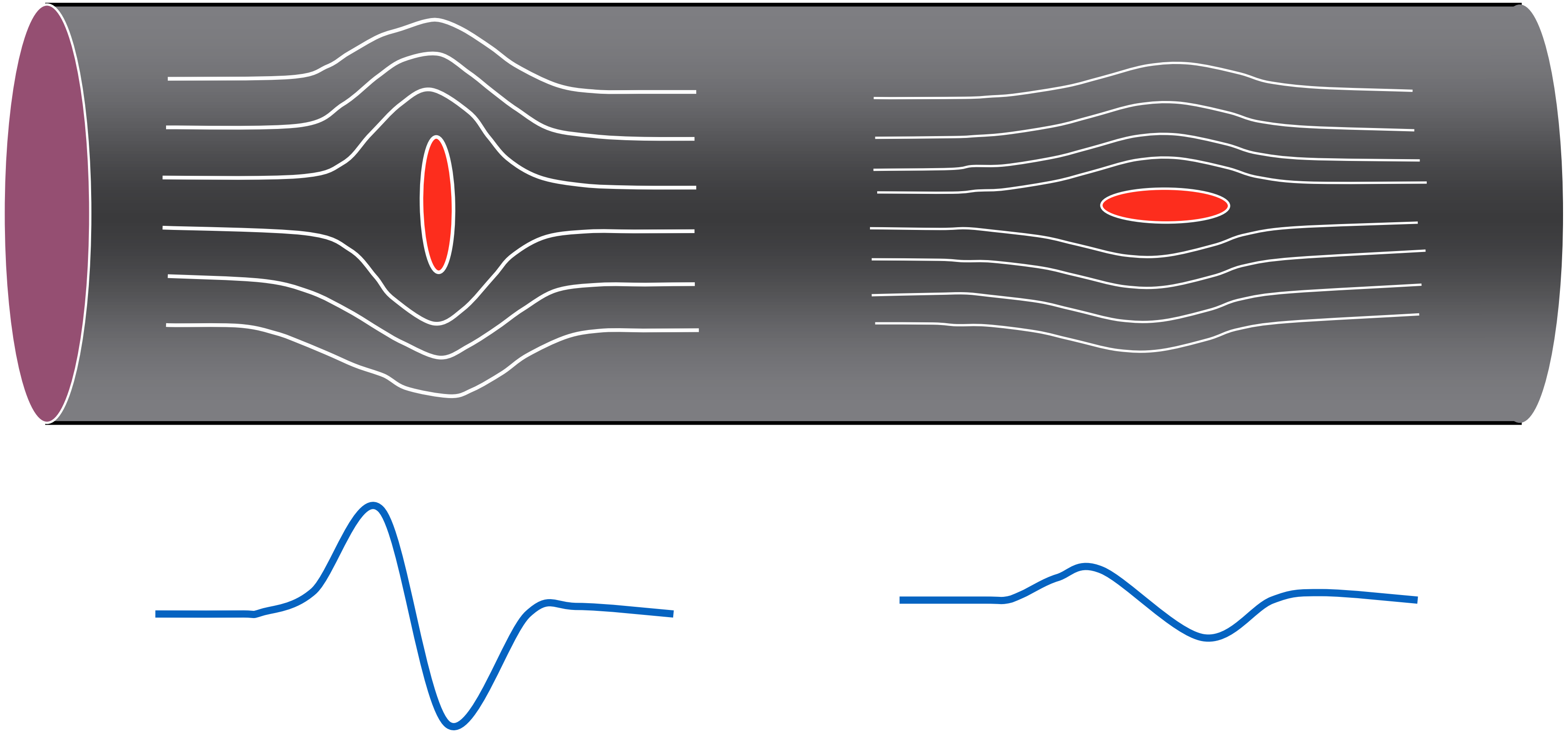
TranScan

Transcan

- *漏磁原理 – 环向磁场*
- *主要适用于:*
- 轴向狭长金属损失缺陷
- *其次还可探测:*
- 直焊缝裂纹

轴向焊缝缺陷引起的爆管事故

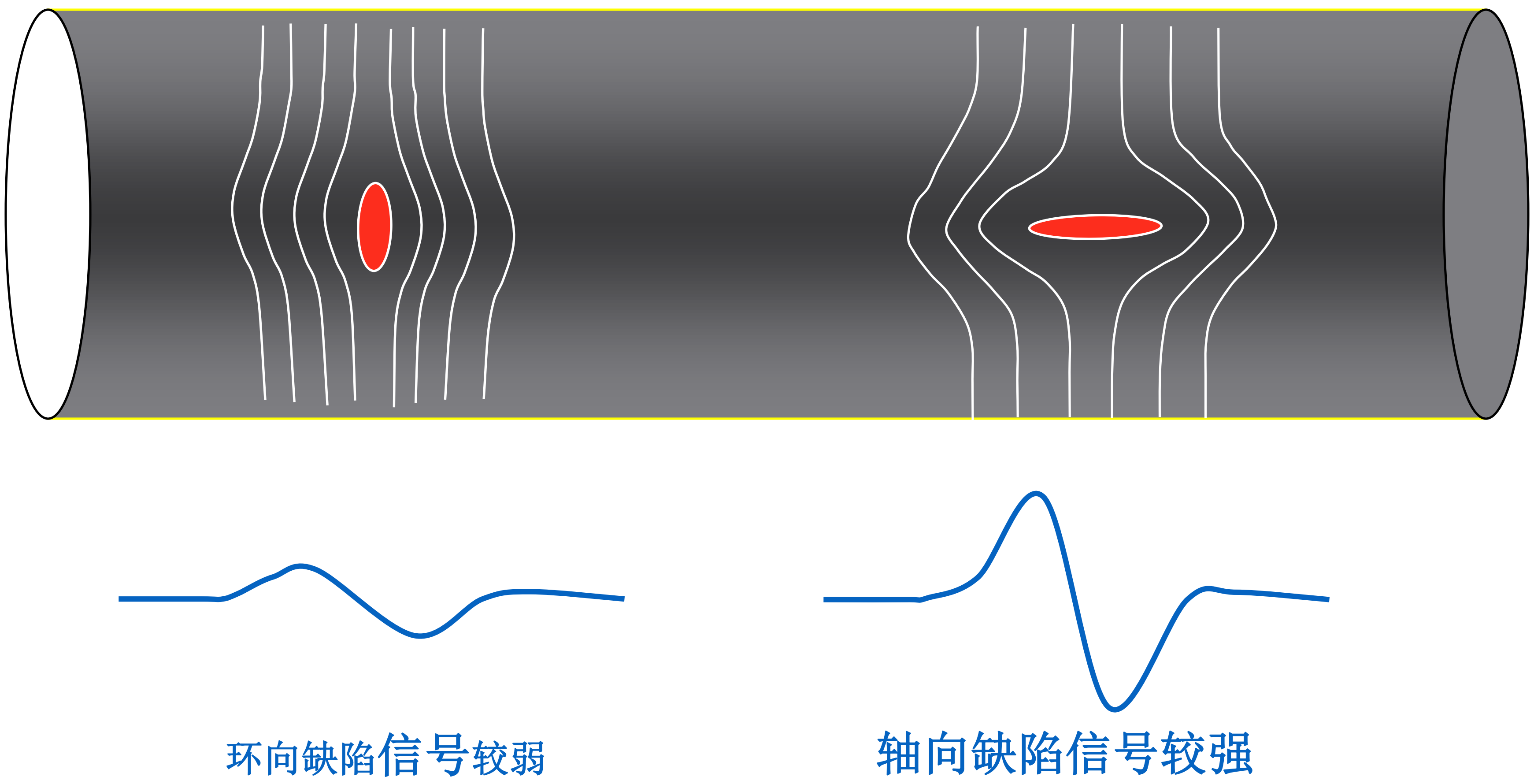
缺陷几何尺寸对传统漏磁检测器磁场变化的影响



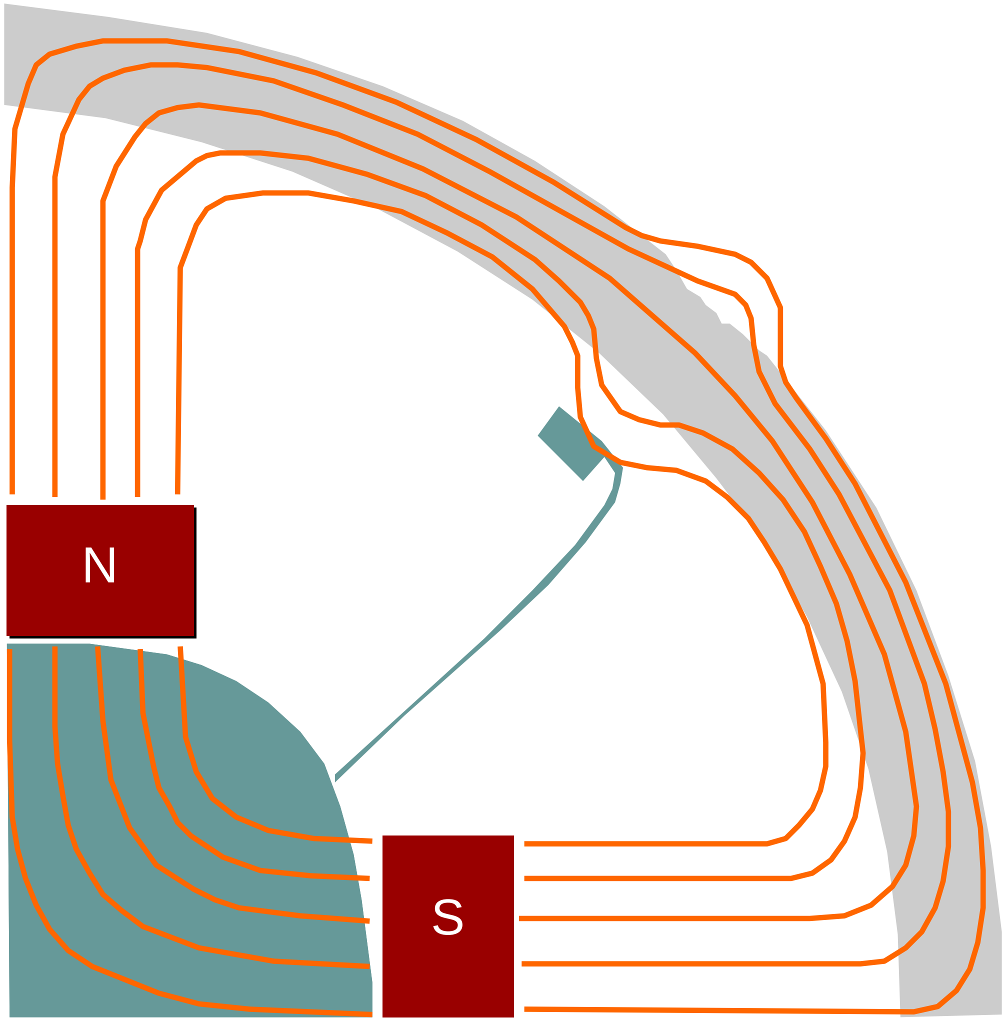
环向缺陷对磁场敏感，信号强

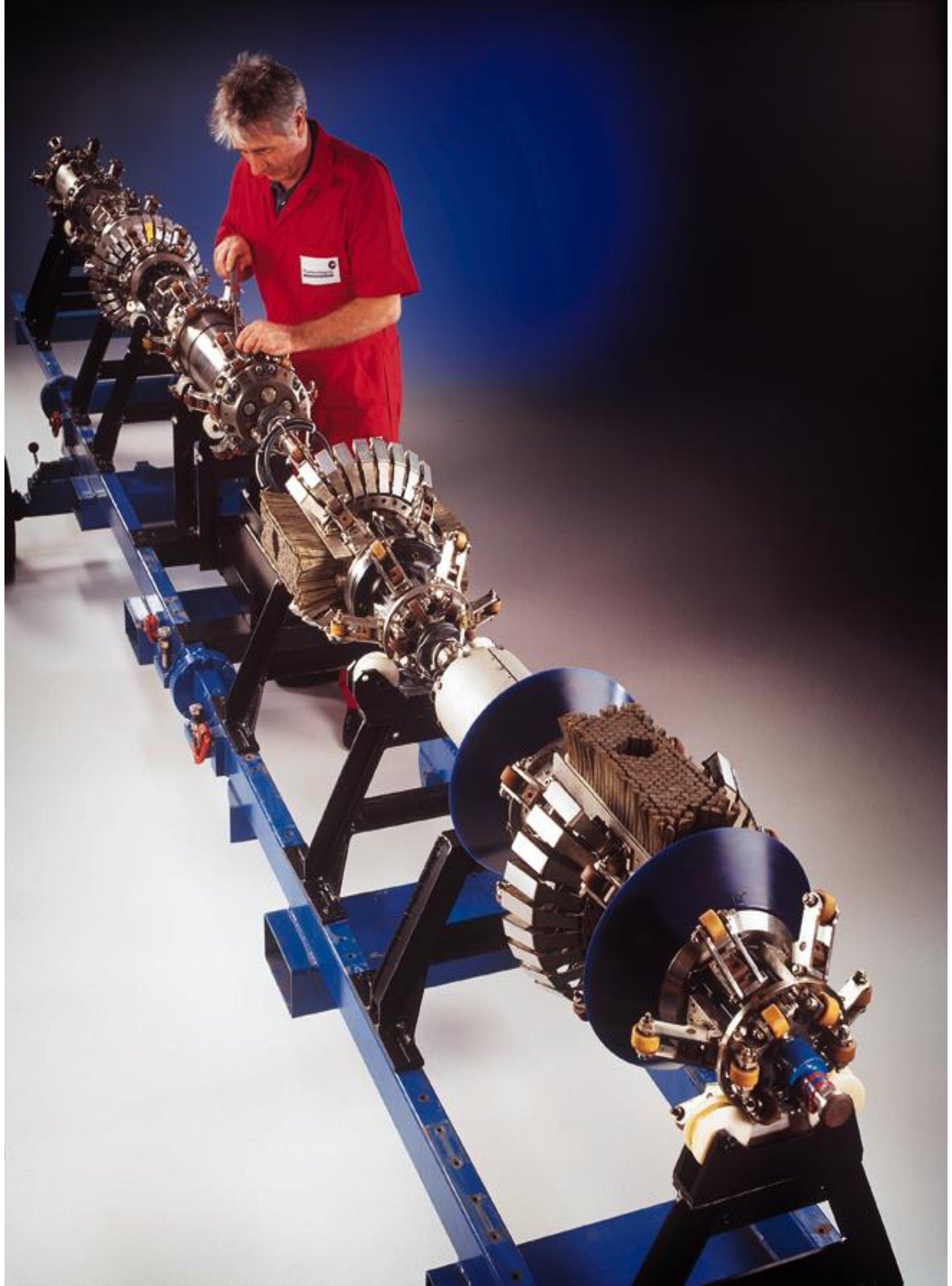
轴向缺陷信号弱

缺陷几何尺寸对环向漏磁检测器磁场变化的影响

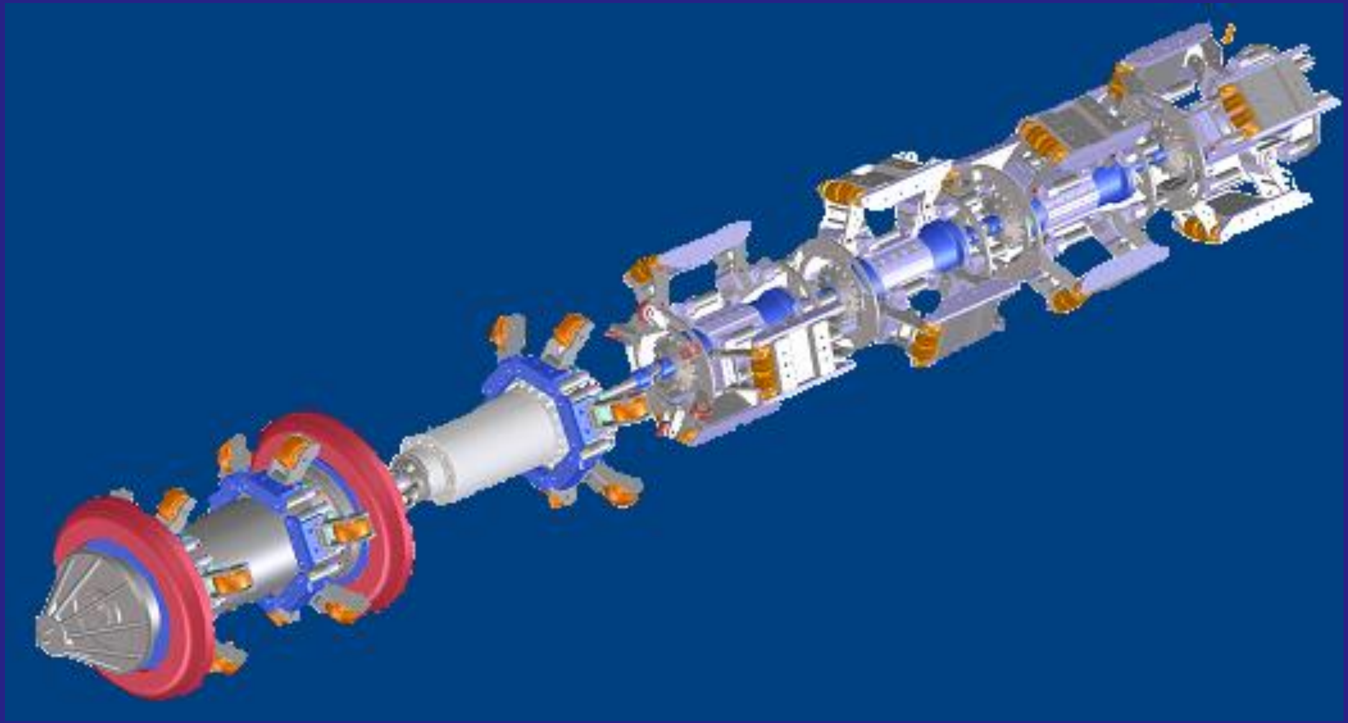


环向检测器磁场分布



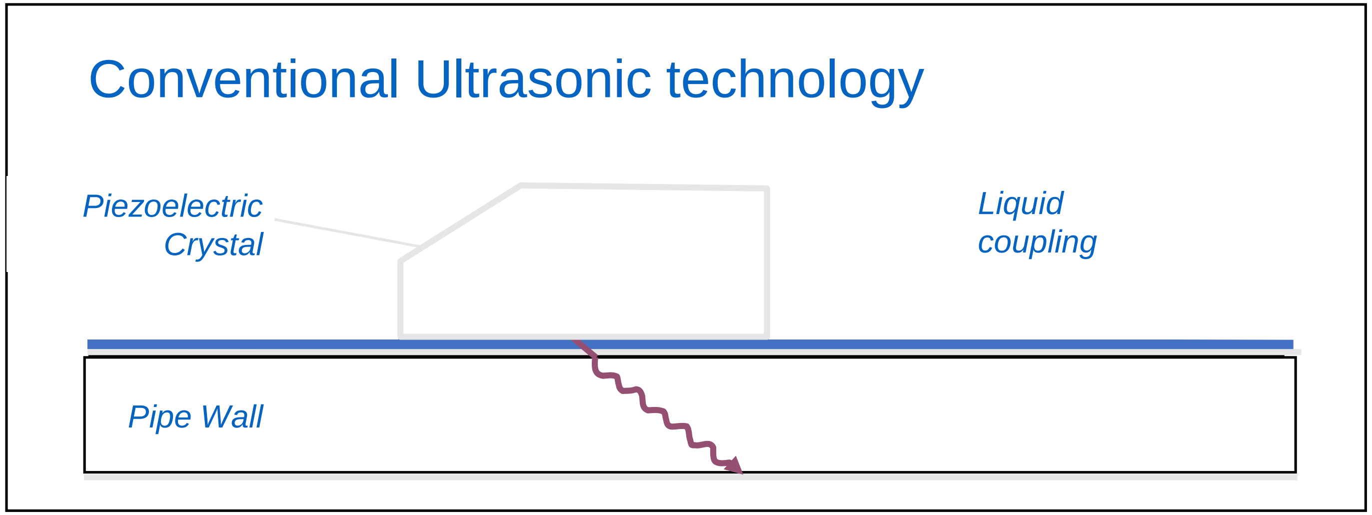


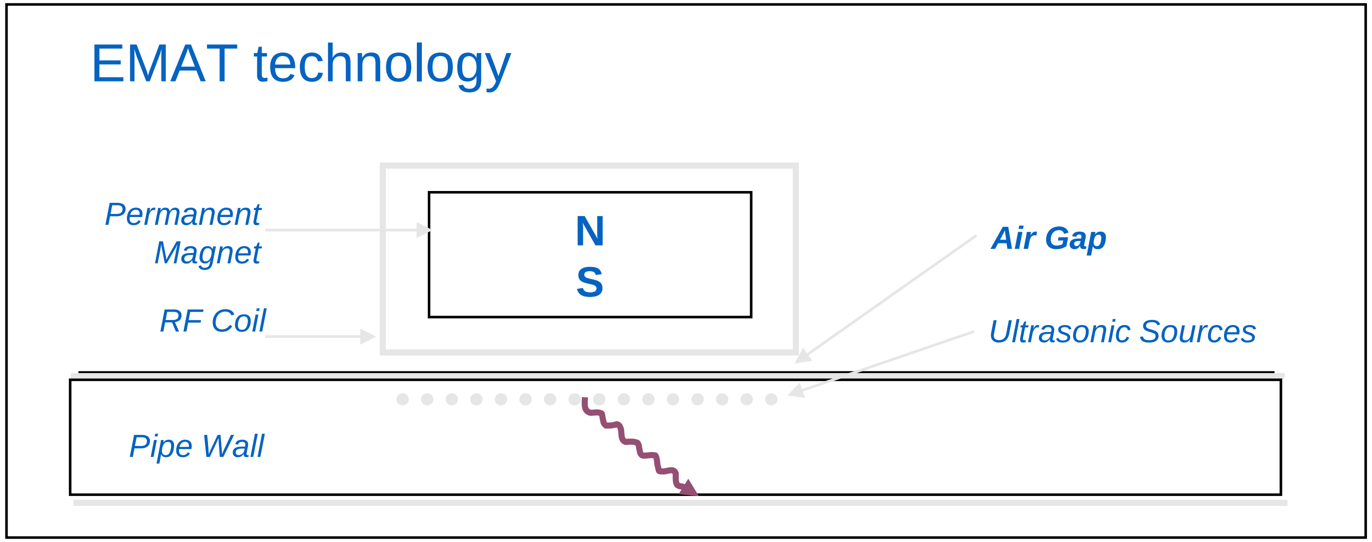
12” TFI tool



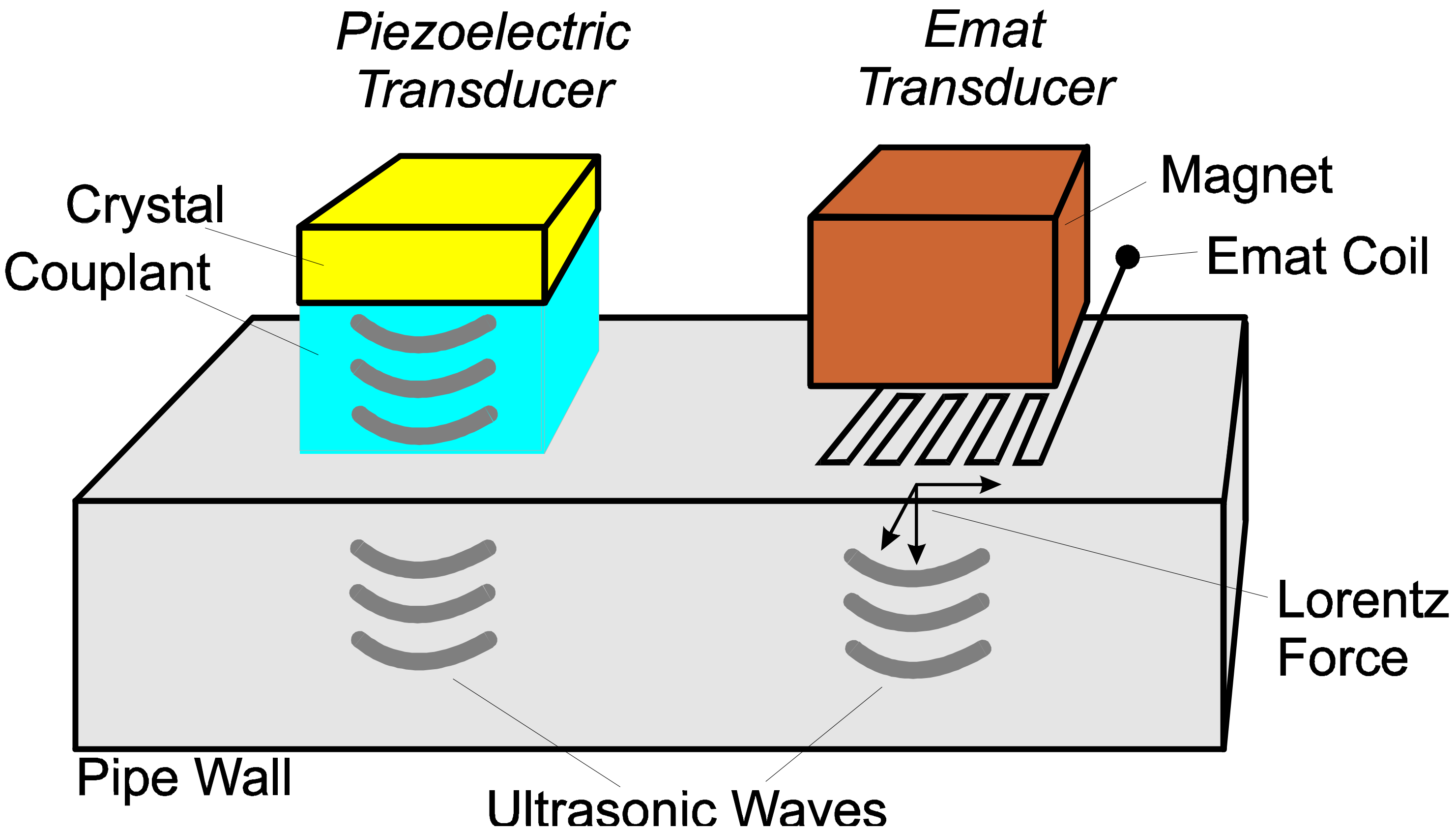
EmatSCAN

高精度输气管线裂纹检测EMAT 技术





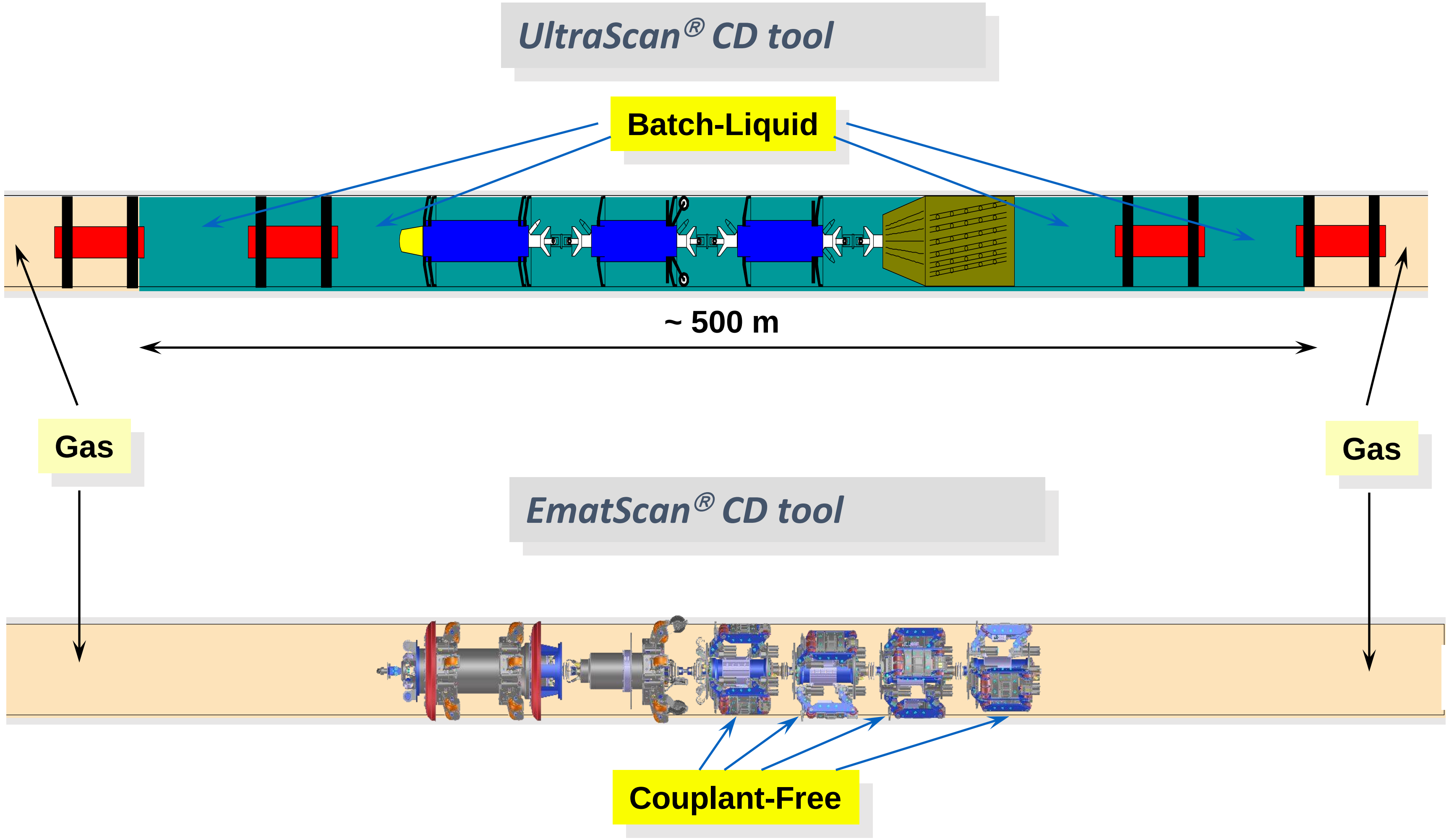
EMAT - Electromagnetic Acoustic Transducer



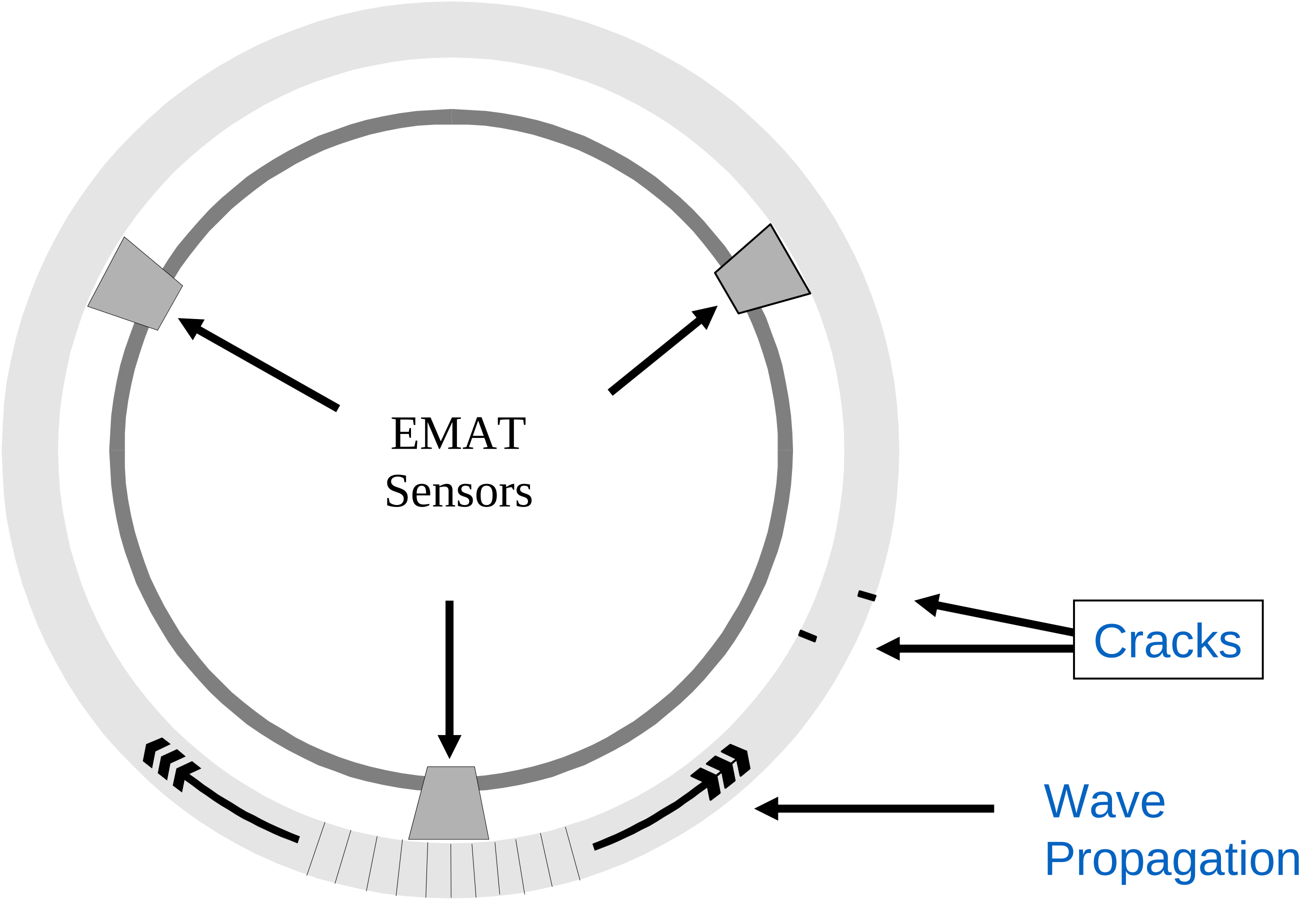
EMAT Principle of Operation:

A high-frequency coil induces eddy currents in the material. The surface currents in the presence of the magnetic field generate a Lorentz force that is transferred to the atomic lattice of the material. This force produces an ultrasonic wave that propagates through the material.

Crack detection in gas pipeline

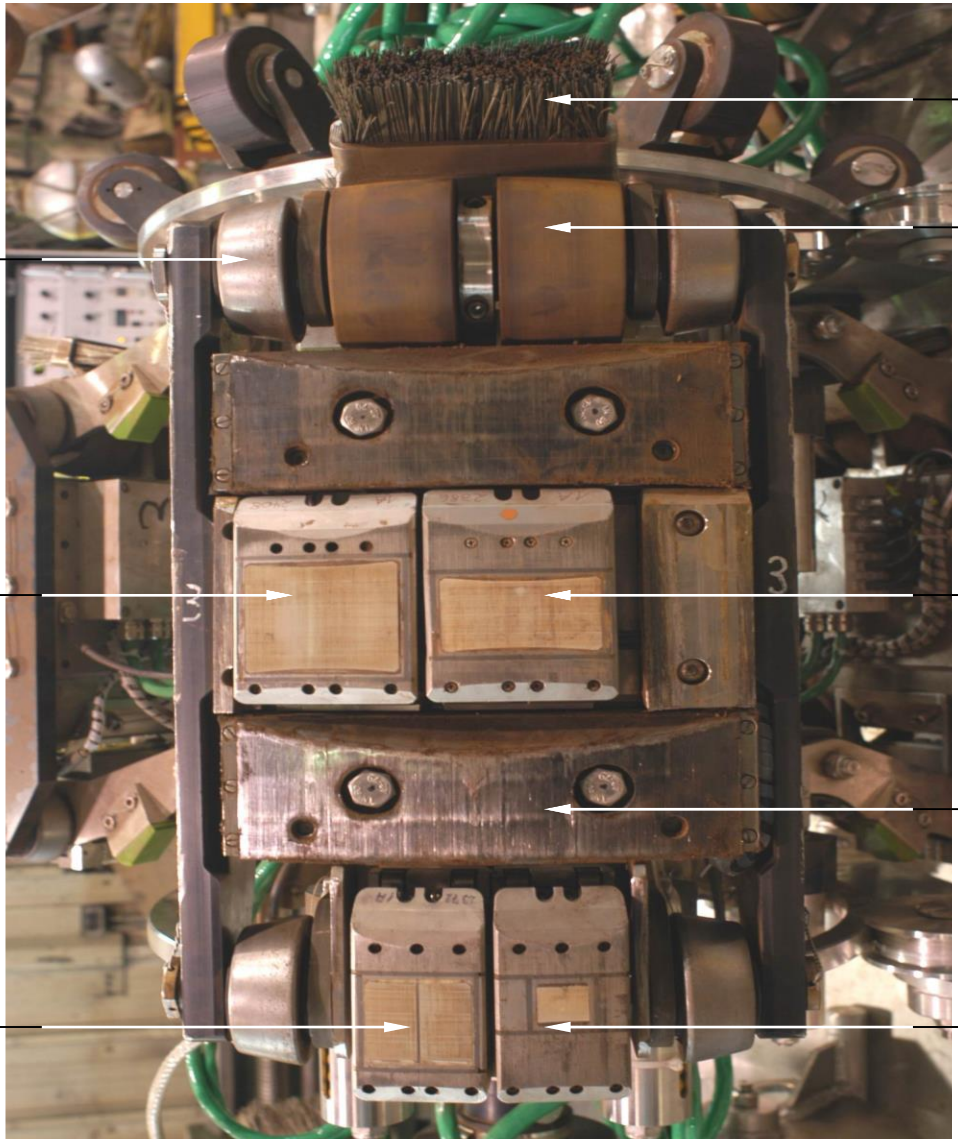


EmatScan 传感器工作原理



- Detection of internal and external crack-like defects
- System of interacting EMAT sensors

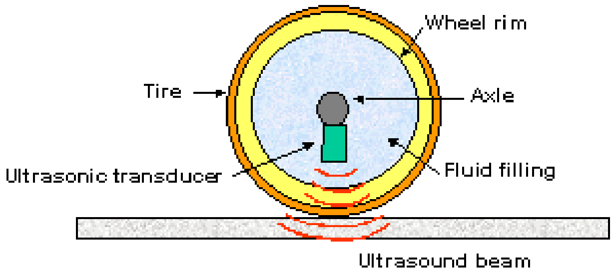
Sensor Arrangement per Sensor Skid

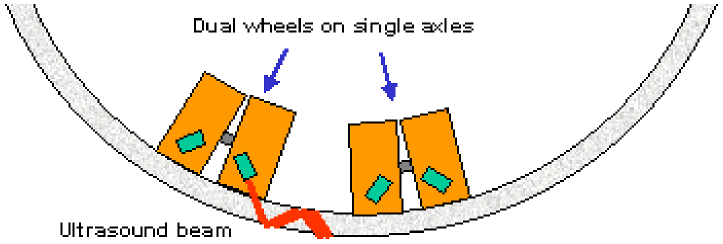


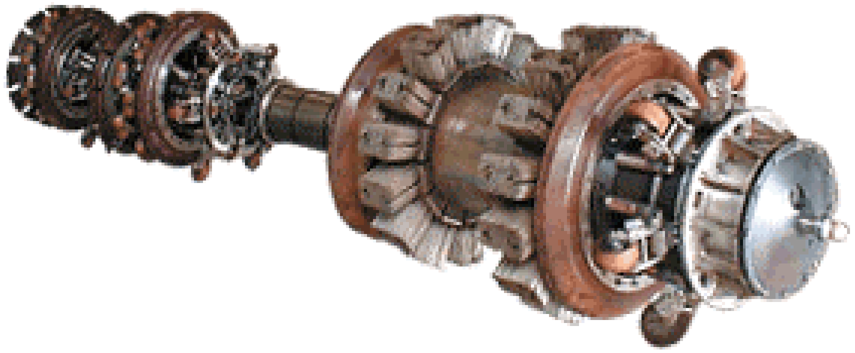

Elastic Wave

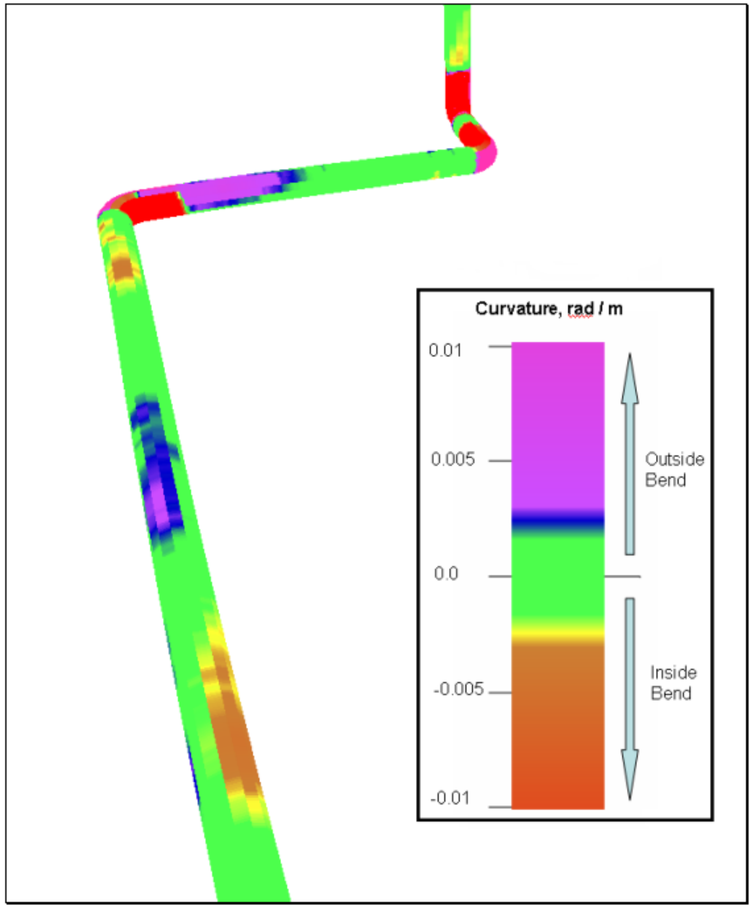
Elastic Wave

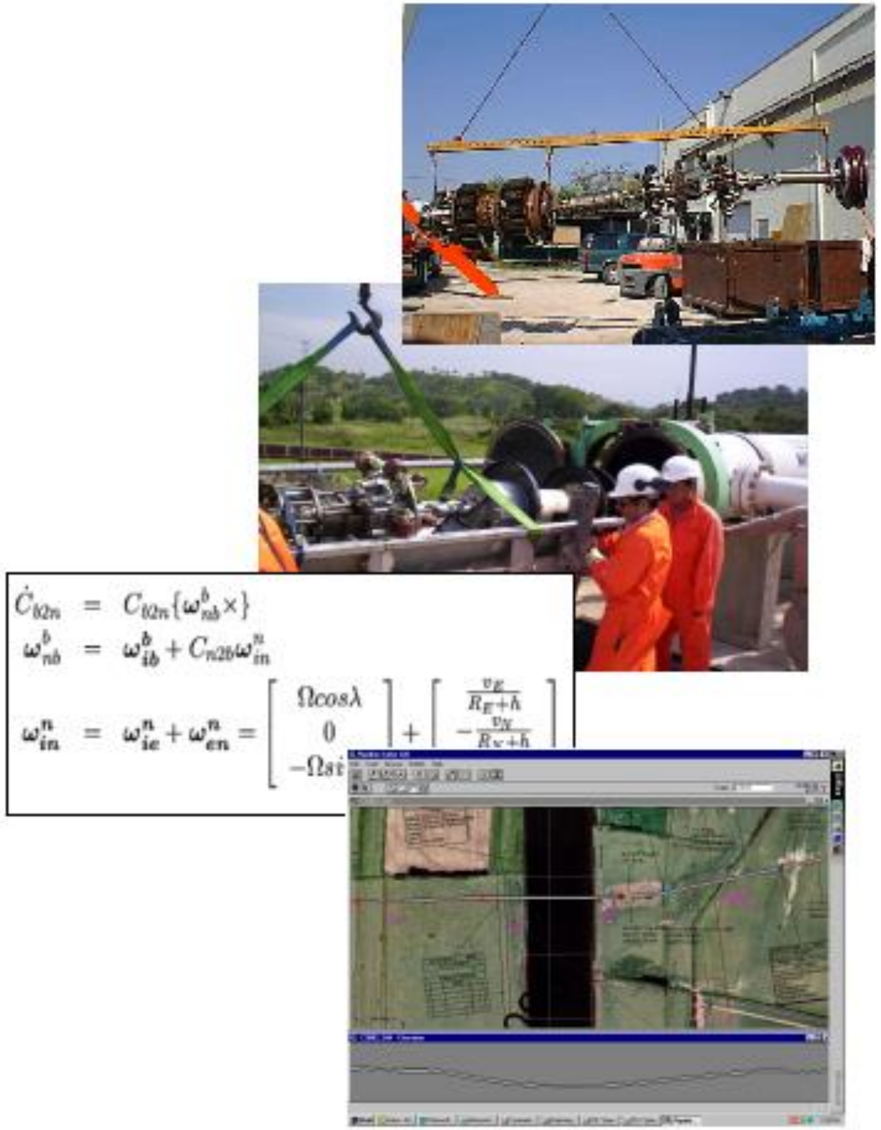
- Based on ultrasonic technology
- Waves injected at 65° travel circumferentially around pipe
- Designed to detect long seam fatigue, SCC, lack of fusion & hook cracks
- Transducers in fluid filled wheels therefore can run in gas pipelines








Curvature, rad / m
0.01
0.005
0.0
-0.005
-0.01
Outside Bend
Inside Bend


$\dot{C}_{b2n} = C_{b2n}\{\omega^b_{nb}\times\}$
$\omega^b_{nb} = \omega^b_{ib} + C_{n2b}\omega^n_{in}$

测绘与应变评估

ScoutScan 定位检测器

- 检测器尺寸范围 12-56英寸
- 实现每节环焊缝定位
- 定位报告间隔为5cm
- 经济实用，可与变形和腐蚀检测器配合使用

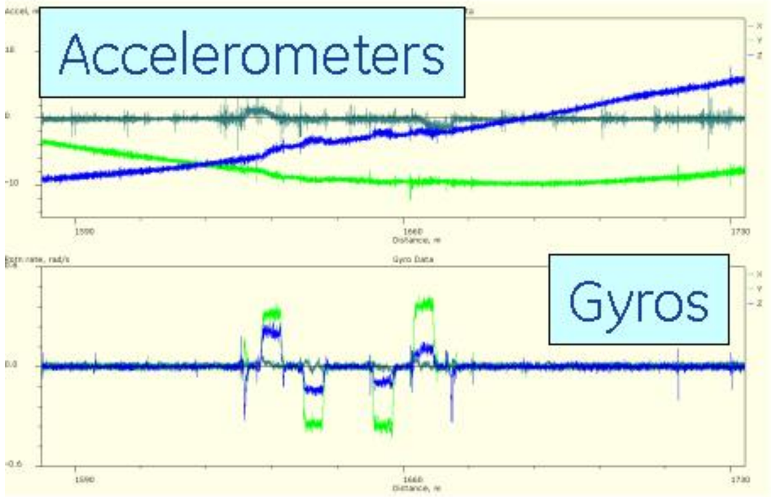
Honeywell 位移测量装置

Mapping Unit
1:2000 Pig Travel
1:4000 Reference spacing

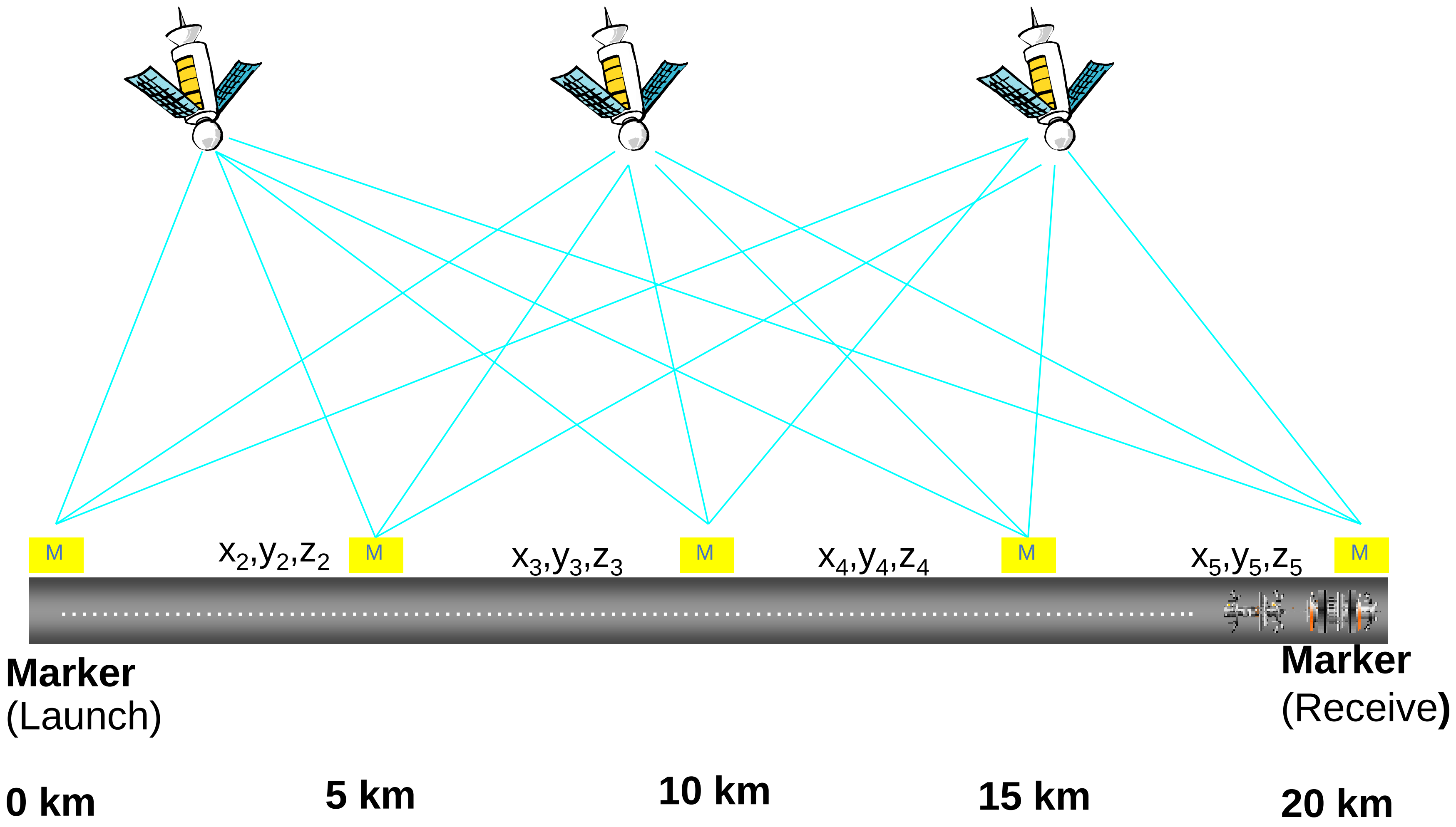
Additional error sources
GPS Survey
Reference correllation

Inertial Measurement Unit (IMU)

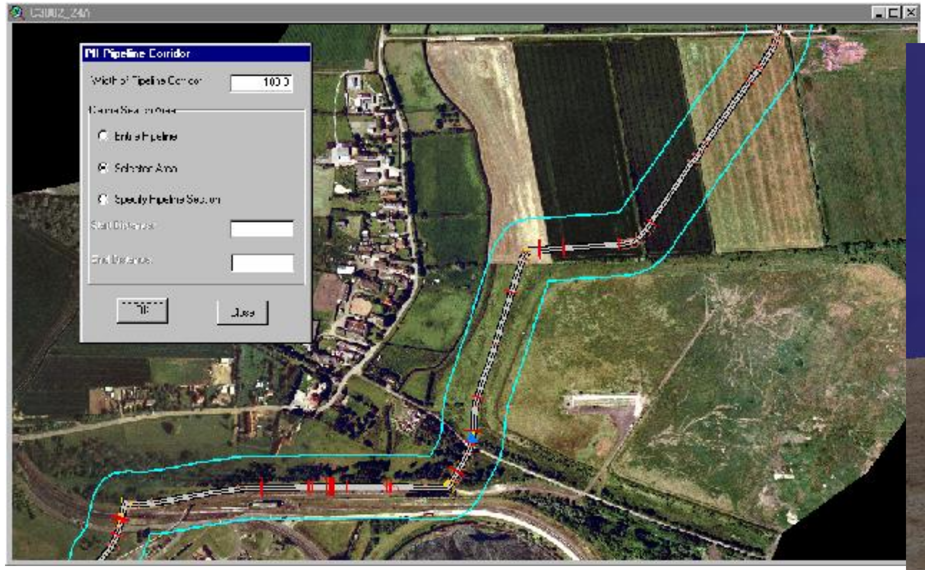
- IMU measures a pig's movement in 3D:
- 3 Gyroscopes measure rotation.三向陀螺仪测量旋转
- 3 accelerometers measure acceleration and gravity
- 加速测量仪测量加速度和重力

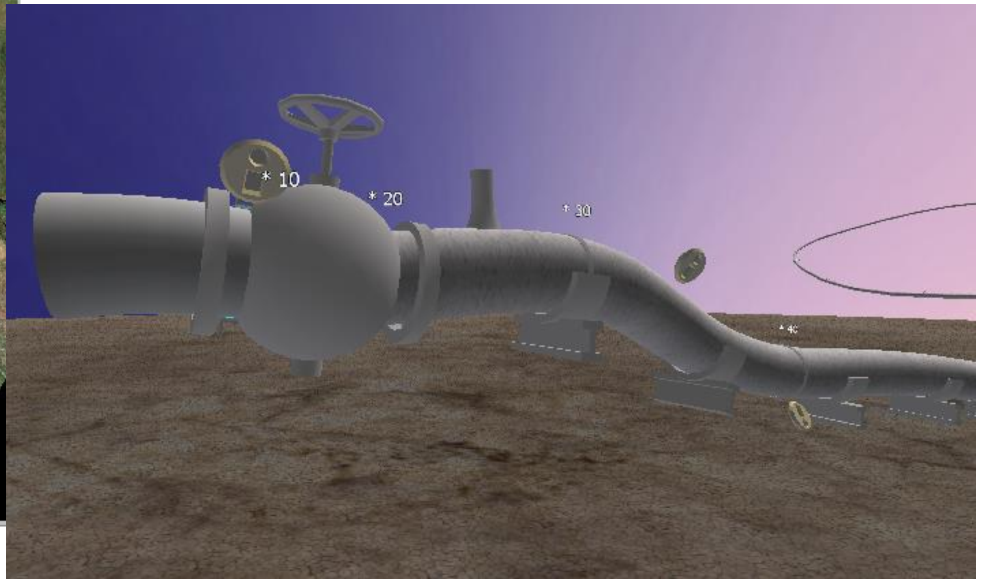


位移测量


M
x_2,y_2,z_2
M
x_3,y_3,z_3
M
x_4,y_4,z_4
M
x_5,y_5,z_5
M
Marker
(Launch)
Marker
(Receive)
0 km
5 km
10 km
15 km
20 km

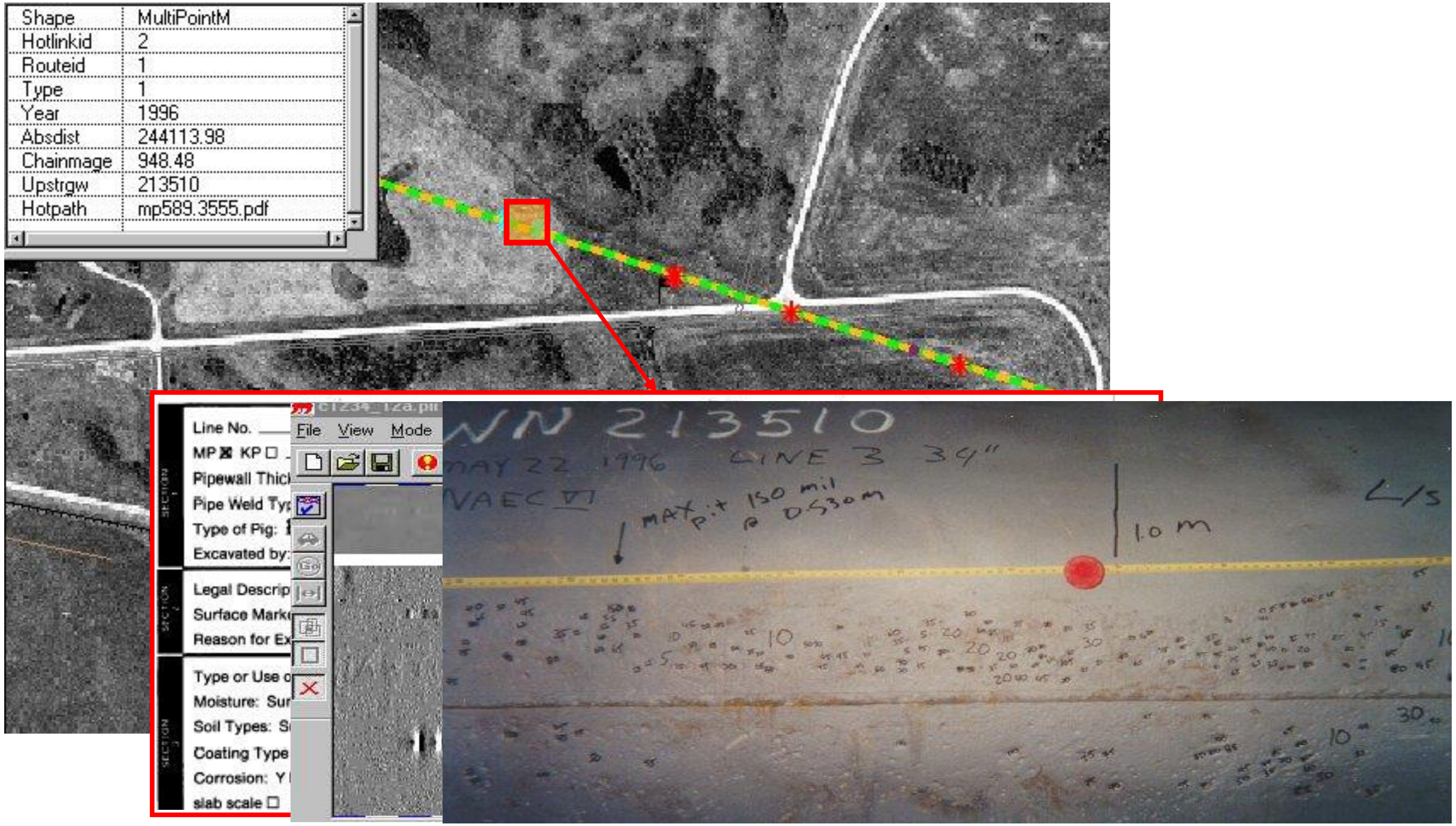
精确定位的好处：



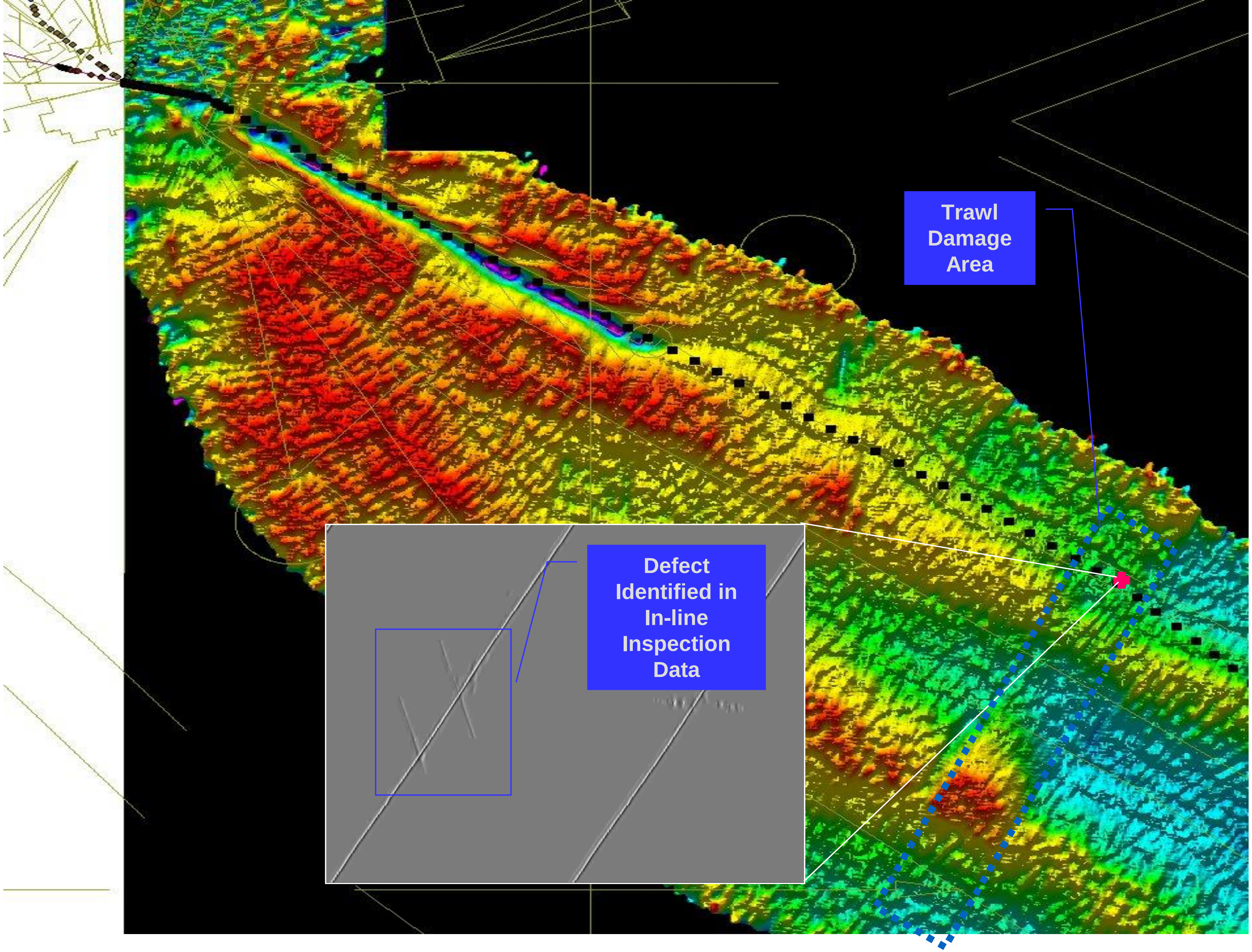


- 准确的缺陷定位
  - 合理制定开挖计划减小开挖成本
  - 准确发现风险点
- 数据管理
- 管线移动监测

完整性数据整合



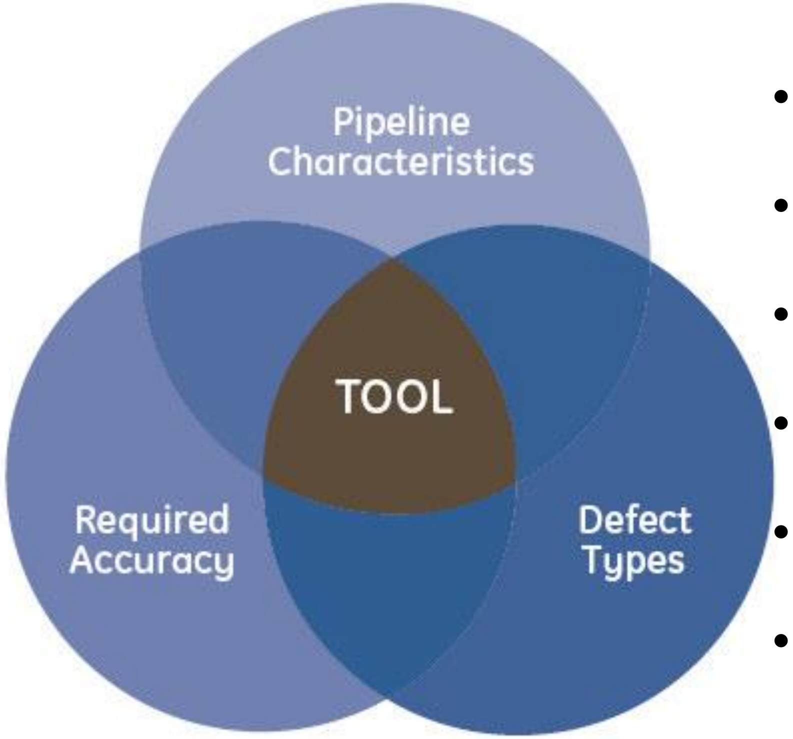
- •GIS地理信息系统把图像数据和检测数据统一起来
- 加强对管道特征的理解
- 便于管道数据管理，提高效率


Trawl Damage Area
Defect Identified in In-line Inspection Data

- 如何选择适合的检测技术

如何选择适合的检测技术

Tool Development and PipeLine Inspection – common set of factors



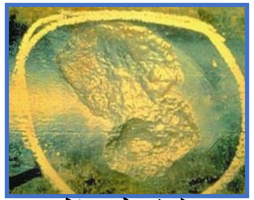
- most appopriate technology最适合的技术
- most appropriate sensor 最适合的传感器
- tool operating window 工具操作窗口
- design parameters 设计参数
- analysis tools分析工具
- decision support支持工具

选择合适的管道检测器-管道本身出发

直径	单一管径的检测器 双管径的检测器.
长度	备用电池模块或者存储器可以有效的完成单程道的检测.
壁厚	检测范围的选择可达到 25-30mm 可以通过: 80-85% of API OD
流速	大直径高压力天然气管线中，检测器运行可达到 5m/s; 速度控制系统可以达到 12m/s
温度	0-40C, 而且可选择达到 60C 连续或者 80C 瞬态
压力	最大可达到 220 bar, 可以改进低压力(<40 bar)天然气管道检测器的动力性

管道缺陷威胁 ...来自腐蚀


焊缝腐蚀


一般腐蚀


夹层腐蚀


侵蚀


点蚀


划痕


泄露

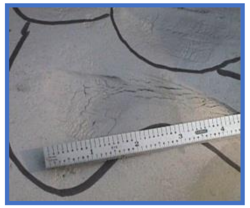
运行者需要的工艺技术可以提供:

- 精确的尺寸
- 高识别
- 可靠的位置
- 腐蚀增长
- 风险评估
- 最小程度的减少停产

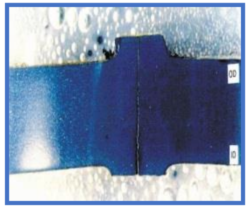
腐蚀 ... 当今最关心的问题

管道缺陷威胁 ... 裂纹

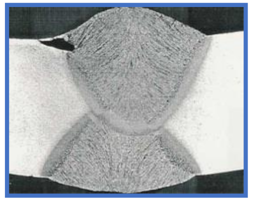
SCC



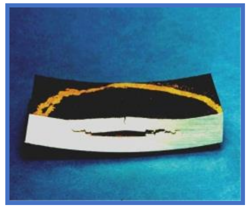
凹坑和裂纹



镕结缺陷



疲劳



HIC

月牙裂纹

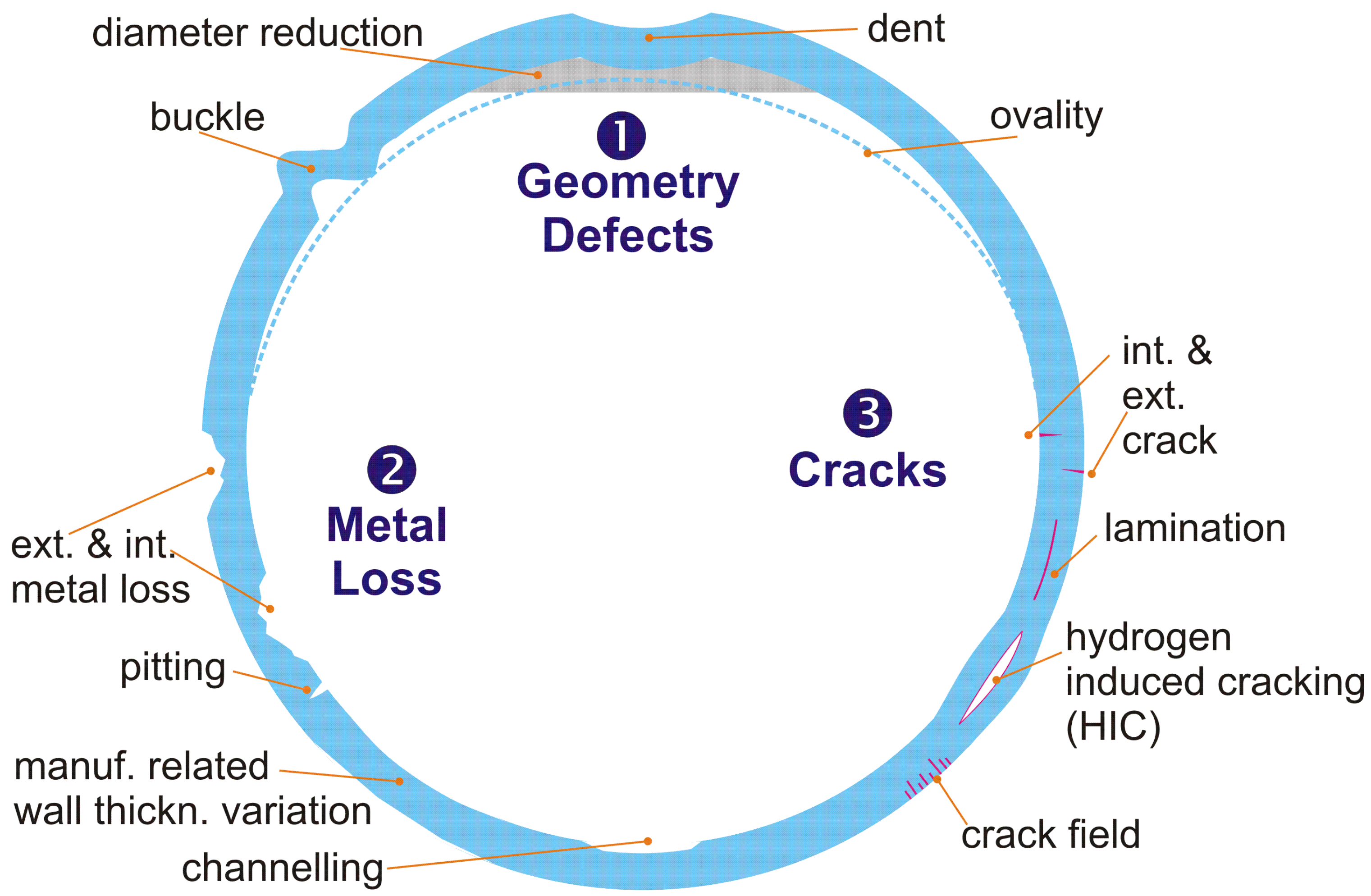
缩皱裂纹

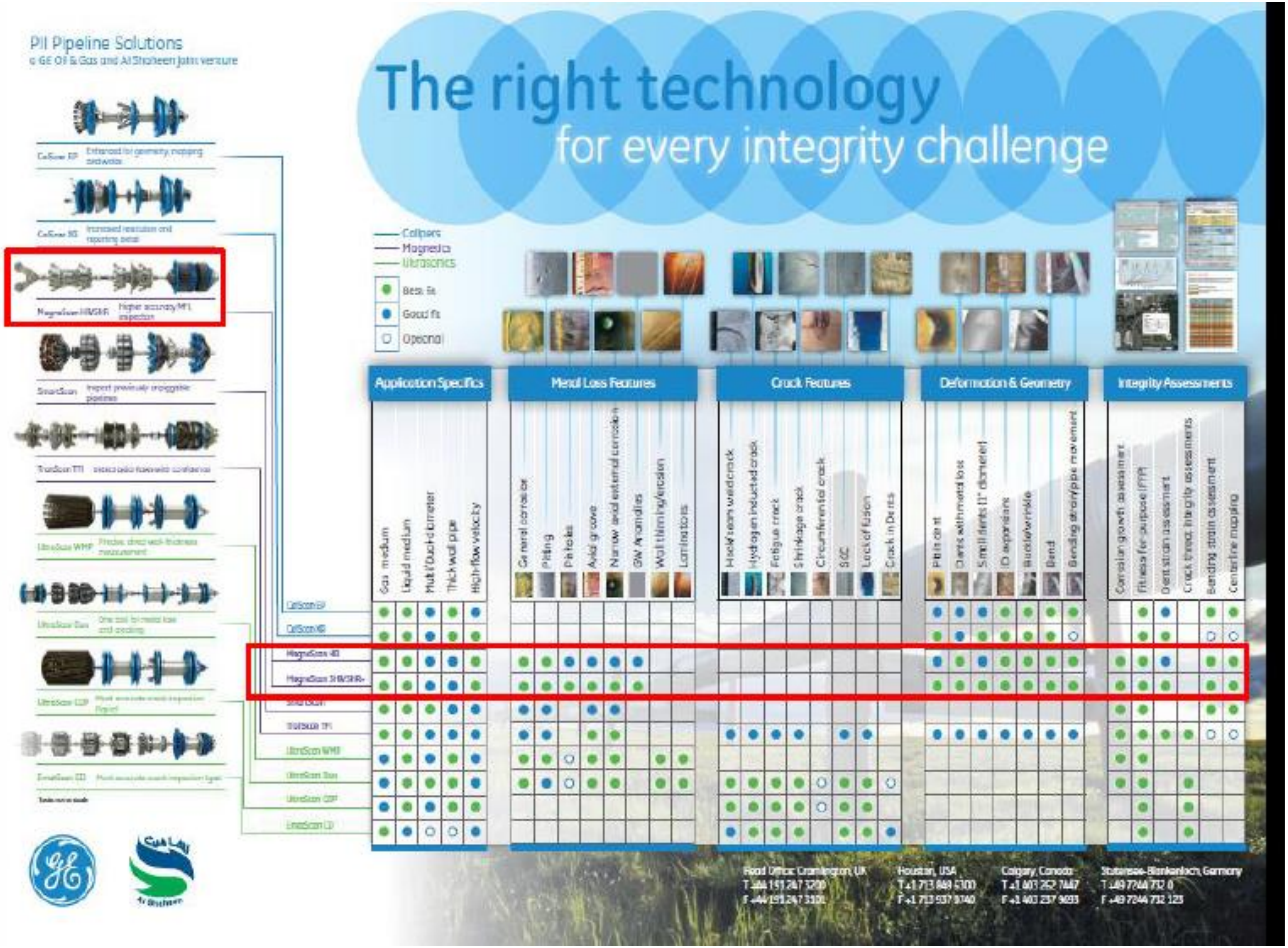
运行者需要的技术
可以提供:

- 临界缺陷检测
- 亚临界缺陷检测
- 可靠位置
- 风险评估
- 最小程度的减少停产

裂纹 ... 很快增加的问题

Pipeline Defects




PII Pipeline Solutions
a GE Oil & Gas and Al Shaheen joint venture
The right technology
for every integrity challenge
Calipers
Magnetics
Ultrasonics
Best fit
Good fit
Optional
Application Specifics
Metal Loss Features
Crack Features
Deformation & Geometry
Integrity Assessments
Gas medium
Liquid medium
Multi/Dual diameter
Thick wall pipe
High flow velocity
General corrosion
Pitting
Pinholes
Axial groove
Narrow axial external corrosion
Wall thinning/erosion
Laminations
Hydrogen induced crack
Fatigue crack
Shrinkage crack
Circumferential crack
SCC
Lack of fusion
Crack in Dents
Plain dent
Dents with metal loss
ID expansions
Buckle/wrinkle
Bend
Bending strain/pipe movement
Corrosion growth assessment
Fitness-for-purpose (FFP)
Dent strain assessment
Crack threat integrity assessments
Bending strain assessment
Centerline mapping
MagneScan HR
MagneScan HR/SHR
UltraScan CD
Head Office: Cramlington, UK
Houston, USA
Calgary, Canada
Stutensee-Blankenloch, Germany

The right technology for every integrity challenge

— Calipers
— Magnetics
— Ultrasonics

● Best fit
● Strong fit
○ Optional

Tools not to scale

Application Specifics

Tool	Gas medium	Liquid medium	Multi/Dual-diameter	Thick wall pipe	High-flow velocity
UltraScan WMP	Strong fit	Best fit	Strong fit	Best fit	Strong fit (latest advancement)
UltraScan DUO	Strong fit	Best fit	Strong fit	Best fit	Strong fit
UltraScan CDP	Strong fit	Best fit	Strong fit	Best fit	Best fit
EmatScan CD	Best fit	Strong fit (latest advancement)	Optional	Optional	Strong fit

Metal Loss Features

Tool	General corrosion	Pitting	Pinholes	Axial groove	Narrow axial external corrosion	GW Anomalies	Wall thinning/erosion	Laminations
UltraScan WMP	Best fit	Best fit (latest advancement)	Optional	Best fit	Best fit		Best fit	Best fit
UltraScan DUO	Best fit	Strong fit	Optional	Best fit	Best fit		Best fit	Best fit
UltraScan CDP								
EmatScan CD								

Crack Features

Tool	Hook/seam weld crack	Hydrogen induced crack	Fatigue crack	Shrinkage crack	Circumferential crack	SCC	Lack of fusion	Crack in Dents
UltraScan WMP								
UltraScan DUO	Best fit	Best fit	Best fit	Best fit		Best fit	Best fit	Optional
UltraScan CDP	Best fit	Best fit	Best fit	Best fit	Optional	Best fit	Best fit	
EmatScan CD	Strong fit	Best fit	Best fit	Best fit		Best fit	Best fit	Best fit (latest advancement)

Deformation & Geometry

Tool	Plain dent	Dents with metal loss	Small dents (1" diameter)	ID expansions	Buckle/wrinkle	Bend	Bending strain/pipe movement
UltraScan WMP							
UltraScan DUO							
UltraScan CDP							
EmatScan CD							

Integrity Assessments

Tool	Corrosion growth assessment	Fitness-for-purpose (FFP)	Dent strain assessment	Crack integrity assessment	Crack growth assessment	Bending strain assessment	Centerline mapping
UltraScan WMP	Best fit	Best fit		Strong fit			
UltraScan DUO	Best fit	Best fit		Best fit	Best fit		
UltraScan CDP		Best fit		Best fit	Best fit		
EmatScan CD		Best fit		Best fit	Best fit		

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○ **latest advancements**

如何评判检测技术好坏

Element 1可靠准确的侧量精度

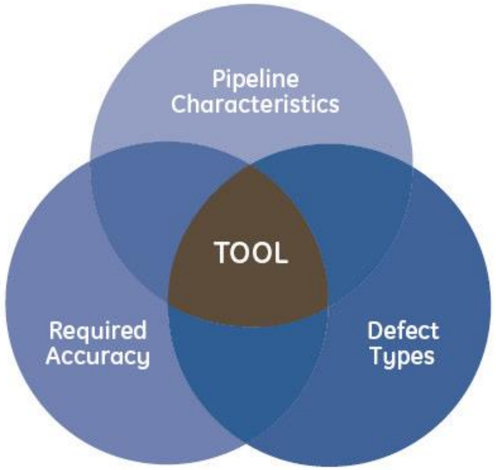
- A reliable and accurate measurement performance for detecting, discriminating and sizing

minimized operational disruptio最小程度影响生产

validated defect characterization accuracy

accurate sizing

reliable location



suitable under variety of conditions
(diameter, speed, product, WT, geometries)适合各种 操作条件，管径，流速，介质，壁厚，几何

high detection & discrimination

repeatable & reproducible data

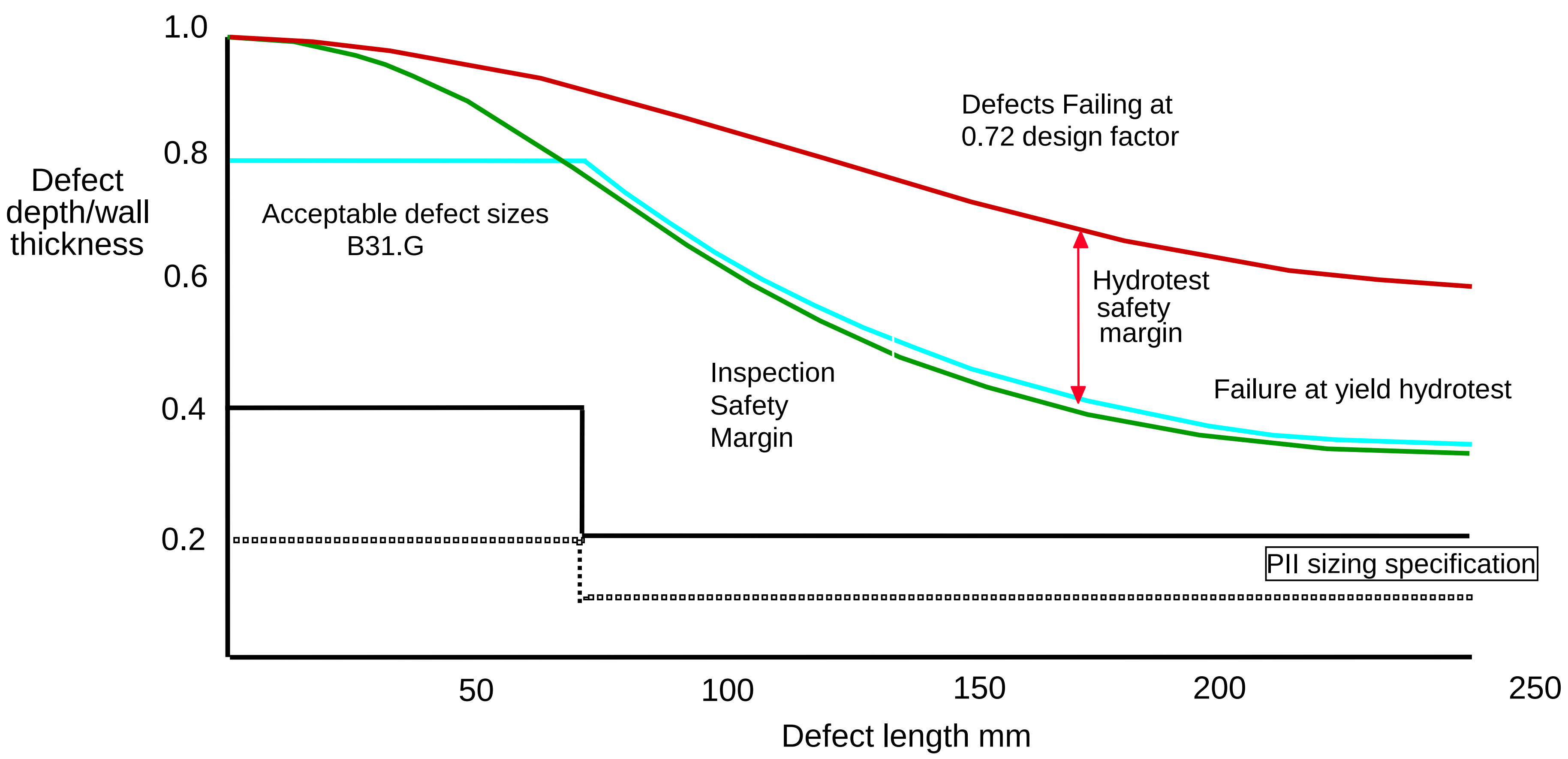
Element 2

- A comprehensive excavation program with accurate field and laboratory direct observation to evaluate ILI tool performance provide reliable data feedback to the ILI vendor for improvement. 综合大量的准确的开挖验证和试验数据，反馈给检测公司提高

Element 3

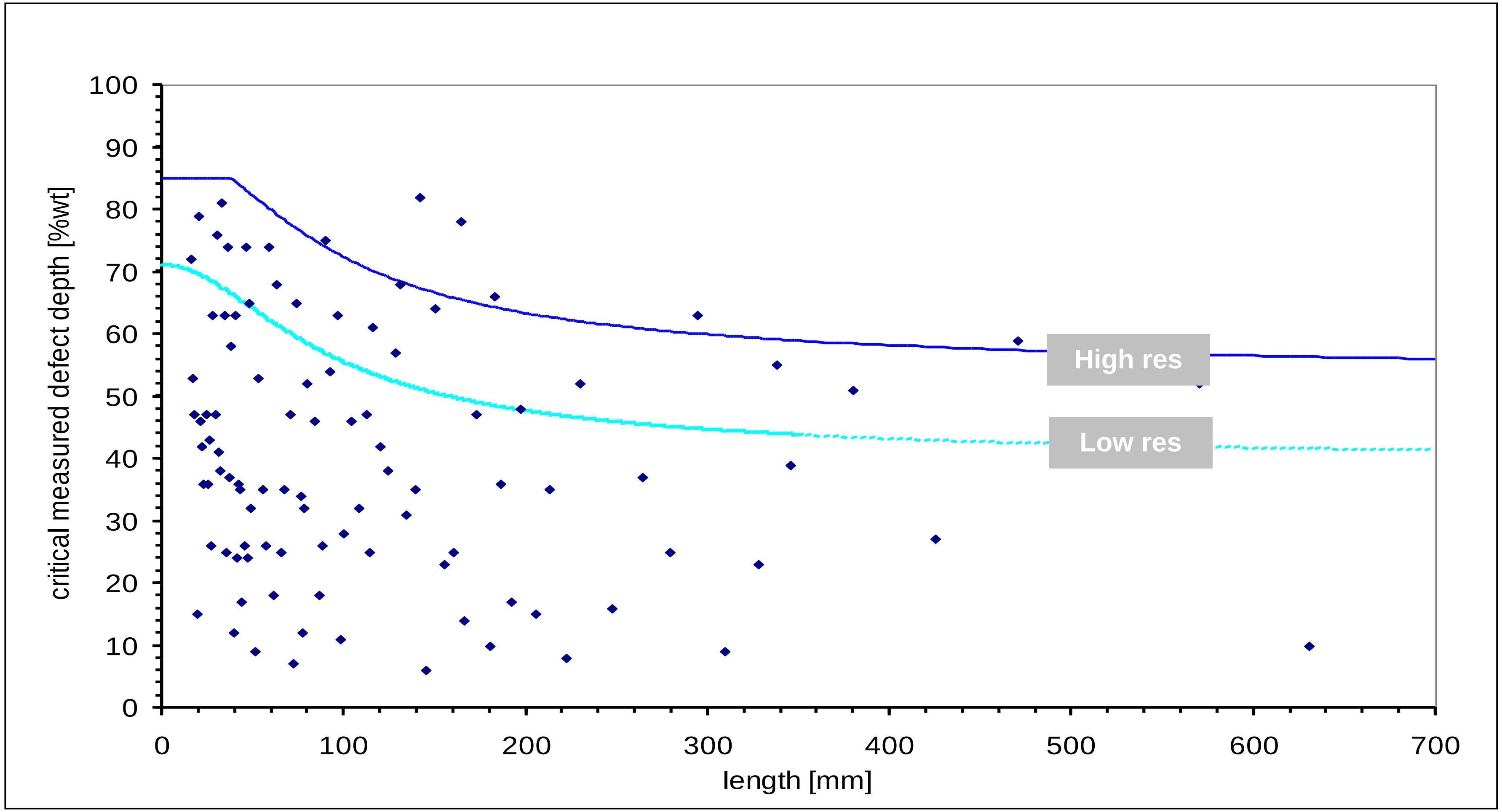
- A failure model /method with material testing data to prioritizing excavation investigation life cycle/re-inspection interval prediction 把内检测数据用于完整性评估，指导修复和再检测周期 .

管道内检测数据与安全评价



高精度的好处

高精度的结果意味着减少修复............



- 超声波与漏磁检测的区别

Which technology to use?

The right technology for every integrity challenge

- ● Optimum specification (green)
- ● Good specification (blue)
- ● Available (orange)
- ● Consult BHGE (grey)

MULTIPLE THREATS

Tool	Defects interacting with strain	Metal loss on dents	Cracks in dents	Cracks in metal loss
UltraScan™ WMP – Higher resolution, higher accuracy direct wall measurement		Good specification		
New MagneScan™ SHRP & VECTRA GEMINI HD – Superior accuracy to optimize dig programs	Optimum specification	Optimum specification	Optimum specification	
New MagneScan™ SHR & VECTRA GEMINI – High accuracy, triaxial MFL with caliper	Good specification	Good specification	Good specification	
New MagneScan™ HR – Next generation high resolution combination MFL	Good specification	Good specification	Good specification	
MagneScan™ HR – High resolution MFL inspection	Good specification	Good specification	Good specification	

GEOHAZARD

Tool	Pipeline movement	Axial strain with AXISS™	Bending strain	Buckle/wrinkle
UltraScan™ WMP				Good specification
New MagneScan™ SHRP & VECTRA GEMINI HD	Optimum specification	Optimum specification	Optimum specification	Optimum specification
New MagneScan™ SHR & VECTRA GEMINI	Optimum specification	Optimum specification	Optimum specification	Optimum specification
New MagneScan™ HR	Optimum specification		Optimum specification	Optimum specification
MagneScan™ HR	Optimum specification		Optimum specification	Good specification

THIRD PARTY DAMAGE & GEOMETRY

Tool	Illegal tapping & pilferage	Real time third party strikes	Hard scale	Gouging	Ovality	Dent strain and fatigue assessment (PIDA)	Complex geometry dents	Dents on welds	Plain dents
UltraScan™ WMP	Optimum specification		Optimum specification	Good specification			Good specification	Good specification	Good specification
New MagneScan™ SHRP & VECTRA GEMINI HD	Optimum specification		Optimum specification	Optimum specification	Optimum specification	Optimum specification	Optimum specification	Optimum specification	Optimum specification
New MagneScan™ SHR & VECTRA GEMINI	Optimum specification		Optimum specification	Optimum specification	Optimum specification	Optimum specification	Optimum specification	Optimum specification	Optimum specification
New MagneScan™ HR	Optimum specification		Optimum specification	Optimum specification	Optimum specification	Optimum specification	Optimum specification	Optimum specification	Optimum specification
MagneScan™ HR	Optimum specification		Optimum specification	Good specification	Good specification	Good specification	Good specification	Good specification	Good specification

MANUFACTURING & CONSTRUCTION

Tool	Bend characterization	Centerline mapping	Wrinkle bends	ID expansions/Roof topping	Laminations & midwall defects	Seam weld anomalies	Spiral weld anomalies	Girth weld anomalies
UltraScan™ WMP	Good specification		Good specification	Optimum specification	Optimum specification			
New MagneScan™ SHRP & VECTRA GEMINI HD	Optimum specification	Optimum specification	Optimum specification	Optimum specification	Good specification		Optimum specification	Optimum specification
New MagneScan™ SHR & VECTRA GEMINI	Optimum specification	Optimum specification	Optimum specification	Optimum specification	Good specification		Good specification	Good specification
New MagneScan™ HR	Optimum specification	Optimum specification	Optimum specification	Optimum specification	Good specification		Good specification	Good specification
MagneScan™ HR	Optimum specification	Optimum specification	Good specification	Optimum specification	Good specification		Good specification	Good specification

CRACKING

Tool	Stress Corrosion Cracking (SCC)	Circumferential cracks	Shrinkage cracks	Fatigue cracks	Seam weld lack of fusion	Hook/seam weld anomalies	Hydrogen induced cracks	Axial cracks
UltraScan™ WMP								
New MagneScan™ SHRP & VECTRA GEMINI HD		Good specification						
New MagneScan™ SHR & VECTRA GEMINI		Good specification						
New MagneScan™ HR		Consult BHGE						
MagneScan™ HR		Consult BHGE						

CORROSION & METAL LOSS

Tool	Wall thinning/erosion	Circumferentially oriented	Narrow axially oriented	Highly corroded	Complex corrosion	Pinholes	Internal	External
UltraScan™ WMP	Optimum specification	Optimum specification	Good specification	Optimum specification	Optimum specification	Optimum specification	Optimum specification	Optimum specification
New MagneScan™ SHRP & VECTRA GEMINI HD		Optimum specification	Good specification	Optimum specification	Optimum specification	Optimum specification	Optimum specification	Optimum specification
New MagneScan™ SHR & VECTRA GEMINI		Good specification	Good specification	Optimum specification	Good specification	Good specification	Good specification	Good specification
New MagneScan™ HR		Good specification	Available	Good specification	Good specification	Available	Good specification	Good specification
MagneScan™ HR		Good specification	Available	Good specification	Good specification	Available	Good specification	Good specification

OPERATIONAL

Tool	Baseline inspection	CRA clad pipe	Unknown cleanliness	Short traps	High-flow velocity	Thick wall pipe	Multi/dual-diameter	Liquid medium	Gas medium
UltraScan™ WMP	Available	Available	Consult BHGE	Available	Available	Available	Consult BHGE	Available	Consult BHGE
New MagneScan™ SHRP & VECTRA GEMINI HD	Available	Consult BHGE	Available	Available	Available	Available	Consult BHGE	Available	Available
New MagneScan™ SHR & VECTRA GEMINI	Available	Consult BHGE	Available	Available	Available	Available	Consult BHGE	Available	Available
New MagneScan™ HR	Available	Consult BHGE	Available	Available	Available	Available	Consult BHGE	Available	Available
MagneScan™ HR	Available	Consult BHGE	Available	Available	Available	Available	Available	Available	Available

MFL Technology

Robust and proven technology which has been in operation for 30+ years

Strengths

Operational

- ✓ Tolerant to debris (more so than UT), detection if debris 'in' corrosion
- ✓ Wide speed range: 0-5 m/s, specs also achieved at higher speeds
- ✓ 4-56"
- ✓ Up to 220 bar
- ✓ Combo technology: Metal loss, geometry & mapping in 1 run

Data

- ✓ Pinhole detection & sizing: spec from 5mm and seeing defects from 2mm in diameter
- ✓ Pits, general ML and circumferential defects
- ✓ Welds (girth & spiral): detection & sizing across weld area + recent circ crack specifications
- ✓ Defects in defects improvements in recent years

Weaknesses

Operational

- Preconditioning sometimes required in thick wall pipe
- Brush design not ideal for dual diameter applications

Data

- MFG discrimination: Laminations, midwall
- Not direct measurement of WT
- Wall thinning
- Channelling corrosion

UT wall measurement Technology

Robust and proven technology which has been in operation for 30+ years

Strengths

Operational

- ✓ Thick wall pipe up to 45mm
- ✓ Wide speed range: up to 2.5 m/s, specs also achieved at higher speeds
- ✓ lower differential pressure
- ✓ 6-52”

Data

- ✓ Direct WT measurement in mm
- ✓ Cladding
- ✓ Seamless pipe wt variations
- ✓ Lamination and Blisters, Manufactured and HIC
- ✓ Pinhole & pitting detection: spec defects from 1mm @ 5mm Ø
- ✓ Channelling corrosion

Weaknesses

Operational

- Liquid medium required
- Line cleanliness sensitivity
- Pressure 120 bar

Data

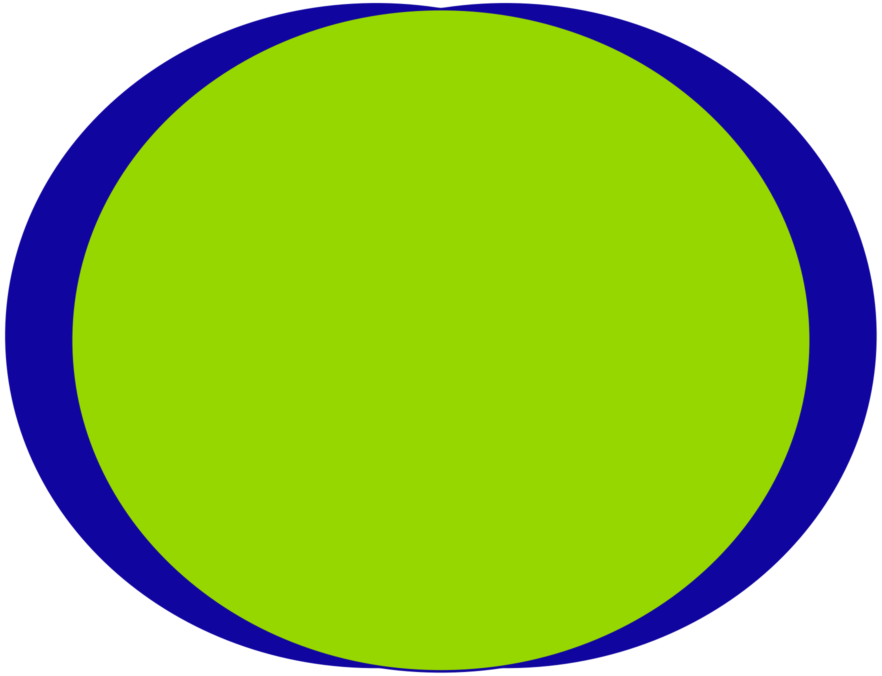
- Pitting sizing: spec from 8mm
- Heavy seamless pattern can cause echo loss on older systems

Which Technology?

Both delivering accurate & reliable data.

MFL:

- Pinholes
- GW defects
- Challenges with pipeline cleanliness
- Higher speeds



MFL or UT

UT:

- Actual WT measurement
- MFG discrimination
- Wall thinning / channel corrosion

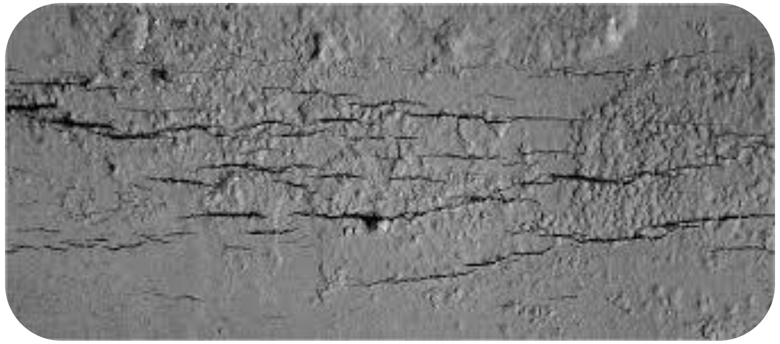
- 最新内检测发展趋势

内检测发展的趋势 ILI Threat Trends…

Corrosion & Metal Loss

- Large, North American operators primarily driving technology improvements
- Focus shifting away from general to complex corrosion and outliers -> ‘defect morphologies’
- Looking for increased confidence in gouges & metal loss in dents

Cracks



- SCC in Gas pipelines: US regulations driving sharp increase in EMAT inspections
- Girth Welds continue to be a challenge driving increase in IMU runs and bending strain assessments
- Axial strain measurement (AXISS) seen as an option to identify high risk areas

Research Objectives

	Research Objective	***Est. Timeline to meaningful impact***
1	Develop and/or validate technology and analytical processes that are capable of characterizing pipeline material properties with sufficient accuracy for application in pipeline integrity assessments.	3 years
2	Develop and enhance ILI technology to reliably detect, size and characterize indications that may be harmful to the integrity of the pipeline.	5 years

Research Objectives

	Research Objective	***Est. Timeline to meaningful impact***
3	Develop, evaluate and enhance NDE technologies and operator & data analyst performance to define the condition and assess the integrity of pipeline, facilities and associated infrastructure from outside or above the pipeline or facility.	5 years
4	Improve the accuracy and application of Fitness for Service methodologies by reducing uncertainties. Define, understand and improve the key factors, including models that are involved in design, construction or integrity assessments of any component in systems covered by PRCI.	5 years

Technology Development Center - TDC

TDC Existing Capabilities

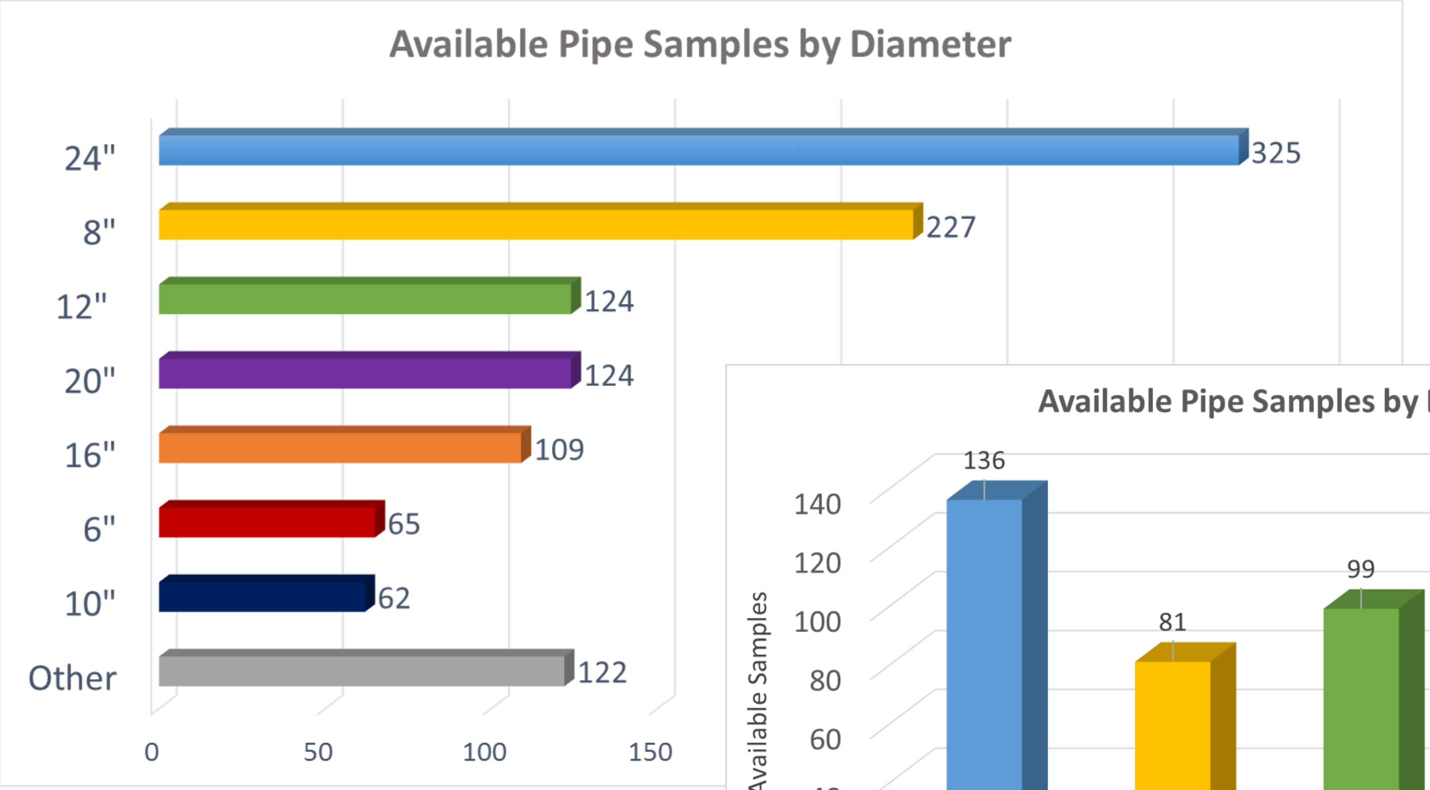
- Services available to PRCI members and nonmembers
  - Pull test facility for In-line Inspection tools
    - 24”, 16”, 12” & 8” pipe strings containing hundreds of fully characterized real & manufactured defects.
    - Main winch is capable of running consistent velocities from 1 mph to 11 mph while pulling over 5,000 lbs.
  - Liquid loop test facility
    - 12” & 6” nominal pipe utilizing water as the liquid medium
    - Variety of configurations ranging from easily piggable to "difficult to inspect"
    - Design incorporates the ability for continuous test cycles at a pressure of ANSI Class 150 (285 psi)
  - Large inventory of pipe Samples with real-world and manufactured defects
  - Qualification testing of NDE professionals and tools
  - Technology demonstrations
  - Warehouse space for conducting research and storing pipe samples sensitive to the elements
  - State-of-the-art meeting space with conferencing capabilities

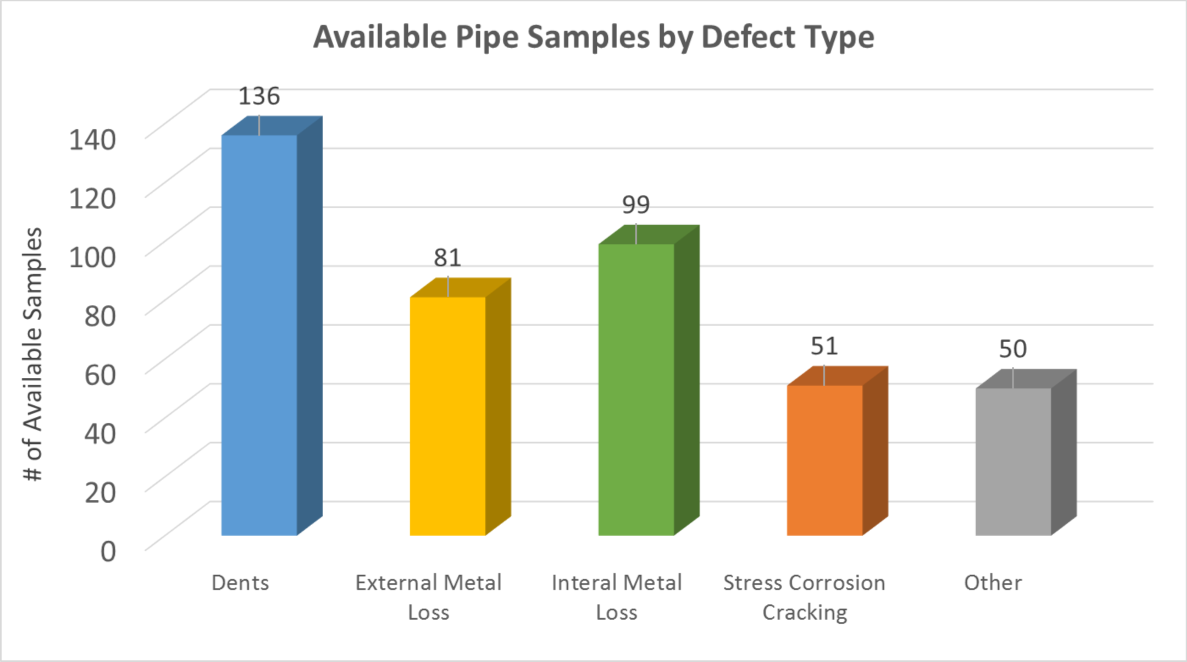
Pull Test Strings

Liquid Test Loop

Pipe Warehouse & Testing Space

Pipe Sample Inventory at TDC





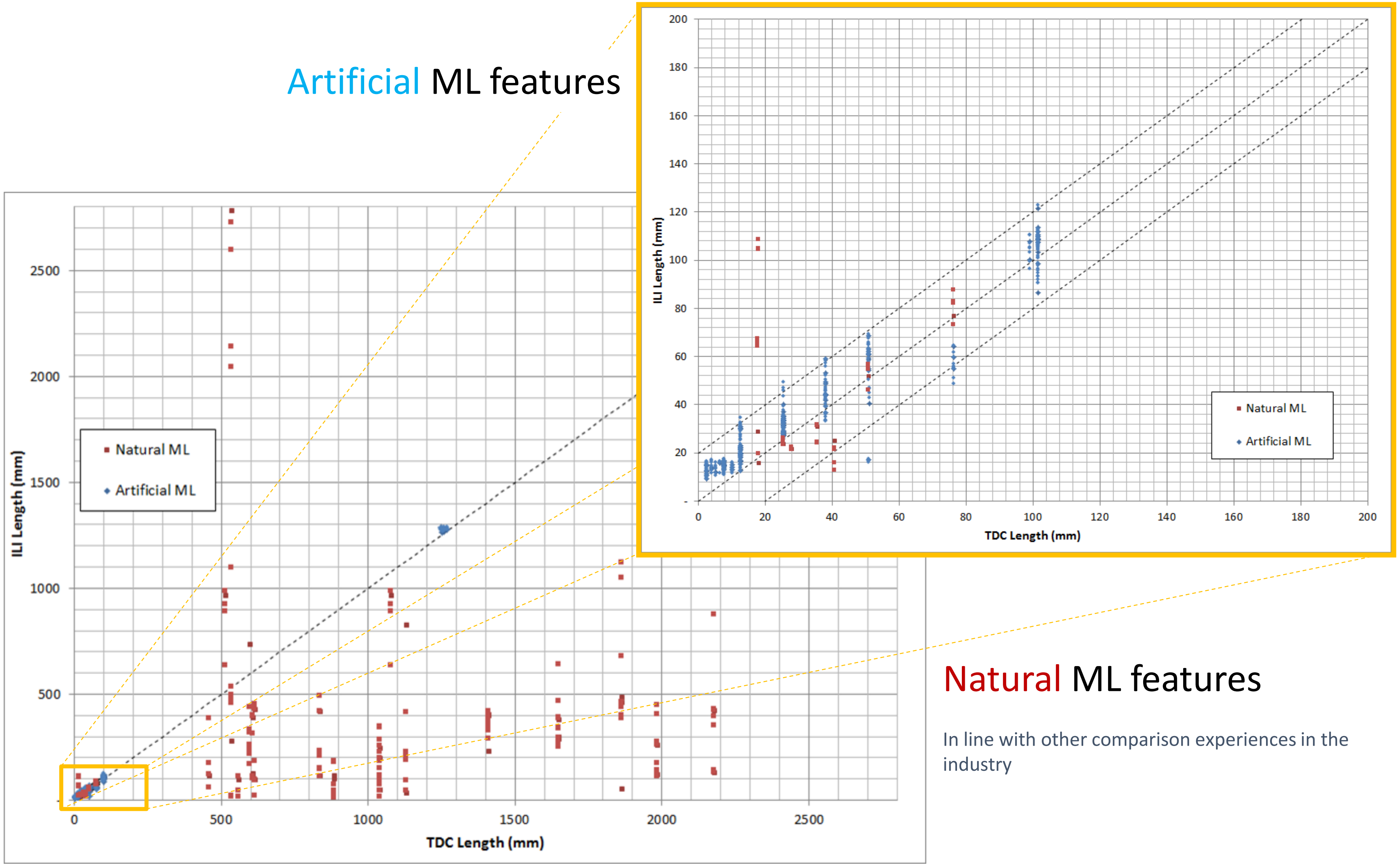
- 1,158 total pipe samples; pipe size range from 2" t

Facility - Pull-Test Winch

- High capacity (up to 40,000 lbf pulling force, 18,143 kgf)
- Software controlled (automatic run and speed control)
- Speed range 0.5 to 11 mph (0.2 to 5 m/s)

Example of Unity Plots (Metal Loss Length)

Artificial ML features

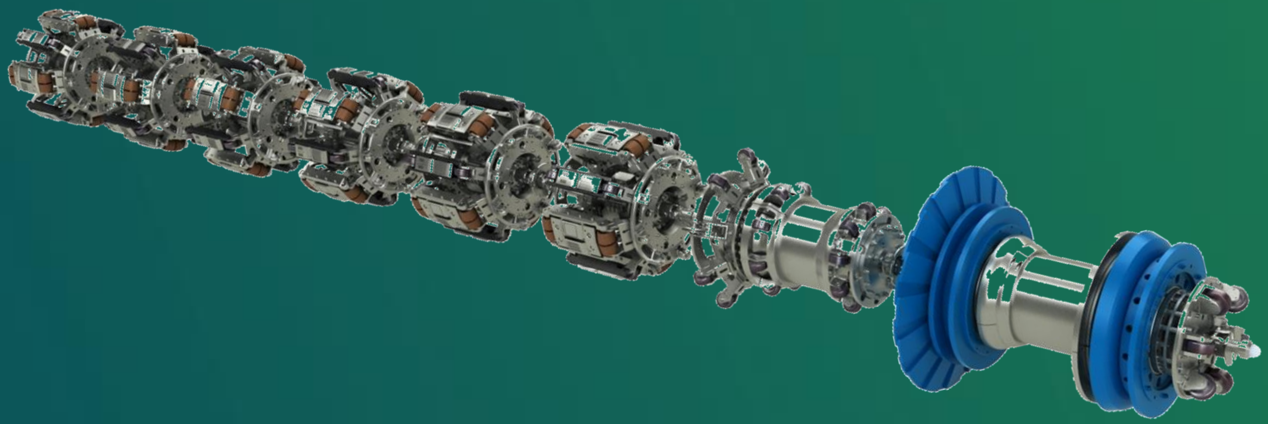


Natural ML features

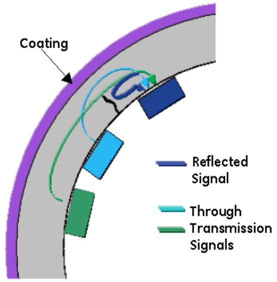
In line with other comparison experiences in the industry

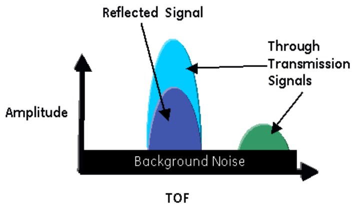
EmatScan
Crack Detection

most accurate crack detection
(gas)



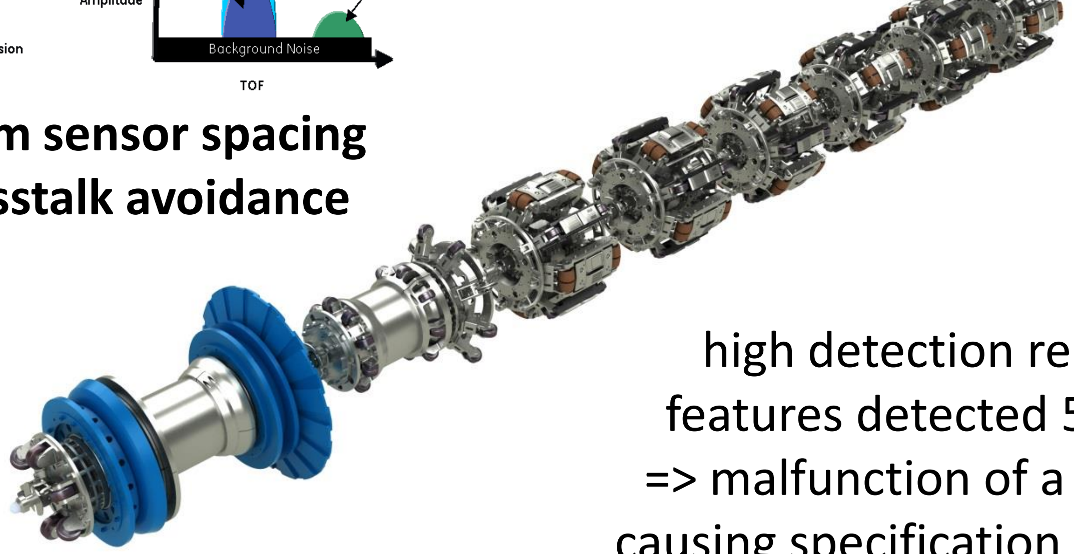
EmatScan^{TM} CD – Tool Overview



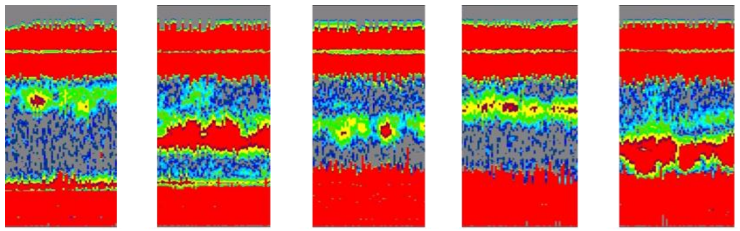


**optimum sensor spacing
for crosstalk avoidance**

6 independent sensor carriers
electronic, data acquisition, pendulum



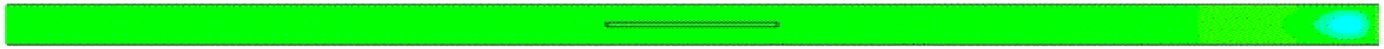
high detection redundany
features detected 5 – 7 times
=> malfunction of a sensor not
causing specification degradation



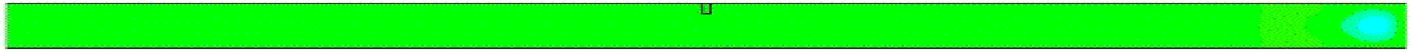
doubled amount of detection
sensor compared to 1st GEN tool
additional feature type
discrimination sensor

EmatScan™ CD – Wave Types

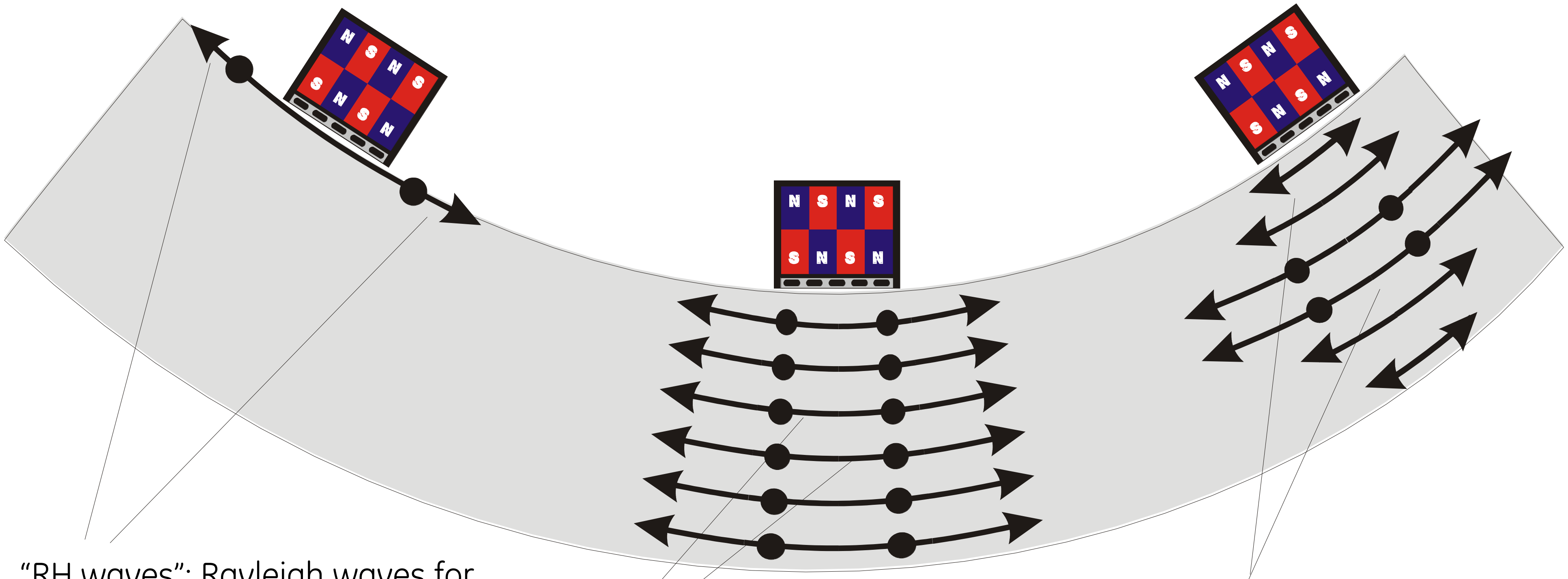
Lamination



Crack



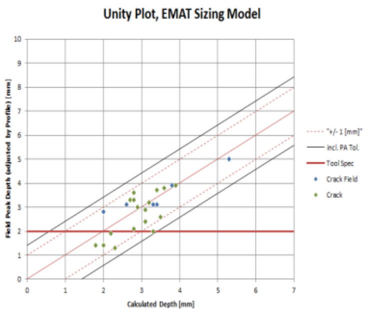
EmatScan^{TM} CD – Wave Types

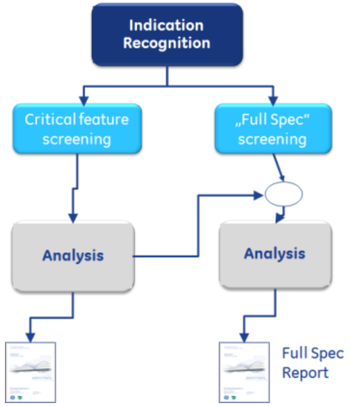


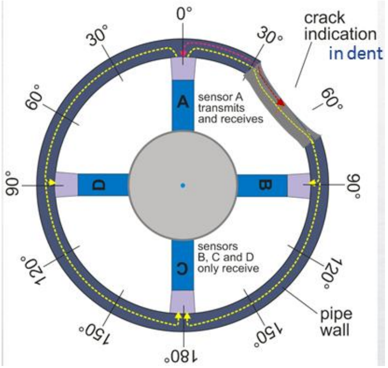
EmatScan™ CD

30“ – 36“

coupling free crack detection in gas pipelines







absolute depth sizing

screening for features which would fail hydrotest

securing POI performance by new discrimination sensor

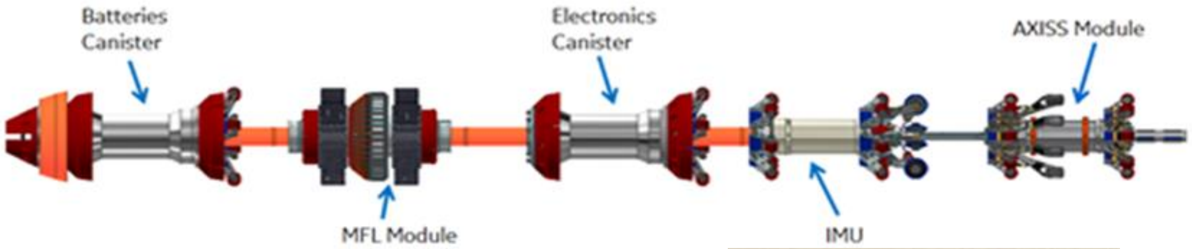
mechanical damage

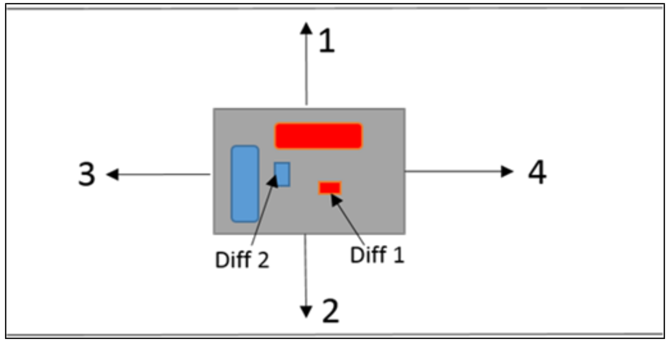
IPC2014-33451
IPC2016-64216

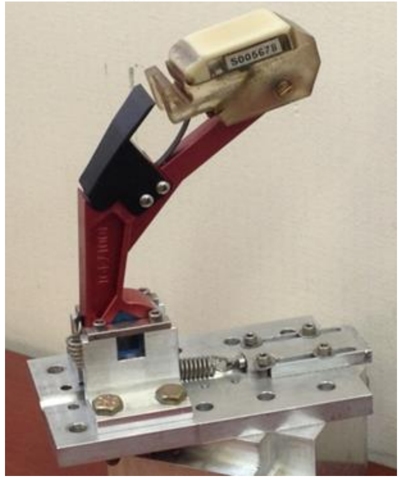
AXISS™
ILI AXIAL Strain Measurement
轴向应变检测

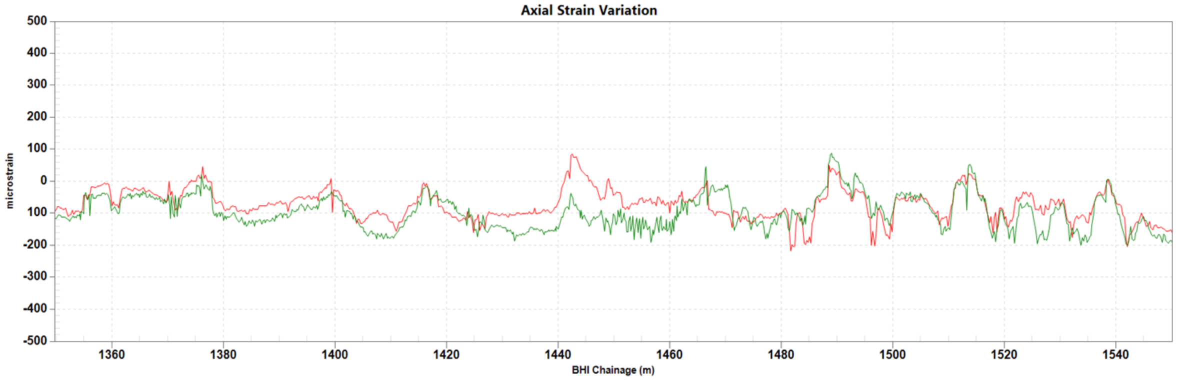
ILI based Axial Strain Technology轴向应变内检测技术

- First inline inspection for axial strain in 2010 第一次轴向应变内检测在2010年
- Applied strain sensor technology used in other industries to pipelines 应变传感器技术在其他工业领域早有应用
- Complete picture of the strain threats to a pipeline when coupled with bending strain与弯曲应变结合可以得到管道的完整应变状态
- Not site specific 并非特定于站点
- Proactively identifies areas subject to significant strain before they become injurious to the pipeline. 主动探测严重应变区域在它们对管道变成有害前
- Absolute strain values can be provided that can now be used in fitness for service decisions绝对应变值可以由于适应性评价









Thank You