A Guide to Understanding AS/NZS 1554.1
Foreword

This Technical Guidance Note contains basic information relevant to the application and use of the standard AS/NZS 1554.1 Structural steel welding Part 1: Welding of steel structures. It is designed to be read in conjunction with the standard, and, to assist users in understanding their requirements. Additional information can be found in Weld Australia’s Technical Note 11 Commentary on the Structural Steel Welding Standard AS/NZS 1554.

Future Revisions

This Technical Guidance Note will be revised from time to time and comments aimed at improving its value to industry will be welcome. This publication is copyright and extracts from this publication shall not be reprinted or published without the Publisher’s express consent.

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A Guide to Understanding AS/NZS 1554.1

1.0 Introduction

AS/NZS 1554.1 was first published as AS 1554.1 in 1974 and co-jointed with New Zealand in 1995. Its principles and practices, in many respects, are similar to or have descended from North American practices through AWS D1.1, although more recently, cognisance has been taken of ISO requirements where relevant.

Throughout its development into the current editions of the AS/NZS 1554 series of standards, the drafting committee has endeavoured to ensure that the standard remains practical in application whilst maintaining a sound technical basis for its requirements.

When applied correctly, sound welds will be produced at minimal cost, which in turn provides specifiers with a high degree of confidence of compliant welds fit for purpose and therefore minimising post-weld inspection and non-destructive examination requirements and associated costs.

2.0 Scope

Section 1 of AS/NZS 1554.1 Scope sets out the general requirements of the standard including the limits of its application. Where the standard is silent on a welding process or the solution proposed by the standard may not be applicable, the fabricator is able to innovate provided that both the fabricator and client agree on a suitable methodology.

Of particular importance within Section 1 though, is that the standard defines the basis for the management of weld quality.

2.1 Management of Quality

2.1.1 Quality Management

To manage weld quality in a fabrication workshop, AS/NZS 1554.1 requires that the fabricator maintains a suitable quality management system. This said, the standard is intentionally silent on the type of system and the level of accreditation (if any) required, these being considered commercial matters outside the scope of the standard. The standard does recommend though that the fabricator applies AS/NZS ISO 3834 to the management of welding operations, particularly where the fabricator is undertaking large or complex fabrications or, infrastructure projects managed by statutory authorities. A well-managed quality system correctly applying the requirements of AS/NZS 1554.1, will in many cases, meet most of the requirements of AS/NZS ISO 3834.3.


2.1.2 Basic Welding Requirements of the AS/NZS1554 Series

Welding application standards such as the AS/NZS 1554 series, typically specify requirements for technical inputs required to control the welding process. They generally do not cover matters considered to be of a contractual nature, nor quality management issues. To correctly understand and apply the standards to general fabrication work, it is important to be aware of the basis of the AS/NZS 1554 standard series, specifically, a weld shall:

(a) be made in accordance with a qualified welding procedure;
(b) be carried out by a welder suitably qualified to carry out such a procedure;
(c) be carried out under the supervision of a suitably qualified welding supervisor; and
(d) comply with the requirements of the standard.

If any one of these pillars is compromised the integrity of the welding process (and product) is compromised and the safety of workers or the public will be placed at risk. Such an approach is crucial in the welding industry given that welding is regarded as a special process, meaning that all inputs must be suitably controlled as the output (i.e. the properties of the weld) cannot be determined without physically destroying the product produced. Whilst weld integrity can be determined to some extent using non-destructive techniques, no method exists to verify the mechanical properties of the weld or structure once welded and hence we must rely totally on the control of all inputs.
3.0 Materials of Construction

3.1 Parent Materials
A broad range of parent materials can be welded to AS/NZS 1554.1 (Section 2), however there are limitations primarily because the materials of construction listed link into the preheat determination methods given within Section 5 of AS/NZS 1554.1. For steels non-compliant with Section 2 of AS/NZS 1554.1, or any steel with a boron content ≥0.0008%, preheat and other requirements are applicable as defined within the Australian Technical Specification SA TS 103 Structural steel welding—Limits on boron in parent materials and Weld Australia’s Technical Note 1 The Weldability of Steels. Briefly, these requirements include:

(a) Verification of preheat requirements; and,
(b) Ensuring that the brittle fracture and Charpy impact properties of the steel are compliant with Appendix B of AS/NZS 1554.1 and Section 10 of AS 4100; and,
(c) Ensuring that the steels are matched with the appropriate welding consumables (Clause 4.6 of AS/NZS 1554.1).

3.2 Backing Materials
There are no special requirements for backing materials within AS/NZS 1554.1, however fabricators should be aware that the weldability group number of the backing material should not be higher than the parent material being welded, particularly for permanently attached backing material. This requirement is essential to assist in minimising the risk of delayed cracking or subsequent weld metal embrittlement during the fabrication process.

3.3 Welding Consumables

3.3.1 General
Welding consumables are required to conform with the listed standards within Section 2 of AS/NZS 1554.1. The standards listed are identical in most respects to the equivalent ISO standard although in a small number of cases, the referenced ISO standards have been modified for safety or other technical reasons. For the gas tungsten arc (GTAW or Tig) process, the referenced Australian standard has not been updated and accordingly, direct reference is also made to the ISO standard for specific consumables.

3.3.2 Care and Conditioning of Consumables
Of significant importance within AS/NZS 1554.1 (Clause 2.3.2), and similarly within AS/NZS ISO 3834, is the general care and conditioning of welding consumables prior to, during and after use. In all cases, the consumables must be stored correctly and if required, conditioned in conformance with the manufacturer’s recommendations. This may include:

(a) Keeping unused consumables in their original packets;
(b) Discarding damaged or contaminated consumables;
(c) Drawing consumables from an electrode store on the basis of first in-first out;
(d) Storing consumables in a warm room (set above ambient temperature) to reduce the risk of rusting and/or moisture pickup;
(e) Correctly drying low hydrogen MMAW consumables in a ventilated electrode oven and storing in a heated portable oven, hot-box or quiver (≥105°C) until required for use.

**NOTE**: Electrode drying temperatures can range from 200° to 450°C depending on the flux coating requirements. Once dried, electrodes can be stored in a heated oven ≥105°C until required for use.

In the absence of manufacturer’s instructions for the care and conditioning of welding consumables, reference can be made to Weld Australia’s Technical Note 3 Care and conditioning of arc welding consumables.

4.0 Details of Welded Connections
Details of welded connections are provided for within Section 3 of AS/NZS 1554.1, and are similar to those within AS 4100 and other Australian steel design standards. Of particular note, Clause 3.1.2.2 (and Appendix H) of AS/NZS 1554.1 draws the fabricator’s attention to the avoidance of lamellar tearing (see also Weld Australia’s Technical Note 6 Control of Lamellar Tearing).
5.0 Qualification of Procedures and Personnel

5.1 General

To understand the requirement of standards in relation to welding procedures, it is important to understand what is meant by the terminology used.

AS 2812 defines a weld procedure as “... a document which details the methods and practices involved in the making of a weld or in the production of a welded component or assembly”.

Standards including AS/NZS 1554.1 require that the weld procedure is qualified by tests or evidence of previous testing, thereby demonstrating that the weld properties conform with the required design strength and property requirements, permitting the procedure to be used on the work. The document used to record these details including the results of tests, is known as a procedure qualification record or PQR.

Once qualified, the variables used in the procedure test form the basis for a welding procedure specification (WPS) document which the welder follows to recreate the weld (with known physical properties) in a production environment. AS 2812 defines the WPS as “a document given to a welder, which specifies the required range of welding variables within which a welder may weld for a specific application so as to assure its repeatability by properly trained welders and welding operators. The variables specified on the welding procedure specification are those recorded on the weld procedure qualification record (PQR) to which a range of essential variables are applied.”

Essential variables are welding parameters which are known to affect the weldment’s properties. Standards set limits on these so as to limit the variation in properties beyond which the procedure needs to be requalified to validate the parameters used and associated weldment properties. Within AS/NZS 1554.1, the essential variables are primarily defined within Clause 4.11 and Tables 4.11(A) and 4.11(B). A change in parent materials is addressed within Clause 4.8.

AS/NZS 1554.1 also defines a range of minor changes in essential variables, these being changes that primarily influence the penetration characteristics of the arc rather than weldment properties per se. A change in welding parameters outside of those deemed “minor” typically requires the procedure to be retested via a macro test to demonstrate that the required penetration into the weld preparation is still being achieved.

For a PQR or WPS to be readily repeatable in production, it is important for weld parameters such as amps and volts to be correctly measured and recorded. This requires the use of a calibrated clamp meter (tong tester) for the measurement of weld parameters or the use of welding machines with output displays of known accuracy. It is also just as important to ensure that similar equipment is used to verify welding conditions for all welding machines where the qualified procedure is to be applied.

For waveform controlled processes, it is also important to record the details of the program and power source in use on the PQR and WPS when used in a waveform controlled mode. Fabricators should also note that most clamp meters will provide erroneous readings when used to measure the amps and volts when waveform controls are active, and therefore the amps and volts reported by the power source should be used for heat input calculations (see ISO/TR 18491 Welding and allied processes — Guidelines for measurement of welding energies and WTIA Technical Note 1 The Weldability of Steels).

The use of power sources without an output display or metering should be avoided as the welding parameters cannot be controlled if not easily verifiable by the welder and supervisor.

5.2 Qualification of Weld Procedures

AS/NZS 1554.1 provides a method for the qualification of weld procedures. Additionally, where certain requirements are met, it limits the amount of testing required to validate a weld procedure. Conditions of qualification where limited testing requirements are applicable are generally known as prequalification or prequalified procedures. Irrespective of the amount of testing specified, the weld parameters used must be documented.
Once a procedure is qualified, a copy of the WPS must be provided to the welder for use on the job. This can be done by any of a number of methods including (but not limited to):

(a) A summary of applicable (approved) parameters for each weld type, consumable and joint attached to the side of the welding machine or at the work station;
(b) A manual of approved procedures at each work station;
(c) Welding machines with pre-programmed welding conditions.

In the above examples, the drawings provided to the welder would need to refer to the appropriate weld procedure. It is important to note that if a welder is not provided with a copy of the WPS in a suitable format with instructions for its use, then it is unlikely that the required procedure will be followed and therefore weld properties and quality cannot be guaranteed leading to requirements for additional non-destructive examination requirements that would otherwise not be necessary.

For guidance on the qualification of weld procedures, refer to Weld Australia’s Technical Guidance Note TGN-SG06 AS/NZS 1554.1: A Guide to the Qualification of Weld Procedures.

NOTES:
1. AS/NZS 1554.1 requires separate qualification of fillet and butt weld procedures.
2. AS/NZS 1554.1 is silent on requirements regarding the authorisation of PQRs and WPS documents. AS 2214 and AS 1796 implies that this is the responsibility of the welding supervisor (or welding coordinator under ISO 14731) - see also Table 2 below.

5.3 Use of Procedures Qualified by Other Manufacturers

Weld procedures qualified by one organisation are able to be used by another organisation. This process is permissible where the qualifying fabricator and the second fabricator are both identified on the procedure and the second fabricator can demonstrate compliance by the production of a satisfactory macro test. This procedure is commonly used where a large fabricator or manufacturer provides subcontractors with procedures specifically for work being undertaken on their behalf. Clause 4.4 of AS/NZS 1554.1 describes the approval process required to ensure traceability to the original qualification tests.

It should be noted that these procedures may also be referred to as Standard Procedures, particularly those conforming with ISO 15612.

5.4 Documentation Requirements

AS/NZS 1554.1 is largely silent on the type of documentation and records required to be prepared and used by the fabricator. Whilst records of tests for example, are specifically mentioned, the standard instead refers the user to Appendix D as a matter for resolution between the fabricator and client. Examples of welding-related documentation that may be required when specified include inspection and test plans (ITPs), quality plans, production plans, welding plans etc. When required, these documents also address many of the items regarded as matters for resolution previously mentioned.

5.5 Qualification of Personnel

5.5.1 Welding supervisors

Within AS/NZS 1554.1, it is a mandatory requirement that all welding be carried out under the supervision of a welding supervisor. As defined in Clause 4.12.1, the welding supervisor’s function is to ensure that the weld process is appropriately managed before, during and after the welding. The results of checks and tests conducted to verify conformance with the drawings, specifications and the standard should be documented.

The welding supervisor would normally be an employee of the fabricator but in some cases may be contracted to the fabricator to perform such functions.

As welding supervision is one of the four key pillars of weld process control in Australian application standards, the expectation is that the welding supervisor will have a working knowledge of the relevant application standard(s), knowledge of the relevant welding technology, basic metallurgy, and general fabrication requirements. Specific areas that the supervisor is trained in are detailed in the Australian standard AS 2214 (and similarly AS 1796-Certificate 10). It is important to note that the syllabus items and competencies required are consistent with the tasks specified within ISO 14731.
Depending on the application standard and specific task, minimum knowledge requirements for supervisors can vary. Within the AS/NZS 1554 series, whilst certification to AS 2214 (or the alternative formal qualifications specified therein) is not mandatory for the Welding Supervisor, such certification does provide evidence of the technical knowledge of a Welding Supervisor for work particularly in the SP weld category and is the preferred minimum option. Regardless of which other alternative qualification or level of experience the welding supervisor qualifies under, evidence is still required of their technical capability and practical experience.

Fabricators wanting to appoint a candidate with qualifications other than the above as welding supervisors under the AS/NZS 1554 standard series, are required to assess the candidate’s skill-set as defined within ISO 14731 (see also AS 2214). They should start by identifying the key tasks that they require the supervisor to perform within the scope of work, materials and welding processes used by the fabricator. In so doing, reference can be made to Table 1 for a summary of ISO 14731’s general requirements and applicable AS/NZS 1554.1 clauses.

For example, Table 2 shows examples of tasks and responsibilities that could be expected of a welding supervisor performing mainly AS/NZS 1554.1 category SP work. The specific level of technical knowledge required should be assessed based on the scope of materials and processes utilised by the fabricator.

In situations where the fabricator needs to undertake more technically challenging work, an alternative available to the fabricator is to contract in a person with higher level skills and qualifications for the duration of the work to provide specific welding supervision and technical advice as required to the fabricator’s staff.
<table>
<thead>
<tr>
<th>ISO 14731</th>
<th>AS/NZS 1554.1</th>
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<tbody>
<tr>
<td>Requirements and technical review including</td>
<td>Section 1, Appendix D <em>Matters for resolution</em></td>
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<tr>
<td>• Standards and supplementary requirements</td>
<td></td>
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<tr>
<td>• Capability of the manufacturer</td>
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<tr>
<td>• Materials &amp; welded joint specifications</td>
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<td>• Quality &amp; acceptance criteria</td>
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<tr>
<td>Sub-contracting</td>
<td>Not specified</td>
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<tr>
<td>Welding personnel</td>
<td>Clause 4.12</td>
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<tr>
<td>• Welders</td>
<td></td>
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<td>• Welding coordination personnel</td>
<td></td>
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<tr>
<td>Inspection &amp; testing personnel</td>
<td>Section 6, Clause 7.4</td>
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<tr>
<td>• Includes NDT personnel</td>
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<tr>
<td>Equipment</td>
<td>Not specified</td>
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<tr>
<td>• Production equipment &amp; ancillaries</td>
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<tr>
<td>• Capacity identified</td>
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<td>• Maintenance records</td>
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<tr>
<td>Welding activities</td>
<td>Sections 4 and 5</td>
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<tr>
<td>• Production plan</td>
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<td>• Weld procedures</td>
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<td>• Work instructions</td>
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<tr>
<td>Storage and handling of welding consumables</td>
<td>Clauses 2.3, 4.6, 5.4</td>
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<td>Storage of parent materials</td>
<td>Clauses 2.1, 2.2, 5.1, 5.4</td>
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<tr>
<td>Post weld heat treatment</td>
<td>Not specified – refer to AS 4458</td>
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<tr>
<td>Inspection and testing</td>
<td>Sections 6 and 7</td>
</tr>
<tr>
<td>Non-conformance and corrective actions</td>
<td>Clauses 4.10, 6.7, 6.8, Appendix D</td>
</tr>
<tr>
<td>Calibration</td>
<td>Not specified</td>
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<tr>
<td>Identification and traceability</td>
<td>Not specified</td>
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<tr>
<td>Quality records</td>
<td>Clauses 4.10, 6.8, Appendix D</td>
</tr>
</tbody>
</table>

Notes:
1. Suitable records documentation should be generated and retained by fabricators working to AS/NZS 1554.1 to demonstrate conformity.
2. Specific production planning requirements are usually a contractual matter upon which AS/NZS 1554 is intentionally silent. Requirements are typically specified contractually in larger or higher risk fabrication.
3. Further detail of requirements can be found in Annex B of ISO14731.
Examples of Competencies Recommended for AS/NZS 1554.1 Category SP Work

- Working knowledge of AS/NZS 1554
- Welding safety
- Basic cost estimation
- Contract review and planning
- Parent materials – selection and care
  - Preheat determination
  - Avoidance of brittle fracture
- Welding consumables
  - Classification, gas and wire selection
  - Storage and handling
- Weld process control
  - Suitability of equipment
  - Distortion control and correction
  - Maintenance of welding machines
  - Application of welding techniques
  - Jigs and fixtures
  - Use of positioners and rotators
  - Understanding of main thermal cutting methods
  - Fatigue minimisation methods
- Weld procedures
  - Drafting, qualifying and approving of both prequalified and non-prequalified weld procedures
  - Fit up, verifying use, measuring and control of weld parameters
  - Preheat application, control, maintenance and measurement including interpass temperature control
  - Application of essential variables

- Weld defects
  - Cause and prevention
  - Detection
  - Compliance assessment
  - Corrective action
- Personnel
  - Welder qualification and supervision
    - Via macro or testing to a procedure
    - Application of AS/NZS ISO 9606-1 and AS/NZS 2980
    - Records
    - Maintenance of qualification
    - Essential variables
  - Inspection personnel
    - NDT and Weld inspectors
- Basic quality management
  - Inspection before, during and after welding
  - Calibration of equipment
  - Quality documentation
    - Inspection and test plans
    - Weld maps
    - Quality plans
    - Production plans
    - Manufacturer’s data reports (MDRs)
  - Traceability
  - Records

Table 2: Welding Supervisor – Examples of competencies recommended for AS/NZS 1554.1 Category SP work

5.5.2 Welding Coordination

Unlike AS/NZS 1554.1, AS/NZS ISO 3834 refers to welding coordination. Welding coordination is a management task and an overview of the process in relation to AS/NZS 1554.1 is shown in Figure 1.

Welding coordinators may be required to perform a variety of tasks, one of which is welding supervision, particularly in smaller fabrication companies. In larger companies, welding coordination tasks may be undertaken by a number of people; however, the welding coordinator retains responsibility for the overall process.

The welding coordinator is required to have sufficient technical knowledge and experience to competently undertake the tasks at hand. The minimum recommended technical knowledge requirements for welding coordination personnel is defined in ISO 14731.

It is recommended that welding coordinators undertaking welding supervision tasks in accordance with AS/NZS 1554 and its parts should at least have a recognised welding supervisor or welding specialist qualification unless more extensive technical knowledge is required in accordance with the contract e.g. welding technologist or welding engineer. Such requirements though remain a matter for resolution between the fabricator and principal.
Welding Coordinator or Equivalent

Coordinates Requirements for Welding
AS/NZS 1554 Part 1 Clause 1.7.1 Quality Management

Fabricators shall ensure that all welding and related activities prescribed within Clause 1.7.2 and this Standard are managed under a suitable quality management system. Such a system should generally comply with the requirements of AS/NZS ISO 3834 and its parts particularly where fabrication activities require the approval of the principal or inspecting authority, or where the fabrication of large, complex or critical structures is being undertaken.

Estimator

Needs to understand production capability for tendering purposes.

Purchasing

Needs to purchase correct steel/welding consumables to procedures. Consumables need to be stored effectively and traceable. Manages subcontracted services, such as NDT, PWHT, fabrication, inspection, etc.

Training

Staff need to be trained and competent. Trade and subcontracted welders need to be tested for competence and approved to that welding type.

Welding Supervisor

Needs to have all welding procedures documented, available for welders. Reviewed per project for welding requirements. Supervisor needs to have authority to enforce procedures. Manages inspection and testing during and after welding. Manages welders.

Manages:
- Systems associated with welding, such as production, planning, weld identification, testing and traceability of all records, steel and consumables;
- Equipment maintenance and calibration, etc.

Looks to work conditions, environment, allocation of qualified personnel, and safety.

- Qualified welders
- Trade welders
- Subcontract welders

Figure 1: Welding coordination overview. The activities listed are typical of those managed by welding coordination personnel (see ISO 14731)
5.5.3 **Welder Qualification**

As described previously, welder qualifications are one of four key input pillars of the AS/NZS 1554 standards, ensuring a quality output of components and structures fabricated to AS/NZS 1554.1. AS/NZS 1554.1 through Clause 4.12.2 requires that welders are suitably qualified to carry out the work. The standard then provides two methods of qualification.

(a) **Qualification via standards**

This method requires welders to undertake qualification tests in conformance with standards such as ISO 9606-1 (AS/NZS ISO 9606-1) and AS/NZS 2980. These standards have their own series of essential variables and welders qualified to these standards remain qualified provided that the welder produces satisfactory welds within the limits of the validity of the qualification. Additional qualification of welders to specific weld procedures is not required when welding within the limits of the qualification.

(b) **Qualification via macro and visual examination**

Welders not qualified via standards are able to qualify by producing a suitable macro taken from a welded test piece reproducing the details of the weld procedure being followed. The qualification remains valid within the limits set out in Clauses 4.12.2.3 and 4.12.2.4.

The method of qualification of welders is a matter for resolution as set out in Appendix D of AS/NZS 1554.1. In many cases, unless there are specific requirements defined within the client’s specification, the fabricator is free to make an economic choice as to their preferred method of qualification of welders. Fabricators utilising a small number of procedures within a narrow range of materials may find it preferable to qualify their welders via the macro and visual examination to each weld procedure used.

Fabricators whose quality programs have been verified to AS/NZS ISO 3834 part 2 or part 3 should note that they are permitted to qualify their welders to national standards such as AS/NZS 1554.1 or AS/NZS 2980 in lieu of the specified ISO 9606-1 (AS/NZS ISO 9606-1) unless otherwise specified – see also AS/NZS ISO 3834-5.

6.0 **Workmanship**

Three items from Section 5 of AS/NZS 1554.1 require special mention:

(a) **Anti-spatter materials**

Anti-spatter fluids and materials (if required) should be used sparingly and never sprayed within a weld joint. If used, the fabricator should ensure that the materials used are compatible with final paint or coating system to be used on the fabricated structure. It is preferable though that the welding process is suitably controlled so that spatter generation is minimal and therefore anti-spatter preparations are not required. Unless specified otherwise, weld spatter should be removed by the fabricator prior to final inspection and/or the application of coating system.

(b) **Preheat**

The method used for the determination of preheat within AS/NZS 1554.1 was originally developed by the Australian Welding Research Association (now Weld Australia) and published in their Technical Note 1 in 1972. The preheat determination method is applicable to many carbon, carbon-manganese, and low alloy steels (other than quenched and tempered steels). The Technical Note was most recently revised in 2017 and republished in 2018. Of particular note, the latest editions of this document proposed a method for dealing with steels containing boron, and steels manufactured to standards other than Australian standards.

The nomographs and group number concept used within the AS/NZS 1554 series are similar to those published within Weld Australia’s Technical Note 1 and are not applicable to steels containing boron. When originally developed, the researchers did not consider the presence of boron within the steels as boron was typically only added to specialty steels at the time. Likewise, it does not feature within the carbon equivalent formula used as the basis for the nomographs.

It is therefore recommended that preheat requirements for steels containing ≥0.0008% boron, and steels not manufactured to Australian standards, have their preheat determined in a manner similar to that recommended in Technical Note 1. Specifically:

(i) The minimum preheat temperature requirements for these steels should be determined in accordance
with manufacturer’s recommendations; or if not available,

(ii) To the welding standard(s) of the country of origin; or if not available,

(iii) Calculate minimum preheat using an internationally used alternative e.g. CET method (BS EN 1011-2).

In all cases, these steels should be considered as non-prequalified.

(c) Assembly

The user’s attention is drawn to the workmanship joint tolerances published in Table 5.2.2 of AS/NZS 1554.1. The intention of the tolerances is to provide an allowance for dimensional variations due to workmanship. It is not permissible to add them to the specific joint dimensions of the prequalified joints in Tables E1 to E4 to increase the range of prequalification for the given joint angles, root face and root gap dimensions etc. The joint dimensions in the tables are those that must be shown on the weld procedures if prequalification is being claimed.

7.0 Quality of Welds

The methods of inspection and acceptance criteria applicable are set out within Section 6 of AS/NZS 1554.1. Three items are worth specific mention:

(a) Permissible acceptance criteria for visual and surface examinations

Table 6.2.2 AS/NZS 1554.1 sets out the general acceptance criteria for visual examination and surface examinations. The table also applies for imperfections found within macro specimens.

When applied to macro examinations, the 5% loss of cross-sectional area limit applies for category SP welding and 10% loss of cross-sectional area for GP welding. The loss of area is calculated by estimating the surface area of each imperfection visible in the macro test, divided by the cross-sectional area of the weld expressed as a percentage.

\[
\text{LoA} (\%) = \frac{\text{Area of imperfections}}{\text{Area of weld metal}} \times 100
\]

The loss of cross-sectional area requirements can only be determined from an examination of the macro specimen (see Notes 4 and 5 of Table 6.2.2).

Where imperfections are observed in a macro specimen, it must be assumed that the imperfection runs the full length of the weld and sentenced accordingly, unless additional sampling or testing determines otherwise.

(b) Weld defects

Imperfections that exceed the limits permitted within Section 6 are classed as defects and typically need to be removed with the weld repaired and reinspected. Imperfections that interfere with surface coatings will also need to be removed and repaired even if determined to fall within acceptable limits.

Fabricators should be aware that where it can be demonstrated that the defect is not detrimental to the end use, usually through the use of fracture mechanics for example, it is permissible to allow the defects to remain. This assessment must be performed by suitably qualified experts in conjunction with the fabricator and client.

(c) Imperfections within the parent material

Imperfections of parent metal origin e.g. non-metallic inclusions detected during an ultrasonic examination, are not normally considered as a cause for rejection. Should such imperfections exceed the limits for weld imperfections or otherwise interfere with the examination of the weld, their presence should be reported to the client and the details included on the examination report. Discrepancies on permissible limits for imperfections within the parent material can arise due to the different acceptance criteria applicable to parent materials compared with those applicable to welds. Note that lamellar tearing is considered a weld defect even though it occurs within the parent material.
8.0 Inspection

Inspection requirements for the client's inspectors are set out within Section 7 of AS/NZS 1554.1 including a recommended level of inspection utilising various inspection methods. For these tests to be undertaken, the extent of testing, type of testing and location of testing must be specified on the drawings or within the specification by the client. There is no obligation on the part of the fabricator to conduct the tests recommended in Section 7 unless otherwise specified by the client.

The standard is otherwise silent on inspection requirements to be undertaken by the fabricator. This said though, the fabricator is responsible for their work and it is the responsibility of the welding supervisor to ensure that all welds are present and comply with the requirements of the client's specification and standard. This includes conducting a variety of inspections, checks and audits before welding, during welding, and after welding as necessary to ensure conformance with these requirements. These checks should be documented and include the name of the welder where relevant. Examples of simple checks that can be performed include:

(a) Dimensional checks on weld preparations;
(b) Verification checks of welding parameters in use;
(c) Verification of preheat and/or interpass temperature applied;
(d) Dimensional checks of completed welds;
(e) Visual examination of completed welds.

Documentation does not need to be extensive and can be as simple as a check list of items for verification. It should include reference to the WPS number and welder’s name where relevant as this record can then be used to verify a welder’s qualifications every six months. It also provides clients with evidence that the weld procedures are being used and followed, reducing the need for subsequent inspection by the client’s inspector and NDE examinations.

Whilst not a requirement of AS/NZS 1554.1, an inspection and test plan (ITP) may be a useful “tool” for the fabricator to utilise in setting out their planned checks and inspections before, during and after welding. It should be noted that the method, location and extent of any NDE examination must be specified by the client in their specification document as AS/NZS 1554.1 is otherwise silent on minimum NDE requirements.

Fabricators should be aware that AS/NZS 1554.1 does not specify any time delay requirements for NDE examination after the completion of welding however many NDE companies will record the time elapsed from the completion of welding to the time of testing, or recommend and apply similar delays to those within AS/NZS 5131. This will enable imperfections such as hydrogen assisted cold cracking to be detected.

9.0 Brittle Fracture

AS 4100 (and other design standards such as AS 5100) requires that all steels selected for use in structures are used within their notch-ductile temperature range. Requirements are defined within Section 10 of AS 4100 and similarly, Appendix B of AS/NZS 1554.1.

Within Appendix B of AS/NZS 1554.1, these requirements specify that the permissible service temperature of the steel (as modified) must be equal to or colder than the design service temperature.

All steels, irrespective of their country of manufacture, are required to comply with these requirements. Steels non-compliant with Section 2 of AS/NZS 1554.1 are required to be assessed as stated in Clause B4.3.4 or B5 of AS/NZS 1554.1. Fabricators should also be aware of the following:

(a) Steels manufactured to standards other than the standards listed in Section 2 of AS/NZS 1554.1 are non-compliant. Table B1 is not applicable to these steels.
(b) For steels manufactured outside of Australia or New Zealand to the standards listed in Section 2 of AS/NZS 1554.1, Table B1 cannot be applied unless compliance with the table is established. Product conformity can be established using the methods within AS/NZS 1163 or AS/NZS 3678 or AS/NZS 3679.1 (as relevant) for example, or if previous test data is available, via a statement of compliance on the manufacturers heat certificate.
(c) For any parent material where conformity cannot be established, the permissible service temperature shall be based on the temperature of impact testing of the steel and modified as required within Appendix B of AS/NZS 1554.1. Table B1 is not applicable to these steels.
10.0 Matters for Resolution
AS/NZS 1554.1 includes an appendix (Appendix D) of matters for resolution which are regarded as being of a contractual nature. Fabricators should discuss these items with their client prior to the letting of the contract. This minimises the risks of disputation and associated costs, assisting both the fabricator and client.

11.0 Other Requirements

11.1 Post Weld Heat Treatment
Post weld heat treatment (PWHT) is mentioned briefly in Appendix B of AS/NZS 1554.1 when dealing with brittle fracture, however, it is rarely required when welding the structural steels listed in Section 2 of AS/NZS 1554.1. If required, it should conform to the requirements of AS 4458. When it is applicable, all non-destructive examinations should be performed after the completion of PWHT and the structure has cooled to ambient temperature. When PWHT is specified, weld procedure tests (see Clauses 4.2 and 4.7 of AS/NZS 1554.1) should include the application of PWHT to the test plate prior to sampling for testing other than for prequalified procedures when:

(a) The welding consumables are deemed suitable for PWHT by their manufacturer e.g. have been classified in the PWHT condition (e.g. “AP” or “P” symbols included in the designation); and,
(b) The parent materials are deemed suitable for PWHT by the steel manufacturer.

12.0 References

12.1 Australian Standards
(a) AS/NZS 1163 Cold-formed structural steel hollow sections
(b) AS 1554:1974 SAA code for welding in building Part 1: Manual welding
(c) AS/NZS 1554.1 Structural steel welding Part 1: Welding of steel structures
(d) AS 1796 Certification of welders and welding supervisors
(e) AS 2214 Certification of welding supervisors — Structural steel welding
(f) AS 2812 Welding, brazing and cutting of metals — Glossary of terms
(g) AS/NZS 2980 Qualification of welders for fusion welding of steels
(h) AS/NZS 3678 Structural steel — Hot-rolled plates, floorplates and slabs
(i) AS/NZS 3679.1 Structural steel Part 1: Hot-rolled bars and sections
(j) AS/NZS ISO 3834 Quality requirements for fusion welding of metallic materials
  Part 2: Comprehensive quality requirements
  Part 3 Standard quality requirements
  Part 5: Documents with which it is necessary to conform to claim conformity to the quality requirements of AS/NZS ISO 3834.2, AS/NZS ISO 3834.3 or AS/NZS ISO 3834.4
(k) AS 4100 Steel structures
(l) AS 4458 Pressure equipment — Manufacture
(m) AS 5100 Bridge design
(n) AS/NZS 5100.6:2017 Bridge design — Part 6: Steel and composite construction
(o) AS/NZS 5131 Structural steelwork — Fabrication and erection
(p) AS/NZS ISO 9606-1 Qualification testing of welders — Fusion welding — Part 1: Steels
(q) SA TS 103 Structural steel welding — Limits on boron in parent materials

12.2 ISO Standards
(r) ISO 9606-1 Qualification testing of welders — Fusion welding — Part 1: Steels
(s) ISO 14731 Welding coordination — Tasks and responsibilities
(t) ISO 15612 Specification and qualification of welding procedures for metallic materials — Qualification by adoption of a standard welding procedure
(u) ISO/TR 18491 Welding and allied processes — Guidelines for measurement of welding energies

12.3 Other Standards
(v) AWS D1.1 Structural welding code — Steel
(w) BS EN 1011-2 Welding — Recommendations for welding of metallic materials — Part 2: Arc welding of ferritic steels
Weld Australia Technical Notes

TN 1 – The Weldability of Steels
Gives guidance on the preheat and heat input conditions (run size, current, voltage) required for acceptable welds and to avoid cold cracking in a wide variety of steels. The Note is applicable to a wide range of welding processes.

TN 2 – Successful Welding of Aluminium
This note covers the major welding processes as they are used for the welding and repair of aluminium and its alloys. Information is given on the processes, equipment, consumables and techniques. It also provides information on the range of alloys available and briefly covers safety, quality assurance, inspection and testing, costing and alternative joining processes.

TN 3 – Care and Conditioning of Arc Welding Consumables
Gives the basis and details for the correct care, storage and conditioning of welding consumables to control hydrogen and to ensure high quality welding.

TN 4 – The Industry Guide to Hardfacing for the Control of Wear

TN 5 – Flame Cutting of Steels
Gives a wealth of practical guidance on flame cutting including detailed procedures for efficient cutting, selection of equipment and gases, practices for identifying and curing defective cutting, methods of maximising economy and other important guidance on the use of steels with flame cut surfaces.

TN 6 – Control of Lamellar Tearing
Describes the features and mechanisms of this important mode of failure and the means of controlling tearing through suitable design, material selection, fabrication and inspection. Acceptance standards, repair methods, specification requirements and methods of investigation are proposed. Four appendices give details on the mechanism, material factors, tests for susceptibility and the important question of restraint.

TN 7 – Health and Safety in Welding
Provides information on all aspects of health and safety in welding and cutting. Designed to provide this information in such a way that it is readily useable for instruction in the shop and to provide guidance to management. Recommendations are given for safe procedures to be adopted in a wide variety of situations in welding fabrication.

TN 8 – Economic Design of Weldments
Principles and guidance are given on methods and procedures for optimising design of weldments and welded joints and connections to maximise economy in welding fabrication. Factors influencing the overall cost of weldments which need to be considered at the design stage are discussed.

TN 9 – Welding Rate in Arc Welding Processes: Part 1 MMAW
Gives practical guidance and information on the selection of welding conditions to improve productivity during manual metal arc welding (MMAW). Graphs are provided showing rates as a function of weld size. The graphs enable a direct comparison of different types of welding electrodes when used for butt and fillet welds in various welding positions.

TN 10 – Fracture Mechanics
Provides theory and gives practical guidance for the design and fabrication of structures, planning of maintenance and assessment of the likelihood of brittle or ductile initiation from flaws in ferrous and non-ferrous alloys. Engineering critical assessment case histories are discussed.

TN 11 – Commentary on the Structural Steel Welding Standard AS/NZS 1554
The Note complements AS/NZS 1554 parts 1 to 7, by presenting background information which could not be
included in the Standard. It discusses the requirements of the Standard with particular emphasis on new or revised clauses. In explaining the application of the Standard to welding in steel construction, the commentary emphasises the need to rely on the provisions of the Standard to achieve satisfactory weld quality.

**TN 12 - Minimising Corrosion in Welded Steel Structures**

Designed to provide practical guidance and information on corrosion problems associated with the welding of steel structures, together with possible solutions for minimising corrosion.

**TN 13 - Stainless Steels for Corrosive Environments (A Joint publication with ACA)**

Provides guidance on the selection of stainless steels for different environments. Austenitic, ferritic and martensitic stainless steels are described together with the various types of corrosive attack. Aspects of welding procedure, design, cleaning and maintenance to minimise corrosion are covered.

**TN 15 - Welding and Fabrication of Quenched and Tempered Steel**

Provides information on quenched and tempered steels generally available in Australia and gives guidance on welding processes, consumables and procedures and on the properties and performance of welded joints. Information is also provided on other fabrication operations such as flame cutting, plasma cutting, shearing and forming.

**TN 16 - Welding Stainless Steel**

This Technical Note complements Technical Note Number 13 by detailing valuable information on the welding of most types of stainless steels commonly used in industry.

**TN 18 - Welding of Castings**

Provides basic information on welding procedures for the welding processes used to weld and repair ferrous and non-ferrous castings. It also provides information on the range of alloys available and briefly covers non-destructive inspection, on-site heating methods and safety.

**TN 19 - Cost Effective Quality Management for Welding**

Provides guidelines on the application of the AS/NZS ISO 9000 series of Quality Standards within the welding and fabrication industries. Guidance on the writing, development and control of Welding Procedures is also given.

**TN 20 - Repair of Steel Pipelines**

Provides an outline of methods of assessment and repair to a pipeline whilst allowing continuity of supply.

**TN 21 - Submerged Arc Welding**

Provides an introduction to submerged arc welding equipment, process variables, consumables, procedures and techniques, characteristic weld defects, applications and limitations. Describes exercises to explore the range of procedures and techniques with the use of solid wire (single and multiple arcs) and provides welding practice sheets, which may be used as instruction sheets to supplement demonstrations and class work, or as self-instruction units.

**TN 22 - Welding Electrical Safety**

Provides information and guidance on welding electrical safety issues: welding equipment, the body and the workplace.

**TN 23 - Environmental Improvement Guidelines**

Provides information and guidance on how to reduce consumption in the Welding and Fabrication industry, while reducing the impact on the environment at the same time.

**TN 25 - Welding Specification for the Water Industry**

Published with the Water Services Association of Australia. Applies to all metal fabrication and repair work involving welding, carried out by a Water Agency (WA) and its Contractors/Subcontractors. Prescribes weld preparation, qualification of welding procedures and personnel, workmanship and inspection requirements for welds related to the arc welding by manual metal arc and other processes approved by the WA responsible Welding Coordinator.