Weld Australia
Technical Guidance Note

AS/NZS 1554.1: A Guide to the Qualification of Weld Procedures

www.weldaustralia.com.au
Foreword

This Technical Guidance Note contains basic information on the qualification of weld procedures, primarily utilising the requirements of AS/NZS 1554.1 as an example. It provides information on the terminology used, and the various methods commonly applied to establish the suitability of the procedure for the defined application. It is designed to be read in conjunction with the standard, and, to assist users in understanding its requirements.

Future Revisions

In future editions of this Technical Guidance Note, it is intended to provide guidance on the weld procedure requirements associated with other standards including the welding of pipelines, pressure equipment and aluminium.

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.

Acknowledgements

The assistance of Mr Stan Ambrose in the provision of information relating to pressure equipment requirements (Appendix A) is gratefully acknowledged.

Disclaimer

While every effort has been made and all reasonable care taken to ensure the accuracy of the material contained herein, the authors, editors and publishers of this publication shall not be held to be liable or responsible in any way whatsoever and expressly disclaim any liability or responsibility for any loss or damage costs or expenses howsoever caused incurred by any person whether the purchaser of this work or otherwise including but without in any way limiting any loss or damage costs or expenses incurred as a result of or in connection with the reliance whether whole or partial by any person as aforesaid upon any part of the contents of this Technical Guidance Note. Should expert assistance be required, the services of a competent professional person should be sought.

Editor

Mr Bruce Cannon
Technical Publications Manager, Weld Australia

Weld Australia

ABN 69 003 696 526
Building 3, Level 3, Pymble Corporate Centre
20 Bridge Street, Pymble, NSW 2073
PO Box 197, Macquarie Park BC, NSW 1670
Phone: +61 (0)2 8748 0100
www.weldaustralia.com.au
About Weld Australia

Who We Are
Weld Australia represents the welding profession in Australia. Our members are made up of individual welding professionals and companies of all sizes. Weld Australia members are involved almost every facet of Australian industry and make a significant contribution to the nation's economy.

Our primary goal is to ensure that the Australian welding industry remains both locally and globally competitive, both now and into the future.

A not-for-profit, membership-based organisation, Weld Australia is dedicated to providing our members with a competitive advantage through access to industry, research, education, certification, government, and the wider industrial community.

Weld Australia is the Australian representative member of the International Institute of Welding (IIW).

Our Mission
Our mission is to represent the interests of members and safeguard the public by ensuring the integrity of in-service welds, and to promote the use of best practice technology and quality systems.

Our Value Proposition
Weld Australia generates revenue through its commercial activities which is then reinvested back into the welding community for the benefit of members.

Weld Australia brings individual and company members together to deliver:

- A forum for the exchange of ideas and the sharing of resources
- A voice to promote the interests of the welding community and shape the market for welding services
- Specialist technical problem solving and a conduit between industry and research organisations
- A pathway for learning and career development and the opportunity to benchmark against world’s best practice

Our Services
Weld Australia provides:

- Events and Seminars
- Technical Publications
- Technical Support and Advisory Services
- Project Management
- Professional Development
- Qualification and Certification

Real Solutions to Real Problems...
Weld Australia has a team of highly qualified welding engineers and technologists available to provide expert advisory services on all welding related matters. With expertise in a wide range of industries, ranging from biotechnology to heavy engineering we have a unique capability to solve your welding problems.

Our advice can help you substantially increase the operational life of your plant and equipment and thereby reduce your maintenance and repair overheads.

Further Information
For further information about Weld Australia and how we can help your business, please visit: www.weldaustralia.com.au.
1.0 Introduction

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.

The use of qualified welding procedures is therefore a mandatory requirement of many application standards and customer specifications, and is the work instruction that is given to the welder. Weld procedures are a key part of the quality system element of process control, and control of these documents is essential.

Prequalified procedures for which qualification testing may not be necessary are also allowed under various standards.

Welder certification and qualification are also an important component of weld procedure control. Welder certification is defined as certifying that a welder has complied with prescribed prerequisites training and examination requirements to attain a specific welding skill. Welder qualification is required to demonstrate the welder’s ability to weld (in accordance with a qualified welding procedure) a specific joint on a test piece, which simulates that joint to the specified requirements given in the application standard.

This Technical Guidance Note discusses the basic steps and terminologies used in writing welding procedures with specific reference to AS/NZS 1554.1. An overview of the process is shown in Figure 1.

![Figure 1: Overview of weld procedure development.](image-url)
2.0 Requirements for Weld Procedures

2.1 General

Why should there be weld procedures and do they need qualifying?

Documented weld procedures are a mandatory requirement of most, if not all, structural and pressure equipment welding application standards. These standards require that the weld procedures be qualified prior to the commencement of welding operations. In some cases, the test pieces required for re-qualification of weld procedures come from plates produced during production welding operations.

A qualified weld procedure is a procedure to which a test weld has been made and the specimens prepared from the test weld have passed the specified requirements contained in the application standard e.g. AS/NZS 1554.1.

Once the weld procedures have been qualified and approved, these same standards require that the weld be deposited only by welders qualified and experienced in the welding operation defined in the qualified welding procedures. The customer will also normally specify that all welding must comply with the relevant application standard. For a weld to meet the quality requirements of a project or contract, the welding processes must be planned and performed under controlled conditions i.e. documented. Aside from being required by the applicable standard or contract, welding procedures are an essential document when the company undertakes projects or contracts that include welded structures as they are an assurance of quality in their own right if correctly applied i.e. they must reflect the welding parameters used on the job.

It should be noted that whilst having an approved welding procedure recorded does not by itself always ensure that the welding it produces will meet the specified requirements, the fabricator and customer can have a high degree of confidence that the requirements will be met. In critical applications, non-destructive examination (NDE) will be required, and in some specific circumstances, metallurgical and mechanical properties of the completed weld may need to be verified through production test plates as required by applicable standards. In less critical applications, the fabricator and customer may elect to use a lower level of NDE thus reducing the cost of the structure.

This Technical Guidance Note outlines a process compatible with Australian and New Zealand welding standards as well as quality standards, and shows the basic steps required to plan, develop and maintain qualified welding procedures. It can be adopted as a guide to developing procedures, and describes how to qualify and use approved welding procedures.

Whilst the standard AS/NZS 1554.1 has been used as the basis for this Technical Guidance Note, its use would be applicable for most national and international standards. However, when drafting weld procedures, it is recommended that the appropriate standards and specifications be referenced. It should be noted that the document layout is normally optional at the discretion of the fabricator and not a mandatory requirement of the application standard.

2.2 Provision to Welders

Once a procedure is qualified, a copy of the Weld Procedure Specification (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 and costs that would otherwise not be necessary.
3.0 Documented Weld Procedures

The process outlined in this Technical Guidance Note refers to standard documents by particular names. A brief description of each document and its use will allow standardised communication about them between all concerned in the welding industry. This should be beneficial to all those persons involved in their use.

These documents provide a basis for reproducing weld procedures that should produce sound welds in an efficient manner without giving rise to defects. They will also give assurance to all involved, and assist in cost effective welding. Typical forms (similar to the AS/NZS 1554.1 format) for the Procedure Qualification Record (PQR) and Welding Procedure Specification (WPS) are shown in Figures 2 and 3.

An example of a completed PQR and WPS document for a gas metal arc (GMAW) butt weld in 20mm plate can be found in Figures 4 and 5.

**WARNING**: The procedures in Figures 4 and 5 have not been tested or qualified.

3.1 Welding Procedure Qualification Record (PQR)

This document is mandatory and is the critical record in the development and production of weld procedures. It is used as a basis for the writing of the weld procedure specification (WPS) document given to the welder, and is a demonstration that the procedure to be used will comply with appropriate standards and specifications. The PQR record is NOT job specific and can be used as a basis for writing many WPSs for many customers (where customer specific procedures may be contractually required). It can also be used to write procedures complying with multiple standards provided that the appropriate tests required by those standards are performed and satisfactory results achieved. This reduces the cost of procedure development as duplicate procedures are not produced.

To use the document, record on this form all measured parameters used in producing the test weld (e.g. from the draft WPS). Record on this same form all relevant destructive and NDE tests and record the outcome of those tests (pass or fail), or reference the documents detailing the results. Verify all details and test certificates as acceptable then submit the PQR to the relevant personnel for approval. Their approval must be recorded on this document prior to any further use. As noted above, this document should not be made either job specific or customer specific. This does not preclude the customer requesting that destructive and/or NDE tests be conducted by independent test laboratories.
Figure 2: Welding Procedure Qualification Record form example.

<table>
<thead>
<tr>
<th>PROCEDURE QUALIFICATION RECORD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material spec/grade</td>
</tr>
<tr>
<td>Fabricator</td>
</tr>
<tr>
<td>Process</td>
</tr>
<tr>
<td>Welding Standard</td>
</tr>
<tr>
<td>Edge preparation</td>
</tr>
<tr>
<td>Weldability group No.</td>
</tr>
<tr>
<td>Specimen thickness</td>
</tr>
<tr>
<td>Preheat temperature °C</td>
</tr>
<tr>
<td>Inter-run temperature °C</td>
</tr>
<tr>
<td>Type and check method</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Run sequence</th>
<th>Joint details</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Joint type &amp; No.</td>
</tr>
<tr>
<td></td>
<td>To Table</td>
</tr>
<tr>
<td></td>
<td>Root gap G mm</td>
</tr>
<tr>
<td></td>
<td>Root face R mm</td>
</tr>
<tr>
<td></td>
<td>Incl. angle $\phi^*$</td>
</tr>
<tr>
<td></td>
<td>Backing</td>
</tr>
<tr>
<td>Specification-Root</td>
<td>Remainder</td>
</tr>
<tr>
<td>Classification-Root</td>
<td>Remainder</td>
</tr>
<tr>
<td>Shielding gas</td>
<td>Flow rate</td>
</tr>
<tr>
<td>Purge gas</td>
<td>Flow rate</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Weld run details</th>
<th>Welding parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.</td>
<td>Side</td>
</tr>
<tr>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Technique</th>
<th>Stringer/weave</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial cleaning</td>
<td>Electrical stick-out mm</td>
</tr>
<tr>
<td>Inter-run clean</td>
<td>Backgouge method</td>
</tr>
<tr>
<td>Nozzle size</td>
<td>Backgouge check</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Test results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test type</td>
</tr>
<tr>
<td>Test by</td>
</tr>
<tr>
<td>Report No.</td>
</tr>
<tr>
<td>Result</td>
</tr>
<tr>
<td>Notes/revisions</td>
</tr>
</tbody>
</table>

| Witnessed by | Approved by |
### WELDING PROCEDURE SPECIFICATION

<table>
<thead>
<tr>
<th>Material spec/grade</th>
<th>to</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISO/TR 15608 group &amp; sub group</td>
<td>to</td>
</tr>
<tr>
<td>Fabricator</td>
<td>WPS No.</td>
</tr>
<tr>
<td>Process &amp; ISO process No:</td>
<td>Date</td>
</tr>
<tr>
<td>Welding Standard</td>
<td>PQR No.</td>
</tr>
<tr>
<td>Edge preparation</td>
<td>Page</td>
</tr>
<tr>
<td>Welding direction</td>
<td>Revision</td>
</tr>
<tr>
<td>Range qualified</td>
<td>Positions</td>
</tr>
<tr>
<td>Preheat temperature °C</td>
<td>PWHT</td>
</tr>
<tr>
<td>Inter-run temperature °C</td>
<td>Hold</td>
</tr>
<tr>
<td>Type and check method</td>
<td>Other</td>
</tr>
</tbody>
</table>

#### Run sequence

<table>
<thead>
<tr>
<th>Joint details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Joint type &amp; No.</td>
</tr>
<tr>
<td>To Table</td>
</tr>
<tr>
<td>Root gap G mm</td>
</tr>
<tr>
<td>Root face F, mm</td>
</tr>
<tr>
<td>Incl. angle Ø</td>
</tr>
<tr>
<td>Backing</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Specification-Root</th>
<th>Remainder</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classification-Root</td>
<td>Remainder</td>
</tr>
<tr>
<td>AS/NZ ISO 9606-1 filler</td>
<td>Remainder</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Shielding gas</th>
<th>Flow rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purge gas</td>
<td>Flow rate</td>
</tr>
</tbody>
</table>

#### Weld run details

<table>
<thead>
<tr>
<th>Weld run details</th>
<th>Welding parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.</td>
<td>Side</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Technique</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stringer/weave</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Initial cleaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical stick-out mm</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Inter-run clean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Backgouge method</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nozzle size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Backgouge check</td>
</tr>
</tbody>
</table>

### Notes/revisions

### Figure 3:
Welding Procedure Specification form example.
This WPS pro-forma includes provision for the additional information required to qualify welders to AS/NZS ISO 9606-1.
**Figure 4:** Welding Procedure Qualification Record example.

This PQR is an example only and has not been qualified.
WELDING PROCEDURE SPECIFICATION

Material spec/grade: AS/NZS 3678-250
ISO/TR 15608 group & sub group: 1.1
Fabricator: TGN Engineering
Process & ISO process No: GMAW (135)
Welding Standard: AS/NZS 1554.1 SP
Edge preparation: Machining/Grinding
Welding direction: Push
Preheat temperature: 25°C min.
Inter-run temperature: N/A
Type and check method: Contact pyrometer

Run sequence

<table>
<thead>
<tr>
<th>Specification</th>
<th>AS/NZS 14341</th>
<th>Fill &amp; Cap: AS/NZS 14341</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classification</td>
<td>B-G49A3U M S4</td>
<td>Fill &amp; Cap: B-G49A3U M S4</td>
</tr>
<tr>
<td>Purge gas</td>
<td>N/A</td>
<td>Flow rate: N/A</td>
</tr>
<tr>
<td>Flux</td>
<td>N/A</td>
<td></td>
</tr>
</tbody>
</table>

Joint details

Joint, No. Butt B-C3
To Table E1
Root gap G 4.0 mm
Root face F, 0.0 mm
Incl. angle 0° 50'
X = 2/3 t.

Weld run details

<table>
<thead>
<tr>
<th>No.</th>
<th>Side</th>
<th>Position</th>
<th>mm</th>
<th>Trade name</th>
<th>Amps</th>
<th>Volts</th>
<th>Polarity</th>
<th>Speed (mm/min)</th>
<th>Heat input (kJ/mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>F (PA)</td>
<td>1.2</td>
<td>LW1-S4</td>
<td>115-135</td>
<td>17-19</td>
<td>DC+</td>
<td>160-200</td>
<td>0.59-0.96</td>
</tr>
<tr>
<td>2-3</td>
<td>1</td>
<td>F (PA)</td>
<td>1.2</td>
<td>LW1-S4</td>
<td>290-350</td>
<td>27-29</td>
<td>DC+</td>
<td>300-400</td>
<td>1.17-2.03</td>
</tr>
<tr>
<td>4-5</td>
<td>2</td>
<td>F (PA)</td>
<td>1.2</td>
<td>LW1-S4</td>
<td>290-350</td>
<td>27-29</td>
<td>DC+</td>
<td>300-400</td>
<td>1.17-2.03</td>
</tr>
</tbody>
</table>

Technique: Push
Initial cleaning: Grinding/power wire brush
Inter-run clean: Grinding/power wire brush
Nozzle size: N/A

Welding parameters

<table>
<thead>
<tr>
<th>No.</th>
<th>Side</th>
<th>Position</th>
<th>mm</th>
<th>Trade name</th>
<th>Amps</th>
<th>Volts</th>
<th>Polarity</th>
<th>Speed (mm/min)</th>
<th>Heat input (kJ/mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>F (PA)</td>
<td>1.2</td>
<td>LW1-S4</td>
<td>115-135</td>
<td>17-19</td>
<td>DC+</td>
<td>160-200</td>
<td>0.59-0.96</td>
</tr>
<tr>
<td>2-3</td>
<td>1</td>
<td>F (PA)</td>
<td>1.2</td>
<td>LW1-S4</td>
<td>290-350</td>
<td>27-29</td>
<td>DC+</td>
<td>300-400</td>
<td>1.17-2.03</td>
</tr>
<tr>
<td>4-5</td>
<td>2</td>
<td>F (PA)</td>
<td>1.2</td>
<td>LW1-S4</td>
<td>290-350</td>
<td>27-29</td>
<td>DC+</td>
<td>300-400</td>
<td>1.17-2.03</td>
</tr>
</tbody>
</table>

Technique: Push
Initial cleaning: Grinding/power wire brush
Inter-run clean: Grinding/power wire brush
Nozzle size: N/A

Approved by: [Signature]

Notes/revisions

1. This procedure may vary due to fabrication sequence, fit-up, material thickness, number of runs etc. within the Essential Variable limits of AS/NZS 1554.1.

Figure 5: Welding Procedure Specification example.
This WPS is an example and has not been qualified. WPS pro-forma includes additional information required to qualify welders to AS/NZS ISO 9606-1.
3.2 Welding Procedure Specification (WPS)
This document is mandatory and is the work instruction that is given to the welder. Some companies combine both the PQR and WPS on one form, and while this may be acceptable, it can lead to complicated documentation and confusion, thus is not recommended practice.

The WPS form has two functions – that of a draft weld procedure, and that of the WPS compiled after the procedure has been qualified.

As a draft weld procedure, also referred to as a preliminary weld procedure or pWPS, sufficient information is written on this form to allow the preparation of a test plate and to carry out the welding so that the test samples required by the qualification testing (to produce the PQR) can be obtained.

For its standard role, the WPS document must reference the PQR on which it is based, and provide the welder with sufficient information to produce the joint required in a controlled manner. It will show essential details such as amps, volts, welding speed, preheat requirements, consumable type(s), welding process and other basic information needed. It must show the range of parameters within which the welder is allowed to work and must not move out of. It must also show all relevant information required by the range of essential variables determined from the welding standards. Where welding is outside the range of these essential variables, the procedure must be re-qualified.

Note that the procedure must include any information to control any item which may adversely affect weld quality (including the metallurgy or mechanical properties in the weld zone or parent metal) e.g. heat treatment, consumable treatment, tacking procedure, gouge method.

Fabricators should also be aware that some customers require these documents to be stamped or approved by their representative prior to the commencement of production welding.

As indicated above, the WPS should be kept simple and uncluttered as it is the document given to the welder. It is strongly recommended that these qualified procedures be highly visible on the job (or at least in the welder’s possession) for ready reference. The fabricator can then call up appropriate procedures on the drawing or other work instructions as required. These documents are not normally job or client specific, although some clients may contractually require their name or reference details on the procedure being used.

3.3 Prequalified Weld Procedures
These procedures are extensively used throughout Australia and New Zealand as allowed by the relevant standards. With these procedures, provided that the fabricator uses approved materials, processes, consumables and approved joints as allowed by the standard, minimal testing is required to validate the procedure. Their use and qualification requirements are the same as those of PQRs and WPSs. The fabricator may be required to demonstrate the ability to comply with the procedure through simple tests, even though they may be deemed “prequalified” e.g. via a macro test. Where prequalified joints are used in the procedure, appropriate reference should be made back to the original joint design in the standard concerned.

3.4 Standard Welding Procedures
These procedures are relatively uncommon in Australia and New Zealand but are used in North America (AWS B2 series) and Europe (ISO 15612). Unlike prequalified procedures, these procedures have been welded, tested and approved by recognised authorities or bodies and then made available for sale. This allows their use within both the terms and conditions set by the qualifier and the range of essential variables applicable to the standard welding procedure, by any fabricator who purchases them. If available and useful, include them in your library of WPSs.

3.5 Other Fabricators Welding Procedures
The AS/NZS 1554 series of standards (and AS/NZS 3992) includes allowance for fabricators to utilise weld procedures qualified by other organisations. Requirements vary but they generally require the original qualifying fabricator to be identified on the procedure so as to provide an audit trail to the original qualification records, and may require the approval of the inspection authority or regulator before their use in is permitted. To utilise these procedures, the fabricator may be required to demonstrate their ability to follow the procedure and achieve the required penetration through the welding of a macro test.
4.0 The Seven Basic Steps for Welding Procedures

There are only a few simple steps in the process of controlling weld procedures; however, each step has its own depth of detail. To plan and control weld procedures the seven steps are:

1. Identify all welds and welding standards (codes) in the work;
2. Determine the method for procedure approval;
3. Prepare draft weld procedures (pWPS);
4. Qualify the drafted weld procedure;
5. Prepare the WPS;
6. Obtain approval for the PQR and WPS;
7. File the PQR and records.

The use of standardised forms is a necessary part of this process and their design should suit the company’s operations. All necessary information must be included. Examples of procedure forms may be found in various standards, for which the user is often free to copy and utilise as needed.

The seven basic steps each have a depth to them depending on the activities required to complete each step. The simple outline given below is for each step of the process.

4.1 Identify All Welds in the Work

This is the place to start the process, not just for projects or contracts that require welding to take place under a quality management system.

The production planning or process control element of the quality system usually requires the identification and planning of the weld process(es). Study all relevant drawings, codes and specifications. After listing or hand sketching all the joint types including the weld size and material type and grade the appropriate method of approval can be determined.

It is recommended that welder requirements be considered at the same time. This part of the planning process can reduce approval costs. By assessing the qualifications and or experience of the welders, unqualified welders may be qualified as they work on the procedure, through their welding of the test plate. By carefully matching the welders with appropriate joints requiring testing, their qualifications may be established, confirmed or validated (see also AS/NZS ISO 9606-1) without further testing against these procedures. Approval tests can also be minimised by developing procedures to the highest standard likely to be required using higher level materials, that allow less critical standards, material types or conditions to be used without requalification e.g. AS/NZS 1554.1 SP category welding is prequalified for similar GP welds.

4.2 Determine the Method of Approval

Application standards typically allow different methods of qualifying weld procedures, so it is important that the procedure writer be familiar with the standard(s) being used. A good understanding of these methods will reduce welding costs. When a procedure is to be qualified to more than one standard, the fabricator will usually test the weld against the most restrictive standard and then do the extra tests required for the remaining standards. Following are some methods for qualifying welding procedures. Further information on AS/NZS 1554.1 weld procedure qualification requirements can be found in Chapter 7 of this Technical Guidance Note.

4.2.1 Previous Welding Experience

This body of information comes from already approved PQRs and WPSs that must include all authentic documentation that shows compliance with requirements.

In quality assured projects or contracts, the documentation may also include any corrective or preventative actions taken, to eliminate any nonconformity’s caused by inadequate or inappropriate welding procedures.

Some standards will allow automatic qualification (without further testing) of a weld procedure when the fabricator can demonstrate, through the successful usage of these PQRs and WPSs, that the procedure was qualified to another national or international standard. The AS/NZS 1554 series are an example of this.
4.2.2 Approved Welding Consumables
The use of approved welding consumables will reduce costs by avoiding extra qualification tests for consumables not approved. Approved welding consumables are manufactured and tested in accordance with the particular consumable standards.

The fabricator must use the consumable within the manufacturers range of approval given by a recognised authority or certifying body. Welding application standards deem these approved consumables as prequalified consumables.

4.2.3 Prequalified Joint Preparations
These joint preparations are prescribed and deemed prequalified in welding application standards.
Where prequalified preparations and prequalified consumables are adopted in welding procedures the extent of qualification testing is minimal. Within AS/NZS 1554.1, only a macro test is mandatory for SP category welds. Testing is not required for certain GP category welds.

It is recognised that some fabricators may consider that the use of non-prequalified joints and/or consumables are more cost effective even though the extent of qualification testing will be increased.

4.2.4 Weld Procedure Tests
These tests are performed on specimens taken from a welded test sample that complies with the welding standard. Careful consideration should be given to the extent of testing as sometimes a higher level of testing may actually reduce costs in the longer term. For example, the use of higher grades of steel may automatically qualify lower grades of steel and higher levels of testing qualify lower levels of testing.

4.2.5 Pre-fabrication Welding Tests
These tests are usually specified as additional requirements for specific projects or contracts. However, a fabricator may elect to use this test due to the new or unproven methods expected during welding. The test samples may not be representative of the standard test pieces nominated in the welding standards. Test samples should be of the same configuration as in the actual work including any constraints or conditions. Welding must be under controlled conditions and all relevant details including any constraints or conditions recorded on the PQR. A photograph may be helpful.

4.2.6 Other Fabricator’s Welding Procedures and Standard Weld Procedures
A fabricator may elect to use other fabricator’s procedures or standard Weld Procedures as a cost saving measure, staying within the range of essential variables allowed without requiring re-qualification. This will maximise potential cost savings.

The procedures are based on independent types of equipment and should be free of any special constraints or conditions likely to be encountered during actual welding operations. Additional factors such as limits imposed by the qualifying organisation or standard, or conditions likely to be encountered during fabrication not considered during the original qualification process, must be considered.

4.3 Prepare a Draft Welding Procedure (pWPS)
Before drafting a weld procedure, ask the following questions:
1. Do I have the client’s specification detailing special/additional requirements?
2. Do I have the necessary standards, of the revision/year nominated by client specification, or the latest edition?
3. Do I have the parent material specification with sufficient detail to allow me to determine the weldability of that material?
4. Do I have the necessary technical literature to assist in determination of the material’s weldability e.g. calculations of preheat, maximum heat input, maximum interpass temperature, requirement for post weld heat treatment (PWHT)?
5. Does my document format detail all of the information required by this welding procedure?
6. Does the client require a specific format?
7. Will this procedure cover the total scope of work or should I consider the ranges of variables to achieve maximum coverage with the minimum number of weld procedures?

8. Is the process/consumable selected suitable for the positions to be qualified, should I consider more processes/consumable types, or less?

9. Do I have the necessary data regarding welding consumables and fluxes/gases to cover the scope of work?

10. Can I rationalise consumables (at no or minimal cost penalty) for a part of the scope of work, to reduce the number of PQRs required? This will also minimise the problems associated with consumable traceability.

11. What are the joint design, access, position, process, standard/specification, environmental conditions?

On the basis of the fabricator’s experience, or from other sources such as the consumable supplier or Weld Australia, draft a weld procedure (pWPS) on the WPS form. The required details can then be reviewed by all personnel involved in using the procedure to ensure accuracy. Wherever possible, weld procedures should be based on previously measured parameters i.e. start with parameters known to be in the welder’s comfort zone. In addition to giving all those involved experience in the development of procedures, it gives the person who is doing the job (i.e. the welder) a chance to review the document for its practicality and usefulness. This should ensure that the details are achievable in the workplace. To complete this step, determine which method of approval is applicable. This will also reveal if a welded test sample is required for each pWPS.

NOTE: Some customers and standards may require draft weld procedures to be approved. In such cases the draft or preliminary welding procedure specification (pWPS) should be approved by the appropriate signatory before undertaking qualification tests.

4.4 Qualify the pWPS

Where a test plate is required then it should be welded in accordance with the pWPS. All parameters (including ambient temperature, plate preheat and interpass temperatures) used during the welding of the test sample must be measured and recorded on the welding procedure qualification record (PQR). The recording of these details is important as the essential variables are applied to this information. Where the proposed details prove to be not achievable, these details and results should be retained. These records can prevent unnecessary costs by avoiding duplicating results that have proved to be unsuccessful. All test results and their references must be included on the PQR. The responsible person must then verify that the information and associated documents comply with the relevant requirements.

Where the regulatory authority or customer requires their representatives to be present during all or part of welding or testing of the test samples, the fabricator is required to provide sufficient notice and make appropriate arrangements to enable the witnessing of the welding and/or testing as appropriate.

Where a test sample is not required or when the pWPS will be covered by a previously approved PQR or Standard Welding Procedure, go to the next step. Note that records of welder qualifications are very important as they provide evidence of their experience and capability as well as proof of ongoing training and maintenance of qualifications.

4.5 Prepare the Welding Procedure Specification (WPS)

From the information contained in the approved PQR and from the associated test result certificates, prepare a WPS. Include all the essential variables and tolerances allowed by the particular welding standard on the WPS. The fabricator should verify that the information contained in the WPS is based on the PQR by checking and signing the WPS to this effect. Note that the customer and/or regulatory authority may wish to verify this document prior to the commencement of production welding.

4.6 Obtain Approval for the PQR and WPS

Where required by the regulatory authority or customer (the principal within AS/NZS 1554), the fabricator must submit the PQR and WPS to the regulatory authority or principal for approval.

4.7 File the Procedure Qualification Record (PQR)

The approved WPS can be added to the library of approved welding procedures in a manner that is most effective for future use. Ensure that the supporting PQR and backup records are filed to demonstrate compliance and are available for re-use when required. File the original WPS as well, issuing an approved copy to the welder for completion of the work. The procedure can be used in the future to demonstrate that qualified welding procedures are available and used where appropriate, for future work.
5.0 Document Control

Welding procedures are a key part of the quality system element of process control. The control of these documents is just as important under the quality system element of document and data control. Give attention to the numbering systems used and how you make and record changes to them. Revision numbers (if used on welding procedures) may indicate that something was changed. Document how this will affect any work or testing carried out prior to the revision date and why the revision was made. Internal or external auditors may request substantiation of these changes. When it takes a long time to answer, your control procedures will come under closer examination.

6.0 Weld Procedure Elements

The weld procedure defines operations in such a manner as to specify control limits on important essential variables used during all the welding operations. This facilitates the control of the welding process which in turns ensures compliance with specified requirements. The following descriptions of each element that make up the welding procedure documents are generic in nature. Each particular situation requires assessment by the fabricator and reference to the application standard.

6.1 Procedure Identification

The method used to identify different procedures must suit each fabricator’s own system; however, each procedure must be uniquely identified. Where the procedure is to be used within a quality management system, the fabricator must comply with the requirements for document and data control in that system.

6.2 Joint Type

This identifies whether the joint is a complete or incomplete butt (i.e. full penetration or partial penetration), corner, tee joint or a fillet joint etc. It will also state if the joint is square, single V, double V, etc.

When the joint type is a prequalified joint as listed within the application standard, it is beneficial for the joint identification number to be included for cross reference purposes.

The prequalified joints shown in the application standards have been selected on the basis that when welded by appropriately skilled and qualified welders, the requirements of the application standard will be met. For this reason, it is important that the fabricator ensure that all welders are appropriately skilled and qualified to use the procedures required of them (see Chapter 8 of the Technical Guidance Note).

6.3 Materials

This refers to the parent metals being welded. Many application standards relating to metals classify grades by a numbering system e.g. AS/NZS 3678-250 is a specific grade of structural steel and AS 1548-PT460 is a specific grade of pressure vessel steel. Other metals such as stainless steel and aluminium have unique numbering systems for each type and grade. There are also a number of steel types whose numbering system relates specifically to their chemical composition (e.g. 1020, 1035 etc.). These numbers are usually a measure of their carbon content (the last two digits of the number) and alloy content (first two digits). In many cases, the higher the number the higher the carbon equivalent. This generally means that the materials become more difficult to weld, usually necessitating preheating temperatures to be increased. Sometimes there are a number of materials to be shown depending on how many materials are being joined in the procedure. The applicable standard(s) that relates to the material(s) being joined and their grade must be shown.

NOTE: Specific projects involving quality requirements beyond those normally encountered in application standards may also require the recording of the test plate heat and serial numbers on the PQR.

6.4 Thickness Range Qualified

The thickness range of material qualified, based on the thickness of the test sample shown in the PQR must be shown. In the case of a joint prepared for qualification under AS/NZS 1554.1, if the test sample thickness is 20mm then the procedure is qualified for the plate thickness range of 10mm to 40mm. This does not mean the same number of passes must be used, but they must be proportionally increased or decreased in relation to the cross-sectional area of the weld.

6.5 Welding Position

This relates to the weld slope and rotation. The positions mostly used are known as Flat (down-hand), Horizontal or Horizontal/Vertical, Overhead and Vertical. In the case of the Vertical position, the direction of welding must also be
stated i.e. up or down. These positions can also be identified by their position symbols such as PA, PB, PF as per the relevant standard e.g. AS 3545.

6.6 Joint Preparation Detail
This detail should show all dimensions of the joint so that joint preparation tolerances may be easily checked.

6.7 Weld Run Location and Sequence
The use of a sketch to show the number of weld runs and the sequence in which runs are deposited must be shown including which side of the joint is being welded in the case of multi-sided joints. Normally the procedure will show side A and side B with side A being the first side welded. This is important when control of shrinkage or distortion is required. Run sequence may also be important in certain joints that are susceptible to laminar tearing (see Weld Australia's Technical Note 6).

6.8 Preheat Requirements
Preheat requirements are determined in accordance with the application standards. Weld Australia's Technical Note 1 gives guidance in calculating preheat requirements for avoidance of hydrogen assisted cracking in the heat affected zone (HAZ) for most commercial steels. It is important to appreciate that this represents the minimum temperature to which the surrounding area of the weld must be heated to prevent cold cracking. This temperature must extend for at least 75mm around the weld, and where heating is applied from an external source it is to be measured at least one minute after removal of the heat source (preferably, not less than one minute for each 25mm of material thickness). For further information on the measurement of preheat, refer to AS ISO 13916.

Arc energy (sometimes referred to as heat input) is required in order to calculate the preheat temperature. The calculation of arc energy uses the Amps, Volts and weld travel speed (mm/min) detailed in the procedure and is usually given in kilojoules per mm (kJ/mm). The formula for calculating arc energy $Q$ is:

$$Q = \frac{\text{Amps} \times \text{Volts} \times 60}{\text{Travel Speed} \times 1000}$$

e.g. A weld is to be produced using a current of 125 amps at 21 volts with a welding speed of 250 mm/min:

$$Q (\text{kJ/mm}) = \frac{125 \times 21 \times 60}{250 \times 1000} = \frac{157500}{250000} = 0.63 \text{ kJ/mm}$$

The procedure should report the method of heating, and the method required to check the temperature. In some cases (e.g. S0 steels and welding to AS/NZS 1554.4) it may be necessary to limit the interrun (or interpass) temperatures to a maximum temperature. In these cases this maximum temperature must be shown on the procedure.

A variety of temperature indicating methods are readily available, including temperature crayons, melting sticks, magnetic temperature dial indicators, infrared pyrometers, contact pyrometers, temperature probes and thermocouples with a recorder etc.

NOTES:
1. To calculate the arc energy for a multi-head arc welding process such as tandem SAW, calculate the arc energy for each individual arc using the amps, volts and travel speed relating to that arc (travel speed will be the same for each arc) and then add each energy to get the total arc energy for the weld.
2. To calculate the arc energy when using controlled waveform welding processes such as pulsed mode or a controlled dip method, the above formula cannot be applied. Where the power source records the energy during a weld run, arc energy may determined by dividing the recorded energy (in kJ) by the length of the run (in mm) to provide a value in kJ/mm. Alternatively, it may be measured - see ISO/TR 18491. For further guidance, contact the manufacturer of the power source.
3. The terms arc energy and heat input are used interchangeably in Australia and New Zealand. Within ISO standards, an arc efficiency factor is used in these calculations. For further information, refer to Weld Australia’s Technical Note 1.

6.9 Joint Preparation Method
When a specified edge method is to be used it must be shown in the procedure. The most common cutting methods used to provide the weld preparations are oxy fuel gas (e.g. oxygen-acetylene), plasma cutting, grinding, shearing, sawing and machining.
6.10 Back Gouging
When gouging is part of the operations used to qualify the weld procedure, the method of gouging must be shown in the procedure. For complete penetration welds it may be a requirement to gouge the weld root back to sound metal before welding the second side, unless the procedure qualification tests show that complete penetration and fusion is obtained without gouging.

Common gouging methods include oxy acetylene, air-carbon arc, plasma gouging, grinding and machining. Any treatment of the gouged groove such as grinding is to be shown as well as any non-destructive (NDE) check testing requirements that may be specified.

6.11 Process
This refers to the welding process such as GMAW, SAW, MMAW, FCAW, etc. It is common to use two different processes in a weld procedure e.g. one process in the weld root, and another for the fill and capping runs.

6.12 Electrode Classification
Welding consumables are classified under respective Australian/New Zealand standards. Manufacturers of welding consumables make the consumable in accordance with the standard in order to use the classification title, and also market them under their own trade names. When the consumable is selected, specify on the procedure the manufacturing standard for that consumable e.g. for manual metal arc welding (MMAW) of low strength carbon, carbon-manganese and low alloy steels, the relevant consumable classification standard is AS/NZS 4855. This standard number should be included in the classification column as well as the weld metal classification within that standard, including any applicable hydrogen content rating. In the latter case, an increase in hydrogen content rating of a welding consumable (e.g. a change from H5 to H10) used to qualify a welding procedure is deemed to be a change in essential variable because of the risk of encountering hydrogen cracking, including within the weld metal.

The consumable trade name should be shown on the PQR and WPS, even though application standards do not normally require this. Where it is necessary to change to a consumable which has the same classification but different trade name, it may be necessary to advise the customer (or the principal) of the necessity and reasons for the change. In critical applications involving specialised tests such as corrosion tests and impact requirements beyond that required in the application standard(s), it is advisable to change consumable trade name without reference to the customer. Specific projects involving quality requirements beyond those normally encountered in application standards may also require the recording of the consumable batch number on the PQR and WPS.

6.13 Flux/Gas
The same requirement for electrodes applies to fluxes and gases. In the case of gases, for other than where the gas is classified in accordance with AS 4882, either the nominal composition of the shielding gas or its trade name must be shown.

6.14 Weld Run Details
This refers to the particular welding operation such as the root run, fill runs and the capping runs or sealing run. Where weaving is to be used, a maximum weave width may need to be specified as required by the application standard.

6.15 Welding Current and Voltage
Welding current (amps) and arc voltage (volts) measurements are often provided by gauges on welding machines. To establish welding procedures, the instruments need to be either correctly calibrated, or, the output validated against test instruments (e.g. calibrated clamp meter). As a rule, DC welding machines use averaging type instruments and the AC welding machines use RMS instruments.

As it is the amperage and voltage across the arc that are important, care must be exercised when using the internal gauges provided on welding machines. Gauges used on GMAW, FCAW, SAW and GTAW machines are usually reliable as the leads extending from these machines to the job are normally short. In cases where long work or return leads are used, leads are coiled (especially around or on ferrous materials) or high currents are used relative to the cables rated capacity, the voltage reported may be much lower across the arc than that indicated on the gauge due to power losses in the cables. Additionally, welding machines with calibrated current markings or settings for MMAW welding should not be relied on for the current conditions as there may be considerable differences associated with the various classes of electrode.
Care should be taken when using external meters with waveform-controlled power sources. When used in waveform mode, conventional meters are highly erroneous and generally the digital displays on the waveform machine must be used. For further information, refer to ISO/TR 18491.

6.16 Wire Feed Speed
The separate recording of wire feed speed is not normally essential, but is useful in continuous wire feed systems as it is a check on the calibration of the current meter.

It is a simple operation to obtain the speed. It involves measuring the amount of wire fed during welding over a 10 second period and then multiplying the measured length of wire by six to give the wire feed speed per minute.

As some machines have an inching control speed that is less than welding speed, make sure that the welding wire feed speed is actually being measured.

In cases where pulsed welding or other waveform controls are being used, wire feed speed should be specified as it is difficult to reliably measure the actual process amperage with a background current and a peak current, both being present. For further information, refer to ISO/TR 18491.

6.17 Travel Speed or Run-out Ratio
Travel speed is the actual welding speed in mm/min and this needs to be timed i.e. time how long it takes a welder to complete a certain length of weld run. The formula for travel speed is:

\[
\text{Travel speed (mm/min)} = \frac{\text{length of weld deposited (mm)}}{\text{time taken to weld (in seconds)}} \times 60
\]

e.g. weld length of 180 mm / 40 seconds x 60 = 270 mm/min

The run-out ratio is a measure occasionally employed for MMAW. It is specified as a ratio and is calculated by dividing the measured length of electrode consumed by the length of weld metal deposited.

6.18 Other Information
This may include such things as the electrical stick-out length (distance from the contact tip to the workpiece), torch angle and whether it is pushed or dragged. It may also include oscillation requirements such as amplitude, frequency and dwell time when relevant.

For structural welding, the combination of amperage, voltage and material thickness given on the WPS may require that preheat be applied to the joint when the thickness of the joint is at the top end of the allowable range even though it may not have been required by the PQR for the thickness tested.

In older pulsed welding process machines, details such as peak current, dwell (background or base level) current, pulse duration and frequency must be set and specified. In modern welding machines, such parameters are often pre-programmed in the machine and cannot be adjusted by the user. In these cases, the program number or identifier should be specified.

6.19 Post Weld Heat Treatment
Post weld heat treatment (PWHT) is not normally required or specified in structural welding. When required though, the full requirements for any weld heat treatment operation after the completion of welding should be specified or at least cross referenced with standard procedures. This requirement includes instructions to control the cooling rate such as “slow cool to ambient temperature”, “allow to cool in sand”, “maintain preheat temperature on completion of welding for x minutes” etc. When specified, PWHT is normally required to conform to the requirements of AS 4458.

6.20 Mechanical Test Certificates and NDE Records
These records are not normally referenced or the results shown on the welding procedure (WPS), but are required on the PQR as indicated previously.
6.21 Approvals
The welding procedure must be signed and authorised prior to its use. Whilst AS/NZS 1554.1 is silent on requirements regarding the authorisation of PQRs and WPS documents, both AS 2214 and AS 1796 imply that this is the responsibility of the welding supervisor (or welding coordinator under ISO 14731).

When required by the Inspecting Authority or principal, the qualified welding procedure must also be approved and stamped or signed by them prior to its use. Note that to gain this approval, the customer may require the witnessing of all operations necessary to qualify the welding procedure or any part of the operations. Most application standards require the fabricator to give reasonable notice to the inspecting authority or principal in advance of the start of welding operations for this reason.

7.0 Qualification of Weld Procedures
7.1 General
AS/NZS 1554.1 provides various methods for the qualification of weld procedures. Additionally, where certain requirements are met, it provides for prequalification or prequalified procedures. In most cases, this means that limited weld testing is required, or in some circumstances, no testing. In all cases, the weld parameters used must be documented.

The standard does not require the tests specified in Clause 4.7 of AS/NZS 1554.1 to be performed by a NATA registered laboratory, and fabricators with suitable facilities are able to prepare and perform their own tests as specified in conformance with the AS 2205 standard series.

As previously discussed, fabricators should be aware that some clients may have specific weld procedure qualification requirements including the witnessing of weld tests and independent assessment of test plates at NATA registered laboratories. As this is a commercial consideration, it is a matter that should be resolved prior to acceptance of the contract (see Appendix D of AS/NZS 1554.1).

7.2 Qualification Requirements
Within AS/NZS 1554.1, the requirements for the qualification of weld procedures are defined in Clauses 4.2 and 4.7.

NOTE: AS/NZS 1554.1 requires separate qualification of fillet weld and butt weld procedures.

7.2.1 Prequalification Requirements
For prequalification where test concessions are generally applicable, requirements are defined within Clause 4.3. In summary, these are:

(a) The joint conditions for butt and fillet welds comply with Clause 4.5 (see Appendix E for the specific joint parameters applicable);
(b) The parent materials comply with Clause 2.1 and Appendix B;
(c) The welding consumables comply with Clause 4.6 and
   (i) Are used within parameter ranges specified by the manufacturer;
   (ii) Are matched to the parent materials (see Tables 4.6.1(A), (B) & (C));
   (iii) Are used where the design service temperature is warmer than the consumable’s impact test temperature.
(d) The workmanship and preheat/interpass temperature requirements comply with Section 5;
(e) There is documentary evidence of a satisfactory macro test (Clause 4.7.4 and Table 4.7.1).

It is important to note that to assist in the avoidance of brittle fracture, all welding consumables must have an impact energy approval rating of 47J (e.g. the ISO type “B” U rating) at or colder than the design service temperature. Consumables with an AWS classification designation only, or only a chemical content specified, do not conform with this requirement unless they also have acceptable ship’s classification society approvals as shown in Table 4.6.1(A) of AS/NZS 1554.1.
8.0 Welding Personnel

8.1 Terminology

The following terms are usually used to describe personnel involved in the welding process:

- **Welder**: a person who performs the welding.
- **Welding Supervisor**: a person employed by or contracted to the fabricator to supervise the welding operations.
- **Welding Engineer**: a professional engineer with full and comprehensive technical knowledge for planning, executing, supervising and testing of all tasks and responsibilities in welding fabrication.
- **Welding Coordinator**: (see AS/NZS ISO 3834 and its parts) a person who has responsibilities in the manufacturing operation for welding and welding related activities and whose competence and knowledge has been demonstrated by e.g. training, education and/or relevant manufacturing experience.
- **Welding Inspector**: a person (not employed by the fabricator) who carries out inspection on behalf of the Inspecting Authority or the principal. Note that some fabrication companies may employ their own welding inspector(s) as part of their quality control; they do not act on behalf of the Inspecting Authority or the principal.

8.2 Qualification of Personnel

Welder certification (to standards such as AS 1796) and welder qualification are subjects that cause much confusion throughout industry. The welder certification code AS 1796 states that welder certification should not be confused with welder qualification, which is specified in appropriate application Standards.

The Glossary of Terms for Welding Standard (AS 2812) defines a welder’s qualification as an assessment of a welder by test or other evidence to establish that the welder has the ability to perform to the level required by regulatory authorities, standards, contractual specifications, or others. Such welders may be certified, but many are not. All welders must be qualified to use the procedures set before them.

Welder certification is defined as certifying that a welder has complied with prescribed prerequisites, training and examination requirements to attain a specific welding skill. Note that some application codes will allow a certified welder to weld certain procedures without additional tests or training i.e. they are prequalified to the extent allowed by that standard.

Welder qualification is required to demonstrate the welder’s ability to weld, in conformance with a qualified welding procedure, a specific joint on a test piece which simulates that joint to the specified requirements given in the standard (e.g. AS/NZS ISO 9606-1, AS/NZS 2980, AS/NZS 1554.1).

Qualifications for welding supervisors are also specified in application standards. There are two standards for certifying welding supervisors in Australia, AS 1796 for the pressure equipment industry, and AS 2214 for the structural industry. International qualifications for welding supervisors and higher levels of qualification are also available through the International Institute of Welding, and these are recognised in AS/NZS 1554.1.

Qualifications for welding inspectors should be at least those required for welding supervisors. The holding of a Weld Australia certificate as a welding inspector or structural welding supervisor is accepted as evidence of qualification for welding inspectors. In New Zealand, weld inspection certification is performed by CBIP.

9.0 Summary

AS/NZS 1554.1 provides various methods for the qualification of weld procedures. Additionally, where certain requirements are met, it provides for prequalification or prequalified procedures. In most cases, this means that limited weld testing is required, or in some circumstances, no testing. In all cases, 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. 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 and associated costs that would otherwise not be necessary.
References

**Australian Standards**

(a) AS/NZS 1554.1 Structural steel welding Part 1: Welding of steel structures
(b) AS 1796 Certification of welders and welding supervisors
(c) AS 2205 Method for destructive testing of welds in metal
(d) AS 2214 Certification of welding supervisors—Structural steel welding
(e) AS 2812 Welding, brazing and cutting of metals—Glossary of terms
(f) AS/NZS 2980 Qualification of welders for fusion welding of steels
(g) AS/NZS 3678 Structural steel—Hot-rolled plates, floorplates and slabs
(h) AS/NZS ISO 3834 Quality requirements for fusion welding of metallic materials
   Part 2: Comprehensive quality requirements
   Part 3 Standard quality requirements
   Part 4 Elementary 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
(i) AS 4458 Pressure equipment—Manufacture
(j) AS/NZS ISO 9606-1 Qualification testing of welders — Fusion welding — Part 1: Steels

**ISO Standards**

(k) ISO 9606-1 Qualification testing of welders — Fusion welding — Part 1: Steels
(l) ISO 14731 Welding coordination — Tasks and responsibilities
(m) ISO 15612 Specification and qualification of welding procedures for metallic materials — Qualification by adoption of a standard welding procedure
(n) ISO/TR 18491 Welding and allied processes — Guidelines for measurement of welding energies
Appendix A: Development of Weld Procedures to AS/NZS 3992

This Appendix gives guidance on the development and acceptance of welding procedures for manufacturers and others who are responsible for pressure equipment manufacture and weld procedures conforming to AS/NZS 3992.

It applies directly to main technical issues in common welding processes. Its principles also apply to other processes. Its aim is to obtain the best compromise of many welding procedure variables to give consistently complying welded joints, first time, on time and at minimum effort and cost.

The iterative method involves obtaining and assessing data, requires test welds and tests, assumes the design drawing is available, and allows the sequence and details to be varied to suit particular requirements and limits.
### Table A1: Development of weld procedures for pressure equipment (see AS/NZS 3992).

<table>
<thead>
<tr>
<th>Procedure Variable</th>
<th>Action</th>
</tr>
</thead>
</table>
| 1. Tender, contract and specification | • Obtain pressure equipment data needed to determine optimum WPS, complying pressure equipment and fair contract e.g. intended service (pressure, temperature, contents, life), size, mass, material, thicknesses, pressure equipment standard and class, location of use and manufacture, number of, conformity assessment, main failure modes, and any special or abnormal treatment, test, requirement or restriction.  
• Consider contractual matters such as variations, urgency, delivery, costs and penalties. |
| 2. Design drawing and manufacturing specification | • Confirm, and identify further technical details influencing WPS e.g. joint thickness, weld type, size, shape, preparation, access, weld position, handling and missing data. |
| 3. WPS and PQR?                     | • Decide if can use a current or modified WPS, need to develop a new procedure, or use a prequalified, borrowed or contracted WPS. Depends on urgency, cost, capability etc.                                      |
| 4. Parent metals                     | • Identify required form, type, grade, strength, composition - to give filler metal and process.                                                                                                          |
| 5. Thicknesses                       | • Identify most common, maximum and minimum - to determine welding process(s) and equipment.                                                                                                           |
| 6. Weld joints                       | • Identify the weld type, backing, preparation, fit up and tolerances for various weld(s).                                                                                                                                 |
| 7. Welding positions                 | • Identify welding positions for production and test welds.                                                                                                                                              |
| 8. Welding process(es)               | • Use data above to select the welding process(es) for production and test welds to give the required joint quality and best deposition rate and minimum total joint cost.  
• Allow for welders, fit-up accuracy, welding machines, backing, rolls, rotators and robots. |
| 9. Welding consumables               | • Select approved filler material, flux to match or be compatible with parent metal composition and properties (tensile strength, impact toughness), and to suit the welding process and procedure. |
| 10. Welding arc energy input         | • Use data above to decide the maximum arc energy per run to fill the weld groove with minimum number of runs, giving the required joint composition (dilution) and properties (yield/proof strength, tensile strength, elongation, hardness, impact toughness).  
• Decide current, polarity, volts and speeds [See Sections 5, 7 and 8 including notes to tables in AS/NZS 3992]. |
| 11. Preheat and interrun             | • Determine temperatures from the PE Standard (e.g. AS 4458), experience and for steel, from standards e.g. AS 4458 and methods in AS/NZS 1554.1 and EN 1101-2. |
| 12. Welding sequence                 | • Select to fill the groove, avoid flaws, control distortion and give the required weld face shape and toe hardness from standards e.g. AS 4458 and methods in AS/NZS 1554.1 and EN 1101-2. |
| 13. Postweld thermal treatments      | • Detail any required delayed cooling, post-heating and PWHT as specified by the pressure equipment standard or design to reduce hydrogen, residual stress and hardness [See AS 4458]. |
| 14. Postweld mechanical treatments   | • Detail any specified treatment e.g. weld toe dressing, peening, cold forming (of welded ends), planishing (of bellows weld), cold stretching, surface treatment and protection to give the required joint properties and performance. |
### Table A1: Development of weld procedures for pressure equipment (see AS/NZS 3992) (continued)

<table>
<thead>
<tr>
<th>Procedure Variable</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>15. Draft pWPS</td>
<td>Based on above data, cover the widest range of essential variables to reduce welds and tests. Note: Butt welds qualify weld metal and HAZ properties for almost all joint types.</td>
</tr>
</tbody>
</table>
| 16. Test Welds     | Use the pWPS to make test weld(s). Keep plate test certificate [See Section 6 of AS/NZS 3992]  
                   | Use plate or pipe thickness approx. = ¼ maximum combined joint thickness.  
                   | Use parent metal and consumable strength grades to qualify most production welds.  
                   | If necessary use similar available material for preliminary trials to check joint preparation, access etc. by workshop macros and bends. Stamp test piece.  
                   | Use complying material and optimum thickness and position in the final test weld. |
| 17. Weld tests     | Ensure joint tensile strength test plate is within misalignment limits to avoid test failure. If practicable, complete workshop tests: visual examination, 2 macros and 2 bends (1 face and 1 root, or 2 side bends) or nick-break tests as a preliminary or final test to avoid failure in more complex expensive tests e.g. radiographic or ultrasonic examination, tensile and impact by test bodies [see Section 7 of AS/NZS 3992]. |
| 18. Final PQR & WPS| Complete, approve and sign by manufacturer or representative, and if practicable, by the inspector. Retain macro specimen to show runs, sequence and surface for inspectors. |
| 19. Improvement     | Consider security or copyright for high cost procedures. Update based on feedback from production welding, test plates, NDT and service and other experience. |
| 20. Owner acceptance| By owner or representative: user, purchaser or independent welding inspector, based on confidence in the manufacturer, conformity assessment system and above data and documents. Recommended for at least hazard level A or B pressure equipment. |
| 14. Postweld mechanical treatments | Detail any specified treatment e.g. weld toe dressing, peening, cold forming (of welded ends), planishing (of bellows weld), cold stretching, surface treatment and protection to give the required joint properties and performance. |
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.