Railway Accident Investigation Unit Ireland

INVESTIGATION REPORT

Broken Rail near Emly, County Tipperary, 22nd February 2023

RAIU Investigation Report No: 2024-R002

Published: 22nd March 2024

Report Description

Report publication

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Report structure

The report structure is written as closely as possible to the structure set out in the "Commission Implementation Regulation (EU) 2020/572 of 24 April 2020 on the reporting structure to be followed for railway accident and incident investigation reports" having regard to "Directive (EU) 2016/798 of the European Parliament and of the Council of 11 May 2016 on railway safety".

Reader guide

All dimensions and speeds in this report are given using the International System of Units (SI Units). Where the normal railway practice, in some railway organisations, is to use imperial dimensions; imperial dimensions are used, and the SI Unit is also given.

All abbreviations and technical terms (which appear in italics the first time they appear in the report) are explained in the glossary.

Descriptions and figures may be simplified in order to illustrate concepts to non-technical readers.

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Preface

The RAIU is an independent investigation unit within the Department of Transport which conducts investigations into accidents and incidents on the national railway network including the Dublin Area Rapid Transit (DART) network, the LUAS light rail system, heritage and industrial railways in Ireland. Investigations are carried out in accordance with the Railway Safety Directive (EU) 2016/798 enshrined in the European Union (Railway Safety) (Reporting and Investigation of Serious Accidents, Accidents and Incidents) Regulations 2020; and, where relevant, by the application of the Railway Safety (Reporting and Investigation of Serious Accidents, Accidents and Incidents Involving Certain Railways) Act 2020.

The RAIU investigate all serious accidents. A serious accident is defined as any train collision or derailment of trains, resulting in the death of at least one person or serious injuries to five or more persons or extensive damage to rolling stock, the infrastructure or the environment, and any other similar accident with an obvious impact on railway or tramline safety regulation or the management of safety. During an investigation, if the RAIU make some early findings on safety issues that require immediate action, the RAIU will issue an Urgent Safety Advice Notice outlining the associated safety recommendation(s); other issues may require a Safety Advice Notice.

The RAIU may investigate and report on accidents and incidents which under slightly different conditions may have led to a serious accident.

The RAIU may also carry out trend investigations where the occurrence is part of a group of related occurrences that may or may not have warranted an investigation as individual occurrences, but the apparent trend warrants investigation.

The RAIU investigation shall analyse the established facts and findings (i.e. performance of operators, rolling stock and/or technical installations) which caused the occurrence. The analyses shall then lead to the identification of the safety critical factors that caused or otherwise contributed to the occurrence, including facts identified as precursors. An accident or incident may be caused by *causal, contributing* and *systemic factors* which are equally important and should be consider during the RAIU investigation. From this, the RAIU may make safety recommendations in order to prevent accidents and incidents in the future and improve railway safety.

It is not the purpose of an RAIU investigation to attribute blame or liability.

Contents

Summary

1 On Tuesday 21st February 2023 a *T3 Possession* was organised on the *Up and Down lines* of the Dublin to Cork mainline to allow for a track section, near Emly Level Crossing (LC), to undergo track maintenance.

2 As part of the track maintenance, *stressing* and welding of the rails had to be undertaken in preparation for *ballast* cleaning.

3 The stressing of the rails was being carried out on the Up line, which involved cutting both rails which was marked by a Iarnród Éireann Infrastructure Manager (IÉ-IM) staff member, the *Person in Charge of Stressing* (this member of IÉ-IM staff was also the Track Delivery Unit Engineer (TDU Engineer) who supervised the works).

4 A welding contractor was engaged to carry out the welding at the site location (110 miles 355 yards), with a team comprising of a lead and second welder (the Welders) and a Weld Supervisor. Prior to the welding, the Welders placed clamps on either side of the first cut rail section and attached *Rail Tensors* to pull the rail ends together until the required *welders gap* was achieved. The rails were then *anchored* by the Chief Civil Engineer's (CCE) Department staff to ensure no movement of the rails, and the rail ends were welded using the *Thermit® SoW-5 welding process* (to be referred to as Thermit SoW-5 for the remainder of the report); the first weld was "dropped" without issue.

5 The Welders then placed the clamps on either side of the next cut location and attached the Rail Tensors in order to pull the rails ends together. On the first attempt when pressure was applied by the Rail Tensors the rails did not hold; on the second attempt, the Rail Tensors failed to pull the rail ends together; but, on the third attempt, the rail ends were pulled to the required welders gap. The Welders then waited to make sure the Rail Tensors held and once they were sure it was holding, the CCE staff fastened down the tension clamps to anchor the rails and the Welders dropped the weld without further issue.

6 The welds were inspected by the Weld Supervisor who was satisfied that there were no visible defects.

7 When the welds had cooled, the Ultrasonic Operator tested the rails, which passed the ultrasonic tests with no defects identified.

8 The T3 Possession was handed back by the *Person In Charge of the Possession* (PICOP) at 05:00 hours (hrs) on Tuesday the 21st February 2023 and normal service resumed on the Up line. A total of twenty-four passenger service trains passed the section on Tuesday and Wednesday morning until the fault was detected.

9 On Wednesday 22nd February 2023, at 07:56 hrs, the Signalman at Centralised Traffic Control (CTC) saw that a *track circuit* (LJ789 on the Up line, near Emly LC) remained occupied after the 07:00 hrs passenger service from Cork to Heuston (Train A205) passed through the location.

10 The Signalman contacted the driver of Train A205 (Driver A205) to ensure the train had passed safely through the affected section of line.

11 At 07:57 hrs the Signalman confirmed with Mallow Level Crossing Control Centre (LCCC) that there was no fault with the signalling equipment at Emly LC.

12 At 07:59 hrs the Signalman contacted the Signal Electrical and Telecommunications (SET) Department to report the track circuit fault. SET staff members deployed to the location, and checked a number of SET *location cases* near the location of the fault; before walking the track and finding a *broken rail*, at the 110 miles 355 yards (the location of the welded rail), at 10:35 hrs.

13 Just as the SET staff member had discovered the broken rail a train was approaching on the Up line. It was the 09:25 hrs passenger service from Cork to Heuston (Train A209) travelling under caution. The SET staff member stepped out to a *position of safety* and signalled the train to stop. Train A209 travelled over the broken rail before coming to a stop.

14 The SET member spoke to the driver (Driver A209) and told them the fault was a broken rail and the train had travelled over it. Driver A209 notified the Signalman of the broken rail and resumed their journey.

15 The Signalman contacted the SET staff member who confirmed that the track circuit fault was as a result of a broken rail.

16 The Signalman took the appropriate actions and signal protection was put in place on the Up line.

17 The Signalman contacted the *Permanent Way Inspector* (PWI) who confirmed that they had been notified of the broken rail. The PWI attended the site of the broken rail, and the rail was clamped and plated.

18 The line re-opened at 11:30 hrs with an Emergency Speed Restriction (ESR) of 10 mph (16 km/h) in place until later that night, when the repairs were undertaken. The ESR was lifted, and normal passenger service resumed at 05:30 hrs on Thursday the 23rd February 2023.

19 A post-incident metallurgical examination of the weld found that the weld broke rapidly from defects introduced during Thermit SoW-5. The position of the defects was within the last areas to solidify (the centre of the weld) with the appearance indicating that the defects were likely to be either a *hot tear* or *shrinkage.* However, given the difficulties encountered by the Welders with the Rail Tensors, it was more likely as a result of a hot tear.

20 The RAIU have identified the following possible causal factor to the defective weld:

- CaF-01 – The *Rail Tensors* did not operate correctly at the time of welding, resulting in the Welders encountering difficulties pulling and holding the rail ends to the required welders gap; which may have caused the Rail Tensors to release enough *holding pressure* to cause a hot tear in the weld.

21 There were no contributory factors identified.

22 The following was identified as a systemic factor:

- SF-01 – Technical Standard for the Stressing of Rail, CCE-TMS-323 (to be referred to as CCE-TMS-323 for the remainder of the report) did not include guidance on actions for welders to take once difficulties were encountered with the Rail Tensors.

23 Although not a factor to the incident, the RAIU make the following additional observations:

- AO-01 – There are inconsistencies throughout the suite of documents related to Thermit Welding Work Instructions I-PWY-1220 (to be referred to as I-PWY-1220 for the remainder of the report) e.g. the welders gap has not been updated in all the relevant documents;
- AO-02 – CCE-TMS-323 requires that the Rail Tensors should remain in place after the weld has been dropped for thirty minutes; however, there is no guidance on how often the Person in Charge of Stressing should check the Rail Tensors within this period of time;
- AO-03 – The CWR Record Sheet (included in the appendices of CCE-TMS-323) has no sections for the Person in Charge of Stressing to recording the following:
    - Serial number or calibration/ recalibration date of the Rail Tensors being used;
    - Pressure gauges readings before, during and after Thermit SoW-5;
    - Periodic time intervals the Person in Charge of Stressing should check the pressure gauges;

- AO-04 – There is no guidance or training for the Person in Charge of Stressing in CCE-TMS-323 in relation to actions to be taken where difficulties are encountered with Thermit SoW-5 (including when Thermit SoW-5 can continue, be restarted or must be abandoned); and, who is responsible for this decision, the Person in Charge of Stressing or their Supervisor;
- AO-05 – At the time of the discovery of the broken rail, the welding contractor was not carrying out recalibration test of the Rail Tensors' pressure gauges, this may have been as a result, in part, of IÉ-IM not:
  - Stating the required frequency for recalibration in CCE-TMS-323;
  - Undertaking checks of the welding contractor's rail stressing equipment;
- AO-06 – The metallurgical examination of the weld identified copious amounts of luting sand in the weld (although noting that this did not contribute to the weld break). The RAIU determined was likely to be as a result of disturbance to the weld set-up during Thermit SoW-5 due to the issues with the Rail Tensors.

24 As a result of the RAIU investigation, the RAIU make the following safety recommendation:

- Safety Recommendation 2024002-01 – IÉ-IM CCE to update CCE-TMS-323, to include a more robust guidance for welders, in relation to recognising when there may be issues with the Rail Tensors; and what actions are to be taken when difficulties arise with the Rail Tensors.

25 The RAIU make the following safety recommendations as a result of additional observations:

- Safety Recommendation 2024002-02 – IÉ-IM CCE should review the current suite of documents related to welding to ensure consistency across the relevant documents;
- Safety Recommendation 2024002-03 – IÉ-IM CCE should develop systems for the management and certification of rail stressing equipment (including contractor's rail stressing equipment), to ensure equipment is regularly serviced and recalibrated at a nominated frequency. These updated requirements should be reflected in the relevant documents;
- Safety Recommendation 2024002-04 – IÉ-IM CCE should review and update the CWR Record Sheet to include sections for recording the serial number and calibration/ recalibration date of the Rail Tensors being used, the pressure gauge readings and the frequency of these checks on the pressure gauges. On completion, ensure staff

are briefed on the changes, and changes should be incorporated into future training programmes for a Person in Charge of Stressing;

- Safety Recommendation 2024002-05 – IÉ-IM CCE should update CCE-TMS-323 to include guidance for the Person in Charge of Stressing, in relation to actions to be taken when difficulties are encountered with Thermit SoW-5 (including when Thermit SoW-5 can continue, be restarted or must be abandoned; and, who is responsible for this decision, the Person in Charge of Stressing or their Supervisor). On completion of the update, Persons in Charge of Stressing should be briefed and the training programme for the role revised with the new guidance.

RAIU Investigation and its context

Decision & motivation to investigate this occurrence.

26 On Wednesday 22nd February 2023 the RAIU on-call Investigator was notified of a broken rail on the Up line track located 110 miles 335 yards on the Dublin to Cork line, near Emly LC.

27 The RAIU conducted a preliminary examination and the RAIU's Chief Investigator made the decision to conduct a full investigation into the incident, given its impact on railway safety (*Article 20* (2)(c) of Directive (EU) 2016/798 of the European Parliament, Article 20, Obligation to Investigate), as under slightly different circumstances the incident may have led to a serious accident with the potential for a fatality or serious injuries, due to risk of derailment as a result of the broken rail.

Scope & limits of investigation

28 The RAIU have established the scope and limits of the investigation as follows:

- Examine the processes around rail welds and the process involved;
- Establish the sequence of events leading up to, during and after the incident;
- Identify any other precursors which led to the incident;
- Determine the mechanism of failure of the broken rail;
- Establish, where applicable, causal, contributing and systemic factors;
- Examine the training of staff involved in the incident.

Technical capabilities & investigation methods

29 The RAIU's Chief Investigator allocated RAIU Senior Investigators, trained in accident investigation, to conduct this investigation, as appropriate.

30 For this investigation, a consultant metallurgist (ms4i) was employed by the RAIU to independently review IÉ-IM's commissioned metallurgical examination of the weld.

31 During the investigation, the RAIU collate evidence through the submission of Requests for Information (RFIs) to the IÉ-IM Safety Department and formal interviewing of relevant staff. Related to this investigation, the RAIU collated and logged the following evidence:

- Photographs taken on the day from the site;
- Witness statements and interview notes from parties involved in the incident;
- The planning and execution of the work being carried out;

- Training and competence records for those directly involved;
- IÉ Rule Book;
- The reporting and response to the incident;
- The metallurgical report from Serco Rail Technical Services (the Serco Report);
- The current IÉ working timetable for the Mainline South & West & Waterford;
- The voice recordings from CTC;
- CCE–TMS–323, Technical Standard for the Stressing of Rail, Version 2.1, operative date 16th April 2019;
- CCE-TMS-422, Management of Rail Stressing Competence, Version 1.1, operative date 1st August 2019 (to be referred to as CCE-TMS-422);
- I-PWY-1220, Thermit Welding Work Instruction, Issue No 1, operative date 12th August 2010;
- CCE–TRK– WKI–003, Rail Test Work Instructions (Ultrasonic) Version 1.0, operative date 7th February 2011 (to be referred to as CCE-TRK-WKI-003);
- CCE-TMS-362, Management of Rail Failures and Requirements for Testing of Rails, Version 1.2, operative date 5th April 2012 (to be referred to as CCE-TMS-362);
- UIC 712R, Catalogue of Rail Defects, 4th edition, February 2002.

32 On review of the above documentation provided by IÉ-IM, it was noted where revisions have been made to CCE-TMS-323. These changes were not reflected in documents CCE-TRK-WKI-003, CCE-TMS-362 and I-PWY-1220. For example, the welders gap was defined in CCE-TMS-323 in 2016 to reflect the introduction of Thermit SoW-5 – single use crucible, but the other documents were not updated[1].

[1] The RAIU consider the absence of updates, to reflect introduced changes, to ensure consistency across the suite of documents, to be an additional observation, AO-01 (paragraph149), which warrants a safety recommendation, Safety Recommendation 2024002-02 (paragraph 163).

Communications & evidence collection

33 Communications were conducted through established processes (such as RFIs).

34 Relevant stakeholders were issued the draft investigation report for comment, comments were reviewed and responses on their comments returned. In this instance the stakeholders were: IÉ-IM (parties and roles), the Welding Contractor, the Third Party Contractor and the Commission for Railway Regulation (CRR)[2].

35 All relevant parties co-operated fully with the RAIU investigation; with no difficulties arising.

Other stakeholder inputs

36 No other parties, such as the emergency services, were required for this incident.

[2] The CRR is the National Safety Authority (NSA) for the Republic of Ireland and is responsible for the regulatory oversight of the Safety Management System (SMS) and enforcement of railway safety in the Republic of Ireland in accordance with the Railway Safety Act 2005 and the European Railway Safety Directive.

Description of the occurrence & background information

Description of the occurrence type

37 The incident involved a broken rail on the 22nd February 2023. In terms of categorisation, the EU Agency for Railways categorisation for this occurrence is an: Incident – Infrastructure.

Background to the works being undertaken.

38 A T3 Possession was scheduled on both the Up and Down lines between Thurles and Charleville (87 *Mile Post* (MP) to 128.0880 MP), between 23:10 hrs on Monday night the 20th February 2023 and 05:30 hrs on the morning of Tuesday 21st February 2023, as per IÉ Weekly Circular 4068.

39 The worksite (located between 110 miles 470 yards and 109 miles 470 yards) was to facilitate track maintenance on the Up and Down lines of the Dublin to Cork mainline as part of a pre-planned programme of engineering works. This included stressing the sections of track in preparation for the ballast cleaner to pass through and eliminating the need for speed restrictions after the cleaning has been completed.

40 The location of the broken rail (see Figure 1) was on the Up mainline from Cork to Heuston at 110 miles 355 yards between Emly LC and Limerick Junction.

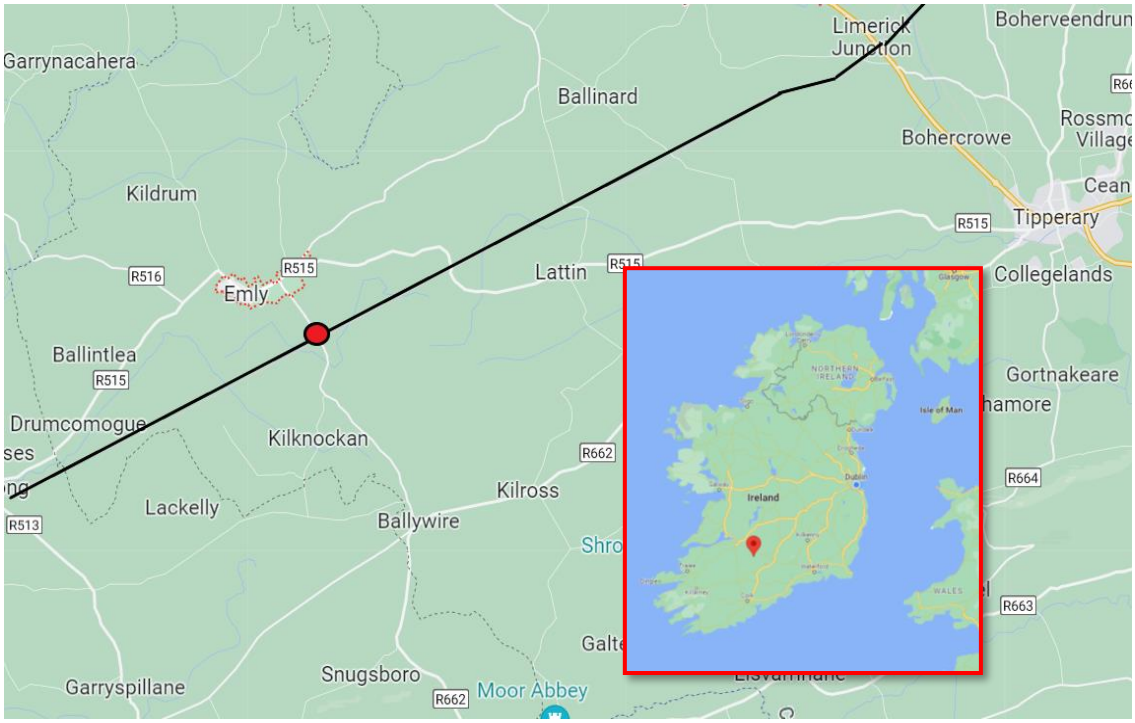


Figure 1 – Location of the incident (see red dot)

41 A minimum temperature of 7.8˚Celcius (C) and a maximum temperature of 11.3˚C were recorded at the Oak Park weather station with rain fall of 1.9mm and a mean wind speed of 8.4 knots for the 21st February 2023.

Deaths, injuries & material damage

42 There were no deaths or injuries as a result of the incident.

43 The rail weld failed and was removed by installing a closure rail there was no damage to the rolling stock that travelled over it.

Parties & roles associated with the incident

IÉ-IM

44 IÉ–IM is the infrastructure manager who owns, maintains, and operates the railway infrastructure in Ireland and operates under a Safety Authorisation certificate issued by the CRR. The IM Safety Authorisation is issued in conformity with Commission Regulation (EU) 1169/2010; the authorisation was renewed on the 24th March 2022 for a period of five years. The IÉ-IM department involved in the incident and relevant to this investigation is:

- IÉ-IM's CCE Department – The CCE Department directs the technical support, business support and safety sections. The CCE Department carries out the inspections and maintenance of track and structures and is divided into three different geographical areas, with offices based at Dublin, Athlone, and Limerick Junction;
- IÉ-IM Operations (Ops) Department – Operates the signalling system, monitors the operation of the network, and provides the first level of response to incidents. The network is controlled from CTC Dublin and several other signalling control locations;
- IÉ-IM SET Department – Carries out the maintenance and repair of the SET equipment on the infrastructure.

45 The IÉ-IM CCE roles involved, directly and indirectly, and respective experiences at the incident, are as follows:

- SET staff members – Attended the site due to the reported fault, found the broken rail and contacted the Signalman; They have their own department;
- PWI – Responded to the call attended the site to examine the broken rail and arranged the subsequent response to the broken rail;
- Person in Charge of Stressing – A member of the CCE Department (TDU Engineer) who was on site on the night the rails were cut, stressed, welded, and tested. The staff member was also the nominated Person in Charge of Stressing and was competent for this role, as set out in CCE-TMS-422;
- PICOP – They handed back the T3 Possession to the Signalman when all works had been completed on the night.

46 The IÉ-IM Operations roles involved, directly and indirectly, and respective experiences at the incident, are as follows:

- The Signalman – The Main Line Signalman at CTC who responded to the track circuit fault confirmed with Mallow LCCC the line was clear and notified SET.

IÉ-RU

47 IÉ-RU is the railway undertaking who owns and operates mainline and suburban railway services in Ireland and operates under a safety certificate issued by the CRR. The RU Safety Certificate is issued in conformity with European Directive 2004/49/EC and S.I. 249 of 2015; the Safety Certificate was renewed on 23rd March 2018 for a period of five years (valid at the time of incident). The IÉ-RU roles involved in this incident and relevant to this investigation are:

- Driver A303 – Driver of Train A303 and was competent to drive the train at the time of the incident;
- Driver A209 – Driver of Train A209 and was competent to drive the train at the time of the incident.

Welding Contractor

48 The Welding Contractor appointed by IÉ-IM, operated the equipment for stressing and welding of the rail on the 21st February 2023. The staff included:

- Weld Supervisor – Supervised the Thermit SoW-5 on 21st February 2023; and at the time of the incident held a current certificate of competency for Thermit SoW-5;
- The Welders (lead and second welder) – who carried out Thermit SoW-5 on the 21st February 2023. The Welders held current certificates of competency for the welding as set out in CCE-TMS-422.

Third Party Contractor

49 The Third Party Contractor appointed by IÉ-IM, operated the equipment for testing the weld:

- Ultrasonic Operator – Attended the site to carry out the ultrasonic tests before the T3 Possession was handed back. At the time of the incident, the Ultrasonic Operator held a current certificate of competency as set out in CCE-TMS-422.

Other consequences as a result of the incident

50 The Up line was closed to all traffic at 10:38 hrs on 22nd February 2023. The PWI attended the scene. The rail was clamped and plated before the line was reopened to traffic at 11:35 hrs on 22nd February 2023 with an ESR of 10 mph (16 km/h) from 110.25 – 110.38 MP.

51 There were delays of up to twenty-five minutes to all passenger trains on the Cork to Dublin and Tralee to Dublin from when the line reopened at 11:35 hrs on the 22nd February 2023 until the end of service that day. Normal service was restored at 05:45 hrs on the 23rd February 2023 when the first Cork to Dublin passenger service resumed on the Up line.

Rolling Stock

52 Twenty-four passenger trains travelled over the welded section of rail, on the Up line, from the 21st February until the time of the weld breaking on the 22nd February 2023; these trains served Cork to Dublin and Tralee to Dublin. The trains involved were MkIV and 22000 InterCity Rail car (ICR).

53 The MkIV push/pull trains consist of a 201 Class locomotive, a catering vehicle, one 1st class carriage, five standard class carriages and a generator car (see Figure 2). The maximum service speed of the train formation is 100 mph (160 km/h).

Figure 2 – MkIV 201 Class Locomotive

54 The ICR 22000 series DMU (Rotem) consists of three car and four car sets (see Figure 3). The maximum service speed of the train formation is 100 mph (160 km/h).

Figure 3 – 22000 InterCity Rail Cars

Signalling & communications

55 The line is operated under the rules and regulations for train signalling by *Track Circuit Block* (TCB) system and is fitted with colour light signals throughout. The Signalman is located at CTC at Connolly Station Dublin.

56 The means of communications between the train drivers and the Signalman on route is through train radio.

57 The infrastructure and all passenger trains using it are also equipped with the *Continuous Automatic Warning System* (CAWS).

Operations

58 Trains travelling towards Dublin are travelling on the Up Line. Trains traveling towards Cork are travelling on the Down Line.

59 The maximum line speed, on both lines is 100 mph (160 km/h) subject to permanent and temporary speed restrictions.

60 In terms of the passengers services relevant to the incident:

- Train A205 – 07:00 hrs passenger service from Cork to Dublin passed over the rail, likely causing the rail to break, and continued on its journey unaffected;
- Train A303 – 07:05 hrs passenger service from Tralee to Dublin;
- Train A209 – 09:25 hrs passenger service from Cork to Dublin.

Infrastructure (Track & Rails)

General description of the track

61 The incident occurred on the Dublin to Cork route, on a section of the Up line between Charleville and Limerick Junction. At the location of the incident the railway is a double track formation. The track is flat bottom, continuously welded rails (CWR) mounted on concrete sleepers, set in ballast.

General description of rail

Rail type

62 The rails used on this track are 54kg/m E1 profile rail from Arcelor Mittal (see Figure 4) manufactured in their Gijon plan in Spain (formally Ensidesa). The rail product is marked “Ensidesa” and purchased through an ongoing contract in place since 2018. The rail is supplied in 36 m lengths and shipped to Waterford Port by the company where it is handed over to IÉ-IM.

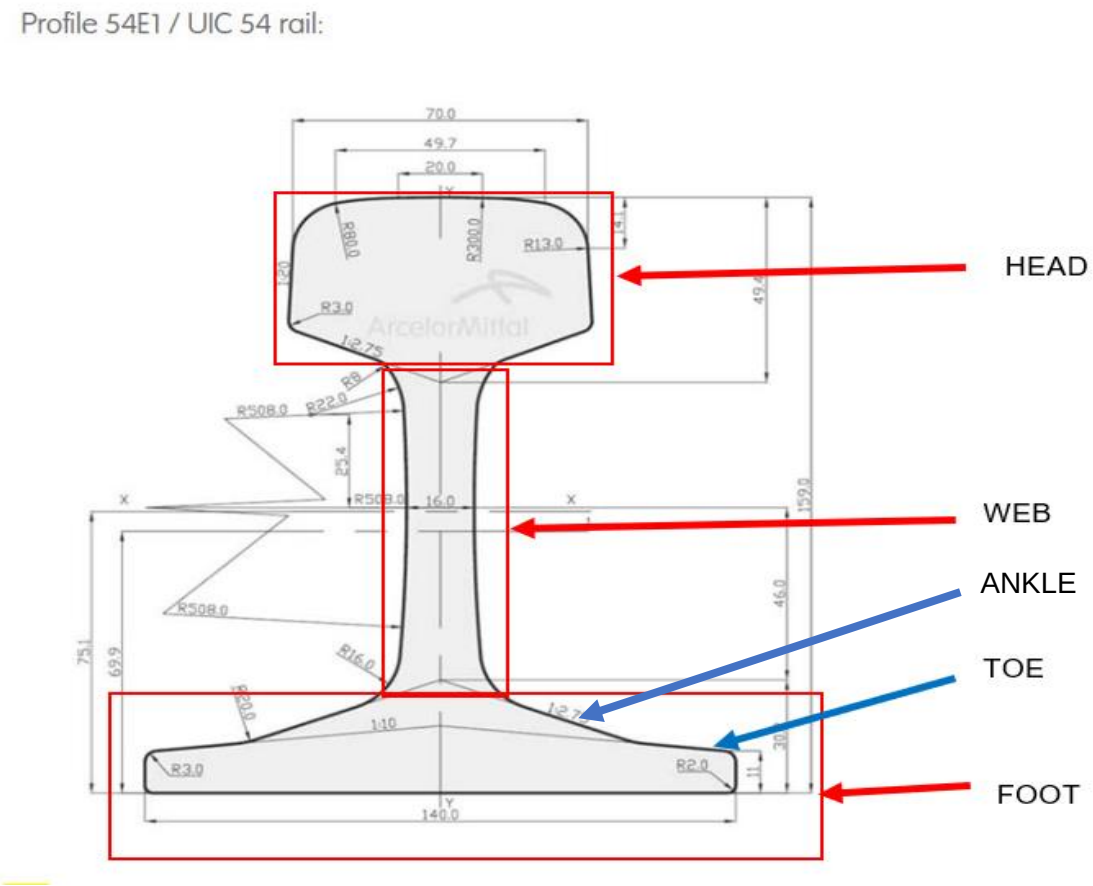


Figure 4 – Rail profile 54 kg E1

Stressing, Welding & Testing of Rails

General description

63 This section of the report outlines the stressing, welding and ultrasonic testing of rails and identifies their associated technical standards; it is meant to be an overview of actions to be taken on-site during the welding process. However, the focus of this investigation is in relation to the stressing of the rails during the welding process and associated equipment.

Methodology

64 Part of the renewal and repairs to tracks involves the stressing of the rails. IÉ-IM carry out the Stressing of Rail as set out in CCE-TMS-323, Technical Standard for Stressing of Rail.

65 The Person in Charge of Stressing ensures that the relevant equipment is on site and the correct work procedures are followed and on finishing the work, completes and submits the appropriate Record Sheet(s).

66 In terms of the stressing, Rail Tensors are normally used (see Figure 5).

Figure 5 – Rail Tensors attached to rail

67 Using the Rail Tensors, both rails are stretched (i.e. stressed) using hydraulic rams (circled Figure 5) and *anchored* at the same time to ensure the equal *Stress Free Temperature* (SFT) in both rails (the permitted SFT in CWR is between 23˚C and 27˚C, with three rail thermometers placed on the rail to monitor temperature. This is to ensure that the temperature is not below the absolute minimum rail temperature for stressing which is -7 ˚C. In addition, both rails must be stressed during the same shift to ensure that the forces remain balanced in both rails.

68 The Rail Tensors are checked for slippage of the clamps or for defects in the pressure gauge dial (see Figure 6 example of a pressure gauge). There is a *valve* on the hydraulic pump that is used to close off the flow of hydraulic fluid (oil) when the rails have been pulled to the required welders gap; this is to safeguard against rail movement.

Figure 6 – Pressure gauge

69 Pulling force is then applied by the Rail Tensors, which is displayed on the pressure gauge (displayed as pound-force per square inch (psi))[3]. The pressure gauge is monitored by the Person in Charge of Stressing during tensioning to ensure no loss of force occurs. CCE-TMS-323 states that the maximum pulling force applied by the Rail Tensors shall not exceed 6553 psi.

70 Prior to the rail undergoing stressing, the rail is unfastened from the concrete sleepers on both sides of the cut location. The rail is lifted free of the sleepers and placed on under *Rollers* at distances set out in CME-TMS-323. This is to allow the rail free longitudinal movement during stressing. *Side Rollers* are used to prevent lateral movement of the rail during stressing. The Rollers and Side Rollers are removed after stressing has been completed and prior to handing back possession. When the required total extension in the rails has been reached and the welders gap is correct, the rails are *anchored* by CCE staff in preparation for Thermit SoW-5. This involves fastening down at least 30 metres (m) of rail to the sleepers on either side of the location to be welded. This is done to help in the alignment and levelling the rails at the weld location and to minimise any disturbance when Thermit SoW-5 takes place.

71 Thermit SoW-5, as set out in I-PWY-1220, is then undertaken. The welders carry out the following: placement of welding equipment, rail alignment (setting the welders gap, which is 29millimetres(mm) +/- 1mm), fitting moulds and iron works, application of *luting sand*. The *box* underneath the location of the rail to be welded has the ballast removed to a depth of between 75 mm to 100 mm. A sand tray is placed in the box so that the luting sand can be placed on the tray to provide a supply to the welders to seal the mould. The sand tray protects the ballast from any spillage of molten metal. The welders are also responsible for rail preheating, portion ignition, stripping the weld, initial and final grinding of the weld,

[3] 1 psi = 6894.76 Pascal.

weld tagging and site clean-up. This includes removing the sand tray and replacing the ballast that was removed from the box.

72 I-PWY-1220 is clear on the requirement that welders should ensure that "no sand enters the mould or the welding gap", further noting that "the rail-end support must be firm to avoid cracking the moulds or the luting sand during the Thermit reaction. Be careful not to step on sleepers, rails or work spanners near the working site as this could disturb the weld set up".

73 After the weld has been dropped, the Rail Tensors must remain in position for at least thirty minutes in order to avoid hot tears. The Person in Charge of Stressing checks the pressure gauge on the Rail Tensors periodically to ensure no loss of holding pressure occurs. There is no defined time or guidance (CCE-TMS-323) on how often the pressure gauges on the Rail Tensors should be checked[4].

74 The Rail Tensors are then removed. The Weld Supervisor checks for any visual defects. Any weld that is suspected of being defective is made safe, either by immediate replacement or by cutting out or fitting clamped fishplates and must be accompanied by a Temporary Speed Restriction (TSR) of 25 mph (40 km/h); this should be reported accordingly.

75 Once cooled, the welds are ultrasonically tested in accordance with CCE-TRK-WKI-003 and CCE-TMS-362. These tests check for defects: horizontally; in lower web and rail foot central area; and rail toes and ankles. The weld is passed when no defects are detected. All tests are recorded on a data logger on site and uploaded onto the *Infrastructure Asset Management System* (IAMS).

[4] CCE-TMS-323 does not define the time intervals the pressure gauge should be checked within the thirty minute period the Rail Tensors remain in place after Thermit SoW-5; the RAIU consider this to be an additional observation AO-02 (paragraph 149), which warrants a safety recommendation, Safety Recommendation 2024002- 04 (paragraph 165).

76 The Person in Charge of Stressing completes the CWR Record Sheet which includes details on the temperatures (and location of temperature gauges), lengths and details of the rail, extension required, time and location of weld[5] (the CWR Record Sheet is in Appendix A of CCE-TMS-323); once completed it is uploaded onto the IAMS.

77 It should be noted, that although CCE-TMS-323 does include some details on actions to be taken when defects are identified, or difficulties arise; there is no guidance on actions to take if difficulties arise with the Rail Tensors[6].

78 CCE-TMS-323 also does not define the conditions/criteria necessary for the Person in Charge of Stressing to make the decision to continue, restart or abandon Thermit SoW-5 process; there is also no guidance on who the Person in Charge contacts when difficulties arise[7].

Rail Tensors

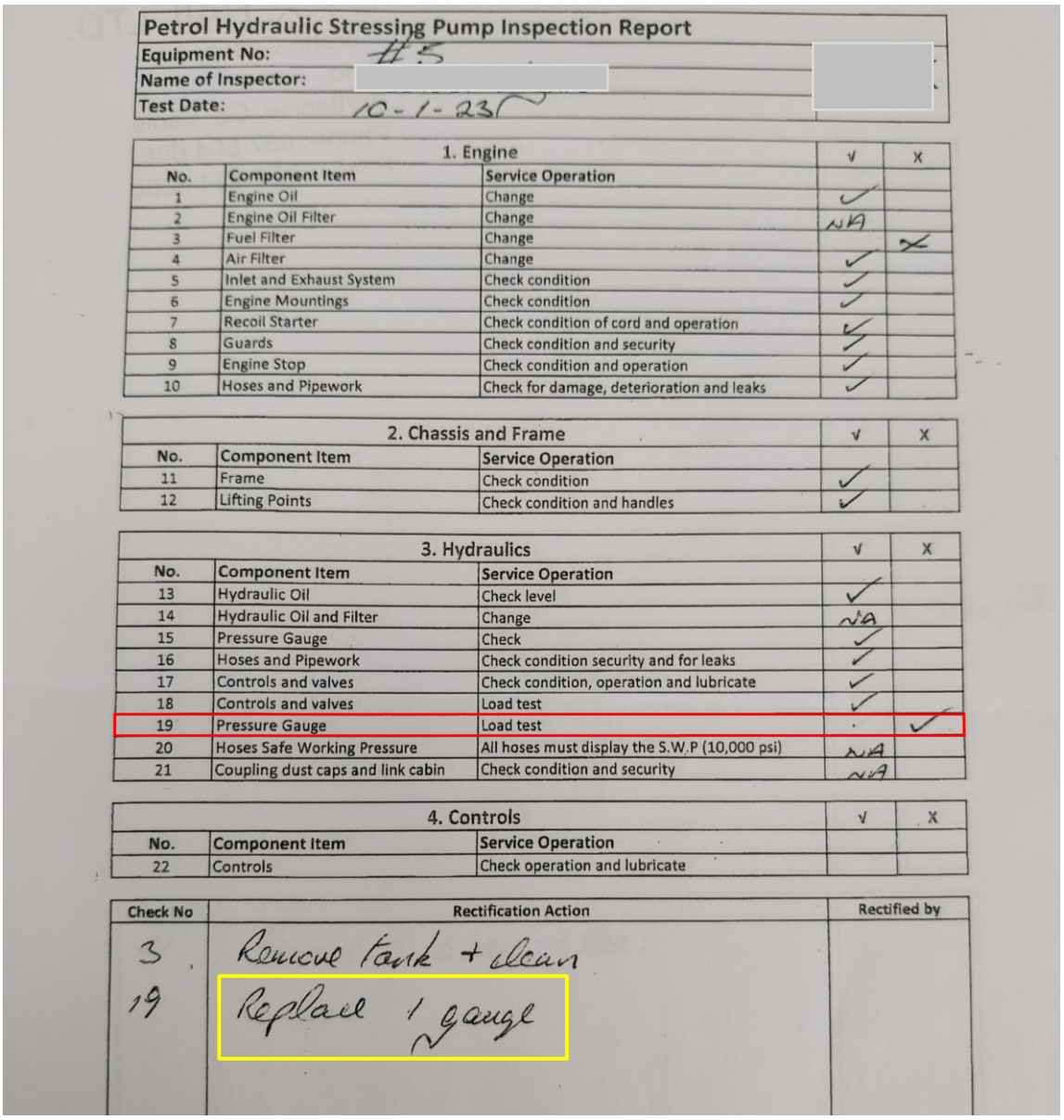
79 The Rail Tensors used by the Welding Contractors, in this incident, was a Permaquip HSM70 Stressor. CCE-TMS-323 gives the maximum capacity of the Permaquip HSM70 as 8519 psi and the maximum *pull force* permitted as 6553 psi.

[5] It is noted that the CWR Record Sheet does not include details on the Rail Tensors serial number, date of calibration/ recalibration the pressure gauge readings before, during and after Thermit SoW-5 and the periodic time intervals the Person in Charge of Stressing should be checking the pressure gauges; the RAIU consider this to be an additional observation, AO-03 (paragraph 149), which warrants a safety recommendation, Safety Recommendation 2024002-04 (paragraph 165).

[6] CCE-TMS-323 does not include any guidance on actions to be taken when difficulties arise on site with the Rail Tensors; the RAIU consider this to be an additional observation, AO-04 (paragraph 149) which warrants a safety recommendation, Safety Recommendation 2024002-01 (paragraph 162).

[7] There is no training on conditions/criteria for the Person In Charge of Stressing to decide when difficulties arise to continue, restart or abandon Thermit SoW-5. There is no guidance on who to consult and no guidance in the training provided to the Person in Charge of Stressing; the RAIU consider this to be an additional observation AO-05 (paragraph 149), which warrants a safety recommendation 2023002-05 (paragraph 166).

80 The Rail Tensors, involved in the incident, were serviced at the Welding Contractors depot at three month intervals and was last inspected and serviced on the 10th January 2023, where one of the pressure gauges was replaced (highlighted yellow in Figure 7).



Petrol Hydraulic Stressing Pump Inspection Report

Equipment No: #5
Name of Inspector: [redacted]
Test Date: 10-1-23

1. Engine			√	X
No.	Component Item	Service Operation		
1	Engine Oil	Change	✓	
2	Engine Oil Filter	Change	NA	
3	Fuel Filter	Change		X
4	Air Filter	Change	✓	
5	Inlet and Exhaust System	Check condition	✓	
6	Engine Mountings	Check condition	✓	
7	Recoil Starter	Check condition of cord and operation	✓	
8	Guards	Check condition and security	✓	
9	Engine Stop	Check condition and operation	✓	
10	Hoses and Pipework	Check for damage, deterioration and leaks	✓	

2. Chassis and Frame			√	X
No.	Component Item	Service Operation		
11	Frame	Check condition	✓	
12	Lifting Points	Check condition and handles	✓	

3. Hydraulics			√	X
No.	Component Item	Service Operation		
13	Hydraulic Oil	Check level	✓	
14	Hydraulic Oil and Filter	Change	NA	
15	Pressure Gauge	Check	✓	
16	Hoses and Pipework	Check condition security and for leaks	✓	
17	Controls and valves	Check condition, operation and lubricate	✓	
18	Controls and valves	Load test	✓	
19	Pressure Gauge	Load test		✓
20	Hoses Safe Working Pressure	All hoses must display the S.W.P (10,000 psi)	NA	
21	Coupling dust caps and link cabin	Check condition and security	NA	

4. Controls			√	X
No.	Component Item	Service Operation		
22	Controls	Check operation and lubricate		

Check No	Rectification Action	Rectified by
3	Remove tank + clean	
19	Replace 1 gauge ✓	

Figure 7 – Stressing Equipment Inspection Report

81 It should be noted, CCE-TMS-323 states, in terms of the Rail Tensors, that the "pressure gauges shall be checked and recalibrated during regular servicing of tensors"; CCE-TMS-323 does not state the frequency of servicing or recalibration[8].

[8] The recommended recalibration interval for most pressure gauges are every twelve months, but in some cases, it may be necessary to recalibrate more frequently.

82 The Welding Contractor has confirmed that the pressure gauges were never recalibrated prior to the incident[9][10].

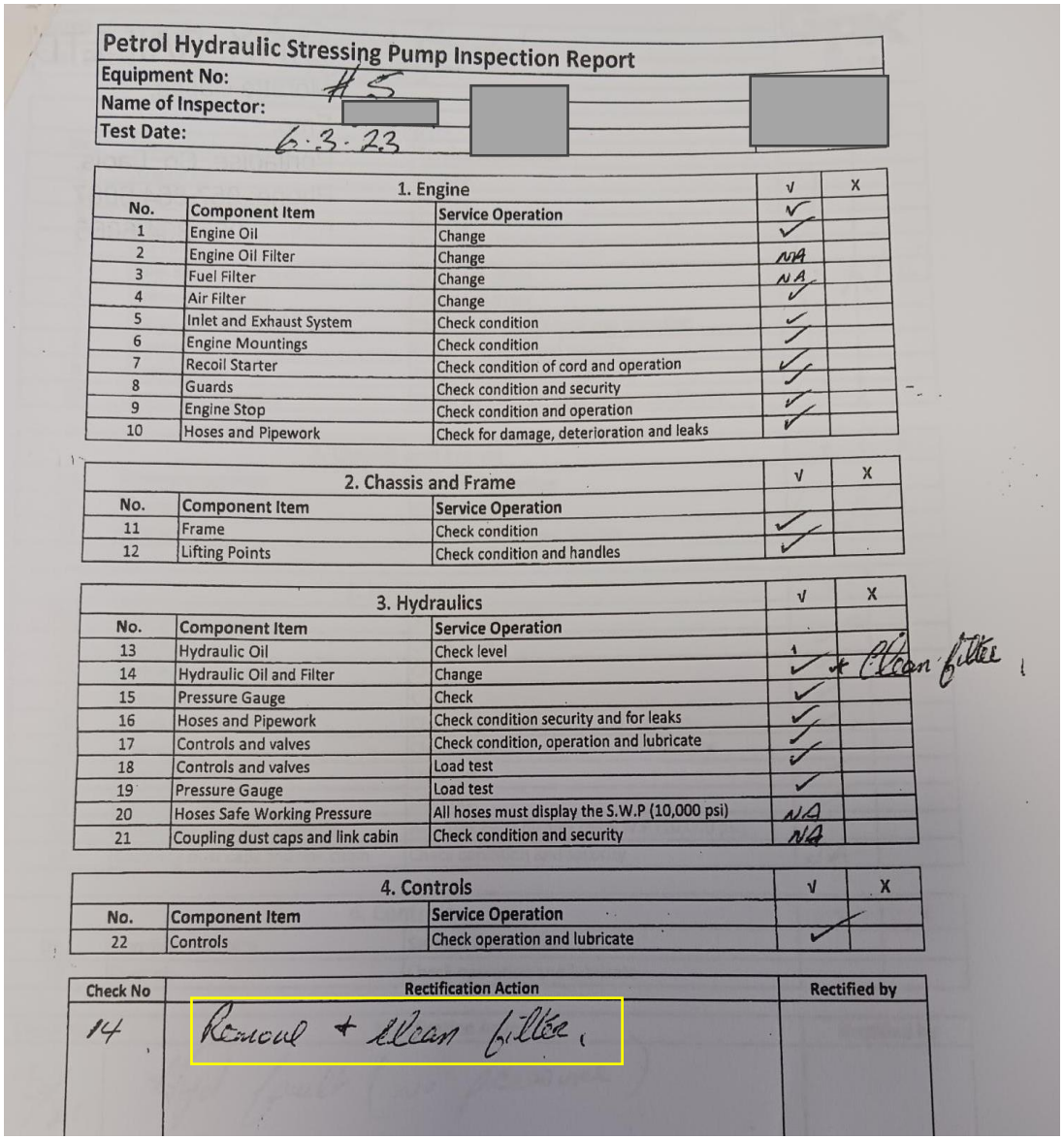
83 Instead of recalibrating the pressure gauges, the Welding Contractor carries out load testing of the equipment at their depot. This involves setting up the Rail Tensors on a section of track (they have for training purposes) clamping the rail and applying hydraulic pressure to the Rail Tensors to check the pressure gauges are working and there are no leaks in the hydraulic system. It is noted that in the service on the 10th January 2023 a load test was not carried out on the new pressure gauge (highlighted red in Figure 7).

84 After the difficulties experienced on the night of the 20th February 2023 the Rail Tensors were returned to the depot and taken out of service until a full inspection of the Rail Tensors was undertaken on the 6th March 2023. The equipment was serviced, and the hydraulic oil was changed with the hydraulic filter cleaned (highlighted yellow in Figure 8). The pressure gauges, hoses controls and valves were checked. Load tests were carried out on the hydraulic controls, valves and pressure gauges (see Figure 8); no defects were recorded.

85 It is noted that the Person in Charge of Stressing emailed their supervisor at 06:30 hrs on Wednesday 22nd February 2023 outlining the difficulties encountered with the Rail Tensors, while also acknowledging that the weld had passed the ultrasonic tests.

[9] The RAIU consider the absence of recalibration of the pressure gauges and the absence of welding contractor equipment checks by IÉ-IM to be additional observation, AO-05 (see paragraph 149) which warrants a safety recommendation, Safety Recommendation 2024002-03 (paragraph 164).

[10] It should be noted that IÉ-IM engaged an external firm specialising in hydraulic systems who service and recalibrate IÉ-IM's equipment since April 2022. Prior to that IÉ-IM's equipment was serviced inhouse in the Portlaoise Sleeper Plant.



Petrol Hydraulic Stressing Pump Inspection Report

Equipment No: #5
Name of Inspector: [redacted]
Test Date: 6.3.23

1. Engine			√	X
No.	Component Item	Service Operation		
1	Engine Oil	Change	✓	
2	Engine Oil Filter	Change	NA	
3	Fuel Filter	Change	NA	
4	Air Filter	Change	✓	
5	Inlet and Exhaust System	Check condition	✓	
6	Engine Mountings	Check condition	✓	
7	Recoil Starter	Check condition of cord and operation	✓	
8	Guards	Check condition and security	✓	
9	Engine Stop	Check condition and operation	✓	
10	Hoses and Pipework	Check for damage, deterioration and leaks	✓	

2. Chassis and Frame			√	X
No.	Component Item	Service Operation		
11	Frame	Check condition	✓	
12	Lifting Points	Check condition and handles	✓	

3. Hydraulics			√	X
No.	Component Item	Service Operation		
13	Hydraulic Oil	Check level	✓	
14	Hydraulic Oil and Filter	Change	✓	* Clean filter
15	Pressure Gauge	Check	✓	
16	Hoses and Pipework	Check condition security and for leaks	✓	
17	Controls and valves	Check condition, operation and lubricate	✓	
18	Controls and valves	Load test	✓	
19	Pressure Gauge	Load test	✓	
20	Hoses Safe Working Pressure	All hoses must display the S.W.P (10,000 psi)	NA	
21	Coupling dust caps and link cabin	Check condition and security	NA	

4. Controls			√	X
No.	Component Item	Service Operation		
22	Controls	Check operation and lubricate	✓	

Check No	Rectification Action	Rectified by
14	Remove + clean filter.	

Figure 8 – Stressing Equipment Inspection report post incident

Post-incident inspection of the broken rail

Serco Report

86 IÉ-IM sent the broken rail to Serco Rail Technical Services for metallurgical analysis.

87 A visual inspection indicated that the weld suffered a complete transverse failure through the approximate centreline (see Figure 9) with a pronounced hollow in the foot of the rail which was partially filled with luting sand (see Figure 10).

Figure 9 – Traverse failure through the centreline of the weld

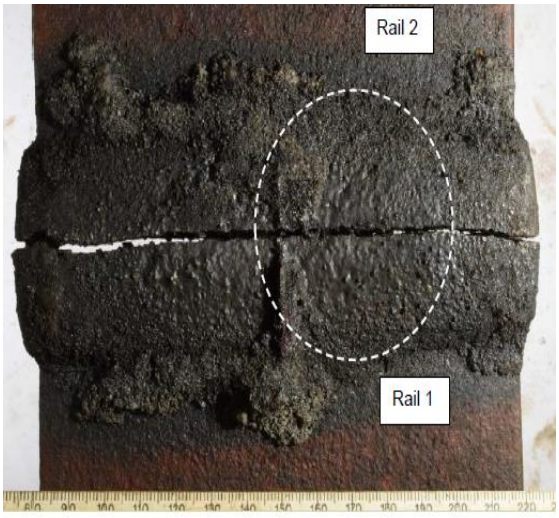


Figure 10 – Underside hollow partially filled with luting sand

88 There were two darkly oxidised regions found on the fractured face of the weld. A triangular shaped area at the foot/web transition and a circular area occupied most of the head area (see Figure 11). The remainder of the weld showed signs of a recent rapid *overload*. And a “hollow” was present across the bottom of the foot (circled red in Figure 11).

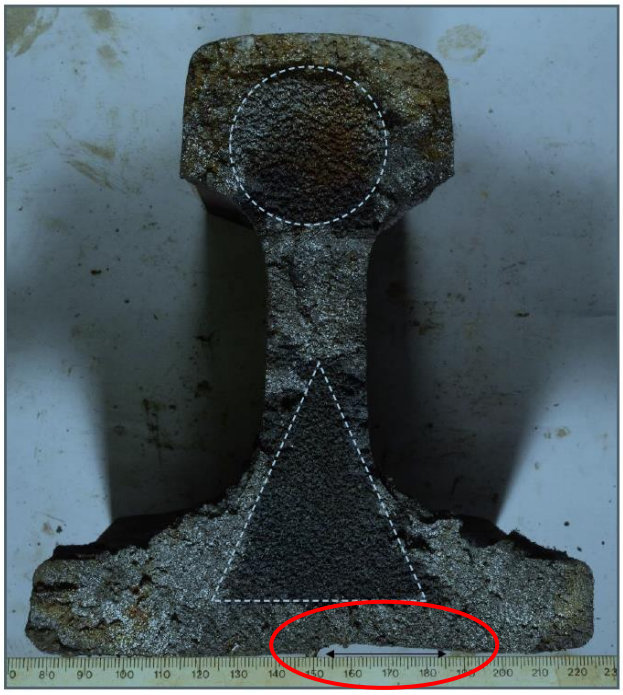


Figure 11 – Fracture face

89 The oxidised region at the web/foot transition were described in the report as consisting of a multitude of sharp “peaks” with dendritic areas in the “valleys” although towards the apex, entirely dendritic regions were also identified in the web indicative of shrinkage. This was distinctly different to the surrounding fracture that was crystalline in nature.

90 The defect in the head (see Figure 12) had a similar appearance to the triangular feature in the web/foot (sharp peaks and dendritic valleys). Unlike the triangular feature only a proportion of the surface was darkly oxidised with the remainder either being lightly oxidised or relatively free of oxidation.

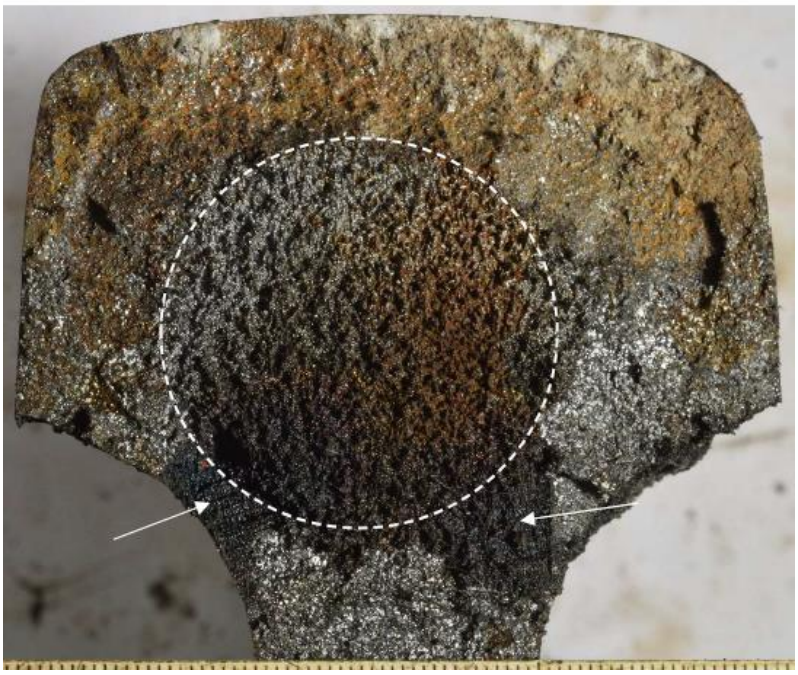


Figure 12 – Fracture face in the head

91 In terms of a metallographic examinations, a near horizontal section was taken through the apex of triangular region for a more detailed examination. The examination showed that the weld fusion had occurred at or near the edge of the weld collar.

92 The microstructure of the weld metal consisted almost entirely of pearlite with some grain boundary ferrite and included a homogeneous dispersion of minute slag inclusions and microporosity.

93 These defects (paragraphs 87 to 93) had occurred in the areas that are the last to solidify during the alumino-thermic welding (thermit welding).

94 The Serco Report concluded that the weld broke rapidly from defects introduced during Thermit SoW-5. Their position within the last areas to solidify combined with the appearance indicated that the defects were likely to be either a hot tear or *shrinkage*[11]. Both are similar in appearance.

95 The Serco Report states that "it appears some difficulties[12] had been experienced obtaining a good fit between the mould and the rail, as copious amounts of luting sand had been applied especially around the underside of the foot where an unusual 'hollow' had been created in the final weld. There is no evidence to suggest that this had become a leakage path for hot metal during the welding".

96 The Serco Report was reviewed by m4si the independent company employed by the RAIU and they were in agreement with the Serco Report that the failure was due to either shrinkage or hot tearing, also noting their similar appearance.

[11] Possible causes of shrinkage would include: improper alignment or fit up of the rails, prior to welding, resulting in too wide a welders gap and/or a tampered welders gap, which was narrower at the top; or inadequate pre-heating of the rails prior to welding or excessively rapid cooling after welding.

[12] At the time of drafting the report, Serco were unaware of the difficulties encountered are discussed in paragraphs 102 to 105 and further analysed in paragraph 142.

Events before, during and after the incident

Events before the incident

97 Engineering works (with six separate worksite) were scheduled from Monday 20th to Sunday the 26th February 2023 on the Up and Down Line from Dublin to Cork.

98 One of the T3 Possessions was the section of track from Thurles to Charleville to facilitate track maintenance on the Up and Down lines of the Dublin to Cork mainline as part of a pre-planned programme of engineering works.

99 On Tuesday 21st February 2023, the track section near Emly LC was being prepared for ballast cleaning. The stressing of the rails was undertaken at this stage to eliminate the need for a speed restriction after the ballast cleaning had been carried out.

100 The stressing was being carried out on a *reverse curve* on the Up Line; this meant that both rails (the rail nearest the six foot and the rail nearest the cess) were cut at *pulling point* locations marked by the Person in Charge of Stressing who also supervised the works. The rail temperatures of 8˚C was recorded for both weld locations.

101 The Welders placed clamps on either side of the cut rail section (on the rail nearest the six foot) and attached a Rail Tensors. The rail ends were pulled together until the required welders gap was achieved. The pressure reading on the Rail Tensors was 5000 psi this was the pressure required to pull the rails to the required welders gap. The valve was closed off. The rails were refastened to the sleepers and prepared for Thermit SoW-5. The weld was dropped at 03:24 hrs.

102 The Welders placed clamps on either side of the cut rail (the rail nearest the cess).

103 On the first attempt when the rails were pulled and the valve was closed off on the Rail Tensors to maintain pressure, the Person in Charge of Stressing noticed a slight movement in the rail. The valve was opened, and the pressure released. The rail was unfastened from the sleepers.

104 On the second attempt, the hydraulic rams on the Rail Tensors did not appear to be working properly, and the rails could not be pulled.

105 On the third attempt the rails pulled to the required welders gap. The valve was closed off and the pressure reading on the Rail Tensors was 4000 psi.

106 The Person in Charge of Stressing stated they put a pencil mark on the hydraulic rams of the Rail Tensors as a visual aid, to ensure that the hydraulic rams did not slip. The Person in Charge of Stressing also monitored the pressure gauge, to ensure that the reading remained static[13].

107 The Welders waited a few moments to make sure the Rail Tensors maintained the holding pressure; the CCE staff anchored the rails by refastened them to the sleepers and the Welders prepared for Thermit SoW-5[14]. The weld was dropped at 03:37 hrs.

108 The Welders stripped the weld, carried out initial and final grinding of the weld, weld tagging and site clean-up. This included removing the sand tray and replacing the ballast that was removed from the box.

109 The Welders finished their work and the Weld Supervisor carried out a visual inspection of the welds, and they were satisfied there were no defects visible and left the site.

110 The Person in Charge of the Stressing remained at the site of the welds until the Ultrasonic Operator attended and performed ultrasonic tests on both welds (outlined in paragraph 75) with both welds passing the ultrasonic tests at this stage. It is noted that, after the works, the Person in Charge of Stressing emailed their supervisor outlining the difficulties encountered with the Rail Tensors (paragraph 85).

111 The PICOP handed back the T3 Possession at 05:00 hrs on 22nd February 2023.

112 Normal line service resumed on the Up Line at 05:45 hrs on 22nd February 2023 with a total of twenty-four passenger service trains using the Up line through Tuesday 22nd February 2023 and on Wednesday morning 23rd February 2023.

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[13] If the holding pressure dropped this could present as a lower reading on the pressure gauge.

[14] I-PWY-1220 is clear on the requirement that welders should ensure that "no sand enters the mould or the welding gap", noting that sand may enter the mould if the sleepers, rails or work spanners are disturbed (paragraph 72). Given the difficulties with the Rail Tensors, there may have been some disturbance to the weld set-up during Thermit SoW-5, whereby luting sand entered the mould; the Welders may not have been aware of this. The RAIU have determined that the presence of "copious" amounts of sand in the weld (as identified in the Serco Report (paragraph 95)) may have been as a result of actions on site. The RAIU consider this to be an additional observation, AO-06 (paragraph 149); however, as a result of measures taken by the Welding Contractor (paragraph 154), the RAIU does not consider an additional safety recommendation is warranted (paragraph 160).

113 At 07:56 hrs on Wednesday 23rd February 2023 the Signalman saw that the track circuit remained occupied after Train A205 passed through track circuit LJ789. The Signalman contacted Driver A205 to ensure the train had passed through the section safely.

Events during the incident on 23rd February 2023

114 At 07:57 hrs the Signalman contacted Mallow LCCC to see if there was a fault at Emly LC. Mallow LCCC confirmed there was no fault showing on their system and that Train A205 had gone through Emly LC.

115 At 07:59 hrs the Signalman contacted the SET Department to report a track circuit fault at track circuit LJ789 on the Up Line.

116 The SET staff members were deployed at approximately 08:10 hrs to the location of the track circuit fault.

117 At 08:56 hrs the Signalman contacted Driver A303 (Train A303 Tralee to Dublin passenger service Up line) to explain that they would have to stop at Signal RC885 because there was a track circuit fault on the Up Line. Driver A303 confirmed the instruction.

118 At 09:03 hrs the Signalman contacted Driver A303 and asked them to examine the line from Signal LJ895 and the repeater Signal LJR353 as there was a track circuit fault. The Signalman explained that the Signal LJ895 may be showing danger (red aspect).

119 At 09:15 hrs the SET staff members arrived at 110 MP checked the SET location case and found no faults, they left the location and travelled to the 109 MP.

120 At 09:29 hrs, Driver A303 contacted the Signalman to say they were at Signal LJ895 which was at danger. The Signalman authorised the movement to pass the signal at danger with further instructions to examine the line from Signal LJ895 to the repeater Signal LJR353 and to obey Signal LJR353. The Signalman told Driver A303 that they made contact with Mallow LCCC and that the barriers are down and safe for the passage of the Train A303 at Emly LC and that Driver A303 would have to contact the Mallow LCCC when they reached Emly LC as the signal would not clear.

121 At 09:55 hrs Driver A303 contacted the Signalman to say they had passed repeater Signal LJR353 and there were SET workers at the SET location case at Emly LC. The CAWS signal upgraded at 109¾ MP. Driver A303 examined the line from Signal LJ895 to repeater Signal LJR353; no defects were identified on the line.

122 At 10:00 hrs the SET staff members arrived at 109 MP and checked the SET location case, found no fault, and began an inspection of the line towards 110 MP.

123 At 10:19 hrs the Signalman contacted Driver A209 to instruct Train A209 to pass Signal LJ895 at danger and proceed up to and obey repeater Signal LJR353.

124 At 10:35 hrs the SET staff members having walked the line found the broken rail.

Events after the incident

125 Just as the SET staff member had discovered the broken rail, Train A209 was approaching under caution on the Up line. The SET staff member stepped out to a position of safety and signalled for the train to stop. Train A209 travelled over the broken rail before coming to a stop.

126 At 10:38 hrs, Driver A209 contacted the Signalman to inform him of the broken rail. Driver A209 resumes their journey on the Up line.

127 At 10:39 hrs, a SET staff member contacted the Signalman and told them that they have found a broken rail and requested signal protection for the Up line, to stop all traffic over the broken rail until the rail could be clamped and an ESR put in place.

128 The Signalman took the appropriate actions and signal protection was put in place on the Up line.

129 The PWI attended site, and the rail was clamped and plated.

130 The Up Line was reopened at 11:30 hrs and an ESR of 10 mph (16 km/h) was put into operation over the section of track with the broken rail. The first train to go over the rail after it was clamped was watched by the PWI to ensure that the clamp held.

131 On 23rd February 2023 the broken rail was removed, and a 10 m section of rail installed and welded into place. The weld on the adjacent rail (poured on the same night) was also removed and replaced.

132 Welds poured on the previous and following nights were re-tested ultrasonically and all were found to pass.

Previous occurrences in previous ten years

133 On the 14th January 2015, there was a broken rail on the Heuston (Dublin) to Cork line on the Down Line located at 89 miles and 445 yards from Heuston. The Thermit SoW-5 weld failed due to gas entrapped within the metal forming holes. The break was from the porosity holes (see arrows in Figure 13) in the weld at the base of the rail foot. There was no sign of any crack propagation from any of the inclusions and it was a fast break. The rail was stressed and welded on the 11th November 2009 and tested by the Ultrasonic Operator on the same night and no defects were found. *Sperry Vehicle Testing* carried out Ultrasonic testing on the 2nd of April 2014 and no defects were found.

Figure 13 – Rail foot defects

Figure 14 – Web defects

134 The conclusion of the broken rail report on the 14th January 2015 was that the proximity of the defects that broke the weld in the foot area would be outside the ultrasonic range of the Sperry Vehicle Testing equipment and the inclusions in the web (see arrows in Figure 14) and head areas would most likely been undetectable, or too small.

Analysis

Mechanism of failure

135 The Serco Report sets out the metallurgical findings of the inspection of the broken weld (paragraphs 87 to 93), concluding that the failure of the weld was likely to be either a hot tear or shrinkage, recognising that both defects had a similar appearance (paragraph 94).

136 The Serco Report did identify that there were “some difficulties had been experienced obtaining a good fit between the mould and the rail, as copious amounts of luting sand had been applied” (paragraph 95). At the time of publication of the Serco Report, Serco were unaware of the exact difficulties on-site. On analysis of the evidence, it is more likely that when the Welders encountered difficulties with the Rail Tensors, they may have disturbed the weld set-up, which may have resulted in the luting sand entering the mould at this stage (footnote14); the Welders may not have been aware of this.

137 The Welders, did however, report difficulties with the Rail Tensors (paragraphs 102 to 105) and the Person in Charge of Stressing did raise concerns about the condition on the Rail Tensors on the day that the welding took place (paragraph 85). The Rail Tensors were taken out of service and post incident inspection of the Rail Tensors did not indicate any obvious physical defects (paragraph 84).

138 The hot tearing indicates that it is likely that after the weld was dropped and before it solidified the Rail Tensors released enough to cause hot tearing; this release may have been slight enough to not present on the pressure gauge. The hot tear would not have been detected, at this stage, by a visual examination by the Weld Supervisor (paragraph 109) or by test by the Ultrasonic Operator (paragraph 110).

139 The ms4i report commissioned by the RAIU was in agreement with the Serco Report in that the failure occurred possibly as a result of shrinkage or hot tearing as both had a similar appearance.

Actions by members of staff on-site during Thermit SoW-5

140 The preparation works on the night of the 21st February (paragraph 100), were in line with CCE-TMS-323 (paragraphs 67 to 69).

141 The Welders dropped the first weld, without any difficulty (paragraph 101).

142 However, the Welders did encounter difficulties with the Rail Tensors not holding in the first instance and not achieving the welders gap on the second attempt, only achieving the stressing requirements on the third attempt. On the third attempt, the Welders waited a few moments to make sure the Rail Tensors held before they began the preparation for Thermit SoW-5 (paragraphs 102 to 105).

143 It is noted that the Welders, under the guidance of the Person in Charge of Stressing did this of their own volition rather that referring to TMS-CCE-323, which did not provide any guidance on what to do when difficulties arise (paragraphs 77 and 78).

144 During this time, the Person in Charge of Stressing was monitoring the pressure gauge, which was displaying a static holding pressure (paragraph 106).

Conclusions

Causal, contributing, and systemic factors

145 The mechanism of failure of the weld (outlined in full in paragraphs 87 to 94), was likely to be as a result of hot tearing, likely as the result of difficulties encountered by the Welders with the Rail Tensors (the Person in Charge of Stressing did raise concerns about the condition on the Rail Tensors on the day that the welding took place (paragraph 137)) whereby it was only on their third attempt that the welders gap was achieved and the holding pressure remained static. The weld was then dropped and before it solidified the Rail Tensors released enough to cause hot tearing; this release may have been slight enough to not present on the pressure gauge (paragraph 138). The hot tear would not have been detected, at this stage, by a visual examination by the Weld Supervisor or by tests by the Ultrasonic Operator (paragraph 138).

146 The RAIU have identified the following possible causal factor to the hot tearing of the weld:

- CaF-01 – The Rail Tensors did not operate correctly at the time of welding, resulting in the Welders encountering difficulties pulling and holding the rail ends to the required welders gap; which may have caused the Rail Tensors to release enough holding pressure to cause a hot tear in the weld (paragraph 142).

147 No contributory factors were identified.

148 The following was identified as a systemic factor in relation to the difficulties encountered by the Welders:

- SF-01 – Technical Standard for the Stressing of Rail, CCE-TMS-323, did not include guidance on actions for welders to take once difficulties were encountered with the Rail Tensors (paragraph 143).

Additional observations

149 Although not a factor to the incident, the RAIU make the following additional observations:

- AO-01 – There are inconsistencies throughout the suite of documents related to I-PWY-1220 e.g., the welders gap has not been updated in all the relevant documents (paragraph 32, footnote 1);
- AO-02 – CCE-TMS-323 requires that the Rail Tensors should remain in place after the weld has been dropped for thirty minutes; however there is no guidance on how often the Person in Charge of Stressing should check the Rail Tensors within this period of time (paragraph 73, footnote 4);
- AO-03 – The CWR Record Sheet (included in the appendices of CCE-TMS-323) has no sections for the Person in Charge of Stressing to recording the following:
  - Serial number and calibration/ recalibration date of the Rail Tensors being used;
  - Pressure gauge readings before, during and after Thermit SoW-5;
  - Periodic time intervals the Person in Charge of Stressing should check the pressure gauges (paragraph 76, footnote 5);
- AO-04 – There is no guidance or training for the Person in Charge of Stressing in CCE-TMS-323 in relation to actions to be taken where difficulties are encountered with Thermit SoW-5 (including when Thermit SoW-5 can continue, be restarted or must be abandoned); and, who is responsible for this decision, the Person in Charge of Stressing or their Supervisor (paragraphs 77 and 78, footnotes 6 and 7);
- AO-05 – At the time of the discovery of the broken rail, the welding contractor was not carrying out recalibration test of the Rail Tensors' pressure gauges (paragraph 81), this may have been as a result, in part, of IÉ-IM not:
  - Stating the required frequency for recalibration in CCE-TMS-323;
  - Undertaking checks of the welding contractor's rail stressing equipment.
- AO-06 – The metallurgical examination of the weld identified copious amounts of luting sand in the weld (although noting that this did not contribute to the weld break). The RAIU determined was likely to be as a result of disturbance to the weld set-up during Thermit SoW-5 due to the issues with the Rail Tensors (footnote 14).

Measures taken since the incident

Measures taken by IÉ-IM since the incident

150 IÉ-IM have undertaken a number of measures following the incident, firstly testing was carried out on the intact weld poured on the other rail on the Up line, which was found to be sound, with no significant defects found.

151 An internal technical investigation was carried out, and completed on the 27th June 2023, which concluded that the rail break occurred due to the progression of a hot tear defect in the weld. The investigation recommended the following:

- A review is to be undertaken of the CCE Controlled Documentation associated with Stress of Rail and Thermit Welding of rail to provide guidance to guide further similar occurrences;
- CWR Record Sheet is to be revised to include a section for general comments to be included in the Record Form;
- A formal certification process is to be implemented for all stressing equipment within IÉ-IM this is to be implemented in early 2024. The Welding Contractors are being included in the formal certification process for stressing equipment. This will include the inspection of the Welding Contractor's premises and asset audit of contractor equipment may be carried out by IÉ to verify that necessary plant, equipment, servicing schedules, support staff and management, storage facilities for consumables, shift reporting system, data management and transport provisions are in place.

Measures taken by the Welding Contractor since the incident

152 A new standard of maintenance had been adapted since the 1st March 2023 with servicing of the Rail Tensors, and associated equipment, every three months. Records of the servicing schedule are up to date with each Rail Tensors having a serving label attached with the date it was last serviced and the next date it is due for service.

153 At the time of the publication of this report all six Rail Tensors, owned by the Welding Contractor had been recalibrated, by an external firm specialising in hydraulic systems.

154 The Welding Contractor has ordered metal covers, designed to fit over the top of the mould, to prevent luting sand entering the mould while the welders are preparing for Thermit SoW-5.

Measures taken by the CRR since the incident

155 The CRR undertake a variety of supervision activities on railway organisations which comprise of audits, inspections (both planned and following occurrences) and meetings with railway organisation personnel.

156 Specific scheduled meetings include periodic safety performance review meetings, CRR outcome review meetings and RAIU Safety recommendations review meetings, etc. CRR Supervision activities are both proactive (planned) and reactive (in response to something such as an accident/ incident) as per the activity types outlined above and commensurate with the levels of risk involved.

157 As part of the CRR's Supervision Plan for 2024 on IÉ-IM an inspection is planned which will encompass sampling on-site welding at multiple sites in order to check site welding processes and implemented risk mitigations across these sites. It should be noted that this activity while envisaged to be undertaken in 2024 will depend on reactive supervision activities which receive prioritisation with respect to resource allocation.

Safety Recommendations

Introduction to safety recommendations

158 In accordance with the European Union (Railway Safety) (Reporting and Investigation of Serious Accidents, Accidents and Incidents) Regulations 2020), RAIU safety recommendations are addressed to the NSA, the CRR, and directed to the party identified in each safety recommendation.

Absence of safety recommendations due to measures already taken

159 A new standard of maintenance has been adapted since the 1st March 2023 with servicing of the Rail Tensors, and associated equipment, every three months including the recalibration of the Rail Tensors (paragraph 152). It is noted that all Rail Tensors have now been recalibrated (paragraph 153), which should, in part address CaF-01 (paragraph 146). As a result, no further safety recommendation in warranted in terms of the in-house recalibration of Rail Tensors; although noting the servicing and recalibration of contractor's stressing equipment should be verified by IÉ-IM; this will be addressed by Safety Recommendation 2024002-03 (paragraph 164).

160 The Welding Contractor has ordered metal covers designed to prevent luting sand entering the mould (paragraph 154). The RAIU consider that this will address the risk of luting sand entering the mould as identified in AO-06 (paragraph 149) and as such no further recommendation is warranted.

161 In general terms, the ultrasonic testing of rails is a reliable means for the testing of Thermit welds, with the last broken rail, as a result of thermit welding, occurring in 2015 (paragraphs 133 and 134). In addition, IÉ-IM carry out ultrasonic testing of the rails with the Sperry ultrasonic testing equipment twice a year. IÉ-IM also carry out track geometry and rail profile testing using a track recording vehicle. As a result, no safety recommendations are warranted related to post welding testing.

Safety recommendations as a result of this incident

162 The Welders encountered difficulties with the Rail Tensors not maintaining sufficient pressure to hold the rails at the required welders gap. To address CaF-01 (paragraph 146) and SF-01 (paragraph 148), the RAIU make the following safety recommendation:

Safety Recommendation 2024002-01

IÉ-IM CCE to update Technical Management Standard, CCE-TMS-323, Technical Standard for the Stressing of Rail, to include a more robust guidance for welders, in relation to recognising when there may be issues with the Rail Tensors; and what actions are to be taken when difficulties arise with the Rail Tensors.

Safety recommendations as a result of additional observations

163 The IÉ-IM CCE documentation associated with rail welding, was not current, in relation to the introduction of the single use crucible, and the welders gap. As a result, the RAIU make the following safety recommendation to address AO-01 (paragraph 149):

Safety Recommendation 2024002-02

IÉ-IM CCE should review the current suite of documents related to welding to ensure consistency across the relevant documents

164 There were issues with the Rail Tensors at the time of welding (paragraph 145). CCE-TMS-323 does not specify servicing or recalibration frequency for the rail stressing equipment, with IÉ-IM CCE not checking whether the Welding Contractor was carrying out servicing or recalibration. As a result, the RAIU make the following safety recommendation to address CaF-01 (paragraph 146) and AO-05 (paragraph 149):

Safety Recommendation 2024002-03

IÉ-IM CCE should develop systems for the management and certification of rail stressing equipment (including contractor's rail stressing equipment), to ensure equipment is regularly serviced and recalibrated at a nominated frequency. These updated requirements should be reflected in the relevant documents.

165 The CWR Record Sheet in CCE-TMS-323 has no sections for the Person in Charge of Stressing to record the serial number and date of calibration/ recalibration of the Rail Tensor being used, the pressure reading on the pressure gauges and the frequency of the checks on the pressure gauges. As a result, the RAIU make the following safety recommendation to address AO-02 and AO-03 (paragraph 149):

Safety Recommendation 2024002-04

IÉ-IM CCE should review and update the CWR Record Sheet to include sections for recording the serial number and calibration/ recalibration date of the Rail Tensors being used, the pressure gauge readings and the frequency of these checks on the pressure gauges. On completion, ensure staff are briefed on the changes, and changes should be incorporated into future training programmes for a Person in Charge of Stressing.

166 There is no training for the Person in Charge of Stressing on when difficulties are encountered on site the conditions/criteria that Thermit SoW-5 can continue, be restarted or abandoned. There is no guidance on who makes the decision is it the Person in Charge of Stressing or their Supervisor; as a result, the RAIU make the following safety recommendation to address AO-04 (paragraph 149):

Safety Recommendation 2024002-05

IÉ-IM CCE should update CCE-TMS-323 to include guidance for the Person in Charge of Stressing, in relation to actions to be taken when difficulties are encountered with Thermit SoW-5 (including when Thermit SoW-5 can continue, be restarted or must be abandoned; and, who is responsible for this decision, the Person in Charge of Stressing or their Supervisor). On completion of the update, Persons in Charge of Stressing should be briefed and the training programme for the role revised with the new guidance.

Additional Information

List of abbreviations

AO	Additional Observations
CaF	Causal Factor
CAWS	Continuous Automatic Warning System
CCE	Chief Civil Engineer
CME	Chief Mechanical Engineer
CoF	Contributory Factor
CRR	Commission for Railway Regulation
CTC	Centralised Traffic Control
CWR	Continuous Welded Rail
DART	Dublin Area Rapid Transport
DMU	Diesel Multiple Units
EU	European Union
ESR	Emergency Speed Restriction
hr	hour
IAMS	Infrastructure Asset Management System
ICR	InterCity Railcar
IÉ-IM	Iarnród Éireann Infrastructure Manager
IÉ-RU	Iarnród Éireann Railway Undertaking
km	kilometre
km/h	kilometres per hour
LC	Level Crossing
LCCC	Level Crossing Control Centre
m	metre
mm	millimetres
MP	Milepost
mph	miles per hour
NSA	National Safety Authority
PICOP	Person In Charge Of the Possession
psi	pound-force per square inch
PWI	Permanent Way Inspector
RAIU	Railway Accident Investigation Unit
RFI	Request For Information
SET	Signal Electrical and Telecommunications
SF	Systemic Factor

SFT	Stress Free Temperature
SMS	Safety Management System
TCB	Track Circuit Block
TDU	Track Delivery Unit
TSR	Temporary Speed Restriction

Glossary of terms

Accident	An unwanted or unintended sudden event or a specific chain of such events which have harmful consequences. For heavy rail, the EU Agency for Railways divides accidents into the following categories: collisions, derailments, level-crossing accidents, accidents to persons caused by rolling stock in motion, fires and others.
Alumino-thermic welding process	An exothermic reaction involving the oxidisation of aluminium by iron oxide.
Anchor	The section of rail is clipped down during stressing operations to ensure that no movement occurs at the fixed end of the length being stressed.
Article 20 of Directive (EU) 2016/798, Obligation to investigation	Article 20 (1) Member States shall ensure that an investigation is carried out by the investigating body referred to in Article 22 after any serious accident on the Union rail system. The objective of the investigation shall be to improve, where possible, railway safety and the prevention of accidents. Article 20 (2) The investigating body referred to in Article 22 may also investigate those accidents and incidents which under slightly different conditions might have led to serious accidents, including technical failures of the structural subsystems or of interoperability constituents of the Union rail system. The investigating body may decide whether or not an investigation of such an accident or incident is to be undertaken. In making its decision it shall take into account: (a) the seriousness of the accident or incident; (b) whether it forms part of a series of accidents or incidents relevant to the system as a whole; (c) its impact on railway safety; and (d) requests from infrastructure managers, railway undertakings, the national safety authority or the Member States.
Ballast	Crushed stone used to support sleepers both vertically and laterally.
Ballast Cleaner	A machine the excavates ballast from under the track, discards the dirt, undersize and oversize pieces, and then returns the good ballast to the track.

Broken Rail	This means any rail which is separated in two or more pieces, or any rail in which a piece of metal becomes detached, causing a gap of more than 50 mm length and more than 10 mm in depth on the running surface. Note: this definition is as per UIC 712R. This definition also applies to a broken weld.
Box (or Crib)	Ballast bed between two adjacent sleepers.
Causal Factor	Any action, omission, event or condition, or a combination thereof that if corrected, eliminated, or avoided would have prevented the occurrence, in all likelihood.
Cess	The space along the running line
Continuous Automatic Warning System	An advisory train control system, AWS works by repeating the aspects shown by the lineside colour light signals on an Aspect Display Unit (ADU) inside the driver's cab. The ADU continuously displays the aspect that was shown by the previous signal until updated approximately 350 m before the next signal. The ADU then displays the aspect shown by that signal.
Contributing Factor	Any action, omission, event or condition that affects an occurrence by increasing its likelihood, accelerating the effect in time or increasing the severity of the consequences, but the elimination of which would not have prevented the occurrence.
Down Line	In this incident, trains travelling to Cork are travelling in the Down direction on the Down Line.
Down Side	Being located on the same side of the railway as the Down Line.
Emergency Speed Restriction	A speed restriction imposed for a short time, at short notice, generally for safety reasons.
Flat bottom rail	A rail section having a flat based rail foot.
Heat Treated Rail	Pearlitic rails subjected to a closely controlled cooling process, which results in a hard-wearing running surface.
Holding pressure	This is the pressure on the Rail Tensors to hold and maintain the welders gap on the rail for Thermit Sow-5.
Hot tear	Caused by rail movement before the weld has set. The hot tear occurs as the weld contracts when solidifying. Causes include: thermal

	contractions, inadequate welding temperature and improper solidification.
Incident	Any occurrence, other than an accident or serious accident, associated with the operation of trains and affecting the safety of operation. For heavy rail, the EU Agency for Railways divides incidents into the following categories: infrastructure; energy; control-command & signalling; rolling stock; traffic operations & management and others.
Infrastructure Asset Management System	Is the internal Geographic Information System used by Iarnród Éireann in the mapping and management of infrastructure assets.
Investigation	A process conducted for the purpose of accident and incident prevention which includes the gathering and analysis of information, the drawing of conclusions, including the determination of causes and, when appropriate, the making of safety recommendations
Location cases	Accommodate railway signalling equipment to detect the location of trains, control the trackside signals and switch the points, etc.
Luting Sand	Sand used to seal gaps around moulds.
Mile Post	Marks distances.
Person in charge of the possession	They are the competent person nominated to manage the possession to ensure the safe and correct establishment of the protection of the possession. Managing access to the Possession area by Engineering Supervisors. Managing the establishment of Engineering Work Sites within the possession. Liaising with the Signalman regarding the passage of the Train in and out of Possession. Controlling the movement of the Train between the Protection and Work Sites. Ensuring that all the forgoing is correctly removed in reverse sequence, the Possession is relinquished, and the Line handed back to the Signalman at the due time.
Permanent Way Inspector	Responsible for overseeing and guiding workplace activities in his CCE location. PWIs shall be familiar with the content of this technical standard and the requirements for the stressing of CWR.

Person in charge of stressing	Those involved in rail stressing procedures, installation and setting of breather switches and the weld repair of common features in stressed CWR shall be competent (refer to clause 2.1.5) for the activity being undertaken and have knowledge and experience of the temperature considerations and technical requirements for the task and are accountable for ensuring that: • They hold the required competency (Level I, II or III) relevant to the task being undertaken in accordance with CCE-TMS-422; • They have the relevant equipment on site; • Follow the correct work procedure; • They complete and submit the appropriate Record Sheet(s).
Position of safety	A place allowing a clearance of at least 1.5 metres between you and the nearest rail of any line on which a train is approaching.
Pull Force	This is the force applied to a rail in order to extend it. The pull force shall not exceed 6553 psi or 1091 psi less than the maximum capacity of the tensors, whichever is the lesser.
Pulling Point	The location at which the rail is to be cut, tension applied, and extension calculated. It shall be at least 4.5 m from a weld or joint, mid-way between two sleepers, and ideally should be the mid-point of the length of track being stressed.
Rail Tensors	Hydraulic devices for extending CWR during stressing. A set of tensors refers to sufficient equipment to tension both rails at the same time. Tensors shall be operated only by persons suitably trained and certificated.
Reverse Curve	A reverse curve or “S” curve is a section of CWR that has a curve to the left or right followed immediately by a curve in the opposite direction.
Rollers	Devices used to support CWR clear of the sleepers in order to allow its free longitudinal movement during stressing. Sometimes referred to as under rollers.
Sand tray	Used in the emptied box to provide a supply of sand for sealing the moulds and to collect spillage and avoid fouling of ballast from Thermit welding process.

Shrinkage	The reduction in volume of liquid metal as it cools to a solid state.
Side Rollers	Support arms that are used to prevent lateral movement of CWR during stressing.
Six foot	The space between one line and another.
Sperry Vehicle Testing	A train is equipped with Sperry monitoring equipment for non-destructive testing of rails.
Stress Free Temperature	The rail temperature at which there is no stress or thermal force in the rail.
Stressing	The process of adjusting the length of CWR installed in the track so that the rail is neither in tension nor compression at a pre-determined temperature. It is used to prevent heat and cold tension after installation of CWR.
Systemic factor	Any causal or contributing factor of an organisational, managerial, societal, or regulatory nature that is likely to affect similar and related occurrences in the future, including, in particular the regulatory framework conditions, the design and application of the safety management system, skills of the staff, procedures and maintenance.
T3 Possession	A possession taken for an agreed period without the facility to run passenger trains in the area during that period until such time as the holder of the possession decides to relinquish it.
Thermit® SoW-5	Thermit SoW-5 is a universal welding process for *flatbottom rails.* It is a proprietary type of alumino-thermic welding process produced by Thermit Welding (GB) Ltd. Thermit is a register trademark of Th. Goldschmidt AG. Goldschmidt Smart Rail Solutions supply the Thermit Welding mix and associated materials.
Track Circuit	An electrical device used to prove the absence of a train on rail tracks to signallers and control relevant signals.
Track Circuit Block	A development of the Absolute Block System, in which track circuiting is applied throughout. A train May proceed to the next stop signal as soon as the line is clear, determined by the operation of the track circuits, provided the overlap beyond the signal is also clear.

Ultrasonic Supervisor	With regard to this standard, the Ultrasonic Supervisor is accountable for ensuring that Ultrasonic testing is carried out and completed according to the schedule set out in the Technical standard CCE-TMS-362 and related technical document. That only competent personnel and the correct tools and other resources are used. That planning and prioritising to ensure that the ultrasonic testing of rails is undertaken in line with frequencies outlined in the standard. That Ultrasonic Operators record and report all defects.
Up Line	In this accident, trains travelling from Cork are travelling in the Up direction on the Up Line.
Up Side	Being located on the same side of the railway as the Up Line.
Valve	A device that opens and closes to control the flow of liquid.
Welders gap	A prepared gap between two adjoining rail ends to accommodate the weld formed during the Thermit welding process. Width of gap is dependent on the Thermit welding process used. Note: Welders gap: 20mm – 22mm, SoW-5 Thermit (long-life crucible) welding process. Welders gap: 28mm – 30mm, SoW-5 Thermit (single shot crucible) welding process. Welders gap: 75mm, wide gap weld (max. width).
Welding Process	Any part of the entire sequence of events from selection of rail before welding to assurance that the finished product conforms to this procedure or any other special requirements.

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