# Progress on Manufacturing of the ITER Vacuum Vessel Equatorial and Lower Ports in Korea

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## Abstract

After the contract with Hyundai Heavy Industries Co., LTD (HHI) for the main port components manufacturing, fabrication preparation activities including mock-up verification are progressed. Korea Domestic Agency (KODA) also has performed detail designs and fabrication feasibility studies for in-wall shield (IWS) of the neutral beam (NB) port and vacuum vessel gravity support (VVGS). In parallel, the fabrication feasibility for the neutral beam duct liner (NBDL) was studied based on the ITER organization (IO) conceptual design model. This paper reports the progress on the manufacture of main ports done by KODA. In addition, detail designs and fabrication feasibility study results for IWS of NB port, VVGS and NBDL are introduced.

## 1. Introduction

### ◆ Procurement scope of Korea

- **KODA is responsible for procuring all port components at the equatorial and lower level of ITER VV**
  - ✓ **Main Ports :**
    - 14 Equatorial Regular Ports
    - 3 Equatorial Irregular(HNB&H/DNB) Ports
    - 6 Lower Cryopump Ports
    - 3 Lower RH Ports
    - 24 Local Penetrations
  - ✓ **Additionally :**
    - IWS for 3 Equatorial Irregular Ports
    - 9 VV Gravity Supports
    - 3 NB Duct Liners
    - Sealing Flanges

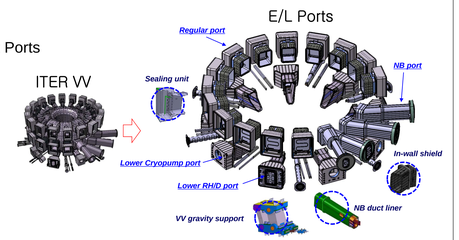



*Fig. 1. All port components procured by KODA at the equatorial and lower level*

### ◆ Progress on manufacturing of the E/L ports in Korea

- **Contract with HHI was awarded in January 2010 for manufacturing of main ports**
- **Preparation activities are going on for main port manufacturing**
  - ✓ Fabrication drawings, engineering analyses, material procurement, qualifications for major fabrication procedures and full-scale mock-up verification
- **Detail designs and fabrication feasibility studies are performed for IWS of NB port, VVGS and NBDL**

## 2. Preparation of main port manufacturing

### ◆ Fabrication design

- **Engineering analysis**
  - ✓ Verification of local thickness reduction effect due to forming and welding distortion analysis

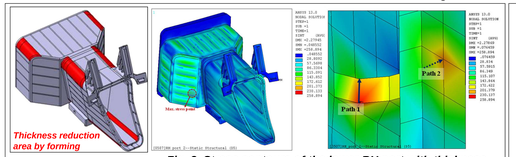
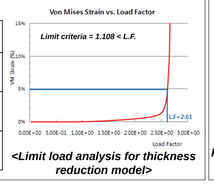



*Fig. 2. Stress contours of the lower RH port with thickness reduction under major load (Cat. II : DW+DP+SL-1)*

*Table I. Comparison of stress intensities*

| Stress intensity | Model | Results [MPa] Path 1 | Results [MPa] Path 2 | Allowable [MPa] at 200° C |
|---|---|---|---|---|
| Pm | Nominal Thickness | 201.20 | 144.00 | $P_m < S_m$=130 $P_L$<1.5$S_m$=195 |
| | Thickness Reduction | 213.60 | 144.10 | |
| | Difference* (%) | 6.16 | 0.07 | |
| Pm+Pb | Nominal Thickness | 248.30 | 231.40 | $P_L + P_b$ < 1.5$S_m$=195 |
| | Thickness Reduction | 258.90 | 236.30 | |
| | Difference* (%) | 4.27 | 2.12 | |
| Peak | Nominal Thickness | 0.03 | 0.07 | - |
| | Thickness Reduction | 0.03 | 0.07 | |
| | Difference* (%) | 0.00 | 0.00 | |




*<Limit load analysis for thickness reduction model>*

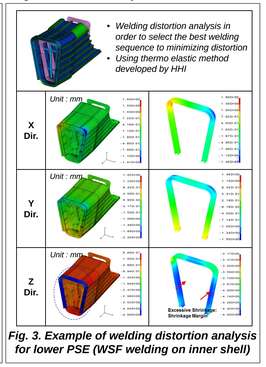



*Fig. 3. Example of welding distortion analysis for lower PSE (WSF welding on inner shell)*

- **2D fabrication drawings are being prepared**
  - ✓ Considering fabrication procedure based on IO official 3D model
  - ✓ All PSE fabrication drawings have been submitted to IO/ANB for approval

### ◆ Material procurement

- **The main material is a nitrogen controlled special grade stainless steel, 316L(N)-IG**
  - ✓ The material suppliers were selected and the procurement contract was completed in middle of 2010
  - ✓ The mass production of raw material started in April 2011 after approval of mill maker's quality system, product/part qualification report and shop qualification by IO/ANB
  - ✓ First warehousing of plates was done in January 2012 and all plate/forging will be delivered within this year

### ◆ Qualifications for major fabrication procedures

- **Welding and NDE qualification**
  - ✓ All pressure retaining parts are shall be full penetration welding and to be inspected by 100% volumetric NDE even at single side accessing region
  - ✓ HHI performing a lot of qualification activities to start port fabrication
    - Welding procedures specifications, filler material acceptance test, welder performance qualification, welding data packages with production weld test procedure
    - Ultrasonic examination qualification test
    - All qualification activities are to be approved by IO and ANB by the end of 2012

### ◆ Fabrication procedure and full-scale mock-up fabrication

- **Fabrication sequence was developed and mock-up fabrication is progressing**
  - ✓ Full-scale mock-up fabrication to verify fabrication feasibility and sequence for lower PSE
  - ✓ The narrow gap TIG welding and NDE techniques are verified through the mock-up fabrication

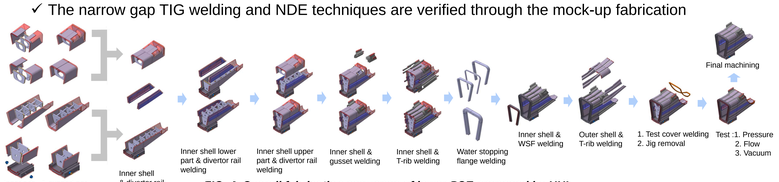



*FIG. 4. Overall fabrication sequence of lower PSE proposed by HHI*


*FIG. 5. Fabrication status of lower PSE full-scale mock-up*

## 3. Procurement preparation of NB IWS, VVGS and NBDL

### ◆ In-wall Shield of NB port

- **Detail design of NB port IWS has been finalized by KODA**
  - ✓ The spaces between inner and outer shells of the NB PE and PSE are filled with IWS
  - ✓ Main purpose of IWS is to provide neutron shielding during the operation
  - ✓ Main material is austenitic stainless steel containing Boron (304B4)
  - ✓ Total 6 different kinds of designs have been developed considering design and code requirements
    - Total number of IWS blocks is 528
    - Total net weight is about 97 tons
  - ✓ Design and construction code for IWS is ASME III NC

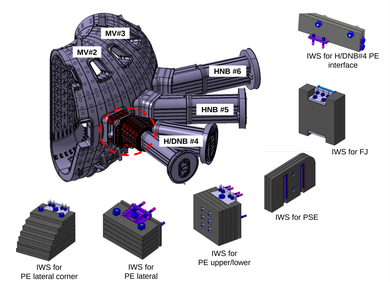



*FIG. 6. Design variations of the IWS of NB port according to its position*

- **Procurement schedule**
  - ✓ The tendering and contract award are planned in November and December 2012, respectively
    - First delivery is IWS for PSE inner space to the port shop in middle of 2014
    - Last delivery is IWS for FJ between PSE and PE to the IO site in February 2016

### ◆ VV Gravity Support

- **KODA performed engineering analyses and fabrication feasibility study including several R&D to support detail design finalization**
  - ✓ The ITER VV is supported by 9 gravity supports which are located under the lower ports of the vacuum vessel
  - ✓ The supports shall sustain all combinations loads from VV and in-vessel components
  - ✓ The VVGS is classified as a SIC component
  - ✓ Design, fabrication and test must comply with the application parts of the French regulation on pressure equipment and follow the RCC-MR 2007(Support Class S1 – RH 1300)

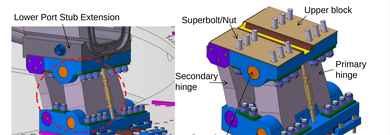



*FIG. 7. Detail design of VVGS*

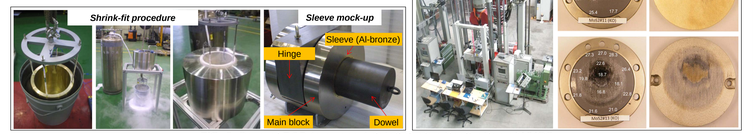



*FIG. 8. Several R&D to support detail design finalization of VVGS*

- **Procurement schedule**
  - ✓ The contract award is planned in May 2013 and the delivery date is end of 2015

### ◆ NB Duct Liner

- **KODA performed fabrication feasibility study including full-scale DL mock-up fabrication**
  - ✓ NBDL is consist of neutron shield (NS) and duct liner (DL) having numerous cooling path
  - ✓ Main function is to protect the VV wall from the high-power neutral beam, to give radiation shielding of the TF coil
  - ✓ KODA made several coupons to verify the weldability between dissimilar materials, narrow space TIG welding and EBW for the cooling manifold module of NBDL
  - ✓ High heat flux test using full-scale mock-up is planned at Korea Atomic Energy Research Institute in December 2012

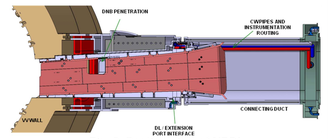



*Fig. 9. Section view of NBDL*

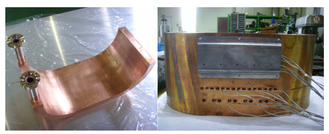


*FIG. 10. Thermocouples embedded full-scale mock-up of DL*

- **Procurement schedule**
  - ✓ Preliminary design review will be held in March 2013
  - ✓ The contract award is planned in August 2015 and the delivery date is October 2018

## 4. Summary

◆ KODA has performed manufacturing preparation activities for main ports including full scale mock-up fabrication since contract with HHI in early of 2010.

◆ Although some qualifications are still proceeding related to welding and NDE, the manufacturing preparation for the main ports is in its final stages and will be completed by the end of this year to start lower PSE fabrication in the beginning of 2013.

◆ KODA will do our best to comply with current main port procurement schedule. KODA also will cooperate closely with IO for procurement of the other components as planned schedule.

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◆ The views and opinions expressed herein do not necessarily reflect those of the ITER Organization.