

ANNEXE 1

**English version of the document :
VEOC-ORCA_CCTP_CNRS DR016_AO2**

PARIS-NORMANDIE DELEGATION

SPECIAL TECHNICAL SPECIFICATIONS

(In french : CCTP = Cahier des Clauses Techniques Particulières)

PUBLIC SUPPLY CONTRACTS

SUBJECT:

**Purchase of Vertical Electrical-Optical Cable (« VEOC ») for new
detection lines for the KM3NeT-ORCA project as part of NEPTUNE
funding by the Normandy region.**

Lot n°01

BUYER :

CNRS-Délégation Paris-Normandie
3 rue Michel Ange
75794 PARIS Cedex 16

CONTRACTUAL FORM:

Single-award framework agreement based on unit prices following a formal open tender procedure in accordance with Articles L. 2124-2, R. 2124-2 and R. 2161-2 to R. 2161-5 of the Public Procurement Code.

This is a supply contract subject to the provisions of the General Administrative Clauses for Public Supply Contracts (CCAG/FCS) issued by the decree of 31 March 2021.

This document comprises 63 pages, including the cover page.

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LISTE DES ABREVIATIONS

CCAG	Cahier des Clauses Administratives Générale = General Administrative Terms and Conditions
CCTP	Cahier des Clauses Techniques Particulières = Special Technical Specifications
CCAP	Cahier des Clauses Administratives Particulières = Special Administrative Terms and Conditions
EPST	Etablissement public à caractère scientifique et technologique = Public scientific and technological institution
FCS	Fournitures courantes ou services = Routine supplies or services
HT	Hors taxes = Excluding taxes
RC	Règlement de la consultation = Consultation rules
RGPD	Règlement général sur la protection des données personnelles = General Data Protection Regulation
PEPR	Programmes et équipements prioritaires de recherche = Priority research programmes and equipment
SCTD	Service centralisé de traitement de la dépense = Centralised expenditure processing service
CNRS	Centre national de la recherche scientifique = National Centre for Scientific Research
LPCC	Laboratoire de Physique Corpusculaire de Caen = Caen Particle Physics Laboratory
NEPTUNE	Neutrino Physics with Telescope Underwater
KM3NeT	Kilomètre cube Neutrino Telescope
ORCA	Oscillation Research with Cosmics in the Abyss
ARCA	Astroparticle Research with Cosmics in the Abyss
VEOC	Vertical Electrical-Optical Cable
BOB	Break-Out Box
BEOC	Break-out Electrical Optical Cable
DU	Detection Unit
DOM	Digital Optical Module
BM	Base Module
PE	Polyethylene
HDPE	High Density Polyethylene
LLDPE	Linear Low-Density Polyethylene
OTDR	Optical Time-Domain Reflectometer
BOM	Bill of Material
PCB	Printed Circuit Board

APPENDICES TO « French CCTP »

Annexe 1	English translation of these Special Conditions of Contract
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In these Special Conditions of Contract:

- The terms "equipment", "supplies" and "materials" refer interchangeably to the materials to be supplied for each lot;
- The term "Contractor", "holder", "supplier" refers to the company that is awarded one or more lots of the contract.;
- The term "Contract" refers to the agreement concluded between the CNRS and the Holder of each lot.

1 Preamble

The provision of the services defined in this document constitutes a contract with a public institution with an obligation of means and results.

The Contractor undertakes that it is able to perform this contract in strict compliance with the obligations set out in the contract documents, in particular with regard to confidentiality, qualification and insurance clauses.

The Contractor shall be deemed, under its responsibility and regardless of any justifications provided, to have received the legal authorisations to perform and to possess the professional qualifications corresponding to the nature and importance of the service covered by this contract. The Contractor shall be solely liable for any consequences that may arise from the fact that these qualifications do not comply with regulations or are incorrect and, in particular, for the consequences of any termination that the CNRS may rightly decide to implement as a result.

In addition to the documents constituting the consultation file, the Contract Holder is required to comply with the specifications and requirements of the decrees, orders, regulations, standards and texts in force on the date of submission of its tender.

2 Presentation

The national centre for scientific research (hereinafter « CNRS » - Centre National de la Recherche Scientifique) is a public research organisation (a public scientific and technological institution, EPST, under the supervision of the Ministry of Higher Education, Research and Innovation). It produces knowledge and puts this knowledge at the service of society.

Its governance is ensured by a chief executive officer, assisted by deputy chief executives.

With over 33,000 employees, a budget of €3.5 billion and a presence throughout France, the CNRS is active in all fields of knowledge, drawing on more than 1,100 laboratories.

Present in all fields of knowledge

As France's leading multidisciplinary research organisation, the CNRS conducts research in all scientific, technological and societal fields. It covers the entire spectrum of scientific disciplines.

The CNRS is active in all major disciplines, grouped into 10 institutes, and focuses on developing collaborations between specialists from different disciplines, particularly with universities, opening up new fields of research that meet the needs of the economy and society.

Present throughout the country

17 regional delegations ensure direct, local management of laboratories and maintain links with local partners and local authorities.

2.1 General context of the project

The NEPTUNE project, funded by the Normandy Region, aims to continue the construction of underwater infrastructure to establish a KM3NeT ORCA underwater observatory for neutrino research, which will ultimately consist of around 115 detection lines and instrumentation for marine and environmental science. It is located approximately 40 km south of Toulon at a depth of 2,500 m.

2.2 Background to the purchase

The 18 optical modules in a detection line must be electrically powered and the measurements they take must be collected by optical fibres.

To achieve this, a cable called VEOC was developed by the NIKHEF research laboratory in Amsterdam exclusively for the KM3NeT experiment.

This contract concerns the supply of electro-optical cables known as VEOC (Vertical Electrical Optical Cable).

This document describes all the contractor's technical contractual obligations. They constitute an obligation of results for the contractor.

2.3 Subject matter of the contract

Purchase of cables VEOC for new detection lines for the KM3NeT-ORCA project as part of NEPTUNE funding by the Normandy region.

Quantity : 14 units. (Estimated quantity in relation to the budget allocation)

2.4 Allotment

This contract is a supply contract.

The contract is divided into 08 separate lots. Each lot is the subject of a separate contract.

Lots	Lot names
01	Cable vertical Opto-Electrique (VEOC)
02	Buoy support structure
03	Electronic card BPS (Base Power System)
04	Penetrator VEOC in Base Module
05	Cylindrical container of the Base Module
06	Electronic card CLB-V6 (Central Logic Board)
07	TSFP optical Transceiver
08	Hydrophone

3 Description of expected equipment and general and technical specifications

3.1 Introduction

This document describes the assembly procedure for manufacturing a vertical electrical optical cable (VEOC) for KM3NeT ORCA. In addition, all tests and inspection points are specified in this document. After manufacture, an acceptance test report is provided by the manufacturer for each VEOC. This report will be uploaded to the KM3NeT Google Drive and database by members of the KM3NeT collaboration. In addition, the manufacturer's checklists and inspection points (photos and/or videos) will be uploaded to the KM3NeT Google Drive.

3.2 General Description of the KM3NeT VEOC

The vertical electrical optical cable (VEOC) is a pressure-compensated oil-filled polyethylene (PE) assembly.

Its function is to establish electrical power and glass fiber connections to each of the 18 Digital Optical Modules (DOM) of a KM3NeT Detection Unit (DU).

A KM3NeT DU is a vertical assembly of DOMs, counting from DOM1 at the bottom to DOM18 at the top of a DU.

ORCA DUs are roughly 200m in height. The VEOC is guided along the vertical DU structure.

At the level of each DOM, a Break-Out Box (BOB) in the VEOC should provide the following functionality:

- 1) Provide connection points for one branched-off fiber and two electrical cables that will go to/come from the DOM penetrator
- 2) A DC/DC converter transforms the backbone 380 V DC to 12 V DC for the DOM. The 380 V cable is fed-through to the remainder of cable
- 3) Feed-through of the remaining fibers (i.e. the ones that are not branched off) without attenuation (i.e no splice connections).
- 4) Provide a closed volume that can be leak-tested and filled with oil

The high-density polyethylene (HDPE) breakout boxes are interconnected with 7mm LLDPE tubes. In addition to these long LLDPE tubes between the BOBs, a shorter piece of LLDPE tube exits every BOB that connects to the so-called DOM penetrator cap which is mounted on the DOM penetrator. This short LLDPE tube is called the break-out electrical optical cable (BEOC).

In addition to 17 similar DOM BOBs there are two other BOB types:

- 1) BOB18. This BOB, being the last one on the VEOC only has two PE welding connections (incoming and breakout) instead of the usual three (incoming, outgoing and breakout) for a DOM BOB.

- 2) The anchor BOB at the bottom end of the VEOC. This BOB is slightly bigger as it needs to allow space for all 24 fibers, including splices.

The VEOC starts at the point where 24 fibers (18 for the DOMs and 6 spares) and 2 copper wires exit the KM3NeT Base Module (BM) that is mounted on the anchor through the so-called base penetrator. The VEOC ends at the level of the top DOM, DOM18. A schematic drawing of a complete ORCA VEOC is shown in Figure 1 and a drawing of the VEOC routing at the DOM level in the final DU configuration is shown in Figure 2.

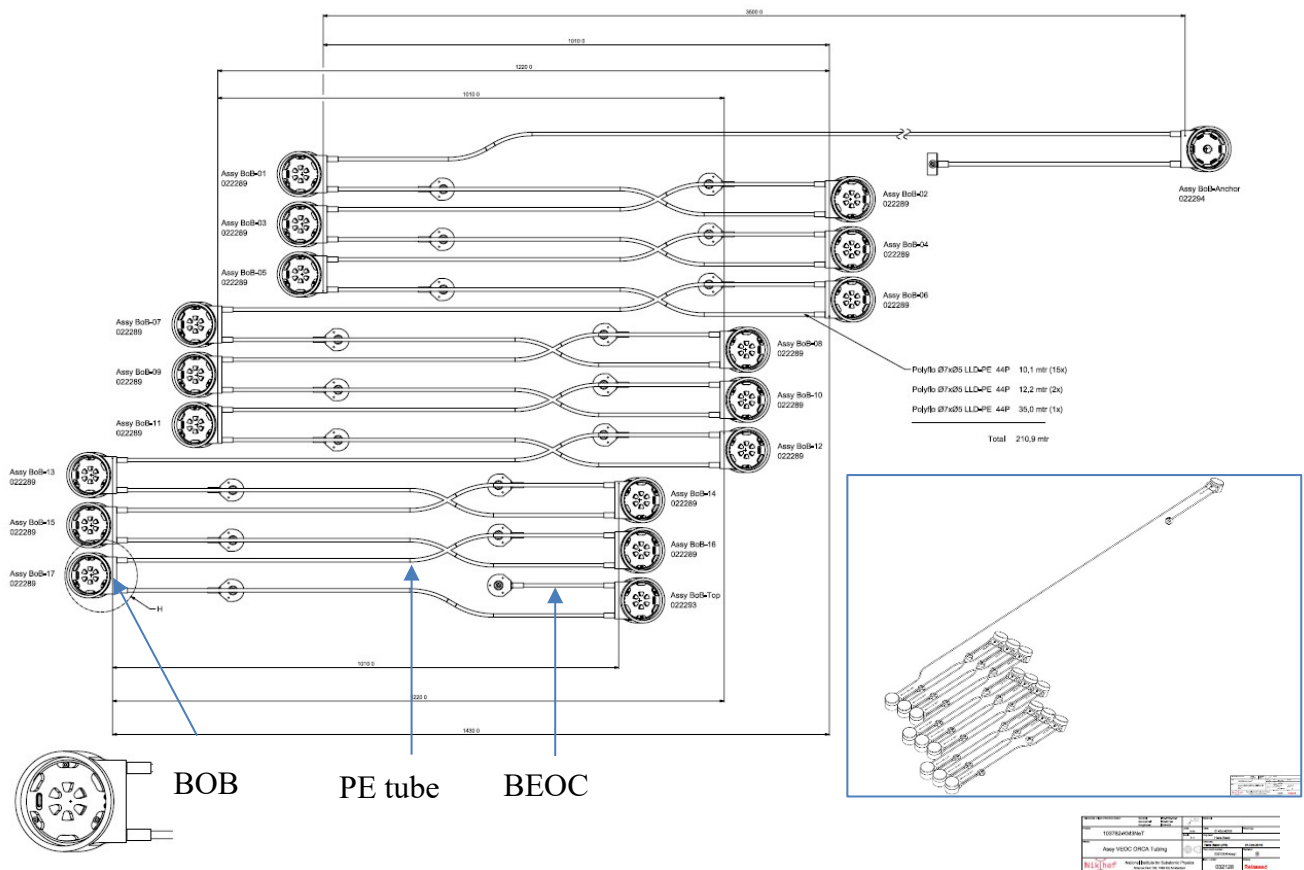


Figure 1 Technical drawing of a completed VEOC. Note the anchor BOB with longer BEOC compared to DOM BOBs on the upper right.



Figure 2 Routing of the VEOC at the level of a DOM. The DU mechanical structure is provided by ultra-high molecular weight polyethylene ropes (Dyneema) shown in red. These ropes also form the mechanical interface with the DOMs.

3.2.1 The DOM Breakout Box (BOB)

At the level of each DOM, a breakout of one optical fiber and two copper cables (red and black) is provided. This is done inside the so-called DOM breakout box (BOB). A BOB contains two compartments: the BEOC side and the VEOC side, which are separated by a diaphragm that contains a fiber and two power cable feedthroughs. Figure 3 shows a schematic picture of a DOM BOB and Figure 4 shows how the fibers are routed and fixed in the BOB.

3.2.2 The DOM BOB VEOC Side

The VEOC side of a BOB provides space to branch-off a fiber and two power cables to the BEOC side and to feed through all other fibers and two power cables to the next BOB. In addition, the VEOC compartment of a DOM BOB houses the DC/DC converter board to convert the voltage of 400 V in the VEOC backbone to the operating voltage of 12 V for a DOM.

3.2.3 The DOM BOB BEOC Side

On the DOM BOB BEOC side, a short section of PE tubing leads to the DOM penetrator: this short section is called the BEOC which ends at the (HDPE) penetrator cap. During DU production, the fiber and copper wires are fed-through from the penetrator and welded/spliced on the BEOC side of the BOB. After successful integration of a DOM in the DU, the BEOC side of the BOB is sealed off with a PE cap using PE welding. Afterwards, the full BEOC compartment (BEOC side of BOB, the BEOC itself and the volume enclosed by the penetrator cap) is filled with oil, using an oil-filling hole in the BOB that is sealed with a screw and an O-ring. Finally, the BOB is attached to the titanium DOM collar using a titanium clamp.

During VEOC production, BOBs are tested for leak-tightness. These leak tests are performed in water, using a tool that temporarily seals the BEOC side of the BOB, as this part remains open until after successful DOM integration, which happens at a KM3NeT DU integration site (i.e. not at the VEOC manufacturing site).

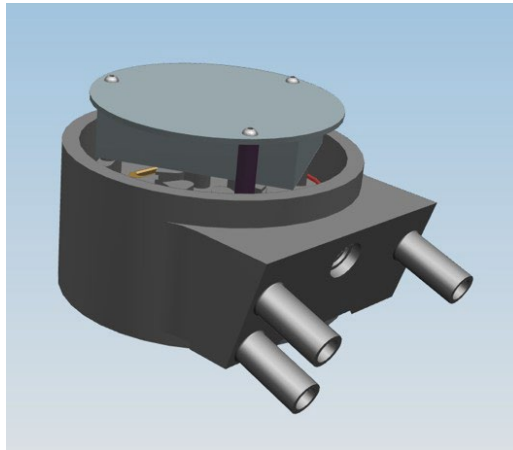


Figure 3 Schematic picture of a DOM BOB showing the VEOC compartment with the mounted DC/DC converter board on top (before closing off the compartment with a PE cover).

In addition, the three PE welding connections are visible.

Upper right: downgoing/incoming VEOC connection.

Upper left: upgoing/outgoing VEOC connection.

Lower left: BEOC connection. Finally, the oil-filling hole for the BEOC compartment (the lower side in this picture) is visible between the three tube connections.

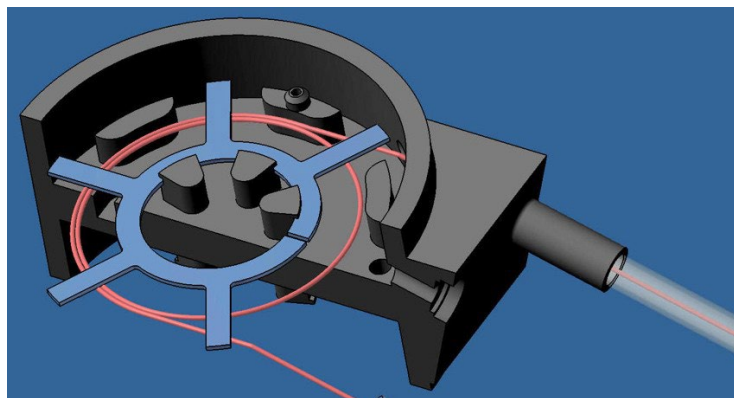


Figure 4 Routing and fixation of the fiber bundle inside the DOM breakout box.

So far, all BOB types were produced by an external manufacturer. There are currently no known problems with delivery times and quality assurance.

4 Technical Requirements VEOC

4.1 Functional Requirements

4.1.1 Mechanical Parts and Connections

- Req.1. The ORCA VEOC configuration shall be according to Table 1 and Section 7
- Req.2. A VEOC shall have 18 DOM BOBs.
- Req.3. In every DOM BOB, 1 fiber and two Alfa wires (see 4.1.3) shall be branched off on the VEOC side of the BOB and fed through to the BEOC side of the BOB.
- Req.4. On the VEOC side of any DOM BOB, the fibers that are not branched off shall be continued to the next VEOC section without splicing.
- Req.5. An ORCA VEOC shall consist of only one oil compartment.
- Req.6. The VEOC shall be constructed using LLDPE tubing with an outer diameter of 7 mm and an inner diameter of 5 mm.
- Req.7. The LLDPE tube from the anchor BOB to the base penetrator shall have an outer diameter of 8 mm and an inner diameter of 6 mm, with a length of 50 +/- 1 cm for ORCA and 65 +/- 1 cm for ARCA
- Req.8. The BEOC tube shall be 21 +/- 1 cm long.
- Req.9. The PE welds shall be free of air inclusions and free of sharp edges
- Req.10. The VEOC shall be filled with Midel 7131 Transformer Insulating Fluid
- Req.11. On either side (VEOC or BEOC) of any BOB, the fiber bundles shall be coiled around the heart of the BOB without mechanical tension.
- Req.12. On either side (VEOC or BEOC) of any BOB, the coiled fiber bundles shall make at least 2 turns in the BOB.
- Req.13. On the VEOC side of any BOB, the fiber bundle shall be kept in place with a nylon star-shaped clip. This clip shall not put any stress on the fiber.

BOB Type	DOM number	Inter-BOB tube length (m)	Total VEOC length (m)	BEOC type
BOB18	18	10.1	210.9	Regular
Regular	17	10.1	200.8	Regular
Regular	16	10.1	190.7	Regular
Regular	15	10.1	180.6	Regular
Regular	14	10.1	170.5	Regular
Regular	13	10.1	160.4	Regular
Regular	12	12.2	150.3	Regular
Regular	11	10.1	138.1	Regular
Regular	10	10.1	128.0	Regular
Regular	9	10.1	117.9	Regular
Regular	8	10.1	107.8	Regular
Regular	7	10.1	97.7	Regular
Regular	6	12.2	87.6	Regular
Regular	5	10.1	75.4	Regular
Regular	4	10.1	65.3	Regular
Regular	3	10.1	55.2	Regular
Regular	2	10.1	45.1	Regular
Regular	1	35	35	Regular
Anchor BOB			0	Anchor BEOC: 50 cm length, 8mm diameter

Table 1 ORCA LLDPE inter-BOB segment lengths

4.1.2 Optical Fibers

- Req.14. The VEOC shall contain two bundles of 12 optical fibers each.
- Req.15. The fibers shall be Draka single-mode Bend Bright XS or equivalent.
- Req.16. The two fiber bundles shall have differently colored cotton wire: one white and the other red.
- Req.17. The color coding of the fibers in every bundle shall be according to EIA/TIA-598
- Req.18. The length of the branched-off fiber at the BEOC side of a DOM BOB shall be at least 30 cm.
- Req.19. The length of the fibers in the anchor BOB shall be at least 200 cm.
- Req.20. *ORCA*: All fibers shall have an attenuation below 0.35 dB when the measurement setup is connected using temporarily splices or 0.5 dB when connectors are used. A maximum splice loss of 0.07 dB applies. The attenuation shall be measured using a stable light source and power meter or an OTDR. Both at wavelength 1550 nm and wavelength 1310 nm with an accuracy of <0.01 dB.

4.1.3 Electrical wires

- Req.21. The VEOC shall contain Alpha EcoWire (fully recyclable) AWG 18 wires with PPE insulation
- Req.22. There will be one red and one black wire strand
- Req.23. Two red and black (high-voltage) electrical wires form the power backbone of the VEOC and shall connect to and from the DC/DC converter in every DOM BOB
- Req.24. Two red and black (low-voltage) electrical wires shall connected from the DC/DC converter to the BEOC side of every DOM BOB to connect to the DOM
- Req.25. The length of the low-voltage Alfa wires shall be 10 +/- 1 cm on the BEOC side and 20 +/- 1 cm on the VEOC side.

4.2 Environmental Requirements

4.2.1 Pressure Requirements

The unit shall be deployed for 15 years at maximum 3500 meter under see level

- Req.26. The VEOC shall be able to withstand a pressure of 2.5 bar without leaking.

4.3 Interfaces

4.3.1 DC/DC Converter

Req.27. In every DOM BOB, one DC/DC converter shall be connected and mounted. This involves six solder joints.

HV_in	HV_GND
HV_out	HV_GND
12 V	12V_GND

Req.28. The solder joints shall be made using lead-soldering

Req.29. During and after mounting of the DC/DC converters, the electrical wires shall not be pinched or damaged

4.4 Manufacturing Requirements

4.4.1 Oil Filling

Req.30. After oil filling of the VEOC there shall be no visible air bubbles in any of the PE tubes

4.5 Manufacturing Report and Acceptance Criteria

Req.31. Acceptance of a VEOC shall be on the basis of key inspection points, a manufacturing report and an acceptance test sheet

Req.32. The manufacturing report and acceptance test sheet shall be delivered in digital format.

Req.33. The manufacturer shall report every incident or anomaly during production to Nikhef by phone and e-mail

Req.34. Each VEOC shall have no more than six repairs in all fibers

Req.35. Each VEOC shall have maximal one repair per fiber

Req.36. In the final report the following measurements shall be reported: electrical tests, fiber attenuation, date/time of visible inspection and leak tests

Req.37. Fiber optical power acceptance criteria are: attenuation below 0.1 dB per 100 m and below 0.1 dB per splice at 1550 nm as measured by OTDR or similar. In addition, every fiber shall be tested at 1350 nm.

4.6 Logistics

4.6.1 Marking

Req.38. The anchor BOB shall contain a sticker that mentions the VEOC serial number

Req.39. The VEOC serial number should be included in the manufacturing report and acceptance test sheet

Req.40. After packaging, the package shall be marked to show its content.

Req.41. All equipment containers, including individual packages and outer cartons, shall be marked with the following information:

- supplier
- part name
- supplier's part number
- manufacturing date
- quantity in container
- purchase order number
- supplier's serial number

4.6.2 Packaging

Req.42. The transport container shall protect the VEOC from damage or induced malfunction during normal shipping and handling.

4.6.3 Transport

Shock indicators must be present on the transport boxes.

The holder assumes all responsibility for transport, including insurance;

Transport costs will be paid by the holder, including any import charges

5 General Overview of the VEOC Assembly Procedure

The VEOC manufacturing process can be summarized in the following basic steps. In addition, for every step the required tests are briefly indicated.

- PE-weld and prepare all sub-assembly PE parts
 - Leak-tightness tests
- Pull the electrical wires and the fiber bundles through the PE tubing and make feedthroughs and connections at every BOB
- Mount the DC/DC converters in the DOM BOBs
 - Fiber connection tests
 - Electrical resistance tests
 - DC/DC converter voltage tests
- Seal the VEOC side of every BOB with a cover (PE weld)
 - Leak-tightness tests
- Fill the VEOC with oil
 - Leak-tightness tests with increased oil pressure.

6 Bill of Material - BOM

6.1 ORCA VEOC BOM

Item description	Drawing number/ reference	Drawing version	Material	# of pieces needed / ORCA VEOC	Supplier	Supplier product code	Comment
BOB18 (top BOB)	Nikhef 20593	B	SIMONA PE-HWU Black 9500	1	CodeP	651001056	
Regular BOB	Nikhef 20592	D	SIMONA PE-HWU Black 9500	17	CodeP	651001063	
Anchor BOB	Nikhef 20594	F	SIMONA PE-HWU Black 9500	1	CodeP	651001064	
BOB cover 29 mm (1 per DOM BOB,	Nikhef 22254	A	SIMONA PE-HWU Black 9500	18	CodeP	651001065	
BOB cover 13 mm (1 for anchor BOB	Nikhef 22255	A	SIMONA PE-HWU Black 9500	1	CodeP	651001066	
Anchor BOB extension ring	Nikhef 29166	A	SIMONA PE-HWU Black 9500	1	CodeP	651001052	
DOM penetrator cap	Nikhef 22261	A	SIMONA PE-HWU Black 9500	18	CodeP	651001062	
Base penetrator cap	Nikhef 22302	B	SIMONA PE-HWU Black 9500	1	CodeP	651000750	
Anchor BOB pillar screw	Nikhef 29167	A	SIMONA PE-HWU Black 9500	1	CodeP	651001067	
Power transit (2	Nikhef 22250	A	CuZn39Pb3	38	CodeP	651001054	
Fiber transit for 1	Nikhef 22257	A	CuZn39Pb3	18	CodeP	651001060	
Fiber transit for 4	Nikhef 22258	A	CuZn39Pb3	6	CodeP	651001059	
BOB sealing screw	Nikhef 22259	A	Ti-6Al-4V	19	Titaniumshop.nl		
BOB sealing O-ring 6 x 1.5 mm (1 for every BOB)			Viton/FKM 70 shore	22	SealSupply	356959	https://www.sealsupply.nl/catalog/product/view/id/905174/s/o-ring-fkm
Base penetrator cap ring	Nikhef 54770	D	Ti-6Al-4V	1	Nikhef		https://drive.google.com/file/d/1b3swgsr4Kke3-NQY4R9AydoVXyji
Fiber star 32 mm	Nikhef 22268	A	3D print	36	Weerg		
Fiber star 13 mm	Nikhef 22270	A	3D print	2	Weerg		
DC/DC converter standoff M2.5, 5 x 20 mm (3 per			PA6	54	Essentra	305252059902	https://www.essentracomponents.com/en-
DC/DC converter screws (3 per DOM BOB) M2.5 x 6, DIN7985			PA	54	Essentra	50M025045P006	https://www.essentracomponents.com/nl-p/machineschr
LLDPE tube 5x1x7mm (211 m			Poly-Flo LLD-PE	215 m	De Gidts & Feldman	2960219	
LLDPE tube 6x1x8			Poly-Flo LLD-PE	0.5 m	De Gidts & Feldman	2960215	
Temporary plastic cover (1 per DOM BOB, 1 per anchor BOB)			LDPE	19	Essentra	12654	https://www.essentracomponents.com/nl-p/kokereindplu
DC/DC converter			PCB	18	Nikhef		
Oil			Midel 7131 transformer	5 ltr	Vielhauer		https://mv-lub.com/about-
Electrical wires			Alpha ECO wire AWG18	Red: 250 m Black: 250 m	MCAP supplier		Procured by VEOC producer, Included in VEOC
Electrical crimp splice (2 for				2	TE Connectivity	34070	https://www.te.com/usa-en/product-
Optical fiber			DR BF 12x SM7B	Red bundle: 300 m (one spool is 600m) White bundle: 300 m (one spool is 600m)	Prysmian		

Table 2 Components used in VEOC ORCA

7 Technical Drawing

7.1 Technical drawing ORCA VEOC

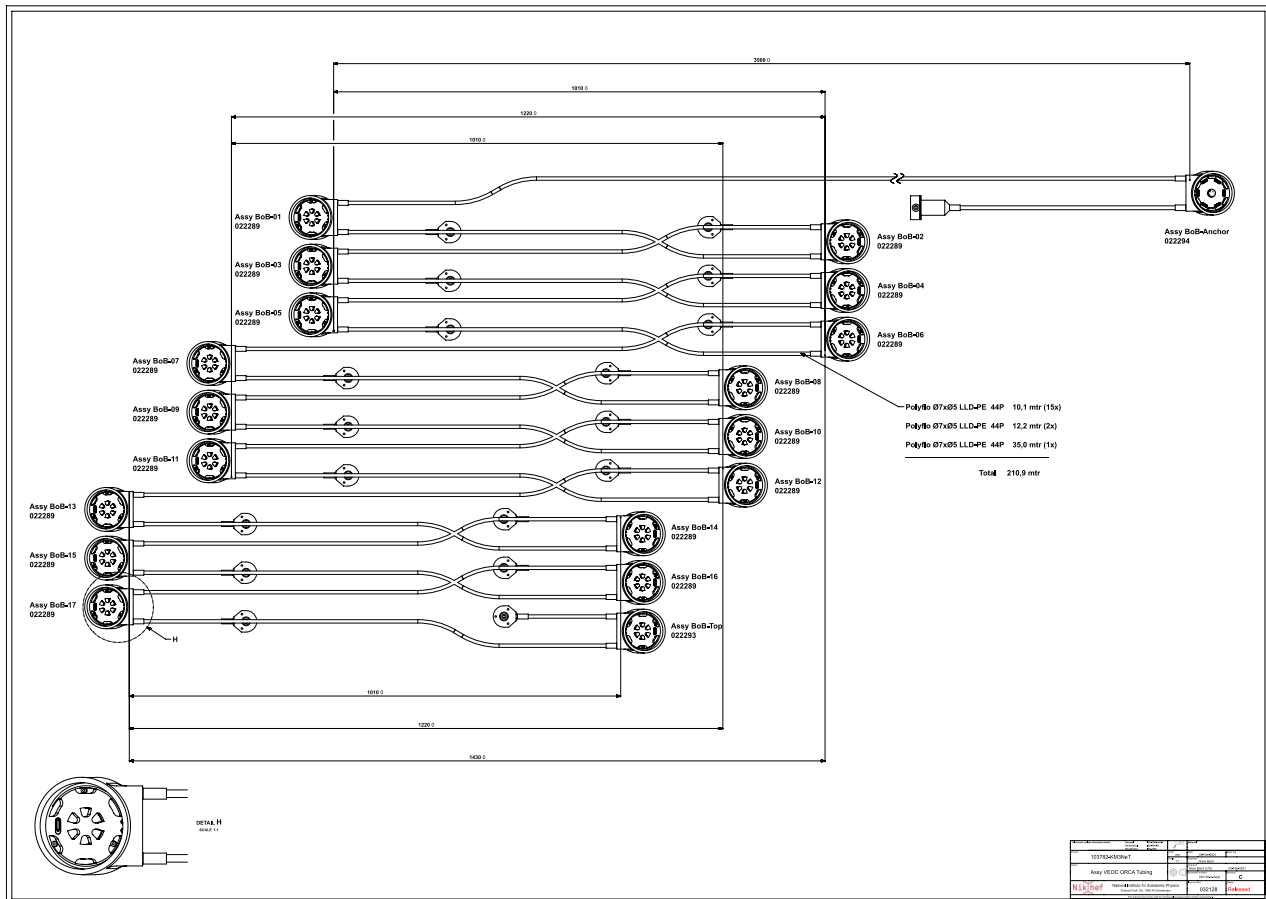


Figure 5 Technical drawing ORCA VEOC (Nikhef drawing number 032128): tubing

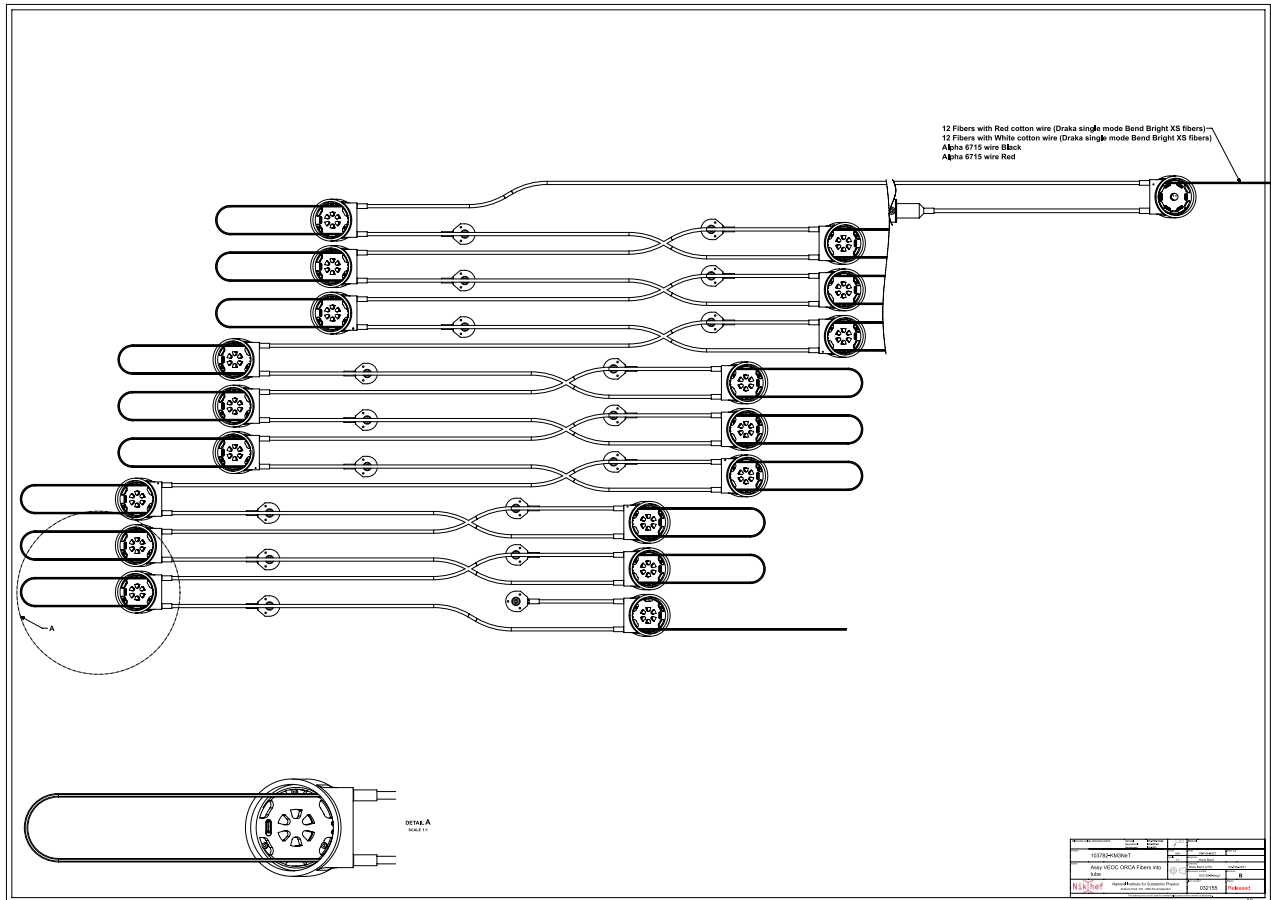


Figure 6 Technical drawing ORCA VEOC (Nikhef drawing number 032155): fibers after feeding them through the tubing



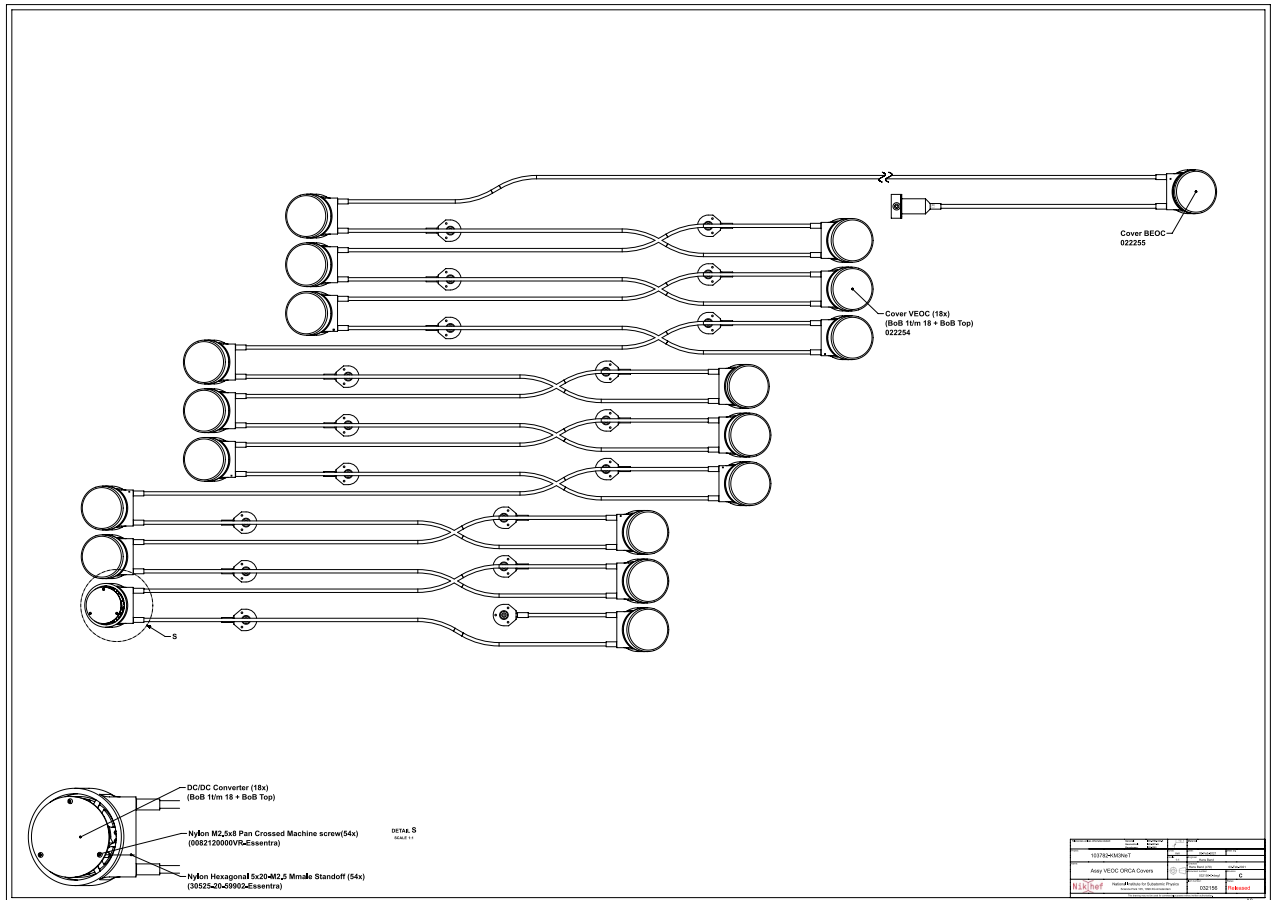


Figure 8 Technical drawing ORCA VEOC (Nikhef drawing number 032156): BOBs after mounting of BOB covers.



7.2 Other Technical drawings

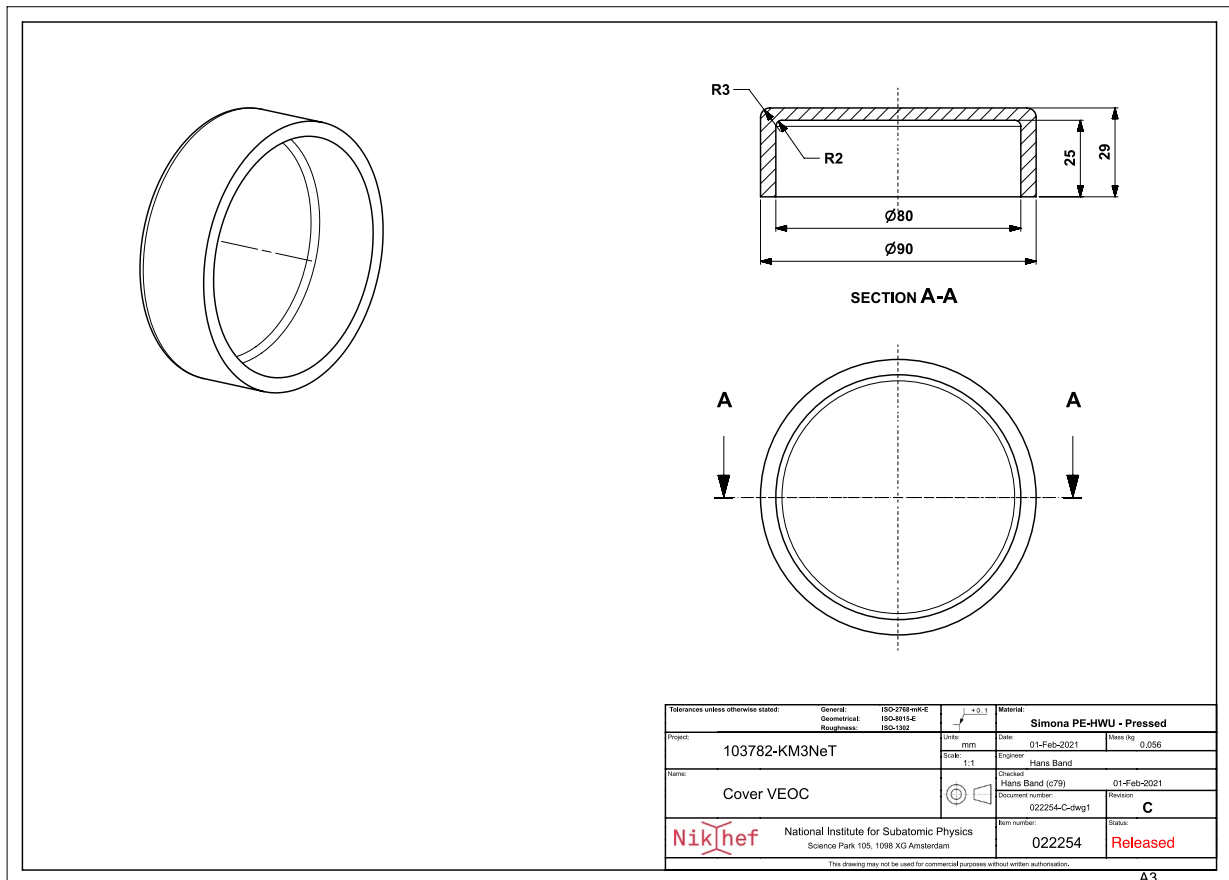


Figure 10 Technical drawing BOB cover, VEOC side

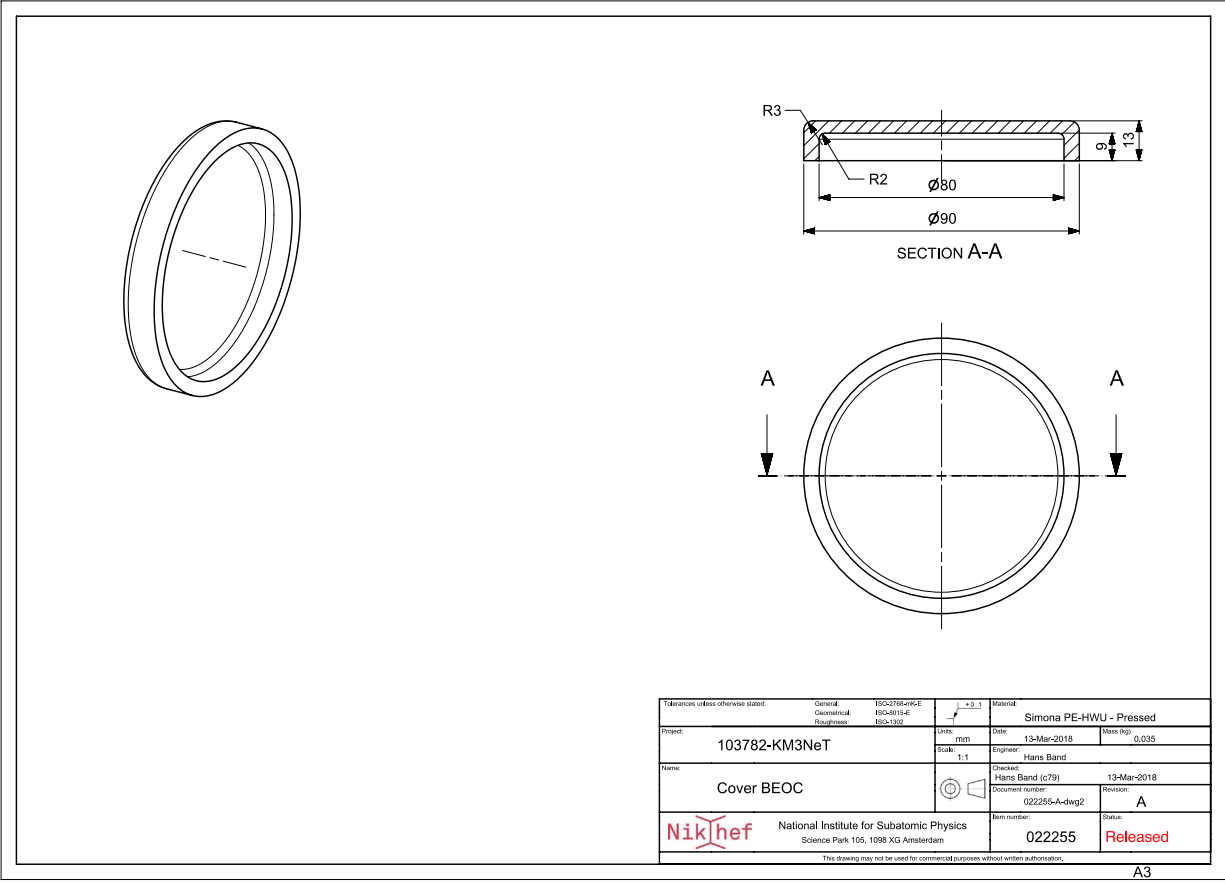


Figure 11 Technical drawing BOB cover, DOM side

8 Detailed VEOC Assembly and Testing Procedure

Technical drawings for the VEOC and its constituent parts are given in Section 7.1.

8.1 PE-Weld and Prepare all Sub-Assemblies

All PE tube welds are performed using the custom-designed welding machine WIDOS 2500 SPS Nikhef described in Section 10.1.

8.1.1 Weld BEOC to DOM Penetrator Cap

- Cut and clean LLDPE 7 mm tubes of length 21 +/- 1 cm. These tubes will now be referred to as the BEOC tubes
- Clean inside of DOM penetrator cap preparing for PE weld
- Mount BEOC tooling in PE welding machine if not already present and use the BEOC molds
- Weld BEOC tube to DOM penetrator cap (18x)
- After welding, gently pull and rotate the tube to check if the weld is tight. There should be no relative movement between the components.

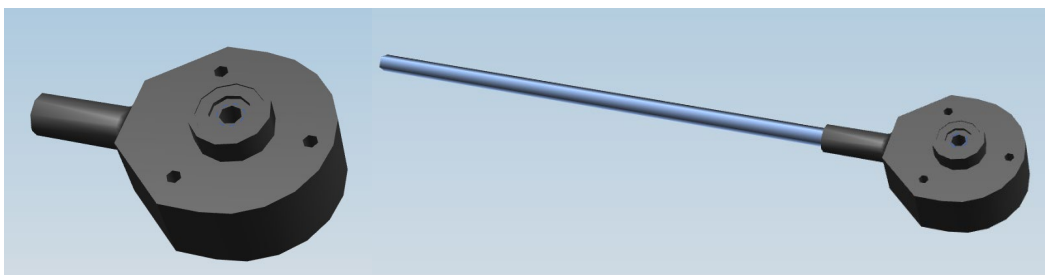


Figure 12 DOM penetrator cap before (left) and after (right) PE welding it to the BEOC.

8.1.2 Weld 8mm PE Tube to Base Penetrator Cap

- Cut and clean LLDPE 8 mm tube, according to the following lengths: ORCA 50 +/- 1 cm
- Clean inside of base penetrator cap preparing for PE weld
- Mount BEOC tooling in PE welding machine if not already present and use the special base penetrator cap molds
- Mount a dummy DOM penetrator cap to override machine security while using the welding slot for the base penetrator cap
- Weld PE tube to base penetrator cap (1x)
- After welding, gently pull and rotate the tube to check if the weld is tight. There should be no relative movement between the components.



Figure 13 Base penetrator cap design (left) and after PE welding (right) to the long (50 cm for ORCA) 8mm LLDPE tube

8.1.3 BOB Preparation

8.1.3.1 Prepare Power Feedthroughs

- Cut red and white power cable:
 - 200 mm $\pm$ 10 mm for VEOC side
 - 100 mm $\pm$ 10 mm for BEOC side
- Crimp wires to power transits as indicated in Figure 14.

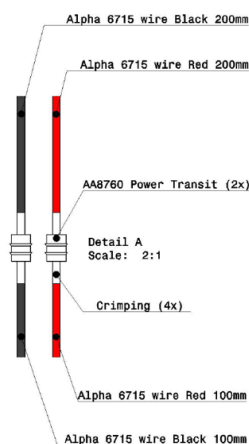


Figure 14 Finalized power feedthrough.

8.1.3.2 Mount Power and Fiber Transits in BOBs

ORCA VEOC:

- Press power transits in all BOBs (2 in every DOM BOB (18x) and anchor BOB)
- Press 1-fiber transit in all DOM BOBs (18x)
- Press 4-fiber transit in anchor BOB (6 per anchor BOB)

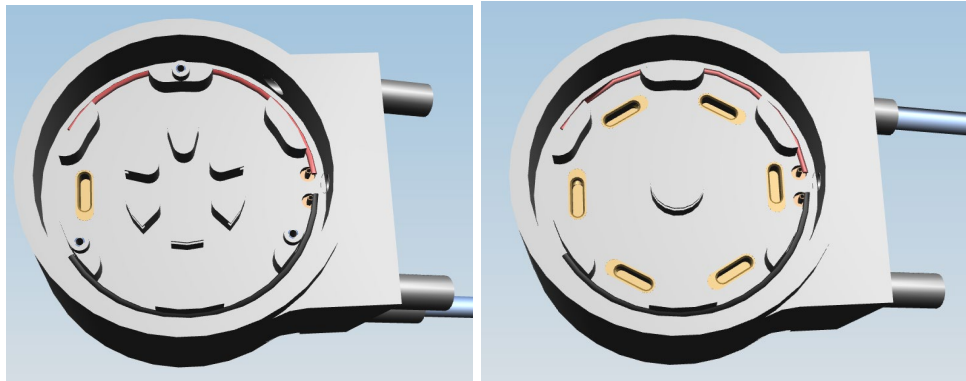


Figure 15 Left: picture of a DOM BOB showing the positions of the power feedthroughs on the right (2x) and the single fiber feedthrough on the left. Right: picture of an anchor BOB showing the positions of the power feedthroughs on the far right (2x) and the 4-fiber feedthroughs distributed around the BOB (6x).

Key Inspection Point:

- Take a picture of every BOB after mounting the power and fiber feedthroughs.

8.1.4 Weld BEOC to DOM BOB

Repeat 17x for standard DOM BOB and 1x for BOB18:

- Ensure that the BEOC+DOM penetrator cap assembly and the DOM BOB stay in line during the welding process.
- Maintain the orientation of the BEOC+DOM penetrator cap assembly with respect to the DOM BOB by keeping them both horizontally aligned as shown in Figure 16.
- Clean inner part of BOB tube fitting where it will be welded with alcohol and special tool and textile.
- Clean the outside of the BEOC with alcohol.
- Straighten the last 20 cm of the BEOC before welding
- Use the silicone insert
- Heating cycle:
 - Heat for 2 min using at a clamp temperature of 140°C (TBC)
 - Cooling until BOB reaches 80°C (~ 5 min)
- Remove from welding machine
- Verify the weld for free passage. This can be done by inserting a tool, e.g. an endoscope (<https://www.endoscoopcamera.nl/product/pce-ve-200-s-video-endoscoop-37mm/>) or equivalent.



Figure 16: End product of DOM BOB to BEOC procedure: 17 x normal DOM BOB (left) and 1 x top DOM BOB (i.e. BOB18, right)

Key Inspection Point:

- After welding, gently pull and rotate the tube to check if the weld is tight. There should be no relative movement between the components.
- Visual check and picture of outside of the welds. Visual check and OK/NOK of the inside passage using endoscope.

8.1.5 Mount the anchor BOB pillar screw

- On the base penetrator cap side of the anchor BOB, mount the anchor BOB pillar screw in the center hole of the anchor BOB



Figure 17: Anchor BOB pillar screw mounted in the anchor BOB. Note: the extension ring visible in the picture above will be welded onto the anchor BOB at a later stage in this procedure.

8.1.6 Weld 8mm PE Tube to Anchor BOB

- Mount base penetrator cap Ti ring on the assembly of the long (ORCA 50 cm) 8 mm PE tube and the base penetrator cap
- Mount the special 8 mm tools in the welding machine and PE weld the anchor BOB to the sub-assembly of the long (ORCA 50 cm) 8 mm PE tube and the base penetrator cap and the base penetrator cap Ti ring

Key Inspection Point:

- After welding, gently pull and rotate the tube to check if the weld is tight. There should be no relative movement between the components.
- Visual check and picture of outside of the welds. Visual check and OK/NOK of the inside passage using endoscope.

8.1.7 Inter-BOB PE Tube Welds

ORCA VEOC:

See Section 7.1 for the technical drawing of an ORCA VEOC and Table 1 for the inter-BOB PE tube lengths.

- The anchor BOB is connected to BOB1 with a 35 m PE tube
- BOB1 is connected to BOB2 with a 10.1 m PE tube
- BOB2 is connected to BOB3 with a 10.1 m PE tube
- Etc. to BOB5
- BOB5 is connected to BOB6 with a 12.2 m PE tube
- BOB6 is connected to BOB7 with a 10.1 m PE tube
- BOB7 is connected to BOB8 with a 10.1 m PE tube
- Etc. to BOB11
- BOB11 is connected to BOB12 with a 12.2 m PE tube
- BOB12 is connected to BOB13 with a 10.1 m PE tube
- BOB13 is connected to BOB14 with a 10.1 m PE tube
- Etc. to BOB18

Key Inspection Point:

- After welding, gently pull and rotate the tube to check if the weld is tight. There should be no relative movement between the components.
- Visual check and picture of outside of the welds. Visual check and OK/NOK of the inside passage using endoscope.

After assembly and testing of the full length of the VEOC, arrange the welded tubes and breakout boxes on the long trays in the assembly hall and fix the BOB on both ends: even BOBs on one side, odd BOBs on the other side of the hall.

Key Inspection Point:

- Perform BOB/BEOC/penetrator cap leak-tightness tests described in Section 9.5

8.2 Wire and Fiber Pulling, Feedthrough and Branching Off

8.2.1 Wire and Fiber Pulling

Pull the wires and fibers through all VEOC tubes and BOBs. In every DOM BOB, pass all fibers from the input (coming from the direction of the anchor BOB) entry to the exit entry (going in the direction of BOB18) of the BOB. Spool the excess length of the fibers around the center of the BOB and fix with the 32 mm nylon star as indicated in Figure 18.



Figure 28 Fiber bundle entering the BOB (upper left) and exiting the BOB (upper right). The excess length of the fibers is fixed under the 32 mm nylon star.

Key Inspection Point:

- Take photos of any and all deviations. Test fiber continuity to every particular DOM BOB with a fault locator/laser shining from the anchor BOB.

8.2.2 Fiber Feedthrough and Electrical Connections in the Anchor BOB

There are two sides of the anchor BOB: the VEOC side connecting to the 'between BOB'/BOB1 for ARCA/ORCA and the BEOC side connecting to the 8mm PE tube running to the base penetrator cap. When producing the VEOC, the fiber bundles are fed through from the VEOC side to the BEOC side.

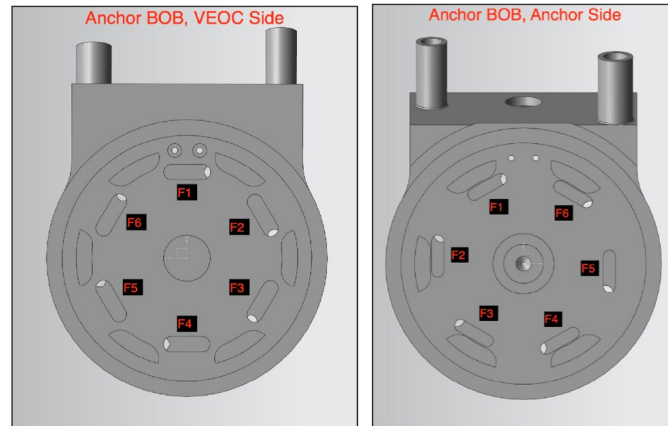


Figure 3 Anchor BOB VEOC side (left) and BEOC side (right) and the corresponding feedthrough numbering.

The VEOC starts off from the anchor BOB containing two bundles of 12 fibers: one red bundle and one white bundle. The 12 fibers in both bundles have the same industry-defined color scheme (TIA-598-C standard):

#1	Blue
#2	Orange
#3	Green
#4	Brown
#5	Slate
#6	White
#7	Red
#8	Black
#9	Yellow
#10	Violet
#11	Rose
#12	Aqua

Figure 20 TIA-598-C standard fiber color scheme

Since the anchor BOB contains six 4-fiber transits labelled F1-F6, here's how the various bundle/fiber colors should be fed through in the anchor BOB:

Anchor BOB feedthrough label	Bundle Color	Fiber Colors
F1	red	blue/orange/green/brown
F2	red	slate/white/red/black
F3	red	yellow/violet/rose/aqua
F4	white	blue/orange/green/brown
F5	white	slate/white/red/black
F6	white	yellow/violet/rose/aqua

Table 3 Anchor BOB fiber feedthrough definition

8.2.2.1 Mounting the Fibers in the Anchor BOB

- Feed the four designated fibers through the fiber transit from the VEOC side to the BEOC side of the anchor BOB
- Glue the fibers to the fiber transit using a droplet of Araldite 2011 glue
- Heat the glue using a heat gun at 50 degrees C to let the glue fill up the fiber transit
- Wait for the glue to cure
- Check fibers for continuity using a fault locator
- On both the BEOC and the VEOC side of the anchor BOB, fix the 4-fiber bundle on the flat surface of the anchor BOB, outside of the feedthrough hole, using silicone mastic Dow Corning 3140 RTV coating.

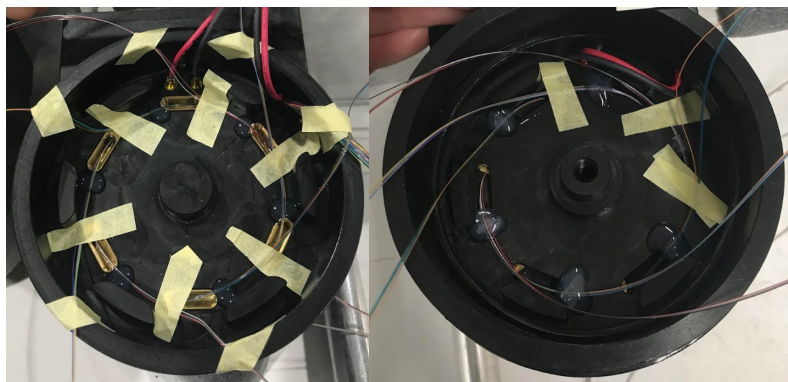


Figure 21 Fixing the 4-fiber bundles on each side of the anchor BOB using a droplet of silicone mastic

- Mount a 13 mm star to carefully store the fiber coils on both sides of the anchor BOB

Key Inspection Point:

- Document any deviations from the prescribed fiber routing in the anchor BOB
- For the anchor BOB provide pictures of
 - Fiber feed-through and silicone fixing of the 4-fiber bundles on both sides of the anchor BOB
 - Fiber coil on the VEOC-side of the BOB including the 13 mm star

8.2.2.2 Electrical Connections in the Anchor BOB

- When splicing and crimping the red and black electrical wires on the VEOC side (i.e. not the base penetrator side) of the anchor BOB, make sure that the splice is well isolated to prevent shorts. To this end, use crimp splices 0-0034070-0 from TE Connectivity. In particular, for the anchor BOB, 2 crimp splices are needed, for both red and black, on the VEOC side of the anchor BOB (i.e. not the base penetrator side).

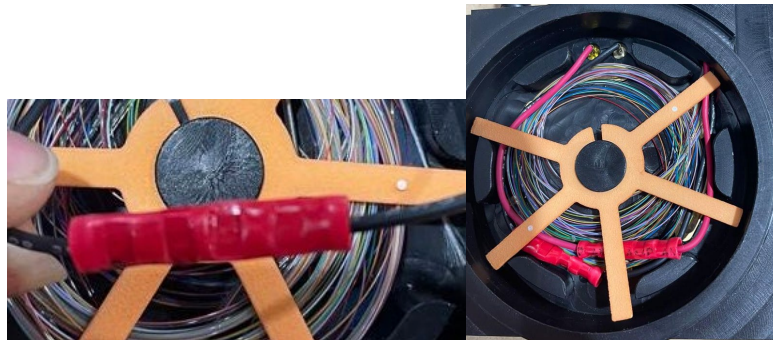


Figure 22 Example of a good splice (left) and how it should be stored safely in the BOB (right)

Key Inspection Point:

- Fill out check-box for mounting the crimp splices correctly

8.2.3 Mounting the Branched-Off Fiber in the DOM BOB

The default fiber routing of a VEOC is shown in Figure 23. Note that the information on the anchor BOB feedthroughs as defined in the previous section is repeated here.

BOB	Nominal bundle color	Nominal fiber color	Nominal anchor BOB feedthrough
BOB 1	red	blue	F1
BOB 2	red	orange	F1
BOB 3	red	green	F1
BOB 4	red	brown	F1
BOB 5	red	slate	F2
BOB 6	red	white	F2
BOB 7	red	red	F2
BOB 8	red	black	F2
BOB 9	red	yellow	F3
Spare	red	violet	F3
Spare	red	rose	F3
Spare	red	aqua	F3
BOB 10	white	blue	F4
BOB 11	white	orange	F4
BOB 12	white	green	F4
BOB 13	white	brown	F4
BOB 14	white	slate	F5
BOB 15	white	white	F5
BOB 16	white	red	F5
BOB 17	white	black	F5
BOB 18	white	yellow	F6
Spare	white	violet	F6
Spare	white	rose	F6
Spare	white	aqua	F6

Figure 4 Nominal VEOC fiber routing

In every DOM BOB:

- Check continuity of the fiber that is to be branched off first by checking with a fault locator/laser shining from the anchor BOB before feeding-through from the VEOC side to the BEOC side of the DOM BOB
- If the fiber is not OK, use one of the spare fibers and document clearly which fiber (bundle color/fiber color) in the anchor BOB connects to which fiber (bundle color/fiber color) in the DOM BOB
- If the fiber is OK, feed the fiber through the fiber transit from the VEOC side to the BEOC side of the BOB
- Glue the fiber to the fiber transit using a droplet of Araldite 2011 glue
- Heat the glue using a heat gun at 50 degrees C to let the glue fill up the fiber transit
- Wait for the glue to cure

- Check fiber for continuity again
- On both the BEOC and the VEOC side of the BOB, fix the fiber on the flat surface of the BOB, outside of the feedthrough hole, using silicone mastic Dow Corning 3140 RTV coating.

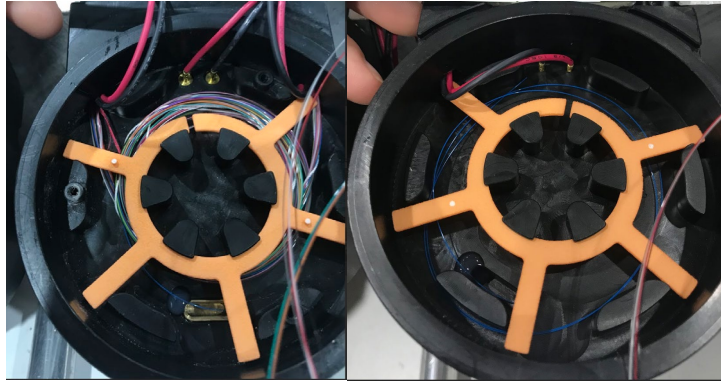


Figure 24 Fixing the fiber on each side of the BOB using a droplet of silicone mastic

- The excess length of the branched-off fiber (minimal 30cm!) shall be stored in the reserved space on the BEOC side of the BOB.
- Use a 32 mm star to securely store the fiber

Key inspection point:

- Document which fiber (bundle color/fiber color) in the anchor BOB connects to which fiber (bundle color/fiber color) in the DOM BOB as indicated in Section 9.10
- For each BOB provide pictures of
 - Fiber feed-through and silicone fixing of the fiber on both sides of the BOB
 - Fiber coil on the VEOC-side of the BOB including the 32 mm star

8.2.4 Soldering and Mounting the DC/DC Converter

8.2.4.1 Preparation of the ORCA DC/DC converter

- On each ORCA DC/DC converter, mount a small cable tie to prevent the converter from opening inadvertently. See Figure 25.

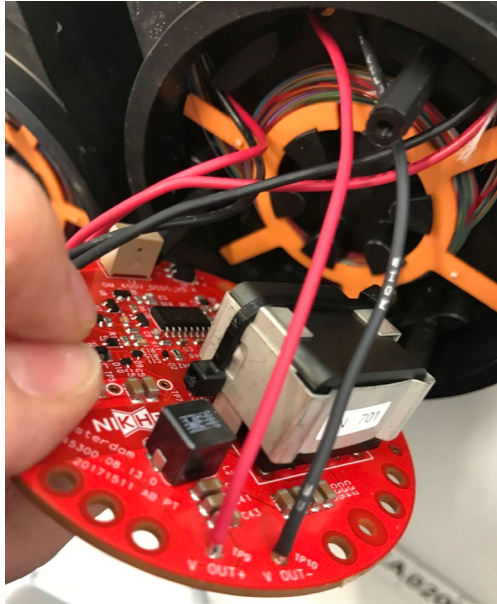


Figure 5 Cable tie around ORCA DC/DC converters

8.2.4.2 Preparation of the Power Wires in the BOB

- On the VEOC side of every DOM BOB, take the 12V red and black wires that come from the BEOC side of the BOB and cut them to a length of 160 ± 20 mm and strip the wire ends to 5 mm
- Take the red and black wires from the entry of the BOB (i.e. the direction coming from the anchor BOB). Cut them to length 75 ± 15 mm and strip the wire ends to 5 mm
- Take the red and black wire from the exit point of the BOB (i.e. going in the direction of BOB18). Cut them to a length of 75 ± 15 mm and strip the wire ends to 5 mm



Figure 6 Preparation of the power cables in the DOM BOBs

8.2.4.3 Soldering the Power Wires to the DC/DC Converter

- Use a soldering iron suitable for lead/tin solder with a 5mm flat point set at a temperature of 440 degrees C.
- Pre-tin the wires ends by using flux and a minimum amount of soldering tin (avoid thickening of wires ends)
- Solder the wire ends to the DC-DC converter board:
 - Incoming and outgoing 375 V (red) and return (black) wires to V_in holes on PCB
 - 12 V (red) and return (black) wires coming from the BEOC side of the BOB to V_out holes on PCB

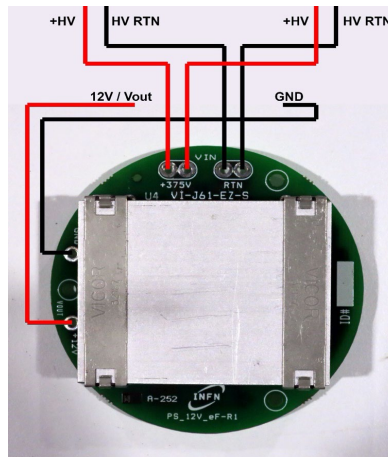


Figure 77 (ARCA) DC/DC converter soldering layout

- Make sure that soldering tin is flowing through the Printed Circuit Board (PCB) holes. Maximum free wire length sticking out of the PCB should be 3mm.
- Maximum distance from soldering to start of wire insulation shall be 2.5 mm

Key Inspection Point:

- Photograph the quality of the solder joints at both sides of the DC/DC converter as shown in Figure 28.

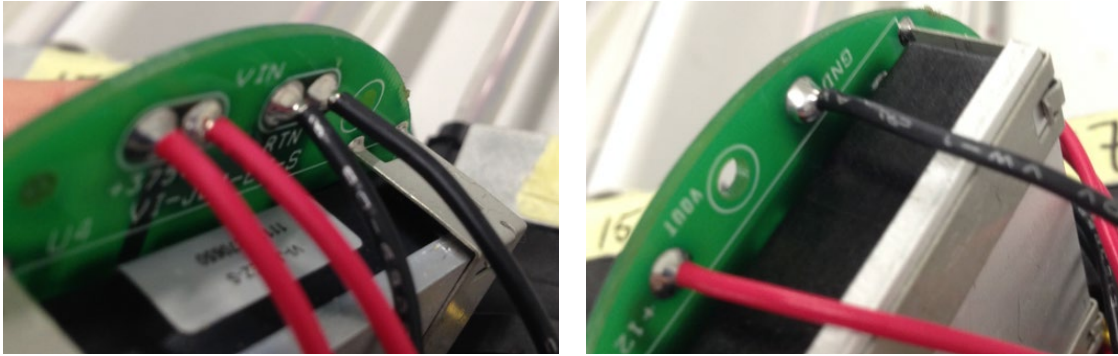


Figure 88 Example of key inspection point pictures for soldering of the power wires to an ARCA DC/DC converter board.
Top: V_{in} 375V (red) and return (black) feedthroughs. Bottom: V_{out} 12V (red) and return (black) wire going to the BEOC side of the DOM BOB.

- Photograph and document the BOB number and the DC/DC converter serial number. For the ORCA DC/DC converters this is the three-digit number on the transformer.

8.2.4.4 Mounting the DC/DC converter in the DOM BOB

For every DOM BOB:

- Mount the nylon DC/DC converter spacers in the DOM BOB
 - ORCA: 5x20 mm
- Gently lower the DC/DC converter, carefully routing the power wires over the nylon 32 mm star that holds down the fibers. Take care not to squeeze and/or damage the copper wires between the PCB and any PE parts and not to damage the fibers.
- Once the DC/DC converter is in place, mount it using the three M2.5x6 nylon screws.

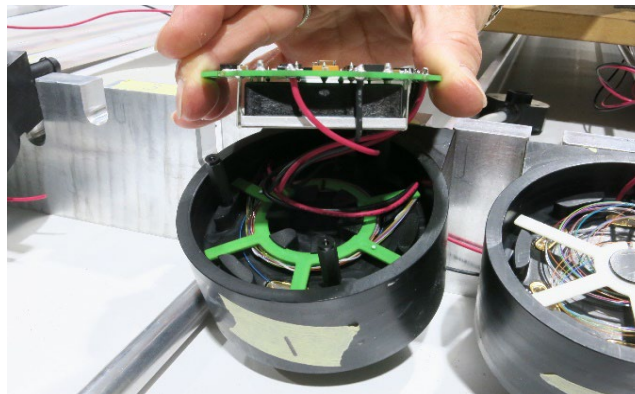


Figure 9 Gently lower the DC/DC converter into place and take care not to damage the wires and fibers.

Key Inspection Point:

- Photograph electrical wire routing inside the BOB after mounting the DC/DC converter.
- Perform the fiber optic attenuation tests as described in Section 9.12
- Perform the electrical resistance tests as described in Section 9.13
- Perform the DC/DC converter voltage tests as described in Section 9.14

8.3 Sealing BOBs

Sealing off BOBs is done by PE-welding a cover on the BOB. These BOB cover welds are performed using a custom-designed BOB cover PE welding tool described in Section 10.2.

Note that there are two types of BOB Covers:

- The 'Cover VEOC' has a height of 29 mm. These are only meant for the VEOC side of DOM BOBs (in particular: not for the anchor BOB) and allows additional space for the DC/DC converter in the DOM BOB
- The 'Cover BEOC' has a height of 13 mm. These are used for all other BOBs and BOB sides

Repeat 18x:

- Weld PE 'Cover VEOC' to the VEOC-side of the 18 DOM BOBs

And :

- Weld PE 'Cover BEOC' to the VEOC side of the anchor BOB
- Weld the PE elevation ring to the BEOC (i.e. non-VEOC) side of the anchor BOB



Figure 30 Elevation ring for the anchor BOB before (left) and after (right) PE welding

NB: these steps finalize the BOB cover welds during VEOC production. After DOM integration at the KM3NeT DU production sites, another 19 'Cover BEOC' are needed to seal the BEOC sides of the BOBs.

After welding the BOB covers, mark each BOB with a sticker on the VEOC-side BOB cover, labelling them from 'anchor BOB', 'BOB 1', etc., all the way up to 'BOB 18'.

Finally, cover the unwelded, open BEOC-side of all BOBs using the temporary plastic Skiffy BOB covers.

Key Inspection Point:

- Fill out the check list for all PE-welds as shown in Section 9.15
- Perform BOB cover leak-tightness tests as described in Section 9.16

8.4 Fill VEOC with oil

Oil-filling of the VEOC is performed using a custom-designed oil-filling machine described in Section 9.3. The oil used is Midel 7131 transformer Insulating Fluid (M&I Materials). Always keep the oil in a closed container to avoid moisture from the air being absorbed in the oil.

- Connect all fill hoses to the oil filling point of the BOBs as indicated in Figure 31



Figure 31 Red oil-filling hose connected to the oil-filling point of the BOB (an ARCA middle BOB in this case)

- Connect the fill hoses according to the table below (see also Figure 9)

BOB Type	IN/OUT
BOB 18 (Top)	IN
BOB 17	OUT
BOB 16	IN
BOB 15	OUT
BOB 14	IN
BOB 13	OUT
BOB 12	IN
BOB 11	OUT
BOB 10	IN
BOB 09	OUT
BOB 08	IN
BOB 07	OUT
BOB 06	IN
BOB 05	OUT
BOB 04	IN
BOB 03	OUT
BOB 02	IN
BOB 01	OUT
BOB Anchor	IN

- After oil-filling is completed, the BOB oil-filling point is sealed with an O-ring (6x1.5mm) and sealing screw, see 32

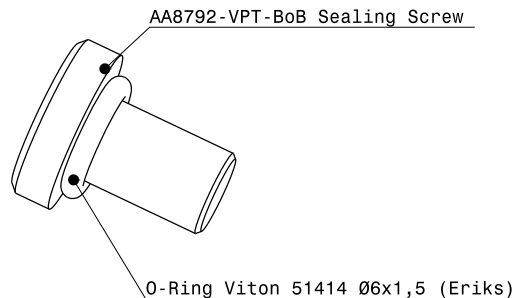


Figure 32 Oil filling screw and O-ring (Nikhef drawing AA9008)

Key Inspection Point:

- After oil-filling, re-perform the fiber optic attenuation tests as described in Section 9.12
- After oil-filling, re-perform the DC/DC converter voltage tests as described in Section 9.14

8.5 VEOC Storage and Transport

After passing the acceptance tests, the VEOC is wound up and stored in a transport container. The transport container shall protect the VEOC from damage or malfunction during normal shipping and handling.

- Note that the windings should be at least 30 cm in diameter to prevent kinks in the PE tube and possible fiber fractures
- Make sure to make one VEOC tube winding between every BOB:
 - ORCA: 18 windings (anchor BOB-BOB1, BOB1-BOB2, ... , BOB17-BOB18)

8.6 Post-Production Step: Over-Pressurize Oil in the VEOC

At the receiving KM3NeT site, the oil-pressure inside the VEOC is elevated to 2 bar (1 bar over-pressure) after degassing the oil, in order to evacuate the last air bubbles and to re-check leak-tightness.

9 VEOC Assembly Report

The VEOC assembly report shall at minimum contain the tables (or similar) in the following sections that summarize the key inspection points and tests as described in the VEOC assembly procedure.

- Nikhef shall receive a digital version of the VEOC assembly report (e.g. a pdf from a hand-written filled out version).
- Using the information in the assembly report, the producer will distill all information that needs to be filled out on the KM3NeT VEOC Acceptance Test Sheet (KM3NeT reference KM3NeT_DU_2019_028) that contains all the relevant information for VEOC acceptance and further integration in the KM3NeT experiment.

9.1 BEOC to Penetrator Cap Inspection Point

Penetrator cap	Date	Visual check	Endoscope check	Picture taken	Signature
Anchor	N/A (post-	N/A	N/A	N/A	N/A
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18 Top					

Note any and all anomalies	
----------------------------	--

9.2 BOB Preparation Inspection Point

BOB	Date	Check position red/black power transit	Check fiber transit	Picture taken	Signatur e
Anchor			6x		
Between					
1					
2					
3					
4					
5					
6					
7					
8					
9					
Middle (ARCA)			6x		
10					
11					
12					
13					
14					
15					
16					
17					
18					

Note any and all anomalies	
----------------------------	--

9.3 BEOC to BOB Inspection Point

BOB	Date	Visual check	Endoscope check	Orientation penetrator cap- BOB	Picture taken	Signature
Anchor -						
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

BOB	Date	Visual check	Endoscope check	Orientation penetrator cap-BOB	Picture taken	Signature
11						
12						
13						
14						
15						
16						
17						
18 Top						

Note any and all anomalies	
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9.4 Inter-BOB PE Tube Inspection Point

BOB	Date	Visual check IN	Endoscope check	Date	Visual Check OUT	Endoscope check	Picture taken	Signature
Anchor					N/A			
Between								
1								
2								
3								
4								
5								
6								
7								
8								
9								
Middle								
10								
11								
12								
13								
14								
15								
16								
17								
18 Top								

Note any and all anomalies	
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9.5 BOB/BEOC/Penetrator Cap Leak-Tightness Inspection Point

The BOBs, BEOCs and penetrator caps of the VEOC, including the associated PE welds are tested for leak-tightness by temporarily sealing the BOBs and penetrator caps using the tool described in Section 10.4. There is a special tool for the temporary sealing of the base penetrator cap, see Section 10.4 as well. The entire VEOC is then air-pressurized at 2.5 bar (1.5 bar over-pressure). The BOB, BEOC and penetrator cap sub-systems are tested for leak-tightness by keeping them immersed in water for 24 hours while monitoring the size of any air bubbles that are formed and caught under a glass cap. Qualification criteria: Air bubble size in tray should not have changed after being immersed in water 24 hours. There is a check on the bubble sizes after 12 hours and a final check after 24 hours. If the bubble size did increase during the 24 hours testing period, the sealing of the tool should be checked first.

BOB		t=12 hrs bubble size (cm)	t=24 hrs bubble size (cm)	Reason for bubble formation (if known, often the tool sealing ring)	Final (OK/NOK)	Pictures of submerged subsystem taken at t=0 and t=24 hours
Anchor						
1	BOB					
	CAP					
3	BOB					
	CAP					
5	BOB					
	CAP					
7	BOB					
	CAP					
9	BOB					
	CAP					
11	BOB					
	CAP					
13	BOB					
	CAP					
15	BOB					
	CAP					
17	BOB					
	CAP					
2	BOB					
	CAP					
4	BOB					
	CAP					
6	BOB					
	CAP					
8	BOB					
	CAP					

BOB		t=12 hrs bubble size (cm)	t=24 hrs bubble size (cm)	Reason for bubble formation (if known, often the tool sealing ring)	Final (OK/NOK)	Pictures of submerged subsystem taken at t=0 and t=24 hours
10	BOB					
	CAP					
12	BOB					
	CAP					
16	BOB					
	CAP					
14	BOB					
	CAP					
18	BOB					
	CAP					

Note any and all anomalies	
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9.6 BOB/BEOC/Penetrator Cap Leak-Tightness Inspection Point

Fiber bundle color		Fiber serial number
ORCA	Red	
	White	

- Use a fault locator or strong laser to check the single fiber continuity

BOB/DO M	Fiber	Bundl e	Fiber useable up to (indicate specific BOB or 'end' if nominal)
1	Blue	Red	
2	Orange	Red	
3	Green	Red	
4	Brown	Red	
5	Slate	Red	
6	White	Red	
7	Red	Red	
8	Black	Red	
9	Yellow	Red	
	Violet	Red	
	Rose	Red	
	Aqua	Red	
10	Blue	White	
11	Orange	White	
12	Green	White	

BOB/DO M	Fiber	Bundl e	Fiber useable up to (indicate specific BOB or 'end' if nominal)
13	Brown	White	
14	Slate	White	
15	White	White	
16	Red	White	
17	Black	White	
18	Yellow	White	
	Violet	White	
	Rose	White	
	Aqua	White	

Note any and all anomalies	
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9.7 Fiber Feedthrough in BOB Inspection Point

BOB	Bundle color	Fiber color	Date	Picture taken before and after spooling fiber up	Fiber length on BEOC side >30cm	Signature
Anchor	All	All			N/A	
Between	All	All			N/A	
Middle	White	All			N/A	
1						
3						
5						
7						
9						
11						
13						
15						
17						
2						
4						
6						
8						
10						
12						
14						
16						
18						

Note any and all anomalies	
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9.8 Fiber Glueing in BOB Inspection Point

Best-before date of the glue	
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BOB	Position of fiber free?	Date	Signature
1			
3			
5			
7			
9			
11			
13			
15			
17			
2			
4			
6			
8			
10			
12			
14			
16			
18			

Anchor BOB	Position of fibers free?	Date	Signature
Bundle 1			
Bundle 2			
Bundle 3			
Bundle 4			
Bundle 5			
Bundle 6			

9.9 Apply Silicon Mastic in Fiber Transits Inspection Point

Best-before date of the silicon mastic	
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BOB		Position of fibers free?	Date	Signature
Anchor BOB	VEOC-side (6x)			
	BEOC-side (6x)			
1	VEOC-side			
	BEOC-side			
3	VEOC-side			
	BEOC-side			
5	VEOC-side			

BOB		Position of fibers free?	Date	Signature
	BEOC-side			
7	VEOC-side			
	BEOC-side			
9	VEOC-side			
	BEOC-side			
11	VEOC-side			
	BEOC-side			
13	VEOC-side			
	BEOC-side			
15	VEOC-side			
	BEOC-side			
17	VEOC-side			
	BEOC-side			
Middle	VEOC-side (6x)			
	BEOC-side (6x)			
2	VEOC-side			
	BEOC-side			
4	VEOC-side			
	BEOC-side			
6	VEOC-side			
	BEOC-side			
8	VEOC-side			
	BEOC-side			
10	VEOC-side			
	BEOC-side			
12	VEOC-side			
	BEOC-side			
16	VEOC-side			
	BEOC-side			
14	VEOC-side			
	BEOC-side			
18	VEOC-side			
	BEOC-side			

Note any and all anomalies	
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9.10 Final Fiber Configuration

BOB	Anchor BOB bundle color	Anchor BOB fiber color	Anchor BOB feedthrough number (F1-F6)	BOB bundle color	BOB fiber color
1					
2					
3					

BOB	Anchor BOB bundle color	Anchor BOB fiber color	Anchor BOB feedthrough number (F1-F6)	BOB bundle color	BOB fiber color
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					

9.11 DC/DC Converter Soldering and Mounting Inspection Point

VEOC Type	Height DC/DC converter spacers	Signature
ORCA	20 mm	

BOB	Serial number DC/DC converter	Picture of soldering on both sides of DC/DC converter	Picture after mounting in the DOM BOB	Date	Signature
1					
3					
5					
7					
9					
11					
13					
15					
17					
2					
4					
6					
8					
10					
12					
14					
16					

BOB	Serial number DC/DC converter	Picture of soldering on both sides of DC/DC converter	Picture after mounting in the DOM BOB	Date	Signature
18					

Note any and all anomalies	
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9.12 Fiber Attenuation Tests

Fiber attenuation is measured using OTDR or similar, shining the laser from the anchor BOB and measuring the attenuation at the DOM BOB.

BOB	Fiber color in anchor BOB	Optical attenuation at 1310 nm [dB]	Optical attenuation at 1550 nm [dB]	Date	Signature
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					

Note any and all anomalies	
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9.13 Electrical Resistance Tests

The measurement device should be calibrated and capable of measuring resistances up to at least 30 MΩ. Measure the resistances on wires using a probe on the PCB boards.

List of mandatory resistance measurements on unpowered boards after all DC/DC converters have been soldered and mounted:

- **R1 measurements:** 18 resistance measurements between HV_IN Return in every BOB (black wire) and the black wire in the anchor BOB
 - Acceptance values: $R \sim 1-10 \Omega$ accounting for wire resistance and connector resistance
- **R2 measurements:** 18 resistance measurements between HV_IN 375V in every BOB (red wire) and the red wire in the anchor BOB
 - Acceptance values: $R \sim 1-10 \Omega$ accounting for wire resistance and connector resistance
- **R3 measurement:** 1 resistance measurement between the red and black wire in the anchor BOB
 - Acceptance values: $R > 1 M\Omega$
- **R4 measurements:** 18 resistance measurements between 12V_OUT return (black wire on the BEOC side) and HV_IN return (black wire) in every BOB
 - Acceptance values: $R > 20 M\Omega$
- **R5 measurements:** 18 resistance measurements between 12V_OUT (red wire on the BEOC side) and HV_IN 375V (red wire) in every BOB
 - Acceptance values: $R > 20 M\Omega$

BOB	R1 measurement	R2 measurement	Date	Signature
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				

BOB	R3 measurement	Date	Signature
Anchor			

BOB	R4 measurement	R5 measurement	Date	Signature
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				

Note any and all anomalies	
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9.14 DC/DC Converter Voltage Tests

The ORCA DC/DC converters 12 V outputs shall be connected to dummy loads to measure the output voltage from the DC/DC converters. Connect 380 ± 30 V using a Delta Elektronika SM 400-AR-4 or similar while limiting the current to 1 A for ORCA VEOCs and 2 A for ARCA VEOCs. Measure the supply voltage between the red and black wire on the DOM BOB BEOC side. Acceptance values: $12.2 \text{ V} \pm 0.4 \text{ V}$. A picture of a dummy load (provided by Nikhef) is shown in Figure 33.

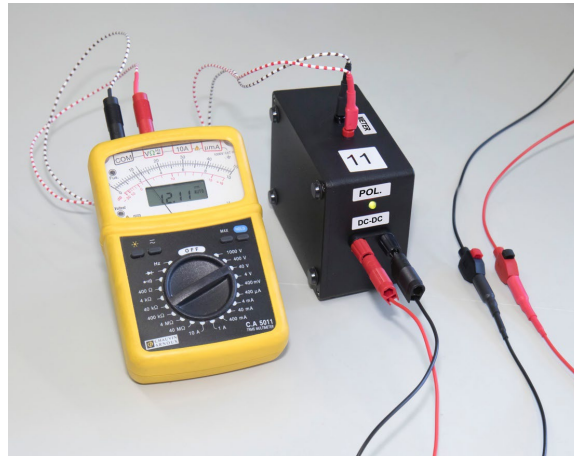


Figure 10 Dummy load (black box) used to measure the DC/DC converter output voltages.

BOB	Dummy load number	Polarity light green?	Voltage	Date	Signature
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					

	Measured	Expected
Current [A]		~ 0.45 A (± 0.1 A) without load ~ 0.58 A (± 0.1 A) with load

Note any and all anomalies	
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9.15 BOB Cover Mounting Inspection Point

BOB	Part 1	Part 2	Date	Signature
Anchor	BEOC cover	Elevation ring		
Between	BEOC cover			
1	VEOC cover			
2	VEOC cover			
3	VEOC cover			
4	VEOC cover			
5	VEOC cover			
6	VEOC cover			
7	VEOC cover			
8	VEOC cover			
9	VEOC cover			
Middle	BEOC cover	BEOC cover		
10	VEOC cover			
11	VEOC cover			
12	VEOC cover			
13	VEOC cover			
14	VEOC cover			
15	VEOC cover			
16	VEOC cover			
17	VEOC cover			
18	VEOC cover			

Note any and all anomalies	
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9.16 BOB Cover Leak-Tightness Inspection Point

This leak-tightness test is different from the one described in Section 9.5. In this case, again the VEOC is air-pressurized at 2.5 bar. But in this case, the BOB is only partially submerged, including only the cover PE weld. Note carefully to not immerse the open BOB end (i.e. the BEOC side) that contains bare fibers and copper wires! The BOB is only kept under water manually for 1 minute. The cover weld is leak-tight if no bubbles are observed on the weld.

BOB	Leak-tight [Y/N]?	Date	Signature
Anchor			
Between			
1			
2			
3			
4			

BOB	Leak-tight [Y/N]?	Date	Signature
5			
6			
7			
8			
9			
Middle			
10			
11			
12			
13			
14			
15			
16			
17			
18			

Note any and all anomalies	
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10 Equipment and Tools

10.1 PE Tube Welding Machine

The PE welding machine is a WIDOS 2500 SPS Nikhef having the following specifications:

1.4.1. Technische Daten

Aufgeführt werden alle wichtigen technischen Daten der Einzelkomponenten.
Sie erlauben eine schnelle Information über Leistungsfähigkeit und Aufbau.

1.4.1.1. WIDOS 2500P SPS NIKHEF Allgemeine Daten

Material:	Thermoplaste
Einspeisung:	max. 16 A
Leistung:	max. 3,6 kW
Versorgungsspannung:	230 V ($\pm 10\%$)
Frequenz:	50 Hz ($\pm 10\%$)
Leitungsquerschnitt:	3 x 1,5 mm ²
Umgebungsbedingungen im Schweißbereich:	- Auf Sauberkeit achten (kein Staub an der Schweißstelle) - Wenn durch geeignete Maßnahmen sichergestellt wird, dass zum Schweißen zulässige Bedingungen angegeben sind, darf – soweit der Schweißer nicht in der Handfertigkeit behindert ist – bei beliebiger Außentemperatur gearbeitet werden. - vor Feuchtigkeitseinwirkung schützen - starke Sonneneinstrahlung vermeiden
max. Arbeitsdruck:	8 bar
Abmaße (BxHxT):	ca. 1090 x 2050 x 750 mm
Heizelemente:	
Leistung je Heizelement:	0,44 kW
Spannung:	230 V
Stromstärke je Heizelement:	1,9 A

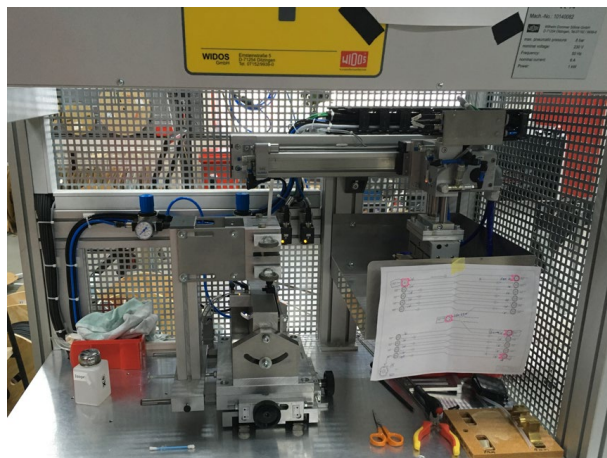


Figure 34 Picture of the VEOC PE tube welding machine.

10.2 BOB Cover Welding Tool

This custom-designed tool is used to PE-weld the various BOB covers on the various BOBs. A picture of the tool is shown in Figure 35.



Figure 115 Manual PE welding tool for welding BOB covers on BOBs and welding the elevation ring on the anchor BOB.

10.2.1 Welding Procedure

- Heat welder up for at least 20 min
- Heat BOB and cover for 1 minute using small distance piece as a spacer
- Heat BOB and cover for 1 minute without small distance piece
- Release and remove heater
- Press BOB and cover together with large distance piece as a spacer for 5 minutes while cooling down

NB: do not clean the welding surfaces with sand paper. You can clean the surfaces with a sharp knife.

10.3 Oil-Filling Machine

The VEOC oil-filling machine was designed and built at Nikhef.

KM3NET Oil fill and degassing system VEOC

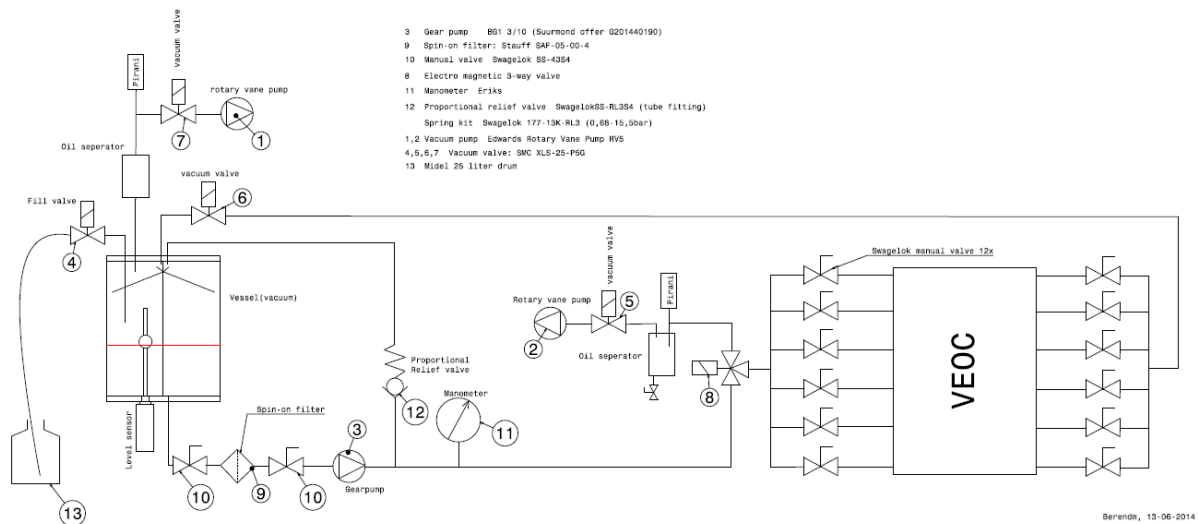


Figure 126 Schematics of the VEOC Oil-Filling Machine.



Figure 37 Picture of the VEOC Oil-Filling Machine.

10.4 BOB Leak-Tightness Testing Tool

10.4.1 DOM BOBs and DOM Penetrator Caps

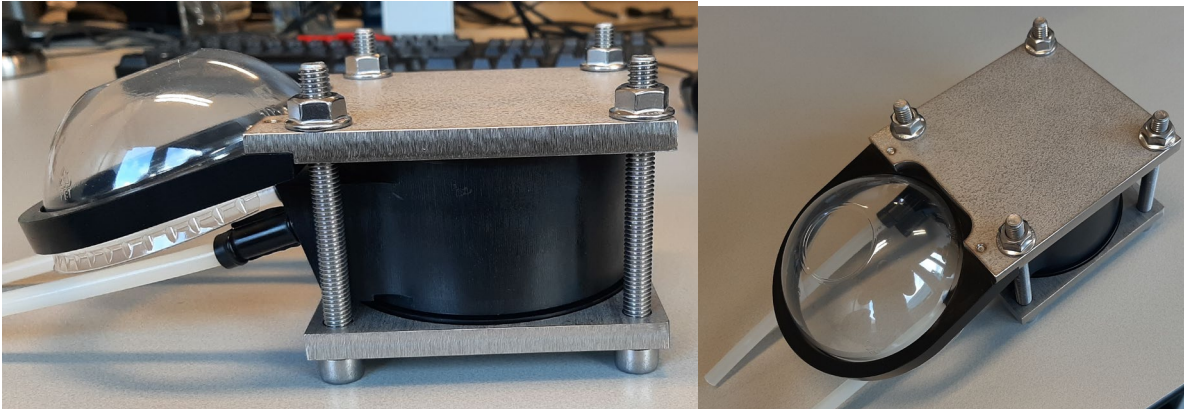


Figure 38 Pictures of the BOB leak-tightness testing tool.

10.4.2 Anchor BOB and Base Penetrator Cap

For the anchor BOB, the same tool can be used as for the nominal DOM BOBs. For the base penetrator cap, a special sealing tool has been developed, see Figure 39 for pictures.

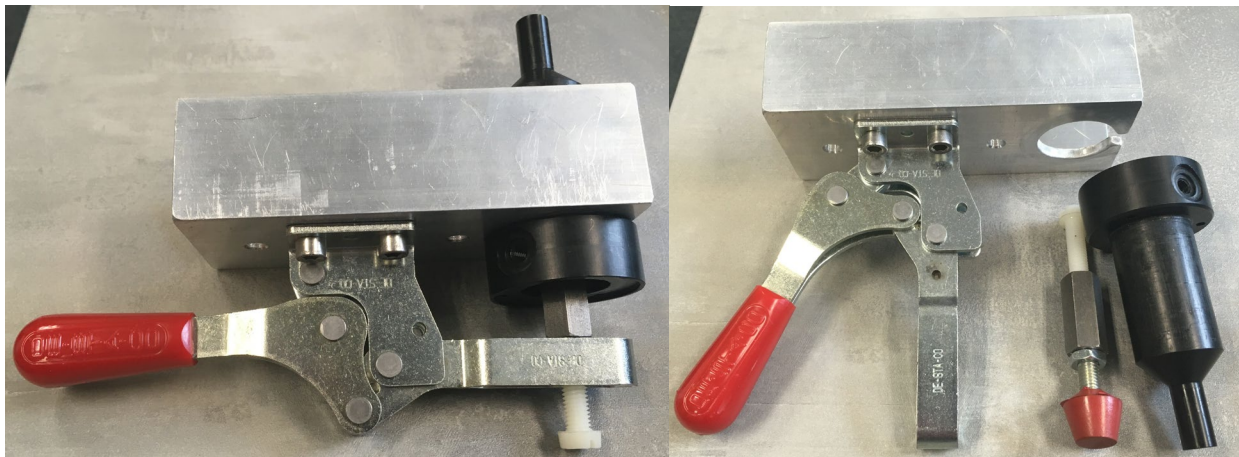


Figure 139 Pictures of special base penetrator cap sealing tool.

11 Tender Documentation

- Documents must be written in French and/or English.
- A schedule for completion and delivery

12 Delivery times / Terms and conditions of delivery and performance of services

Delivery is at the expense of the holder.

The delivery time must be stated in the tender by the contractor, provided that it does not exceed the maximum time limit.

Delivery may be made in several batches, which must be specified in the quotation.

12.1 Maximum delivery time for all products

Maximum time limit : 15 months

12.2 Delivery terms and premises layout

Deliveries are made on working days from Monday to Friday between 9am and 12pm and between 2pm and 5pm.

Packaging and delivery shall be borne by the contractor.

The contractor is responsible for packaging, packing, loading and stowage operations.

The risks associated with transport to the place of delivery are borne by the contractor.

The exact date of delivery of the services will be agreed upon between the laboratory and the contractor

The services delivered by the contractor or their representative must be accompanied by a delivery note drawn up in duplicate, specifying:

- ✎ The date of dispatch,
- ✎ Tender references,
- ✎ Identification of the contractor,
- ✎ Identification of delivered supplies.

Damage caused by deliveries and installations:

The holder remains liable for any damage of any kind caused by their agents or the carrier to equipment: buildings, land, plantations, installations, etc.....

The CNRS reserves the right to carry out itself or have carried out, on behalf of the holder, the repair of any damage caused.

12.3 CNRS Technical Correspondents

Jérôme PERRONNEL
Laboratoire de Physique Corpusculaire de Caen - LPCC
6 Boulevard Maréchal Juin
14050 Caen cedex
France

12.4 KM3NeT Technical Correspondents

Daan VAN EIJK
Nikhef
Science Park 105,
Amsterdam 1098 XG,
Netherlands

12.5 Delivery locations / Access

Delivery must be made to the following address:

Nikhef
Attn. Daan VAN EIJK
Science Park 103
1098 XG Amsterdam
The Netherlands

13 Verification operations

Upon delivery, the CNRS carries out the following checks and tests:

- Visual inspection
- Documentation control

13.1 Final acceptance of services

Final acceptance shall be declared within a maximum of two weeks after delivery, following the checks described in § 6 and the provision of the documentation listed in § 5.1