Inaugural Workshop of the BINDT Working Group on NDT for Heritage Boilers

Alresford Goods Shed, Mid Hants Railway • Thursday 13 February 2020 • 10h00-17h00

Co-sponsored by the Mid Hants Railway and the British Institute of Non-Destructive Testing

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BINDT
THE BRITISH INSTITUTE OF NON-DESTRUCTIVE TESTING

...engineering safety, integrity & reliability

Inaugural Workshop of the BINDT Working Group on NDT for Heritage Boilers

Chair: Robert Smith, Professor of NDT at the University of Bristol,
Director of the UK Research Centre in NDE and Past President of BINDT.
Co-sponsors: Mid Hants Railway and BINDT.

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Introduction

The British Institute of Non-Destructive Testing (BINDT) Working Group on NDT for Heritage Boilers was created as one of the recommendations of the BINDT Workshop on NDT Requirements for Heritage Railway Boilers, held in February 2018, and this was its inaugural workshop/meeting. The group is to recommend potential improved NDT methods, NDT training and qualifications, validation methods for NDT techniques and samples required for validation and pre-inspection calibration. The other main recommendation of the requirements workshop was for the Heritage Railway Association (HRA) to form a group for reviewing the HRA boiler codes of practice (guidance notes), including allowables for defect types, safety factors going beyond the original design documents and including more on NDT with input from the above BINDT Working Group.

The following is a summary of the other requirements from the workshop:

- Define new NDT methods to find small defects in the known problem areas and surrounding environment. Monitoring of defects should be undertaken.
- It is important to use suitably trained NDT operators and a list of those who have the required training, qualifications and experience in each method should be considered.
- A review of the HRA guidance notes is required to include NDT and this review should be undertaken by a group that includes the insurers, who agree a process and establish a central repository for sharing experiences of working with boilers of specific types.
- It is important to review the defect allowables standards for the heritage sector to encompass these defects, allowing for the long period of generation of defects and the potential for monitoring defects.
- A central illustrated repository for shared information about failure modes and NDT inspections on specific boiler types/locomotive types would future-proof the heritage sector as we lose the first-hand experience and a suitable host needs to be found for this.
- Guidance on the advantages and disadvantages of different NDT methods is required.
- Guidance on NDT best practice, where possible, would provide a starting point, a validated NDT solution, allowing the competent person to consider it as their recommended inspection.
- Training and certification of in-house staff is needed, for example to NDT 'Level 1 limited' just for ultrasonic stay inspection.
- Provision of test samples is needed, both for validation and for proving the functionality of the equipment at the time of inspection.
- A process for validation of the reliability of NDT procedures (techniques) is required.

Working Group objectives

The objectives of the new group are taken from the BINDT Workshop on NDT Requirements for Heritage Railway Boilers, the report of which is available to download from the BINDT website. The objectives are listed on the web page for the working group, which is also on the BINDT website, as follows:

1. To develop and evaluate potential improved NDT methods for heritage boiler inspection and to make available the outcomes of the evaluations in terms of capabilities and limitations.
2. To create a recommended practice for ensuring that NDT inspections can be relied upon to accurately reflect the boiler condition, including oversight of NDT training, experience and qualifications.
3. To create a best practice guidance document for appropriate NDT methods, including information to assist in the choice of the most appropriate method.
4. To make possible the validation and sign-off of NDT written procedures for specific inspections.

5. To collect, design and manufacture samples required for validation of NDT techniques and calibration blocks for pre-inspection calibration.
6. To create a central illustrated repository for shared information about failure modes, experiences and NDT inspections on specific boiler types that would future-proof the heritage sector as we lose the first-hand experience.

Strategy for technique validation

A proposed strategy for technique validation was presented and is illustrated in Figures 1 to 3 in the case of plate corrosion. The process begins with a scientific study of detectable defect size *versus* severity using an artificial specimen with a series of simulated defects, see Figure 1 (top). Subsequent studies of the effects of various defect attributes, such as roughness and edge effects, allow a mark-up in detectable defect size, see Figure 1 (middle). Similar effects of real *versus* artificial structure are then determined with other samples, see Figure 1 (bottom). An example of how this works out in terms of a graph of detectable defect size *versus* metal loss is shown in Figure 3.

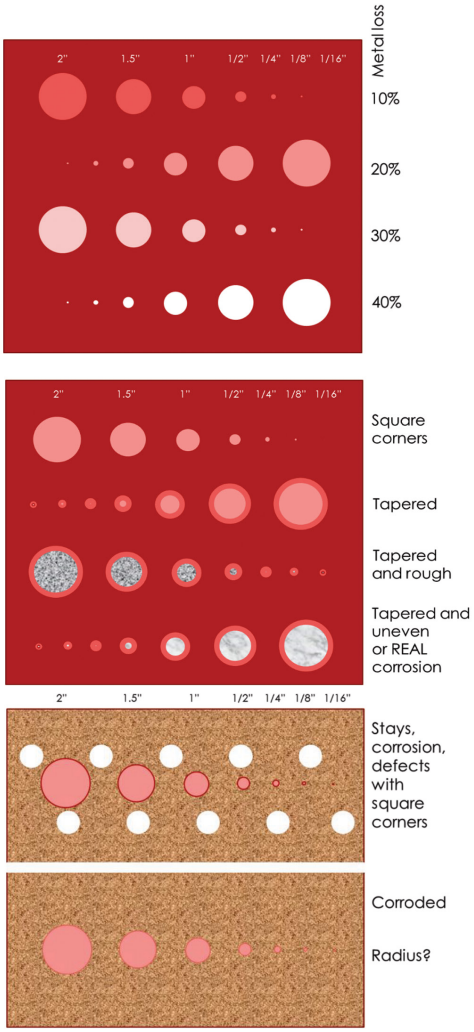

Figure 1. Proposed reference corrosion samples with artificial defects and surface roughness: the top image shows a sample for determining detectable defect size versus metal loss; the middle sample allows for determination of the difference in detectable defect size for realistic defects compared with artificial defects; and the lower samples allow the effects of realistic versus artificial samples to be assessed

		Defect	
		Artificial	Real
Structure	Artificial	Full study	
	Real		

Figure 2. Table showing how a scientific study of defect detectability in an artificial structure with artificial defects can be read across to a real structure and real defects

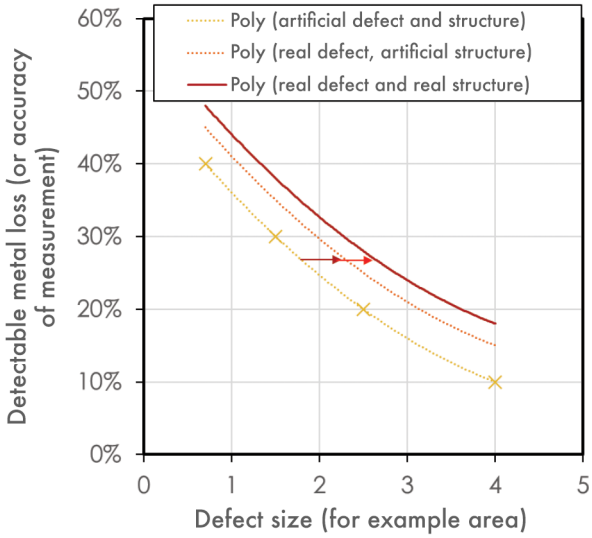

Figure 3. Example graph showing how the dependence of detectable defect size varies with metal loss for a real structure (solid line); also shown is the process for determining this from a study of artificial defects and structure followed by an investigation of the effects of artificial versus real structure and artificial versus real defects

Breakout sessions

1. Evaluation of NDT methods (Joe Buckley)

Methods to evaluate

The methods can be divided into key problem areas as follows:

- **Steel boiler tubes:** (IRIS or remote-field eddy current or magnetic flux leakage) corrosion on outside of steel boiler tubes where an internal rotating probe could be used to measure thickness.
- **Surface-breaking cracks**: magnetic particle inspection (MPI) is used a lot. Eddy current is easier as it is quicker and does not need so much surface preparation.
- **Internal cracking along a line between stays**: angle-probe ultrasound would be useful but techniques would need to be developed.
- **Cracked stays**: standard ultrasonic testing (UT) with a conventional probe works well on smooth stays and wire brushing may be sufficient to clean off enough corrosion product. Otherwise, a UT membrane probe (such as for spot welds) could be used or phased array with suitable coupling (as demonstrated by Richard Thompson of Baker Hughes).

Also, a low-frequency tap testing method may detect cracked and partially cracked stays better than the hammer.

- **Grooving at the foundation ring**: phased array with a flexible array probe or flexible stand-off. A small electromagnetic acoustic transducer (EMAT) may also work.
- **Corrosion thickness measurement:** UT with surface preparation or EMAT, possibly pulsed eddy current on larger areas.

It is important to consider remote visual approaches such as the Mentor system demonstrated by Baker Hughes, which can perform stereoscopic 3D profile mapping on the end of a guided borescope.

Much equipment is expensive, so consideration should be given to having a consortium-supported lending library of equipment or a rental scheme for the industry.

Advantages and disadvantages

What are the criteria relating to advantages and disadvantages?

- The ability to cope with the surface condition and how much preparation is required.
- The availability of trained NDT technicians, especially for advanced techniques.
- How well we know what defects are expected. Some techniques are only applicable if this is known.
- Access issues. Preparation may escalate.

Validation samples

A library of real samples with real defects would be useful for technique validation. There are lots of real samples available from all the scrapped boilers! Simulated defects and surface conditions to evaluate performance would be possible.

Photographs and records of samples would be needed. They may be locations on a locomotive in a yard, for example.

We then need a knowledge base of what defects are in the samples and where, as well as the ability to check whether we have samples of each type of defect.

Calibration blocks

It was felt to be too early to say much until we have worked out what NDT methods we need to cater for. Simulation of defects will depend on the NDT method.

Some calibration blocks are to verify the equipment is working properly, both before and after the inspection, and some are to set the test parameters accurately. Other blocks may have realistic defects and component features to check that the operator, written procedure and equipment, when combined, are capable of finding the required size of defect, especially for low-skilled operators who may be less happy with making changes from the test-block to the real component.

We must establish how these are linked to the library of samples and to the samples used for training and evaluation of methods.

Do we have operators training on real samples or simulated samples, or both, and how do we manage that? We cannot do the training at the location at which the reference library of samples is stored.

Do we simulate surface condition? It is very difficult to simulate corrosion over a long period. Maybe we could simulate the whole component with a range of defect types and sizes.

2. Best practice document (Andy Wright)

Objective

After NDT has been carried out at the ten-year inspection, there should be no hidden defects remaining. Current HRA documents do not give any real guidance on NDT. Hence, the objective of this guidance document would be providing guidance to the competent person, the rolling-stock user or the railway society about available NDT techniques, their limitations, where they can be used and what sort of defects they could find. The NDT inspector needs to have a close working relationship with the competent person, whoever it is.

Scope

The scope includes steel and copper fireboxes and all the attachments to the boiler such as superheaters, flue tubes (including braised), etc, and extends beyond heritage railways to road vehicles, boats, etc. It does not just relate to ten-year overhaul inspections but could include in-service defects.

Whilst a document can state what the detectable defect size should be, restricted access and surface condition can adversely affect this, so it tends to be a judgement call.

Audience

The audience includes many people, such as HRA members, repair companies, NDT operators, inspection authorities (whether independent or big companies) and the heritage industry including museums and the National Trust, which have traction engines. Mainly, however, the audience is the responsible person, the boilersmiths who oversee the repair of the boilers.

Accessibility of the document is important; it should be easy to find and freely downloadable (in fact, the HRA guidance notes are easily found and free to download – RAS managed to do it really quickly, but it is not currently obvious which guidance documents contain anything about NDT).

Level of detail

A general scope of work covers: a method statement, what techniques are available to use, how to use them and areas in which they can be used in looking for different defects. So, a general NDT guidance note giving defect type and size as well as the detailed knowledge that exists about specific locomotive types that need specific NDT methods could be included, for example Black Five back-heads. These could be incorporated in the schemes of examination of the boiler. Then, the competent person has guidance on what special NDT is required for a specific type of locomotive boiler.

It is important to have images in the document and pointless to have reams of text when a simple picture could be enough to explain what is needed.

3. NDT training (Bob Rollason and Meurig Davies)

Five- and ten-year mandated NDT inspections

At present, NDT inspectors are contracted in with heritage boiler experience and super-duper kit.

Training has to assume a go/no-go specification for the NDT technician. It is important that the NDT technician is not required to make a 'fitness to run' decision. An engineer needs to specify allowable defect size and then the NDT technician should work to that.

In-house NDT inspections for inspection-based maintenance, restoration decisions and costings

There is no major issue with this (it is done in other sectors), provided there is adequate training and experience of the operator. In-house NDT needs to be monitored, preferably by an outside agency, to build confidence in NDT. However, in-house NDT needs equipment.

Younger boiler technicians need to learn from more experienced people. If you are trained on NDT equipment, are you going to use it enough to retain competence? MTD runs two-day NDT awareness courses to provide an idea of an NDT method. There are also BINDT apprenticeships in NDT (www.bindt.org/education-and-training/Apprenticeships).

Some companies are concerned that they will pay to train someone who may then leave. A solution is to put in a pro-rata repayment system where if someone leaves within five years, for instance, then they have to pay back a pro-rata proportion of the training costs.

Once qualified, for example with a Level 1 (limited) for certain specific inspections, it would need to be decided whether that is sufficient or whether additional site-specific training is required.

Someone needs to be designated as responsible for the NDT that is carried out and able to instruct the NDT technician to carry out a particular NDT work instruction in a particular location. That person also needs to be responsible for determining competence of the NDT technician to carry out the inspection and could choose a combination of in-house employer-based boiler-specific training/certification and generic training such as the PCN Scheme run by BINDT. PCN has a category, 48: 'Thickness measurement and corrosion monitoring', which may be ideal.

An HRA NDT Team was suggested. The team would have experience of steam railway boilers.

The NDT technician needs a specification to work to and should not be left to make engineering decisions about fitness to run for the next five years. It is important that the wealth of experience is transferred to a written practice stating what has to be inspected and to what standard.

The process could involve an appreciation course, general theory examinationm and then in-house training with surveillance from within the company or from outside. Once there is a best practice guidance document, a specific boiler examination could be based on that.

We could go down the route of having a written practice for the industry or company where all the required training and experience is specified and then go to generic PCN certification for outside validation, bringing the industry into an internationally recognised system.

[RAS: This is similar to EN 4179 for aerospace where a 'Responsible NDT Level 3' is designated or contracted into each company. HRA could specify something similar. In fact, a National Heritage Railway or Heritage Boiler NDT Board could be set up to oversee the scheme, like the National Aerospace NDT Board.]

4. Shared repository (Becky Peacock)

Scope of information on failure experiences

This will be a forum sharing what others are doing with reports on hot spots on various boiler types/locomotives. Illustrations and videos will be beneficial as they widen accessibility and are an easy way to share information. The boiler codes of practice would be enhanced by this information.

Scope of information on NDT methods and experiences

A glossary of NDT techniques, what they are and what they are useful for is needed, with details of new techniques also given. It could go beyond the best practice guidance by being more specific to boiler type. A matrix of methods against defect types with illustrations would be good, and/or a flowchart for deciding which method.

Information about what others are doing will be useful, along with a list of NDT inspectors with boiler training/experience. This would be really useful for specialist inspections. Also, a list of suppliers would be beneficial.

Where would it be hosted?

This needs the widest audience but should be 'managed'. This should be a 'living' repository with version numbering, where suggested edits are considered and decided on by a consultation panel of leaders in their fields, as a group decision.

An eNewsletter or service bulletin should be sent out when it is changed. It will need to be accessed at different levels with passwords: (i) all users; (ii) editing user; and (iii) eNewsletter sign-up.

It could be on a website that already exists and is used by the community, maybe that of the Boiler and Engineering Skills Training Trust (BESTT) or HRA.

Or perhaps it should have a standalone website and go beyond railway boilers, opening up other funding sources if we include boats.

Sources of funding

A host would probably be needed, someone to prepare the proposal, head up the work and feed through the paperwork. Maybe this could be BESTT. Suggested sources include:

- HRA has members that are groups
- Heritage Lottery Fund
- Arts Council, Subject Specialist Networks (SSNs)
- National Traction Engine Trust
- If boats are included in the scope, this opens up other sources of funding.

NDT method evaluation

A quick survey of likely methods was proposed, to be followed up with a more detailed study with funding, if available. It would be very useful to have some funding as future commercial sales would not be a driver for a supplier to put the effort in.

Proposed Executive Committee

A few people were asked if they were interested in joining an executive committee to help progress these suggestions and the following people agreed:

- Becky Peacock, National Waterways Museum
- Sam Rowbotham, Mid Hants Railway
- Andy Netherwood, APN (Heritage) Engineering Services
- Andy Wright, British Engineering Services (BES)
- Robert Smith, Professor of NDT, University of Bristol, and Director of the UK Research Centre in NDE.