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OFFICE OF RAIL REGULATION

2 May 2013

Carolyn Griffiths
Chief Inspector of accidents
RAIB
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GU11 2HP

Dear Carolyn

RAIB Report: Passenger train derailment near East Langton, Leicestershire

I write to report[1] on the consideration given and action taken in respect of the recommendations addressed to ORR in the above report, published on 30 January 2012.

Annex A to this letter provides details of the consideration given/action taken in respect of each recommendation where all 4 recommendations either implemented or are being implemented. Annex B and Annex C provides the detail of the individual responses from each end implementer and are provided as separate documents..

We do not intend any further action n respect of these recommendations unless we become aware that any of the information provided becomes inaccurate, in which case I will write to you again[2].

We expect to publish this response on the ORR website on Mon 20 May 2013

Yours Sincerely

Chris O'Doherty

1 In accordance with Regulation 12(2)(b) of the Railways (Accident Investigation and Reporting) Regulations 2005

2 In accordance with Regulation 12(2)(c)

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Initial consideration by ORR

All four recommendations were addressed to ORR when the report was published on 30 January 2012.

After considering the recommendations ORR passed recommendations 1 and 3 to Bombardier, recommendation 2 to ROSCOs, Contracting Entities and Entities in Charge of Maintenance and recommendation 4 to East Midlands Trains asking them to consider and where appropriate act upon them and advise ORR of its conclusions. The consideration given to each recommendation is included below. Supporting information (individual responses) is provided at Annex B, C and D.

Recommendation 1

The purpose of this recommendation is to reduce the risk of recurrence of a similar final drive gearbox failure on the Meridian and similar fleets.

Bombardier Transportation, in conjunction with Voith, should undertake a design review of the final drive gearboxes and axles used on the Meridian and Voyager fleets (Class 220, 221 and 222) and, where appropriate, implement design and maintenance improvements, including verification of the over-temperature detection, to reduce the risk from loss of output bearing interference fits on the axles.

Actions taken or being taken to address the recommendation

Bombardier responded on 12 April 2012 with the following:

Bombardier and RAIB have conducted a number of reviews of the axle design during the investigation to assess if improvements can be made. These include a review of the fatigue calculations for the original axle design and the recalculation of the interference fits associated with both of the axle mounted gearbox support bearings. The recalculation considered the effect of the hollow axle and the effect of the shrink fit gearwheel on the axle. An interim change to the dimensions of new axles was introduced from January 2011.

A further review is on-going today with Voith, taking into account Timke,n the bearing manufacturers, recommendations. This is considering whether further improvements might be made to the axle, and what these should be. A small increase to the bearing journal dimensions, over and above those made in the interim design change made already is thought to be beneficial in reducing the risk of fretting without compromising the integrity of the bearings.

However, at this point, the exact sizes or the degree of compensation for the angular deflection ('tapering') of the bearing seat caused by the adjacent gear has not been concluded. Mathematical modelling and validation tests will be required in order to determine the optimum design.

A further meeting is planned with Voith and further consultation is planned with Timken to ensure that all the necessary aspects of the design review are considered properly. It is estimated that this process may take up to six months from today.

The fusible plugs were shown to operate under tests at Crewe in 2010 and during the destructive tests at Voith in Germany. Also the very high temperatures created during the East Langton derailment burned the paint from the final drive casing over the entire bearing carrier (where the fusible plug is now mounted) and a considerable area of the adjacent gear case. This burning is evidence that the paint reached a temperature of 350^{o}C – 400^{o}C, greatly exceeding the 145^{o}C required to melt the fusible plugs. This was taken as adequate evidence that had the fusible plugs been fitted at East Langton, they would have operated. However, there is no conclusive evidence that the fusible plugs would operate in sufficient time for the train operator to bring the train to a standstill under all conditions of speed and ambient temperature. For this reason Bombardier has employed a specialist consultancy to create a thermal model which can be used to demonstrate this point. Today, this model is almost complete and validated. Bombardier expects that the results of the modelling will be available during Q2, 2012.

Class 172 models of Turbostar have B5000 style bogies which are similar to those on the Class 22x fleets. These have hollow axles and ZF final drive gearboxes with an interference fit gear on the axle. A separate Risk Assessment has been carried out for these vehicles. This has been published to the owners and operators of these fleets. These fleets have also been fitted with fusible plugs from new

Further and concluding information was received on 19 October 2012:

Bombardier has now concluded its review of the Class 220 and 222 axle designs. We have made some updates to the dimensions of the bearing seats for the final drive which take into account the outcomes of our internal reviews and the discussions with both Timken and Voith. This alternative design will be offered to all owners and operators of Class 220 and 222 trains through their normal engineering change process. It is expected that the alternative design will reduce the risk of axle fretting between the bearing and the axle.

The validation of the fusible plugs has been completed and has been presented to East Midlands Trains. This validation shows that the fusible plug will detect the heat from a failing bearing under all credible conditions.

Bombardier provided ORR with a copy of:

- Validation Report: ‘HEAT EXCHANGE EFFECTS IN A RAIL VEHICLE GEARBOX’ Report No. TEA-004755-22-CR-03A’ and
- BT Presentation ‘East Langton Fusible Plug Analysis’; which summarises the content of this very complex and detailed analysis.

ORR decision

ORR in reviewing the received from Bombardier has concluded that in accordance with the Railway (Accident Investigation and Reporting) Regulations 2005, it has:

- taken the recommendation into consideration; and
- taken action to implement it

Status*: Implemented*

Recommendation 2

The purpose of this recommendation is that safety lessons from the East Langton investigation, in particular that a final drive output bearing failure can lead to axle failure, are captured in procedures for the design and assembly of final drive gearboxes at new build and overhaul, to maintain adequate bearing interference fits.

ROSCOs and other Contracting Entities (purchasers of rolling stock), and Entities in Charge of Maintenance (responsible for overhaul of rolling stock) should review, and where appropriate improve, the design, manufacture and overhaul procedures used for final drive gearboxes in their current and future fleets, in particular those featuring hollow axles, by checking that they adequately address the following factors:

- reduction in the size of output bearing seats due to shrinkage arising from other nearby interference fits and/or wear during service;
- bearing bore growth during the service life of the bearing (e.g. obtained by measuring a sample of bearings);
- bearing seats being made undersize; and
- detection of overheating output bearings

Summary

The following operators responded confirming that their fleets do not use final drive gearboxes and therefore the recommendation is not applicable;

Devon & Cornwall; Direct Rail Services; GB Railfreight and Freightliner.

In addition to Train Operating Companies and Freight Operating Companies responses were also received from Alstom, Angel Trains, Bombardier, Eversholt, Hitachi, Porterbrook and Siemens. A number of the responses were replicated between ECMs, ROSCOS and operators demonstrating that dialogue has taken place between relevant industry bodies.

The responses demonstrated that the following types of fleets were reviewed, taking into consideration the four points of the recommendation: Class 17x, Class 39x, Class 14x, Class 15x, Class 16x, Class 43, Class 31x, Class 220, Class 221, HST, Class 121, Class 37x, Class 32x, Class 45x, Class 33x, Class 36x, Class 395, Class

46x, Class 18x, Class 13x, Class 37x, Class 170, Class 91, Class 66, Class 350, Class 507, Class 508/1, Class 380, Class 444, Class 483.

Of the above fleets, only the Class 172 has similar final drive architecture to the Class 222 with hollow axles. Hollow axles are also present on Classes 357, 67, 60, 92 and 91.

ORR notes that the circumstances of this incident constitute a 'first' for UK Rail and, as such recognise that the learning points from the incident needed to spread across the industry. However ORR also recognises that there is a limitation to it's viraes in this matter in that our powers only extend across Uk rail dutyholders. This limitation is also known and accepted by RAIB with the consequential note to the recommendation (copied below for ease of reference) to cover non UK rail dutyholders. This combined approach has ensured that the lessons learnt have been raised in both the UK and abroad with all identified dutyholders, with those in the UK confirming they have considered the issues for their current fleets and will take them into account for any new.

Note for information relating to Recommendation 2: In conjunction with the publication of this report, the RAIB has written to the European Rail Agency (ERA) to request their assistance with the dissemination of the identified issues to national safety authorities and national investigation bodies in other member states of the European Union, for their information and action as appropriate to their circumstances.

ORR also recognises that this can only constitute a 'snapshot' of dutyholders relevant at the time of this process occurring. However it is a) not reasonably practicable to attempt to predict the who or what of future industry design; b) recognising this, the coverage of all current UK operators coupled to coverage of UK ROSCOs, coupled to coverage of all current passenger vehicle manufacturers means that to the greatest extent reasonably possible, the learning points have been passed on and confirmed as being recognised by these dutyholders.

Steps taken or being taken to address the recommendation

Full details of reviews and final drive arrangements for each operator can be found at Annex B.

A number of TOCs did not address the issue of future fleets in their initial response. ORR wrote again to these TOCs and has received confirmation that the results of the reviews will be taken into account when new fleets are commissioned from all TOCs apart from First Great Western, London Midland and South West Trains.

Separate and independent to the ORR / RAIB Recommendation Handling process, ORR is also aware that industry is currently independently (through the VVSIC) considering whether any guidance should be included in a Key Technical Requirements document.

ORR decision

ORR in reviewing the responses and considering the documents provided has concluded that in accordance with the Railway (Accident Investigation and Reporting) Regulations 2005, ROSCOs, Entities in Charge of Maintenance including TOCs where appropriate have taken the recommendation into consideration and reviewed, and where appropriate improved, the design, manufacture and overhaul procedures used for final drive gearboxes in their current fleets. They have also confirmed this will be taken into account for new fleets in the future.

ORR will seek confirmation that First Great Western, London Midland and South West Trains will take into account the results of reviews will be taken into account when new fleets are commissioned.

We do not propose to take any further action in respect of this recommendation unless we become aware of an inaccuracy in which case we will write to RAIB again.

Status: - Implemented

Recommendation 3

The purpose of this recommendation is to improve the failure detection capability of oil sampling regimes for final drive gearboxes to reduce the risk of future axle failure.

Bombardier Transportation should review the final drive oil sampling regime on the Meridian and similar fleets (including consideration of sampling frequency and consistency, action levels, oil colour and use of cumulative trending) and, where necessary, make changes to maximise effectiveness in detecting impending failures

Summary

Bombardier Transportation (BT), whilst disagreeing with the RAIB's findings, commissioned an independent expert to conduct a review of the oil sampling practices. This review has resulted in a number of recommendations and an action plan which is included below.

ORR did not direct this recommendation to other bodies however, a number of train operators also provided a response, these are included at Annex C for information.

Steps taken or being taken to address the recommendation

Bombardier

On 12 April 2012 Bombardier provided the following information :

Bombardier do not agree with the RAIBs findings on oil sampling, as the actual oil sample records for the failed final drive do not indicate that the final drive was in distress over the months leading up to the accident. Accordingly we do not believe that oil sampling should be considered to be causal.

However, the detailed scrutiny of the oil sampling histories of a range of final drives which were stripped down and examined during the investigation has allowed a better understanding of the way the sample results reflect the condition of the internal parts of the gearbox.

To a large part, the frequency of the oil sampling process depends upon the oil check and change frequency for the gearbox. This itself is dependent on the utilisation of the trains with the TOC concerned. Bombardier will validate the sampling frequencies of the different fleets along with the related action levels.

A broader study has been started with our oil sampling analysis company, Finning, to establish whether there are further process improvements which can be made to sampling consistency by the use of special tools and training.

The usefulness of trending and cumulative trending is being reviewed. Finning use a different approach to cumulative trending to that used by RAIB and by Bombardier in the East Langton investigation. The strengths and weaknesses of these different approaches are being examined.

Updates to the action levels for Classes 220, 221 and 222 have already been made. Different action levels are used for Class 220/221 and 222 fleets due to their different utilisation factors and oil change periodicities.

A staff brief was given to all Class 222 maintainers showing acceptable colours for oil samples and this has been added to the oil sample analysis for classes 220 and 221. Following our reviews with Finnings, it is not thought that this analysis can be automated readily, so a manual check is likely to be the final solution adopted.

It is anticipated that the full review of oil sampling processes will be completed within 6 months.

The following update was provided by Bombardier in October 2012:

As explained in our previous letter, Bombardier does not agree with the RAIB's findings on oil sampling, as the actual oil sample records for the failed final drive do not indicate that the final drive was in distress over the months leading up to the accident and in fact the sampling data strongly indicates that spinning of the inner bearing ring was not the cause of the failure.

Bombardier has commissioned an independent expert to conduct a review of the oil sampling practices in the light of this.

Bombardier provided ORR with a copy of a report, titled: 'Bevel Gearbox Axle Drive Units Best Practise Predictive Condition Monitoring by Oil Analysis, Report Number RBR-12-06-04A'.

There are a number of recommendations in this report which BT has reviewed. Our action plan is set out below:

Recommendation	BT Comments on recommendation	Action to be completed by:
11.1 The oil sampling procedures should be reviewed to ensure that they include a requirement to take an oil sample within 3 hours of a vehicle coming to a standstill.	We have considered this recommendation carefully, but cannot find a way to implement this within the present depot facilities. Trains are maintained during the day shift but finish their previous service the evening before. The depot inspection roads are in use during the night preparing trains for service the following day. As the report shows, we have details of how the levels of contaminants in the oil are affected by standing time. This standing time will be taken into account when the trigger levels are reviewed in response to recommendation 11.7	None
11.2 Bombardier should review the oil sampling instructions to ensure that it adequately reflects the OE suppliers' recommendations with respect to assessment of magnetic drain plugs and the like.	We will review the Maintenance Instructions for alignment with the OEMs recommendations. The Class 17x and 22x Maintenance Instructions will be updated to incorporate revised instructions relating to magnetic drain plugs and magnetic dipsticks if required.	April 2013
11.3 Consideration should be given to implementing a method of tracking oil analysis results by gearbox serial number	This recommendation makes it easier to identify trends in particular gearboxes. Today it is more time consuming to carry out analysis for fleets where this is not provided. This has already been implemented for the Class 222 fleet and the Class 170/3 fleet at Crofton. However the analysis company used for the Class 220 and 221 fleets cannot provide this service without additional information. A review is to be held with the analysis company and this will be implemented if possible.	Complete April 2013
11.4 The procedure to review the colour and appearance of oil when the sample is drawn should be extended to the Class 172 fleet.	BT also considers that this recommendation should be extended to cover the Class 168, 170 and 171 fleets of Turbostars. The Vehicle Maintenance Instructions (VMIs) will be updated to incorporate this requirement	April 2013

Recommendation	BT Comments on recommendation	Action to be completed by:
11.5 The operator / maintainer should have a clear procedure that defines the actions which should be taken in the event of limits being breached. In this respect the Central Rivers “three strikes and remove,” criteria has a lot to commend it. It is clear, unambiguous and not open to any interpretation issues.	This recommendation can only be applied in full by BT where it has a Fleet Maintenance contract, since the decision as to whether or not a train should be operated lies mainly within the responsibilities and processes of the TOC concerned. BT will adopt this best practice process at sites where we have this responsibility. The VMIs will be updated to include the action limits for the contamination levels and the rejection criteria (ref 11.7 below).	April 2013 April 2012
11.6 Class 172 Oil Sampling frequency should be increased to a minimum of one every 60 days. This represents a doubling of the frequency on the Class 172/0,1 sub-fleets and trebling of the frequency on the Class 172/3,4 sub-fleets	The maintenance of the final drives of Class 172 is currently under review. This recommendation will be considered as a part of the review process and updates will be made to the maintenance schedule if deemed necessary.	March 2013

Recommendation	BT Comments on recommendation	Action to be completed by:
11.7 Bombardier as the train manufacturer should (in the first instance) advise all of their clients what their recommended limits for gearbox contaminant should be and the standards that should be used to measure those limits.	Currently, BT has transcribed the oil sample recommendations from the gearbox manufacturers into the VMIs. In some cases these recommendations have been enhanced based on operational experience with a particular fleet. As a result of there being differing manufacturers and experiences, there are significant differences in sampling strategy from fleet to fleet. In the light of the learning points from East Langton, a further review of the elements tested and action limits will be undertaken. The VMIs will be updated to specify the minimum requirements for particular fleets, taking into account any maintenance constraints that may affect the sampling process (see 11.5 above) Please note that the action limits for Class 222 and the oil sampling process for Classes 220 and 221 have already been updated following the incident at East Langton.	June 2013
11.8 There should be a definition of what constitutes a competent oil analysis laboratory, i.e. the tests they should be able to perform, their staff training and competence, equipment calibration, ISO9001 compliance etc. This ideally should be an industry standard	This will be incorporated in the review proposed in response to 11.7	June 2013

Recommendation	BT Comments on recommendation	Action to be completed by:
11.9 Oil Analysis should be purchased against a defined suite of specified tests. It should not be the case (as it is at present) that you purchase what the analysis laboratory wishes to sell you and that often this is price driven. Operators should define to the labs what limits should be applied to all of the oil physical parameters and contamination levels.	This will be incorporated in the review proposed in response to 11.7	June 2013
11.10 Assessment of a gearbox condition based on an assessment of Cumulative Iron content (using either a simple or complex model) has no merit.	This is a statement and requires no further action	None
11.11 The Class 222 should have a simple cumulative limit for Nickel set at 8 ppm	This recommendation is based on an analysis of historic records for the Class 222 fleet. For this approach to be successful in detecting distressed final drives, there has to be a complete and error free oil sample history going back several years. This is very difficult to achieve in practice as the oil samples are being taken in a very dirty environment in difficult conditions. An alternative method of achieving a similar result is the adoption of the 3-Strikes process allied to revised limits as proposed in 11.7. BT will review the alternative approaches and incorporate these into the standardised sampling process.	Mar 2013

Recommendation	BT Comments on recommendation	Action to be completed by:
11.12 The Class 172 should also be subject to an 8ppm limit on cumulative Nickel (until such time as it is possible to cross-reference actual gearbox condition against oil sample analysis results).	The same limits will be applied as for other Class 22x fleets until such time as more detailed information about the performance of the ZF gearbox becomes available	Mar 2013
11.13 The current Class 168 / 170 / 171 fleet limits for Iron and Copper that would appear to be in general use should be reduced. It is suggested that similar Iron limits to those used for the Voith Transmissions (100ppm Caution, 300ppm Critical) would be a good first step.	The VMIs will be reviewed an updated following the review in 11.7 above. As most of these trains are not maintained by Bombardier, Porterbrook, the owners of most of the fleets will be invited to take part in the review	Apr 2013
11.14 The oil laboratory should be made aware of when a new (or overhauled gearbox) has been fitted to a vehicle in order that they can apply a short term increase to bedding in material limits such as PQ and Iron.	It is Bombardier's belief that the existing process which is used for the Class 220 and 221 fleets achieves this in a better way. If successive samples exceed the trigger limits due to running in causing high levels of contamination of the oil, then the oil is changed and further sampling is required. Final drive gearboxes normally bed in over a 3 month period, after which the levels of contamination reduce. If a gearbox fails to bed in correctly, it would trigger an automatic removal from service for investigation. This process will be adopted for the Class 222 fleet in future (see 11.5 above)	None

ORR decision

ORR in reviewing the received from Bombardier has concluded that in accordance with the Railway (Accident Investigation and Reporting) Regulations 2005, it has:

- taken the recommendation into consideration; and

- is taking action to implement it.

We do not intend to take any further action unless we become aware of an inaccuracy in what we have reported in which case we will write to you again.

Status: ***Bombardier taking action to implement the recommendation***

Recommendation 4

The purpose of this recommendation is that train crew are familiar with, and practised in, on-board alarm handling procedures so that correct and timely action is taken to minimise adverse consequences of an out-of-course incident.

East Midlands Trains should provide practical, rolling stock specific, initial and refresher training, that includes the simulation of on-board emergency and out-of-course situations. This should enable drivers and train crew to maintain their understanding of, and familiarity with, correct alarm handling in various scenarios

Summary

East Midlands Trains has provided information to demonstrate it has met the intent of the recommendation specifically on out of course incidents. ORR did not direct this recommendation to other operators however a number have responded these responses are included at Annex D.

Steps taken or being taken to address the recommendation

East Midlands Trains

In its initial response dated 12 April 2012, East Midlands Trains explained:

East Midlands Trains has already initiated a review of their basic training/conversion packages for both train crew and drivers to ensure that practical, theoretical and simulated training in response to emergency and out of course situations fully embrace the lessons learnt. The target completion date for this review is the end of May 2012.

The review will take account of some of the work that East Midlands Trains has already completed such as revised operating instructions, an updated version of the Interactive Virtual Train (IVT) and the RED 32 DVD which includes a reconstruction of the circumstances of the East Langton derailment, including interviews with the key staff involved, focussing on the response of the train crew to the incident.

On completion and approval of the content of the review, the output will be used to develop a one off refresher training for all train crew and drivers. The RED 32 reconstruction and subsequent discussion about the train crew response and what

lessons can be learned will form a central part of this briefing. East Midlands Trains has set a target date of the end of December 2012 to develop this training and deliver it to all staff.

The output of the review will also be used to carry out a review of both the train crew and driver competence management process and briefing cycles to ensure that they include simulation of on board emergency and out of course situations to prevent knowledge fade.

Finally, East Midlands Trains is developing an interactive driver training aid targeted specifically at the class 222 fleet taking into account the additional amount of information presented to the driver by the train management system. East Midlands Trains has set a target date of August 2012

ORR wrote to East Midlands Trains in November 2012 requesting confirmation if its actions. The response is below.

East Midlands Trains identified a number of actions and work streams to ensure recommendation 4 of the RAIB report was robustly addressed. These were broken down into driver specific actions and On-train actions which are summarised below

- *Review the basic training/conversion packages for drivers and on train staff to ensure that practical, theoretical and simulated training in response to emergency and out of course situations fully embraces the lessons learnt*
- *Ensure as part of the review completed initiatives are included in the basic training/conversion packages for Drivers and On Train staff i.e. upgraded IVT, Red 32 DVD, revised operating instructions*
- *Using the output from the review of the basic training/conversion packages, develop a one off refresher briefing for current drivers and on train staff to ensure that practical, theoretical and simulated training in response to emergency and out of course situations fully embraces the lessons learnt, including upgraded IVT, Red 32 DVD, revised operating instructions*
- *Using the output from the basic training conversion, carry out a review of the driver and on train competency management process and the customer host briefing cycles to ensure that they include simulation of on board emergency and out of course situations to prevent knowledge fade.*
- *The output of the review and any recommended changes to be presented to BSSC for formal approval*
- *Develop an interactive driver training aid targeted specifically at class 222, taking into account the additional amount of information presented to the driver by the train management system*
- *Deliver the one off refresher briefing to all EMT drivers and on train staff.*

East Midlands Trains utilises the Compass system as an incident and tracking database, the actions above were entered into database and tracked through to completion and closed out as detailed below

East Midlands trains has conducted a full review of all training, briefing processes and material relevant to the issues identified in the East Langton investigation report.

As a result of this a number of actions have been taken to meet the recommendations of the report and prevent a reoccurrence of the circumstances associated with the incident.

The actions taken include:

- *Notice case items and briefings on the circumstances of the incident*
- *A Meridian bogie has been put on display to train crew with ribbon bolts deployed as example of the axle overheating indication*
- *Drivers and on train training and assessment material has been reviewed and amended to include a greater emphasis on the actions required in response to cab indications and rough riding*
- *An on-going briefing cycle which includes the use of the Red 32 DVD which focuses on the drivers actions*
- *The competence management system assessment criteria and associated questions have been updated relating to class 222 traction*
- *The safety briefing process is being utilised for training and refreshing*

To supplement these actions a further improvement in the delivery of basic training concerning stopping a train in an emergency was introduced in the form of a 'dummy' passenger communication device. This was as a result of an unrelated incident, but also has relevance to East Langton recommendation.

Derby train crews were also re-briefed on this process through the team talk briefings.

A class 222 IVT program has been developed to be used to simulate situations of serious vehicle defects and the associated cab indications.

EMT wanted a free roaming scenario based package that enables a user to demonstrate the action that they would take in the event of an emergency or out of course situation on a Class 222 Meridian. The scenarios are based upon the hard wired fault indications, pass-com and egress operation, with multiple scenarios for elements like 'bogie fault' that may have multiple different meanings

The user will be able to choose where they would need to visit on the train to rectify a defect, and the CGI will reflect any change made by the user. The path of the package will track when the user makes a correct or an incorrect answer. Where incorrect, a prompt will be provided, but details will be logged for review at the end of the sequence. The final printed sign off sheet details the length of time the candidate has taken to complete the scenario, and an overall percentage score.

It is intended that this package will be available for drivers to use for safety discovery learning between formal assessments. It will also be used for training. In order to ensure our drivers are always up to speed, the package will be embedded within our CMS on rules days, and it is the intention that it will be possible for the assessor to print out a summary sheet at the end of a scenario to place on a drivers file. This will include comments if deficiencies have had to be worked through.

A full working version of all fault flows was received on 30 January 2013. This package is the first of its kind and extremely complex in nature, hence the time it has taken to develop. The end result does however enable drivers to be taken through emergency and out of course scenarios to ensure that they are drilled on the actions required to make a situation safe.

This has been incorporated into the STUD briefing process and will now be used during basic and conversion training courses. It will also form a very valuable additional assessment tool.

As previously alluded to we have taken a view that we would wish to aim for further improvement in this area and have identified potential follow up recommendations beyond those required by the RAIB report.

Issues under consideration currently include;

- *Review traction specific actions taken in this report and consider relevance to other traction types operated by EMT.*
- *A provision of a sticker on the 222 cab desk reminding of the rules when a red fault light occurs*
- *Ensure all previous IVT disks are removed from circulation*
- *Reviewing and consolidating the instructions to on train staff concerning out of course events such as rough riding and incorporate all instructions in a user friendly document.*
- *Introducing a formal process to identify the relevance of the content of the RED DVDs to each of the EMT grades and ensuring it is effectively delivered to the appropriate staff*

ORR decision

ORR in reviewing the received from East Midlands Trains has concluded that in accordance with the Railway (Accident Investigation and Reporting) Regulations 2005, it has:

- taken the recommendation into consideration; and
- taken action to implement it.

We do not intend to take any further action unless we become aware of an inaccuracy in what we have reported in which case we will write to you again.

Status: ***Implemented***

Responses to recommendation 2

Alstom

The following table and comments relate to the fleets currently maintained and/or of which Alstom provide a technical input with the Train Operating Company responsible. Predominantly the more applicable stock is identified in the table below. As such a number of points may be replicated with the relevant TOCs concerned as this information was also requested and issued to them.

	Factor	Response for 175 train sets	Response for 390 train sets
1	*Reduction in size of output bearing seats due from shrinkage arising from other nearby interference fits and/or wear during service.*	*The Class 175 wheelset does employ an interference fit to secure the gearwheel to the axle. However the axle is solid, which limits any shrinkage.* *Also see response to item 3 below.* *The gearbox OEM (Voith) has assured Alstom that the design interference fit (between the output bearing and the axle) is robust.*	*The Class 390 wheelset design does not employ an interference fit to secure the gear wheel to the axle. No other axle components are fitted with an interference fit sufficient to cause shrinkage of the output bearing seats.* *The gearbox OEM (Voith) has assured Alstom that the design interference fit (between the output bearing and the axle) is*
2	*Bearing bore growth during the service life of the bearing (e.g. obtained by measuring a sample of bearings)*	*A sample of gearboxes passing through overhaul will have the output bearings removed, and the bearing bores and axle diameters measured. The over hauler has been requested to use a three-point gauge which will provide valuable data on the actual interference fit after service operation. Additionally, the inner rings of all new Class 175 output bearings,*	*The next thirty Class 390 gearboxes to be overhauled (commencing in April 2012) will have the output bearings removed, and the bearing bores and axle diameters measured. The over hauler has been requested to use a three-point gauge which will provide valuable data on the actual interference fit after approximately 750,000 miles of service operation.*

		has also been requested to be measure (using a three-point gauge). This along with accurate measurement of axles will ensure the required interference fit is met.	*Additionally, the inner rings of all new Class 390 output bearings has also been requested to be measured (using a three-point gauge). This along with accurate measurement of axles will ensure the required interference fit is met.* *Alstom have completed an Engineering Change with the output bearing supplier (Timken) so that the bearings are guaranteed to be thermally stable to 150°C. This further reduces the risk that inner ring growth due to retained austenite transforming to martensite can occur and increase the inner ring bore diameter.*
3	*Bearing seats being made undersize*	*Alstom have specified that whenever the output bearings are removed, the axle diameter (at the output bearing seat) is measured to confirm it is within the specified tolerance.* *Any failures will be recorded so the data can be analysed.*	*Alstom have specified that whenever the output bearings are removed, the axle diameter (at the output bearing seat) is measured to confirm it is within the specified tolerance.* *Any failures will be recorded so the data can be analysed.*
4	*Detection of overheating output bearings*	*The Class 175 bogie does not currently include any monitoring equipment. The cost of introducing an output bearing temperature monitoring system to*	*The Class 390 Final Drive already incorporates one probe to detect overheating of the input pinion bearing assembly; these*

		the Class 175 fleet is considered to be disproportionate when compared to the safety benefit (and also when taking into consideration the actions highlighted above).	*bearings are monitored as they are the most highly loaded in a Class 390 Final Drive.* *Alstom will carry out a feasibility study into whether this single temperature probe should be re-positioned to one of the two output bearings or whether additional temperature probes can be included in the existing system to monitor the output bearings. If a feasible solution can be identified Alstom will undertake a cost benefit analysis (as per RSSB guidance) to compare the costs versus the safety benefit.*

With respect to other Stock of which Alstom have an interface with. The design of the drive arrangement on Metro - Northern Line Tube stock is quite different as the motor rotates in parallel with the axle and with the transmission through a double reduction gearbox that is axle mounted. The other pertinent point is that the axle is solid. The output shaft bearings are renewed at overhaul with all trains having been through a bogie overhaul in the last 2 years.

Consequently Alstom have no experience of output shaft bearing failures with this type of arrangement. However, we will review the overhaul specification to provide assurance that the interference fit requirements have been correctly specified and are checked during refit of the gearbox. With respect to Tram vehicles of which Alstom are also connected to at Nottingham i.e. Bombardier Incentro trams. These have individual stub axles for each wheel with the drive motor and gearbox mounted at 90 degrees to the wheel. As such we don't believe any parallels can be drawn with the original incident identified.

Finally it should also be noted that Alstom undertake within their Exam regimes, for various stock, oil sampling as good practice to pick up any long term rotation / procession of components on axles.

Angel Trains

Angel Trains has seriously considered the implications of the RAIB report into the East Langton incident. This was a highly unusual incident, the subsequent investigation and test programme by RAIB in conjunction with relevant stakeholders has not conclusively proven a cause. Notwithstanding this Angel Trains agrees that significant loss of fit of the final drive output bearings on the axle is not a design condition and should be avoided.

2.1 (Reduction in the size of output bearing seats due to shrinkage arising from other nearby interference fits and/or wear during service)

(a) Angel Trains has reviewed the design of final drives fitted to its vehicles to consider their sensitivity to output bearing fit and likelihood of loss of fit. The Angel Train fleets with final drive type transmissions may be grouped as follows, medium speed diesel multiple units class 142, 150, 153, 156, 158, 165, 166, 172, 175, high speed diesel multiple units class 180, and high speed electric multiple unit class 390 (Pendolino). Vehicles fitted with gearboxes with coaxial input/output shafts such as Class 43 High Speed Train power cars and contemporary electric multiple units such as class 466 and older transmission types such as 317 with an axle hung motor and suspension tube arrangement have been excluded from detailed review as they fall outside the definition of final drive as shown in the RAIB report and long experience has shown that these to date have not suffered similar failures.

The older self-changing gears (SCG) final drives fitted to the class 142 have a shrink fit gear, combined with a solid axle and relatively slender hub and stress relieving groove between the gear hub and nearest output bearing. The Gmeinder final drive fitted to Class 150, 153, 156, 158, 165, 166 also has a solid axle with a bolt on gearwheel. The Voith final drive fitted to class 175/180 has shrink fit gear with the adjacent output bearing hard up against the hub, but with a solid axle. The class 390 has a Voith final drive combined with a small bore (65mm) hollow axle and bolt on gearwheel. None of these arrangements combine the critical factors of heavy shrink gearwheel with gear side output bearing hard up with slender hollow axle (110mm bore 45mm wall thickness). No action is proposed for these classes.

Voith and other suppliers of final drive overhaul services have confirmed that they check the seat dimensions of both new and used axles prior to assembling final drives. Class 142 axles fitted with SCG final drives suffer some fretting but this is under control and the level of fit has recently been increased to reduce fretting.

Angel Trains do not consider that any additional measures are required for SCG/Gmeinder/Voith final drive arrangements described above. The extent of experience over a much longer period than the class 222 B500 Voith arrangement shows these drives to be reliable. Neither the SCG nor the Gmeinder share the critical features of a large bore/slender radial wall thickness combined with shrink fit gear and adjacent output bearing as found in the class 222 B5000 arrangement.

The class 172 has a ZF final drive with a very similar architecture to the class 222 design and the same slender hollow axle. The risk presented by class 172 final

drives has been mitigated by the fitment of on board Hot Final Drive Detection (HFDD) which connects to the on board Hot Axlebox Detection (HABD) system and warns the driver should an axle bearing or final drive axle bearing run hot. In addition the class 172 final drives are fitted with 'ribbon bolts' which have an enlarged head featuring a cavity with a ribbon enclosed by a fusible cap. Should the temperature exceed the set point of the cap (124˚C) the ribbon is released serving as an early warning to maintenance staff.

(b) As above Angel Trains consider that only the class 172 ZF final drive shares its critical features with the class 222. The class 172 has only just entered service and the first wheelset/final drive overhaul is planned to be in 8 years' time. AT are yet to specify the overhaul these drives receive, but will ensure it takes account of the East Langton recommendations as regards the measurement of bearing seats to assess acceptability for reuse, and also output bearing inner ring bores, if the manufacturer permits re use of these items. As above on board HFDD and ribbon bolts have been fitted to mitigate this residual risk.

2.2 (Bearing bore growth during the service life of the bearing (e.g. obtained by measuring a sample of bearings)

(a) AT considers that the length of experience with SCG and Gmeinder final drives fitted to the classes above validates that the degree of bearing bore growth is at a tolerable level and controlled by current overhaul procedures and therefore that no monitoring of bearing inner ring growth during service life is required. Similarly the risk with solid/small bore axles fitted to class 175, 180 AND 390 is considered tolerable.

(b) AT propose to implement the recommendation by monitoring the degree of bearing bore growth experienced by class 172 ZF final drive output bearings at first overhaul. AT will work with Bombardier and ZF to specify either new bearings to be fitted at overhaul, or the extent of any permitted bore growth to be specified and measured if the bearings are allowed to be reused. If any final drives undergo premature overall, AT will take the opportunity to measure output bearing boxes.

(c) As detailed in 2.2 (a)

2.3 (Bearing seats being made undersize)

(a) Voith and LH Group Services were contacted as representative over-haulers and they confirmed that both new and used axles had their output bearing seats checked prior to final drive assembly. AT and Porterbrook are jointly re issuing the Gmeinder and SCG final drive overhaul specifications and will add a clause to state that both new and used axles shall have the output bearing seat diameters checked prior to final drive assembly.

(b) As 2.3 (a) Gmeinder and SCG overhaul specifications will require the measurement of output bearing seats prior to final drive assembly. Voith and ZF overhaul their final drives (where fitted to the AT fleet) to their own specifications. AT

has requested a written confirmation from both parties that their internal procedures include checks of new and used axle dimensions. Finalisation of the Gmeinder specification and Voith/ZF confirmations are expected by May 2012, completion of the SCG specification is expected by the end of July 2012.

(c) See 2.3 (a) and (b)

2.4 (detection of overheating output bearings)

(a) AT considers that the length of experience with SCG and Gmender final drives fitted to the classes above, and the lower sensitivity of Voith final drives fitted to class 175, 180 and 390 validates the risk of overheating bearings on these classes to be acceptably low. On class 172, the on board Hot Axle Box Detection system (HABD) (Required due to the inboard axle bearing fitted not being visible to track mounted detectors) has been extended to protect the final drives to form the HFDD system. Bombardier have justified that the rate of heat flow from failing output bearings to the plug location, in combination with the temperature setting ensures that the alarm will trigger before the axle is at risk of failure. In addition 'ribbon' bolts have been fitted as described above and normal inspection of the bogie as specified in the Vehicle Maintenance Instruction (VMI) calls for checks of these.

(b) See 2.4 (a)

(c) See 2.4 (a)

As regards future fleets, AT will seek to incorporate the lessons learnt in future industry standards such as ATOC 'Key Technical Requirements' document.

Cross Country

1.1.1. Class 220

Review of design procedures

As a result of the East Langton incident, the Bombardier internal axle design procedures have been amended to highlight the need to consider the influence of the hollow axle. In addition, Voith (gearbox manufacturer) internal design procedures also fully consider the influence of the hollow axle (as recognised in RAIB paragraph 199 (design selection of the bearing fits)). The selection of the required interference fits will remain will remain the responsibility of the gearbox supplier but Bombardier will review the selection during the design process to ensure that the hollow axle is correctly considered. For the class 220 vehicles this ring growth has been measured and shown to be acceptable if the original 'as-designed' interference criteria are obtained at assembly.

Review of manufacturing procedures

Bombardier and Voith have both reviewed their manufacturing procedures and are confident that all aspects of hollow axles are satisfactorily addressed by the revised processes put in place in the supply chain. This ensures that any axles proposed for

use (or re-use) have the bearing seats checked with the gearwheel installed, and mitigates any risk of manufacturing undersize axles.

1.1.2. Class 221

During investigation work into final drive periodicity extension, a number of class 221 final drives have been examined during strip down at Bombardier's Crewe facility.

The opportunity was taken to measure the outside diameters of the axles and inner diameters of the bearings to calculate the actual in-service interference. Comparison of the reports, which were produced to support the periodicity extensions, clearly demonstrates that the interferences seen on the Class 221 axles are significantly higher than those for the class 220 axles.

During the East Langton investigation, advice was sought from Timken, the bearing manufacturer, on the minimum safe in service interference for continued operation. Timken advised that a minimum interference of 0.025mm was appropriate, taking into account the deformation of the axle as a result of the fit of the gearwheel and the phenomenon of bearing ring growth.

Based on the measured axle bearing seat and inner bearing diameters, the calculated interference for class 221 bearings is significantly higher than the minimum acceptable (0.025mm) and remains higher than the minimum design interference (0.075 – 0.120mm). The worst case interference value calculated for the class 221 data was 0.078mm).

In order to gain a better understanding of the interference of the gearbox output bearings, and to support the gearbox overhaul periodicity extension work, an additional check was introduced on all class 22x axles during overhaul at Crewe. The wheelset route card now requires that the gearbox bearing seat diameter is measured (both gear end and non gear end) and recorded on the route card. Minimum acceptable dimensions and the interventions required are specified on the route cards. It should also be noted that it has not been considered necessary to amend the design parameters of the interferences in the case of the class 221 axles.

1.1.3 HST

The transmission design on HST power cars is different to that on Class 220/221. The HST power car axle design is not compromised with transmission bearings shrunk onto the axle, as the only bearings, on the axle are those mounted in the axlebox itself. The transmission bearings are held within a separate gearbox and the drive transmitted by a quill tube and series of traction links.

1.1.1 Class 170

Class 170 vehicles utilise final drives manufactured by ZF, which unlike the Voith final drives fitted to the 22x units utilise a solid axle and a crown wheel bolts to a forged flange on the axle. This type of final drive configuration is therefore not susceptible to final drive output bearing seat diameter reduction.

1.2 *Bearing bore growth during the service life of the bearing (e.g. obtained by measuring a sample of bearings).*

*1**.2.1 Class 220***

The selection of the required interference fits for the axle/journal/gearbox output bearing will remain the responsibility of the gearbox supplier. However, Bombardier will review the bearing size selection during the design process for future axles/gearboxes to ensure that issues relating to hollow axles are considered, and that consideration of bearing bore growth (ring growth) has been addressed correctly. For class 220 vehicles, ring growth has been measured and shown to be acceptable providing the original as-designed interference criteria are achieved at.

1.2.2 Class 221

Calculated interference fit of gearbox output bearings from data obtained during class 221 final drive overhaul periodicity extensions has demonstrated that interference fits for the class 221 gear wheel end output bearings are not significantly affected by inner ring growth. Bearings from the gearboxes sampled for the overhaul periodicity extension exercise were removed and measured to enable the calculated interferences to be determined. Together with the measurements taken of the output bearing seats, these measurements demonstrate that the interference fits remain within the design tolerances and significantly above the minimum safe interference (see also previous comments on overhaul in section 1.1.2).

1.2.3 HST

The transmission design on HST power cars is different to that on Class 220/221. The HST power car axle design is not compromised with transmission bearings shrunk onto the axle, as the only bearings, on the axle are those mounted in the axle box itself. The transmission bearings are held within a separate gearbox and the drive transmitted by a quill tube and series of traction links.

1.2.4 Class 170

The RAIB report (point 114) stated that 'inner ring growth is a known phenomenon' and that allowance is made for this bore growth in the interference by the bearing manufacturers'. Given this and the length of experience the vehicle owners (responsible for final drive overhaul) has with ZF final drives, it is believed that the degree of bearing growth is at a tolerable level and controlled by current overhaul procedures.

1.3 Bearing seats being made undersize

1.3.1 Class 220

Review of overhaul procedures

Bombardier will review wheelset Component Overhaul Instructions (COI) that have been written by the company to ensure that they include measurements with pass/fail criteria for bearing journals on axles. For the class 220 COI, this will be

completed in advance of the next final drive overhaul scheduled for January 2013. In the interim period, Bombardier's final drive overhaul facility at Crewe is checking the output bearing seat diameter of every wheelset undergoing final drive disassembly when the adjacent gearwheel is installed, and is replacing thje axle if specific limits are exceeded.

Bombardier's facility at Crewe is also adopting a policy of selective fit of bearings (selecting specific bearings for specific axles) on axles that exhibit slightly undersize bearing seats, in order to maximise interference between bearing and axle. The limits for adoption of undersize seats are tightly controlled, and in any final drives so affected are recorded and subject to a limitation on overhaul life of 500,000 miles. This change was adopted from August 2010.

A further policy introduced at Bombardiers Crewe facility is the use of a revised design for new axles. This includes a greater wall thickness and increased diameter bearing seats to ensure the design interface is maintained.

1.3.2 Class 221

A review of the overhaul process has taken place and the bearing seat diameters of all axles are now routinely measured during the wheelset build process at Bombardier's Crewe facility. The class 221 final drive Component Overhaul Instruction is currently being updated to include specific references to this requirement.

1.3.3 HST

The transmission design on HST power cars is different to that on Class 220/221. The HST power car axle design is not compromised with transmission bearings shrunk onto the axle, as the only bearings on the axle are those mounted in the axlebox itself. The transmission bearings are held within a separate gearbox and the drive transmitted by a quill tube and series of traction links.

1.3.4 Class 170

During manufacture the dimensions of axles are checked to ensure they are to specification. This is also generally re checked by the over-hauler (whom is RISAS approved) during assembly of final drives.

1.4 Detection of overheating output bearings

1.4.1 Class 220

A system to detect overheating final drive gearbox bearings was designed and installed on the class 220 fleet during summer 2010. The system provides indication to the driver via the Train Management System (TMS) and Bogie Fault indication lamp (hard wired) that a final drive has reached at least 146 degrees C, and requires an inspection. Additional fusible 'ribbon bolts' (set to 124 degrees C) are installed to provide a backup indication to train crew at the line side, and also to maintenance personnel that a bearing is operating at elevated temperatures.

1.4.2 Class 221

Consideration was given to incorporating an overheating output bearing detection system on class 221, similar to that introduced on Class 220. However, following completion of a comprehensive risk assessment, it was concluded that the design of the axle is sufficiently different in the case of Class 221, such that a bearing failure is no more likely to cause axle failure on this class of vehicle than on any other class fitted with axle mounted gearboxes (with the exception of Class 220 and Class 222).

The technical arguments within this risk assessment have been reviewed by an Independent Competent Person (ICP) within Bombardier. The overall risk assessment process has been reviewed and endorsed by a Network Rail accredited Independent Safety Assessor (ISA).

Notwithstanding the decision not to install an overheating output bearing system for Class 221, ribbon bolts as fitted to Class 220 gearboxes have also been installed on class 221 gearboxes. However due to differences in the design of bogie/wheelset, in the case of the Class 221 units, it is not possible to see the ribbon bolts on these vehicles when viewed from the trackside because they are obscured by the in board brake discs. It is thus only possible to observe the ribbon bolts form beneath the vehicle when it is over a maintenance pit. As such this ribbon bolt is only relevant to Maintenance personnel.

1.4.3 HST

In view of the axle design discussed in 1.1.3 above, and there being no reported HST power car axle failures, it is not necessary to introduce a system for the detection of overheated output bearings.

1.4.4 Class 170

The class 170 fleet has an excellent safety record in terms of final drive performance, with no reported history of final drive output bearing failure. On this basis it is not considered necessary to monitor the temperature of final drives

Arriva Train Wales

The trains operated by ATW with final drives are class 121, 14x, 15x and 175. All of these units have different final drives with solid axles and therefore do not have the same combination of critical features found in the final drives of the class 222 units. ATW has not experienced any significant issues with final drive axle bearings on any of these units.

The responsibility for undertaking the majority of axle and final drive overhauls on these fleets rests with leasing companies Angel Trains Limited and Porterbrook Leasing Company Limited for class 14x and 15x units, and Alstom Transport Limited for class 175 units. ATW is responsible for the overhaul of the class 121 unit and a

small quantity of class 143 units, which are overhauled to common industry overhaul specifications.

These organisations have provided responses on this matter separately to ORR. We have copies of the letters and are satisfied with the information and actions they contain in so far as they apply to the rolling stock we operate.

C2c

C2c operate class 357 vehicles only, these are maintained by Bombardier at East Ham depot. C2c have discussed this recommendation with Bombardier and Bombardier have confirmed they will respond centrally via the relevant NIR for overall gearbox strategy. While the gearbox installed on the 357 fleet is similar in nature to that on the 22x, they are in fact not the same part and have different associated specifications. The 357 COI is currently under review, and any pertinent improvements will be incorporated for the next overhaul phase.

In terms of local actions, Bombardier are in the process of introducing routine gearbox oil sampling at a 45k periodicity which would identify any breakdown of bearing condition either by increase in tell-tale element levels or wear debris analysis.

Chiltern Railways

Chiltern Railways operate the following fleets with final drive gearboxes:

Class 121/960 – These vehicles have a F239 final drive. They are used at a maximum speed of 40mph in passenger service and 60mph in departmental duties. When required, their final drives are overhauled using best practice as there is no historical specification that we aware of for these vehicles. This is not ideal but we are happy that the risks of final drive failure can be managed in this way given the age and limited use of these vehicles. It is likely that if there was a risk of wear/movement of the final drive output bearing on the bearing seat that this would have been detected historically and would be a known issue. We are not aware of this from our use of these vehicles.

Class 165 – This has a Gmeinder GM190 final drive mounted on a solid axle. The final drive design and arrangement is well established and has been in use in the rail industry for over 30 years. A range of design and maintenance improvements have been made over the years. The final drives are overhauled to a common ROSCO specification CR/CI0567. This covers measurement of the output bearing seat. We feel that this adequately covers the risks raised by the RAIB report supported by recent operating experience.

Class 168 – this fleet has a ZF part numbers: 5080005006, 5080004006, 508,0076021, 5080074011 final drives mounted on a solid axle in both 120mm and 130mm axle diameter variants. It is widely used across the UK class 168/170/171

Turbostar fleet. All our power wheelsets are returned to ZF for the final drive overhaul. This includes a magnetic particle inspection and ultrasonic testing of each axle plus a visual examination to check for any signs of scoring or drainage on all seats. On fitment ZF check the back seat with a feeler gauge to ensure the input bearings are fully seated against the back-face and all bearings are 100% replaced. ZF is reviewing its process and are implementing a dimensional check of the Output Bearing Seat following the East Langton incident.

Class 172/1 – this fleet has a ZF final drive mounted on a hollow axle. It is an evolution of the class 220/222 bogie in use with all class 172 fleets. The East Langton incident occurred during the engineering development phase of the fleet and as a result it was modified to include in service final drive monitoring as part of the axle bearing monitoring equipment. We have not reached the point where it is necessary to overhaul a final drive with this fleet and are therefore yet to prepare an overhaul specification. It is likely that we will use ZF for the overhaul of these final drives as we currently do for the class 168 fleet. We expect to conduct the first overhaul of these wheelsets in 2017 and will prepare a specification in 2016 for this.

In conclusion, we have reviewed the overhaul specifications for final drives fitted to our units and believe that the risks highlighted by the East Langton report are adequately managed by existing specifications for vehicles built before 2005. We will take note of the east Langton report when we prepare an overhaul specification for our class 172/1 units.

Colas Rail

Colas Rail is an Entity in Charge of Maintenance (ECM) but does not undertake invasive maintenance procedures on drive axles or their associated final drives. Colas Rail service exchange these items and fit either new or re-conditioned units; therefore we do not produce, follow or influence overhaul procedures for these items but instead rely upon the expertise and experience of the Original Equipment Manufacturer or relevant RISAS contractor.

Colas Rail will ensure that contractors that provide drive axles and associated final drives are forwarded a copy of the RAIB report requesting that they pay particular attention to recommendation 2 of the report. The Colas Rail audit procedure A6-288 "Audit Protocol of Safety Critical Suppliers" has been amended to incorporate the recommendation and will henceforth form part of the audit of these suppliers where appropriate.

DB Schenker

Class 67 Locomotives

Introduced 1999/2000: These locomotives are fitted with hollow axles, having outside bearings (as opposed to inside bearings as per class 222 vehicles) and Siemens (Flender) final drive units.

We are in discussion with Siemens as to Siemens:

1. *Providing an assessment of the design and technical opinion/calculation as to risk of failure;*
2. *Providing details of the measured bore sizes of the bearings that have already been removed through the overhaul process (although it is to be noted that this data is small);*
3. *Providing details of the bearing seat sizes of the axles that they have stripped and the new axles that have been fitted;*
4. *Detailing any proposal as to a system to detect irregular bearing temperatures;*
5. *Detailing any proposal to carry out oil sampling, since currently none is proposed by Siemens.*

In addition DB Schenker has also reviewed bore size for this hollow axle design, and would advise that the axle wall thickness is 77.5mm beneath gear wheel seat (noting that the axle journal is not adjacent due to having outside axle journal bearings) and 75mm thick at gearbox bearing seat.

<u>Class 60, Class 92 Locomotives</u>

Introduced 1990s and 1994 respectively. These locomotives are fitted with hollow axles, having outside bearings and normal design traction motor suspension motor.

DB Schenker has reviewed the bore sizes for these hollow axle designs, and would advise:

1. *For Class 60 Locomotives: the axle wall thickness is 84mm beneath gear wheel seat (noting that the axle journal is not adjacent due to having outside axle journal bearings) and 83.5mm thick at suspension tube bearing seat;*
2. *For Class 92 Locomotives: the axle wall thickness is 76mm beneath gear wheel seat (noting that the axle journal is not adjacent due to having outside axle journal bearings) and 73.5mm thick at suspension tube bearing seat.*

We are further reviewing the axle stress calculations together with return of experience data from our wheelset over-haulers.

<u>Former National Power Coal Hopper Wagons</u>

Introduced 1995. The wagons are fitted with LTF25 bogies having wheelsets with solid axles, inside bearings (as per class 222 vehicles), with no traction system fitted (i.e., trailer wheelsets).

- *Bearings fitted built in fusible plug that dumps the air brake pipe if bearings are running warm (since due to being inside bearings, they are not viewed by Network Rail's infra-red Hot Axle Box detectors);*
- *The axle was redesigned (twice) for this particular build of wagons – the previous designs having suffered cracks in the area under the bearing seat;*
- *The maintenance of these vehicles requires an on-going check for any lateral play in the bearing assembly (this is an indication of excessive end float due to relaxation of the interference fit assembly of components);*

- *The vehicles fitted with this bogie (some vehicles have been retro-fitted with TF25 bogies, having conventional outside bearings which are view by Network Rail's infra-red Hot Axle Box detectors) are all stored awaiting decision as to future use. Even if the vehicles were to be returned for service with their existing LTF25 bogies, before they return to service the vehicles require their wheelsets and bearings to be overhauled;*
- *When in previous operation, EWS and DB Schenker implemented strict operating rules as to any activation of a fusible plug (indicating higher than normal operating temperature of the bearing) and action to be taken.*

DB Schenker remaining traction & rolling stock

The remaining DB Schenker traction & rolling stock are fitted with solid axles having outside axle journal bearings.

Assembly is undertaken in accordance with OEM instructions. We constantly monitor axle and bearing scrapping rates to understand what is occurring in order to prevent failures (and not just those associated with the risks that led to the class 222 axle failure)

Devon and Cornwall Railways

DCR do not routinely operate and do not maintain (or contract maintenance) vehicles fitted with final drive units

Direct Rail Services

Recommendation not applicable although noted. DRS do not operate vehicles with hollow axles or this style/type of final drive. Recommendation will be considered for any future builds of locomotives/rolling stock

East Coast

East Coast has reviewed the RAIB Report into the Derailment near East Langton on 20 February 2010.

After due consideration, our Head of Engineering is of the opinion that Recommendation 2 is not relevant to our current fleets of rolling stock (Class 43 and Class 91) for the following reasons:

- *The design of the transmissions on both HST power Cars (Class 43) and Class 91 are different to the design of a Voyager/Meridian. In both cases the axle designs are not compromised with transmission bearings shrunk onto axle itself. The only bearings on a Class 91 or Class 43 axle are mounted in the axlebox itself. In both cases the transmission bearings are held with a separate gearboxes and the drive is transmitted by a quill tube and a series of traction links; and*
- *Class 43 have solid axles and Class 91 have hollow axles.*

In addition, the Class 91 is fitted with a Transmission Failure Detection System (TFDS) which detects overheating bearings in the gearbox and traction motors and automatically applies the brake in the event of a serious failure (TFDS activation). To

date there has never been a failure of either a Class 43 or Class 91 axle and both axles are subject to an Ultrasonic Axle Testing regime. Also, as part of both gearbox overhaul specifications, bearings are regularly checked and measured. At the present time there are no plans to amend the design of either final drive transmission.

We therefore do not see any need to implement the relevant recommendation.

East Midlands

East Midlands trains do not maintain o overhaul the class 222 fleet, this work is sub contracted to Bombardier Transportation Services Ltd. East Midlands Trains have worked closely with the Bombardier Class 222 Project Team and their overhaul facility at Crewe, to confirm that they are taking suitable measures to address this recommendation and will continue to monitor their progress in implementing these measures until all the issues are closed to our satisfaction.

Bombardier and Voith have already introduced updated processes for the specification and design of hollow axles with interference fit bearings and gearwheels. These incorporate making appropriate allowance for all the factors identified in the RAIB investigation.

In addition, Bombardier is conduction a review of the Component Overhaul Instructions (COIs) for which they have responsibility at Crewe. These instructions define the checks required before an axle is permitted to be re-used. For classes 220, 221, and 222, additional checks have already been implemented on the axle journal dimensions. The COI for classes 220 and 221are currently under revision and these updates will be incorporated. The finished COI will be reviewed and approved by an independent Safety Assessor in accordance with industry practice. The class 222 COI will be updated later this year to reflect experience up to that time and will also follow the same approval path.

Ribbon bolts and fusible plugs have already been fitted to all final drives on the Class 222 Fleet plus providing either a visible indication to maintenance staff or a direct warning to the driver that a bearing has overheated. Tests have been conducted at Bombardier Crewe and at the Voith facility in Germany to demonstrate the operation of the fusible plugs, further thermal modelling is being carried out by Bombardier to conclusively prove their effectiveness.

Eurostar

The class 372 design is at least 20 years old and is based on early French TGV designs, therefore as such manufacturing is not an issue.

The design of the class 222 gearbox has been compared to that of the class 373 final drive gearbox:

- *The thickness of the material between the outer surface of the axle and the bore diameter under the gearbox bearing is 50% greater than in the case of the 373*

- *The gearbox bearing is spaced from the gearwheel on the 373 by a 9.5mm spacer. In addition there is a stress relieving groove 22.5 mm wide on the 373 between the bearing hub and the gear hub.*

Thus it is concluded that the risk of a dangerous diminution of the bearing seating diameter under the inner race is significantly less in the case of the class 373 compared to the class 222 and it is considered that the class 373 gearbox will not suffer the same failure.

Overhaul

During gearbox overhaul many critical dimensions within the assembly are checked against limits and recorded. No similar issues in class 373 gearboxes have arisen.

Maintenance

While there is no continuous monitoring of oil temperature in class 373 gearboxes oil samples are taken periodically to check for ferrous content and oil levels, colour and odour are checked at every examination visit to depot

In addition to the operation of the class 373 fleet, Eurostar is in the process of procuring new trains (to be designated class 374) based on Siemens Velaro high speed train platform.

We have discussed this incident with Siemens, who confirmed that they were aware of the circumstances and understood the failure mechanisms. They have also provided the necessary assurances that there will not be similar issues with their own design

Class 374 trains will have sensors fitted to monitor the axle bearing temperatures.

Eversholt Rail group

Eversholt Rail Group owns two fleets with hollow axles, Class 91 locomotives and class 222 diesel electric multiple units.

Class 91

The final drive on this locomotive is bogie frame mounted and the axle passes through the hollow final drive output shaft and quill tube, with the drive transmitted through flexible links that connect the final drive to the quill tube to the driven wheel. In this design, the final drive output bearings seat on the output shaft, not on the axle.

The transmission on this locomotive has been subject to reviews of its design, overhaul and maintenance with significant development work carried out in the 1990s. This resulted in detailed design changes to achieve effective interference fits, improved controls over the manufacturing and overhaul quality and improved condition monitoring of the final drive through oil analysis. The transmission is fitted with a number of failure detection devices which monitor vibration levels, bearing temperatures on the traction motor and final drive input and excessive motion on the traction motor and cardan shaft. The transmission is also fitted with a Safeset torque limiting coupling.

These changes have been implemented to address specific issues with the high speed and high power rating of this transmission which has a low unsprung mass. The work carried out on this locomotive does not read across to other fleets.

Class 222

The actions on this fleet are already well documented in the RAIB report and are being addressed by Bombardier. Final drive output bearing over-temperature detection was fitted shortly after the East Langton derailment. Bombardier has introduced additional checks at overhaul to achieve the intended interference fits of the final drive output bearings on the axle and will subsequently introduce detailed design changes to the axle to achieve this consistently.

Other fleets

Many of the fleets owned by Eversholt Rail Group are EMUs and diesel electric locomotives with nose suspended traction motors mounted on a suspension tube on the axle. This arrangement is used on Classes 66, 313, 315, 318, 320 321, 322, and 455. All these fleets have solid axles and the design, maintenance and overhaul regime has proved to be very robust through many years of service experience. Suspension tube bearing defects are a rare event as these are conservatively rated bearings for the loads that they take. It is not proposed to make any changes to the maintenance regime for these wheelsets.

The more modern EMU fleets have frame mounted traction motors with an axle mounted gearbox. This arrangement is fitted to our Class 334, 365, 375, 376, 395 and 465 fleets. Again all these fleets have solid axles and the design, maintenance and overhaul regime has not identified any significant risks with the axle mounted output bearings. Hitachi has undertaken a review of the class 395 arrangements, as this is a high speed application. They have stripped down one wheelset for review and this has confirmed that the components were within tolerance.

Eversholt Rail Group also owns a small number of DMU fleets, Classes 158, 168, 170 and 185, we have reported separately below on Class 185 as the as the final drive design has some similarities with the class 222 arrangement. Classes 158, 168 and 170 have flange mounted gear wheels on the axle so there is no compression on the final drive bearing seats. All these fleets have solid axles and the design, maintenance and overhaul regime has not identified any significant risks with the axle mounted output bearings.

The service experience and feedback from the overhaul and maintenance regime has not identified any significant risk of loss of interference fit of final drive output bearings on these fleets. It is not proposed to fit any system to detect overheating output bearings.

Class 185

The class 185 final drive has many similarities to the Class 222 as it is a Voith right angle drive transmitting similar power to the axle although it is a master/slave arrangement similar to the normal DMU design. The final drive has a crown wheel shrunk onto the axle and the gear side bearing is adjacent to the gear as with the Class 222 design. However, it is a solid axle and the Voith design codes have proved to be robust. The final drives have not yet reached their planned overhaul mileage but Siemens has undertaken some condition assessments to support the decision on overhaul periodicity. Where the axle diameters and bearing bores have been measured, these have been found to be within the original design tolerances. No temperature detection is fitted to the bearings.

Siemens who undertake the maintenance of this fleet on behalf of the train operator, have undertaken to introduce additional checks at future overhauls to ensure that the correct interference fits are maintained with both new and overhauled components. Based on the evidence available, they have not identified a significant risk regarding loss of interference fit on the Class 185 final drive and are not proposing any increased measures regarding the detection of overheating output bearings. They have reviewed their approach to condition monitoring through oil analysis and have made some improvements.

Eversholt Rail Group has completed its review in accordance with recommendation 2 of the RAIB report. Where fleets have hollow axles, the risks are understood and have either been addressed historically (Class 91) or have current actions in place (Class 222). The review for our other fleets has not identifieds any ares where further action is required.

First Great Western

FGW operate the following multiple unit types that are fitted with final drives: Classes 143, 150, 153, 158, 165, 166 & 180.

The Class 143 has been in service in the industry for 27 years and utilises final drives manufactured by Self-Changing Gear Ltd (SCG). These are assembled on solid axles and have a shrink fitted gear, however the hub is in the form of a sleeve and there is also a stress relieving groove and a lateral spacer between the gear hub and the adjacent output bearing.

It is known that some Class 14X axles have suffered damage in the past due to rotation of the inner race of the final drive output bearing, but we are not aware that any axles have shown evidence of abnormal heat input. This would indicate damage being caused by bearing ring creep rather than gross spinning, as in the case at East Langton. The issue of bearing ring creep was identified by the industry prior to the publication of the RAIB report into the derailment at East Langton and an increase in the powered axle bearing seat diameter to reduce future occurrences is currently being reviewed with our ROSCO.

Classes 150, 153, 158, 165 & 166 were introduced variously between 1984 and 1993. All these classes utilise final drives manufactured by Gmeinder, which are assembled on solid axles. The assembly of the gearwheel to the axle differs from that of the Meridian final drives in that the gearwheel is bolted to a flange, which is forged and thus integral to the axle and therefore does not compress the axle. In this final drive, the output bearings are not adjacent to the gearwheel flange.

Class 180s were introduced in 2000 and are fitted with final drives manufactured by Voith Turbo. These are also assembled on solid axles and have a shrink fitted drive gear.

First Hull Trains contacted Angel Trains, the owner of the Class 180 fleet, and Railcare, the Spares Manager for the overhaul of Class 180 wheelsets and final drives, on behalf of FirstGroup on the 8th February to bring this recommendation to

their attention and requesting what overhaul checks and procedures are in place to ensure that adequate bearing interference is maintained.

Angel Trains advised First Hull Train on 20th March that they are currently investigating the arrangement with solid axles fitted to their axles in conjunction with the other ROSCOs, RAIB, Alstom and Bombardier. Their investigation is not yet complete but once complete intend formally responding to yourselves. Currently Angel Trains advise that they believe that solid axles are at a much lower risk as the extent of gear side output bearing seat shrink is negligible with a solid axle.

RAIB Recommendation 2 has four bullet points which are referred to in sequence in the below numbered 1 to 4.

1 *Reduction in the size of output bearing seats due to shrinkage arising from other nearby interference fits and/or wear during service.*

From the initial descriptions of final drives operated by FGW, we do not operate any that have a final drive configuration that would be susceptible to output bearing seat diameter reduction arising from nearby interference fits. This is because all classes operated by FGW have solid axles which would be subject to very little elastic deformation when compared with the relatively thin walled hollow axle in the Meridian design.

The final drive output bearing seat on the axle is measured at overhaul to check for wear and any axles under the specified tolerance are rejected. We have noted above the known bearing ring creep on Class 14X axles and that mitigations are in place to address this issue.

2 *Bearing bore growth during the service life of the bearing (e.g. obtained by measuring a sample of bearings)*

The RAIB report at paragraph 114 states that "inner ring growth … is a known phenomenon" and that "allowance is made for this bore growth in the interference fits recommended by the bearing manufacturer". It is also noted that at paragraph 148 "Voith … did not undertake any analysis to assess the effect of the gear interference fit on the fit of the adjacent GE bearing" and that "Voith's custom and practice for solid axles was carried straight through to this hollow axle design which features a relatively thin (45 mm) walled hollow axle in the area of the output bearing seats".

Given both these statements and the length of service experience with SCG, Gmeinder and Voith final drives fitted to our fleets, we believe that the degree of any bearing bore growth is at a tolerable level and controlled by current overhaul procedures.

3 *Bearing seats being made undersize*

The evidence of the bearing seat of the bearing that failed at East Langton being undersize is circumstantial; however the loss of design interference bearing fit due to the elastic compression of the axle through fitting the

gearwheel on the axle has been demonstrated by measurement and calculation.

During manufacture and overhaul (subject to confirmation of Class 180 overhaul as described previously) the dimensions of axles are checked and confirmed to be within tolerance. Furthermore, the repeatability of axle diameter measurement has improved over recent years since the introduction of snap gauges in place of micrometers.

Given the significant service experience gained on fleets operated by FGW, we do not consider that bearing seats being made undersize to be a credible risk to the final drive and this axle integrity of the fleets we operate.

4 Detection of overheating output bearings

The RAIB report at paragraph 150 states that: "there were no known previous similar failures to alert the industry about the potential for an axle failure arising from a final drive output bearing failure". Whilst we are aware that this was raised by RAIB as an underlying factor, we believe that the relatively thin walled hollow axle and loss of bearing inner ring interference fit with the axle bearing seat was a significant factor which is not present in our fleets with solid axles. For both this reason and the significant service experience without a history failure of final drive output bearings on our fleets demonstrates a level of safety without the need to implement temperature monitoring.

First Capital Connect

Improve the design procedures used for final drive gearboxes in current and future fleets

The First Capital Connect New Trains Team are aware of this requirement and will be requiring the builder of the new train to demonstrate how they intend to design any final drive gearboxes should they wish to include them in the build.

Improve the manufacture procedures for final drive gearboxes in current and future fleets

The First Capital Connect New Trains Team are well aware of this requirement and will be requiring the builder of the new train to demonstrate how they intend to manufacture any final drive gearboxes should they wish to include them in the build.

Improve the overhaul procedures used for final drive gearboxes in current and future fleets

The only existing First Capital Connect fleets with anything remotely similar to the final drive arrangement are classes 365 and 377, although neither of these designs include a cardan shaft arrangement as per the class 222 DEMUs.

First Capital Connect is already working with the owners of our 365 units with a view to improving component overhaul specifications and will continue to do so.

First Capital Connect will also work closely with the leasing company (and Southern) to develop and/or review overhaul procedures for our class 3777/5 units as and when such overhauls become due on First Capital Connect fleet. At appropriate contract review meetings, the First Capital Connect new trains team (and others within First capital Connect) will seek assurances from the builder as to how they intend to overhaul any final drives that they may choose to build into the trains.

Pay particular attention to those fleets featuring hollow axles

The First Capital Connect new trains team are well aware that the builder of the new train may propose to use hollow axles for their product and will ensure that the builder gives adequate assurances as to the safety of the design.

It is noted for all the that the following factors are key

- *Reduction in the size of output bearing seats due to shrinkage arising from other nearby interference fits and/or wear during service*
- *Bearing bore growth during the service life of the bearing (e.g. obtained by measuring a sample of bearings)*
- *Bearing seats being made undersize*
- *Detection of overheating output bearings*

First ScotRail

Class 15x and Class 170 (Turbostar) fleets are the only vehicle classes within First ScotRail operations that re fitted with final drives.

Class 15x

The First ScotRail 15x fleets which comprise Classes 156 and 158, were introduced between 1987 and 1991. These classes utilises final drives manufactured by Gmeinder which are assembled on solid axles with a final drive output bearing seat of either 180 or 190mm nominal diameter. The assembly of the gearwheel to the axle differs from that of the Meridian (Class 222) final drives in that it is bolted to a flange forged on the axle and therefore does not compress the axle. In addition, the final drive output bearings are not adjacent to the gearwheel flange.

Since service introduction the First ScotRail 15x fleets have accumulated in excess of 220 million miles.

Class 156 and Class 158 Gmeinder final drives are overhauled by Pullmans Rail Ltd and Wabtec in accordance with CR/C10567 and a C4 overhaul periodicity of 650,000 miles

Class 170 Turbostar

The First ScotRail Class 170 Turbostar fleet was introduced between 1999 and 2003. These units utilise final drive manufactured by ZF, which like the Gmeinder final drives fitted to 15x units, utilise a solid axle and a crown wheel bolted to a forged flange on the axle

Since service introduction the First ScotRail class 170 Turbostar fleet has accumulated in excess of 106 million miles.

Class 170 ZF final drives are overhauled by Bombardier Crewe and ZF Nottingham in accordance with COI(Customer Overhaul Instruction) 3EEC200000-4064 Issue 5 and a C4 periodicity of 715,000 miles.

Recommendation 2

2.1 Reduction in the size of output bearing seats due to shrinkage arising from other nearby interference fits and/or wear during service

As detailed above First ScotRail does not operate any vehicles with a final drive configuration that is susceptible to final drive output bearing seat diameter reduction arising from nearby interference fits.

In relation to the wear of the final drive output bearing seat on the axle, all axles have their critical dimensions measured at overhaul and any axles that do not meet the specified tolerance are rejected. First ScotRail has reviewed with our over-haulers and is not aware of any axles that have suffered wear of the bearing seat during service.

2.2 Bearing bore growth during the service life of the bearing (e.g. obtained by measuring a sample of bearings)

The RAIB report (point 114) states that 'inner ring growth is a known phenomenon' and that 'allowance is made for this bore growth in the interference fits recommended by the bearing manufacturers'. First ScotRail acknowledge this and with confirmation from the ROSCOs and over-haulers consider that the degree of bearing bore growth is at a tolerable level and controlled by current overhaul procedures

2.3 Bearing seats being made undersize

During manufacture the dimension of axles are checked and confirmed to be within tolerance, and these are rechecked by the over-haulers (all of whom are RISAS approved) during assembly of the final drives. Furthermore, the repeatability of axle diameter measurement has improved over recent years since the introduction of snap gauges which has replaced micrometers.

Given the significant service experience gained on First ScotRail fleets and in consultation with the over-haulers and ROSCOs, First ScotRail does not consider the bearing seats being made undersize to be a credible risk to the final drive and axle integrity of its operated fleets

2.4 Detection of overheating output bearings

First ScotRail considers that its experience with Gmeinder and ZF final drives gained over 320 million vehicle miles, with a history of no failures of final drive output bearings demonstrates the safety of the fleet without the necessity to monitor the temperature of final drives.

Therefore First ScotRail has concluded in conjunction with ROSCO and over-hauler information that no further measures are required in relation to the risk of final drive output bearing failures on First ScotRail operated fleets.

Freightliner

Freightliner has reviewed its active locomotive fleet which consists of Classes 08, 66, 70, 86 and 90. None of these locomotive types have a final drive arrangement. All our locomotives have nose suspended traction motors mounted on a suspension tube on the axle and have solid axles. We do not propose to make any changes to the maintenance regime.

GB Railfreight

At present GB Railfeight Ltd does not operate or intend in the near future operate final drive gearboxes. As such the above recommendations do not apply to GB Railfreight Ltd.

Grand Central Trains

Grand Central believes that this recommendation also applies to the final drives of the class 180 DMUs which we lease from Angel Trains. Can you please advise of the action that Angel Trains intends to take in respect of this recommendation.

See response from Angel Trains above.

Greater Anglia

Abellio Greater Anglia operate two types of diesel multiple unit trains where a final drive wheelset is present, the Class 153/156 trains (which were designed/built by British Rail and manufacturing contractor) and the Class 170 trains, built by Adtranz/Bombardier. None of these train types utilise hollow axles on their wheelsets; both types have solid axle wheelsets. From the RAIB report it can be seen solid axles do not exhibit the same characteristics of shrinkage on interference fitted components, such as roller element bearings.

In addressing specific item 1) and the adequacy of procedures to address possible reduction in the size of the output bearing seats due to shrinkage arising from other nearby interference fits and/or wear during service both the Gmeinder and ZF design final drives utilise solid axles and have the crown gearwheel affixed to a flange forged on the solid axle by way of threaded fasteners. There is no shrink fitting of this component on the flange/axle and therefore this does not influence the output bearing performance. The output bearings are also not adjacent to the gearwheel flange.

In addressing specific item 2) and the adequacy of standards for understanding bearing bore growth during service life and item 30 the adequacy of controls for bearing seats being made undersize, Abellio Greater Anglia do not own any

intellectual property rights to the final drive overhaul specifications. The Class 153/156 and Class 170 diesel multiple units we operate are leased from Porterbrook Leasing Co Ltd and under the terms of our lease agreement industry agreed specifications are used. Advice received from Porterbrook Leasing technical engineers confirms that they do not own or lease any vehicle types with a final dive configuration that is susceptible to output bearing seat diameter reduction arising from nearby interference fits.

For Class 153/156 the Gmeinder final drives are overhauled to specification CR/CI0567, currently issue 2 (July 2005) and for the class 170 ZF final drives are overhauled to specification RM100. Both specifications call for the critical dimensions measured at overhaul, and any axles or casings that do not meet the specified criteria are rejected, or re worked to an approved repair procedure. The service experience accumulated since introduction of the Class 153/156 and Class 170 trains demonstrates that the level of bearing bore growth on both Gmeinder-type and ZF-type final drives is at an acceptable level, and is adequately controlled by the existing overhaul procedures component overhaul periodicities. During both original manufacture and subsequent overhaul the dimensions of axle bearing journals are checked and confirmed to be within tolerance. All of the overhauling contractors used by Porterbrook leasing and Abellio Greater Anglia hold current accreditation for RISAS for the supply of final drive wheelset assemblies.

Abellio Greater Anglia regularly monitors the operational performance of final drives and any confirmed or suspected failure is subject to an appropriate level of investigation; this is in accordance with the principles set out in Railway Group Standard GE/RT 8250. The common failure mode currently experienced by the Gmeinder type final drive is input shaft support bearing failure, both in early and mid-life mileage ranges. Each of the failures we have experienced has not resulted in the wheelset seizing or prevented the rotation of the wheelset, and has been identified through oil sample results and/or detection of inconsistent oil colour or smell, and usual presence of debris on the sump magnetic drain plug. However the failure mode detailed in the East Langton report has not been identified as a root cause of the failures experienced by Greater Anglia on its Class 153/6 trains. The operational performance of the class 170 final drive gearbox, in our experience, is significantly better; however that represents their more modern design and manufacture.

The operational and safety performance of the final drives is not only covered by our internal safety monitoring systems, but is also shared at regular technical and commercial forums with Porterbrook Leasing Co Ltd. On behalf of the train operators Porterbrook (and other rolling stock owning companies) regularly review and update the technical specifications to overcome recurring issues. Any such change to specification is agreed with Abellio Greater Anglia via a documented engineering Change/review process.

The specific issues of bearing bore growth and bearing seats being made undersized are not known fault areas on either the Gmeinder or ZF type final drive.

Where issues are identified during the overhaul of either final drive type the overhauling contractor regularly provides feedback to both Porterbrook Leasing Co and Abellio Greater Anglia over the condition of the equipment. Porterbrook advise us that their overhaul contractor are not aware of any final drive axles on Class 153/156 or Class 170 trains that suffer wear of the bearing seat during service. The critical factor for axle scrapping is usually scoring or corrosion of the body, or scoring damage to the hub or journal diameter during wheel pan or axlebox bearing removal. As such factors dominate the axle life cycle and attrition the effects of undersize/worn final drive bearing seats are not observed during overhaul.

Regular audits are undertaken with the overhauling contractors of the final drive wheelsets; this is an on-going process and will continue across all partners in the industry including the contractors own periodic re-accreditation to RISAS. Where necessary Abellio Greater Anglia will review the salient points from the East Langton report and include these in the scope of their next scheduled audit, or discuss with Porterbrook Leasing to undertake an audit on behalf of the industry on their supplier.

- *In addressing specific item 4) and the adequacy of existing detection methods for overheating output bearings Abellio Greater Anglia Class 153/156 and Class 170 trains are not fitted with automatic heat detection sensing equipment on any output bearing arrangement. The existing detection method is via visual inspection of the output bearing housing, and is carried out at routine intervals for both train types. Further, periodic oil changes are undertaken, and samples of the oil taken for chemical analysis in order to trend changes ion chemical composition of the oil. The magnetic drain plugs fitted to both types of final drive are also inspected for metallic debris during the oil sampling/draining processes. Clear instructions are contained in the Vehicle Maintenance Instructions to be taken if and where debris is found on the magnetic plug, or in the event of discolouration of oil, or advice of adverse oil sampling. Abellio Greater Anglia are going to review the periodicity of oil sampling, and undertake an investigation into the control limits /chemical science behind the oil sampling regime to ensure it remains fit for purpose; we expect this review to be complete by end of September. To date Porterbrook and other owners of Class 153/156 and Class 170 trains are unaware of a confirmed failure of final drive output bearing thus further reinforcing the excellent service experience of the Gmeinder and ZF final drive designs.*

In summary

- *We do not operate traction types with hollow axles;*
- *The effect of interference fits from nearby equipment on the shrinkage/reduction in output bearing seats is not relevant to the Gmeinder and ZF type final drive wheelsets fitted to the Class 153/156 and Class 170 diesel trains we operate;*
- *The existing contracted overhaul specifications are controlling any risks arising from undersize bearing seats as evidenced by the lack of credible failure incidents with the Gmeinder and ZF final drive wheelsets;*
- *The Gmeinder and ZF final drive output bearings are not fitted with automatic or tell-tale heat detection devices;*

- *The existing arrangements for oil sampling will be subject to review to ensure the periodicity and control measures remain fit for purpose;*
- *The overhaul contractors are subject to regular audit by industry partners, and are themselves accredited to RISAS for the supply/repair of final drive wheelset assemblies;*
- *The operational and safety performance of final drive wheelsets is subject to monitoring in accordance with Railway Group Standard GE/RT 8250*

Heathrow Express

Heathrow Express operates two Electric Multiple Unit types,

- *The Siemens/CAF class 332 introduced in 1996*
- *The Siemens class 360/2 “Desiro” introduced in 2005*

Both train types are maintained by Siemens Transportation Ltd (STL) at the dedicated train care facility (TCF) at Old Oak Common in west London.

Having reviewed the RAIB report we have concluded that the key issues concerning the initial derailment of the vehicles at East Langdon are attributable to a loss of interference fit of the axle-mounted output bearing, arising from a combination of inner ring growth of the bearing plus axle journal "shrinkage" due to adjacent interference fit components on the axle.

In terms of “applicability” to existing Heathrow Express rolling stock fleets, there are a number of points to note:

- *Neither the class 360 or 332 utilise hollow axles - both are of solid construction.*
- *The output bearings of the class 332 drive are not axle mounted - they are contained within the gearbox assembly and drive to the axle is provided by means of an interference fit flange. There are no other interference fit components mounted adjacent which could compromise this fit.*
- *On the class 360, the gearbox output bearings <u>are</u> axle-mounted, and on the gear-end of the axle, the bearing is separated from the nearby interference fit gearwheel by a spacer. The two components are, therefore, not absolutely adjacent as was the case with the failed Meridian drive.*
- *Furthermore, during UAT investigations and scheduled condition assessments of 360 gearboxes, several bearing sizes and axle diameters on a range of gearboxes at around 700k - 800k miles service have been measured and found to be within original design limits, confirming that inner ring growth is <u>not taking place</u>. Measurement & examination of bearing seats is a key part of the overhaul process on an on-going basis.*

In addition Siemens have been asked, as a manufacturer, by the ORR to respond directly to some of the recommendations, and they will share this response with us in due course. They will also examine whether there are any other opportunities for "best practice" which should be adopted, but in the interim, We believe there to be no direct risk to our fleets on the basis of key design differences and evidence obtained from assessment of "in-service" components.

Hitachi

See attachment

First Hull Trains

Hull Trains only operate a small fleet of Class 180 units. The Class 180 was introduced in 2000 and are fitted with final drives manufactured and overhauled by Voith Turbo. These final drives are assembled on solid axles and have a shrink fitted gear drive.

On 8 February 2012 we contacted Angel Trains (the owner of the Class 180 fleet) and Railcare who act as the Spares Manager for the overhaul of the wheelsets and final drives fitted to our Class 180 fleet bringing this recommendation to their attention and requesting what overhaul checks and procedures are in place to ensure that adequate bearing interference is maintained.

Angel Trains advised us on 20 March that they are currently investigating the arrangement with solid axles fitted to their axles in conjunction with the other ROSCOs, RAIB, Alstom and Bombardier. Their investigation is not yet complete but once complete intend formally responding to ORR. Currently Angel Trains advise that they believe that solid axles are at a much lower risk as the extent of gear side output bearing shrink is negligible with a solid axle.

Specifically they advise

- *A solid axle does not suffer from elastic shrink to any meaningful extent and so is inherently secure and resistant to fretting. Bearing seat diameters are checked at overhaul. The Class 180 utilises a solid axle and would not be susceptible output bearing seat diameter reduction arising from nearby interference fits*
- *The RAIB investigation has revealed that bore growth of up to 20 Microns may be expected over the life of this size of bearing. Angel Trains advise that in the absence of other factors that reduce fit the minimum design fit of the output bearing can tolerate this loss.*
- *RAIB in the report put forward the theory that the bearing seats may have been manufactured undersize. This is something that Bombardier strongly refutes and the evidence for this is circumstantial. During manufacture the dimensions of axles are checked and confirmed to be in tolerance.*
- *Angel Trains do not consider at this time that the safety benefits arising from the fitment of a dedicated on board hot final drive detection system would be proportionate to the implementation costs. Hull Trains has considered the factors surrounding the failure of the Class 222 and consider that the relatively thin walled hollow axle and loss of bearing ring interference fit with axle bearing seat was a significant factor which is not present in the Class 180 fleet with solid axles. Accordingly we concur with Angel's view that installation*

of a dedicated on board hot final drive detection system would not be appropriate.

Angel Trains confirm that they will advise further when they have completed their review – see response from Angel Trains.

London Midland

Class 139 – 2 vehicles

These vehicles operate at low speed (20mph maximum) over a short distance on the Stourbridge branch separate from the rest of the network. Each vehicle has one driven solid axle fitted with a double reduction helical spur gearbox. The first overhaul event has not yet been reached. Risk of catastrophic failure is considered to be extremely low and no further remedial measures are considered necessary.

Class 150 - 6 vehicles
Class 153 – 8 vehicles

These vehicles are fitted with Gmeinder final drives assembled onto solid axles. The gearwheel is bolted to a forged flange which does not compress the axle and the final drive output bearings are not adjacent to the gearwheel flange. These fleets have accumulated considerable service mileage since introduction in the mid 1980s and undergone several final drive overhaul cycles with no relevant failures. Current overhaul procedures measure critical dimensions and reject out of tolerance components. No further remedial measures are considered necessary.

Class 170 - 52 vehicles

These vehicles are fitted with ZF final drives, assembled onto solid axles. The gearwheel is bolted to a forged flange which does not compress the axle and the final drive output bearings are not adjacent to the gearwheel flange. The fleet has accumulated considerable service mileage since introduction in the early 2000s and undergone several final drive overhaul cycles, with no relevant failures. Current overhaul procedures measure critical dimensions and reject out of tolerance components. No further remedial measures are considered necessary.

Class 172 – 69 vehicles

These vehicles have been recently introduced into service during 2011 and are fitted with ZF final drives assembled onto hollow axles in a similar arrangement to the Class 222 vehicles within the report. A risk assessment has been undertaken by Bombardier to confirm continued safe operation in service with respect to output bearing failure. In particular:

- *Bombardier have given assurances that the Class 172 final drive design took into account reduction in the size of output bearing seats due to shrinkage arising from the adjacent crown wheel interference fit and possible future wear in service;*

- *Similarly, in the specification of bearing interference fits, the design took account of bearing bore growth;*
- *Accurate process controls were in place during manufacture to ensure that bearing seats were not made undersize;*
- *Overheating final drive output bearings are detected by a fusible plug which activates an alarm in the driver's cab and by 'ribbon bolts' to provide an early indication to maintenance staff*

Although scheduled final drive overhauls are not yet due on the Class 172 fleet, an investigation into a recent unrelated failure of slave final drive input bearings on unit 172338 is currently on-going. The opportunity will be taken to check critical output bearing dimensions and to develop an improved oil sampling regime as part of this investigation. It is anticipated that this work shall be complete by July 2012.

Class 321 – 28 vehicles

These vehicles are fitted with a suspension tube arrangement mounted onto a solid axle. The gearwheel is a shrink fit onto the axle adjacent to the suspension tube gear end bearing. The fleet has accumulated considerable service mileage since introduction and undergone several gearbox overhaul cycles, with no relevant failures. Current overhaul procedures measure critical dimensions and reject out of tolerance components. No further remedial measures are considered necessary.

Class 323 – 78 vehicles

These vehicles are fitted with a quill drive arrangement connecting the traction motor to the gearbox assembled onto a solid axle. The gearwheel is a shrink fit onto the axle adjacent to the output bearings. The fleet has accumulated considerable service mileage since introduction and undergone several gearbox overhaul cycles, with no relevant failures. Current overhaul procedures measure critical dimensions and reject out of tolerance components. No further remedial measures are considered necessary.

Class 350 – 268 vehicles

These vehicles are fitted with an IG Wattheuw gearbox mounted on a solid axle. The design features axle mounted output bearings adjacent to an interference fit axle mounted gearwheel. During 2011 and 2012 Siemens has undertaken extensive investigation and condition assessment of gearboxes in connection with maintenance optimisation and future UAT developments, including measurement of output bearing seats and bearing inner race bores. No out of tolerance measurements have been recorded. All future overhauls specify the requirement to record these diameters and carry out visual examination for irregularities. No further measures are considered necessary.

London Overground Rail Operations Ltd (LOROL)

LOROL has a fleet of eight class 172units which use a derivative (B5006) of the B005 bogie design used on the Voyager (Class 22x) involved in the incident.

Following this incident a National Incident Report (NIR) was raised informing the industry of the incident which graphically identified a broken hollow axle probably as a result of a catastrophic axle mounted gearbox failure.

This NIR led to the class 172 train manufacturer (Bombardier) providing an improved gearbox failure warning in the form of

(i) an extension of the pneumatic Hot Axle Box Detector to the gearbox which triggers an HABD warning to the driver if the gearbox fails.

(ii) Provision of a wax plug that melts on the application of heat which in turn releases a ribbon thus drawing attention in the event of failure.

The final drives fitted to a class 172 are manufactured by ZF and are a master/slave arrangement driven by an interconnecting carden shaft whereas Voyagers have a Voith installation

LOROL's fleet of Class 172 trains will not require their first overhaul until 2016 so the overhaul specification has not yet been developed. When that overhaul specification is developed it will take into account the lessons learned from the RAIB report.

The only other fleet that LOROL operates is the Class 378 EMU which does not have a final drive. The Class 378 has an Electrostar bogie which is the latest development of the Bombardier Series 3 EMU bogie.

Merseyrail

The NIR 2571 describes the failure of a final drive bearing which resulted in an axle failure and ultimate derailment. In this case the failure of a bearing was in a transmission type (final drive) on an axle design not fitted to Class 507/508/1 units, the axle type described being (hollow axles), as opposed to Monobloc (solid) axles as used on Merseyrail stock.

Subsequent reports and discussions at industry forums, suggest there may have been "build-up of tolerances" issues when pressing on the bearing of the gearbox final drive. The axle was compressed slightly, considered enough to cause the axle inner race to move on the axle when it began to seize.

The practice of removing and fitting axle end bearings is a process not performed by Merseyrail, but by an approved wheelset over hauler. Merseyrail wheelsets are supplied through the owners (Angel Trains) managing agent (currently Unipart Rail UK Ltd). Companies contracted to overhaul wheelsets for Merseyrail vehicles are required to be certified to the rail industry approved scheme currently RISAS. Presently Unipart Rail contracts Luchhini Ltd to overhaul Merseyrail's wheelsets, and they are RISAS certified.

The Class 222 final drive referenced is not of similar design or similar in application, to that fitted to Class 507 & 508/1 EMU's, which do not have final drives or associated cardan drive shafts, therefore the traction forces and strains applied to these components will be different. The transmission of traction to the wheelsets on

Merseyrail vehicles is via a direct traction motor pinion to gearwheel interface, the gearwheel being mounted on the axle shaft. There is no history to date of similar axle end failures due to interference fit tolerances.

Although not the same components as fitted to Merseyrail stock, the fact that it was a bearing failure in relation to an axle makes it, in principle a common issue. Therefore consideration was given to current 507/508/1 maintenance plan task requirements, with regard to preventative action, and identification of bearing problems. However, on review Merseyrail Engineers decided that no additional actions were necessary over and above those that are already in place. National Incident reports are always considered for any suitable additional preventative action, that could also be included in 507/508 unit maintenance plans.

Below are some of the Merseyrail initiatives and actions that have been taken in respect of wheelsets;

a) *Merseyrail has a number of engineering staff certified, as competent in the inspection of axle bearings, all having undergone specific specialist training. These staff have their underpinning knowledge and understanding of bearing inspection checked as part of the companies competence assessment system.*

b) *All axle boxes on class 507/508 units have temperature indicator stickers applied. Maintenance plan task UX 0602 Bogies and Underframe examination, performed every exam requires the reading of the axlebox temperature stickers and a comparison against other axles on all related vehicles. Any axle temperature indications suspected to be abnormal are to be reported and investigated.*

An alternative temperature indicator, such as the ribbon bolts referred to in the Urgent Safety Advice (USA), have been investigated, however to fit them in a position near enough to the axle bearing to be visible to all, proved difficult. Axle end mounted components such as WSP probe housings and axle earth return assemblies meant that fitment of ribbon bolts on nearly all axle ends was not possible.

c) *Merseyrail has had all axle end covers painted yellow; this colour is known to discolour in reaction to heat, more rapidly than standard black paint. This simple practise was taken directly from the bearing course mentioned in item (a) and is intended to aid in the identification of excessive heat on axles box's, it is widely used on vehicles and locomotives in the rail industry.*

<u>Maintenance Plan tasks specific to wheelsets</u>

The Vehicle maintenance Instruction (VMI) tasks summarised below require specific actions in respect of wheelset examination.

VMI tasks UW 0680 Wheels and Axles examine and UW 9610 Wheels Gauge Axle & Brake Disc, both require the inspection of every wheelset for integrity, including checks for signs of overheating or corrosion anywhere on a wheelset.

Task UW 0107 Axle Ultrasonic Test, performed at intervals of not more than 125k miles, includes a requirement for the inspection of axle bearing grease for signs of degradation due to water ingress, metallic contamination and corrosion.

Currently the Merseyrail network infrastructure does not have a Hot Axle Box Detection (HABD) system installed. Network Rail were approached with a view to having the system installed. However, a risk assessment was performed by Network rail and as a result; it was deemed a HABD was not justified.

Safety monitoring

In addition to the above actions, we can confirm that Merseyrail reviews and monitors National Incident reports including updates at several forums, they are:

Fleet Safety Review Group meeting:

Held four weekly: Normally attended by: the Engineering Director, The Head of Safety, The Professional Head of Engineering, Depot Manager and other nominated safety and engineering department staff. This meeting monitors all applicable NIR's and Safety Related Defect Reports received.

Merseyrail & Angel Trains Ltd Technical Review meeting:

Held four weekly, attended by Merseyrail and Angel Engineers; all applicable NIR's that have owner involvement are discussed.

Unipart Rail & Merseyrail supplier review meeting:

Held four weekly, all NIR's that concern materials and equipment used on Merseyrail stock supplied via Unipartrail are discussed.

Technical Safety Review Group meeting:

Normally held four weekly: This is an industry forum attended by TOC's, Vehicle owners, Network Rail and Technical Engineering support companies. The meeting monitors safety issues including all NIR's applicable to group members, and is used to provide cross company co-operation in the resolution of safety related issues.

Northern

Point 1

Northern do not operate any stock that has hollow axles which the report highlights as being at risk. Solid axles do not exhibit the same characteristics of shrinkage for interference fit components.

Gmeinder drives have flange bolted drive gearing and do not utilise shrink fit components in the area of the output bearing.

Point 2 and 3

Northern operate a diverse fleet of vehicles that are leased from all three main ROSCO's. Northern do not own any of the overhaul specifications and are

contracted to use industry documentation. These are detailed in the following table to indicate vehicle owner and relevant specifications.

Unit Type	***ROSCO***	***Drive Type***	***Drive Overhaul Specification***
142	*Angel Trains*	*SCG*	*CR/CI 0590*
144	*Porterbrook*	*SCG*	*CR/CI 0590*
150/1/2	*Angel Trains* *Porterbrook*	*Gmeinder*	*CR/CI 0567*
153	*Angel Trains* *Porterbrook*	*Gmeinder*	*CR/CI 0567*
155	*Porterbrook*	*Gmeinder*	*CR/CI 0567*
156	*Angel Trains* *Porterbrook*	*Gmeinder*	*CR/CI 0567*
158	*Angel Trains* *Porterbrook* *Eversholt*	*Gmeinder*	*CR/CI 0567*
321/2	*Eversholt*	*No final drives fitted*	
323 [maintained by Alstom]	*Porterbrook*	*No final drives fitted*	
333 [maintained by Siemens]	*Angel Trains*	*No final drives fitted*	

Northern have experience of difficulties with both the drive types in the recent past. However, the failure mode detailed in the East Langton report have not been identified as a root cause of the failures experienced by Northern.

Discussions on specification changes to mitigate known failure modes are undertaken at regular contract reviews with ROSCO's. Northern's position currently is as follows for the two main drive types:

SCG – CR/CI 0590

Specification is currently under industry review and rewrite for drive overhaul following the documented failures on class 14X units experienced by Northern. These failures have been subject to RAIB investigation and the final report is expected to be published by end of April 2012. Recommendations from this report will be incorporated into the revised specification when available.

The specific issues of bearing bore growth and bearing seats being made undersized are not known fault areas of this drive type. Currently these areas would need to be flagged to Northern by the overhaul agent from results and findings from this activity. Consideration to include this in relevant review meetings will be undertaken.

Gmeinder – CR/CI 0567

Specification is currently under industry review and rewrite for drive following a low number of failures of the drive type. This is being led by ROSCO's.

The specific issues of bearing bore growth and bearing seats being made undersized are not known fault areas of this drive type. Currently these areas would need to be flagged to Northern by the overhaul agent from results and findings from this activity. Consideration to include this in relevant review meetings will be undertaken.

The length of service experience, which is much longer with the Gmeinder arrangement than Voith Meridian design, strongly indicates that the fit selected and degree of inner ring growth experienced by output bearings in the Gmeinder application results in a secure bearing which does not suffer from slipping inner rings. There is a known problem with fretting on Gmeinder output bearing outer rings, which is dealt with on detection at overhaul by re-machining the housings oversize and fitting new oversize bearings to re-establish the design bearing outer ring fit.

Robust audit regimes are in place with suppliers of the drive types indicated. This is an on-going process and along with industry partners will continue. Areas of future audits will take into account the findings of the East Langton report and similar future reports.

Northern only procure wheelsets and drives from RISAS accredited suppliers

Porterbrook

Class 14x

The 14x vehicles (143 and 144) have been in service for 27 years and utilise final drives manufactured by Self Changing Gear Ltd (SCG) these are fitted to solid axles with a final drive output bearing seat diameter of a nominal 203mm. This is larger than the final drive output bearing seat diameter of Meridian axles (nominally 200mm). The 14x final drive has a shrink fitted gear, but the hub is in the form of a

sleeve and also there is a stress relieving groove and a lateral spacer between the gear hub and the nearest output bearing.

There have been a number of 14x axles that suffered damage due to rotation of the final drive output bearing inner race, however no axles have shown any evidence of abnormal heat input, which implies that the damage is caused by bearing ring creep as opposed to gross spinning. The issue was identified by the industry prior to publication of the RAIB report into the derailment at east Langton and measures have been put in place to reduce further occurrences.

Porterbrook's 14x fleet has accumulated over 195 million miles since service introduction.

Class 15x

The 15x fleet which comprises Classes 150, 153, 155, 156, 158 and 159 were introduced between 1984 and 1992. All these classes utilise final drives manufactured by Gmeinder which are assembled on solid axles with a final drive output bearing seat of either 180mm or 190mm nominal diameter. The assembly of the gearwheel to the axle differs from that of the Meridian final drives in that it is bolted to a flange forged on the axle and therefore does not compress the axle. In addition the final drive output bearings are not adjacent to the gearwheel flange. Since introduction the Porterbrook 15x fleet has accumulate over 1.569 billion vehicle miles.

Turbostar

The Turbostar fleets comprise classes 168, 170 and 171 and were introduced between 1987 and 2005. These units utilise final drive manufactured by ZF, which like the Gmeinder final drives fitted to 15x units utilise a solid axle and a crown wheel bolted to a forged flange on the axle.

Since service introduction the Porterbrook Turbostar fleet has accumulated over 670 million vehicle miles

Class 172

The ZF final drive fitted to the Class 172 is the most relevant comparator to the Meridian fleet as this combines the B5000 hollow axle design and a shrink fit gear and adjacent output bearing. However Bombardier has given assurances to Porterbrook that the Class 172 final drive design took account of the reduction in diameter of the bearing fit due to the adjacent shrunk fitted crown wheel, and that due consideration was also given to the correct fit of the bearings.

The Class 172 has an on board hot axle detection system which is required due to the inboard axle bearing fitted not being visible to track mounted detectors and this has been extended to protect the final drives. A fusible plug is installed in the final drive which will trigger an alarm in the drivers cab if the plug melts. In addition 'ribbon' bolts have been fitted which have an enlarged head featuring a cavity sealed with a fusible cap. Should the temperature exceed the set point, the fusible cap will

melt and release the ribbon. This is intended to be an early warning to maintenance staff that undue heat is being generated.

Specific to recommendation 2

2.1 Reduction in the size of output bearing seats due to shrinkage arising from other nearby interference fits and/or wear during service

As detailed above, with the exception of 172, Porterbrook does not own any vehicles with a final drive configuration that is susceptible to final drive output bearing seat diameter reduction arising from nearby interference fits. The Class 172 contains two levels of service mitigation to identify the overheating of the final drive output bearing.

In relation to the wear of the final drive output bearing seat on the axle, all axles have their critical dimensions measured at overhaul and any axles that do not meet the specified tolerance are rejected. With the exception of CLASS 14x Porterbrook is not aware of any axles that suffer wear of the bearing seat during service, and as detailed above mitigations are in place to address this issue on 14x going forward.

2.2 Bearing bore growth during the service life of the bearing (e.g. obtained by measuring a sample of bearings)

The RAIB report (point 114) states that inner ring growth is a known phenomenon and that 'allowance is made for this bore growth in the interference fits recommended by the bearing manufacturers'. Given this and the length of experience with SCG, Gmeinder and ZF Turbostar final drives, Porterbrook believe that the degree of bearing bore growth is at a tolerable level and controlled by current overhaul procedures. In addition the 172 final drive is protected by two levels of service mitigation and underwent very detailed design scrutiny at manufacture by Porterbrook, Bombardier and ZF prior to introduction to traffic and with knowledge of the developing findings of the Meridian failure at east Langton.

2.3 Bearing seats being made undersize

The evidence of the bearing seat of the bearing that failed at east Langton being undersize is circumstantial; however the loss of bearing fit due to the interference between the gearwheel and the axle has been shown by measurement and calculation.

During manufacture the dimension of axles are checked and confirmed to be within tolerance, and this is generally rechecked by the over-haulers (all of whom are RISAS approved) during assembly of the final drives. Furthermore the repeatability of axle diameter measurement has improved over recent years since the introduction of snap gauges in place of micrometers.

Given the significant service experience gained on Porterbrook's fleets and the mitigations in place on the Class 172 Porterbrook does not consider the bearing seats being made undersize to be a credible risk to the final drive and axle integrity of its fleets.

2.4 Detection of overheating output bearings

Porterbrook considers that its experience with SCG, Gmeinder and ZF Turbostar final drives gained over 2.438 billion vehicle miles, without a history failure of final drive output bearings demonstrates the safety of its fleet without the necessity to monitor the temperature of final drives.

The 172 due to the nature of the inboard axle bearing allows relatively easy monitoring of the final drive out put bearings and this was fitted during manufacture of the vehicles. Porterbrook does not therefore consider any further work is justified on the Class 172.

Siemens

Siemens rolling stock currently falls into three product groups:

Siemens/CAF/EMU

Drive manufacturer: ZF AG
Drive Type: HSH-BA17-275
Axle Type: Grade A1T solid axle
First service entry: 1998
Number in service: 240 as follows

Fleet	*Operator(s)*	*Population of drives*
332	*BAA Heathrow Express*	*112*
333	*Northern Rail*	*128*

This transmission design does not feature axle mounted output bearings.

Siemens Desiro UK EMU

Drive Manufacturer: I.G. Wattheuw
Drive type: DUK410 axle mounted transmission
Axle type: Grade A4T solid axle
First service entry: 2002
Number in service as follows

Fleet	*Operator(s)*	*Population of drives*
350/1	*London Midland*	*240*
350/2	*London Midland*	*296*
360/1	*Abellio Greater Anglia*	*168*
360/2	*BAA/First Gt Western*	*40*
380	*First Scotrail*	*304*
444	*South West Trains*	*360*
450	*South West Trains*	*1016*

This design of transmission does feature axle mounted output bearings adjacent to an interference fit axle mounted gear wheel.

Siemens has undertaken investigation and condition assessment work on Desiro EMU transmissions during 2011-2012 in association with maintenance optimisation

and future U.A.T. developments. This has involved independent evaluation of output bearing fits by ESR Technology, including 9 axles and 18 bearings from transmissions with service mileages between 328,000 miles and 1,059,000 miles. Additionally, one further axle and two new bearings were examined during the rebuild process. All axles were measured with the gearwheel in position and in every case both the output bearing seats and bearing inner race bores were found to be within manufacturing tolerances. No evidence of bearing creep or gross movement has been identified.

As an additional control measure, a further sample of three axles were measured in greater detail using a Co-ordinate Measuring Machine during the gearbox overhaul process, which confirmed that manufacturing tolerances had again been maintained.

In order to provide on-going assurance that satisfactory interference fit is maintained through the overhaul process (the throughput of which will be increasing substantially during late 2012), our contractor, Lucchini UK has undertaken to measure and record both the output bearing seat and bearing inner race bore diameters to verify that compliance with manufacturing tolerances is maintained.

Furthermore, a visual examination is carried out with pictorial reference to examine the output bearing seats for irregularities which may indicate compromised interference fit.

These arrangements are specifically documented within the relevant Overhaul & Repair Specification.

At this stage, we are unable to provide assurance that the same process is applied in the event of a new axle being introduced; however, Siemens undertakes to ensure that this procedure is implemented by 30th April 2012.

Siemens Desiro UK DMU

Drive manufacturer: *Voith*
Drive type: *SK485 Master & Slave axle mounted final drives*
Axle type: *Grade A4T solid axle*
First service entry: *2006*
Number in service: *306 (Master + Slave)*

Fleet	*Operator(s)*	*Population of drives*
185	*Transpennine Express*	*306*

This design of final drive does feature axle mounted output bearings adjacent to an interference fit axle mounted gear wheel, in both Master and Slave variants, which are identical in design in this respect.

A small number of condition assessment activities have taken place in association with maintenance optimisation activities, but these have not specifically reported on the condition of the axle/output bearing interface.

One final drive unit has been examined in detail after 935,000 miles service, including measurement of the output bearing seats and bearing inner race bores. Both were found to be within manufacturing tolerances.

A scheduled overhaul programme to be undertaken by Voith Turbo Limited shall commence during 2012 comprising of an initial quantity of 77 final drives (a combination of both Master & Slave units). The current Voith local overhaul work instruction demands measurement of the output bearing seat to verify that manufacturing tolerances have been maintained.

It is Siemens intention to standardise the practice of measuring and recording both the output bearing seat and bearing inner race bore diameters (including a visual examination for signs of irregularity) during the overhaul of all types of axle mounted transmissions including the introduction of new axles. We therefore undertake to ensure that this procedure is adopted prior to commencement of the forthcoming overhaul programme.

Similarly, the condition assessment programme will continue in parallel with the scheduled overhaul and arrangements shall be made henceforth to capture information pertaining to the interference fit of the output bearings

Summary

In conclusion, the response regarding Siemens rolling stock products in the UK can be summarised as follows:

- *All Siemens rolling stock fleets feature solid axles, thereby significantly reducing the risk of loss of interference fit of axle mounted output bearings arising from the effect of adjacent interference fit components.*
- *The Siemens/CAF built EMU transmission design does not feature axle mounted output bearings.*
- *Evidence has been captured from Desiro UK EMU transmissions and Desiro UK DMU final drives which confirm that the manufacturing tolerances of these components have been adequately maintained during a range of service life.*
- *Arrangements are in place, or anticipated, to measure and record both the output bearing seat and bearing inner race bore diameters and complete a visual assessment for signs of irregularity in order to verify that compliance with manufacturing tolerances is maintained.*

The following actions are noted in respect of this point:

- *Siemens are to ensure that a procedure is in place regarding the introduction of new axles within Desiro UK EMU transmissions by 30 April 2012.*
- *Siemens are to ensure that a procedure is in place for the verification of final drive output bearing interference fits, including the introduction of new axles, within Desiro DMU final drives prior to commencement of the scheduled overhaul programme during 2012.*
- *Based on the evidence available, Siemens has not identified a significant risk regarding loss of interference fit on either Desiro EMU transmissions, or Desiro*

DMU final drives and, therefore, is not proposing any increased measures regarding the detection of overheating output bearings.

- *Siemens has completed a review of oil sampling regimes used on all Desiro UK fleets and is implementing a number of improvements.*

Southeastern

Southeastern has undertaken an initial fleet by fleet review of design, maintenance and operation which is summarised in the table below. It should be noted that all Southeastern operated units have solid axles (unlike the class 222 unit which experienced this incident) which reduces the effect of multiple interference fits on the axle and would significantly increase the time to failure should this failure mode be experienced .

Fleet	*Summary of review outcome*	*Further action proposed*	*Date for completion*
Class 465 and 466 'Networker'	*Design – units have solid axles, no experience of output bearing interference fit degrading in service* *Running maintenance - routine visual inspection, examination of metallic particles in gearbox oil and oil change is in place. 465/0 and 1 units have routine oil sampling.* *Operation – These fleets operate on low average speed services with frequent station stops. The time to, and consequences of, failure reduce the risk posed to this fleet.*	*Review of wheelset and gearbox overhaul specifications, jointly with ROSCOs, to ensure output bearing interference fits are achieved and any evidence of degradation is captured at overhaul*	*Sept 2012*
Class 375 and 376 Electrostar trains	*Design – units have solid axles, no experience of output bearing interference fit degrading in service.* *Running maintenance - routine visual inspection, examination of metallic particles in gearbox oil and oil change is in place* *Operation – These fleets operate on lower average*	*Reviews of wheelset and gearbox overhaul specifications, jointly with Bombardier Transportation and Eversholt Rail, to ensure output bearing interference fits are achieved and any evidence of degradation is captured at overhaul.*	

	speed services with relatively frequent station stops. The time to, and consequences of, failure reduce the risk posed to this fleet.		
Class 395 Hitachi High Speed Train	*Design – units have solid axles. The units are early into their service lives, no experience of output bearing interference fit degradation to date.* *Running Maintenance – routine visual inspection (every 14 days) gearbox oil sampling and change is in place.* *Operation – this fleet operates on HS1 at speeds of up to 140MPH. Stops are more frequent and average speed lower on this commuter service than on an Inter-City line*	*Undertake further design review of the gearbox and wheelset, with Hitachi. Request information on in service performance on other (non UK) Hitachi manufactured fleets.* *Review of wheelset and gearbox overhaul specifications, jointly with Hitachi, to ensure interference fits are achieved and any evidence of degradation is captured at overhaul.* *Review how this or similar failure modes would be evident to train crew.*	*Sept 2012*

Southern

Southern predominantly operates a fleet of DC EMUs which do not have a mechanical final drive arrangement similar to the one on the Class 222 Meridian unit involved in the incident. In addition all these units are fitted with solid axles. For these reasons Southern has determined that no further assessment is required with regards to those fleets in respect of the incident, and recommendation 2 of the report.

In addition Southern operate a small fleet of Class 171 Turbostar vehicles which do have a final drive arrangement, however this final drive arrangement is manufactured by ZF and uses solid axles. The assembly of the gearwheel is different to that of a Meridian unit, in that it is bolted to flange forged onto the axle, and therefore does not compress the axle. The UK Turbostar fleet has operated successfully since introduction in 1995 with no evidence of failures of the type that occurred at East Langton. Taking each bullet point of recommendation 2 in turn with respect to the Class 171 fleet

1) <u>Reduction in the size of output bearing seats due to shrinkage arising from other nearby interference fits and/or wear during service</u>

The 171 fleet in common with other Turbostar fleets does not have a final drive arrangement with any nearby interference fits which could cause reduction in the size of the output bearing seats. In relation to the wear of the final drive output bearing seat on the axle, the overhaul instructions ensure that all axles have their dimensions measured and any axles that are not within the specified tolerance are rejected.

2) <u>Bearing bore growth during the service life of the bearing (e.g. obtained by measuring a sample of bearings)</u>

As the RAIB report points out (paragraph 114) 'inner ring growth is a known phenomenon' and that 'allowance is made for this bore growth in the interference fits recommended by the bearing manufacturers. Given this and the length of experience with ZF Turbostar final drives in the UK, it is Southern's belief that the degree of bearing bore growth is at an acceptable level and that the current overhaul process controls this.

3) <u>Bearing seats being made undersize</u>

During manufacture the dimension of axles are checked and confirmed to be within tolerance. The axles used on the Southern 171 fleet were made by manufacturers who had been assessed as competent to supply wheelsets in accordance with Standard GM/RT2470 Wheelset Supplier Qualification and its predecessors. Any new axles or, overhauls of existing axles will be supplied by RISAS qualified suppliers. For these reasons, undersize bearing seats are not considered to be a risk.

4) ZF final drives in Turbostars do not have a history of failure of output drive bearings, and given the extensive UK service of these final drives in the Turbostar fleet, Southern do not believe that there is a case for fitting temperature monitoring systems to these units.

To conclude, having reviewed the report and the configuration of the vehicles of Southern fleet, it has been determined that the risk of a similar incident to that which occurred near East Langton is controlled to a tolerable level due to the existing measures in place.

South West Trains

South West Trains operate five fleet types, Class 158/9, Class 444,450 (Siemens Desiro), Class 455, Class 458, (Alstom Juniper) and Class 483 (Island Line).

Class 455 and Class 483 are of the suspension tube arrangement for transmission of power from Traction Motor to Axle. This arrangement is of different design to that of Class 222 employing gear cases lubricated with Crater Grease and suspension tube bearings lubricated with grease.

Desiro and Juniper axle gearboxes are of similar design in that power is transmitted through an oil fitted gearbox from traction motor to axle. The traction motor is mounted transversely across the bogie unlike the Class 222 where the traction motor

is mounted longitudinally with power transmitted through a prop-shaft. Due to transversely mounted traction motors utilised in the Desiro and Juniper fleet, and the gearing arrangement within the gearboxes the thrust loading experienced by the output bearing is significantly different to that experienced on the 222 fleet.

Both fleets have been subject to routine gearbox oil sampling for a number of years and no adverse trends have been identified, and neither fleet has suffered catastrophic, undetectable failure of output bearings.

A review of the overhaul specification for both axle and gearbox types requires tight tolerance checking of bearing boxes and bearing seats to be complied with and therefore we do not believe we are at risk.

Class 158 and 159 units employ a Gmeinder final drive driven by a prop shaft and are of the same configuration as a Class 222 where drive is taken through level gears. A review has been undertaken on both the Gmeinder overhaul procedure (CR/CI0567) and the wheelset datasheet for Class 158/159 power axles (IBTS0648/CR0908) and tight tolerances are specified and checked for output bearing boxes and bearing seats history has shown that these final drives do not give failures akin to that seen on a Class 222, however, the condition of the final drive oil is monitored through inspection of magnetic filler plugs and oil sampling undertaken every 30,000 miles as part of routine maintenance. Criteria are defined for action to be taken dependent upon oil condition of the oil identified, and if specific criteria are met, axles are changed out.

Due to the level of routine maintenance and robust overhaul procedures in place for Class 158/159 motor wheelsets, South West Trains do not believe itself to be at risk from the undetected failure mode seen on Class 222.

In conclusion South West Trains believes the power axle overhaul across its fleet is sufficiently robust to prevent occurrence of the failure witnessed on Class 222m, and therefore proposes to take no further action with respect to recommendation 2.

Transpennine Express

Recommendation 2 - Class 185

Reduction in the size of output bearing seats due to shrinkage arising from other nearby interference fits and / or wear during service

The final drive assemblies fitted to the Class 185 units feature axle mounted output bearings adjacent to an interference fit axle mounted gear wheel, both Master and Slave variants, being identical in design in this respect. TPE notes that the Class 185 is fitted with a solid axle which is therefore likely to be more resistant than the hollow axle involved in the East Langton incident to adverse influence of one interference-fitted component on the quality of interference fit achieved on another. To the extent that this condition is cited by the report as a possible causal factor, the fact of the solid axles on Class 185 units may reasonably be supposed to reduce the likelihood

of the failure condition precursor happening relative to a level less than that on a hollow axle design.

Prior to this recommendation a small number of condition assessment activities had taken place in association with maintenance optimisation activities, but these did not specifically report on the condition of the axle/output bearing interface.

One final drive unit has been examined in detail after 935,000 miles service, including measurement of the output bearing seats and bearing inner race bores. Both were found to be within manufacturing tolerance.

A scheduled overhaul programme will commence in May 2012, encompassing an initial batch of 116 final drives (a combination of both Master & Slave units). The overhaul specification requires measurement of the output bearing seat to verify that manufacturing tolerance have been maintained.

Bearing bore growth during the service life of the bearing (e.g. obtained by measuring a sample of bearings).

Siemens has committed to standardise the practice of measuring and recording both the output bearing seat and bearing inner race bore diameters (including a visual examination for signs of irregularity) during the overhaul of all types of axle mounted transmissions including the introduction of new axles, and it will therefore deploy procedure prior to commencement of the forthcoming overhaul programme.

Similarly, the condition assessment programme will continue in parallel with the scheduled overhaul and that programme specification will be amended to include the validation of the interference fit of the output bearings during this process.

Detection of overheating output bearings.

Siemens states that in considering the evidence it does not consider that an overheat detection system would add worthwhile benefit to the Class 185 final drive arrangements. Having regard to the findings of the report, the above analysis of the Class 185 configuration, the outcomes of the checks done to date and the enhancements to the future overhaul instructions, TPE accepts Siemens' advice on this matter.

Recommendation 2 - Class 170

Reduction in the size of output bearing seats due to shrinkage arising from other nearby interference fits and/or wear during service

Just as Siemens observed in respect of the Class 185 units, so Bombardier notes that the CL170 axle is solid, affording increased resistance to axle radial deflection during interference fit of one component affecting the quality of fit of another.

Moreover, Bombardier notes that on the Series 3 bogie used on the Class 170 units the gearwheel is not mounted with a heavy interference fit but rather mounted on a flange formed on the axle and secured by sixteen bolts screwed into tapped holes on the gearwheel. It therefore not possible for the installation of the gearwheel on the

Series 3 to adversely affect the interference fit of the gearbox output bearings in the manner cited in the RAIB report into the East Langton incident.

Components which are mounted adjacent to the gearbox output bearings are the labyrinth seal rings which are a light interference fit and spacer rings which have no interference. Bombardier considers that that the installation of these light- or no-interference fit components will not affect the quality of interference fit of the output bearings.

Bearing bore growth during the service life of the bearing (e.g. obtained by measuring a sample of bearings).

The overhaul documentation has been reviewed as recommended. There are two classifications of overhaul currently specified in the Bombardier Transportation COI for the Class 170 Turbostar final drives:

- Intermediate overhaul
- Standard overhaul

The intermediate overhaul is not intrusive and consists of a run on a purpose-built test rig to perform vibrational analysis, followed by removal of the top cover and a visual inspection of the gearbox interior to validate the findings. In the standard overhaul, all axle interfacing components including shafts are removed and are visually examined for wear and damage to the mating surfaces. The output bearings are renewed 100% at the standard overhaul. Overhauls conducted to date have revealed no evidence of wear or damage and Bombardier's opinion is that likelihood of bearing bore growth is therefore very low. Having regard to the lack of damage discovered to date, Bombardier does not propose the introduction of measurement into the overhaul instructions.

Bearing seats being made undersize.

CL170 overhaul instructions do not currently specify that bearing seats are measured for undersize condition, but having regard to the absence of damage or wear found during all overhauls to day and the resistance of the design to the 'degraded interference fit' causal factor, Bombardier does not consider this step to be necessary for this design..

Detection of overheating output bearings.

Bombardier notes that Turbostar DMUs have been in operation for over twelve years, during which time there have been no reported incidents of failing final drive gearbox output bearings. From the facts presented above relating to the design differences between Series 3 bogie wheelsets and the B5005 series bogie wheelsets involved in the East Langton incident, Bombardier advises that it considers the level of risk associated with CL170 final drive design configuration to be acceptable, and that there is therefore no requirement to fit a temperature detection system to the Turbostar Series 3 bogie gearbox output bearings. Having considered the East

Langton report, the analysis of the CL170 design configuration set out above, and the findings of inspections to date, TPE accepts this recommendation.

Responses to recommendation 3

Cross Country

Class 220/221

The current Class 220/221 oil sampling procedure P/3022 (Issue H) incorporates improvements to reflect the factors identified by the RAIB, and provides accurate and timely indication of abnormal behaviour

The current oil sampling regime now includes a level of cumulative analysis and is not considered that further improvements are needed in order to meet the recommendations of the RAIB report. Notwithstanding this Bombardier is proposing to carry out a further review of oil sampling to identify any additional improvements that can be made to what is already considered a robust regime, and expects to deliver its conclusions by the end of September 2012.

In summary, since the East Langton incident changes to the oil sample regime have:

- *Significantly reduced time between analysis of an oil sample giving a caution or critical indication and it being re sampled*
- *Introduced re sampling prior to an oil change on a final drive which has returned a critical sample (to rule out contamination of the previous sample and also identify a 'runaway' failure mode in a drive)*
- *Introduced caution and critical trigger levels for nickel and chromium elements in order to identify a final drive on which the gearbox output bearing is losing interference*
- *Introduced a super critical indicator in cases where a sample analysed indicates a significant deviation from the expected result. In this case, such a final drive will be removed from service within 48 hours of a super critical notification.*
- *Changed the re sample periodicity following an oil change in order to identify more effectively those final drives which are exhibiting signs of abnormal wear*
- *Adopted new criteria to identify those final drives which repeatedly reach cautionary levels between oil changes (i.e. the saw tooth effect). Previously these were likely to have been treated as isolated incidents. These criteria provide a cumulative measure of final drive oil contamination as they identify trends across a longer period than between individual oil changes.*
- *Introduction of fleet-wide oil change following ingress caused by adverse weather conditions*
- *Introduction of checks for opacity and unusual aroma. When such cases are advised, the final drive will be withdrawn from traffic within 48 hours*

HST

Due to the different design of transmission on HST power cars compared to the Voyager/Meridian fleets, oil sampling is not currently undertaken. Based upon the significant experience with the HST power car gearbox and there being no reported failures of the associated axle type, it is not proposed to introduce an oil sampling process.

Class 170

The current oil sampling process for class 170 final drives has proven reliable in providing early indication of potential problems. At this time, it is not therefore considered necessary to introduce changes to the process.

Arriva Train Wales

ATW operates a robust process spectrographic oil analysis process for final drives. Samples are taken at the shortest frequency exam ('A' exam) and results are reviewed promptly by experienced staff. Any arising action is taken swiftly and in accordance with a documented process. This process has been assessed as being 91% successful in identifying and removing from service final drives with incipient failures that could lead to catastrophic failure. Alstom also employ spectrographic oil analysis on the class 175 fleet, again with samples being taken at the shortest exam frequency

First Capital Connect

An oil sampling regime is already in place for gearboxes fitted to 377 units (VMI 4006 and 4006b). First Capital Connect will work to ensure that this is effective and give adequate advance warning of any impending failure modes. Class 365 units also have regular attention to the gearbox oil (VMI 4.3, 4.4 and 4.6 to ensure continued fitness for purpose.

Heathrow Express

Whilst this recommendation is primarily addressed to Bombardier transportation Ltd and the maintenance regime for Meridian and other similar Diesel Electric Multiple unit fleets we would like to advise that Maintenance of Heathrow Express rolling stock is undertaken in compliance with the current relevant Siemens (STSL) Company standards concerning periodic maintenance of Electric Multiple Unit types.

First Hull Trains

First Hull Trains have initiated an oil sampling regime of final drives following the publication of NIR 2805 where one had previously not existed. The appropriateness and effectiveness of this measure is being monitored.

London Overground Rail Operations Ltd (LOROL)

LOROL carries out routine oil sampling every 20,000 miles. LOROL has insisted on routine oil sampling with a view of implementing condition monitoring methodologies.

Siemens

During 2011, a complete internal review was completed on the oil sampling arrangements for all Desiro UK EMU fleets from scheduling and collection of the

samples, through to the Third Party analysis and results evaluation. This resulted in a number of improvement and standardisation points being identified throughout the process which, working in partnership with our supplier, are currently in implementation.

With regard to the Desiro UK DMU fleet, the relevant points from the above review will also be implemented where applicable. Additionally, following a recent technical review, specific alterations have been made to the oil sampling regime, including reduction of the critical levels for copper and zinc contaminants and a temporary reduction in the sampling periodicity. The latter measure is associated with the approaching overhaul programme, following which a return to the previously certificated periodicity is anticipated.

Responses to recommendation 4

Cross Country

Class 220/221

Practical training of drivers on the Cross Country driving simulators includes incident scenarios. These recreate various level 3 alarms and faults to ensure the driver carries out correct actions. This training is carried out annually and ensures that drivers are subjected to a diverse selection of train incidents that could be experienced in the course of their duties

Specific faults and failures information is briefed to drivers by means of the 4 monthly Cross Country safety briefing.

HST

Specific faults and failures information is briefed to drivers by means of the 4 monthly Cross Country safety briefing.

Class 170

Specific faults and failures information is briefed to drivers by means of the 4 monthly Cross Country safety briefing

Arriva Trains Wales

ATW has a Competency Management System that makes sure train crew maintain their knowledge with alarm systems relevant to specific traction. ATW shall include the Red 32 DVD, which shows a reconstruction of the bogie derailment on an East Midland train, into the train crew Safety Training and Update Day (STUD). STUD will provide refresh training on specific alarms applicable to traction types and ATW shall sample train crew knowledge and understanding through unobtrusive monitoring

Colas Rail

Colas Rail undertakes formal train driver assessments of its drivers either once or twice a year to a formal assessment plan. The driver assessment forms part of the Colas Rail Competence Assessment System for on-track machine and locomotive drivers. The assessments are undertaken with the driver and a qualified assessor in accordance with company procedures. Two elements of the procedure, specific to the report, include: "Respond to Service Faults and Failures" and Respond to Out of Course Situations and Potential Hazards"

Devon and Cornwall Railways

A traction bulletin has been issued outlining the requirements for DCR Diving Standards Managers to establish any additional training or guidance that is provided to our customers train crew in light of the derailment and or these recommendations

are assimilated into the traction training function of the DCR Competence Management System.

Direct Rail Services

DRS Operations should review traction training and operational instructions issued to Drivers relating to in cab warning lights indications they may observe on all traction operated by DRS

First Capital Connect

First Capital Connect operates Driver Only Operation, and therefore has no 'On Board Train Crew' other than the driver, however out of course incident and alarm management is embedded in the current training and on-going competency management.

Grand Central Trains

We have briefed all of our train-crew on this incident and the learning points using the Red 32 DVD. We are also looking at our competence management system to enhance this through the use of simulators and scenario based refresher training for staff. As Grand Central is now part of the Arriva Group, we are hoping to set up these enhancements in conjunction with our fellow Arriva organisation Cross Country Trains who have facilities at Derby for this.

Heathrow Express

All Heathrow Express train driving staff are trained and assessed in fault diagnosis and response on entry into the driving grade, subsequent refresher training and briefing on "in cab alarms / warnings" is undertaken in co-operation with Siemens Transportation maintenance technicians at Old Oak common depot in order to ensure that all parties are able to cohesively recognise and prioritise their actions should a train encounter a defect or fault.

Refresher training events are planned taking cognisance relevant operational incidents / accidents affecting Heathrow Express operations and industry reports where transferable lessons may be incorporated.

Heathrow express' train driver competence management system criteria (E3.3A) describe the actions of a driver encountering a system / vehicle fault, individual competence is verified by workplace assessment observation or scenario based questioning.

On Board staff also receive training and regular re-briefing on the importance of vigilance within the workplace and reporting non urgent and emergency situations to the train driver

First Hull Trains

First Hull Trains has already initiated a review of emergency situations including on board handling procedures which is being briefed to train-crew as part of their safety days.

London Overground Operations Ltd (LOROL)

LOROL drivers are trained in their response to alarms as part of initial training. That includes the different response to yellow alarms (advisory) and red alarms (those that require an immediate response). As part of LOROL's response to this RAIB recommendation we are reviewing the training content to make sure all the possible red alarm situations are covered in sufficient detail. If necessary changes will be made to the training content following this review.

In addition the next Safety Training and Update Day (STUD) cycle for drivers will include refresher training on correct alarm handling. The latest STUD cycle for drivers includes practical briefing and training in train evacuation – in particular using the detrainment device on Class 378 units and de training from one unit to another alongside.

Northern Rail

Northern do not have rolling stock installed with automatic heat detection on any output bearing arrangement. Inspection of output bearings, or any visual bearing, is included in scheduled examination inspections. A summary of these is as follows:

- *Scheduled task in all Vehicle Maintenance Instructions to inspect drives for issues of distress*
- *Periodic oil changes and inspections of magnetic plugs for debris build up*
- *Clear instructions are contained in the VMI for actions to take if debris found either on magnetic plug or discolouration of oil*

Northern are conducting a review of methods in place to detect suspect final drive prior to failure. This review will include the following methods:

- *Staff training and briefing on drive failure detection*
- *Review of maintenance documentation and periodicity to ensure robust and suitable*

Evaluation of monitoring techniques to highlight potential drive failures