# NEW ELECTRONIC COMPONENTS

# AND SOFTWARE

# FOR SINGLE AND MULTI-CHANNEL

# ULTRASONIC INSPECTIONS

# OF PIPING AND COMPONENTS

Authored by

J. Kretow and K. Pavros, QNET St. Petersburg

B. Rockstroh and W. Kappes, Fraunhofer-IZFP

Translated to English by

M. Dalichow and M. Calcamuggio, QNET USA

Presented at the conference “Phenomena and Applications of Ultrasound – Ultrasonic Flaw Detection in Russia”, held in honor of the 100-year birthday of Professor Sokolov, in June 1997 in St. Petersburg, Russia.

# 1. INTRODUCTION

Quality-controlled production, pre-service and in-service inspections of piping and vessel welds, turbine shafts, and other steel products such as railroad wheels or railroad tracks for internal discontinuities, cracks and corrosion requires ultrasonic inspection systems with powerful hardware- and complex software components.

The scientists and engineers of the Fraunhofer-IZFP have developed a new family of ultrasonic testing systems based on micro-electronic components that 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.

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 (synthetic aperture focusing technique) analysis module provides three-dimensional views of the inspected zones in various cross-sections, helping the qualified technician to accurately determine type, location and size of detected discontinuities.

# 2. SINGLE-CHANNEL ULTRASONIC BOARD PCUS 10/11

The PCUS-10/11 ultrasonic board was designed for PC-aided manual ultrasonic inspections and certain automated applications limited to four channels. All analog and digital components for example transmitter, receiver, amplifier, A/D converter, A-scan processor, and PC-interface (ISA-bus), required for ultrasonic inspections, are contained on a single ¾ length PC board (see Figure 1).

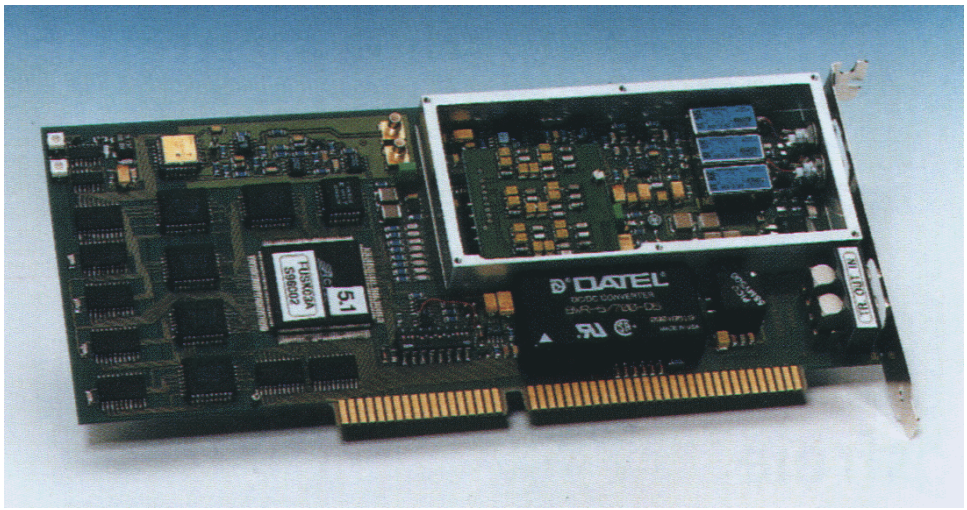


Figure 1: Single-Channel Ultrasonic Board PCUS 10/11

This plug-in board can be used in either portable PC's or in any size desktop PC having a vacant ISA slot. The low power consumption (less then 5W) along with a power-suspend feature permits the operation with battery powered portable PCs. The technical capabilities of the PCUS 10/11 ultrasonic board are comparable to modern digital scopes for ultrasonic testing. The frequency ranges from 0.5 MHz to 20.0 MHz (-3 dB) at a dynamic range of 100 dB. One broadband filter and three narrow band filter 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 signal is digitized at rate of 80 MS/sec (Mega Samples per second).

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 2 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 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 3). Echo dynamics can be recorded and averaged for a maximum of 32 consecutive individual A-scans.

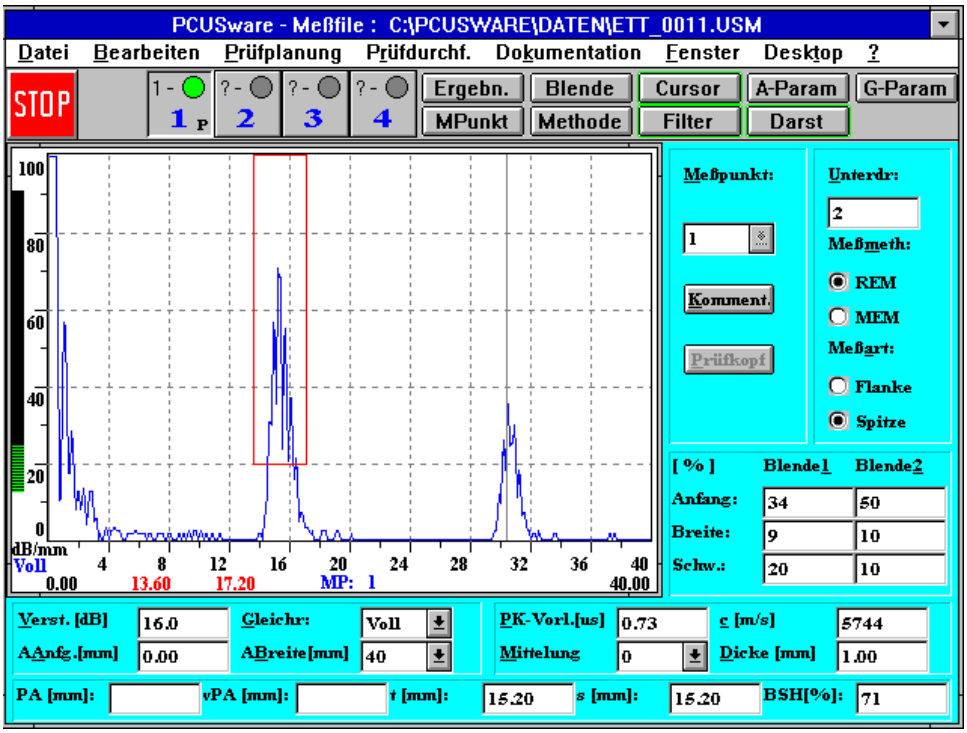


Figure 2: PcusWare™ Main Menu

The system can store up to 100 individual A-scans along with their associated parameter settings in a single data file. 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 may be recalled at any time.

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.

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. Automated or hand 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.

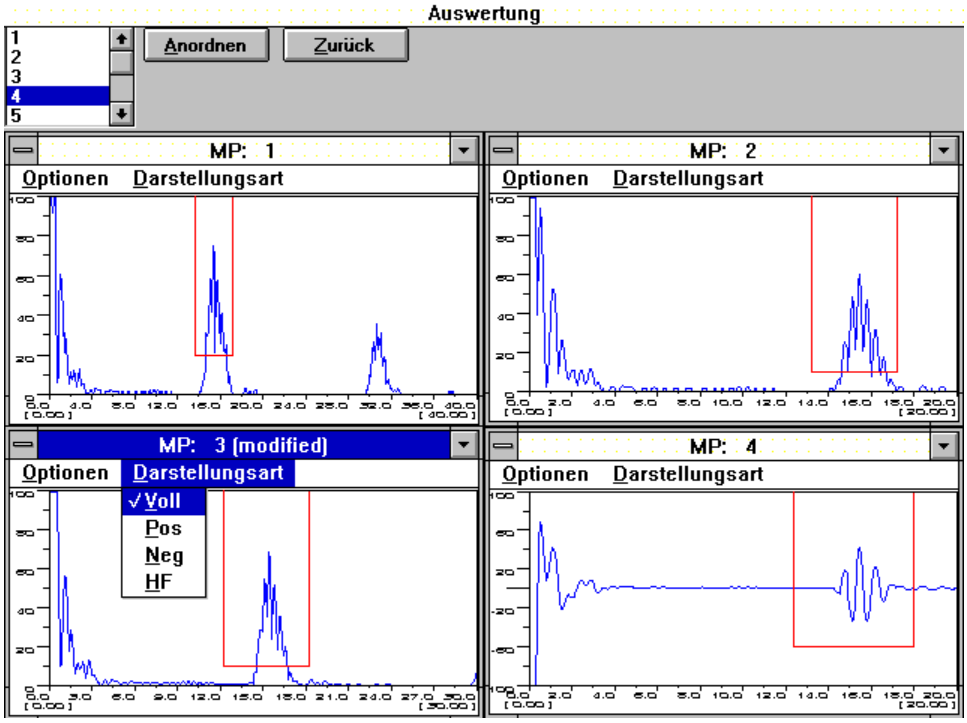


Figure 3: Multiple A-scan Display

Since the PCUS 10/11 system records all ultrasonic data in their native RF format, more advanced analysis tools such as synthetic aperture focusing technique (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. Figure 4 shows an example of a post-processed SAFT indication display of a pre-heater nozzle (crack at the nozzle-to-vessel weld root) ultrasonic examination [2].

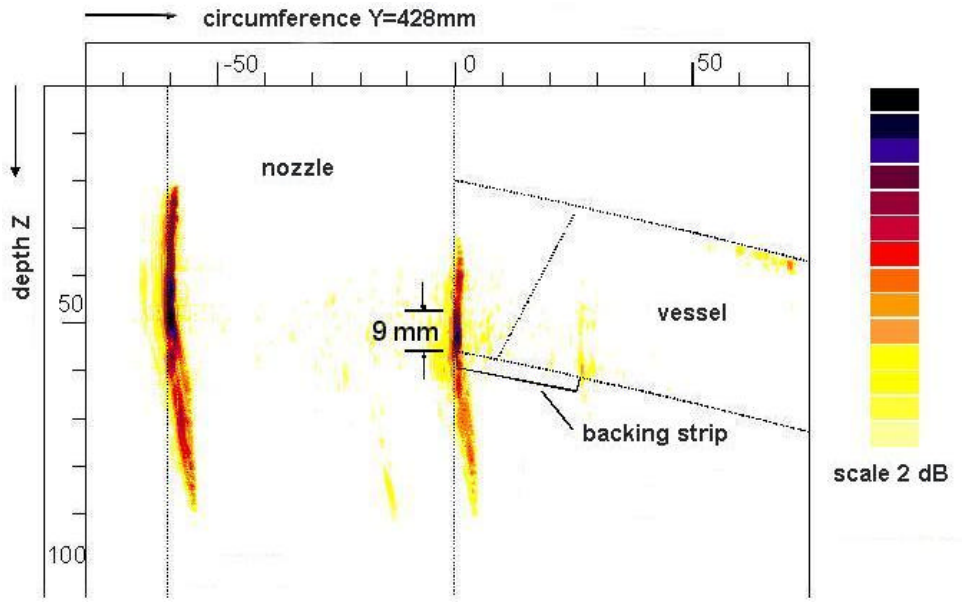


Figure 4: SAFT Reconstruction of Root Cracking

## 3. 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. A 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 that can be expanded to eight channels. Several different upgrade options permit the expansion to a maximum of 64 channels, thus providing custom tailored systems 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 0.3 MHz to 15.0 MHz (-3 dB) at a dynamic range of 100 dB. 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 40 dB. The conversion of analog data into digital data (A/D rate) can be selected from 80 MS/sec at 10 bits or 40 MS/sec at 12 bits, dependent upon the inspection task; the data sampling frequency can be selected in accordance with the examination frequency. Figure 5 shows a schematic diagram of the PCUS 40 electronics.

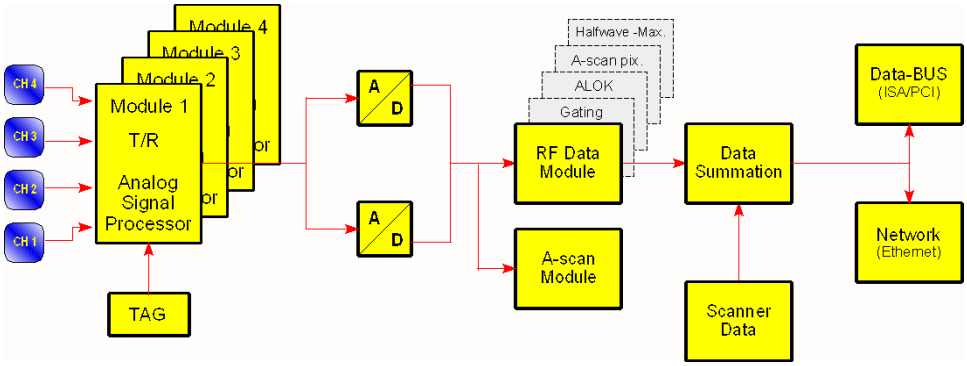


Figure 5: PCUS 40 Multi-Channel System

Various data acquisition modes can be selected to correspond to 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 method has been proven especially advantageous for ISI of reactor pressure vessels and pipeline using multi-channel pigs when high-speed inspections and large amounts of ultrasonic data call for high detection sensitivity and data reduction [3.4].

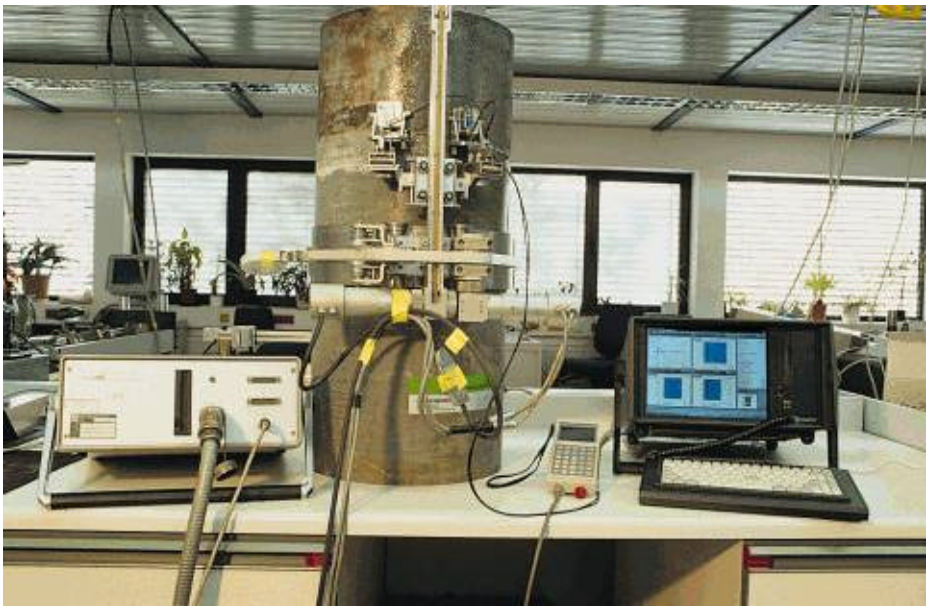

Figure 6: Portable PCUS 40 System w/ Pipe Scanner and Scanner Control

The PCUS 40 system is available as a portable system (see Figure 6) with a maximum of eight ultrasonic channels. Other system configurations to accommodate a maximum of 64 channels have been designed as desktop/tower/industrial PC, 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 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 7 below. Analysis of the acquired ultrasonic data is performed by 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.

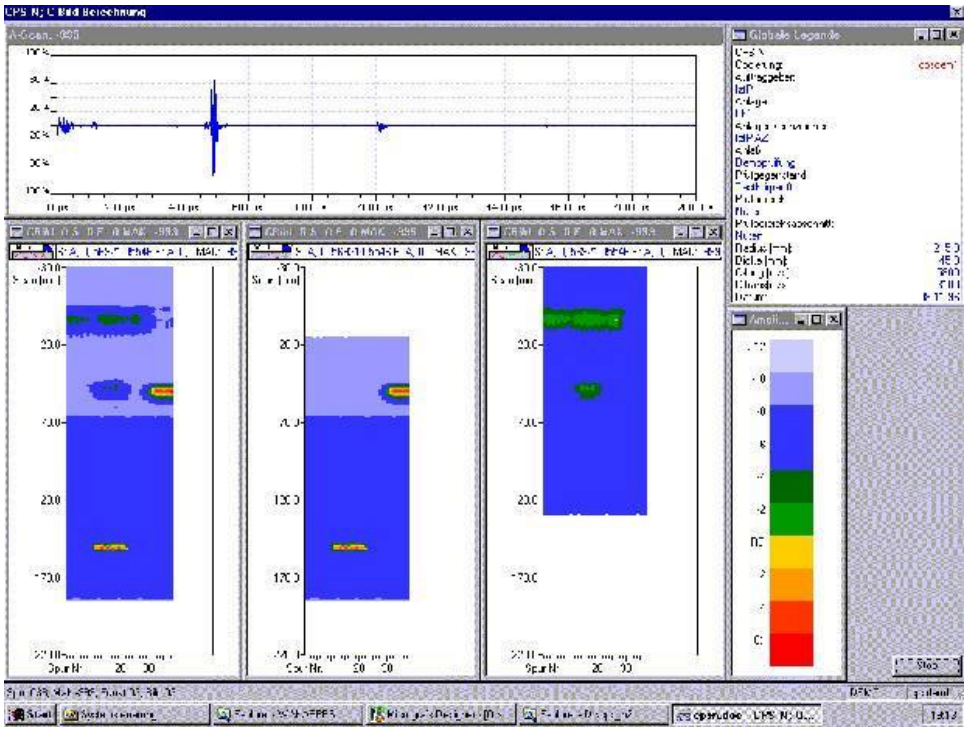

Figure 7: CPS-N™ Online Display of A-scan and C-scan Images

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.

## 4. 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 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.

## 5. 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 Hochdruckwärmetauschern*
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