Safety Analysis Vacuum Vessel

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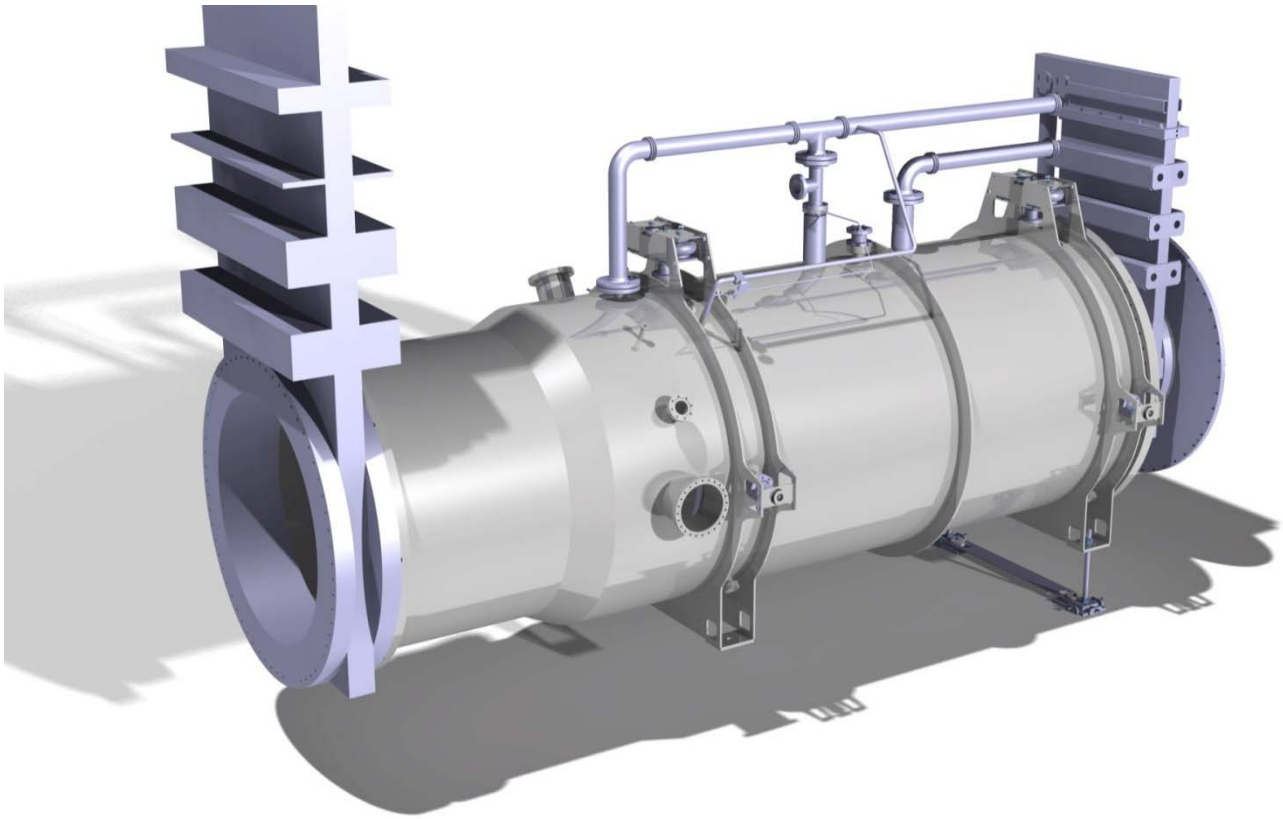
47110-MT-00003	**AA1322**	Status: In Work	Revision: A.3
Project: **Gravitational Waves Virgo Cryogenic Link**			
Department: **Mechanical Technology**		Top folder: **West End Tower Cryostat**	



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M.J. Kraan	M. Doets, C. Snippe	

Abstract:

The scope of this document is the safety of the West End Tower Vacuum Vessel which will be used at Virgo (Italy). The system has to comply with the Pressure Equipment Directive (PED) 97/23/CE. The French construction code for pressure apparatus CODAP (Code De Construction des Appareils a Pression) is used to verify the stresses. With a volume of 5500 liter and a design pressure of 1.5 bar, the vacuum vessel is classified in PED category III.

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1 GENERAL DESCRIPTION

The current Virgo vacuum level needs to be improved by about a factor of hundred in order to be compliant with the required Advanced Virgo sensitivity. Such an improvement requires baking out the interferometer arms. To separate these arms from the towers that hold the mirrors and allow the bake-out, four cryogenic vacuum links will be installed.
Cryogenic vacuum links are the classical solution to stop the migration of water from unbaked towers to interferometer (ITF) arms.

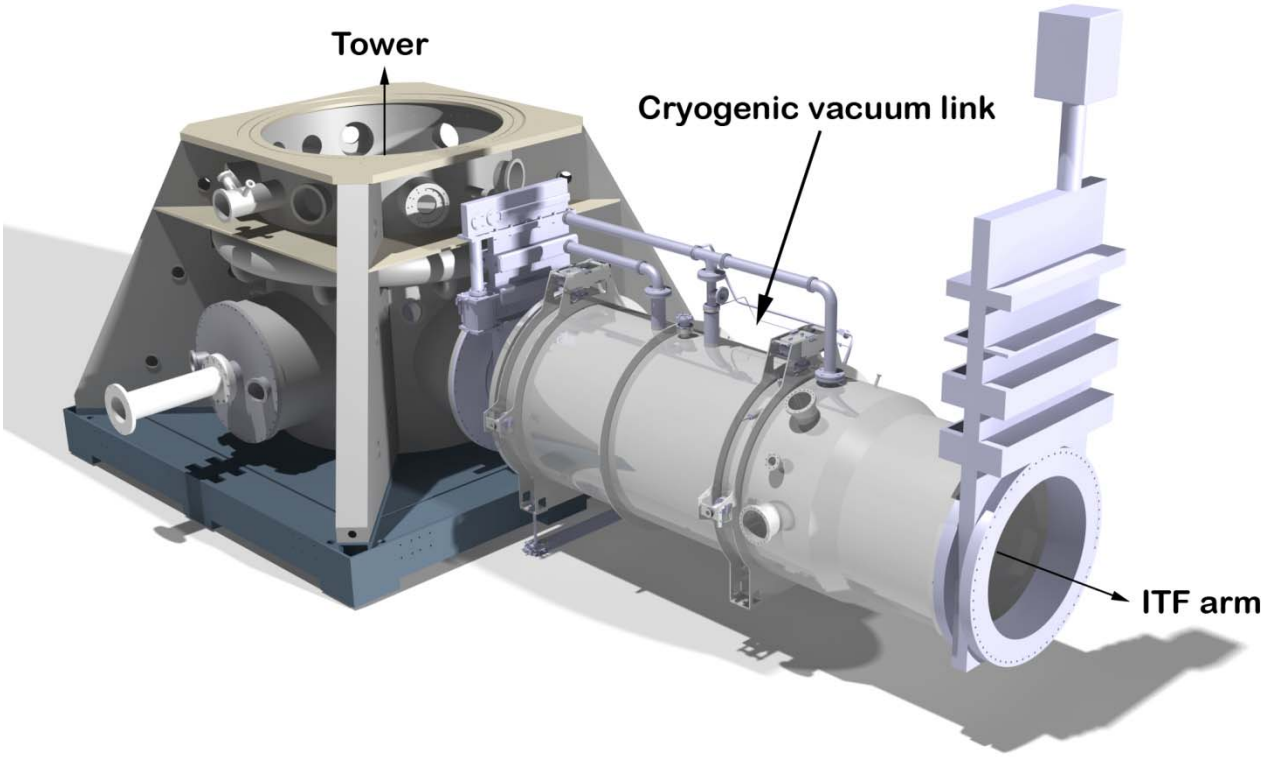


Figure 1, the cryogenic vacuum link.

The outer vacuum vessel will be constructed from stainless steel 304L. Reinforcement ribs are welded to the outside of the vessel to avoid buckling of the structure. The vessel is equipped with pump-out and service ports. A stainless steel hydro-formed bellow is foreseen at one end of the vacuum vessel as a connecting piece between the trap and the tower. This bellow will have a 700 mm inner diameter and can accommodate expansion of the structure. The other connection is an existing DN1000 valve. See also Figure 6 at page 8

Inside the vacuum vessel a cold part of the cryogenic vacuum link will be constructed from aluminum. The inner surface of this link is cooled with liquid nitrogen. This cold part is isolated from the vessel by using two air springs and designed in such a way that thermal expansion does not induce stresses in the outside vacuum vessel.

The system will be building up and tested at an extern company. The final performance tests will be done at Nikhef before installing at Virgo. For this the cryogenic vacuum link will be closed with two end caps, and one extra the support will be added. See next Figure 2 and Figure 3:

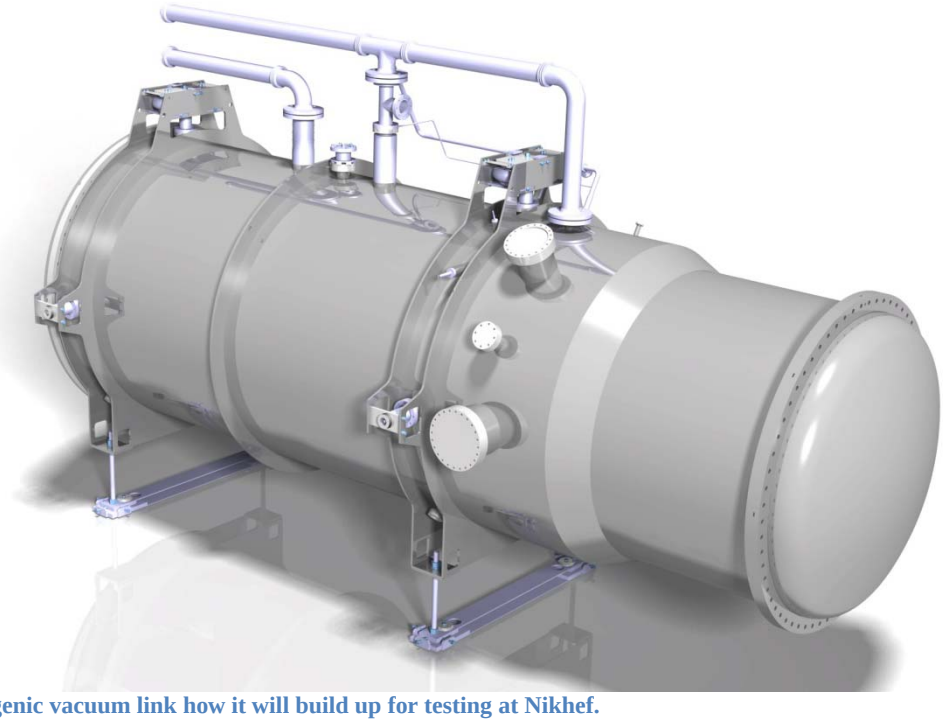


Figure 2, the cryogenic vacuum link how it will build up for testing at Nikhef.

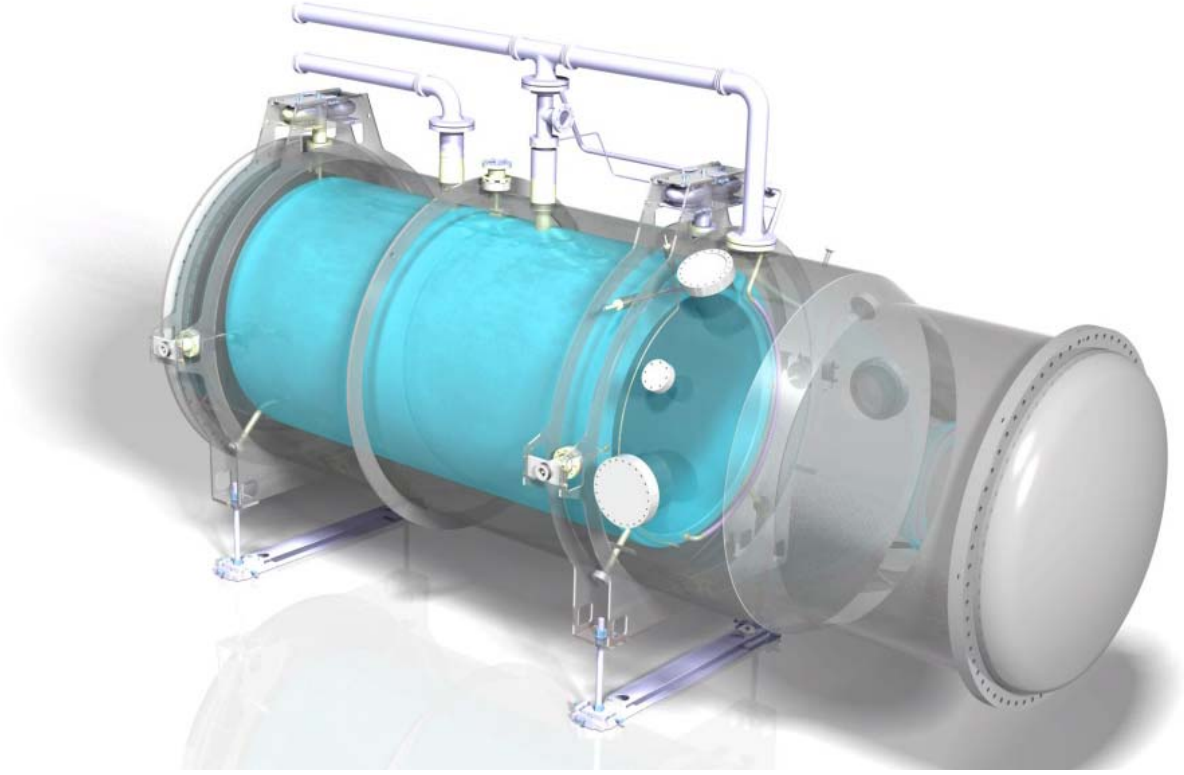


Figure 3, inside the vessel a cold part is mounted (cyan), supported on four ribs at the outside of the vessel.

2 SAFETY

To prevent failure of the system, the system has to equipped with a burst discs on the vacuum vessel and a relief valve for the nitrogen vessel. The calculations are done based on a burst discs which opens at a pressure difference of max. 1.5 bar (absolute pressure inside the vessel = max. 2.5 bar) Both safety systems are venting through a stainless steel safety line for personal safety. See the following Figure 4:

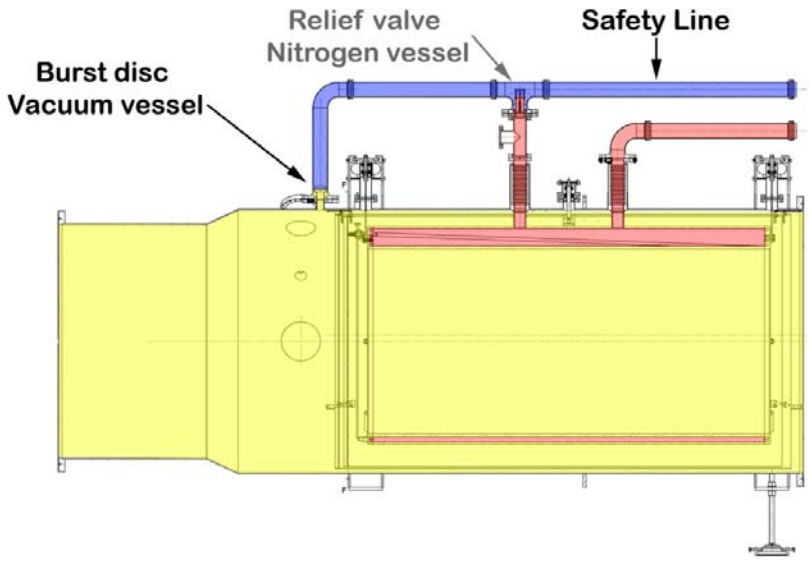


Figure 4, two burst discs preventing the vessels. Yellow = vacuum | red = nitrogen | blue = safety line.

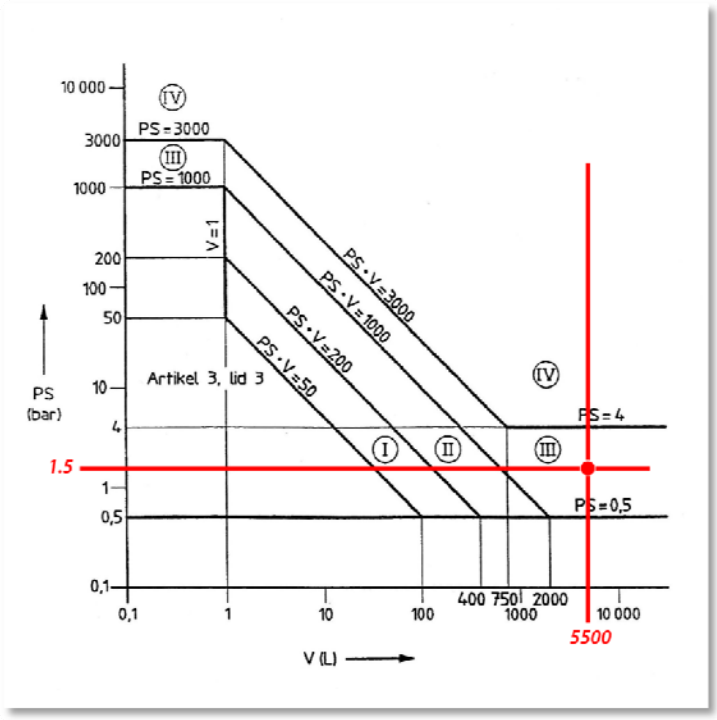
3 DEFINING PED CATEGORY

The **P**ressure **E**quipment **D**irective (97/23/EC) was adopted by the European Parliament and the European Council in May 1997. The PED is a European Single Market Directive that covers pressure equipment and assemblies with a maximum allowable pressure PS greater than 0.5 bar.

Pressure equipment: Pressure vessel
Media: Nitrogen (N)
Group: Non dangerous media
Phase: Gas
Vessel volume: V = 5500 Liter
Design Pressure (PS): 1.5 bar

PS . V = 9900 [bar.l]

Tabel 1. defining the PED category for non dangerous gasses. The red lines indicate the vessel properties.



Following Tabel 1, the vessel must be classified in ***category III***
The following modules are available for category III: B1+D, B1+F, B+E, B+C1, H

4 CALCULATIONS (FINITE ELEMENT ANALYSIS)

Finite element analyses are done for to investigate the expected stresses and deformations. The French construction code for pressure apparatus (CODAP) is used to verify the stresses. Following the chosen *construction class B* and *welding coefficient z=0.7*, the stress limits according to CODAP **for austenitic stainless steels** are:

- Global zones: $f = f_3 = R_m / 3.5$
- Weld regions: $f_w = z \cdot R_m / 3.5$
- Peak regions: $f_p = 1.5 \cdot f_3$
- Peak/Weld regions: $f_{pw} = 1.5 \cdot f_w$

R_m= minimum guaranteed value ultimate tensile strength at room temperature

Finite element analyses are done with the finite element analysis module of Ideas ™. Results of the stress analysis are presented in terms of Von Mises equivalent stress. In addition the calculated deformations from the stress analysis and the stability (buckling) are presented. The quality of the FEA is verified using the strain energy error norm. A value below 7% is recommended by the IDEAS^{TM} software.

4.1 Operational conditions

Half of the pressure vessel is modeled, as the vessel is symmetric about YZ, see Figure 5 .

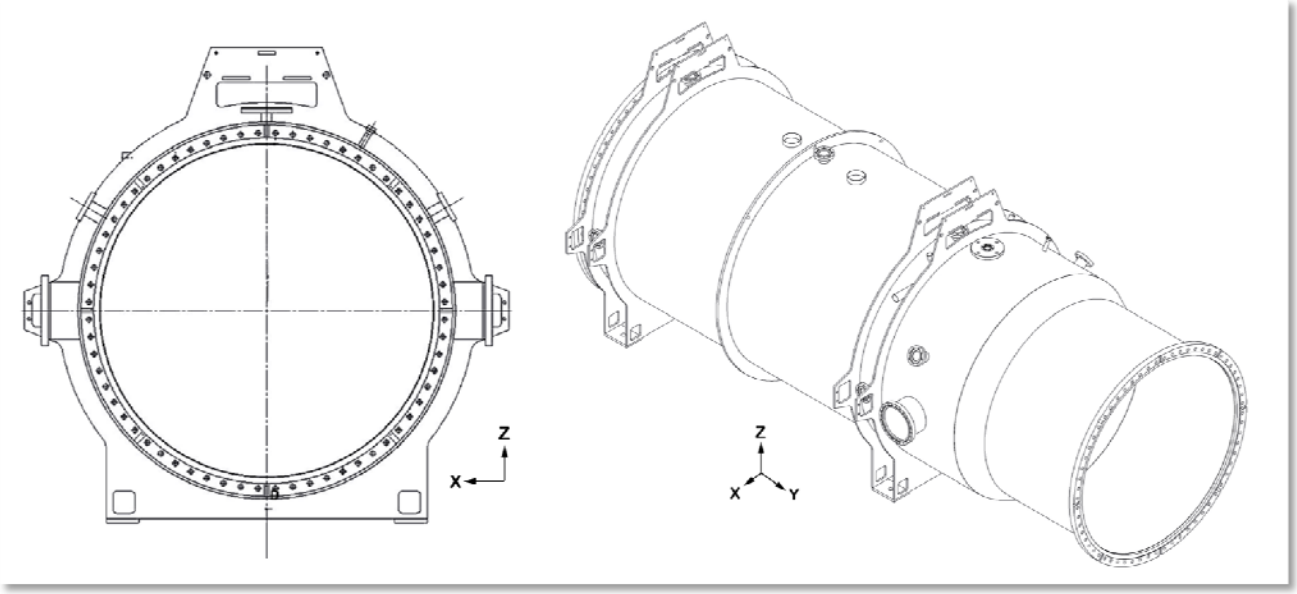


Figure 5. the vessel is symmetric about YZ.

The design pressure PS of the vessel is between -1bar (vacuum) and +1.5bar (2.5bar absolute pressure inside the vessel). Normal operational condition is vacuum. The 2.5bar absolute internal pressure will be determined by a burst disc which has to open at a max. pressure difference of 1.5bar.

This can be caused of a failure of the inner cold part which is cooled with liquid nitrogen. The vacuum vessel will be baked out at 150°C. Operational temperature of the vessel will be 20°C. The main support of the vessel is the big valve at the left side, see Figure 6.

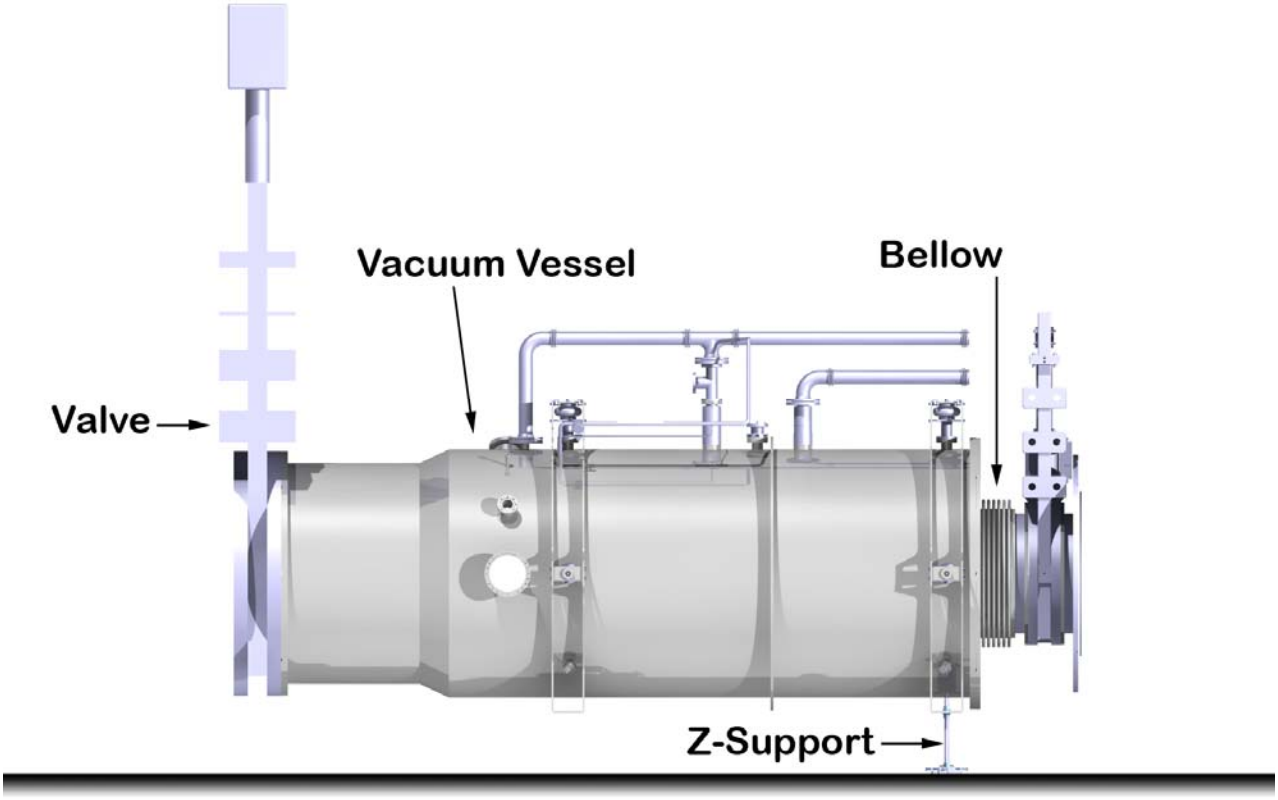


Figure 6, supports of the vacuum vessel.

This support on the left (valve) side can be considered as rigid. At the other end the vessel is supported in Z direction by two studs of 12mm and designed in such a way that thermal expansion does not induce stresses in the vessel. The vacuum vessel is connected by a stainless bellow which can accommodate thermal expansion of the structure.

The inner cold part, filled with liquid nitrogen, is hanging with air filled bellows on two ribs of the vacuum vessel, see Figure 7 and Figure 8. The total weight of this aluminum vessel (550 kg) with liquid nitrogen (±300 Liter | 250 kg) on the four flanges is 800 kg (8000 N).

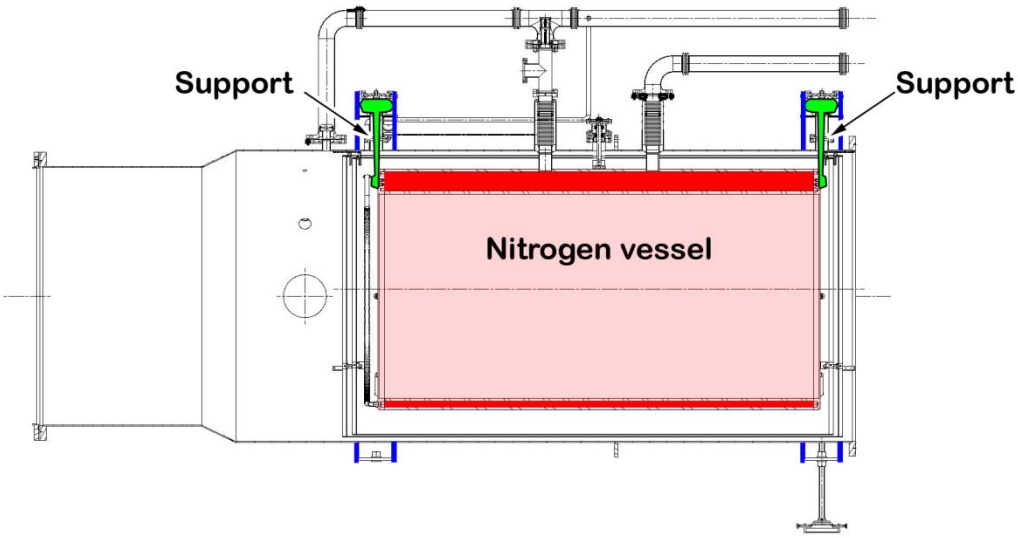


Figure 7. two suspensions of the cold part (nitrogen vessel) inside the vacuum vessel. Blue are the ribs and green are the suspensions of the inner cold part.

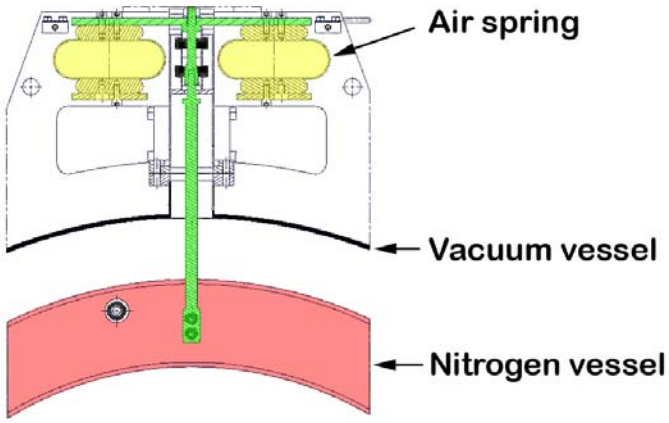


Figure 8. detail of the suspension.

Tabel 2, summary of the operational conditions

Operational conditions	
Design Pressure	-1 bar (vacuum) and + 1.5 bar
Design Temperature	20°C (1.5 bar) and 150°C (vacuum)
Additional load	8000 N (weight nitrogen vessel)

4.2 The FEA model

The FEA model is built up from 3D solid parabolic tetrahedron and 2D Thin Shell parabolic quadrilateral elements. All loads are applied without any safety factors.
The vessel is verified for two conditions:

1. Pressure +1.5 bar | temperature 20°C
2. Pressure -1 bar | temperature 150°C

See for all FEA model constrains the following Figure 9:

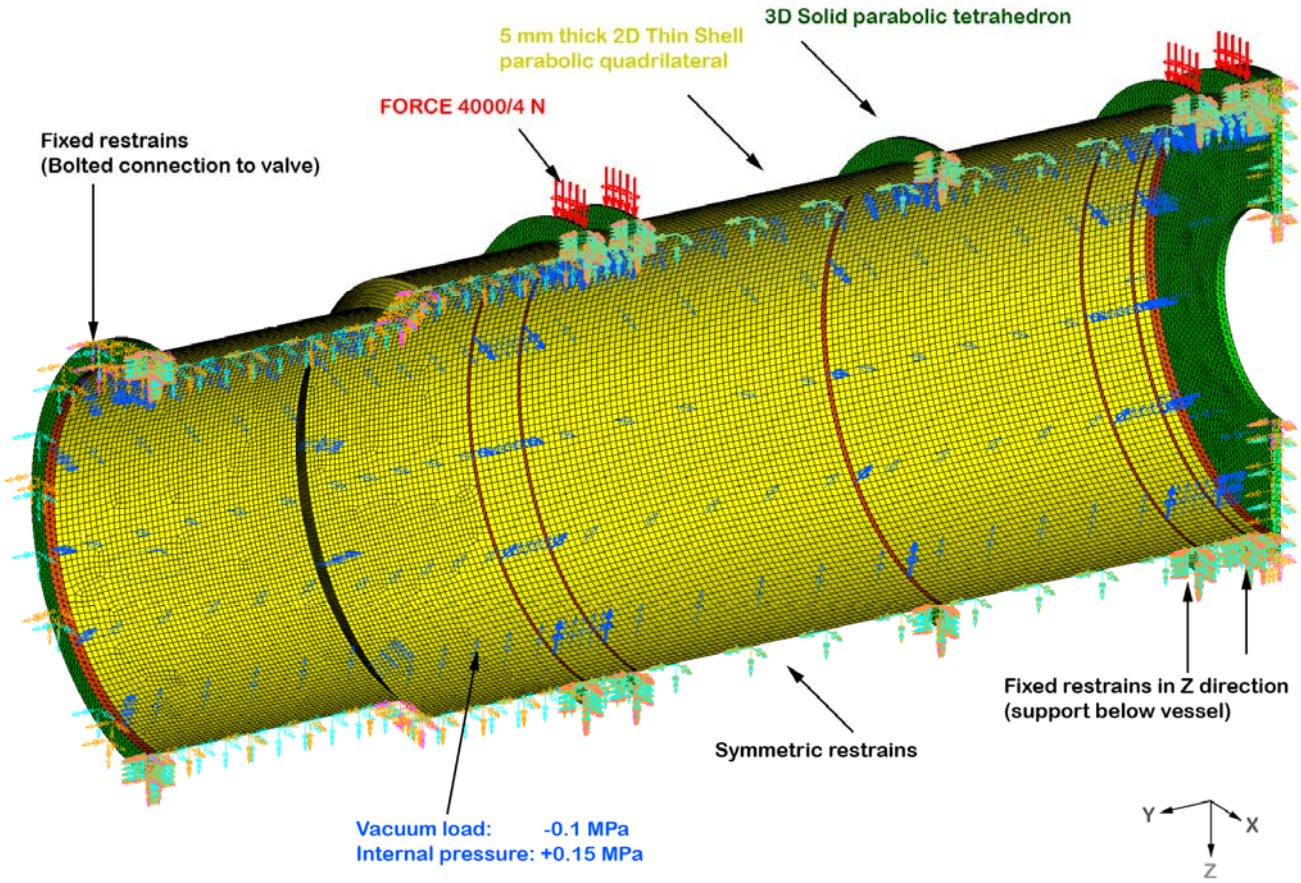


Figure 9, FEA model with constrains of the vacuum vessel.

4.3 Material

The vessel will be made from AISI 304L. The material has been selected based on the corrosion requirements and the welding ability of the material. A summary of the mechanical properties is given in Tabel 3.

Tabel 3, *properties AISI 304L (* Battelle *Structural Alloys Handbook)*

			20-25 °C	150 °C
Tensile strength	R_m [MPa]	min.	520	482
Yield strength	$R_{p\ 0.2\%}$ [MPa]	min.	193	186
Young's modulus	E [GPa]	min.	200	190
Density	ρ [g/cm^3]		7.85	e
Poisons ratio			0.30	
Elongation at break	A5 [%]	min.	50	
Brinell hardness	HB	max.	70	

The stress limits according to CODAP are:

1. Pressure 1.5 bar | temperature 20°C

Global zones: $f = f_3 = \frac{R_m}{3.5} = \frac{520}{3.5} = \mathbf{148}\ MPa$
Weld regions: $f_w = \frac{z \cdot R_m}{3.5} = \frac{0.7 \cdot 520}{3.5} = \mathbf{103}\ MPa$
Peak regions: $f_p = 1.5 \cdot f_3 = 1.5 \cdot 148 = \mathbf{222}\ MPa$
Peak/Weld regions: $f_{pw} = 1.5 \cdot f_w = 1.5 \cdot 103 = \mathbf{155}\ MPa$

2. Pressure -1 bar | temperature 150°C

Global zones: $f = f_3 = \frac{R_m}{3.5} = \frac{482}{3.5} = \mathbf{137}\ MPa$
Weld regions: $f_w = \frac{z \cdot R_m}{3.5} = \frac{0.7 \cdot 482}{3.5} = \mathbf{96}\ MPa$
Peak regions: $f_p = 1.5 \cdot f_3 = 1.5 \cdot 137 = \mathbf{205}\ MPa$
Peak/Weld regions: $f_{pw} = 1.5 \cdot f_w = 1.5 \cdot 96 = \mathbf{144}\ MPa$

4.4 Tube calculation

Design Pressure: $\boldsymbol{PS_{max}} = 1.5\ bar\ (\ 0.15\ MPa)$
Inside diameter: $\boldsymbol{D_{in}} = 1350\ mm$
Outside diameter: $\boldsymbol{D_{out}} = 1360\ mm$
Wall thickness: $\boldsymbol{t} = 5\ mm$

The vessel can be considered as thin-walled vessel because the D_{in}/t ratio (1350/5=270) is higher than 10 (often cited as 20).

Radial (Hoop) stress: $\boldsymbol{\sigma_r} = \frac{F}{A} = \frac{PS \cdot D_{in}}{2 \cdot t} = \frac{0.15 \cdot 1350}{2 \cdot 5} = 20.3\ MPa$

Axial stress: $\boldsymbol{\sigma_a} = \frac{F}{A} = \frac{PS \cdot D_{in}{}^2}{D_{out}{}^2 - D_{in}{}^2} = \frac{0.15 \cdot 1350^2}{1360^2 - 1350^2} = 10.1\ MPa$

4.5 FEA results

4.5.1 Internal pressure analysis

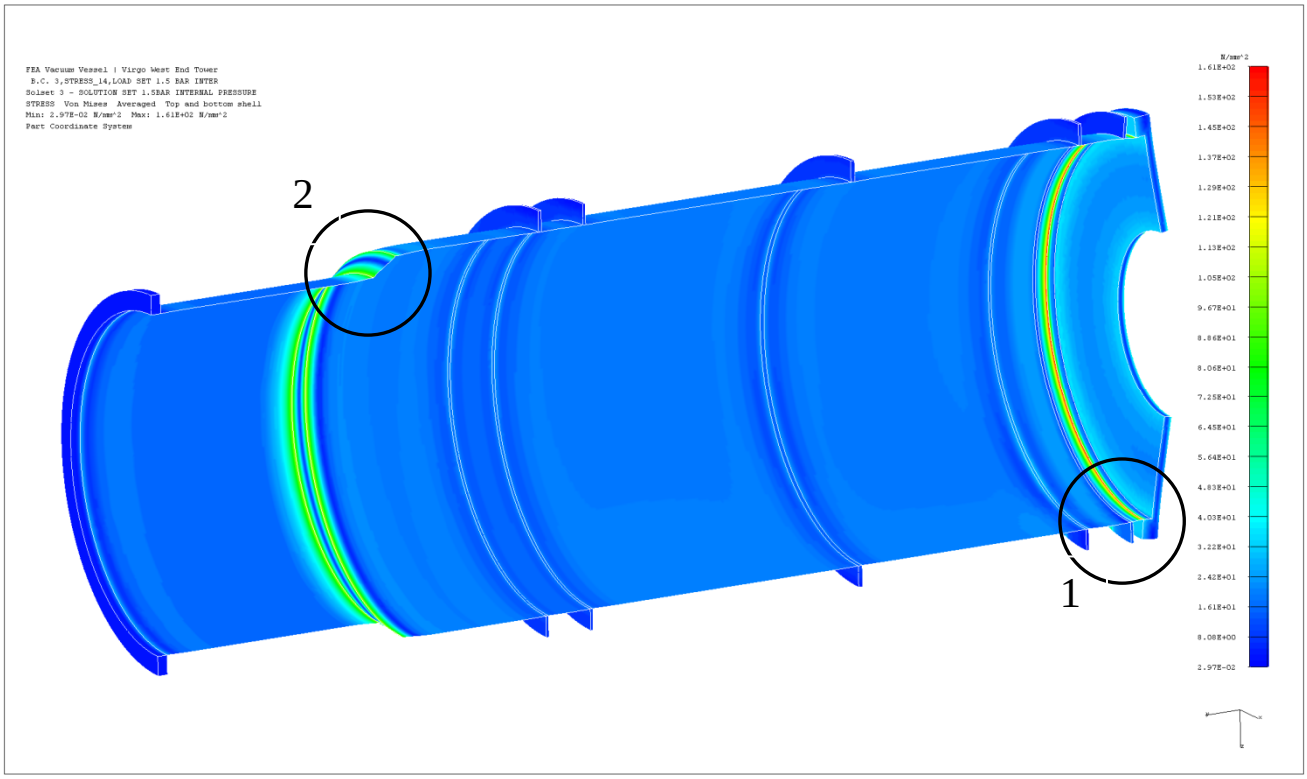


Figure 10, internal pressure *stress result* | *max stress = 161 Mpa* | See details in next figures.

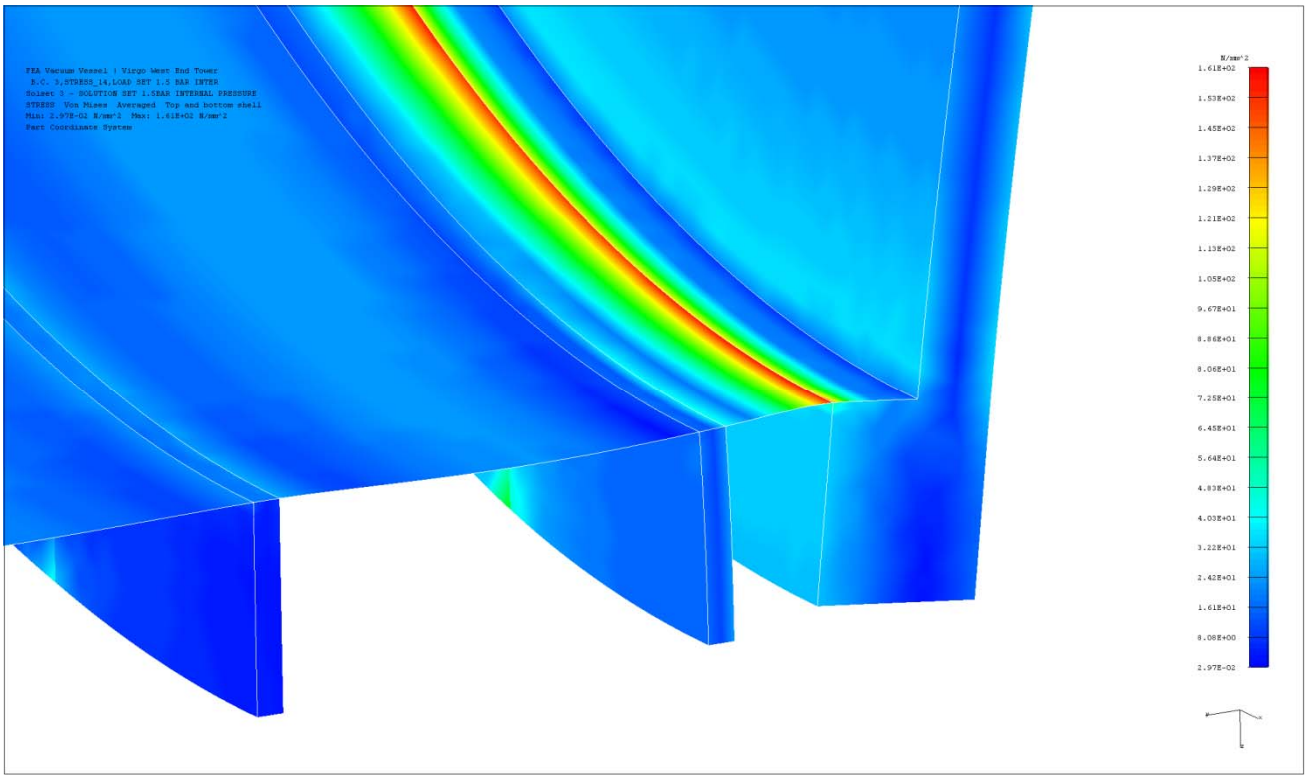


Figure 11, detail 1 stress at the right flange | max 161 MPa

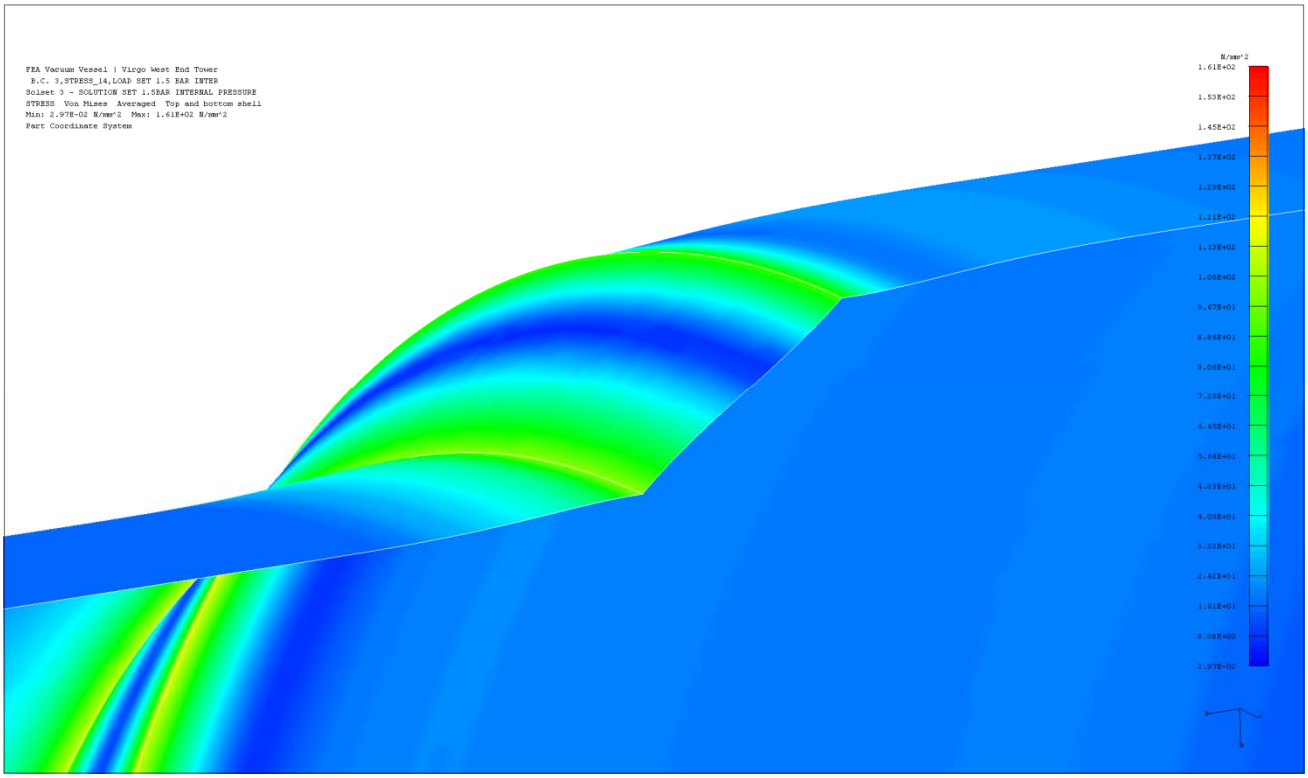


Figure 12, detail 2 stress at the transition | max 113 MPa

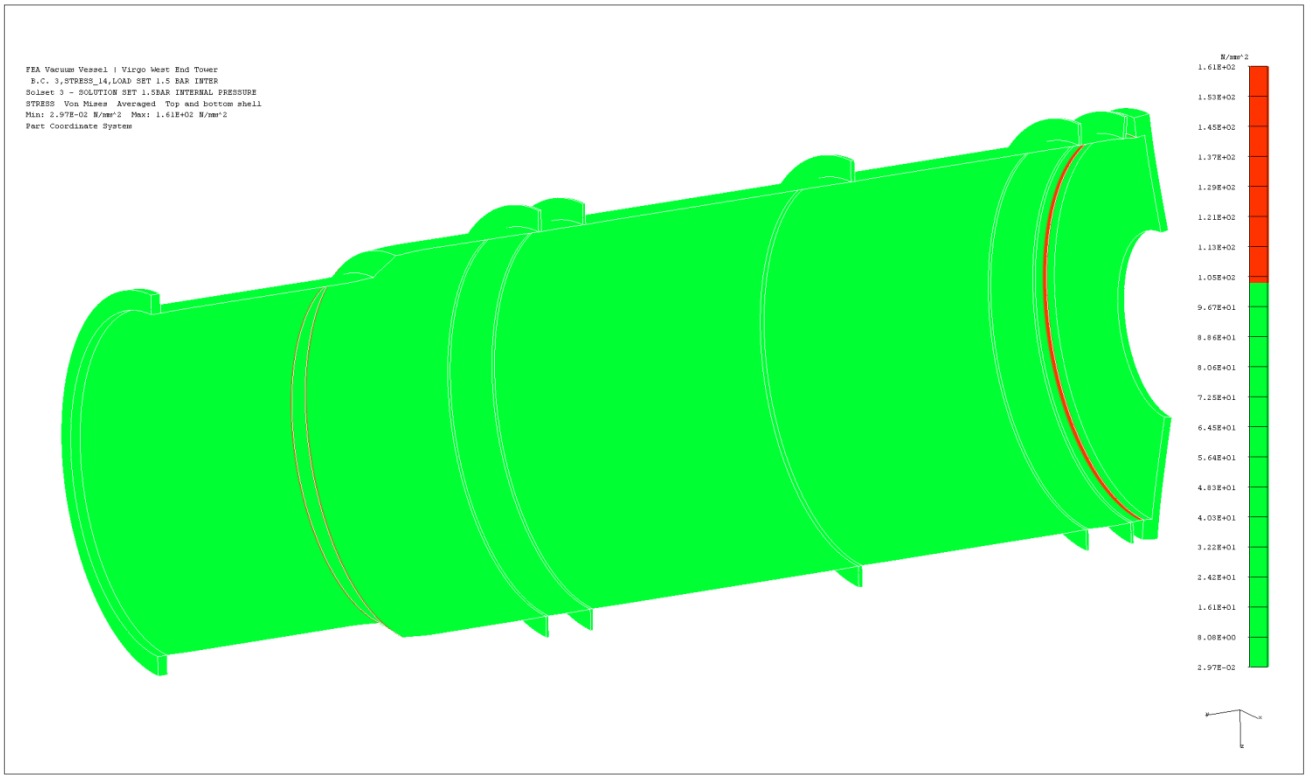


Figure 13, limited stress to 103 MPa (CODAP limit weld regions).

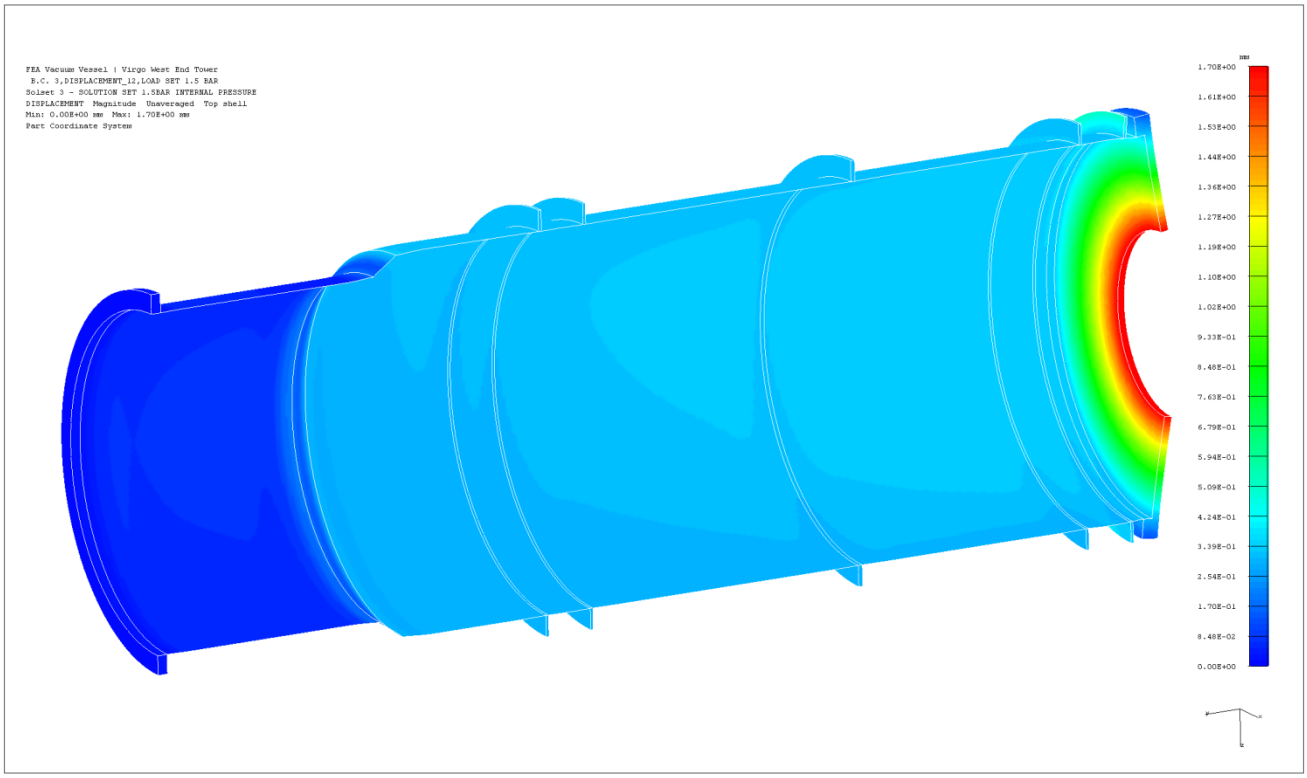


Figure 14, internal pressure *displacement result | max displacement = 1.7mm.*

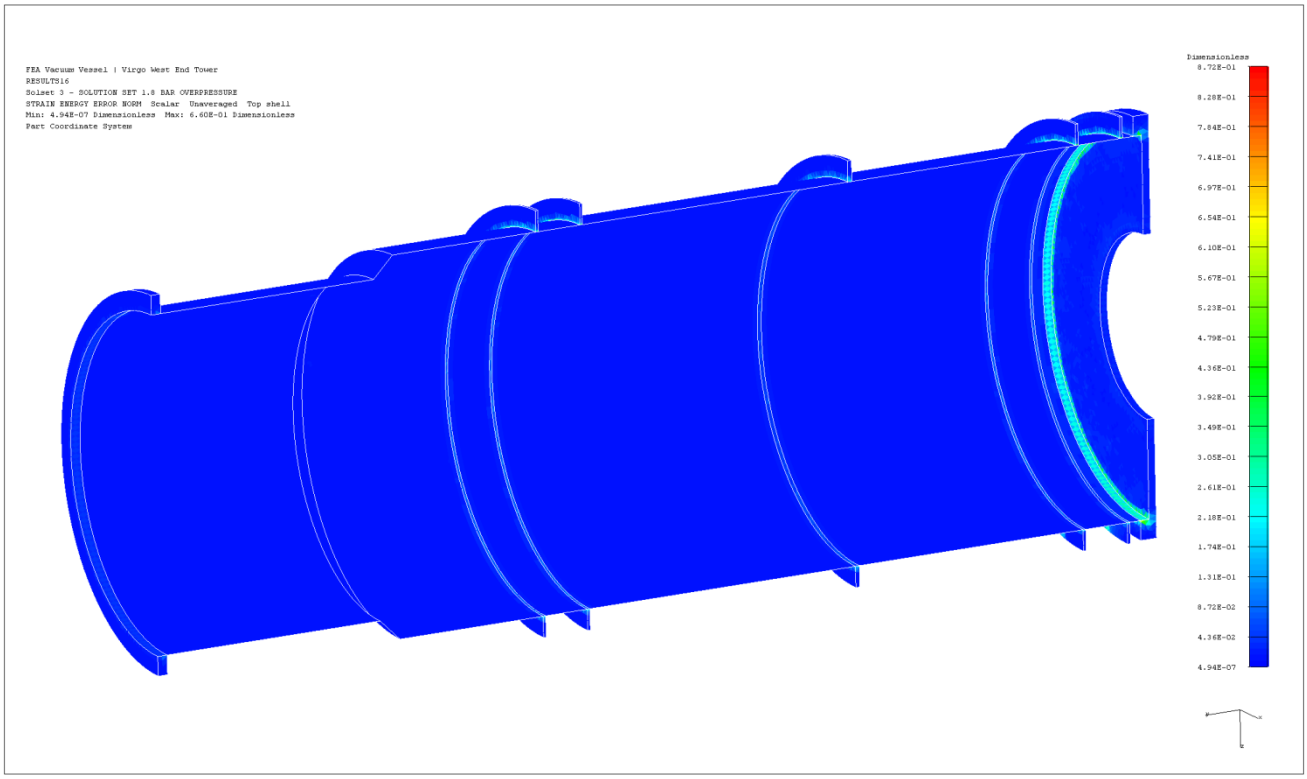


Figure 15, *strain energy error norm = 4%.*

4.5.2 Vacuum analysis

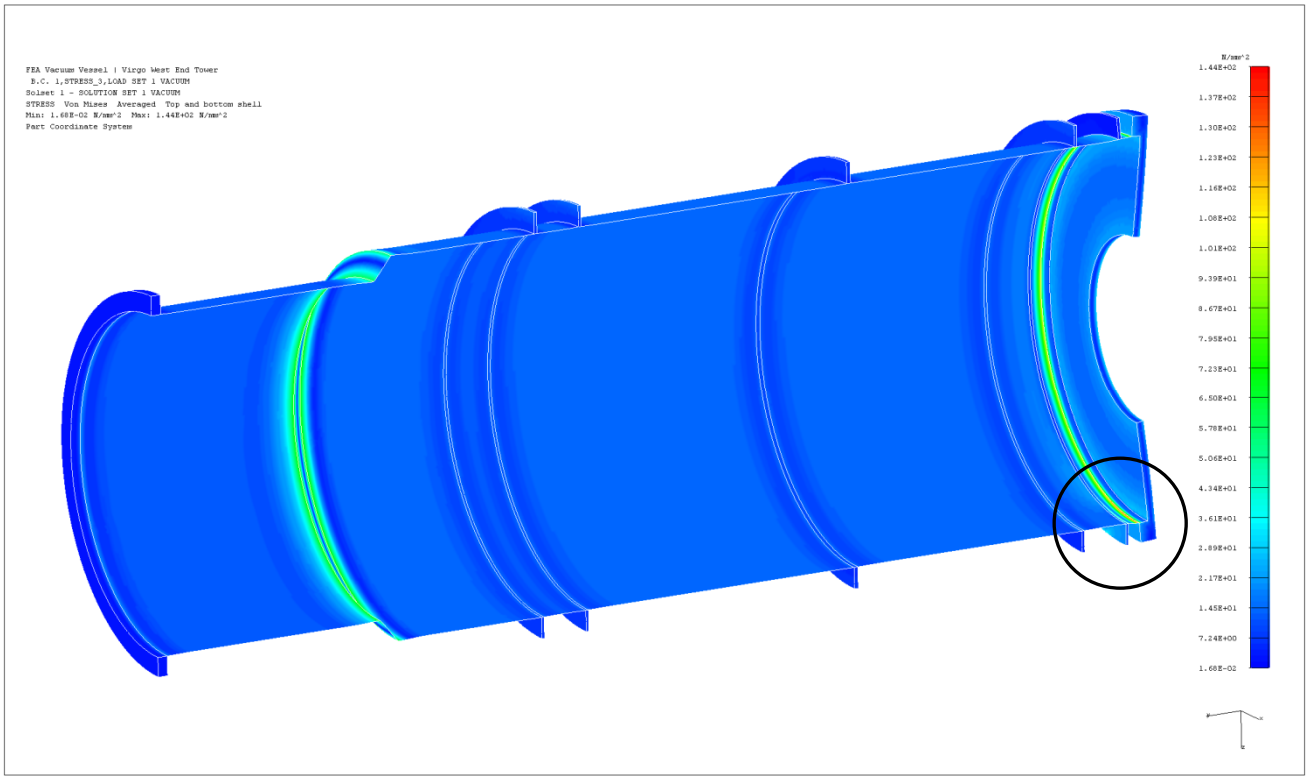


Figure 16, vacuum *stress result* | *max stress = 144 Mpa* | See detail in next figures

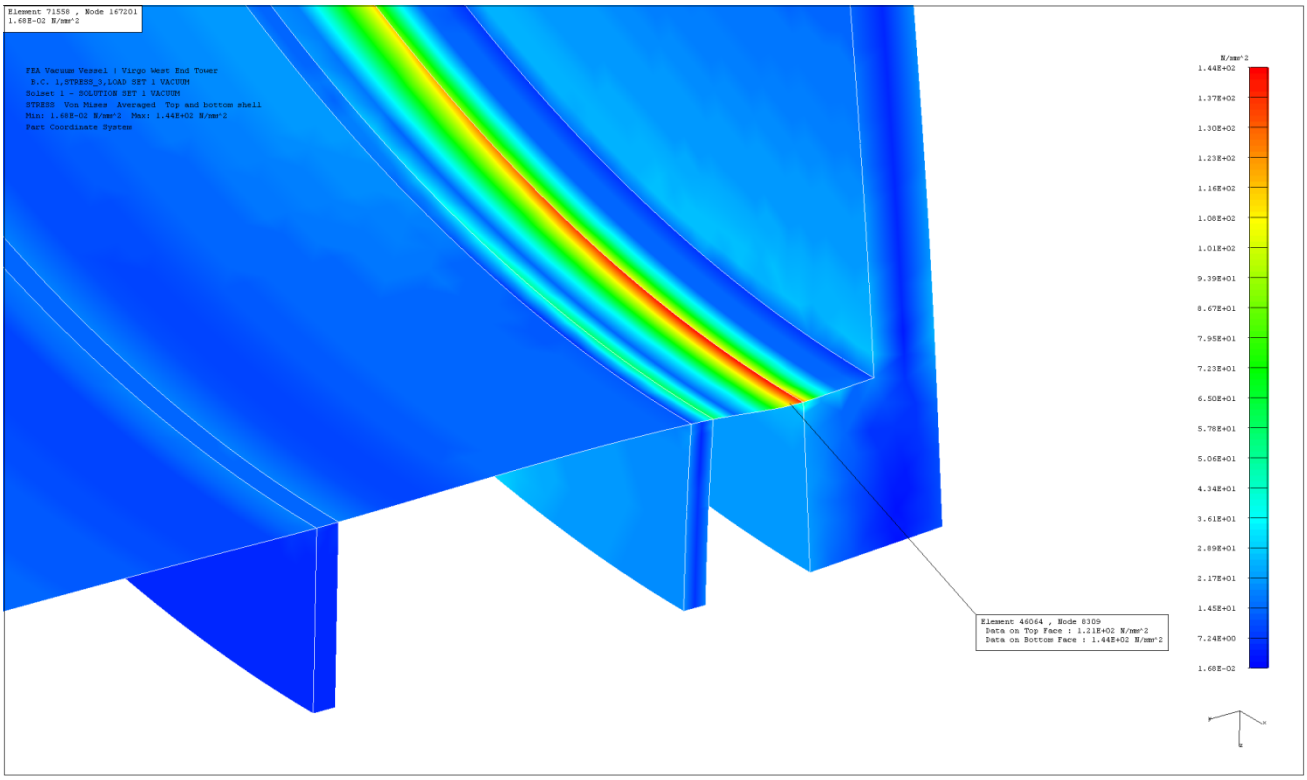


Figure 17, detail stress at the right flange | max 144 MPa

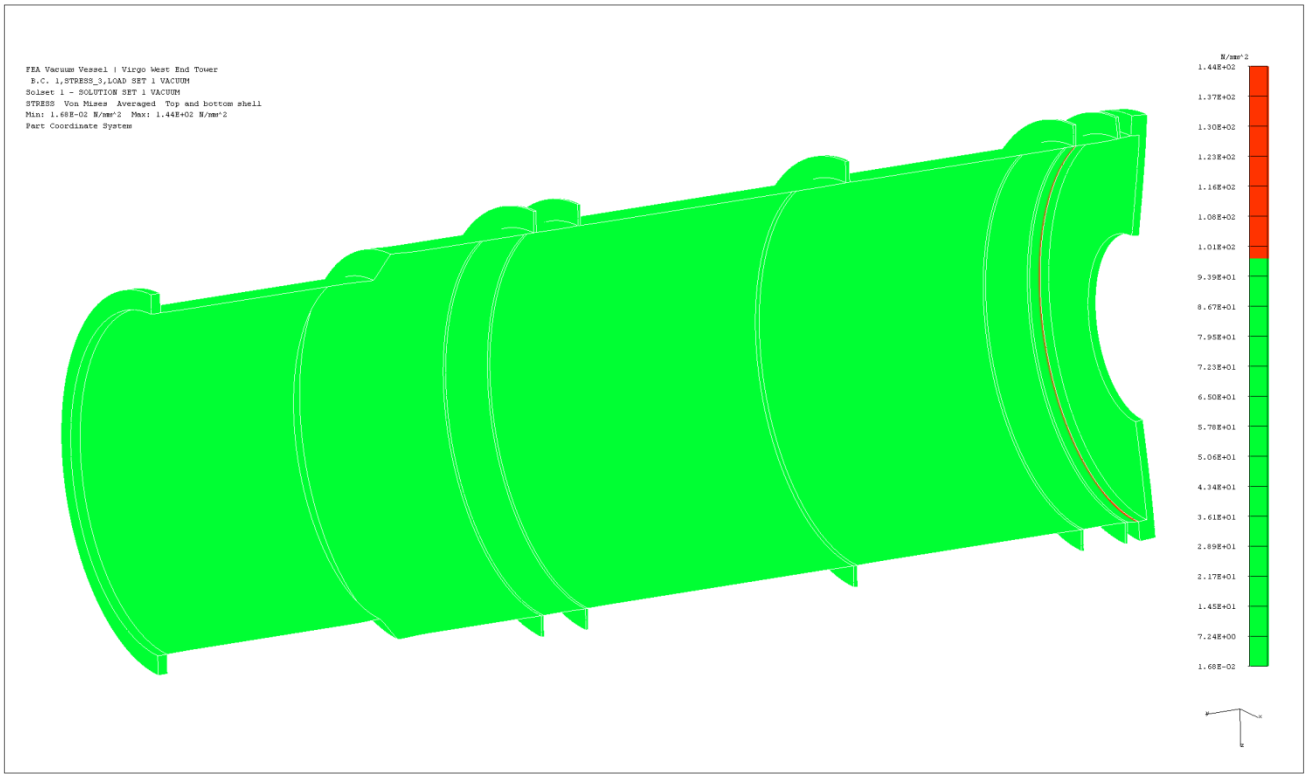


Figure 18, limited stress to 96 MPa (CODAP limit weld regions).

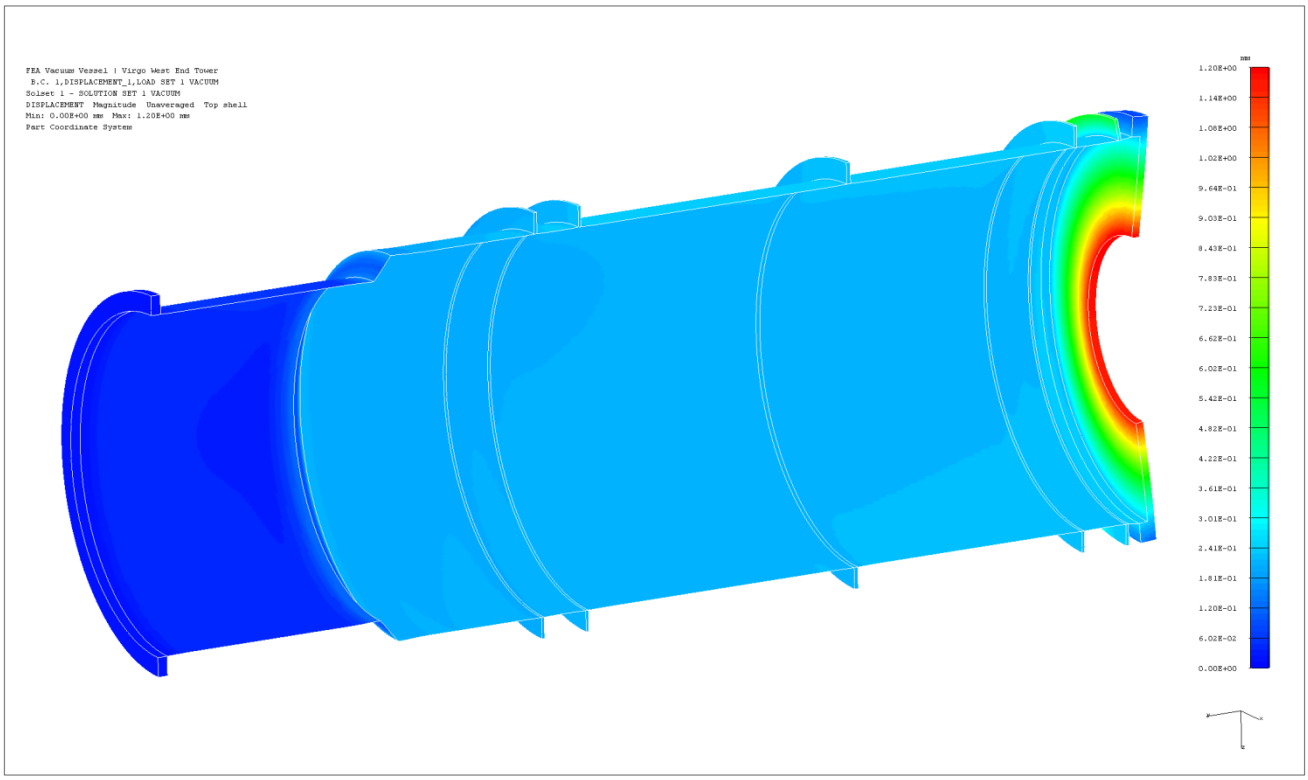


Figure 19, vacuum *displacement result | max displacement = 1.2 mm.*

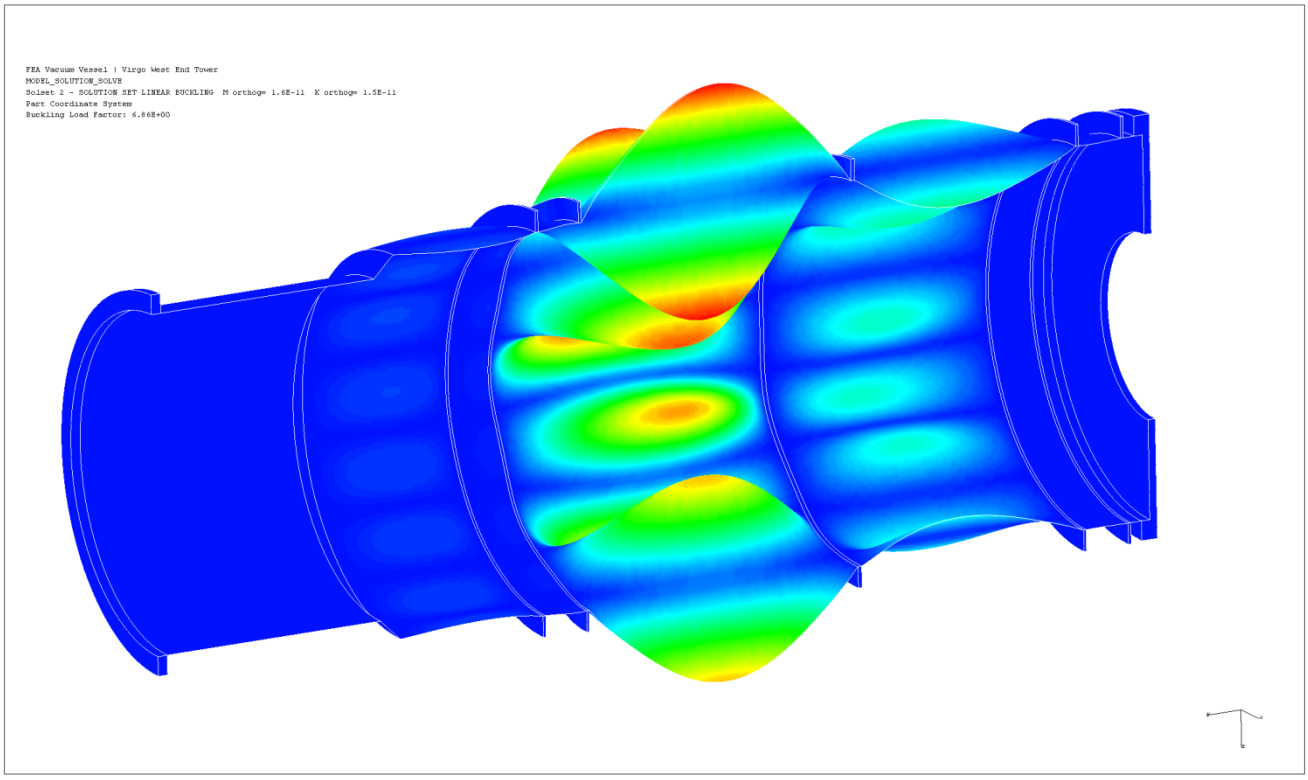


Figure 20, vacuum *first normal mode result* | buckling factor = 6.8.

5 RESULTS OF THE ANALYSIS.

The results are compared with the requirements defined by the CODAP. The limitations of the analysis are presented, and the compliance with the code is verified.

Assuming the internal pressure analysis, simulation shows that the expected max stress (161 MPa) is well below the acceptable values of 222 MPa for Peak regions. Detail 1 in Figure 11 shows that the peak of 161 MPa is situated next to the weld region. Detail 2 in Figure 12 shows the transition part between the two diameters of the tube which has the highest (peak) stress in weld regions. Maximum is 113 MPa which is well below the limit of peak/weld regions (155 MPa). Stresses in other weld regions are well below the CODAP limit of 103 MPa. Tube calculation also shows that the general stresses (20.3 MPa) in the vessel are far below the acceptable value for global zones (148MPa) and in the same range as the simulation shows (17 – 25 MPa). The stainless steel hydro-formed bellow at one end of the vacuum vessel has to accommodate an expansion of 1.7 mm.

Assuming the vacuum analysis, the calculation shows that the expected max stress (144 MPa) is well below the acceptable values of 205 MPa for Peak regions. Same as said in the internal pressure result, Figure 17 shows that the peak of 144 MPa is situated next to the weld region. Figure 18 shows that all weld regions are below the CODAP limit of 96 MPa for weld regions. Buckling analysis shows a buckling factor of 6.8, where a factor of 3 is required, which can be considered as safe. The tolerances for the fabrication of the vessel will ensure that the shape of the vessel will be in accordance with the model. The stainless steel hydro-formed bellow at one end of the vacuum vessel has to accommodate a compression of 1.2 mm.

The global value for the strain energy error norm in the vessel of 4% is below the 7% which is recommended by the IDEAS™ software.

6 SUMMARY

Presented is the safety analysis of the vacuum vessel which will be used at the Virgo institute in Italy. The system must comply with the Pressure Equipment Directive (PED) 97/23/CE. The French construction code for pressure apparatus (CODAP) is used to verify the stresses.

The vessel will be made of AISI 304L. The vessel has two design conditions. An internal pressure of 1.5 bar (nitrogen; in case of a failure of the inner cold part) at 20 ^{o}C and a vacuum (-1 bar; normal optional condition) at 150 °C (bake out of the system).

1. Pressure +1.5 bar | temperature 20°C
2. Pressure -1 bar | temperature 150°C

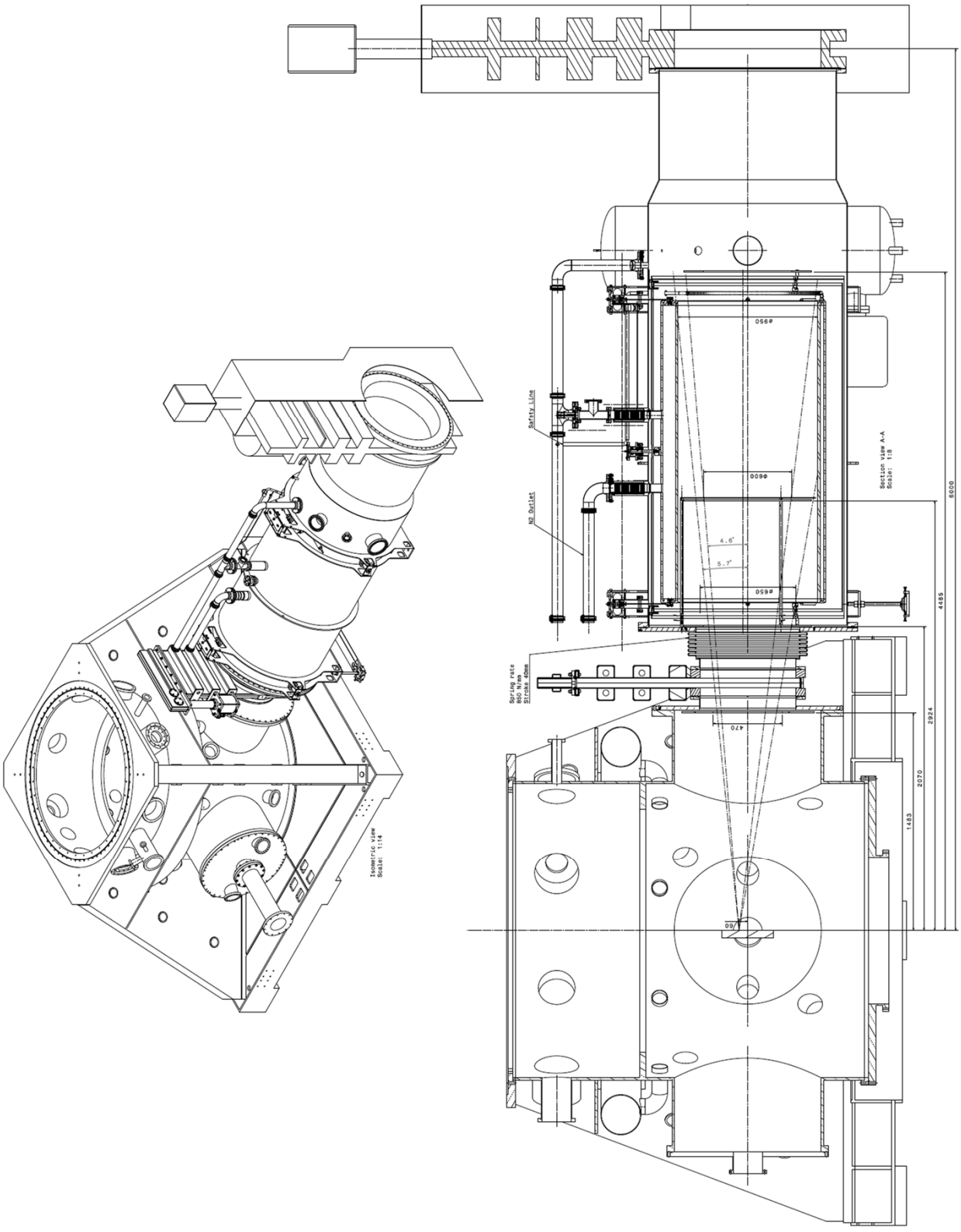
To prevent failure of the system, the system has to equipped with a burst disc which opens at max 1.5 bar absolute pressure.

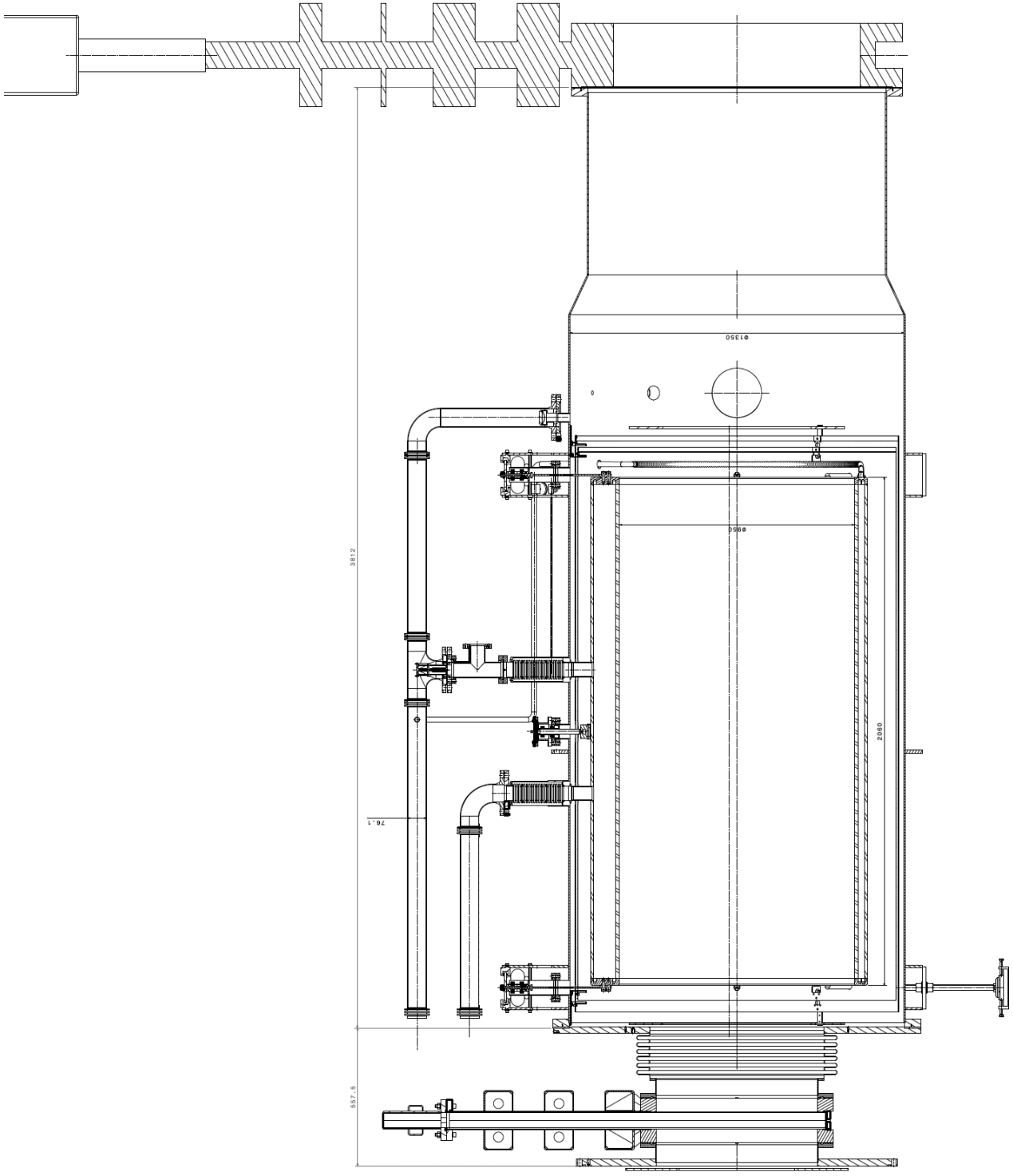
With a volume of 5500 liter and a design pressure PS of 1.5 bar, the vacuum vessel is classified in PED category III.

Analysis shows that the vessel is in compliance with the requirements put forth by the CODAP. Also the stability requirements (buckling) lay within the requirements of the CODAP.

7 APPENDICES

7.1 Main technical drawings

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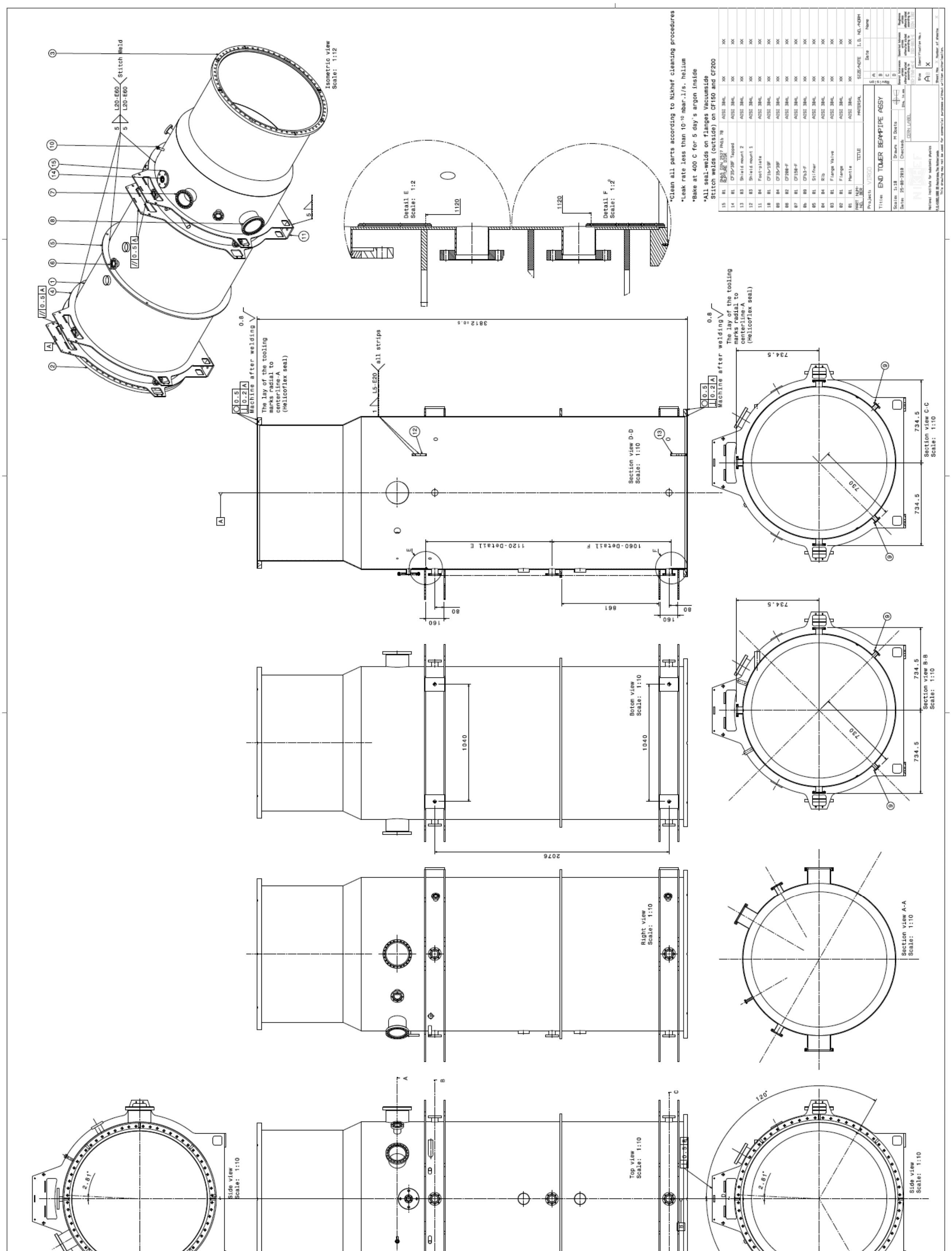
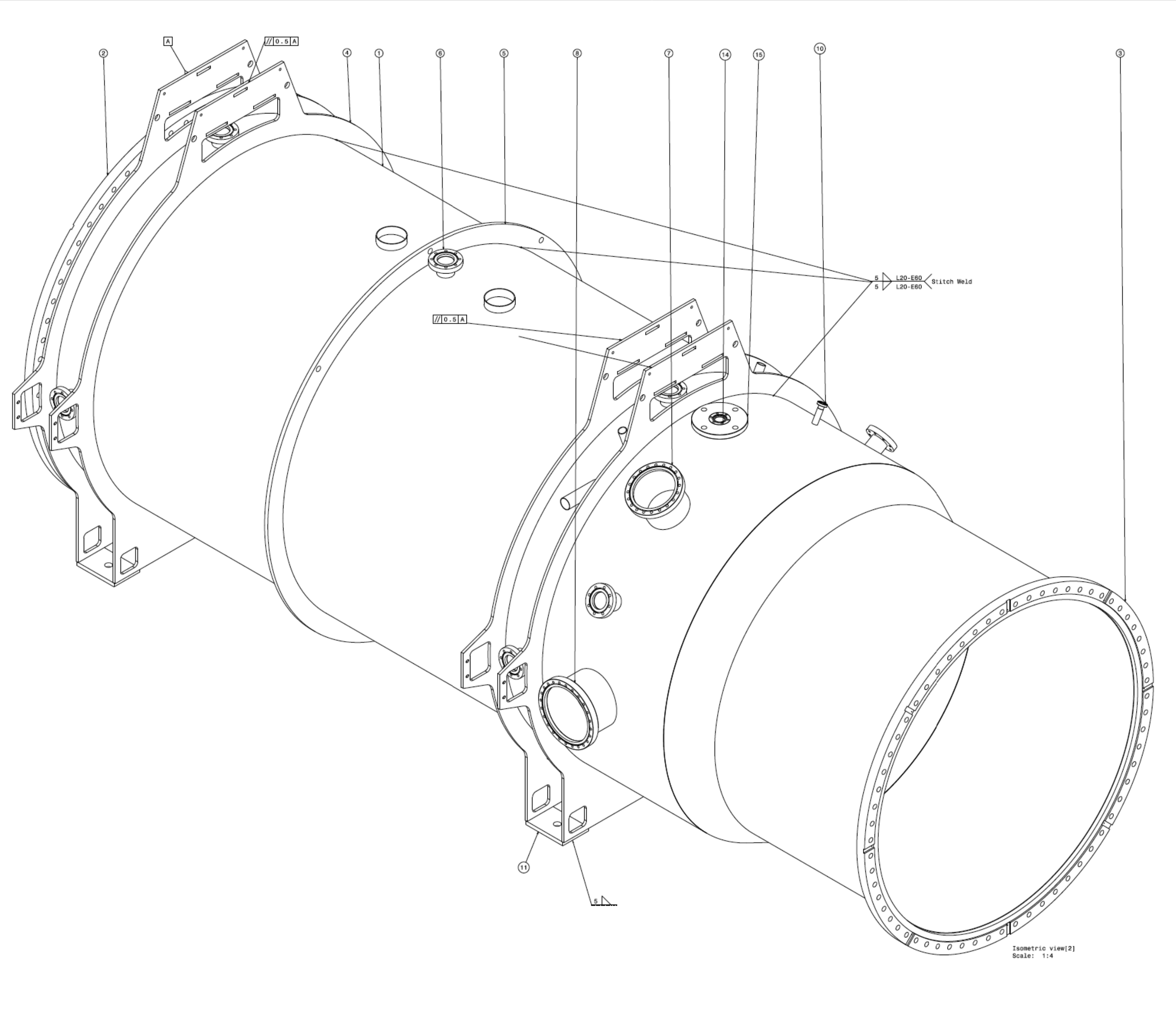


*Clean all parts according to Nikhef cleaning procedures
*Leak rate less than 10-10 mbar.l/s. helium
*Bake at 400 C for 5 day's argon inside
*All seal-welds on flanges Vacuumside
Stitch welds (outside) on CF150 and CF200
END TOWER BEAMPIPE ASSY
Isometric view
Scale: 1:12
Section view D-D
Scale: 1:10
Section view C-C
Scale: 1:10
Section view B-B
Scale: 1:10
Section view A-A
Scale: 1:10
Boton view
Scale: 1:10
Right view
Scale: 1:10
Top view
Scale: 1:10
Side view
Scale: 1:10
Detail E
Scale: 1:2
Detail F
Scale: 1:2
Machine after welding
The lay of the tooling marks radial to centerline-A
(Helicoflex seal)



*Clean all parts according to Nikhef cleaning procedures

*Leak rate less than 10^{-10} mbar.l/s. helium

*Bake at 400 C for 5 day`s argon inside

*All seal-welds on flanges Vacuumside
Stitch welds (outside) on CF150 and CF200

PART NO.	NUM-BER	TITLE	MATERIAL	SIZE/NOTE	I.D. NO./NORM
15	01	DN65 DIN 2527 PN16 70 RUPTURE DISK	AISI 304L	XX	XX
14	01	CF35/38F Tapped	AISI 304L	XX	XX
13	03	Shield mount 2	AISI 304L	XX	XX
12	03	Shield mount 1	AISI 304L	XX	XX
11	04	Foot-plate	AISI 304L	XX	XX
10	01	CF16/19F	AISI 304L	XX	XX
09	04	CF35/38F	AISI 304L	XX	XX
08	02	CF200-F	AISI 304L	XX	XX
07	01	CF150-F	AISI 304L	XX	XX
06	09	CF63-F	AISI 304L	XX	XX
05	01	Stifner	AISI 304L	XX	XX
04	04	Rib	AISI 304L	XX	XX
03	01	Flange Valve	AISI 304L	XX	XX
02	01	Flange	AISI 304L	XX	XX
01	01	Mantle	AISI 304L	XX	XX

Project: VIRGO

Title: END TOWER BEAMPIPE ASSY

Scale: 1:10 Drawn: M Doets

Date: 25-08-2010 Checked:

Dim. in mm

CERN LABEL

Revision	Date	Name
A		
B		
C		
D		

General tolerances unless otherwise stated according to ISO-2768-mK-E

Geometrical tolerances unless otherwise stated according to ISO-8015-E

Roughness unless otherwise stated according to DIN 1302

Size A0 Identification No.: X

Sheet No: X Number of sheets: X

NIKHEF National institute for subatomic physics P.O.41882,1009 DB Amsterdam,The Netherlands

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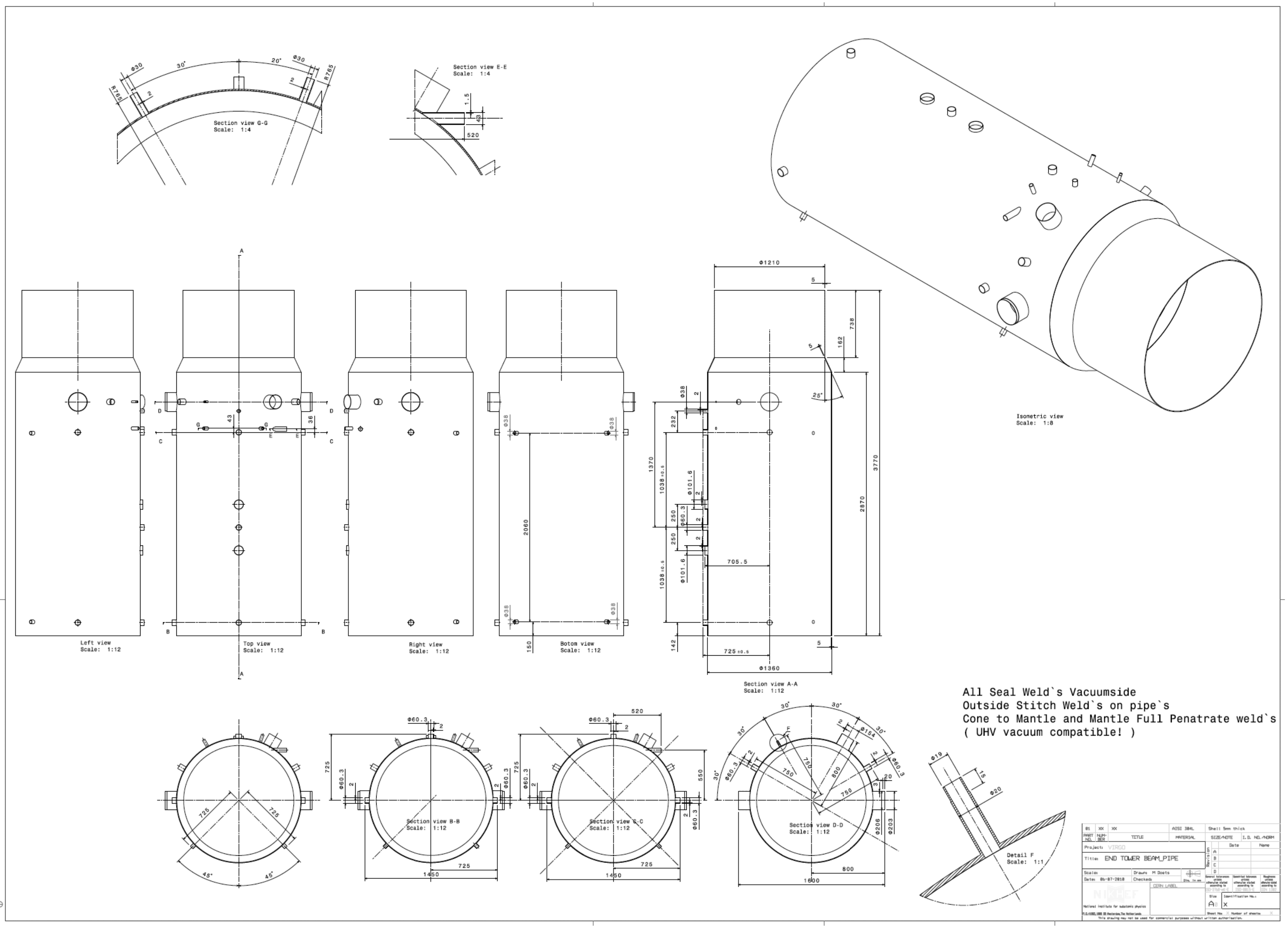

Section view G-G
Scale: 1:4
Section view E-E
Scale: 1:4
Isometric view
Scale: 1:8
Left view
Scale: 1:12
Top view
Scale: 1:12
Right view
Scale: 1:12
Bottom view
Scale: 1:12
Section view A-A
Scale: 1:12
Section view B-B
Scale: 1:12
Section view C-C
Scale: 1:12
Section view D-D
Scale: 1:12
Detail F
Scale: 1:1
All Seal Weld`s Vacuumside
Outside Stitch Weld`s on pipe`s
Cone to Mantle and Mantle Full Penatrate weld`s
(UHV vacuum compatible!)
01 XX XX AISI 304L Shell 5mm thick
PART NO. NUMBER TITLE MATERIAL SIZE/NOTE I.D. NO./NORM
Project: VIRGO
Title: END TOWER BEAM_PIPE
Scale:
Drawn: M Doets
Date: 06-07-2010
Checked:
CERN LABEL
Revision A B C D Date Name
National institute for subatomic physics
P.O.41882, 1009 DB Amsterdam, The Netherlands
Size A0
Identification No.: X
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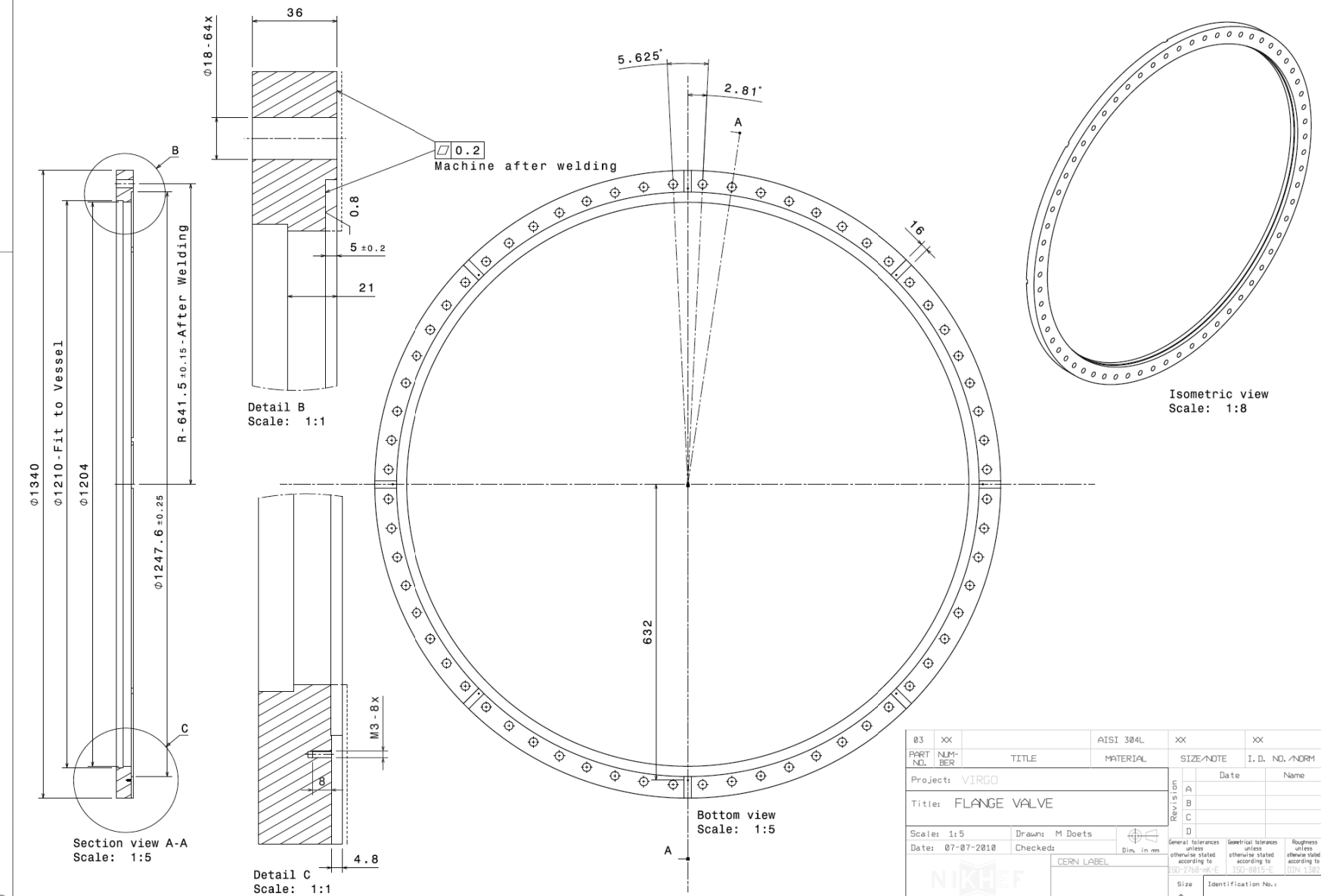

03	XX		AISI 304L	XX	XX
PART NO.	NUMBER	TITLE	MATERIAL	SIZE/NOTE	I.D. NO./NORM

Project: VIRGO

Title: FLANGE VALVE

Revision		Date	Name
	A		
	B		
	C		
	D		

Scale: 1:5 | Drawn: M Doets | Dim. in mm

Date: 07-07-2010 | Checked:

CERN LABEL

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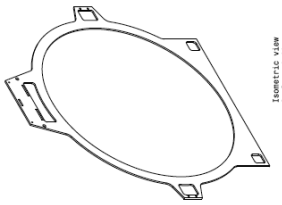
General tolerances unless otherwise stated according to ISO-2768-mK

Geometrical tolerances unless otherwise stated according to ISO-8015-E

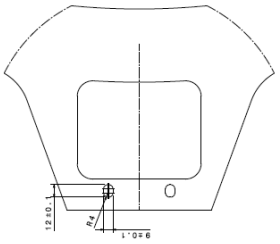
Roughness unless otherwise stated according to DIN 1302

Size A2 | Identification No.: X

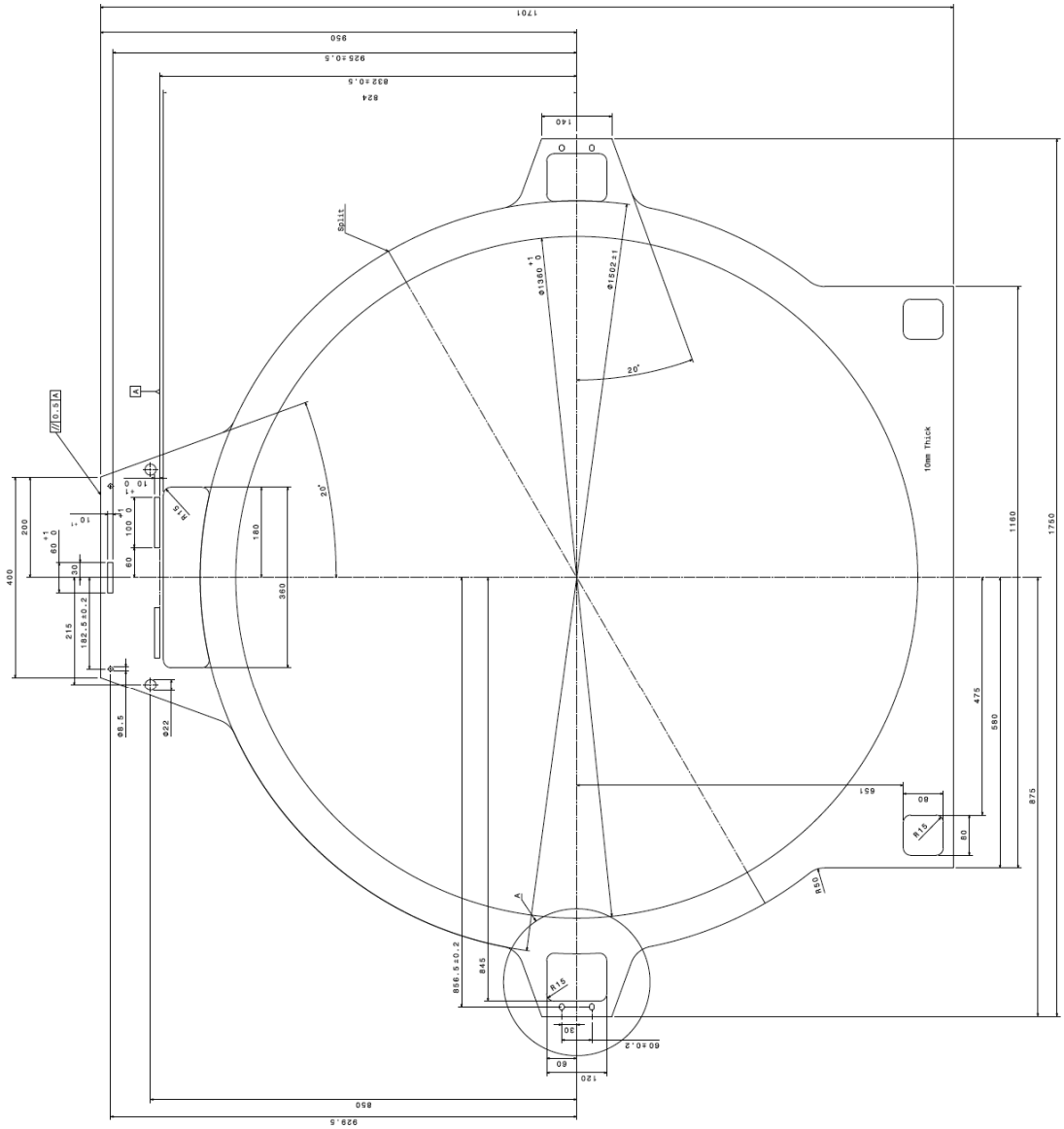
Sheet No: X | Number of sheets: X

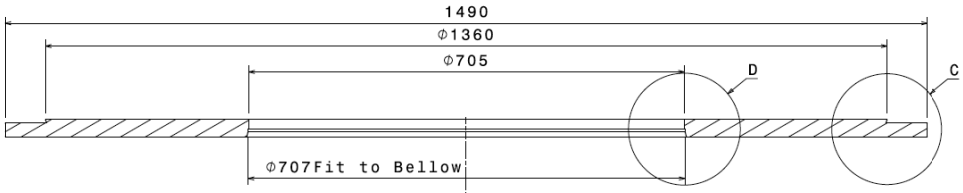


Isometric view
Scale: 1:10

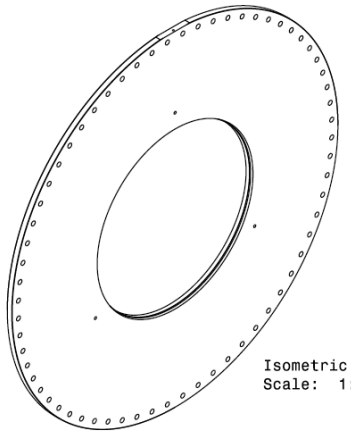


Detail A
Scale: 2:3

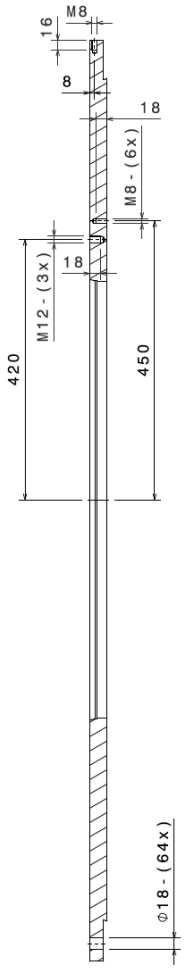




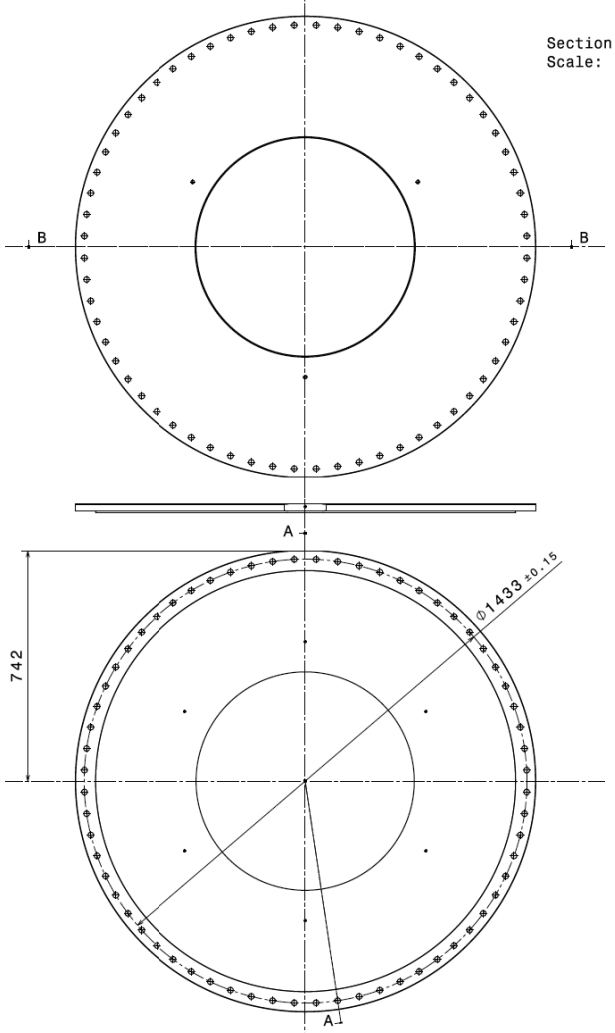
Section view B-B
Scale: 1:5



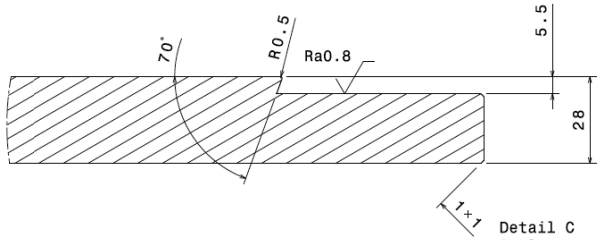
Isometric view
Scale: 1:10



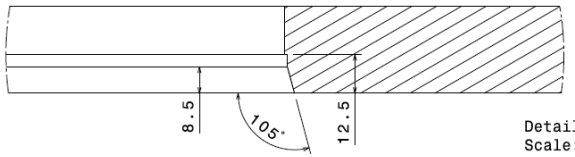
Section view A-A
Scale: 1:5



Scale: 1:10



Detail C
Scale: 1:1



Detail D
Scale: 1:1

01	XX	XX	AISI 304L	XX	XX
PART NO.	NUMBER	TITLE	MATERIAL	SIZE/NOTE	I.D. NO./NORM

Project: VIRGO

Title: CRYOSTAT FLANGE

Revision	Date	Name
A		
B		
C		
D		

Scale: 1:10 | Drawn: M Doets | Date: 27-08-2010 | Checked: | Dim. in mm

General tolerances unless otherwise stated according to ISO 2768-mK | Geometrical tolerances unless otherwise stated according to ISO 8015-E | Roughness unless otherwise stated according to DIN 4762

CERN LABEL

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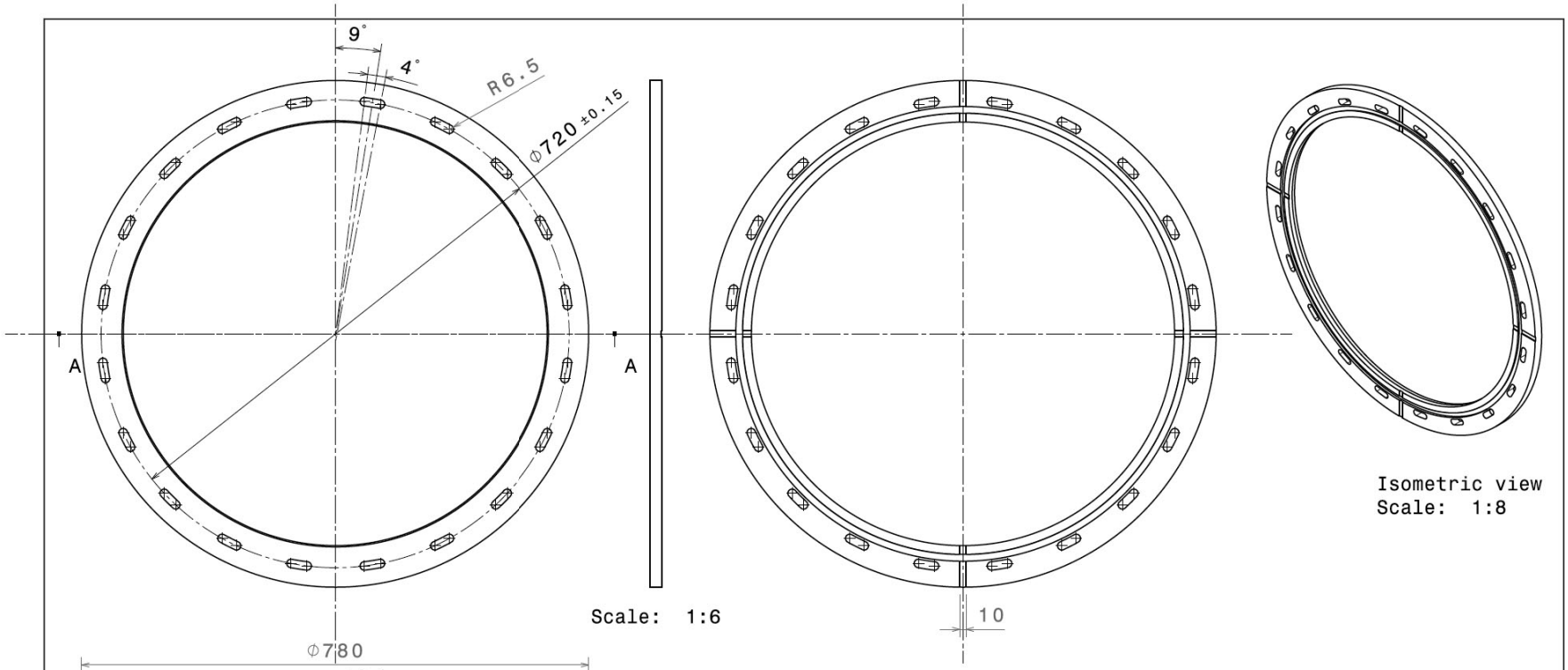
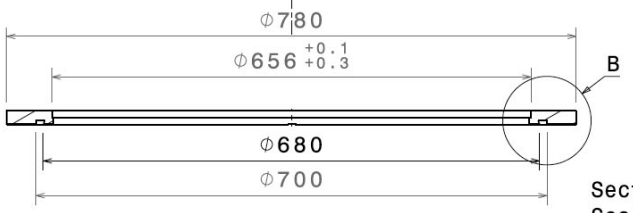
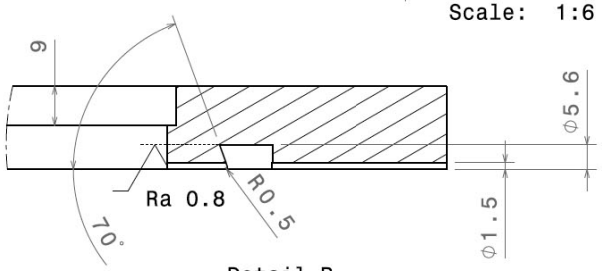
Size A2 | Identification No.: X

Sheet No: X | Number of sheets: X





Section view A-A
Scale: 1:6



Detail B
Scale: 1:1

03	XX	XX	AISI 304L	XX	XX
PART NO.	NUM-BER	TITLE	MATERIAL	SIZE/NOTE	I.D. NO./NORM

Project: X

Title: VALVE FLANGE

Revision		Date	Name
	A		
	B		
	C		
	D		

Scale: 1:6 | Drawn: M Doets | Dim. in mm

Date: 27-08-2010 | Checked:

General tolerances unless otherwise stated according to	Geometrical tolerances unless otherwise stated according to	Roughness unless otherwise stated according to
ISO-2768-mK-E	ISO-8015-E	DIN 1302

CERN LABEL

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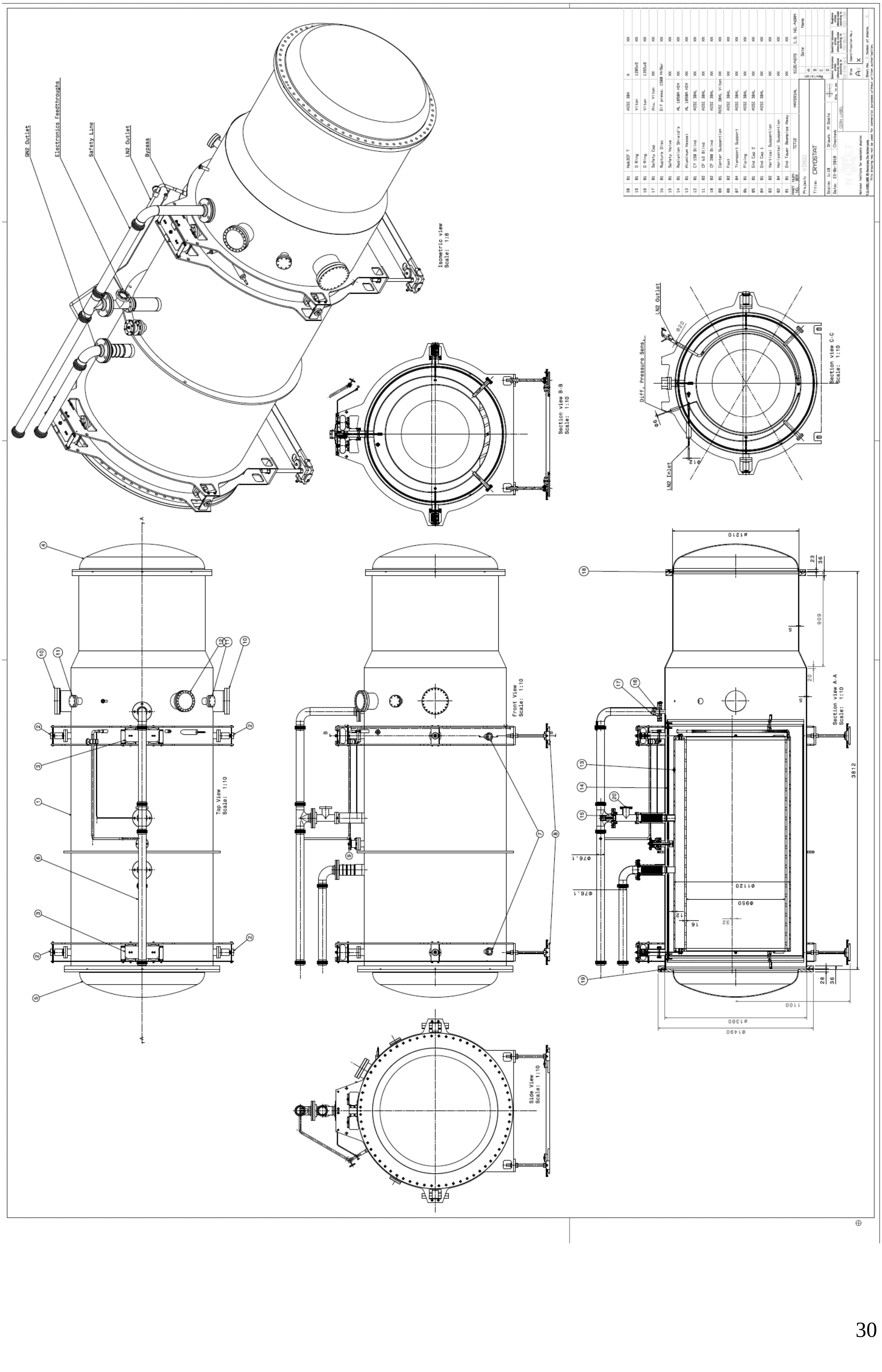
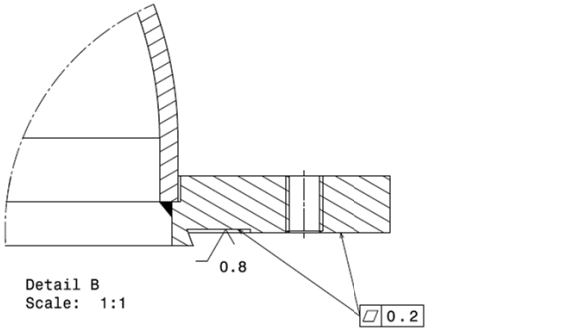
National institute for subatomic physics
P.O. 41882, 1009 DB Amsterdam, The Netherlands

Size A3 | Identification No.: X

Sheet No: X Number of sheets: X

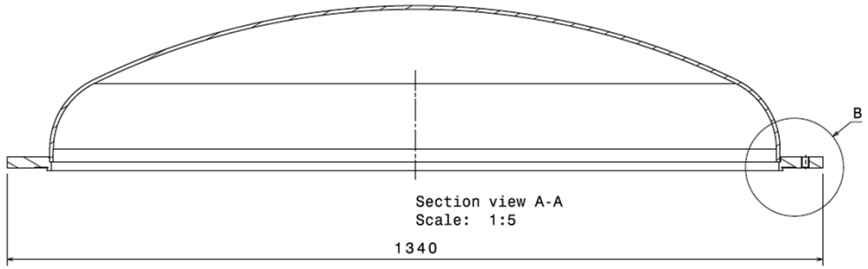


GM2 Outlet
Electronics Feedthroughs
Safety Line
LN2 Outlet
Bypass
Isometric view
Scale: 1:8
Section view B-B
Scale: 1:10
Diff. Pressure Sens.
LN2 Outlet
LN2 Inlet
Section view C-C
Scale: 1:10
Top View
Scale: 1:10
Front View
Scale: 1:10
Section view A-A
Scale: 1:10
Side View
Scale: 1:10
CRYOSTAT

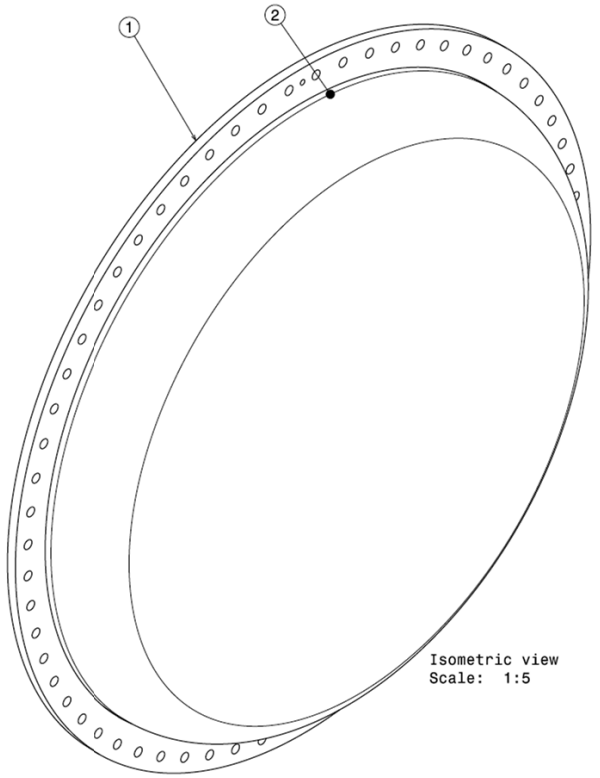


Detail B
Scale: 1:1

Machine after welding?



Section view A-A
Scale: 1:5



Isometric view
Scale: 1:5

*Clean all parts according to Nikhef cleaning procedures

*Leak rate less than 10^{-10} mbar.l/s. helium

PART NO.	NUMBER	TITLE	MATERIAL	SIZE/NOTE	I.D. NO./NORM
02	01	10% Head	AISI 304L	DIN 28011 D-1200xb	
01	01	Flange	AISI 304L	D-1340x23	XX

Project: VIRGO

Title: END CAP 1

Scale: 1:5 | Drawn: M Doets

Date: 24-06-2010 | Checked:

Dim. in mm

Revision	Date	Name
A		
B		
C		
D		

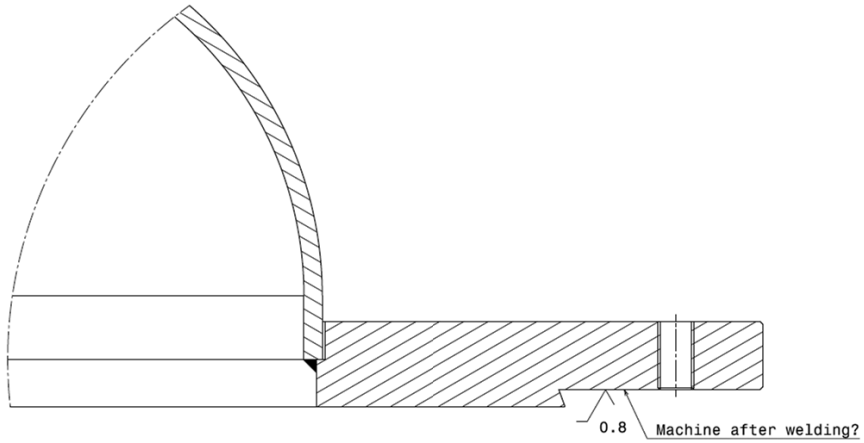
General tolerances unless otherwise stated according to	Geometrical tolerances unless otherwise stated according to	Roughness unless otherwise stated according to
ISO-2768-mK-E	ISO-8015-E	DIN 1302

CERN LABEL

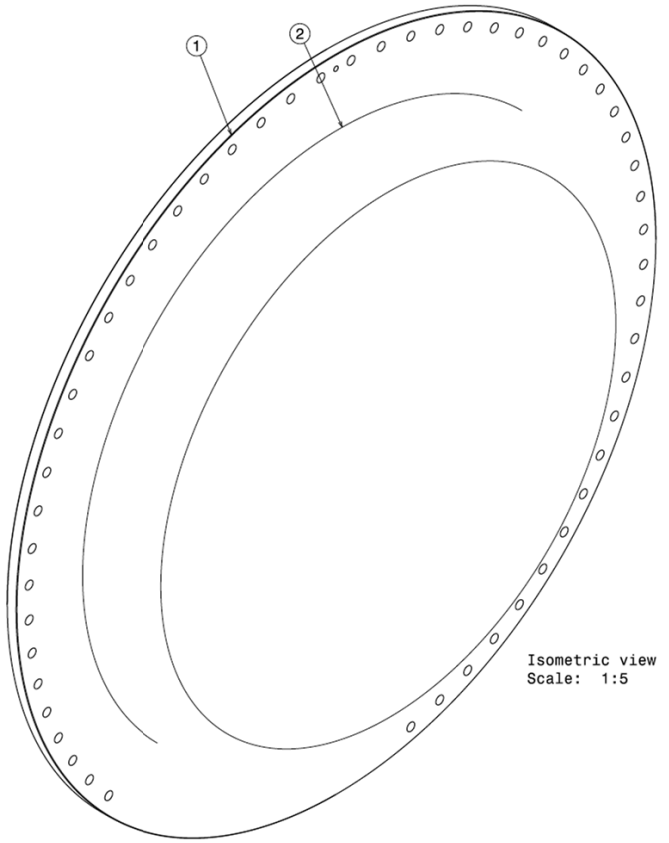
Size A2 | Identification No.: X

Sheet No: X | Number of sheets: X

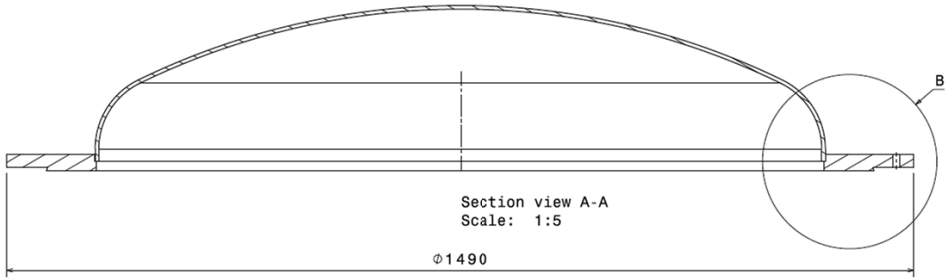
National institute for subatomic physics
P.O. 41882, 1009 DB Amsterdam, The Netherlands



Detail B
Scale: 1:1



Isometric view
Scale: 1:5



Section view A-A
Scale: 1:5

*Clean all parts according to Nikhef cleaning procedures

*Leak rate less than 10^{-10} mbar.l/s. helium

PART NO.	NUMBER	TITLE	MATERIAL	SIZE/NOTE	I.D. NO./NORM
02	01	10% Head	AISI 304L	DIN 28011 D-1200x6	XX
01	01	Flange	AISI 304L	D-1490x28	XX

Project: VIRGO

Title: END CAP 2

Revision: A, B, C, D — Date — Name

Scale: 1:5 | Drawn: M Doets | Date: 25-06-2010 | Checked: | Dim. in mm

General tolerances unless otherwise stated according to ISO-2768-mK-E | Geometrical tolerances unless otherwise stated according to ISO-8015-E | Roughness unless otherwise stated according to DIN 1302

CERN LABEL

Size A2 | Identification No.: X

Sheet No: X | Number of sheets: X

National institute for subatomic physics
P.O. 41882, 1009 DB Amsterdam, The Netherlands

7.2 Contents of the PED modules

Module	Description
A	Manufacturers attend to internal manufacturing control, themselves producing and storing the documentation. The authorized body not involved.
A1	Manufacturers attend to internal manufacturing control, themselves producing and storing the documentation. The authorized body monitors the final verification through unannounced visits.
B	Manufacturers draw up the technical documentation and provide samples. The authorized body examines the technical documentation and undertakes the necessary testing of the samples and issues an EEC type testing certificate.
B1	The manufacturer draws up the technical documentation. The authorized body examines the technical documentation and issues an EEC construction testing certificate.
C1	Manufacturers ensure that production conforms to the specifications of the type approval. The authorized body monitors the final verification through unannounced visits.
D	Manufacturers use a documented quality assurance system that covers production, final inspection and testing. The authorized body audits, approves and monitors the quality assurance system.
D1	As D but manufacturers must also draw up and file technical documentation for the equipment.
E	Manufacturers use a documented quality assurance system that covers final inspection and testing. The authorized body audits, approves and monitors the quality assurance system.
E1	As E but manufacturers must also draw up and file technical documentation for the equipment.
F	Manufacturers ensure that production conforms to the specifications of the type approval or the construction testing certificate. The authorized body inspects each product. The authorized body issues a certificate of conformity.
G	The manufacturer draws up and submits the technical documentation. The authorized body examines the technical documentation, manufacture and each individual product. The authorized body issues a certificate of conformity.
H	Manufacturers use a documented quality assurance system that covers construction, production, final inspection and testing.
H1	As H but manufacturers must also apply for construction approval from the same authorized body that monitors the quality assurance system.