

## Specification for a Cryofree Cooling System

### Technical specification for Helium Based Cooling system required for Advanced Laser system

#### 1. Introduction

The Science and Technology Facilities Council (STFC), a part of United Kingdom Research and Innovation (UKRI), are developing their in-house bespoke “DiPOLE” advanced laser technology. STFC require a new cryogen free cooling system to stably control the temperature of the laser system amplifier head whilst extracting the heat load generated by the pump lasers. Upon successful demonstration of a prototype, the new cooling system is expected to form an integral part of the future “DiPOLE” technology. STFC successfully produced a 10J, 10Hz system (100W), a 100J, 10Hz system (1kW) and are in the process of developing a 15J, 100Hz system (1.5kW).

The brief of the cooling system is to control and maintain the temperature of the “DiPOLE” laser amplifier heads (which could be more than one per system). A prototype system shall be developed and proven to provide effective cooling for a single amplifier head running at 15J, 100Hz (as well as the design for a production unit). Upon successful demonstration of the prototype, there shall be the option to develop a production cooling system that can cool up to three amplifier heads with a single refrigeration unit. These two sets of requirements are presented in this specification, but the production cooling system should be adaptable to all possible variations of the “DiPOLE” laser (number of heads, cooling power etc). Time, cost and quality are important aspects of the delivery.

#### 1.1 Scope of the contract

This specification covers the supply of a cooling system comprising:-

- The design, manufacture, test, supply and installation of a prototype cooling system (based on a sealed helium coolant loop that is cooled using a stand-alone cryogen free refrigeration unit or equivalent and approved option)
- The design of the production cooling system (based on a sealed helium coolant loop that is cooled using a cryogen free refrigeration unit or equivalent)
- The manufacture, test, supply and installation of the production cooling system (based on a sealed helium coolant loop that is cooled using a cryogen free refrigeration unit or equivalent), **as an option**, dependent upon the successful testing of the prototype.
- An Experimental Physics and Industrial Control System (EPICS) compatible local control system.
- All cabling and pipework required to the amplifier head interface points specified herein.
- Factory acceptance testing of the system demonstrating performance across the ranges specified herein
- Attendance at STFC’s RAL site to undertake and confirm the adequacy of the installation and to set up and demonstrate the plant, reconfirming performance of the equipment over the ranges specified herein.
- Reports and documentation as stated herein.

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- Full technical construction file and certification, in reproducible form, attesting to compliance with European Trading Regulations (CE marking)
- CE declaration of conformity
- Certificate of conformity to this specification
- Operating and maintenance manuals in English (UK)
- Specialist plant and equipment as is necessary to support the safe assembly, testing and installation of the system
- Provision of cooling system support and servicing

The cooling system(s) shall be delivered to STFC where it/(they) will be integrated with other hardware and tested. Delivery shall be in accordance with INCOTERMS 2015 DDP.

All equipment supplied shall be suitable for operation in the UK and Europe. All equipment supplied must meet European Regulations and, where appropriate, shall be CE marked.

The design rights of the prototype system and the production system shall be the ownership of STFC, such that if the production design is complete, STFC have the option to arrange manufacture with another supplier if deemed necessary.

## 1.2 Reports and documentation

In addition to all the required documents and reports mentioned in the text within this document, the Supplier will provide the following:

- a) Documentation and minutes for agreed review meetings with customer (minimum three meetings) within one week of the meeting for approval.
- b) Detailed Factory and Site Acceptance Test Procedures
- c) Quality management plan including quality control measures, reviews and acceptance test procedures
- d) Factory and Site Acceptance Test Reports including proofs of compliance
- e) Full support documentation for all items of equipment and software, including all installation, operation and maintenance manuals in English, provided prior to hardware delivery. Where components that require operating manuals and maintenance manuals are supplied by third parties, manuals in English (UK) shall be supplied as supporting documentation. (Refer also to section 2.6) Installation instructions shall be provided a minimum of 2 months in advance of delivery of the hardware to STFC.
- f) Full engineering drawing pack and design file within two weeks of design approval including but not limited to:
  - Process and Instrumentation Diagram (P&ID)
  - Detailed drawings of the General Assembly (for the production model this shall include detailed design drawings for the production model that would allow manufacture)
  - 3d models (STEP, IGES or Parasolid) that contain all the required dimensions and information (location of mounting points, certified lifting and handling features,

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electrical connections, power requirements, safety connections etc.) for mechanical, electrical, control and safety systems integration of all equipment supplied.

- o Electrical drawings
  - o Software coding and documentation
- g) A costed list of recommended spare items and an expected service lifetime of the hardware shall be estimated. The spares list and estimated service lifetime shall be provided within two weeks of detailed design review.
- h) Environmental, Safety and Health report identifying any provisions which require to be made to ensure safe operation, maintenance and end-of life disposal of the equipment, a list of applicable regulations and methods of disposal for items requiring replacement during maintenance. Special considerations (e.g. gases disposal) necessary for final disposal of the equipment at end of life shall also be highlighted. This shall be supplied a minimum of one month prior to final delivery of the equipment to RAL.
- i) Substances which require consideration under the UK Control of Substances Hazardous to Health regulations (COSHH) shall be identified and full and complete data sheets provided. COSHH sheet shall be supplied within two weeks of the detailed design review. (Refer also to section 2.5)
- j) Any lifting equipment or lifting points shall be appropriately designed, analysed and proof tested in compliance with Lifting Operations and Lifting Equipment Regulations (LOLER). All resulting documents shall be provided a minimum of one month prior to final delivery of the equipment to RAL.
- k) Quality Assurance Documents for the completed device with copies of all specified material certificates (e.g. type 3.1), details of all quality control checks, inspection records, pressure tests, immunity tests and further, all intermediate test results prior to final delivery. (Refer also to section 1.5)
- l) Full technical construction file, certification and declaration of conformity, in reproducible form, attesting to compliance with European Trading Regulations (CE marking) shall be supplied with the final hardware delivery.

All documentation shall be supplied in English. STFC reserve the right to reject documentation if it is not written in a sufficiently clear and understandable style. All test documentation must be submitted to STFC for approval prior to use.

### 1.3 Options

The main contract terms are based upon delivery of the prototype system, with the design development of a production system occurring in parallel. The following cost options should be included in the tender response (in response to award question AW5.3):

- 1) Manufacture and delivery of the production system. Note that STFC will choose to exercise this option dependent upon the success of the prototype and other factors.

### 1.4 Timescales

Suppliers shall provide a logically linked, work breakdown based project plan showing the total delivery time and indicating critical path activities and major milestones such as design reviews,

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hazard and operability studies proving the suitability of design under operation and maintenance, delivery of major components, factory acceptance tests, etc.

Note: Whilst STFC expect to be asked to attend both design reviews and hazard and operability studies and may participate in these, the output of such reviews and studies is for the use of the supplier and is actionable where the supplier deems fit. It is not STFC intent to sign off or approve the design. The supplier is responsible for ensuring the delivery of a safe, suitable and sufficient design.

STFC anticipates that the delivery time for the prototype cooling system will be around 10 months from contract placement (but must not be greater than 18 months) and delivery of a production cooling system, where the option is exercised, will be around 8 months. This assumes that design development for both systems is undertaken in parallel. Suppliers should provide an explanation if their delivery time differs from this expectation.

### 1.5 Payments

Where title in these goods shall pass to STFC following any payment made, insurance of the goods will remain the responsibility of the supplier until they are formally delivered to and accepted by STFC. Warranties will commence on delivery to STFC (or from Site Acceptance Test).

### 1.6 Quality Assurance and Quality Control

Where the supplier holds certification to any national or international standards, copies of these certifications shall be provided.

## 2. General Conditions of the Contract

### 2.1 Basis of the Contract

The contract will be based on the following documents:

- a) The specification.
- b) All other documents issued with the contract including Standard Conditions of Contract.

### 2.2 Supplier's responsibilities

The Supplier shall be responsible for meeting all the technical requirements including testing, certification and compliance.

The Supplier shall be required to communicate effectively with STFC at all stages of the contract in order to resolve any technical issues or problems that arise in a timely and efficient manner.

### 2.3 Project management

#### 2.3.1 Points of contact

At the start of the contract the Supplier must assign a Project Manager who will be responsible for progress reporting and who shall act as single point of contact with STFC. The supplier shall also provide a lead point of contact for technical matters. All written correspondence and instructions shall be copied to both PM and lead technical contacts.

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### 2.3.2 Programme and Progress Reports

The Supplier shall issue a detailed, logically linked programme covering the design, manufacturing, and testing phases in sufficient detail to permit regular progress monitoring. Progress monitoring will be conducted by teleconference or videoconference. Updates to the project programme and a brief written dialogue explaining salient changes will be provided at least one working day before each conference call.

### 2.3.3 Inspections

STFC reserves the right to carry out periodic and/or spot contract inspections at the Supplier's premises and, where deemed necessary, that of its subcontractors. Contract inspections will be concerned with contract compliance issues including Programme, Quality, Performance and Confidentiality.

In tandem with providing STFC with a monthly updated programme update, the Supplier will propose a schedule of relevant evidence, both physical and documentary, that will assist to demonstrate actual monthly progress at the Supplier's premises throughout all contract stages, in line with programme milestones.

### 2.3.4 Contract Completion

The Contract will be complete when the complete system has been delivered at the Rutherford Appleton Laboratory site and the supplier has reviewed the installation of all assembled system components and has undertaken a satisfactory acceptance test demonstrating compliance with the agreed specification and further, when all finalised supporting documentation, hazard management, safety management, maintenance and operating manuals, quality assurance dossier, electrical and mechanical drawings and models have been received and accepted by STFC.

### 2.3.5 Deviation from the specification

During the construction, all proposed deviations from the design or specifications must be submitted to STFC in writing. STFC will give its approval or refusal in writing.

It is expected that the Supplier's own Change Control Procedure will maintain a record of approvals. If at any stage of the contract it is clear that an advantage could be gained by introducing a modification then the Supplier is encouraged to bring this to the attention of STFC.

### 2.3.6 Subcontractors

For subcontracts in excess of £10,000 STFC reserves the right to be informed of details of the work to be subcontracted, the name of the subcontractor and the type and location of the subcontractor's premises. This is where a 'subcontractor' is a person or body undertaking work on behalf of the supplier.

STFC may wish to discuss with such sub-contractors their methods of design and manufacture and also their quality and testing systems and other supply functions as is deemed necessary.

STFC may require written evidence of a formal contract between the Supplier and any sub-contractor, including the legal and contractual obligations that have been established. Information on delivery time scales will be essential. Where a subcontract is assigned, the confidentiality clauses in the contract between STFC and the contractor shall be maintained.

STFC is guaranteed the right of access to the premises of any such sub-contractor for progress meetings, inspection purposes, and witnessing of tests etc.

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## 2.4 Reliability and maintenance

All equipment shall be manufactured in accordance with appropriate well-proven techniques and recognised good engineering practice as are available at the time of construction. The system shall be capable of operating for extended periods, in excess of six months, without requiring maintenance. The supplier shall provide a process description of any routine maintenance protocols that are necessary together with listings of holding spares for such activities. The design shall permit scheduled periodic maintenance to occur with the system in situ.

## 2.5 Safety and hazard management

The Supplier shall carry out a safety assessment of the equipment and its operation. This shall be fully documented in the corresponding manuals. Any safety and risk assessments carried out as part of the contract shall be supplied to STFC.

Consideration should be made to hazards that exist at all stages of the life of the equipment, including installation, commissioning, operation, maintenance, repair, decommissioning and disposal. The analysis should include hazards that may occur during fault conditions and should include all potentially hazardous materials. The hazard management system should:

- Identify hazards
- Reduce severity
- Mitigate likely hazards (preferably through appropriate engineering design)
- Predict casualty rates and the severity of injuries that could be incurred

A hazard database or HAZOP study, identifying all hazards associated with the equipment and the adopted mitigations shall be provided by the Supplier in outline at the Design Review and in final form as part of the delivered documentation package.

STFC expect that all design proposals shall include appropriate safety margins in all mechanical and electrical aspects and particularly in relation to pressure and temperature. Designs will comply with relevant UK and EU regulations.

## 2.6 Manuals

Detailed installation, operation and maintenance manuals shall be prepared for the system. The manual shall include detailed assembly/disassembly and alignment instructions, routine maintenance requirements, fault diagnosis instructions, start-up, shut-down and conditioning procedures. Appropriate mechanical and electrical schematic drawings and diagrams supporting the assembly, diagnosis and maintenance shall be provided.

The maintenance schedule shall include a description and justification for each operation, the conditions under which it must be performed and an estimate of the time required.

## 2.7 Layout and location

Any systems designed shall be suitable for installation in a laser laboratory at the Rutherford Appleton Laboratory.

### 3. Outline Technical Requirements for Helium Cooling System required for a laser amplifier head

The following section describes the technical requirements for the cooling system. Requirements indicated by the word 'shall', 'will' or 'must' are to be considered as essential to STFC.

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Any requirements that significantly impact the delivery timescales or cost should be indicated by the supplier in their bids.

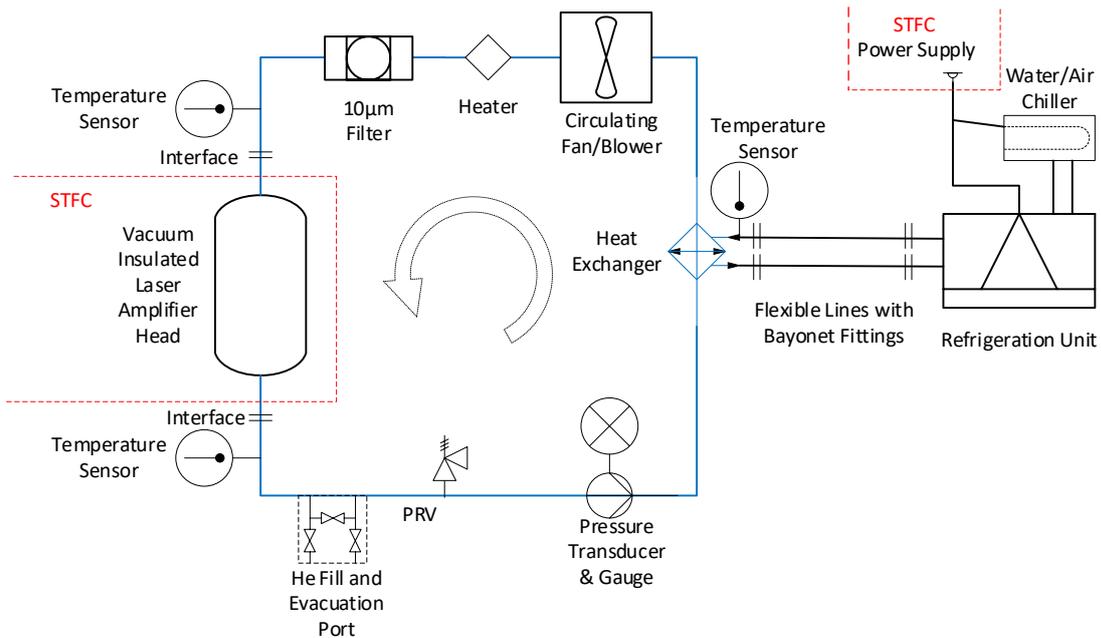
- The system shall run on demand to suit commissioning of the laser system, but the expected operating regime is as described below:
  - The initial cooldown of the helium circuit will likely occur at the start of the week
  - The system will be used for 8 hours per day and 5 days per week. The helium circuit will be allowed to warm naturally overnight, where this is deemed the most efficient use of the system.
  - The system should be capable of withstanding this cyclic loading. Where fatigue life is likely to limit the number of cycles that can be accommodated, this will be stated by the supplier at the Design Review.
  - Access to the cryostats during operational periods is likely to be limited so monitoring etc., should be possible entirely through the control system.
  - The operating life of the laser system is expected to be in the region of 15 years.

### 3.1 Cooling system requirements

The diagram below is a schematic view of a proposed prototype cooling system that consists of:

- One auto-cascade refrigeration system
- At least one circulating system for impelling helium through the laser amplifier and associated housing components
- Heat exchanger within the helium circuit (not housed in the refrigeration system)
- Cryogenic transfer lines for connecting
  - Auto-cascade unit to the circulator system (transporting refrigeration gases)
  - Circulator system to the laser amplifier head (transporting helium)
- Adjustable support structure for all elements of the system

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**Fig. 1: Schematic of laser amplifier with helium circulating circuit with refrigeration cooling.**

This specification defines the helium gas circulating circuit required to cool a laser amplifier and the refrigeration unit; i.e. everything in the above schematic (Fig. 1.) except the laser amplifier and power supply, which will be provided by STFC.

Note: The supplier may choose to develop the schematic above or propose an alternative solution meeting the same end. The above schematic includes only the functional aspects and does not consider all safety features required to compliment this functionality that would be required to fulfil the brief for a safe, suitable and sufficient design. The contractor must provide any and all such features, where he deems these are required, as integral parts of his design and supply.

**The envisaged prototype system consists of:**

- a) A refrigeration unit (around 5kW cooling capacity at 140K or below)
- b) Insulated flexible lines between the refrigeration unit and the circulator with simple bayonet fittings (or equivalent)
- c) A circulator units, consisting of
  - i. Suitably sized oil free fan(s) to circulate the helium
  - ii. An auto-cascade to helium circulator loop heat exchanger (HX).
  - iii. A method of regulating the Helium temperature in a stable manner (If a heater is selected, it must be a sealed unit with an Inconel outer sheath or similar and it shall include independent over temperature protection)
  - iv. A helium circuit fill and exhaust port (isolatable)
  - v. A helium circuit evacuation port (isolatable and of suitable size to attain vacuum level of  $1 \times 10^{-3}$  mbar)

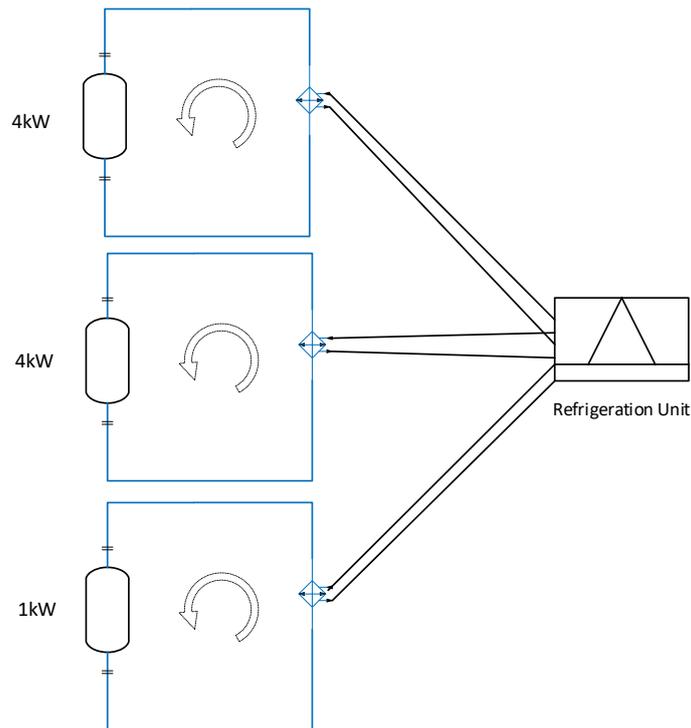
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- vi. A helium circuit pressure transducer (including a bourdon type gauge which reads pressure without requiring power)
  - vii. Pressure relief valve and any safety devices necessary
  - viii. Provision for all exhausts from PRV's, bursting discs etc., to be captured to allow venting externally to the laser operating area.
  - ix. A method of determining mass flow rate (potentially using the pressure transducer, fan speed and the fan curve)
  - x. Temperature sensors measuring Helium temperature at helium gas input and helium gas output of the amplifier head. (Sensors shall be duplicated at key points where their replacement under maintenance is not practicable).
  - xi. Insulation minimising heat loading resulting from input from the room to cold elements
  - xii. Insulated pipework to interface with the laser amplifier head. Method of interface (bayonet, weld, bolted flange) to be determined.
- d) An automated control system with remote historical trending capability. Compatibility with an overarching EPICS control system shall be proven.
  - e) A support system for the circulating circuit with suitable adjustability facilitating easy positioning and alignment
  - f) A dummy amplifier head with heater to simulate the conditions of the laser for offline functional system testing. Dummy heads will be required for both the prototype and the production system.

**OPTION: Production System**

The most demanding application envisaged involves a single auto-cascade refrigeration unit servicing three amplifier heads, all operating at a stable temperature of 140K as the gas flows into the gain media. Two of the helium circulator loops provided will, at 140K, provide heat rejection from the amplifier gain media of 4kW plus any additional estimated losses from pipework, black body radiation, heat input from circulator fan, etc. The third helium circulator shall, at 140K, provide heat rejection of 1kW from the amplifier gain media plus any additional estimated losses.

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**Fig. 2: Schematic of production system for multiple laser amplifiers**

**The envisaged production system consists of:**

- a) A refrigeration unit (capable of heat rejection of 9kW plus losses at 140K)
- b) Insulated flexible lines between the refrigeration unit and each circulator circuit using simple bayonet fittings (or equivalent)
- c) Three circulator units, each consisting of
  - i. A suitably sized oil free fan(s) or blower(s) to circulate the helium
  - ii. A refrigerator gas to helium gas heat exchanger (HX).
  - iii. A method of regulating the Helium temperature in a stable manner. (If a heater is selected, it shall be a sealed unit with an Inconel outer sheath or similar with over temperature protection.
  - iv. A helium circuit fill and exhaust port (isolatable)
  - v. A helium circuit evacuation port (isolatable and of suitable size to attain vacuum level of  $1 \times 10^{-3}$  mbar)
  - vi. A helium circuit pressure transducer (including a bourdon type gauge which reads pressure without requiring power)
  - vii. Pressure relief valve and any safety devices necessary
  - viii. Provision for all exhausts from PRV's, bursting discs etc., to be captured to allow venting externally to the laser operating area.
  - ix. A method of determining mass flow rate (potentially using the pressure transducer, fan speed and the fan curve)

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- x. Temperature sensors measuring Helium temperature at helium gas input and helium gas output of the amplifier head. (Sensors shall be duplicated at key points where their replacement under maintenance is not practicable).
  - xi. Insulation minimising heat loading resulting from input from the room to cold elements
  - xii. Insulated pipework to interface with the laser amplifier head. Method of interface (bayonet, weld, bolted flange) to be determined.
- d) An automated control system with remote historical trending capability for each circulator unit. Compatibility with an overarching EPICS control system is desirable.
  - e) A support system for each circulating circuit with required adjustability for positioning and alignment
  - f) There should also be facility to block one or more of the refrigerator to circulator transfer lines such that either one, two or three circulators could be attached to the system whilst the system remains capable of achieving the required parameters.

**3.1.1 Normal operating conditions (for the prototype system)**

The circulator for the prototype will be optimised for operation under the following conditions:

- a. Helium mass flow rate: 200 g/s (this corresponds to a volume flow rate of 224 m<sup>3</sup>/h at 9.3 barA and 140 K)
- b. Pressure: 9.3 barA (at 140K)
- c. Temperature stability in helium flowing into the amplifier head +/-0.5 K or better
- d. Absolute temperature (at input to amplifier head): 140 K

**3.1.2 External Heat loads**

The system shall be designed to consider system generated heat loads (such as fans) and normally expected heat loads (such as room thermal radiation). For information, STFC have estimated the heat load associated with the 15J, 100Hz amplifier head (i.e. the prototype systems) is up to 4 kW, excluding system generated and normally expected heat loads.

**3.1.3 Operating Flow Range Performance, Accuracy, Stability**

The helium flow has been modelled through the amplifier head. The supplier shall model the flow through the transfer lines to inform the minimum conditions necessary to achieve uniform and turbulent flow necessary to efficiently and uniformly cool gain media slabs within the amplifier head.

- a. A helium mass flow rate of between 10g/s and up to 220 g/s should be achievable. This flow rate must be demonstrated for an equivalent pressure drop as to that provided by the STFC supplied amplifier which has been calculated at 11kPa, at 9.3 barA and 200 g/s mass flow rate.
- b. The minimum internal flow pipe diameter is expected to be in the range 50 mm. The diameter will be discussed and finalised during the design review.

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- c. The flow conditions of the helium circuit shall be tested by replacing the amplifier with a dummy head containing an orifice plate which produces the aforementioned pressure drop. The Supplier will provide the dummy head assembly for test purposes (in the same material as the STFC supplied amplifier head).
- d. The helium flow shall be measured or computed to provide an indication of helium mass flow in the system with a working range of 5g/s to 250g/s. If a flow meter is selected, it shall be capable of working reliably in the specified temperature range and shall be provided with a calibration certificate. The control system shall provide readings for mass and volumetric flow.

**3.1.4 Operating Pressure Range, Performance, Accuracy, Stability**

- a. The operating pressure range for the helium circuit will be  $1 \times 10^{-3}$  mbarA (vacuum) to 20 barA at room temperature. Where there is a prescribed limit to the vacuum that may be drawn on the helium circuit, this must be identified within the tender return. The helium circulator circuit shall be pressure-tested to at least 1.5X the maximum working pressure. For the purposes of pressure testing, the helium circulator circuit does not include the amplifier head. This will be tested separately by STFC. The line connectors to the STFC amplifier head shall be blanked off. These blanks shall be supplied to STFC with the circulator. A pressure test certificate shall be supplied with the vessel to include the blanks. The circulator assembly shall be CE marked in accordance with the EU Pressure Equipment Directive.
- b. The helium circuit shall contain a minimum of one pressure sensor to monitor the helium pressure in the system. The pressure sensor range shall be 0 to 25 barA but it shall be capable of withstanding the necessary test pressure. It shall be capable of reading reliably at temperatures between 90 K and 320 K. A calibration certificate is required for the pressure sensor. An additional pressure gauge which requires no power source or read-out electronics (e.g. Bourdon type) is required so that helium pressure can be monitored during power outages. Gauges shall also be vacuum compatible to avoid damage during pump and purge cycles.
- c. The helium circulator with the fan removed and blanked must be proven to be leak tight to  $10^{-8}$  mbar/s or better. With the tender return, the supplier shall provide details of a suitable test that will be completed to determine the helium integrity of the circulator system.
- d. All components within the helium gas of the circulator must be entirely oil free. Where lubricant is necessary to prevent threads galling etc. then silver plating should be considered. If silver plating is not suitable then approval from the client must be sought for an alternative.
- e. The helium circuit shall contain at least one suitable pressure safety relief valve (set at 10% above the maximum working pressure). This PRV will also provide the pressure relief system for the amplifier head. The amplifier head analysis is based upon a maximum working pressure of 22bar(A) so the PRV shall not be set higher than this level. Further safety relief valves shall be added to the system as deemed appropriate during the supplier’s pressure system safety analysis for compliance with the PED. All SRVs and PRVs used shall be supplied with calibration certificates and where appropriate PED certified.

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- f. The helium circuit input and exhaust port shall be fitted with a manual diaphragm shut off valve with Swagelok fittings (¼"VCR male) or equivalent approved by STFC to minimise risk
- g. The helium circuit evacuation port shall be fitted with a suitable vacuum valve, which can withstand the maximum allowable pressure.
- h. Provision shall be made for all exhausts from PRVs, bursting discs etc. to be captured to allow venting externally to the laser operating area.
- i. The requirements of the EC Pressure Equipment Directive and the UK Pressure Systems Safety Regulations (Year 2000) shall be followed.

**3.1.5 Operating Temperature Range, Performance, Accuracy, Stability**

- a. The system must be capable of operating at helium gas temperatures (measured at the input to the amplifier head between 140 K and 300 K when subjected to a 0 to 4kW amplifier heat load in addition to the inherent heat loads on the system.
- b. Absolute accuracy for temperature of the helium gas: +/- 2 K or better.
- c. Temperature stability (peak-to-peak) of helium gas in upper transfer line: +/- 0.5 K or better. After settling-down, the temperature is to be kept within this range for amplifier heat loads between 0 and 4 kW.
- d. The helium circuit shall contain at least two temperature sensors (measuring helium gas temperature) at positions relevant to the control system (see Fig. 1). The position of these sensors shall be considered to prevent disruption of flow at entry to the STFC supplied amplifier head.
- e. The helium circuit temperature sensors shall provide signals for monitoring and controlling the helium gas temperature in the system.
- f. The rate of change of temperature (at input to the amplifier head (see Fig. 1)) shall be regulated by the control system and shall not exceed +/- 15 K/min.
- g. Cooling rate, settling time and over/undershoot during cool-down: when changing the set-point temperature to a value lower than the current value, the system shall behave as indicated in Figure 2.

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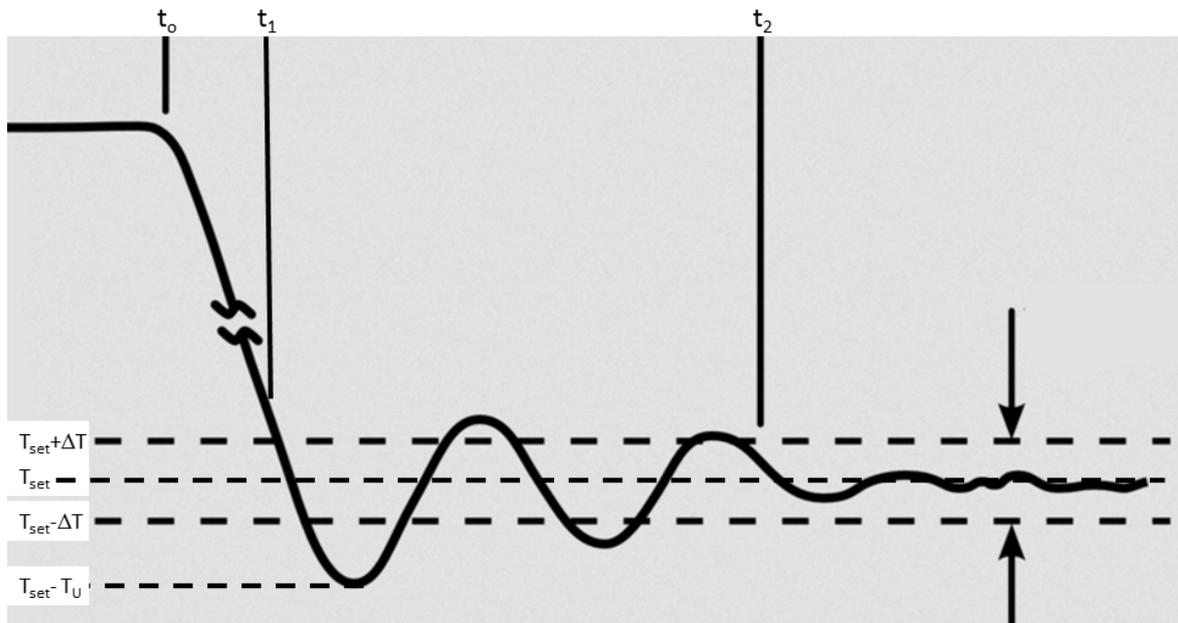


Figure 2: Indicative Cool down behaviour

h. Meaning of parameters in Figure 2 is:-

- $t_0$ : system starts cooling
- $t_1$ : system starts to reduce cooling power
- $T_{set}$ : set point temperature
- $t_2$  and after: actual temperature stays within range  $T_{set} \pm \Delta T$ .
- $T_U$ : maximum undershoot

Permitted values:

- Cooling rate between  $t_0$  and  $t_1$ : maximum permitted by cooling capacity, but limited to 10K/min
- Time between  $t_1$  and  $t_2$ : 5 min maximum
- $\Delta T: \leq 0.5K$
- $T_U$ : 5K maximum

The performance as described above is to be demonstrated without a heat load on the amplifier.

### 3.1.6 Operating Parameters for the Production System Option

The production system will require two circuits identical to the requirements of the prototype system as detailed in sections 3.1.1 to 3.1.5.

The third circuit would require the same general conditions, except it should be optimised for the following parameters:

- a) Helium flow rate: 30 g/s (range from 10g/s to 40g/s)
- b) Pressure 9.3 barA (at 140K)

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- c) Absolute temperature (at input to amplifier head): 140 K
- d) Pressure drop through head: 3kPa
- e) Amplifier Head Heat Load: 1kW
- f) Minimum expected internal diameter of inlet: 40mm

The cooling power of the production system shall be controllable such that individual circuits can be operated in isolation as necessary..

### 3.1.7 Spatial Constraints and Technical Requirements

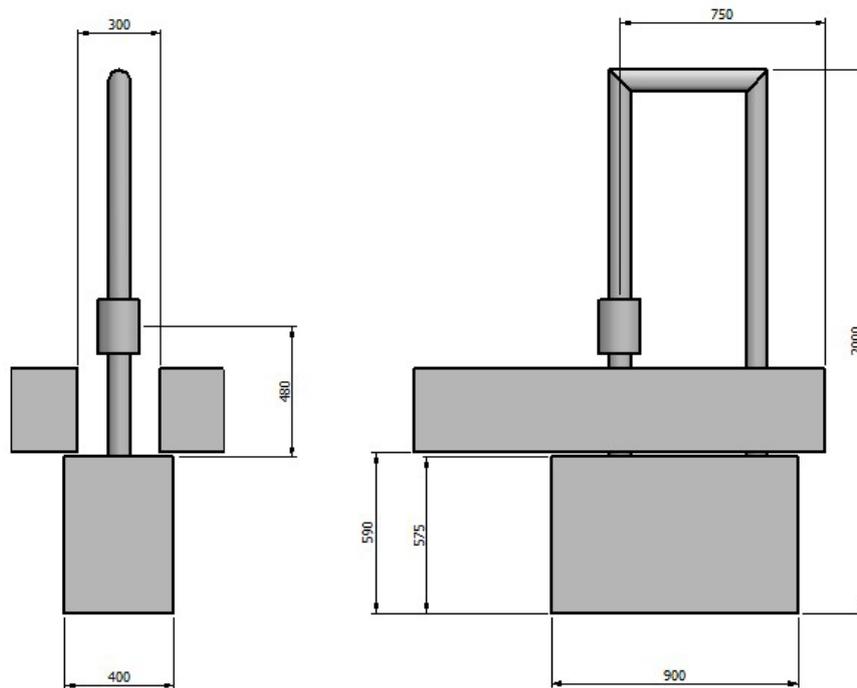
Laboratory space is highly constrained, so space saving solutions will score better in the evaluation, particularly in the vicinity of the amplifier head. The cooling system will be installed in a laser laboratory which has the following maximum dimensions:

- a. The maximum ceiling height in the UK lab is 2.8 m.
- b. The maximum door height into either lab is 2.0 m.
- c. The maximum door width into either lab is 1.4 m.
- d. The circulator should be within a space envelope of 600 x 1000 x 1000mm (excluding gas lines to the amplifier head(s))
- e. The refrigerator should fit within a 900 x 900 x 1200mm space envelope, excluding the externally mounted chiller.
- f. The length of and size of helium gas lines between the circulator and amplifier head should be minimised. These are expected to be 2 to 3 metres in length. See Figure 3.
- g. The length of coolant lines between the circulator and the refrigerator should be in the order of 10 to 20 metres so that the refrigerator can be placed to reach all of the circulators in the production model.
- h. The coolant lines between the circulator and the refrigerator should be as flexible as possible.
- i. The design must incorporate a method of manoeuvring and aligning each circulator assembly to the amplifier head. Ideally the circulator and amplifier head would be mounted on a single support unit, potentially with the joint between amplifier and transfer lines being permanent (e.g. welded). The positional reference for the amplifier head (and thereby the circulator) is the optical table.
- j. The circulator is to be mounted on roller ball castors which have levelling capability and a method for stabilising or locking position (e.g. feet) once the desired position has been achieved.
- k. The circulator and refrigerator shall be supplied with fully certified lifting facilities suitable for transportation and lifting of the system by crane or pallet truck compliant with LOLER.
- l. The location of the valves and gauges on the circulator and refrigerator should be such that they can be easily accessed to make adjustments and read values, but not such that they can get easily snagged or damaged during installation and operations.

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- m. Were the system circulator or refrigerator to require assisted air cooling, air flow must be appropriately directed to avoid the laser system tables.
- n. Where vacuum is used for insulation, cavities shall be pumped down to better than  $5 \times 10^{-3}$  bar and, where permanently sealed, designed for a 5 year life.
- o. Vacuum in the cooling system shall be independent from the vacuum space of the amplifier head. The supplier shall provide the vacuum break or barrier at the interface.
- p. Pump out ports to be KF25/KF40 compatible, to have resealing plugs and a tool is to be furnished to enable pull down and sealing of the vacuum cavities. These shall have appropriate safeguards against overpressure (including calibration certificates).
- q. It is desirable to have an indication of vacuum level within vacuum cavities that do not require the pull out plug to be removed.
- r. Any insulated components shall not show signs of condensation or ice build-up with laboratory air conditions of up to 65% humidity and temperatures between 20°C and 30°C.
- s. An RGA test is to be performed on all helium pipework to ensure that the helium circuit contains no trace of hydrocarbon contamination.
- t. A suitably sized vacuum pumping port to permit evacuation of the helium circuit shall be supplied.
- u. The system shall be self-sufficient and shall not require infrastructure (other than a power supply)
- v. Helium line bends or changes in section shall not introduce an uneven flow condition in the amplifier head (both horizontal planes) or these changes should be compensated for with flow conditioning system such as honeycomb screens or meshes.
- w. Access to the amplifier head access panel shall not be obstructed by the any parts of the cooling system.
- x. Careful attention to the design and selection of the heat exchanger, heater, bypass and control valves will be necessary to ensure the total system pressure drop is kept to a minimum and temperature stability can be maintained.
- y. Ergonomic accessibility to the work face required to safely connect, inspect and work on these elements, including any specialised tooling perceived necessary, shall be provided. It must be possible to remove components for maintenance or repair within the constraints of the lab (e.g. ceiling height).
- z. The metal surfaces of the cryostat and pipework shall have a uniform consistent finish with no scratches, defects or weld marks. Painted surfaces are to be scratch free.
- aa. All electrical componentry shall be housed in a suitable wall mounted cabinet to at least IP55.
- bb. The electrical cabinet and all electrical cabling shall comply with the Low Voltage Directive 2014/35/EU

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**Figure 3: Image anticipated set-up of the prototype system circulator**

### 3.1.8 Services and Environment

STFC can make the following available:

- a. Pneumatic dry nitrogen at 7 bar(g) through a 6 mm OD flexible pipework connection to cryostat. (Compressed air can be provided but this must be highlighted in the bid)
- b. Helium (high purity) bottled supply for filling the cryostat and pipework to interface with the cryostat.
- c. 230 Volts single phase earthed neutral and earth, within a tolerance of +10% / -6% at 13A.
- d. 400 Volts three phase and earth +10% / -6% at 125A.

The environment that the cooling system will be housed in is a scientific laser laboratory:

- e. The lab is a cleanroom to ISO7 (class 10,000) in which dust is undesirable and equipment surfaces must be accessible and easy to clean.
- f. Nominal temperature 21degC
- g. Nominal humidity of 50%, but can increase to 65%.
- h. The supplier should make provision for containing and retaining all necessary small pipework and cabling so that the installation is tidy and professional in appearance to match the rest of the laser system.

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- i. The noise level in the laboratory must be kept within appropriate limits. All elements of the cooling system shall not exceed 60dB(A) under normal operating conditions and no greater than 85dB(A) under transitional conditions (i.e. not lasting more than 15 minutes)
- j. Vibrations shall be kept to a minimum, particularly around the amplifier head. Vibration isolating mounts may be used on refrigeration units and water to air chillers to minimise transmission of vibration to the lab floor.

**3.1.9 Cleanliness & Filtration of helium gas flow**

Helium circuit cleanliness is critical to the laser operation. The circuit must be free of particulates and organics when initially commissioned. During amplifier operation, in the event of internal failure, or by simple abrasion from moving parts in motor(s) or valves, there is a risk that particulate contamination may enter the helium gas line. To prevent the build-up and unwanted circulation of these particulates (minimum particulate size to be 10 µm) a method by which the helium gas can be filtered is required. A real-time filtering system is preferable, either for full or partial helium flow; however, if the pressure drop penalty associated with this is too high, then an off-line bypass filtration loop may be considered. With the system off-line the helium gas could be manually diverted around this filtration loop at a low flow rate to filter the gas prior to full operation of the system. The Supplier should recommend a solution that would provide a filtration capability without interfering with the required performance characteristics of the system, and cost this option separately. It shall be possible to access, clean and check the integrity of the filter.

All pipework internals associated with the helium system must be cleaned and cleared of contaminants to a standard suitable for use with Oxygen service “Oxygen Clean” and for ultra-high vacuum (UHV) components. Specifically, this means:

- a. That no oil or grease is used in any part of the helium circuit and in particular within any unsealed bearings of the fan.
- b. For sealed bearings, if lubrication is essential to operation, it shall have an outgassing rate below  $1 \times 10^{-8}$  mbarl/scm<sup>2</sup>.
- c. Additionally, any pumps or compressors that are used in manufacturing and testing or purging the Helium circuit must be oil, grease and contaminant free.
- d. The supplier side of the vacuum lines shall be oil and grease free in order to avoid contamination of vacuum equipment
- e. The supplier shall draw up a procedure for ensuring and testing the “oxygen clean” cleanliness of the system and include this in the quality management process to be agreed by STFC and the supplier.
- f. All system pipework shall be etch pickle cleaned throughout to achieve an oil free “bright polished” surface finish to a standard which would be suitable for oxygen use “oxygen clean”. Solvent cleaning, though this may form a part of the process, is insufficient as hydrocarbons or particulate left within the system can either plate out on or damage optical components potentially causing severe damage to long lead high cost components. Refer to the European Industrial Gases Association guideline IGC Doc 33/06/E for guidance on cleaning and packaging. It should be noted that under a wipe test with white filter paper, a

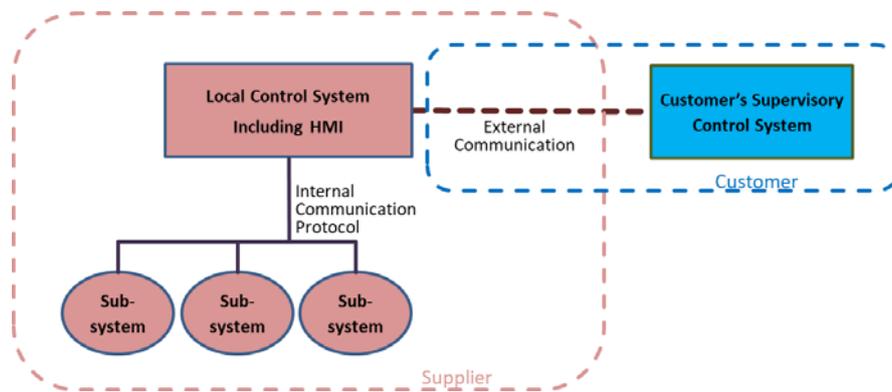
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light oxide contamination is, for this application, unacceptable. This applies to both cryostat and transfer lines.

The requirement for an oil free system also applies to all components exposed to vacuum and particularly those that are exposed to the vacuum space surrounding the amplifier head.

### 3.2 Control system

The System shall contain its own local control and data acquisition system, including an HMI (human-machine interface, also called user interface), so the System can be controlled locally and operated stand-alone. The user interface must be capable of being removed and remotely connected using an umbilical.



**Figure 4: Illustration of control system architecture, indicating areas of responsibility of the Supplier, of the Customer, and where an interface needs to be agreed.**

The size for the HMI/user screen shall be 14" (across diagonal) or larger to ensure details on the screen can be easily read.

Once delivered, the System shall allow full integration into an overarching supervisory control system developed by STFC. The supervisory control system will be developed using EPICS (see <https://epics.anl.gov/>), an open-source distributed control system framework used in many large-scale science facilities, such as particle accelerators or synchrotron light sources. The system shall be unlocked for remote control prior to delivery.

To this end, the local control system shall provide an interface, for remote control and monitoring of the System, which is compatible with EPICS. Ideally, the local control system will provide an EPICS driver. Alternatively but, less desirable, the local control system shall then expose an interface (for example Telnet, raw TCP, RJ-45 E-Cat, RS232, Modbus, CAN-bus) to allow for a full integration of the device into the supervisory control system. Details of the Application Programming Interface (API) can be worked out collaboratively and iteratively with STFC.

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All Process Variables (PVs) that EPICS requires access to shall be located in a single block to simplify location of the necessary PVs.

'Remote Desktop' solutions such as VNC, or replicating the local HMI on a remote PC, are not acceptable as they do not provide the level of integration expected and required by STFC's supervising control system.

The application code for both the controller (e.g. PLC) and the User Interface (e.g. HMI) software must be provided, including any software tool/license required to view the code.

Providing remote access/control of the device directly (i.e. bypassing the local control system) and/or to low-level hardware communication software libraries is also not acceptable; the whole system must be seen as a black-box from the supervising control system with at least the following requirements:

- a. The control functionality needs to include everything required for day-to-day operations of the System. Advanced functions that would only be used during set-up or maintenance of the System do not need to be made available to the supervisory control
- b. All data, including errors/faults/alarms that is acquired by the local control system should also be available to the supervisory control system
- c. A "health signal" to indicate whether the system is OK or not.
- d. A command indicating which error was last produced.
- e. The ability to set the IP address for external communication.

It is desirable to have a "read only" web browser access to the HMI for the initial commissioning phase of the system. This can be disabled once the system is fully commissioned and integrated at STFC.

Under both remote control and local control it shall be possible to change key parameters without shutting down and restarting the system to initiate the change.

### 3.2.1 User Interface

The System will provide a user interface (or control panel) for stand-alone operation that displays actual and set values for all important parameters at the same time. This will include, but may not be limited to

- Temperature readings for the various sensors
- Rate of temperature change (ramp)
- Valve positions
- Fan speed
- Flow rate (mass and volumetric)
- Heater power
- Helium pressure (actual value only)

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- State of digital inputs and outputs
- Alarms and trips

Additionally, the user interface shall include at least two graphs on which the history of any of those parameters can be selected and displayed over a variable length of time, from 1 hour to 8 hours minimum, but it is desirable to have up to 2 weeks historical data available. For longer term data recording, the frequency at which data points are taken can be changed accordingly.

### 3.2.2 Digital Interlock Inputs and Outputs

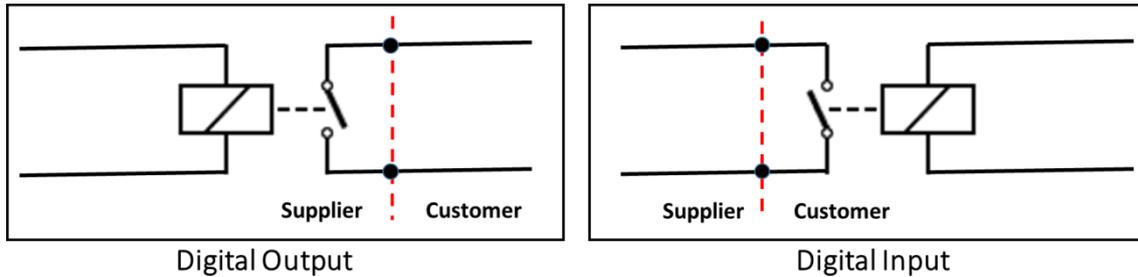


Figure 1: Illustration of digital outputs and inputs.

- System shall include a number of digital inputs and outputs for interlock signals to ensure that the System is only operated when safe to do so and to ensure that external equipment is only operated when the System can provide sufficient cooling.
- Inputs shall interrogate a potential-free contact supplied by Customer, contact closed means True (safe to continue).
- Outputs shall be implemented as a potential free contact that can be interrogated by Customer.
- Outputs to be provided: 2 off
  - Laser enable
  - Spare
- Inputs to be provided: 3 off
  - Vacuum o.k.
  - Oxygen level o.k.
  - Spare
- Functionality of outputs
  - When certain parameters are within defined boundaries, the output signals 'true' by closing the internal potential free contact. Details see in Section Alarms...
- Functionality of inputs:
  - The system can only operate when the signals on all inputs are 'true', i.e. the external potential free contacts that the System interrogates, are closed. If one input goes from 'true' to 'false' the system shuts down (goes to Off mode, see below).

### 3.2.3 Operating Modes

- **Off** (shut down): fan and heater powered down, all valves in a safe state (powered down).

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- **Manual mode:**
  - All parameters controlled manually (fan speed, heater power, valve positions), with safeguards against damaging System. For details see in Section 3.2.4
  
- **Automatic mode:**
  - To automate the following operating regimes and transition between them:
    - Circulator Start-Up: Start-up of fan/blower
    - Cool-Down: Cool-down to set-point with defined temperature ramp (if set-point lower than initial temperature), with defined volume or mass flow.
    - At Temperature: Control of temperature when at set-point with defined volumetric and mass flow.
    - Warm-Up: Warm-up to set-point with defined temperature ramp (if set-point higher than initial temperature), with defined volume or mass flow.
  - Typically, PID or other closed feedback loops will be implemented to control cooling or heating power, based on measured vs set temperature, and to control fan speed based on measured vs set flow rate.
  - For cool-down and warm-up, typically the set-point temperature is continuously changed according to the set ramp rate. If the difference between ramped set-point and actual temperature becomes too large (because of limited heating or cooling capacity), the ramp will be paused (set-point held constant) until temperature catches up.

### 3.2.4 Alarms, trips, safeguards, Digital Output Limits

- Definitions:
  - **Alarm:** a parameter falls out of a specified range, but it is still safe to operate the system, so only a visual and audible warning will be generated.
  - **Trip:** a parameter falls out of a specified range where it is no longer safe to operate the system (example: temperature limit exceeded), or where there is an indication that the System will get into an unsafe regime (example: system will overheat because of insufficient cooling capacity). The system will undertake an emergency shutdown and provide the operator with a visual and audible warning. It is expected that a trip will be preceded by an alarm so the user has time to take corrective action before the system trips.
  - **Safeguards:** apply in Manual mode, protect systems from damage by, for example, dead-heading the fan or running the heater without sufficient coolant flow, making it over-heat.

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- **Digital Output Limits:** a digital output only signals True when certain relevant parameters are within defined limits (different from alarm and trip levels). Limits and parameters will be determined during the design phase of the project, and are likely to include helium temperature, pressure and flow.

The system shall clearly show the reason for the alarm or trip to allow the operator to act accordingly. The alarm or trip shall continue to show until the operator has acknowledged and cleared the alarm or trip at the HMI.

The safe operating ranges and thereby the alarm, trip and digital output limits will be fully defined at the design review and are likely to include the following:

- To low or too high temperature on any sensor (circulator, refrigerator or heater)
- Too low or too high He pressure.
- Too low helium flow: in Automatic mode, set-point flow can't be reached within certain time after starting up fan or changing flow set-point, even with fan at maximum speed.
- Insufficient cooling power: He temperature keeps increasing (deviation from set-point becomes too large) when in Cool-Down or At-Temperature mode.
- Sensor malfunction.

During the design phase of the project, it will also be defined whether and how these levels can be changed by operators. A possible solution is to define access/permission levels in the local control system, and that permission to change certain values is only granted after entering a password.

### 3.2.5 Atypical modes

#### 3.2.5.1 Cryostat emergency shutdown procedure

In the event of a system malfunction, or power loss to the laboratory, a cryostat emergency shutdown procedure will be activated, such that the system goes to a state where the risk of damage to itself or to the surroundings is minimised. It will include:

- Shutting down the fan/blower
- Shutting down the heater
- Isolating the refrigerator cooling from the circulator or shutting down the refrigerator
- Signalling laser to shut down (open potential free contacts)

### 3.3 Control Racks

Suppliers are asked to provide a quote for standard racks. Racks need to be able to fit through a 2 m high door when on castors hence a 38U limit in height is appropriate. Heat loading to the laboratory environment shall be minimised wherever possible.

All cabling between components and racks that need disconnecting for transport shall have terminations at each end to enable simple re-installation.

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Provision shall be made to allow the local control HMI unit to be disconnected from its mounting position, e.g. on the cryostat, and fed by an umbilical, some 7m in length.

## 5. Safety and Standards

Copies of all aforementioned certificates and declaration including supporting technical construction files shall be provided to RAL and shall also be retained by the supplier for a period of 10 years.

The system must be CE marked to indicate that it complies with the relevant regulations (e.g. pressure equipment, low voltage and EMC directives). A declaration of conformity shall be supplied. The safety standards with which the system will comply must be stated in the tender response.

## 6. Electrical supply

All system power connections supplied will have plugs for the United Kingdom conforming with these standards (both external and internal to the system, if applicable). The maximum current rating for a single phase supply is 13A; the total power rating for all external supplies, including three phase where requested, should not exceed 60 kW. It is preferable to use Industrial connectors.

A detailed description of the electrical supply requirements for the proposed system design should be included in the tender response.

Sufficient electrical safety measures must be in place to ensure that the complete system is capable of withstanding a failure of the mains electrical supply without causing, or increasing the likelihood of, damage or deterioration to any component associated with the system.

## 7. Operating environment

The supplier must specify the environmental conditions required for storage and operation of the system and the environmental impact of the system and its components, e.g. noise levels and vibration. The supplier will also be expected to consider the end of life disposal of the equipment in his supporting manuals.

## 8. Lifetime & warranty

- The equipment shall be guaranteed for 24 months after delivery or 12 months after final acceptance, whichever happens later. Warranty to include, as a minimum, any failure of system or components within the system resulting from design or manufacturing errors to be remedied by the supplier at its cost within 1 month of the failure being made known to the supplier.
- Any components requiring replacement due to unexpected wear or similar, shall be replaced by the supplier at its cost.

## 9. Serviceability and spares

- The availability of all components (or of equivalent components that can replace original components) that may need replacing over the service life of the system shall be in accordance with EEC rules.

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- Filters/pressure transducers etc need to be accessible and replaceable

## 10. Project Plan and Payment

Bidder to provide a logically linked plan, which will form the basis of ongoing monitoring as per section 2.3.2.

### 10.1 Kick off

A kick-off meeting must take place within the first month of the contract in which the Supplier will present the plan for the execution of the contract and a quality assurance plan.

### 10.2 Final Design Review

STFC and the Supplier must agree the final design at the final design review to be held at the Rutherford Appleton Laboratory, UK. At least 5 working days before this meeting, the Supplier must issue the Final Design Report, drawings and models detailing the proposed design. This design is to be presented and reviewed at the Final Design Review and judged by STFC or their representative to have met their requirements. Only after acceptance of the final version of the Final Design Report can manufacture commence. At the Final Design Review the Supplier must present the detailed final design, including:

- The overall design, reason for design choices and design calculations for the system.
- An outline of maintenance, operating and hazard management documents.
- A complete list of components.
- The production drawings.
- Complete, dimensioned assembly and component drawings.
- A detailed manufacturing and testing programme, with regular milestones to allow progress to be monitored.
- The inspections and test schedules, including the plan for factory tests Full details of on-site testing proving compliance with this specification is to be undertaken.

### 10.3 Approval Prior to Manufacture

Unless otherwise agreed in writing, STFC must approve the final design presented at the final design review before the Supplier proceeds to ordering of any materials, components or equipment required to fulfil this contract.

It should be noted that this approval does not obviate the Supplier of any responsibility for the design, suitability and safety of the equipment supplied.

For long-lead items, where awaiting the final design review may adversely affect the overall equipment delivery schedule, the Supplier is requested to seek permission to order materials, components or equipment prior to the review.

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## 11. Packing

The items must be robustly packaged to prevent damage or contamination during transit. All items will be inspected following delivery and damaged items rejected. All packaging must be capable of being re-used for onward shipment of the equipment should STFC so desire. Delivery shall be DDP in accordance with incoterms 2010.

Packaging should be capable of being re-used to permit final delivery of the equipment to the German client.

## 12. Shipped Condition

Details of the shipment procedures and associated equipment must be approved by STFC before any shipments are made.

## 13. Quality assurance and testing

### 13.1 Quality assurance programme

The Supplier shall follow a quality assurance program compliant with ISO-9001 for the design, manufacture and testing of all systems and equipment provided by them.

The Supplier will provide the full contact details of its Quality Manager, or member of staff responsible for quality approval and processes no later than two weeks after the signing of the contract.

A quality plan will be generated by the Supplier and this documentation will be made available to the Customer. The Plan should be based around the 'Bill of Materials' for the complete deliverable which shows the detail concerning the inspection and testing criteria of each individual part. The plan must also indicate details concerning the documented processes and quality control records that will be used and made available to the Customer.

The supplier must be transparent and provide traceability of items on the 'Bill of Materials'.

The Supplier must provide a Quality Assurance document for the supplied equipment, certifying that it conforms to the specification, and containing all material certificates, records, the results of all inspections and tests, and procedures used including a procedure to ensure the cleanliness of the system.

### 13.2 General arrangements for tests

Any tests undertaken at the factory and on-site must establish that all items of the manufactured equipment completely meet the performance requirements described in this specification.

STFC/HILASE reserve the right to require additional or more extensive tests to be conducted in the event of marginal equipment performance.

The Supplier must formulate acceptance test procedures for the system and will provide the facility and instrumentation to perform all relevant tests. The proposed test procedures are subject to customer review and acceptance. STFC will reserve the right to witness all tests and will be the sole arbiter as to their satisfactory completion.

Review and acceptance by STFC/HILASE does not release the Supplier from the responsibility to correct errors, oversights and omissions nor to ensure conformance to the specifications in this document.

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### 13.3 Factory Acceptance Tests

The system must be fully assembled, aligned, commissioned and tested at the Supplier's site prior to approval to ship. Suppliers are invited to propose details of what could be reasonably demonstrated to provide assurance that the system meets the required specification.

STFC expects the supplier to demonstrate functionality of the following elements of the system as a minimum, prior to STFC visiting:

- Software PID Control
- Software Interlocks, Trip & Alarms
- Helium flow rate operating ranges
- Helium temperature operating ranges
- Pressure system integrity
- Fan/blower capacity
- Thermal Insulation
- Cyclic loading (for full ranges)
- Long term operation (e.g. 5 days continuously)

The supplier shall then supply reports to STFC that demonstrate the compliance and functionality. Upon review of these reports, STFC and their authorised representatives shall be provided with access to the premises of the Supplier for the purposes of repeat inspection and the witnessing of fundamental tests. STFC shall be notified at least 10 working days in advance of any test date to allow necessary travel arrangements to be made.

All tests must be properly recorded on test certificates and the results submitted to STFC (for both supplier testing and for STFC witnessed testing).

In the event of a test failure and the carrying out of subsequent rectification work, STFC reserves the right to require the full repetition of all tests carried out.

The supplier shall provide a "dummy head" arrangement, including simulated heat load and all equipment necessary to permit the testing of the system at works.

### 13.3 Final Acceptance

The supplier shall be represented on completion of installation of the equipment at STFC, utilising the supplier installation manual. Comments on the manual will be provided for the supplier to update. The supplier's representative shall satisfy himself that the installation is appropriate for the commissioning and final acceptance testing of the equipment to be carried out. A final acceptance test will then be carried out by the supplier with STFC personnel witnessing the test. The supplier's representative and STFC witnesses will sign the test schedule and note any defects on an agreed list, the contents of which must be completed prior to the final contractual payment being made. The operating manual shall also be reviewed whilst the system is in operation during this test.

As installation periods vary, the supplier should include a period of five days attendance at RAL in their price. Fixed and firm rates, inclusive of subsistence, to extend this period at the discretion of STFC shall

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also be provided. It should be noted that any increase in the attendance period required for the supplier to rectify defects in his equipment shall be to the suppliers account.

It is also a condition of final acceptance that the Supplier must have provided to STFC's satisfaction, full documentation as noted within this specification, to cover all systems embodied within this contract prior to the final contractual payment being made.

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