Rail Delivery Group

National Rail

RDG Guidance Note: Selection and Assurance of Fasteners for Legacy Fleets

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About this document

Explanatory Note

The Rail Delivery Group is not a regulatory body and compliance with Guidance Notes or Approved Codes of Practice is not mandatory; they reflect good practice and are advisory only. Users are recommended to evaluate the guidance against their own arrangements in a structured and systematic way, noting that parts of the guidance may not be appropriate to their operations. It is recommended that this process of evaluation and any subsequent decision to adopt (or not adopt) elements of the guidance should be documented. Compliance with any or all of the contents herein, is entirely at an organisation's own discretion.

Other Guidance Notes or Approved Codes of Practice are available on the Rail Delivery Group (RDG) website.

Executive Summary:

Use of fasteners for older, BR Legacy fleets is explained as a risk area, with adoption of a red-amber-green risk 'triangle' proposed to highlight the need for when more detailed risk evaluation is required, following the methodology of the CSM-RA. A series of generic risk issues associated with fasteners is provided, together with example case studies.

Issue Record

Issues 1 of this document was previously published as: EC/GN007.

Issue	Date	Comments
1	April 2019	First industry release after detailing content and purpose and refining.

This document is reviewed on a regular 3 year cycle.

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Contents

1 Purpose and Introduction

1.1 Purpose

This Guidance Note aims to provide guidance on the procurement and use of fasteners (nuts, bolts, washers) on BR Legacy fleet vehicles. Aspects of the content may also be of benefit to users of more modern fleets.

It is intended for use by TOCs (FOCs) / ROSCOs / ECMs. It is aimed at those who own or are users of maintenance documentation for use on BR legacy fleets (including any changes / modifications that may be made from time to time); those who are translating such maintenance documentation into local depot instructions; and those people involved with the purchasing of fasteners and managers of supply chains.

A risk-based, rather than prescriptive, approach is promoted. This recognises that each individual application can be different with its own specific risk profile, according to vehicle type, owner, maintenance arrangements and depot logistics.

A variety of case studies are provided, to bring the guidance to life and to illustrate the diverse range of applications of the guidance.

A comprehensive list of accessible reference documentation is provided, including regulatory requirements and standards – these are listed in Part 5

1.2 Background

Older, legacy fleets of vehicles (generally those introduced prior to 1994 privatisation on GB mainline railways) are typically from an era when fasteners (nuts / bolts / washers) were specified to BS (or DIN) or OEM part number. The rationale behind why a certain fastener combination is specified for a certain joint is generally not known beyond the original design authority. By contrast, newer fleets will generally have fasteners fitted in accordance with contemporary ISO specifications, with some traceability to design considerations for the particular joint design / fasteners specification.

British Rail (BR) did have a rationale for the selection of fasteners and used its own design guides, resulting also in standardised torque loadings. The design guides transferred to BREL and subsequently Adtranz and Bombardier. However, other manufacturers and consultancies had their own design guides and so fleets other than BR-BREL-Adtranz- Bombardier introduced different practices and progressive mods have introduced further variations within a fleet. Any consistency at original design and build has most likely been lost over time and progressive changes, however well-intentioned, can increase the risk through use of different types of fasteners and fastening arrangements.

Many of the DIN standards currently specified for fasteners were replaced by ISO standards in the 1990's with the DIN standard subsequently being withdrawn. Whereas many of these standards did form the basis of European EN and International ISO standards, there are some subtle differences which means that direct equivalence cannot always be assumed. However, many fasteners to DIN standards are often more readily available than the equivalent ISO standard.

To support the continued operation of legacy fleets, drawings and specifications can be in use for maintenance activities that refer to out of date standards or an OEM that no longer exists or has been taken over by another entity. Whereas the maintenance documentation (VMI, VOI) themselves are likely to have been updated, the specification for the fasteners can still refer to the older BS / DIN / OEM part numbers.

Legacy fleets were designed in an era that pre-dated contemporary methods for determining and documenting the rationale for design, such as FMEA and other forms of quantified risk assessment. Typically, only if there has been a failure and subsequent investigation will there be a greater understanding of a particular joint and the reasons why a particular fastener might be specified. Changes to fastener specifications could have occurred at depot level (eg a change away from original OEM specifications) in BR days without recourse to contemporary risk assessment techniques.

As the end user and ultimate duty holder, the onus is on the train operator (TOC, FOC), in conjunction with the ECM (where that is a separate organisation), to manage the risk arising from:

- Managing changes associated with use of fasteners.
- Specifying equivalent fasteners when attempting to procure against old or out of date specifications.
- Supply chain risk.
- Workshop practices.

1.3 The risk-based approach

ROGS Reg 19 requires a transport operator to:

1. “make a suitable and sufficient assessment of the [safety] risks” for their railway operations;
2. apply the Common Safety Methods; and
3. undertake review when “there has been a significant change” affecting existing assessments or where they have become invalid.

Reference to the Common Safety Methods and significant change inter alia implies use of the Common Safety Method for Risk Evaluation and Assessment (CSM-RA), EU Regulation 402/2013. Note that, in the context of the use of fasteners, the word ‘significant’ does not necessarily imply ‘major’ in terms of the scale of the change. A seemingly innocuous change to the specification for a fixing design for a prime safety critical component (eg an underfloor engine mounting) can invoke catastrophic risk and should qualify for the application of the CSM-RA Risk Management Process.

EU Regulation 445/2011/EU concerning Entities in Charge of Maintenance (ECM) has requirements under the maintenance management function for risk management (Annex III, I.2.3, covering the risks arising from change.

RIS-2750-RST ‘Rail Industry Standard on Supplier Assurance’ sets out a risk-based approach when considering the levels of assurance to be applied to supplied products and services. The degree of risk assessment activity for a prime safety critical, “catastrophic risk” (high outcome, low probability) would be expected to be greater than for routine, low risk items. Tackling assurance of supply in a prioritised, risk-based manner is likely to be considered a reasonable approach.

This Guidance Note thereby brings attention to the link between these aspects of legislation / standards and the contemporary risk-based assurance framework to enable duty holders to discharge their safety responsibilities to an appropriate level. Where possible, this will also enable cost benefits to be realised from a global supply chain without compromising safety or reliability.

NOTE: It is not the intention that any of the controls or other actions outlined in this document be routinely applied in a retrospective manner. However, increased awareness of the criticality of fastener specification issues could lead to a review in some critical applications for which a measure of proactive action might be appropriate.

2 Fasteners Risk Considerations

2.1 The fasteners triangle

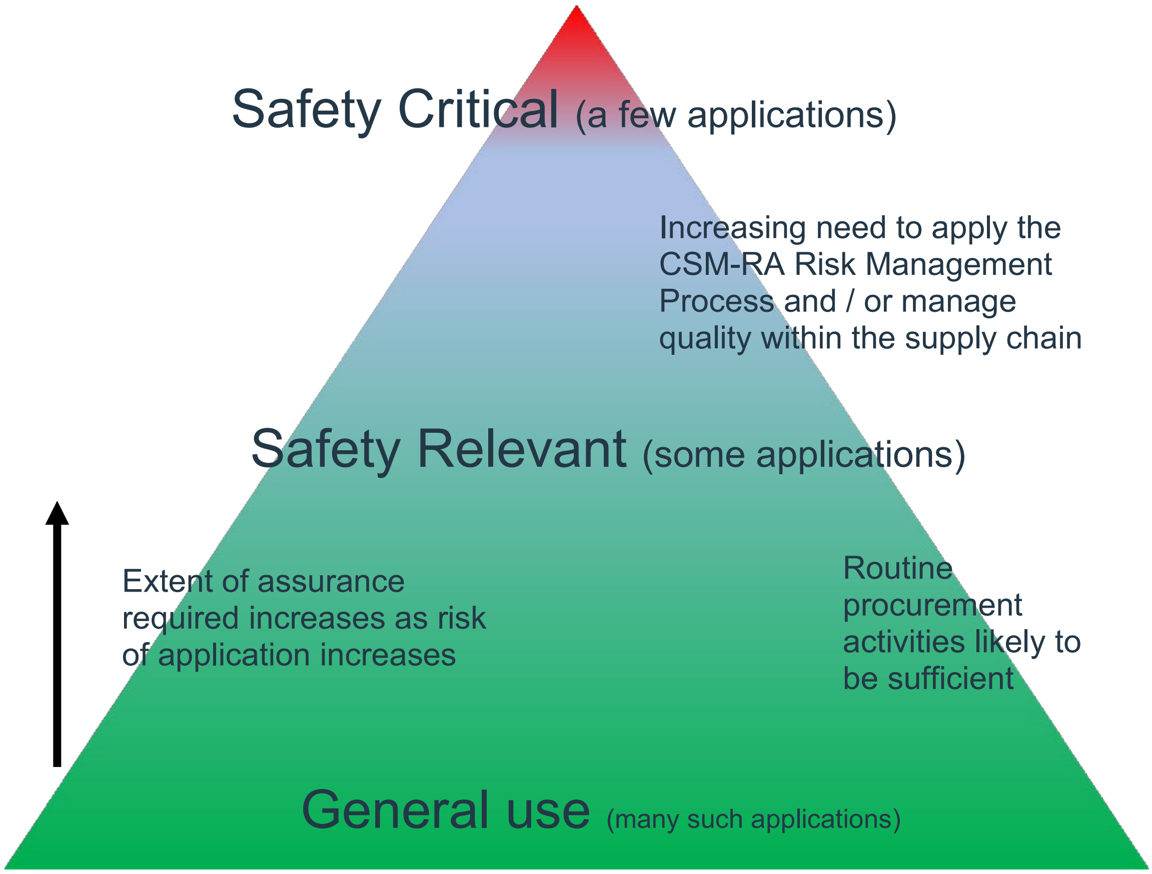


Figure 1 *Diagram illustrating the relative levels of use of fasteners and the extent of risk management required*

Figure 1 above illustrates the relevant levels of criticality of fasteners used on rail vehicles and the corresponding extent of assurance activities required. It can be summarised as follows (the percentage numbers quoted are purely for illustrative purposes and should not be taken as definitive):

- 80% (say) General Use – no special restriction on purchasing should be required over and above routine quality control levels. The exact choice of fastener is unlikely to be critical. An equivalence chart could be used to determine a modern equivalent from legacy “cat numbers” and established documentation.
- 15% (say) Safety Relevant – care should be undertaken when specifying type and grade of fastener to be used or when undertaking change / modification. Typically, such fasteners are used to retain critical components but where additional aspects such as locating lugs, support brackets or secondary retention devices offer some degree of risk mitigation. Each application should be considered on its own merits but examples in this category could include final drives, drive shafts, traction motors, radial arms, primary suspension, lifeguards, etc. Care is required to ensure that fasteners are supplied against a stated standard / specification and that the correct fasteners and assembly processes are used; competent supply chain management is otherwise usually sufficient to control the risks.

- 5% (say) Safety Critical – a situation where a single-point failure could lead to a serious accident, typically derailment risk as a result of detachment. Additional controls are typically necessary to address the quality of the fastener and the assembly of the joint. Any change / modification to an established, proven fastener arrangement would require consideration under the CSM-RA, possibly involving specialist risk techniques such as FMEA and / or engineering design expertise.

The fasteners triangle (Figure 1) should not be thought of as three discrete zones but rather a graduating scale of criticality which allows for all conceivable applications to be afforded appropriate risk-based priority.

For any change to high risk joints, the relationship between torque loading, angular tightening and preload will need to be established by testing to avoid the variability arising from design assumptions. It is also good practice to undertake periodic testing of batches of fasteners to ensure that their ongoing production continues to achieve the design intent of the application. For a very small number of safety critical joints (eg Cl.91 drive link bolts), this may include bench testing of an assembled fastening in a simulation replicating the application.

For 'general use', an equivalence chart can be all that is required. However, caution is advised over routine use of generic charts without understanding fully the application that fasteners are being used for, particularly towards the 'safety relevant' part of the triangle. Each user needs to review their own individual needs, which may be subtly different from another user of a similar fleet (usage, maintenance arrangements, etc may be different, for example), and construct equivalent charts that are tailored to their own needs.

2.2 Generic risk considerations for Fasteners

The following risk considerations are provided to assist Duty Holders when considering changes to fastening arrangement or otherwise investigating an issue associated with fasteners. They are designed to assist with a Hazard Identification (HAZID) exercise (or equivalent) under the CSM-RA and have been grouped together to match the types of risk summarised in 2.2.5 above.

Design-based risks when undertaking change or modification

Does the joint involve underframe or bogie mounted equipment? This has traditionally been the biggest source of risk for fastened joints. Items such as engines and drive trains, Motor Alternator sets, shoe beams have all featured in accidents involving detachment. Components attached to bogies and particularly axle ends are in a high frequency vibration environment. As a result of 'lessons learnt', fixing arrangements for such high-risk components are usually well-understood and carefully specified. In some cases, secondary retention devices are feasible control measures. Where new or changed fastener arrangements for this type of equipment are regarded as 'Safety Critical' (top 5% of Fasteners Triangle), they should be accorded appropriate CSM-RA based evaluation.

What was the purpose of the joint for? A holistic understanding of the design of the joint, how it is intended to function and the interaction with the surrounding structure is necessary to understand any changes being contemplated. There have been examples where (for example), Grade 10 or 12 bolts were specified instead of the more usual Grade 8.8, leading to over-stressing of the surrounding area (in other words, implementing an improvement in one area can create a problem in another – potentially more catastrophic - area).

Generally, Grade 8.8 fasteners is the preferred strength grade. Grade 12.9 fasteners are not normally recommended due to concerns over hydrogen embrittlement.

Understanding and accurate specification of material class is as important as dimensional criteria when determining and specifying fasteners.

Use of prevailing torque (locking) nuts. In the 1980s, BR adopted the use of Philidas nuts – these were preferred to ni-lock nuts due to the risk of the latter's nylon coating melting in high temperature applications. Prevailing torque nuts (such as Philidas) can help but are not a substitute for a correctly tightened joint. An uncoated Grade 8.8 M16 fastener may be tightened to 240Nm. By contrast, the torque required to move a prevailing torque nut, such as a Philidas nut, will be of the order of 30Nm so a very low proportion of the applied torque and insufficient to retain a nut within an incorrectly tightened fastener assembly in a high vibration environment. Additionally, the prevailing torque properties of such devices diminishes with re-use (see further under 3.2.5.3)

Use of washers. A good joint has the minimum number of interfaces, so cleanliness and flatness are important. Washers increase the risk that the joint will come loose (the extra interface can result in additional settlement of the joint) so should be used only where necessary to spread the load under the nut or bolt head to prevent embedding either at assembly or in the in-service vibration environment. Spring washers are largely ineffective; in fact, studies have shown that they can exacerbate a situation, particularly in a vibration environment.

Thread protrusion. Established practice is that a bolt should protrude at least two threads beyond the end of the outer face of the nut to be sure of a secure fastening. Bolts are designed with a chamfer on the end of the thread, so the first thread is not fully formed; the 'two threads' rule is partly on account of this, to ensure full engagement of the thread proper. This is based on the principle that the bolt will always fail first, provided that it engages with all the threads in the nut.

RDG Key Trains Requirement document (KTR). Appendix 5 of the KTR is entitled 'Choice of fasteners' and contains requirements, recommendations and guidance that may be of relevance when undertaking design change modifications involving use of fasteners.

Maintenance-based risks as a consequence of change

Maintenance issues arising from design changes. BR generally specified standard fasteners specification and torque loadings, aligned to its design guides, so the working practices were relatively straightforward – standardisation reduced the risk of confusion. Over the years, a number of design changes have been introduced that are individually satisfactory but can cause issues for the vehicle maintainer as there are detailed differences. Examples include sander brackets on T3 bogies, which are mounted on the radial arm in a similar way to the lifeguards. However, subtle changes in fastener strength, fastener coating and torque loading create a risk of incorrect assembly.

Where several design organisations have been involved over the life of the fleet, there are often several different torque figures used for the same fastener used in different locations, typically a consequence of using different design guides. In such circumstances, there may be an opportunity to standardise such arrangements although caution should be exercised to ensure that the design of each fastening situation is clearly understood when making a change in the name of standardisation.

Fastener coatings. Fastener coatings have changed over time from uncoated nuts and bolts to EZP coatings on one or both without recognition of the changes in thread friction and hence torque / end load relationship that this introduces. EZP coatings can cause hydrogen embrittlement on Grade 12.9 fasteners and so a cold coating process such as Geomet® is preferred*. There have been examples where a Grade 12.9 fastener is EZP coated but the specification requires de- embrittlement before coating. Whilst technically correct, this introduces a risk of fastener failure if the de-embrittlement process is missed. Fastener coating is a specialised process and its short and long-term effects can be complex (the latest version of the relevant standard is ISO 4042:2018 Fasteners - electroplated coating systems). Care should therefore be taken when contemplating any change from proven arrangements. (*other high specification non-electrolytic coating systems available and in use in the UK)

Use of lubricants. In the 1980s, BR generally used uncoated Grade 8.8 fasteners without any lubrication. By the late 1980s, the BT41 bogie on the MkIV coach had lubricated fasteners with a reduced torque loading to achieve the correct preload but this was combined with BR AWS equipment where BR fastener practices and torque loadings were used and some fasteners that used Loctite. These factors could alter thread friction from $\mu = 0.08$ to $\mu = 0.35$, with a proportionate change in preload. This risk is increased at maintenance and overhaul locations that may be working on multiple fleets with different design philosophies. A number of manufacturers (Alstom and CAF, for example) use coated and / or lubricated threads. Where lubricant is applied, it must be used under the bolt head as well as on the threads. Use of lubricants can increase the risk of thread stripping.

Dangerously similar components. There can be fastener components that are visually similar but have very different properties. In the case of bolted joints, this might be a subtle difference in fastener length or a different fastener grade that makes it easy to use the wrong component or apply the wrong torque loading.

Maintenance specification issues. For legacy fleets, it can be the case that changes that have taken place over time are not fully reflected within maintenance specifications leading to a situation where such specifications are at variance with the actual configuration of the vehicles. This can include drawings and specifications referring out of date references for fasteners. This can cause issues for depot staff translating specification information onto shopfloor documentation such as job / route cards and check sheets.

Procurement risks when changing fastener specification

Equivalence of ISO versus older BS or DIN fasteners. In general, an ISO fastener will have prevailing characteristics that are equal to, or superior to, former BS or DIN equivalents. However, ISO 272 (Fasteners – Hexagon Products – Width Across Flats) reduces the across flats dimension of M10, M12 and M14 fasteners by 1 mm compared to that specified in the DIN standards and certain British Standards (such as BS 3692). This change (which was otherwise made to promote consistency across all thread sizes) has the potential to increase the bearing stress acting on the joint if replacing existing DIN/BS M10, M12 or M14 fasteners to ISO. One practical consideration of this is that a different socket size is consequently required.

Where practical, the use of a washer underneath the bolt head and nut will largely negate the above effect and hence the ISO fasteners can be introduced with minimal risk (but see 3.2.1.4). Otherwise, a risk evaluation may be necessary for the joint individually, the extent of which would be related to where the joint lies within the fasteners triangle.

In cases when washers are not used, especially when the fasteners are property class 10.9, either ISO fasteners should be trialled or, alternatively, an assessment completed of the bearing stress acting on the joint, considering its material properties to assess if there is likely to be an issue.

If risks such as those highlighted above are not managed adequately at the procurement stage, then it can be the case that the supplier makes the 'decision' over which fastener to source in the absence of a clear specification.

Thread protrusion. In certain cases, the ISO equivalent of a BS / DIN nut is dimensionally taller and hence will reduce the degree of thread protrusion past the nut. Consequently, an assessment is needed that the bolt length is sufficient to give adequate thread protrusion.

Nut detachment / thread stripping. Nuts conforming to the ISO standard for all-metal prevailing torque type nuts (ISO 7042) have proof loads and prevailing torque characteristics that are equal to, or superior to, nuts specified to the equivalent BS / DIN standards (BS 4929-1 or DIN 980). The consequence of this is:

- ISO first-removal torques are greater than BS equivalents for all thread sizes and hence in terms of preventing nut detachment, the ISO standard is superior.
- Many nuts made to certain DIN standards have reduced loadability compared to the ISO equivalent. A nut having a lower proof load is at increased risk of thread stripping.

Use of a lubricant can lead to increased risk of thread stripping, particularly when the torqued load is close to the proof load of the bolt. An investigation into stripped threads for a Cl.465/466 lifeguard bolts identified that the torque required was at 0.85 of the proof load of the bolt. Without lubrication or special coating this did not cause a problem; it was the use of lubricant that caused the threads to strip.

Other risks arising from change of specification. There can be other reasons for changing specification, possibly as part of a modification or due to non-availability or unacceptably long lead times of the specified fastener. This can inadvertently introduce risk. For example, an uncoated nut may have been replaced with an EZP nut. Later, the uncoated bolt is replaced with an EZP bolt. The individual change in thread friction is not significant but the combination of the two changes affects the torque / end load relationship.

Some suppliers can claim to offer a direct replacement for a fastener specified to an obsolete standard but this advice must be treated with caution as the supplier might not have full knowledge of the application. Legacy BS / DIN fasteners might not always be available from stock, leading to pressure to source an alternative. This in turn might lead to the items being manufactured, effectively as 'specials'. Not only might this entail supply issues such as lead time and batch size but also introduce risk due to the atypical production approach.

Procurement risks (fastener quality) during supply

What is the appropriate level of supplier assurance? In the modern, global market, an understanding of the supply chain involved is required to fully identify risk with the use of fasteners. RIS-2750-RST contains some useful information on this. The first level supplier may in fact only be a distributor who is sourcing the actual fasteners from an undisclosed source (or at least one that is not readily apparent to the end user).

It is a practical reality that the majority of UK manufacturers either specialise in volume parts for higher added value sectors (aerospace, automotive etc) or use more responsive (but expensive) manufacturing techniques to supply smaller volumes, making it difficult to compete in the UK. Sources of supply may be frequently changed as the distributor seeks the most cost-effective supply solution, often from an overseas supplier. Such situations can be controlled by contract terms, for example requiring the supplier to advise of change of source supply. Purchasers should be wary of advantageous price changes; a significantly lower cost can be accompanied by loss of quality and / or service detrimental. The integrity of suppliers' quality assurance system and sourcing policies are critical in such circumstances.

For higher risk fasteners, suppliers should be selected that have technical knowledge and understanding of the critical nature of the application. Depending on circumstances, good practice would be for the fastener supplier to visit the depot / workshop to better understand how their product is being used. Periodic testing of sample items or batch sampling upon delivery might be an option to gain the necessary level of assurance.

Delivery of fasteners to workshop. Delivery of fasteners to the workshop environment typical invokes QMS controls such as delivery inspection, sample testing and appropriate segregation and storage. The degree of these activities should reflect the relevant area of the fasteners triangle. Such activities are typically the responsibility of the stores department; however, some procurement solutions involve the supply of fasteners direct to shopfloor 'Kanban' bins, with bin replenishing undertaken directly by the supplier. Such scenarios can be controlled by contract terms and periodic audit of the arrangement. It is recommended that use of shopfloor bins is focussed on standard grade 8.8 bolts, with any higher-grade fasteners, for specific applications, being held in the stores.

Workshop practice risks

Torque tightening. Modern torque-tightening equipment can provide improved control and auditability of fastener tightening. For example, an "intelligent" torque wrench can be programmed for both torque and angular rotation so that if, say, there are 12 x M16 fasteners to tighten, it will record that 12 x fasteners have been tightened to the applied torque and will detect if one of the fasteners has been tightened twice and another one missed as it will check the rotation needed to apply the torque. This is not fool proof and is expensive but it is a solution that is being adopted in some parts of the supply chain as it provides traceability.

Human performance. In certain high-risk examples, there is a high reliance on human performance in term of the staff who need to tighten fasteners; however, fasteners tend to be treated as low risk items in the supply chain because they are generally low value in cost terms. Such issues have been highlighted in recent studies, notably RSSB research project T774 into the effects of human factors in axle inspection. The content and recommendations of such studies should be understood and communicated effectively through the supply chain, as the risks that are obvious to the duty holder may not be apparent to a sub-supplier who is several steps removed from the risks associated with the operational railway.

Control of fasteners within the workshop. The advent of QMS within railway workshop environments has addressed common issues such as correct storage and labelling, traceability, etc. Nonetheless, the risk remains of mis- use – inadvertent or otherwise – of fasteners. Most safety relevant and all safety critical applications generally prescribe 100% changeout of fasteners when replacing components. Not only is this the logical approach from a simple cost-benefit analysis but it avoids the risk of diminished performance as a result of re-use. Nonetheless, there have been occasions where used and new fasteners have been found in the same storage container, potentially available for further use.

3 Case Studies

3.1 Fasteners case study – Cl.158 Cardan shaft fasteners (NIR3058)

Summary	Investigation into defective bolts highlights the longevity of the supply chain and the benefits of adopting modern ISO standards with consolidation to one manufacturer.
Background	Whilst undertaking a wheelset change on a Class 158, it was evident some of the M14 Cardan Shaft fasteners did not tighten correctly. Fitment of the nut proved inconsistent and removal of the fasteners proved difficult resulting in severe thread stripping. Initial findings identified the suspect bolts to have been marked 'BCSF'. Testing was undertaken on fasteners supplied by an alternative source giving satisfactory results, indicating the problem lied with 'BCSF' stamped bolts. Similar tests were carried out on the M16 fasteners with the same results observed.  Bolts also displayed variable locking properties. When testing a batch of fasteners, it was possible to run the locking nut significantly past the end of the bolt. This occurred on two bolts. The nut was then tried on other bolts and it displayed locking properties indicating that the issue was with the bolt formation.
Scope	All BCSF M14 and M16 bolts were quarantined to prevent further supply. An investigation was undertaken by Unipart Rail Ltd [URL], involving their supplier and independent industry experts. A sample of defective and compliant bolts were sent for thread forming and metallurgical investigation. Load testing was carried out on "re worked" & rejected BCSF bolts after being torque tightened to the required limits. The effective joint interface clamping force was measured and compared with the OEM design authority tolerances for the cardan shaft joint integrity.

Analysis & Findings	Bolts with head stamping 'BCSF' were found to exhibit the thread stripping and nut removal concerns (other head markings were found not to be affected). The independent investigation identified that bolts stamped with 'BCSF' had a different thread form. On tightening, the inconsistent thread form of the 'BCSF' bolts meant they would not freely engage with the thread of the nuts and would

3.2 Fasteners case study – BX1 & BT13 Brake Hanger Brackets

Summary	Review of history of the brake hanger fastener arrangement highlights a variety of design and maintenance issues affecting joint integrity
Background	The BX1 and BT13 bogie type is fitted to a range of EMU fleets dating from the 1970s, including classes 313, 314, 315, 317, 318, 319, 320, 321, 322, 455, 507 and 508. The typical use of such units on frequent stop, inner-suburban services means that the joint is subject to significant cyclic loads due to the high number of braking applications. This has exposed a number of design weaknesses in the brake hanger bracket fastening arrangement, with a long history of failures including at least one mainline derailment recorded. The original tapping plate arrangement was augmented by the use of 'Tappex' inserts to counter the effects of wear. A through bolted arrangement is now the preferred solution and many bogies have been modified to this arrangement. Maintenance arrangements have been implemented over the years as a result of lessons learned.  
Scope	A study of the content of previous NIRs raised to highlight the various issues that can affect the integrity of the joint.
Analysis & Findings	The content of the following NIRs has been reviewed: • NIR1291 Brake Hanger Fixing Bolts (This relates to the derailment of 313106 at Willesden on 4th March 2002) • NIR1302 Brake Support Bracket Securing Bolts with Tappex Inserts (Class 318) • NIR1433 Class 314 Brake Support Bracket Failure (came adrift) • NIR1446 Brake Support Hanger Bracket (Class 313) • NIR2008 BX1 Brake Hanger Bracket Repair Process (Class 507/8) • NIR2317 BT13 and BX1 brake hanger bracket cracks (Class 455) • NIR2430 Class 318 Brake Hanger Bracket Bolt missing • NIR2715 Class 507 Brake Hanger Bracket Bolt Broke • NIR2893 Class 313 Brake Hanger Bracket Bolt Failure • NIR2916 Failure of bolt on Through-bolted Brake Hanger Bracket (Class 313) The following issues are highlighted in the above NIRs: • A lack of surface flatness between the mounting face of the bracket and the bogie transom mating area can be a cause of failure. Specification CR/TP1118 incorporates a combined surface flatness

tolerance of 0.25mm. Surface flatness can be affected by corrosion in this area.

- Poor alignment between the bogie transom and the brake hanger.

The tapping plate arrangement proved to be a less robust method of assembly than a through-bolted joint. The adoption of Tappex inserts,

3.3 Fasteners case study – Cl.150 Lifeguard failure

Summary

Fatal accident caused by failure of fasteners for critical components highlights the rationale behind modern maintenance practices.

Background

On 11th Nov 1988, train 2F31, the 22:10 train from Blackpool North to Liverpool Lime Street, formed of two-car DMU 150 209, became derailed immediately after passing over a junction just south of St Helens Central Station. As it did so, the leading end struck the abutment of a bridge, crushing the front left side of the cab, causing the driver to be killed instantly. 16 passengers in the leading vehicle (52209) also received minor injuries.

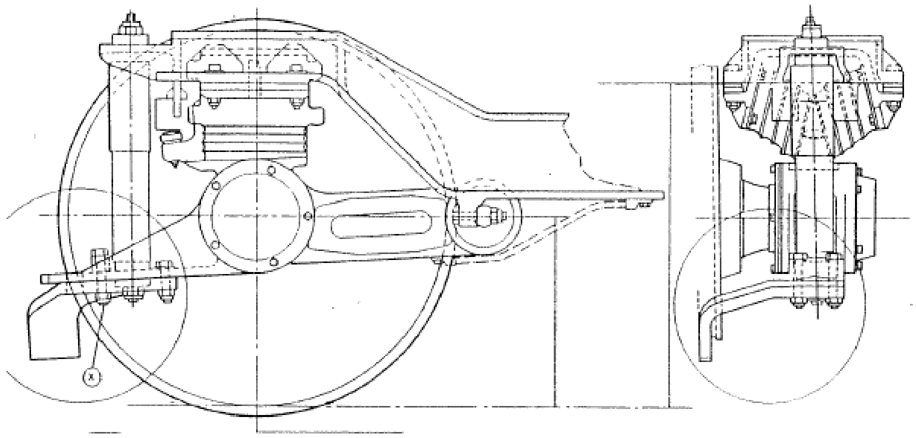
Detailed examination of the accident site showed that the derailment occurred because the left leading lifeguard came into contact with the diverging check rail of the obtuse crossing of the junction, causing the flange of the left-hand leading wheelset to climb over the running rail immediately beyond the nose of the crossing.

Scope

The accident was investigated and reported in a HSE railway accident report, in relation to the inquest into the death of the driver which resumed on 21st Nov 1989. This sought to establish the root cause of the accident.

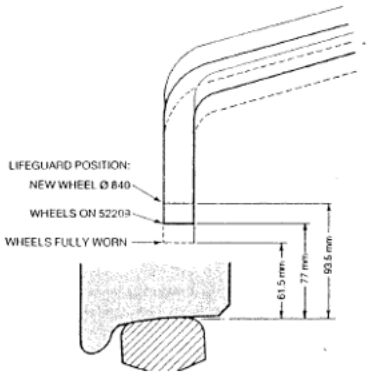
Analysis & Findings

Traditional designs of the lifeguard fixings had been by bolts fitted with castle nuts locked in place by split pins through holes in the bolts. The drawback to this arrangement was that the holes and castellations must be in line and, therefore, the nuts may not be tightened fully, reducing somewhat the strength and hence the effectiveness of the lifeguard.



To meet the lifeguard impact load specification for the Class 150 type, a newer type of fixing, comprising four 20 mm diameter bolts secured by ‘bent beam’, Philidas nuts, was adopted. Although a ‘bent beam’ nut requires additional torque to move on the thread, the important factor is the design pre-load. The design drawing for the Class 150 bogies specified 476 Nm, for which a 3 ft (1m) torque wrench would be required, equipment that was, at the time, not normally carried by artisan staff but available for use at main depots.

If the nuts are disturbed for any reason and not subsequently re-torqued to the correct figure, Philidas nuts may become loose through vibration in service.

	Continuous re-checking of the torque can lead to a loss of effectiveness of the self-locking feature; Philidas Ltd advised the HSE inspector that they could be used up to ten times and tightened to the prescribed torque and still behave satisfactorily. On 8 September 1988, following a defect report in traffic, the leading left-hand lifeguard on car No 52209 was found to be slightly loose, all bolts being present but slightly loose. The nuts were tightened using a ring spanner and a short ratchet tool by an outstation maintenance supervisor, who was otherwise unaware of the considerable torque required to secure the newer type of nut. BR's own investigation led to the following conclusions as to the sequence of events leading to the derailment: a) The two inner bolts of the left-hand leading lifeguard on vehicle No 52209 were missing and had probably been missing for several hundred miles before the derailment occurred. b) The outer two bolts on the lifeguard were in position but were loose at the time of the derailment. Both of these bolts had probably been loose for several hundred miles before the derailment. c) The lifeguard was loose enough to be hanging down towards the rail, at an angle of about 8'. d)The amount by which the lifeguard was loose was possibly enough to reduce the nominal clearance to rail track from 77 mm to 27 mm. e) The loosely hanging lifeguard on vehicle No. 52209 struck a substantial concrete block (and possibly other pieces of concrete) at a speed of about 45 mph some one and a half miles before St Helens Central Station on the evening of 11 November 1988. f) The impact of the lifeguard on the block would have been sufficient to bend the bolts, elongate the holes in the lifeguard, further reducing the clearance to the rail head.  Immediately following the incident, a fleet check was undertaken of the lifeguard bolts of Class 150s, revealing: • 1 lifeguard missing • 1 lifeguard bent and subsequently changed • 2 bolts missing (on separate units) 14 bolts on various units required tightening to the prescribed torque
Deliverable(s) or lessons learnt	The report made recommendations of relevance to fasteners as follows: Self-locking nut and bolt assemblies (as an example of components that are the subject of special instructions) should be identified by sealing or comparable means so that people who do not have access to information readily are aware that special instructions exist and can take appropriate action. All rolling stock fitted with lifeguards secured by self-locking nuts shall be subject to a common practice of replacement of both nuts and bolts on detection of looseness. (BR had already committed to this practice on account of its own investigations in the aftermath of the accident). The accident graphically highlighted that more modern types of fasteners are not fool proof and require specific maintenance arrangements and instructions accordingly.

Impact and / or feedback

The accident happened at a time when the wider adoption of quality / safety management systems was just starting to be implemented by British Rail. The outcome of the investigation and the corresponding recommendations may therefore seem rather basic, almost naïve by current standards; however, the accident serves as a continual reminder of the rationale behind modern day maintenance practices.

3.4 Fasteners case study – Britannia slide bar bolts

Summary

Fatal accident caused by failure of fasteners for critical locomotive components highlights poor design in relation to ease of maintenance

Background

On the 21st January 1960, whilst working the 9.5pm Glasgow to London express passenger train, part of the motion assembly of Britannia steam locomotive No.70052 became detached at around 45mph near Settle, resulting in damage to the formation of the adjacent running line. This caused a passing freight train to be brought into collision with the express train, causing extensive damage to the leading coaches, result in 5 fatalities and 9 injuries.

Examination of the locomotive showed that the two bottom right hand slide bars had fallen off, causing the motion parts to become detached.

Photograph 1. The Britannia locomotive showing the displaced motion assembly.

Scope

The accident was investigated and reported in a Ministry of Transport railway accident report, dated 19th April 1960. This sought to establish the root cause of the accident.

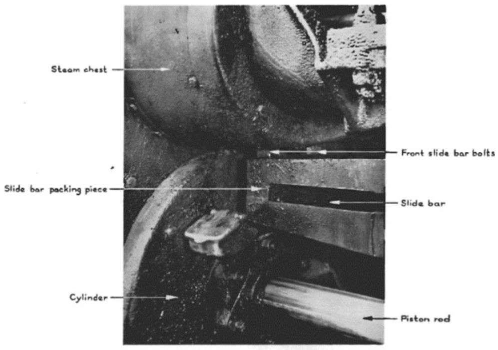
Analysis & Findings

The accident report records that an extensive search of the line took place and many of the missing components were found at various places along the route, the first some 33 miles from the scene of the eventual accident.

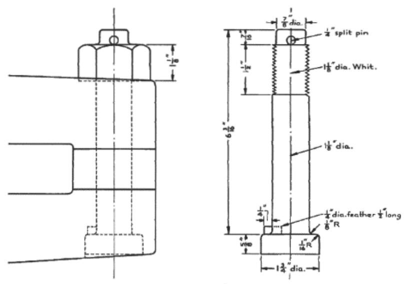
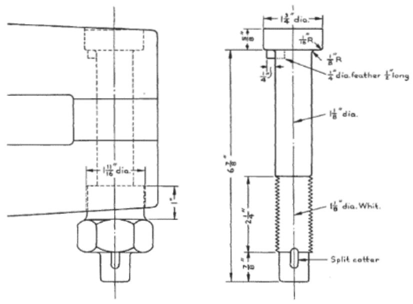
The driver had reported a noticeable ‘knocking’ from the motion earlier in the journey and had stopped at Garsdale station to examine the locomotive but was unable to find anything untoward (the report acknowledges the extreme weather conditions on a dark, January night).

The bolts had been reported as loose (and tightened up) at nine separate inspections in between its last overhaul and the day of the accident.

The investigation into the accident identified that the design of the front fixings of the slide bars made it difficult to tighten the nuts at the top of the bolt assembly, including the insertion of the split pin, due to the presence of the adjacent steam chest cover.



Photograph 3. Front end of slide bar assembly before modification

Deliverable(s)	A relatively simple redesign (which was actually in hand at the time of the accident) reversed the position of the nut and bolt arrangement, and replaced the split pin with a cotter, as illustrated by the following drawings:  FIG. 8 FRONT SLIDE BAR BOLT BEFORE MODIFICATION  FIG. 9 FRONT SLIDE BAR BOLT AFTER MODIFICATION
Impact and / or feedback	The modified arrangement allowed for much easier examination by depot staff and no further difficulties were reported on this class of engine or others fitted with similar arrangements. Although an historical accident, the 'design for maintenance' lesson learnt is nonetheless as valid in the contemporary era. Of note is that two members of the 'Britannia' class (Nos. 70000 and 70013) survive into preservation and both have been active on the GB mainline railway, along with other steam locomotives with similar fixing arrangements.

4 Definitions and Glossary

AWS	Automatic Warning System
BR	British Rail
BREL	British Rail Engineering Ltd
BS	British Standard
DIN	Deutsches Institut für Normung (German Institute for Standardisation)
ECM	Entity in Charge of Maintenance
EN	European Norm (Standard)
EZP	Electro-Zinc Plated
FMEA	Failure Modes & Effects Analysis
FOC	Freight Operating Company
ISO	International Standards Organisation
NR	Network Rail
OEM	Original Equipment Manufacturer
QMS	Quality Management System
RDG	Rail Delivery Group
ROSCO	Rolling Stock Leasing Company
RSSB	Rail Safety & Standards Board
TOC	Train Operating Company
VMI	Vehicle Maintenance Instruction
VOI	Vehicle Overhaul Instruction

5 References

ROGS	The Railways and Other Guided Transport Systems (Safety) Regulations 2006 (as amended) Statutory Instrument 2006 No.599
CSM-RA	Commission Implementing Regulation (EU) No 402/2013 on the common safety method for risk evaluation and assessment
ECM	Commission Regulation (EU) No 445/2011 on a system of certification of entities in charge of maintenance for freight wagons
RIS-2750-RST	Rail Industry Standard on Supplier Assurance EN1090-
2:2008	Execution of steel structures and aluminium structures Part 2: Technical requirements for the execution of steel structures
VDI2230	Systematic calculation of highly stressed bolted joints
BS 3692	ISO metric precision hexagon bolts, screws and nuts
BS 4929-1	Steel hexagon prevailing torque type nuts
BS 7608:2014	Guide to fatigue design and assessment of steel products
DIN 267-15	Fasteners – Technical delivery conditions – Prevailing torque type nuts DIN
931-1	M1.6 to M39 hexagon head bolts (replaced by ISO 4014)
DIN 980	All-metal prevailing torque type hexagon nuts (replaced by ISO 7042) ISO
272	Fasteners – Hexagon Products – Width Across Flats
ISO 898-1	Mechanical properties of fasteners made of carbon steel and alloy steel. Part 1: Bolts, screws and studs with specified property classes – Coarse thread and fine pitch thread.
ISO 898-2	Mechanical properties of fasteners made of carbon steel and alloy steel. Part 2: Nuts with specified property classes - Coarse thread and fine pitch thread.
ISO 2320	Fasteners – Prevailing torque steel nuts – Functional properties ISO
4014	Hexagon head bolts - Product grades A and B
ISO 4042	Fasteners - electroplated coating systems
ISO 7042	Prevailing torque type all-metal hexagon nuts - Property classes 5, 8, 10 & 12

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