SAFETY ASSESSMENT FEDERATION

Guidelines

Pressure Systems

Guidelines for Competent Person-Repairs or Modifications to Pressure Systems

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CONTENTS

1. INTRODUCTION

Repairs or modifications are often required on pressure systems. It is essential that they are carried out to suitable standards and that they are safe. The purpose of this document is to provide guidance for Competent Persons on repairs or modifications to pressure systems under the Pressure Systems Safety Regulations and other repairs where the same integrity is required. It will also be helpful to users, owners and repair companies in providing documentation for the work and the level of detail required. It addresses like for like repairs and modifications that do not change the function or purpose of the system.

Most repairs to pressure equipment will involve welding of pressure parts so this document focuses on this aspect.

Repairs or modifications that change the original characteristics of pressure equipment may need to be subject to the requirements of the Pressure Equipment Safety Regulations 2016 (PESR)

Any repairs that will change the original design may require justification from the repair company including calculations that will need to be verified by the Competent Person e.g. compensation for larger openings.

2. SCOPE

This document specifies the requirements for repairs and modifications that involve welding on pressure containing parts of the system or other primary containment applications.

Other types of repairs or modifications not involving welding should be carried out to similar control and documentation requirements.

Welding on structural parts should be carried out to suitable standards but is outside the scope of this document.

3. PRESSURE SYSTEMS SAFETY REGULATIONS 2000

Whilst PESR should be considered when assessing the requirements for repairs and modifications to pressure systems, the following Regulations relating to the use of pressure equipment (PSSR) are particularly relevant:

Regulation 13: *"The employer of a person who modifies or repairs a pressure system at work shall ensure that nothing about the way in which it is modified or repaired gives rise to danger or otherwise impairs the operation of any protective device or inspection facility"*

Guide 13 para 173: The duty holder for this regulation is the employer of the person engaged to carry out the repair or modification.

ACOP para 174: When designing any modifications (including extensions or additions) or repairs to the pressurised parts of the system, whether temporary or permanent, the following should be considered:

- The original design specification
- The duty for which the system is to be used after the repair or modification, including any change to relevant fluid
- The effects any such work may have on the integrity of the pressure system
- Whether the protective devices are still adequate
- Continued suitability of the Written Scheme of Examination

ACOP para 176: Any repair or modification (including extensions or additions) should be designed in accordance with appropriate standards, considering the expected future duty of the system as well as the original design specification. It should be done by a person competent to do such work.

ACOP para 177: Where substantial modifications or repairs (including extensions or additions) are to be carried out which might increase the risk of system failure, the user should consult a person who is competent to advise before work begins.

The user/owner must also ensure the Written Scheme of Examination (WSE) remains valid before further use, detailed in paragraph 118 of the ACOP to Regulation 8

ACOP para 111- Repair/modification The scheme should, where necessary, specify the type of repair or modification which needs to be examined by the competent person carrying out examinations under regulation 9 before the system is put back into use. Alternatively, the user/owner may decide to draw up a

comprehensive written method to be followed for certain specified repairs or modifications to all or some of the systems.

This will generally require the owner/user to contact the Competent Person before the repairs or modifications are carried out.

Regulation 14: *"The user of an installed system and the owner of a mobile system shall keep:*

...any such previous reports if they contain information which will materially assist in assessing whether -
...any repairs or modifications to the system can be carried out safely"

> **ACOP para 179**: The user / owner should keep the following documents readily available:
>
> ...all other reports which contain information relevant to the assessment of matters of safety.

Sections 5 and 6 give examples of documents that may require to be kept and should be retained for the life of the component.

> **ACOP para 180**: In deciding whether a report contains relevant information, the user / owner should take account of ...previous history of repair and any significant modifications to the system.

4. PED / PE(S)R

Pressure Equipment Directive (PED) transposed into UK Law as Pressure Equipment (Safety)Regulations 2016

Repair of plant 'in-service' will come within the scope of the Pressure Systems Safety Regulations Regulation 13.

Guideline A-03 to PED advises that pressure equipment subject to modification that changes its original characteristics, purpose or type, after being put into service may need to be considered a new product and potentially require the involvement of a Notified Body.

Generally, repairs will not require consideration under the PE(S)R. e.g. the replacement of a complete superheater would require CE marking; however, the replacement of the complete tube-bank using the original headers would not.

5. REPAIR DOCUMENTATION

PSSR Regulation 14 requires that documentation is kept that will enable the Competent Person to assess whether a pressure system is safe for continued use.

This section outlines and describes the typical documentation required from a suitable repair company when proposing to carry out repairs to the pressure envelope of pressurised plant.

It should be noted that the documents outlined below would be required prior to commencement of any repairs; the possible exceptions are materials and consumable certificates that may be submitted for review later in the process.

5.1. Method statement

This document details a step-by-step procedure for the repair being carried out. It would typically contain the following information:

- Plant identification including manufacturer, design standard, original materials of construction, serial/plant number, safe operating limits, etc.
- Location.
- Details of the repair being undertaken including a sketch of the location.
- Repair procedure including preparation, inspection requirements, proposals for NDT and hydraulic testing (including pressure to be applied) on completion.
- Any special procedures required – for example specific bending requirements, pre or post weld heat treatment.
- Confirmation that repair materials are compatible with the component.

The Competent Person will review the method statement and specify inspection stages and tests to be witnessed where required.

Note 1: This does not remove the responsibility of the repairer to complete stage testing to ensure the integrity of the completed repair.

Note 2: NDT required by the Competent Person must be carried out by a suitably qualified person, (normally PCN level2) approved by the Competent Person. The Competent Person will generally require witnessing the final hydraulic test (if required) on completion of the repairs.

Note 3: It should be noted that repairs are carried out in the 'field' and preparation/fit up of repairs in this scenario can vary from welding documentation that is prepared in a 'shop' environment, the Competent Person will need to apply judgement (with guidance from the subsequently noted standards) on the suitability of such arrangements.

5.1.1. Pressure testing

Established practice in relation to manufacture and repair to Pressure equipment generally specify a pressure test on completion of manufacture, to demonstrate mechanical integrity and freedom from leaks. It therefore follows that repairs or modification to such equipment (e.g. when involving welding) should also undergo a pressure test. This would normally be a hydraulic test but in certain situations it may be impracticable to perform such a test, i.e. where the contents are not compatible with water, the equipment is not designed for the weight of water etc. It is recommended that the Competent Person refers to ACOP L122 paragraph 51 for details of the criteria for verification. Other testing methods, such as 100% volumetric NDT testing (of the repair) can be substituted in lieu of hydraulic testing, however in practice the "first fill" of the pressure equipment effectively becomes a pressure test. Pneumatic testing should only be applied when the condition of the existing plant can be fully established and that adequate safety precautions can be implemented during the test.

Details of the test pressure can normally be found on the equipment data plate; however, it will need to be confirmed that the original design pressure has not been de-rated before applying the original test pressure.

The Competent Person is advised to consult SAFed guidance document PSG21 - Pressure Testing Guidance - for details of test criteria.

5.2. Welding Documentation

The Competent Person would normally be expected to consult, review or ascertain the existence of the accompanying welding documentation to include:

Welding Procedure Specifications (WPSs) (ISO 15609)

Welding Procedure Qualification Records (WPQRs) (ISO 15614 series)

Welder Qualification Test Certificates (WQTCs) (ISO 9606 series)

5.2.1. Welding Procedure Specification (WPS)

The WPS gives details of how the welding is to be performed giving information on the specific welding task to be completed and is job specific.

Its purpose is to aid the planning and quality control of the welding operation. This documentation will be supported by the welding certification forms. (SAFed forms are numbered E1 to E4).

Note. Sometimes a repairer will send copies of all their weld procedures. This is not satisfactory as it is necessary to specify the actual procedures to be used and not for the competent person to attempt to interpret which procedure is to be used by the welder.

5.2.2. Welding Certification (Reference SAFed Guidelines on Approval Testing)

When reviewing welding certification, the accreditation of the issuing company and the companies issuing prolongations should be assessed. In all cases the Competent Person will satisfy themselves with the competence of the organisations involved before proceeding, i.e. the organisation is accredited by UKAS (or equivalent) for witnessing / certifying welding procedures and certifying welders, as opposed to being a test house that only does the mechanical tests etc.

Acceptance of Welder Approval and Weld Procedure Approval should also address the type of joint (butt weld, branch connection, fillet weld and tube to tube plate). Any other joint may be addressed using BS EN ISO 15613. Any design specification or application standard requirements e.g. phase counting, impact testing or all weld tensile must be incorporated into the Weld Procedure Approval.

Welding certification comprises of:

Certificate E1 — Welding Procedure Qualification Record

This gives details of the specific type of weld a procedure has been certified to carry out in accordance with:

5.2.2.1. ISO 15614-1 1 butt, branch and fillet welds

5.2.2.2. BS EN ISO 15614 Part 8 tube to tube sheet

5.2.2.3. BS EN ISO 15613 Nonstandard joint (e.g. stay bar welding).

Certificate E2 — Details of Weld Test.

This gives details of what actually took place during the test weld being manufactured.

Certificate E3 — Test Results, gives details of NDT and Mechanical testing results.

The above three certificates are all required to complete a weld procedure qualification record.

Certificate E4 — Welder Qualification Test Certificate - This is the individual welder approval part of the qualification. There must be an E4 certificate for each welder with a range of approval relevant to the welding being performed. The E4 contains the information relating to the welder's competence and is detailed below.

Please note: Forms are no longer identified as E1 through E4 although it is still common practice to refer to them as such**.**

The Competent Person shall check that the qualification, testing and documentation are suitable for the equipment to be repaired.

Note: Where the repair and the modification necessitate conformity assessment to the Pressure Equipment Directive a harmonised standard should be ideally used. Where ASME IX is used for weld procedure and welder qualification testing and certification, further testing will be required as determined by the notified body, with a statement from the issuing RTPO / Notified Body to conform its acceptance to the PED.

5.2.3. Detailed Information on the E4 Welder Qualification Test Certificate (WQTC)

The certificate will indicate the range of designated variables that have been addressed in an individual approval, these are listed below in the order generally displayed on WQTC certification; Applicable Welder Qualification Standard

Welding Process (Common examples):

5.2.2.1.1.1 111 - Manual metal arc (MMA) 111

5.2.2.1.1.2 131 - Manual Metal Inert Gas (MIG)

5.2.2.1.1.3 135 - Manual Metal Active Gas with solid wire electrode (MAG)

5.2.2.1.1.4 136 - Manual Metal Active Gas with flux cored electrode (FCAW)

5.2.2.1.1.5 138 - Manual Metal Active Gas with metal cored electrode (MCAW)

5.2.2.1.1.6 141 – Tungsten Inert Gas Welding with solid wire electrode (TIG)

5.2.2.1.1.7 142 – Autogenous (No filler) Tungsten Inert Gas (TIG)

Product type:

5.2.2.1.1.8 P – Plate,

5.2.2.1.1.9 T - Tube

Type of weld:

5.2.2.2 BW butt weld

5.2.2.3 FW - fillet weld

5.2.2.4 TEW - tube end weld

Material group according to CR ISO 15608 common examples below (for more detail refer to standard). It should be noted ASTM and ASME materials are largely grouped as 11.1 and 11.2:

1: Carbon Manganese Steels

- Carbon Steels with a specified Re ≤ 275 N/mm2
- 1.2 Carbon Steels with a specified Re >275 N/mm2 / ≤ 360 N/mm2
- 1.3 Carbon Steels with a specified Re > 360 N/mm2
- 1.4 Carbon Steels with improved atmospheric corrosion resistance

2: Thermo-mechanically treated fine grain steels & cast steels with >Re 360 N/mm2

3: Quenched & Tempered Steels

4: Low vanadium alloyed Cr Mo steels

5: CrMo steels free from Vanadium

6: Highly alloyed with Vanadium - CrMo steels

7: Ferritic, Martensitic & Precipitation Hardened Stainless Steels

8: Austenitic stainless steels Ni ≤ 35%

- 8.1 Austenitic stainless steels Ni ≤ 19%
- 8.2 Austenitic stainless steels Ni > 19%

10: Austenitic ferritic stainless steels

- 10.1 Austenitic ferritic stainless steels with %Cr ≤24% (Duplex)
- 10.2 Austenitic ferritic stainless steels with %Cr >24% (Super Duplex)

11: Steels as per Group 1 except 0.25%, C ≤0.85%

21: Pure aluminium

22: Aluminium manganese / magnesium alloys – Non heat treatable

23: Aluminium magnesium alloys – Heat treatable

24: Aluminium Silicon Alloys

31: Copper

32: Copper-zinc alloys

33: Copper-tin alloys

41: Pure Nickel

42: Nickel Copper alloys

43: Nickel Chromium alloys,

44: Nickel Molybdenum alloys

45: Nick Iron Chromium alloys

51: Titanium

Consumable Type - common examples

below Nm No filler (Autogenous)

A: Acid flux covering

B: Basic flux covering or electrode core

C: Cellulosic flux covering

M: Metal powder – electrode core

R: Rutile flux covering or electrode core

S: Solid electrode

Thickness of test piece: t

Diameter of test piece: D

Welding positions e.g.

Flat	(PA)	
Horizontal vertical	(PB)	
Horizontal	(PC)	
Horizontal overhead	(PD)	
Overhead	(PE)	
Vertical up / Vertical up Inclined		(PF / PH / H-L045)
Vertical down / Vertical down Inclined		(PG / PJ / J-L045)

Welding details.

bs welding from both sides

lw leftward welding

mb welding with backing strip

ml multi-layer

nb welding without backing

rw rightward welding

sl single layer

ss single side welding

5.2.4. Prolongation/validation of the E4 — Welder Qualification Test Certificate

The certificate should be prolonged for use by the Employer/Supervisor at 6 monthly periods for a total of 2 or 3 years, depending on the prolongation option chosen – this is provided that the welder is still regularly working within the initial range of qualification, it should be noted that a prolongation sheet identifying EN ISO 9606-1 (or appropriate standard such as ISO 9606-2, ISO 9606-3, ISO 9606-4, ISO 9606-5, ISO 14732 etc) would be acceptable.

Note 1: It is still possible for EN 287-1 certificates to be under prolongation providing all the rules of the current harmonised standard (EN ISO 9606-1) have been followed.

If the certification has been maintained by the employer and correctly prolongated it will continue to be acceptable.

Option 9.3c for prolongation in EN ISO 9606-1 does not accord with the essential safety requirements of the Pressure Equipment Directive (PED) and methods 9.3a and 9.3b are the only acceptable methods as below

A. The welder shall be retested every 3 years.

B. Every 2 years, two welds made during the last 6 months of the validity period shall be tested by radiographic or ultrasonic testing or destructive testing and shall be recorded. The acceptance levels for imperfections shall be as specified in Clause 7. The weld tested shall reproduce the original test conditions except for thickness and outside diameter. These tests revalidate the welder's qualifications for an additional 2 years.

The Competent Person should ensure that the E4 certificate has been signed by the Employer/supervisor within the last 6 months, if this is not the case then the certificate is invalid.

Every two years from issue the Inspecting authority may approve an additional 2 year prolongation, provided that documentary evidence is in place as per the applicable clause in the relevant standard (EN ISO 9606-1 Section 9.3b) to support the welders continued skill in using the welding procedures and volumetric or destructive tests have been carried out on samples of the welder’s production.

The Competent Person should check to ensure that the E4 certificate has both the 6 monthly signature from the Employer/Supervisor and where required the signature for any prolongation.

The Competent Person should see a copy of this documentation when available and a copy should be kept with the repair documentation.

Note 2: Care should be taken to verify the welder identification and the form for any evidence of unauthorised editing.

5.2.5. Material certificates

The material used for the repair must be suitable for the required duty and of the required thickness. Normally this will be the same or equivalent specification to that used in the original manufacture unless a change of material has been agreed by the Competent Person.

The material certificate(s) should be from the original manufacturer and not produced by the material supplier/stockist. The certificate should be in accordance with EN 10204: 3.1 or 3.2 for the main pressure bearing parts and 2.2 for other pressure bearing components such as nozzles. It should clearly show that the material matches that given in the method statement. Where practical the material should be identifiable through all stages of the repair.

5.2.6. Consumables details

Consumables should be supplied with material certification whose designation will match that shown in the E1 Certificate or the WPS.

6. REPORTS OF TESTING

Any reports and certificates issued during the repair process should be kept. At the end of the repair, the Competent Person should issue a report of examination stating the following:

- The repair has been completed in accordance with supplied documentation.
- All testing is now complete
- The component is safe to return to service following any examination requirements in accordance with the Written Scheme.

Note: For complex, long running repairs, where several key personnel may have changed e.g. the Competent Person, there should be inter stage reports issued which document progress.

7. CHANGES TO THE WRITTEN SCHEME OF EXAMINATION

The Competent Person responsible for the Written Scheme of Examination should be advised of any repairs to the pressure equipment and consider whether the scheme is still suitable. Depending on the type/severity of the repair changes to the Scheme may need to be made, i.e. increasing frequency, specific targeted NDT/examination etc to ensure that the risk of failure is suitably mitigated.

8. TEMPORARY REPAIRS

Where circumstances prevent an immediate permanent repair from being carried out (Procurement of repair material etc.) then temporary repairs can be considered. Similar requirements to those for permanent repairs will apply and it must be ensured that the plant is safe to operate until the opportunity arises for a permanent repair to be carried out. The temporary nature of these repair needs to be addressed in the documentation supplied and referenced in a report for the item, including the date by which the permanent repair is be carried out. There may be a need to reduce the safe operating limits of the system and or the periodicity for future examinations.

Any temporary repairs should be reflected within the report produced following examination, including responsibility for the ongoing inspection to ensure system integrity is maintained (i.e. discuss the nature of the temporary repairs with the owner of the system to establish who will undertake any monitoring of the repairs).

APPENDIX 1 Competent Person involvement in repairs or modifications to PS

A1.1 Boilers and Pressure Vessels

Whilst it is important to repair all vessels in a proper and safe manner, the Competent Person has an involvement in those parts of the system which are examined in accordance with the written scheme. Most design and construction codes for boilers and pressure vessels require the involvement of an independent third party in the design and construction. Also, for most boilers and pressure vessels covered in a WSE the Pressure Equipment Safety Regulations (2016) is likely to require the involvement of a "Third Party" in their original construction. Hence it is both appropriate and logical to apply similar requirements when these boilers and pressure vessels are subsequently repaired or modified. The Competent Person should therefore approve all repairs to boilers and pressure vessels covered by the WSE. Depending on the complexity of the work the involvement would normally commence prior to the work being undertaken so that the method of repair can be agreed. This is then followed by inspections during the work itself.

A1.2 Protective Devices

The protective device is the most critical item in a pressure system as it is the ultimate protection against exceeding the safe operating limits. Hence great care needs to be taken when considering repairs. It is normal practice on an item such a safety valve to replace it rather than attempting a repair, unless it is simply the replacement of a part. However, care should be exercised with both replacement of parts and replacement of the entire valve to ensure like for like replacement is achieved. The wrong spring will result in a completely different set of characteristics and a different valve of the same nominal size could have a considerably different discharge capacity. The published data from a

manufacturer's catalogue below illustrates the point.

Valve	size mm	set pressure bar	capacity kg/hr
Fig 542	50	10	2350
Fig 500	50	10	5925

Documentation and records relating to such repairs/replacements should be retained and whilst the Competent Person does not normally need to be directly involved it is important to ensure he is made aware of any such work. Depending on the adequacy of the documentation provided he may require a test of the protective device to demonstrate satisfactory functionality. This would certainly apply if the level controls on a steam boiler were replaced for example.

A1.3 Pipework

A lot of pressure systems pipework is excluded from the WSE on the basis that a defect giving rise to danger is unlikely to occur and the energy involved is low. Pipework that is included in a WSE and undergoes repair probably does not pose the same level of risk as would a boiler or pressure vessel under repair. Also, unlike pressure vessel codes piping codes do not normally specify the involvement of an inspection body. However, it needs to be recognised some pipework can potentially pose as much risk as a pressure vessel if it failed. Refer to PSG 05 - In-service examinations of pressure systems pipework - for further information.

PSSR only addresses the dangers arising from the sudden release of stored energy and the scalding effects of steam. Nevertheless, the risks arising from the leakage of a hazardous fluid from pipework cannot be ignored. To set some form of benchmark where the competent person should be directly involved in the repair process, the Pressure Equipment Directive again serves as a useful guide. Where the PED risk category for a particular piping system requires the involvement of a notified body during manufacture (risk category II and above – see tables 6 and 9) then the Competent Person should have some direct involvement in the repair. Even when the Competent Person is not directly involved, they should undertake some form of review of the documentation relating to the repair.

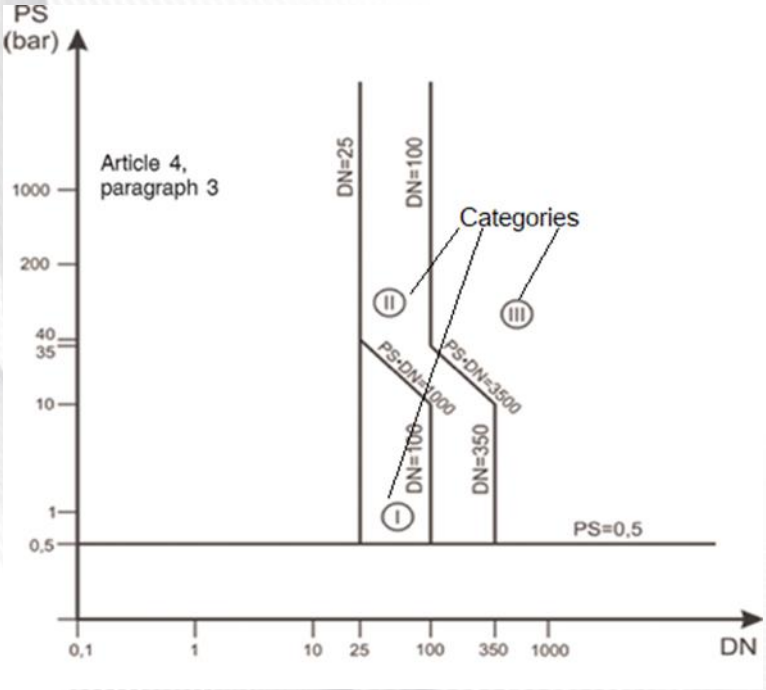


Table 6 Piping referred to in Article 4 (1) (c) (i) first indent (See Page 18)

This table refers to piping which contains a Group 1 gas as defined in the P.E.D. (Toxic, Oxidising, Flammable, And Explosive)

Article 4, paragraph 3 is a reference to the application of Sound Engineering Practice (S.E.P.)

Category II and above piping needs full involvement of the Competent Person in the repair/modification.

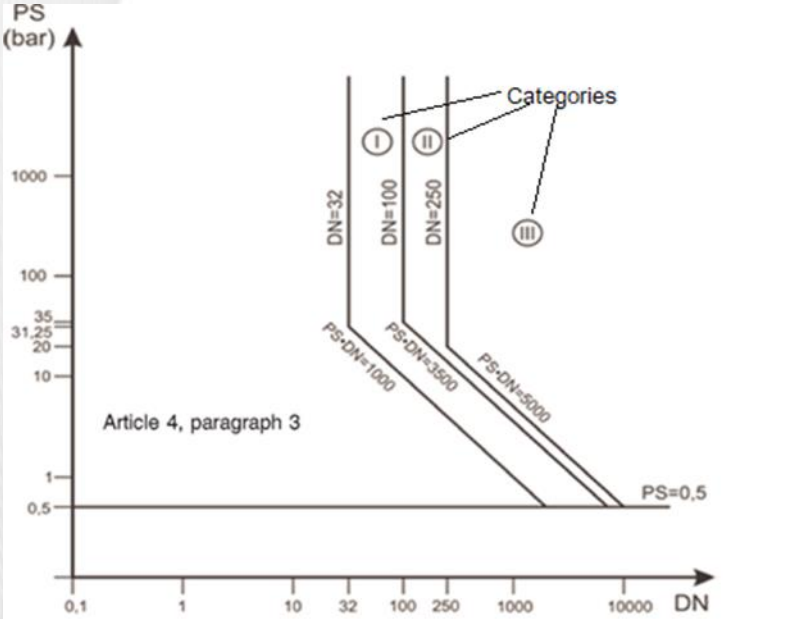


Table 7 Piping referred to in Article 4 (1) (c) (i) second indent (See Page 18)

This table refers to piping which contains a Group 2 gas as defined in the P.E.D.

Article 4, paragraph 3 is a reference to the application of Sound Engineering Practice (S.E.P.)

Category II and above piping needs full involvement of the Competent Person in the repair/modification.

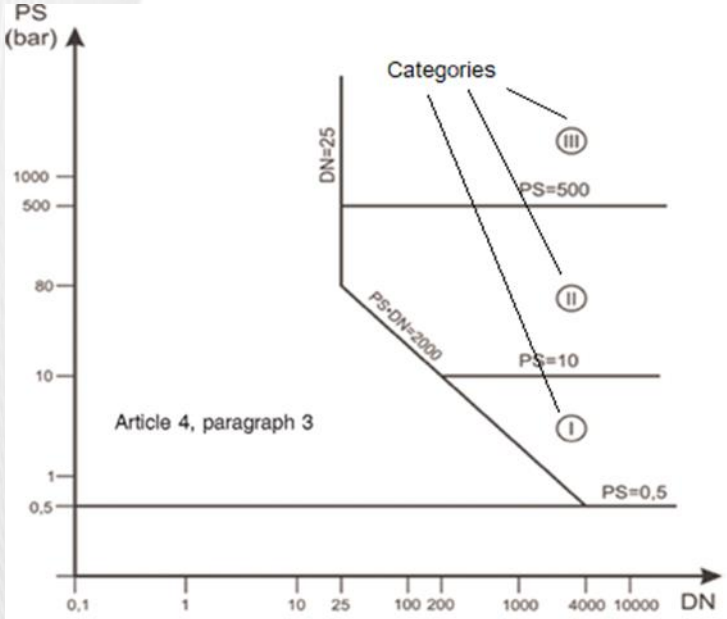


Table 8 Piping referred to in Article 4 (1) (c) (ii) first indent (See Page 18)

This table refers to piping containing Group 1 Liquids as defined in the P.E.D.
NOTE: Article 4, paragraph 3 is a reference to the application of Sound Engineering Practice (S.E.P.)
Category II and above piping needs full involvement of the Competent Person in the repair/modification.

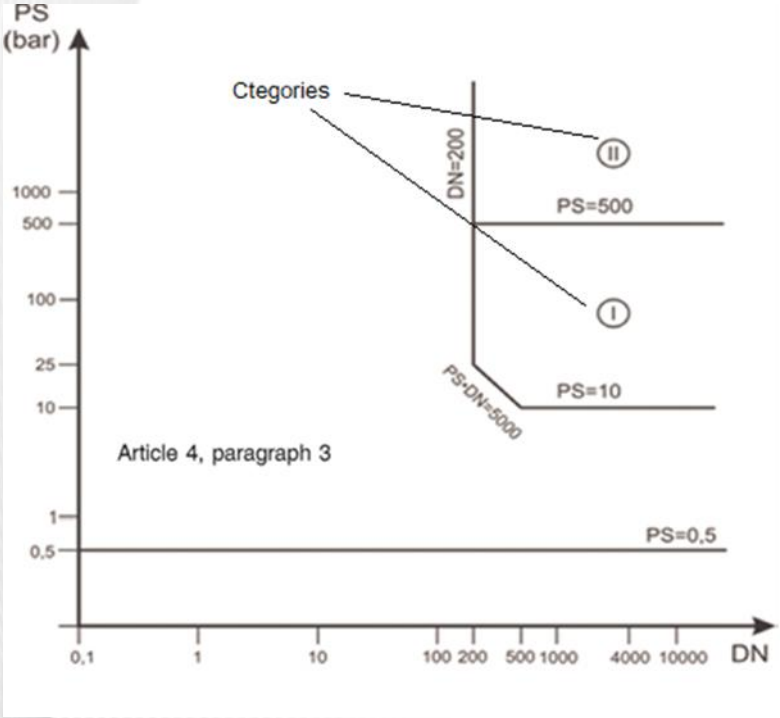


Table 9 Piping referred to in Article 4 (1) (c) (ii) second indent (See Page 18)

This table refers to piping containing Group 2 Liquids as defined in the P.E.D.
NOTE: Article 4, paragraph 3 is a reference to the application of Sound Engineering Practice (S.E.P.)
Category II and above piping needs full involvement of the Competent Person in the repair/modification.

Extract from PED:-

PED Article - 4(1)(c) piping intended for:
(i) gases, liquefied gases, gases dissolved under pressure, vapours and those liquids whose vapour pressure at the maximum allowable temperature is greater than 0,5 bar above normal atmospheric pressure (1 013 mbar) within the following limits:
— for fluids in Group 1 with a DN greater than 25 (Annex II, table 6),
— for fluids in Group 2 with a DN greater than 32 and a product of PS and DN greater than 1 000 bar (Annex II, table 7)
(ii) liquids having a vapour pressure at the maximum allowable temperature of not more than 0,5 bar above normal atmospheric pressure (1 013 mbar) within the following limits:
— for fluids in Group 1 with a DN greater than 25 and a product of PS and DN greater than 2 000 bar (Annex II, table 8),
— for fluids in Group 2 with a PS greater than 10 bar, a DN greater than 200 and a product of PS and DN greater than 5 000 bar (Annex II, table 9).

APPENDIX 2 List of typical repair documentation

Documents normally supplied with a welded repair as applicable:

A. Method statement, including sketches / drawing
B. Material Certificate(s)
C. Welding Procedure(s) and welder qualification(s)
D. Welding consumable certificate(s)
E. Results of Non-Destructive Testing
F. Non-Destructive Testing Personnel certification
G. Hydrostatic Test Certificate(s)
H. Pressure Gauge calibration certificate(s)
I. Results of any PWHT.
J. Reports of any concession(s)

APPENDIX 3 Temporary and permanent repairs

A3.1 Introduction

This appendix addresses the subject of temporary and permanent repairs in more detail; it also identifies some commonly used repair techniques and gives guidance to their application and suitability.

A3.2 Temporary and permanent repairs

In addition to the information contained in this document, further guidance relating to temporary and permanent repairs can be found from various sources, including but not limited to the following:

- API 510: Pressure vessel inspection code: in-service inspection, rating, repair and alteration (specifically section 8).
- ASME PCC-2: Repair of pressure equipment and piping.

A3.3 Temporary repairs

Temporary repairs should be removed and replaced with suitable permanent repairs at the next maintenance opportunity, they may only remain in place for a longer period of time if evaluated, approved, and documented by a person competent to do so.

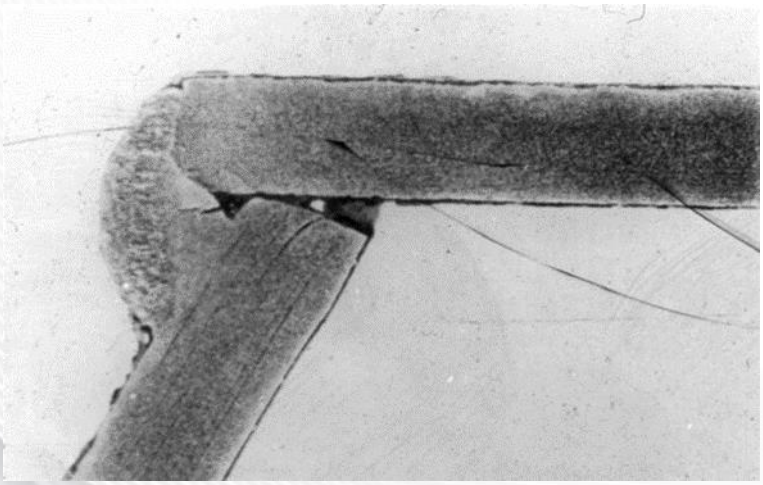
Any temporary repair applied to a pressure vessel may require a review of the Written Scheme of Examination to ensure all relevant parts are examined adequately.

A3.3.1 Fillet welded patches

In general, fillet welded patches will not normally be accepted as a suitable repair technique for crack like defects, some of the reasons for this are shown below:

- The damaged material may not be removed from the item.
- The patch can effectively become a projectile that could be forced off the item due to the stresses imposed.
- The geometry of the patch (importantly the lack of a full penetration weld) imposes local bending stresses in the region of the weld and early failure.
- The defect remains under the patch – it is virtually impossible to establish further growth either visually or by using an NDT technique.

Use of a fillet welded temporary repair over corroded region of heat exchanger



Evidence of a crack like defect

Fillet-welded patches may be used to make **temporary** repairs to damaged, corroded, or eroded areas of pressure vessel components**.** Cracks shall not be repaired in this manner, unless:

- The crack growth has stopped, been arrested or can be accurately predicted for all potential forms of propagation.
- The effect of the crack like defect is evaluated using detailed analyses (e.g. Finite element analysis, linear elastic fracture mechanics, or similar engineering critical assessment).

Temporary repairs using fillet-welded patches shall be approved by a Competent Person and Engineer; in addition, they require special design consideration, especially related to weld joint efficiency. A fillet- welded patch shall not be installed on top of an existing fillet-welded patch.

Fillet welded patches consist of a repair plate being fitted that closely matches the original component's exterior or interior surface. The repair plate is sized to cover the area exhibiting damage, both at the time of repair and for that damage anticipated for the repair design life.

The repair shall **not** be used for high hazard applications or when the damage mechanism, extent of damage or likely future damage cannot be established.

A3.3.2 Documentation associated with temporary repairs should include:

- Location of the temporary repair.
- Specific details about the repair, e.g. material of construction, thickness, size of welds, NDT performed.
- Details of analyses performed.
- Requirements for future inspections.
- Due date for installing permanent repair.
- The inspection plans should include monitoring the integrity of the temporary repair until permanent repairs are complete.

A3.4 Permanent repairs

Typical methods for permanent repair include:

- Excavating the defect, and blend-grinding to contour.
- Excavating a defect and repair welding of the excavation.
- Replacing a section or the component containing the defect (insert or set-in patch).

- Weld overlay of corroded area.

The repair technique chosen will depend on the nature of the defect, size, location etc. and requires acceptance by the Competent Person prior to the repair commencing.

Particular consideration needs to be given when repairing a crack at a discontinuity, where stress concentrations are high, (e.g. crack in a nozzle-to-shell weld or furnace to end plate weld in shell boiler).

Note: Consideration should also be given to the specific situation with fatigue cracks where a localised welding repair to an excavated crack may result in undetected micro cracks local to the repair site propagating into cracks. It is therefore important when performing localised welding repairs to remove

sufficient material from the repair site to ensure any weld is deposited on sound metal.

A3.4.1 Insert plates or set-in patch

This is the preferred method of repairing damaged sections of pressure equipment, in particular those containing crack-like defects.

Damaged or corroded shell plates may be repaired by removing a section and replacing it with an insert patch (set-in patch), to suitable standards, taking into account the original design code.

The repair procedure should take account of the following:

- Suitable NDT of welds to confirm integrity of repair should be carried out. Defect acceptance limits of the appropriate design standards should be taken into account.
- All insert plate corners should be rounded to a 25mm minimum radius.
- Weld proximity to existing welds should be detailed in the method statement and reviewed by a Competent Person prior to commencement of the repair. It is not advised to carry out repair welds in close proximity to existing welds, typically less than twice material wall thickness.

A3.4.2 Weld build up / overlay

This repair technique involves the application of weld metal to restore the thickness of an item of pressure equipment.

Weld overlay is typically applied to areas of general or local loss of wall thickness (e.g. pitting, erosion). The purpose of this repair method is to restore a component's thickness and / or corrosion allowance to original. Careful consideration should be given when using this method to restore the item's suitability for pressure containment. Additionally, the technique is not suitable for repairing crack like defects.

When carrying out the technique, it is vital to ensure via NDT that the underlying material is sound and free from defects, this will give confidence in the integrity of the final repaired region.

A3.4.3 Tube to tube sheet welds

Tube to tube plate welds may be designed as strength welds required to support the tube plate, or seal welds. These joints may be seen by repairers as less significant than other repairs as the potential for catastrophic failure is low but an inadequately made tube to tube sheet weld can have a reduced service life.

From a welding engineering perspective, the issue surrounds the very different thicknesses in the tube sheet to tube and the positional requirements which make it difficult for the welder to complete a sound weld.

APPENDIX 4 Typical Shell Boiler Inspection Requirements

A4.1 Introduction

This appendix addresses the typical inspection requirements that a competent person will require to make for some of the most common types of repair or modification on horizontal multitubular steam and MT/HT hot water boilers. The list is not exhaustive, and inspection requirements may need to be amended on a case-by-case basis. The inspection requirements specified are intended to align with the original construction standards such as BS 2790 with additional requirements where considered to be best practice.

A4.2 Types of repairs and modification

The most common repairs and modification applying to shell boilers are:

- 'D' Patch repairs in the furnace, access ring, shell welds attaching to the tubeplate
- tube end repairs/replacements
- localized grinding and re-welding repairs to letterbox sections,
- bar stay repair
- gusset stay repair
- feed water inlet nozzle repair or modification.
- wastage repair on mudhole or manhole door
- fitting of new level probe nozzle standpipes into the shell

A4.3 'D' Patch repairs

The preferred type of repair for a fatigue crack (either at toe of a fillet weld or root of a single-sided weld) at the corner joints on shell boilers is to use a 'D' patch. For cracking into the tube plate, it will generally be necessary to remove a 'D' patch from the furnace to gain access to the crack for a grind and weld repair.

When the crack is in a small diameter furnace or extends for a substantial proportion of the circumference of a furnace, it may well be more practical to replace the complete ring.

When deep repairs are required, the metallurgical changes and residual stresses from welding can lead to early recurrence of cracking in these areas.

If further cracking is detected at the original repair site at future examinations, it is not good practice to fit a 'D' patch within a 'D' patch. The original patch should be removed and replaced with a slightly larger patch or complete ring.

Gouging out and weld repair of cracks from the outside is not recommended. This is because of the difficulty of:

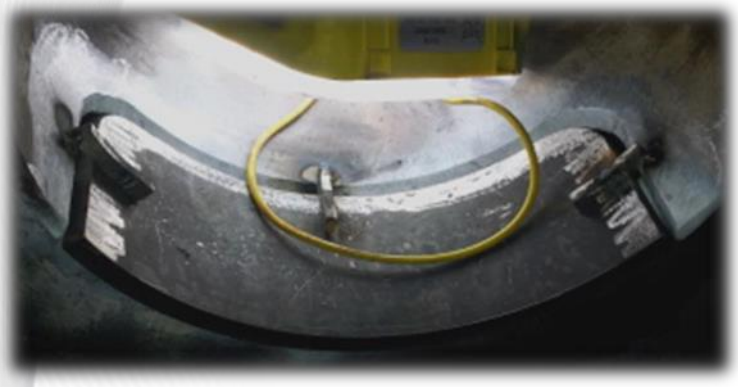
- ensuring complete removal of the defect
- obtaining an adequate root profile.

Again, the metallurgical and residual stress effects could lead to early recurrence of cracking in these areas.

For a 'D' Patch repair, half ring or full ring the following inspections will usually be required:

- Review method statement, drawing/diagram, weld procedure qualification record and welder qualifications.
- Review NDT reports of magnetic particle inspection after the removal of the damaged plate.

- Visual examination of the tack-up/set-up.



- Review of the material certificates for the patch plate and weld consumables and identify the material via the heat/cast number.
- Visual examination of the completed repair welds – internal and external where access allows.
- Review NDT reports of ultrasonic examination and magnetic particle inspection of the completed repair welds. Note: The butt weld should be flushed to allow better coverage of the weld from a UT perspective.
- Witness hydraulic test on completion.

A4.4 Tubes and tubeplates

Where tubes are to be replaced due to tube end cracking or pinhole corrosion etc, this should be done on a like for like basis wherever possible (e.g. expanded, seal weld, 'J' prep as original).

Cracking in tube ends will need to be repaired by removing the tube and associated cracking. Usually there will be more than one cracked tube and it will be necessary to initially carry out MPI of the whole tubeplate to ascertain the extent of the cracking. The following inspections will apply when tubes are being removed:

- Review method statement, drawing/diagram, weld procedure qualification record and welder qualifications.
- Competent person to review NDT reports of Magnetic particle inspection after the removal of the defective material is carried out (only in the case of tube end cracking).
- Visual examination after the removal of the defective tubes.
- Review of the tube material and weld consumable certificates and identify the material via the heat/cast number.
- Visual examination of the completed repair welds.

- Competent person to review NDT reports where Magnetic Particle Inspection of the completed repair welds has been carried out.
- Witness hydraulic leak test on completion. As it is not normally necessary to carry out a proof pressure test for tube replacements the test pressure only needs to be sufficient for leak detection.

A4.4.1 Temporary repairs to tubes

Tube leakage due to corrosion or blockage

Damaged tubes should normally be replaced but where it is impracticable to do this immediately then it is permissible to fit blanks. Where tubes are to be blanked due to pinhole corrosion leakage etc, this should be agreed with the competent person, with a guideline that no more than 10% of the total tubes in a single pass being blanked. It should be regarded as a temporary repair with the tubes in question replaced at the earliest opportunity e.g. next planned shutdown. The following inspections will apply when tubes are being blanked:

- Review method statement, drawing/diagram, weld procedure qualification record and welder qualifications.
- Review of the blank material and weld consumable certificates and identify the material via the heat/cast number.
- Visual examination of the completed repair welds.
- Competent person to review NDT reports if magnetic particle inspection of the completed repair welds has been carried out.
- Witness hydraulic leak test on completion. As it is not normally necessary to carry out a proof pressure test for simple tube blanking the test pressure only needs to be sufficient for leak detection.
- Future examination reports should state the total number of tubes plugged and if additional tubes are plugged at this time.

Tube end cracking

In some situations, it may not be possible to instigate an immediate repair by tube removal and replacement. In such cases it is acceptable for a temporary ‘grind out and weld repair’ to be carried out.

Note: As this is classed as a temporary repair the tubes in question should be replaced at the earliest opportunity.

Cracks in the tube or the tubeplate should be removed by grinding out followed by re-welding. The following inspections will apply:

- Review method statement, drawing/diagram, weld procedure qualification record and welder qualifications.
- Visual examination of the completed repair welds.
- Competent person to review NDT reports where magnetic particle inspection of the completed repair welds has been carried out.
- Witness hydraulic leak test on completion. As it is not normally necessary to carry out a proof pressure test for simple tube blanking the test pressure only needs to be sufficient for leak detection.
- The report should clearly identify which tubes have been subject to repair, to enable the
- temporary repair to be removed at the next shut down.

A4.5 Rectangular letter box sections between furnace and combustion chambers

Typical letter box design

Certain boiler designs incorporate a combustion chamber which is rectangular in cross section. This is welded to the side of the furnace, creating a 'letterbox opening'. The welding at the corners of the letterbox can be prone to cracking in service. This can normally be repaired by grinding out and re- welding. The following inspections will apply:

- Review method statement, drawing/diagram, weld procedure qualification record and welder qualifications.
- Visual examination after the removal of the defect
- Competent person to review NDT reports where magnetic particle inspection of the defect removal has been carried out.
- Review of the certification for the welding consumables.
- Visual examination of the completed repair welds.
- Competent person to review NDT reports of Magnetic Particle Inspection of the completed repair welds.
- Witness hydraulic test on completion.
- The examination report should state the extent of repair and its specific location to enable future monitoring.

A4.6 Stay Bars

Cracked or wasted stay bars will usually be replaced on a like for like basis. This includes re-instating any 'tell-tale' holes. The following inspections will apply:

- Review method statement, drawing/diagram, weld procedure qualification record and welder qualifications.
- Visual examination of the tack-up/set-up.
- Visual examination of the completed repair welds.
- Ultrasonic Examination and magnetic particle inspection of the completed repair welds to be carried out by a suitably qualified practitioner. Competent person to review NDT reports.
- Witness hydraulic test on completion.

A4.7 Gusset stays

Typical image of gusset stays

Where cracking occurs in the attachment welds, gusset stays will usually be repaired by grinding out and removing defects. If the whole stay is to be replaced it should be on a like for like basis. The following inspections will apply:

- Review method statement, drawing/diagram, weld procedure qualification record and welder qualifications.
- Visual examination of the tack-up/set-up or grind out (as applicable).
- Review of the gusset material (where applicable) and weld consumable certificate and identify the material via the heat/cast number.
- Visual examination of the completed repair welds.
- Ultrasonic examination and magnetic particle inspection of the completed repair welds to be carried out by the Repairer. Competent person to review NDT reports.
- Witness hydraulic test on completion.

A4.8 Feed water inlet nozzles

Where cracking occurs at the feed water nozzle weld to the shell this is usually an indicator of problems with either the design or operation of the boiler. Consideration may need to be given to the type of repair in order to eliminate future occurrences of the problem. This might include:

- Thermal sleeve
- Larger nozzle
- Reinforcement pad or shell insert pad.

An initial NDT examination should be carried out to ensure no cracks have propagated into the shell. The following set of inspection requirements will apply:

- Review method statement, drawing/diagram, weld procedure qualification record and welder qualifications.
- Visual examination of the tack-up/set-up.
- Review NDT reports. It is recommended magnetic particle inspection is applied after the removal of the damaged material.
- Review of the pipe material and weld consumable certificates and identify the material via the heat/cast number.
- Visual examination of the completed repair welds.
- Review NDT reports Magnetic Particle Inspection of the completed repair welds.
- Witness hydraulic test on completion.

A4.9 Mudhole or manhole door wastage

There are established methods for the repair of fabricated or McNeill type doors where the door spigot gap has increased. This normally utilises weld overlay to the door, frame or plate edge dependent on where degradation has taken place and subsequent machining of the joint face. Generally welding should not be carried out on pressed doors as the heat applied may cause the door face to distort causing sealing issues.

- Review method statement, drawing/diagram, weld procedure qualification record and welder qualifications.
- Visual examination of the completed repair welds.
- Witness Hydraulic test and NDT as required.

A4.10 Level Probe Standpipe Installations

Where new level probe standpipes are to be fitted, or existing standpipes enlarged to incorporate different probes, the following set of inspections will apply:

- Where the standpipes are new or are larger than the original arrangement then a design assessment to the original code of construction should be carried out to ensure the proposed nozzle openings are adequately reinforced. Their proximity to other openings in the shell should also be considered.
- Review method statement, drawing/diagram, weld procedure qualification record and welder qualifications.
- Visual examination of the tack-up/set-up.
- Review of the material certificates and identify the pipe/flange material via the heat/cast number.
- Visual examination of the completed repair welds.
- Competent person to review NDT reports of Magnetic Particle Inspection of the completed repair welds.
- Witness hydraulic test on completion.

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