ENSA (Grupo SEPI)

PORT TUBES & NN-BAR FRAME TO MONOLITH VESSEL WELDING ON FIELD

Critical Design Review

15/03/2021

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INTRODUCTION

The aim of this slideshow is to expose the ENSA work for the welding on site of components of the Monolith Port Blocks to the Vessel. The content of the slides will be:

- Definition of work team & schedule
- Definition of welding book
- Definition of chosen weld edge preparation, filler material and welding process.
- Definition of chosen backing gas method
- Definition of tolerances pre- and post-welding
- Definition of chosen NDT techniques
- Definition of optimal installation sequence
- Definition of mock-up activities
- Definition of risk mitigation

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INTRODUCTION

The scope of the works is under the contract 5EC8 and is focused in the welding of the 39 Port Tubes, the NN-Bar Frame and the Connection Pipe to the Monolith Vessel, works to be carried out on site at ESS' facilities in Lund, Sweden.

The scope of the ENSA works consist:

- Welding area preparation (installation of protections, checking and maintenance of cleanliness, preparation of welding tooling and backing gas).
- Welding of 39 Port Tubes + 1 NNBar Frame + 1 Connection Pipe.
- Non-destructive testing of the welds.
- Shape control after welding using a dummy.

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INTRODUCTION

Works must fulfill the next standards:

- Construction code: EN 13445
- Legal requirements: Directive 2014/68/EU (PED)
- Mechanical classification: Classification MQC4
- Welding procedures: EN ISO 15614-1
- Welds acceptance criteria: EN ISO 5817 (Class B)
- Welders qualification: EN ISO 9606-4/ EN ISO 14732
- Visual testing (VT): EN ISO 17637/ EN ISO 23277
- Dye penetrant test (PT): EN ISO 3452-1/ EN ISO 5817 (Level B)
- Radiographic Test (RT): EN ISO 17636-1 (Class B) / EN ISO 10675-1 (Level 1) / EN ISO 19232-3 (Class A)

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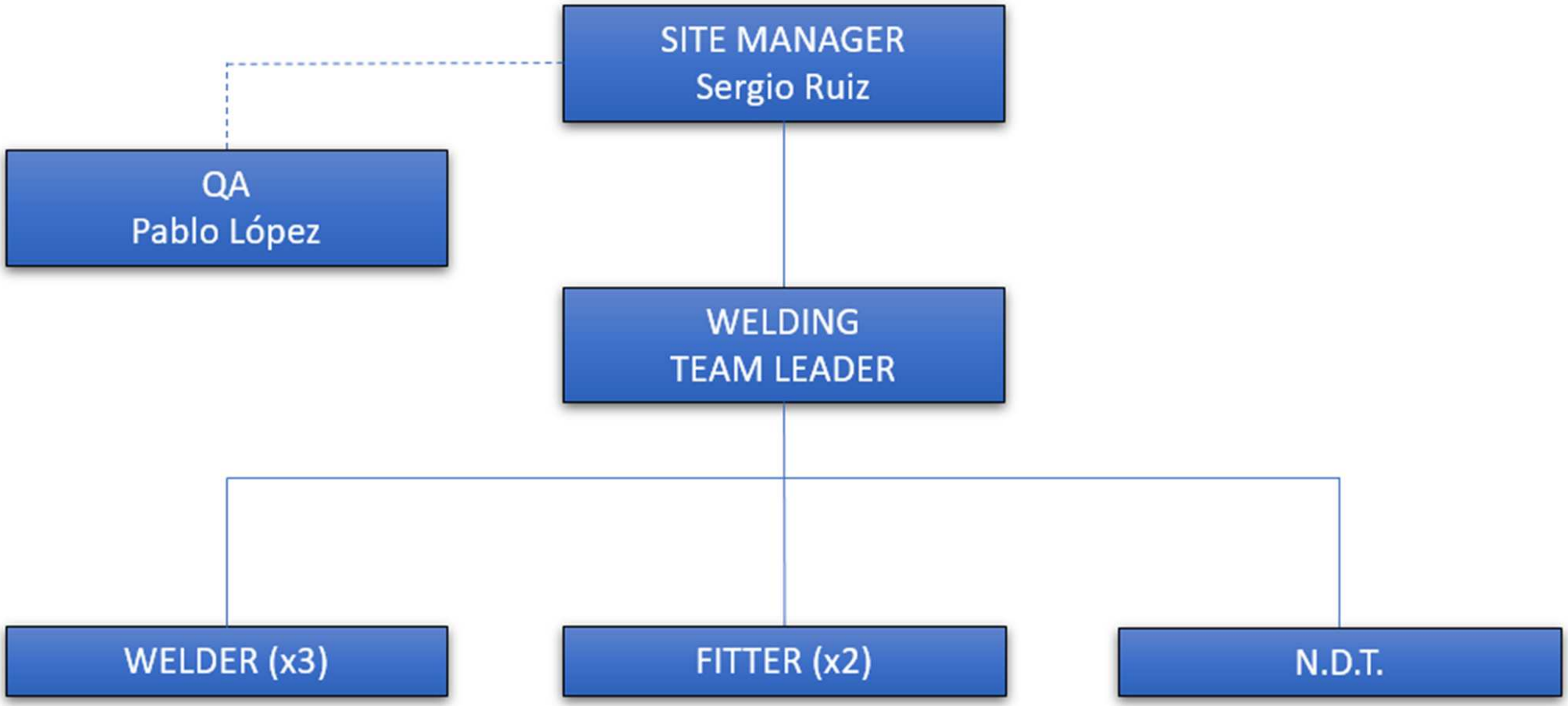
WORK TEAM CHART



- Ensa's working hours will be 8 h/day, 5 days a week.
- The schedule for develop all the project will be 2 months.

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WELDING BOOK

Welding Book is the document that encompasses all the information to better understand the intended performance of welding works. Within this document it is included:

- Procedure Qualification Report, PQR. *Ready for approval*
- Welding Procedure Specification, WPS. *Ready for approval*
- Welding Map, WM (drawing with welds location, geometry and tests). *Ready for approval*
- Welders Performance Qualification Report, WPQR.

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WELDING BOOK

PROTOKOLL FRÅN PROCEDURKVALIFICERING (WPQR)
WELDING PROCEDURE QUALIFICATION, TEST CERTIFICATE (WPQR)

ÅF-KONTROLL

SWEDAC ACKREDITERING 4390 EN 45 004 (A)

WPQR-nr/WPQR No.	Referens nr/Reference No	Uppdragsnr/Comm. No.	Sida/Page
012	ÅFS/575	200111	3(3)

Provningsresultat/Test results

Visuell inspektion Visual examination	Enligt krav /Acceptable	Radiografisk provning* Radiography*	Enligt krav /Acceptable
Penetrant, magnetpulverprovning* Penetrant, magnetic particle test*	Enligt krav /Acceptable	Ultraljudprovning* Ultrasonic*	-

Dragprovning/Tensile Tests: EN 895 Temperatur/Temperature: +20 °C

Typ nr/Type No	Rp0,2 N/mm²	Rm N/mm²	A %	Z %	Brottställe Fracture location	Anmärkning Remarks
Fordran Requirement		Min 485				
T1, T2	-	597, 605			Base metal/Base metal	

Bockprovning/Bend Tests: EN 910 Dorndiameter/Former Diameter: 40 mm

Typ nummer/Type No.	Bockningsvinkel/Bend angle	Förlängning*/Elongation*	Resultat/Results
FB-1	180°		Enligt krav /Acceptable
RB-1	180°		Enligt krav /Acceptable
FB-2	180°		Enligt krav /Acceptable
RB-2	180°		Enligt krav /Acceptable

Slagprovning*/ Impact Test*: NA — Typ/ Type: — Storlek/ Size: — Fordran/ Requirement:

Anv. läge/riktning Notch locations/directions	Temperatur °C Temperature °C	Värden Values 1	2	3	Medelvärde Average	Anmärkning Remarks

Hårdhetsprovning*/Hardness Test*: NA

		Mätpunkternas lägen (skiss) * Location of measurements (sketch)*
Typ/Provkraft Type/Load		
Grundmaterial Parent material		
HAZ HAZ		
Svetsgods Weld metal		
Anmärkningar Remarks		

Makroundersökning/Macro examination: ☒ Enligt krav /Acceptable

Mikroundersökning/Micro examination: ☐

Proven utförda enligt fordringarna angivna i Test carried out in acc. with the requirements of	EN ISO 15614-1:2004
Laboratorierapport, referensnummer Laboratory report, reference No.	WR 3281, PT 4924, RT 8099, PM 11805, EM-6244
Provningsresultat Test results	Enligt krav /Acceptable
Proven utförda i närvaro av Test carried out in presence of	ÅF-Kontroll AB, Thomas Carlström

Granskarens namn, datum, signatur Examiner name, date and signature	ÅF-Kontroll AB, 2006-11-08, Karin Velander *Karin Velander*

* Om så erfordras/If required

WPQR rev. 0

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ensa

WPS NO. **5EC8WT201**

ESPECIFICACION DEL PROCEDIMIENTO DE SOLDADURA (WPS)
WELDING PROCEDURE SPECIFICATION (WPS)

PAG Nº / SHEET 1 / 3

REV. No. 02

EN ISO 15609-1

PQRs: WPQR-012, WPQR-010

PROYECTO / PROJECT	CLIENTE / CLIENT	COMPONENTE / COMPONENT	CONTRATO / CONTRACT	APLICACION / APPLICATION
ESS MONOLITH PORT TUBES WELDS ON FIELD	ESS BILBAO	NEUTRON PORT TUBE	5EC8	MANUFACTURE

WPS No. 5EC8WT201 — REV. No. 02 — DATE 25-1-2021

PROCESO/s DE SOLDADURA / WELDING PROCESS: 141 (EN ISO 4063)

TIPO (S) / TYPE (S): ☒ MANUAL / MANUAL — ☐ PARCIALMENTE MECANIZADO / PARTIALLY MECHANISED — ☐ AUTOMATICO / AUTOMATIC

OBJETO / SUBJECT

SOLDADURA ENTRE MATERIALES GR 8.1 MEDIANTE PROCESO 141 MANUAL
WELDS BETWEEN GR 8.1 BASE METALS BY MEANS OF 141 MANUAL PROCESS

JUNTA/ ASSEMBLY

DISEÑO DE LA JUNTA / JOINT DESIGN: SEE SKETCH IN PAGE 3 & NOTE 5 / Ver sketch y nota 5

RESPALDO / BACKING: ☒ SI / YES ☒ NO / NO

MATERIAL DEL RESPALDO / BACKING MATERIAL: BASE METAL OR WELD DEPOSIT (SEE NOTE 6) / Material base o soldadura (ver nota 6

METODO DE ELIMINACION DEL RESPALDO / BACKING ELMINATION METHOD: ☐ SI / YES ☒ NO / NO

☐ AMOLADO / GRINDING ☐ MECANIZADO / MACHINNING

PREPARACIÓN DE LA JUNTA, LIMPIEZA INICIAL Y ENTREPASADAS / METHOD OF GROOVE PREPARATION INITIAL AND INTERPASS CLEANING

☒ CEPILLADO / BRUSHING ☒ AMOLADO / GRINDING ☒ OTROS (MECANIZADO) / OTHER (MACHINING)

METAL BASE / BASE METAL

AGRUPAMIENTO Y ESPEC. DE MATERIAL BASE (s/ ISO/TR 15608) / BASE MATERIAL SPEC. & GROUPING (acc. to ISO/TR 15608 / 2000): Gr. 8.1 a/to Gr. 8.1

RANGO DE ESPESOR / THICKNESS RANGE
- MATERIAL BASE / BASE METAL: BW : 3-22 mm; FW : ≥ 5 mm
- DEPOSITO / WELD METAL: BW : 3-22mm; FW : no restriction / sin restricción

DIAMETRO / DIAMETER: (Ø>500 mm) &/or (Ø>150 mm PA/PC Rotating / rotando)

MATERIAL DE APORTE / FILLER METAL

MAT. DE APORTE / FILLER METAL: SI / YES ☒ NO / NO ☐

CLASIFICACION, FABRICANTE, NONBRE COMERCIAL... / CLASSIFICATION, MANUFACTURER, TRADE NAME...: EN 12072 / EN ISO 14343: G/W 19 12 3L (Note 4 / Nota 4)

FLUX CLAS., NOMBRE COMERCIAL... / FLUX (CLASSIF. TRADE NAME...): N. App.

FORMA DEL PRODUCTO DEL HILO (SOLIDO, TUBULAR...) / FILLER WIRE PRODUCT FORM (SOLID FLUX CORED....)

SOLIDO / SOLID ☒ TUBULAR / FLUX CORED ☐ METAL CORED / METAL CORED ☐

POSICION / POSITION (EN ISO 6947)

POSICION DE SOLDADURA / WELDING POSITION: All except PG & J-L045 / Todas excepto PG & J-L045

PROGRESION DE SOLDADURA / WELDING PROGRESSION: PF ☒ ASCEND. / UPWARD ☐ DESCEND. / DOWNWARD

OTROS / OTHER: N. App.

PRECALENTAMIENTO / PREHEATING

TEMP. DE PRECALENTAMIENTO / PREHEATING TEMPERATURE: Sin / Without (Nota 2 / Note 2)

TEMP. ENTRE PASADAS / INTERPASS TEMPERATURE: 140ºC max.

POST CALENTAMIENTO / POSTHEATING HYDROGEN BAKE: N. App.

TRATAMIENTO TERMICO / HEAT TREATMENT

RANGO DE TEMPERATURA / TEMPERATURE RANGE: N. App.

DURACION / TIME RANGE: N. App.

OTROS / OTHERS: N. App.

PQR and WPS ready for approval

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EDGE PREPARATION, FILLER MATERIAL AND WELDING PROCESS

Facing the welding of the components to the vessel, and considering the applicable contractual requirements, the recommendations and the requirements for the fabrication of the components, special attention has been taken on the next variables:

- Welding accessibility
- Environmental conditions
- Cleanliness
- Tolerances and distortions
- Not anchored equipment

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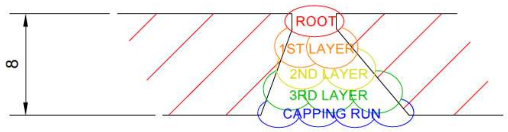
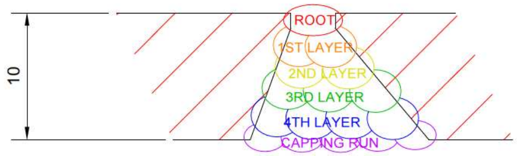
EDGE PREPARATION, FILLER MATERIAL AND WELDING PROCESS

Taking previous considerations, the selected parameters have been:

- Manual GTAW (TIG) as welding process
- Uncovered G 19 12 3L (316L / 1.4404) rod as filler material



Port Tube



NNBar

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EDGE PREPARATION, FILLER MATERIAL AND WELDING PROCESS

- **Low temperature** must be considered in the Welding Procedure Specification (**WPS**). Standard temperature use to be about 15 to 20ºC, but in Lund could descend below 0ºC; therefore, temperature range in WPS must be wider than usual. Moreover, local heating devices (i.e. air heaters) should be available on site.

- At least one **reparation cycle** has been considered in the documentation.

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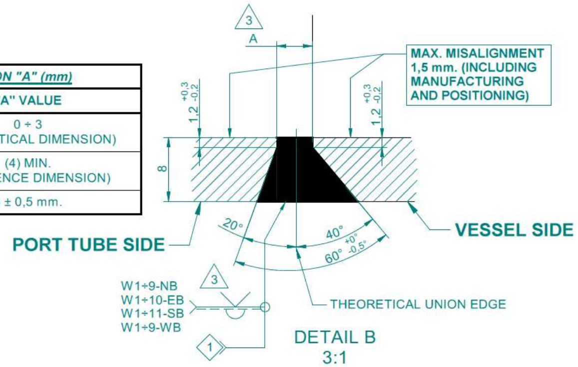
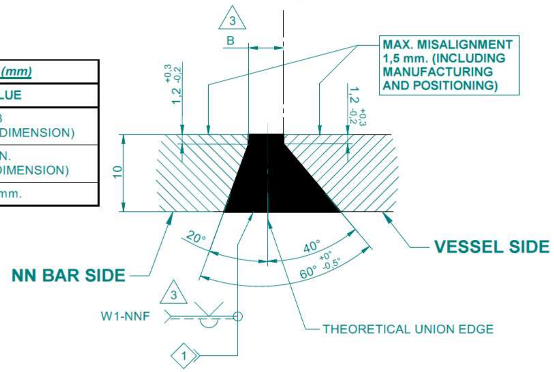
EDGE PREPARATION, FILLER MATERIAL AND WELDING PROCESS

- The design of the bevels must allow to have a good access to the welder that should have the best possible visual control of the work, that is why an **asymmetric weld edge preparation** has been chosen.

VALUES FOR DIMENSION "A" (mm)	
CONDITION	"A" VALUE
POST-WELD	0 ÷ 3 (THEORETICAL DIMENSION)
AFTER TACK-WELDING	(4) MIN. (REFERENCE DIMENSION)
AFTER ASSEMBLY	6 ± 0,5 mm.



ALUES FOR DIMENSION "B" (mm)	
CONDITION	"B" VALUE
POST-WELD	0 ÷ 3 (THEORETICAL DIMENSION)
AFTER TACK-WELDING	(4) MIN. (REFERENCE DIMENSION)
AFTER ASSEMBLY	6 ± 0,5 mm.



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EDGE PREPARATION, FILLER MATERIAL AND WELDING PROCESS

- **Argon as protective gas.** Argon supply is under the scope of ESS and shall meet the composition Ar 99,99% (Class I1 acc. to ISO 14175).

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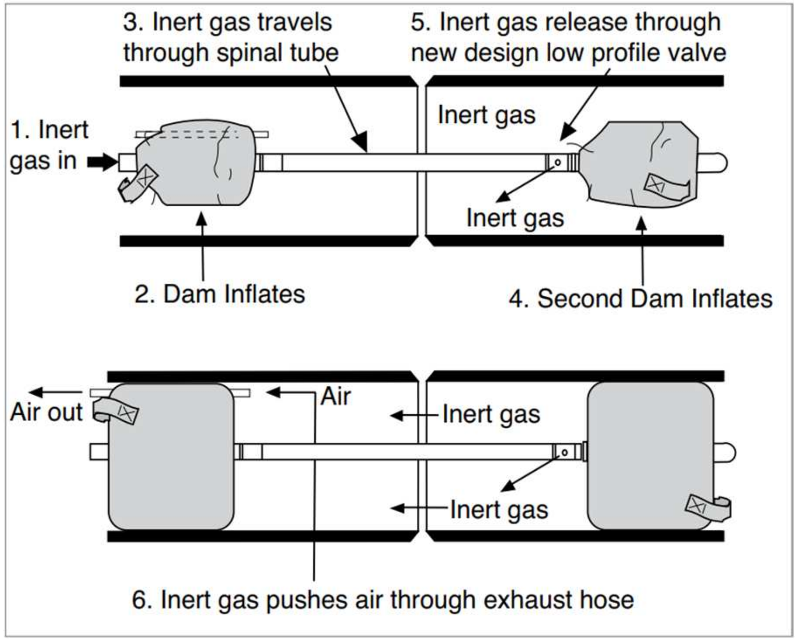
DEFINITION OF BACKING GAS METHOD

Connection pipe

Connection Pipe weld can be considered as a common pipe weld. The shielding gas must be confined by the inner part of the pipe while welding by the outer side.



– Weld purge plugs – Source: Huntingdon Fusion Techniques – HFT (https://www.lgtechniek.be/fileman/Uploads/Documents/Huntingdon/HFT.pdf)

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DEFINITION OF BACKING GAS METHOD

Port Tubes and NNBar

For the tack welding stage two devices has been developed (diffusers). They also can be used for small repairs (20-40mm).

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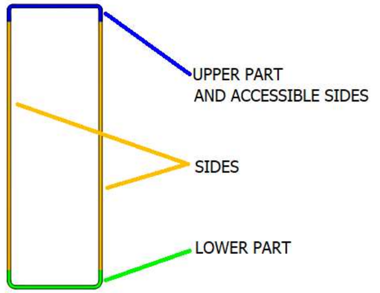
DEFINITION OF BACKING GAS METHOD

Port Tubes and NNBar



A) UPPER PART & DIRECT ACCESSIBLE SIDES
These areas are fully accessible. The system will be local (just need to install on the root side) and completely removable. Common means:

- Fiberglass tape
- Ceramic weld backing
- Welding glasses

B) SIDES – NO DIRECT ACCESS

Welds between two equipment. Adopted solution will be to confine the shielding gas by using modular enclosures. Completely removable.

- Fiberglass tape
- Welding glasses
- Rubber (NBR, EPDM, …) gaskets
- Inflatable hoses

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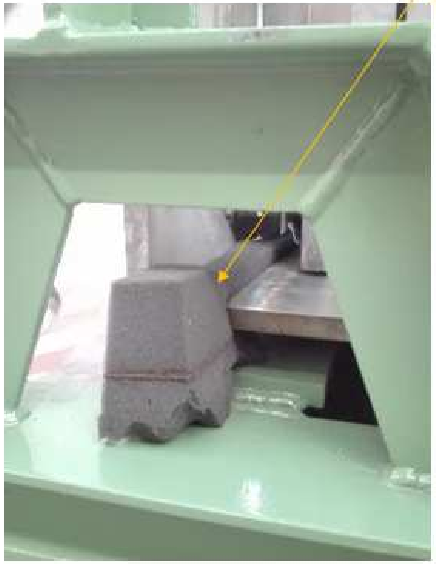
DEFINITION OF TOLERANCES PRE AND POST WELDING

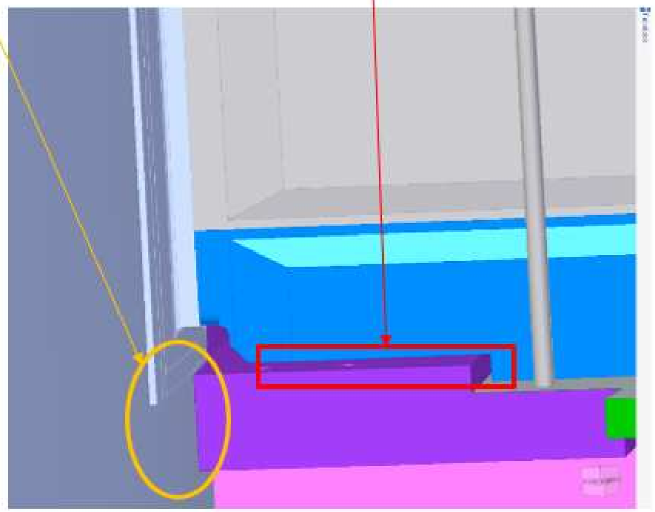
Port Tubes and NNBar

C) LOWER PART
No accessible areas. Adopted solution will be to confine the shielding gas by enclosing volumes near the welds. Some permanent parts will remain, materials will be agreed between parts.

- Fiberglass tape
- Rubber foam (NBR, EPDM, …)
- Inflatable hoses

Spongy material and neoprene rubber.

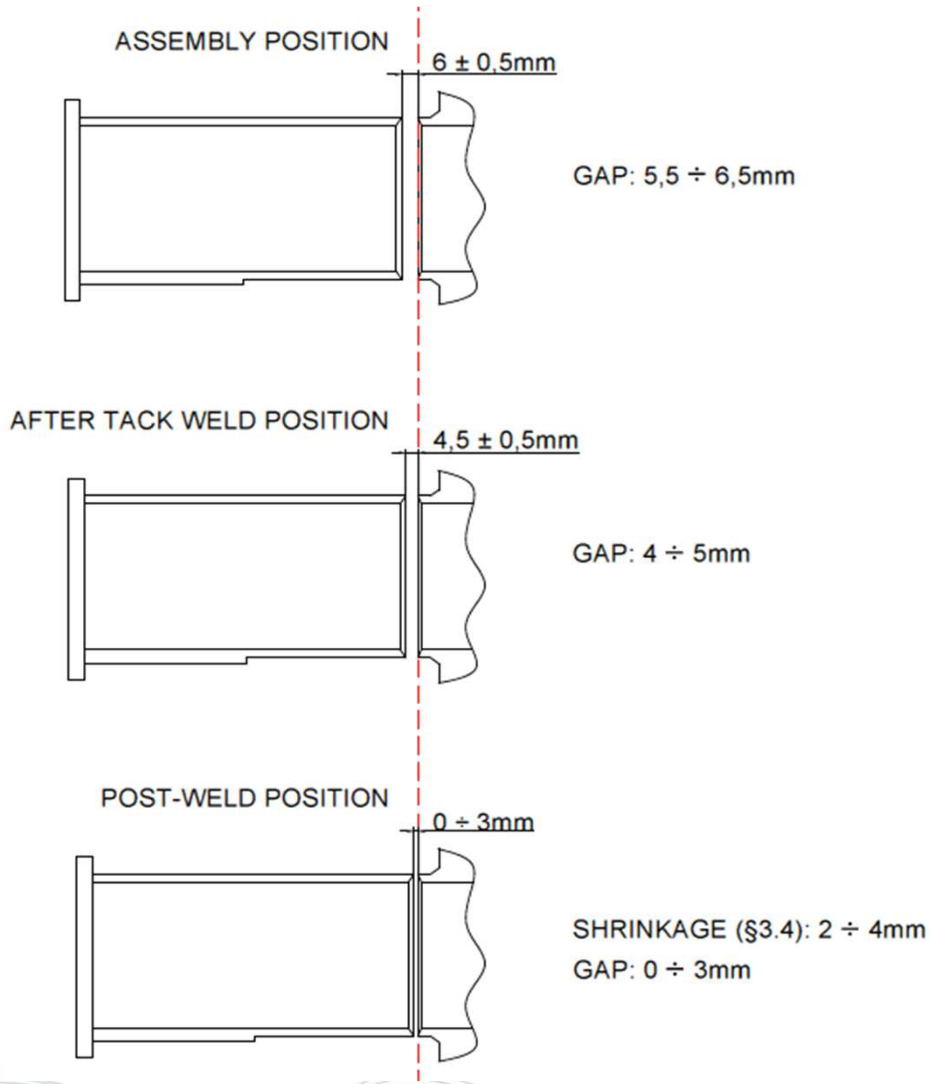




DEFINITION OF TOLERANCES PRE AND POST WELDING

Port Tubes and NNBar

Needed gap (space between weld edges) for welding is at least 4mm after tack welding.



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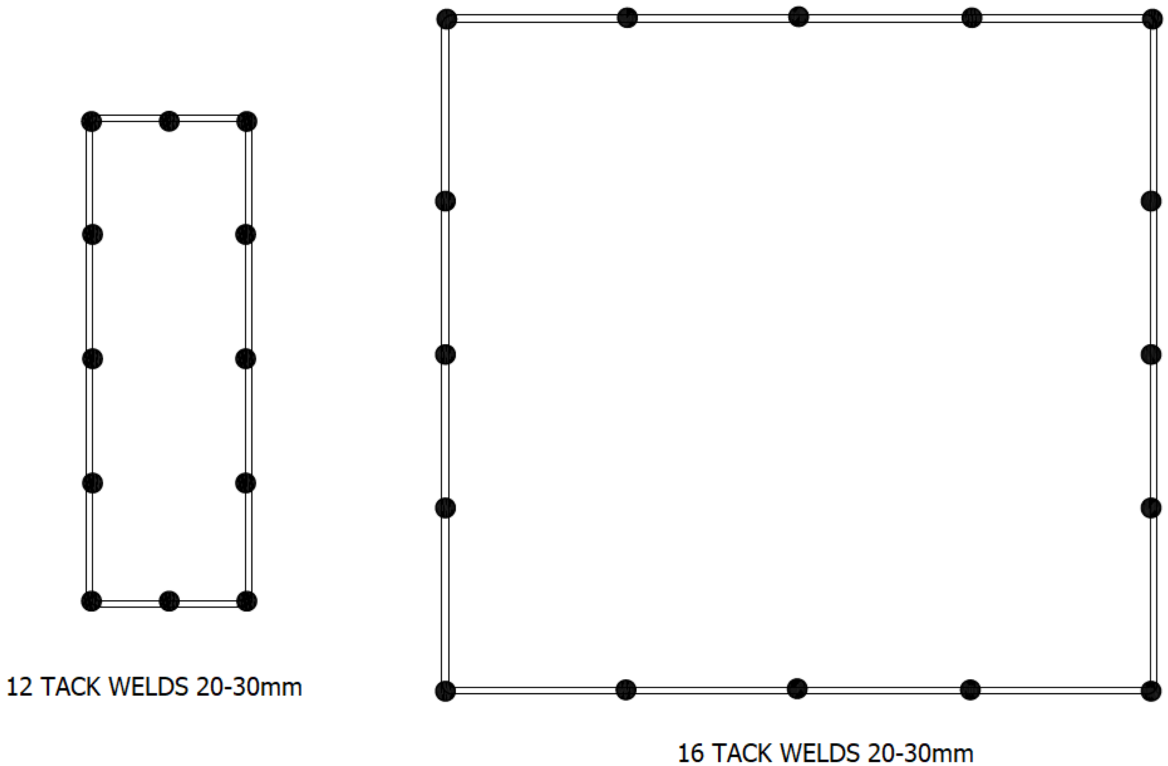
DEFINITION OF TOLERANCES PRE AND POST WELDING

Port Tubes and NN-Bar

- The next step will be to tack welding of the component to the vessel and, after re-checking the correct position, to fully weld the component.



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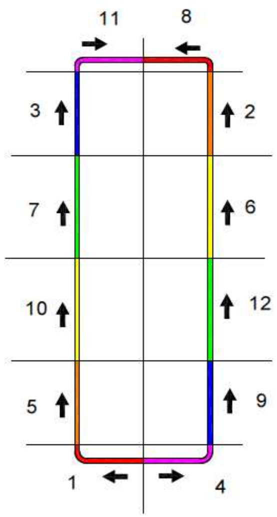
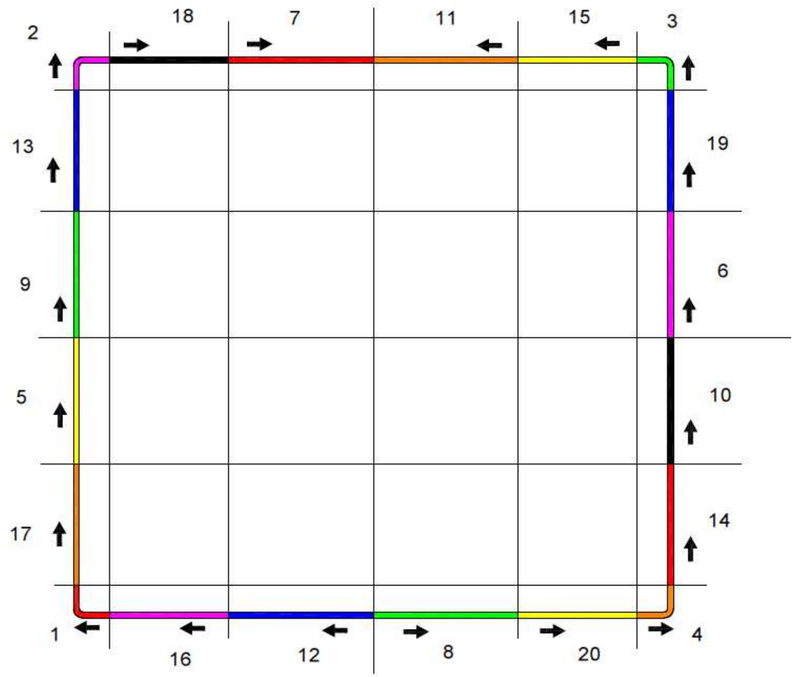
DEFINITION OF TOLERANCES PRE AND POST WELDING

Port Tubes and NN-Bar

- Low thickness of the weld will help to reduce distortions in the welding section. Based in previous experiences Ensa considers that expected local deformation in welding section is that the vertical welds will move away from the position before welding (sides will become wider) but required shape tolerance compared to the status before welding can be met



12 SECTORS 100-150mm



20 SECTORS 150-200mm

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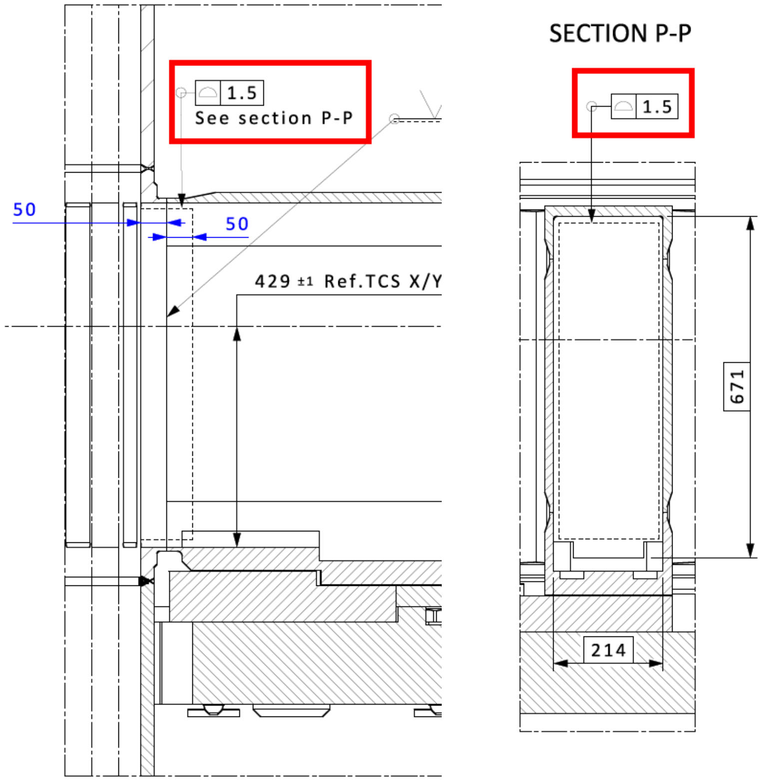
DEFINITION OF TOLERANCES PRE AND POST WELDING

Port Tubes and NN-Bar

Shape Tolerance (profile of the surface)



As this requirement exists for fabrication, this part of the Port Tube is machined at the very end of the fabrication and counting on that the weld edge preparation of the vessel will meet the requirement, no problems are expected to meet the request

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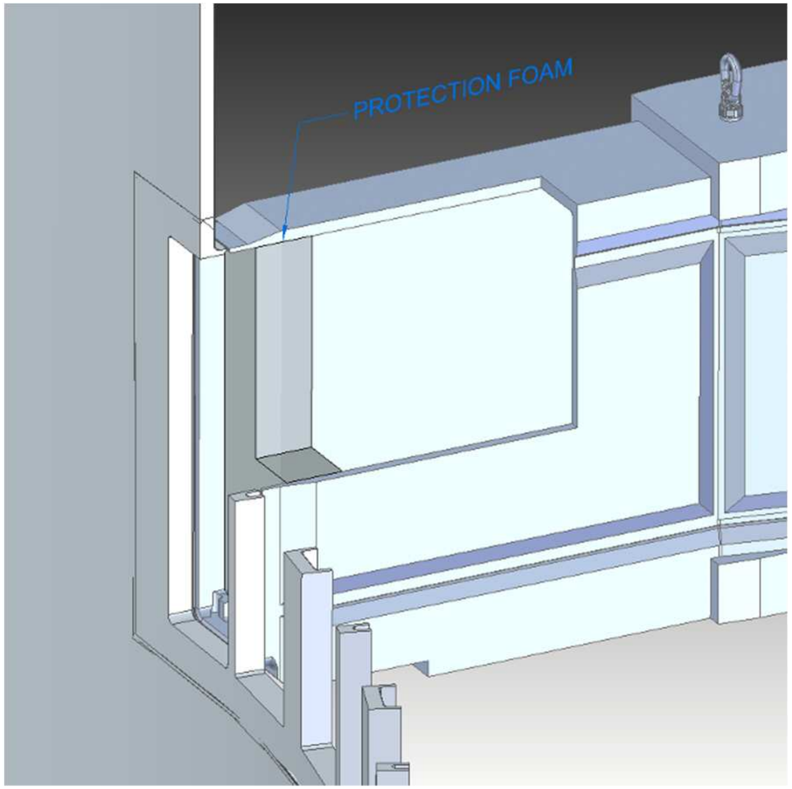
OPERATIONS RELATED WITH WELDING

Cleanliness during welding.



- The tooling for maintaining the cleanliness in the Port Tuber and NNBAR consist in a foam-body-shield that will be manually placed into the component from the extreme to be weld to the vessel and settled as close as possible to the edge but keeping in mind not to obstruct welding operations.
- For the vessel is required a protection before starting the welding works. Out of Ensa´s scope.

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OPERATIONS RELATED WITH WELDING

Grinding operations

- Grinding is a common and needed process for a proper examination and acceptable superficial quality of the welds. Despite GTAW (TIG) process is very clean and reduce the appearance of spatters, it is expected the necessity of grinding during and after welding in order to have a smooth transition between weld and base material and avoid areas that could obstruct the examination and generate a misinterpretation. Acceptance criteria for welds are given in EN ISO 5817, §Table 1.In case of any repair is needed, grinding is unavoidable.

- Considering the high level of cleanliness required in vacuum side of the components, it has been studied the way of impact as less as possible this requirement.

- Secondly to grind the welds by (nuclear industry) common means until the last surface finish pass, that should be soft ground according to the same soft grinding means referred in the Port Tubes instruction for the inner surface by the instructions that have been studied.

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OPERATIONS RELATED WITH WELDING

Grinding operations

Manual brushing

Electrical brushing

Soft grinding

Coarse grinding

The grinding operation will follow the next steps:

- 1º Coarse grinding to remove most of the material
- 2º Soft grindig for fine finishing
- 3º Electrical and manual brushing only for removing spatters

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OPERATIONS RELATED WITH WELDING

Repair plan

In case of detection of any rejectable indication on welds or base material after performing NDT, the reparation instructions to follow are:

Surficial defects on welds:

- Temporal marking and record (report) of the area.
- To grind the area to be repaired according to methods
- Complete weld thickness if necessary (reparation cycle #1)
- New performance of NDT

Internal defects on welds:

- Temporal marking and record (report) of the area.
- To grind the area to be repaired according to methods
- Complete weld thickness (reparation cycle #1)
- New performance of NDT

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DEFINITION OF NDTs METHODS

Examinations prior welding

- Meeting EN 13445-5, section §6.4.2, a **visual examination** shall be performed to the weld edge preparation of the components before welding operation.
- In the same case the Vessel and the Connection Pipe should have this test done before the positioning of the components.
- Additionally, 100% **dye penetrant test** will be performed on Port Tubes and NNBar Frame components at the very final stacke of the fabrication and before shipping, and Ensa recommends performing it on Vessel and Connection Pipe.

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DEFINITION OF NDTs METHODS

Examinations during and after welding:

Welds and adjacent areas shall have a proper surface finish that allow to carry out a proper examination. That means that grinding operations will be performed on the inner side of components in order to reach the best conditions for the examination.

During welding:

- VT and PT after root weld and where achievable. This is not a contractual requirement, but they will be performed as an in-process check.

After welding:

  - 100% VT by the weld surface side + where achievable by the root weld side*NOTE.
  - 100% PT by the weld surface side + where achievable by the root weld side.
  - RT inspection to an extent as high as possible, but at least 10% of the welding total length.

*NOTE: Additional checking with endoscope will be performed on the root side of the welds.

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DEFINITION OF INSTALLATION SEQUENCE

The Monolith Vessel's shell has a thickness of 25mm, and the thickness increases to 50mm in the windows where the components will be welded. Despite the welding thickness is 5 to 5mm (Acc. Pipe) 8 to 8mm (Port Tubes) and 10 to 10mm (NNBar) it must be considered that there are 41 components to weld all around to a stainless steel vessel and the risk of global distortion has to be studied because, amongst others, the equipment are floating.

Considering the Port Tubes and the NNBar, here lays the importance of an alternated welding sequence searching to reduce as much as possible accumulated tensions and heat provided to the components, searching as less distortion in components as possible.

For the works, 3 welders working simultaneously in 3 different ports have been considered.

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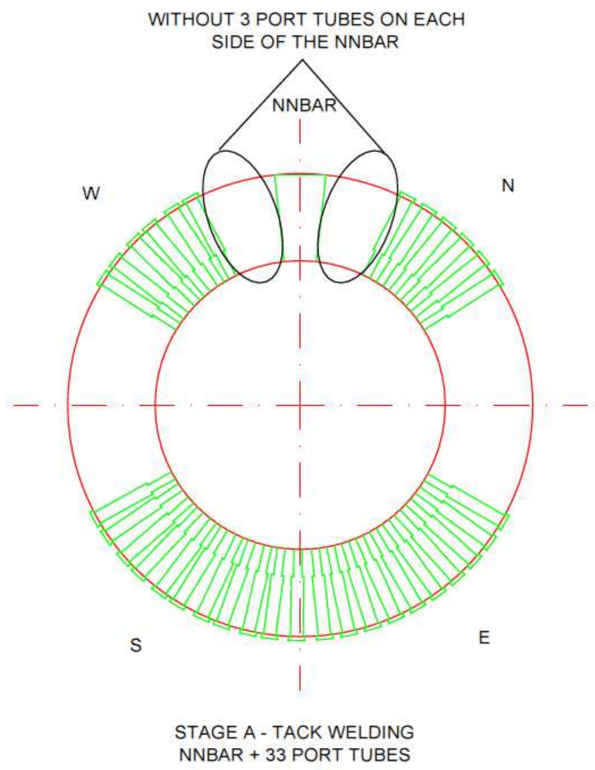
DEFINITION OF INSTALLATION SEQUENCE

A) To tack weld NNBar and 33 Port Tubes (all except the 6 neighbors to NNBar, see figure 16)



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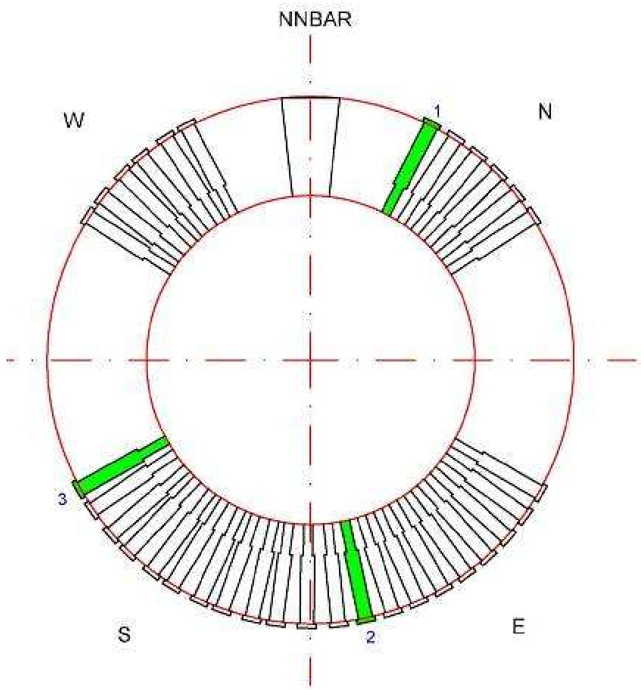
DEFINITION OF INSTALLATION SEQUENCE

B) To finish 15 Port Tubes previously tack welded.
In the figure 17 it is shown the proposed sequence. This sequence should be taken as an example, the final sequence should be agreed between Ensa and ESS.



STAGE B.1 - FULL WELDING
3 PORT TUBES

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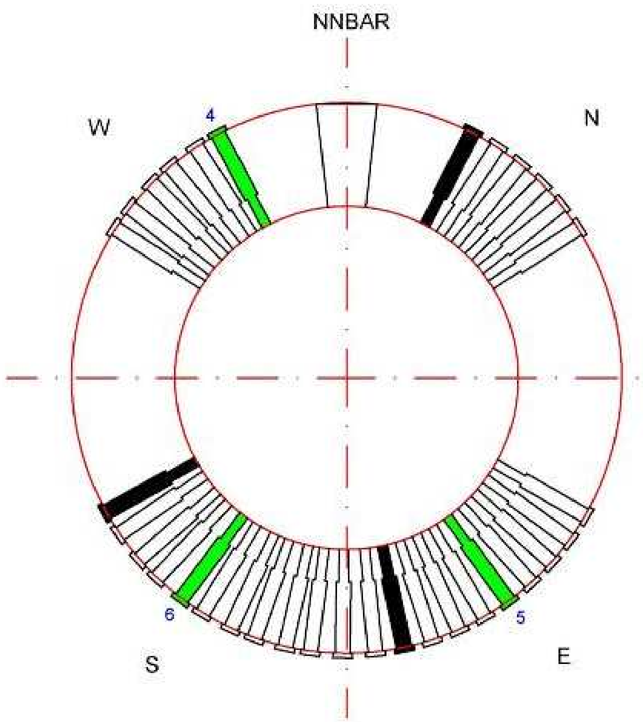
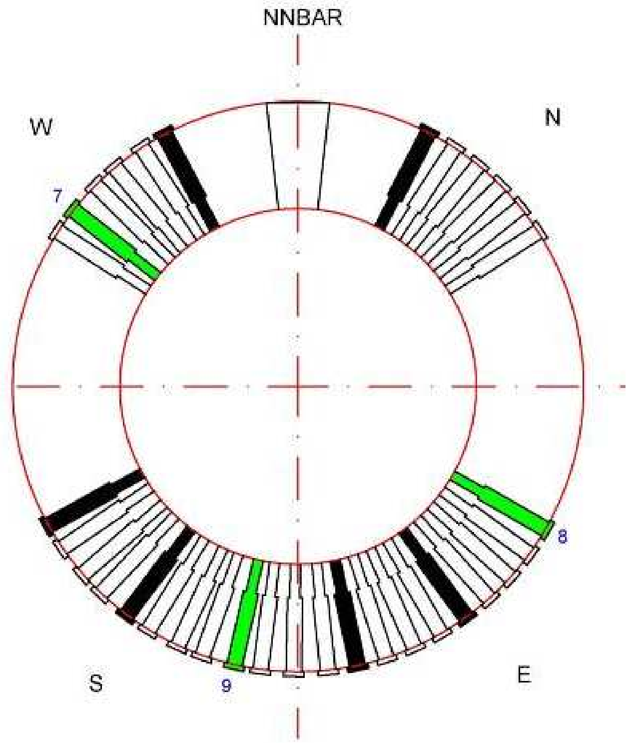
DEFINITION OF INSTALLATION SEQUENCE



STAGE B.2 - FULL WELDING
3 PORT TUBES



STAGE B.3 - FULL WELDING
3 PORT TUBES

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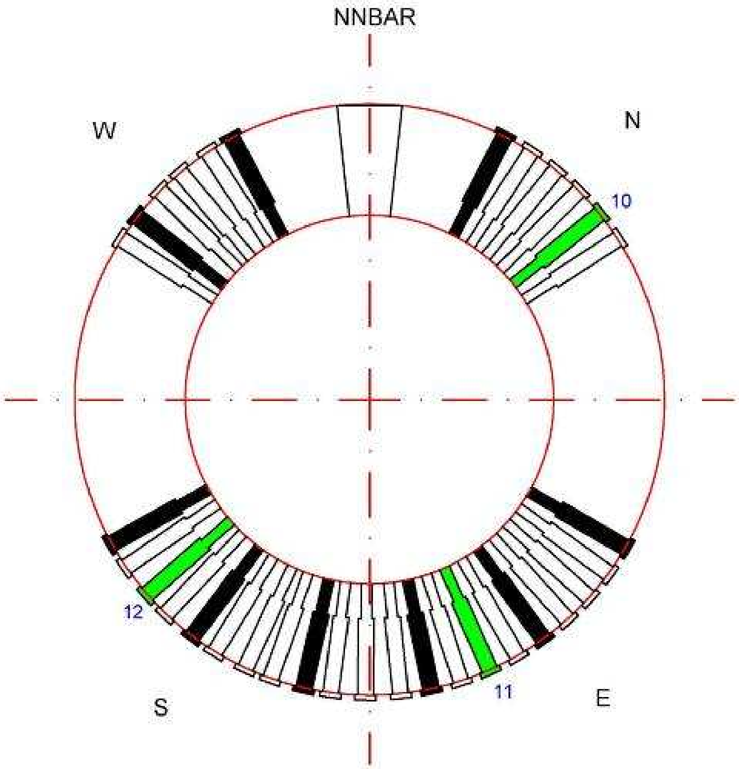
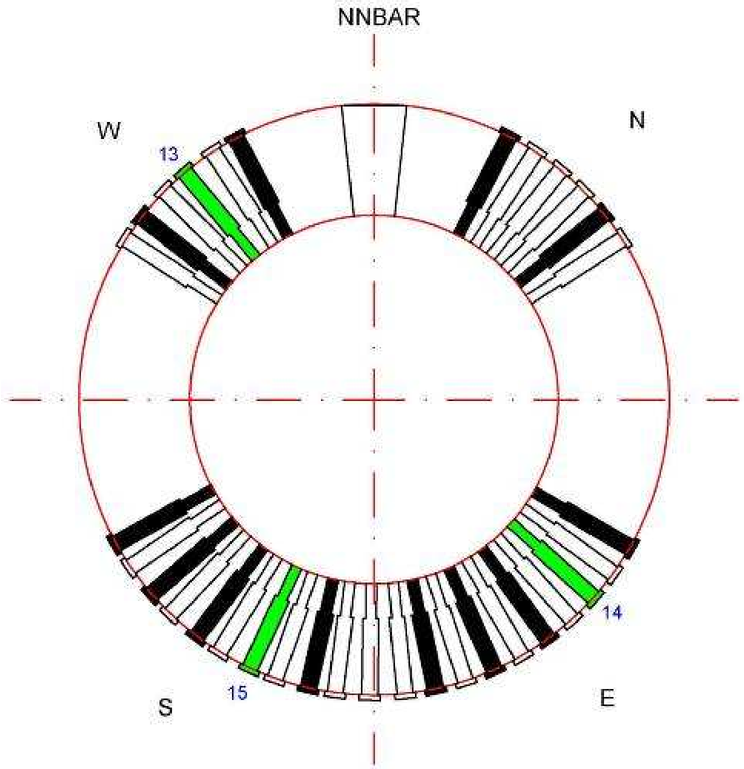


STAGE B.4 - FULL WELDING
3 PORT TUBES



STAGE B.5 - FULL WELDING
3 PORT TUBES

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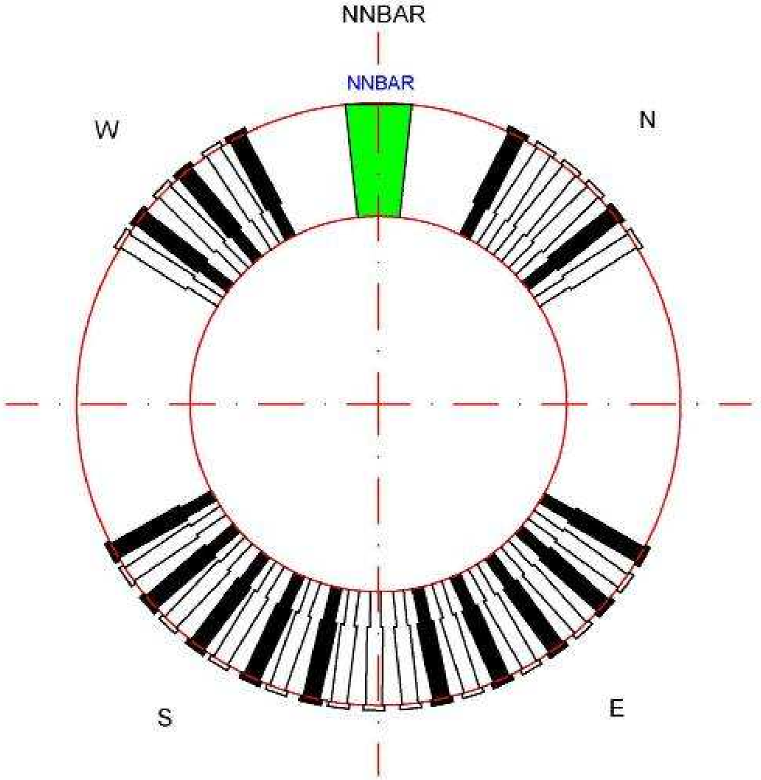
DEFINITION OF INSTALLATION SEQUENCE

C) To finish weld NNBar, including NDTs

Once 15 Port Tubes are completely welded a good position on the learning curve will have been reached. Next step is to fully weld NNBar and perform the NDTs to existent welds.



STAGE C - FULL WELDING
NNBAR + NDT TO NNBAR AND
ALREADY WELDED PORT TUBES

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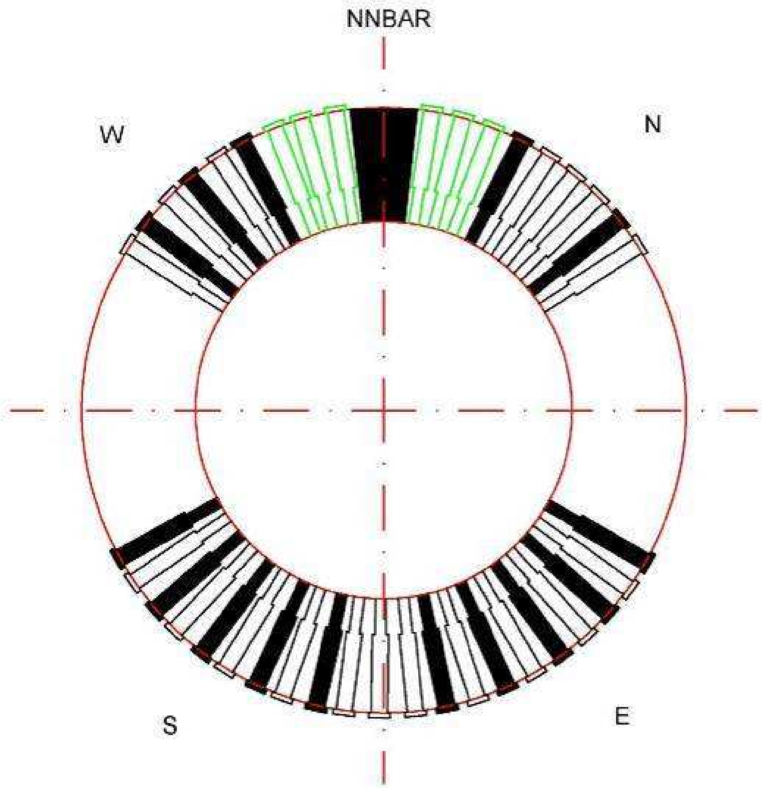
DEFINITION OF INSTALLATION SEQUENCE

D) To tack weld 6 remaining Port Tubes

After successful NDT's results on NNBar, the risk of lack of access for a repair due to closing the space near NNBar is reduced.



STAGE D - SPOT WELDING
REMAINING 6 PORT TUBES

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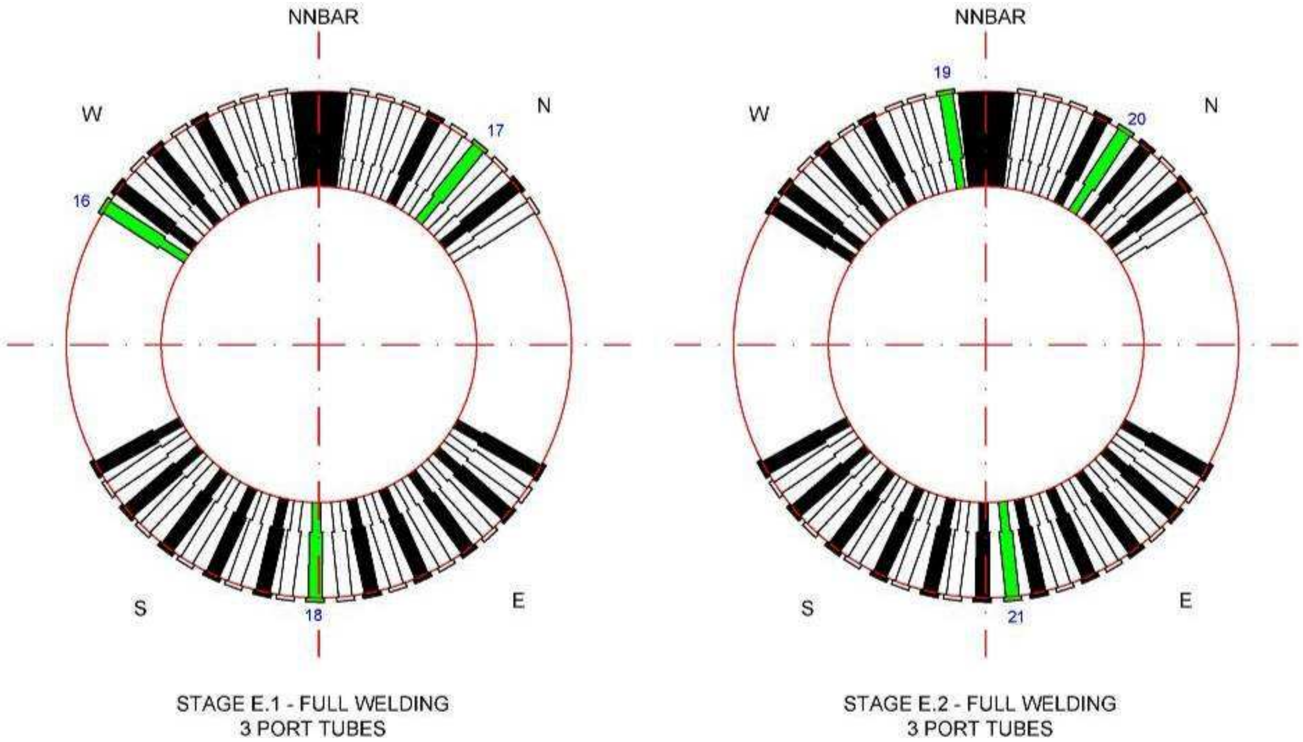
DEFINITION OF INSTALLATION SEQUENCE

E) To finish welding all the remaining Port Tubes
In this stacke the rest of Port Tubes can be also completely welded.



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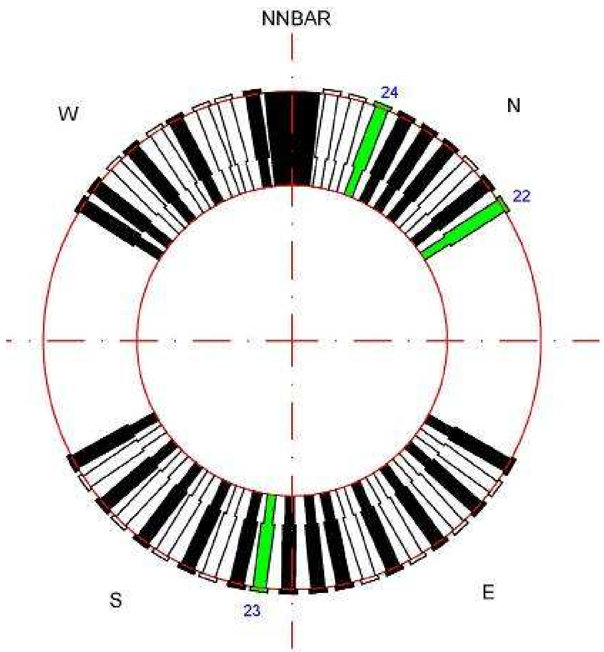
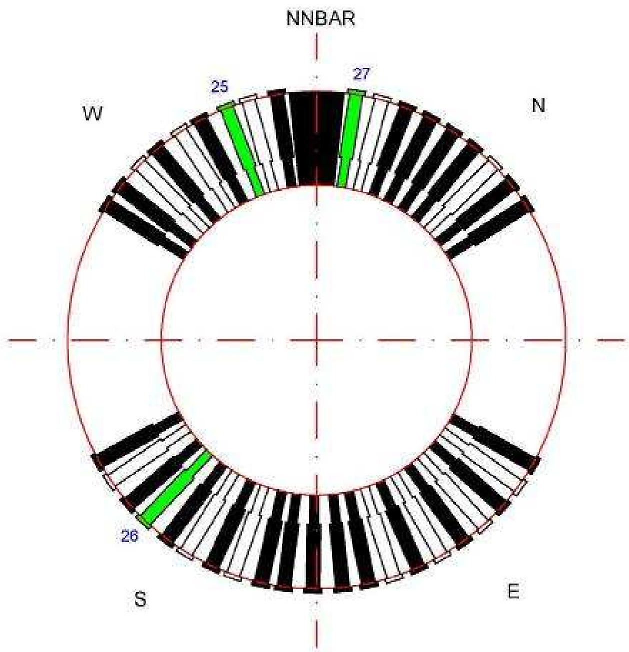
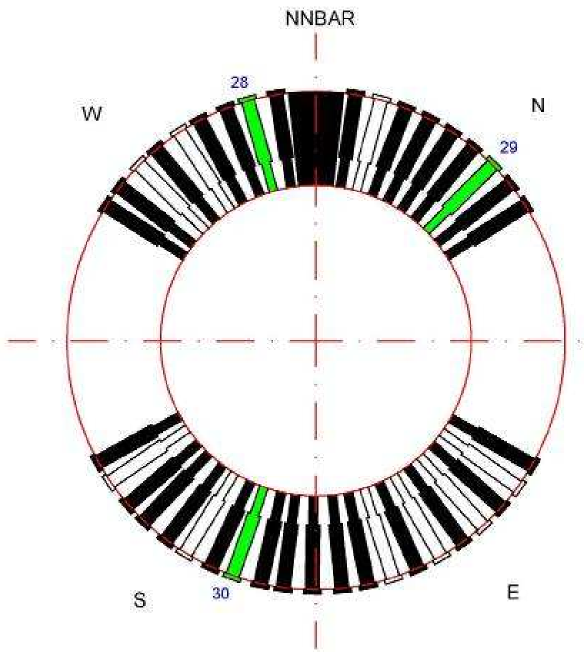


STAGE E.3 - FULL WELDING
3 PORT TUBES



STAGE E.4 - FULL WELDING
3 PORT TUBES



STAGE E.5 - FULL WELDING
3 PORT TUBES

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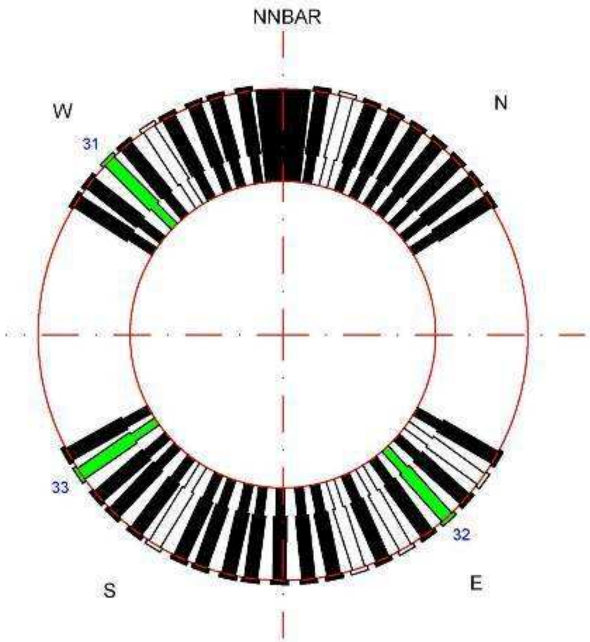
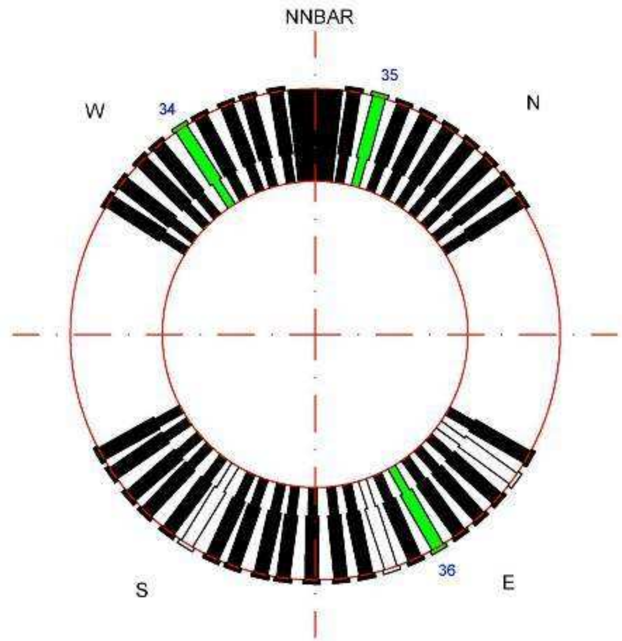
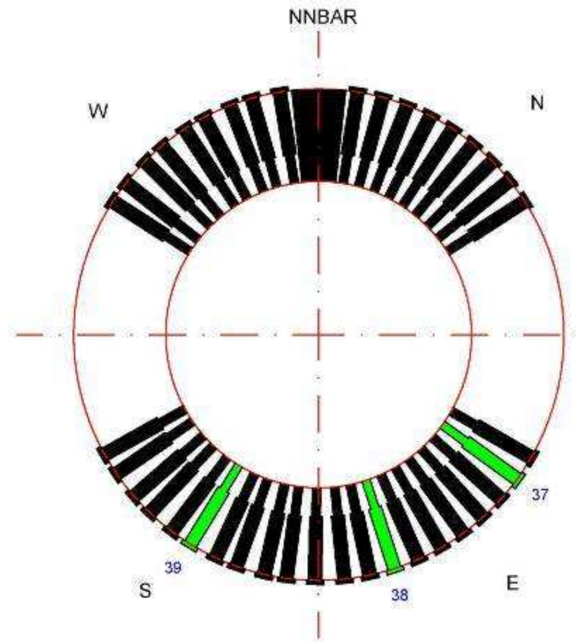
DEFINITION OF INSTALLATION SEQUENCE



STAGE E.6 - FULL WELDING
3 PORT TUBES



STAGE E.7 - FULL WELDING
3 PORT TUBES



STAGE E.8 - FULL WELDING
3 PORT TUBES

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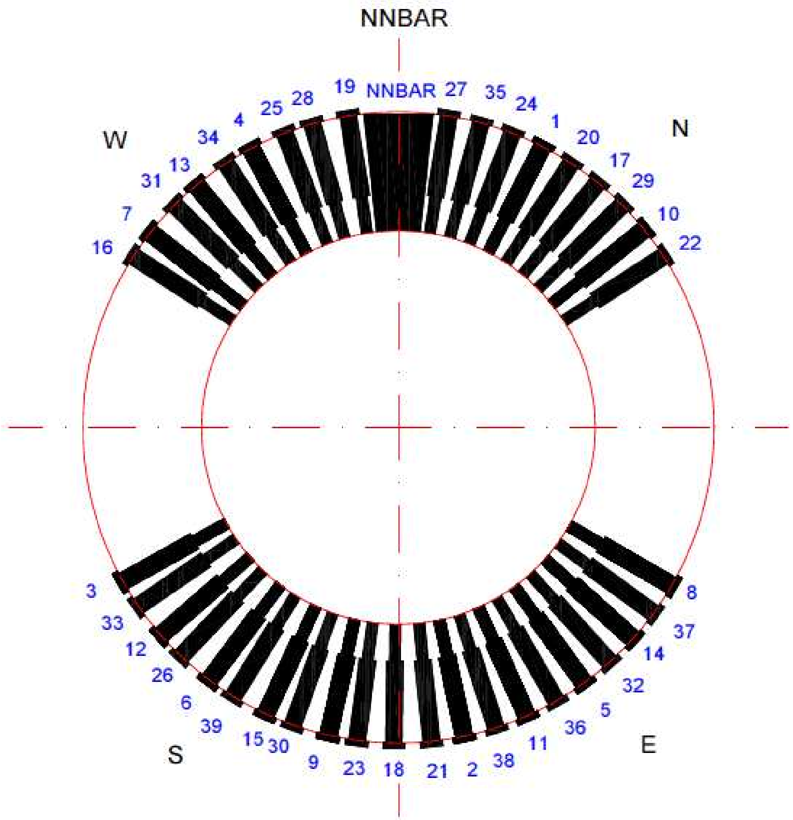
DEFINITION OF INSTALLATION SEQUENCE

Summary

Step	Operation	Ports
A	Tack weld 33 Port Tubes + NNBar	33 PT + NNBar
B	Complete weld of 15 Port Tubes	15 PT
C	Complete weld of NNBar	NNBar
D	Tack weld of remaining 6 Port Tubes	6 PT
E	Complete remaining welds	24 PT



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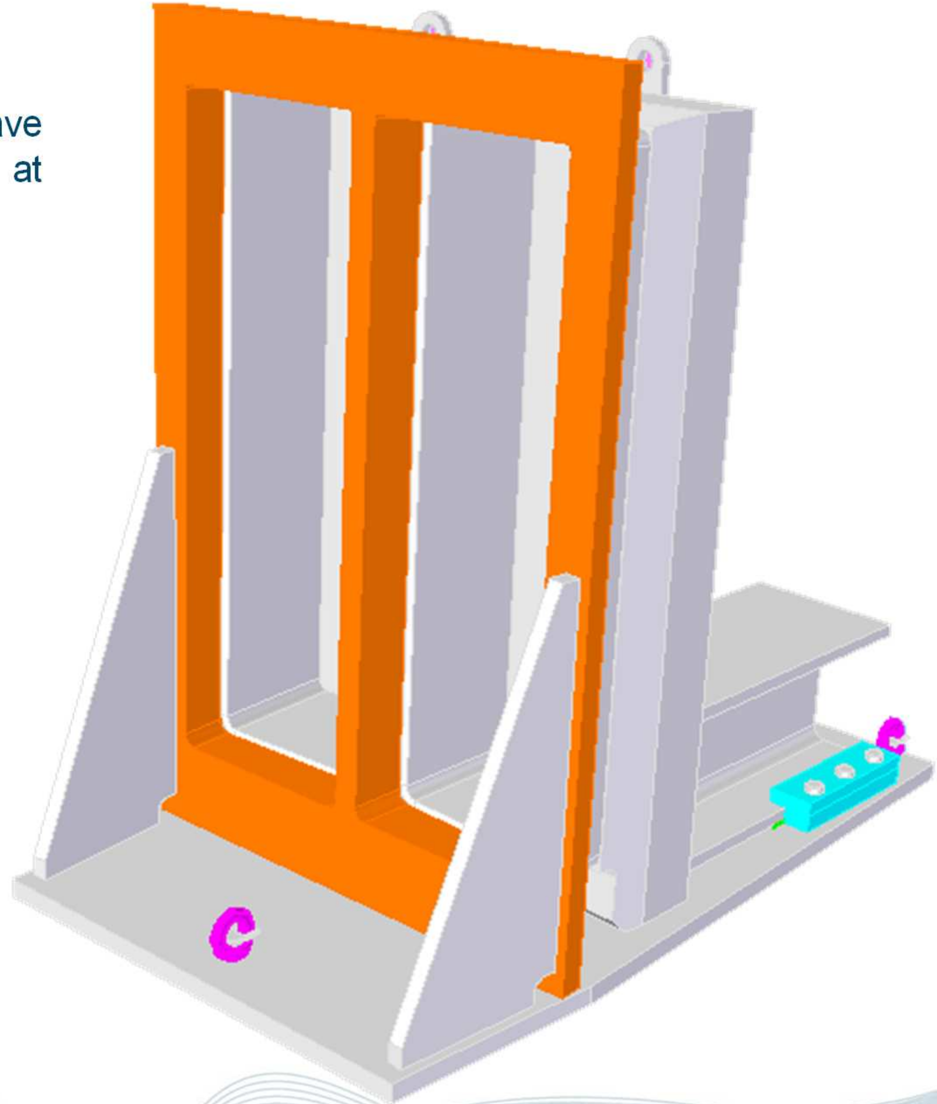
DEFINITION OF MOCK-UP

Mock-up 2

In this slides we present the works that have been carried out on the ESS' mock up at Ensa's facilities during December 2020.



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DEFINITION OF MOCK-UP

Mock-up 2

- While the root pass of the first window was being welded, the gap between edges decreased from 3,5 - 4,6mm to almost 0mm in the zones between existent spot welds. To mitigate this issue, for the second window (right) it was decided to increase the number of the tack welds to maintain a gap that allows introducing the welding rod and, therefore, ensure a proper penetration of the root pass.
- Also tack welds in the 4 corners are useful and provides a more rigid surface, obtaining less deformation.
- After analyzing of the values shows that increasing the number of tack welds means reducing shrinkage after the root pass, even when right window was not fully tack welded while root welding the left window.
- For the root pass of the right window the length of the sectors of each pass were reduced, action that helped to reduce the shrinkage value.

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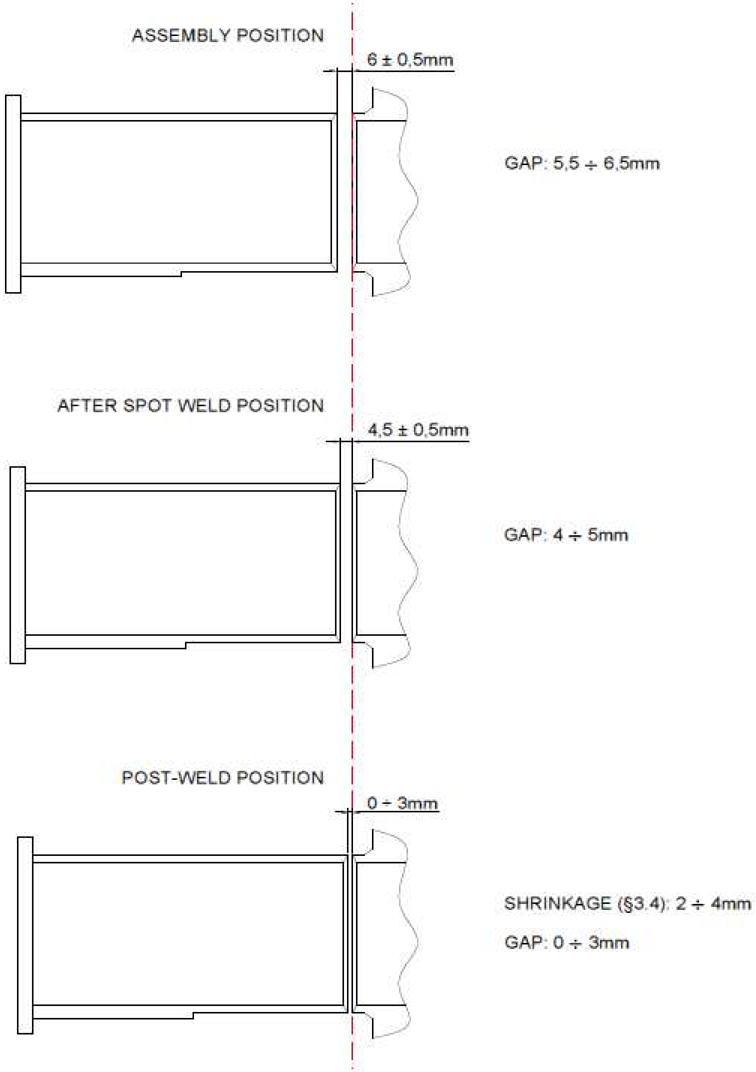
DEFINITION OF MOCK-UP

Mock-up 2

- Actual condition of welding free-to-move pieces reinforces the importance of keep a GAP between edges enough for inserting the TIG welding rod. After both windows root pass completion, Ensa considers that the value of the GAP after tack welding should be 4,5 ± 0,5mm. A GAP below 4mm impacts in the root penetration pass, increasing the welding time and amperage, causing the piece to absorb more heat, and consequently, more deformations. Welding drawings have been revised to include this information.

- After the completion of the Mock Up welding, and considering the use of welding wedges to control the relative movement between edges, Ensa considers that a forecasted shrinkage due to tack welds and to obtain a welding scenario with all the guarantees, the target GAP for the assembly stage could be 6 ± 0,5mm.

- In conclusion, obtained values of shrinkage in ESS Mock Up, due to the effect of the analyzed weld, are between 3 - 5mm. Ensa considers that by applying the improvements (more tacks, shorter weld-sectors and help of weld-wedges) the estimated shrinkage value, will be in a range of 2 - 4mm.



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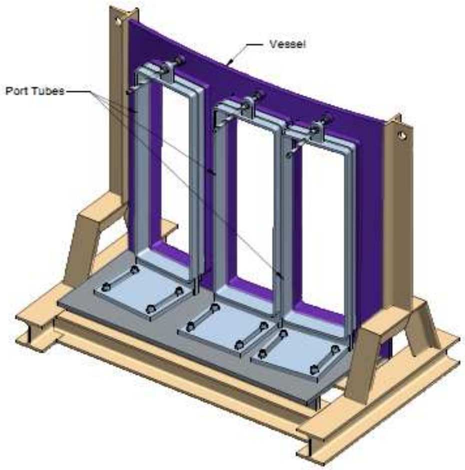
DEFINITION OF MOCK-UP

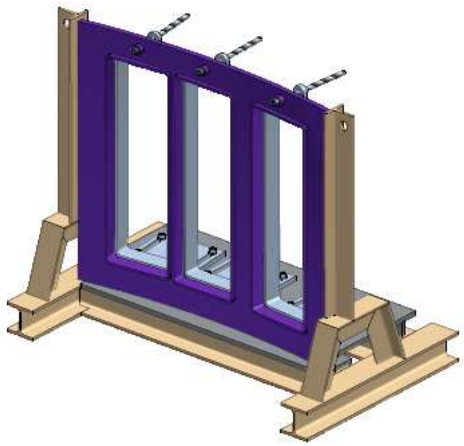
Mock-up 3

Due to the geometrical difficulties of the welding operations Ensa will fabricate a mock-up for:

- Training the backing gas system assembly.
- Checking the welders accessibility for achieving a good weld quality and a proper realization of the works.
- Checking the correct accessibility for the performance of proposed NDTs.

The mock up is made of standard 1.4404 material and consists in a model that represents 3 Port Tubes "Windows".





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DEFINITION OF RISK MITIGATION

		Risk description			Action Plan description	
Nr. #	**Category**	**As a result of...**	**There is a risk that...**	**Resulting in...**	**Description**	**Documents**
1	SITE	Adverse environmental conditions.	**Temperature, humidity, wind, lighting, ..., impacts on weld quality.**	Increase the possibility of repairs. Increase the schedule.	**Welding documentation shall foresee low temperatures. Provide local heating devices. Ask for enclosures for weather protection. Use of portable lamps to ensure sufficient lighting for the work.**	Welding table
2	SITE	Work organization.	**Hindrances in the workplace.**	Increase the schedule. More dificult accesses.	**Ask ESS for periodic information regarding the site conditions. Inform ESS about detailled working plan.**	Feasiblity study Open topics list
3	COMPONENT	Transportation / movement of equipment.	**Equipment weld edges can be damaged.**	Low quality of welds. Repairs.	**Protect weld edges after final machining. Perform NDT to weld edges before welding. Foresee repair of base material (grinding or welding build up)**	Welding table Inspection Points Plan
4	COMPONENT	Installation of equipment. Poor machining of weld edges.	**Misalignment of weld edges.**	Low quality of welds. Repairs.	**Increase final machining follow up. Foresee repair of base material (grinding or welding build up)**	Welding table Inspection Points Plan
5	COMPONENT	Transportation, storage and handling. Welding and grinding operations.	**Poor equipment inside cleanliness.**	Additional cleaning operation. Increase the schedule.	**Install temporary covers for inner protection. Issue an on site cleanliness procedure.**	On site cleanliness procedure
6	WELDING	Welding inside the Port Tubes.	**Lack of access and visibility.**	Low quality of welds. Repairs.	**Design of the weld edges must improve the welder visibility. Welding sequence that avoids works on consecutive equipment.**	Weld edge drawing Feasibility study

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DEFINITION OF RISK MITIGATION

		Risk description			Action Plan description	
Nr. #	Category	As a result of...	There is a risk that...	Resulting in...	Description	Documents
7	WELDING	Root weld (back side)	**Lack of access and visibility.**	Excesive / lack of penetration. Repairs.	**Design of the weld edges must improve the welder visibility. Welding sequence that avoids works on consecutive equipment for the 15 first Port Tubes. Continuos checking of root pass. Aditional NDT during root pass. Include back pass option in welding documentation.**	Welding table Inspection Points Plan Feasibility study
8	WELDING	Tack / Root weld.	**GAP between weld edges is reduced.**	Lack of penetration of root weld. Repairs.	**Control of the GAP before tack welding. Improve tack and root weld sequence increasing the tack wekds number and reducing root sectors dimension. Use of wedges to keep the minimum GAP.**	Feasibility study
9	WELDING	Floating equipment.	**Deviations in position.**	Equipment out of positional tolerance.	**Tack weld the most of equipment and use them as stiffener --> Fix the Vessel. Welding sequence in star pattern.**	Feasibility study
10	WELDING	Bad position of welders.	**Defects in the welds.**	Re-work. Repairs.	**Trainig of welder on representative coupons. Fabrication of Mock up. Study best position of the scaffold.**	Mock Up. Dwg 5EC8CRQS001 for platforms.
11	WELDING	Grinding after welding.	**Damage of base material of the component.**	Re-work. Repairs.	**Increase surveillance of grinding operations. Foresee repair base material by welding build up.**	Welding table Inspection Points Plan Feasibility study
12	NDT	Back side of the welds.	**Poor weld surface.**	Low quality of weld surfaces from NDT perspective.	**Include back pass option in welding documentation. Foresee grinding by the outside as much weld as possible.**	WPS
13	NDT	Testing the welds.	**Lack of access and visibility.**	Increase the schedule. Technically dificult accesses.	**Foresee the NDT to be performed on welds and consider the welding sequence to improve the % of NDTs**	Feasibility study

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CONCLUSIONS

After the study of all the above points the conclusions after Ensa's analysis are:

- Preferably sequence of assembly is to tack weld 33 Port Tubes (all the Port Tubes except the neighbors to NNBar) and NNBar Frame.
- Regarding shrinkage, it is expected to have a reduction in the radial direction of the components (Port Tubes and NNBar Frame) of about 2 to 4mm.
- No deviations on tangential or height position are expected provided that the Port Tube component is bolted to the Port Block Bottom Plate and properly fixed.
- Expected local deformation in welding section is that the vertical welds will move away from the position before welding (sides will become wider) but required shape tolerance compared to the status before welding can be met.
- To grind welds and adjoining base material surfaces (~50mm wide) is necessary for a proper quality and examination of the works done.
- To perform RT to an extent as high as possible, but at least 10% of the welding total length.

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ENSA (Grupo SEPI)

Domicilio Social
Avda. Juan Carlos I, nº8
39600 Maliaño (Cantabria) (España)
Tel.: +34 942 20 01 01
Fax: +34 942 200 148

www.ensa.es

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