

**Procedure order for testing of Flash Butt welding joints by Phased Array ultrasonic weld tester**

**1. Background:**

A new technique of Phased Array ultrasonic testing (PAUT) is being used for weld testing by some of the World Railways. Phased Array Ultrasonic technique (PAUT) is an advanced non-destructive ultrasonic technique that permits the shaping and steering of the ultrasonic beam angles and enhanced beam coverage. The Phased Array beam sweeps like a searchlight through the object, thus more sensitive in detecting the defects compared to conventional UT. For determining the adequacy and suitability of PAUT weld tester on Indian Railways, Research Design and Standards Organisation (RDSO) has conducted field trials of one of the PAUT weld tester on NE Railway. On the basis of performance of PAUT weld tester and outcome of the field trials following advantages have been observed:

- 1.1 No need to change the probe for different angles in Phased Array ultrasonic weld tester.
- 1.2 It is capable to detect the unwanted fins at different orientation which cause the stress concentration in the weld.
- 1.3 It displays the defect in various forms i.e. A-Scan, B-Scan, C-Scan & S- Scan for better analysis.
- 1.4 It displays the defect location more accurately.
- 1.5 It has mechanized probing.
- 1.6 It displays the decoupling between probes and probing surface.
- 1.7 Phased Array ultrasonic beam sweeps like a searchlight through the object with varying angles from 36 to 76 degrees, resulting in a recordable image that reveals the defects inside a rail or weld.
- 1.8 PAUT system permits the shaping and steering of the ultrasonic beam angles and enhanced beam coverage.

**2. Scope:** This procedure order covers the following aspects of outsourcing agencies involved in Flash Butt weld (FBW) testing by Phased Array ultrasonic tester (PAUT) System.

- 2.1 Verification of Phased Array ultrasonic weld tester (PAUT)
- 2.2 Verification of competency of Operators for FB weld testing by PAUT weld tester
- 2.3 Approval of Quality Assurance Plan (QAP)
- 2.4 Verification of competency of Quality Control In-charge

**3. Generic Specification:**

- 3.1 PAUT weld tester should display detailed analysis of defect signals in 'A', 'B', 'C' and 'S' Scan which allows the operator to determine a defect shape index. PAUT weld tester should be capable to display all these scans which provide visual information about the location and co-ordinates of the defects, approx. defect size.

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- 3.2 Different types of presentation of defect signal in PAUT weld tester is given as under:
- 3.2.1 **A-Scan presentation:** In A-scan presentation the horizontal axis represents depth of defect where ultrasonic beam travelled, the vertical axis represents the amplitude of any signals, measured as a percentage of the full height of the display screen. As per USFD Manual, Revised-2022 classification of defect carried out from A-Scan.
- 3.2.2 **B-Scan presentation:** The B-scan presentation is a profile (cross-sectional) view of the test specimen. In the B-scan, the time-of-flight (travel time) of the sound energy is displayed along the vertical axis and the linear position of the transducer is displayed along the horizontal axis. From the B-scan, the depth of the reflector and its approximate linear dimensions in the scan direction can be determined.
- 3.2.3 **C-Scan presentation:** It refers to the image produced when the data collected from an ultrasonic inspection is plotted on a plan view of the component. The image of the results of an ultrasonic examination showing a cross-section of the test object parallel to the scanning surface. The C-scan does not have to be a single cross-section but often shows a combination of measurements obtained through the whole thickness.
- 3.2.4 **S-Scan presentation:** It refers to a sector or sectoral scan which is produced when a phased Array is used to electronically sweep an ultrasonic beam through a range of angles. It shows a two-dimensional view of all amplitude and time or depth data from all focal laws of a Phased Array probe, corrected for delay and refracted angle.
- 3.3 The PAUT weld tester should have mechanical scanner to ensure the installation of probes in the zone of welded joint and movement along the weld.
- 3.4 The PAUT weld tester should have multichannel continuous recording of flaw detection information for the FB welded joints in real time.
- 3.5 Angle of steering of the ultrasonic beam of PAUT through the object should be from  $36^{\circ}$  to  $76^{\circ}$  and frequency of PAUT weld tester probes should be between 2 to 5 MHz.
- 4. General Guidelines for verification of PAUT weld tester:**
- 4.1 The firm shall approach RDSO for verification of their Phased Array ultrasonic weld tester, competency of USFD operators and Quality Assurance Plan (QAP). After verification of Phased Array ultrasonic weld tester, competency of USFD operators and QAP by RDSO, firm can participate in tenders. The firm will provide following details of equipment (PAUT weld tester) to be used in ultrasonic testing of FB welds to Metallurgical & Chemical Directorate (M&C Directorate) of RDSO at the time of verification:
- 4.1.1 Make.... Model.... Serial number.... year of manufacturing.... and codal life (OEM certified)....
- 4.1.2 Details of Probe :
- Frequency : It should be 2 to 5 MHz
  - No. of elements : As per OEM
  - Angle of steering : from  $36^{\circ}$  to  $76^{\circ}$
  - Number of probes : As per OEM
  - Couplant : Oil/grease or any other as advised by OEM
- 4.1.3 Mode of operation of system: Mechanized arrangement for probe movement.
- 4.1.4 Facility to display: must include A- Scan, B- Scan, C-Scan and S- Scan.
- 4.1.5 Details of control unit: Electronic Unit / PC tablet etc.



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- 4.1.6 Calibration procedure: Whether any standard block is required (approved by OEM) or otherwise.
- 4.1.7 Sensitivity setting procedure: To be done by any standard block (approved by OEM) or otherwise.
- 4.1.8 Details of records: In the form of defect location (H/W/F), depth of defect (from top of the Rail or any other reference point, surface distance in mm from probe to defect, amplitude in % (in case of A-Scan), approx. size of defect (in case of B-Scan).
- 4.1.9 Defect classification system: Defective / Non-defective.

**5. Verification procedure of Phased Array ultrasonic Tester (PAUT) :**

- 5.1 The performance of Phased Array ultrasonic weld tester shall be verified by M&C Directorate of RDSO. Sensitivity setting block offered by agency shall also be verified by M&C Directorate and duly stamped.
- 5.2 The agency shall deposit prescribed fee as per norms of RDSO for the same in advance as advised by M&C Directorate of RDSO.
- 5.3 The agency shall depute one certified USFD Operator cum Analyzer trained and certified by OEM as per clause 8 of this document for entire verification process of PAUT system at RDSO.
- 5.4 The capability of Phased Array ultrasonic weld tester will be shown to representative of M&C/RDSO by the firm at M&C Directorate, on the artificial and natural defects available at M&C Directorate of RDSO.
- 5.5 The Phased Array ultrasonic weld tester shall exhibit 60% of FSH or better signals from flaw as compared to the conventional weld tester of IR when tested on artificial defects mentioned in Manual for Ultrasonic testing of Rails and Welds , Revised 2022 and shall be capable to detect natural defects on test pieces available at M&C Directorate of RDSO.
- 5.6 The Phased Array ultrasonic weld tester under test shall exhibit equal or better coverage of weld sections in detection of flaw as compared to the conventional weld tester of IR.
- 5.7 After verification, the approval certificate with unique number indicating machine make & number, validity etc. will be issued by M&C Directorate of RDSO.
- 5.8 This approval certificate will be valid for half of the codal life of the equipment. As such, recertification will be done only once in service life of machine. Codal life of the PAUT equipment has to be declared by OEM.

**6. Testing of FB welds by Phased Array ultrasonic tester (PAUT) System:**

- 6.1 After calibration and sensitivity setting, complete scanning (head, web & foot) of FB weld joint shall be done by PAUT system carefully. During scanning, proper coupling must be ensured.
- 6.2 Recording of all the test data/parameters required along with A-Scan, B-Scan, C-Scan & S-Scan for analysis.

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**7. Defect classification by Phased Array ultrasonic weld tester for FB welds:**

Any FB welded joint when tested and observed having any flaw/moving signal during analysis shall be considered as defective. Further action is to be taken as per RDSO's Manual for Flash Butt Welding of Rails (Reprint - April 2022) along with its latest revision and updated correction slips.

**8. Verification of competency of Operators for FB weld testing by PAUT weld tester:**

- 8.1** The operator should fulfil the following requirements for ultrasonic testing of welding joints by Phased Array weld tester:
  - 8.1.1** The operator should have valid competency certificate for welding joints testing by conventional UT method, issued by the M&C Directorate of RDSO as described in IRS-T-53.
  - 8.1.2** The operator should have competency certificate issued by OEM after completing requisite training for operation and data analysis of Phased Array ultrasonic weld tester.

**9. Quality Assurance Program (QAP) :**

The firm will have to submit Quality Assurance Plan (QAP) for Ultrasonic Testing of FB welds by Phased Array ultrasonic weld tester (PAUT) for outsourcing and furnish the following information in the QAP, while submitting QAP to RDSO. The QAP shall necessarily have following contents:

- 9.1** Name of agency/ firm, registered address along with contact number & mailing address.
- 9.2** Registration certificate, details of GST registration, PAN number and ISO certificate.
- 9.3** Total number of Phased Array ultrasonic weld tester (PAUT) system for FB weld testing.
- 9.4** Total number of competent operators for testing of FB welds by PAUT system.
- 9.5** Quality Control In-charge.
- 9.6** Details of calibration and sensitivity setting block.
- 9.7** QAP shall be approved on the basis of verification of Phased Array ultrasonic weld tester (PAUT) system for testing of FB welding joints, competency of USFD operators & Quality Control In-charge and other information given by the firm in Quality Assurance Plan. The validity of QAP shall be 3 years. After this period QAP shall be renewed based on the machines available with firms, qualified operators, performance of operators and other relevant factors.
- 9.8 Self-assessed capacity:** The self-assessed capacity shall be calculated as per following criteria:  
For total no. of FB welding joints in a year: One Phased Array ultrasonic weld tester, one operator, 25 days of working in a month and 60 welds per day at site and 80 welds per day at Flash butt welding plant.

**10. Verification of competency of Quality control In-charge:**

- 10.1.** In order to have a proper implementation of QAP the firm shall have a proper quality control organization headed by a Quality Control In-charge, having RDSO certification as described in IRS-T-53 for Quality Control In-charge. He shall be responsible for maintaining the operator training record and to undertake continuous monitoring of performance of all the operators, carry out the test checks of work done of all operators working under him and ensure that all operators have been imparted proper training for the duties assigned to them.



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- 10.2. In addition to above, the Quality control In-charge should have competency certificate issued by OEM after completing requisite training for operation and data analysis of Phased Array ultrasonic weld tester.

**11. Documentation:**

- 11.1 The firm shall determine and record all information as specified below pertaining to Recording of Data with respect to the detection of flaw:

Daily test report gives a summary of the day's testing

- Date and time of testing (should come in auto mode and non-editable)
- Model and Sl. No. of equipment (should come in auto mode and non-editable)
- Name of operator :
- Railway & Division :
- Block section :
- Weld ID No. :
- Line- Single line/UP/DN/SL/NL3L/4L
- Classification of Weld: Defective/non-defective
- Amplitude (in case A-Scan in %) :
- Approx. size of defect (in case of B-Scan in mm) :
- Location of defect (H/W/F) :
- Depth of defect from Rail Table or any other reference point (in mm) :
- Surface distance from probe to defect (in mm):
- Other relevant details (as per request of Zonal Railways) :

Note: Agency shall submit a declaration from OEM that the date, time, model & sl.no. are non-editable in machine & report.

**12. Test Check:**

- 12.1 Defective FB welding joints shall be test checked in presence of Railway officials and agency's authorized representative. During test check, testing will be carried out by the agency's operator with hand probing using phased array probe of PAUT equipment at desired angle where in the defect was detected during mechanized probe movement scanning. The percentage of test check to be carried out is as follows:

- 12.1.1 25% of first 100 numbers of defective FB welding joints selected randomly,  
 12.1.2 Subsequently, 10% of remaining defective FB welding joints selected randomly.

- 12.2 In addition to it, 10% of non-defective FB welding joints marked by PAUT selected randomly covering whole stretch, shall be test checked in presence of Railway officials and agency's authorized representative. During test check, testing will be carried out by the agency's operator with hand probing using phased array probe of PAUT equipment at desired angle.

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- 13.1** Firms can participate in tenders only after verification/certification of their Phased Array ultrasonic tester (PAUT) system for testing of FB welding joints and verification of competency of USFD operators, Quality Control In-charge and Quality Assurance Plan (QAP) by RDSO.
- 13.2** Addition/ deletion/ change of Quality Control In-charge, USFD operator for PAUT system, machine (PAUT system), QAP etc. shall be dealt as per IRS T-53.
- 13.3** The certification of machine/ system is done by RDSO initially. Regular check on test piece having artificial defects mentioned in Manual for Ultrasonic testing of Rails and Welds, Revised 2022 shall be ensured by Zonal Railways. Any deterioration in performance shall be advised to RDSO.
- 13.4** As the role of RDSO is limited to verification/certification of machine and verification of competency of USFD operator & QAP, the concerned authority finalizing the tenders shall be responsible for checking and ensuring that the firm meets the minimum technical and financial eligibility criteria. The eligibility criteria are not the part of QAP, as QAP is meant basically to regiment the Quality control system. As such, availability of RDSO approved QAP with firm shall in no way be construed that RDSO has checked and verified eligibility criteria. It is reiterated that assessing the capability of the firm, checking eligibility criteria and other relevant factors will be the sole responsibility of tendering authority. Technical eligibility criteria has been defined in Annexure-II attached herewith. This procedure order contains general technical guidelines, final tender document shall be framed by concerned Zonal Railway considering the extant policies.
- 13.5** Zonal Railways shall test check the capability of the operator and ultrasonic test system from time to time. These test checks can be carried out as per this procedure order. Before commencement of work by PAUT weld tester in all concerned Zonal Railways where Phased Array testing of FB welds has been allowed, firm shall arrange a demonstration at RDSO regarding operation and data analysis of PAUT system for officials of Zonal Railways.
- 13.6** The operator shall possess original / photocopy attested by Railway officer, of the valid competency certificate issued by RDSO as per provisions of IRS-T-53 and certificate issued by OEM for FB weld testing by PAUT weld tester while performing testing of FB welds in the field and produce the same to railway officials when demanded. Zonal Railways shall put in place a mechanism to maintain day to day records of operators employed by the contractor along with equipment used (Sr. No. of machine etc.).
- 13.7** The approval of QAP by RDSO does not certify the agency's eligibility for meeting required norms. Technical eligibility criteria has been defined in Annexure-II attached herewith. The Zonal Railways shall ensure the compliance about firm's capability, eligibility criteria and other requirements as per extant instructions.
- 13.8** On the basis of advice/ complaint raised by railway, RDSO shall critically review/ check the QAP of agency alongwith performance verification of PAUT system.
- 13.9** M&C Directorate of RDSO shall act as third party to investigate whether the defect was detectable at the time of USFD testing or not. The decision of RDSO shall be final and binding on both the parties and this decision is not arbitrable.

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- 13.10** The surface of Rail on both sides of FB weld at least 100 mm from centre of weld and around profile has to be smooth enough and free from spatter for free movement of probes along the rail profile to avoid loss of coupling.
- 13.11** FB welds should be properly ground as per Para 8 of Manual for Flash Butt Welding of Rails (Reprint - April 2022) along with its latest revision and updated correction slips to avoid the collar signals in PAUT testing of FB welds. In case, after grinding signal does not disappear in PUAT testing, then signal shall be treated as coming from a defective welding joint. However, if any ultrasonic testing is done without proper grinding and a signal is obtained, then the report should be submitted with remarks of signal obtained and based on this report, Zonal Railway / welding agency has to get the FB weld ground and re-tested.
- 13.12** In case of any obstruction (clear space not available for proper fitting of probes of PAUT, due to bolt hole in vicinity of FB welds) in Phased Array ultrasonic weld testing, then manual hand probe of Phased Array weld tester is to be used for scanning of FB weld.
- 13.13** Based on the feedback received from Zonal Railways, this procedure order will be modified in consultation with M&C Directorate of RDSO.
- 14. Safety:** All personnel employed in testing by PAUT system are responsible for ensuring that they as well as their fellow employees are performing their jobs in a safe and professional manner and adhere strictly to the safety protocol established by Indian Railways.

**This Procedure order will be applicable w.e.f. ....June, 2023.**

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