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Function: Track & Civil
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Non-Destructive Testing of Rail

ETA-01-05

Applicability

ARTC Network Wide SMS

Publication Requirement

Internal / External

Primary Source

NSW Standards TES 03, TES 05, TEP 15, TEP 16, TEP 17, TEP 18, TEP 19, the Rail Fail Form and Manual RC 2407, ETE-01-03

Document Status

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1.0	28 Mar 24	Standards	Stakeholders	Manager Track & Civil Standards	Head of Engineering Standards 15/04/2024

Amendment Record

Amendment Version #	Date Reviewed	Clause	Description of Amendment
1.0	28 Mar 24	1.4, 2.1, 2.4, 3.1.3, 3.3.2, 4.2, 4.5.1, 7.2, 7.2.1 & 7.3	Renumbered from ETE-01-03. Document references updated throughout. NDT qualification and re-certification sections updated to remove reference to American Society of NDT document.

Table of Contents

1 Introduction

1.1 Purpose

This standard sets requirements for non-destructive testing (NDT) of rail and welds. This includes, but is not limited to:

- Ultrasonic Testing by:
  - Handheld Equipment
  - Trolley
  - Rail mounted continuous testing equipment
- Dye Penetrant Testing
- Magnetic Particle Testing
- Visual Inspection

1.2 Scope

This standard applies to all track, including turnouts, where detailed inspection of rails and welds is carried out as per ETS-01-00.

This standard also applies in tracks where, although detailed inspection is not mandated, an ad hoc inspection has been directed by corridor management due to condition or operating circumstance.

1.3 Document Owner

The Head of Engineering Standards is the Document Owner. Queries should be directed to standards@artc.com.au in the first instance.

1.4 Reference Documents

The following documents support this procedure:

- ETS-01-00: Section 1: Rail
- AS 1085.20 Railway track material – Welding of steel rail
- AS 2083 Calibration blocks and their methods of use in ultrasonic testing
- AS 2207 Non-destructive testing – Ultrasonic testing of fusion welded joints in carbon and low alloy steel
- ETG-01-03 Manual for Non-Destructive Testing of Rail
- ETP-00-01 Written Practice for the Training, Competency Assessment and Certification of Personnel in Non-Destructive Testing
- AS ISO 9712 Non-destructive testing – Qualification and certification of NDT personnel.

Where a conflict exists between two standards the most recent ARTC standard shall be adhered to.

1.5 Definitions

The following terms and acronyms are used within this document:

TERM OR ACRONYM	DESCRIPTION
A-scan	The A-scan presentation displays the amount of received ultrasonic energy as a function of time

1.6 Limitations of this Standard:

It is recognised that NDT is not 'infallible'.

There are limitations of existing ultrasonic techniques, including:

- Some defects can lie in zones of the rail that are not tested ultrasonically: the critical untested area being the foot of the rail and the first ~5mm below the head surface.
- There is no positive (failsafe) feedback to confirm that the angled probes (70º and 38º) have continuous contact with the rail.
- There is no positive (failsafe) feedback to confirm that the angled probes (70º and 38º) are penetrating the depth of the rail.
- AS 2207 recommends that probes with incident angles greater than 20° to the major expected reflecting surface should not be used.

2 Personnel Qualifications

2.1 Non-Destructive Testing Qualifications

NDT shall only be carried out by personnel who have been assessed as competent in accordance to ETP-00-01 Written Practice for the Training, Competency Assessment and Certification of Personnel in Non-Destructive Testing.

Testing methods are as described in ETG-01-03 Manual for Non-Destructive Testing of Rail or as approved by Manager Track & Civil Standards.

2.2 Visual Capability

All Ultrasonic testers must be able to:

- Read a Jaeger Number 1 Chart at a distance of not less than 305mm
- Be capable of distinguishing and differentiating contrast between colours and shades of grey used in the method.

All Ultrasonic testers shall carry out a visual check annually.

Note: These competencies are in addition to other ARTC requirements for items such as Safeworking, medical requirements, etc.

2.3 Records

Records shall be kept with respect to each certification of:

- Name of certified employee
- Level of certification method
- Procedures in which they have been assessed as competent
- Examination results
- Competency assessment tool
- Dates of certification
- Signature of Employer's Representative.

2.4 Re-Certification

Shall be in accordance with ETP-00-01 Written Practice for the Training, Competency Assessment and Certification of Personnel in Non-Destructive Testing.

3 Non-Destructive Testing Requirements

3.1 Existing Rail and Welds

3.1.1 Testing and classification of defects

Existing rails and welds shall be tested for new and existing rail defects. All identified defects shall be classified, sized and reported as new or existing.

Identified rail discontinuities shall be classified by type and size according to the ARTC standards.

3.1.2 Testing Frequency: principles of rail break reduction

Management of total rail break risks should include root cause analysis of all break types to maintain an acceptable risk level that incorporates;

- suitable ultrasonics testing frequency for defects feasibly found by that process
- for all remaining break causes outside the scope of ultrasonic mitigation, alternative inspection and prevention strategies must be applied, including but not limited to;
    - maintaining stress free temperature within acceptable limits to reduce tensile loads on the rail
    - prevention of rail deflection in bending that fatigues the foot
    - quality controls on welding process and geometry
    - minimisation of rail damage to external surface (non-wheel related)
    - minimisation of rail stress by abnormal wheel loading forces (impact and static)
    - prevention of corrosion deeper than minor surface coating

3.1.3 Management of testing frequency

Test frequency for each line section shall be published in the Technical Maintenance Plan. The main factors to consider when proposing a change to test frequency are:

- broken rail rate per kilometre (as defined in 2. below)
- broken Rails as a % of the Total defect rate per kilometre, counting only breaks and defects that could be detected by ultrasonics probe arrangements utilised.
- MGT and Axle Loading changes that have occurred or are planned on a given track segment (compared against previous history)
- further guidance on the testing frequency is provided in ETG-01-03 Manual for Non-Destructive Testing of Rail.

The following requirements shall apply when reviewing and changing the existing test frequency;

1. Changes to increase or decrease a test frequency must follow the ARTC Change Management Process including risk assessment and notification to Regulators.
2. Testing should be undertaken at a frequency that supports maintaining the combined rail and weld breaks at or below 0.02 breaks per km per year, subject to;
    a. The 0.02 breaks per km per year data is to be collated using only full rail breaks that could have feasibly been found during continuous car testing. Data is not to include large

b. defects that did not crack through the section, and foot breaks caused by defects outside the zero-probe capability-to-find are not to be included.

c. Insulated Rail Joints are not to be included in this rail breaks count.

3. Rail break/km/year averages shall be calculated over enough kilometres and years to demonstrate trends and rail break concentrations.

4. The recommended maximum adjustment to the testing frequency at any one time shall be:

   a. In the case of a shorter interval: the new testing interval should not be shorter than ⅓ of the previous interval

   b. In the case of a longer interval: the new testing interval shall not be longer than 1½ times the previous interval.

   c. In the case where the track section has had significant new rail replacement, or significant change in the type of traffic MGT quantity or typical axle load, the following factors shall be considered;

      i. A new testing frequency should be applied with a timing that considers the risk of early failures i.e. the Bathtub maintenance principle following commissioning of the new track.

      ii. A risk assessment process to ensure scale of change in the loading factors affecting rail defect growth (MGT, TAL etc) have been correctly linked to the likelihood of breaks occurring.

3.1.3.1 Points & Crossing frequency

The through and diverging legs of Points and Crossings should be inspected as per the frequency of the respective track they connect to. Where either the through or the diverging leg of Points and Crossings connect to non-ARTC tracks the inspection should be based on the risk to ARTC i.e. the ARTC components are tested however there may be risk to ARTC tracks from defects in the non- ARTC components not being tested adequately by the interface owner.

3.1.3.2 Crossover frequency

All crossovers connected to tracks that are tested shall be identified.

The test frequency for crossovers should be at a frequency of 15 MGT during the service life of the rail or as specified otherwise by ARTC e.g. in an approved Technical Maintenance Plan.

- The crossover area begins and ends at the toe of switch of each turnout, extending through the diverging rails and associated track section between.
- When proposing to vary established testing intervals, the proposing officer must document the basis for the change.
- Where it is not practical to schedule testing of crossovers by rail mounted continuous ultrasonic testing equipment alternate methods should be considered, for example use of hand-held equipment for testable areas. For untestable areas of the crossovers, treat as per section 3.2.

Where crossovers are used by exception only, and may experience less than 1MGT per year, testing shall be at the discretion of the relevant ARTC authority. Rail may be tested more frequently or less frequently at the discretion of the relevant ARTC authority

3.2 Points and Crossings testability issues

There are components in the points and crossing which cannot be tested effectively by either the rail mounted continuous ultrasonic testing equipment or hand-held ultrasonic equipment. These areas shall be visually inspected by a competent rail safety worker; this can be done during Track Patrol, General or Detailed Points and Crossings inspections, they include:

- the narrow section of switch blades
- manganese crossing components,
- parts of the rail foot as per mainline testing (anywhere outside of the zero-probe web zone)

Housed points missed by the rail mounted continuous ultrasonic testing equipment (as it may need to lift probes to avoid damage) should be tested by handheld equipment at the same frequency as the continuous testing.

Different legs of a turnout may require different frequencies of test depending on their actual tonnage.

Figure 1 illustrates the test capability of turnouts and diamonds. Where a section marked ‘tested’ is not tested by continuous rail testing it must be hand tested.

Note: Only rails traversed by the test car will be tested.

It may not be possible to test some rails marked for testing due to their material. In these instances, visual inspection is required.

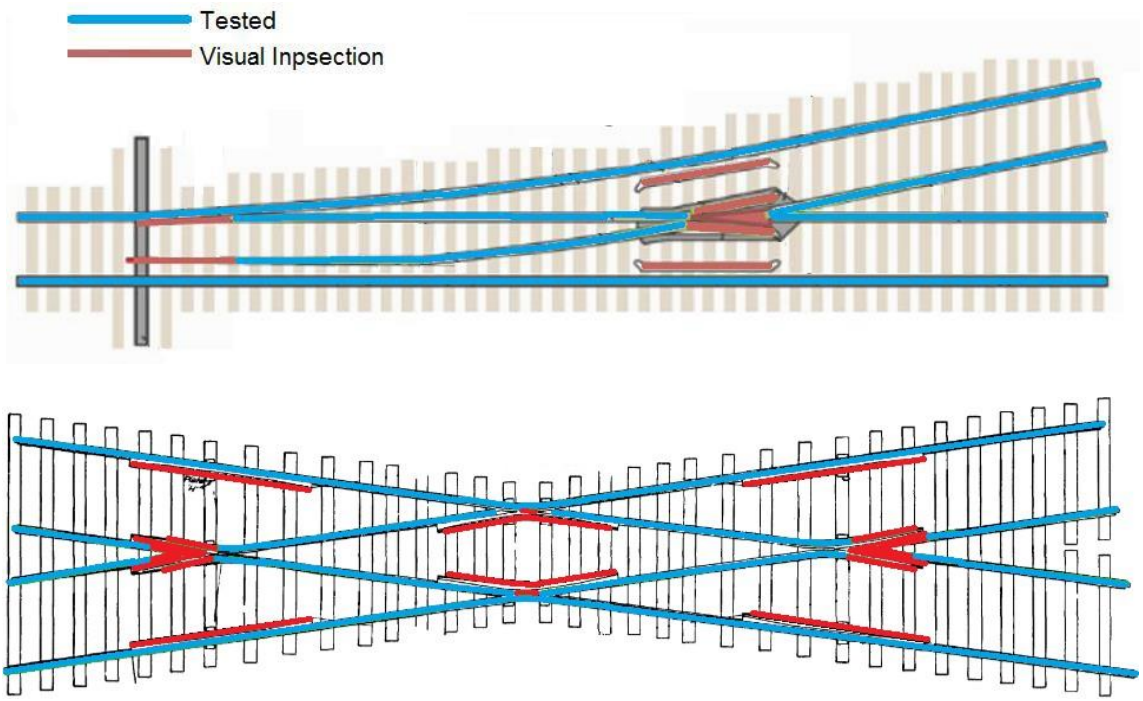

Figure 1: Test capability depending on travel direction of the rail flaw detection car

3.3 NDT of New Welds (Aluminothermic, Wire Feed (Fluxcore) and Flashbutt)

3.3.1 General

All new welds shall be tested. Testing shall include visual inspection, ultrasonic inspection and geometric inspections.

Testing shall be carried out:

- All tracks - no sooner than 5 hours after grinding (where practicable 24 hours after grinding is preferred)
- Tracks rated ≥ 30 tonne axle load - not later than 14 days of being installed.
- Tracks rated < 30 tonne axle load - not later than 3 months of being installed.

3.3.2 Ultrasonic Inspection of Welds

The ultrasonic test shall be carried out in accordance with the methods contained in ETG-01-03 Manual for Non-Destructive Testing of Rail.

3.3.3 Visual Inspection of Welds

The visual inspection shall be carried out in accordance with;

- Appendix E “Visual Inspection and Alignment” of AS 1085.20 Railway Track Material – Welding of Steel Rails
- relevant ARTC standards for welding quality.

For weld visual inspection and response guide refer to ETG-01-03 Manual for Non-Destructive Testing of Rail.

3.3.4 Geometric Inspection of Welds

The ultrasonic inspector shall carry out an inspection of the Weld Geometry in accordance with Rail Weld Geometry Standards

3.3.5 Inspection of Punch Marks

Where welding has been carried out as part of a restressing of the rails the ultrasonic inspector shall examine the punch marks on the rail. A measurement is to be taken of the length between punch marks and recorded on the Welders’ Return Form.

4 Ultrasonic Testing

4.1 General Guidance to Ultrasonic Testing Philosophy

The following sections are intended to standardise the existing technologies to enable consistency amongst the various testers. It is not intended to limit the innovation and development of new techniques or equipment. ARTC recognises the limitations of current techniques and actively encourages any improvement to testing capabilities. Where variance to the following standard is required, an application for a waiver should be sought from the Manager Standards.

4.2 Calibration Process

All ultrasonic equipment shall be re-calibrated within the intervals specified in Section 4.2.1. Calibration test methods shall be carried out in accordance with the requirements of AS 2083 and as detailed in ETG-01-03 Manual for Non-Destructive Testing of Rail.

4.2.1 Calibration and Equipment Inspection Periods

Table 1: Calibration Schedule for Ultrasonic Testing Equipment

INSTRUMENT FEATURES	RECORDING INTERVALS	DOCUMENTATION REQUIREMENTS
Vertical linearity	12 months	Yes
Horizontal linearity	12 months	Yes
Probe shoe condition	Daily	Not Required
Angle beam probe index point	Daily	Yes
Angle beam probe beam angle	Daily	Yes
All probe gain reserve (OSG) >20dB,	12 months	Yes
Calibration Blocks	2 Years	Yes
Pulse Count (Machine only)	Daily	Yes

4.2.2 Calibration Blocks

The following blocks shall be used for calibrating the hand-held ultrasonic equipment:

- Block V1 (from AS 2083)
- Block V2 (from AS 2083) may also be used for field calibration

Rail Specific Gain Calibration Block Figure 2: Rail Specific Gain Calibration Block. This block is 250mm x 75mm x 25mm with a 1.5mm side-drilled hole (SDH) 50mm from the top surface and 50mm from one end.

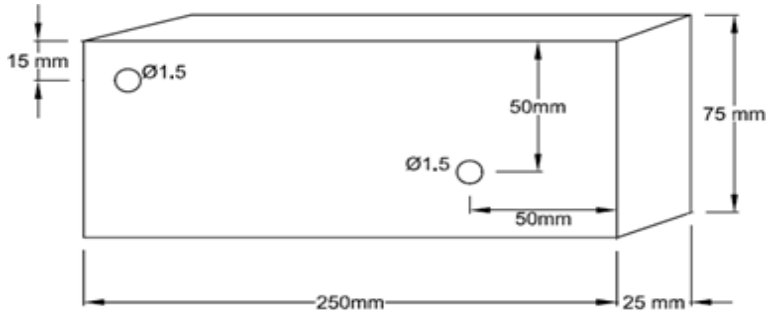

Figure 2: Rail Specific Gain Calibration Block

Note: New modified blocks now have an additional 1.5mm hole drilled across the block at a depth of 15mm.

4.2.3 Calibration Settings for Hand Test Probes

Hand testing probes shall be calibrated for range and sensitivity as shown in Table 2

Table 2: Calibration Settings

PROBE	ANGLE	FREQUENCY	RANGE CALIBRATION	SENSITIVITY CALIBRATION
Probe 1 Single 70°	70°	2MHz	Normal Rail tests 0-200mm Bolt hole Tests 0-250mm	80% FSH from a 1.5mm SDH @ 25mm depth, plus 6dB for scanning
Probe 2 38°	38°	2MHz	0-250mm	80% FSH from a 1.5mm SDH @ 50mm depth, plus 6dB for scanning
Probe 3 Single 0°	0°	2MHz	0-200mm	80% FSH from a 1.5mm SDH @ 50mm depth, plus 6dB for scanning
Probe 4 Twin 0°	0°	2MHz	0-200mm	80% FSH from a 1.5mm SDH @ 50mm depth, plus 6dB for scanning
Probe 5 Small 0°	0°	4MHz miniature	0-100mm	80% FSH from a 1.5mm SDH @ 50mm depth, plus 6dB for scanning
Probe 6 Single 70°	70°	4-5MHz	0-100mm	80% FSH from a 1.5mm SDH @ 15mm depth of V1 block, plus 6dB for scanning
Alternative Probe 6 Twin 70°	70°	4-5MHz twin	0-100mm	80% FSH from a 1.5mm SDH @ 25mm depth, plus 6dB for scanning

Note: FSH = Full Screen Height SDH = Side Drilled Hole

4.2.4 Continuous Test Car Calibration

The continuous test car is required to calibrate the machine daily. The exact method of calibration shall be agreed between the contractor and ARTC representative. It could include:

- Technical measurement of the machine's testing equipment as detailed in ETG-01-03 Manual for Non-Destructive Testing of Rail
- Recorded comparison of car measurements against the hand testing sizes (handheld equipment having been calibrated in accordance with Section 4.2 of this document)
- Checks of defect identifications against known sections of defects.

It is recommended that auditing checks are periodically carried out on the performance of the car using an undisclosed test track

4.2.5 Pre-test Checks

In addition to calibration checks, all equipment should have pre-test checks as appropriate to its use.

4.3 Environmental Requirements Ambient Temperature

Continuous Rail Testing should not be programmed to be ultrasonically tested at times where rail temperature is likely to exceed 50°.

Where possible, the Continuous Rail Testing should be programmed at times when the rail temperature is likely to be below the Stress-Free Temperature (SFT) of the Rail.

Where the rail is programmed to be tested less than 3 times a year, the test should not be programmed during the summer months.

4.4 Equipment Requirements

All ultrasonic testing equipment shall have enough resolution, sensitivity and accuracy to be capable of identifying and recording the following minimum defect sizes:

- Transverse defect in weld 10mm height
- Transverse defect in rail 5mm height
- Longitudinal defect 10mm length
- Bolt hole cracks >10mm oblique length
- Multiple transverse defects: identify separate defects of 20mm separation.

4.4.1 Resolution

The equipment should be capable of readily resolving adjacent reflectors with a separation along the beam axis of 2.5 wavelengths. The resolution requirements are shown in Table 3

Table 3: Resolution requirements

NOMINAL FREQUENCY (MHZ)	COMPRESSION WAVE PROBES (MM)	SHEAR WAVE PROBES (MM)
2.0	7.4	4.1
2.5	5.9	3.3
4.0	3.7	2.0

4.5 Equipment Technical Specifications

4.5.1 General

The ultrasonic testing equipment shall employ A-scan presentation and shall have a reserve sensitivity of at least 20dB at the maximum beam path used. The equipment and probes shall be capable of operation within a frequency range of 2MHz to 6MHz.

Digital units may have calibrations stored in the database and recalled as needed, in which case the calibration should be checked before use. The frequency at which these calibrations need to be documented is set out in ETG-01-03 Manual for Non-Destructive Testing of Rail.

The use of other equipment types will be considered if the user can demonstrate, using known defects, that the equipment is at least as effective at detecting internal defects as the above equipment.

4.5.2 Handheld Ultrasonic Equipment

The ultrasonic probes in Table 4 are the specified minimum for hand testing in ARTC. The ultrasonic inspector should carry all six probes.

Table 4: *Ultrasonic Probes for Handheld Rail Testing* [1, 3]

NAME	SHAPE & SIZE	MEASUREMENT ANGLE	FREQUENCY
Probe 1 Single 70°	'14x14'mm to '20x22'mm	70° ± 2°	2.0 – 2.5 MHz
Probe 2 38°	'14x14'mm to '20x22'mm	38° ± 2°	2.0 – 2.5 MHz
Probe 3 Single 0°	24mm diameter	0° ± 2°	2.0 – 2.5 MHz
Probe 4[2] Twin Crystal 0°	7x18mm	0° ± 2°	2.0 - 2.5 MHz
Probe 5 Small 0°	10mm diameter	0° ± 2°	4.0 – 5.0 MHz
Probe 6 Single or Twin Crystal 70°	'10 x 10'mm or 3.5 x 10mm	70° ± 2°	4.0 - 5.0 MHz

Notes:

1. *These probes are specified to standardise current probe usage: refer to section 4.1 of this document for the introduction of other equipment.*
2. *Probe 4 is an alternative to Probe 3*
3. *The Probes specified are the minimum requirements for general testing of rail and welds. Other probes maybe used to target other areas or specific rail defects.*

70° Probe: This probe is used to ultrasonically examine the railhead area for defects of a transverse nature only, including weld defects. All probing with a 70**°** probe should be done in both testing directions. 70**°** probes were originally chosen for use in unidirectional track where transverse defects (TDs) tend to occur at 18 - 22º. However, with bi- directional track the TDs can be more vertical and do not always reflect the 70º

38° Probe: Defects located by this probe include bolt hole cracks and defects of a transverse nature in the web and flange (section below the web only). All probing with a 38**°** probe should be done in both testing directions from the running surface of the rail.

0° Probe: This probe is used to ultrasonically examine the full rail depth. Defects located by this probe include bolt hole cracks and longitudinal defects of a vertical or horizontal nature in the head, web and flange (in the section below the web only).

4.5.3 Rail Mounted Continuous Ultrasonic Testing Equipment

An audible alarm shall be fitted to the 0° ultrasonic probe to indicate 'loss of bottom echo' over any length greater than 10mm.

The minimum specified probes for continuous ultrasonic testing equipment in ARTC are shown in Table 5

Table 5: Minimum Ultrasonic Probes for Continuous Rail Testing

NAME	MEASUREMENT ANGLE	SIGNAL FREQUENCY
Probe 1 Forward and rear facing 70°	70° ± 2°	2.0 – 2.5 MHz
Probe 2 Forward and rear facing 38°	38° ± 2°	2.0 – 2.5 MHz
Probe 3 Single 0°	0° ± 2°	2.0 – 2.5 MHz

Note:

The Probes specified are the minimum requirements for continuous testing of rail and welds. Other probes maybe used to target other areas or specific rail defects.

Use of a 45º probe in place of the 38º probe may be considered in conjunction with the relevant ARTC representative.

4.5.4 Couplant

For normal rail testing, water will be used as a couplant. This can be thickened with methyl-cellulose (e.g. wallpaper paste) if necessary. A detergent (i.e. dish washing liquid or truck wash) can be added to the water as a wetting agent.

However, water should not be used if the rail temperature is below 0º C unless the operator is satisfied that an antifreeze additive has been added to enable the correct testing procedure.

Oil may be used as a couplant on calibration blocks.

AS 2207 mandates that couplants used in calibration are the same as those used during testing.

In exceptional circumstances diesel may be used as a couplant over short distances. Care should be taken to minimise the amount used and to record the location.

4.6 Continuous Ultrasonic Testing

Continuous ultrasonic testing shall be carried out on a face. The continuous testing contractor shall demonstrate that they have capability to detected at least 90% of all previously known, small defects listed as reportable in ARTC Standard; Section 1: Rail and any other related rail defect standards.

Evaluation of detection capability may be made by comparing a subsequent run with previously known small defects for the same run as follows:

$$\frac{number\ of\ corresponding\ defects\ found\ on\ subsequent\ run}{number\ of\ small\ previously\ known\ defects} \times 100$$

Previously known defects removed before the subsequent run as well as new defects shall be excluded from the comparison.

The frequency and scale of the evaluation shall be determined by the ARTC Project Manager appropriate to the capability being demonstrated by the contractor.

All anomalous indications found during the Continuous ultrasonic testing shall be evaluated manually.

The continuous ultrasonic testing car is required to record the rail temperature. At least two temperature readings should be taken daily to capture the maximum and minimum temperatures.

4.6.1 Management of Human Factors

The testing process, and the conditions in the car vehicle should be optimised to help the operator concentrate on the data being analysed and to minimise the risk of a missed defect. This includes:

- Good use of post analysis facilities of recorded data
- In-car working conditions and temperature
- Computer screens that are adequately protected from sun glare
- Monitoring that the car speed on track is compatible with the ability of the operator to accurately analyse data presented
- Safe working is adequately catered for outside the time allowed for test analysis
- Fatigue management of operators (consideration of operator rotation with hand testers)
- Undue pressure on time allowed in section i.e. sensible track access scheduling
- Peer development and regular training in compliance with this document
- Monitoring of operators' performance in terms of % of defects identified.

4.7 Assessment Required of any Ultrasonic Shielding

During ultrasonic testing there shall be continuous monitoring of positive indications of normal test procedure working correctly, e.g. continuous back wall echo as per section 4.5.3, grain structure, heat affected zone etc. This section describes how to assess and respond to levels of ultrasonic shielding and the testability of rail that is not meeting the positive indications requirement.

There are several causes of shielding, the primary causes are any of, or combinations of, those listed in

Table 6:

Table 6: ***Causes of shielding***

CONTAMINATION	POSITION	SURFACE DAMAGE
Dirt and debris	Excessive head side wear	Rolling Contact Fatigue (RCF)
Rail lubricants	Rail cant angle relative to the probe	Gauge corner cracking
Rust		Squats and wheels-burns
		Pitting e.g. road crossings

These conditions can cause a partial or complete loss of back wall echo (LBWE) on the zero probe Levels of shielding severity, actions and response times are given in

Table 7, for the purposes of this table:

- LBWE as expected at bolt holes, turnout components etc, shall be disregarded provided there are no indications of real defects (that are suspected to not be caused by the back- wall disruption).
- Shielding and untestable rail is to be reported to the relevant ARTC authority and recorded according to requirements set out in section 0. The reports are to be entered into the defect database.

The background aims of

Table 7 are summarised in the following points:

- Due to the differing methods of operation, the requirements for response actions to shielded rail will also differ for various equipment technologies. High speed running (generally >40km/h), and automatic defect sizing vehicles, will generally have a slightly different sequence and time priority of actions to follow, when compared to traditional low speed (≤40km/h) methods with additional chase cars. This has required the table detailing initial response to shielding to be split into two main methods.
- The initial aim of the process is to confirm the cause(s) of shielding, and where feasible and if testability will be improved, require the test car to re-test at low speed if practical.
- If after re-testing, or if retesting by car is not possible, the second aim is to confirm shielding causes and exact lengths through inspections and hand-testing. Where the cause of shielding is found to be due to surface damage and/or rail position and side wear, the risk can usually no longer be addressed through testing actions alone.
- For smaller cases of LBWE the table is aiming to report the early stages of the deterioration, so remediation can be planned before untestable lengths are reached. Rail replacement and metal removal processes are required to address LBWE once the lengths reach too far.
- Finally, where the LBWE is confirmed in a size and condition which masks the true size of any existing or potential new internal defect(s), apply appropriate risk mitigation.

All lengths in mm in the table refer to the longitudinal length of LBWE along the rail head.

Table 7: Assessment of shielding, response times and actions

1. Shielding Definition	
Shielding must be reported when *any* of the following occurs with car testing at normal speed: • LBWE greater than 50mm length has been found, OR • gain had to be turned up, OR • if the rail is generally difficult to test, OR • operator suspects that one or more probes are not giving valid results.	
2. Contractor Actions (test car)	
1. For testing regimes that require manual classification and sizing of defects (typically low speed with a chase car) the test car is to stop immediately and take actions: a. Track should be examined to identify cause of loss of detection. b. Rail should be cleaned if necessary, or car probes adjusted, and re-tested at 5km/h with additional couplant if necessary. c. If the rail is still unable to be tested at this stage the test car shall report shielding, specifying the length and suspected cause within 1 days of testing. 2. For automated testing regimes (typically high speed with no chase car), a detailed report of LBWE lengths shall be supplied within 1 day of testing, there is no requirement for retesting at slower speeds on shielded locations.	
3. ARTC Actions (local team managed)	
ARTC Corridor Management for the affected track section shall arrange for the reported shielding cause to be actioned within the latitude of the relevant ultrasonic testing timeframes or within 7 days of reporting, whichever is the later. To resolve the shielding issue one of the following actions must be taken to confirm LBWE length: 1. Affected rail locations will be retested either by car or by hand, to determine accurate LBWE lengths, OR 2. LBWE length reported by the contractor is directly used to proceed to the actions listed below. If a length of LBWE is confirmed in steps 1 or 2 outlined above, the following actions below shall apply;	
4. Confirmed LBWE Condition	**5. Action**
LBWE less than or equal to 50mm	No further action
LBWE length greater than 50mm, but less than or equal to 200mm	The responsible asset engineering authority is to assess the LBWE area reported and derive a rail rectification strategy to occur within timeframes that prevent the LBWE growing beyond 200mm length. For example (but not limited to) possible rail rectification strategies could include: • Immediate grinding using a hand operated or mainline grinder • Change of grinding strategy, including frequency and/or amount of metal removal • Rerailing, closure install or on a face
Unable to size a defect identified previously.	Track speed shall be restricted to 40km/h until works are performed to restore testability (works; rail replacement or grinding/milling metal removal of the shielded surface depth and successful re-testing).
For any of the following conditions, • LBWE length greater than 200mm • more than one LBWE patch (excluding squats) per metre, with each patch being between 50 to 200mm in length • Squatted rail: if there is less than 60mm of testable rail between squats, thereby preventing the	Track speed shall be restricted to 40km/h until works are performed to restore testability (works; rail replacement or grinding/milling metal removal of the shielded surface depth and successful re-testing). This response action may be varied by a person with CER competency, up to a maximum track speed restriction of 80km/h, based on documented risk evaluation. For example (but not limited to), LBWE can be higher risk with; • boltholes and welds masked • mudholes/pumping • passenger, heavy haul or high >50 MGT traffic • tight curvature <R600m

70° probe from detecting a transverse defect under either squat	LBWE cases not greatly affected by high risk factors or conditions may have their response varied by such CER approved risk evaluations.

5 Alternative Non-Destructive Testing Techniques

Alternative Non-Destructive Testing techniques for example dye penetrant testing and magnetic particle testing are not required to be programmed on a cyclic basis, but can be used as a means of detecting, confirming or sizing rail cracks with or without ultrasonic testing as required.

Where alternative methods are used, equipment and products should comply with the relevant Australian Standard. Personnel shall complete specialist training in all NDT Testing techniques and shall be certified for each technique.

All testing methods and frequencies shall ensure that the broken rail risk profile is not compromised

6 Classifying Defects

All rail and weld internal and surface defects, and weld geometry shall be classified in accordance with ARTC standards.

6.1 Naming System of Defects

Defects which can be identified using non-destructive testing are illustrated in Figure 3.

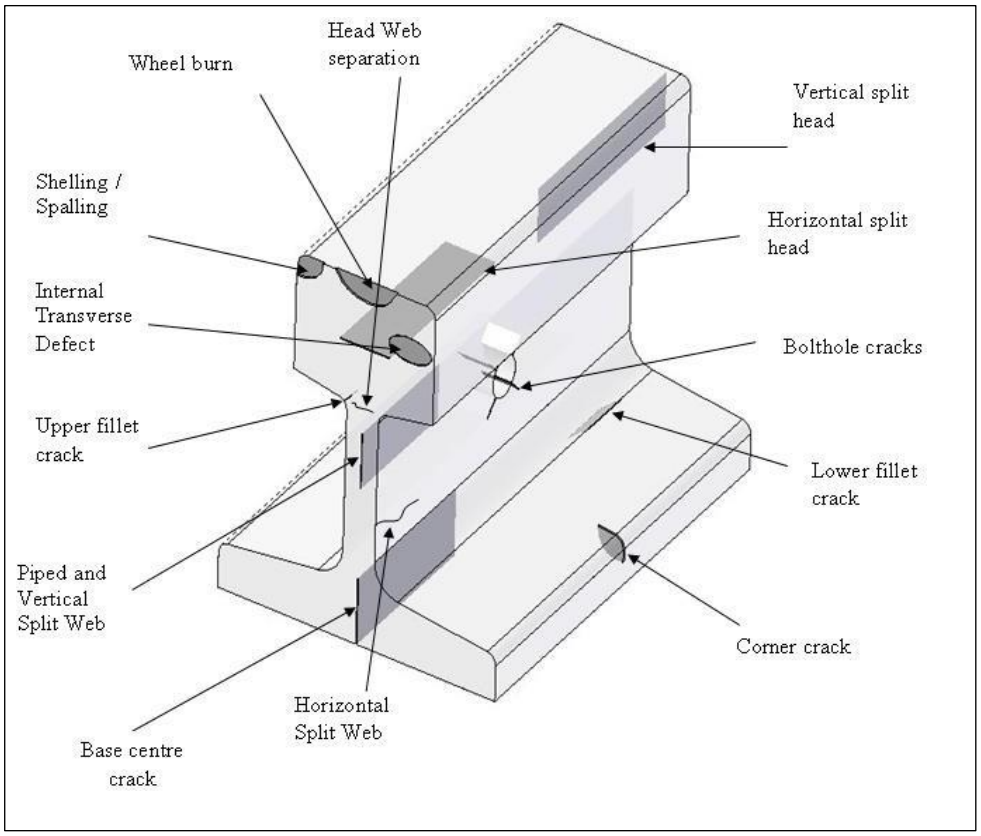

Figure 3: Internal rail defects definitions

6.2 Sizing Defects

All indications exceeding 40% of full screen height at **evaluation sensitivity** shall be measured for precise size. All defects shall be recorded in mm. See Section 7 for reporting requirements.

All defect sizing should be determined by using the “last significant echo” method. Any loss of back wall echo or other known reflectors (during hand test sizing) shall be investigated by visual inspection and scanning from the other faces of the rail.

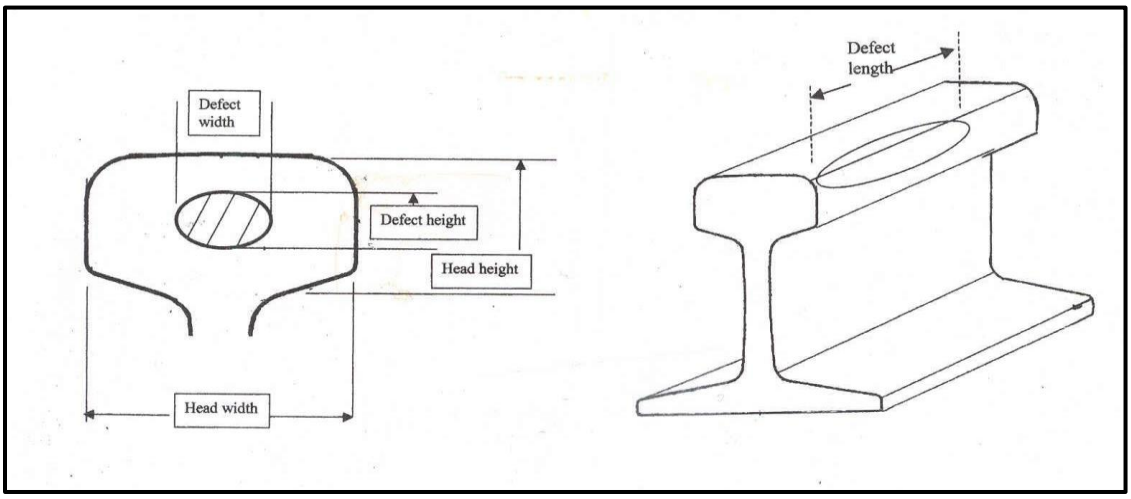

Figure 4: Definition of Defect Dimensions

All indications exceeding 40% of full screen height at evaluation sensitivity shall be evaluated for size. Sizing should be done by the last significant echo method

7 Recording and Reporting Requirements for Rails and Welds

7.1 Format of Reports

Electronic Record keeping is recommended. Where electronic means are used a daily back-up must be made.

Where paper-based systems are preferred ARTC has published forms that may be used. These forms are not mandatory; the collection of the information can be done on other forms or in an electronic spreadsheet. Inspection reports need to contain the reportable data listed in all parts of this section 7, regardless of the format used.

7.2 Inspection Report

Every ultrasonic test and weld geometry test undertaken shall be recorded. Form ETA0105F-01 Record and Report of Ultrasonic Test may be used. Any defects found should be reported as per section 7.2.3 below.

A record of every ultrasonic test shall be kept. The report shall be kept even if no defect is found; or if defect found is small and is not referred to as ‘reportable’ or ‘to be monitored’ in the defect standards.

7.2.1 Ultrasonic Test Records

The ultrasonic test records may be kept electronically or using paper-based forms such as ETA0105F-01 Record and Report of Ultrasonic Test, and should record (as a minimum):

- Date
- Location of test
- Name of the operator
- Ultrasonic flaw detector (type, serial No)
- Probes used (type, serial No)
- Couplant used
- Test results
- Any variations from the requirements of this procedure
- Any test restrictions
- Rail temperature:
    - At each point where Hand Testing has occurred
    - Continuous Car Testing: At least two temperature readings daily to capture the Maximum and minimum temperature

7.2.2 Weld Test Records

A record of every Weld Test shall be kept electronically or using paper-based forms. In addition to the requirements of 7.2.1 above, the Weld Test report shall include:

- the weld Number
- date of test location of weld
- result of visual inspection

- result of ultrasonic inspection
- result of geometric inspection.

7.2.3 Defect Reports

All sizeable rail or weld, internal or surface defects, or any weld geometry defect, shall be reported. Form ETA0105F-02 Rail Flaw Report may be used. This is to provide a record where a defect is found or if the geometry of a new weld is found to be substandard. This can be on an individual form, however when the continuous ultrasonic testing is carried out it is more likely to be stored in a spreadsheet.

In addition to the requirements of 7.2.1 above, the Defect report shall include as a minimum:

- The location of the defect with respect to the kilometrage posts to within ± 5 metres per 1,000m of the last km post encountered or GPS co-ordinates for each defect.
- Each defect is to be allocated an identification number.
- The rail in which the flaw is located, shall be shown. The down rail is the left rail when facing in the direction of increasing kilometrage. The up rail is the rail opposite the down rail.
- If in a turnout – the turnout number
- Date of test
- Type of defect
- Size of defect. Additional to the size classification, the actual length of the flaw shall be indicated
- Any action already applied (e.g. speed restriction, defect plated etc.)
- Where two or more defects are found within one (1) metre of each other, the actual separating distance of the defects shall be indicated.

Additional requirements where a satellite car is used to perform a detailed assessment:

- In the case of defective welds, the type of weld shall be indicated i.e. Thermit (T), Flash Butt (FB) or Wire Feed (WF)
- Hand Tests carried out & results
- Rail specification (e.g. rail size, presence of rail wear, SC or HH etc.)

These records will be kept electronically in the relevant Asset Management System.

Note *ARTC Rail Defects Handbook gives more detail on the various defect modes*

7.3 Shielding Reports

Any areas of ultrasonic ‘shielding’ found using the ultrasonic testing car shall be reported. Form ETA0105F-03 Rail Surface Condition Report may be used. The report may be paper based or recorded as an electronic database.

The report should record as a minimum:

- Date
- Location of test
- Degree of difficulty in measurement

- Speed of test
- Name of the operator
- Ultrasonic flaw detector (type, serial No.)
- Probes used (type, serial No.)
- Any variations from the requirements of the procedure
- Any test restrictions
- Couplant used
- The following data, which can generally only be collected in the case of a slow speed car with chase/satellite vehicle
    - Suspected reason for shielding (Gauge corner cracking, head checking, grease etc.)
    - Rail temperature
    - Any additional tests (at reduced speeds, dye penetrant etc.) and their results.

Note *This can be on an individual form, however when the continuous ultrasonic testing is carried out it is more likely to be stored in a spreadsheet.*

8 Site Marking

8.1 Rail Defect Marking

8.1.1 GPS Coordinates

Paint marking is not mandatory when defect locations are being reported using GPS coordinates.

8.1.2 Paint Marking

Where paint is used to mark rail assessed as requiring remedial action or reassessment the following paints can be used: Yellow, Orange or colour agreeable to ARTC. The date of examination and identification code of the ultrasonic operator is also to be marked on the rail.

The paint shall be on the foot, web and side of head, and where possible:

- The defect; type, boundary and remove-by date, could also be marked with white paint
- The defect priority can be marked with paint colours in addition to the yellow marking.

Where defects are classified and sized by hand the defective rail shall be marked for a length of 200mm, showing the location of the defect and its identification number.

8.2 Weld Quality Examination Marking

All new field welds are to be paint marked to identify that they have either passed or failed the weld quality requirements of ARTC rail and welding standards.

8.2.1.1 Weld Integrity (when visual defect and ultrasonic inspection completed)

All new field welds when *ultrasonically tested and checked for visual weld defects,* are to be sprayed with paint on both sides of the rail adjacent to the weld (to assist visual location from either side of the track). Painting shall be undertaken as follows;

- If the weld quality passes visual and ultrasonic inspections, it shall be painted with **one blue vertical line** on the web;
    - reaching from foot to head and,
    - approximately 100mm away from the weld collar.
    - Paint shall not be placed on the weld itself i.e. nowhere on the collar (head, web and foot), the collar must always be visible and paint-free.
- If the weld is found to contain an internal (ultrasonic) defect or visual defect, or both, it shall be painted as per 8.1.2 above.

8.2.1.2 Weld Geometry (when rail head geometry inspection completed)

All new field welds, when checked for *weld geometry*, are to be sprayed with a paint dot on the web on both sides of the weld area (to allow visual location from either side of the track). Painting shall be undertaken as follows;

- If the weld quality *passes* weld geometry inspections, it shall be painted with **one blue dot**
- on the web;
    - Dot being roughly 30 to 50mm diameter
    - approximately 100mm away from the weld collar
    - Paint shall not be placed on the weld itself i.e. nowhere on the collar (head, web and foot), the collar must always be visible and paint-free.
- If the weld quality *does not pass* weld geometry requirements, it shall be painted with **one yellow dot** on the web;

A weld that has passed requirements of both 8.2.1.1 and 8.2.1.2. as satisfactory, when looked at from either side of the track, would appear as one blue vertical line 100mm away from the collar to one side of the weld, and one blue dot on the web 100mm away from the weld on the opposite side of the weld.

An example is shown in Figure 5

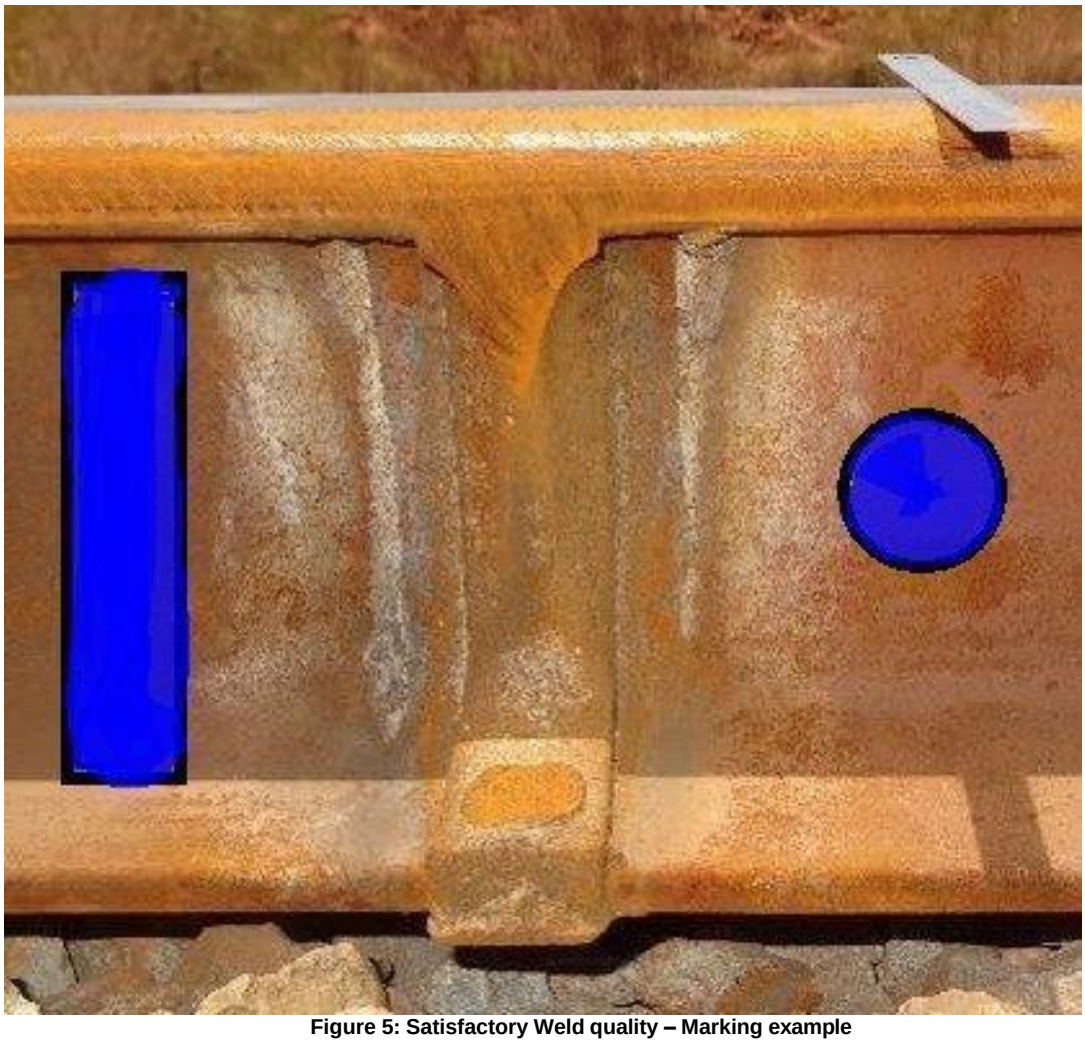

Figure 5: Satisfactory Weld quality – Marking example