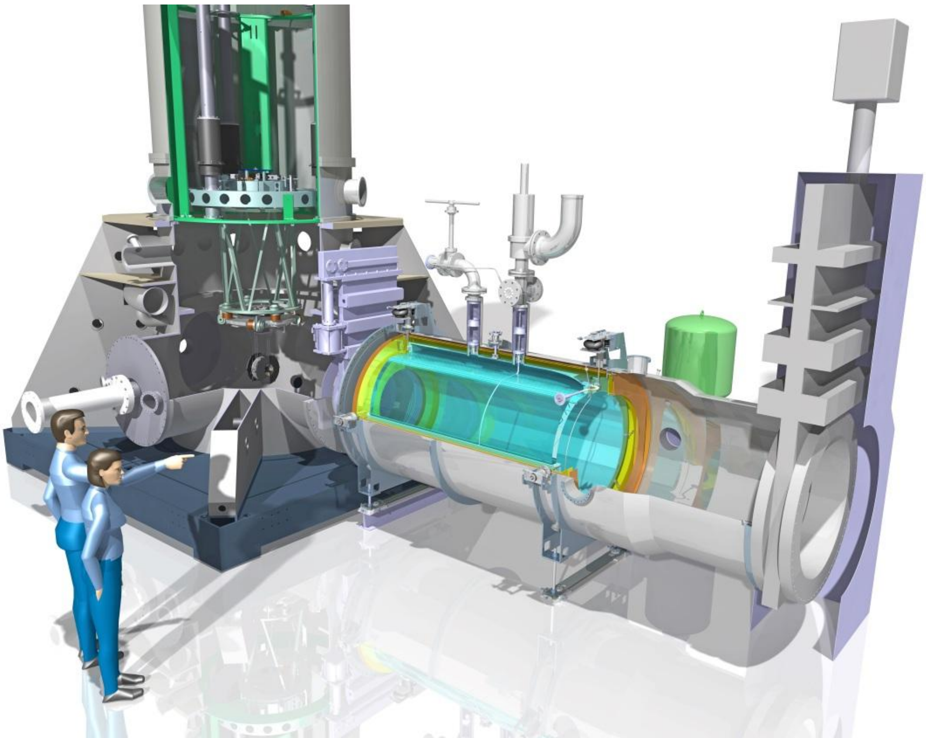
Technical Description of the Cryolinks

Nikhef number:	Item number:	Date: **19/12/2012**	Page: **1 of 10**
47110-MT-00007	**AA2830**	Status: In Work	Revision: A.6
Project: **Gravitational Waves Virgo Cryogenic Link**			
Department: **Mechanical Technology**		Top folder: **West End Tower Cryostat**	



Contact: K. de Roo, kderoo@nikhef.nl

Created by:	*Checked by:*	*Approved by:*
K. de Roo	J. van den Brand / M. Doets	J. van den Brand / M. Doets

Written by:

J. van den Brand, M. Kraan, M. Doets, K. de Roo

HISTORY OF CHANGES			
Rev. No.	Date	Pages	Description of changes
A	05-05-2011	All	Initial version
A2	21-06-2011	All	Comments added
A3	06-08-2011	All	Comments added
A4	16-11-2012	All	General description for Cryolinks tendering
A.5	28-11-2012	All	Comments added
A.6	19-12-2012	All	Second review

CONTENTS

1. INTRODUCTION

The Virgo project is a physics experiment for the detection of gravitational waves (see https://wwwcascina.virgo.infn.it/). The Virgo detector for gravitational waves is based on a Michelson Interferometer with two orthogonal arms each 3 km long. Multiple reflections between mirrors located at the extremities of each arm extend the effective optical length of each arm up to 120 km.[(1)]

In order to reach the extreme sensitivity required, the whole interferometer attains optical perfection and is extremely well isolated in order to be only sensitive to the gravitational waves. Scientists have developed most advanced techniques in the field of high power ultra-stable lasers, high reflectivity mirrors, seismic insulation and position and alignment control for the project.

The Advanced Virgo project is an enhancement of the sensitivity of the interferometer by a factor 10. One of the enhancements is to improve the present vacuum level in the interferometer arms by a factor 100. This will lower the phase noise for the YAG light scattering from the residual gas inside these arms.

The present system operates at about 10^{-7} mbar (dominated by water) although it has been designed and tested to reach a base pressure below 10^{-9} mbar (dominated by hydrogen) after an overall bake out. With the Cryolinks the interferometer arms can be separated from the towers that hold the mirrors and allow bake out of the arms, also the migration of water vapour from the unbaked mirror towers to the ITF arms can be decreased. With these measures a base pressure below 10^{-9} mbar can be reached.

In total 4 Cryolinks will be installed for Advanced Virgo; West End tower Cryolink, North End tower Cryolink, West Input tower Cryolink and the North Input tower Cryolink.

This document provides background information about the Cryolinks. The emphasis of this document is on the mechanical design of the Cryolinks.

[1] http://www.ego-gw.it/public/virgo/virgo.aspx

2. GENERAL DESCRIPTION OF THE CRYOLINKS

The Cryolinks will be installed at the West End tower, North End tower, West Input tower and the North Input tower. A Cryolink can be separated from the mirror tower with a DN630 valve and with a DN1000 valve the Cryolink is separated from the ITF arm, an example of the installation is given in Figure 1. The Cryolink is mounted directly on the DN1000 valve and with adapter pieces the Cryolink is mounted to the valve on the mirror tower.

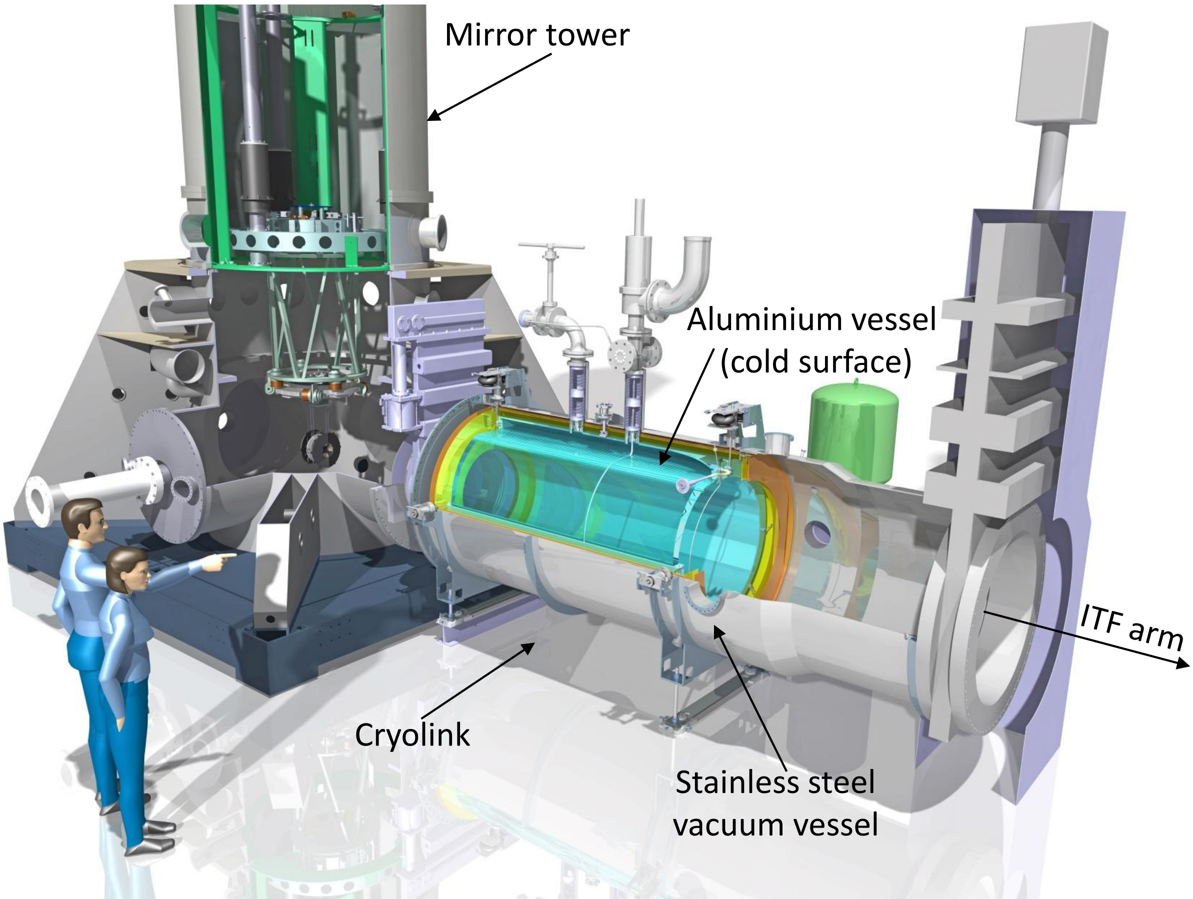


Figure 1: *Installation of a Cryolink at a mirror tower*

Mainly a Cryolink consists of a vacuum vessel of stainless steel and an aluminium vessel that function as a cold surface. The aluminium vessel is suspended inside the vacuum chamber and will be filled with liquid nitrogen during normal operation to cool down its surface down to -196 °C. Two aluminium heat shields are mounted between the stainless vacuum vessel and aluminium vessel. Detailed information about the stainless steel vessel and the aluminium vessel is given in the following chapters.

First a prototype West End tower Cryolink is assembled and tested. The remaining three Cryolinks will be ordered together. The three stainless steel vacuum chambers of the Cryolinks will have slightly different lengths due to their location, while the aluminium cold cryostats inside these chambers will be identical vessels.

A view of the Cryolink assembly is given in drawing **1.00.000 Cryostat assy_Sheet_1.pdf** and in the Annex to this document.

3. CRYOLINK PRESSURE EQUIPMENT

The Cryolink is designed by Nikhef and is checked by the design standard PED/AD2000. The category and module according to PED requirements that apply to the Cryolink is: *Category: None, Module: None.*

The legal obligations with regard to the PED requirements that apply to the Cryolink is article 3, section 3: products; Pressure equipment beyond the directive, must be designed according the in the member states applicable directives of good craftsmanship.

Despite that the PED is not applicable, the Cryolink is treated as pressure equipment. This means that the mechanical behaviour of the aluminium vessel is tested by pressuring. The pressure will be 1.43 times the maximum operating pressure (1.5 bar absolute pressure). The burst disc value of the stainless steel vessel is checked by using the certificate.

The design pressure of the aluminium vessel is 1.5 bar absolute and the vessel will be equipped with a relieve valve which opens at 0.5 bar with respect to atmospheric pressure.

The design pressure of the stainless steel vacuum vessel is 1.5 bar absolute. The vessel will be equipped with a burst disk in combination with a safety disk on an O-ring as safety device and connected to the UHV system. The burst pressure is set at 0.5 bar.

4. ALUMINIUM VESSEL

The aluminium vessel is suspended via flexible head-bridges on two sets of air springs (vertical direction) and four rubber springs (horizontal) within the vacuum vessel, since the cold surface will move due to thermal expansion (about 4 mm/m) with respect to the vacuum vessel. This suspension system also acts as a heat bridge that minimizes thermal losses due to heat conduction.

The aluminium vessel will be employed with two capacitive level sensors designed by Nikhef, 10 PT100 temperature sensors and one differential pressure sensor, see Figure 2. Three of the temperature sensors can be replaced, while seven PT100 sensors are mounted in a permanent manner. The sensors are installed on strategic places partly inside the aluminium vessel.

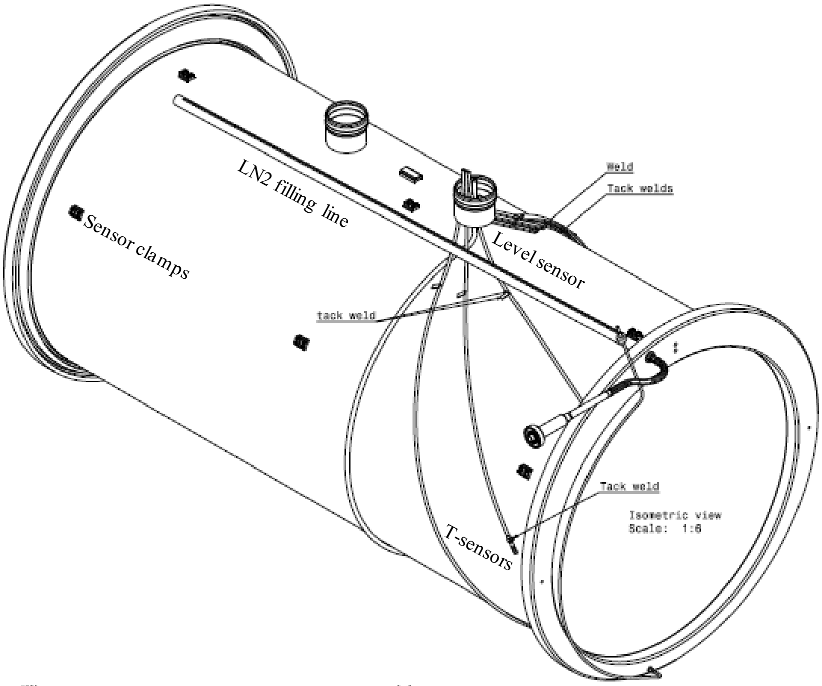


Figure 2: *Schematic view of inside of the aluminium vessel with two capacitive level sensors, 10 temperature sensors and one differential pressure sensor*

The aluminium vessel will be filled with liquid nitrogen (LN_2) during normal operation of the Advanced Virgo experiment. Therefore the aluminium vessel is employed with a LN_2 filling line to reduce seismic noise from the flow. The LN_2 level will be controlled with a precision of ±5 mm by means of the capacitive sensors or the differential pressure sensor.

The inner aluminium vessel wall is placed asymmetrically off-axis by 32 mm. In this way the LN2 surface is maximized to 550 mm over the full length.

Specifications aluminium vessel:*
Dimensions: length 2023 mm

- Inner vessel: inner diameter of 950 mm and outer diameter of 980 mm
- Outer vessel: inner diameter of 1096 mm and outer diameter of 1120 mm

Volume: 380 litre → LN_2 volume 300 litre

Material: AW-5083

External pressure: 0 bar absolute

Internal pressure: 1 to 1.5 bar absolute

Temperature range: -196 to +140 °C

Temperature sensors: supplied by Nikhef

Differential pressure sensor: supplied by Nikhef

Capacitive sensor: from drawings

Welds specifications: from drawings

All parts must be suitable for Ultra High Vacuum and be cleaned according to the Nikhef cleaning procedures for vacuum parts.

Table 1: *Operational conditions for the aluminium vessel*

Operation	***Temperature [°C]***	***Inside pressure [mbar]***	***Outside Pressure [mbar]***	***Medium***
Normal operation	-196	1000	10^{-9}	LN2
Filling	-196	1000	10^{-9}	LN2
Emptying	-196 to 20	1300	10^{-9}	GN2/LN2
Regeneration	140	1000	10^{-9}	GN2
Bake out	140	1000	10^{-9}	GN2
Testing	20	0	1000	Vacuum

*If the specifications deviate from the drawings, the drawings prevail

5. STAINLESS STEEL VACUUM VESSEL

The vacuum vessel, the end caps and CF blind-off flanges will be constructed from stainless steel 304L[(2)]. 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 which are all carried out with all-metal seals. Helicoflex seals are used to connect the Cryolink to the DN1000 valves and the side flange of the Cryolink.

Stainless steel hydro-formed bellows are foreseen as an adapter piece between the trap and the tower. These bellows have a 700 mm inner diameter and can accommodate expansion of the structure. This is needed during installation of the links, while also thermal expansion during bake-out must be accommodated. The particular construction has been chosen in order to minimize the atmospheric load on the structures when the tower is vented. Moreover, the present design facilitates the assembly of the link.

Specifications stainless steel vacuum vessel:*

Dimensions: outer diameter of 1350 mm (not including the reinforcement ribs)

- Length of 3186 mm (North End)
- Length of 3212 mm (West Input)
- Length of 3036 mm (North Input)

Material: 304L

External pressure: 1 bar absolute

Internal pressure range: Ultra high vacuum $<10^{-9}$ mbar to 1 bar absolute

Temperature range: +5 to +140 °C

Welds specifications: from drawings

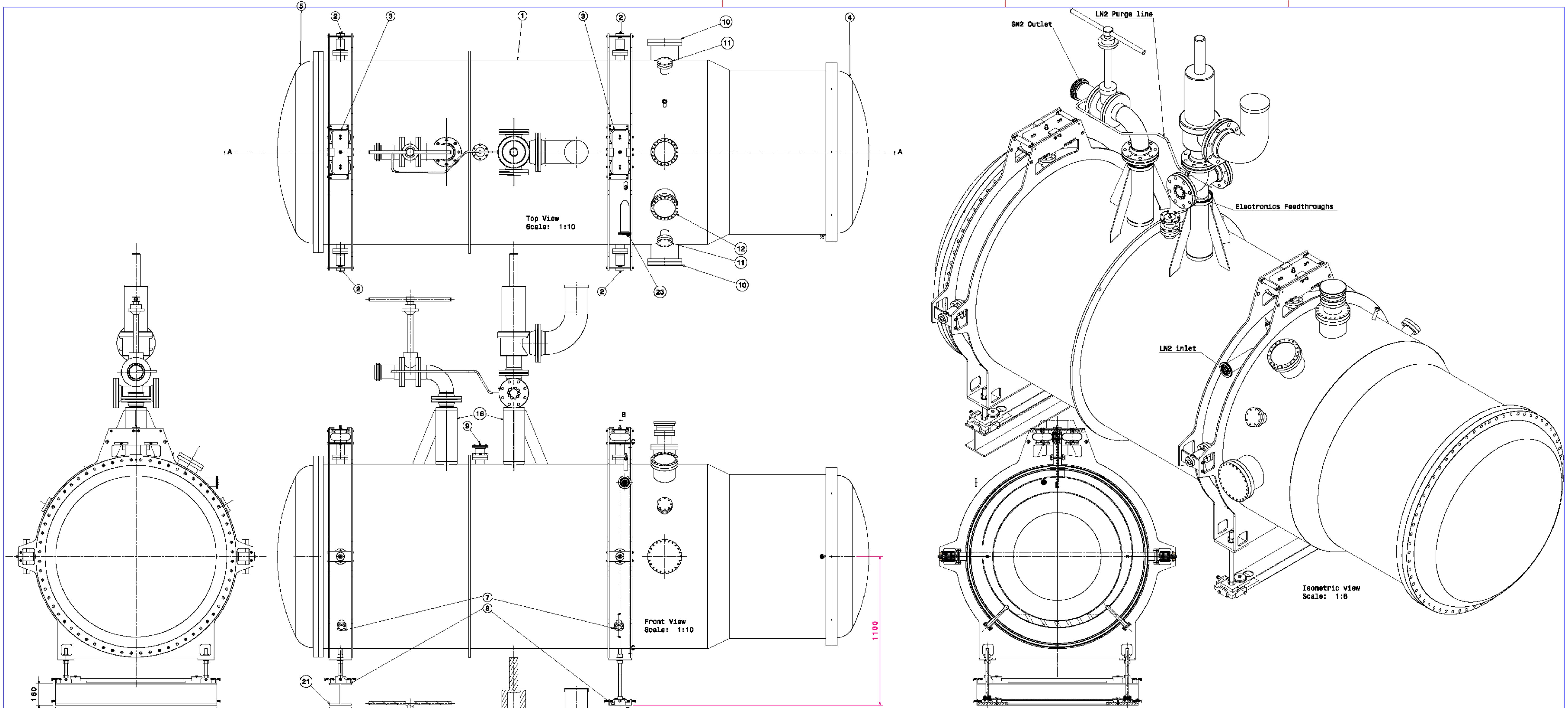
All parts of the outer vessel must be suitable for Ultra High Vacuum and be cleaned according to the Nikhef cleaning procedures for vacuum parts.

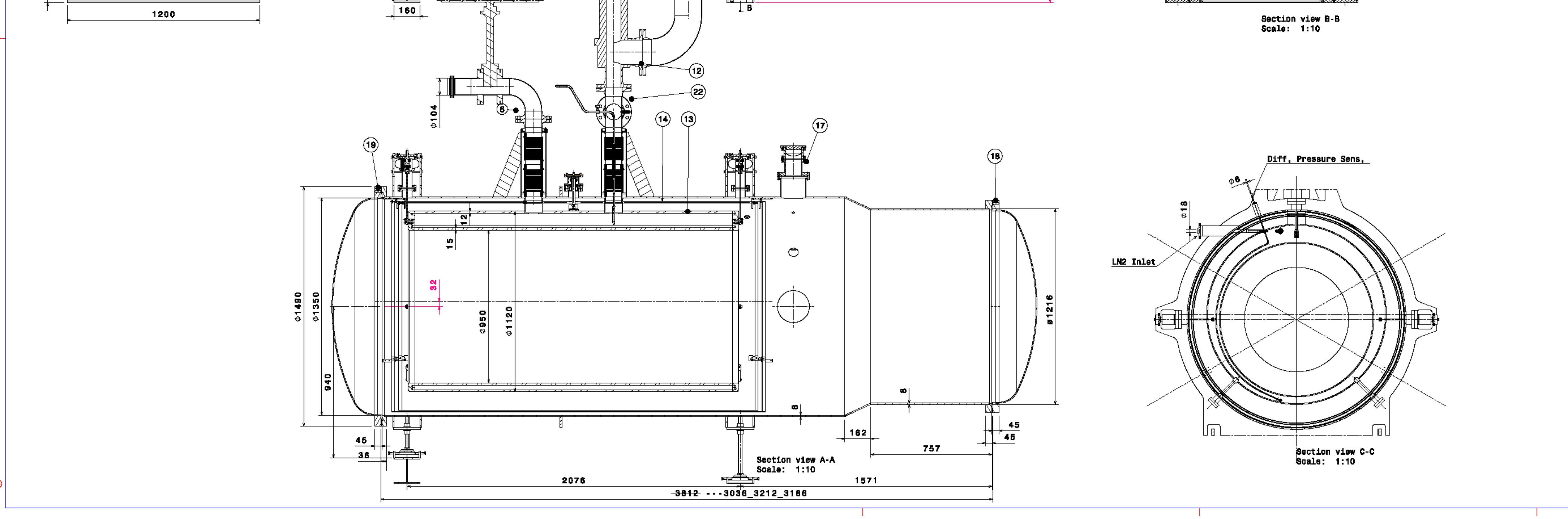
Table 2: *Operational conditions for the stainless steel vacuum vessel*

Operation	***Temperature [°C]***	***Inside pressure [mbar]***	***Outside pressure [mbar]***	***Medium***
Normal operation	20 (5-40)	10^{-9}	1000	Vacuum
Venting	20 (5-40)	1000	1000	DRY AIR / GN2
Regeneration	140	10^{-9}	1000	Vacuum
Bake out	140	10^{-9}	1000	Vacuum

[2] The use of stainless steel 316L has been discussed, but provides no advantage at liquid nitrogen temperature.

*If the specifications deviate from the drawings, the drawings prevail





For: West input: North End: and North input use the drawings bellow

01	01	WEST INPUT Tower Beampipe Assy			1.30.000
01	01	NORTH End Tower Beampipe Assy			1.40.000
01	01	NORTH INPUT Tower Beampipe Assy			1.20.000

PART NO.	NUMBER	TITLE	MATERIAL	SIZE/NOTE	I.D. NO./NORM
23	01	LN2 Inlet			IL.03.000
22	01	Savety outlet	AISI 304L		1.16.000
21	01	H Beam	Steel	160x160x600	
20	01	XX	XX		XX
19	01	O Ring	Viton	1255x8	XX
18	01	O Ring	Viton	1355x8	XX
17	01	Rupture disk assy			1.14.000
16	01	Bellows	AISI 304L		1.13.000
15	01	Safety Valve assy			1.12.000
14	01	Radiation Shield's	AL 1050A H24		1.11.000
13	01	Aluminum Vessel	AL 5083		1.10.000
12	01	Cf 150 Blind	AISI 304L		
11	02	CF 63 Blind	AISI 304L		
10	02	CF 200 Blind	AISI 304L		
09	01	Center Damper			1.09.000
08	02	Foot	AISI 304L		1.08.000
07	04	Transport Support	AISI 304L		1.07.000
06	01	G LN2 outlet	AISI 304L		1.06.000
05	01	End Cap 2	AISI 304L		1.05.000
04	01	End Cap 1	AISI 304L		1.04.000
03	02	Vertical Suspention			1.03.000
02	04	Horizontal Suspention			1.02.000
01	01	West End Tower Beampipe Assy			1.01.000

Project: VIRGO

Title: CRYOSTAT

Revision	Date	Name
A		
B		
C		
D		

Scale: 1:10 | Drawn: M Doets
Date: 14-11-2012 | 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

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

Size: A0
Identification No.: 1.00.000
Sheet No: X Number of sheets: X