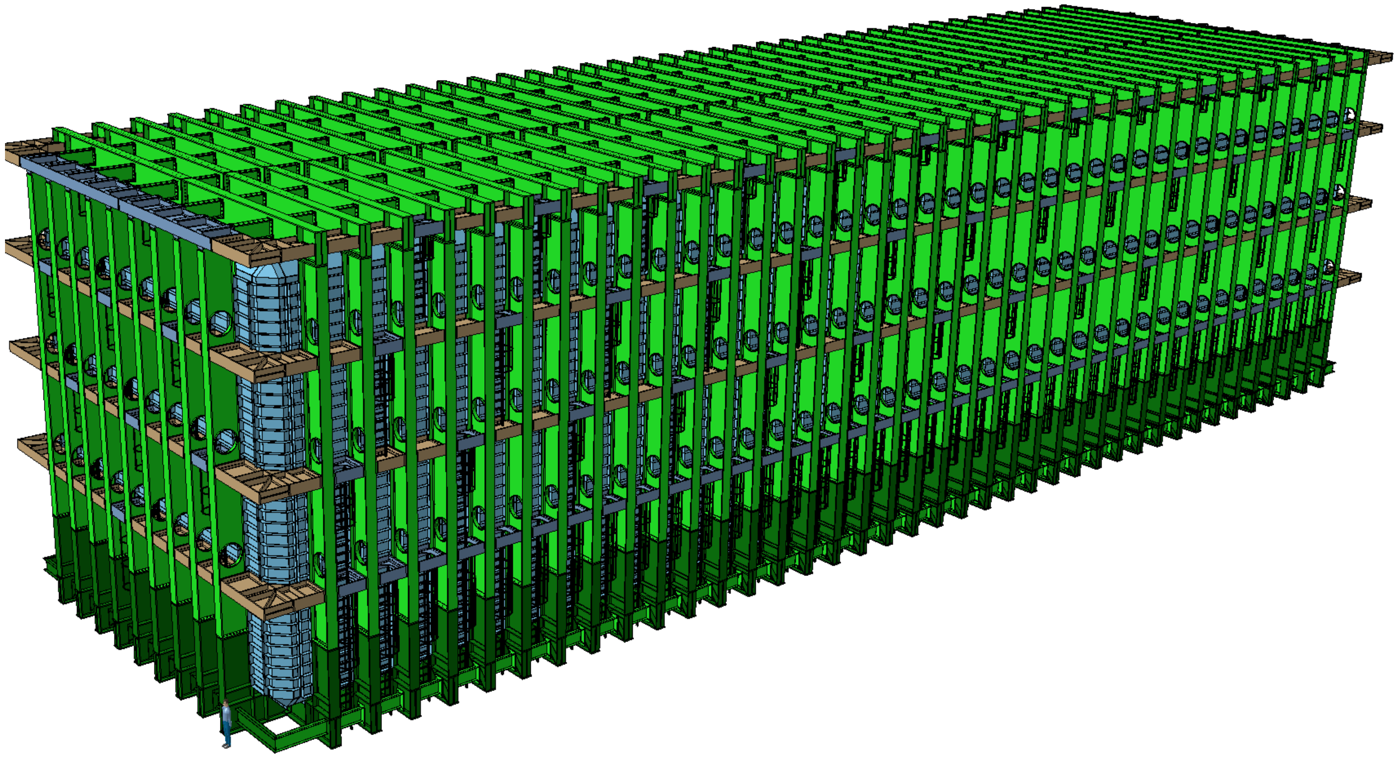

# Answers to referees questions of 21th August

Author  CERN team

LBNF Cryostat, final design review

SURF, 21-22 August 2017

CERN Fermilab Sanford Underground Research Facility

# List of Questions

1) There was much discussion about the warm membrane transferring load to the I-beam structure. There are clamps used to assure fit. The engineers were also commenting on dealing with weld shrinkage. During assembly of the warm liner, it will be possible to make adjustment for shrinkage. In the discussion about assembly, please include discussion of order of welds and how the final welds in the system account for that last bit of shrinkage. That would just be to make sure the last part of liner fits well to the balance of structure for load transfer.
2) A possible weakness in the design is the non-attachment of the warm membrane to the outer big beams. They made a point to say that there was no connection. I saw they are only attached by clamps in a few places for welding. Before the warm membrane becomes a full box that is self supporting, it could collapse inward. Especially the warm membrane at the top. How does that stay up?
3) What is the plan for qualifying the welds on the internal cold membrane, e.g. die penetrant, radiography, etc.
4) Do specifications exist for the warm structure welds?
5) Can you provide the document that cross references Eurocode 3 with AISC 360? This may be needed for the peer review and for the review by the South Dakota PE.

1) There was much discussion about the warm membrane transferring load to the I-beam structure. There are clamps used to assure fit. The engineers were also commenting on dealing with weld shrinkage. During assembly of the warm liner, it will be possible to make adjustment for shrinkage. In the discussion about assembly, please include discussion of order of welds and how the final welds in the system account for that last bit of shrinkage. That would just be to make sure the last part of liner fits well to the balance of structure for load transfer.

**The welding procedure will be qualified. Based on this qualification test, the shrinkage will be assessed and the size of the panels will be determined accordingly.**

**The size of the panel will include some extra-length needed to accommodate the shrinkage. It is recalled that the installation is a step-by-step procedure during which any corrective measure can be taken at each step.For example a larger gap for welding between panels may be envisaged (and welds qualified beforehand) in order to compensate progressively for shrinkage.**

**This procedure will anyhow be integral part of the work to be established by the manufacturing company.**

2) A possible weakness in the design is the non-attachment of the warm membrane to the outer big beams. They made a point to say that there was no connection. I saw they are only attached by clamps in a few places for welding. Before the warm membrane becomes a full box that is self supporting, it could collapse inward. Especially the warm membrane at the top. How does that stay up?

**The clamps have been designed (both for the walls and for the roof) to take the weight of the membrane panels (including insulation) and will be present during the entire life cycle: from installation (including welding) up to operation. Consequently, the clamps will prevent at any time the inward collapse of the membrane.**

3) What is the plan for qualifying the welds on the internal cold membrane, e.g. die penetrant, radiography, etc.

A) The assembly firm, by contract will perform there standard weld QC: die penetrants, tests of leaks with vacuum bags at the $10^{-6}$mbar/l*s

B) We (CERN, LBNF) will perform our own leak checks:
- He in the insulation volume +50mbar
- vacuum boxes on the welds, attached to a mass spectrometer sniffer

goal: $10^{-9}$mbar/l*s

We have done this for the WA105 first cryostat and we will do the same for protoDUNE
By contract the firm wil repair any problem we will find

**4) Do specifications exist for the warm structure welds?**

***Yes. They do exist.***

**The welding requirements are set by CERN inline with EN1090-1 and EN1090-2.**

**Namely:**

*Welding plan (§ 7.2 of EN 1090-2:2008)*

*Qualification of welding procedures (§ 7.4.1 of EN 1090-2:2008)*

*Qualification of welding personnel (§ 7.4.2 of EN 1090-2:2008)*

*Records of inspection of welds*

*Welding material certificates*

**They were discussed with the main company in charge of producing the test pieces and currently two main documents are developed by them:**

*Inspection and Test Plan*

*Welding Book*

**Where all the specifications, fabrication, examination methods and accepting criterias are described in great details.**

# Inspection and Test Plan

| Cimolai S.p.A. | INSPECTION AND TEST PLAN | Doc ref.: CIM-ITP-2017023<br>Rev.: 00<br>Date: 31/07/2017 |
|---|---|---|

## INSPECTION AND TEST PLAN

Project: **LBNF - TEST PIECES**

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

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

Project Ref.: **2017-023**

*Revision matrix:*

| Rev. | Date | Issued | Checked | Approved |
|---|---|---|---|---|
| 00 | 31/07/2017 | Scaini S. | D'Anna E. | Punzo F. |
| | | | | |
| | | | | |

# Welding Book

| Cimolai S.p.A. | WELDING BOOK | Doc ref.: CIM-WB-2017023<br>Rev.: 00<br>Date: 01/08/2017 |
|---|---|---|

## WELDING BOOK

Project: **LBNF - TEST PIECES**

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

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Project Ref.: **2017-023**

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|---|---|---|---|---|
| 00 | 01/08/2017 | Scaini S. | Quaia G. | Punzo F. |
| | | | | |
| | | | | |

# Welding Book (extract)

| | | | |
|---|---|---|---|
| CIMOLAI<br>Pordenone - Italy<br>Cimolai S.p.A. | WELDING BOOK | Doc ref. : | CIM-WB-2017023 |
| | | Rev. : | 00 |
| | | Date : | 01/08/2017 |

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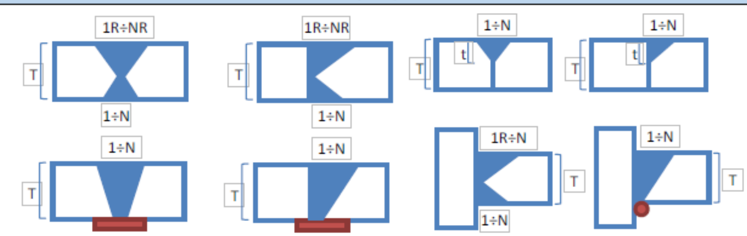
| GENERAL | | | | | |
|---|---|---|---|---|---|
| WPS | 04 | Rev. | 00 | Date | 01/08/2017 |
| PQR | ISO-057 | Code/ Spec. | EN 15614-1 | | |
| Welding process | 136 (FCAW) | Automation grade | Partly Mechanized | | |

| 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-20$CO_2$) | 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 |

**SKETCH**




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 |

# Inspection and Test Plan (extract)

| Cimolai S.p.A. | INSPECTION AND TEST PLAN | Doc ref.: CIM-ITP-2017023<br>Rev.: 00<br>Date: 31/07/2017 |
|---|---|---|

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**5.1 Extent of Non Destructive Examination**

The extent of Non Destructive Examination is based on the requirements of EN 1090-2, paragraph 12.4.

| | VT<br>EN ISO 17637 | MT<br>EN ISO 17638 | UT<br>EN ISO 17640<br>Technique A |
|---|---|---|---|
| *Fillet Welds (FW)* | 100 % | 5 % | / |
| *Partial Joint Penetration (PJP)* | 100 % | 10 % | / |
| *Complete Joint Penetration (CJP)* | 100 % | 10 % | 10 % |
| *Technical Joints, if any (Complete Penetration Splice Joints) and Weld Repairs* | 100 % | 100 % | 100 % (if CJP) |
| *Acceptance criteria* | EN ISO 5817<br>Level C | EN ISO 23278<br>Level 2X | EN ISO 11666<br>Level 3 |

**5.2 Selection of areas to be subjected to examination**

When the extent of examination is <p>% (less than 100%), the area of joints to be inspected shall be selected on the basis of Annex C of EN 12062, as per following table.

| Length of joint | Selection of area to be inspected | *Example*<br>*<p>% = 20%* |
|---|---|---|
| Length of welds<br>≥ 900 mm | Each weld shall be examined over a length of minimum <p>%. The area to be examined shall include:<br>• welds start and stops,<br>• weld intersections<br>• areas where weld aspect is irregular | *Fillet weld, length 5000 mm*<br>*Examine a length of (5000 x 20% = ) 1000 mm* |
| Length of welds (Note 1)<br>< 900 mm | A number <p>% of randomly selected welds shall be examined in their entire length. | *Nr. 16 filet welds, each length 500 mm*<br>*Examine the entire length of (16 x 20 % = 3,2, to be round in excess) 4 welds* |

Note 1: the welds shall have similar characteristics, e.g. fillet welds with same throat thickness and obtained by the same welding process.

**5) Can you provide the document that cross references Eurocode 3 with AISC 360? This may be needed for the peer review and for the review by the South Dakota PE.**

The codes AISC360 and Eurocode 3 are recognized to be equivalent.
Equivalent means not the same, but same results.

This was clearly stated and agreed in MOU CERN EDMS 1554082:
« The design of the warm steel supporting structure is performed per the European standard for steel structure design and construction EN1993 - EUROCODE 3, which is equivalent to U.S. ANSI/AISC 360. “
Also the latest version of FESHM 5031.7: MEMBRANE CRYOSTATS (08.2017) refers to this memorandum for the LBNF/DUNE and SBN programs .

A cross check have been performed by CERN only on one beam case (see detailed attached analysis)

For this specific example the EU code gives a capacity of 1388.2kN and the American one 1387.85kN.
Formulas look different but if we analyze them carefully we can see that the same aspects (e.g. imperfections, partial safety factors, local stability…) are considered ..