ISONIC PA AUT

Automatic Ultrasonic Inspection of Girth Welds Combining Phased Array, TOFD, and Conventional Pulse Echo Techniques

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Unique cutting edge technology solution for high-speed automatic ultrasonic inspection of girth welds

In the newly constructed gas and oil off-shore and on-shore pipelines pipes are girth-welded automatically then rapidly inspected, coated, and buried. Detection, evaluation, and repair of defects in the welds must be very quick in order not to affect the construction cycle therefore high-speed automatic ultrasonic testing (AUT) of girth welds is incredibly demanded as sole codes accepted alternative to radiography

AUT is implemented through scanning of weld along fusion line using several probes situated on the OD surface from both sides of girth weld. Traditionally frame with ultrasonic probes and position encoder is carried by traction unit (scanner) along orbital travel band and the umbilical connects probes, position encoder, and scanner's motor to ultrasonic pulsing-receiving, control, data processing and recording electronics, which is placed either in the truck cabin (on-shore inspection) or in a separate room on the lay barge (off-shore inspection) at the distance of up to few tens meters from the scanning deck. A team of operators handles the AUT system: usually there are two operators involved into placement of scanning stuff onto the pipe and one operator responsible for control of scanning, observation of the indications and recording process, and taking GO/NO GO decision

AUT of girth welds is regulated by couple of codes such as ASTM E-1961, API 1104, and DNV 2000 OS-F101, according to the which weld volume is divided into multiple horizontal thin slices (zones) in the cap, fill, hot pass, and root areas. Designated zones are insonified one by one through sequence of independent pulsing-receiving shots. Use of phased array (PA) technology significantly minimizes quantity of probes involved into multiple zone insonification thanks to electronic beam steering. This simplifies scanning stuff and accelerates the inspection. Use of several TOFD and conventional probes simultaneously with PA probes provides complete coverage of the weld volume at every cross-sectional position along fusion line: PA probes do implement pulse echo and tandem technique for the detection of various compact and longitudinal defects; conventional probes perform inspection for the detection of transversal defects (K- and X- schemes), detection of laminations in the heat affected zone in parent material, etc.; TOFD probes implement complimentary technology allowing detection of compact and longitudinal defects through receiving of diffracted signals. Ability of defect detection in each zone is provided through calibration of the system on specially manufactured blocks containing certain number of artificial reflectors, which's location, orientation, shape, and dimensions represent variety of flaws to be sensed and recorded

Practical use of traditional PA AUT stuff over several years highlighted a number of inconveniencies experienced by the inspection providers:

- Big expensive, heavy, bulky, and vulnerable umbilical causing relatively high operational cost as well as low signal to noise ratio and high power consumption due to transfer of analogue signals through tens meters length wires
- Insufficient quantity of A/D converters leads to use of multiplexing and elevating pulse repetition rate further increasing power consumption
- Insufficient quantity of pulsing-receiving channels requires more than one scanning revolution and / or making compromise by using the wedges of PA probes also for TOFD to inspect single girth weld completely, this slows the overall speed of AUT
- Overheat of electronics caused by high power consumption requires water-cooling or frequent shutdown breaks during work shift

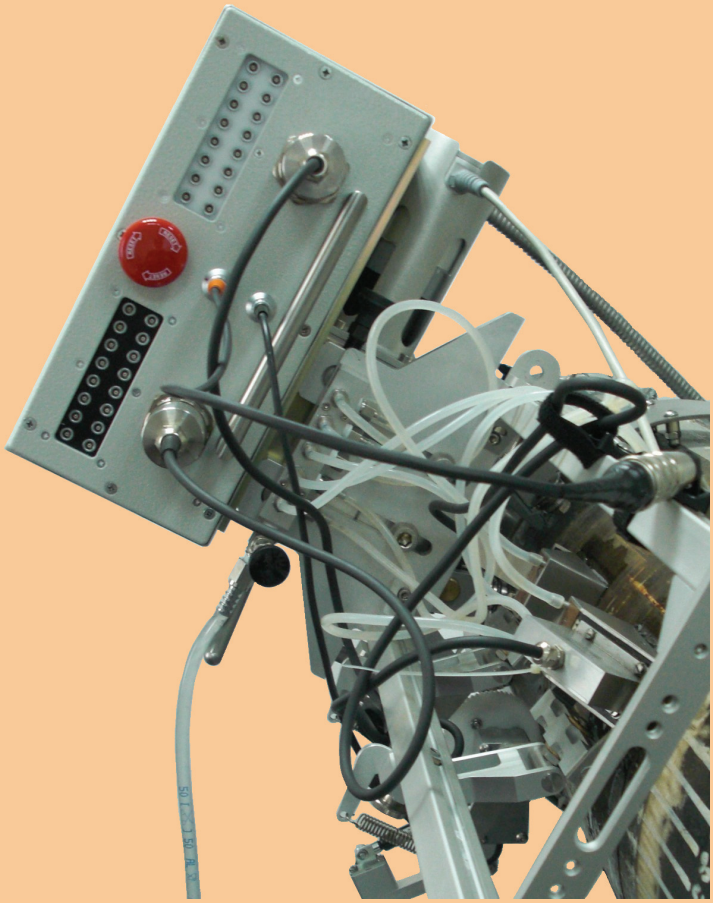
ISONIC PA AUT system from Sonotron NDT represents cutting edge technology solution for high-speed AUT of girth welds bringing practical implementation to the highest convenience level

ISONIC PA AUT instrument is packed into rugged portable light weight (6.8 kg only) IP 67sealed case, which is fitted onto the scanner's chassis; regular remote PC connected to instrument through Ethernet provides full control, data acquisition and imaging in real time, thus no big expensive, heavy vulnerable umbilical – just thin light armoured tube carries DC wires and LAN cable, which are connected to the machine through specially designed rotating terminal

Probes signals are sampled and pre-processed in real time on-board; the digitised raw inspection data is transferred to remote PC for further processing, storage, and imaging. Fully digital through-Ethernet control and data transfer provide practically unlimited length of distance to remote PC enabling flexibility of creating control rooms or multiple monitor stations throughout the barge / factory / weld station, etc

Probes are connected to **ISONIC PA AUT** using short cables – comparing to transfer through long umbilical this provides much better signal quality significantly improving signal to noise ratio and dynamic range

Further improvement of signal to noise ratio and dynamic range is achieved through firing probes with unique bi-polar square wave initial pulse reaching up to 300 Volt peak to peak for PA probes and up to 400 Volt peak to peak for the conventional and TOFD probes. Duration and amplitude for both positive and negative half-waves of the initial pulse may be tuned in wide range. Additionally it is provided high stability of firing amplitude selected by an operator while leading and falling edges of bi-polar initial pulse are electronically boosted



There is no limit for quantity of PA probe elements composing emitting aperture – all elements of each PA probe connected to **ISONIC PA AUT** may fire simultaneously if necessary. Advanced low noise design provides the ability of up to 100 dB analogue Gain for PA, TOFD, and conventional probes

ISONIC PA AUT performs 16-bit 100 MHz sampling rate digitising of signals obtained by all elements of receiving aperture at parallel independently on their quantity (aperture size) – there is no multiplexing involved; the digitised signals are phased (phase-shifted) and superimposed on-the-fly according to the desired focal law so each superimposed A-Scan is formed and memorized in the buffer in real time during the entire pulsing-receiving shot

ISONIC PA AUT performs complete raw data capturing allowing play-back of all A-Scans obtained during the scanning; this provides full compliance with ASME 2235 Code Case related to use of ultrasonic inspection in lieu of radiography

Rational power management eliminates heating problem; thanks to extremely low power consumption water or another type cooling is never required for **ISONIC PA AUT**

In the **ISONIC PA AUT** each pulser receiver for TOFD and conventional probes may be operated in both modes – dual and single, i.e. use of dual element probes, TOFD insonification, K- and X-scheme for pitch-catch detection of transversal defects with shear waves, etc employ only one channel per task

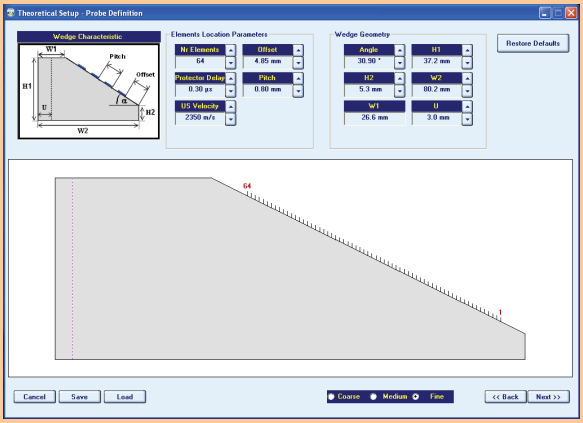
Typically **ISONIC PA AUT** comprises 128 PA channels allowing simultaneous use of two 64-elements probes and 16 conventional channels, which are totally separated from PA stuff; it is easy upgradeable to 512 PA channels for future state of the art use, for example matrix PA technology allowing 3D beam steering vs today's 2D. Quantity of conventional channels may be upgraded to 32 or 64 as well

One regular PC may control and acquire data from several **ISONIC PA AUT** systems simultaneously (up to 16) allowing rational organization of AUT job on-site and minimizing manpower involved

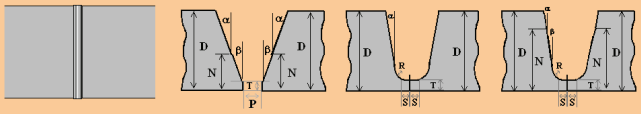
Pre-scanning Routine – Stage 1: Theoretical Setup Wizard

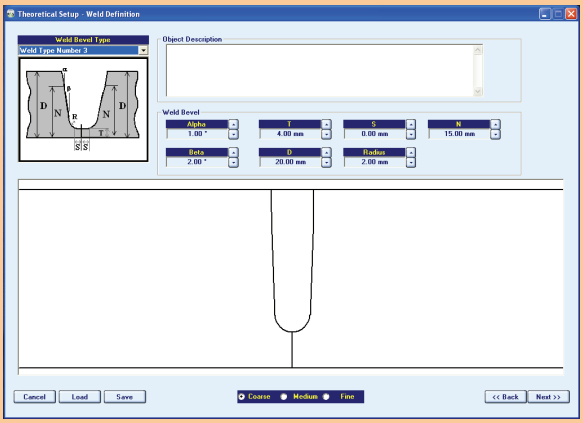
Theoretical rays tracing procedure is required for operating of PA probes – it is necessary to cover weld bevel surface and weld volume completely. Ray tracing for the **ISONIC PA AUT** is performed through very intuitive *Theoretical Setup Wizard*, which guides through:

- *Probe Definition* dialogue for entering parameters of PA probes and wedges

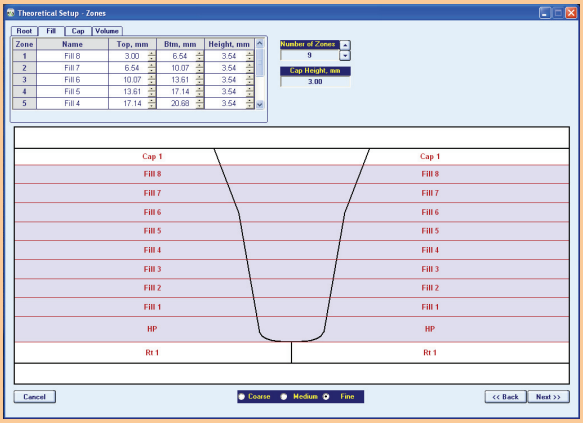


- *Weld Definition* dialogue for selection of appropriate weld bevel from data base and entering related geometry and dimensions

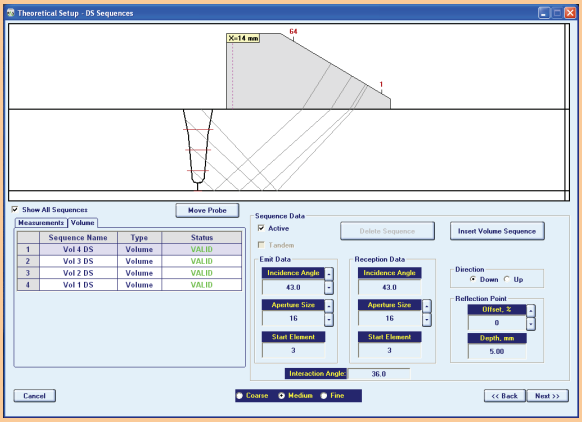


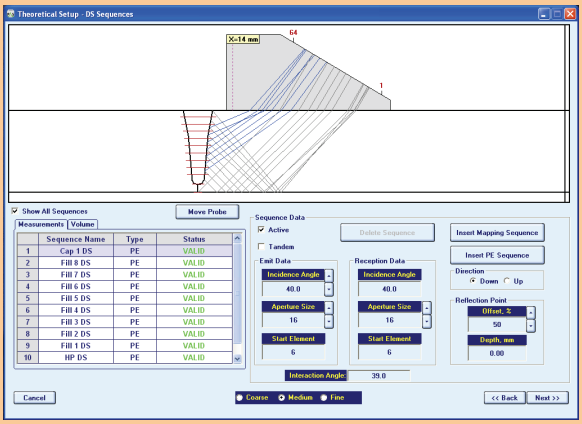


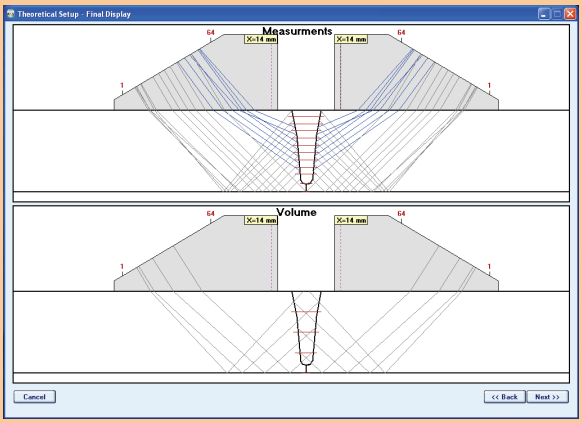
- *Zones Definition* dialogue for "slicing" of weld volume, cap, hot pass, and root areas into zones to be insonified in each qualified position of PA probe:



- *Ray Tracing* dialogue for determining of zone-by-zone insonification scheme (pulse echo or tandem; incidence angles; emitting and receiving aperture; focal distance) and appropriate positions for PA probes from both sides of the weld (Upstream – Downstream)



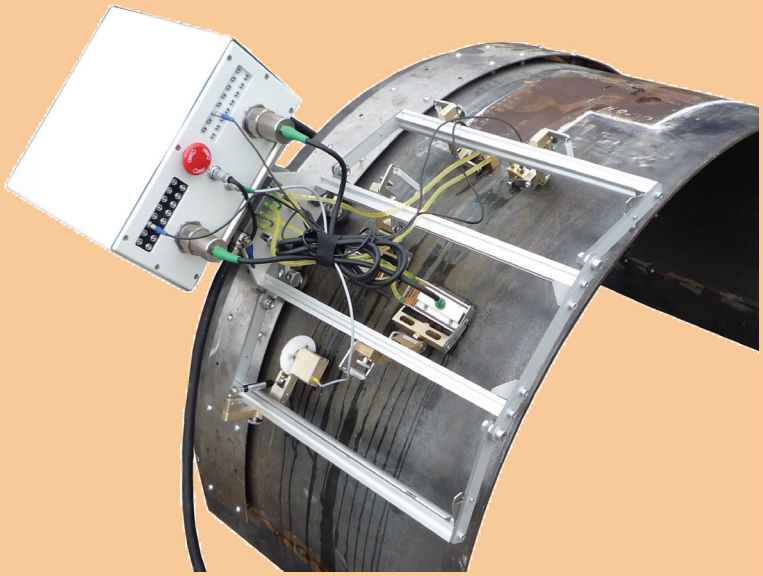




Movies illustrating examples of the ray tracing routine are available for download at:
http://www.sonotronndt.com/RepInfo/IPAAUT/TS.wmv
http://www.sonotronndt.com/RepInfo/IPAAUT/TS30deg.wmv

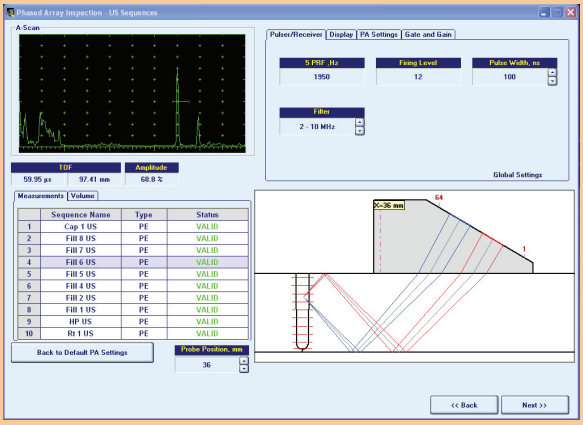
Pre-scanning Routine – Stage 2: Ultrasonic Setup Wizard

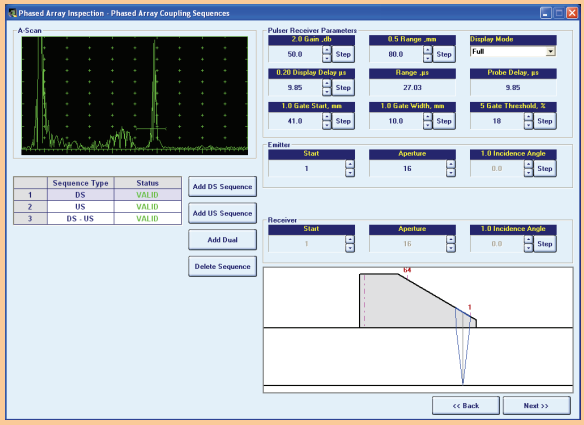
Ultrasonic setup is performed on specially manufactured calibration block including a number of artificial reflectors, which's location, orientation, shape, and dimensions represent variety of flaws to be sensed and recorded. Calibration blocks are manufactured for each pipe diameter, wall thickness, weld bevel, etc. by such a way that all defects may be detected and recorded through one revolution scan along the hypothetic fusion line. Typically calibration block is shaped as piece of pipe allowing setup of complete scanning stuff; each section containing artificial defect is appropriately marked on the OD surface of the pipe

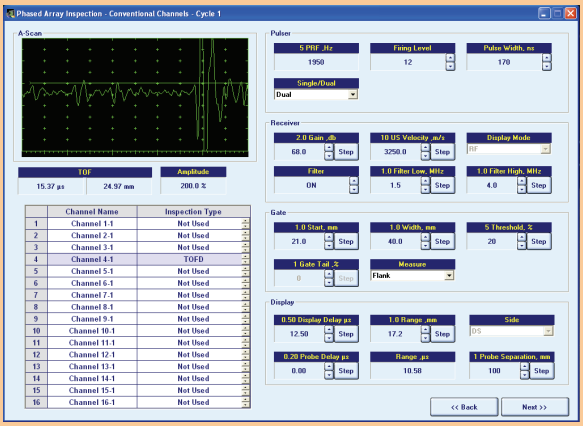


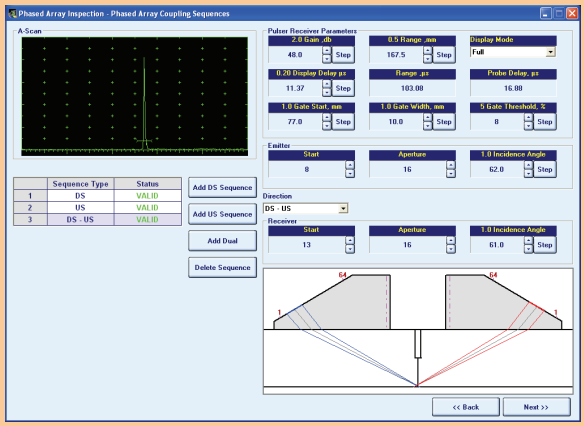
Initial goal of the operator is one-by-one placement of appropriate probe either PA, TOFD, or conventional into every predefined position and providing necessary settings (Gain, Gate, Aperture, etc) ensuring detection and resolving of all artificial defects

Continuous coupling monitoring is a must for AUT and the appropriate pulsing receiving shots to be calibrated for PA and conventional probes as well. In the **ISONIC PA AUT** it is possible to use as coupling reference either longitudinal wave back wall echo or through-transmitted signal between two probes or combination of above techniques









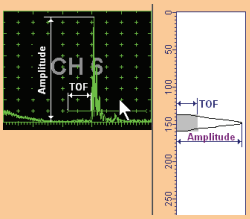
Final screen of *Ultrasonic Setup Wizard* relates to configuration of the *strip chart*. *Strip chart* is a method of AUT data presentation whereas each pulsing-receiving shot is continuously recorded into corresponding strip

ISONIC PA AUT may form strips of the following types:

PE

Amplitude / TOF Pulse Echo Strip represents peak amplitude and time of flight for signals matching with Gate and exceeding it's threshold level

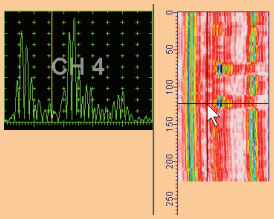
Position of *Amplitude Line* on the strip is proportional to the signal height. Echo amplitude equal or exceeding 100% of A-Scan height brings *Amplitude Line* trace to full strip width level



Width of gray *Time of Flight (TOF) Rectangle* is proportional to the signal position in the Gate. For signals, which's time of flight measurement point matches with the Gate end width of gray *Time of Flight (TOF) Rectangle* is equal to the full strip width

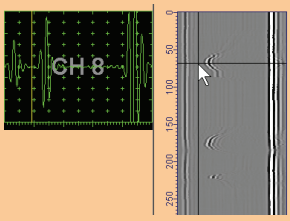
For geometry echoes matching within specially designated Gate Tail the *Amplitude Line* is not produced, just *TOF Rectangle*

Map



Up to 256 Colors Palette **Map Strip** represents sequence of A-Scans whereas color of points for each horizontal line is coded according to corresponding signal level and default palette

TOFD

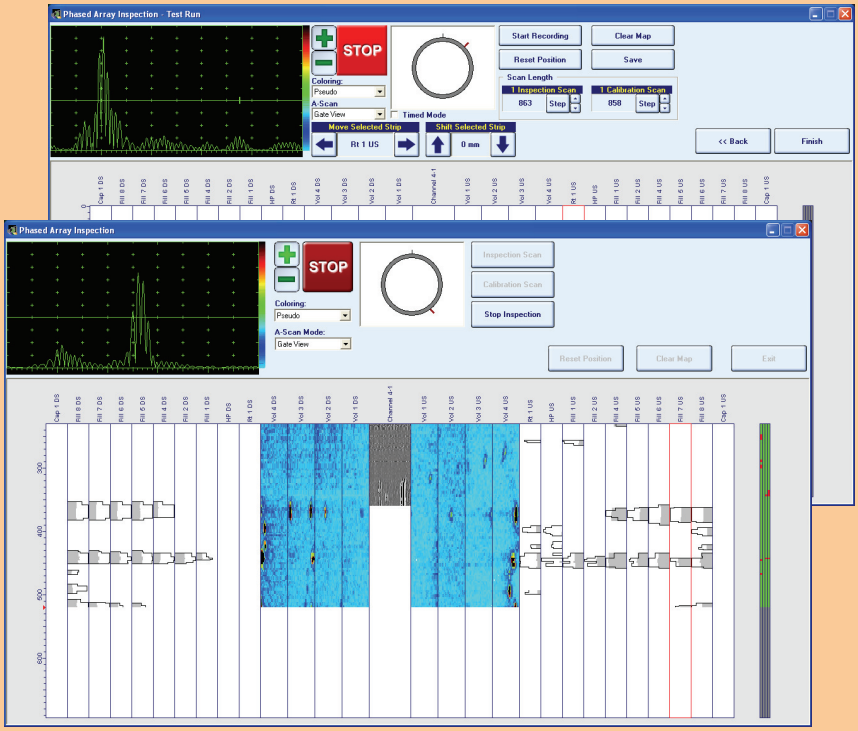


256 gray levels **TOFD strip** represents sequence of RF A-Scans whereas brightness of points for each horizontal line is modulated according to corresponding signal level

Coupling

Coupling Strip is formed through comparing amplitude of reference signal with the gate threshold. Green *Sufficient Coupling* record is provided for signals exceeding gate threshold; red *Insufficient Coupling* record is provided in opposite case

Reshaping of *Strip Chart* is possible through manipulating position / lateral displacement of each strip according to the probes fitting into the scanning frame:



Calibration scanning is performed then in automatic mode to ensure that all artificial defects are sensed, resolved, and recorded at proper locations

Ultrasonic Setup Wizard is finished with creation of complete *Inspection Setup File*; inspection becomes possible at any moment after said file is uploaded into scanning routine

Movie illustrating scanning of calibration block for 273 mm OD pipe is available for download at:
http://www.sonotronndt.com/RepInfo/IPAAUT/IPAAUTCalBlockScan01.wmv

Movie illustrating screen of remote PC controlling ISONIC PA AUT whilst scanning of calibration block for 273 mm OD pipe is available for download at:
http://www.sonotronndt.com/RepInfo/IPAAUT/IPAAUTCalBlockScanScreen01.wmv

Movie illustrating scanning of calibration block for 1219 mm OD pipe is available for download at:
http://www.sonotronndt.com/RepInfo/IPAAUT/IPAAUTCalBlockScan02.wmv

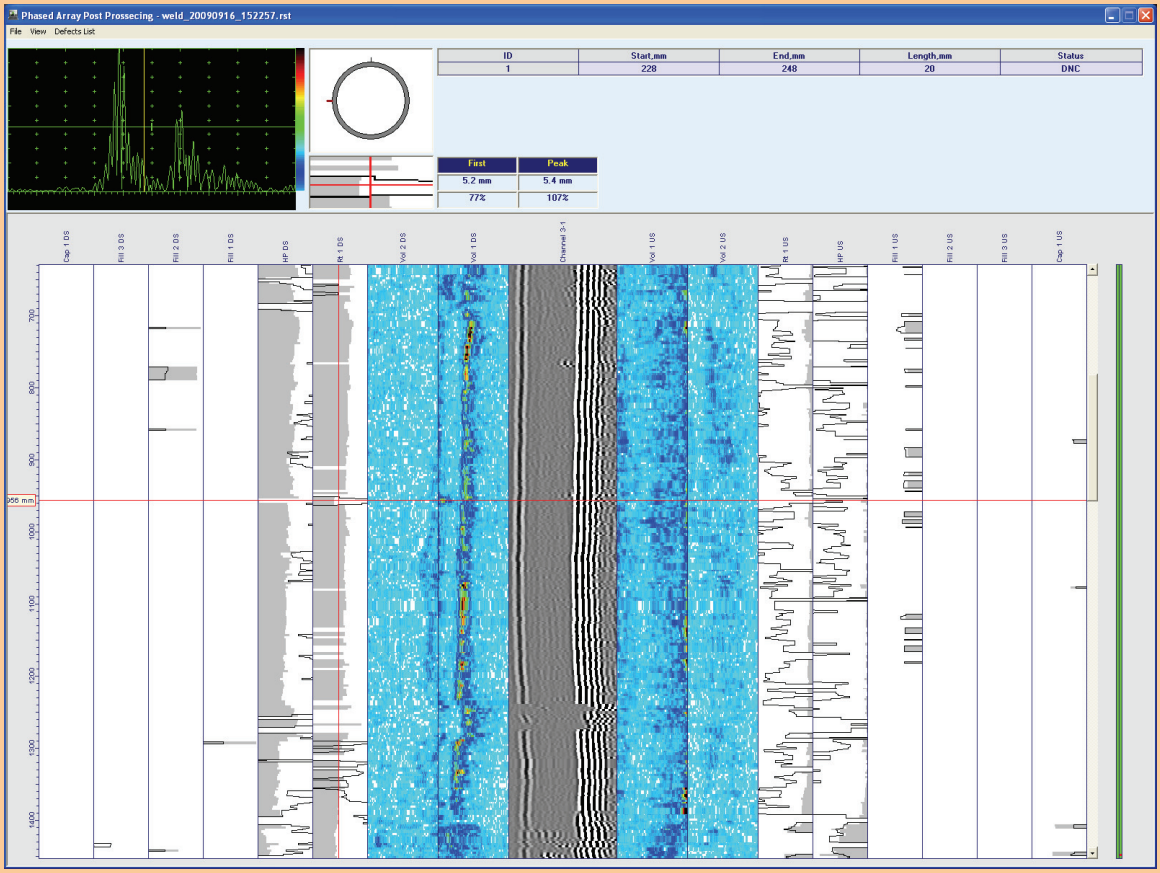
Movie illustrating screen of remote PC controlling ISONIC PA AUT whilst scanning of calibration block for 1219 mm OD pipe is available for download at:
http://www.sonotronndt.com/RepInfo/IPAAUT/IPAAUTCalBlockScanScreen02.wmv

Scanning and Postprocessing

Movies illustrating scanning of girth weld on site are available for download at:
http://www.sonotronndt.com/RepInfo/IPAAUT/IPAUT_70MM_SEC.wmv - for 273 mm OD pipe
http://www.sonotronndt.com/RepInfo/IPAAUT/OD1219.wmv - for 1219 mm OD pipe

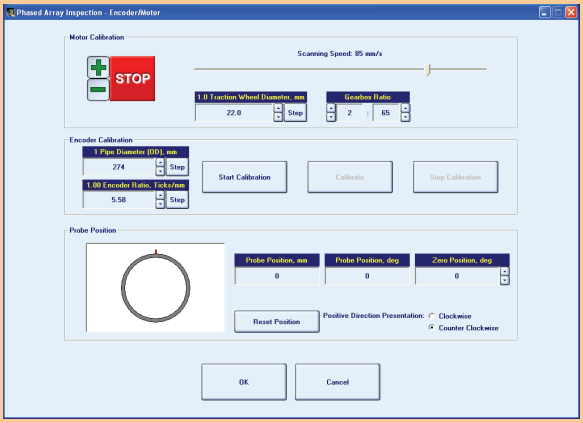
Whilst scanning the raw A-Scan data obtained by PA, conventional, and TOFD probes is transferred to remote PC along with corresponding position encoder data. Remote PC provides raw data recording and forms strip chart in real time. Whilst scanning operator may monitor live A-Scans for every strip. Inspection results file compressing complete raw data bulk is created automatically on completion of scanning

At postprocessing stage it is possible to play back captured A-scans, to mark, size, and evaluate defects, to create defects list, etc

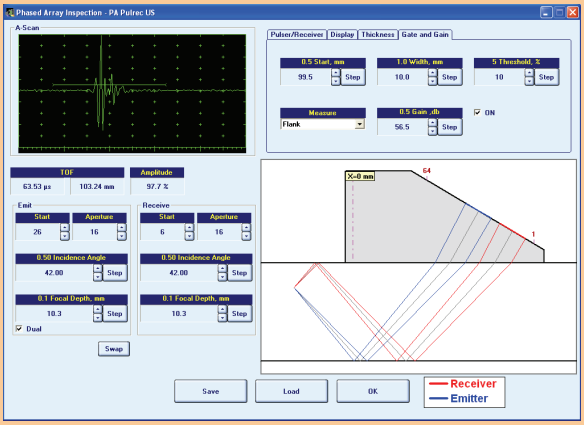


Built-in Utilities

Entering scanner parameters (gearbox rate, driving wheel diameter), encoder calibration and entering scanning speed are performed in dialogue mode through simple user interface



Every probe either PA, conventional, or TOFD may be driven independently through appropriate pulser receiver screen. This feature is very useful for various purposes such as verification of wedges, studying of phased array focusing effects, etc



Multiple Units Operation

One regular PC may control and acquire data from several **ISONIC PA AUT** systems simultaneously (up to 16) allowing rational organization of AUT jobs on-site and minimizing manpower involved

ISONIC PA AUT – Summary

- Up to 512 channels for connection of phased array probes
- Up to 64 channels for connection of conventional probes for pulse echo and TOFD inspection
- Parallel A/D conversion and on-the-fly digital phasing and superimposing of PA elements signals, no multiplexing involved
- Free setting of emitting and receiving aperture accumulating up to 512 elements each
- Controlled by remote PC through Ethernet, multiple units operation possible
- Easy-to-follow ray tracing, calibration, and strip chart forming wizard
- Real time strip chart recording and presentation with complete capturing of raw data A-Scans
- Ultimate ultrasonic performance for PA, conventional and TOFD probes
- Rugged IP 67 case mountable on scanner
- No need in long bulky umbilical for probes connection
- Coordinate encoder input
- Motor powering and control port
- No water or other type of cooling required

Technical Data

Single Pulser Receiver Channel for PA, Conventional, and TOFD Probes

Pulse Type:	**Bipolar Square Wave**
Initial Transition:	**≤7.5 ns (10-90% for rising edges / 90-10% for falling edges)**
Pulse Amplitude:	**Smoothly tunable (12 levels) 50V … 300 V peak to peak into 50 Ω - PA Probes** **Smoothly tunable (12 levels) 50V … 400 V peak to peak into 50 Ω - Conventional and TOFD Probes**
Half Wave Pulse Duration:	**10…600 ns independently controllable in 10 ns step**
Modes (for conventional pulse echo and TOFD probes channels only):	**Single / Dual**
PRF:	**10...5000 Hz controllable in 1 Hz resolution**
Analogue Gain:	**0...110 dB controllable in 0.5 dB resolution**
Advanced Low Noise Design:	**85 μV peak to peak input referred to 80 dB gain / 25 MHz bandwidth**
Frequency Band:	**0.2 … 25 MHz Wide Band**

Firing of Phased Array Probes

Phasing:	**0…100 μs with 5 ns resolution**
Emitting aperture:	**1…N controllable in 1 element resolution, whereas N = 64 or 128(typical) or 256 or 512**

A/D Conversion and DSP

A/D Conversion:	**Parallel 100 MHz 16 bit**
Receiving Aperture:	**1…N controllable in 1 element resolution, whereas N = 64 or 128(typical) or 256 or 512**
Digital Filters (for phased array and conventional pulse echo and TOFD channels):	**32-Taps FIR band pass with lower and upper frequency limits controllable with 0.1 MHz resolution**
Phasing and superimposing of signals for the entire receiving aperture:	**On-the-fly 0…100 μs with 2.5 ns resolution**

Data Storage and Presentation

Method of data storage:	**100% raw data capturing**
Data presentation at inspection / postprocessing stage:	**Strip chart composed by an operator, the following types of strips are possible:** • **Amplitude / TOF Pulse Echo Strip (PE)** • **Map (CB-Scan)** • **TOFD** • **Coupling (Yes/No stroke)** • **A-Scan for any strip selected by an operator**
Postprocessing features:	**Play-back A-Scans** **Sizing of indications**

General Data

On-Board (satellite) Computer CPU:	**AMD LX 800 - 500MHz**
RAM:	**512 Megabytes**
Internal Flash Memory - Quasi HDD:	**4 Gigabytes**
Interface:	**Ethernet**
Operating System:	**Windows™XP Embedded**
Linear Scanning Speed:	**20…100 mm/sec controllable in 1 mm/sec resolution**
Encoder interface:	**Incremental TTL encoder**
Motor Control Output:	**DC powering / RS 232 control - stepped motor**
Housing of Electronic Box:	**IP 67 rugged aluminum case mountable on scanner**
Dimensions of Electronic Box:	**295X174X346 mm (11.62"×6.85"×13.62")**
Weight of Electronic Box:	**6.8 kg (14.95 lbs)**