

## 1. SCOPE

This document describes a suggested process by which weld repairs to components containing unidentified metals and alloys can be carried out. It is intended for maintenance engineers and welding coordinators involved in the maintenance and repair of plant and equipment. The process described follows the principles of AS/NZS ISO 3834 "Quality requirements for fusion welding of metallic materials" to enable the repairer to carry out repairs in a systematic manner, and the basic assumption made is that if the material cannot be identified, under no circumstances should welding be attempted. This Guidance Note does not include pressure equipment where repairs must be carried out using AS/NZS 3788.

## 2. REPAIR CONTRACT – DESIGN AND CONSTRUCTION SPECIFICATION

Where the repair is being carried out under contract between a Client (owner or operator of the equipment) and a repair facility, the first step is to review the contract and determine the contractual requirements governing the repair. The next step is for the Client to decide if the repair will be temporary or permanent. Temporary repairs must be well documented and given a limited life. Detailed knowledge of the Design Specification and Construction Specification are required to ensure the repair weld will meet the performance requirements. At this stage the defect acceptance criteria, requirements for non-destructive testing and post weld heat treatment should be specified by the Client

## 3. DESIGN CONDITIONS & SERVICE ENVIRONMENT

Review the design and service conditions of the component to be repaired. The following factors are significant:

- a) What is the operating temperature? Is it high temperature service, cryogenic service, and what is the design temperature? Has the component operated outside the design temperature range?
- b) What has been the applied stress range? This is particularly important in fatigue failures.
- c) Is there a corrosive environment, and if so, what are the important corrosive species?
- d) Does the component operate in a marine environment?
- e) Is wear involved? If so, is it erosion, abrasion, impact wear, etc?
- f) Can the mechanical properties of the component be determined?

Determination of these factors will provide specific information needed to select the appropriate weld repair material and procedure. The service environment under which the repair will be made needs to be considered at this stage. Specifically determine if the item to be welded has been in contact with any flammable or potentially toxic product. Determine if purging will be necessary prior to the repair. Is the area a confined space?

## 4. DRAWING REVIEW

Request the drawings from the original equipment manufacturer. These will often have a Bill of Material describing the materials used to make the component. When original drawings are not available other means of material identification as described in this document will be required.

## 5. DETERMINING THE REASON FOR THE REPAIR

Determine why the repair is needed. The following are the main reasons:

- |   |  |
|---|--|
| a) Fatigue                              | b) Corrosion                                     |
| c) Wear                                 | d) Brittle Fracture                              |
| e) Existing weld failure                | f) Mechanical damage – Impact loading - Buckling |
| g) Existing Heat Affected Zone Cracking |  |

Fatigue fracture is listed first because this is the predominant failure mode in rotating equipment, aluminium structures and heavy engineering structures (drag-lines, booms, buckets etc). Weld repair

of a fatigue failure will require specific precautions, and it must be remembered that if the mechanical loading does not change, a repeat incidence of the failure is inevitable.

## **6. METAL CLASSIFICATION**

Identify if the metal or alloy to be welded is a casting, forging, extrusion, wrought product or fabricated component. A cursory examination can be used to identify the material form followed by a secondary, more detailed determination to identify the alloy.

### **6.1 Cursory Examination**

Is the component a Casting, Forging, Extrusion, Fabricated Product or Machined Component? – Carry out a Visual Inspection.

Is the component Magnetic or Non Magnetic? – Use a magnet

Is the component a Stainless Steel? Use a magnet and perform a visual Inspection

Is the component a Light Metal such as Aluminium or Magnesium? Check the weight and colour

Is the component a copper-based alloy such as Brass, Bronze, Monel, Phosphor Bronze? Check the colour.

Is the component made from Titanium? Drawings will generally be available if titanium has been used.

### **6.2 Metal Analysis**

Portable analysers are available that provide on-site analysis of the material in question. Quite often the contractor hired to perform the analysis will also match the composition results with an equivalent alloy. Refer to TN 20 “Repair of Pipelines” for details on performing material sampling. If an equivalent alloy can be identified, its weldability criteria can be applied to the weld repair. Be aware the some portable analysers such as the Metascope are very useful in giving a broad idea of material composition but will not, for example, give the carbon content of structural steels or castings.

### **6.3 Determination of Material Weldability**

For unidentified materials the first step to determine whether it is weldable is to look for welds elsewhere on the component. Metals and alloys fall into two categories, those where an existing weld is present and those without. The existence of welds on the component is an immediate indication that the material is weldable and that the welds were probably made to a recognised national standard. The existence of a weld gives no information on post weld heat treatment. Some heat treatable aluminium alloys are solution treated and aged after welding, and no visual examination can ever replace a full chemical analysis.

Lack of welds indicates that welding was not part of the original manufacturing process. It does not necessarily mean the material is not weldable but adds to the complexity of the repair and identification of an appropriate specification to cover the repair maybe difficult. Again, if the composition is unknown, do not attempt to weld.

### **6.4 Detailed Determination**

Is the component one of the following?

A casting, either Cast Iron or Cast Steel?

A Structural Steel of low, intermediate or high strength?

An Alloy Steel used in a low temperature application?

A Stainless Steel? If so, is it Austenitic, Ferritic, Martensitic or Duplex.

An Aluminium or Magnesium Alloy?

Looking at these in further detail:-

#### **6.4.1 Ferrous Castings**

Ferrous castings likely to be encountered fall into four categories, grey cast iron, white cast iron, cast steel and austenitic manganese steel. With grey or nodular cast iron the carbon is present in the form of graphite either as flakes (grey cast iron) or spheres (nodular) cast iron. With white cast iron the carbon is present in the form of iron carbide which is also known as cementite.

Grey cast irons have historically found a wide range of applications such as engine blocks and machining equipment (lathes etc). The use of white cast iron is generally limited to high wear applications such as pump bodies. Steel castings are also used in applications traditionally made by cast iron requiring the differentiation of cast steel, grey cast iron and white cast iron. There are certain proprietary cast irons such as the Meehanites, and these can be grey or white. Items made from these materials are made using patented pouring and solidification techniques to give specific surface properties, and with a number of these grades no attempt should be made to weld repair.

In order to differentiate between cast steel (which is weldable with the right precautions) grey cast iron (which is repair weldable with extreme care) and white cast iron (which is not weldable), drilling with a 5mm diameter high speed drill can be used. Drilling steel produces chips and shavings that are easy to recognise. Drilling grey cast iron will produce a fine, graphite like dust and drilling white cast iron will quickly result in a blunt drill. Grinding can also be used to differentiate grey cast iron from steel based on the extent and colour of the grinding sparks, but an experienced eye is needed.

Technical note 18 "Welding of castings" provides valuable information on the welding of both ferrous and non-ferrous castings. There are a number of techniques available for welding cast irons, but all require specialist advice and close supervision.

#### **6.4.2 Structural Steels**

Structural and low alloy steel can be categorised from a weldability perspective by determining the hardness and chemical composition. The hardness test provides a good indication of the tensile strength of the steel and the chemical analysis can be used to determine its carbon equivalent and hence weldability.

The carbon equivalent of the steel is the key to determining the weldability of the steel which is achieved by referring to WTIA Technical Note 1 "Weldability of Steel". This document will provide advice on the welding precautions required particularly pre-heat requirements and the need for post weld heat treatment.

Structural steels vary in yield strength from 250 to over 500MPa with corresponding welding consumables available to provide matching strength capabilities. Steels with yield strengths up to 350Mpa are readily weldable with the common welding processes and with generally available welding consumables. As steel strength increases beyond 350MPa welding becomes progressively more demanding with selection of appropriate welding consumables and determination of pre-heat, inter-pass temperature and control of welding parameters becoming increasingly important.

#### **6.4.3 Low Alloy Steels**

For low temperature applications expect to find low carbon contents (< 0.15%) and low sulphur contents (< 0.01%). Weld metal containing nickel additions will generally be required to provide the required low temperature toughness properties.

For high temperature applications, the likelihood of unidentified materials is remote.

#### **6.4.4 Stainless Steels**

Stainless steels are generally classified as Ferritic, Austenitic, Martensitic or Duplex. These are terms that describe the microstructure and are a resultant of the chromium and nickel balance. The Ferritics are seldom used in structural applications because, except in very thin sections, they are essentially un-weldable. Massive heat affected zone grain growth and loss of notch toughness after welding means that no attempt should be made to repair weld them.

The Austenitics are non-magnetic, easy to recognise and readily weldable with few if any precautions. The two most common types are 304 and 316, and unless an alloy analyser is available, repair weld with a 316L consumable. In industries such as Petrochemical, grades such as 321 and 347 will be found, and these can be welded with a 347 consumable.

Martensitic types are seldom used in structural applications and require sophisticated welding procedures and close supervision if repair welding has any chance of success. Avoid repair welding on Martensitic stainless steel if possible.

Duplex stainless steels are used when the corrosive environment is too severe for the Austenitics, and to maintain corrosion resistance after welding, it is necessary to control the Austenite/Ferrite balance. The three types of Duplex generally encountered are 2304, 2205 and 2507, and it is essential to identify the grade. Do not attempt to repair weld Duplex stainless steels unless you know the composition and have welding procedures qualified by mechanical and corrosion tests.

More demanding repairs require detailed information on the operating temperature and operating environment which will dictate the alloying requirements and hence classification of the weld deposit to produce satisfactory operating results. WTIA technical note 13 "Stainless steels for corrosive environments" will help determining the type of stainless steel and technical note 16 provides the necessary information to carry out weld repairs.

#### **6.4.5 Aluminium Alloys**

Aluminium alloys generally fall into seven different, but distinct, alloy groups. Most can be welded with just two types of welding consumable with the main concern being avoidance of hot cracking. For the 1XXX, 3XXX and 7XXX alloys can be welded with the Silicon containing filler metal AA4043. As previously mentioned, the 7000 series alloys are heat treatable, and some are solution treated and aged after welding. Be aware of the loss in strength if repair welding is contemplated. Alloy 4043 has a lower strength and lower melting point than many of the aluminium alloys providing a good consumable for repair applications with good resistance to hot cracking. For the magnesium containing 5XXX series alloys a filler metal that more closely matches the parent metal composition is required. The most common filler metal is AA5356 which can be used for most applications.

Welding processes for Aluminium repair are either GTAW for small repairs or GMAW for larger repairs. WTIA technical note 2 "Successful welding of aluminium" provides all the information necessary to carry out welding repairs.

#### **6.5 Welding Dissimilar Metals**

Only a limited range of dissimilar alloys can be welded together with two fundamental factors that determine weldability being the comparative melting points of the two alloys and the production of brittle inter-metallic compounds. For dissimilar alloy welding a consumable is required that is compatible with both metals to be welded together.

Certain manufactures produce welding consumables that they claim can be used for virtually any ferrous weld repair application. Some of these consumables are nickel based which are compatible with a wide range of steels and cast irons. The relatively low tensile strength of nickel results in a weld deposit with relatively low residual stress resulting in a weld that is more resilient to cracking in situations where a hard brittle heat affected zone is produced as a result of welding.

Other consumables are based on the 312 composition, which contains 27 - 30% chromium and 9 - 12% nickel. This gives a mixed austenite/ferrite deposit, very similar to a duplex. The high ferrite content is very resistant to hot cracking and the consumable is useful as a buttering layer. Also, the high cost of nickel based electrodes and the 312 types means that for large repairs, production of a "butter layer" onto the unidentified material is often utilised. Stainless steel electrodes, particularly the austenitic E309L designation, can also be applied in a wide variety of carbon steel to stainless steel repair applications.

Non-ferrous dissimilar alloys are generally brazed together using a suitable low melting point filler metal possessing appropriate mechanical properties.

## 7. CANDIDATE SPECIFICATIONS

Having established the service history, the reason the repair is required and the material the next step is choose an appropriate specification to cover the welding activity. The AS 1554 series of Australian welding standards provide requirements for welding structural steel, quenched & tempered steel, and stainless steel. Aluminium is covered under AS 1665.

## 8. PROCEDURE QUALIFICATION

Generally it is necessary to qualify a welding procedure to demonstrate that the resultant weld will be fit for purpose. For “one-off” repair welds a qualification process utilising the preparation and testing of a weld can be impractical due to the difficulty of extracting material upon which to do the procedural test weld. An alternative approach is to use written documentation to qualify the weld. Use is made of past welding procedures on similar applications and the similar material grades to act as evidence of a successful procedure. Under AS 2885 for pipelines, these situations are called “Supervised Welds” and require the presence throughout repair welding of a qualified Welding Engineer.

## 9. WELDER QUALIFICATION

Welder qualification will be necessary to demonstrate that the welder has the necessary skills to produce a sound weld. For repair weld or “one-off” weld situations it may be necessary to simulate the repair weld configuration using similar material to that to be welded but the same welding consumable, welding process and welding position. Welder qualification requirements will be provided in the appropriate specifications listed in section 7.

## 10. DOCUMENTATION

Each step of the weld repair process from contract review through to welder qualification requires documentation. Prior to embarking on the repair it is recommended to obtain approval from the client on the proposed repair technique and to receive confirmation that the anticipated service environment into which the repair weld will go into service has been correctly identified.

## 11. REFERENCES

WTIA Technical Notes

TN 1 – Weldability of Steel

TN 2 – Successful Welding of Aluminium

TN 13 – Stainless Steels for Corrosive Environments

TN 15 – Welding and Fabrication of Quenched and Tempered Steel

TN 16 – Welding Stainless Steel

TN 18 – Welding of Castings

TN 20 – Repair of Steel Pipelines

Welding Cast Irons – C. L. M. Cottrell

Repair and Reclamation – Edited by R.E. Dolby and K. G. Kent – The Welding Institute

Australian Standards

AS/NZS ISO 3834 “Quality requirements for fusion welding of metallic materials”

AS/NZS 1554.1:2004 Structural Steel Welding Part 1: Welding of steel structures

AS/NZS 1554.4: 2004 Structural Steel Welding Part 4: Welding of high strength quenched and tempered steel

AS/NZS 1554.5: 2004 Structural Steel Welding Part 5: Welding of steel structures subject to high levels of fatigue loading

AS/NZS 1554.6: 1994 Structural Steel Welding Part 6: Welding stainless steel for structural purposes

AS 2074-2003 Cast Steels

AS/NZS 1665:2004 Welding of Aluminium Structures

AS 2980-2004 Qualification of welders for fusion welding of steel

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<b>NDNP TECHNOLOGY DIFFUSION ACTIVITY # 27</b>	 Welding Technology Institute of Australia ABN 69 003 696 526	<b>Document No:</b> 9.4.7 - QR - 001
	<b>NATIONAL DIFFUSION NETWORKS PROJECT TECHNOLOGY QUESTIONNAIRE Defence Industry Group Repair Welding of Unidentified Metals &amp; Alloys</b>	<b>Revision No:</b> Rev 0
		<b>Page 1 of 2</b> <b>Date:</b> 13 Dec 2005

As part of the WTIA National Diffusion Networks Project the Defence Industry Sector has identified the need to improve repair welding capabilities particularly when the specific metal or alloy is unknown. The WTIA has prepared a technical guidance note "Repair Welding Unidentified Metals and Alloys" that provides a methodology to undertake such repairs. As a valued technology expert in this area we would like you to be part of the Technology Expert Group to review this document. Please complete this questionnaire so that we can gauge the success of meeting this need.

**Objective 1: Identify the need for repair welding unknown metals and alloys**

Naval vessels represent a group of welded structures that contain many different metals and alloys that often require repair welding. This document provides a systematic method to go about determining how to go about a repair welding project that fulfills the needs of parties concerned. How well does the document achieve these aims?

poor  average  good  very good

Comments: \_\_\_\_\_

**Objective 2: Identify appropriate technology receptors**

This document was written for Welding Coordinators and Maintenance Managers involved in fabrication and repairs for the Defence Industry. Are these people the appropriate individuals we should be targeting?

yes  no

What other types of companies and/or personnel do you suggest we target? \_\_\_\_\_

**Objective 3: Identify current best practice for repair welding**

The document was written to reflect current best practice for repair welding unidentified metals and alloys. Do you envisage opportunities for the use of this practice in industry?

yes  no

If yes, what and where, if no why not? \_\_\_\_\_

**Objective 4: Is the information provided clear, concise and accurate?**

yes  no

If not, why? \_\_\_\_\_

**Objective 5: Broad dissemination of technology to the Defence Industry**

Please indicate how best to disseminate this technical guidance note to the appropriate Industry Recipients

Free Website Download  Poster  Pocket Guide  Pamphlet

If poster, what size? A1  A2  A3  Laminated  What selling price? \$

Any other format for the information? \_\_\_\_\_

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**Objective 6: Continuous Improvement**

Please Identify areas where the document can be improved or return the document with your recommended additions/amendments. Alternatively, please use the area below to provide any additional comments.

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Respondents Name: \_\_\_\_\_ Company: \_\_\_\_\_ Phone: \_\_\_\_\_

Fax: \_\_\_\_\_ Email: \_\_\_\_\_ Date: \_\_\_\_\_

**Please Fax (02 9748 2858) or E-mail (j.baker@wtia.com.au) your response.**

**Your prompt response is appreciated.**

The WTIA has joined forces with industry and government to create a 3.5 million dollar Technology Support Centres Network. This network will assist industry to identify and exploit world's best technology and manufacturing methods to establish a vibrant Australian industry beyond 2006. Together we will be implementing a step by step process which will lead to ongoing viability and greater profitability for all concerned:



- (1) Determine your technological and manufacturing needs;
- (2) Identify world's best practice;
- (3) Draw upon the network to implement world's best practice at your site

