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Optical Detector Lab

Cryotiger Cryostats for the cooling of scientific CCDs at ESO

A suitability discussion

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CHANGE RECORD

ISSUE	DATE	SECTION/PARA. AFFECTED	REASON/INITIATION DOCUMENTS/REMARKS
0.1	5.5.2002		draft
0.2	27.5.2002		requirements section new
1.0	4.6.2002		changes, corrections
2.0	13.1.2003		Changes suggested by J.L.L.

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APPLICABLE DOCUMENTS

[1] VLT Electronic Design Specification VLT-SPE-ESO-10000-0015
[2] Electromagnetic Compatibility and Power Quality Specifications Part 1 VLT-SPE-ESO-10000-0002.
[3] Electromagnetic Compatibility and Power Quality Specifications Part 2 VLT-SPE-ESO-10000-0003.
[4] VLT Environmental Specification VLT-SPE-ESO-10000-0004.

REFERENCE DOCUMENTS

[5] Phillip MacQueen: Cryotiger, Communcation to CCD-world on December 5, 2001
[6] Les Saddlemyer: Cryotiger, Communication to CCD-world on December 4, 2001
[7] IGC Polycold Systems Inc., DATA sheet of Cryotiger, www.polycold.com
[8] David Hula and Bernd Kasparick: Private communication at the Semicon fair in Munich, 4,2002
[9] Jerry Cabak: Cryotiger at Keck telescope, Communication to CCD-world at May 15, 2002
[10] Bacon et al.: Proposal for VLT 2nd generation instrument, 2002

ABBREVIATIONS USED AND GLOSSARY

CCD Charged coupled device (imager for optical wavelengths)
CFC Continuous flow cryostat
CRYOTIGER Modified closed cycled cooler from Polycold without moving parts in the cold end (head)
MUSE Multi-Unit Spectroscopic Explorer
ODT Optical Detector Team

1 Scope:

Scientific optical CCD detectors are generally cooled with Peltier coolers or with liquid nitrogen cryostats. Since some years it is reported from the astronomical community the use of an alternative detector cooling: Closed cycle coolers. But these imply some disadvantages: Relative high costs and needed maintenance, because their cooling head contains movable parts, which have a lifetime of less than some years. Also the very high cooling power of a closed cycle cooler is not needed for optical detectors. For this another industrial standard was developed, which overcame the mentioned disadvantages. A highly reliable closed cycle cooler without moving parts called CRYOTIGER, which is now offered by Polycold, USA. In the mean time it was tested at several observatories [7] [5] [6]. This system is optimized for reaching temperatures of the same range like liquid nitrogen. The reports sound encouraging, so that ODT at ESO is now considering to test a so called CRYOTIGER cooling head, which later should be used at the ODT detector test-bench. If this test would be successful, several CRYOTIGER coolers probably could by used in parallel at the planned MUSE project, which is a second generation VLT spectrograph. This project would require so many conventional liquid nitrogen cryostats that a proper operation only is possible with a high amount of manpower. This document shows why this new cooling concept looks very promising: It seems very easy to operate and it could save manpower and costs compared with the presently used liquid nitrogen cooling systems. This paper also gives some data about the CRYOTIGER, then a construction is presented and discussed, which adapts a Cryotiger cryostat to the present CCD heads, without modifying it. Later this development would give to ESO the possibility to exchange most liquid nitrogen based cryostats/cooling systems. A possible time-schedule for the upgrade of the ODT test-bench with a Cryotiger Cryostat system is given at the end.

2 Introduction:

Cryotigers are getting more common for cooling of scientific optical CCD detectors:
Phillip MacQueen from McDonald Observatory reports in [5] about 4 years of successful use of a Cryotiger connected to his CCD cryostat at a high resolution spectrograph (resolving power of 120000). Les Seddlemeyer reports in [6] about a one year successful experience of the use of a Cryotiger at his imaging CCD at the 1.8m Plaskett telescope in Canada. Both state, that the gas lines to and from the Cryotiger are the only challenge bringing this system to the telescope and both report, that this type of cooling is unrivalled in terms of price/reliability/performance if compared with liquid nitrogen cooling and other solutions known to them. Also at the Keck telescope in Hawaii an upgrade of the HRES instrument is planned with a Cryotiger [9]. At ESO several Infrared Detectors are cooled with the first mentioned type of closed-cycle cooler. Some years ago it was demonstrated by the ESO Integration Lab, that this type of cooling is also suitable to optical CCD cryostats. Nevertheless for 20 years ESO has been using liquid nitrogen cooling systems for the cooling optical CCDs. After this time the following assessments can be reported: The lifetime of such a system is estimated with approx. 10-20 years. The headache is, that one needs a lot of manpower, when producing or buying the liquid nitrogen, moving the large, quite expensive vessels, filling and/or connecting the cryostats with these vessels, maintaining also the filling devices and last but not least in addition facing security issues with all these liquid nitrogen equipments and their handling.

Requirements of Cryostats foreseen for cooling of Optical CCDs

CRYOSTAT TYPE	CRYOTIGER based cryostat	LN2 based cryostat
REQUIREMENTS		
Few manpower needed	Yearly maintenance. In between no manpower needed	Daily LN2 filling with bath cryostat. Weekly exchange of large LN2 vessel with continuous flow cryostat (CFC)
Acquisition/manufacturing costs (in kEUR) low Low maintenance costs (in kEUR/10years)	Cost of CCD head: 4 Cost of cryostat: 13 Cost of w-cooler:5 Cost of electricity: 5 Cost of manpower: 5 Sum(10years): 32	Cost of CCD head: 4 Cost of cryostat: 10 - 13 Cost of liquid nitrogen and supplies: 10 - 20 Cost of manpower: 55 - 100 Sum(10years): 79(CFC) –137(bath cryostat)
Long lifetime more than 10y	10 years or more	15 years or more
Long autonomy	Half a year	48 hours with bath cryostat 330 with continuous flow cryostat
Safe operation	to be done (inflammable high pressurized gas)	Liquid nitrogen hazard for people Leak danger with spilling LN2
EMC part 1 & 2 According to Doc.No.: VLT-SPE-ESO-10000-0002 VLT-SPE-ESO-10000-0003	Cold end does not require electricity; Compressor is CE, UL and S293A Approved	CFC Controller produces noise at FIERA?
VLT environmental specifications VLT-SPE-ESO-10000-0004 : -10 until +30 deg. Celsius	Compressor to be done	OK
No vibration at telescope (to be tested by Franz Koch)	Very low vibration at cold end because no moving parts (Existing closed cycle coolers with moving parts in the head give more vibration and are used e.g. at ISAAC	OK
No heat dissipation into telescope hall	Compressor dissipates 510 W and water cooled version is needed	CFC Controller dissipates heat of approx. 50 W Table is continued on next page

CRYOSTAT TYPE	CRYOTIGER based cryostat	LN2 based cryostat
REQUIREMENTS cont.		
System usable at a) Code Focus b) Nasmyth Focus c) Cassegrain Focus	 OK with long gas pipes as reported from other observatories with long gas pipes up to 66 meters, to be investigated	 OK Bath Cryostat OK CFC only with special de-rotator Only bath cryostat
Temperature provided to CCD head at cold-finger <= 100 Kelvin	95 Kelvin with Pt14 gas	approx. 80 Kelvin
Cooling Power > 5 Watt for a mosaic of 2 x 2kx4k CCDs	6 Watt	6 Watt with 48h hold-time (bath) >=6Watt with CFC
No contamination induced by Cooler	OK	OK
Cool Down time less than 12 hours	OK	OK with standard CCD head
Weight of cooler in cryostat Backpart should be small	Less than 8 kg	Bath cryostat: 25 kg CFC: 10 kg
Remotely controllable	Yes	Bath cryostat: No CFC: Yes
Vacuum volume of cooling system should be small	aprox. 5 liter	approx. 5-10 liter
Possibility to operate one cooling system with more than one cooling head e.g.: MUSE	Yes with less cooling power, 2 heads are maximum	Bath cryostat: No CFC: Yes (VIMOS)
Insensitivity against power fail	System warming up during power off	Bath: Yes CFC: Warming up during power off

This table refers to a standard type CCD cryostat with a maximum of a 2 x 1 CCD mosaic of two 2048x4096 pixel Marconi or MIT/Lincoln Lab CCDs, like currently used at FORS2 and EMMIred.

From this results the following conclusion: The current cryostats are more expensive because man power intensive. ODT prefers to use this manpower for other purposes than liquid nitrogen maintenance and therefore investigates the solution using a Cryotiger.

3 Technical description of a CRYOTIGER Cooler

Figure 1: Cryotiger cooling head (Cold End) and two flexible gas lines (for gas in/out)

The Cryotiger system consists of a head or "Cold End" which is 145mm long with a diameter of 73 mm, which has to be placed inside of a vacuum chamber. The overall dimension is 230 mm of length and 110 mm diameter. Its weight is 1.7 kg.
From the two offered main options the "Standard Cold End" seems to be sufficient for present standard cryostat requirements. The present standard ESO CCD cryostats have a cooling power consumption of approx. 6 Watt as considered with 2 x 1 mosaic of CCDs of two 2048x4096 pixel Marconi CCDs. With the Cryotiger option this power consumption will be a bit less, because there is no liquid nitrogen vessel in the cryostat and no filling line, which have losses, which are included in the above given cooling power.
Therefore it is estimated, that a Cryotiger cooling power of 5 Watt should be sufficient at temperature of approx. 95 Kelvin.

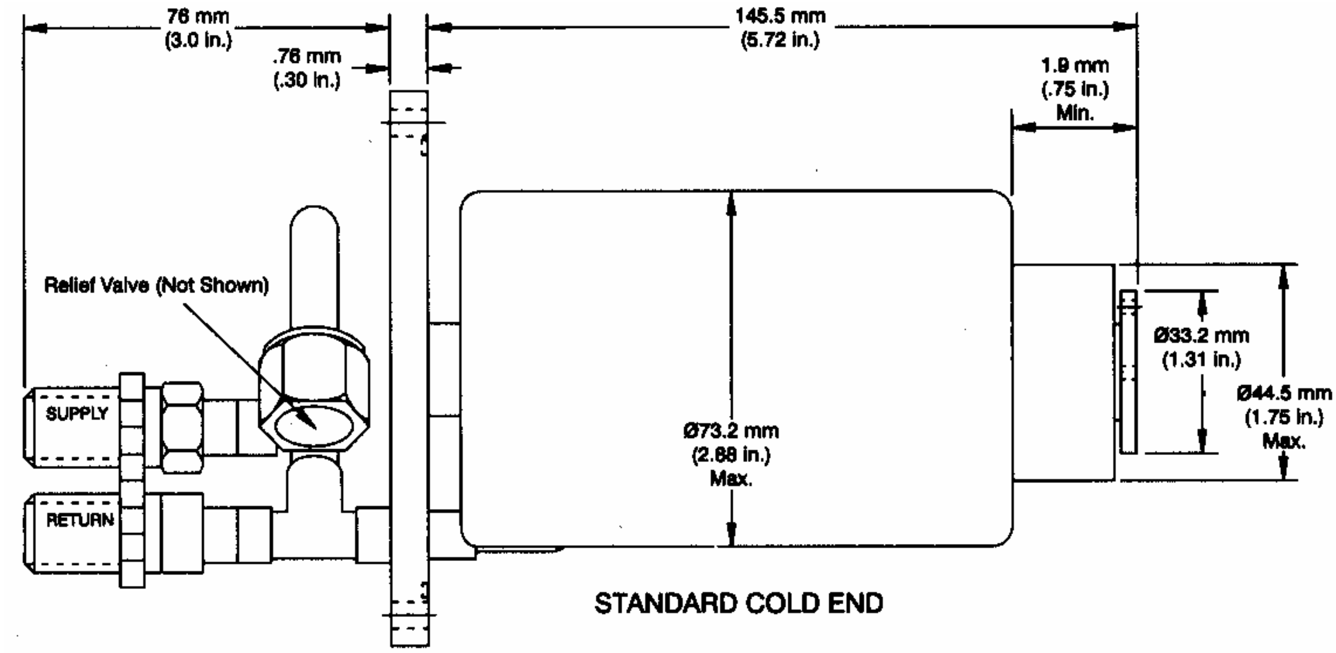


Figure 2: Dimensions of the Standard Cold End (seen from the side)

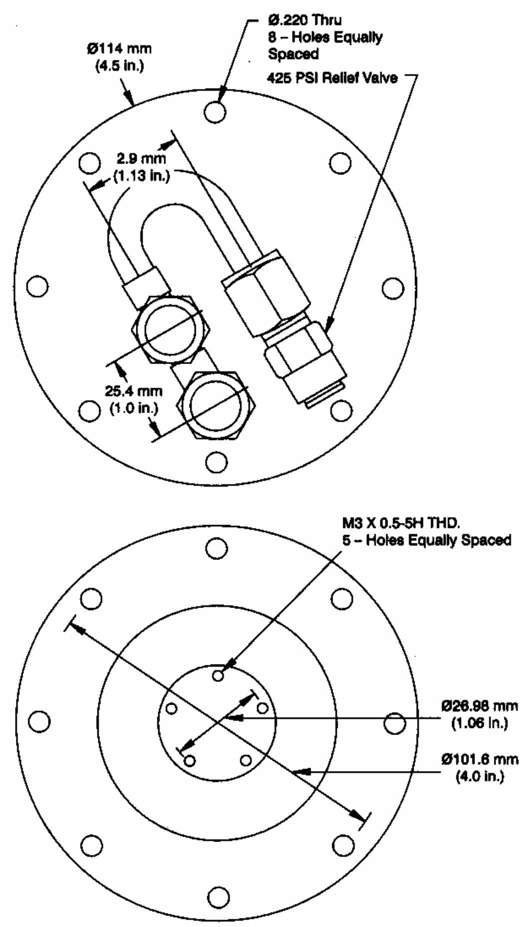


Figure 3: Dimensions as seen from behind and from the front

The cooling power and temperature range of a Cryotiger is selectable as an option when ordered (by the gas brand used), but also can be changed later with a refilling of another gas type.

The principle of a Cryotiger is that of a closed cycle cooler. There are no moving parts at the cold head.

The cold-head itself is nickel plated for the use in a high vacuum chamber.

A special gas mixture is pressed through (with a pressure of 14-19 bar) up to 50 meters long gas line and expands near the top of the cold head. This happens inside its system of gas channels in order to cool down only the top of the cold head, which has diameter of 33.2 mm and a thickness of 3 mm. The gas expansion is provoked by a remote compressor connected to the other end of the gas line.

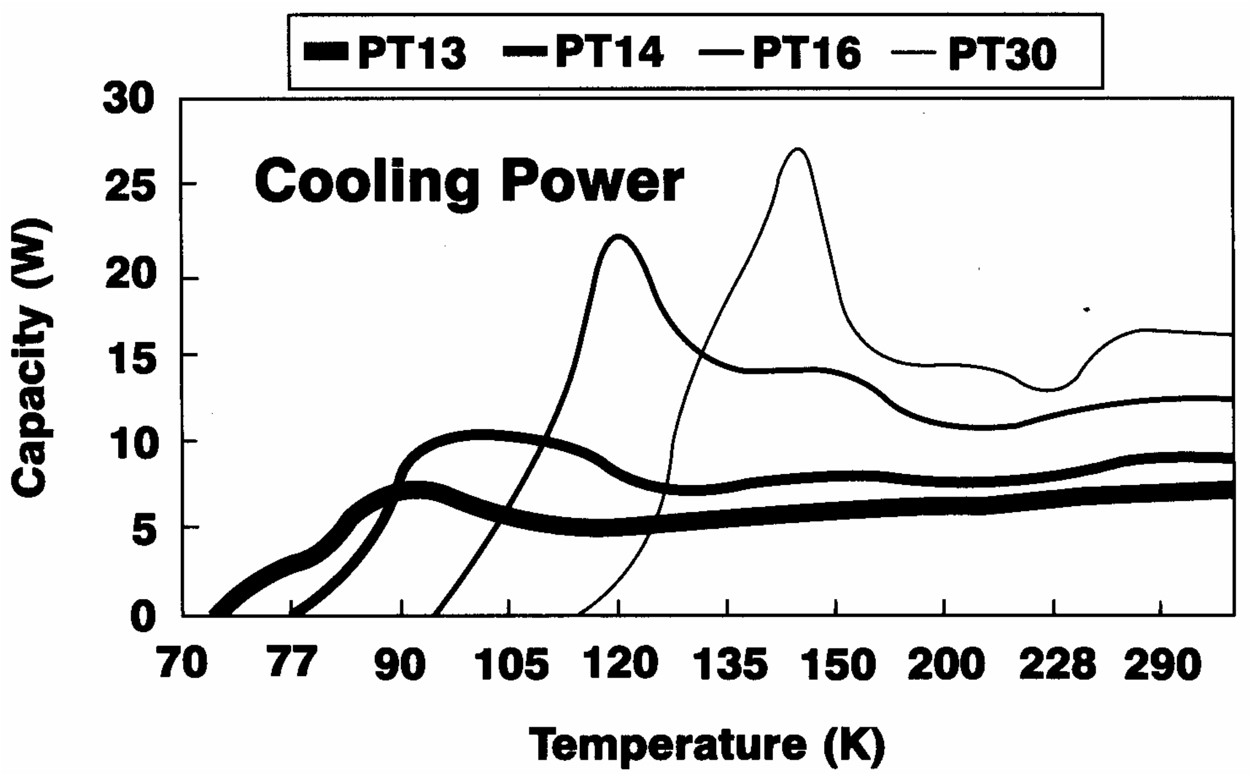


Figure 4: Cooling power of Cryotiger at the cold head achieved with different gas brands

The goal is to replace only the Cryostat tank or so-called backpart and to leave the CCD head unmodified. Therefore the gas brand PT14 appears to be suitable, because this gives a similar performance as the liquid nitrogen cooler. Moreover it gives a cooling power of approx. 6 Watt at 90 K. Also other observatories have selected this gas brand (see [5] and [6]).

Figure 5: Flexible stainless steel Gas lines from 1.5m to 66 meters length are available

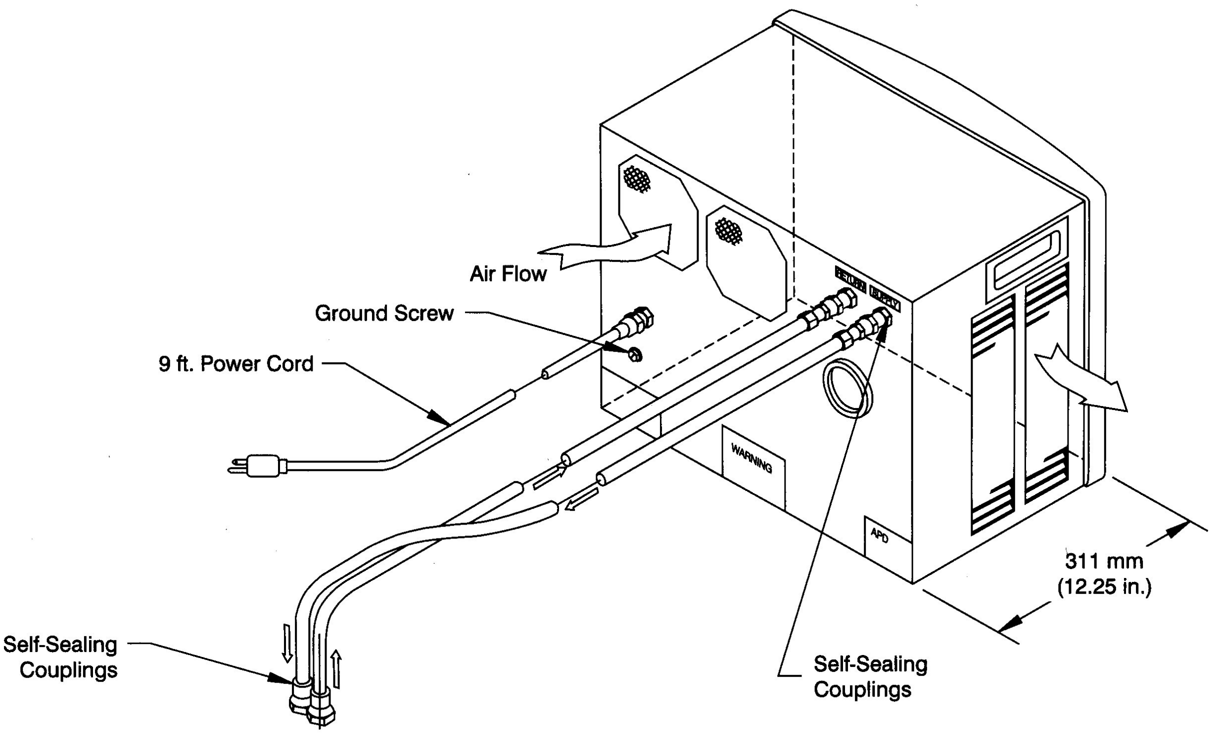
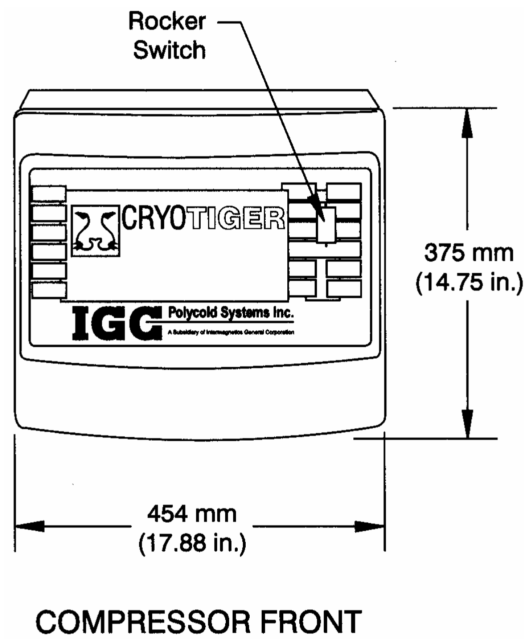


Figure 5: Compressor of Cryotiger



The gas line connects the Cold End with a compressor. This is advertised as very robust and durable, because it consists of standard household refrigerator compressor parts. It can be operated with 220 V/ 50 Hz. Its power consumption is approx. 520 Watt. The noise of this air-cooled compressor is given with 56 dBA. Its weight is 32.2 kg. All gas couplings are self-sealing, but they should not be connected and disconnected too often. There are reports[5][6], that if the couplings are reconnected in a humid environment, after some months a freezing in the head can happen. This has the consequence, that there is no more cooling. In this case Phillip MacQueen recommends [5] to warm up the system to 2-6 degree Celsius two times in order to get rid of the ice. He recommends this as a regular maintenance every 3-4 months to prevent unscheduled Cryotiger shutdowns.

4 Possible Constraints

- Vibration (after some reports no issue even at telescopes)
- Undesired stop of heat pumping due to frozen out gas humidity
  (can be solved by maintenance, as explained above)
- Extremely torsion stiff gas pipes (only at the telescope an issue)

5 Proposed cryostat housing

The proposed Cryotiger cryostat housing should adapt the Cryotiger cooler to the present CCD head. If this is successful, a present bath-cryostat as well as a CFC cryostat can simply be replaced with the new Cryotiger cryostat within some minutes.
The only issue for the Cryotiger seems to be the applicable load onto the cold end. This should not exceed 1.4 kg. Therefore a special support of the cold end has to be constructed, which fixes and supports the cold end without too big thermal losses. If this is possible, the present spring loaded cold finger of the CCD head can be applied to the extended cold end.

Design Ideas:

- Cryotiger cryostats should be mechanically compatible with present cryostats and therefore fir to the existing CCD heads
- Fiber glass support plate to take the load from the spring loaded cold finger (attached to the cold–finger with a stainless steel ring)
- Fiber Glass plate, which is enforced with fiber glass rips on the backside
- Molecular sieve filled with active charcoal placed on the inner side of the fiber glass plate. Charcoal does not need a heater for regeneration. The molecular sieve is thermally connected to the cold finger with a copper wire
- Vacuum valve and vacuum gauge are connected with clamps at the side of the cryostat to the flange interface to the CCD head
- Dimensions of the Cryotiger cryostat with and without CCD head:
    - Diameter without CCD head: 150 mm
    - Length without CCD head without gas connectors: 158 mm
    - Length without CCD head with gas connectors: 240 mm
    - Overall length with CCD head without gas connectors: 280 mm
    - Total overall length: 360 mm

The costs of this cryostat adapter to the Cryotiger are estimated with 2k EUR.

Scetch of proposed construction of the complete Cryotiger cryostat see next page:

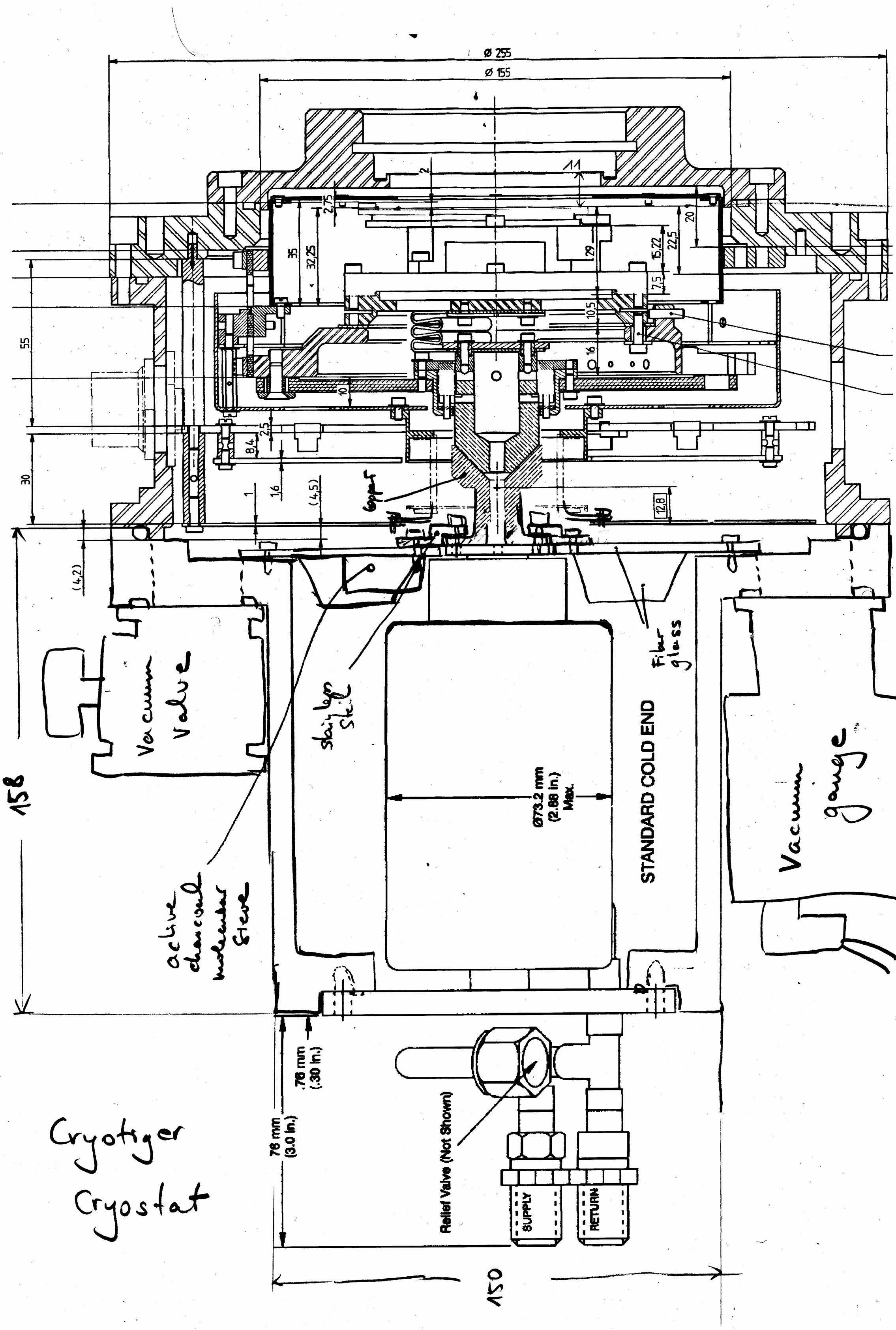


Figure 6: Preliminary scetch of complete Cryotiger Cryostat (CC)

6 Conclusion and Proposed Schedule of Realization

All conditions are fulfilled according to the information from the Cryotiger data sheet to justify buying at least one Cryotiger for upgrading the ODT test-bench. Moreover reports from different observatories around the world encourage even to plan upgrades of cryostats at the telescopes in La Silla and Paranal.

In the following table a proposed time-schedule is given for the procurement and implementation of a Cryotiger for the use in the ODT detector test-bench, where the current CFC cryostat costs a lot of manpower and where sometimes important measurements have to be stopped, because no liquid nitrogen is available. Possible vibrations of the Cryotiger are not an issue at the test-bench operations. Moreover due to many cycles (mount, start-up, shutdown, dismount) this would be a hard test for the Cryotiger for later applications at the telescopes.

June 2002:	***Order of one Cryotiger system. Price for only one system is 11588.- EUR at the German distributor: FerroTec GmbH, 72622 Nürtingen Maybe the order can be placed directly to the US (in order to save money) from IGC Polycold Systems Inc., Lakeville California, USA Delivery time is approx. 11 weeks (from FerroTec)***
July 1:	***Start with construction of cryostat housing***
August 2002	**Finish of design Order for manufacturing of parts Vacations of Sebastiger**
September 2002	**Delivery of parts, surface treatment of parts (electro-polishing)**
October 2002	**Washing and baking of parts Delivery of Cryotiger**
November 2002	**Assembly of Cryotiger with Cryotiger cryostat and first tests.**
December 2002	**Final integration of Cryotiger cryostat into the ODT test-bench**

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