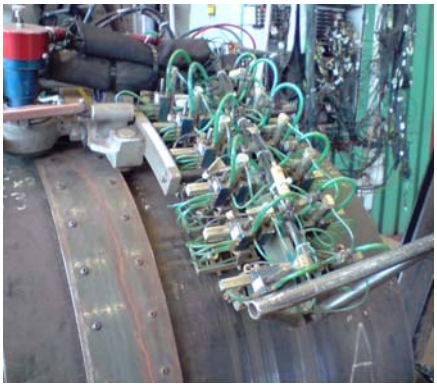
IBC Onshore Pipeline Engineering
Training Course
London

June 2016

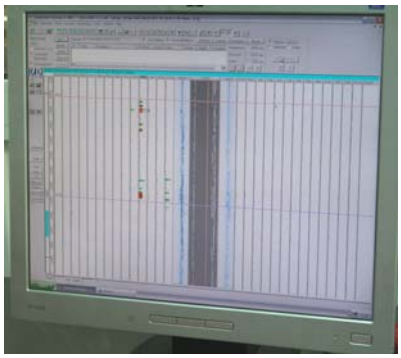
Automatic ultrasonic testing (AUT)



Alan Denney

What it does

- A scanner consisting of a series of ultrasonic probes is clamped to a band which has been preset on the pipe
- The scanner is rotated around the pipe.
- The probes emit focussed ultrasonic beams. Defects reflect these beams which are collected by the probes
- These signals are read by the system and displayed on a screen
- The operator 'sentences' the signals against the agreed defect acceptance criteria



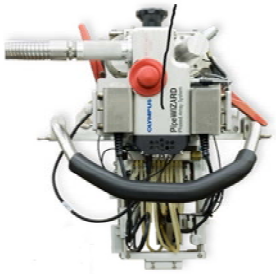
The scanning head

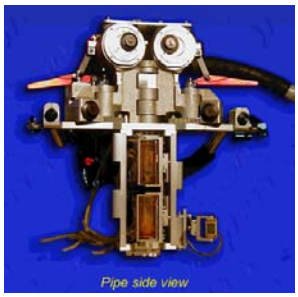
Provides a housing for the UT transducers;

Travels circumferentially around the pipe weld holding the UT probes at a fixed distance from the weld centreline.

Contains the encoder, which supplies circumferential position and speed information.

Scan speed can be up to 150mm per second



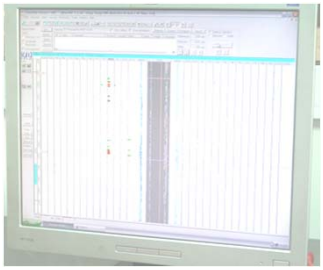


AUT

The AUT system comprises:-

- The scanning head,
- The band on which it runs
- The umbilical
- The control unit
- The computer system
- The interpretation program

Scan presented on computer screen



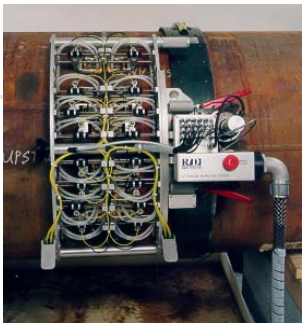
Instrumentation

The instrumentation consists of:-

- A motor drive control unit
- A data acquisition unit containing the pulser/receivers
- an industrial high speed personal computer for display and storage

Alternative types of scanner, and probes

The original scanners consisted of a tray of separate probes - each one set up to focus on one part of the weld



Current systems work on Phased Array technology

The number of probes is reduced making the scanner relatively light and easily handled

PA systems are readily modified for inspecting different wall thicknesses, diameters and materials by simply re-calling a set-up in the software.

Phased Array AUT system

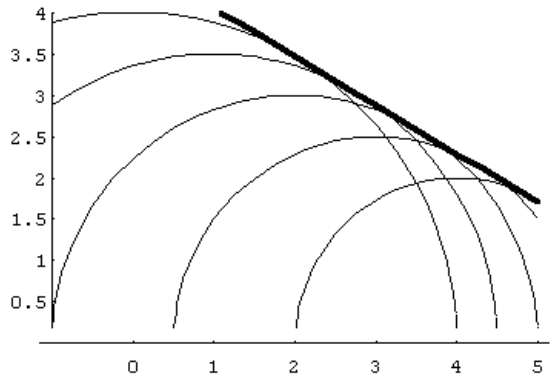
- Each probe is an array of elements, each element pulsed separately with its own time delay generator.
- One probe is the equivalent of many fixed angle probes
- By adjusting the time delay between elements, it is possible to generate any type of probe - normal beams, angled beams, focused or unfocused beams, shear waves or longitudinal waves,

Phased array systems have:

- Smaller height zones – giving more precise defect height reporting
- Improved defect characterisation by multi-angle approaches

The principle of phased array

Wavefront propagating from delayed signals – creating an angle beam

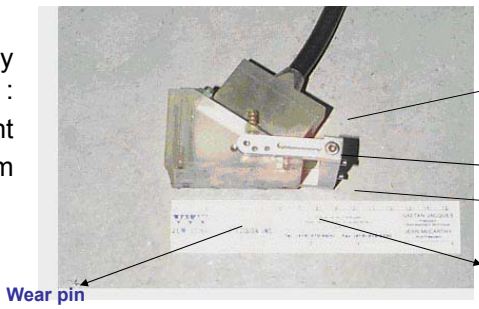


The probe, or transducer

Typical phased array probe :

7.5 MHz, 64 element

10mm x 60mm

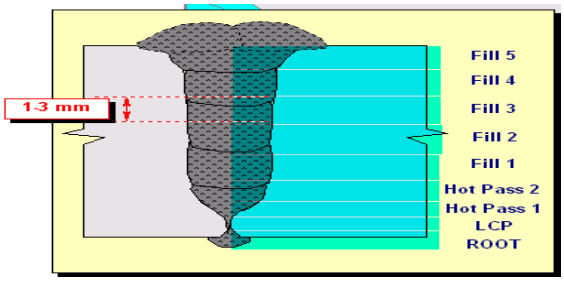


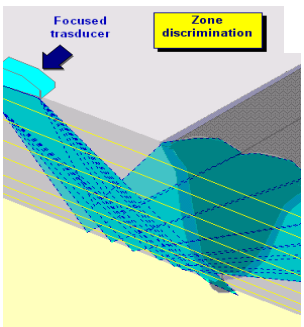
The array consists of duplicated probes on either side of the weld centreline.

The other probe visible is a Time of Flight Diffraction (TOFD) probe

AUT - Zone discrimination

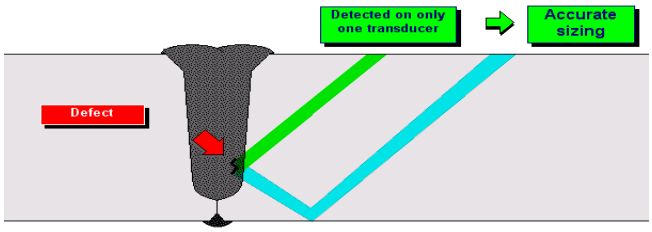
The weld is divided into zones through the thickness





The ultrasonic transducers are focused at the optimum angle for each zone.

Zone discrimination

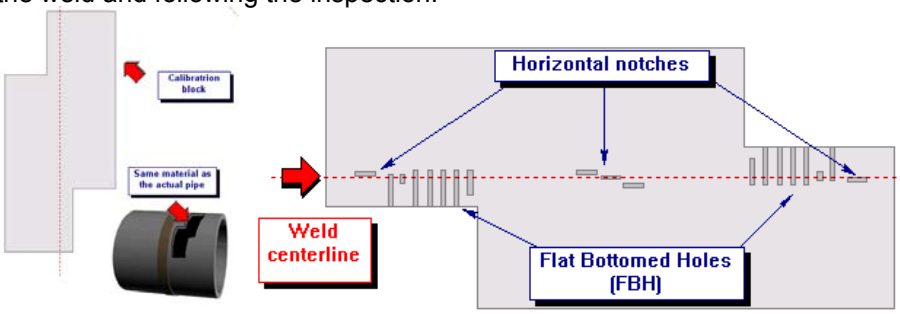


- Zone discrimination permits accurate sizing
- A signal detected on only one transducer comes from a defect less than (or equal to) that zone's height.

The calibration block

A calibration block is manufactured for each diameter, wall thickness, bevel and material.

Calibration is carried out both before inspecting the weld and following the inspection.



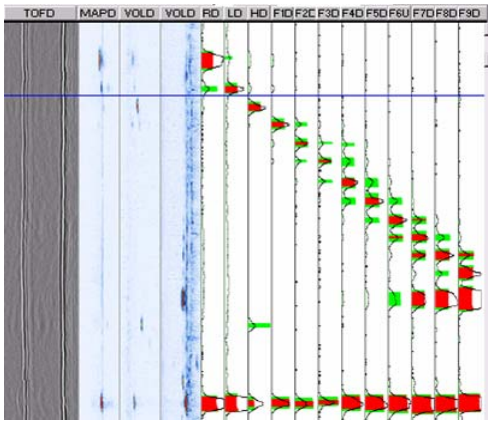
The software

The primary window in which weld data is displayed is called the *strip chart*.

The software is a Windows application

Each strips corresponds to a different inspection zone

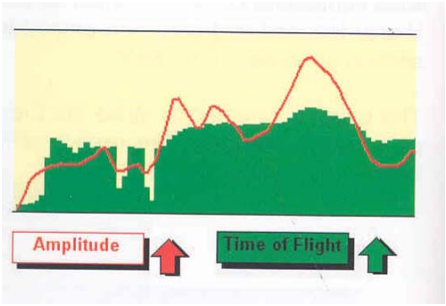
At the vertical centre of the strip chart is the TOFD channel



Information seen on the trace (R/DTech)

Each strip on the chart provides the Operator with two information elements:

- Echo amplitude: the signal strength of an indication.
- Time of Flight (TOF): the position of an indication within the target zone related to a reference position.



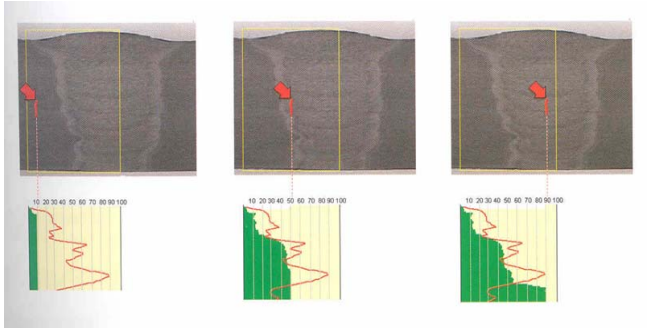
These two pieces of information are used (in combination with the other information) to locate, identify and size all relevant indications.

Position of signal relative to the gate

Signal with low TOF (e.g. 10% of the distance through the gate) arise from reflectors before the fusion line;

Signals with TOF of 40-50% come from the calibration reflector position (fusion line);

Signals at the end of the gate (90%) typically are mid-weld

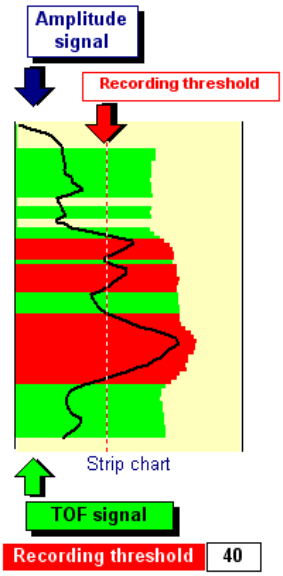


Amplitude threshold

The TOF signal is colour coded green or red, based on signal amplitude.

The TOF indication is red if the signal is above the *recording threshold*.

The selected *recording threshold* is derived from the specification and the acceptance criteria.



Depth sizing and positioning of indications

The height and depth of defects is first assessed from the zone information.

- An indication occurring within a single zone is located in that zone and is assumed to start at the bottom of that zone.
- If the signal has a small component in the zone below the main signal the operator may conservatively estimate the flaw to be at the bottom of the lower zone.
- Where signals are seen in adjacent channels corrections are made for size based on correction tables

Table III: Zone Height Correction Table GMAW .30.2 mm WT

Design

Zone	Rt1	Rt2	HP	1	2	3	4	5	6	7	8	CN
Height (mm)	1	1	2.4	3	3	3	3	3	3	3	3	3

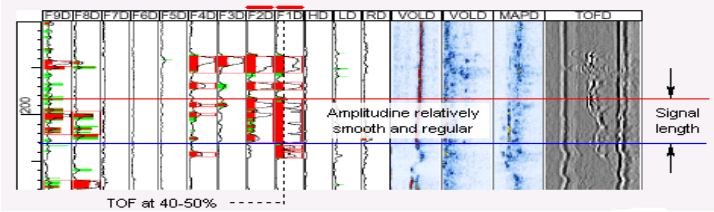
Corrected

% FSH Signal Amplitude (*)	Rt1	Rt2	HP	1	2	3	4	5	6	7	8	CN
5	0.1	0.2	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1
10	0.1	0.3	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.1
15	0.15	0.5	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.15
20	0.2	0.6	0.5	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.2
25	0.25	0.8	0.6	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.25
30	0.3	0.9	0.7	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.3
35	0.35	1.1	0.8	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	0.35
40	0.4	1.2	1	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	0.4
45	0.45	1.4	1.1	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	0.45
50	0.5	1.5	1.2	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	0.5
55	0.55	1.7	1.3	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	0.55
60	0.6	1.8	1.4	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	0.6
65	0.65	2	1.6	2	2	2	2	2	2	2	2	0.65
70	0.70	2.1	1.7	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	0.70
75	0.75	2.3	1.8	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	0.75
80	0.80	2.4	1.9	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	0.80
85	0.85	2.6	2	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	0.85
90	0.90	2.7	2.2	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	0.90
95	0.95	2.9	2.3	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	0.95

[*] The signal amplitude shall be from the reference calibration.

Sizing and positioning of indications - length

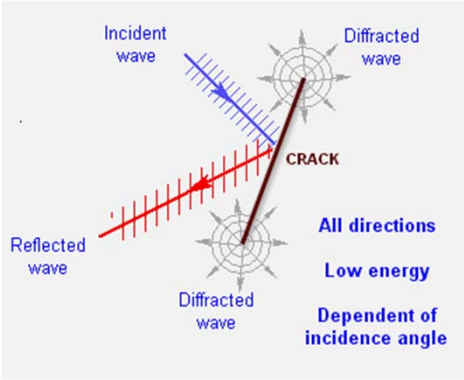
- The defect length is the length over which the amplitude exceeds the threshold level.



- If two defect signals come close together they are evaluated to see if they should be classified as a single defect under the *interaction rules*
- interaction assessment is based on the space between the defects in relation to the defect size as measured

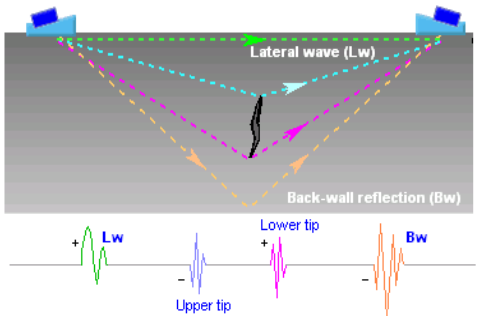
TOFD – the principle 1

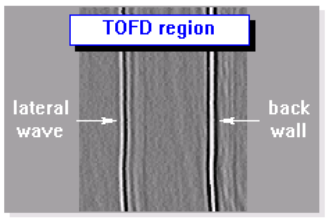
- The probe emits a wave – the incident way
- Normal pulse-echo ultrasonics is detecting the reflected wave when this hits the defect.
- However the tips of the defect are sources of spherical diffracted waves.
- TOFD is dependent on the diffracted waves and their detection.



- The diffracted waves propagate in all directions. They are low amplitude
  - typically 20 to 30 dB below the amplitude of reflected waves.

TOFD – the principle 2

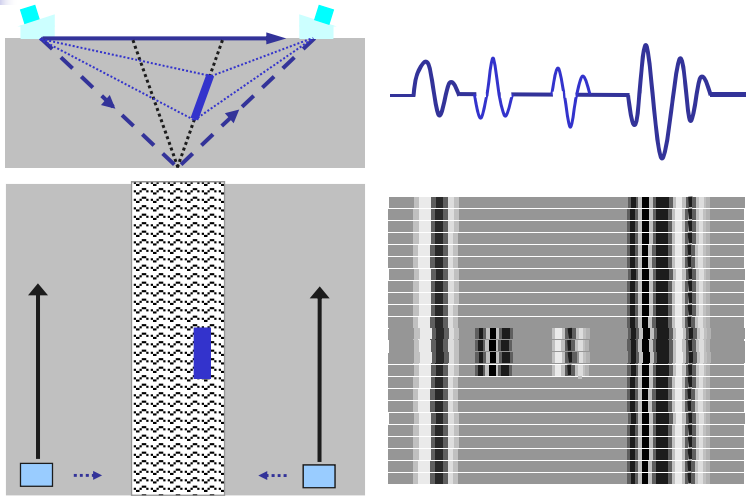




The lateral wave (Lw) (sub-surface) and the back wall reflection are clearly visible. Defects show up between the two as diffraction signals.

- The transmitter and the receiver are separate and a fixed distance apart.
- They are positioned symmetrical to the weld centreline.

Data Visualization



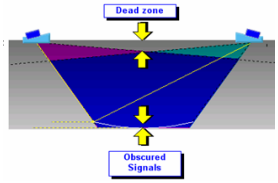
TOFD - advantages

- TOFD provides a clear image of the weld immediately
- TOFD readily shows which defects are surface-breaking.
- TOFD provides accurate sizing of defect face heights, and can be used to confirm findings from pulse echo channels.
- TOFD can detect defects which are not detected with pulse-echo (for reasons of their alignment)

Misoriented defects

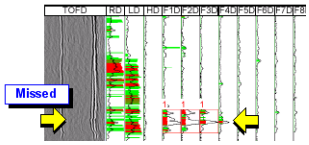
TOFD - limitations

- TOFD has a "dead zone" a couple of mm deep at the surface.
- Near-back-wall TOFD signals can be obscured.



We rely on pulse-echo channels to give information in these zones

- TOFD signals are low amplitude, and flaws can be missed.



- It can be difficult to establish precise defect location in the axial direction; this can be resolved by looking at the pulse-echo channels.
- TOFD tends to "over-emphasize" mid-wall defects.
- TOFD is not normally a code-approved procedure. Thus all accept-reject decisions should be made using the pulse-echo data.

Advantages of AUT over Radiography

Safety

- Elimination of radiation hazard
- Elimination of harmful chemical waste

Environmental advantages

- No film required – hence fewer materials used
- No chemicals used in processing, hence no disposal

Practical advantages

- Fast access to inspection record
- Improved inspection cycle time
- No NDT equipment inside the pipe
- Ability to use inspection results as a process control

Detection advantages of AUT

- An increased probability of detecting critical defects - planar defects and root defects
  - (Radiography is good for detection of volumetric indications such as inclusions, clusters of porosity and individual pores)
- AUT has the ability to size defects
  - Defect face height
  - Defect depth relative to pipe surfaces
  - Defect position relative to weld centreline
  - Defect length
- AUT generally identifies more indications per weld than radiography and manual UT.

The Probability Of Detection (POD) of defects is better with AUT than with radiography

Advantages – defect acceptance standards

- AUT gives accurate sizing of the defects
- Fracture mechanics provides the ability to analyse the criticality of flaws
- By combining the two we derive fitness-for-purpose acceptance criteria (instead of workmanship ones)
- This reduces repairs significantly and saves the damage done repairing trivial defects

AUT saves construction costs by

- Making it possible to use fitness for purpose acceptance criteria, which minimises the rejection rate and hence repair time.
- Giving rapid feedback on the overall weld quality – permitting corrective action

Advantages of AUT over Manual UT

- Manual UT (MUT) typically identifies less than half the number of indications found by AUT.

This is due to:

- The probe angles used (which are limited in MUT)
- The different methods of calibrating, which are less stringent and sensitive with MUT than with AUT
- Human factors

Critical items for AUT

PIPE MATERIAL

- Different sources of the pipe material
- The surface condition of the pipe
- Wall thickness variation and different wall thicknesses
- Coating cut-back
- The treatment of the longitudinal seam in welded pipe

WELDING

- Bevel profile and bevel tolerances
- Welding shrinkage
- Heterogeneous welded joints
- The anticipated defect types
- How repairs are to be inspected

ON SITE

- Scribe line accuracy – used for setting the band
- Logistics
- Pipe temperature
- Personnel

Locating the band

Acknowledgements

Alan Denney acknowledges the use of material provided by the following organisations:-

- Saipem Ltd
- Saipem SpA
- The Welding Institute
- Olympus
- Other equipment providers

THE END