8. On-Depot Fault Finding

This section covers No Fault Found (NFF) process and systemic faults that often materialise as repeat defects. This section contains information to help with the diagnosis and rectification of these faults.

8 On-Depot Fault Finding

This section explores root cause analysis and the development of a permanent solution for the fault, which may be:

1. Modifications to the train design
2. Additional training and development of staff
3. Addressing supply chain quality issues

Topics covered in this section are as follows:

8.1 Standardising fault-finding

8.2 Novel testing and inspection equipment

8.3 Developing the establishment of fault-finding within an organisation

Other sections of the 20PP related to on-depot fault-finding are:

- *Section 7* – The Depot, which includes details on the human resources aspect of depots
- *Section 9* – The Vehicles, which describes good practice in data collection and analysis, repeat defects and trends

8.1 Standardising fault-finding

One of the most effective ways to define a process is through a continual improvement loop. Jumping to conclusions when fault-finding often leads to incorrect diagnosis and repeat faults. For example, if a driver reports that the train will not move, then a hasty assumption that there is a fault with the traction could be wrong; there could be any number of reasons, such as a fault with the door interlocking system.

The flow chart below shows the 5 high-level steps for fault-finding and is based on two principles: DMAIC and OODA. The OODA loop (Observe, Orientate, Decide, Act) is a continuous cycle used when the correct solution to a problem needs to be found fast with several iterations and is useful for depot maintenance. DMAIC (Define, Measure, Analyse, Improve, Control) is part of the 6 Sigma process and is more useful when time is not a constraining factor. By combining these principles, the flow chart gives guidance on how to arrive at the root cause of the problem quickly whilst creating learning points for future processes.

Step 1: Identify the features and conditions of the fault

a) Asking the right initial questions is vital to speeding up the fault-finding process. Whoever is creating the work order must give and receive the correct information.
b) What are the **symptoms**? Collecting and processing information from sources such as OTDR, CCTV or drivers' reports produce more accurate diagnosis.
c) Broken components are not necessarily the root cause in themselves and may be a symptom of another fault in the system. A system-based approach is best, whereby inputs, processes and outputs are compared to the component specification; there may be an issue between the train and the component.
d) It is important to carry out visual inspections as well as functional tests using existing VMIs and VMPs.

Example: The quality of information from drivers' reports, especially when the unit has limited telemetry, can greatly assist the collation of information on symptoms. GWR issue drivers with prompt cards to use if an HST set fails in service to help them get the unit moving. When the unit gets to the depot, drivers can report that they have completed certain tests to help eliminate potential faults. The prompt cards are complemented by a guide for maintenance controllers, which ensures that the right cards are used, and the process followed by the drivers can be verified.

Step 2: Check the vehicle history and documentation

a) Using the vehicle history, faults can be identified as intermittent, repeat or hard. This will determine how to proceed and whether the fault is active.
b) When dealing with repeat faults, any previous work carried out should be reviewed. This relies heavily on the reporting process, which is covered in a later step. For intermittent faults, the process should be accurately logged so that it can be referenced if the fault occurs again.
c) Historical data of the fault should be reviewed, including change control, modification levels, drawings, etc., as should the vehicle's Failure Mode and Effect Analysis (FMEA).
d) As a minimum, fault-finders need wiring diagrams, all system schematic diagrams, functional specifications and interface specifications for the systems they are working on.
e) Industry groups, such as fleet comparison user groups, are helpful to compare fleet issues but information obtained from these sources should be treated with caution and should not replace existing industry processes (such as raising an NIR).

Step 3: Make an informed hypothesis as to what the fault is, create a work order and repair the fault

a) The fault-finder should have a starting point for further investigation, and broadly know the scale of it for maintenance planning and resource requirements. The key now is to work systematically and record all information relevant to the root cause.
b) When testing the failed component, the VMI and fault-finding guides should be followed; experience can sometimes be a hindrance. The root cause can be overlooked if fault-finders are too hasty in diagnosing the fault without considering the symptoms.
c) Any modifications or changes must be approved by all relevant parties (maintainer, owner, operator), recorded and added to keep drawings up-to-date.
d) It is vital that the fault can be simulated to confirm the diagnosis.
e) If the fault cannot be found, an expert opinion could be sought from the warranty team and the supply chain; whichever party overhauled the system should be consulted in the initial instance.
f) By now the fault-finder should have identified the nature and cause of the fault. Once the failure mode is known, a plan can be created to decommission the train, repair and then recommission it.

Example: Below is an example of a fault-finding procedure used by Angel Trains when the HVAC equipment fails. Following a flowchart such as the one below ensures that the correct procedure is followed, and fault-finders ensure that the root cause is identified.

Step 4: Testing and reporting

a) The repair needs to be tested thoroughly to ensure it has been rectified and no other new fault modes have been introduced as part of the investigation.
b) A functional test should be carried out to confirm that the system is now functioning correctly in accordance with the VMI as this is the certified maintenance plan supporting the safety case.
c) Where a component is continually showing NFF, asset tagging should be used to find rogue offenders. Components can be tracked in several ways, by asset tag, bar code and component serial number. Monitoring equipment such as data loggers or temperature indicator strips can also be used.
d) Reports should as a minimum replicate each phase of the process and the key findings.
    i. Test data and parameters should be included in electronic format for further analysis. Scanned copies of written reports are acceptable providing they are filed correctly.
    ii. Where fault-finding has been limited by testing equipment then a process to allow recommendations on how to improve testing equipment should be made.
    iii. The report should focus not only on the technical aspects of the job but also on softer elements, such as team work and listening to feedback from operations.

Example: Lockheed Martin have developed their own test rig, the LM-STAR. It is adaptable, can easily integrate new testing capabilities tests all components from the supply chain on the same rig. If there are any quality issues, Lockheed Martin can address them and does not accept an NFF.

Example: London Midland use the computer-based system Equinox to report and record faults. Technicians populate the system with their repair notes and all defects are coded and grouped for future reference. Repeat defects are monitored using screens connected to the network that display data from the last 28 days in places critical to the business. This means that all the data is readily available to technicians. In order to make this effective, technicians should be given guidance on the level of detail required. The MMS needs to ensure the information is captured and the work report cannot be closed without sufficient information.

Example: Alstom have a test rig (shown in *Figure 1*) that can simulate a train in service in order to test the traffic management systems. This means that the root cause can be identified through trial and error without the unit failing in service. The rig has tested over 500 TMS components and over 350 CCTV components, of which only 24% and 35% respectively were assessed as NFF. All these items were returned to stores for train use and no repair costs were incurred.

Figure 8.1: Alstom's TMS simulator at Oxley Depot

Example: GWR carry out in-house overhaul and repair on certain components (e.g. load regulator electronic modules). All work, including defects, is recorded in a database maintained by the ride inspector team. This enables repeat defects to be highlighted and monitored for trends. The Electrical Test Room (ETR) at GWR also has a test rig that allows prolonged testing of any affected modules to find intermittent faults that may not be obvious under normal testing conditions. The test rig also allows for live testing of high-voltage electrical equipment under controlled conditions away from the vehicle, allowing the vehicle to stay in service while defective components are found.

Step 5: Review, rectification and training

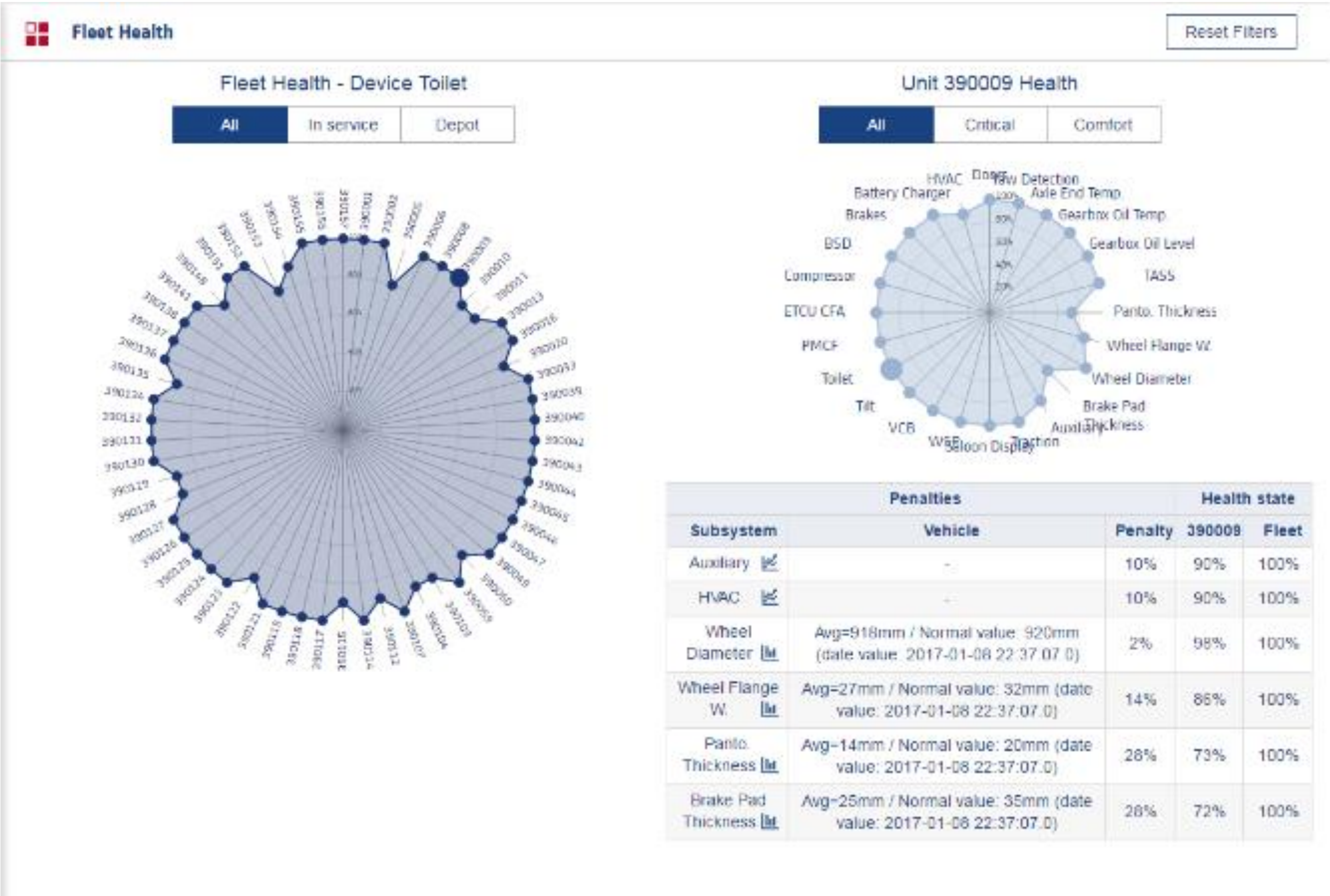
a) Fault-finders need to own the problem and find a permanent solution.
b) VMIs and fault-finding guides should be regularly updated and reviewed in light of work carried out, especially where the fault could have been identified as part of routine maintenance.
c) The vehicle's FMEA may also need updating to include any new failure modes identified during fault-finding.
d) Training and competence need to be assessed to ensure that lessons have been learnt.
e) Information on any changes needs to be passed on to all relevant personnel, including fleet operations, as maintenance may have affected the way guards and drivers interface with the equipment. There may be an issue with operation of the defective equipment that could be a training issue for the whole industry.
f) The use of public advertisement, such as the stickers on Virgin Trains West Coast's toilets, can help reduce the likelihood of a fault reported by the public.
g) Skills availability across teams and shifts needs to be balanced to ensure there are always adequately skilled staff for fault-finding work. A skills matrix to manage skill shortages/deficiencies across shifts is one way of managing skill availability.
h) Fault-finders should not make any modifications without the correct engineering change approval.

Example: Alstom use a Root Cause Analysis (RCA) as part of their review process. If a unit fails in service and the fault is a suspected repeat failure or due to previous incorrect intervention, an RCA should be raised against the relevant department or site. This allows the business to understand the root cause and put in place preventative action. After the RCA has been completed and the root cause found, the report is added to a tracker which is distributed to Head of Operations and Fleet Engineer.

8.2 Novel testing and inspection equipment

To support systematic fault-finding, equipment to access train wiring to test for inputs and outputs and monitor functions should be a minimum requirement. Train wiring schematics/diagrams can help locate a feed from the relay panel, but actual test looms may require fabrication to break in' to train wiring. Where PLCs and control units are used, specialist diagnostic equipment will be required to test processes and fault-finders may need specific IT training to support these specialist diagnostic tools.

Example: Alstom use a Health Hub scanner in conjunction with a Fleet Health application to monitor fleet performance. After the unit has passed through the scanner, information on wheel profiles, brake pads, pantographs and component position is collated into the health checker (as seen in *Figure 2*). This allows them to monitor defects and build an accurate database of faults and where they occur on the network. The monitoring software also allows TMS events to be recorded in real time.



Penalties				Health state	
Subsystem	Vehicle	Penalty	390009	Fleet	
Auxiliary	-	10%	90%	100%	
HVAC	-	10%	90%	100%	
Wheel Diameter	Avg=918mm / Normal value: 920mm (date value: 2017-01-08 22:37:07.0)	2%	98%	100%	
Wheel Flange W.	Avg=27mm / Normal value: 32mm (date value: 2017-01-08 22:37:07.0)	14%	86%	100%	
Panto. Thickness	Avg=14mm / Normal value: 20mm (date value: 2017-01-08 22:37:07.0)	28%	73%	100%	
Brake Pad Thickness	Avg=25mm / Normal value: 35mm (date value: 2017-01-08 22:37:07.0)	28%	72%	100%	

Figure 2: Alstom train management tool

8.3 **Developing the establishment of fault-finding within an organisation**

8.3.1 Establishment of fault-finders

The following should be considered at the beginning:

a) What are the volume, nature and type of faults experienced?
b) What type of fault-finders are required; fleet or system?
c) How many fleets or systems will each fault-finder be accountable for?
d) How long will it take to rectify a fault?
e) Have training courses/days been planned and is there adequate cover for these periods?

By considering these points, depots can plan how many fault-finders they are looking to recruit or develop from existing maintenance technicians. Once that has been decided, technicians need to be incentivised to become fault-finders with enticements such as career progression, increased responsibility and rewards.

Once potential fault-finders are identified (desirable skill sets are detailed later), a clear training and development programme needs to be set out to chart their skills and allow them to understand the role properly. Succession planning is a vital element to ensure that there is a continuous flow of experienced fault-finders to mentor new fault-finders. The new apprentice levy is an excellent opportunity.

8.3.2 Features of a fault-finder – soft skills

Soft skills are important as often fault-finders must work as part of or support a maintenance team and be able to clearly explain faults to their peers. They need to explain the fault clearly to non-technical staff and be confident enough to challenge design elements of the system, e.g. by evidencing facts using data.

They must be inquisitive by nature, be able to reflect on their own performance and identify their strengths and weaknesses. Fault-finders should be disciplined, organised, accurate and methodical and be able to confidently express their ideas.

Examples: Southern use a core group of team technicians for fault-finding who support each maintenance team.

8.3.3 Features of a fault-finder – technical skills

Their ability to see the bigger picture and understand the consequence of a poor or late job should motivate them, as should their ability and desire to learn new skills and progress in their career. Fault-finders need to have experience of complex systems engineering, such as commissioning experience. A good basic knowledge of electricity and mechanical systems combined with computing are essential core skills. Along with knowledge of train systems, fault-finders should have some operational knowledge, so they can judge the standard of an acceptable train in service and understand the reason for their work. They will naturally become more specialised in a certain area due to over-exposure to a specific system. In this case, it is important that they:

a) Can pass their knowledge on to other people using their strong communication skills
b) Retain their knowledge of the entire train as staffing numbers and the depot may require them to work on any part of the train. Knowledge is best retained through recording work done and running refresher courses on the different subsystems on board.
c) Consider how the work they are doing can be broken down into chunks (train/subsystem for fleet/systems engineers)

With the introduction of new trains, there is an increasing need for fault-finders to have a solid understanding of IT and software for trains with advanced telemetry. It is increasingly vital for fault-finders to be able to support and maintain their own diagnostic equipment as IT departments do not have the skillset to do so.

8.3.4 Training and development

Depots should make use of all available training methods, such as simulators like Alstom's TMS test rig and Interactive Virtual Training such as 5lamps (shown below). Using different training methods allows for subject-specific training whilst still appreciating the whole system. As an extra incentive for training and development, some depots offer technicians the opportunity of gaining recognised qualifications in engineering and maintenance.

Example: GWR have an in-house testing facility for central door-locking equipment, electrical converters, HVAC and some catering equipment. As well as providing a controlled test environment for fault-finding, these facilities also provide an ideal training facility for new starters and apprentices as well as enhancing fault-finding skills for depot staff.

Example: Alstom provide their technicians with a Level 3 training programme for train systems (traction, AWS, HVAC, etc.). It is based around PowerPoint presentations and supported by a

question paper. Technicians have to successfully complete the question paper prior to commencing the competence assessment process.

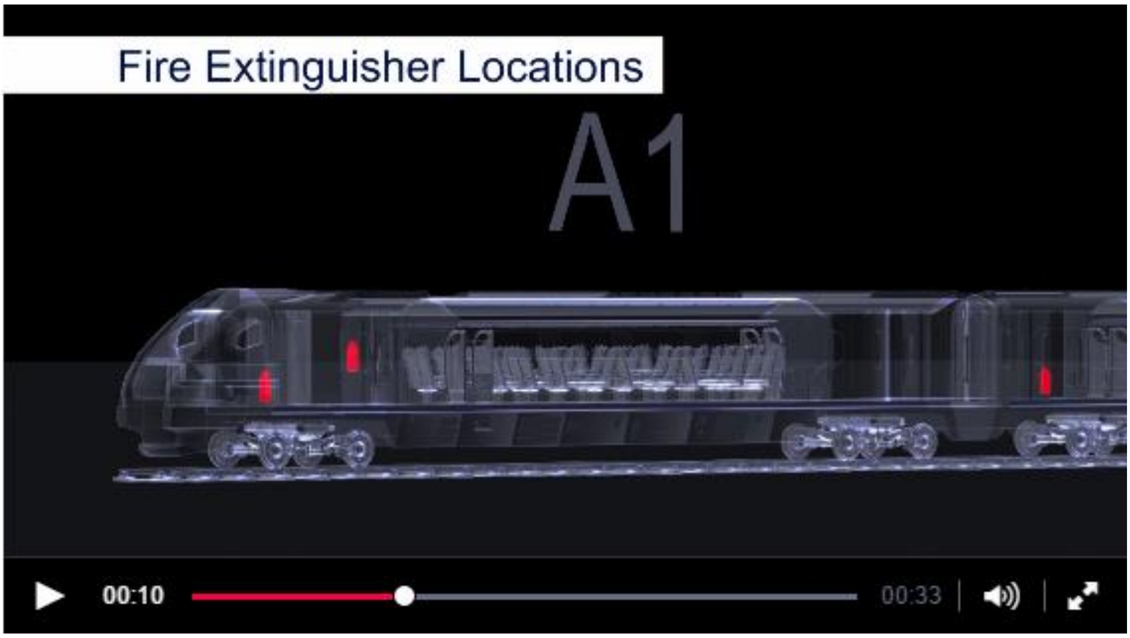


Figure 3:5 5lamps software simulation

The above simulation was made for East Midlands Trains. The short video shows the location of the on-board fire extinguishers, the different types of extinguishers and when to use them. It is used by train drivers and on-board staff for training. Using simulations is a powerful tool as components can be disassembled and analysed quicker in a virtual environment than in real life. There are simulations for different operators, Network Rail and other industries available at: 5 Lamps Media

Training does not have to only be delivered on depot. OEMs, supply chain, overhaulers, consultancies and he UK Rail Research and Innovation Network (UKRRIN) can be used for expert training as well as collaboration on research projects to increase depth of understanding. Companies may not wish to disclose commercially sensitive information, so compromise may be necessary.

The use of bespoke testing equipment for verifying a NFF diagnosis can also benefit training as well as lowering the cost of sending components back to the supplier for fault diagnosis.

Finally, a feedback loop with periodic reviews should assess the quality of training. Fault-finders should be encouraged to be honest with their reviews and all feedback should be taken into consideration when reviewing the training material and programme. The information gathered needs to be shared with the appropriate people to bring about change and ensure that fault-finders are receiving the best level of training possible.