7. Inspection and Testing

A variety of non-destructive techniques is used for weld inspection and is described in this Section. Inspection is expensive, never 100% effective and may involve destruction of the component. It is aimed at detecting defective workmanship, rather than preventing defects from occurring. It is essential that every effort be made to make the component properly, rather than rely on inspection to identify faults.

Less important non-conformities can be inspected for randomly. Where the risk of critical non-conformities (defects) is unacceptably high, 100% inspection should be performed. However, no inspection technique is completely infallible. The risk of defective work must be minimised by suitably qualified people carrying out the production work to written process instructions.

7.1. Flaws, Non-Conformities and Defects

All commercial material contains imperfections. In this book, the following terms are used.

- Flaw, Discontinuity or Imperfection: A deviation from perfection in a material. As well as large detrimental flaws, this includes atomic scale imperfections such as solute atoms, lattice vacancies, dislocations and larger imperfections such as impurity particles. The three terms are synonymous although the terms 'flaw' and 'imperfection' tend to denote a lowering in quality.
- Non-conformity: A flaw that if found, fails to meet the prescribed standard. It does not necessarily cause rejection of the material.
- Defect: A flaw that when assessed fails to meet the prescribed standard, and causes rejection of the material. The material has to be repaired or scrapped.

In most NDT publications, the term 'defect' is synonymous with 'non-conformity'. The distinction is subtle and only becomes important when considering random inspection or acceptance based on a fitness-for-purpose assessment.

7.2. Inspection Integrity

Inspectors must not be influenced by those responsible for production and progress. In the past inspectors have been pressured to accept defective work to avoid cost and schedule impact. The risk to the fabrication is unacceptable. Product failure may seriously impact public or operator safety and risk environmental damage. The fabricator should realise that they are exposed to expensive consequential damage claims.

7.2.1. Accreditation of Inspection Bodies

The National Association of Testing Authorities, Australia (NATA) has operated the world's first and most widely accepted accreditation scheme for inspection laboratories for many years. Full use of the scheme ensures testing is of the highest integrity. It should be used wherever possible, and particularly where testing is a contract requirement.

Several points are worth noting about the scheme.

- NATA accredits organisations (laboratories) and not individuals, although the laboratory must have a number of named individuals with recognised skills who are authorised to sign reports.
- NATA has rules regarding the way testing is undertaken and the content, issue, control and archiving of reports. These rules cover the individuals allowed to undertake tests, the test equipment used, the way results are reported and the disposition of test evidence (such as radiographs and field records).
- An organisation gains accreditation by a process of peer review. To maintain its accreditation it must submit itself to regular audit by NATA.
- An organisation is only accredited for the types of testing for which it has been reviewed and is current. These test types can be restricted. For example, accreditation may be for radiography of a limited range of materials.
- Organisations performing testing in accordance with NATA rules may endorse reports with the NATA logo. A test authority may issue a report without NATA endorsement if testing is not done within NATA rules. It is incumbent on the purchaser of the testing to order NATA reports when required.
- A fabricator that has accredited in-house inspection is required to satisfy NATA of the independence of the inspection department from production areas. It is therefore not necessary to insist on third party inspection.
- NATA accreditation covers a variety of testing techniques including NDT, chemical analysis and mechanical tests. However, it is not fully comprehensive. For example, there is no NATA accreditation for visual inspection.

7.2.2. Qualifications in Inspection

People using the major inspection techniques can gain qualifications issued by the following bodies, all of which are recognised in Australia.

- Australian Institute of Non Destructive Testing (AINDT)
- Certification Scheme for Weldment Inspection Personnel (CSWIP). This scheme originates in the UK.
- American Society of Non Destructive Testing (ASNT)

7.3. Management of Inspections

All inspection methods are only effective if properly organised. Construction codes and standards often define the inspections that are to be performed, but sometimes the engineer has considerable discretion. It is important the following matters are addressed:

- The extent of inspection and method of choosing samples
- The test method to be used
- The acceptance criteria for any flaws which might be found

7.4. Level of Inspection

It is necessary to determine the quantity of inspection during the design and planning stage. This will depend on the criticality of the weld in question as discussed previously. A partial inspection may save money, however it must be realised that non-conforming flaws are likely to occur in the un-inspected portion. The inspection plan must ensure that the risk of a serious undiscovered defect is low.

7.4.1. Inspection Cost

Some NDT can be expensive, and sometimes inspection costs are equivalent to fabrication costs, so a careful decision is important. It typically takes one hour to inspect one metre of weld using the ultrasonic method provided access is good and the weld does not contain large numbers of indications that are above the sensitivity level set. It takes one hour to inspect five metres of seam using magnetic particle inspection in similar circumstances. The cost of radiographs is closely related to the number of shots. Generally, each 300mm of weld requires one radiograph, although there may be circumstances where it is possible to expose several lengths of film simultaneously.

7.4.2. Importance of Inspection

The level of inspection should be dependent on the chance of a defect being found in a weld and on the criticality of the weld. Flaws that are acceptable in non-critical welds are defects in critical items.

The chance of a flaw occurring is dependent on the welding procedure. It is important procedures are correct and are followed to avoid serious problems like weld cracking. Mechanised welding processes are less likely to deposit random flaws than manual ones. When faults occur, mechanised procedures are likely to produce long lengths of defective weld. There is therefore a case to limit the inspection of mechanised welds to just the ends and random points in between, rather than the whole weld length. This is because there is less chance a critical defect will be missed.

Only the designer knows the importance of each joint. Therefore, there is merit in them being involved in selection of welds to be inspected. The level of inspection should be increased around critical areas.

The aim of any inspection is to detect trends in performance and correct them. Testing should be undertaken early to ensure problems are detected and corrected. Leaving inspection to the end of the project is likely to lead to disaster.

7.4.3. Amount of Inspection

Sometimes 100% inspection is required. More usually only a proportion of the item is inspected.

a) Full Inspection

100% inspection of a weld implies that the full length of all welds in that category is to be inspected by the nominated inspection method. The chance of missing an important defect is real but small. Even with 100% inspection it must be realised that inspection methods are fallible. Some non-conformances will be missed, depending on the sensitivity of the method and the diligence of the inspector. Variation of technique will affect sensitivity and interpretation of the standard may vary from one inspector to another. A discontinuity considered compliant by one inspector may be considered non-conforming by another.

Where a large number of non-conforming flaws are found, it is likely there are many discontinuities which narrowly pass the inspection standards, with the possibility that a fraction of these have been miss-interpreted as compliant. This risk is one reason why safety factors are used in design codes.

b) Random Inspection

Random inspection has a higher risk of missing non-conformities, yet it may be appropriate for welds of lower criticality. In specifying random inspection, care needs to be taken to ensure the sample inspected is appropriate. Random inspection should not be used for examining for critical defects.

Specifications commonly indicate a percentage inspection (5%, 10%) and leave it to the fabricator and inspector for interpretation. It is important the sample selected is chosen at random, so that the welder is not aware which welds are to be inspected. In the worst case, the fabricator selects the proportion inspected, sometimes inadvertently by denying the inspector access to more remote parts.

The sample examined should represent a proportion of a logically defined batch. When manual welding techniques are employed, it should include some of each welder's work. It may include work done by each procedure or each welding process. The selection should target the regions where non-conformities are more likely and the most critically stressed areas. If non-conforming welding is found, it is necessary more of this batch will be examined to determine if the non-conformity is a chance event or a symptom of an endemic problem. Steps can be taken to determine the cause of the non-conformities and corrections made to correct the problem. If the batch examined is not logical, then the risk of the problem extending beyond the sample must be considered. Not to do so should lead to a loss of confidence in the fabrication.

c) Statistical Sampling Techniques

There are various methods of selection of random samples based on a mathematical treatment of the probability of determining if a batch contains defects or not. Australian Standards AS 1199 and AS 1399 describe the principles involved. These statistical sampling techniques are appropriate to large batches of similar items, and not structural fabrication, which usually does not fall into this category. In this case welds are not usually identical and are in relatively small numbers.

7.4.4. Identification of Defects

It is important to establish and follow a standard practice when discovering a defect to ensure all defects found are repaired, that repairs are not performed in the wrong location, and the occurrence of a defect is recorded. The established practice in Australia is that:

- The positions of defects are marked with a brightly coloured paint marker (usually blue) on the workpiece. Any alternative to a paint marker must be durable. Chalk should not be used.
- Only defects are marked in this colour. Pens of this colour are only issued to inspectors. All other marks (material identification, sentencing to scrap) are made in different colours.

- Defects from NDE methods are recorded on a NATA report. The defect location is measured from a reference datum established by a standard practice.

7.5. Visual Inspection

Final visual inspection is the most important inspection method despite being relatively cheap. It is regarded as the primary inspection method for welds. This is because many of the defects discovered (particularly lack of cleanliness, spatter, incomplete or excessive welding, rough profile) may be particularly important, and yet are easy to repair. In addition, many surface defects may interfere with other NDT techniques.

Final visual inspection is not sufficient. The fabricator's inspector or welding supervisor must make regular visual inspections before and during welding to ensure welds are made in accordance with procedure to minimise the risk of defects and ensure weld properties are as required.

7.5.1. Inspection Procedure

There is no Australian Standard describing a test method for visual inspection, although there is a British Standard (BS 5289). The inspector must ensure that there is sufficient light and that the access is adequate to ensure the area inspected is systematically and thoroughly scanned. Visual aids, such as mirrors, torches, gauges, rulers and magnifiers are used to assist the inspection. Feeling the surface also aids interpretation. The surface being inspected must be sufficiently clean. It is quite usual for defects that were missed on the original inspection, to be revealed when the fabrication is shot blasted to a uniform grey colour for painting.

7.6. Pre-welding Inspection

This is undertaken by the boilermaker, pipe fitter or fabrication inspector as appropriate to the level of quality required. Included in the inspection are:

- Dimensions of components
- Material identification of components
- Weld joint dimensions
- Weld joint cleanliness and freedom from surface defects
- Quality of tack welds
- Adequacy of fixtures, clamps or braces

7.6.1. Verification of Welding to the Approved Procedure

In many cases it is essential to verify that the welding procedure is followed, to ensure welds will meet the required standard. This can be done by random checks of the following factors on a frequent basis. Such checks can be as frequent as is necessary, and are often required daily.

- Preheat and interpass temperatures
- Consumable types
- Gas flow rates
- Treatment of tack welds

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Contents