(MFL) DATA ANALYSIS BASIC INTRODUCTION

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Rosen Europe B.V. · June 2022

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DEPARTMENT STRUCTURE

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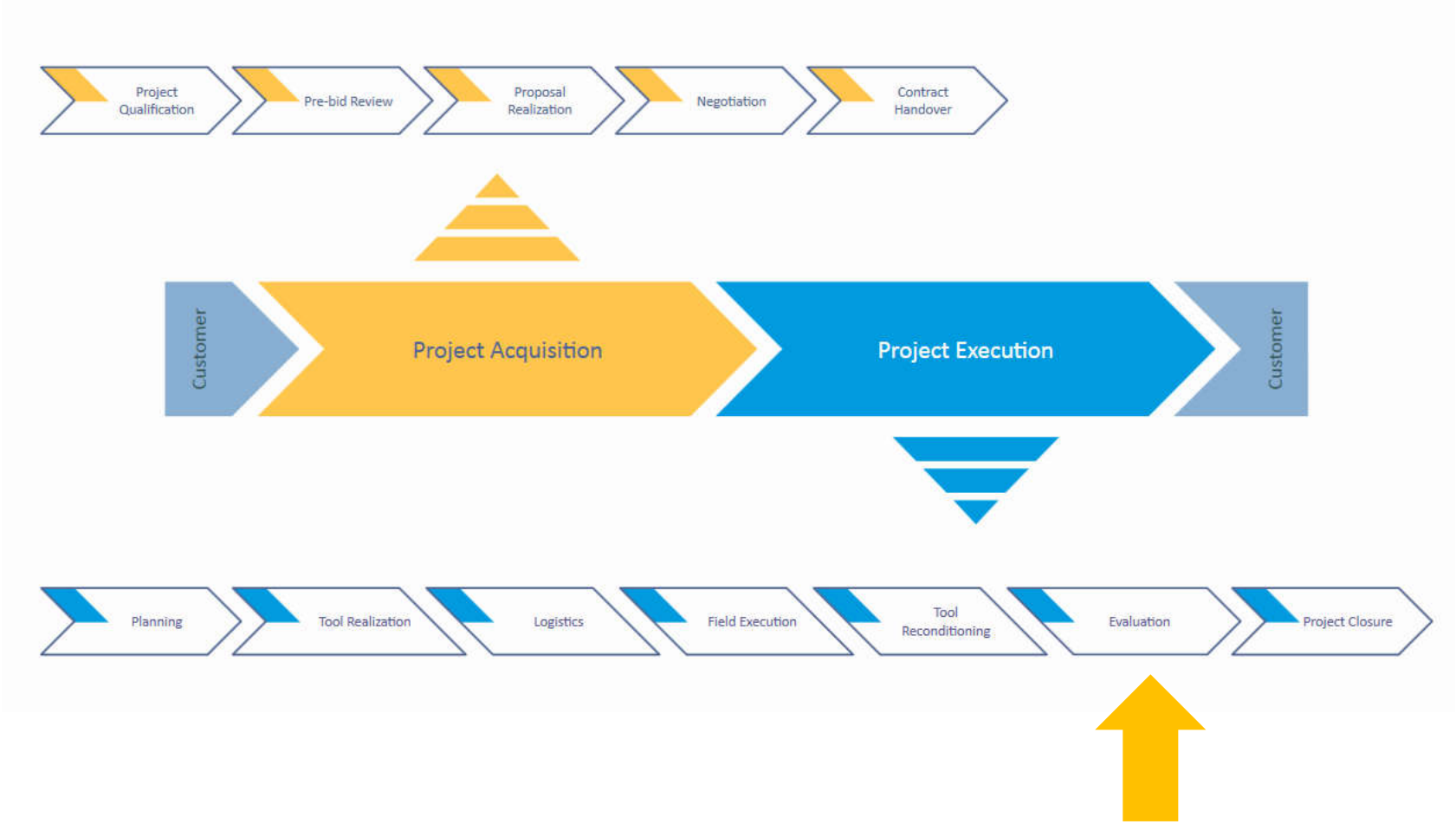
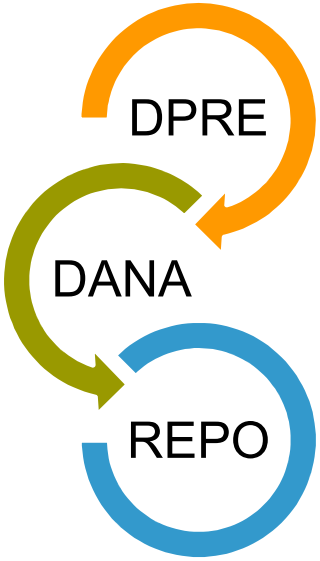


DEPARTMENT STRUCTURE



Data Preparation:
input → information + raw data
output → readable data + quality statement + databases

Data Analysis:
input → results from Data Preparation + reporting requirements
output → features ≥ reporting threshold + reference

Reporting:
input → results from Data Analysis + reporting requirements
output → Preliminary & Final Reports / RoSoft

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REPORTING SETUP AND SYSTEM COLLECTION

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During a Kick-Off-Meeting (performed after contract award) with the responsible Project Manager we:

- Discuss the reporting requirements and - if needed - check with client
- Commit deadlines based on contract

Based on the reporting requirements (part of contract / scope of work) we:

- Generate a project related Preliminary Report
- Generate a project related Final Report
- Generate a project related RoSoft setup

Most of the Final Reports are based on **POF** requirements.

REPORTING SETUP AND SYSTEM COLLECTION

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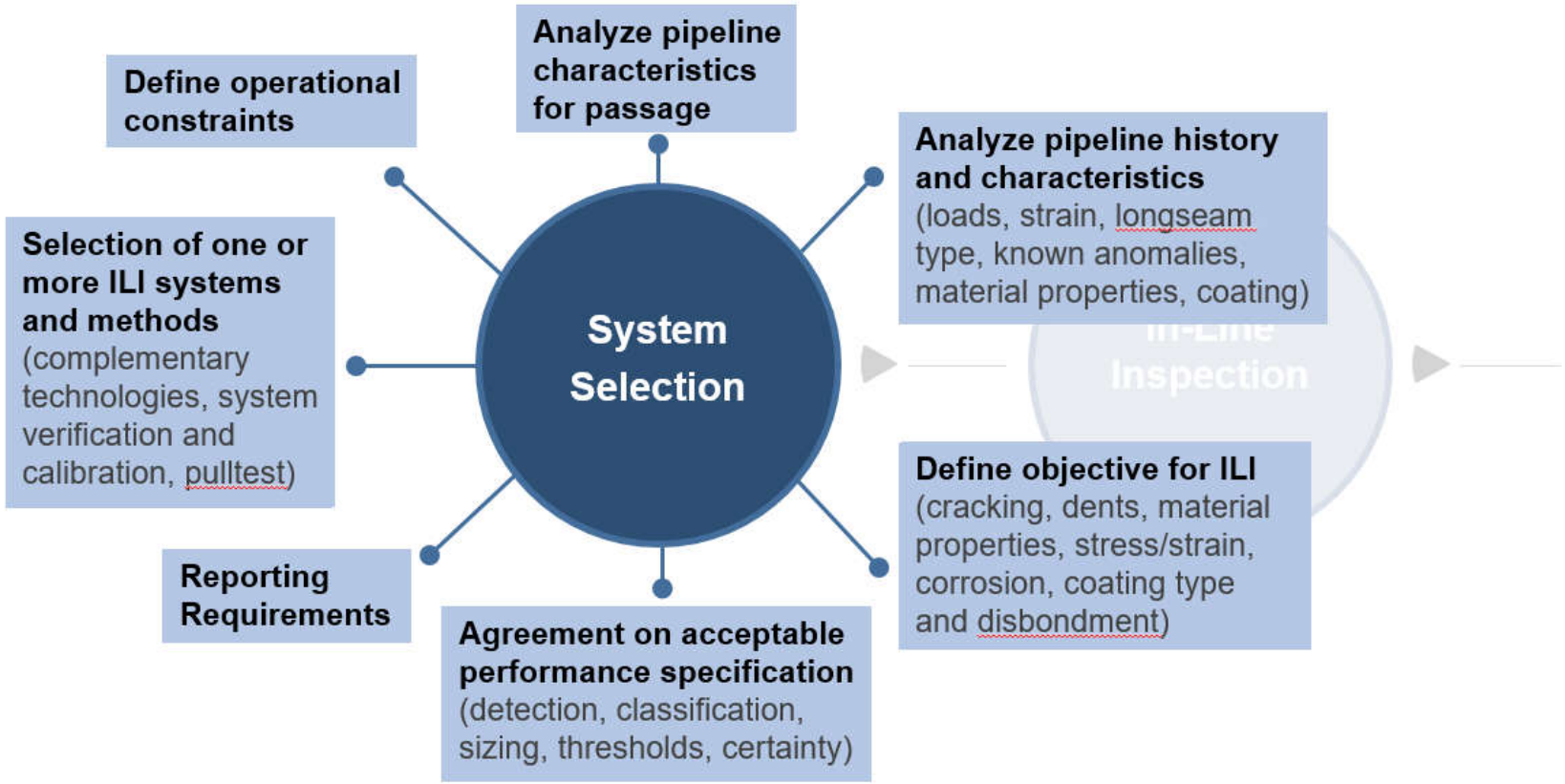
This should be the way how to collect system for costumers:



REPORTING SETUP AND SYSTEM COLLECTION

…but usually all is already clearly defined in the tender documents respectively in the ‘Scope of Works’, such as:

- Inspection technologies
- Reporting thresholds
- Contents of Preliminary and Final Reports
- etc….

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PIPELINE OPERATORS FORUM (POF)

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The major steps in the process of an in-line inspection of a pipeline are:

1. Pipeline cleaning and preparation - accessibility, negotiability, and propulsion
2. Work at site - the inspection
3. Data analysis and reporting

In the past different vendors have used their individual formats for these reports and sometimes they will still do this today. In order to make it easier to compare reports and findings from different vendors the pipeline industry has set up the Pipeline Operator Forum (POF).

A large number of operators from around the world, onshore and offshore, are members of this group. They have worked out recommendations on how the findings of ILI inspections should be reported.

The recommendations include a proposed structure, definitions of defect categories, the required general content as well as specific items a good quality report should contain.

www.pipelineoperators.org

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PROJECT INFORMATION PACKAGE

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The information package is received from operations which includes:

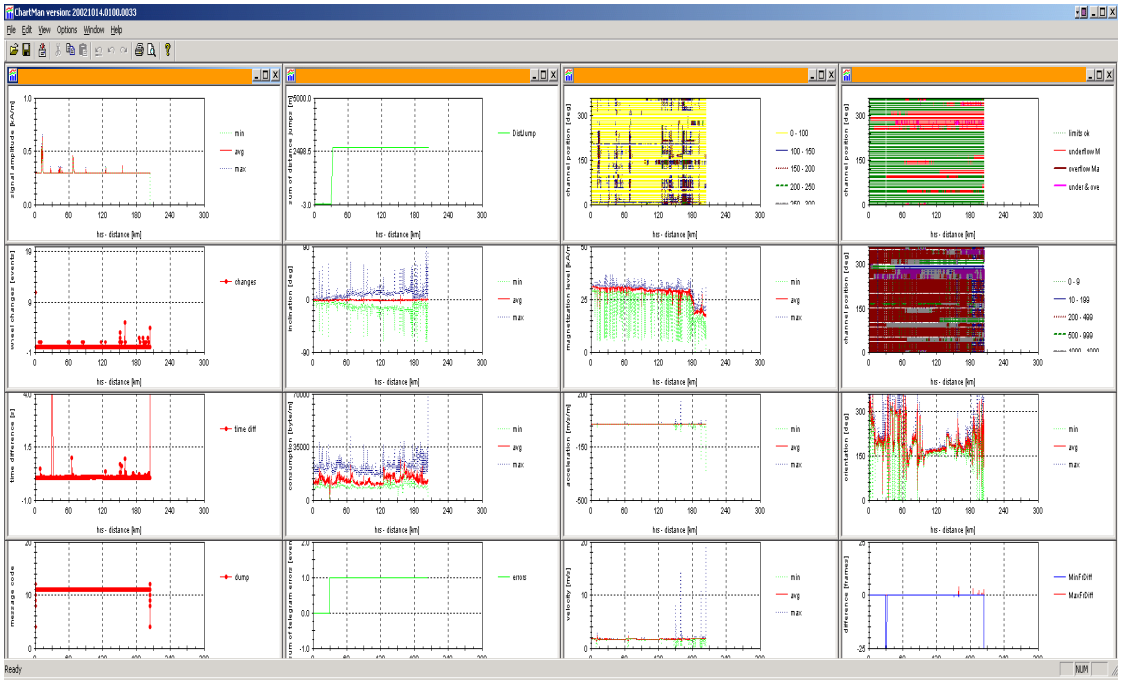
- Data on external Hard-Drives, Flash-Memory's etc.
  - Original Data from the Tool
  - Backup Data
- Above Ground Marker (AGM) / Magnet Marker (MM) Location Sheets
- Parameter Manuals
- Field Work Reports + Onsite Report
- Data Check Graphics
- Technical Questionnaire / Pipe Information

CONTENTS

DATA QUALITY CHECKS

The recorded data is checked for quantity and quality using several graphics such as:

- Memory Consumption
- Data Quantity
- Odometer Data
- Electronic Status
- Rotation
- Channel Statistics
- Speed
- Magnetization Level
- Calculated Wall Thickness

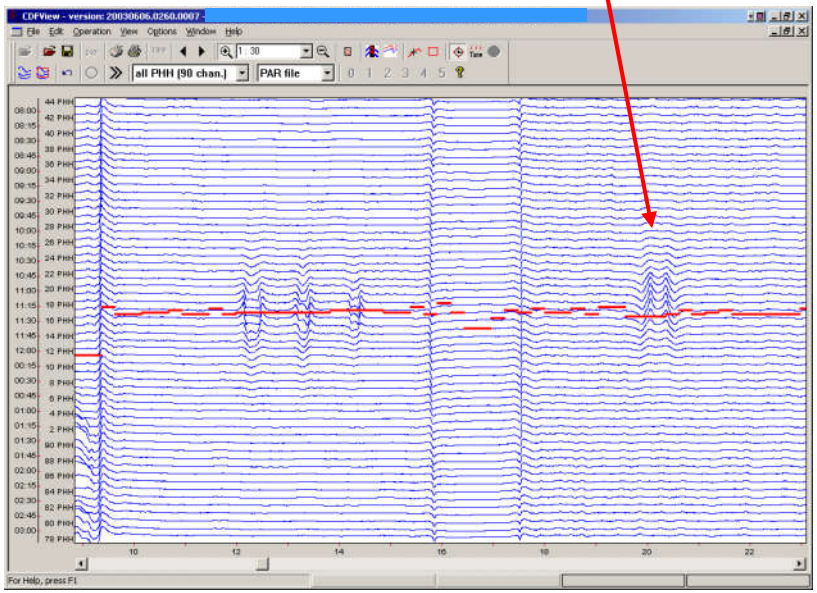


DATA QUALITY CHECKS

After checking the graphics, the data is transformed into a viewable signal format and calibrated.

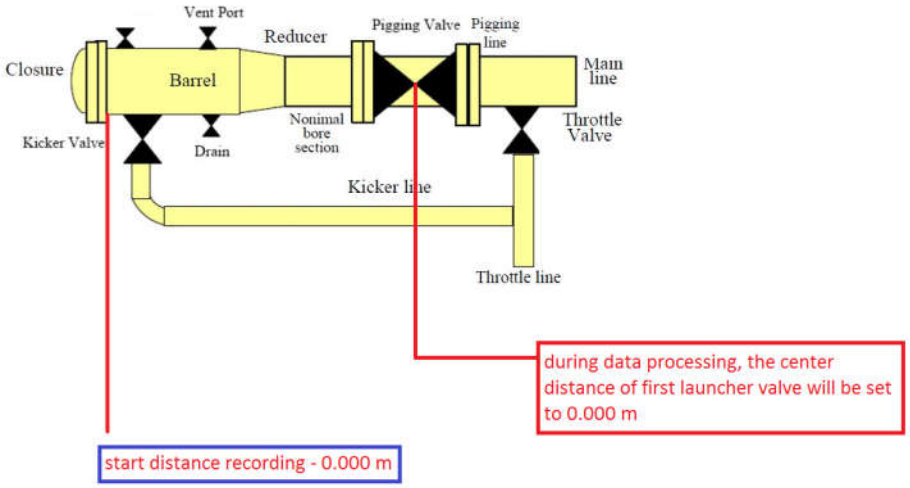
The data integrity and orientation are confirmed….

Magnet @ 12:00

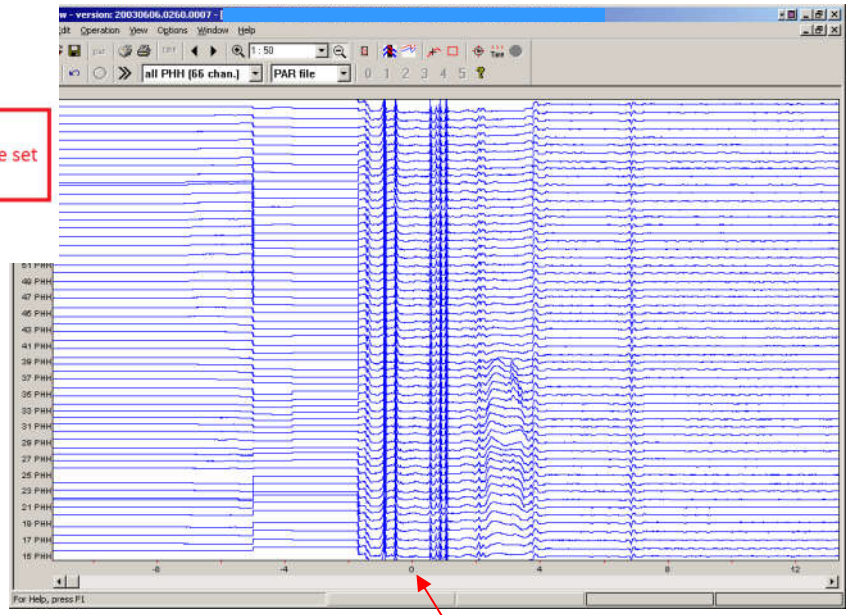


DATA QUALITY CHECKS

… and the launcher valve is typically set to 0.00 m



…this also explains, why often the first distances are negative….



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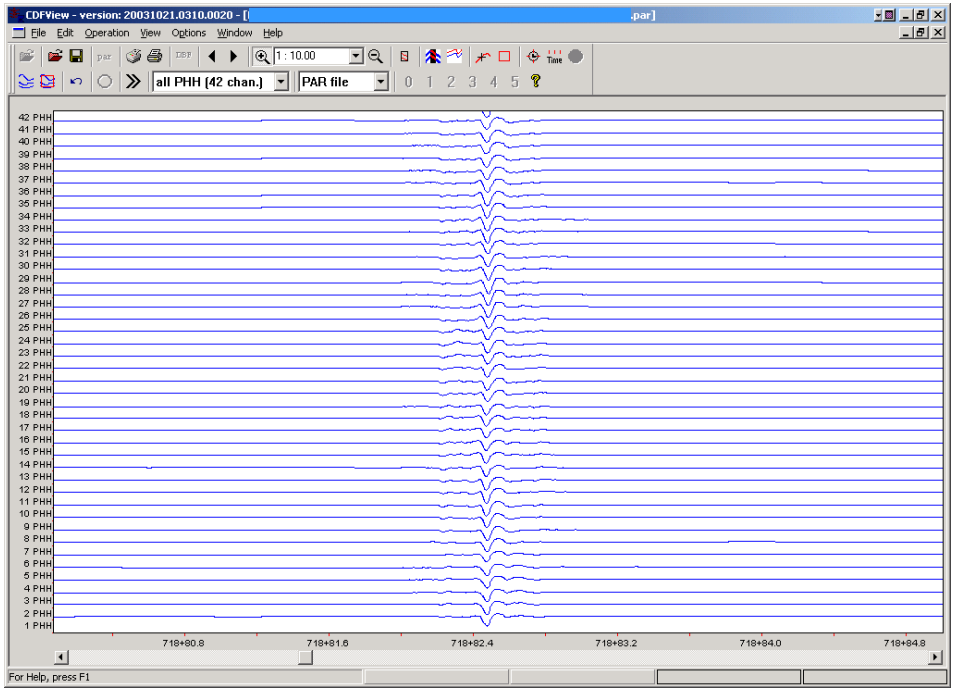
WELD AND FEATURE SEARCH

Software routines are executed to look for certain characteristics of the data. The software is searching for girth welds locations, longitudinal welds positions and the position of transition areas ‘spiral weld / girth weld’.

Additionally, for most tools also a bend search can be performed.



The weld search looks for negative and/or positive amplitudes occurring on a percentage of the sensor data across the circumference. When this criteria is met, an entry is made to a database with the corresponding log distance.

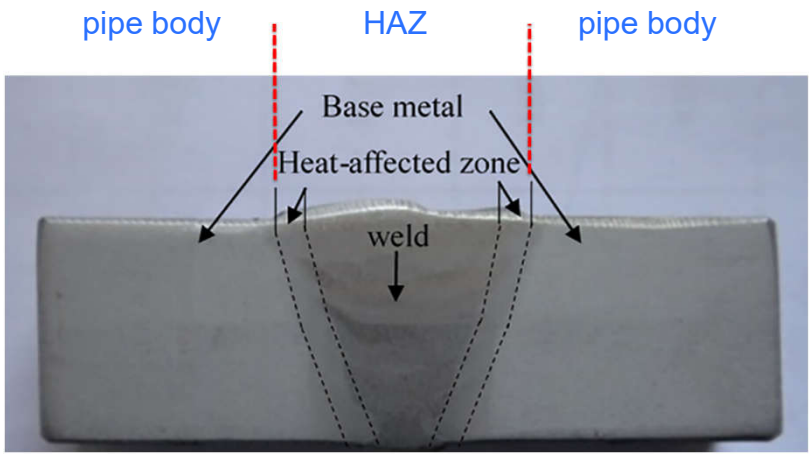
WELD AND FEATURE SEARCH

In pipelines, the term ‘defect / feature / anomaly’ refers to any unintentional deviation of parent pipe material due to corrosion, manufacturing, construction, or third party.

Features divided into two (2) location classes / categories (locclass):

- Weld (W) features → located in the weld / Heat Affected Zone (HAZ)
- Joint (J) features → located in the pipe body

Different specifications / accuracies depending on the location classification!



Since POF2009:

HAZ = Heat Affected Zone:
± 2A = if t > 10 mm otherwise
A = 10 mm

WELD AND FEATURE SEARCH

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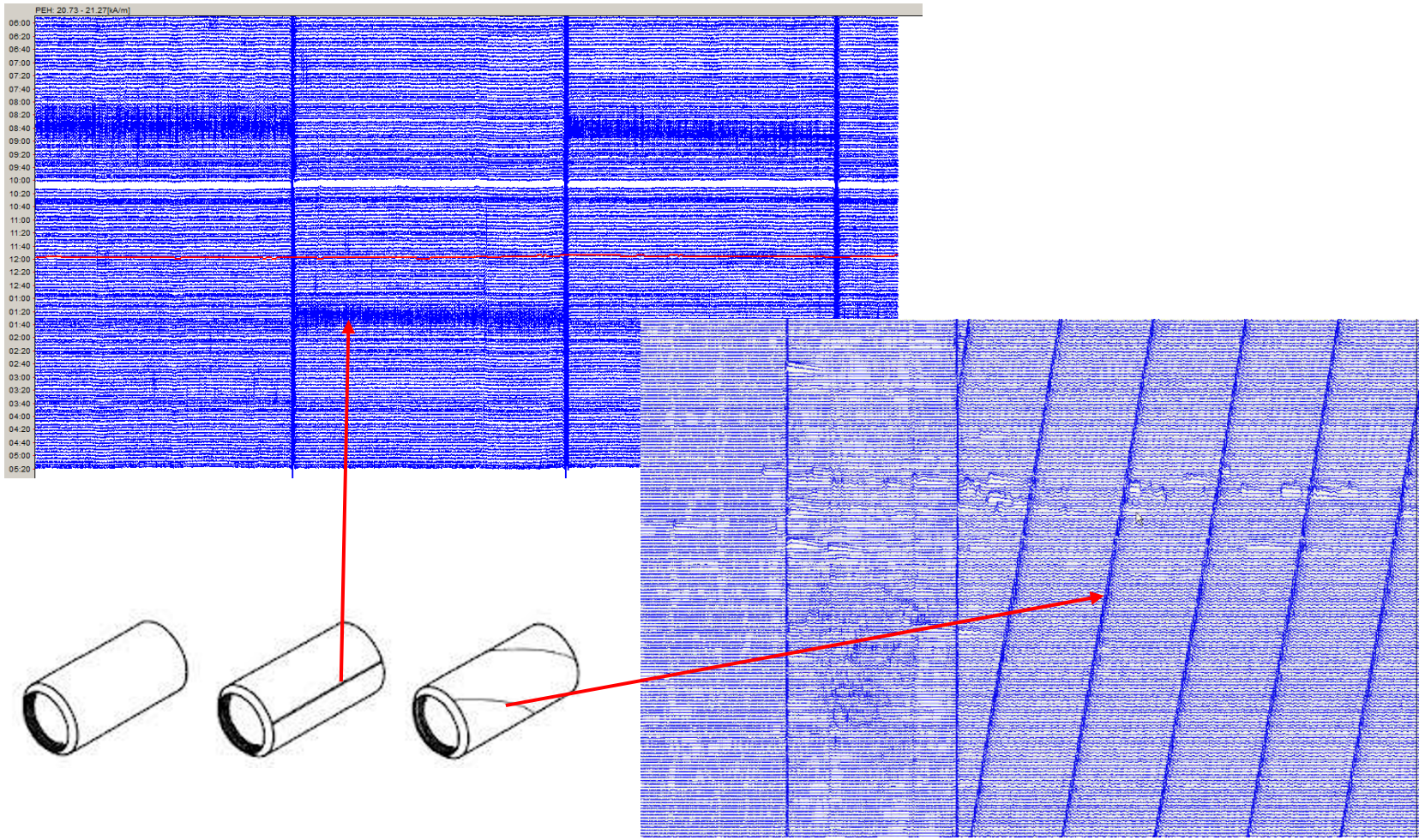
Example for longitudinal & spiral welds:



WELD AND FEATURE SEARCH

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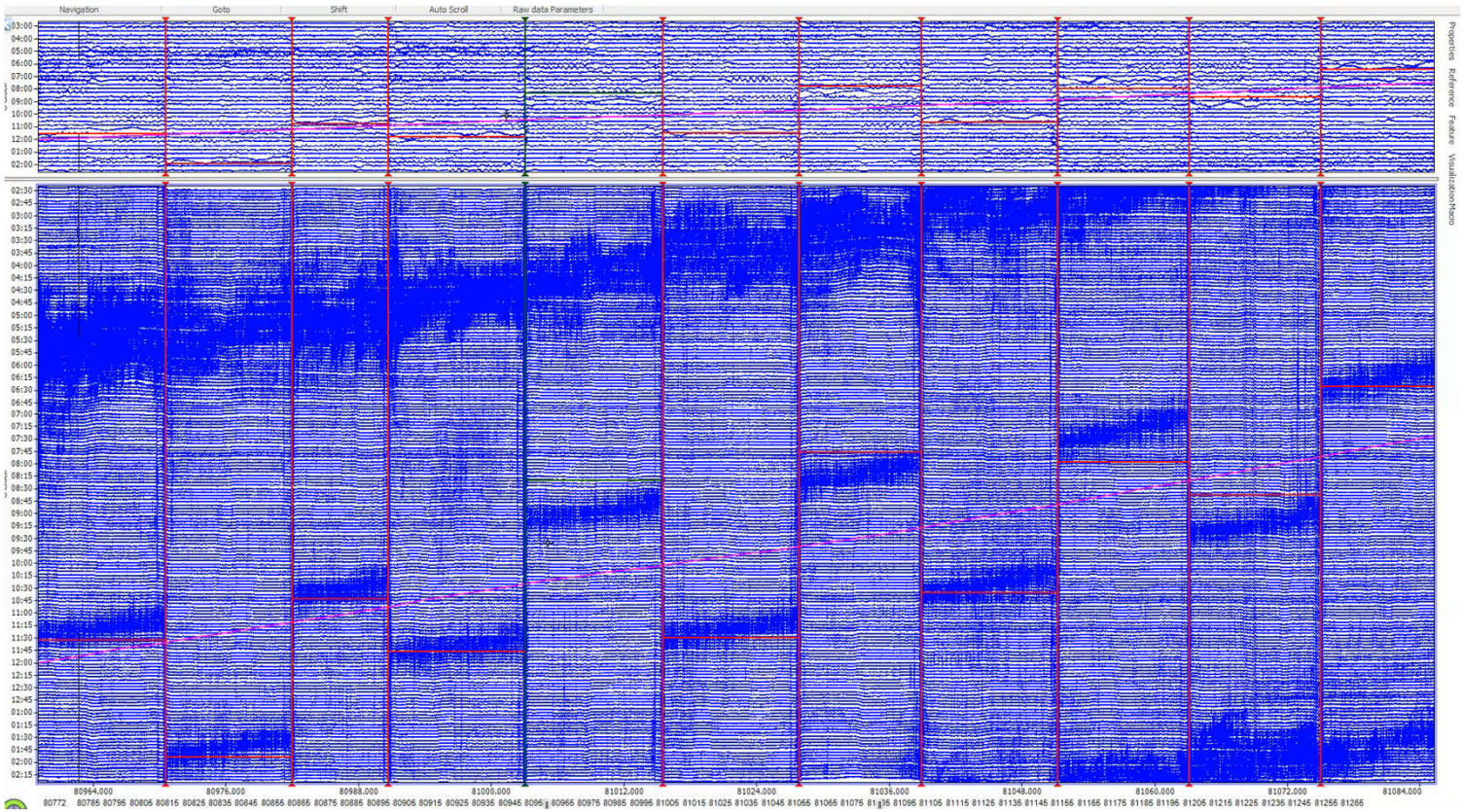
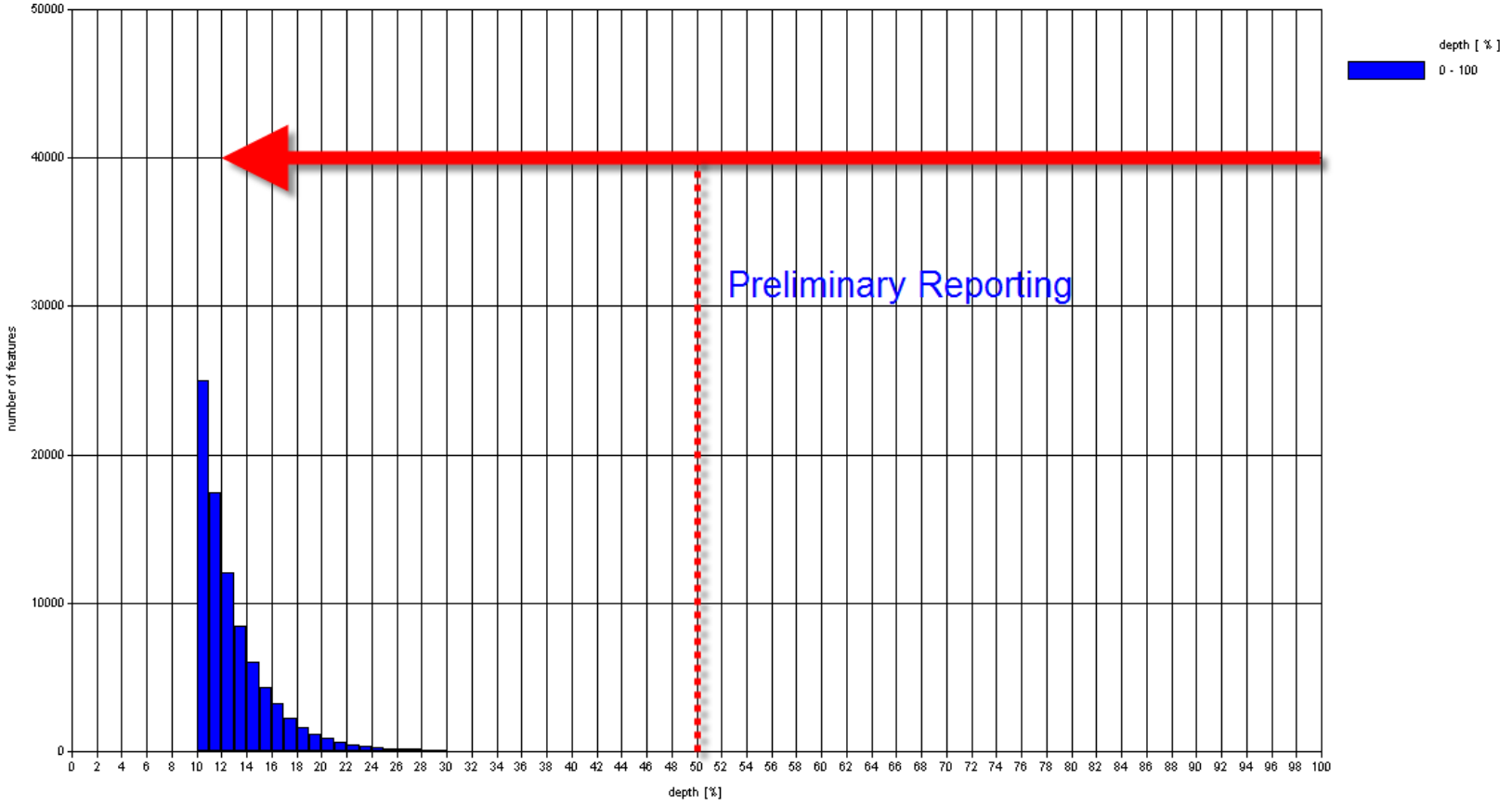
Example for longitudinal weld evaluations:



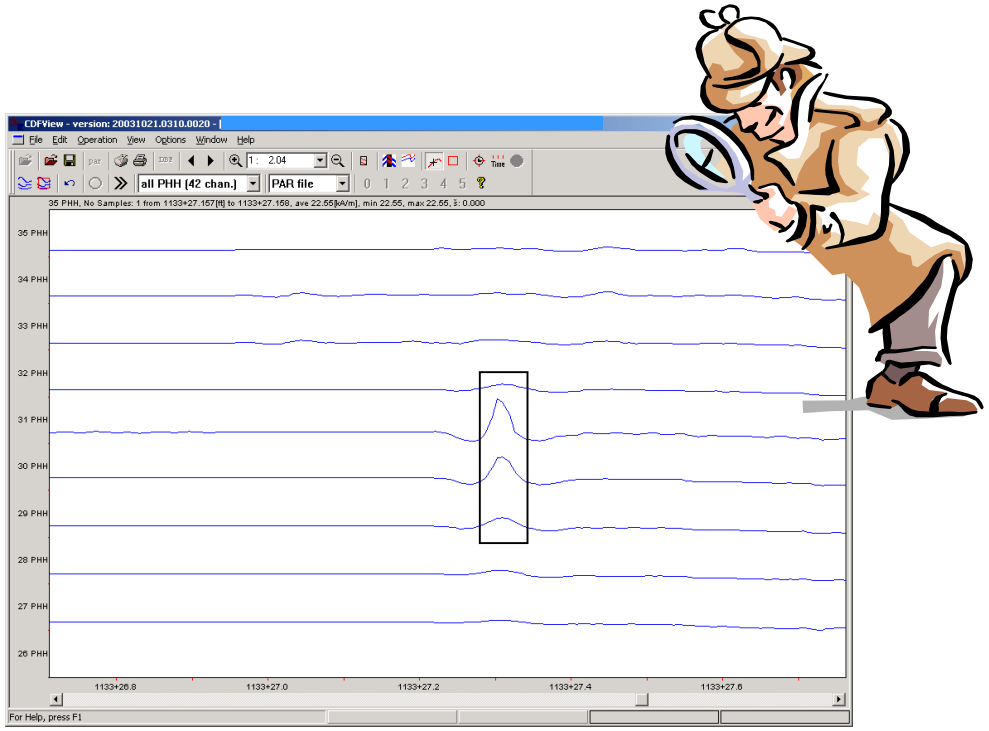
WELD AND FEATURE SEARCH

The general direction of feature evaluation: starting with the deepest and ending with the less deep metal loss features.

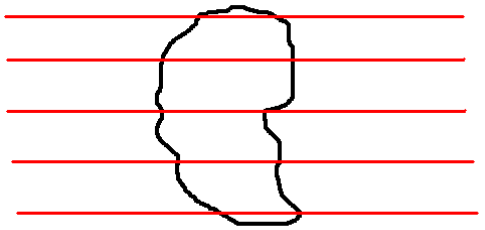


WELD AND FEATURE SEARCH

The feature search looks for positive amplitudes occurring on the recorded data of each sensor. After this, a following step assembles any adjacent positive amplitudes as suspect features at that specific log distance and degree. For XGP/EGP a similar search is applied to find IDAN's.



PHH sensors passing a feature:



WELD AND FEATURE SEARCH

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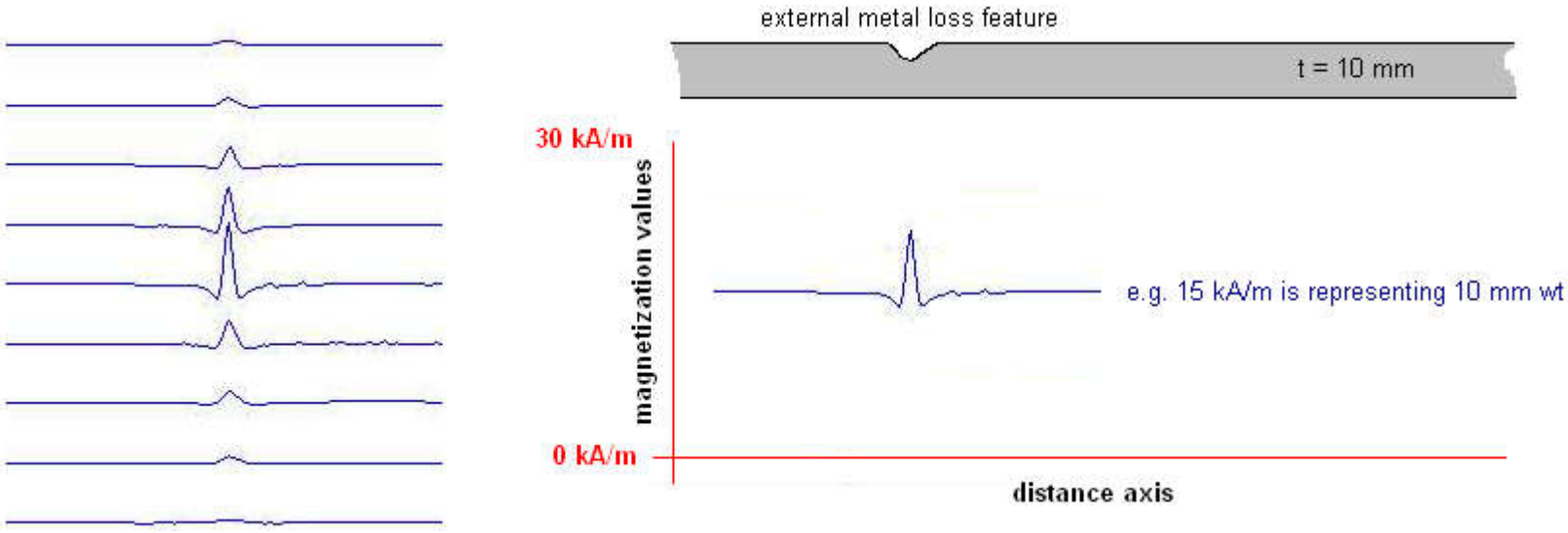
Signal Recognition



More metal → lower magnetization

Less metal → higher magnetization

WELD AND FEATURE SEARCH

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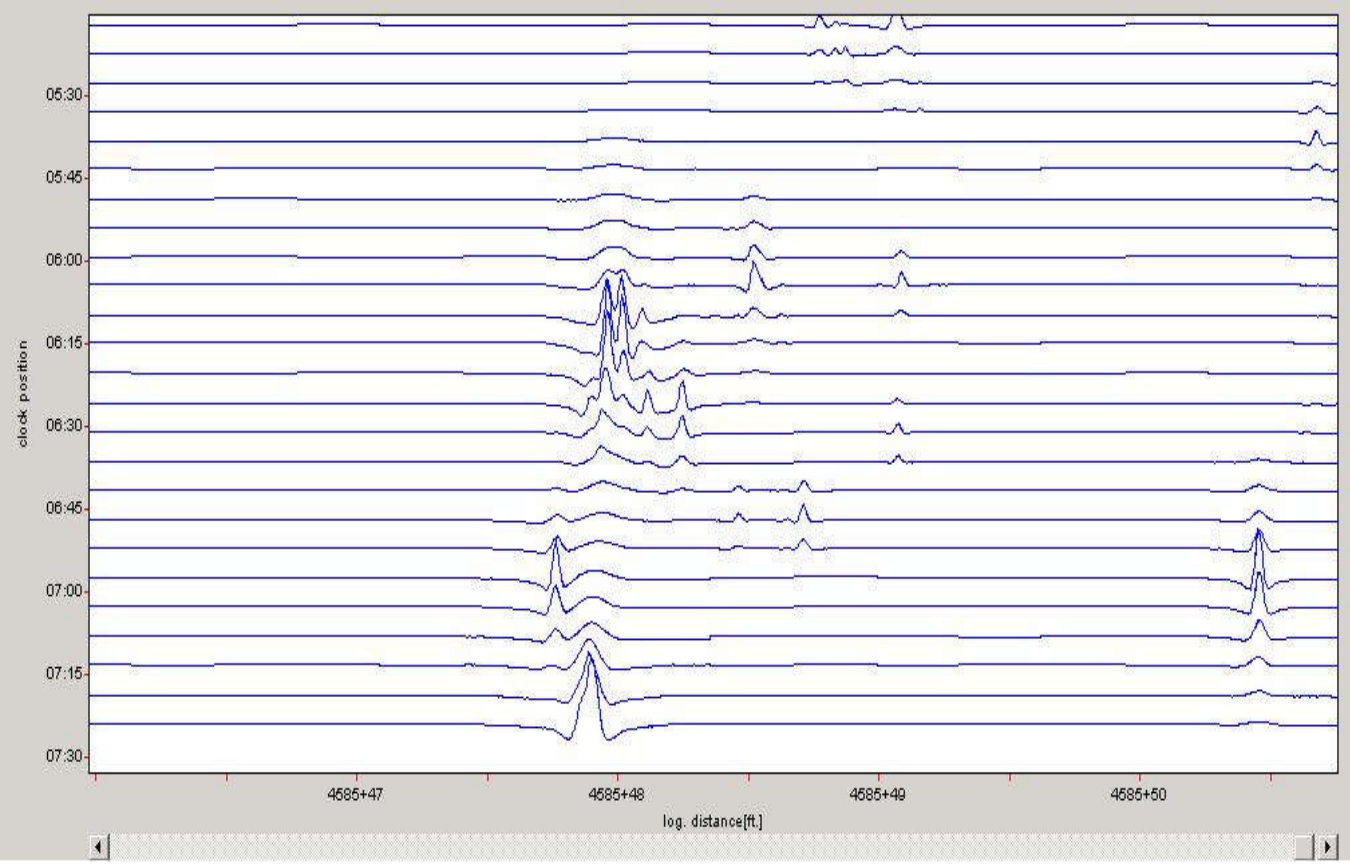
Corrosion, partly complex:



WELD AND FEATURE SEARCH

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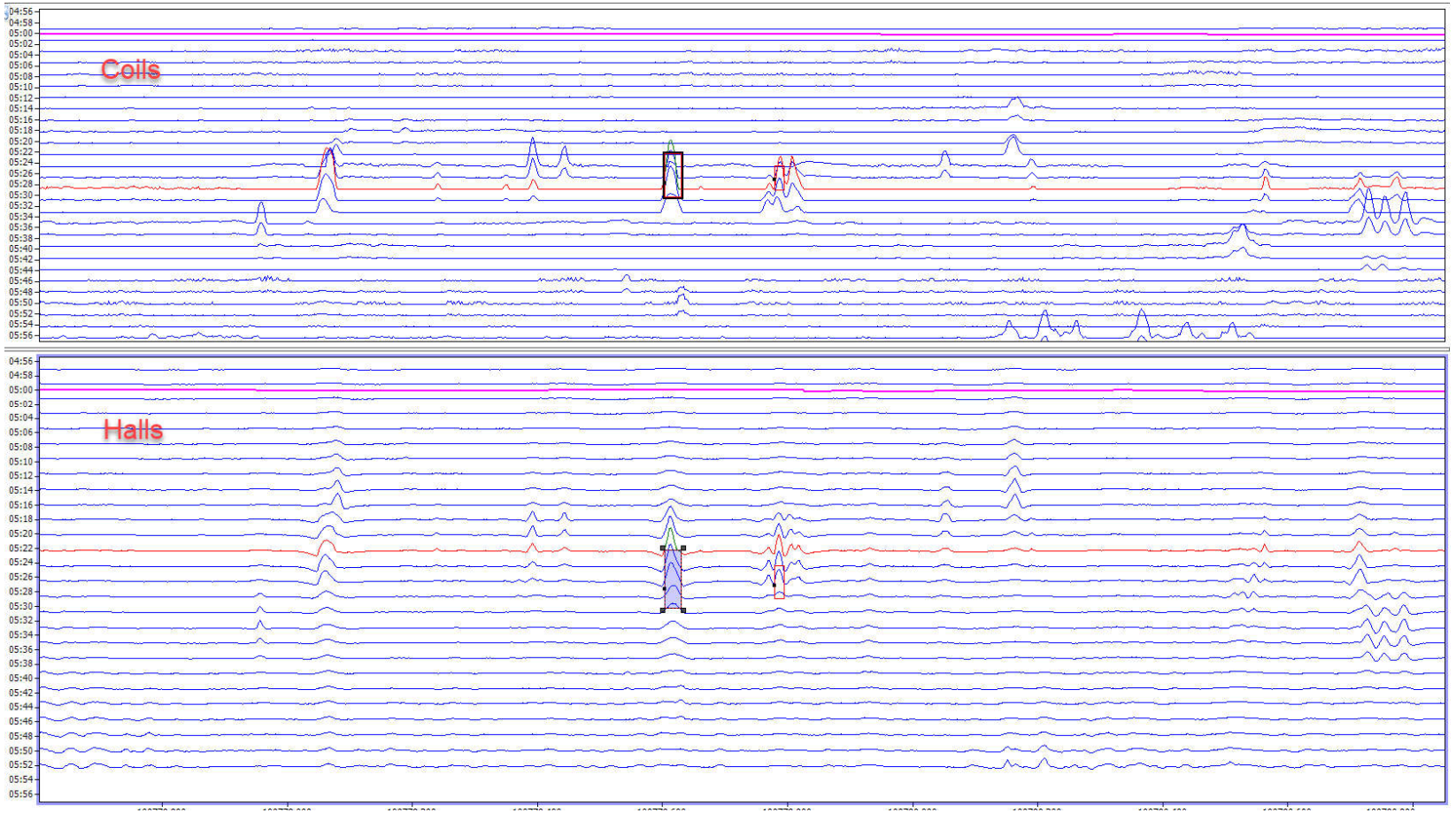
Corrosion, internal:



WELD AND FEATURE SEARCH

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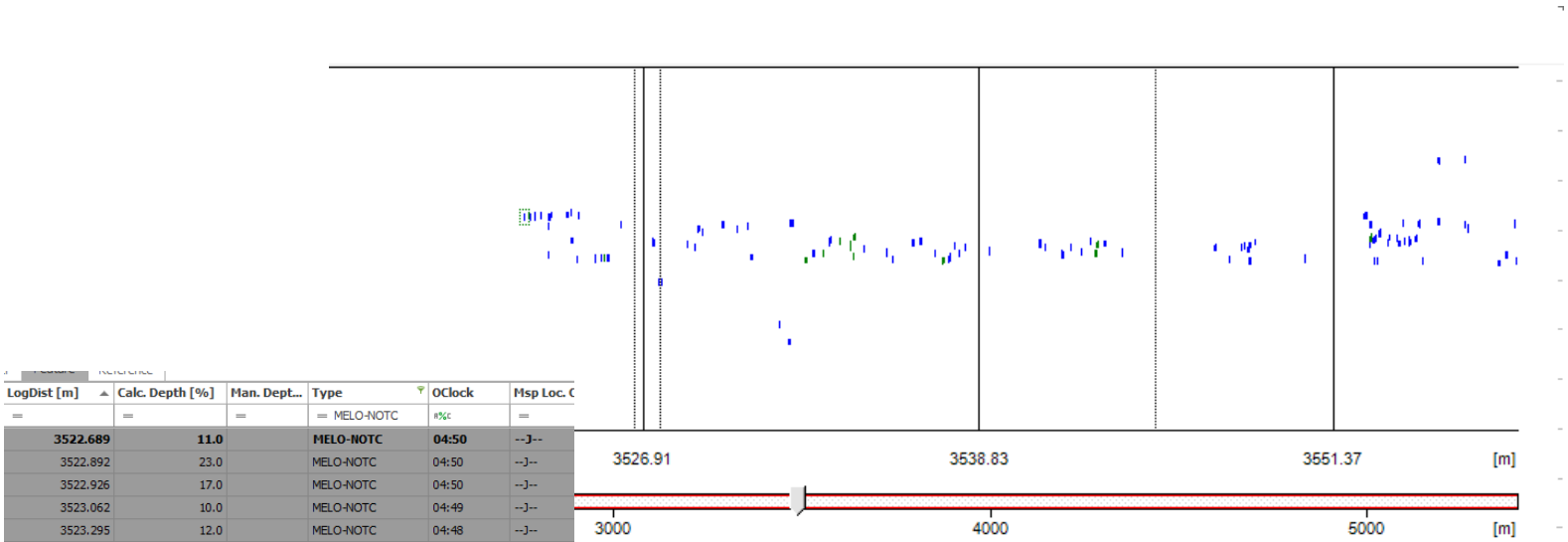
Corrosion band:



LogDist [m]	Calc. Depth [%]	Man. Dept...	Type	OClock	Msp Loc. C
=	=	=	= MELO-NOTC	#%c	=
3522.689	**11.0**		**MELO-NOTC**	**04:50**	**--J--**
3522.892	23.0		MELO-NOTC	04:50	--J--
3522.926	17.0		MELO-NOTC	04:50	--J--
3523.062	10.0		MELO-NOTC	04:49	--J--
3523.295	12.0		MELO-NOTC	04:48	--J--
3523.549	15.0		MELO-NOTC	06:06	--J--
3523.551	12.0		MELO-NOTC	05:09	--J--
3523.587	10.0		MELO-NOTC	04:51	--J--
3523.641	11.0		MELO-NOTC	04:46	--J--
3524.218	10.0		MELO-NOTC	04:46	--J--
3524.361	15.0		MELO-NOTC	04:41	--J--
3524.377	10.0		MELO-NOTC	05:37	--J--
3524.582	13.0		MELO-NOTC	06:15	--J--
3524.642	10.0		MELO-NOTC	04:47	--J--
3525.218	19.0		MELO-NOTC	06:13	--J--
3525.428	10.0		MELO-NOTC	06:11	--J--
3525.544	21.0		MELO-NOTC	06:12	--J--
3525.661	10.0		MELO-NOTC	06:12	--J--
3526.135	10.0		MELO-NOTC	05:04	--J--
3527.250	11.0		MELO-NOTC	05:40	--J--
3527.518	18.0		MELO-NOTC	07:00	--J--
3528.495	10.0		MELO-NOTC	05:44	--J--
3528.753	11.0		MELO-NOTC	05:50	--J--
3528.872	10.0		MELO-NOTC	05:14	--J--

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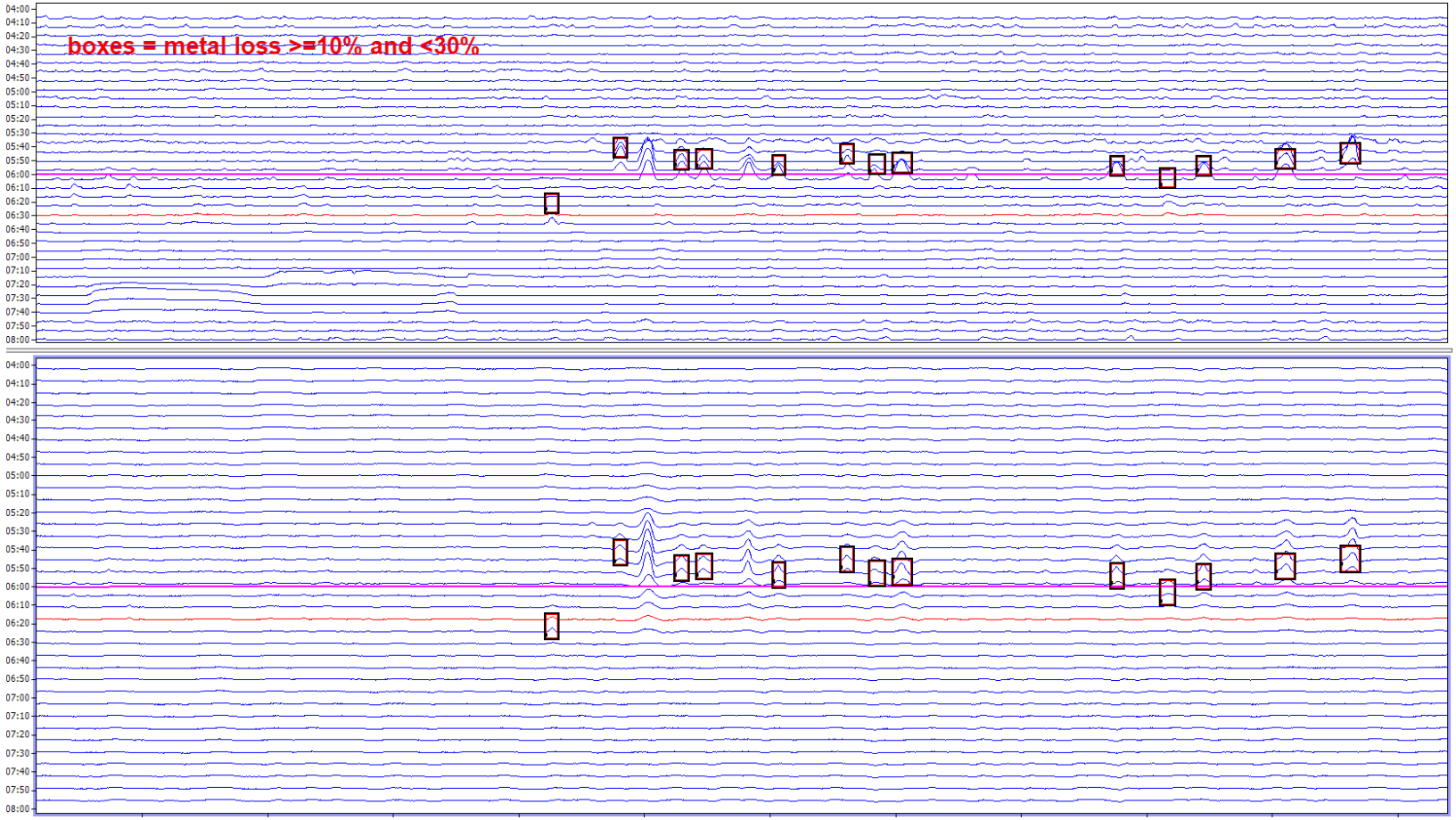
WELD AND FEATURE SEARCH

Corrosion:



WELD AND FEATURE SEARCH

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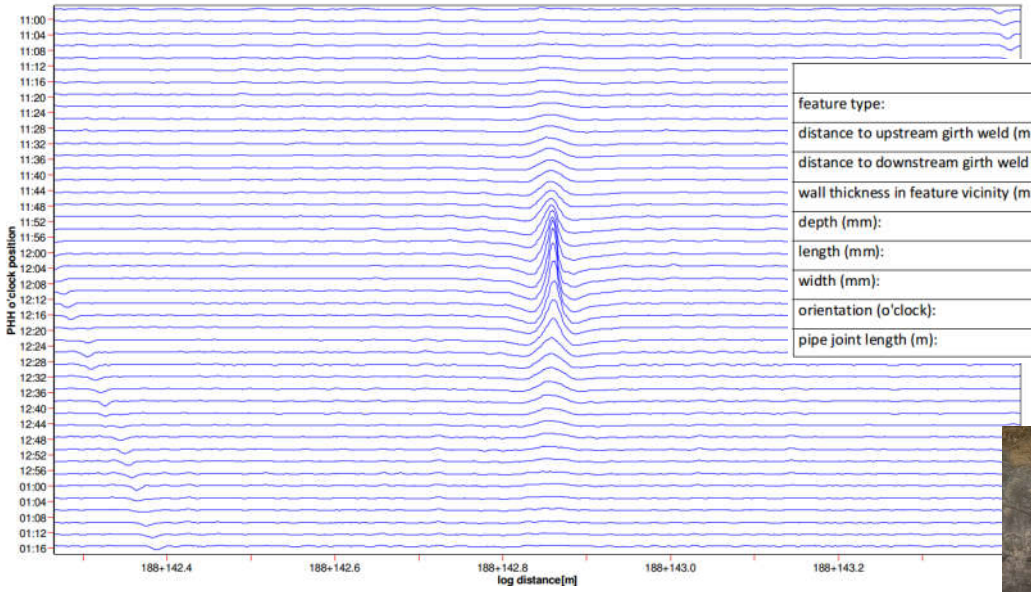
Corrosion:



	Predicted	verified
feature type:	**External corrosion**	**External corrosion**
distance to upstream girth weld (m):	**10.427 M**	**10.427 M**
distance to downstream girth weld (m):	**1.590 M**	**1.590 M**
wall thickness in feature vicinity (mm):	**6.40 MM**	**5.21MM to5.44MM**
depth (mm):	**78 %**	**85%**
length (mm):	**34 MM**	**40 MM**
width (mm):	**29 MM**	**40 MM**
orientation (o'clock):	**00:02 h**	**00:02 h**
pipe joint length (m):	**12.017 M**	**12.017 m**

WELD AND FEATURE SEARCH

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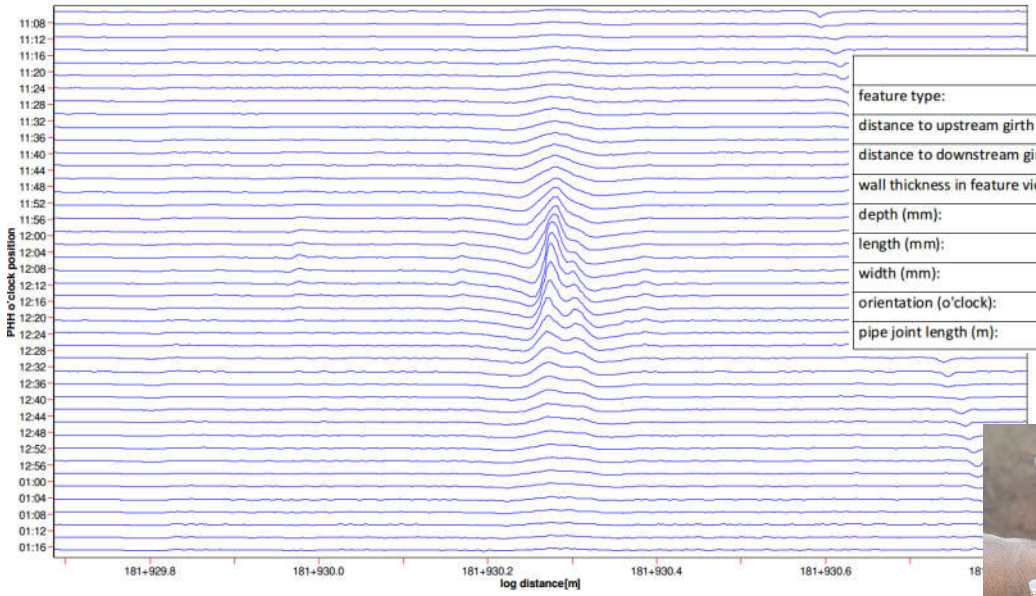
Corrosion:



	Predicted	Verified
feature type:	**External corrosion**	**External corrosion**
distance to upstream girth weld (m):	**1.030 M**	**1.030 M**
distance to downstream girth weld (m):	**11.042 M**	**11.042 M**
wall thickness in feature vicinity (mm):	**6.40 MM**	**5.15MM to5.83MM**
depth (mm):	**78 %**	**88%**
length (mm):	**42 MM**	**70 MM**
width (mm):	**27 MM**	**60 MM**
orientation (o'clock):	**00:08 h**	**00:08 h**
pipe joint length (m):	**12.072 M**	**12.072 m**

WELD AND FEATURE SEARCH

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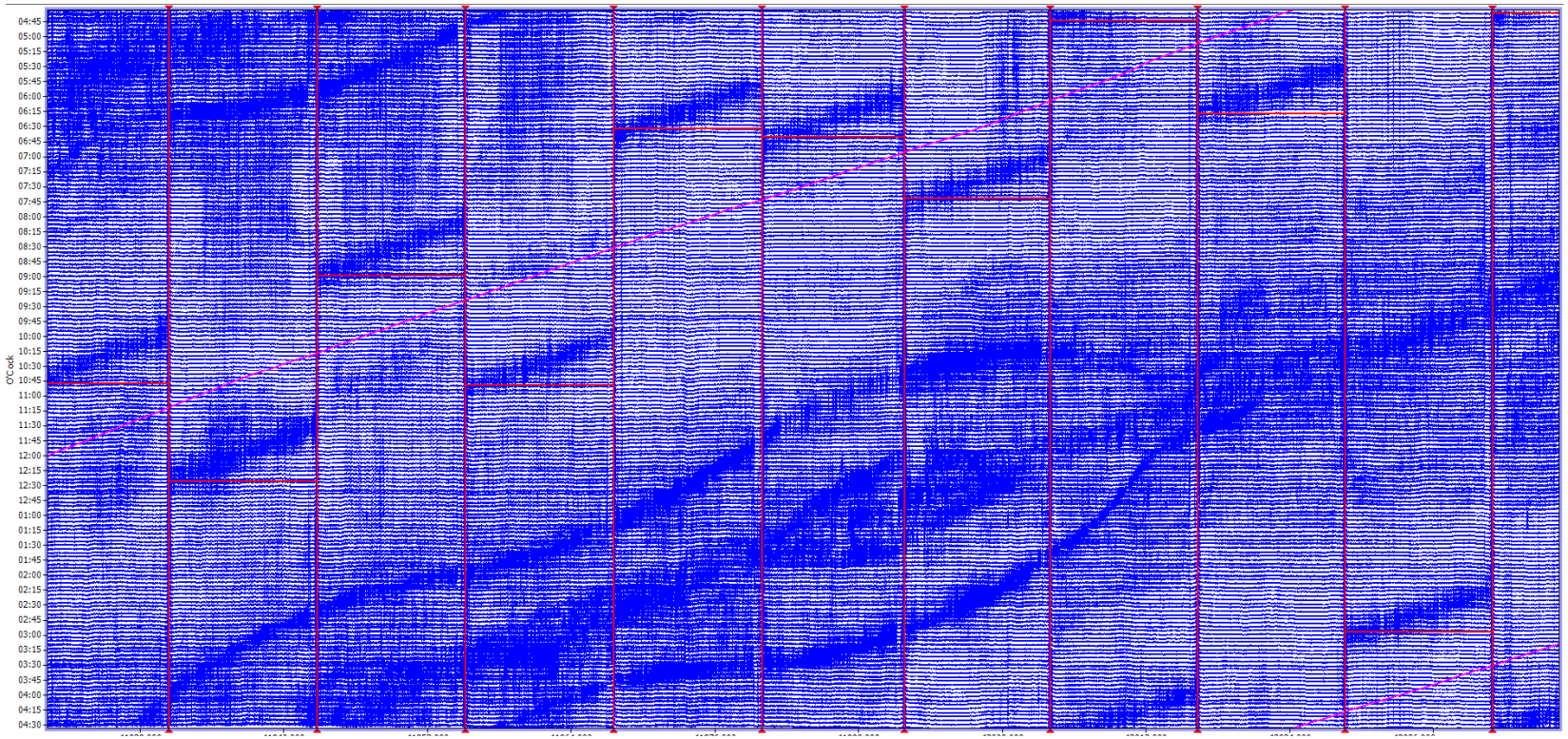
Corrosion in long seam pipes:



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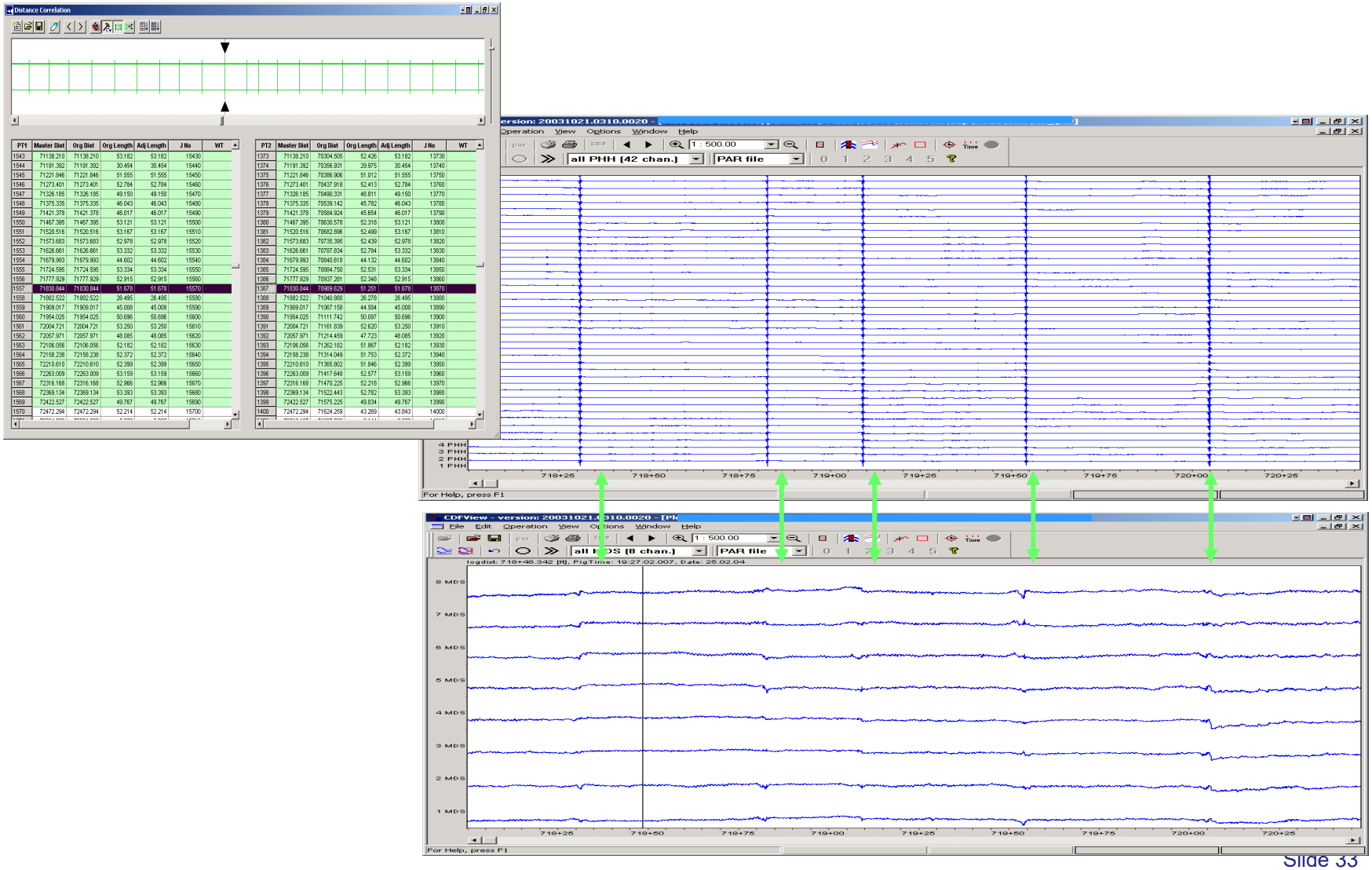
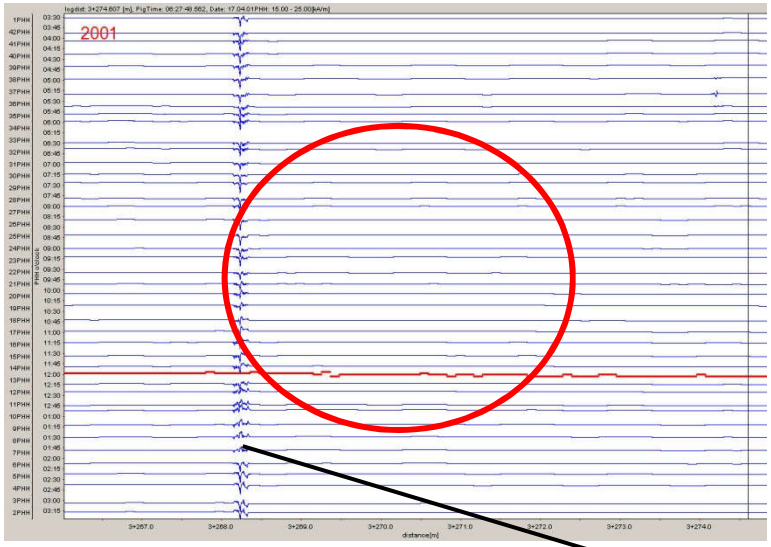
DATA DISTANCE CORRELATION

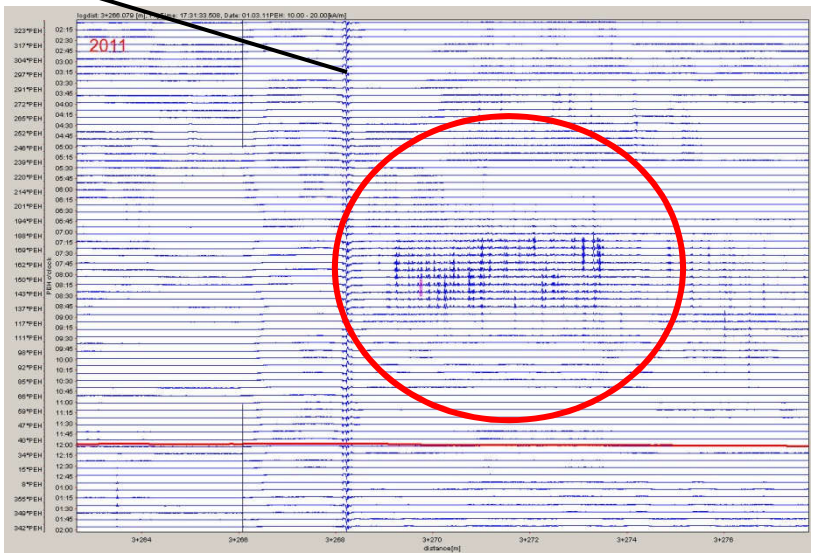


DATA DISTANCE CORRELATION

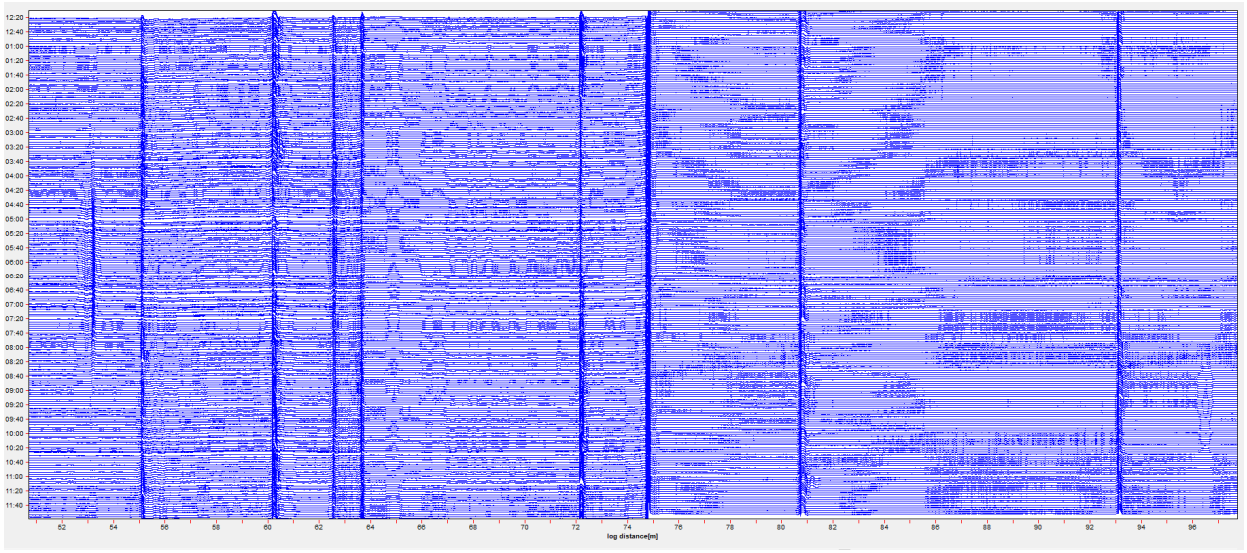


CDP data
recorded in 2001

CDP data
recorded in 2011

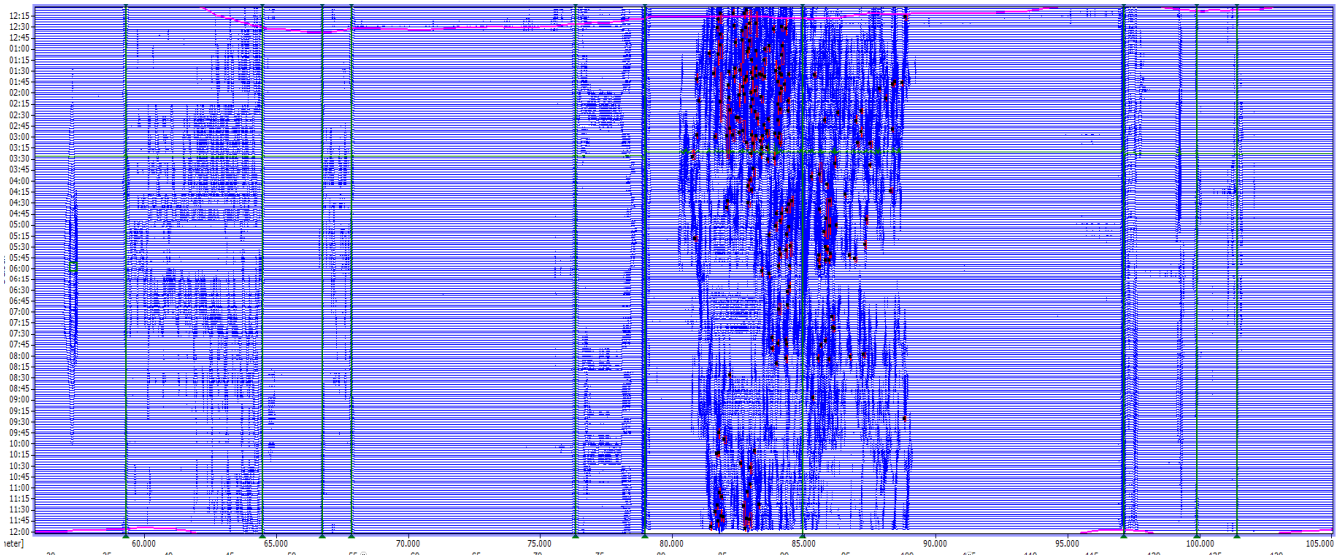


DATA DISTANCE CORRELATION



MFL-A data 2012:

no defects



MFL-A data 2020

totally corroded up to 85%

external corrosion

(coating failure)

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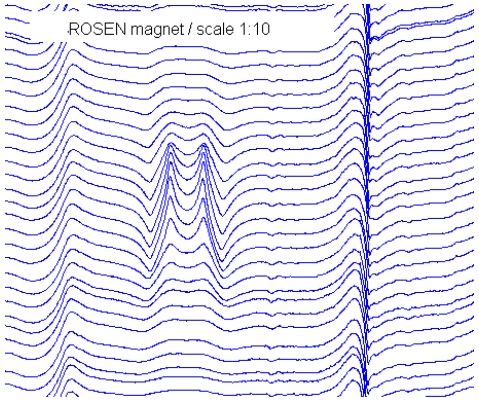
MARKER EVALUATION

- Above Ground Markers (AGM) are used to facilitate the digging activities.
- The AGMs are placed above ground on top of the pipeline during the pig run.
- The AGMs and the tool are synchronized before and after the run.
- The AGM records the tool passage at a certain time. That time is then compared to the tool time and the distance where this time occurred.
- MMs (Magnet Markers) are directly fixed to the pipe and are visible in the MFL data (CDP/AFD).



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RESULT DATABASES

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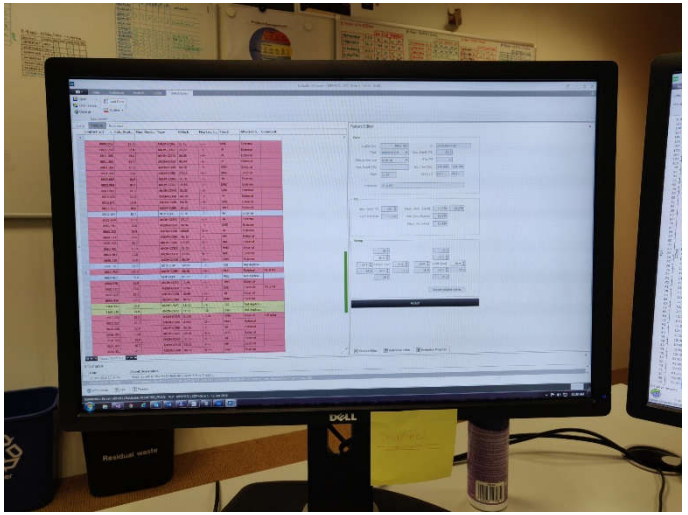
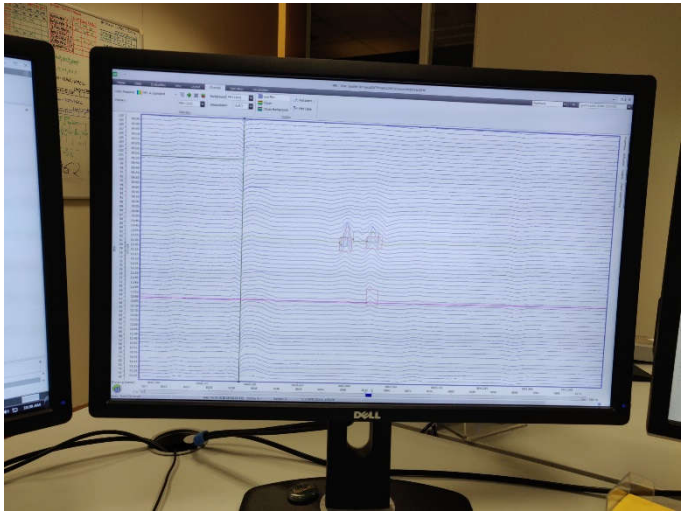
Data Analyst Workplace:

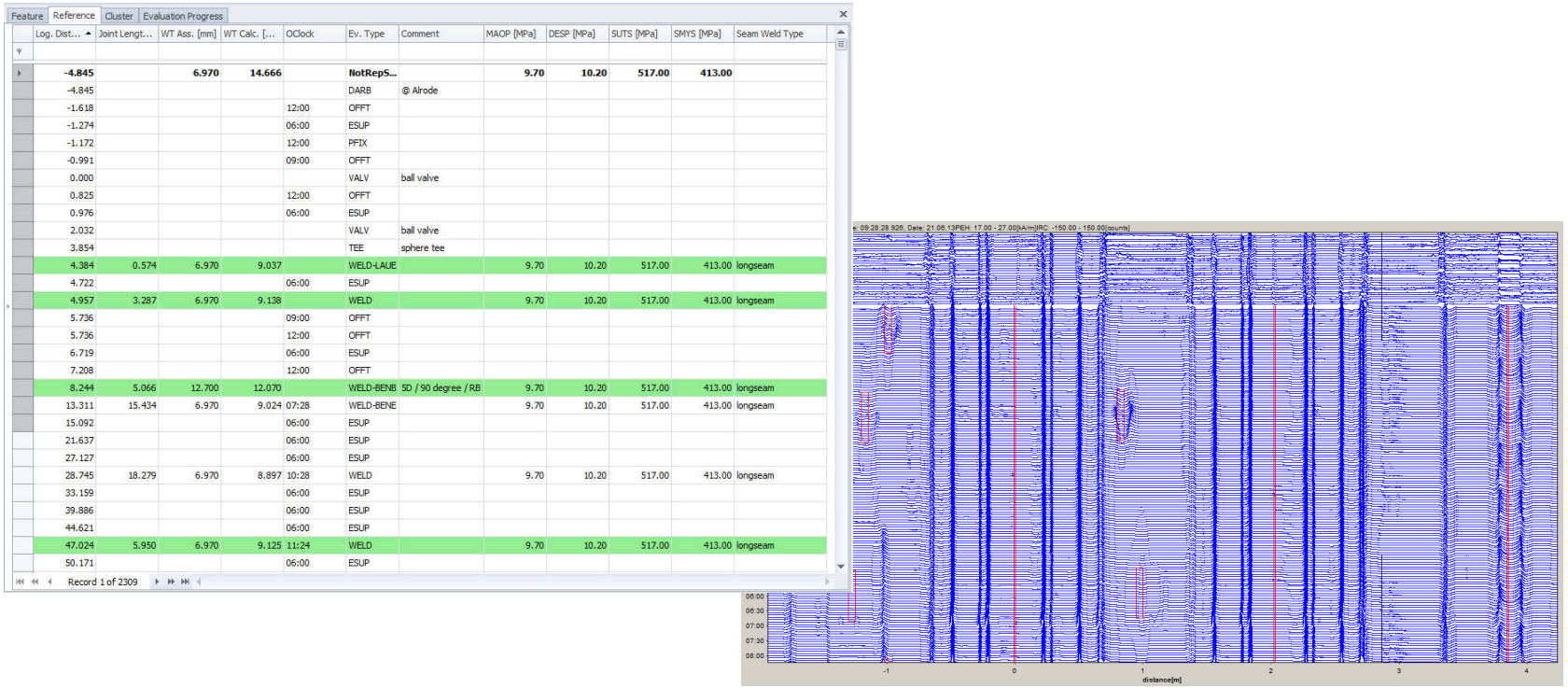




RESULT DATABASES

The weld search and feature search result in two primary databases that will be used to identify all events detected during the inspection.

The ‘**reference**’ database includes all detected weld locations and eventually contains all installations, long seam orientation, spiral weld connection, bends and markers as well.



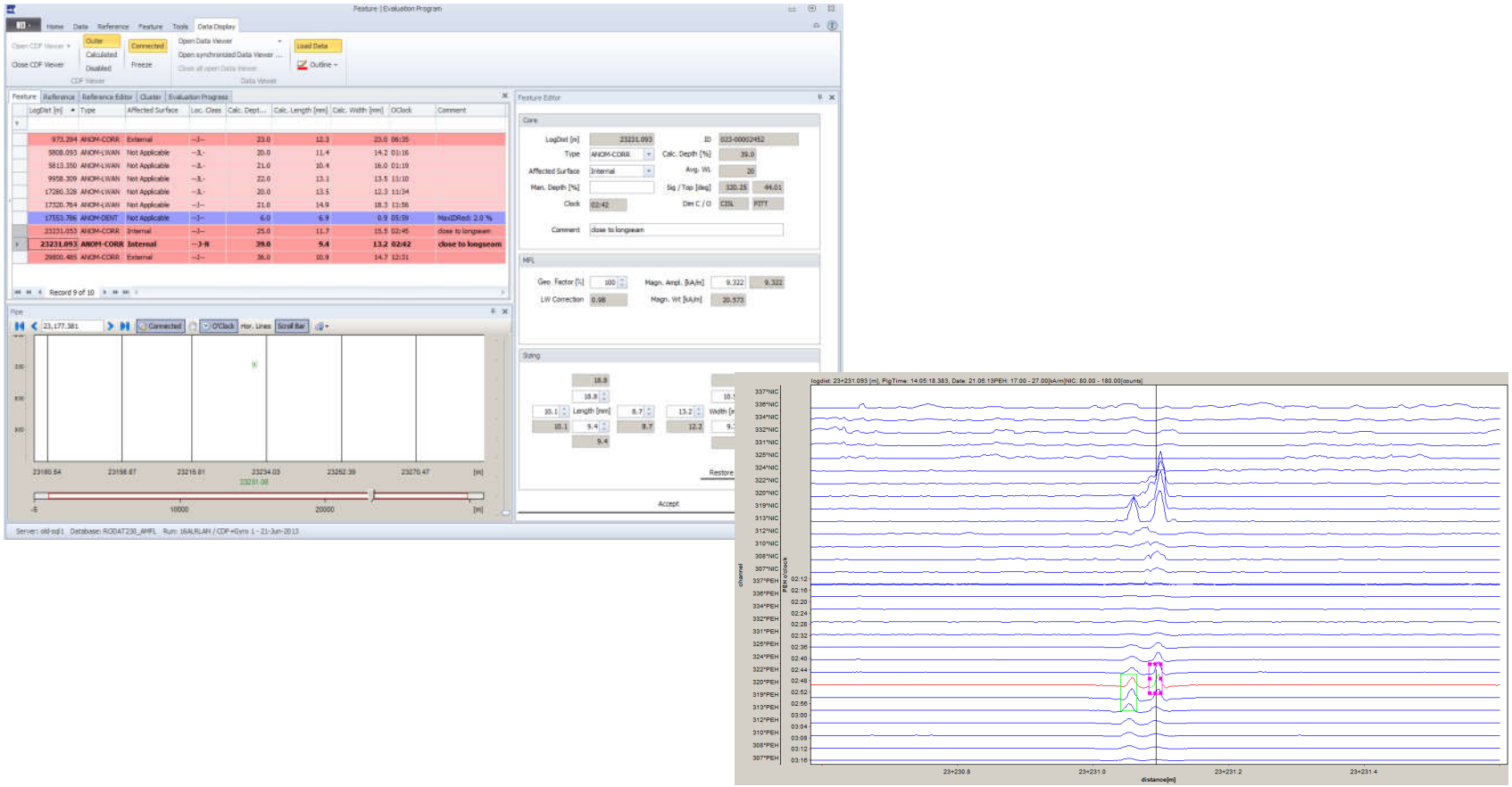
Feature | Reference | Cluster | Evaluation Progress

Log. Dist...	Joint Lengt...	WT Ass. [mm]	WT Calc. [...	OClock	Ev. Type	Comment	MAOP [MPa]	DESP [MPa]	SUTS [MPa]	SMYS [MPa]	Seam Weld Type
-4.845		**6.970**	**14.666**		**NotRepS...**		**9.70**	**10.20**	**517.00**	**413.00**	
-4.845					DARB	@ Alrode					
-1.618				12:00	OFFT						
-1.274				06:00	ESUP						
-1.172				12:00	PFIX						
-0.991				09:00	OFFT						
0.000					VALV	ball valve					
0.825				12:00	OFFT						
0.976				06:00	ESUP						
2.032					VALV	ball valve					
3.854					TEE	sphere tee					
4.384	0.574	6.970	9.037		WELD-LAUE		9.70	10.20	517.00	413.00	longseam
4.722				06:00	ESUP						
4.957	3.287	6.970	9.138		WELD		9.70	10.20	517.00	413.00	longseam
5.736				09:00	OFFT						
5.736				12:00	OFFT						
6.719				06:00	ESUP						
7.208				12:00	OFFT						
8.244	5.066	12.700	12.070		WELD-BENB	5D / 90 degree / RB	9.70	10.20	517.00	413.00	longseam
13.311	15.434	6.970	9.024	07:28	WELD-BENE		9.70	10.20	517.00	413.00	longseam
15.092				06:00	ESUP						
21.637				06:00	ESUP						
27.127				06:00	ESUP						
28.745	18.279	6.970	8.897	10:28	WELD		9.70	10.20	517.00	413.00	longseam
33.159				06:00	ESUP						
39.886				06:00	ESUP						
44.621				06:00	ESUP						
47.024	5.950	6.970	9.125	11:24	WELD		9.70	10.20	517.00	413.00	longseam
50.171				06:00	ESUP						

Record 1 of 2309

RESULT DATABASES

The ‘**feature**’ database includes all detected suspect signals that could indicate pipeline anomalies.



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WELDS, INSTALLATIONS AND FEATURES

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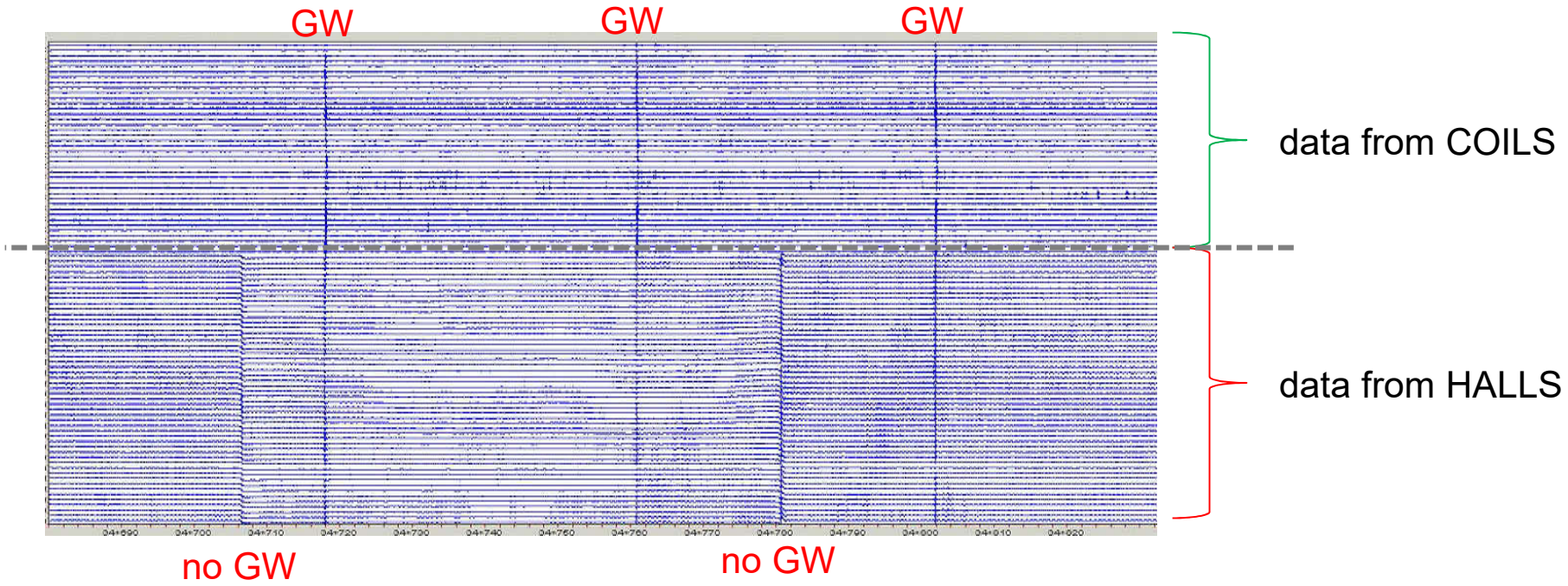
Different events of the pipeline generate unique patterns on the data that are interpreted as events on the line segment.

The signal data analysis is performed in two stages; (1) reference verification, and (2) anomaly (feature) verification

- **REFERENCE**: Girth welds (GW)



WELDS, INSTALLATIONS AND FEATURES

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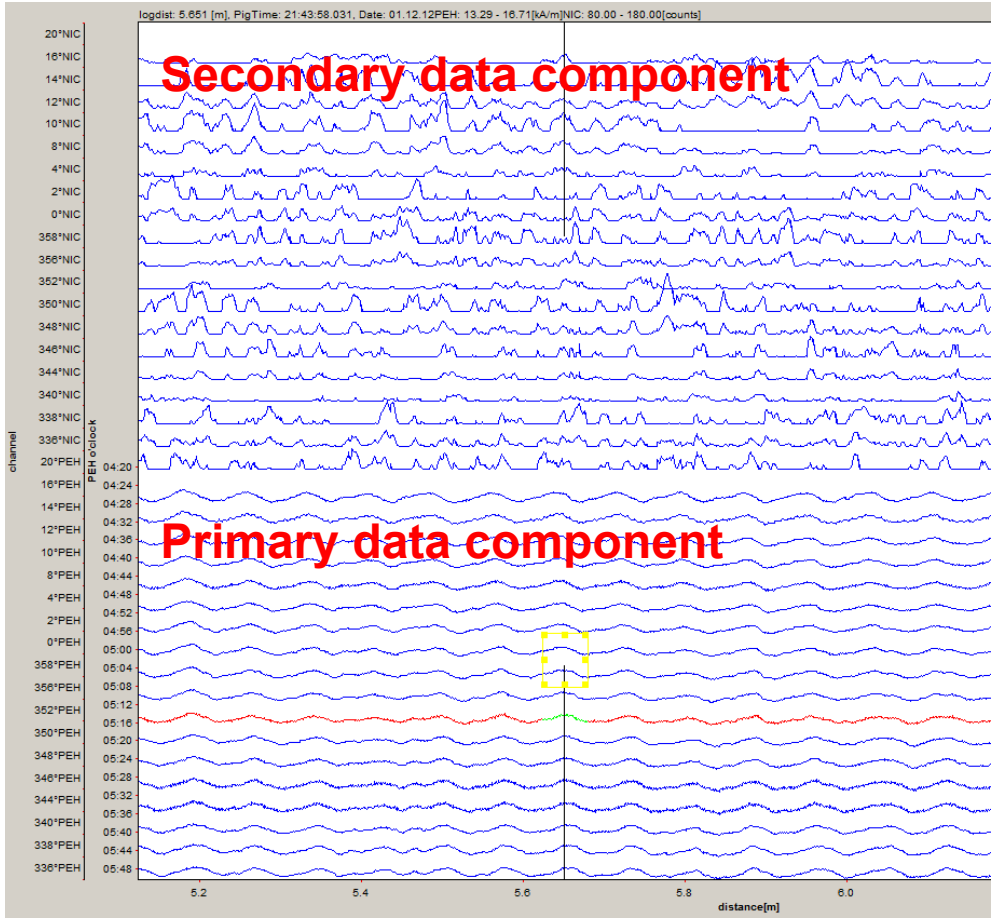
Enlarged area of seamless pipe…



WELDS, INSTALLATIONS AND FEATURES

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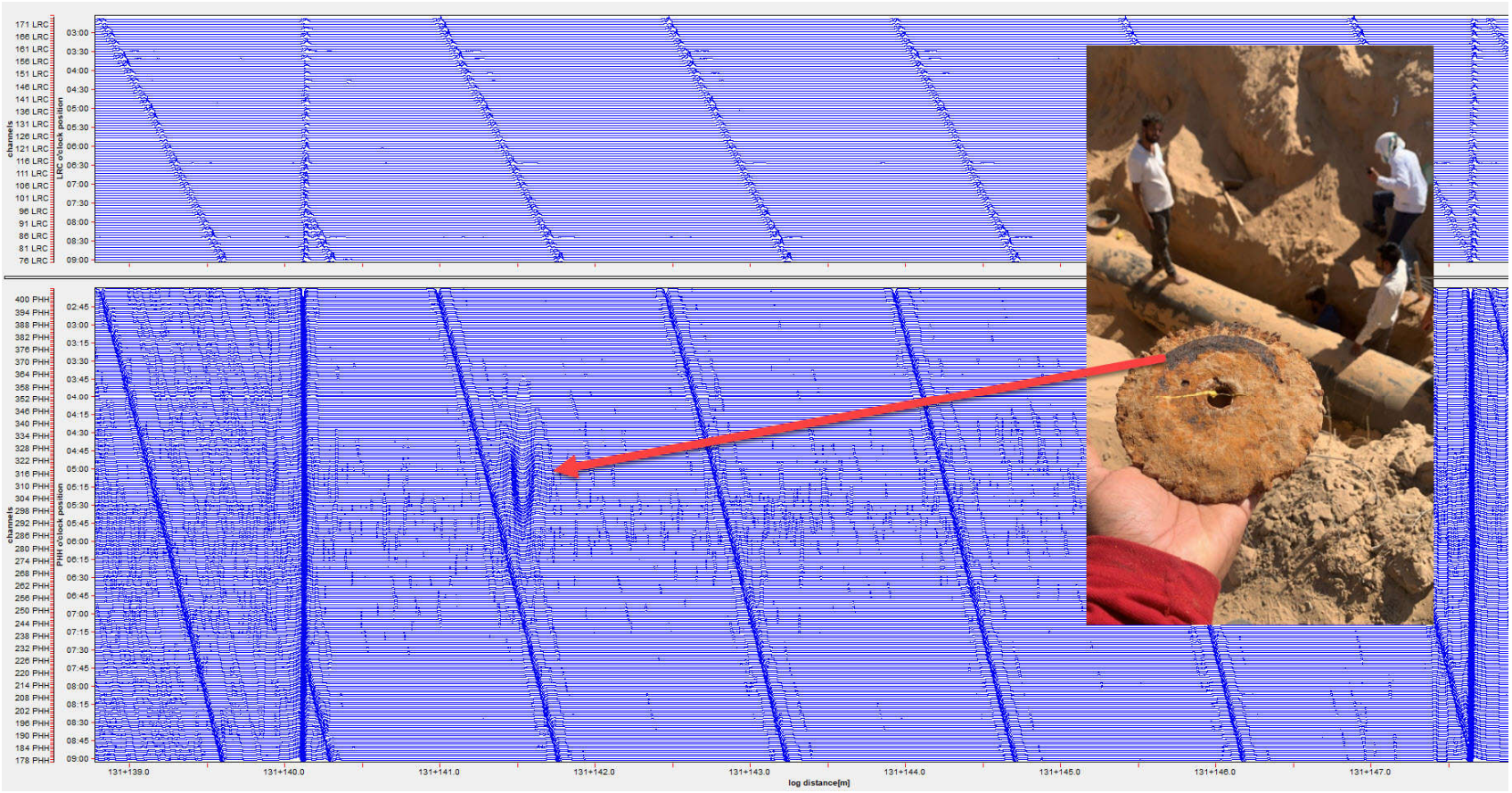
Attachments / Pipe Fixtures / Close Metal Objects



WELDS, INSTALLATIONS AND FEATURES

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Attachments / Pipe Fixtures / Close Metal Objects

WELDS, INSTALLATIONS AND FEATURES

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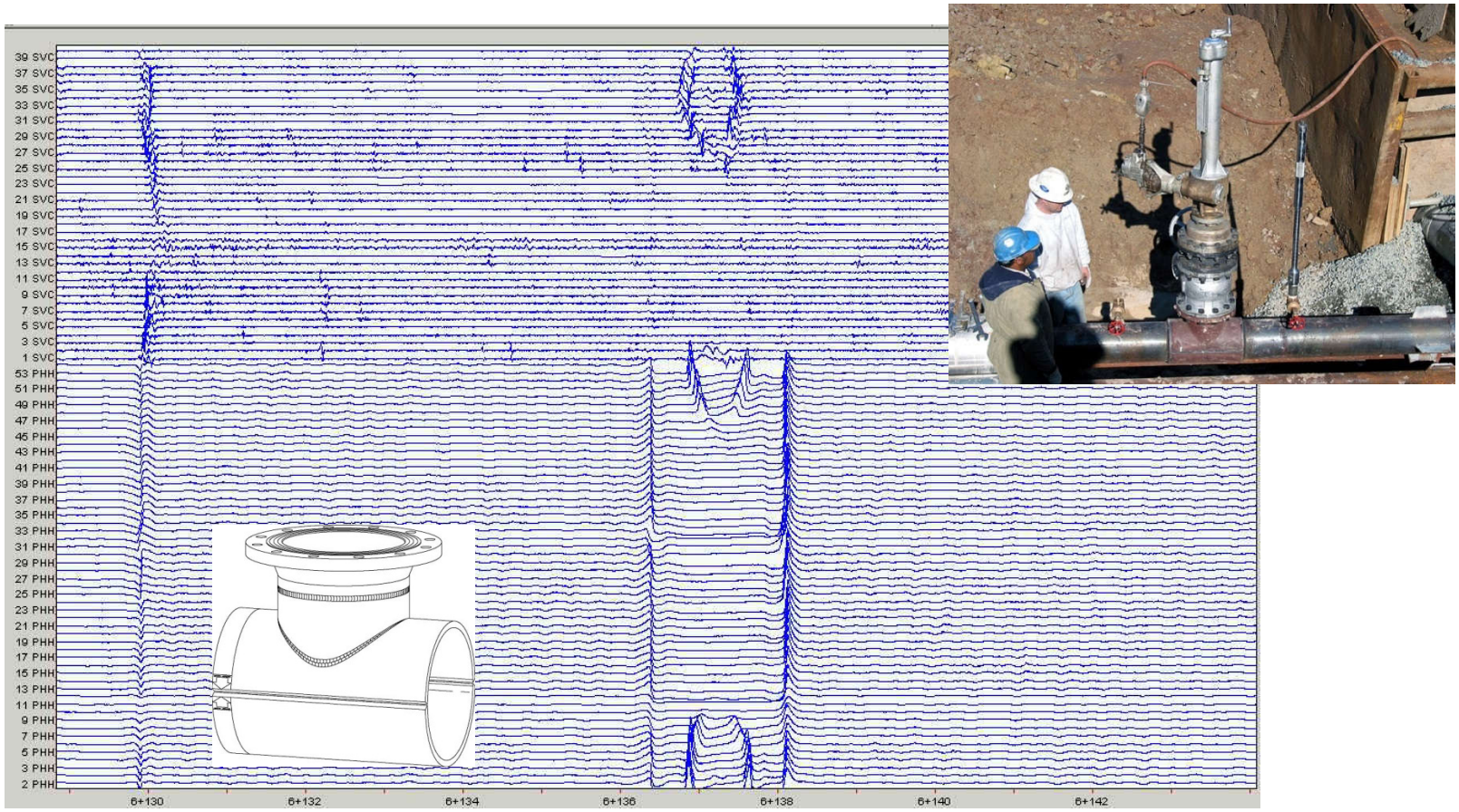
Hot Tap:



WELDS, INSTALLATIONS AND FEATURES

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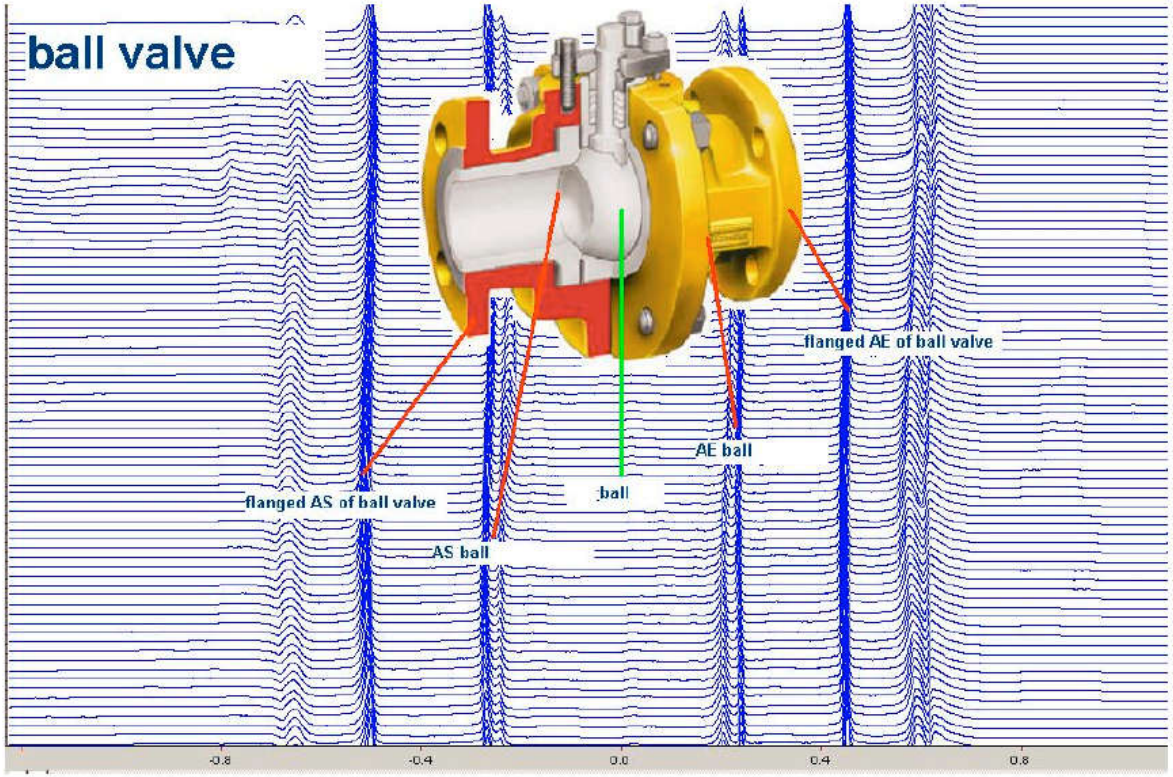
CG/06/28/2004

Standard Ball Valve

Below please find an example for a standard ball valve (16"). The example shows the PHH signals in a scale of 1:10 as well as the corresponding picture of a ball valve.
Please note, in some cases also the bolts of the ball are visible in the data, located at 06:00 h and 12:00 h (not visible in this example).



WELDS, INSTALLATIONS AND FEATURES

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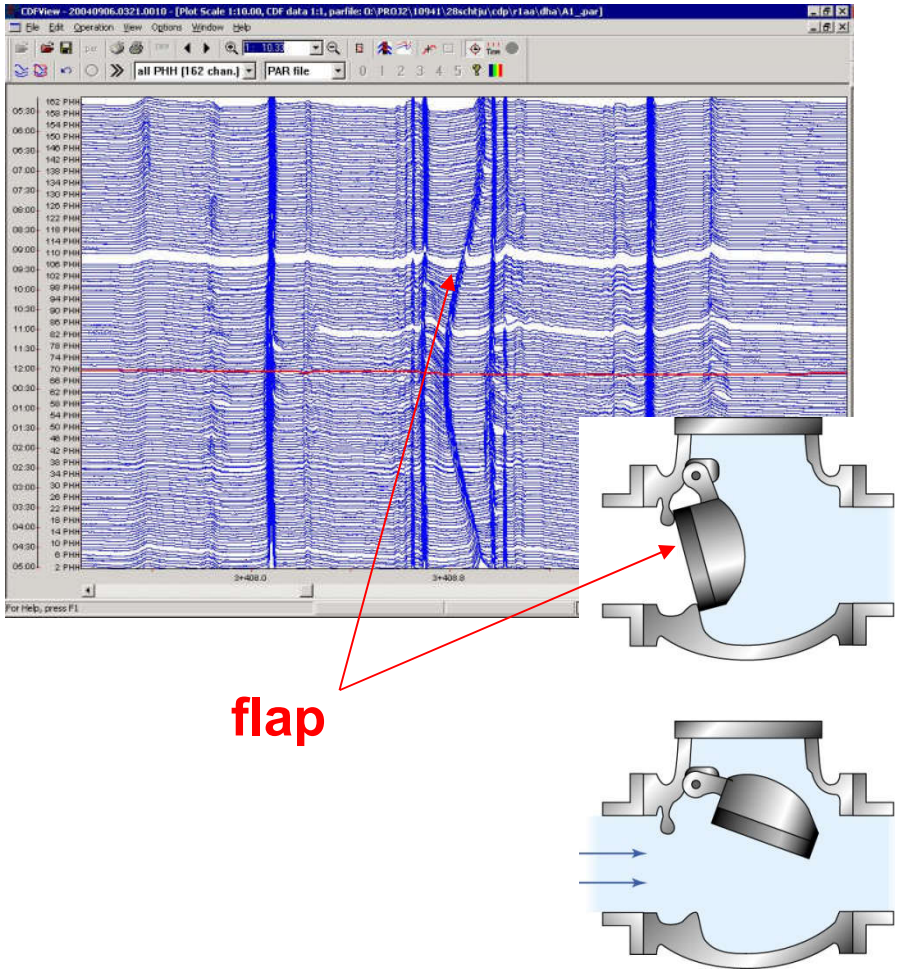
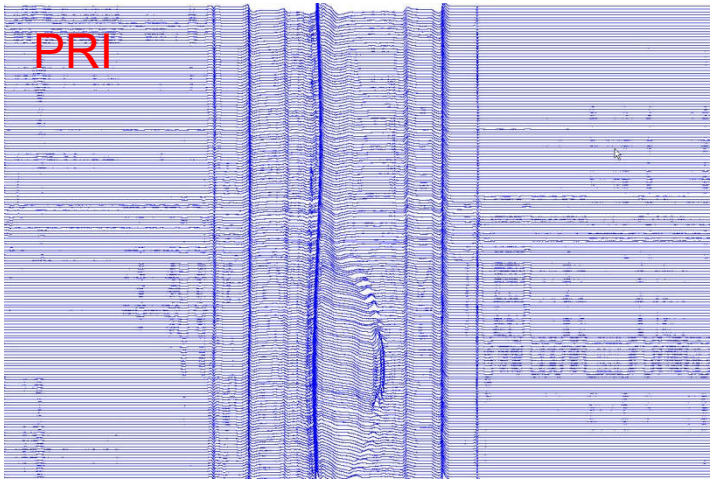
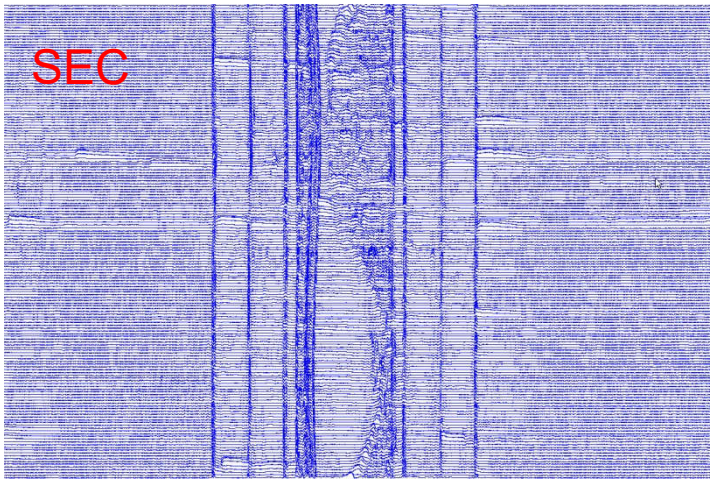
Check Valve:





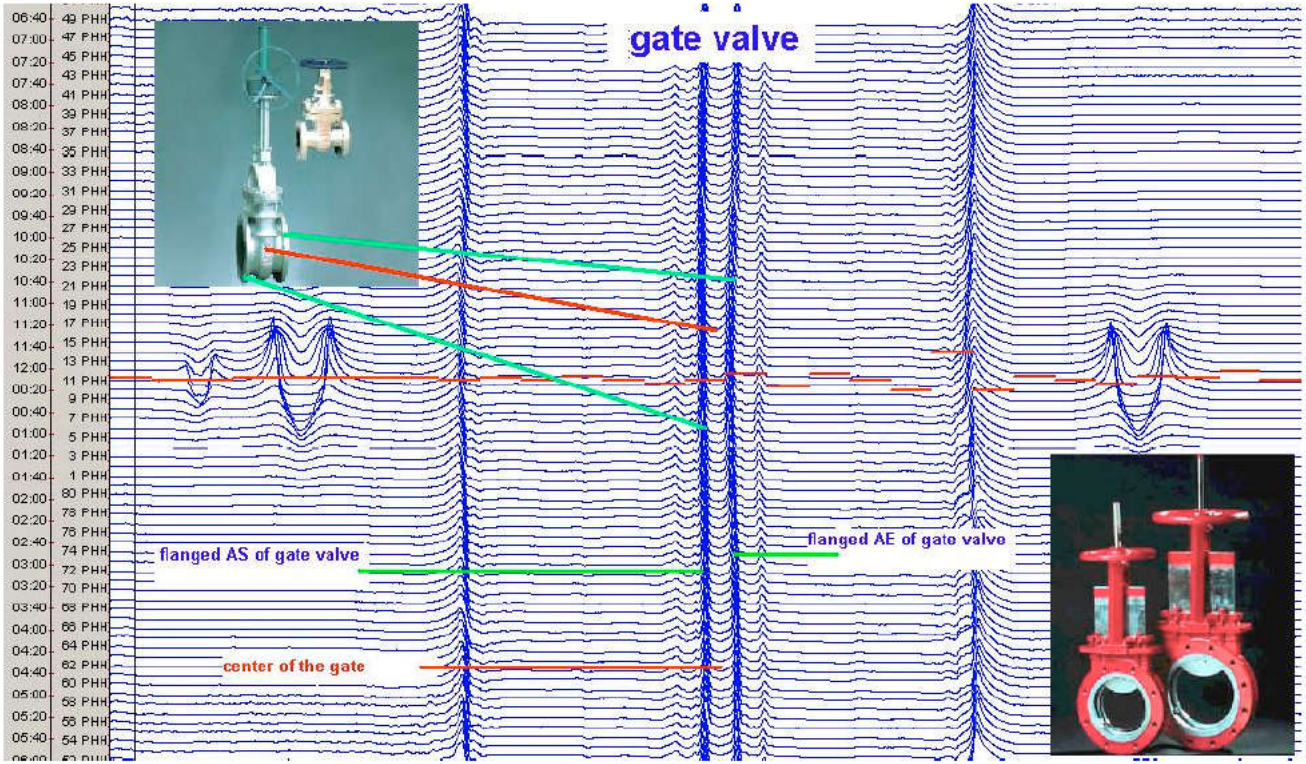


WELDS, INSTALLATIONS AND FEATURES

CG/06/28/2004

Standard Gate Valve

Below please find an example for a standard gate valve (16"). The example shows the PHH signals in a scale of 1:20 as well as the corresponding picture of a gate valve.



WELDS, INSTALLATIONS AND FEATURES

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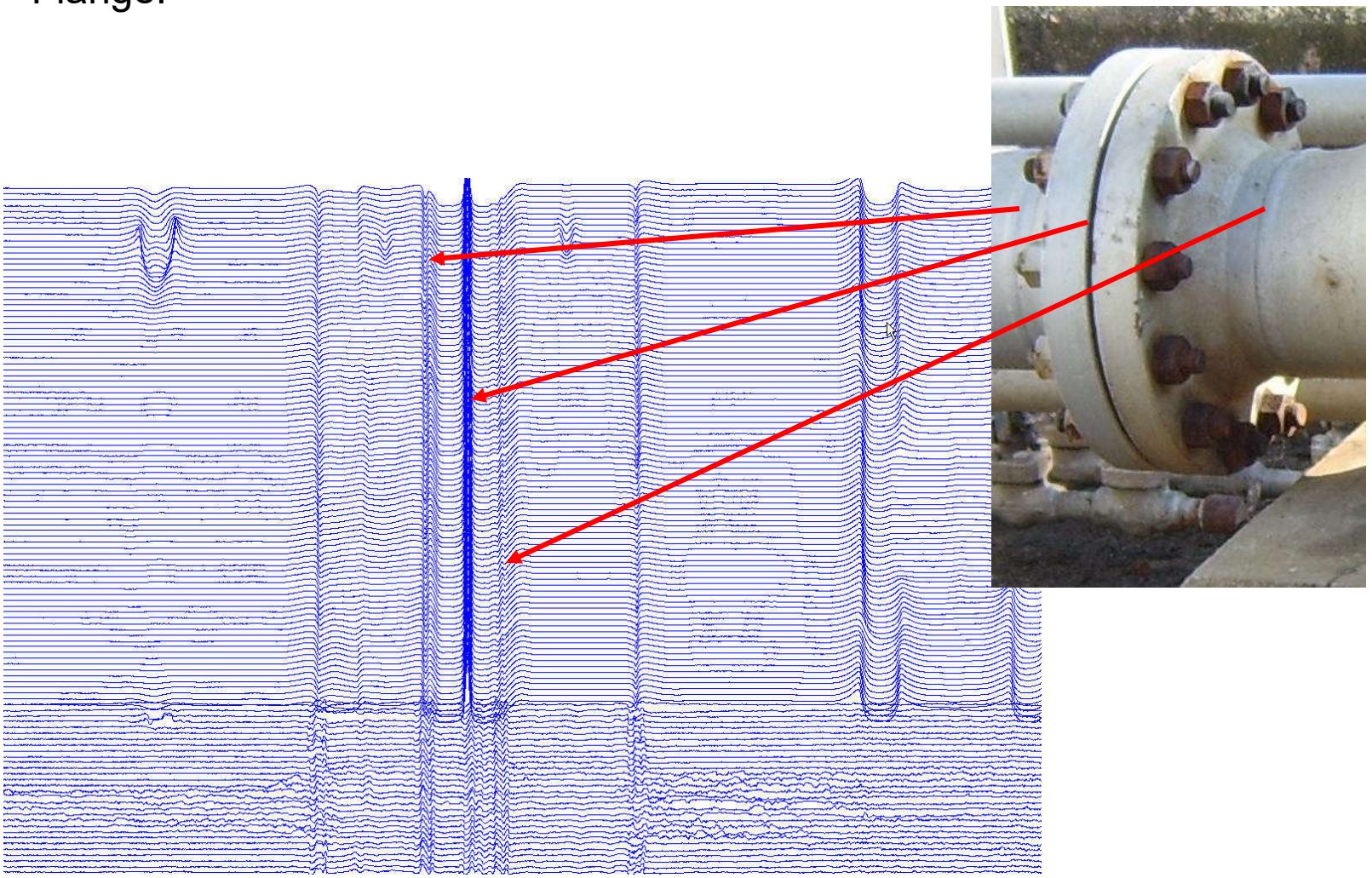
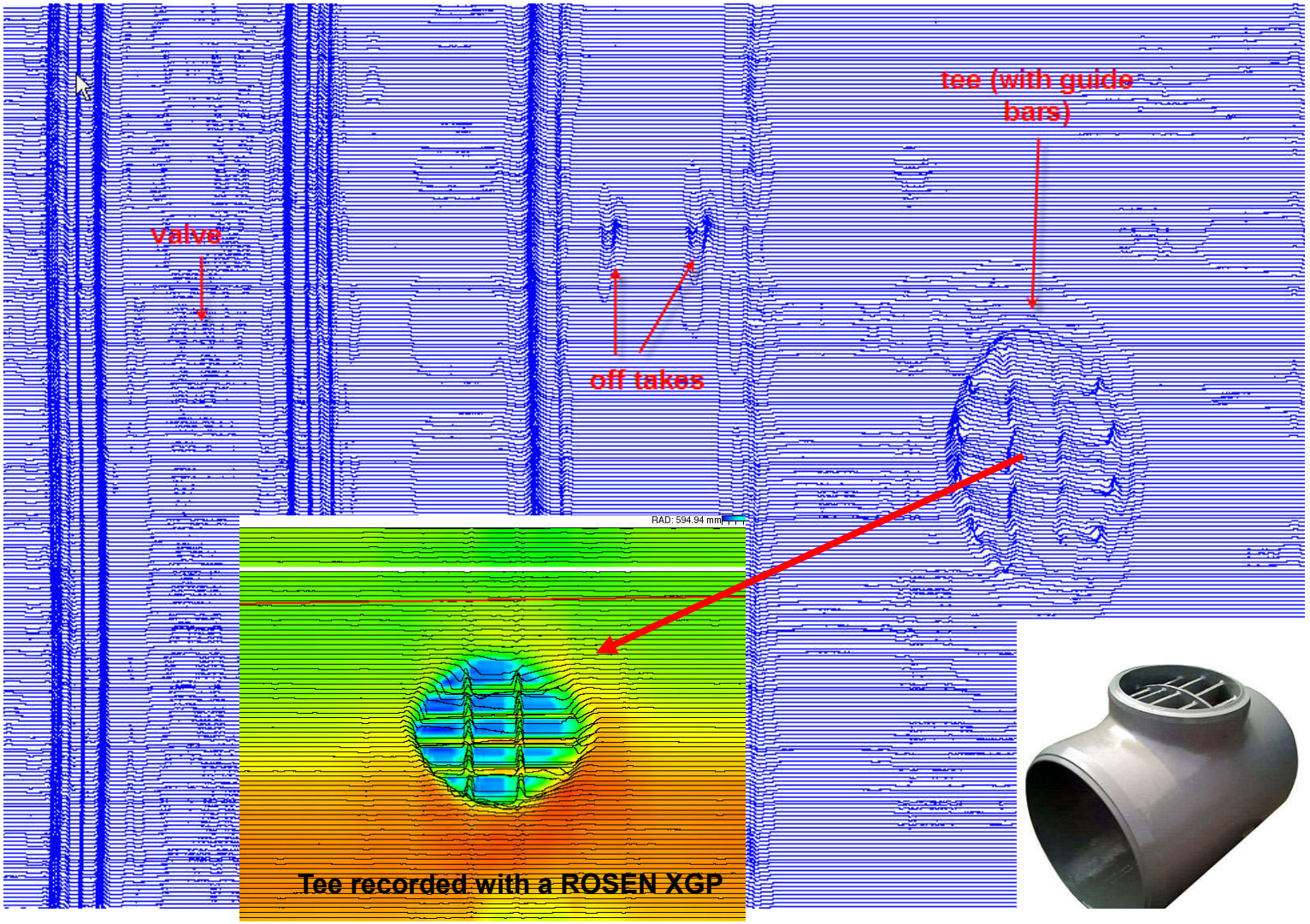
Flange:



WELDS, INSTALLATIONS AND FEATURES

Tee:



WELDS, INSTALLATIONS AND FEATURES

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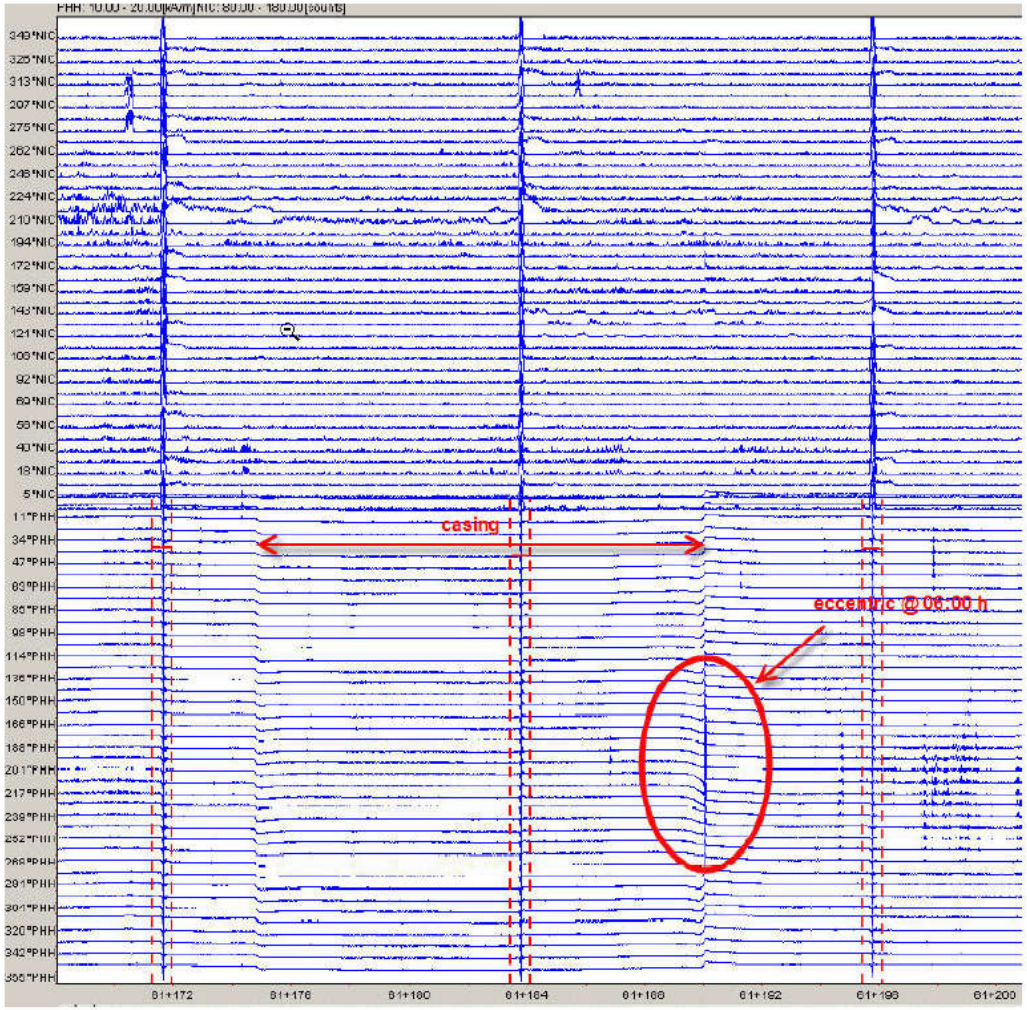
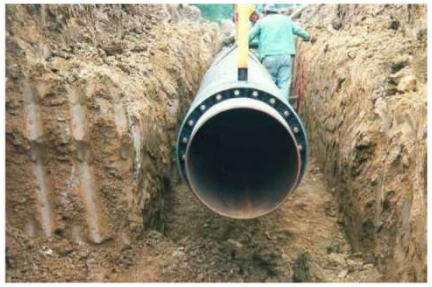
Casing / eccentric casing:



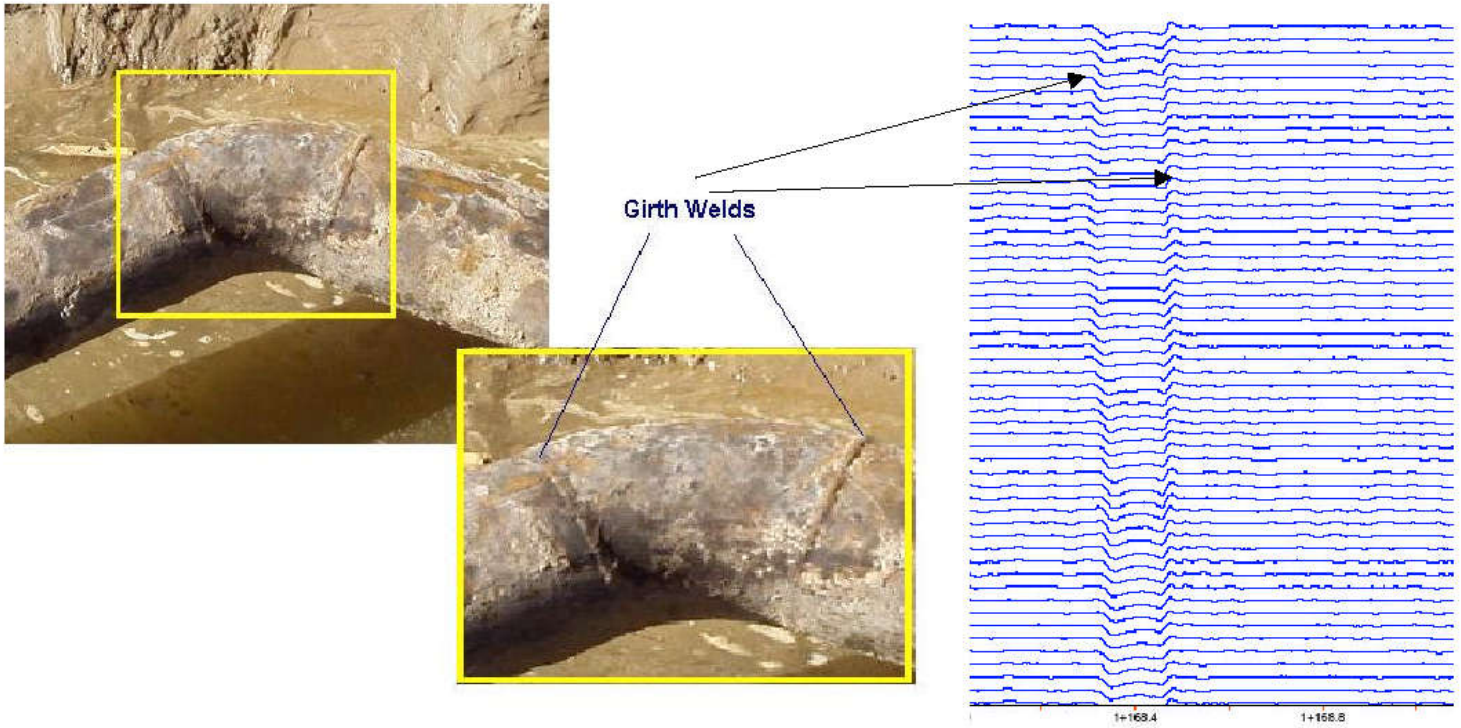


WELDS, INSTALLATIONS AND FEATURES

CG 10/26/2004

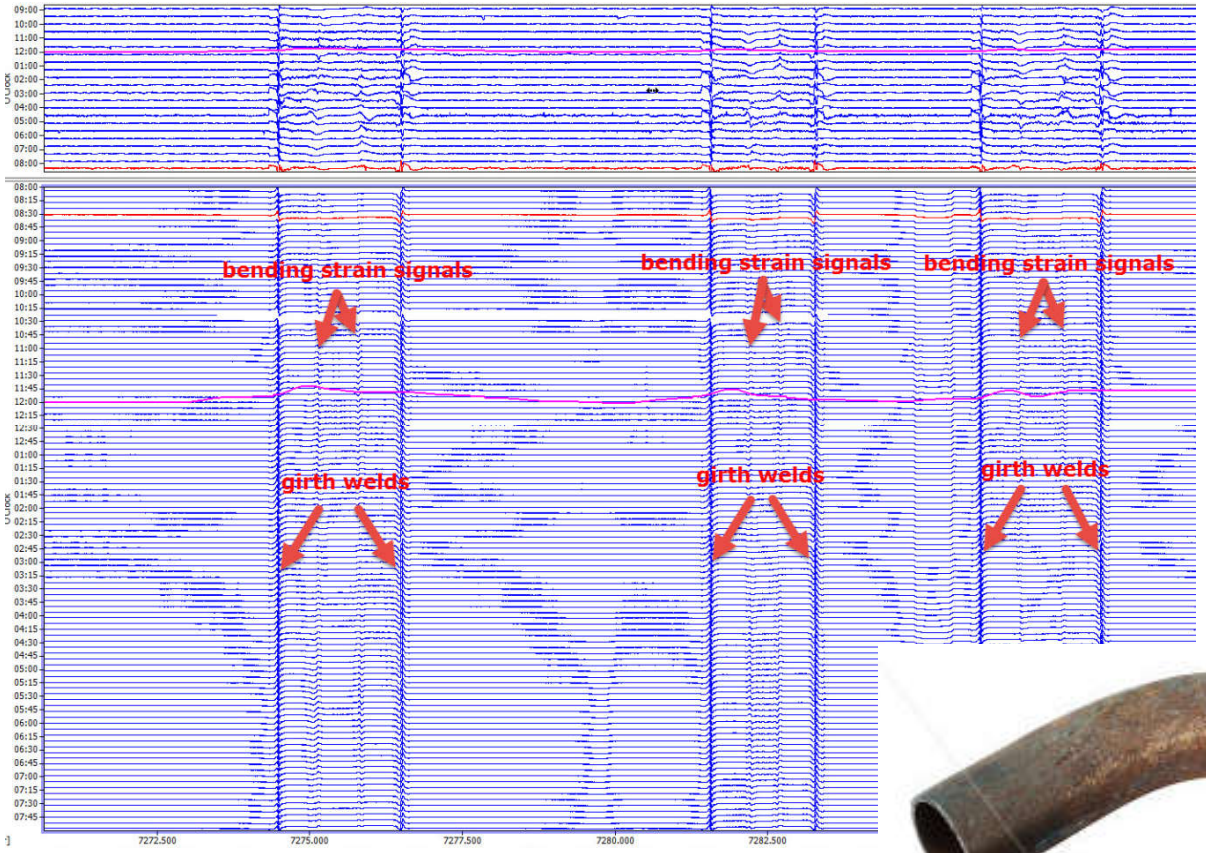
Elbow Fitting

A kind of very short bend, that makes an angle in a pipe. Sometimes cut out of a regular factory bend. In some cases very critical for CDP passage, especially when angle >=90 degree. Mostly with higher wall thickness than the next D/S and U/S joints. The shorter the distance between the two girth welds, the higher the girth weld signal eccentricity on the survey log.



WELDS, INSTALLATIONS AND FEATURES

Bends:



WELDS, INSTALLATIONS AND FEATURES

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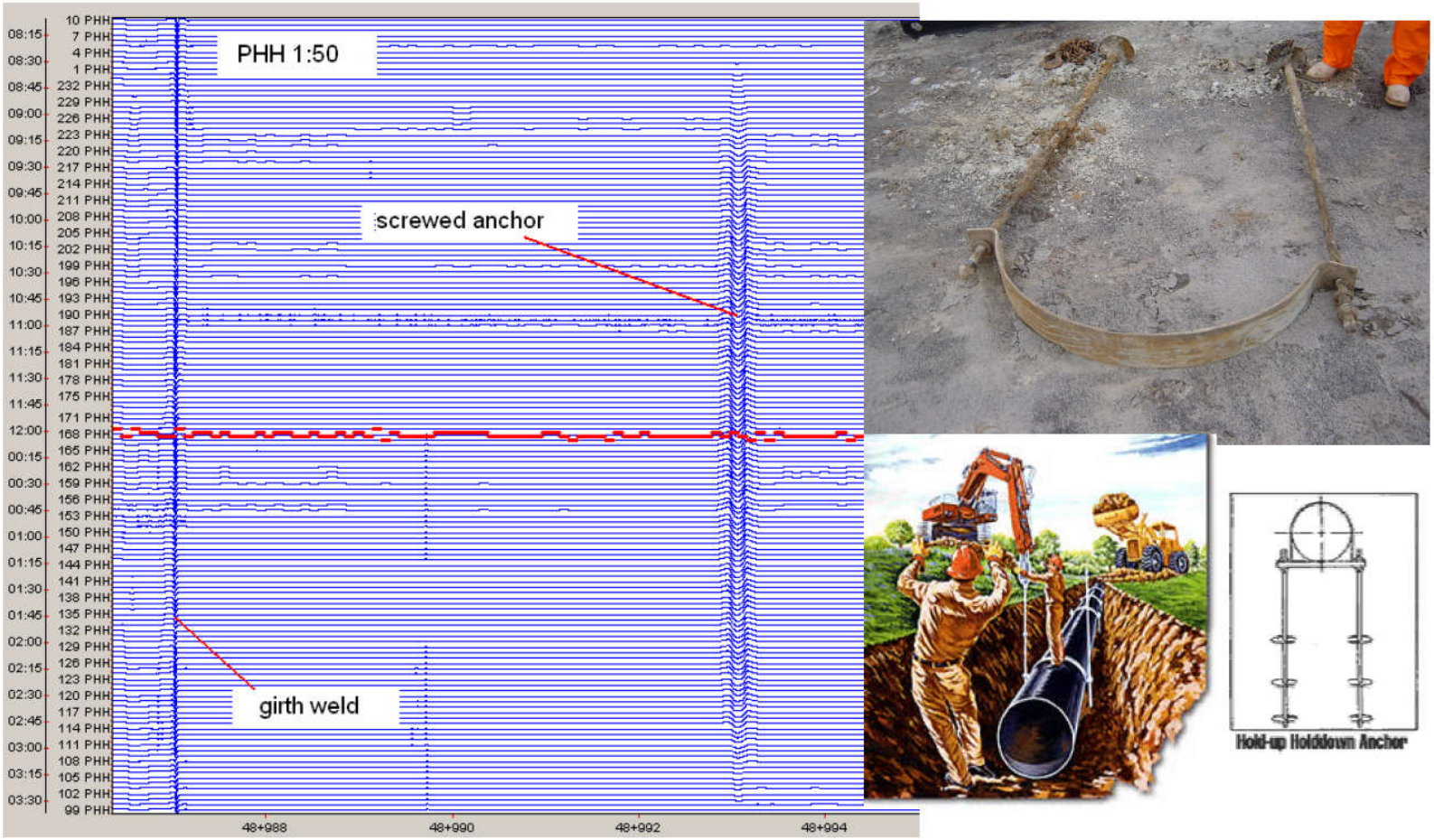
Anchor / screw anchor:



WELDS, INSTALLATIONS AND FEATURES

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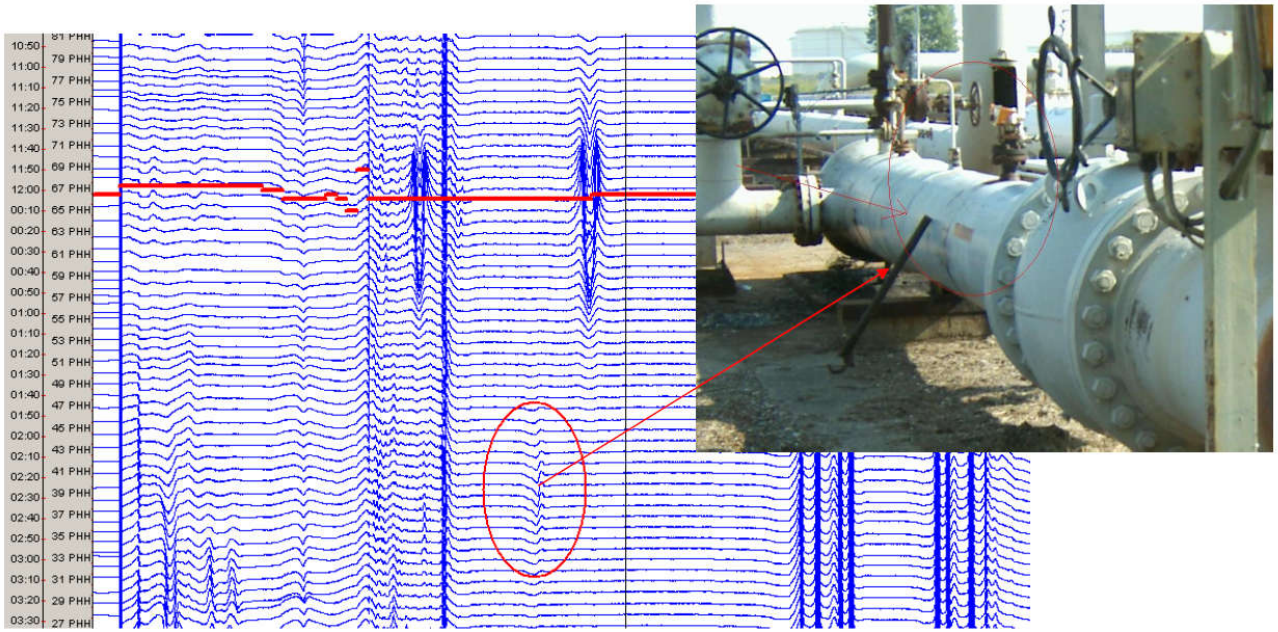
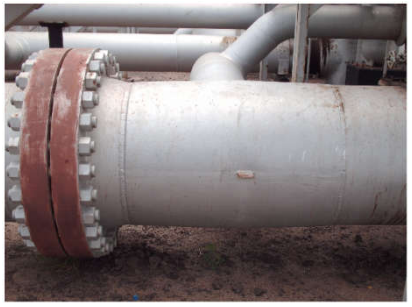
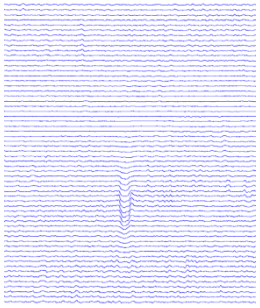
Pipeline Fixture / attachment:

Below please find an example for a funny 'attachment': a big wrench was placed against the launcher trap. Good visible on PHH. It was reported as attachment at 03:00 h.







WELDS, INSTALLATIONS AND FEATURES

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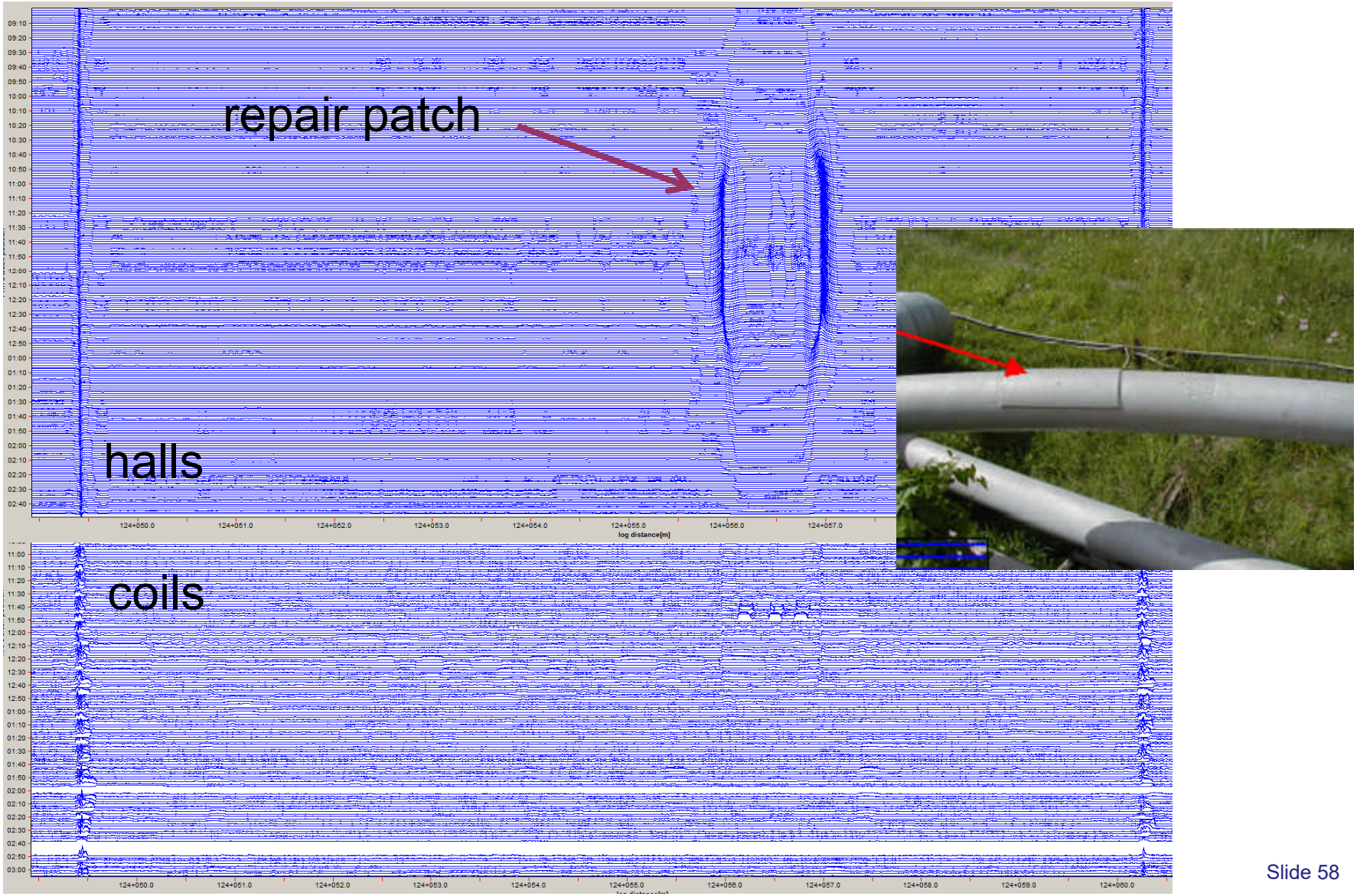
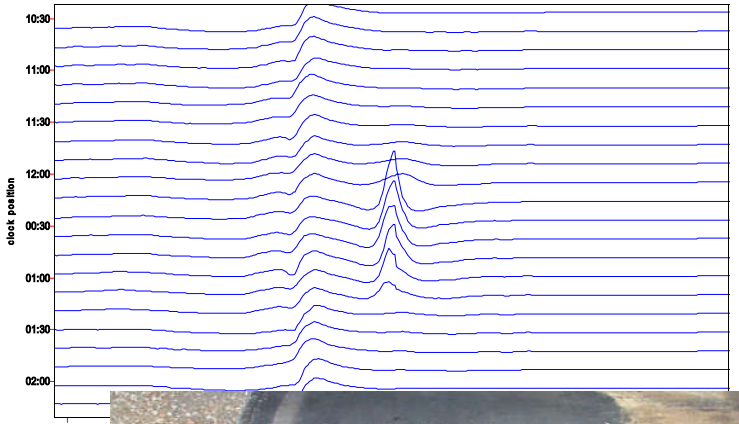
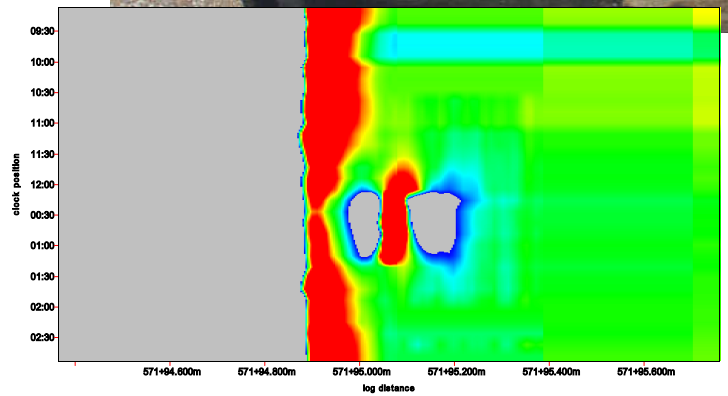
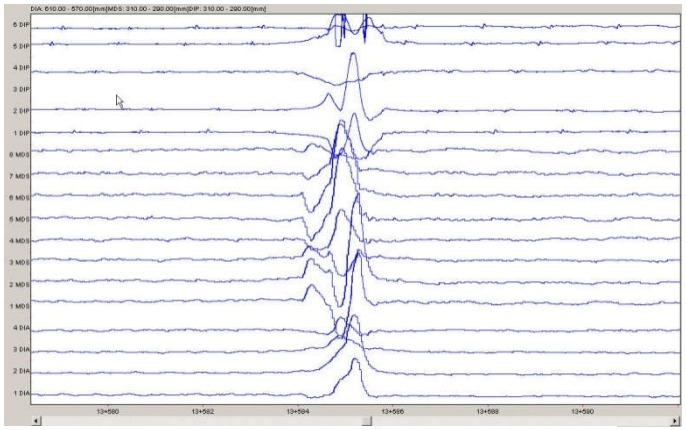
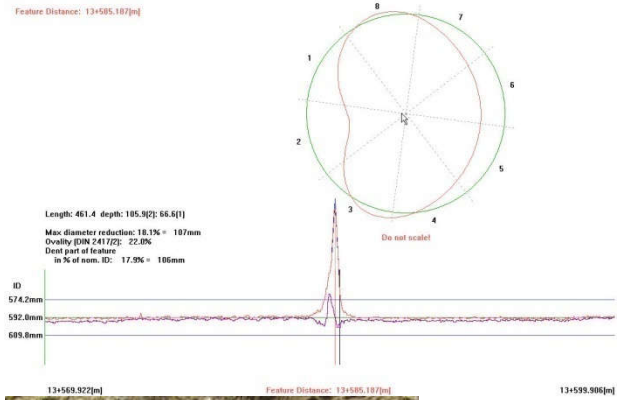


WELDS, INSTALLATIONS AND FEATURES





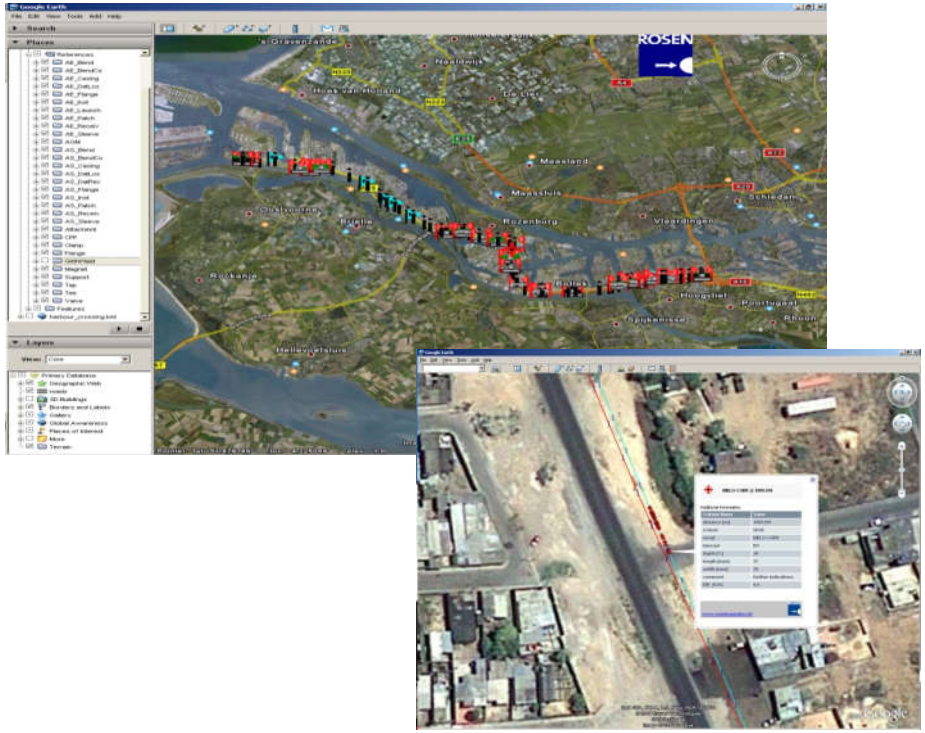




CONTENTS

INTEGRATION OF XYZ SURVEY RESULTS

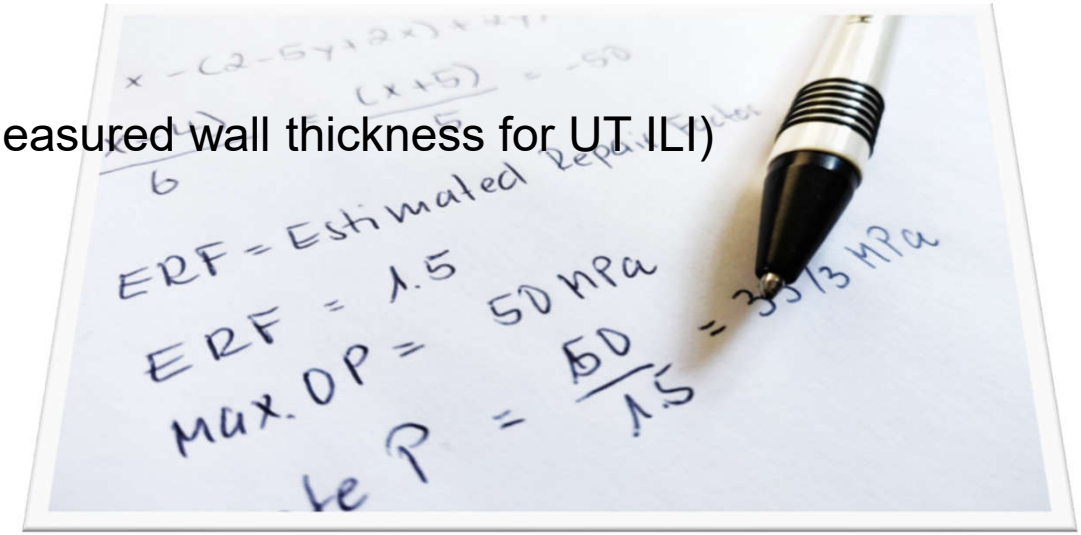
In case the inspection tool was equipped with a gyro unit, ROSEN can provide clients with (XYZ) coordinates for all events recorded. These coordinates can also be visualized within GoogleEarth® with a direct link implemented in ROSOFT:



CONTENTS

CALCULATION AND OUTPUT

Once the evaluation is finalized, the information received from the client such as:



- Nominal Wall Thickness (measured wall thickness for UT ILI)
- Design Pressures
- MAOP
- SMYS / SUTS *
- etc.

will be utilized for ERF calculation. ERF = **E**stimated **R**epair **F**actor = Ratio between the max operating pressure and the safety pressure;

* SMYS = Specified Minimum Yield Strength (hardness)
SUTS = Ultimate Tensile Strength (> collapse)
SUTS > SMYS

CALCULATION AND OUTPUT

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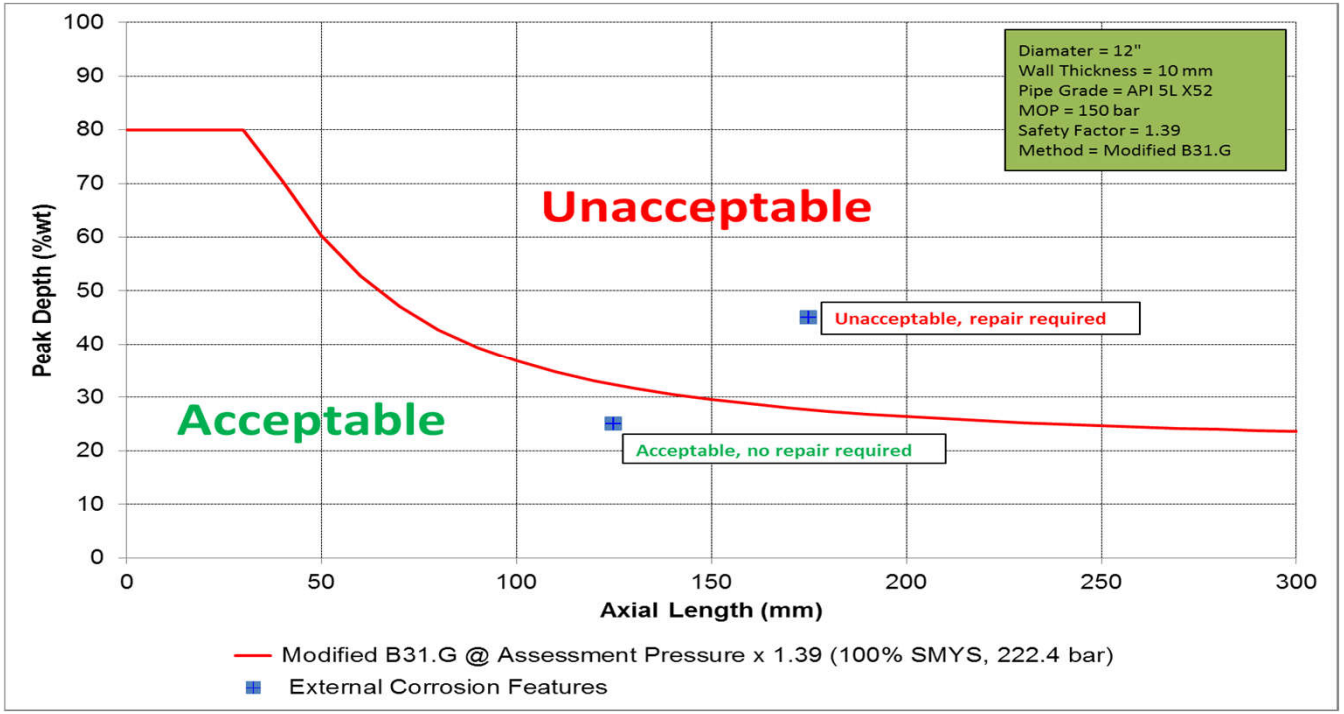
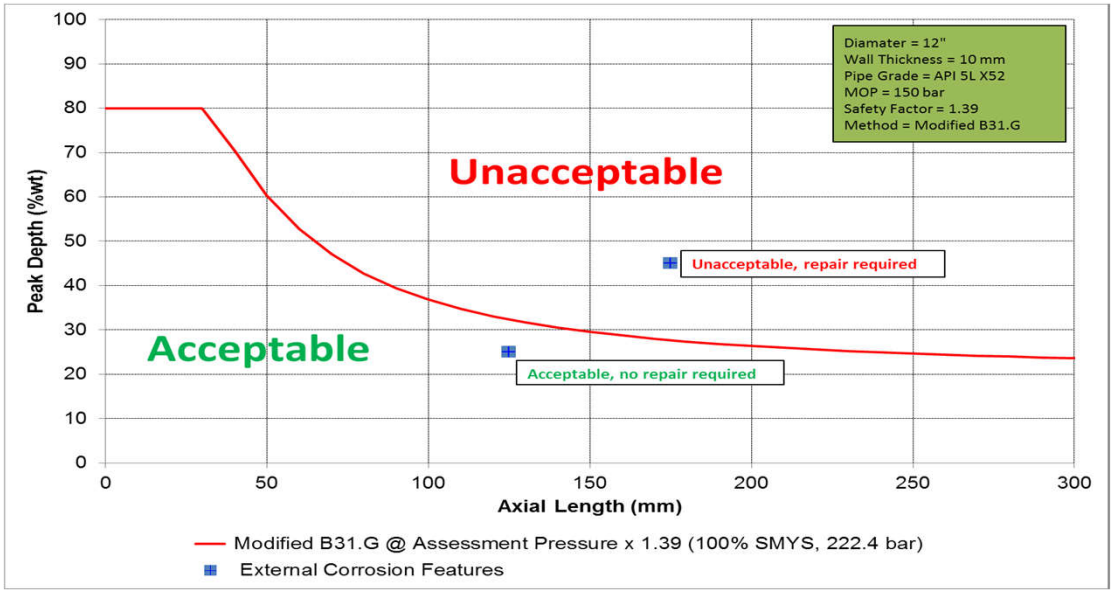
ERF = Estimated Repair Factor: a kind of severity value for corrosion anomalies. ERF = M(A)OP / Safety Factor (or defect failure pressure) → Defect failure pressure = M(A)OP / ERF. Example:

M(A)OP = 10 MPa and ERF = 1.5 → Defect failure pressure = 6.67 MPa, which is < M(A)OP! → immediate action necessary!!



CALCULATION AND OUTPUT



Acceptance Curves

Note that **'acceptance' curves are not 'failure' curves**:

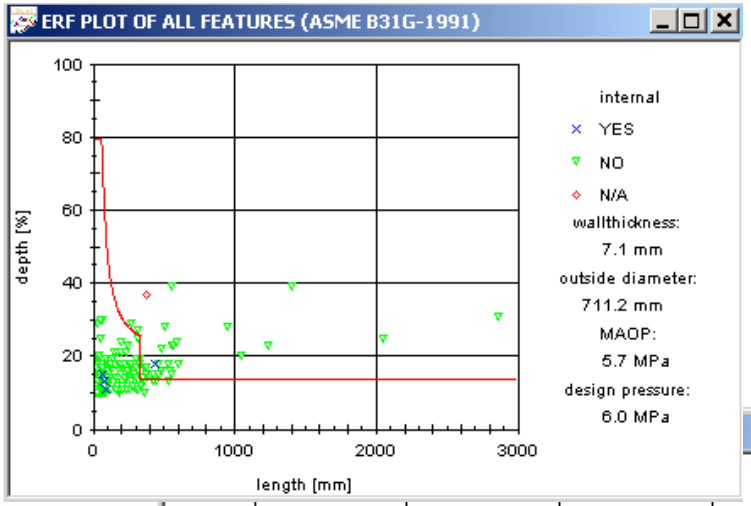
If the defect is below the acceptance curve, it is acceptable and does not need repairing. This acceptable defect will not fail.

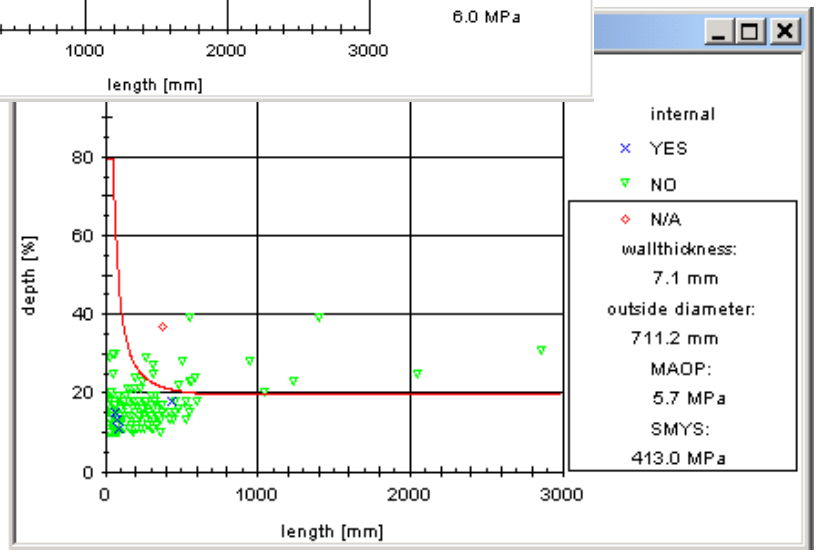
If the defect is above the acceptance curve, it is not acceptable and needs repairing. This unacceptable defect will not necessarily fail the structure, as the acceptance curves contain safety factors.

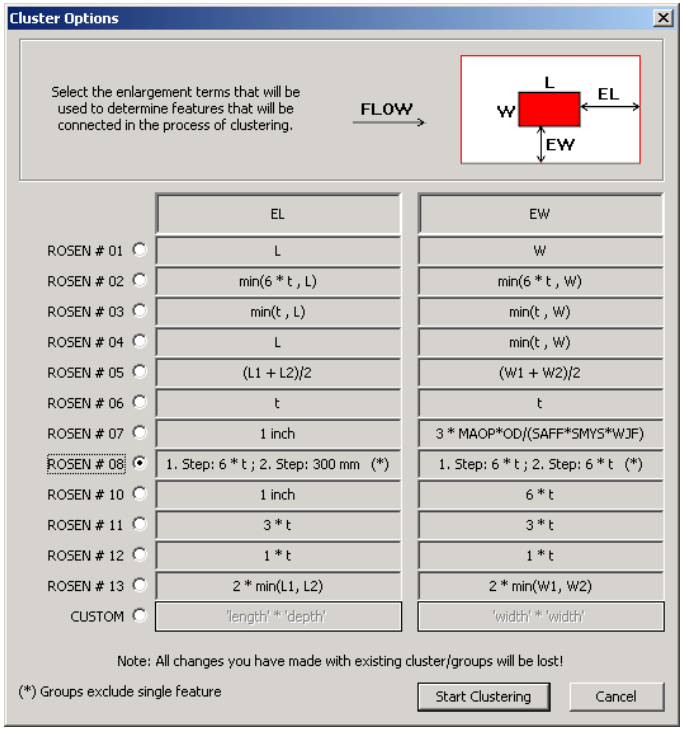
Failure curves do not contain safety factors – if the defect is above the failure line, it will fail the structure.

CALCULATION AND OUTPUT

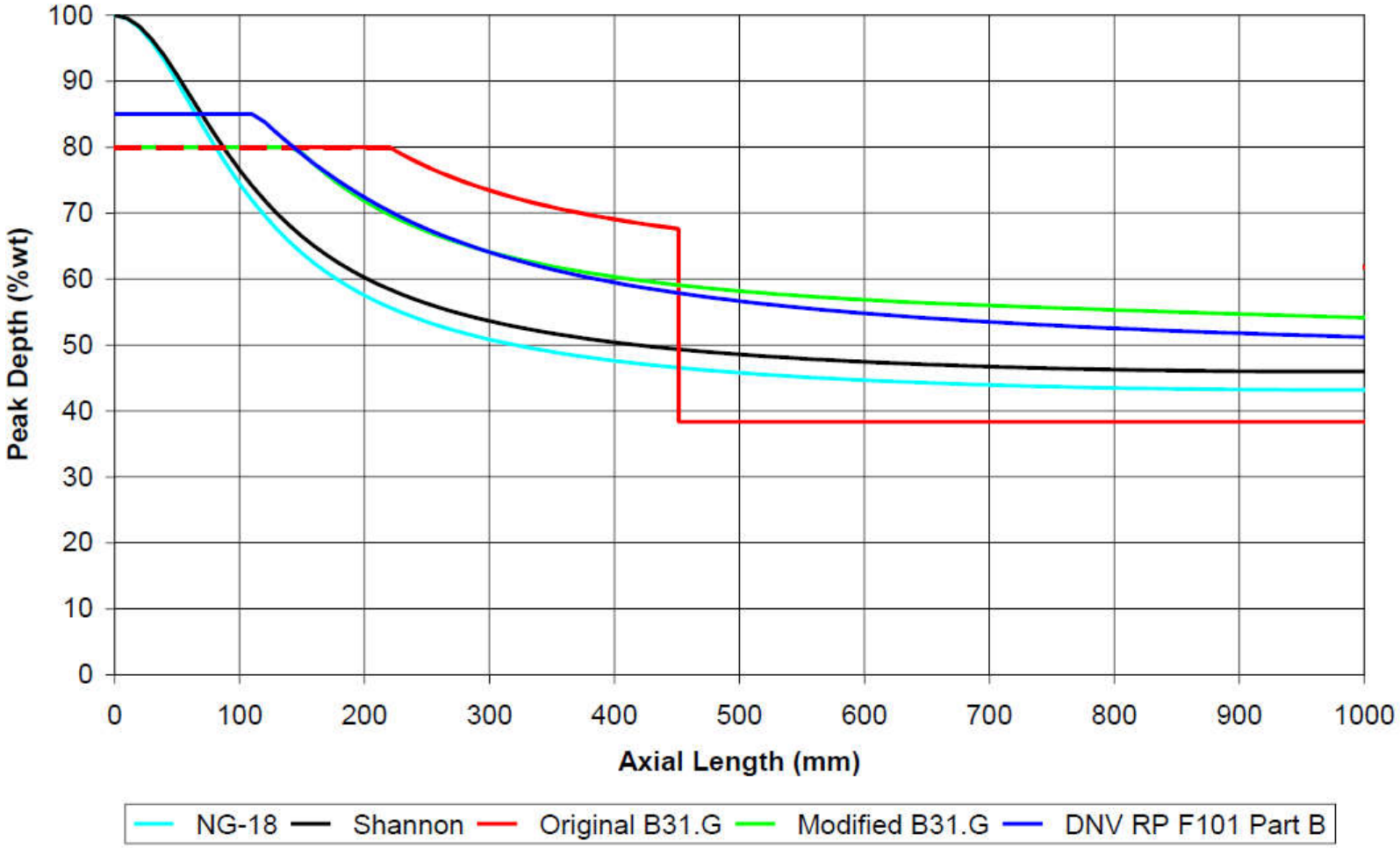
Calculation procedures will establish relative distances, anomaly dimensions, anomaly classifications, etc., as well as apply signal interaction criteria and industry corrosion assessment standards such as RSTRENG or ASME B31G.







CALCULATION AND OUTPUT



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Evaluation the Remaining Strength of Corroded Pipe

B31.G, Modified B31.G and RSTRENG

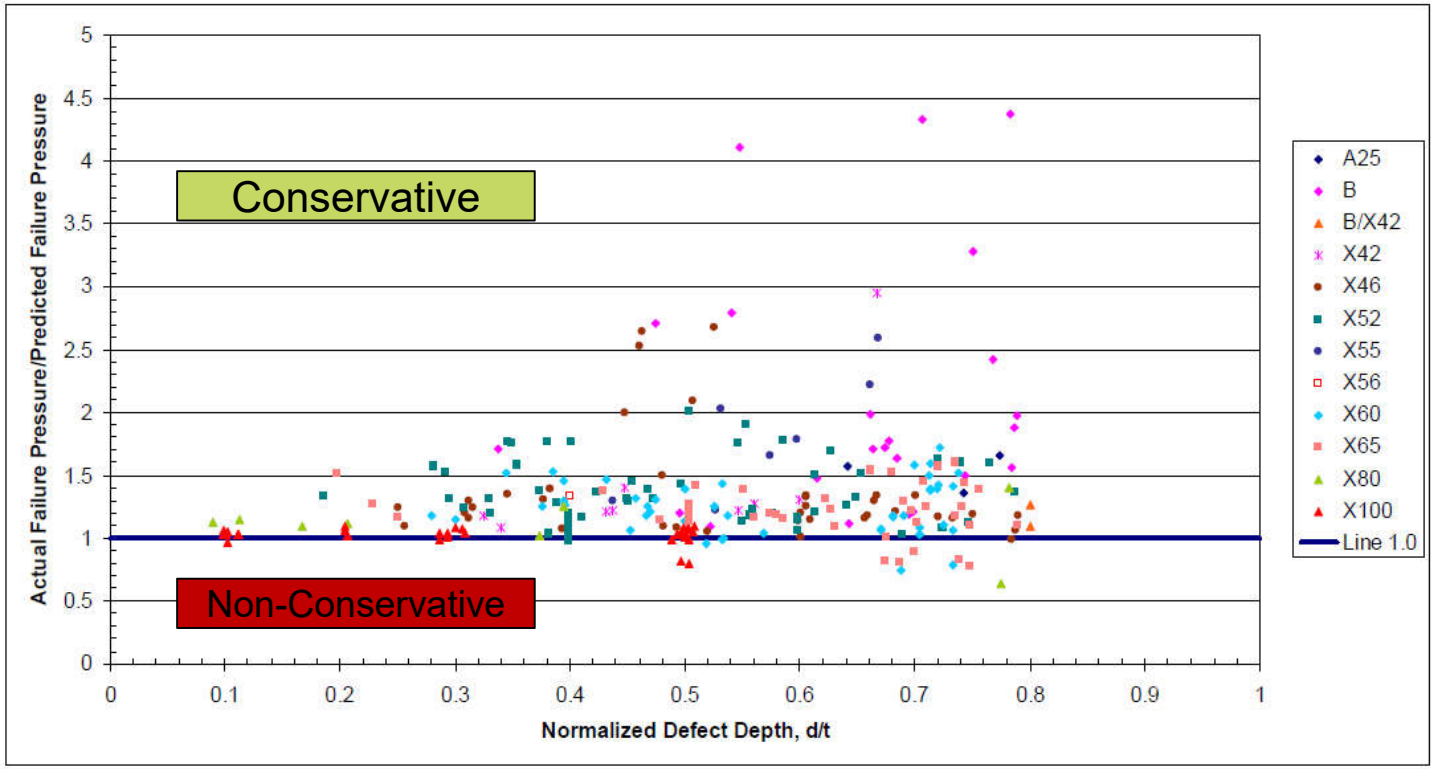
Background

The initial procedure for evaluating remaining strength was developed after pressuring actual corroded pipe to failure. Several hundred, full-size, full-scale tests using actual field pipe specimens of all types of defects were completed.

The larger the corroded area the lower the failure pressure. The tougher the steel the larger the defect that can be tolerated.

CALCULATION AND OUTPUT

B 31G



Example:

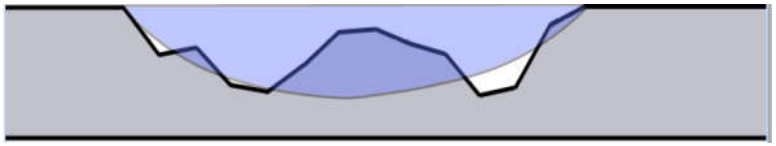
(a) Actual FP = 200 bar
(b) Predicted FP = 100 bar

(a) / (b) = 2.0

→ actual failure pressure was 2x higher than the predicted failure pressure

(a) / (b) < 1 →

Actual FP < Predicted FP!!



CALCULATION AND OUTPUT

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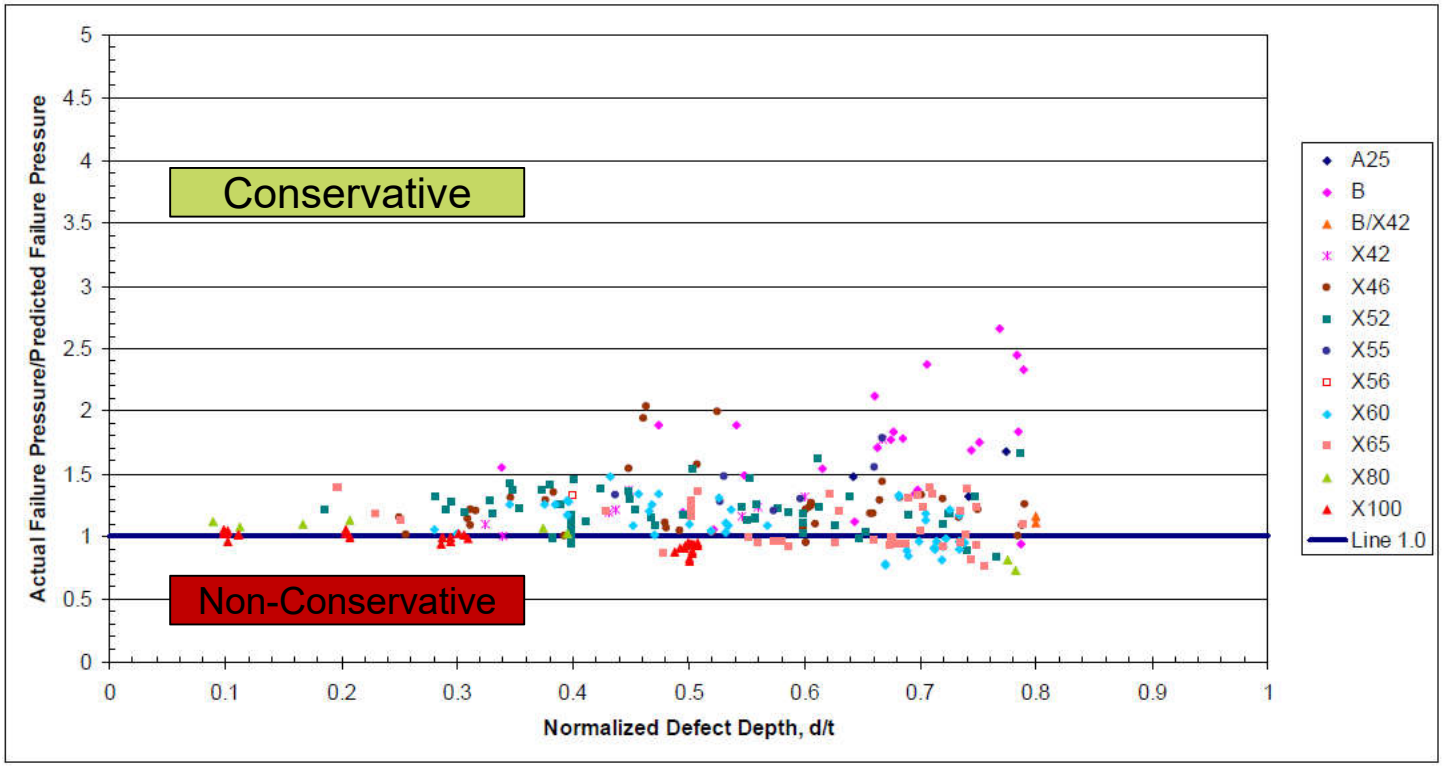
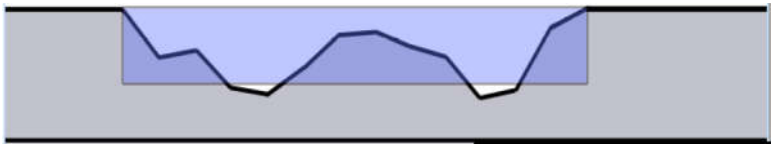
Modified B 31G





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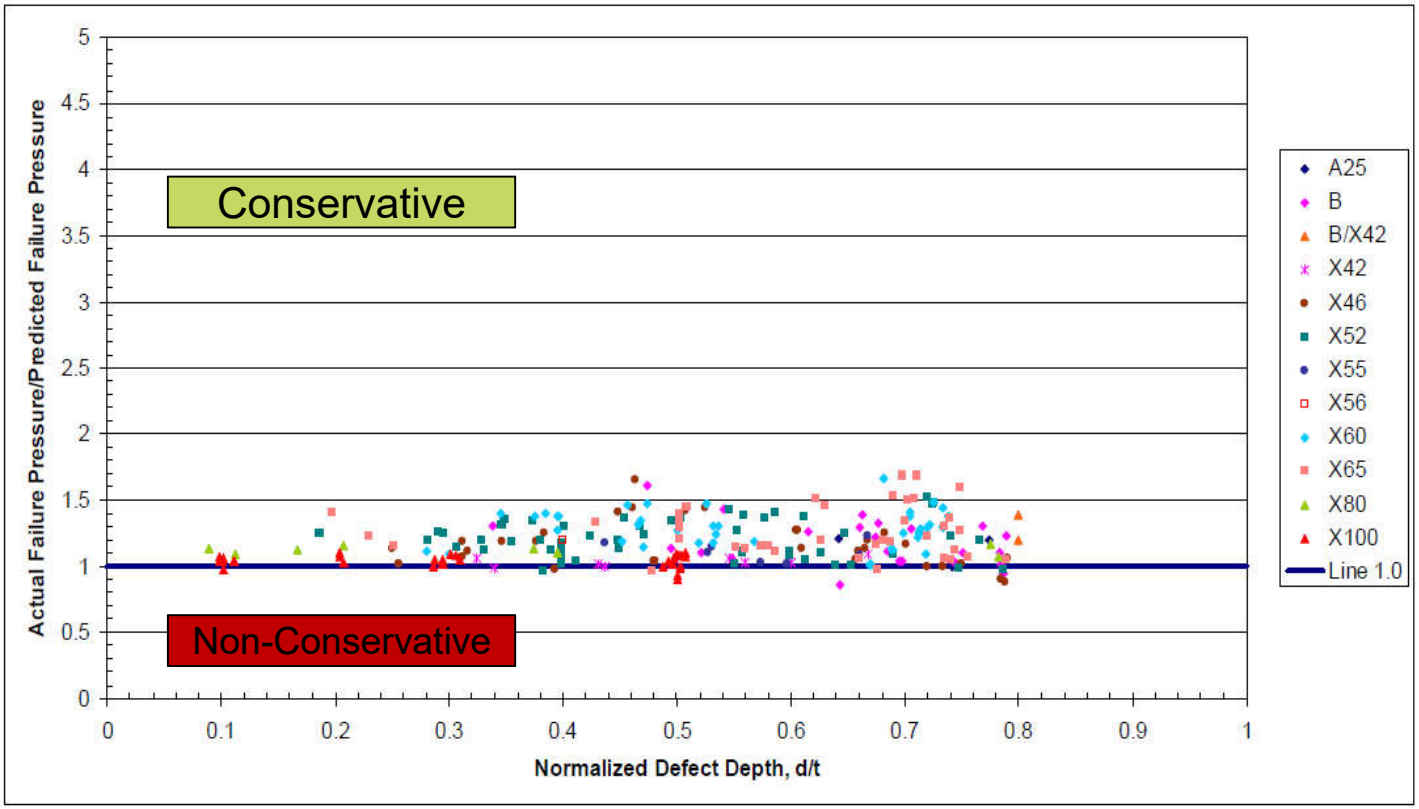
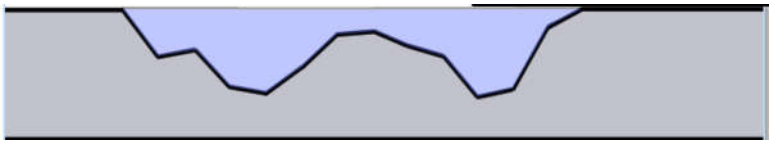
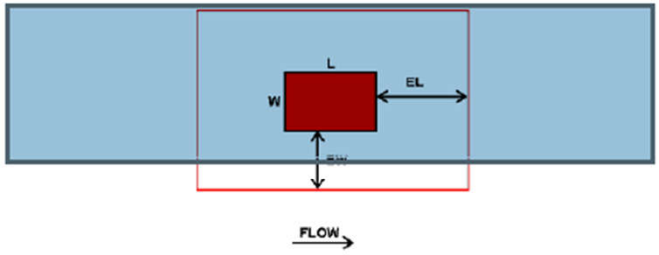
RSTRENG Effective Area

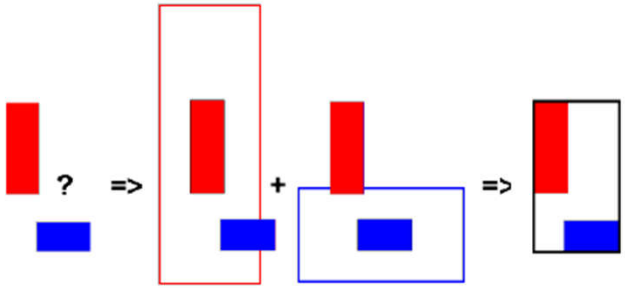




CALCULATION AND OUTPUT

- Clustering and ERF of Corrosion Anomalies
- Preliminary report does not usually include Clustering of ALL anomalies and the ERF (Estimated Repair Factor).
- ERF and Clustering (POF) are performed in Final Report and ROSOFT



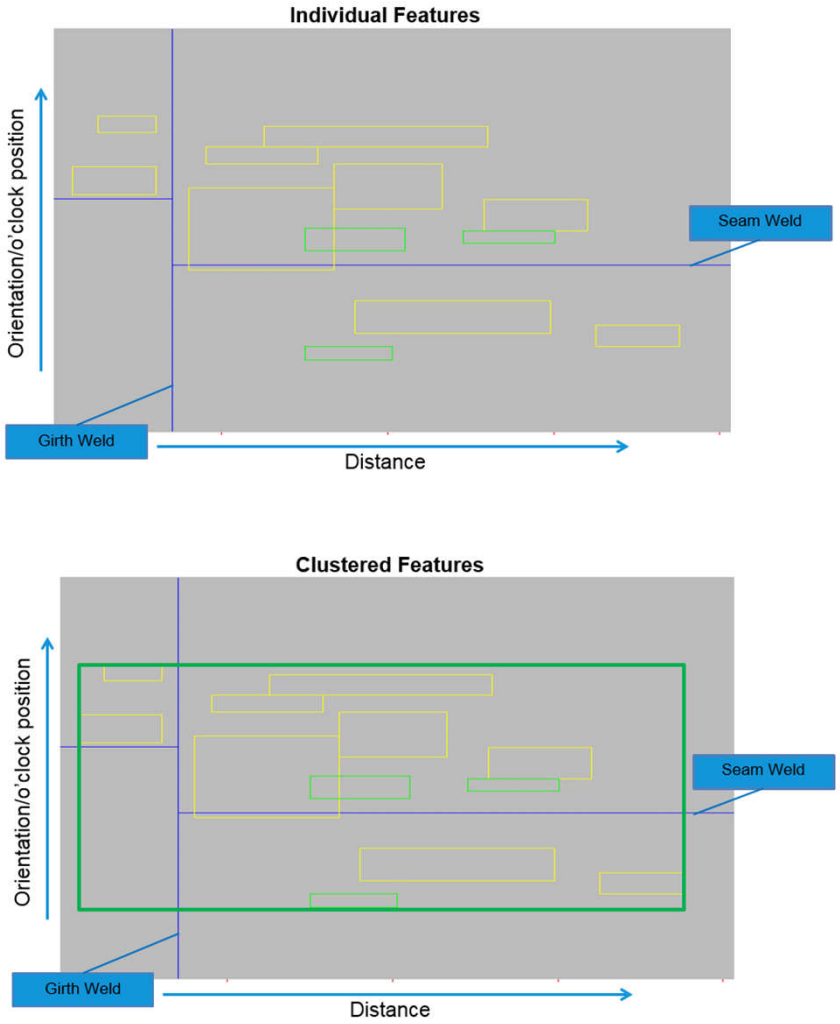


$$ERF = \frac{MAOP}{DFP}$$

DFP	= Defect Failure Pressure in [MPa]
P_{design}	= internal design pressure in [MPa] (Safety Factor 0.72)
MAOP	= Maximum Allowable Operating Pressure in [MPa]
c	= max. Depth of the corroded area in [mm]
t_n	= assigned nominal wall thickness in [mm]
G	= $0.893L/\sqrt{Dt_n}$
L	= axial length of the cluster in [mm]
D	= nominal outside diameter of the pipe in [mm]

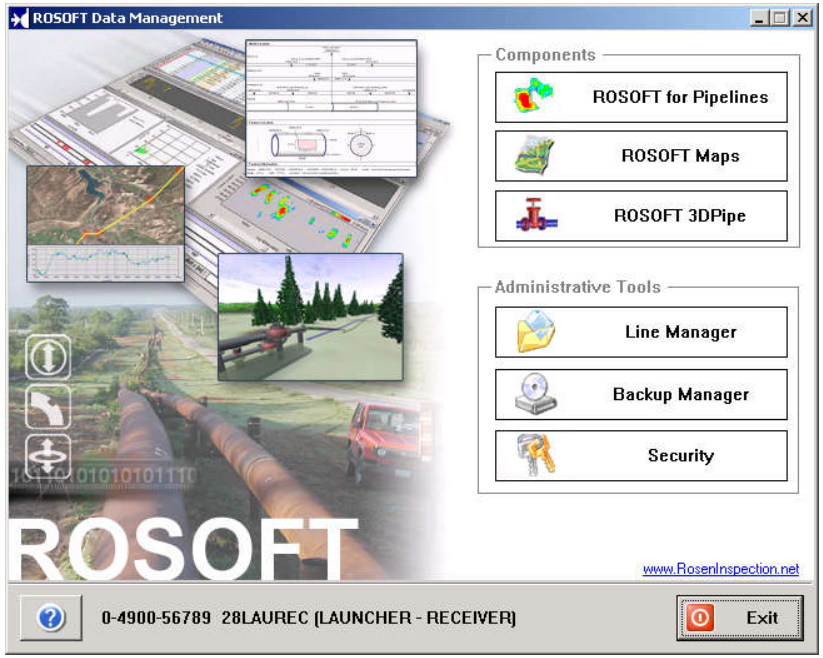
DFP – Based on calculations in ANSI / ASME

CALCULATION AND OUTPUT



CALCULATION AND OUTPUT

Once the calculation is completed and verified the Inspection Survey Report and ROSOFT client software are prepared.



CONTENTS

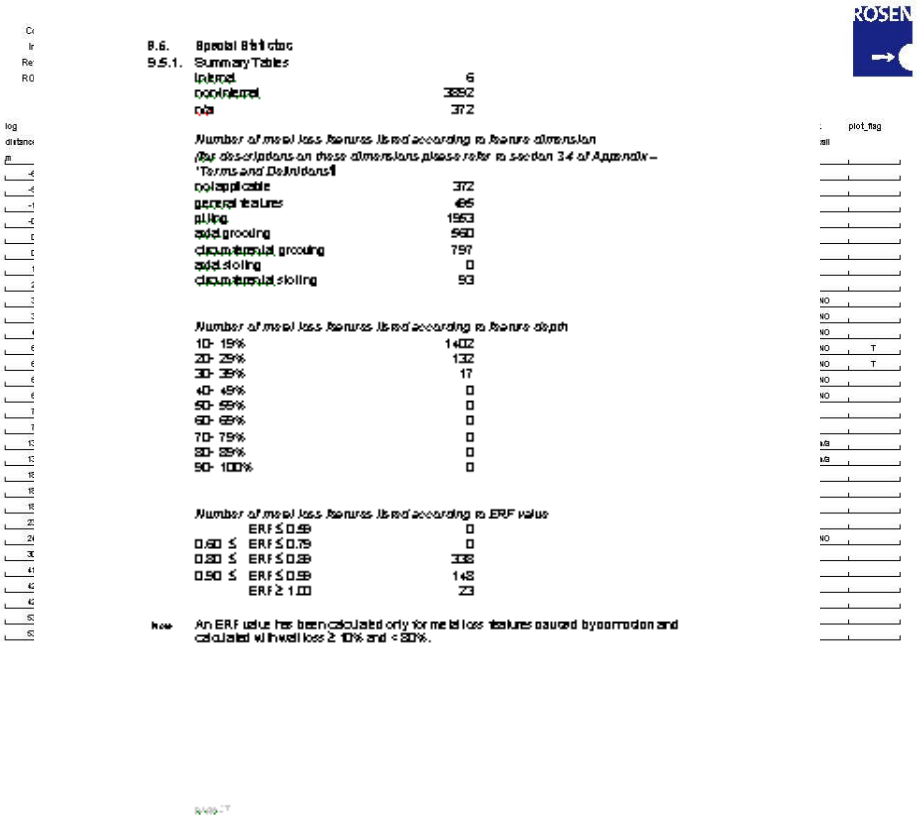
INSPECTION SURVEY REPORT

The Inspection Survey Report (based on POF) includes:

- Management Summary
- Pipeline Data
- Field Work Activity Report
- Data Quality Description
- Inspection Results

  in the form of:

  – Lists
  – Graphs
  – Statistics



Client: Pipeline Company
Date: June 25, 2003
ROSEN Project No.: D-10000-10395
ROSEN Line Name: 22" LAU-RIEC

8.6. Special Statistics
9.5.1. Summary Tables

internal	6
non-internal	3892
n/a	372

Number of metal loss features listed according to feature dimension
(for descriptions on these dimensions please refer to section 3.4 of Appendix – 'Terms and Definitions')

not applicable	372
general features	495
pitting	1953
axial grooving	960
circumferential grooving	797
axial slotting	0
circumferential slotting	93

Number of metal loss features listed according to feature depth

10- 15%	1402
20- 25%	132
30- 35%	17
40- 45%	0
50- 55%	0
60- 65%	0
70- 75%	0
80- 85%	0
90- 100%	0

Number of metal loss features listed according to ERF value

ERF ≤ 0.59	0
0.60 ≤ ERF ≤ 0.79	0
0.80 ≤ ERF ≤ 0.89	338
0.90 ≤ ERF ≤ 0.99	148
ERF ≥ 1.00	23

Note: An ERF value has been calculated only for metal loss features caused by corrosion and calculated wall-wall loss ≥ 10% and < 80%.

INSPECTION SURVEY REPORT

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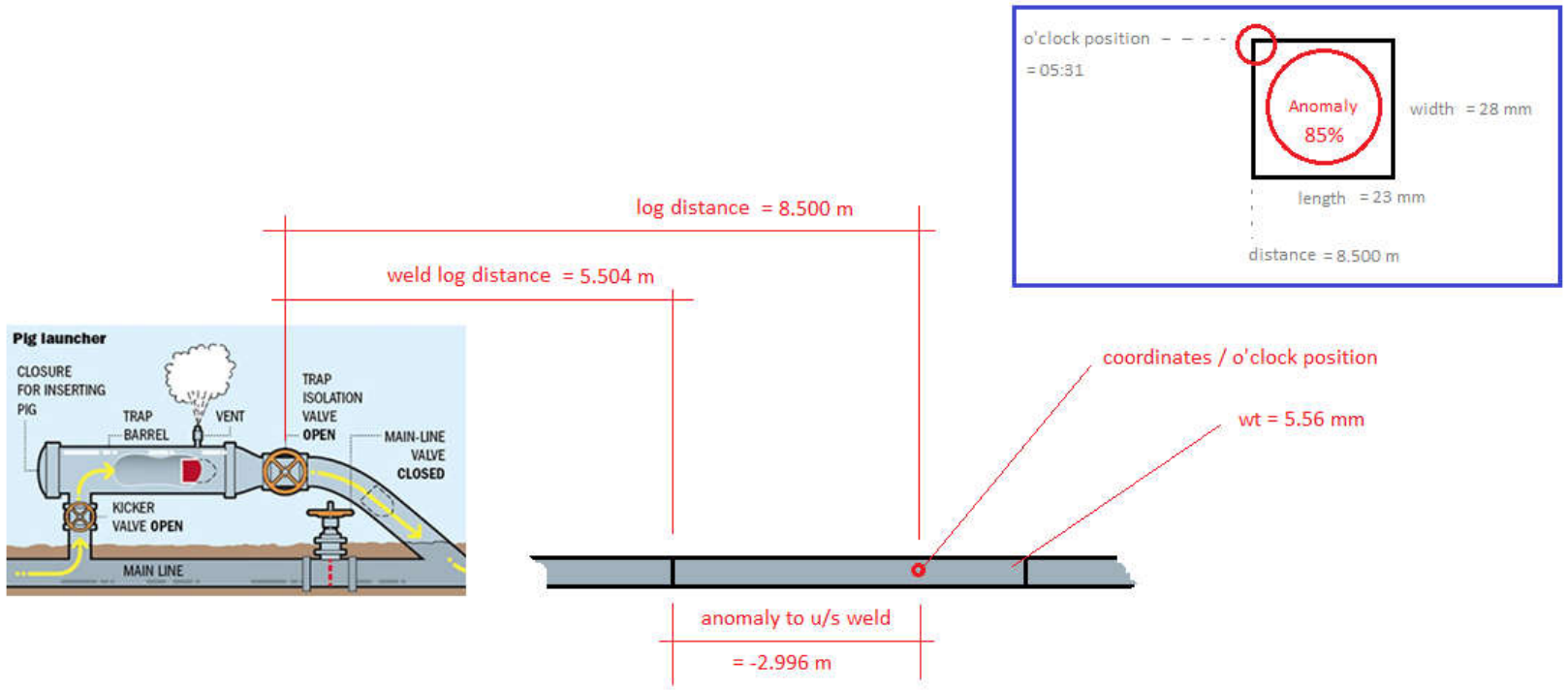
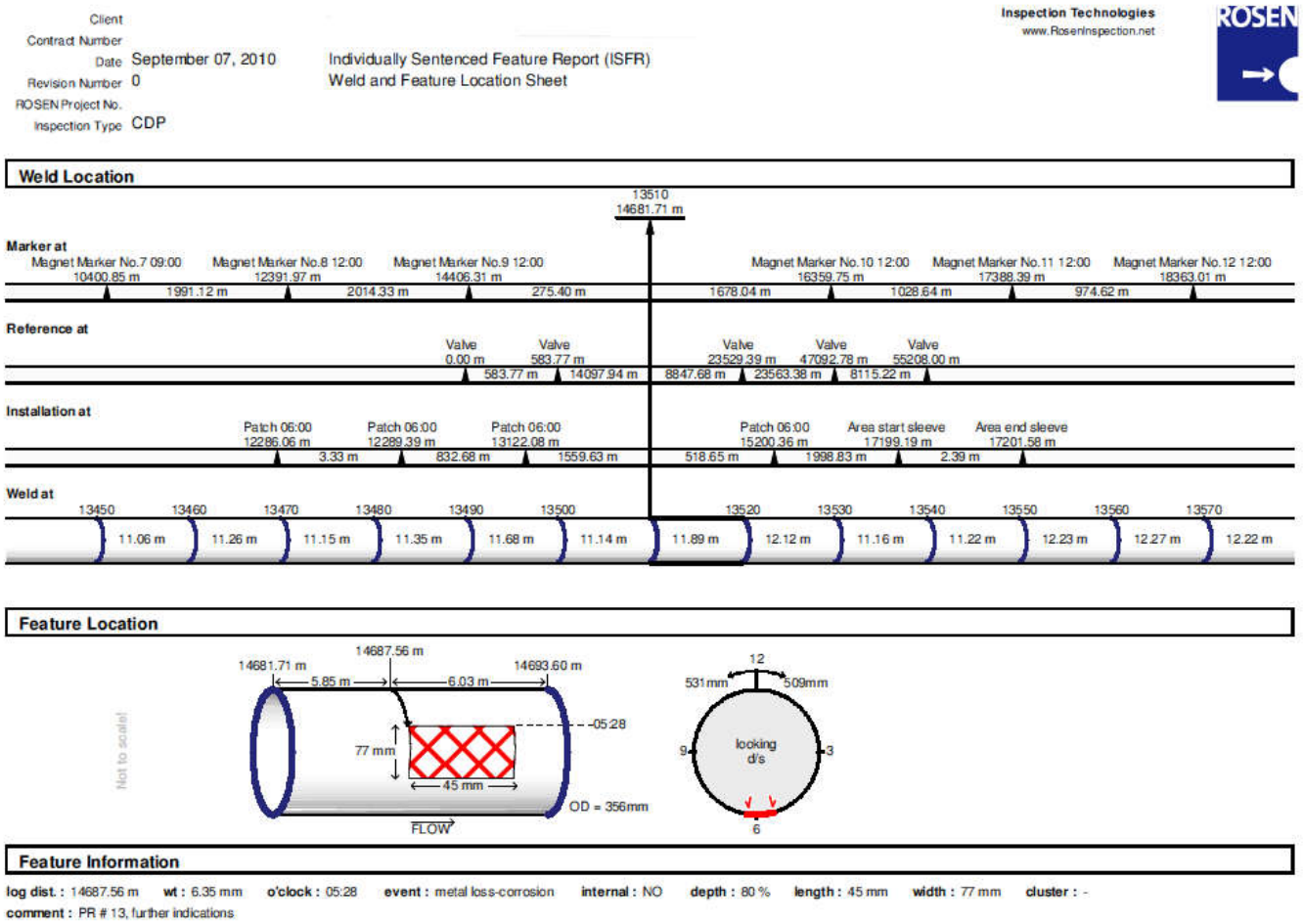
Example: List of Anomalies → anomaly location

weld log distance m	anomaly to u/s weld m	joint length m	wt mm	log distance m	easting m	northing m	heighting m	o'clock orient.	anomaly type	anomaly identification	outer dime.	length mm	width mm	max. depth %	ERF 0.85 dL	surface location	comment	location class	cluster	cluster ID
5.504	-2.996	11.974	5.56	8.500	641449.01	3861569.98	152.03	05:31	Anomaly	Corrosion	PITT	23	28	85		EXT		--J--	-	



INSPECTION SURVEY REPORT

All results / information / findings gathered during the inspections
run finally together in the ‘Individually Sentenced Feature Report’ (Dig Sheet):



Client
Contract Number
Date September 07, 2010
Revision Number 0
ROSEN Project No.
Inspection Type CDP

Individually Sentenced Feature Report (ISFR)
Weld and Feature Location Sheet

Inspection Technologies
www.RosenInspection.net

Weld Location

13510
14681.71 m

Marker at
Magnet Marker No.7 09:00 10400.85 m
Magnet Marker No.8 12:00 12391.97 m
Magnet Marker No.9 12:00 14406.31 m
Magnet Marker No.10 12:00 16359.75 m
Magnet Marker No.11 12:00 17388.39 m
Magnet Marker No.12 12:00 18363.01 m
1991.12 m | 2014.33 m | 275.40 m | 1678.04 m | 1028.64 m | 974.62 m

Reference at
Valve 0.00 m
Valve 583.77 m
Valve 23529.39 m
Valve 47092.78 m
Valve 55208.00 m
583.77 m | 14097.94 m | 8847.68 m | 23563.38 m | 8115.22 m

Installation at
Patch 06:00 12286.06 m
Patch 06:00 12289.39 m
Patch 06:00 13122.08 m
Patch 06:00 15200.36 m
Area start sleeve 17199.19 m
Area end sleeve 17201.58 m
3.33 m | 832.68 m | 1559.63 m | 518.65 m | 1998.83 m | 2.39 m

Weld at
13450 | 13460 | 13470 | 13480 | 13490 | 13500 | 13520 | 13530 | 13540 | 13550 | 13560 | 13570
11.06 m | 11.26 m | 11.15 m | 11.35 m | 11.68 m | 11.14 m | 11.89 m | 12.12 m | 11.16 m | 11.22 m | 12.23 m | 12.27 m | 12.22 m

Feature Location

14687.56 m
14681.71 m
5.85 m
6.03 m
14693.60 m
05:28
77 mm
45 mm
OD = 356mm
FLOW
Not to scale!

12
531mm
509mm
9
3
looking d/s
6

Feature Information

log dist. : 14687.56 m **wt :** 6.35 mm **o'clock :** 05:28 **event :** metal loss-corrosion **internal :** NO **depth :** 80 % **length :** 45 mm **width :** 77 mm **cluster :** -
comment : PR # 13, further indications

INSPECTION SURVEY REPORT

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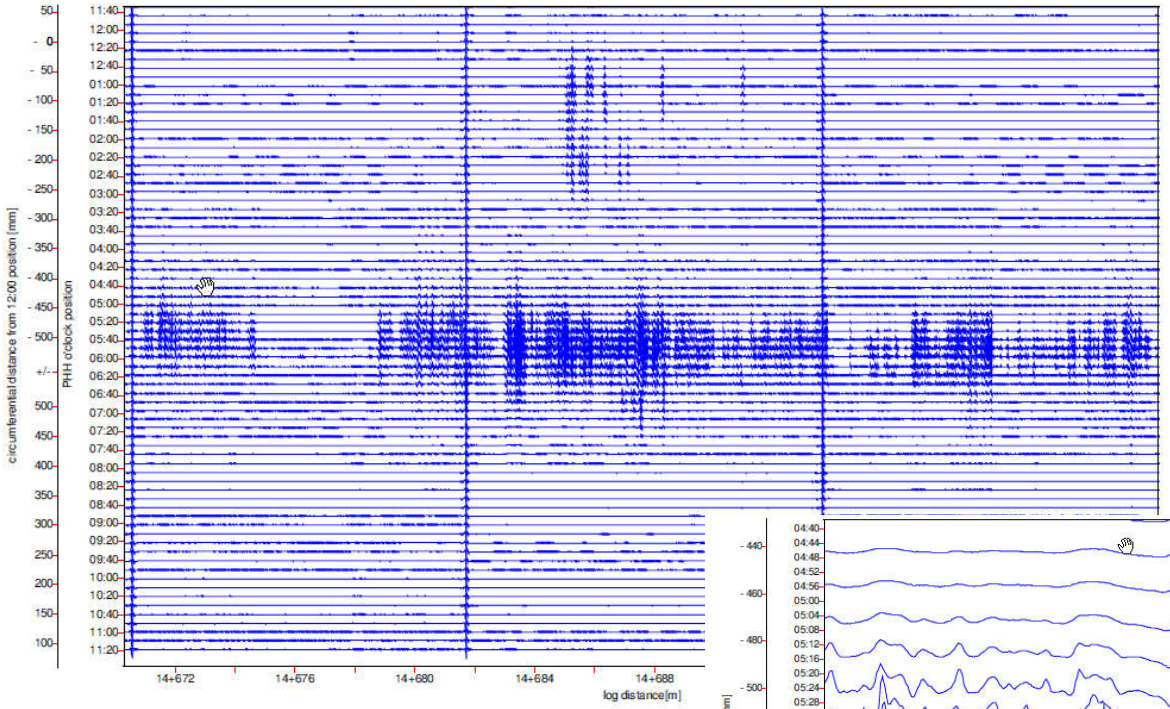
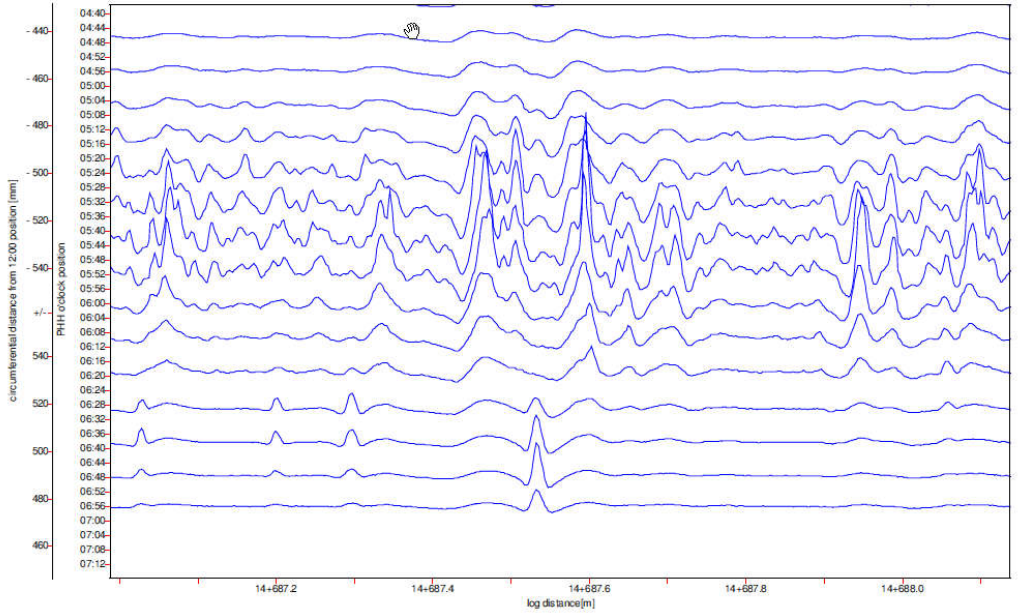


1:150 / +/- 6 h

1:5 / +/- 1.5 h



CONTENTS

ELECTRONIC DATA REPORTING

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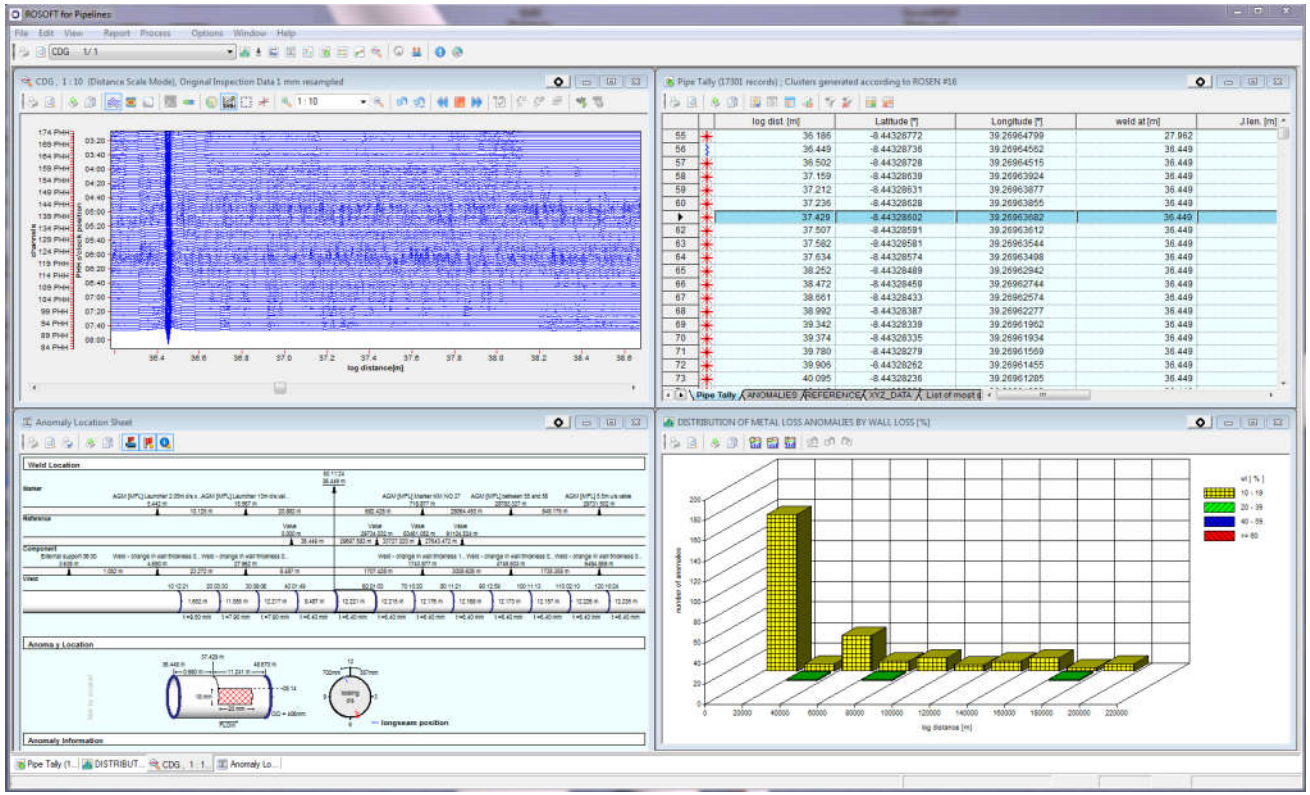
A ROSOFT Electronic Data Package is included with each Inspection Survey Report. ROSOFT gives operators interactive access to:

- Lists
- XYZ Results
- Graphs
- Dig Sheets
- Signal data



THANK YOU FOR JOINING THIS PRESENTATION.

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