

# Pulse-Tube Dilution Refrigerator with 14T magnet

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## Procurement Specification / Cahier des Clauses Techniques Particulières

|  |                         |                     |
|--|-------------------------|---------------------|
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## I. APPLICABLE AND REFERENCE DOCUMENTS

| N° | Reference | Title             | Issue |
|----|-----------|-------------------|-------|
| CM |           | Compliance Matrix | 1     |

## II. ACRONYMS AND ABBREVIATIONS

|     |   |
|-----|---|
| CM  | Compliance Matrix                                     |
| CU  | Control Unit  |
| DR  | Dilution Refrigerator                                 |
| GHS | Gaz Handling System                                   |
| LoS | Line of Sight   |
| MXC | Mixing chamber  |
| NA  | Not Applicable  |
| NE  | Not Evaluated   |
| PC  | Partially Compliant                                   |
| PSE | “Prestations Supplémentaires Eventuelles” (= Options) |
| PT  | Pulse Tube  |
| TBC | To Be Confirmed                                       |
| TBD | To Be Defined   |
| TC  | Temperature controller                                |

### III. INTRODUCTION / PURPOSE OF THE DOCUMENT

Institut Neel QuNES group is enquiring for a cryofree dilution refrigerator with a 14T magnet, and a bottom loader sample exchange mechanism.

The technical requirements for this apparatus are listed in the next sections of the document. A summary of these requirements in the form of a compliance matrix can be found in [CRT].

**Req. III.1:** The supplier shall fill the compliance matrix [CRT] with as much detail as possible in order for the customer to undergo a fair and documented comparison between the different technical proposals.

**Req. III.2:** The compliance matrix shall include details on the way the performances are guaranteed by the supplier (see [CRT]). The validation of the performances is preferably performed by tests. Validation by design, by calculation or by analogy can also be envisaged.

**Note:** In the following sections and in [CRT], we give, for each requirement:

- The reference number (**Ref.**)
- The **designation**
- The **requirement**, which corresponds to the requirement the system shall provide. Deviations may or may not be accepted, depending on the criterion parameter (see below). If accepted, such deviations will have an impact on the evaluation of the associated requirement.
- The criterion (**Crit.**) applicable on the requirement (see above):
  - MA. Mandatory
  - EV. Evaluated

The criterion (**Crit.**) parameter is given for all requirements. It will be used in the evaluation of the proposals: “MA” means “killing factor” (the full proposal cannot be considered anymore), “EV” will be associated with a weighting factor to evaluate the proposal.

## IV. TENDER FIRM OFFER (TRANCHE FERME)

### IV.1 DR PERFORMANCE REQUIREMENTS

The dilution refrigerator must include a superconducting solenoid as described in the part §IV.3 as well as a bottom loading sample exchange system §IV.4. The required performances of the dilution refrigerator are detailed in the table below.

| Ref    | Designation  | Requirement  | Crit. | Comment  |
|--------|--|--|-------|--|
| IV.1.1 | DR must be a Cryofree, meaning it does not require the user to transfer liquid helium        | Cryofree   | MA    |  |
| IV.1.2 | Minimum temperature  | $\leq 10$ mK   | MA    | As measured on the MXC plate and with compressor bypassed.   |
| IV.1.3 | Minimum temperature in the sample container  | Should be minimal  | EV    | As measured in the sample container (see section Bottom Loading).  |
| IV.1.4 | Maximum temperature while the magnet is at 14T   | Should be maximal  | EV    | As measured on the MXC plate.  |
| IV.1.5 | Cooling power at 100mK on the MXC  | $\geq 300$ $\mu$ W   | EV    |  |
| IV.1.6 | Cooling power at 100mK in the sample container   | Should be maximal  | EV    |  |
| IV.1.7 | Cooling time of the DR from 300K to base temperature with solenoid magnet and bottom loading | $< 96$ h   | EV    |  |
| IV.1.8 | Galvanic isolation from the GHS and the pulse tube compressor                                | Complete ground isolation between the DR and the GHS, and between the DR and the pulse tube compressor (isolation resistance $> 1$ GOhm) | EV    | Use Swagelok or equivalent electrical isolator for the condensing lines and standard Teflon/plastic centring rings with plastic clamps for the still line. |
| IV.1.9 | General DR ergonomics  | Accessibility of electrical and vacuum connectors, and convenience of installing custom electronics into the DR                          | EV    |  |

Table 1: Cryogenic performance

### IV.2 PULSE TUBE COOLER

The Pulse Tube cooler shall be adapted to fulfil the above requirements.

**Req. IV.2.1:** The pulse tube cooler should have a cooling power  $\geq 1.5$ W at 4.2K

(Crit. MA).

**IV.3 SUPERCONDUCTING SOLENOID**

The dilution refrigerator must include a superconducting solenoid.

| Ref.   | Designation   | Requirement   | Crit. | Comment |
|--------|---|---|-------|---------|
| IV.3.1 | Superconducting solenoid equipped with persistent switch, diode quench protection, current leads and electrical feedthrough | $\geq 14\text{T}$ at 4.2K<br>Bore $\geq 70\text{mm}$  | MA    |         |
| IV.3.2 | Magnet power supply   | Enables reaching 14 T in less than 1 hour (from 0 T). | EV    |         |
| IV.3.3 | Sweep rate of the current into the solenoid to maximum field  | Should be maximal                                     | EV    |         |

**IV.4 BOTTOM LOADING SAMPLE EXCHANGE SYSTEM**

The dilution refrigerator must include a bottom-loading sample exchange system that include a sample container, a loader for the sample container, and the corresponding sample holder docking interface on mixing chamber plate.

| Ref.   | Designation                                   | Requirement   | Crit. | Comment |
|--------|---|---|-------|---------|
| IV.4.3 | The DR must have a bottom loading mechanism   | Bottom loading  | MA    |         |
| IV.4.2 | Bottom loader mechanism handling              | Time to connect the sample container, to the MXC plate from starting the loading, should be minimal | EV    |         |
| IV.4.3 | Sample container (that is loaded into the DR) | diameter $\geq 60\text{mm}$   | EV    |         |
| IV.4.4 | Bottom loading ergonomics                     | Handling and repairability  | EV    |         |

**IV.5. GAS HANDLING SYSTEM**

Specific requirements for the Gas Handling System (GHS) are:

| Ref. | Designation | Requirement | Crit. | Comment |
|------|-------------|-------------|-------|---------|
|------|-------------|-------------|-------|---------|

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|--------|---|--|----|---|---------------|
| IV.5.1 | No membrane compressor running in circulation mode (steady state), even with maximum current in the current leads | Compressor, if present, should be bypassed during normal operation. If compressor contains a membrane, compressor must have double membrane. | EV | If compressor is present, the GHS must be equipped with a bypass circuit  |               |
| IV.5.2 | Mixture contamination - molecular   | Oil free pumps / compressors   | EV |   |               |
| IV.5.3 | Mixture contamination - molecular   | As a minimum: LN2 trap with a LN2 tank   | EV | Other standard means (e.g. charcoal trap), if any, shall be detailed  |               |
| IV.5.4 | Safety  | The GHS, together with monitoring system, shall ensure automatic recovery of the mixture in case of trouble                                  | EV | List of potential issues to be detailed and way they are handled, e.g. :<br>- Power shut down<br>- Inlet line clogging<br>- Air into vacuum jacket<br>- etc |               |

## IV.6 HE - MIXTURE

The system must be delivered without mixture or  $^3\text{He}$ . It can be delivered either empty of helium or with the correct amount of  $^4\text{He}$  in the dump of the GHS but without  $^3\text{He}$ .  $^3\text{He}$  (and  $^4\text{He}$ , if empty) will be added to the GHS to adjust the  $^3\text{He}/^4\text{He}$  mixture at CNRS during installation.

## IV.7 MONITORING SYSTEM

The monitoring system main requirements are:

**Req. IV.7.1:** Elapsed time for each of the components requiring maintenance (Pulse tubecooler, pumps, compressor, etc) shall be recorded and easily accessible (**Crit.** EV).

**Req. IV.7.2:** The system shall provide automatic cool down of the DR from room temperature to the minimal temperature (**Crit.** EV).

**Req. IV.7.3:** The system shall provide automatic warm up procedure, including mixture recovery (**Crit.** EV).

**Req. IV.7.4:** The DR shall be equipped with a pressure gauge so as to control the vacuum jacket. The type of gauge shall be indicated (**Crit.** EV).

## IV.8 TEMPERATURE MEASUREMENT

The system shall include a temperature control. The temperature control main requirements are:

**Req. IV.8.1:** The system shall comprise at least one thermometer at the following levels: MXC, cold plate, still plate, 4K plate, and 60K plate (**Crit. EV**).

**Req. IV.8.2:** All thermometers shall be calibrated (**Crit. EV**).

**Req. IV.8.3:** The temperature controller must be able to monitor a temperature as low as 10mK (**Crit. EV**).

**Req. IV.8.4:** The system shall comprise at least 1 heater at MXC level and 1 heater at still plate (**Crit. EV**):

**Req. IV.8.5:** The system shall enable an extra temperature measurement (2 twisted pairs) down to the sample container to enable the user to install and monitor its own thermometer. This thermometer wiring must be connected and monitored by the temperature controller provided by the supplier. The type of connector will be determined in the early phase of the project (**Crit. EV**).

**Req. IV.8.6:** The system shall enable wiring (1 twisted pairs) down to the sample container to enable the user to connect an extra heater in the sample container. This wiring must be connected and the user heater should be controllable by the temperature controller provided by the supplier. The type of connector will be determined in the early phase of the project (**Crit. EV**).

## IV.9 INTERFACE REQUIREMENTS

### **IV.9.a IMPLEMENTATION IN THE EXPERIMENTAL ROOM**

**Req. IV.9.a.1:** The supplier shall provide the main dimensions of the major components: at least DR, GHS, Control Unit, LN2 dewar, and compressor of pulse tube (**Crit. EV**).

Note that the PT compressor will be located in the basement, beneath the experiment room. The distance between the PT remote valve and the compressor is estimated to be about 20 meters.

**Req. IV.9.a.2:** The ceiling height of the experimental room is 3.6m, installation and DR operation should be possible with this ceiling height (**Crit. EV**).



## IV.9.b MECHANICAL INTERFACES OF THE DR

Concerning mechanical interfaces of the DR, main requirements are as follow:

| Ref.     | Designation  | Requirement   | Crit. | Comment  |
|----------|--|---|-------|--|
| IV.9.b.1 | Experimental space at the MXC plate                              | $\phi \geq 300$ mm                                    | EV    | Actual dimensions to be provided.  |
| IV.9.b.2 | drawings of individual plates (60 K, 4K, still, cold plate, MXC) | Drawings with mechanical interfaces shall be provided | EV    | The drawings shall at least include: <ul style="list-style-type: none"> <li>- Main dimensions at each stage (e.g. side and cut views)</li> <li>- View of available space at each stage (e.g. top and bottom view of each plate)</li> <li>- List of ports at 300K together with their use, e.g. temperature readout, customer LoS, etc</li> </ul> |

## IV.10. RELIABILITY

Reliability / maintenance issues are of outmost importance.

**Req.IV.10.1:** The supplier shall provide, within the technical proposal, the list of elements requiring maintenance and provide technical details on the maintenance to be performed. An example of table is given in Appendix (§VIII) (**Crit.** EV).

**Req.IV.10.2:** The DR unit assembly shall use a minimum of indium seals. Indicative location of indium seals to be provided (**Crit.** EV).

**IV.11 WIRING****IV.11.a DC WIRING**

The supplier must quote the installation of the following DC wiring with the following specification:

| Ref.             | Designation                                       | Requirement   | Crit. | Comment  |
|------------------|---|---|-------|--|
| <b>IV.11.a.1</b> | Quote 96 shielded dc lines from 300K to MXC plate | 8 sets of shielded 12-twisted pairs of Phosphor Bronze. | EV    | Each 12-twisted pairs must be shielded with braid connected to the connector ground on both extremities.<br><b>Break out at 4K.</b><br>Micro-D connector at 4K plate and MXC plate |
| <b>IV.11.a.2</b> | Room temperature connectors for DC wiring         | Jaeger or fisher hermetic panel connectors              | EV    | To be decided  |

**IV.11.b RF INSTALLATION SET AND WIRING**

The supplier must quote the installation of the following RF installation set and wiring with the following specification:

| Ref.             | Designation                                    | Requirement  | Crit. | Comment |
|------------------|--|--|-------|---------|
| <b>IV.11.b.1</b> | Quote RF installation set<br>20 SMA on one LoS | 300K: hermetic feedthrough 20 SMA F/F<br>50K : 20 SMA F/F bulkheads, gold-plated<br>4K : 20 SMA F/F bulkheads, gold-plated<br>MXC: 20 SMA F/F bulkheads, gold-plated<br><br>Bandwidth: 18GHz | EV    |         |

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| IV.11.b.2 | Quote RF installation set<br>7 SMA on one LoS             | 300K: hermetic feedthrough 7 SMA F/F<br>50K : 7 SMA F/F bulkheads, gold-plated<br>4K : 7 SMA F/F bulkheads, gold-plated<br>Still : 7 SMA F/F bulkheads, gold-plated<br>CP : 7 SMA F/F bulkheads, gold-plated<br>MXC: 7 SMA F/F bulkheads, gold-plated<br><br>Bandwidth: 18GHz | EV |                         |                |
| IV.11.b.3 | Quote 20 RF lines on one LoS from room temperature to MXC | Bandwidth: 18GHz  | EV | Detail the full wiring. |                |
| IV.11.b.4 | Quote 7 RF lines on one LOS from room temperature to MXC  | Bandwidth: 18GHz  | EV | Detail the full wiring  |                |

## IV.12 MISCELLANEOUS

### IV.12.a DOCUMENTATION

**Req. IV.12.a:** The supplier shall provide, in the course of the project, all necessary documentation to operate the system and ensure proper maintenance. This includes at least:

- User Manual with detailed operation instructions, troubleshooting, software description
- Maintenance plan
- Calibration data for thermometers, flowmeter, etc
- Interface drawings updated according to the “as built” system
- Factory test report (at supplier’s premises).

- Test protocol (for the test at customer's premises)
- Acceptance test report (after successful tests at customer's premises)
- All required documentation in English: certificates of conformity, calibration certificates, etc

For an easier implementation of the experiment (coils, samples, etc) 3D STEP files of the system would be helpful (**Crit.** EV).

## V. NON-MANDATORY OPTIONS (PSE FACULTATIVE)

In this section, we define a list of non-mandatory options that can be proposed by the supplier.

### **V.1 ADVANCED ANTI-VIBRATION SYSTEM**

CNRS may want to minimise the level of exported vibrations. Systems such as a very low vibration support structure might be proposed.

**Req. V.1.1:** The supplier shall provide the basic list of components / features comprised in the option.

**Req. V.1.2:** The supplier shall provide all technical details relative to this option e.g.:

- Performance
- Drawings
- Update of mass budget

### **V.2 AUXILIARY PUMPING UNIT**

The auxiliary pumping unit is used to pump out air from the mixture lines (inlet and outlet lines) and also to pump the vacuum jacket.

### **V.3 SAMPLE HOLDER**

Non-magnetic sample holder to be placed in the sample container with more than 40 DC lines and more than 4 RF lines.

### **V.4 CRYOGENIC FILTER**

Cryogenic filters for the DC lines.

### **V.5 ROOM TEMPERATURE FILTER**

To be mounted directly on the DR room temperature connectors for the DC lines.

**V.6 BREAKOUT BOX**

Breakout box at room temperature to address the DC lines.

**V.7 HELIUM 3**

$^3\text{He}$  price per STP liter.

**V.8 WARRANTY EXTENSION**

Costs of possible warranty-related extensions.

**V.9 ADDITIONAL SAMPLE CONTAINER**

One more sample container for the bottom loading.

**VI. DELIVERY TIME**

Important evaluation criterion will be the delivery time. Ideal delivery time would be less than 6 months (Crit. EV).

**VII. WARRANTY**

| Ref.  | Designation   | Desired               | Crit. | Comment |
|-------|---|-----------------------|-------|---------|
| VII.1 | Guaranteed support service for debugging and technical assistance | Response time < 1 day | EV    |         |
| VII.2 | Warranty  | $\geq 2$ years        | EV    |         |

## VIII. APPENDIX 1: MAINTENANCE TABLE, AN EXAMPLE

An example of table for the maintenance activities is provided below:

| Component           | Type of activity | Frequency | Estimated cost | Comment |
|---------------------|------------------|-----------|----------------|---------|
| LN2 trap            | Purge            | TBD       | NA             |         |
| Flowmeter           | Calibration      | TBD       | TBD            |         |
| Temperature sensors | Calibration      | TBD       | TBD            |         |
| Turbo Pump          |                  |           |                |         |
| Scroll pump         |                  |           |                |         |
| Compressor          |                  |           |                |         |
| PT Compressor       |                  |           |                |         |
| PT Cold head        |                  |           |                |         |
| GHS valves          |                  |           |                |         |

Table 2: Example of table for the maintenance plan. The list of components in this table is not exhaustive.

## IX. APPENDIX 2: LIST OF COMPONENTS, AN EXAMPLE

| Designation                | Comments / Details  |
|----------------------------|---|
| Pulse Tube Cooler Assembly | Compressor + Cold Head + Flex lines + Documentation           |
| Current leads              | Type of materials, etc  |
| DR Assembly                | Including thermometers and heaters                            |
| Support plate              |   |
| Complete GHS system        | Pumps, compressors, valves, safety devices, mixture tank, etc |
| Auxiliary pumping unit     | Option  |
| LN2 Trap                   |   |
| LN2 dewar for trap         |   |
| Monitoring software        |   |

Table 3 : Example of table for the list of components.

END OF THE DOCUMENT