Science & Technology Facilities Council

National Satellite Test Facility (NSTF)

Liquid Nitrogen Supply Design Statement of Work

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RAL Space

CHANGE RECORD

Issue	Date	Section(s) Affected	Description of Change/Change Request Reference/Remarks
Draft	05/09/19		First draft
1	18/09/19	Section 4 added.	First issue
2	19/09/19	Requirements	Bulk storage daily loss rate
2	29/09/19	Applicable documents	AD08: STFC Safety Code No 33 (SC33) Safety of Pressure and Vacuum Systems
2	29/09/19	Requirements	LN38 to include SC33
3	09/10/19	Responsibility	Section 3.5 added to clarify roles and responsibility
4	11/10/19	1.3	Added AD9 - plinth drawings
5		3.3	Changed plinth design to verification of plinth drawings. Note added that more than one supplier of bulk storage tanks shall be identified.
6	21/10/19	3	Comments from Projects Services contractor

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1. PREAMBLE

1.1 SCOPE

This document applies to the design of the liquid nitrogen supply system for the NSTF.

1.2 PURPOSE

This document describes the work to be performed in designing the liquid nitrogen supply for the National Satellite Test Facility, building R114. It does not cover the manufacture and installation of the liquid nitrogen supply system, as this will be performed by the NSTF main works contractor.

1.3 APPLICABLE DOCUMENTS

AD #	APPLICABLE DOCUMENT TITLE	DOCUMENT ID	ISSUE / DATE
1	Site Coordinates – Setting Out	NSTF-0100-1C-00-PL-A-200-9001	P03
2	Ground Floor Plan GA	NSTF-0100-1C-00-PL-A-200-0001	P19
3	Lower Roof GA	NSTF-0100-1C-03-PL-A-200-0001	P16
4	Sections A and B GA	NSTF-0100-1CC-ZZ-SE-A-250-0002	P05
5	Interface Control Drawing HVT460	C24.935-ICD	F
6	Interface Control Document	NSTF-LSC-ACS-IF-002	H
7	Thermal Vacuum Chamber LN2 System P&ID	C24.935-SI.L0 SHT 4 OF 23	B
8	Safety of Pressure and Vacuum Systems	STFC Safety Code No 33 (SC33)	Rev.1.7 2018
9	Plinth Drawings	AD9_Plinth.zip	n/a

1.4 REFERENCE DOCUMENTS

RD #	REFERENCE DOCUMENT TITLE	DOCUMENT ID	ISSUE / DATE
1	LN2 pipework proposed route and dimensions	NSTF-0300-1C-XX-SK-M-500-1018	3

2. DESCRIPTION OF LIQUID NITROGEN SUPPLY

The NSTF consists of a large building (approximately 70 m x 50 m) housing testing facilities and clean rooms, intended to perform environmental testing on satellites ranging in size from 1 tonne to 7 tonnes. The test facilities include a large thermal vacuum chamber (7.0 m internal diameter x 12 m long) that has thermal shrouds to heat and cool test items placed inside. The shroud panels can be cooled to 95 K using a cold nitrogen gas system and heated to 400K by heating the cold nitrogen gas using a heat exchanger. Cooling for the nitrogen gas is to be provided by liquid nitrogen (LN2), and under worst-case conditions, the rate of consumption of LN2 is predicted to be around 2.5 tonnes per hour. The liquid nitrogen, stored in bulk storage tanks, needs to be transported to the point of use via a thermally insulated pipe to minimise evaporation and ensure the quantity of bubbles in the LN2 is less than 2%. The most thermally efficient solution is to use a super insulated vacuum line (SIVL).

After the liquid nitrogen has been used for cooling purposes, the now gaseous nitrogen has to be vented to atmosphere in a safe manner. An exhaust vent, or stack, is necessary to ensure the nitrogen gas does not accumulate around air intakes to the building or around locations were personnel might congregate. The optimal location for this exhaust vent is within the scope of the design work described in this document.

In addition to the supply of LN2, a gaseous nitrogen (GN2) system is needed to supply clean, dry nitrogen to various locations inside the NSTF building. The most efficient way of providing the GN2 is by using boil-off gas from the bulk storage tanks. However, when demand is high it will be necessary to vaporise some of the LN2 in a vaporiser system. The temperature of the GN2 needs to be between 15 and 35 °C, so additional heating of the boil-off gas will be required. Design of the GN2 distribution pipework around the NSTF building is also within the scope of work described herein.

The safety of the entire system needs to be carefully considered to ensure personnel and equipment are safe under all determinable conditions. Pressure relief valves need to be included in the design, along with an easily accessible emergency shut off system to stop the flow of LN2 from the bulk storage tanks.

3. STATEMENT OF WORK

3.1 SCOPE OF WORK

The scope of work covers the detailed design of the NSTF LN2 supply system only. Manufacture, installation and commissioning will be performed by the main works building contractor for NSTF. Therefore, the detailed design must be documented at a sufficient level to allow non-experts to tender, procure and install the full system requirements. Installation details must also be provided unless the information can be obtained from identified suppliers and/or installation specialists.

3.2 REQUIREMENTS

The requirements for the LN2 supply are defined in Appendix A of this document.

3.3 WORK TO BE PERFORMED

The appointed design consultant shall be responsible for all design aspects of the LN2 supply system such that compliance to the requirements can be demonstrated. The following is a list of tasks expected to be undertaken. However, the suppliers shall identify any missing tasks in their offer with reasons why they are needed.

Bulk Storage

- The size and number of tanks shall be established
- Storage pressure and temperature calculations
- Suppliers of bulk storage tanks shall be identified (Note: more than one supplier shall be identified).
- A list of equipment needed to maintain the bulk storage tanks at their required temperature and pressure
- Verification of plinth design to support the bulk storage tanks (see AD-9)
- Detailed design of any safety devices
- Refill strategy, i.e. size and number of deliveries needed to maintain required fill level during peak consumption times.
- Compound plans and arrangement of equipment (Note: Compound fence design is outside the scope of work)
- Coordination and planning around the existing building design

Gaseous Nitrogen Supply

- Detailed design of the vaporizers needed to generate the volume of GN2 from LN2
- Detailed design of the GN2 pipework including filters and driers
- Detailed design of any safety devices
- Pipework cleaning methodology
- Flow calculations to demonstrate compliance to flow requirements
- Coordination and planning around the existing building design

LN2 Supply Line (SIVL)

- SIVL routing from bulk storage tank to point of use in TVAC plant room
- SIVL size calculations
- SIVL trench requirements and dimensions
- Estimation of LN2 quality (% of liquid versus bubbles) at point of use
- Design of safety devices and vents
- Coordination and planning around the existing building design

Exhaust

- Establish optimum location of exhaust vent using plume analysis or other modelling tools
- HAZID analysis
- Detailed design of exhaust system including any extraction fans, etc.
- Detailed design of any safety features
- Equipment list with part numbers and supplier details
- Coordination and planning around the existing building design

Overall System

- Develop P&I diagram for complete system
- Calculations to demonstrate compliance to requirements
- HAZOP analysis
- Develop installation instructions
- Budget installation costs and programme
- Coordination and planning around the existing building design
- Identify all interfaces and building infrastructure requirements to support the system
- Non-branded design information to level of detail to allow construction procurement

3.4 DELIVERABLE ITEMS LIST

The following list of documents shall be delivered during the contract. The format of each deliverable is also indicated below.

The delivery date must be no later than 30th April 2020.

ID	Title	Format	Milestone/Delivery Date
D1	Preliminary design report	PDF	T0 + 2 months
D2	Final design report	PDF	T0 + 4 months
D3	HAZID analysis report	PDF	Contract completion
D4	HAZOP analysis report	PDF	Contract completion
D5	Plot plans and equipment arrangement	PDF	Contract completion
D6	Equipment list	PDF	Contract completion
D7	Supplier list	PDF	Contract completion
D8	P&I Diagram(s)	PDF	Contract completion
D9	SIVL Routing CAD Model	Revit or Revit compatible 3D CAD model	T0 + 3 months & contract completion
D10	Exhaust Routing CAD Model	Revit or Revit compatible 3D CAD model	T0 + 3 months & contract completion
D11	Setting out drawings for SIVL and Exhaust pipework	AutoCAD 2018	T0 + 3 months & contract completion
D12	Installation Instructions	PDF	Contract completion
D13	Budget cost for installation and commissioning	PDF	Contract completion
D14	Project schedule for installation and commissioning	MS Project	Contract completion

Notes:
T0 = Contract Kick-off

3.5 RESPONSIBILITY

The design of the LN_2 supply will ensure that all requirements detailed in Appendix A have been satisfied and the expected performance suitably assured by analysis, modelling etc. Assuming the LN_2 system has been manufactured to the proposed design specification, the bidder will be responsible for non-compliance to the requirements. STFC will ultimately be responsible to ensure the LN_2 system is built to the design proposal by its chosen building contractor.

4. OWNERSHIP OF DELIVERABLES

Ownership of all Deliverables provided under this contract – including, as per clause 17 of the Contract Terms, all Intellectual Property Rights – shall vest in UKRI.

APPENDIX A – REQUIREMENTS

ID	Requirement Description	Requirement Detail
LN1	Liquid nitrogen (LN2) System Description	The liquid nitrogen system shall comprise the following elements; Bulk storage tanks Liquid transfer line Nitrogen gas generator Exhaust (vent to atmosphere)
LN2	LN2 storage capacity	The bulk storage tanks shall have a capacity greater than 86 useable tonnes. Notes: 1. Assumes working density of 0.74 kg per litre 2. Useable means it excludes any LN2 needed to maintain the temperature and pressure of the bulk storage tanks
LN3	Bulk storage tank size	The bulk storage tanks shall be sized to fit in a compound of dimensions 9.017 m x 19.721 m. Notes: 1. The compound has to also accommodate any ancillary equipment such as evaporators and pipework.
LN4	Future expansion	The bulk storage tanks shall be designed such that a 30% increase in storage capacity can be added at a future date without having to increase the size of the compound
LN5	Bulk storage pressure sensors	The tanks shall have a manual and an electronic pressure sensor showing the internal pressure.

ID	Requirement Description	Requirement Detail
LN6	Bulk storage level sensors	The tanks shall have an electronic level sensor.
LN7	Bulk storage sensor outputs	The output from the storage tank sensor shall be available to a computer located inside the NSTF thermal vacuum control room.
LN8	Bulk storage tank filling	During filling of the tanks any potential change required in the internal pressure and temperature shall not affect the flow rate of LN2 to the test equipment. Notes: The use of two tanks will allow one to be filled whilst the other is supplying LN2 to the test equipment. However, other configurations could be considered.
LN9	System losses	The loss of LN2 from the complete system shall be less than 0.5% per day.
LN10	LN2 flow rate	The LN2 flow rate at the end of the transfer line shall be greater than 2.5 tonnes per hour.
LN11	LN2 pressure	The pressure of the LN2 at the end of the transfer line shall be greater than 8 bar (gauge).
LN12	LN2 quality	The LN2 at the exit of the transfer line shall have less than 2% bubbles when the temperature of the SIVL is at steady state.
LN13	Transfer line connection to equipment	The transfer line shall connect to a flanged steel pipe with an internal diameter of 60.3 mm and wall thickness of 3 mm. Flange details are TBD.
LN14	Transfer line performance	The transfer line shall be designed to keep parasitic heat loads to less than 2 W/m when averaged over its entire length.

ID	Requirement Description	Requirement Detail
LN15	Transfer line environmental conditions	Parts of the transfer line will be exposed to the weather and shall be capable of operating for a period of 10 years (with regular maintenance) without loss of performance under the environmental conditions given below;
LN16	Transfer line environmental conditions - temperature	Temperature ranging from -16 to + 50 deg C
LN17	Transfer line environmental conditions - humidity	Humidity ranging from 0 to 100%
LN18	Transfer line environmental conditions - sunlight	Direct exposure to sunlight
LN19	Transfer line route	Parts of the transfer line shall be located in a trench below ground level. The trench will be protected by a load bearing cover, but it is not waterproof. The trench will have suitable drainage to avoid filling with water. Other parts of the transfer line will be above ground and exposed to the weather.
LN20	Transfer line length	The transfer line length will depend on the final route selected (which is part of the design scope). The transfer line shall start at the bulk storage tanks and extend to the LN2 inlet connection shown in AD5 located in room G.32 (see AD2). However, initial estimates indicate the line will be between 50 m and 100 m in length, with ~ 80% of the line in a outdoor trench.
LN21	Transfer line venting	The transfer line shall incorporate vents (if deemed necessary) to prevent gas locking.
LN22	Nitrogen gas generator description	A nitrogen gas generator is needed to supply pressurised gaseous nitrogen to fixed points located in clean rooms, and other areas of the National Satellite Test Facility (NSTF) . To avoid the need for refillable pressurised gas cylinders the gaseous nitrogen should be generated from the liquid nitrogen stored in the bulk storage tanks.

ID	Requirement Description	Requirement Detail
LN23	Gaseous nitrogen (GN2) capacity/flow rate	The diversified normal load shall be 115 Nl/s. Vaporisers shall be sized for this flow to be continuous. Notes: 1. Nl/s means Normal litres per second and means flow rate in normal conditions, i.e. 95 Nl/s means 95 l/s at 1 bar (absolute).
LN24	GN2 pressure	The GN2 shall be supplied at 9 bar pressure.
LN25	GN2 temperature	The GN2 temperature at the point of use shall be between 15 and 35 deg C.
LN26	GN2 availability	The GN2 supply shall be available 24 hours a day for a continuous period of 3 weeks.

<table>
<tr><td>LN27</td><td>GN2 supply points</td><td>The GN2 shall be supplied to the following locations;
<table>
<tr><th>Location</th><th>Equipment</th><th>Normal Load</th><th>Diversity Factor</th><th>Diversified Loads</th><th>Pressure</th></tr>
<tr><th></th><th></th><th>Nl/s</th><th></th><th>Nl/s</th><th>Bar</th></tr>
<tr><td>G.13 Vibration Test Hall</td><td>1 No. outlet</td><td>5</td><td>50%</td><td>2.5</td><td>9</td></tr>
<tr><td>G.14 Main area</td><td>2 No. outlet</td><td>5</td><td>50%</td><td>2.5</td><td>9</td></tr>
<tr><td>G.15 Mass properties</td><td>1 No. outlet</td><td>5</td><td>50%</td><td>2.5</td><td>9</td></tr>
<tr><td>G.22 Cleanroom 1</td><td>4 No. outlet</td><td>5</td><td>50%</td><td>2.5</td><td>9</td></tr>
<tr><td>G.27 Airlock</td><td>1 No. outlet</td><td>5</td><td>50%</td><td>2.5</td><td>9</td></tr>
<tr><td>G.28 TVAC Clean</td><td>2 No. outlet</td><td>5</td><td>50%</td><td>2.5</td><td>9</td></tr>
<tr><td>G.29 TVAC EGSE</td><td>2 No. outlet</td><td>5</td><td>50%</td><td>2.5</td><td>9</td></tr>
<tr><td>G.30 Cleanroom 2</td><td>4 No. outlet</td><td>5</td><td>50%</td><td>2.5</td><td>9</td></tr>
<tr><td>G.32 TVAC Chamber</td><td>Vacuum Chamber System</td><td>75</td><td>100%</td><td>75</td><td>9</td></tr>
<tr><td></td><td>Total</td><td>115</td><td></td><td>95</td><td></td></tr>
</table></td></tr>
<tr><td>LN28</td><td>GN2 water content</td><td>Water content in the GN2 shall have a dew point of -70 deg C.</td></tr>
<tr><td>LN29</td><td>GN2 particulate content</td><td>The GN2 shall not contain particulates bigger than 0.1 mm.</td></tr>
<tr><td>LN30</td><td>GN2 interface to distribution pipework</td><td>The Supplier shall define the interface between the GN2 generator and NSTF GN2 distribution pipework.</td></tr>
<tr><td>LN31</td><td>GN2 distribution pipework</td><td>The Supplier shall design the GN2 distribution pipework inside the NSTF building.</td></tr>
<tr><td>LN32</td><td>GN2 distribution pipework - Material</td><td>Copper shall be used for the GN2 distribution pipework.</td></tr>
<tr><td>LN33</td><td>Exhaust description</td><td>The LN2 will be used in the NSTF Thermal Vacuum Chamber (TVAC) to cool its thermal shroud. The LN2 is used to cool a stream of GN2 by direct injection into the stream, the consequence of which is that the volume of the stream increases as the LN2 evaporates and the excess volume then has to be vented. An exhaust is</td></tr>
</table>

		therefore required to safely vent the (mainly) GN2 away from the TVAC shroud cooling system. As nitrogen is an inert gas it is permissible to vent to atmosphere.
LN34	Exhaust flow rate	The exhaust shall be designed to vent GN2 at a maximum flow rate of 1700 Nm3/hr
LN35	Exhaust temperature	The exhaust shall be designed to cope with GN2 at a temperature ranging from 90 to 400 K. Water condensation (and ice formation) on parts of the exhaust line inside the NSTF building shall be minimised through the use of insulation and/or heaters.
LN36	Exhaust LN2 trap	Under certain conditions it is possible that small amounts of LN2 will be present in the exhaust stream. Therefore, the exhaust system shall incorporate a trap, with a volume of 100 litres (TBC during the design phase), to prevent LN2 from exiting the exhaust and falling on surrounding surfaces. The trap shall be equipped with a heater to vaporise any LN2 that has collected.
LN37	Exhaust location	The exhaust exit shall be located to avoid GN2 being ingested into the NSTF air handling units (located in the plant area directly above the TVAC plant room), and to minimise the risk of pockets of nitrogen forming in areas where people may congregate (i.e. at ground level). A Hazard Identification Study (HAZID) shall be performed to identify the safest location and means of venting the GN2.
LN38	Safety overview	The LN2 system shall be suitable for its intended purpose and shall conform to the appropriate design, construction and installation codes of practice. In particular, the system must conform to the Pressure Systems Safety Regulations 2000 and SFTC Safety Code No 33 (Safety of Pressure and Vacuum Systems).
LN39	Connected equipment	The LN2 system shall take into account the design of the connected equipment. Piping and Instrumentation diagrams (P&ID) of the connected equipment is supplied in Appendix A.
LN40	Pressure Relief Valves (PRVs)	Pressure relief valves (PRVs) shall be included to protect the connected equipment from over-pressure situations. PRVs shall also be included to protect the LN2 (and GN2) system from over-pressure situations.
LN41	Emergency shut-off	An emergency shut-off system shall be included to isolate the liquid transfer line from the bulk storage tanks. The emergency shut off shall be manually actuated via a remote control unit located in the TVAC plant room (room G.32 of the NSTF).
LN42	HAZOP	A Hazard and Operability Study (HAZOP) shall be performed on the final design. Any measures necessary to reduce risks to an acceptable levels shall be implemented.