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Non-destructive Testing methods - Technical Issues

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This document is for information purposes only and does not form part of the criteria for accreditation for NDT facilities. It has been prepared in order to provide clients with information concerning specific technical issues that have repeatedly arisen at NATA assessments in relation to commonly used NDT methods. Recommended practice for situations that may not be well defined in commonly used standards are described, as well as some explanatory detail in relation to specific criteria contained in the current Non-destructive Testing ISO/IEC 17025 Application Document and associated appendices.

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Section 1: General

1. Recording and Reporting of Test Temperature

Some published standards (such as AS 2062 and AS 2452.3) contain requirements relating to temperature that only apply when the temperature is outside the specified ranges. By implication, the absence of a quoted temperature in NDT data sheets would indicate that the test was conducted within the limits. While the inclusion of a prompt within penetrant testing data sheets for recording of temperature may be desirable, there appears to be no basis within AS 2452 for this to be considered mandatory. However, as any temperature outside the range would need to be noted, the NDT personnel would be expected to be able to demonstrate how they ascertain compliance with temperature limits during testing and the action to be taken if the temperature of the test object were to be outside the range listed in the relevant method. Further detail in regard to recording temperature for penetrant testing is provided in Section 2.

2. Position Mapping using Encoders

It is becoming increasingly common to see scanning probes incorporating a position encoder attachment (in order to establish test probe position with respect to a test object). Use of an encoder is associated with mapping of data, e.g., in-service tube testing, development of B-scans, C-scans etc. The scanning can be either manual or mechanized (examples of mechanized scanning include ultrasonic crawlers, IRIS systems, and pipeline AUT units).

Such testing is not fundamentally different from non-encoded scanning but it is important to establish that an actual probe position is accurately indicated by the test equipment in order to avoid inaccuracy in defect location etc. Where testing involves position mapping based on encoder output, the following should be taken into consideration and, where applicable, verified for performance.

- Encoder resolution.
- Datum settings.
- Accuracy of position encoder and/or position algorithm.

3. Extent of NDT (Percentage Coverage)

Where a contract or order specifies an extent of testing that is less than 100%, decisions in relation to testing could adversely affect the integrity intended for the fabrication. For example, AS 1554.1 states in Note 2 of Table 7.4 “Where less than 100% of NDE is required, a program for testing should be drawn up by the principal and approved by the design engineer”, however, in the great majority of instances there is not a program of testing drawn up by the principal and approved by the design engineer that can be provided to the NDT provider. Consequently, the selection of welds to be tested is often made by the fabricator and may not always be based on an impartial process that is informed by knowledge of the design. Further, when non-conformances are detected, there is often no specified requirement for extent of subsequent testing.

In order to eliminate the uncertainty involved with ‘spot’ non-destructive testing, NDT facilities are encouraged to request that:

- a testing program be drawn up where 100% testing is not required and that;
- the process for an increased level of testing in instances where initial testing reveals unacceptable discontinuities be specified.

Section 2: Surface Methods

1. Surface Illumination

The required conditions to ensure that a test area is inspected using illumination of sufficient brightness, without glare, to detect discontinuities and the level of illumination necessary, may vary across the range of general engineering specifications and testing environments. Key variables include:

- Discontinuity type
  Discontinuity acceptance levels
  Surface condition
  Test object configuration
  Ambient lighting – indoors, outdoors, bright sunlight, dull background etc.
  Test location, e.g., in confined spaces, access limitations etc.

NATA's general approach in the assessment of surface methods testing is to request the facility to outline its strategy for achieving compliance with the illumination levels specified in the relevant test methods. The assessment team needs to be satisfied that the strategy is both valid and appropriate in terms of the key variables listed above so that the integrity of the testing is not compromised.

If it is known that the test area has not been inspected under conditions of illumination that comply with the relevant method, this would represent a 'test restriction' and would need to be reported as such. For such situations, at least, it would be recommended practice to measure and report the illumination level and this may be a stated requirement in some test methods.

2. Light Meter Limitations

Light meters in NDT are used to indicate the output of UV lamps or ambient light levels relative to threshold values that are considered to provide a desirable testing environment. Unless otherwise specified by the customer or in the test standard, light meter readings are generally regarded as indicative in nature. Regardless of this, it is important to take into account the following regarding the use of light meters and NDT facilities would be expected to be in a position to advise on any limitations applicable to their light meters.

Some black light meters do not distinguish between infra-red and ultra-violet radiation.
Other meters do not distinguish between visible and ultra-violet light.
Some meters are specifically for measuring the output of fluorescent UV lights and require a correction factor to be applied for measurement of UV spotlight intensity.

3. Testing Media

In Australia, magnetic particle and penetrant testing are often performed to AS 1171 and AS 2062 respectively. These standards describe compliance of testing media (consumables) in terms of specific overseas standards and this can sometimes create confusion in regard to demonstration of compliance. The following information is provided to assist companies in understanding the relationship between certain standards and approvals for testing media.

In the case of penetrant testing, AS 2062 refers to a military specification MIL-I-25135 (now AMS 2644) for consumables requirements. In the case of magnetic particle testing, AS 1171 contains reference to ASTM E 1444 for the requirements for magnetic media (both powders and inks). While ASTM E 1444 does detail the standard practice for magnetic particle testing, it is not a performance standard for materials and for this reason conformance of magnetic media is usually stated in terms of the relevant Aerospace Material Specification (AMS) documents (which are published by the Society of Automotive Engineers) as called up in ASTM E 1444. In regard to contrast paint, AS 1171 does not specify a performance standard for the paint, however, reference is made to BS 5044 as an informative item.

Manufacturers of testing media typically indicate the compliance specification on the container itself. For magnetic media, products can be labelled as meeting the relevant AMS specification or can reference other standards such as AS 1171 or ASTM E 1444 which call up the relevant AMS specification (there appears to be no requirement within the general engineering sector for contrast paint used in magnetic particle testing to comply with a published material specification). For penetrant testing materials, products can be labelled as meeting the AMS 2644 (or MIL-I-25135) specification or can reference other standards such as AS 2062 which call up a relevant material specification. In the case of penetrant consumables, the nomenclature

QPL-25135 or QPL-AMS-2644 can also be applied which indicates approval under the “Qualified Products List” of the Department of Defence of the United States Government which provides evidence of an independent compliance assessment to the relevant specification.

4. Magnetic Particle System Performance Checks

Consumables

Where NDT facilities use compatible combinations of commercial products for which batch compliance certificates to the relevant specifications (refer previous item) are held, additional performance checks of the combinations of consumables are not normally expected, unless otherwise stated in the test specification.

AS 1171 Figure 2 Test Block

The AS 1171 Figure B2 steel bar test piece is used by many accredited NDT facilities as a means of checking overall magnetic particle testing system performance. However, there is a difference of opinion as to the test bar’s applicability to assessment of system performance of the magnetic flow method using a yoke electromagnet. It is possible for a facility to stipulate within their documented internal procedure an alternative means for checking the overall system performance (for yoke applications) by specifying a test piece other than the Figure B2 test bar. However, the Figure B2 test bar involves the use of a slightly subsurface flaw to increase difficulty of detection, thus providing a worthwhile check on a range of factors including magnetic field strength, consumable function, operator technique, visual acuity & lighting conditions.

5. DC Magnetization

Magnetic particle testing using DC magnetisation can be less sensitive than the equivalent technique using AC magnetisation, however, it is acknowledged that DC magnetisation is sometimes the only practical option.

Even if DC magnetisation is only offered in cases where there is no alternative, the obligations for method validation remain and, typically, the following items would form part of a validation submission:

- circumstances in which the technique may be used in preference to AC magnetisation;
- defined material types for which the technique is considered to apply,
- reliability limitations of the method, including consideration of material thickness, defect types and sizes,
- set-up parameters and reference to the equipment model(s) used; and
- validation data pertaining to the range of applicability described in the scope of the procedure based on testing using the equipment model(s) and technique described in the procedure.

In order to ensure NDT facilities use the best method available, requests to provide DC magnetisation *as a routine alternative* to AC magnetisation would be considered on the basis of evidence demonstrating the equivalence of the procedure to AC magnetisation. For this purpose, Probability of Detection data would normally be relevant. It is understood that this type of validation may be beyond the resources of many NDT companies and may require collaborative effort among companies together and/or the use of available published research.

6. De-magnetization

It is expected that NDT facilities ensure that materials tested using magnetic techniques do not exhibit residual magnetism exceeding levels stated in the testing specification or that would otherwise have a potentially adverse affect on the service life of the test item. NATA’s general approach in the assessment of such testing is to request the facility to outline its strategy for ensuring appropriate control of residual magnetism. While typically this is less of an issue with magnetization involving the use of hand yokes, the assessment team needs to be satisfied that testing personnel involved in any magnetic particle testing have an adequate understanding of the strategy for controlling residual magnetism.

7. Magnetic Particle Testing over Paint

It is NATA's policy not to accredit non-destructive testing facilities for performing of magnetic particle testing through paint (ISO/IEC 17025 Field Application Document – Non-destructive Testing), even though it is acknowledged that some test methods do make provision for such testing. Magnetic particle testing on painted surfaces may result in non-detection of defects as painted surfaces typically reduce, and possibly even negate, the effectiveness of a test. A painted surface may mask other discontinuities with potential for growth and ultimate failure of the object, such as undercut.

Performing magnetic particle testing on painted surfaces inevitably involves many variables or unknowns and, while the risks associated with some of these issues might be managed, it is beyond NATA's resources to ensure that appropriate risk management controls are consistently applied by the facilities which it accredits. For example, while Appendix C of AS 1171 provides for conducting magnetic particle tests on painted surfaces, there are listed prerequisites that would often be quite difficult to achieve in practice and there is also a specific prohibition of the technique for examination over painted surfaces "on components that are subject to high stresses or cyclic loading" which excludes many types of items that are commonly tested using magnetic particle techniques.

8. Magnetic Particle Testing – Field Indicators

Most NDT facilities that are accredited for magnetic particle testing possess field indicators for verifying the adequacy of magnetization applied to a test object. Notwithstanding the limitations in performance of these devices, there is a long history of acceptance of these as a means of satisfying the requirement for demonstrating the adequacy of applied magnetization and this continues to be regarded as an acceptable approach.

9. Surface Preparation for Penetrant Testing

Contaminants such as dirt, grease, oil, rust, scale and paint can reduce the reliability of, or even negate the test, and it is essential that these be removed. Chemical cleaning methods are, generally speaking, more effective than mechanical methods, because chemical treatments are able to remove contaminants within surface-breaking discontinuities. However, all cleaning must not adversely affect the component (or the testing media being used). Mechanical working of the test surface, e.g., grinding, buffing, sand or shot blasting may produce a clean surface but deform it such that discontinuities are closed over. This is particularly so when dealing with soft metals such as aluminium. An etch may be required after mechanical working of these test surfaces to eliminate the deformed layer.

10. Test Surface Temperature for Penetrant Testing

The requirements of AS 2062 sometimes create confusion in regard to recording of test temperature.

Clause 4.2 requires test temperature to be noted if it is outside the range 15°C to 40°C. It is considered that a notation of "<15°C" or ">40°C" is sufficient acknowledgment of such conditions. Importantly, AS 2062 requires the penetrant dwell time to be increased in accordance with the penetrant manufacturer's recommendation if the test surface temperature is below 15°C. Likewise, it must be ensured that the penetrant does not dry out on the test surface in hot conditions. Therefore, appraisal of test environment and surface temperature by NDT personnel, as well as compliance with the consequent precautions for testing in hot or cold conditions, would be expected in order to demonstrate compliance with AS 2062.

There is a further statement in Clause 3.3 indicating that the test surface is to be between 5°C and 50°C. This temperature range will adequately cover the vast majority of penetrant tests carried out in Australia. A surface below 5°C will feel uncomfortably cold upon touch, whilst a temperature of 50°C or more will feel uncomfortably hot and tactile perception and personal observation are adequate measures by which to judge surface temperature. Temperature measurement e.g., by contact pyrometer, would entail additional equipment and calibration that may not be justified on the basis of adding any value to the test.

Section 3: Radiographic Testing

1. Radiographic Viewer Brightness

Where a minimum brightness (**luminance**) for radiographic viewers is specified in order to achieve the stated minimum requirements for radiographic film brightness, the use of differing terms luminance and illuminance can create confusion.

Luminance is a measure of the brightness of a surface and the SI unit is the **candela per square metre** (cd/m^2). **Illuminance** is the quantity of light falling on one unit area of a surface and the **'Lux'** is the unit commonly used. Illuminance is inversely proportional to the square of the distance between the light source and the surface, and proportional to the cosine of the angle made by the normal to the surface with the direction of the light.

NDT facilities generally possess illuminance meters, which measure *lux*, and some of these meters have a luminance-converter attachment which fits onto the meter – the **resultant reading is then multiplied by the correction factor for the attachment** and this results in a luminance value for the source. The correction factor is provided by the supplier of the attachment.

For facilities possessing an illuminance meter without a luminance-converter attachment, it is possible to make a reasonable estimate of the luminance by placing the meter's detector facing the viewer screen and in contact with it and then **multiplying the measured illuminance value (in lux) by π to obtain a luminance value (in cd/m^2)**. This procedure assumes that the viewer face is a perfect diffuser (i.e. that the intensity at a given angle is proportional to the cosine of the angle) and also that the detector responds according to the cosine of the incident angle. In a real world the viewer face is unlikely to meet the above requirement exactly. A detector may also have a diffusing dome but, even so, there will remain some deviation from a perfect cosine response. The luminance value obtained using this approach is only an approximation but generally the resultant value will be a reasonable estimation.

Many illuminance meters cannot read at high enough levels to measure the illuminance at the viewer screen. In such instances, measurement may be made at a distance from the screen and the illuminance at the screen estimated using the Inverse Square Law. The luminance conversion may then be subsequently applied to this estimated value.

Facilities should also be aware that there are additional sources of error in both of the above approaches, such as imperfect seating of the detector on the surface of the viewing screen and inaccurate detector frequency response (some illuminance meters may respond to infra-red light as well as visible light).

Regardless of the method for determining the adequacy of viewer intensity, accredited NDT facilities will need access to viewing equipment which permits effective viewing and interpretation of radiographs within the density range specified by the method or application standard, or within internal process control requirements. It is quite acceptable for high intensity viewers to be used to *augment normal viewing equipment* for examination of radiographs with density greater than the useful range of the normal viewer.

2. Recording and Reporting of IQI Sensitivity in Weld Testing

The commonly used standard AS 2177 is not specific in its requirements for recording and reporting IQI sensitivity where there are multiple radiographs of a single weld to be viewed, e.g. a panoramic exposure of a circumferential weld in a pressure vessel. While the *minimum* sensitivity achieved is required to be reported, (section 4.3(i)) the standard does not require the sensitivity achieved on each film to be shown on the report. However, in regard to the data recorded it is expected that, as there is a requirement in AS 2177 to have an IQI on each film, that the IQI will be viewed on each film, and a record be made as evidence of such viewing (the record might either be that of the feature observed, e.g., 'Wire 13' or the calculated sensitivity achieved).

3. Computed and Direct Radiography

Computed radiography involves the use of a storage phosphor imaging plate (IP) and corresponding read-out unit and digital software which converts the information contained on the IP into a digital image. Direct radiography (also known as digital radiography) uses an amorphous selenium / silicon flat plate placed behind the test object to directly convert the x-ray energy into a digital signal.

As these techniques simply produce a digital version of an image instead of a radiographic film, the traditional requirements for qualification of the technique/procedure, technician qualifications, set up, interpretation of results, reporting of results etc, are still applicable.

There are various functions of the imaging systems that are able to be manipulated in order to obtain an acceptable image and so the competence of the operator is critical to the quality of the final image produced and interpreted.

Additional considerations arise from the use of the specialized imaging equipment including:

- Access to change system parameters once these have been set and the procedure qualified;
- Equipment performance checks;
- Comparison between digital image and film radiography (sensitivity).

Also, as the quality of the image is dependent on the resolution of the screen or monitor, the following considerations arise:

- Specified limit on screen pixel drop off;
- Specified requirement for optimum screen brightness;
- Maximum allowable ambient light levels for viewing;
- Allowable magnification of the image.

Furthermore, as the images are electronic, this raises additional issues in relation to records storage and control:

- How the electronic scans are identified;
- Ensuring identification of a particular scan cannot be duplicated;
- Scans filing, storage and back-up (e.g., hard drive/removable drive/optical disc).

Section 4: Ultrasonic Testing

1. Limitations Arising from Geometry

If the beam path length is less than required for effective testing due to focusing and/or dead zone issues, detection of defects at, or near to, the testing surface may not be possible using A-Scan ultrasonic testing, unless the geometry of the item allows for an alternative beam path. There are also known limitations associated with weld geometry and, in particular, partial penetration or fillet weld configurations can preclude effective testing. Alternative ultrasonic techniques, such as phased array, can offer greater flexibility in overcoming these restrictions but, as for any technique, facilities must be able to demonstrate an effective validation process that is relevant to the item to be tested.

2. Surface Roughness of Test Items

The need to physically measure the roughness of a surface to be ultrasonically tested is raised from time to time. Some methods, including AS 2207, include requirements for surface roughness. On the other hand, commercially available surface roughness comparators are of limited practical use as profiles are stylised and bear limited resemblance to many surfaces, particularly corroded surfaces. It is considered that the note for the above-mentioned clause, stating that "*Hot-rolled steel with totally adherent millscale generally complies with this requirement"* was intended to provide operators with a practical guide. While reference to AS 2207 may well provide an operator with the necessary justification for refusal to test an unsuitable surface at a client's insistence, it is not expected that a surface comparator be routinely used prior to testing, unless required by the customer or specified within the specified test method. A important aspect to be established at NATA assessment is whether NDT personnel have an understanding of what represents a suitable surface for ultrasonic testing.

3. Material Composition for "Calibration" (Standardization) and Reference Blocks

A wide range of "calibration" blocks are described in AS 2083 which are referred to in ISO/IEC 17025 Field Application Document – Non-destructive Testing as *standardization blocks*. AS 2083 stipulates that such blocks are to meet specific requirements in relation to material composition. In contrast, for blocks described as "reference" blocks, i.e., possessing features relevant to the specific item under test, the only relevant AS 2083 requirement appears in AS 2083 Section 9, requiring that such blocks be produced from material that has been ultrasonically tested in accordance with AS 2083 clause 1.5.1.

4. Ultrasonic Standardisation Blocks – Grain Size and Surface Roughness

There are in-house manufactured and commercially purchased blocks in everyday use for which grain size certification is unavailable; nevertheless these may have formed the basis for historically reliable testing. Additionally, it may not be possible to determine the grain size of these blocks without causing irreparable damage. Therefore, unless precluded by the customer or by the test standard, it is considered reasonable that NDT facilities verify the attenuation characteristics of such blocks through direct comparison with similar blocks for which the grain size has been authoritatively determined. Typically, variation greater than 1 dB over the test range (or an appropriate maximum range determined by the facility) would be recorded, and subsequently applied when using such blocks for performance checking or reference.

In relation to the surface finish of standardization blocks, AS 2083 specifies a maximum surface roughness of 0.8 µm R_a for calibration blocks. While commercially produced blocks would normally have the surface roughness certified, it can generally be assumed that grinding or fine machining of surfaces may be expected to achieve a finish which is sufficiently fine so as to comply with the 0.8 µm R_a requirement.

5. Knowledge of Beam Profiles

The ISO/IEC 17025 Field Application Document – Non-destructive Testing states that beam profiles are to be determined in cases where beam profile sizing methods are specified. The 20dB drop and 6dB drop sizing methods are commonly used methods that are based on beam profiles.

6. Ultrasonic Testing of Castings – Ferritic Steels and Irons

Spheroidal graphite cast irons (SG iron, nodular iron are alternative names) are common throughout industry and are frequently substituted for steel castings. There are a number of grades, with a range of microstructures ranging from predominantly ferritic to a ferrite/pearlite matrix of varying proportions of each constituent, and tempered structures. These castings may be successfully tested ultrasonically, using techniques similar to those used for ferritic steel castings, however, AS 2574 sets out methods for ultrasonic testing of heat treated ferritic *steel* castings and as such is not applicable to SG iron castings. Therefore, reference to AS 2574 in lieu of developing a specific test procedure is not considered appropriate for SG iron castings.

The microstructure of other cast irons, such as grey cast irons, is fundamentally different to that of SG irons, and are typically not amenable to ultrasonic examination.

7. Acceptance of Steel Castings

There are instances where castings are unable to be completely scanned, due to casting shape/ contour, surface finish, inaccessibility, cast grain size and other reasons. Such instances represent a 'test restriction' and need to be reported as such. Accordingly, any statement in regard to acceptability cannot be extended beyond the volume able to be tested in accordance with the Standard. Other test restrictions may apply from time to time, e.g., use of probe size and frequency outside those specified, and in such cases the limits to the statement of acceptability need to be similarly conveyed in a clear manner within the test report.

AS 2574 Table 5.1(d) specifies acceptance criteria for steel castings based on the results of ultrasonic testing. However, it does not specifically provide for the case where there is a loss (attenuation) of back echo (BWE) which is equal to or greater than the 50% limit specified for recording in Table 5.1(b), but where this loss is not associated with any recordable discontinuity echo. While recording and reporting of the area over which a loss of 50% or greater BWE occurs is expected, it is not possible to make an acceptability statement since this is unable to be determined from Table 5.1 (b).

Section 5: Electromagnetic Testing

1. Electromagnetic Testing over Coatings

Eddy Current Testing

While eddy current testing is not as sensitive as magnetic particle testing of surfaces from which the paint has been removed, it can still be an acceptable method provided that its limitations are understood. Such limitations include:

- coating thickness (refer ISO 17643 – *Non-destructive testing of welds – Eddy current testing of welds by complex plane analysis*, and/or the equipment manufacturer's specifications);
- assessment of variations in coating thickness (considerable variation in coating thickness often occurs at the toes of welds);
- coating conductivity (coatings with metallic content are not suitable for eddy current testing so there needs to be a defined means for establishing the suitability of any coating);
- recognition that discontinuities detected through a coated surface should be characterised by another NDT method, such as magnetic particle testing with local paint removal.

Alternating Current Field Measurement (ACFM)

ACFM has the ability to test for surface breaking cracks under coated surfaces. It has the advantage of not being as sensitive as eddy current testing to variations in coating thickness and is also able to be used with metallic coatings. As above, detection reliability issues, for example in relation to coating thickness still need to be addressed.