



Cryolinks for Advanced Virgo

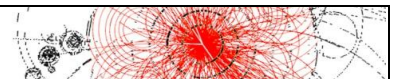
Tender information

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Abstract:

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. This note describes the tendering information supplied to companies in order to provide quotations for the prototype cryolinks. Quotations for the remaining three cryolinks will be requested at a later stage.

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HISTORY OF CHANGES

Rev. No.	Date	Pages	Description of changes
A	05-05-2011	All	Initial version

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1. INTRODUCTION

The Virgo project is a physics experiment for detection of gravitational waves. The enhancement of the sensitivity by a factor 10 for Advanced Virgo, requires an improvement of the present vacuum level. This will lower the phase noise for YAG light scattering from the residual gas inside the 3 km long interferometer (ITF) 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.

The residual pressure in the ITF arms has to be reduced by a factor of 100 to reach an enhancement in sensitivity by a factor of 10. By means of cryogenic links the migration of water from unbaked mirror towers to the ITF arms can be decreased and a base pressure below 10^{-9} mbar can be reached.

Cryolinks will be installed between the mirror towers and the existing DN1000 valves of the Virgo experiment. The vacuum vessels of the cryolinks will have different lengths (links at the end-towers are 6000 mm long, and at the input-tower 5400 mm). Aspired are four identical cold vessels in the cryolinks. Since the optical design is not completed at this point, it may be that the dimensions of the prototype will slightly deviate from that of the other links.

2. SCOPE

This document details the programme of work of the Virgo cryolinks and consists of:

- Contractor obligations
- Applicable documents
- Requirements
- Project schedule
- Discrepancies, non conformance, emergency and failure reporting
- General description of the cryolinks

3. CONTRACTOR OBLIGATIONS

The contractor obligations include:

- Manufacture of the cryolinks
- Quality control and testing
- Required documentation (paragraph 5.6)
- Packing, transport and delivery to Nikhef

The contractor shall be exclusively liable for the correct execution of the works and for meeting all the requirements contained in the drawings and project documentation.

4. APPLICABLE DOCUMENTS

The following are applicable documents in their latest revision status for this programme:

- Project information <http://www.nikhef.nl/~jo/prr>
- The purchase order and its terms and conditions ...
- Statement of work ...
- Specification ...
- Unit drawings: Cryostat
<http://www.nikhef.nl/pub/departments/mt/projects/virgo/cryogeniclinks/drawings/Cryostat/>

It is the responsibility of the contractor to thoroughly understand the documents above. Any questions shall be directed to Nikhef for clarification.

4.1 Precedence

The following precedence shall be used by the contractor in interpreting the documents in case of conflicting requirements. In case of conflict between various documents, the contractor is requested to raise the discrepancy to Nikhef. The first document has the highest precedence:

- The purchase order and its terms of conditions
- The statement of work
- The specification
- Unit drawings: Cryostat
- Other applicable documents

5. REQUIREMENTS

This section details the requirements for directives, certifications, engineering, production, factory acceptance test and documentation.

5.1 Directives and certifications

For design and manufacturing of the cryostat the following directives must be applied:

- ✓ 97/23/EC PED, Pressure Equipment Directive
- ✓ Pressure equipment design code AD2000
- ✓ Testing according to PED and AD2000
- ✓ The supplier must be PED H/H1 certified

The supplier must be certified for:

- ✓ Quality ISO 9001
- ✓ Welding quality according to ISO 3834-2
- ✓ Safety VCA** or equivalent (VCA** is Dutch SCC** certification)

5.2 Engineering

Main requirements for the cryostat with respect to the Virgo experiment are:

- ✓ All parts must be suitable for Ultra High Vacuum (UHV $<10^{-9}$ mbar)
- ✓ Displacement noise of the cryostat from seismic motion of the floor and possible bubble noise must be prevented
- ✓ EC Declaration of Conformity

5.3 Production

Requirement to take in account during production are detailed in this section.

Welding

- ✓ Welding description (WPS) acc. to EN15607, ADHP2/1
- ✓ Welding method (PQR) acc. to EN15614, ADHP2/1
- ✓ Welders Qualification acc. to EN287-1, ADHP3
- ✓ Orbital welding acc. to EN1418, ADHP3
- ✓ Visual weld inspections (100%) ISO 5817 level B or better
- ✓ After welding the welds must be pickled or brushed with a stainless steel brush
- ✓ All welds must be TIG welds

Cleanliness

- ✓ Parts and assemblies must be cleaned to Oxygen Clean acc. to EN12300
- ✓ Parts, tools and assemblies must be cleaned suitable for UHV application acc. to NIKHEF procedure "Cleaning procedure vacuum parts/Stainless and Aluminium"
- ✓ Production must be performed with processes (especially during handling and where cooling and cutting oils are involved) suitable for UHV application
- ✓ Production (after cleaning), assembly and storage must be performed in a clean and dust free area

- ✓ After each important step in production a check is required using an UV light in a darkened surrounding, to check for dust and grease
- ✓ Final cleanliness is checked by using a mass-spectrum meter to check for residue materials

Tolerances

- ✓ As indicated on drawings
- ✓ Tolerances acc. to ISO2768 Part 1
- ✓ General Tolerances unless otherwise stated acc. to:ISO-2768 -MK-E
- ✓ General Tolerances unless otherwise stated acc. to: ISO-8015-E
- ✓ Roughness unless otherwise stated: DIN 1302

Materials

- ✓ Materials acc. to ADW2 and ADW10, suitable for low temperature (80K) and elevated temperature (373 to 423K) usage

Testing during production and installation

- ✓ Visual weld inspection and dimensional check
- ✓ Cleanliness
- ✓ Vacuum test
- ✓ Helium leak test; Test with Helium mass spectrometer (max. 10^{-10} mbar.l/s per weld and 10^{-9} mbar.l/s per assembly)
- ✓ Pressure test acc. to PED and AD2000, also in case of cat. SEP (Sound Engineering Practice PED art 3.3)
- ✓ NDE; X-ray (min 10% of all butt welds, random during production, 100% of longitudinal welds for AL inner vessel) acc. to ADHP0 (vessels) and ADHP100R (piping)
- ✓ Dye Penetrant test (min 10% of all socket welds, random during production) for welds that are not inside the UHV application. Welds at the envelope of the UHV are not DP tested.
- ✓ Certification of materials from suppliers.

5.4 Factory acceptance test

The factory acceptance test will consist of the following tests:

- ✓ Cold Helium leak test using mass spectrometer($< 10^{-10}$ mbar)
- ✓ Cold function test with LN2
- ✓ Check on safety valve and break disc values (using the certificate)
- ✓ Vacuum level test ($< 10^{-9}$ mbar)
- ✓ A test using a spectrum analyzer to determine the residue inside the chamber

With the cold function test with liquid nitrogen a check for cold spots, a valve function test, level sensor test, test of all instruments and sensors and a test of all heaters will be done. These tests will be done while the process lines are cooled down for at least two hours. The P&ID will be checked during the tests.

5.5 Packaging and transport

Packing and method of delivery must ensure that the physical integrity is maintained and not affected by the packaging and method of transport chosen. The packaging and method of transport shall prevent damage, theft and loss, contamination of any form, degradation, and exposure to any elements that may affect the performance of the cryostat.

Each cryostat is to be separately packed in...

The phase separator...

The marking and labelling of the package shall include, but not be limited to, the following:

- ✓ Shipping address and contracting person
- ✓ Instruction to contact the contracting officer at Nikhef upon arrival
- ✓ Contents description, Item identification(s) and serial number(s)
- ✓ Orientation for opening and storage “THIS SIDE UP”
- ✓ Unpacking instructions (or their location)
- ✓ Location of travel documents

The contractor is responsible for the packing, shipping, and transport of all deliverable items to Nikhef, Amsterdam, The Netherlands.

5.6 Documentation

The documentation will consist of:

- ✓ Result of the calculations
- ✓ As built drawings (Lay-out and interface details)
- ✓ Safety guidelines and manuals
- ✓ Installation, Operation en Maintenance Manuals
- ✓ Spare parts list
- ✓ Declaration of conformity and/or CE certificate
- ✓ Quality and Inspection plan
- ✓ Welding documents
- ✓ NDE results
- ✓ Test certificates
- ✓ Material certificates

6. SCHEDULE

The programme is divided into several phases. Phase 0 starts with submission of the tender and ends in contract placement. It includes a qualification status review to ensure that the bidders understand the programme requirements and to verify they have indeed the resources and experience needed. During phase 1 the manufacturing work instructions and process will be reviewed. Phase 1 ends with an acceptance or rejection review. For packaging and transportation a review is held in phase 2 before delivery.

<i>Activity</i>	<i>Duration</i>	<i>Start Date</i>	<i>Completion Date</i>
Phase 0	11 wks		
Send out invitation to tender		23-05-2011	
Qualification status review	6 wks	30-05-2011	08-07-2011
Contractor selection	1 wk		
Finalisation of contract	3 wks		
Pre-contract placement review			
Contract award	1 wk		
Phase 1	42 wks		
Manufacturing work instructions and process review			
Acceptance or rejection review on account of FAT			
Phase 2	2 wks		
Packaging and transportation review			
Delivery of prototype cryolink			

7. DELIVERABLE HARDWARE

The scope of supply for the initial order is concerned with the prototype cryolink. After successful completion, the scope will be extended to include 3 additional cryolinks.

The following hardware is considered a deliverable in this programme:

<i>Item</i>	<i>Quantity</i>
Prototype Cryostat, end-caps, CF blind-off flanges with all fasteners and gaskets (O rings on large flanges for first test). Drawing: 1.00.000	1
Cryostat, end-caps, CF blind-off flanges with all fasteners and gaskets (O rings on large flanges for first test). Drawing: 1.00.000	3
Prototype phase separator and transfer line (length about 2 meters)	1
Phase separator and transfer line (length about 2 meters)	3
Prototype Bellow connection. Drawing: 2.01.00	1
Prototype Tower to valve assembly. Drawing:2.02.000	1
Bellow connection. Drawing: 2.01.00	3
Tower to valve assembly. Drawing:2.02.000	3

Deliverable documentation

Programme reviews

Programme management

8. DISCREPANCIES, NON CONFORMANCE, EMERGENCY AND FAILURE REPORTING

The contractor shall issue an emergency report in the event that any occurrence (including but not limited to mishaps, discrepancies, failures or other types of non-conformances occurring during manufacturing, testing of operations) may delay or hinder the achievement of a key event, The contractor shall submit within 1 week of the occurrence by fax or e-mail a report which shall inform Nikhef of the nature of the occurrence, possible impact on the programme and suggested plan of action.

It is at the sole discretion of Nikhef to accept or reject hardware associated with a non-conformance unless an approved deviation or waiver has been received by the contractor.

9. GENERAL DESCRIPTION OF THE CRYOLINK

The cryolinks have a cold surface of aluminium with a length of 2023 mm and an inner diameter of 950 mm. Baffles with 600 mm inner diameter will be bolted to a stainless steel vacuum vessel via support bars. These baffles are connected with spring lips that are welded to the inner cylinder of aluminium. The vacuum vessel has an outer diameter of 1350 mm (without reinforcement ribs) and has a length of 1350 mm at the input mirror and at the end mirror a length of 3812 mm. Reinforcement ribs will be welded to the outside of the vessel to avoid buckling of the structure. Helicoflex seals are used to connect the cryolink to the DN1000 valves and the side flange of the cryolink. The connections to the bellows on top are made with dry Viton rings. The vacuum vessel is equipped with various pump-out and service ports. A view of the cryostat assembly is given in BIJLAGE 1.00.000 Cryostat assy_Sheet_1.pdf.

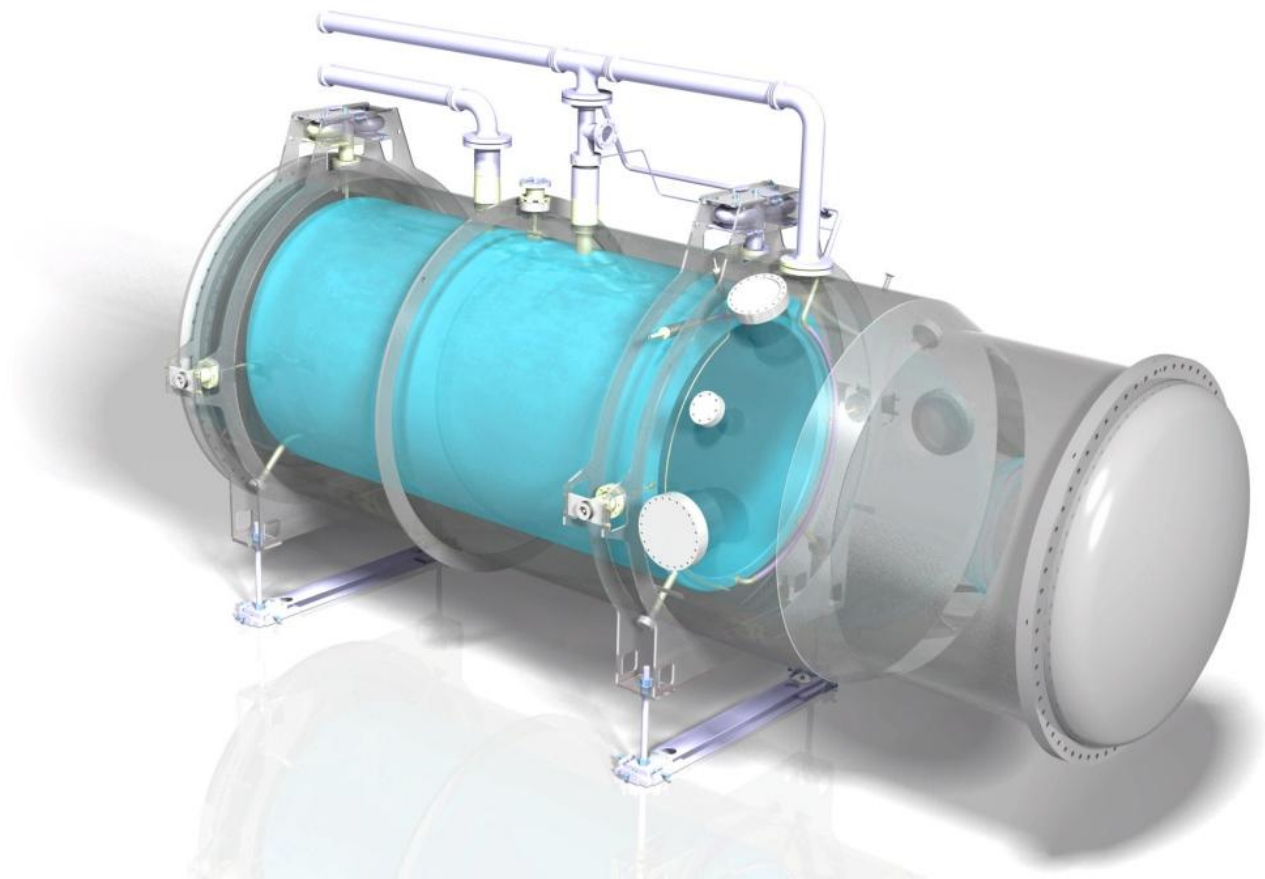


Figure 1: *Isometric view of the cryolink with cold surface indicated in blue.*

The design of the cryolink is determined by a number of main constraints: the requirements from the physics, which is to enlarge the sensitivity of the Virgo experiment and the safety risks with reference to the Virgo experiment.

9.1 Aluminium inner vessel

The aluminum inner vessel is mounted inside the vacuum vessel and is the cold part of the cryostat (LN2 vessel). The inner vessel will be constructed from Aluminium AW-5754 [Al Mg3].

The cold part is suspended via flexible head-bridges on two sets of air springs (vertical direction) and four rubber springs (horizontal). The external design pressure is UHV and +1.5 bar (absolute pressure) inside the double walled vessel, at temperatures of -196 °C and +140 °C. The vessel will be equipped with a relieve valve which opens at 0.5 bar with respect to atmospheric pressure.

A level controller (differential pressure measurement), a capacitive sensor and needle valves are employed to fill the vessel and maintain the level at a precision of ± 10 mm. A set of four temperature sensors will check the level measurement and temperature.

The aluminium inner vessel has been designed by Nikhef. Finite Elements Analyses are performed and the design is checked by the design standard PED/AD2000. The design pressure is 1.5 bar absolute at a temperature of -196 °C. The evaluated limits are 140 °C (bake out) at a pressure of 1.5 bar absolute and 20 °C at a pressure of -1 bar absolute. The PED classification of the aluminium vessel is category II. All parts must be suitable for Ultra High Vacuum and be cleaned according to the Nikhef cleaning procedures for vacuum parts.

9.2 Stainless Steel outer vessel

The stainless steel outer vessel is the vacuum vessel and will be constructed from stainless steel 304L. The end caps and CF blind-off flanges that will be mounted on the outer vessel will also 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.

The stainless steel parts will be baked at 400 °C for five days with Argon inside the vessel. The design pressure is UHV ($< 10^{-9}$ mbar) and +1.5 bar absolute with a temperature range of +20 °C to +140 °C. The vessel will be equipped with a rupture disk which opens at +0.5 bar pressure difference with respect to atmospheric pressure.

The stainless steel outer vessel has been designed by Nikhef. Finite Elements Analyses are performed and the design is checked by the design standard PED/AD2000. The design pressure is 1.5 bar absolute at a temperature of 20 °C. The evaluated limits are 400 °C at a pressure of 1 bar absolute and 140 °C at a pressure of -1 bar absolute.

The PED classification of the stainless steel vessel is category III. With the rupture discs of +1.5 bar absolute, the vessel isn't a pressure vessel according to the PED standard. The vessel is considered a pressure vessel because of the resulting damage to the experiment when anything would go wrong.

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.

9.3 Phase separator

The phase separator is positioned as close to the application as possible, to prevent heat in leak and resulting GN2 bubbles. The process line is positioned under a slight downward angle, to allow for available air bubbles to rise and be removed. The nitrogen in the Phase Separator is at ambient pressure, but can at any later stage optionally be pressurized (to max. 0.5 bar) using a pressure regulated degas valve. This enables quick filling and cooling down. The filling line to the experiment

is made flexible, to prevent transfer of vibrations to the experiment. A schematic view of the phase separator is given in **BIJLAGE Separator and transfer line**.

The safety valve is chosen at 1.5 bar absolute to prevent overpressure in the cryostat. The phase separator should comply with PED directive.

9.4 Operational conditions

The operational conditions of the cryostat are given for the aluminium vessel and the stainless steel vessel.

Table 1: Operational conditions for the aluminium vessel

<i>Operation</i>	<i>Temperature [°C]</i>	<i>Pressure [mbar]</i>	<i>Medium</i>
Normal operation	-196	1000	LN2
Filling	-196	1000	LN2
Emptying	-196 to 20	1300	GN2/LN2
Regeneration	140	1000	GN2
Bake out	140	1000	GN2

Table 2: Operational conditions for the stainless steel vacuum vessel

<i>Operation</i>	<i>Temperature [°C]</i>	<i>Pressure [mbar]</i>	<i>Medium</i>
Normal operation	-196	10^{-9}	-
Venting	20	1000	?
Regeneration	140	10^{-9}	-
Bake out	140	10^{-9}	-