JWES-CP-0902E

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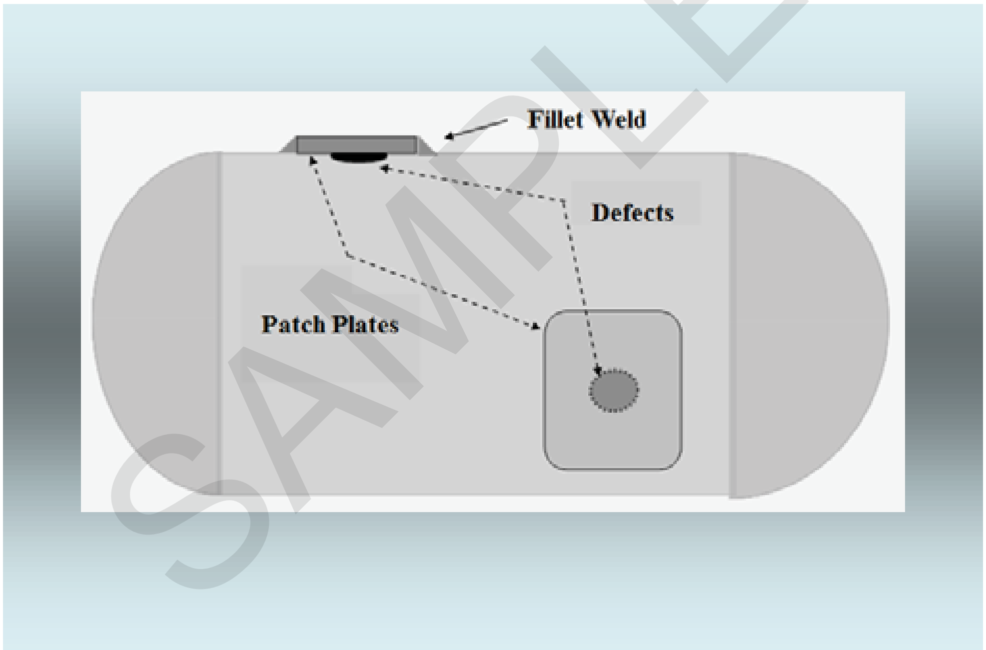
Guidelines for Repair Welding of Pressure Equipment
in
Refineries and Chemical Plants



Chemical Plant Welding Research Committee

The Japan Welding Engineering Society

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Foreword

A number of process plants such as refineries, chemical and power plants have undergone long-term operation more than forty years not only in Japan but also in other industrial nations. This means that the equipment maintenance of these plants has become an emerging key technology to ensure safe and reliable operation of plants. Thereby, the role of repair welding has increased to a larger extent, causing a great demand for the development of systematic and practical recommended practices of repair welding.

The Chemical Plant Welding Research Committee, hereafter the Committee, issued “Guideline for Repair Welding Procedure” in 1983 and revised it in 1993, as one of main activities of the Committee. Since it has been more than 10 years after the last revision, the renewal of the Guideline is highly requested by industries for an advanced issue including practical know-how.

With this background, the Working Group for Repair Welding of Pressure Equipment was launched in 2001 in the Committee, and advanced to the Subcommittee on Repair Welding for Pressure Equipment (Chaired by E. Yamamoto) in 2004. The Sub-committee, consisting of 35 members of qualified engineers including end users, material suppliers, equipment fabricators, engineering constructors, maintenance and inspection coordinators, commenced a buildup of work examples and practical fact sheet on repair welding procedure for pressure equipment.
During the activities of Phase I, the Sub-committee formed a basis for technical database of repair welding by the survey of more than 100 literatures and references. In addition, the latest status was reviewed of regulations, codes and standards related to repair welding of pressure equipment in Japan and overseas including ASME and API.

In Phase II activities, the repair welding guideline was developed as an engineering reference including the analysis of cause of damage, the equipment diagnosis by fitness-for-service (FFS) assessment, the study on necessity and availability of repair welding, practical procedure of repair welding and post-repair maintenance. The products of the activities were released at the National Symposium year by year, and presented also at International Conferences such as ASME-PVP with remarkable attentions.

In 2009, those activities were compiled into one handbook, Committee issue CP-0902, “Guidelines for Repair Welding of Pressure Equipment in Refineries and Chemical Plants” as the first practical repair welding guideline. The contents of CP-0902 were presented in 6 papers at ASME-PVP Conference, Baltimore, ML in 2011, and a part of them was announced at ICPVT-13 Conference, London, UK in 2012. Furthermore, the summary of the PVP conference papers has been published in ASME Journal of Pressure Vessel Technology in 2013.

Oil refinery and petrochemical industries have strongly called for standardization of the repair welding practices of pressure equipment in service. In compliance with these needs, the Committee has played an important role in the standardization work of repair welding for post-construction maintenance. The results have been published in July 2012 as the Japan Welding Engineering Society Standard, WES 7700 “Repair Welding of Pressure Equipment.” WES 7700 consists of 4 Parts; Part 1: General, Part 2: Flaw excavation and repair welding, Part 3: Butt-welded insert plates and Part 4: External fillet welded patches. Follow-up works are under progress to promote WES 7700 in the industries and related regulatory bodies.

Maintenance standards for plant equipment are primarily composed of three specifications; inspection, assessment and repair of equipment. Although procedures for fitness-for-service (FFS) assessment and risk-based inspection (RBI) have been standardized in advance, the standardization of flaw repair methods has not well developed. The issue of this guideline will form a substantial contribution to the safe operation of plant equipment in the world.

The Committee has published hereunder the Handbook, CP-0902E, English version of “Guidelines for Repair Welding of Pressure Equipment in Refineries and Chemical Plants” for the maintenance of pressure equipment in process plants in the world.

The Committee exerts efforts to develop and improve the repair welding technologies for pressure equipment and appreciates any cooperation and cordial support for our activities from worldwide engineers in various industries.

October, 2014

Prof. Dr. Eng., Fumiyoshi Minami
Chairman of the Chemical Plant Welding Research Committee
The Japan Welding Engineering Society

Chemical Plant Welding Research Committee
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Symbols (and Abbreviated Terms)

No.	Abbreviations	Full Terms
(NDE)		
N1	**NDE**	Nondestructive Examination
N2	**PT**	Liquid/Dye Penetrant Examination
N3	**MT**	Magnetic Particle Examination
N4	**UT**	Ultrasonic Examination
N5	**RT**	Radiographic Examination
N6	**VT**	Visual Examination
(Welding,Fabrication)		
W1	**SMAW**	Shield Metal Arc Welding
W2	**SAW**	Submerged Arc Welding
W3	**MIG**	Metal Inert Gas Welding
W4	**MAG**	Metal Active Gas Welding
W5	**GTAW**	Gas Tungsten Arc Welding
W6	**FCAW**	Flux Cored Arc Welding
W7	**EGW**	Elecrogas Welding
W8	**PWHT**	Postweld Heat Treatment
W9	**DHT**	Dehydrogenation Heat Treatment
W10	**WPQT**	Welding Procedure Qualification Test
W11	**WPQR**	Welding Procedure Qualification Record
W12	**WPS**	Welding Procedure Specification
(Corrosion)		
C1	**SCC**	Stress Corrosion Cracking
C2	**ClSCC**	Chloride Stress Corrosion Cracking
C3	**SSC**	Sulfide Stress Cracking
C4	**HIC**	Hydrogen Induced Cracking
C5	**SOHIC**	Stress Oriented Hydrogen Induced Cracking
C6	**HTHA**	High Temperature Hydrogen Attack
(FFS,RBI,Maintenance)		
F1	**FFS**	Fitness-For- Service
F2	**RBI**	Risk Based Inspection
F3	**EPC**	Engineering, Procurement and Construction
F4	**O&M**	Operation & Maintenance
F5	**PLM**	Plant Life -cycle Management

F6	SDM	Shut Down Maintenance
(Metallurgy)		
M1	HAZ	Heat Affected Zone
M2	Ceq.	Carbon Equivalent
M3	TMCP	Thermal Mechanical Control Process
(Society, Organization)		
S1	JWES	Japan Welding Engineering Society
S2	AWS	American Welding Society
S3	IIW	International Institute of Welding
S4	ASME	American Sosiety of Mechanical Engineers
S5	JSME	Japan Sosiety of Mechanical Engineers
S6	API	American Petroleum Institute
S7	JPI	Japan Petroleum Institute
S8	HPI	High Pressure Institute of Japan
S9	KHK	High Pressure Gas Safety Institute of Japan
S10	METI	Ministry of Economy ,Trade and Industry
S11	MHLW	Ministry of Health,Labour and Welfare
S12	FDMA	Fire and Disaster Management Agency
S13	NACE	National Association of Corrosion Engineers

Part4 Material Degradation and Repair Welding

4.1 Factors to be considered before repairs

4.1.1 General

Repair methods have to be selected properly taking account of materials, damage mechanisms, weldability, and so on. In order to prevent recurrence of the damage and ensure safe repair work, Part 1 - General in this document should be reviewed carefully before starting the repairs, in which necessary information for the assessment of repairs is described.

The following are the typical factors to be considered before repair:

a) Causes and mechanisms of the damage
b) Severity and extent of the damage, including suitable NDE for damage detection
c) Method to remove the damaged area
d) Weldability, including necessity and feasibility of de-embrittling heat treatment
e) Necessity and feasibility of PWHT
f) NDE to examine the soundness of the repairs
g) Necessity and feasibility of hydrostatic testing

It should be noted that, since improper repair welding may cause other serious problems, studies for minimizing repair welding are also very important.

4.1.2 Special consideration

Attention has to be paid to PWHT and hydrostatic testing, because these may be required by codes or regulations. This means that, in some cases, it may be a reason to abandon the repair welding, if PWHT or hydrostatic testing is not feasible, even though repair welding itself can be carried out successfully and there is no metallurgical concern. As an alternative to PWHT, the temper bead welding technique may be considered, provided that owner and applicable codes and regulations permit it.

4.2 Repair welding on damaged materials

In this section, the key points for particular repair welding cases on damaged materials are described.

4.2.1 Stress corrosion cracking (SCC)

SCC refers to environmental assisted cracking of specific materials caused by the simultaneous presence of tensile stress and a specific corrosive environment. SCC is the one of the most popular damages in refining and petrochemical industries, and likely to recur even in the short period after repairs if appropriate repair including prevention measures are not implemented.

4.2.1.1 Chloride stress corrosion cracking (Cl SCC)

a) Removal of cracks

Since Cl SCC in austenitic stainless steels occurs in the form of fine cracks extending over a wide area, PT is the most reliable detection method. After the extent of SCC was determined, the cracks have to be removed as much as possible before repair. For a long crack, both ends of the crack should be removed first to prevent crack propagation during the crack removal work. PT should be done after the crack removal work to confirm no crack was remained.

If the thickness after removing the cracks by grinding is still more than the minimum required thickness or judged as having enough thickness by FFS assessment, no repair welding (weld buildup) is necessary, and the ground surface can be left as is. In this case, the surface should be ground smoothly with a fine grinder (fine rotary files) to lower the residual stress on the ground surface.

b) Key factors for repair welding

If repair welding is necessary, the following have to be considered to prevent the recurrence of Cl SCC:

- Use of Cl SCC resistant materials
- Proper welding procedure to lower residual stress

Since local repair welding can cause excessive residual stress, improper repair welding would lead to the recurrence of Cl SCC even in short period. In order to lower residual stress, repair welding on only a small area should be avoided, and proper welding sequence should be examined in addition to the development of

4.2.4.3 Examples of repair welding

Two typical examples of repair welding methods on reactors in hydro-processing units made of heavy-wall Cr-Mo steels with stainless steel cladding are introduces hereunder.

a) Repair of Nozzle Neck Weld

Figure 4.2-5 shows the repair procedures actually applied to the defected quench nozzle, NPS 4 inch, of residue desulfurizing reactor made of 2.25Cr-1Mo steel, which had been operated for 10 years.

Sequences of the repair works are as follows:

- Removal of defects under preheating more the 150°C, using arc air gouging and grinding
- Inspection of gouged surface to confirm no defects on the removed area
- DHT at 350°C for 2 hours
- Buildup welding in the gouged cave of Cr-Mo base metal under preheating more than 200°C, using
- manual electrodes (AWS E9016-B3)
- Dry powder MT after completion of Cr-Mo welding, under maintaining preheating temperature
- DHT at 350°C for 2 hours
- UT, wet MT and PT on whole repaired area of Cr-Mo steel welds, after the material temperature cooled
- down to the ambient
- Overlay welding under preheating more than 100°C using E309L electrodes
- PT on the overlay welds at the ambient temperature
- PWHT at 690°C for 8 hours, where the insulation blanket was applied to cover the whole length of the
- shell plate including the repaired nozzle
- Finishing smoothly by grinding on the repaired area without any sharp edges less than 50mm^{R}
- MT, UT and PT on the whole area related to the repair and the subsequent PWHT

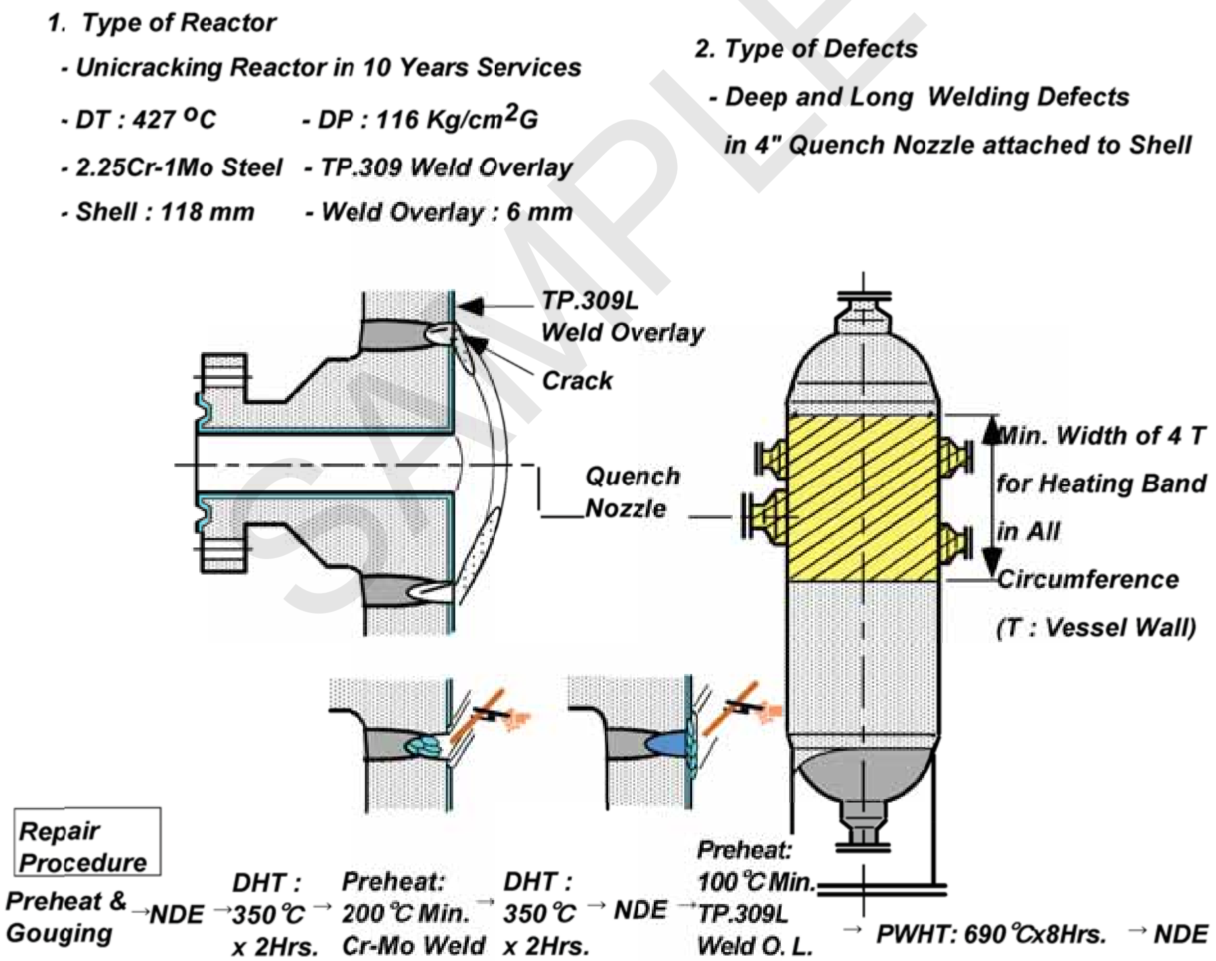

Figure 4.2-5 Repair welding of nozzle attachment weld