

GENERAL SPECIFICATION

PIPING VALVES VESSELS

GS EP PVV 631

Phased Array Inspection (PAUT)

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1. Scope

This specification defines the Company minimum requirements and details the general conditions for performing Phased Array Ultrasonic Technique (PAUT) examination on fine grain C-Mn (Carbon-Manganese) steel welds for Pressure Vessels and Piping systems.

Use of PAUT is limited to the below conditions and is subjected to approval of Company before to proceed:

- A substitution to conventional volumetric Non Destructive Technique (NDT) such as Radiographic Testing (RT) or Manual Ultrasonic Testing (MUT)
- A substitution to Time Of Flight Diffraction (TOFD) ultrasonic technique as defined in [GS EP PVV 630](#)
- A combination with any other volumetric NDTs.

Implementation of PAUT shall be considered since design and fabrication sequence stages, this in order to ensure sufficient clearance on both sides of the weld are made available for allowing PAUT scanning and full weld volume coverage.

In any case, use of PAUT as a standalone technique shall fully comply with the appropriate design code and present specification.

For equipments, which shall be designed and built according to ASME codes ([ASME BPVC Section VIII Div 1](#) or [ASME BPVC Section VIII Div 2](#) for pressure vessels, [ASME B31.3](#) for process piping) and amended respectively by [GS EP PVV 211](#), [GS EP PVV 171](#), PAUT shall be carried out according to [ASME BPVC Section V](#) article 4, amended with respective construction code requirements or applicable code cases and the ones stated in the present specification.

For equipments, which shall be designed and built according to European pressure vessels code [BSI PD 5500](#) and amended by [GS EP PVV 212](#), PAUT shall be carried out according to the rules of [ISO 13588](#), with the amendments stated in the present specification. Previous written acceptance by the Inspecting Authority (IA) is required before any fabrication takes place.

The terms of use of PAUT are restricted, in the present specification, to the following welding configurations:

- For Pressure vessels, Longitudinal, Circumferential and set-In nozzle butt welds with WT (Wall Thickness) ≥ 25 mm.
- For Piping, Circumferential pipe to pipe butt welds with WT ≥ 6 mm and with OD (Outside Diameter) $\geq 2"$ or DN (Nominal Diameter) ≥ 50 mm.

PAUT examination on fitting welds is not permitted by this specification.

PAUT shall be performed at each manufacturing stage required by the relevant design code and after Post Weld Heat Treatment (PWHT) if any.

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2. Reference documents

The reference documents listed below form an integral part of this General Specification.

The order of precedence of the applicable documents shall be:

- The present General Specification
- The applicable Codes and Standards.

Unless otherwise specifically indicated in writing by the Company, the Supplier shall work in accordance with the requirements specified herein and the applicable requirements of the latest editions at date of Contract award of the referenced Codes and Standards, whenever requested in the present specification.

Where this specification states no overriding requirements, the referenced Codes and Standards shall apply in its entirety.

In the event of conflict, Codes or Standards equivalent to those referred to herein shall not be substituted without written approval from the Company.

Approval of equivalent standards will not, in any way, remove responsibility from Supplier to meet the requirements of the applicable Code and amended herein.

External Documents

Unless otherwise stipulated, the applicable version of these documents, including relevant appendices and addendums, is the latest revision published at the effective date of this document.

Reference	Title
Below, reference documents for equipments to be built according to BSI PD 5500 Code:	
BSI PD 5500	Specification for unfired fusion welded pressure vessels
EN 12668 (Parts 1; 2; 3)	Non-destructive testing - Characterization and verification of ultrasonic examination equipment - Parts 1; 2; 3
EN 16392-2	Non-destructive testing - Characterisation and verification of ultrasonic phased array equipment - Part 2: Probes
EN 583-2	Non-destructive testing - Ultrasonic examination - Part 2: Sensitivity and range setting
ISO 13588	Non-destructive testing of welds - Ultrasonic testing - Use of automated phased array technology
ISO 15626	Non-destructive testing of welds - Time-of-flight diffraction technique (TOFD) - Acceptance levels
ISO 17640	Non-destructive testing of welds - Ultrasonic testing - Techniques, testing levels, and assessment
ISO 2400	Non-destructive testing - Ultrasonic testing - Specification for calibration block No 1

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Reference	Title
ISO 9712	Non-destructive testing - Qualification and certification of NDT personnel
ISO 16811	Non-destructive testing - Ultrasonic testing - Sensitivity and range setting
ISO 18563 (Parts 1; 3)	Non-destructive testing - Characterization and verification of ultrasonic phased array equipment - Parts 1; 3
Below, reference documents for equipments to be built according to ASME Codes:	
ASME B31.3	Process Piping
ASME BPVC Section VIII Div 1	Rules for Construction of Pressure Vessels - Division 1
ASME BPVC Section VIII Div 2	Rules for Construction of Pressure Vessels - Division 2 Alternative Rules
ASME BPVC Section VIII Div 3	Rules for Construction of Pressure Vessels - Division 3 Alternative rules for high pressure vessels
ASME BPVC Section V	Non destructive examination
ASTM E164	Standard Practice for Contact Ultrasonic Testing of Weldments
ASTM E2192	Standard Guide for Planar Flaw Height Sizing by Ultrasonics
ASTM E2491	Standard Guide for Evaluating Performance Characteristics of Phased-Array Ultrasonic Testing Instruments and Systems
ASTM E2700	Standard Practice for Contact Ultrasonic Testing of Welds Using Phased Arrays

Total General Specifications

Unless otherwise stipulated, the applicable version of these documents, including relevant appendices and addendums, is the latest revision published.

Reference	Title
GS EP PVV 171	Steel piping fabrication
GS EP PVV 211	Design and fabrication of pressure vessels according to ASME VIII
GS EP PVV 212	Design and fabrication of pressure vessels according to BSI PD 5500
GS EP PVV 611	Welding of pressure containing piping and equipment
GS EP PVV 630	TOFD Inspection

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3. Definitions and Abbreviations

3.1 Definitions

Authorized Inspection: Organization Independent from the Manufacturer and responsible for monitoring the equipment manufacture from the reception of the raw materials to the delivery of the equipment.

This Authorized inspector shall insure that the following are respected:

- The regulations when they are applicable to the equipment concerned by the specification herein
- The technical requirements in the Buyer's order.

The type, number and distribution of the documents to be compiled by this Authorized inspection shall be defined in the contract binding Company or the Engineering Company.

This Authorized inspection may be Company or the Engineering Company.

Contractor: Natural person or legal entity that establishes the order and provide the inspection and examination services covered by the specification herein, this specification is an integral part of the order.

Company: End user.

Engineering Company: Natural person or legal entity who carries out the services corresponding to the design and supply of the equipment covered by the specification herein and in particular collects or establishes the data allowing the manufacturer to size the equipment so that it can satisfy the process function for which it is destined.

Manufacturer: Manufacturer has the responsibility of complying with all of the applicable requirements and assuring that all work done by others also complies.

Shall: Verbal form used to indicate requirements strictly to be followed.

Approval: A written response from the Company confirming agreement to a proposal by the manufacturer or inspection services company.

3.2 Abbreviations

ACG	Angle Correction Gain
AI	Authorized Inspector
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
AUT	Automated Ultrasonic Testing
BSI	British Standards Institution
C-Mn	Carbon-Manganese
CPY	Company
CTR	Contractor

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DN	Nominal Diameter
EN	European Standards
ECA	Engineering Critical Assessment
FSH	Full Screen Height
HAZ	Heat Affected Zone
IA	Inspection Authority
ID	Inside Diameter
MPAUT	Manual Phased Array Ultrasonic Testing
MUT	Manual Ultrasonic Testing
NDT	Non Destructive Testing
OD	Outside Diameter
PAUT	Phased Array Ultrasonic Testing
PC	Personal Computer
PWHT	Post Weld Heat Treatment
RF	Radio Frequency
RT	Radiographic Testing
SAFT	Synthetic Aperture Focusing Technique
SAW	Submerged Arc Welding
TCG	Time Correction Gain
TOFD	Time Of Flight Diffraction
UT	Ultrasonic Testing

4. Technique capabilities requirements

PAUT shall ensure proper detection and evaluation of longitudinally oriented defects.

In addition, Examination of transversally oriented defects is required for:

- On all pressure vessels welds
- On all Piping welds, in case of transverse cracking is suspected.

For instance, when:

- Welds are performed with high energy welding processes such as Submerged Arc Welding (SAW)
- Use of high strength welding consumables
- Narrow gap bevel.

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4.1 Examination of longitudinally oriented defects

A technique is considered capable if all the below requirements are fulfilled:

- 100% of the weld metal volume and adjacent parent material including HAZ (Heat Affected Zone) are fully interrogated with suitable probe access and sufficient scanning zone width from both sides of the weld.
- Perpendicularity tolerances between fusion lines (or a defect of a given orientation) and beams remains within $\pm 6^\circ$ in order to generate an optimum beam/discontinuity interaction.

4.2 Examination of transversally oriented defects

A technique is considered capable if 100% of the weld metal volume and adjacent parent material (including HAZ) are fully interrogated thanks to one of the scanning options detailed below:

	Option 1	Option 2*	Option 3
Probe access scanning	From the weld bead and with suitable surface condition for scanning	From the parent material	When sufficient clearance is available on both sides of the welds (parent material)
Scanning technique	PAUT / Weld interrogation with beams parallel ($0^\circ/180^\circ$) to the weld axis	PAUT / beams oriented between ($15/20^\circ - 160/165^\circ$ approximately) to the weld axis	PAUT or AUT (single element probes) in pitch and catch mode (V tandem technique)

* Option 2 is subjected to Company approval.

4.3 Specific cases

4.3.1 Definition of Limitation

As soon as a weld zone is not being properly interrogated for detection and/or evaluation under the requirements detailed in sections 4.1 and 4.2, then this case shall be defined as a limitation.

The following configurations (but not limited to) shall be considered as limitations to the technique detection and evaluation's capabilities:

- Single access combined to geometry response
- Restricted access in terms of scanning zone width
- Presence of internal accessories, supports which interfere with scanning or beam skipping
- Beam orientation regarding fusion lines modified by tapering (inside or outside) or component curvature (along the primary axis)
- Specific bevel orientations, (e.g. vertical fusion line of K bevel, set-in nozzles without any access from nozzle ID surface)
- Material anisotropy and/or attenuation
- Scanning from clad and/or weld overlay.

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Each limitation case shall be subjected to Company approval.

Each limitation case shall be clearly identified and treated specifically in the procedure, by detailing:

- The improvement of the testing strategy
- The improvement of the weld configuration such as cap flushing, internal tapering of piping with smooth slope
- The implementation of additional NDT method or techniques.

Each limitation shall be assessing through trials on demonstration blocks and ray tracing and approved by Company.

4.3.2 Pressure vessels with wall thickness above 50 mm

When height/length based acceptance criteria are used, for butt welds with thickness greater to 50 mm, TOFD technique complementarily to PAUT shall be implemented.

Time Of Flight Diffraction (TOFD) shall be performed following [GS EP PVV 630](#) requirements.

4.3.3 Clad / overlaid pressure vessels

PAUT scanning from clad and/or weld overlay is subjected to Company approval.

Reference and validation blocks shall include clad/weld overlay of exactly the same configuration as the production ones.

When height/length based acceptance criteria are used, for clad/overlaid butt welds, TOFD technique complementarily to PAUT shall be implemented.

Time Of Flight Diffraction (TOFD) shall be performed following [GS EP PVV 630](#) requirements.

5. Requirements for personnel

The requirements for personnel are given as per below table:

ASME components	PD 5500 components
Examination personnel shall be qualified and certified following a procedure or program as described in ASME BPVC Section V article 1 T-120 (e), (f), (h) and (i).	Personnel shall be qualified to an appropriate level in accordance with ISO 9712 or equivalent in the relevant industrial sector + provision of 6.1 of ISO 13588 .

In addition:

Only level 2 or 3 technicians shall perform the instrument checking, setting, calibration and data collection activities.

Only level 2 or 3 technicians shall prepare the procedure and the scan plans.

Only level 2 or 3 technicians shall analyse the data, interpret the results and generate the report.

The procedure and final data package shall be reviewed and approved by a PAUT level 3 or UT Level 3 specialist being experimented with PAUT technique. The review shall include the

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ultrasonic data records, the data interpretations and the flaw evaluations / classifications reports performed by all the qualified UT/PAUT Level 2 or 3 teams involved on project.

Personnel shall demonstrate, through documentation, previous practical experience in PAUT examination:

- 6 months for pressure vessel welds when testing pressure vessel welds
- 3 months on piping welds when testing piping welds, (6 months for high pressure piping welds as defined in **GS EP PVV 611**).

The documentation shall clearly show the personnel qualification regarding the task in which he is involved in:

- Scan plan generation
- Instrument setting and calibration, according to specific standards
- Data collection with the same instrument as those used for the project
- Data analysis and results interpretation.

Also, the personnel shall be trained to the performance of manual PAUT defect detection and characterisation. Training and experience shall be documented and shall be subjected to Company approval.

6. PAUT system requirements

PAUT shall be implemented in semi-automated or automated mode.

Manual PAUT (MPAUT) without encoder device and data recording is permitted to be used under the following conditions:

- Complementary investigations needed for the defect/indication characterization previously detected thanks to the semi or fully automated scanning method.
- Detection and evaluation of transversally oriented defects when semi or fully automated scanning performance is demonstrated not efficient to Company.
- Weld configurations for which the use of an encoder device is demonstrated not practicable. Then another traceable technique or method shall be used in complementary to this technique and shall be subjected to Company approval.