Diseño del Criostato del Receptor de Banda Ancha

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1. Introduction

This report summarizes the design of the Broad-Band VGOS cryogenic receiver for the RAEGE radio telescope installed at Yebes Technology Development Center.

The receiver is based on a two stages closed cycle cryocooler (SHI RDK-408S2), the cold stage below 10 K and the intermediate stage, below 40 K.

Specifications

Frequency band*	2-14 GHz
Physical Temperature	< 70 K intermediate stage < 20 K cold stage
Pressure	< 10^{-5} mbar
Pressure Leaks	< $1 \cdot 10^{-5}$ mbar·l/sec
Gain	> 25 dB
Noise Temperature	< 30 K
Input	Vacuum window to QRFH feed calibration: SMA
Output	2 linear polarizations: SMA
Output impedance	50 Ω

Table 1: Receiver specifications

* IVS Frequency Band for VGOS Geodetic Observations.

2. Cryostat Geometry

The next figures show the cryostat design:

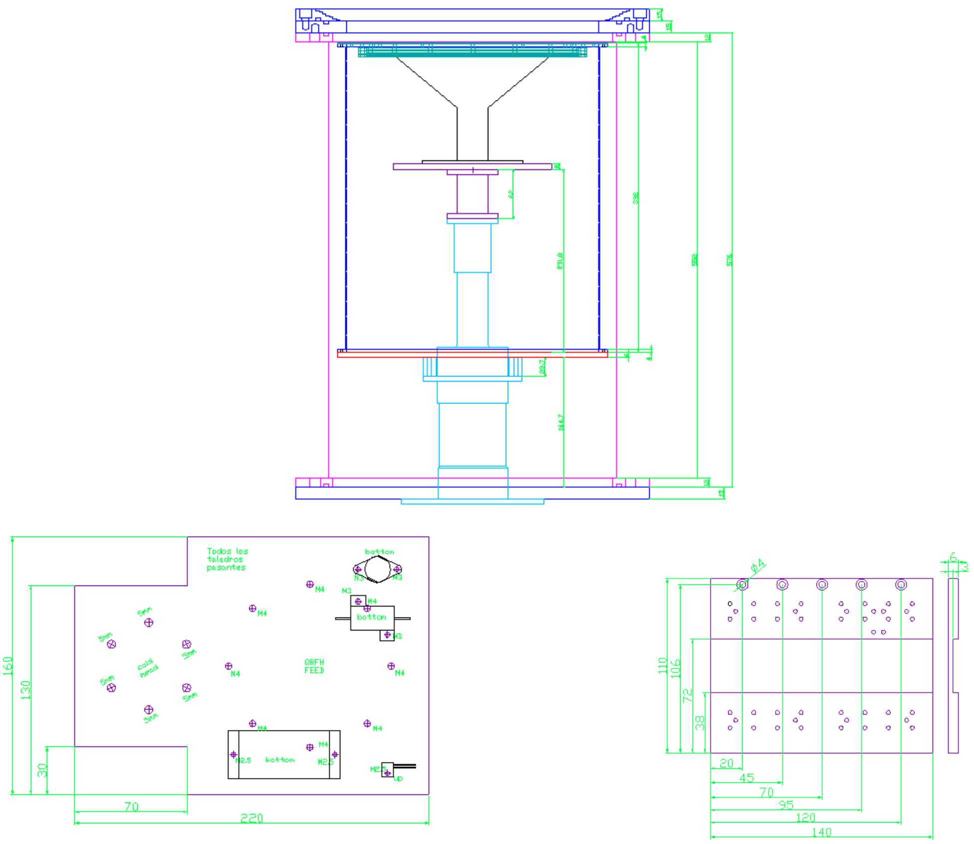


Figure 1. Cryostat overview: cold head (light blue), vacuum case (pink and dark blue), radiation shield (blue), intermediate stage (red) and cold stage (violet).

The cryostat will be built over a Sumitomo SRDK-408S2 cold head in a cylindrical dewar made of stainless steel. Top and bottom cover are made of aluminum. In the top cover a vacuum window lets the broadband radiation goes through. In the bottom cover there are all the RF connectors (signal outputs and calibration inputs), vacuum flanges, pressure monitor, DC cabling and housekeeping connectors.

Inside the cryostat there is a cylindrical radiation shield made of aluminum and with multilayer isolation (MLI). The temperature of this stage is less than 40 K.

Removing the radiation shield, the entire receiver can be easily reached. It is the coldest part of the receiver at temperature <10 K. The cold stage is made of copper.

RF cabling: The cables that connect the cold stage (3dB-90deg hybrids) with the room temperature stage (SMA output connectors) are made of coaxial semi-rigid stainless steel cable, UT-085. The directional couplers (calibration signal injection) are connected directly to the feed (QRFH) outputs (2 linear polarizations, channels A and B).The cables from the couplers outputs to the LNAs inputs are coaxial hand-formable, UT-141. The cables carrying the calibration signal from the SMA calibration input connectors (ambient temperature) to the coupler CPL input are also semi-rigid stainless steel UT-085 cable.

2.1. Vacuum case

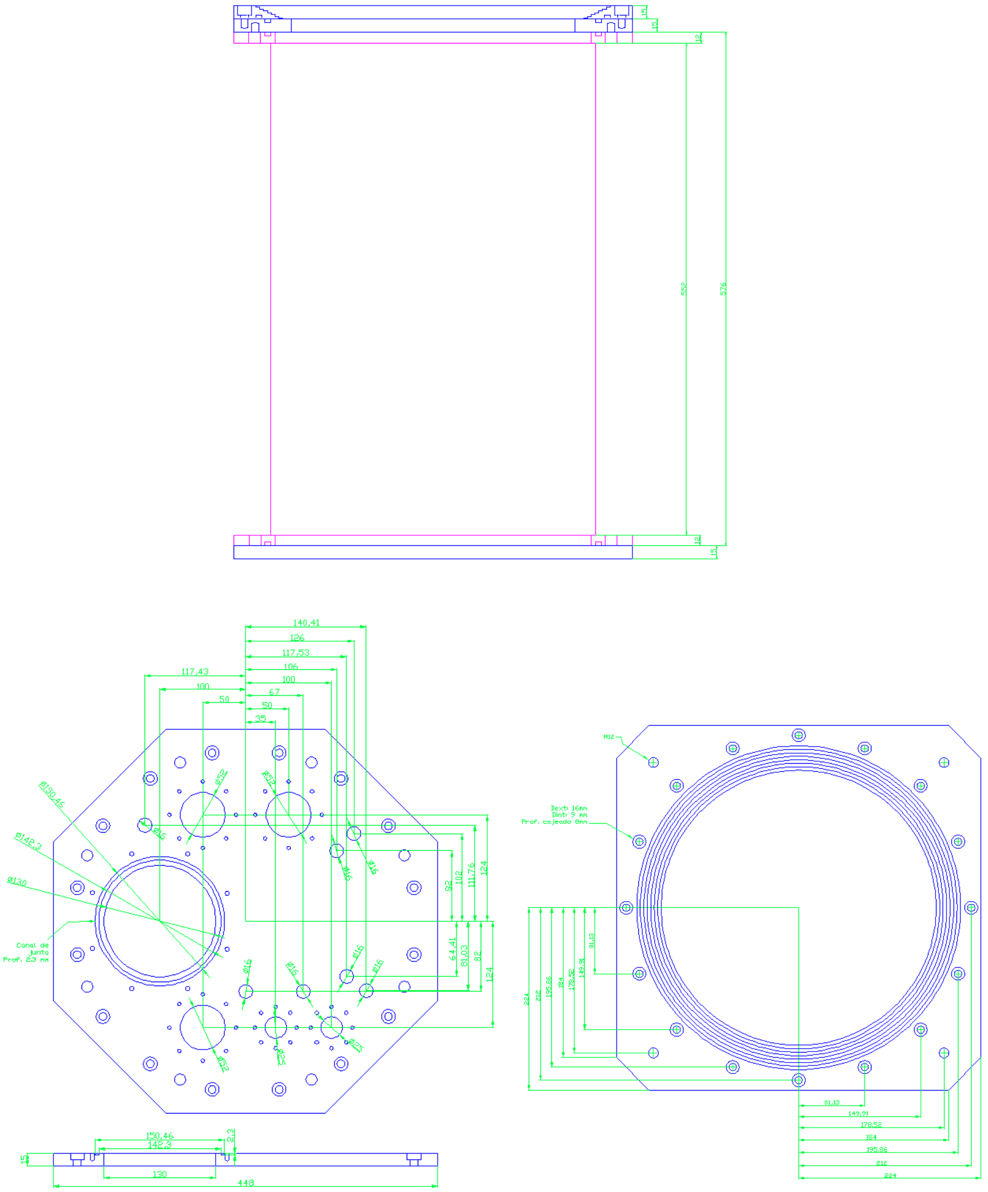


Figure 2. Dewar design: cylinder, bottom and top covers.

The dewar consists of three main parts: stainless steel cylinder and aluminum top and bottom covers. At the top cover the vacuum window is installed.

The dewar lower flange has several inputs/outputs for different uses:

- Cold head connection: to place the cold head in the right position.
- Two apertures with transitions for the vacuum control (pressure sensor and vacuum valve).
- Five Fisher hermetic connectors for the housekeeping control and monitoring, and amplifiers biasing.
- Four SMA hermetic connectors for the RF signals (calibration inputs and RF outputs).

Inside the dewar, at the bottom cover, there is an aluminum plate to carry out the transition between room temperature DC wiring and the cryogenic wires, using DB connectors.

2.1.1. Vacuum Seals

O-rings: main specifications and locations are presented in the table below:

Viton Seals	Type	d_1 (mm)	d_2 (mm)	Reference	Qty
Sumitomo Cold Head - bottom flange	OR VI	142	3	503.328	1
Vacuum case - bottom and top flanges	OR VI	365	5	304.143	2
Top flange 1 - Mylar	OR VI	365	5	304.143	1
Top flange 2 - Mylar	OR VI	385	5	673.715	1
Vacuum flanges - bottom flange	OR VI	28	4	670.265	2
SMA and K connectors flange - bottom flange	OR VI	58.42	2.62	305.517	3

Table 2: Vacuum seals Epidor. [3]

2.1.2. Vacuum Window

The vacuum window goal is to allow transition (physical, electromagnetic and vacuum) between the signal and the triband feed. For this receiver, a vacuum window made of Mylar (Polyethylene terephthalate film, thickness 0.5 mm) was selected.

2.2. Intermediate stage and radiation shield

The intermediate stage is an aluminum plate of 6 mm thickness and 342 mm diameter, screwed onto the first stage of the cold head. Attached to this plate there is an aluminum cylinder to cover the cold stage and reduce the radiation load. The radiation shield is covered with multilayer isolator, MLI (8 layers with a total thickness of ≈4 mm) to reduce the radiation thermal load between the intermediate and cold stages.

The Mylar layers used are NRC-2, crinkled aluminized Mylar film 0.006 mm, with a reflectivity of 0.03. The NRC-2 exhibit excellent thermal insulation efficiencies when the pressure inside the receiver is less than 10E-4 mbar (the pressure reach inside the dewar is usually below 10E-6 mbar).

On the intermediate stage, there are placed several housekeeping devices: temperature sensor, heating resistor, thermostat and zeolites based vacuum trap. These devices have the following characteristics:

- Heating resistor: 100 Ω, 25 W.
- Zeolites regeneration resistor: the vacuum trap includes a 100 Ω and 2.5 W regeneration resistor.
- Temperature sensor: DT-670 Lakeshore Si-diode.
- Thermostat: 70° ± 3°.

The housekeeping devices allow to achieve a better vacuum inside the cryostat and help to warm up faster the receiver in case it is necessary.

Another important element, at the intermediate stage, is the infrared filter. It is located on the top cover of the radiation shield. The infrared filter is used to decrease the thermal load to the cold stage (infrared radiation that goes into the cryostat through the window of the vacuum case). It is made of extruded polystyrene foam (3 ± 0.3 mm thickness, 0.033 W/mK thermal conductivity at 40°C, 35 kg/m3 density). The filter consists of three foam layers separated by nylon washers 0.8 mm.

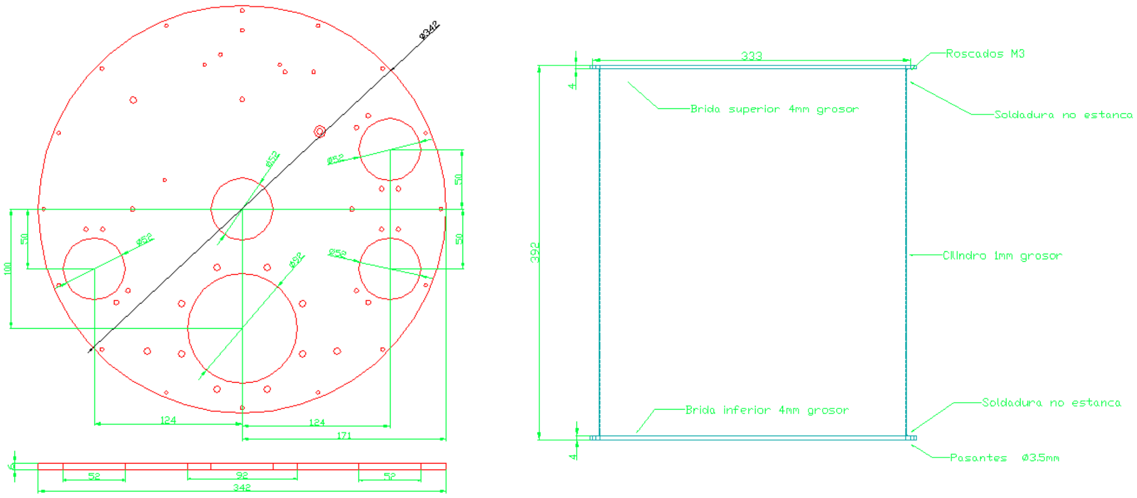


Figure 3. Intermediate stage design and radiation shield.

2.3. Cold stage

The cold stage consists of a copper plate of 8 mm thickness screwed onto the second stage of the cold head and other plates, where LNAs, hybrids, couplers, housekeeping devices, etc., are placed. The housekeeping elements have the same specifications than the used for the intermediate stage. The QRFH feed is connected directly to the copper plate to achieve temperatures under 20 K.

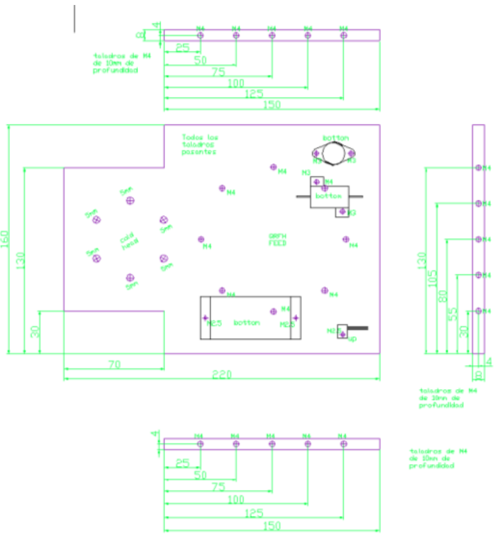


Figure 4. Cold Cu plate design

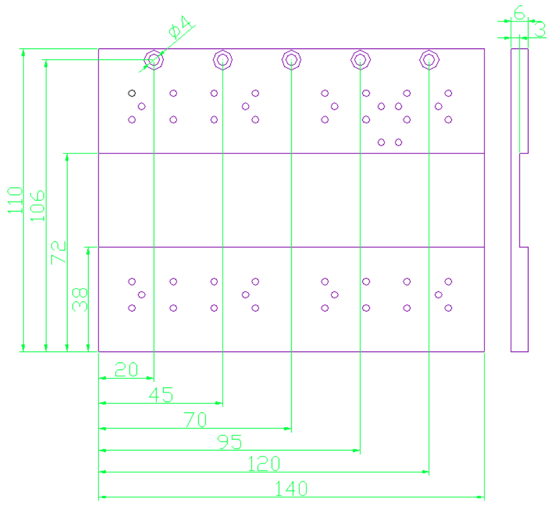


Figure 5. Cold stage plate designed for LNAs integration.

2.4. Amplifier setting-up

The cryostat will contain broadband low noise amplifiers attached to both QRFH feed outputs. The optimum final setup is still being under study:

- Balanced configuration.
- Single LNA configuration.

Before the amplifiers, connected directly to the feed outputs, there are the directional couplers for the calibration signal injection (noise and phase).

2.5. Internal DC wiring

There are 5 hermetic Fischer connectors at the vacuum case bottom plate:

- One of them with 16 pin for monitoring signals and housekeeping.
- Four of them with 11 pin for the amplifiers biasing signals.

The next figures show the Fischer connectors pin-out (11 and 16 pin):

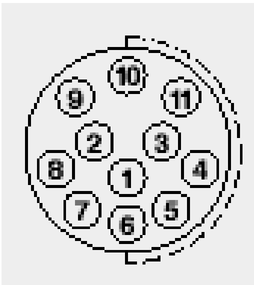


Figure 6: 11 pin Fischer
(connector view, red point up).

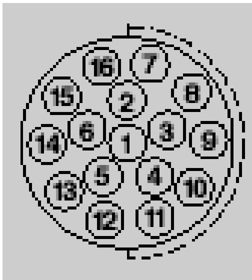


Figure 7: 16 pin Fischer
(connector view, red point up).

The DC wiring will be done using small section long cables to reduce the load due to conduction.
The pin number correspondence between the hermetic fischer connectors and the DB9 and DB15 connectors in the dewar bottom plate is always 1 to 1.

The next table indicates the pin-out association between connectors.

Pin-Out DC connections Yebes Broad-Band receiver:

QRFH Receiver House-keeping signals				
Fischer pin	**Signal**	**DB25 pin**	**Banana**	**DB25 cart**
1	ti+	3-4		3-4
2	ti-	15-16		15-16
3	tc+	6-7		6-7
4	tc-	18-19		18-19
5	tf+	9-10		9-10
6	tf-	21-22		21-22
7	free			
8	free			
9	calef_on		red	5
10	regen_on		yellow	1
11	gnd_res		black	11
12	calef_mon		red (test)	8
13	regen_mon		black (test)	2
14	free			
15	free			
16	free			

Table 3: Fischer Connector (C7) 16 pin (housekeeping) correspondence with the DB25 connector.

Fischer Pin	MDM9 Pin	Signal
1	1	Gnd
2	2	Vd1
3	3	Vg1
4	4	Vd2
5	5	Vg2
6	6	Vd3
7	7	Vg3

Table 4: Fischer Connector (C1) 11 pin (A1 LNA) correspondence with the MDM9 connector.

Fischer Pin	MDM9 Pin	Signal
1	1	Gnd
2	2	Vd1
3	3	Vg1
4	4	Vd2
5	5	Vg2
6	6	Vd3
7	7	Vg3

Table 5: Fischer Connector (C2) 11 pin (A2 LNA) correspondence with the MDM9 connector.

Fischer Pin	MDM9 Pin	Signal
1	1	Gnd
2	2	Vd1
3	3	Vg1
4	4	Vd2
5	5	Vg2
6	6	Vd3
7	7	Vg3

Table 6: Fischer Connector (C3) 11 pin (B1 LNA) correspondence with the MDM9 connector.

Fischer Pin	MDM9 Pin	Signal
1	1	Gnd
2	2	Vd1
3	3	Vg1
4	4	Vd2
5	5	Vg2
6	6	Vd3
7	7	Vg3

Table 7: Fischer Connector (C4) 11 pin (B2 LNA) correspondence with the MDM9 connector.

Several pins and wires have been left free taking into account future upgrades (amplifiers changes).

2.5.1. Low Noise Amplifiers biasing wiring

Next figure show the pin-out for the amplifier biasing connectors:

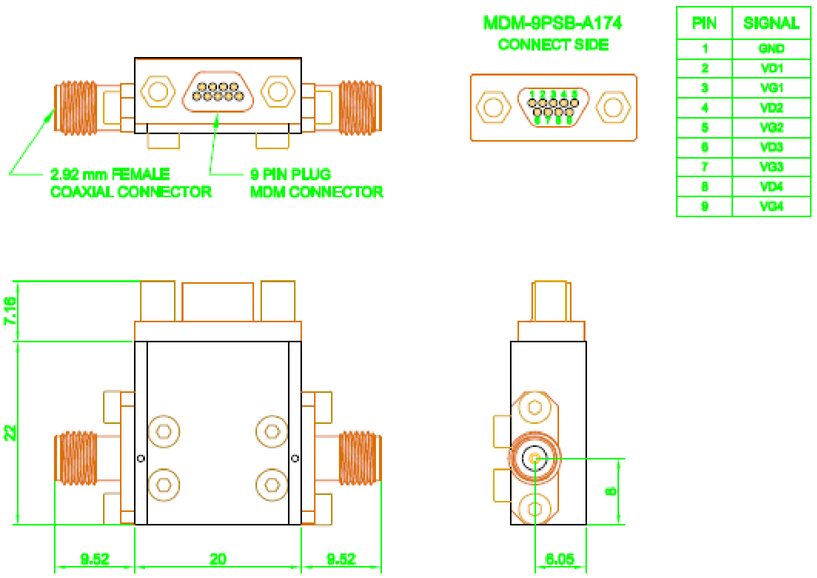


Figure 8. LNAs biasing pin-out.

2.5.2. Housekeeping wiring

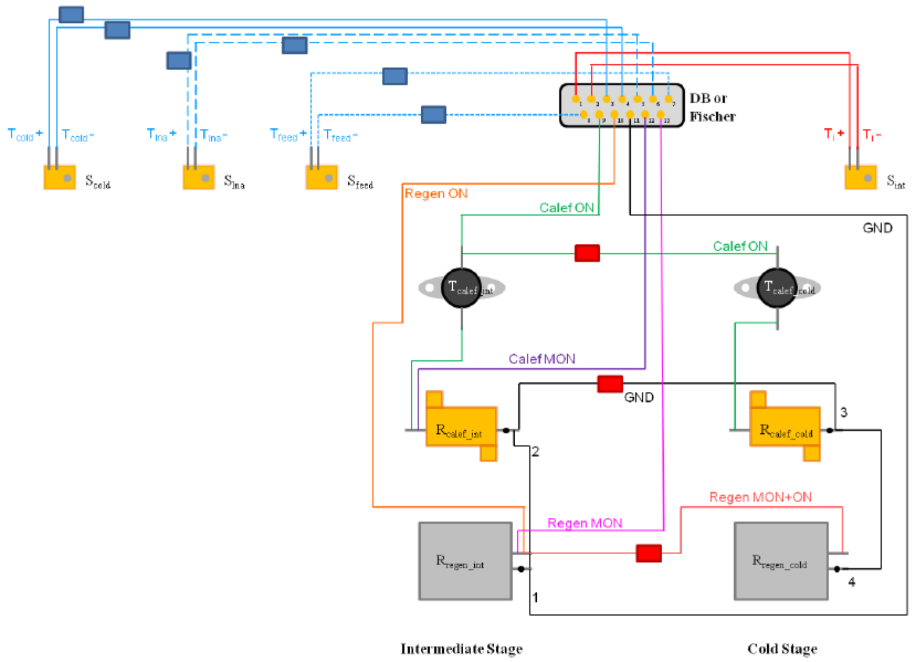


Figure 9: House-keeping circuit design.

There is a 16 pin Fischer connector placed at the room temperature stage (300 K) for the cryostat internal monitoring signals: heating resistors, zeolites regenerators, temperature sensors and thermostats.

Fischer Pin	Signal	Description
1	Ti+	Intermediate stage temperature sensor (+)
2	Ti-	Intermediate stage temperature sensor (-)
3	Tc+	Cold stage temperature sensor (+)
4	Tc-	Cold stage temperature sensor (-)
5	Tf+	Feed temperature sensor (+)
6	Tf-	Feed temperature sensor (-)
9	Calef_on	Signal to activate the heaters
10	Regen_on	Signal to activate the zeolites regeneration
11	GND_res	Ground
12	Calef_mon	Heaters monitoring
13	Regen_mon	Regenerators monitoring

Table 8. Housekeeping signals description.

A cable is supplied to connect the receiver with the different housekeeping signals. One end has the Fischer connector o be plugged to the receiver. The other end contains the following elements:

QRFH Receiver House-keeping signals				
Fischer pin	**Signal**	**DB25 pin**	**Banana**	**DB25 cart**
1	ti+	3-4		3-4
2	ti-	15-16		15-16
3	tc+	6-7		6-7
4	tc-	18-19		18-19
5	tf+	9-10		9-10
6	tf-	21-22		21-22
7	free			
8	free			
9	calef_on		Yellow	5
10	regen_on		Red	1
11	gnd_res		Black	11
12	calef_mon		Black	8
13	regen_mon		Red	2
14	free			
15	free			
16	free			

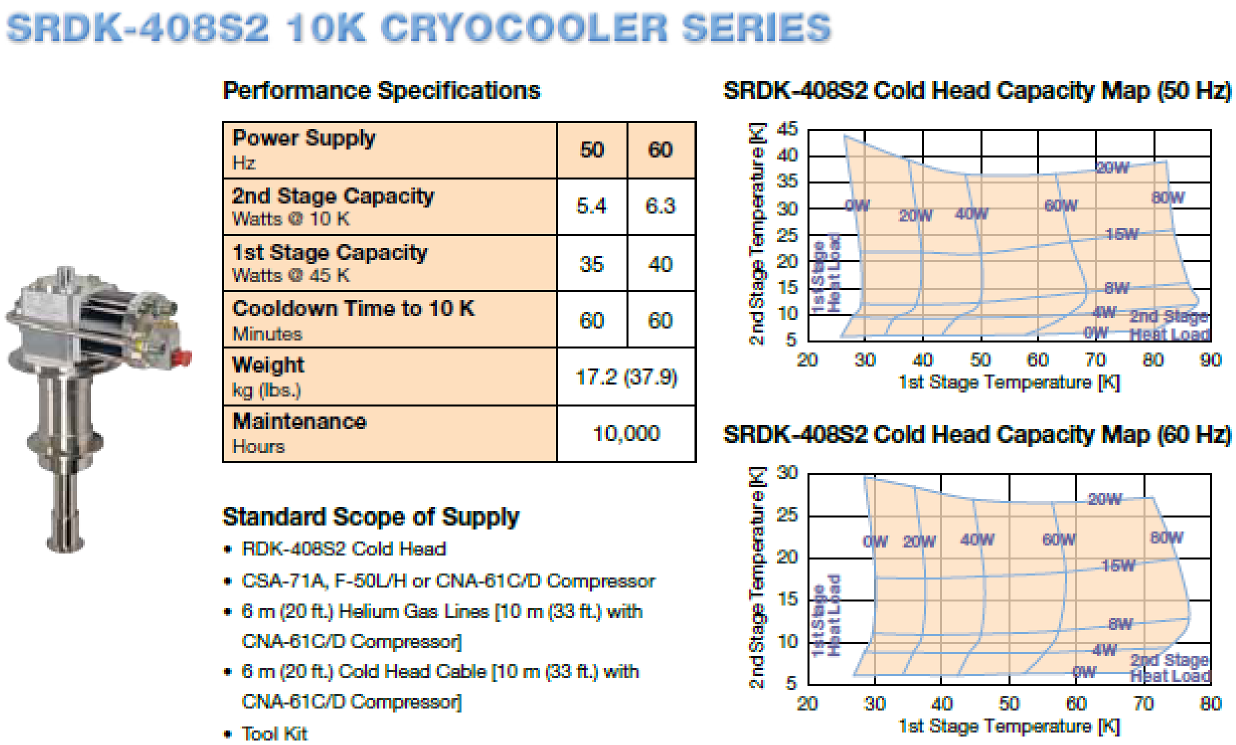
Table 9. Housekeeping 5 m cable description.

So, there is a cable connecting the receiver (Fischer female connector) with the cart back platen (DB25 female connector). There is another cable connecting the cart back platen (DB25 female connector) with the temperatures monitoring system (Lakeshore DB25 male) and the power supply for the resistors.

- DB-25 connector: to Lakeshore 218 system (positions one, two and three) DT 670 sensors.
- Banana connectors: to power supply for the receiver heating and zeolites regenerating.

3. Cryogenic system

This receiver uses a SHI (Sumitomo Heavy Industries) Cold Head Model SRDK-408S2, with the following characteristics:



SRDK-408S2 10K CRYOCOOLER SERIES

Performance Specifications

Power Supply Hz	**50**	**60**
2nd Stage Capacity Watts @ 10 K	5.4	6.3
1st Stage Capacity Watts @ 45 K	35	40
Cooldown Time to 10 K Minutes	60	60
Weight kg (lbs.)	17.2 (37.9)	
Maintenance Hours	10,000	

Standard Scope of Supply

- RDK-408S2 Cold Head
- CSA-71A, F-50L/H or CNA-61C/D Compressor
- 6 m (20 ft.) Helium Gas Lines [10 m (33 ft.) with CNA-61C/D Compressor]
- 6 m (20 ft.) Cold Head Cable [10 m (33 ft.) with CNA-61C/D Compressor]
- Tool Kit

Figure 10. Typical refrigeration capacity of the model SRDK-408S2 cryocooler (50 Hz).

The associated Sumitomo compressor is CNA-61C/D model.

4. Appendix

4.1. Vacuum transducer and controller

Vacuum Technology

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HPS® Products

Series 970

COLD CATHODE TRANSDUCER FAMILY

The 970 Series is a family of compact, low cost, general-purpose transducers that utilize from one to four sensors- cold cathode, MicroPirani™, and Piezo technologies. Combining these sensing technologies enables a wide measurement range from atmosphere to 10^{-8} Torr. In addition to its small size, broad range and lower cost, the 970 Series can be operated via digital communication or as an autonomous analog unit.

Features & Benefits

- Small footprint design provides a compact transducer solution saving tool real estate
- Single transducer provides a wide measurement range of 10^{-8} Torr to atmosphere (972B and 974B models), eliminating the need for multiple gauges
- The MEMS based MicroPirani sensor in the 972B and 974B allows low auto cold cathode turn-on pressure (user programmable from 2×10^{-4} to 1×10^{-3} Torr) for enhanced reliability
- The cold cathode anode module design is user serviceable to decrease downtime and save external repair costs
- All transducers include both analog and digital communication for ease of operation
- MicroPirani is automatically zeroed during pump down cycle for improved accuracy (972B and 974B models)
- Mountable in any orientation for ease of use and flexibility of design
- Simplified interface via a single smoothed analog output that combines the individual sensor measurements
- Three user configurable relays for process control
- Alternate analog output and electrical connectors available to match other vendors' gauges and facilitate an easy upgrade
- Can be used with the PDR900 controller for easy set up
- RoHS and CE Compliant

Applications

The Series 970 Transducers are compact, low cost measurement solutions for vacuum users operating within the pressure range of atmosphere to 10^{-8} Torr. The small size of the Series 970 transducers makes them ideal for system integrators looking to reduce footprint and enable miniaturization. Applications include:

- Analytical equipment (mass spectrometer control)
- Scanning electron microscopes
- Coating systems
- Semiconductor loadlock pressure control
- General vacuum base pressure measurement

Vacuum Gauging

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PDR900

SERIES 900 CONTROLLER

The PDR900 power supply and readout unit is a stand-alone, single channel controller for use with the Series 900 digital vacuum transducers. The instrument sets new standards for vacuum gauge controllers and can be used as a stand-alone power supply readout unit or as a tool for configuration, calibration and diagnostics of system integrated transducers in OEM applications.

Features & Benefits

- LCD menu display for easy user interface
- Easy to read 5 digit LED display
- Three high power set point relays for process control
- Auto setup permits plug and play functionality
- Leak detection tool for system diagnostics
- Data logging tool for process monitoring
- Simplified setup and configuration of transducer parameters
- Front panel indicators provide clear, concise overview of setpoint relay status
- Alarm function provides warning in case of vacuum line or venting failure
- Code protection function to prevent unauthorized access to critical settings
- Calibrate transducers quickly and easily
- Ease of operation via analog output and digital communication
- Robust, compact design can be used on the bench or rack mounted
- Light-weight, aluminum housing is ideally suited for field service applications
- World-wide universal power supply, 100 to 240 VAC/ 50-60 Hz
- RoHS and CE compliance

Description

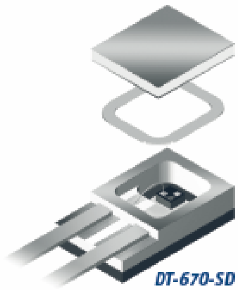
The PDR900 controller is the ideal solution for vacuum measurement, configuration of digital transducers and advanced system diagnostics. The controller features an easy to use menu-driven user interface, which guides the user through setup and configuration of remote transducer parameters.

The readout unit communicates digitally with the transducer which eliminates analog measurement noise coupling via transducer cables. The unit automatically detects the transducer type, and can be used with both RS232 and RS485 transducers.

4.2. Temperature sensors specifications

32 Sensors

Silicon Diodes



DT-670 Silicon Diodes

DT-670-SD Features

- Best accuracy across the widest useful temperature range—1.4 K to 500 K—of any silicon diode in the industry
- Tightest tolerances for 30 K to 500 K applications of any silicon diode to date
- Rugged, reliable Lake Shore SD package designed to withstand repeated thermal cycling and minimize sensor self-heating
- Conformance to standard DT-670 temperature response curve
- Variety of packaging options

DT-670E-BR Features

- Temperature range: 1.4 K to 500 K
- Bare die sensors with the smallest size and fastest thermal response time of any silicon diode on the market today
- Non-magnetic sensor

DT-621-HR Features

- Temperature range: 1.4 K to 325 K*
- Non-magnetic package
- Exposed flat substrate for surface mounting

** Calibrated down to 1.4 K, uncalibrated (Curve DT-670) to 20 K*

***CAUTION:** These sensors are sensitive to electrostatic discharge (ESD). Use ESD precautionary procedures when handling, or making mechanical or electrical connections to these devices in order to avoid performance degradation or loss of functionality.*

DT-670 Series Silicon Diodes offer better accuracy over a wider temperature range than any previously marketed silicon diodes. Conforming to the Curve DT-670 standard voltage versus temperature response curve, sensors within the DT-670 series are interchangeable, and for many applications do not require individual calibration. DT-670 sensors in the SD package are available in four tolerance bands – three for general cryogenic use across the 1.4 K to 500 K temperature range, and one that offers superior accuracy for applications from 30 K to room temperature. DT-670 sensors also come in a seventh tolerance band, Band E, which are available only as bare die. For applications requiring greater accuracy, DT-670-SD diodes are available with calibration across the full 1.4 K to 500 K temperature range.

The bare die sensor, the DT-670E, provides the smallest physical size and fastest thermal response time of any silicon diode on the market today. This is an important advantage for applications where size and thermal response time are critical, including focal plane arrays and high temperature superconducting filters for cellular communication.

PACKAGING OPTIONS BO, BR, CO, CU, CY, ET, LR, MT

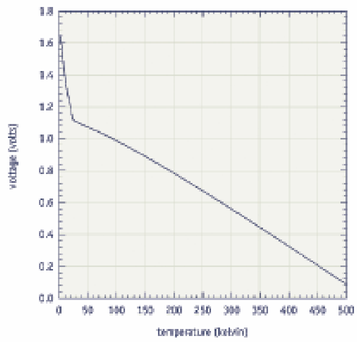
The Lake Shore SD Package – The Most Rugged, Versatile Package in the Industry

The SD package, with direct sensor-to-sapphire base mounting, hermetic seal, and brazed Kovar leads, provides the industry's most rugged, versatile sensors with the best sample to chip connection. Designed so heat coming down the leads bypasses the chip, it can survive several thousand hours at 500 K (depending on model) and is compatible with most ultra high vacuum applications. It can be indium soldered to samples without shift in sensor calibration. If desired, the SD package is also available without Kovar leads.

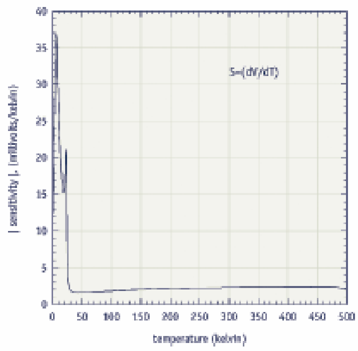
DT-621-HR Miniature Silicon Diode

The DT-621 miniature silicon diode temperature sensor is configured for installation on flat surfaces. The DT-621 sensor package exhibits precise, monotonic temperature response over its useful range. The sensor chip is in direct contact with the epoxy dome, which causes increased voltage below 20 K and prevents full range Curve DT-670 conformity. For use below 20 K, calibration is required.

Typical DT-670 Diode Voltage Values



Typical DT-670 Diode Sensitivity Values



www.lakeshore.com Lake Shore Cryotronics, Inc. (614) 891-2244 fax: (614) 818-1600 e-mail: info@lakeshore.com

4.3. Temperature monitor

112 Cryogenic Instruments Model 218 Temperature Monitor

Model 218 Temperature Monitor

Model 218 features

- Operates down to 1.2 K with appropriate sensor
- 8 sensor inputs
- Supports diode and RTD sensors
- Continuous 8-input display with readings in K, °C, V, or Ω
- IEEE-488 and RS-232C interfaces, analog outputs, and alarm relays
- Available in two versions: Model 218S and 218E
- CE certification
- Full 3 year standard warranty

4.4. Vacuum window

Technical Information - Polyethylene terephthalate

Close

Polyethylene terephthalate

Polyester, PET, PETP

We stock and supply the following standard forms:

Common Brand Names: Arnite, Dacron, Hostaphan, Impet, Melinar, Melinex, Mylar, Rynite, Terylene, Trevira

General Description:

General Description: The most common thermoplastic polyester, this polymer is often called just "polyester". This often causes confusion - not only is the chemically similar PBT also a (thermoplastic) polyester, the most common resin system used in GRP is also a polyester system - and also often called just "polyester". (In this latter case, however, the polyesters are chemically unsaturated and are "free-radical polymerised" into a thermoset).

PET is a hard, stiff, strong, dimensionally stable material that absorbs very little water. It has good gas barrier properties and good chemical resistance except to alkalis (which hydrolyse it). Its crystallinity varies from amorphous to fairly high crystalline; it can be highly transparent and colourless but thicker sections are usually opaque and off-white.

It is widely known in the form of biaxially oriented and thermally stabilised films usually referred to by their main brand names Mylar, Melinex or Hostaphan. Strictly speaking, these names should be used only for this type of film whose properties are different from, and in several respects superior to, those of "ordinary" PET film.

These "Mylar®-type" films are used for capacitors, graphics, film base and recording tapes etc. PET is also used for fibres for a very wide range of textile and industrial uses (Dacron®, Trevira®, Terylene®). Other applications include bottles and electrical components.

Chemical Resistance

Acids - concentrated	Good-Poor
Acids - dilute	Good
Alcohols	Good
Alkalis	Poor
Aromatic hydrocarbons	Good-Fair
Greases and Oils	Good
Halogenated Hydrocarbons	Good-Poor
Halogens	Fair-Poor
Ketones	Good-Fair

Electrical Properties

Dielectric constant @1MHz	3.0
Dielectric strength (kV mm^{-1})	17
Dissipation factor @ 1kHz	0.002
Surface resistivity (Ohm/sq)	10^{13}
Volume resistivity (Ohmcm)	$>10^{14}$

Mechanical Properties

Coefficient of friction	0.2-0.4
Hardness - Rockwell	M94-101
Izod impact strength (J m^{-1})	13-35
Poisson's ratio	0.37-0.44(oriented)
Tensile modulus (GPa)	2-4
Tensile strength (MPa)	80, for biax film 190-260

Physical Properties

Density (g cm^{-3})	1.3-1.4
Flammability	HB
Limiting oxygen index (%)	21
Radiation resistance	Good
Refractive index	1.58-1.64
Resistance to Ultra-violet	Fair?
Water absorption - equilibrium (%)	<0.7
Water absorption - over 24 hours (%)	0.1

Thermal Properties

Coefficient of thermal expansion ($x10^{-6}$ K^{-1})	20-80
Heat-deflection temperature - 0.45MPa (C)	115
Heat-deflection temperature - 1.8MPa (C)	80
Lower working temperature (C)	-40 to -60
Specific heat (J K^{-1} kg^{-1})	1200 - 1350
Thermal conductivity @23C (W m^{-1} K^{-1})	0.15-0.4
Upper working temperature (C)	115-170