WELDING BOOK

Project: **LBNF - TEST PIECES**

Client: **European Organization For Nuclear Research - CERN**

Trade Contractor: **Cimolai S.p.A.**

Project Ref.: **2017-023**

Revision matrix:

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0 DESCRIPTION OF REVISIONS

Rev. 00 First issue.

1 SCOPE

This document, further referred to as Welding Book (WB), defines the welding requirements for the fabrication of the steel elements named “LBNF Test Pieces”.

This document is based on the requirements of EN 1090-2: Execution of Steel Structure and Aluminium Structures- Part 2: Technical Requirements for Steel Structures.

2 REFERENCE SPECIFICATIONS

[1] EN 1090-2: Execution of Steel Structure and Aluminium Structures- Part 2: Technical Requirements for Steel Structures.

[2] EN ISO 15614-1: Specification and qualification of welding procedures for metallic materials – Welding procedure test – Part 1: Arc and gas welding of steel and arc welding of nickel and nicker alloys

[3] EN ISO 15609: Specification and qualification of welding procedures for metallic materials – Welding Procedure Specification – Part 1: Arc welding

3 PERSONNEL REQUIREMENTS

Welders and welding operators shall be qualified according to the requirements of EN ISO 9606-1: Qualification testing of welders – Fusion welding and EN-ISO14732: Qualification testing of welding operators and weld setters for mechanized and automatic welding of metallic materials.

4 MATERIALS REQUIREMENTS

Base materials to be used for welded connections, as per project design, are the following:

- Steel rolled elements, beams and angles: S460ML (EN 10025-1; EN 10025-4).

5 FABRICATION AND EXAMINATION

5.1 Handling

Materials shall be handled using common device (magnets, brackets, clamps, etc.), taking care to minimize surfaces damaging.

If temporary lifting lugs are required, welding shall be performed in accordance to a qualified WPS.

5.2 Welding edge preparation

Welding edge may be prepared by thermal cutting, grinding or machining, except otherwise noted in the relevant WPS. In case of thermal cutting of heavy sections (≥40 mm), the surfaces shall be ground to bright metal.

Surfaces on which weld metal is to be deposited shall be smooth, uniform, and free from fins, tears, cracks, and other discontinuities which would adversely affect the quality or strength of the weld. Surfaces to be welded, and surfaces adjacent to a weld (for an extension of at least 50 mm on each side), shall also be free from loose or thick scale, slag, rust, moisture, grease, and other foreign material that would prevent proper welding or produce objectionable fumes.

5.3 Fitting

The parts to be welded shall be fitted following drawing requirement by adequate means, such as temporary attachments, mechanical fastening or tack welds (the latter performed preferably on the back-weld side of double-sided welds).

Tack welds, if included in the final joint, shall be adequately tapered and inspected for defects.

Welds for fitting purposes shell be performed by qualified welders, in accordance to a qualified WPS.

The following tolerances applies with regards do drawings dimensions:

	Full penetration double side Full penetration single side with backing Partial penetration		Full pen. single side without backing	
Groove welds	Angle or preparation	±10 °	Angle or preparation	±10 °
	Root face	not relevant	Root face	±1 mm
	Root gap (full pen. only)	0÷ +4 mm [1)]	Root gap	±2 mm [1)]

Fillet welds	Root gap	[0.5+0.1a] mm (max 2mm)

1) whenever higher gap is present, proceed with buttering of root zone on one or both members to reduce the gap to an acceptable size before performing the root pass

Variations in excess of those indicated above are not cause of fit-up rejection, but need to be referred to Cimolai Welding Coordination department for approval or correction.

5.4 Preheating and interpass

Preheating, if necessary with regards to WPS requirements, may be applied by gas burners, heating pads or induction equipment, at Cimolai discretion.

Temperature may be measured by pyrometric crayons, thermometers or thermocouples.

Interpass shall be measured on the weld area right before the starting of next passes.

When dissimilar thickness are to be joined, preheat shall be based on the thickest member.

5.5 Welding

Welding shall be performed in accordance to an approved WPS.

The welder, prior to initiating welding, shall verify the correctness of the preparation, the cleanliness of the edges and, in cases where preheating is not required, the absence of any trace of humidity on the edges. If humidity is present it will be necessary to dry it by heating the parts to be welded.

The procedure and sequence shall be such as will minimize distortion and shrinkage:

- Insofar as practicable, all welds shall be made in a sequence that will balance the applied heat of welding while the welding progresses.
- The direction of the general progression in welding on a member shall be from points where the parts are relatively fixed in position with respect to each other toward points having a greater relative freedom of movement.
- In assemblies, joints expected to have significant shrinkage should usually be welded before joints expected to have lesser shrinkage. They should also be welded with as little restraint as possible.
- If helpful in preventing distortion, welds may be performed using skip welding technique or balancing passes for double sided welding.

Root pass shall be followed as soon as possible by at least two hot passes, to avoid cracking phenomena. As a general rule, the filling passes shall follow execution of the first pass as rapidly as possible. Welding will be performed continuously upon completion to the maximum extent possible.

Back gouging, when required, will be performed to sound metal.

In case of thermal processes, e.g. arc-air, the minimum preheating shall be the same required for welding, and the surface shall be ground to bright metal before back welding.

If post-heating is required by the WPS, it shall be performed whenever it’s necessary to cool down under the preheating temperature.

For lengths of welding in the vertical position, the uphill progression will be used.

To avoid end defects, run-on and run-off plates will be placed at the beginning and end of each weld, whenever possible.

After slag has been removed, the surface of each run, if not sufficiently smooth (or when presenting roughness, incision, etc.) will be smoothed by grinding. Any irregular or defective beginnings or ends of welds will be dressed in the same way.

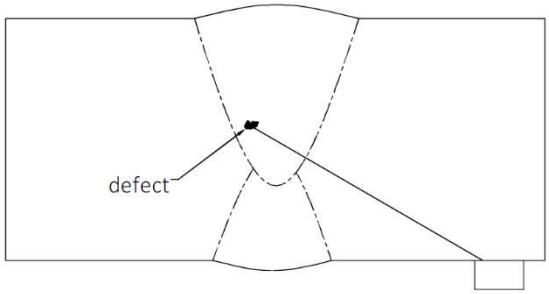
5.6 Nondestructive testing of welds (NDT)

NDT will be performed in accordance to relevant NDT procedures, to the extent required by the relevant Inspection and Test Plan.

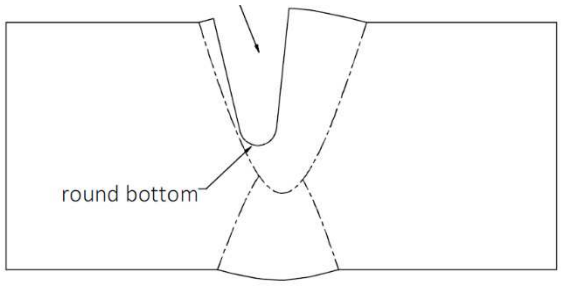
6 GENERAL REPAIR PROCEDURE

The following sequence shall be adopted in case of any welding repair (see Figure 1)

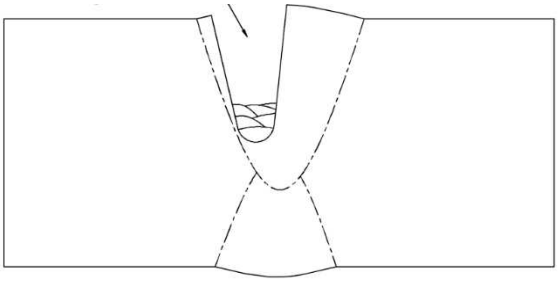
1. The area to be repaired shall be identified.
2. The defect shall be completely removed by grinding, carbon-arc gouging or burring tool, preparing a well-shaped groove for further welding.
3. The groove shall be inspected by Visual Testing (VT) plus Magnetic Particle Testing (MT) or Dye Penetrant Testing (PT).
4. The welding of the groove shall be performed in accordance to one of the approved Welding Procedure Specifications to be used for the original joint.
5. The repaired area shall be subjected to the same set of NDT's as foreseen for the original weld.



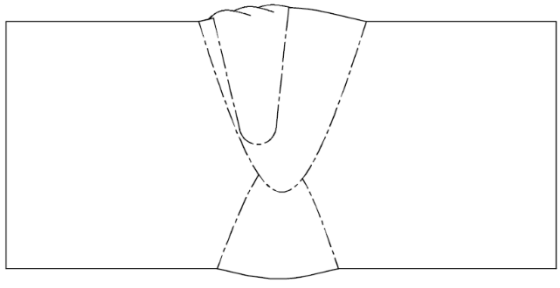
1. identification of the defective area.



2. open the groove enough to guarantee the correct stick-out.
3. NDT inspection of the groove.



4. Fill the groove according to a WPS approved for the original weld.



5. Perform a full set of NDT (eg. VT, MT, UT).

Figure 1 Weld repair sequence

7 LIST OF WPSs

WPS	REV	WPQR	Filler Metal	Process	Position	Type	T [mm]	t; a [mm]
1	00	IS0-061	Lincoln Supramig HD EN ISO 14341-A G46 4 M 3Si1	135-S	PB	FW sp;mp Partly mech.	≥ 5	a = 5 mm sp a = 6 mm sp a = 7 mm sp a > 7 mm mp
2	00	ISO-079	Bohler Ti52 T-FD T46 4 P M 1 H5	136	PF	FW sp;mp Partly mech.	≥ 5	a = 5 mm sp a = 6 mm sp a > 6 mm mp
3	00	ISO-056 ISO-058	Lincoln Supramig HD EN ISO 14341-A G46 4 M 3Si1	135-S	PA	GW (CJP÷PJP)	12,5÷200	t: 12,5÷200
4	00	ISO-057	Bohler Ti52 T-FD T46 4 P M 1 H5	136	PC,PF	GW (CJP÷PJP)	12,5÷50	t: 12,5÷50
5	00	ISO-085 ISO-086	Wire Oerlikon OE-SD3 1 Ni 1/4 Mo EN ISO 14171-A: SZ Flux Oerlikon OP121TT EN ISO 14174 SA FB 1 55 AC H5	121+ 121-T	PA	GW (CJP÷PJP)	12,5÷200	t: 12,5÷200

NOTES

1) GW = Groove Weld
   - CJP = Complete joint penetration
   - PJP = Partial joint penetration
   - T – PJP = T joint, partial penetration

   FW = Fillet Weld
   - sp = single pass
   - mp = multi pass

2) PA = flat
   PB = flat-horizontal
   PC = horizontal
   PF = vertical (uphill progression)
3) T = base material thickness
4) t = weld thickness for GW
   a = throat size for FW
5) the brand name may vary, provided the EN classification doesn't change

7.1 2017023-WPS-01

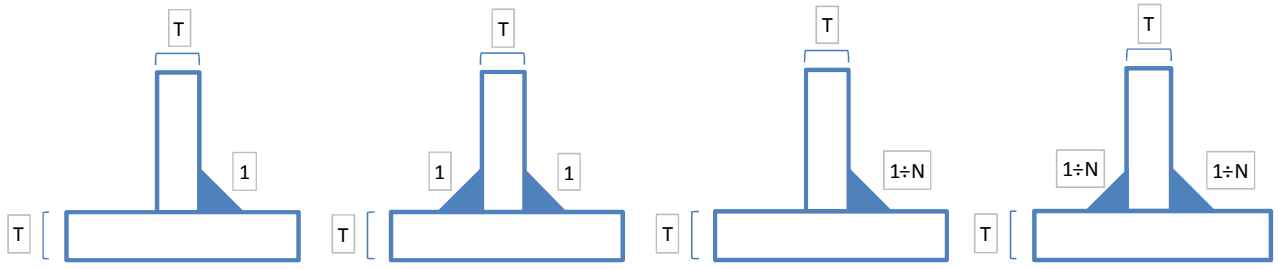
GENERAL					
WPS	01	**Rev.**	00	**Date**	01/08/2017
PQR	ISO-061	**Code/ Spec.**		EN 15614-1	
Welding process	135-S (GMAW-spray arc)	**Automation grade**		Partly Mechanized	

FILLER METAL / GAS							
Type	Solid wire	**Brand**	Lincoln Supramig Hd	**Diameter [mm]**	Ø 1.2		
Designation & Class.	EN ISO 14341-A G46 4 M 3Si1						
Protection gas	EN ISO 14175 M21-ArC-20 (80Ar-20CO_2)	**Nozzle [mm]**	12÷16	**Gas flow [l/min]**	16÷22		
Backing gas	No						

BASE METAL TYPE AND THICKNESS				
Type and grade	EN 10025-2÷4 : S355÷S460 (JR,J0,J2,K2,N,NL, ML)		**Group**	1.2÷2.1
Thickness	**Butt weld**		**Fillet weld**	
	T –base metal [mm]	n.a.	***T – base metal [mm]***	≥ 5
	t – weld metal [mm]	n.a.	***a – throat thickness [mm]***	See welding param.

WELDING PARAMETERS								
Throat (Layer)	**Position**	**Process**	**Diameter**	**Current**	**Voltage**	**Current tp.**	**Travel speed**	**Heat input**
[mm]	**-**	**-**	**[mm]**	**[A]**	**[V]**	**-**	**[mm/min]**	**[kJ/mm]**
5 (1)	PB	135-S	1.2	280÷315	29÷32	DC EP	265÷285	1.37÷1.83
6 (1)	PB	135-S	1.2	305÷325	32÷34	DC EP	230÷280	1.67÷2.31
7 (1)	PB	135-S	1.2	300÷320	32÷34	DC EP	200÷240	1.92÷2.61
MP (1÷N)	PB	135-S	1.2	315÷335	32÷34	DC EP	330÷480	1.00÷1.66

SKETCH



PREHEAT / INTERPASS / PWHT					
Min preheat	20 °C			**Max interpass**	200 °C
PWHT	No	**Temperature**	-	**Holding time (hrs)**	-

TECHNIQUE			
Joint type	Fillet weld	**Preparation**	thermal cut, grinding or machining
Cleaning	Grinding and Brushing	**Back gouging**	Not applicable
Nr of runs	Single and Multi Pass		
Single/multi arc	Single	**Electrodes spacing [mm]**	n.a.
Oscillation	String	**Stick out [mm]**	10÷20

Notes	*Prepared:* Simone Scaini– Date: 01/08/2017 CIWE/IT/100114A
	Checked and approved: Gianluca Quaia – Date: 01/08/2017 CEWT/IT/30579

7.2 2017023-WPS-02

GENERAL					
WPS	02	Rev.	00	Date	01/08/2017
PQR	ISO-079	Code/ Spec.		EN 15614-1	
Welding process	136 (FCAW)	Automation grade		Partly Mechanized	

FILLER METAL / GAS							
Type	Flux cored wire	Brand	Bohler Ti 52 T-FD		Diameter [mm]	Ø 1.2	
Designation & Class.	EN ISO 17632-A T46 4 P M 1 H5						
Protection gas	EN ISO 14175 M21-ArC-20 (80Ar-20CO_2)		Nozzle [mm]	12÷16	Gas flow [l/min]	16÷22	
Backing gas	No						

BASE METAL TYPE AND THICKNESS				
Type and grade	EN 10025-2÷4 : S355÷S460 (JR,J0,J2,K2,N,NL, ML)		Group	1.2÷2.1
Thickness	Butt weld		Fillet weld	
	T –base metal [mm]	n.a.	*T – base metal [mm]*	≥ 5
	t – weld metal [mm]	n.a.	*a – throat thickness [mm]*	See welding param.

WELDING PARAMETERS								
Throat (Layer)	Position	Process	Diameter	Current	Voltage	Current tp.	Travel speed	Heat input
[mm]	-	-	[mm]	[A]	[V]	-	[mm/min]	[kJ/mm]
5 (1)	PF	136	1.2	225÷245	24÷26	DC EP	230÷270	0.96÷1.33
6 (1)	PF	136	1.2	235÷255	23÷25	DC EP	150÷180	1.44÷2.04
MP (1÷N)	PF	136	1.2	220÷240	23÷25	DC EP	240÷300	0.81÷1.20

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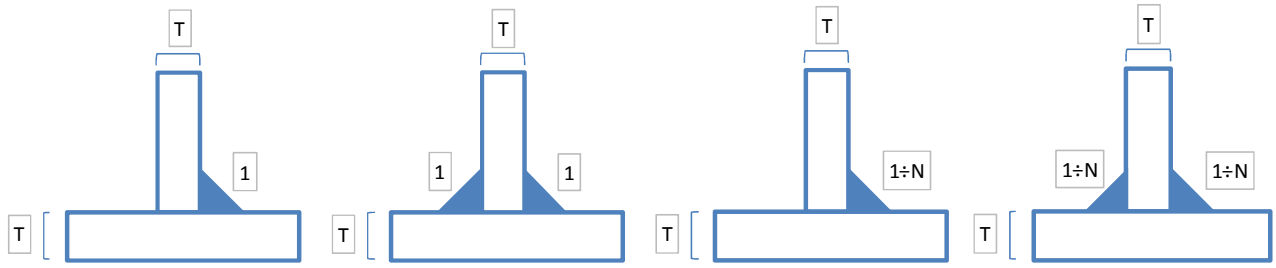

PREHEAT / INTERPASS / PWHT					
Min preheat	80° C			Max interpass	200 °C
PWHT	No	Temperature	-	Holding time (hrs)	-

TECHNIQUE			
Joint type	Fillet weld	Preparation	thermal cut, grinding or machining
Cleaning	Grinding and Brushing	Back gouging	Not applicable
Nr of runs	Single and Multi Pass		
Single/multi arc	Single	Electrodes spacing [mm]	n.a.
Oscillation	String	Stick out [mm]	10÷20

Notes	*Prepared:* Simone Scaini– Date: 01/08/2017 CIWE/IT/100114A
	Checked and approved: Gianluca Quaia – Date: 01/08/2017 CEWT/IT/30579

7.3 2017023-WPS-03

GENERAL					
WPS	03	**Rev.**	00	**Date**	01/08/2017
PQR	ISO-056 ; ISO-058		**Code/ Spec.**	EN 15614-1	
Welding process	135-S (GMAW-spray arc)		**Automation grade**	Partly Mechanized	

FILLER METAL / GAS							
Type	Solid wire	**Brand**	Lincoln Supramig Hd	**Diameter [mm]**	Ø 1.2		
Designation & Class.	EN ISO 14341-A G46 4 M 3Si1						
Protection gas	EN ISO 14175 M21-ArC-20 (80Ar-20CO_2)		**Nozzle [mm]**	12÷16	**Gas flow [l/min]**	16÷22	
Backing gas	No						

BASE METAL TYPE AND THICKNESS				
Type and grade	EN 10025-2÷4 : S355÷S460 (JR,J0,J2,K2,N,NL, ML)		**Group**	1.2÷2.1
Thickness	**Butt weld**		**Fillet weld**	
	T –base metal [mm]	12.5÷200	***T – base metal [mm]***	n.a.
	t – weld metal [mm]	12.5÷200	***a – throat thickness [mm]***	n.a.

WELDING PARAMETERS								
Runs	**Position**	**Process**	**Diameter**	**Current**	**Voltage**	**Current tp.**	**Travel speed**	**Heat input**
-	-	-	**[mm]**	**[A]**	**[V]**	-	**[mm/min]**	**[kJ/mm]**
1÷3; 1R÷3R	PA	135-S	1.2	285÷310	29÷32	DC+	250÷280	1.42÷1.90
4÷N; 4R÷NR	PA	135-S	1.2	275÷295	29÷31	DC+	300÷350	1.09÷1.46
Cap	PA	135-S	1.2	270÷290	29÷31	DC+	350÷410	0.92÷1.23

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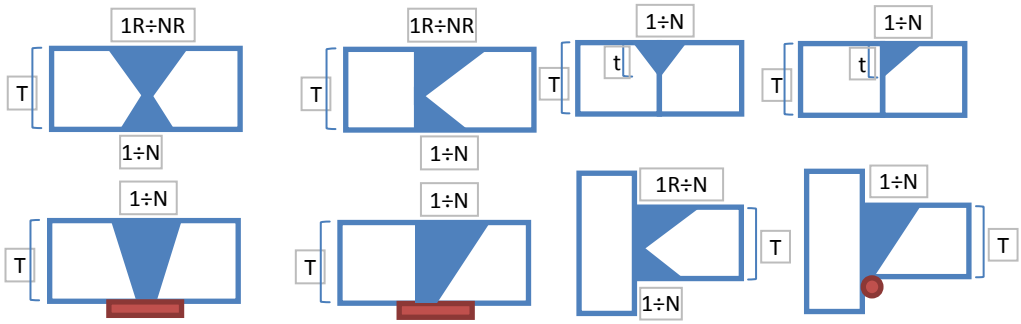

Actual dimensions and welding details are represented in the Fabrication Drawings issued for the job.

PREHEAT / INTERPASS / PWHT					
Min preheat	20 °C for 12,5 ≤ t ≤50mm; 60 °C for 50 < t ≤200mm			**Max interpass**	200 °C
PWHT	No	**Temperature**	-	**Holding time (hrs)**	-

TECHNIQUE			
Joint type	Groove weld	**Preparation**	thermal cut, grinding or machining
Cleaning	Grinding and Brushing	**Back gouging**	Arc-air/grinding (if applicabile)
Nr of runs	Multi Pass		
Single/multi arc	Single	**Electrodes spacing [mm]**	n.a.
Oscillation	String	**Stick out [mm]**	10÷20

Notes	*Prepared:* Simone Scaini– Date: 01/08/2017 CIWE/IT/100114A
	Checked and approved: Gianluca Quaia – Date: 01/08/2017 CEWT/IT/30579

7.4 2017023-WPS-04

GENERAL					
WPS	04	**Rev.**	00	**Date**	01/08/2017
PQR	ISO-057	**Code/ Spec.**		EN 15614-1	
Welding process	136 (FCAW)	**Automation grade**		Partly Mechanized	

FILLER METAL / GAS							
Type	Flux cored wire	**Brand**	Bohler Ti 52 T-FD	**Diameter [mm]**	Ø 1.2		
Designation & Class.	EN ISO 17632-A T46 4 P M 1 H5						
Protection gas	EN ISO 14175 M21-ArC-20 (80Ar-20CO_2)	**Nozzle [mm]**	12÷16	**Gas flow [l/min]**	16÷22		
Backing gas	No						

BASE METAL TYPE AND THICKNESS				
Type and grade	EN 10025-2÷4 : S355÷S460 (JR,J0,J2,K2,N,NL, ML)		**Group**	1.2÷2.1
Thickness	**Butt weld**		**Fillet weld**	
	T –base metal [mm]	12.5÷50	***T – base metal [mm]***	n.a.
	t – weld metal [mm]	12.5÷50	***a – throat thickness [mm]***	n.a.

WELDING PARAMETERS								
Runs	**Position**	**Process**	**Diameter**	**Current**	**Voltage**	**Current tp.**	**Travel speed**	**Heat input**
-	-	-	**[mm]**	**[A]**	**[V]**	-	**[mm/min]**	**[kJ/mm]**
1÷4; 1R÷4R	PC	136	1.2	280÷295	29÷30	DC EP	220÷265	1.47÷1.93
5÷N; 5R÷NR				260÷280	27÷29	DC EP	360÷410	0.82÷1.08
Cap				210÷230	25÷27	DC EP	300÷340	0.74÷0.99
1÷6; 1R÷6R	PF	136	1.2	220÷230	27÷28	DC EP	150÷180	1.58÷2.06
7÷N; 7R÷NR				190÷210	27÷28	DC EP	110÷125	1.97÷2.57
Cap				160÷180	24÷25	DC EP	220÷250	0.74÷0.98

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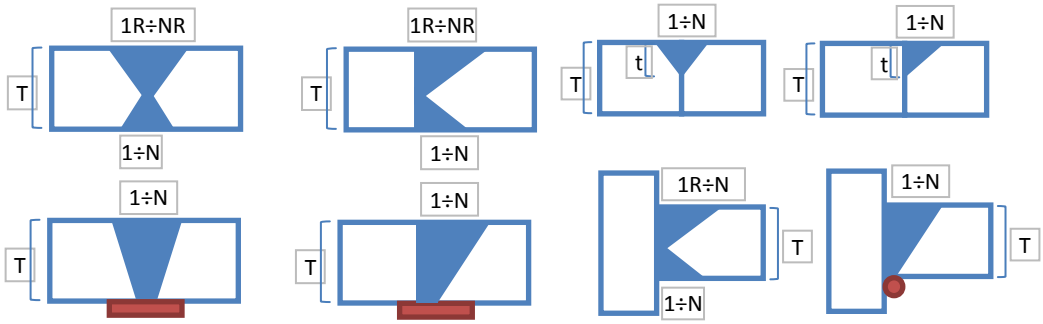

Actual dimensions and welding details are represented in the Fabrication Drawings issued for the job.

PREHEAT / INTERPASS / PWHT					
Min preheat	20 °C			**Max interpass**	200 °C
PWHT	No	**Temperature**	-	**Holding time (hrs)**	-

TECHNIQUE			
Joint type	Groove weld	**Preparation**	thermal cut, grinding or machining
Cleaning	Grinding and Brushing	**Back gouging**	Arc-air/grinding (if applicabile)
Nr of runs	Multi Pass		
Single/multi arc	Single	**Electrodes spacing [mm]**	n.a.
Oscillation	String	**Stick out [mm]**	10÷20

Notes	*Prepared:* Simone Scaini– Date: 01/08/2017 CIWE/IT/100114A
	Checked and approved: Gianluca Quaia – Date: 01/08/2017 CEWT/IT/30579

7.5 2017023-WPS-05

GENERAL					
WPS	05	**Rev.**	00	**Date**	01/08/2017
PQR	ISO-085; ISO-086		**Code/ Spec.**	EN 15614-1	
Welding process	121 + 121 Tandem		**Automation grade**	Fully mechanized	

FILLER METAL / GAS		
Type	Wire – Flux combination	
	Wire	**Flux**
Brand	OE-SD3 1 Ni 1/4 Mo	OP121TT
Dimensions [mm[	Ø 4	N.A.
Designation & Class.	EN ISO 14171-A: SZ	EN ISO 14174 SA FB 1 55 AC H5

BASE METAL TYPE AND THICKNESS				
Type and grade	EN 10025-2÷4 : S355÷S460 (JR,J0,J2,K2,N,NL, ML)		**Group**	1.2÷2.1
Thickness	**Butt weld**		**Fillet weld**	
	T –base metal [mm]	12.5÷200	***T – base metal [mm]***	n.a.
	t – weld metal [mm]	12.5÷200	***a – throat thickness [mm]***	n.a.

WELDING PARAMETERS									
Runs	**Position**	**Process**	**Diameter**		**Current**	**Voltage**	**Current tp.**	**Travel speed**	**Heat input**
-	-	-	**[mm]**		**[A]**	**[V]**	-	**[mm/min]**	**[kJ/mm]**
1÷4 1R÷4R	PA	121	4.0		520÷560	28÷30	DC EP	550÷620	1.41÷1.83
5÷N 5R÷NR	PA	121 Tandem	Lead Trail	4.0 4.0	560÷600 580÷650	29÷31 34÷35	DC EP AC-SW	800÷900	2.39÷3.11

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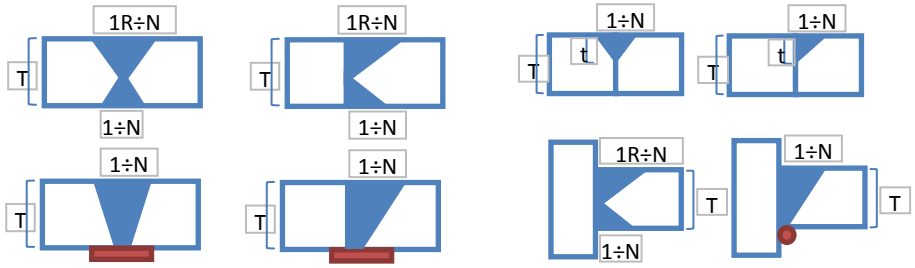

Actual dimensions and welding details are represented in the Fabrication Drawings issued for the job.

PREHEAT / INTERPASS / PWHT					
Min preheat	100 °C for t ≤ 100 mm / 125 °C for t > 100 mm			**Max interpass**	200 °C
PWHT	No	**Temperature**	-	**Holding time (hrs)**	-

TECHNIQUE			
Joint type	Groove weld	**Preparation**	Thermal cut, grinding, machining
Cleaning	Grinding and Brushing	**Back gouging**	Arc-air/grinding (if applicabile)
Nr of runs	Multi Pass		
Single/multi arc	Single	**Electrodes spacing [mm]**	n.a.
Oscillation	String	**Stick out [mm]**	20÷30

Notes	*Prepared:* Simone Scaini– Date: 01/08/2017 CIWE/IT/100114A
	Checked and approved: Gianluca Quaia – Date: 01/08/2017 CEWT/IT/30579