NEW ELECTRONIC COMPONENTS

AND SOFTWARE

FOR SINGLE AND MULTI-CHANNEL

ULTRASONIC INSPECTIONS

OF PIPING AND COMPONENTS

Authored by

Bernd Rockstroh, Wolfgang Kappes,

Reinhard Weiss, and Dr. Eckhardt Pridöhl,

Fraunhofer-IZFP

Translated to English by

M. Dalichow and M. Calcamuggio, QNET USA

1. ABSTRACT

Highly integrated electronic components permit the development of ultrasonic pulser/receiver and A/DC cards for integration into personal computers. Complete analog and digital electronic circuits are combined on a single printed circuit board (PCB) designed for ISA and PCI bus computer systems. In combination with the PCUSWare software, both cards are used for PC-aided manual and/or semi-automatic ultrasonic inspections. Thus, a simple and complete documentation of the exam and its associated parameters will support any company QA/QC system. The PCUS 10/11 and IZFP's CPS software are used for single-channel automated flaw detection and can be combined with IZFP's SAFT software for high-resolution and accurate flaw analysis.

The modular concept of the PCUS 40 electronics provides the foundation for inexpensive and compact multi-channel testing systems for inservice inspection at plants and production line-integrated testing stations, to assure the quality of a broad range of steel manufacturing products. The PCUS 40 system can be configured to record the complete RF waveform, if required. If high-speed inspections or large number of search units (channels) is required, the PCUS 40 system can be configured for a variety of data-reduction algorithms, e.g. ALOK. The modular arrangement of the CPS-N software package (Windows NT) permits a customer-specific design of the user interface, databases, application functions, etc.

2. INTRODUCTION

The scientists and engineers of the Fraunhofer-IZFP have developed a new family of ultrasonic testing systems based on micro-electronic components. In combination with a modular software architecture and suitable PC hardware these new products permit custom configuration for a wide range of client-specific applications – from simple PC-aided manual ultrasonic inspections through automated inspections using compact and portable systems with up to four channels to sophisticated multi-channel systems for the ultrasonic inspection of heavy components.

High component integration and the powerful processing capabilities of today's PC systems allow the integration of electronic components for multi-channel systems into portable computers, thus providing compact and simple to operate instruments to the ultrasonic inspector in the field.

The inspection software contains modules for setup, examination, analysis and reporting. Various databanks provide substantial information on inspection parameters such as inspection procedure requirements, component geometry and history, material characteristic, heat treatment, operating temperature and pressure, etc. The integration of the SAFT (**S**ynthetic **A**perture **F**ocusing **T**echnique) analysis module provides three-dimensional views of the inspected zones in various cross-sections. This tool helps the qualified technician to accurately determine type, location and size of detected discontinuities important for fracture mechanics analysis and the assessment of the components lifetime.

3. SINGLE-CHANNEL ULTRASONIC BOARD PCUS 10/11

The PCUS 10 and PCUS 11 ultrasonic boards were designed for PC-aided manual ultrasonic inspections and certain automated applications. All analog and digital components for example pulser, receiver, amplifier, A/D converter, A-scan processor, and PC-interface (ISA or PCI bus), required for ultrasonic inspections, are contained on a single PC board. Figure 1 depicts the PCUS 10 card, which requires a ¾ length ISA slot on the PC motherboard.

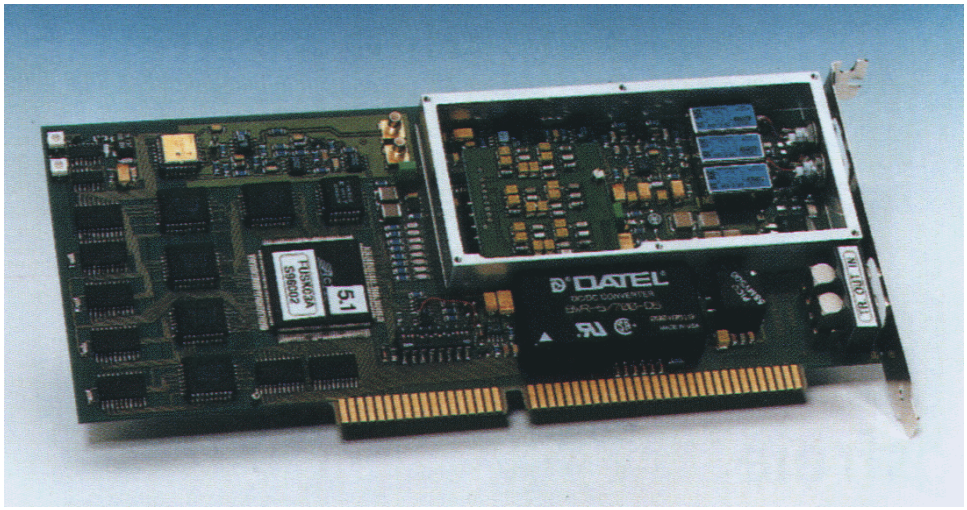

Figure 1: Single-Channel Ultrasonic Board PCUS 10

The PCUS 11 card was designed especially for automated or semi-automated inspections at high scanning speed (high data rates) by using the fast PCI bus.

These plug-in boards can be used in either portable PC's or in any size desktop PC having a vacant ISA or PCI slot. The low power consumption (less then 5W for the PCUS 10) along with a power-suspend feature permits the operation with battery-powered portable PCs. Depending on the selected host PC, splash proof (see Figure 2) and/or cold-weather packages permit use of the system in harsh field environments.

The technical capabilities of both the PCUS 10 and PCUS 11 ultrasonic boards are comparable to modern digital scopes for ultrasonic testing. The frequency ranges from 0.5 MHz to 20 MHz (-3dB) at a dynamic range of 100dB. One broadband filter and three narrow band filters allow tuning of the pulser to closely match the frequency of the search unit in use. Optional plug-in filter modules for specific applications are available. The ultrasonic signals are digitized at a rate of 80 MHz-A/DC at 10 bit for the PCUS 11 (8 bit for the PCUS 10). In addition, the PCUS 11 features a hardware-TGC with a range of 40dB that permits the construction of time-gain-correction curves with a maximum of 256 points.

Figure 2: Ruggedized Portable PC with PCUS 10

In combination with IZFP's PCUSWare™ software, running under Windows 3.1® and Windows 95®, a complete digital ultrasonic testing instrument is available for a large variety of laboratory and field applications. All system functions are controlled from the PC monitor using the keyboard and/or computer mouse. The user interface layout can be arranged to meet the users needs. A databank provides support for effortless managing of inspection variables such as search unit data, component data, calibration settings, etc. Figure 3 depicts the PcusWare™ main menu.

Two gates are available for the display of amplitude height and soundpath information during angle beam or straight beam inspection; amplitude readings can be displayed for edge or peak mode. A-scans can be displayed and recorded in full-wave mode, RF mode, and positive or negative half-wave mode. The A-scan display modes may be changed after recording during analysis of individually recorded A-scan data (see Figure 4). Echo dynamics can be recorded and averaged for a maximum of 32 consecutive individual A-scans using PCUS 10, and a maximum of 128 consecutive individual A-scans using PCUS 11.

The system can store up to 100 individual A-scans along with their associated parameter settings in a single data file. The number of data files is limited by the available space on the hard disk. Furthermore, the system allows storage of comments entered by the user for all recorded A-scans.

For reporting of inspection results, the system can provide hard copies including the A-scan image, current system settings and complete A-scan information along with the user's comments. Previous system settings as well as previously recorded inspection data can be recalled at any time.

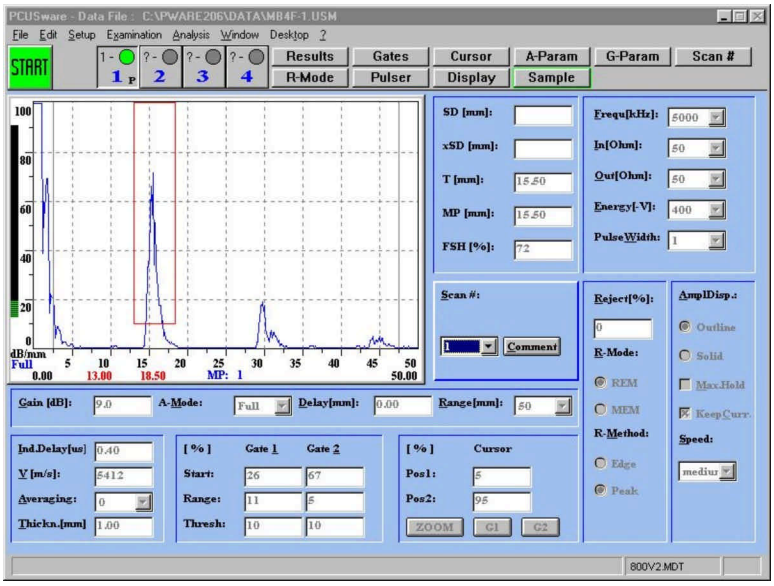

Figure 3: PCUSWare™ Main Menu

The addition of up to three PCUS 10/11 boards permits operation as a multi- channel ultrasonic testing instrument for applications with multiple (up to four) search units in series, hardware configuration permitting. A maximum of four different parameter sets (different search units, wave modes, material velocity, sweep range, etc.) can be assigned to the four (logical) channels when using a single card configuration.

The PCUS 10/11 system can be combined with a hand scanner or with any automated scanners. The optional interface card provides for transfer of search unit(s) positioning data for small scope piping inspections or analysis scans. The PCUS 11 card was designed especially for automated or semi-automated inspections at high scanning speed (high data rates).

Automated or semi-automated (manual scanner) ultrasonic inspections would utilize the CPS™ software package. The CPS-N™ software contains the necessary input modules required for system setup, data acquisition, data analysis and data reporting. During inspection, the software can display a maximum of four A-scan and four C-scan presentations simultaneously online (real-time). Individual and composite A-scans, C-scans, and composite CBD-scans are available for data analysis providing top, side, and end views of the examination volume.

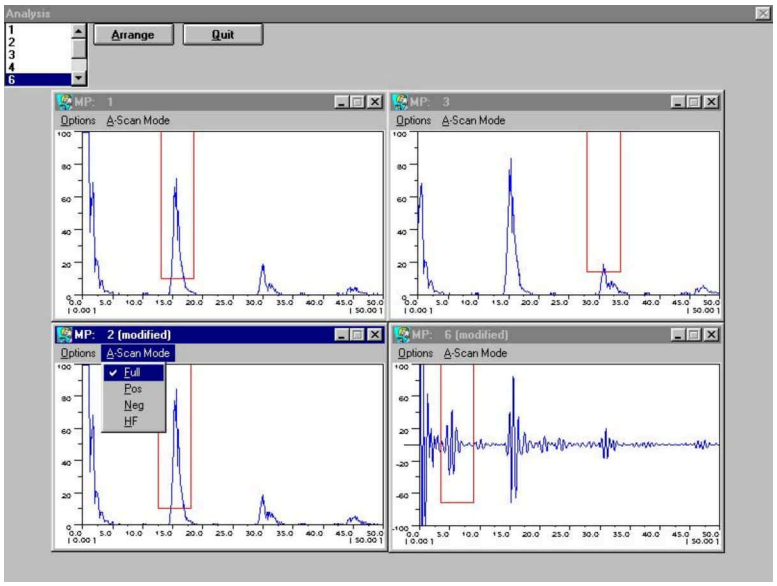

Figure 4: Multiple A-scan Display

Since the PCUS 10/11 system records all ultrasonic data in their native RF format, more advanced analysis tools, such as SAFT, can be used for the disposition of ultrasonic indications. The optional SAFT [1] analysis module provides processing of tree-dimensional indication displays, which allows easier determination of type, location, and size of suspect indications.

The following example of a post-processing SAFT analysis of a pre-heater nozzle crack [2], where cracking typically occurs in the root area and in backing strip-weld area, demonstrates the need for advanced techniques. The automated examination was performed from the vessel shell using 2MHz and 4MHz, 70° shear wave search units as shown in Figure 5.

Figure 5: Automated Pre-Heater Nozzle Examination

Data analysis was performed utilizing B-scan, C-scan, and D-scan presentation post-processed by the SAFT algorithms. Position and depth of the flaw was determined from the B-scan image. Figure 6 displays the reconstructed image with a 9mm deep crack at the root of the nozzle-to-shell weld. Grinding, as part of the repair process, following the examination confirmed the essential information (flaw location, size, and depth) that were provided by the SAFT-reconstruction analysis.

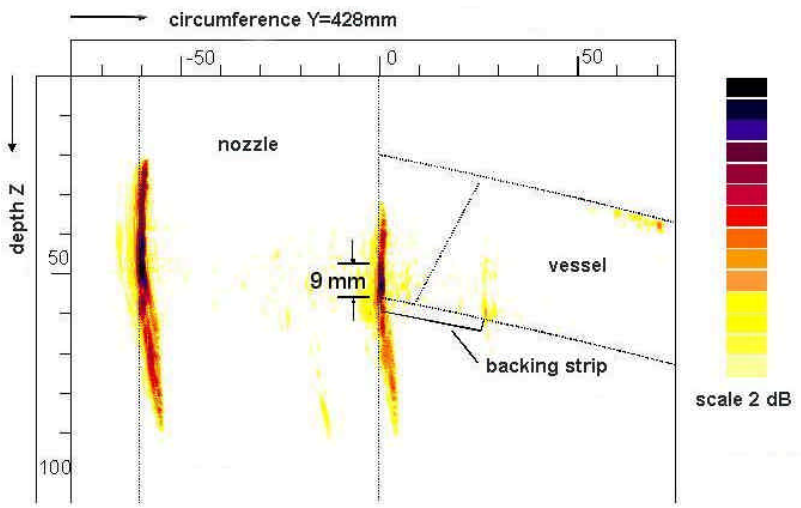

Figure 6: SAFT Reconstruction of Root Cracking

4. MULTI-CHANNEL ULTRASONIC SYSTEM PCUS 40

The new modular design of the PCUS 40 system components allows arranging compact and economical multi-channel systems for various automated ultrasonic inspection applications. Modern software packages provide the ultrasonic inspector with the necessary support for examination setup, data acquisition, data analysis, and documentation (reporting) of the inspection results. The PCUS 40 ultrasonic instrument consists of several boards installed in a commercially available PC. The basic PCUS version comprises all electronic components for a four-channel ultrasonic instrument expendable to 64 channels. The flexibility of the PCUS 40 system provides custom tailored configurations for ultrasonic testing of piping and vessels in chemical, petrochemical, and power plants or production-line and pre-service inspection of steel (and other suitable) products.

The usable frequency of the PCUS 40 system ranges from 300 kHz to 15 MHz (-3dB) at a dynamic range of 100dB. A TGC (Time Corrected Gain) module permits entry of any reference points or reference lines (DAC) for the compensation of acoustic and/or other material-related energy losses in a range of 40dB. The analog/digital data conversion (A/DC) rate can be selected from 80 MS/sec (10 bits) or 40 MS/sec (12 bits), depending on the inspection task. The data sampling frequency can be selected independently from the chosen examination frequency. Figure 7 shows a schematic diagram of the PCUS 40 electronics.

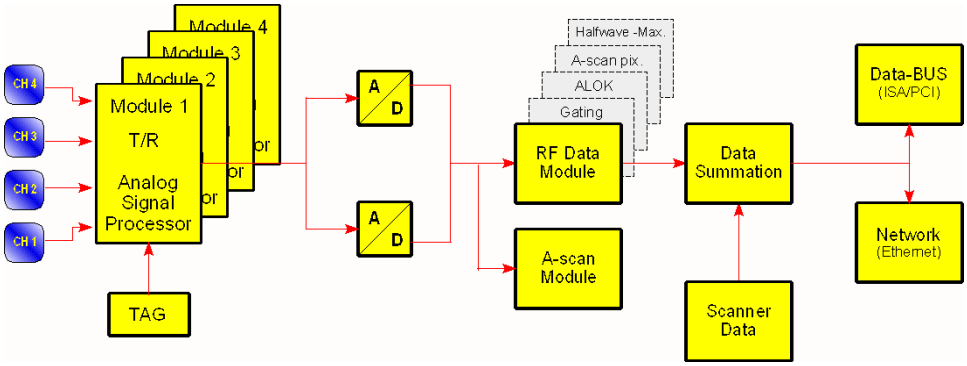

Figure 7: Block-diagram PCUS 40 Multi-Channel System

Various data acquisition modes can be selected to correspond to the individual inspection tasks requirements. For example: If SAFT analysis is required, the system would be set to acquire the ultrasonic data in the RF mode; or, if massive amounts of data from a reactor pressure vessel examination are expected the system would be set to collect data in the ALOK mode. The ALOK (local amplitude curves) method has been proven advantageous for ISI of reactor pressure vessels and pipelines (using multi-channel pigs) when high-speed inspections and large amounts of ultrasonic data call for high detection sensitivity and data reduction [3, 4].

The PCUS 40 system is available as a portable system with a maximum of eight ultrasonic channels as shown in Figure 8.

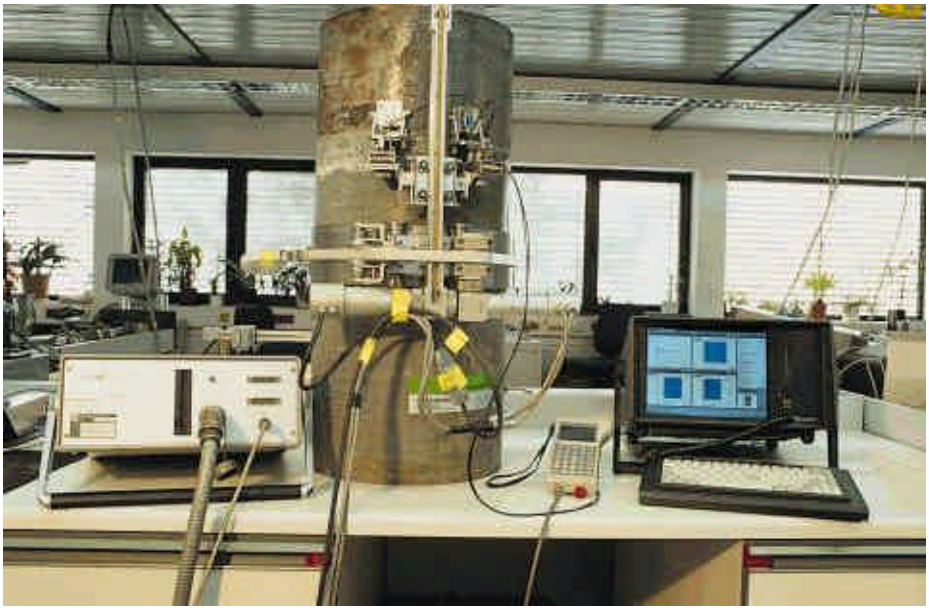

Figure 8: Portable PCUS 40 System w/ Pipe Scanner and Scanner Control

Other system configurations to accommodate a maximum of 64 channels have been designed as desktop, tower, and industrial PC casings, stand-alone rack-mount systems or combination rack-mount system, where the operator console is separated from the electronics compartment.

The CPS-N™ software (operating under Windows NT®) comprises setup menus including system, search unit, component and global parameters, data acquisition menu, data analysis menu, and reporting menu. The data acquisition menu displays A-scan and/or C-scan presentations of up to four ultrasonic channels simultaneously (online) to support real-time control of system and search unit functions as depicted in Figure 9 below. Analysis of the acquired ultrasonic data is performed using A-scan, B-scan, C-scan and D-scan displays; composite top, side, and end view images (CBD-scan) help the user during data analysis. In addition, the SAFT module provides further analysis enhancements. If required, the CPS-N™ software can be customized to virtually any specific requirements.

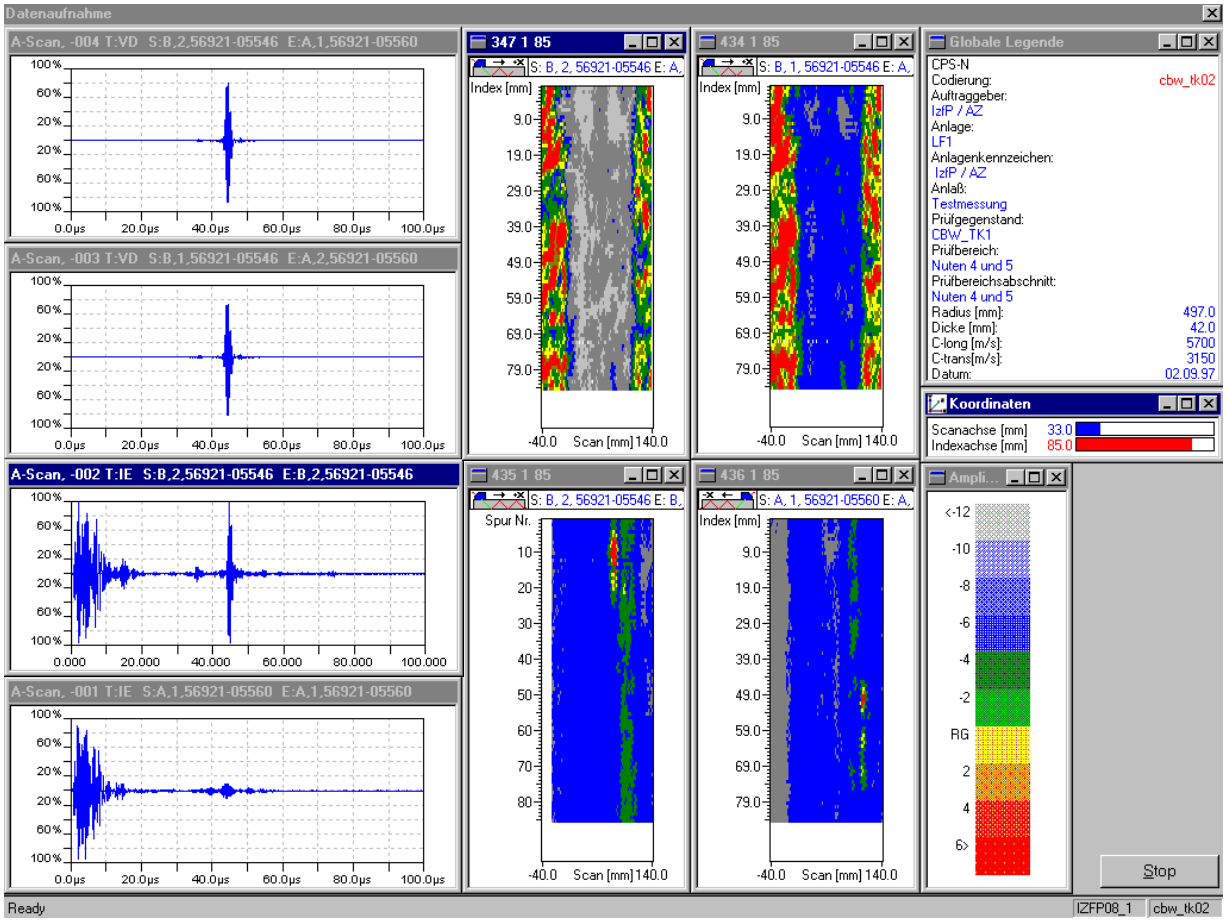

Figure 9: CPS-N™ Online Display of A-scan and C-scan Images

For the ultrasonic testing of components having complicated geometric conditions, the PCUS 40 system can be combined with IZFP's digital Phased Array front end to control piezoelectric search units [5]. To examine anisotropic materials with horizontally polarized shear waves (SH-waves) [6], an EMAT Phased Array front end is also available.

5. CONCLUSION

Ultrasonic plug-in boards were developed based on highly integrated electronic components. The PCUS 10/11 provides all of the analog and digital circuits required on a single ¾ length ISA (or full-size PCI) board, thereby rendering a complete testing instrument when combined with IZFP's PCUSWare™ for manual ultrasonic inspections.

Special software features provide simple and easy to use tools to merge inspection data and results into any Quality Control system. To perform single-channel automated inspections, particularly flaw analysis with SAFT, or four-channel automated UT inspections, the PCUS 10/11 system is used in conjunction with the CPS-N™ and CPS-SAFT™ software package.

The modular electronic components of the PCUS 40 system allow configuring compact and economical multi-channel ultrasonic systems for inspections in industrial plants as well as configurations for process-integrated testing systems in the steel industries. The PCUS 40 system using the CPS-N™ software allows the recording of the complete RF-wave form, and thus provides all the information required for a detailed description of ultrasonic indications and material flaws. If high-speed data acquisition with a large number of ultrasonic channels is required, the PCUS 40 system permits data reduction utilizing ALOK data reduction algorithms. If required, the CPS-N™ software can be customized to virtually any customer-specific requirements.

6. REFERENCES AND LITERATURE

[1] W. Müller, V. Schmitz, G. Schäfer
Reconstruction by the Synthetic Aperture Focusing Technique
Nuclear Engineering and Design, 1988, pp. 393 –404

[2] J. Liers, R. Weiß, B. Rockstroh, W. Jager
Zerstörungsfreie Werkstoffprüfung an Stutzenschweißnähten von
VGB Kraftwerkstechnik 76 (1996), Heft 1

[3] W. Kappes, R.K. Neumann, H.K. Stanger, F. Höh, O.A. Barbian
Datenaufnahme und -verarbeitung bei der automatisierten Ultraschallprüfung mit dem ALOK-Verfahren
DGZfP-Seminar über Automatisierung in der Ultraschallprüfung
Berichtsband Nr. 17, Berlin, 1988

[4] H. Willems
UltraScan CD - Ultrasonic Crack Detection Tool - Overview -
Pipetronix GmbH, Lorenzstr. 10, D-76297 Stutensee

[5] G. Brekow, A. Erhard, G. Schenk, W. Rathgeb
*Ultrasonic Inspection of Complicated Geometry of Pressure Vessels with Phased Array Probes*Proceedings of the 10th International Conference on NDE in Nuclear and Pressure Vessel Industries
Glasgow, Scotland, June 1990

[6] M. Kröning, G. Hübschen, H.J. Salzburger
Detection of Defects in Dissimilar Metal Weld Joints
German-Russian Seminar, St. Petersburg, May 1993