Safety Services Guidance

Guidance on Specifying Safety Critical Welds

Key word(s) :	Safety critical welds, design, weld failures, structural design, load, fatigue, competent persons
Target audience :	Principal Investigators, Senior Academics, Workshop Managers, Workshop Supervisors, Coded Welders

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Introduction

1. This document provides guidance to ensure that a proper process is followed in the specification of any safety critical welding to be carried out at the University of Manchester. In addition, it also provides information to anyone wishing to undertake projects in which welding may be involved.

2. At the University of Manchester, anyone designing or specifying projects which include welds must have regard to this document. The person responsible will usually be the Principal Investigator or Senior Academic in charge of a research programme. This individual will usually need to involve others with specific skills and competencies, such as Workshop Supervisors and coded welders. It may sometimes be necessary to consult external expertise. (See flow chart for decision process below)

Guidance

3. Welding is the most common method used for joining steel fabrications largely because of the speed at which joints can be made and the reliability and strength of these joints in service. However because most welding operations are now relatively simple to perform it is all too easy to forget the complexity of the chemical and metallurgical actions that are taking place when the weld is being deposited. Therefore, not surprisingly welds can occasionally fail. The most common causes of weld failures can be attributed to:

4. **Overload: -** Failure to design the work properly and take into account the stresses likely to occur can lead to welds being of insufficient strength to cope with the stresses and loads imposed on them.

5. **Joint design: -** Due to the design of the equipment / fabrication, the welder is unable to manipulate the welding electrode adequately and is therefore unable to ensure good fusion is obtained, leading to a weld of insufficient strength.

6. **Bad welding practices: -** When carrying out welding it is important to ensure that the work is done in accordance with good practices, and that consideration is given to all aspects of the welding and the environment in which it is performed.

7. **Metallurgical Failure: -** Materials that are to be welded have to tolerate severe thermal changes created by the welding process without deterioration of their mechanical properties. The metallurgical composition of certain types of metal may make them unsuitable to weld or may require special controls to be imposed during the welding operation. Where this is not taken into account failures can occur.

8. **Weld Defects: -** These are usually attributed to the welder's inability to set up and manipulate the welding equipment, although bad joint design and faulty welding equipment can also be responsible.

9. Welding activities which include safety critical welds may include:

    - Work with pressure vessels
    - Work where safety and strength are critical factors
    - Work where equipment is subject to stresses and failure could cause injury
    - Work where equipment requires mechanical lifting
    - Load bearing structures
    - Equipment to be used by, or sold to outside bodies (such as industrial sponsors)

10. A suitable and sufficient risk assessment should be completed for the work being undertaken.

Structural Design of Welded Joints

11. The first stage when considering the undertaking of any welding activity is to ensure that the weld is correctly designed to meet its required purpose and meets the requirements of all relevant standards. This design should be carried out by a competent person (eg appropriately qualified and experienced structural, mechanical or welding engineer, see appendix 1 for details on competence). The design should take into account the following factors:

    - What is the purpose of the weld?
    - Is the weld required to carry load as part of a pressure retaining or load bearing structure?
    - Is the component subject to fluctuating loads sufficient to be of concern for fatigue failure?
    - Is the weld made on the surface of a stressed member in a pressure retaining or load bearing structure?
    - What are the consequences of potential failure of the welded joint or of the component or structure?

12. Any weld which is required to carry load as part of a pressure retaining or load bearing structure, or is subject to fatigue loading, or which is made on the surface of a stressed member in such a structure, or for which the consequences of failure could represent a hazard to life or property is defined by this guidance document as a 'Critical Weld'. Welds which do not fall into these categories are defined as 'Non-Critical Welds'.

13. The design of any component, pressure retaining or load bearing structure containing critical welds must be notified in advance to the **Head of Safety Services**.

14. It is the designer's responsibility to ensure that the materials specified are suitable for welding. Where necessary, confirmation of this should be sought from appropriate staff in the School of Materials or from a suitably experienced external consultant.

15. Where there is a relevant British Standard Design Code for the type of component or structure concerned, both the structure itself and the welding requirements shall be designed in accordance with that code. Particular attention is drawn to the fact that the fatigue performance of welded structures is a specialist field and requires specialist design considerations.

16. Once the geometric and strength requirements of the welded joint have been defined, the design should be recorded in the form of an engineering drawing. The specification for the weld details should be indicated using symbols to BS 499-1:2009 for the type and size of weld. The size of fillet welds should be specified by leg length in millimetres.

Welding Procedure Specification

17. The design of the welding procedure for any **critical weld** (ie the way in which the weld is to be made) should be carried out by a competent person. It may be necessary for this to be carried out by an external consultant if appropriate expertise is not available within the School concerned or elsewhere within the University. Where such expertise is not available contact should be made with the Head of Safety Services for recommendations of appropriate external organisations.

18. The output from the design of the welding procedure should be a welding procedure document which specifies the following requirements:

    - A sketch of each type of welded joint involved, showing the geometry and thicknesses of the parts to be joined, the weld preparations required and the number and size of weld runs required
    - Parent material type
    - The welding process to be used
    - The welding position in which the weld is to be made
    - The type and size of welding consumables to be used at the various stages of completing the weld
    - The welding conditions, eg for arc welding current, arc voltage, travel speed, and any preheat requirements, for other types of welding the relevant controlling parameters.
    - Any surface preparation required before welding is carried out.
    - Any special requirements for storage of welding consumables prior to use.

19. For carbon manganese steels, welding procedures should be designed in accordance with BS EN 1011-2:2001.

20. Particular attention should be paid to whether preheat is necessary for welding thick steels or steels with a high carbon equivalent or low alloy steels. Reference should be made to other British Standards for specific applications.

21. At the start of any project which involves any **critical welds**, ie the structure or component is pressure retaining or load bearing, or the consequences of failure are hazardous, a procedure test sample shall be prepared using the proposed materials, geometry and welding procedure. This sample shall be tested in accordance with the requirements of BS EN 1011-2:2001 or other relevant standard. These tests may include some or all of the following:

    - Either non destructive testing or production of a 'macro section' to demonstrate soundness of the joint and freedom from defects
    - Hardness of the weld metal and the heat affected zone
    - Cross weld tensile tests for butt welds
    - Face, root or side bend tests
    - Charpy V notch impact tests

22. Acceptance requirements for the procedure tests shall be set by the competent person specifying the weld procedure. The mechanical testing shall be carried out by a suitably experienced workshop, laboratory or test-house and may be witnessed by an independent body. If the tests are satisfactory the results shall be recorded with the procedure test sheet as approved by the competent person.

Welder Qualification

23. For any **critical weld,** the welding operators must have demonstrated their competence by completing welder qualification tests in accordance with the appropriate British Standard Specification. A list of some relevant Standards is given in the Table 1 at the end of this guidance document.

24. For welder qualification purposes the welder must complete satisfactory joints of the same basic type as for the required work, eg butt weld, fillet weld, pipe joint etc. using the same welding process and broad type of consumables as are required for the work. The test welds must be completed in material of the similar thicknesses and in the same welding position as for the required work. The welding of the qualification test pieces should be witnessed by an independent party and the test pieces stamped to identify the welders concerned.

25. The completed test pieces should be examined visually for uniformity of finish and general satisfactory quality. For any **critical welding requirements,** the welder qualification test pieces shall be examined either by breaking them open (nick break test) or by non destructive testing to confirm freedom from flaws or unacceptable imperfections.

Welding Equipment

26. The person carrying out the welding is responsible for ensuring that the right welding equipment is used and that the capacity of the welding plant and ancillary equipment is adequate for the welding procedure to be used. The welding plant should be regularly checked and maintained in accordance with manufacturer's guidelines. Additionally, the requirements of the Electricity at Work Regulations will apply for hard wired equipment.

27. All electrical plant used in connection with the welding operation must be adequately earthed. The welding return cable from the work piece should be of adequate cross section, connected as close as possible to the point of welding.

28. Means of measuring the welding instrument parameters should be available, either as part of the welding equipment, or by the provision of portable instruments. Such parameters may include arc voltage, welding current, wire feed rate, welding speed, shielding / purging gas flow rates and temperature of parent / weld metal.

Completed Welding

29. All completed welding should be visually inspected both by the welder and by a competent independent person to check that it complies with the requirements of the drawing and specification for the work concerned. Particular attention should be paid to ensure that all welds are in the correct position and are of the correct size and the surface finish of the welds is satisfactory.

30. For **critical welds,** the designer should specify whether non-destructive testing is required on completion of the welding and if so, which welds are to be tested and by what method. The designer should also specify acceptance requirements for any non-destructive testing to be carried out. Again, reference should be made to requirements of any relevant codes.

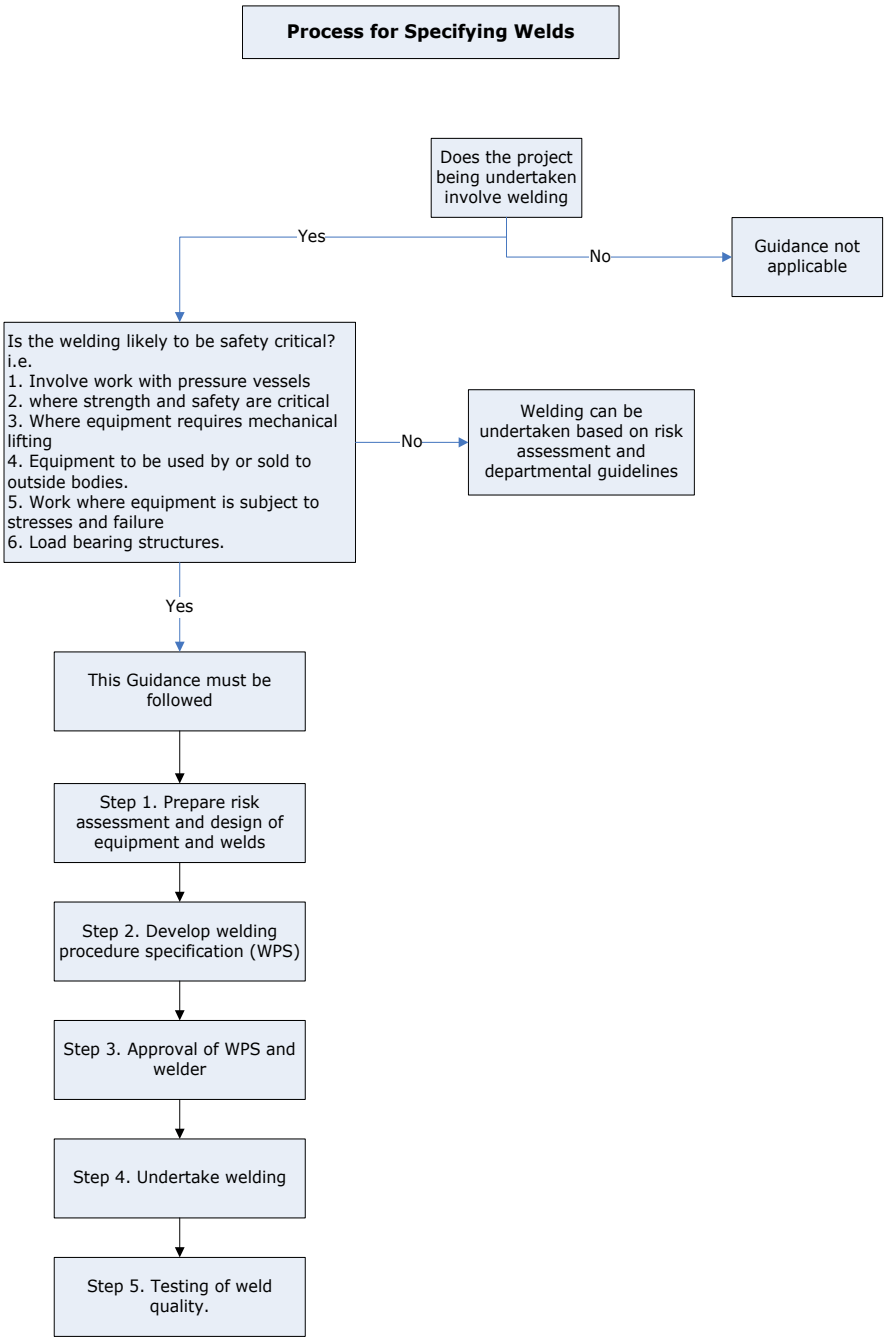
31. In the case of pressure retaining equipment, an hydraulic proof test must by carried out at a pressure specified by the designer which is above the normal operating pressure and within the safe limits for the vessel, before the vessel goes into service. This test must be carried out before any pressurisation by gas or air is carried out.

Table 1: Useful Welding British and International Standards

Where welding operations are required for specialist applications then the following codes or standards should be applied:

		Welding standard	
Application	**Application code/standard**	**Procedure approval**	**Welder approval**
Pressure Vessels	PD 5500 BS EN 13445 series ASME B&PV Section III-NB (Nuclear) ASME B&PV Section VIII	BS EN ISO 15614 ASME B&PV Section IX	BS EN 287 BS EN ISO 9606 ASME B&PV Section IX
Process Pipework	BS 2633 BS 4677 ANSI/ASME B31.1 ANSI/ASME B31.3 BS 2971	BS EN ISO 15614 ASME B&PV Section I BS EN ISO 15614-1 (if required)	BS EN 287 BS EN ISO 9606 ASME IX ASME IX BS 4872/BS EN 287
Structural Fabrication	BS EN 1011 BS 8118	BS EN ISO 15614-1 BS EN ISO 15614-2	BS EN 287 BS EN ISO 9606-2 BS 4872
Storage Tanks	BS EN 14015 BS EN 12285 API 620/650	BS EN ISO 15614-1, -2 BS EN ISO 15614-1, -2 ASME IX	BS EN 287 BS EN ISO 9606-2 ASME IX

For work to be carried out for international purposes other standards such as those laid down by the American Welding Society (AWS) or the American Society of Mechanical Engineers (ASME) may be required.


Process for Specifying Welds
Does the project being undertaken involve welding
Yes
No
Guidance not applicable
Is the welding likely to be safety critical? i.e.
1. Involve work with pressure vessels
2. where strength and safety are critical
3. Where equipment requires mechanical lifting
4. Equipment to be used by or sold to outside bodies.
5. Work where equipment is subject to stresses and failure
6. Load bearing structures.
No
Welding can be undertaken based on risk assessment and departmental guidelines
Yes
This Guidance must be followed
Step 1. Prepare risk assessment and design of equipment and welds
Step 2. Develop welding procedure specification (WPS)
Step 3. Approval of WPS and welder
Step 4. Undertake welding
Step 5. Testing of weld quality.

References:

British Standards	
Standard Number	**Title**
BS EN 287-1:2004	Approval testing of welders for fusion welding – Steels
BS EN ISO 15607:2003	Specification and approval of welding procedures for metallic materials. General rules for fusion welding
BS EN ISO 15609-1:2004	Specification and approval of welding procedures for metallic materials. Welding procedures for arc welding
BS EN ISO 15614-1:2004+A2:2012	Specification and qualification of welding procedures for metallic materials. Welding procedure test. Arc and gas welding of steels and arc welding of nickel and nickel alloys
BS EN ISO 15614-2:2005	Specification and qualification of welding procedures for metallic materials. Welding procedure test. Arc welding of aluminium and its alloys
BS EN ISO 15610:2003	Specification and qualification of welding procedures for metallic materials. Qualification based on tested welding consumables
BS EN ISO 15611:2003	Specification and qualification of welding procedures for metallic materials. Qualification based on previous welding experience
BS EN ISO 15612:2004	Specification and qualification of welding procedures for metallic materials. Qualification by adoption of a standard welding procedure
BS EN ISO 15613:2004	Specification and qualification of welding procedures for metallic materials. Qualification based on pre-production welding test
BS 499-1:2009	Welding terms and symbols Glossary for welding, brazing and thermal cutting
BS EN 12285-2:2005	Workshop fabricated steel tanks. Horizontal cylindrical single skin and double skin tanks for the aboveground storage of flammable and non-flammable water polluting liquids
BS 2971: 1991	Specification for class II arc welding of carbon steel pipe work for carrying fluids.
BS 4677: 1984	Specification for arc welding of austenitic stainless steel pipe work for carrying fluids.
BS 4872-1:1982	Specification for approval testing of welders when welding procedure approval is not required. Fusion welding of steel.
BS 4872-2: 1976	Specification for approval testing of welders when welding procedure approval is not required. TIG and MIG welding of aluminium and its alloys
BS EN 1011-2:2001	Welding. Recommendations for welding of metallic

	materials. Arc welding of ferritic steels
PD 5500:2009+A3:2011	Specification for unfired fusion welded pressure vessels
BS EN 1999-1-4:2007+A1:2011	Eurocode 9. Design of aluminium structures. Cold-formed structural sheeting
BS EN 1999-1-1:2007+A2:2013	Eurocode 9: Design of aluminium structures. General structural rules

Appendix 1

Competence

The term "competent person" is not defined in any regulations, but characteristics of a competent person can be inferred from HSE guidance.
To be competent, a person has to have: -

- technical knowledge
- adequate experience
- understanding of the systems
- understanding of the hazards
- ability to recognise if it is safe for work to continue
- understanding of relevant current best practice
- awareness of one's own limitations
- willingness and ability to supplement existing experience and knowledge
- knowledge of legislation

Designer Competence

For a person to be competent to design a weld then the following are **also** required: -

- A degree in engineering
- Membership of the Welding Institute
- Knowledge of applicable welding techniques, processes, technology etc.

Welder Competence

For a welder to be competent to carry out a weld checks need to be made on their knowledge and ability before being allowed to proceed as specified in the guidance document.

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Related Procedures	Chapter 17: Acetylene cylinders
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