



EQUIPMENT SPECIFICATIONS

Ref. DSBT-CDC-25-64-1.0 - **DEPARTMENT of LOW TEMPERATURE SYSTEM**

Version A

Date of issue: June 26th, 2025

Hydrogen liquefier

Free distribution

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1. PURPOSE

The specifications set out the supply, on behalf of CEA, of a hydrogen liquefier and a vacuum insulated storage tank for research purposes. The equipment shall be installed in a maritime-type container to facilitate transport from one site to another via road vehicle.

If the supplier is unable to draw up the required technical specifications or documents, this shall be clearly specified in its commercial bid by filling in at least the “Supplier’s Comments” area of these specifications.

2. DEFINITION

In this document, the contractor is referred to as “the supplier”.

The instructing party is referred to as “CEA”.

3. GLOSSARY

DSBT :	Département des systèmes Basses Températures – Low Temperature System Department
PMAD:	Prise en Main A Distance (Remote control access)
DCE:	Determination of Categorical EXclusion
DOE:	Dossier des Ouvrages Exécutés (As built file)
EMAS:	Eco-management and audits scheme
FAT :	Factory Acceptance Tests
GH2:	Gaseous hydrogen
LH2:	Liquid hydrogen
HMI:	Humain Machine Interface
PID:	Piping and Instrumentation Diagram
RDP:	Remote Desktop Protocol
SAT:	Site Acceptance Tests
PLC:	Programmable Logic Controller
SIF:	Safety Instrumented Functions
UPS:	Uninterruptible Power Supply

4. CUSTOMER – SERVICE PROVIDER CONTACT

The technical contacts for the basic and additional services are:

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5. CONFIDENTIALITY

The supplier undertakes to keep confidential and shall refrain from disclosing to any third party, without written approval from CEA, the whole or part of information and/or knowledge belonging to CEA or any third party, that it may obtain or may have obtained during the service performed on behalf of CEA.

6. PLANNING OF THE MANUFACTURING

The planning of the contract will be organised in two major phases:

- The study of the equipment adapted to the CEA technical specifications. This phase will be ended by the delivery of documents allowing the analysis of this phase. The supplier will have to wait the CEA acceptance before launching the manufacturing,
- The manufacturing of the equipment.

7. TECHNICAL SPECIFICATIONS

7.1 External functional analysis

7.1.1 F0-Regulation, Codes and Standards

The present function is covered in §11.

7.1.2 F1-Safety

The present function is covered in §11.

7.1.3 F2-Transportable

The equipment shall be transportable from a site to another through Europe on a standard trailer and not thanks to an oversize cargo. This constraint is mandatory and shall be taken into account during the design phase with respects of the external dimensions and maximum weight.

In order to ease the handling, the equipment shall be designed for forklift handling only.

The use of specific mechanical locking devices for the transportation shall be avoided; the equipment shall ensure the required stiffness by itself.

The design shall allow flushing and inerting easily the hydrogen circuits with nitrogen at pressure lower than 500 mbarg. In contrast, CEA would like to maintain helium circuits underpressure, with regard to the regulation that apply to the transport of dangerous goods on road. With this solution, the installation will be considered as a refrigeration machine and is exempted to specific procedure if the total mass of compressed helium is under 12 kg which seems realistic at this step of the project.

7.1.4 F3-Environnement of use

The equipment shall be designed to be used and stored outdoor or on industrial sites. As a way of consequence, specific measures shall be integrated to avoid pest damages (rodents, wasps, etc.).

The fitup and hookup of the equipment will vary from a site to another hence it is necessary to add and remove remote vent stacks (hydrogen, etc.) specific requirements are give in §11.

Specific measures shall be taken regarding the risk of lighting, the document justifying the sizing of the equipment regarding this specific risk shall be delivered to CEA. The maximum

installation slope will be indicated as the noise level at a distance indicated by the manufacturer.

The electrical equipotential bonding of the equipment must be ensured, and the equipment must be capable of being grounded at a single connection point.

7.1.5 F4–Software and instrumentation

A local Human Machine Interface (HMI) controlled by a Windows PC is required.

The equipment has to be equipped with a Programmable Logic Controller (PLC), it has to be a SIEMENS S1500 or a SCHNEIDER M580 serie or technically equivalent. It has to be possible to open the code with the Siemens or Schneider tools. The use of an equivalent equipment is possible but has to be discussed with CEA.

Some hard interlocks have to be implemented without going through the control command (example: emergency stop, the equipment has to stop quickly and safety independently of actions on the control unit). In other words, the safety instrumented functions cannot rely only on the PLC. In the same philosophy, the supplier shall demonstrate the independence of critical safety barriers that are implemented on the equipment.

An exchange memory is required to operate the equipment with another one, typically the waited information are:

- ON / OFF status,
- Pressure of the hydrogen storage,
- Temperature of the hydrogen storage,
- Liquid level of the hydrogen storage,
- Temperatures of all cold head stages.

This memory has to be updated at least every 0.1 s.

The signals have to be recorded for fault identification; the storage capacity has to be enough for six months at a one hertz frequency. The configuration of the installation has to be recorded as the alarms.

Typically, the pressure of the bath has to be regulated with proportional components to obtain a stable and precise value of this parameter.

At least the supply valves for the gaseous hydrogen and those for the liquid hydrogen have to be equipped with position sensor.

It shall be possible to control the equipment remotely through a wired connection (Ethernet ModBus TCP). The distance between the PLC and the computer is fixed to 80 m or it shall be possible to set a remote control of the computer. If the supervision stops (control computer), the system has to continue to operate safely through the PLC.

Absolute pressure sensors are preferred over relative ones. The precision of the pressure sensor has to be better or equal to 0.1 % of the full measurement scale.

For thermometers the precision has to be 0.5 % of the temperature measured.

The level of liquid hydrogen shall be monitored with two independent, reliable and accurate measuring technics.

CEA need to know the real position of all the valves link to safety during each operating phases.

About the control of the installation, if the supplier wants to perform another proposition, CEA is ready to study it even if the preferred solution is those described in this section.

7.1.6 F5-Produce liquid hydrogen

The targeted production rate of liquid hydrogen is about 15 kg/day from gaseous hydrogen bundles at an initial pressure varying from 200 to 300 barg. The connection to the cylinder rack will be made in accordance with the gas bundle European cylinder standard. The equipment will include the necessary pressure reducers and safety valves.

The equipment shall include the technology to convert the orthohydrogen to parahydrogen during the liquefaction to achieve at least 95 % of parahydrogen in the final product.

The electrical and fluidic interfaces shall be clearly identified and use fitting or connectors easily available on the market.

CEA asks as an **alternative offer** the possibility to use limited additional utilities:

- only electrical power to liquefy hydrogen from hydrogen bundles which means without liquid nitrogen precooling,
- without the use of water for the compressor cooling,
- and only gaseous nitrogen for the actuation of valves.

The exact production capacity in the storage will be indicated by the supplier and will become contractual as a minimum value. The supplier will indicate at which pressure the capacity is guaranteed.

7.1.7 F6-Store and release liquid hydrogen

The equipment shall store at least 1 m³ of **liquid hydrogen** without boil-off during at least 2.5 days without consumption. To meet this requirement an **operating pressure** up to 5 bar (to be confirmed by the supplier) is needed and will be the required pressure. An operating pressure at 10 bar is asked as an **alternative offer**.

The cool down time from room temperature to a detectable level of liquid has to be indicated by the supplier.

The hydrogen tank has to be able to resist to an external pressure of 1 barg.

The working pressure during liquefaction in the storage is an open point (greater or equal to atmospheric pressure) and will be discussed with CEA.

The equipment shall be able to ensure a release flow rate of 0.1 kg/s (1.4 l/s) with an overall pressure loss of the downstream line equal to 1 barg and 2 bara in the storage. The pressure in the storage has to be stable which means that a method to compensate the reduction of liquid amount has to be proposed by the supplier. A transfer line with an internal diameter of about 15 mm seems required. This point has to be estimated by the supplier with the real geometry of the equipment.

7.1.8 F7-Maintenability

The maintenance shall be part of the design phase of the system. The replacement of critical parts shall be as easy as possible. A maintenance plan will be elaborated and delivered to CEA. The list of the required spare parts is asked with the indication of the mean time before maintenance for each component.

It is imposed by the European pressure equipment directive but it is reminded that the list of the controls to perform to keep the equipment operational is also required. The number of

cycles to consider for the pressure risk is 5000. If another value is considered, it has to be indicated by the supplier.

CEA asks as an **option** to supply a set of kit maintenance of cold head.

7.1.9 F8-Documentation and training

The present function is covered in §12 and §14.

7.1.10 F9-Storable

The equipment will be stored between each test campaign outdoors and this need to be taken into account in the design phase. For long storage period, the liquefier will be inerted with nitrogen and it shall be an automatic procedure.

Periodic checks (leak check, visual inspection, etc.) shall be as easy as possible which means that disassembly has to be limited.

7.1.11 F10-Operation

Flushing and pumping devices will be delivered with the equipment and shall work with hydrogen and nitrogen gaseous bundles with an initial pressure varying from 200 to 300 barg.

7.2 Existing references

All competitors will be asked to give a list of existing references of such a product or of similar products. CEA will ask to see existing references either in-house or in operation at customer sites.

7.3 Material

All stainless-steel parts must be made of grade 1.4404 to mitigate the risk of hydrogen embrittlement. In addition, the supplier shall demonstrate that the ferrite content in the welds is compatible with the intended application.

7.4 Expected specifications for factory acceptance test (FAT) and site acceptance test (SAT)

All the measuring techniques deployed by the supplier shall be well calibrated for the FAT. The supplier shall be able to deliver on request to CEA all the relevant certificates of calibration.

7.4.1 Process and equipment specifications

The process and equipment specifications are described in §13.

7.4.2 Measurement equipment specification

The hydrogen storage shall be equipped with several sensors that have to be recorded:

- A pressure sensor with an uncertainty better than 0.1 % of the full scale. The full scale has to correspond to the maximum operating pressure of the storage.
- Two level probes wired to the vacuum vessel output connector, only one electronic is required for the measurement.

A set of thermometers is required as described in section 7.1.5, the uncertainty as to be 0.5 % of the measured temperature.

R"

7.5 Information technology equipment

The computer delivered with the equipment shall be set up with a Windows 11 Entreprise (24H2 version and later) Operating System and shall be compatible with the SYMANTEC Endpoint Protection 14.3 RU8 antivirus.

The hardware shall enable networking and shall feature at least network (see 7.1.5).

The acquisition data shall be supplied as result files that can be transferred onto the network. The file format must be easy to read (txt type, csv type...).

The system must have a remote supervisory system. This supervisory system shall feature a read only profile of the parameters. It shall not be possible to perform any action on the operation of the equipment.

Additional profiles will allow to make the following functions:

- User for the operating of the equipment
- Maintenance technician for the configuration of the equipment
- Administrator (only for the system administrator staff)

Remote control access of the computer equipment from the Internet shall not be authorised for the maintenance or commissioning phases. If, for technical reasons, remote control access from an Intranet be required, the supplier shall specify such requirement in its bid. It shall provide the list of all the remote actions that may occur on the equipment using the remote control access. CEA will then carry out an analysis to determine whether or not CEA grants an exception, without this being constituted as a commitment. In any case, the implementation of remote control access shall give rise to a reduction by the supplier which shall be specified in the bid. By default, the remote control access shall then be implemented via RDP (Remote Desktop Protocol) software.

In case parameters of the system can be modified, the supplier will have to indicate in the offer the elements of **analysis of security of this system of supervision allowing to demonstrate that the security of the equipment remains mastered by technical means independent from the system of supervision**. If these elements are not briefly known at the time of the offer, the supply of these elements will constitute a deliverable in the putting into service.

8. WORK ENVIRONMENT, PLACE OF INSTALLATION, SUPPLY LIMITS

8.1 Environment, Facilities

The supplier shall include in its bid the fluid requirements, electrical power supply and any other required interfaces.

The total weight of the equipment shall be included in the bid.

The liquefier will be equipped with a 5 m long insulated flexible transfer line. It is not required to be able to disconnect it from the liquefier. It will be equipped with a Johnston coupling delivered by CEA at its end. The drawing is given in Figure 1. The supplier will have to connect its liquid hydrogen pipe with the internal Johnston pipe (42.4 x 1.6 mm) and the external pipe for the vacuum (88.9 x 2 mm).

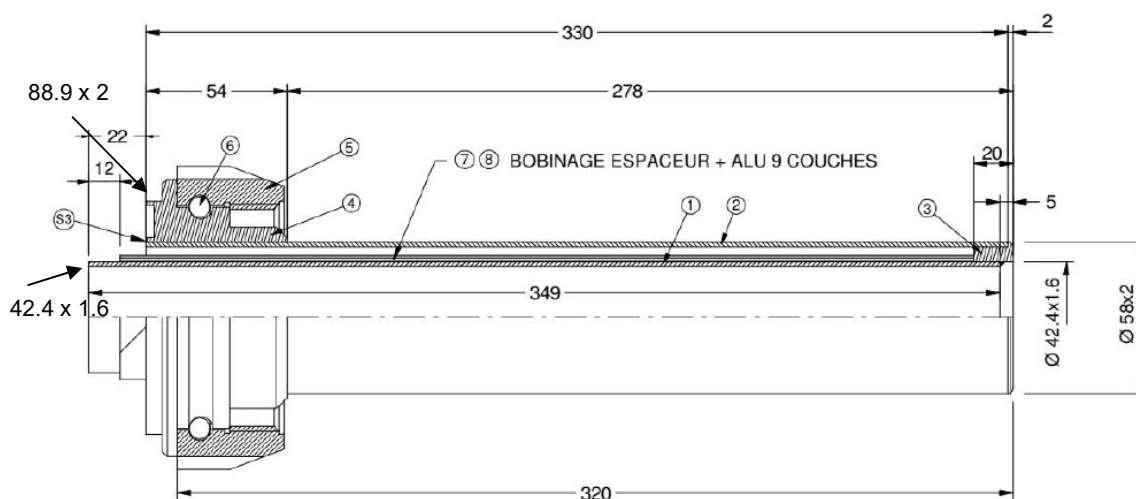


Figure 1: Johnston interface at the end of the flexible line

8.2 Delivery

Any item of equipment delivered shall bear the order number as well as the recipient's name. The supplier shall plan all measures for unloading and installing the equipment.

A user manual as described in section 12.

Delivery shall be performed between 8 a.m. and 4:30 p.m. from Monday to Friday.

The requirement for the transportation is indicated in the commercial document of the call for tender.

Unloading the equipment with a forklift must be possible.

The equipment must not be transport in an exceptional convoy.

The equipment and peripherals shall be delivered in a clean condition and packaged in a proper manner.

All transport trays, pallets and packaging crates shall be removed by the supplier as the processing of packaging waste. They are not managed by CEA.

8.3 Conditions for performing work on the CEA site (if required)

In cooperation with the supplier and its subcontractors (if any), CEA shall draw up the overall prevention plan for the equipment installation and commissioning services.

As equipment lending, including safety equipment, is prohibited by CEA, the supplier and its subcontractors (if any) shall provide the required safety equipment for preventing the specific risks caused by its work. It shall be responsible for replacement and repair of said equipment and, as applicable (without compensation from CEA), it shall train and acquaint its staff with the use thereof in keeping with regulations. Said equipment shall comply with the regulations in force and the supplier shall possess a certificate of conformity.

The supplier and its subcontractors (if any) shall provide collective safety equipment designed to prevent accidents stem from the work (marking out of the work areas, marking out of the traffic areas; marking out of the handling areas, marking out and implementation of barriers around pits, height differences, etc.). It shall perform and ensure their removal insofar as the service no longer requires the presence of marking systems.

9. LEAD TIMES

The equipment will be installed on site and received within a desired timeframe defined by the supplier.

It is possible to specify additional intermediary lead times (study file, safety file, Detailed preliminary design, etc.).

10. QUALITY

The supplier shall apply a quality management system that is of the same level as ISO 9001 for all its activities.

Any significant and/or repeated failures to comply with the specifications shall be notified to the supplier (anomaly email or improvement sheet) in order to perform corrective actions within a stipulated timeframe. In the event of failures or should said corrective actions not be performed, penalty shall be applied to the service provider in reference to the contract.

CEA Grenoble reserves the rights to inspect the effective operation of the system at any time, via quality audits which may be performed at the service provider's premises and on the CEA Grenoble site.

Any measurements taken by the supplier for acceptance tests shall comply with the requirements of paragraph 7.6 of ISO 9001 (control of monitoring and measuring devices). Should the supplier subcontract these measurements, they shall be supplied with a certificate of conformity.

11. SAFETY AND CONFORMITY

As set forth in CEA's general purchasing conditions, the supplier undertakes to consider safety as an absolute priority in the design, preparation and performance of the services subject of the Contract.

The supplier shall read and apply the "Rules applicable to outside companies working at the Grenoble centre" (refer to chapter 4, "Applicable documents").

The supplier and its subcontractors (if any), irrespective of their rank, shall apply the legal and regulatory provisions pertaining to safety and environmental protection.

The equipment shall comply with the regulations in force.

The equipment shall be CE certified, feature a "CE marking" and shall be accompanied by a CE declaration of conformity (refer to chapter 12 "Documentation").

CEA will ask to a notify body to help him to verify the conformity of the equipment with the applicable regulations. CEA personnel will participate to this inspection. The supplier shall deliver a planning with at least 2 inspection slots: end of design phase and during the FAT.

11.1 Risk analysis

The supplier shall provide a risk analysis for the equipment and include all the associated items of safety equipment, their actions and servo-controls.

Said analysis shall highlight the specific risks related to the equipment and provide substantiation for the associated protection measures. If any all-residual risks must be provided with guidances to mitigate them.

The supplier shall transmit this analysis to CEA right from the design phase (refer to § 12 "Documentation").

The supplier shall demonstrate that the safety functions are independent and sufficient. The supplier shall demonstrate in particular that the safety instrumented functions are independent on all the line: sensor(s), logic solver/safety relay, final element (actuator, etc.).

CEA has identified different errors in standard ISO21013-3 to size the safety devices. Unfortunately, these errors always underestimate the required size of these components. In consequence, they will be sized thanks to the following reference: "Techniques de l'ingénieur – BE9814". This document exists in French and English, it is provided in the annex.

11.2 Risks related to facilities and machines

The equipment shall comply with the regulations in force, especially the "Machinery" Directive 2006/42/EC.

11.2.1 Power supply disconnection and separation device

A power supply disconnection and separation device shall be provided on the equipment, for each source of energy of the machine.

11.2.2 Emergency stop

Emergency stop buttons shall feature protection against unintentional operation. See the example on the photo opposite.

11.2.3 "Service" nitrogen or compressed air connection

If the equipment uses compressed air or nitrogen to control valves or actuator, one or more bleeding devices shall also be provided to allow the residual pneumatic energy stored within the machine to be dissipated after closing the general shut-off valve. This dissipation shall be carried out without any risk for the exposed personnel.

11.3 Risks related to electricity

11.3.1 Generalities

The equipment shall comply with the regulations in force, in particular the following Directives:

- "Electrical Equipment" 2017/35/EU;
- "Electromagnetic compatibility" 2014/30/EU;
- "Restriction of the use of certain hazardous substances in electrical and electronic equipment" (2011/65/EU).



11.4 Risks related to explosion

Due to the use of hydrogen, it is not intended to run the installation in hazardous areas but the equipment can create its own one with the associated risks. A venting system is then required to collect all the hydrogen exhausts and to reject them in a safe area, the vent stack sizing and its elevation will be sized accordingly. The vent line must notably withstand an internal detonation of an hydrogen air mixture, the sizing must consider the vent line geometry and possible shock wave reflections. The vent stack has to be removable for transport or long storage. The vent line must start from a flange if the CEA wishes to extend the line for any reason. The proposed solution has to be presented to CEA in the call for tender answer.

The installation shall comply with the regulations in force, especially the Machinery Directive 2006/42/CE.

As the equipment is likely to generate an explosive atmosphere, the supplier shall perform an explosion risk assessment and substantiate the choice of certified ATEX equipment. The ATEX zoning plan as well as the certificates of conformity of the ATEX items of equipment shall be supplied to CEA.

11.5 Risks related to handling

For those parts of the equipment requiring handling (pumping units, chamber lids, covers, etc.), in particular during maintenance or installation operations, suitable lifting means shall be provided and described in the safety instructions of the equipment.

Systems integrated into the equipment shall be given preference over removable systems.

11.6 Risks related to pressure vessels

The equipment shall comply with the regulations in force, especially the following directive:

- "Pressure" Directive 68/2014/EC.

For equipment subject to this Directive, the supplier shall provide the complete design file of the equipment (drawings, design notes, etc.) as well as all necessary information to compile the operating file of the pressure equipment and allow commissioning inspection operations to be performed.

The supplier shall communicate the inspection and requalification intervals for the items which are to be inspected.

11.7 Risks related to work at height

In the event that use, maintenance or installation operation of the equipment require access at height, the supplier shall give priority to the installation of collective protective equipment (e.g.: built-in work platform with handrail complying with the standards in force) or, failing that, provide personal protective equipment (e.g.: anchoring points or lifelines complying with the standards in force). In the latter case, the technical documents shall very clearly refer thereto, so that the associated regulatory checks can be implemented.

Where necessary, the associated personal protections may be required.

These shall have been validated by CEA.

11.8 Risks related to noise

The equipment shall comply with the regulations in force, in particular the "Machinery" Directive 2006/42/EC.

11.9 Risks related to temperatures

The equipment shall comply with the regulations in force, in particular the "Machinery" Directive 2006/42/EC.

11.10 Signalling

The equipment shall comply with the regulations in force, in particular the "Machinery" Directive 2006/42/EC.

Residual risks shall be indicated on the machine by means of regulatory hazard pictograms (triangles with yellow background), accompanied by additional text when applicable. In this case, this text shall be written in French.

11.11 Regulatory inspections

CEA shall have the necessary regulatory inspections carried out by an authorised organisation of its choice, in order to verify that the supplied equipment complies with the regulations.

The Supplier shall remedy any non-conformity in the shortest time possible without being able to claim any compensation. Depending on the severity of the detected anomalies, CEA may

decide to suspend the commissioning operations until the problems have been solved (refer to Article 30 of chapter 11 of the General Purchasing Conditions).

11.11.1 Inspection of the work equipment

The equipment supplied shall comply with the regulations in force in France.

These regulations include European texts.

The equipment shall comply with the various standards applicable

The general rules specified by the "Machinery" Directive 2006/42/EC on the use of work equipment and protection measures shall be complied with.

CEA may have an inspection of the work equipment carried out at the place of manufacture by an inspection organisation it will have previously selected. The report issued further to this inspection at the place of manufacture shall be free of any non-conformity. In the event of any non-conformity which would not have been remedied, a second inspection shall be carried out after the equipment is installed on the site.

11.11.2 Regulatory electrical inspection

Once the equipment is installed on the site and prior to commissioning, CEA shall have a regulatory electrical inspection carried out by an inspection body of its choosing.

11.12 Road transportation

As the equipment will be transportable, the technical specifications must take into account the requirements of the applicable regulation, notably these given by the Agreement concerning the International Carriage of Dangerous Goods by Road (ADR), and the Transportable Pressure Equipment Directive (Directive 2010/35/EU). The design of the equipment shall ease the transportation regarding the application regulation (purging, inerting, pressures < 500 mbarg, etc.). The equipment will be transported at room temperature, with all parts free of hydrogen: the hydrogen circuits will be purged and inerted with nitrogen, which must be considered in the design. To our understanding, it will be possible to keep gas non dangerous (typically helium for hydrogen liquefaction) under pressure during transportation without specific constraint if the total mass is under 12 kg. The Supplier will have to verify this value.

The equipment shall be transportable in a standard road trailer and it must not fall into the scope of oversize transport regulation.

12. EQUIPMENT DOCUMENTATION

The supplier undertakes to provide:

- The user's manual written in French and in English.
- The servicing and maintenance manual.
- The work equipment inspection.
- The regulatory electrical inspection.
- The CE declaration.
- The equipment safety analysis and in particular the supervisory system, the safety instructions and risk identification.
- The drawings (3D model in .step format of the envelope...).
- The drawings (2D model in .pdf format of the envelope...).
- The as-built drawing and file.
- The piping and instrumentation diagram
- The electrical schemes

- The ATEX zoning diagram of the equipment, as well as the certificates of conformity of the ATEX devices.
- Any other document required by the applicable regulations.
- Instrumentation calibration certificates if any.
- Liquid hydrogen flow measurement control.
- All the documents associated to the compliance with European Directives especially the Pressure Equipment Directive 2014/68/UE.

13. ACCEPTANCE CONDITIONS

Acceptance is given after complete delivery of the equipment and at the end of the installation and commissioning operations, and after satisfactory tests by the supplier. If there were any remarks during the pre-acceptance (if it was carried out in the factory, see 11.11.1 Checking work equipment), it will be necessary to check that the solutions provided comply with the safety requirements.

Criteria for granting acceptance:

- Supply of the documents stipulated in the "Documentation" paragraph 12.
- Tests described in section 13.1 validated

The acceptance Test is organized with 2 steps (FAT and SAT).

A procedure for checking and testing the equipment must be proposed by the supplier. This procedure shall include the controls and tests required by the CEA as described in sections 13.1. and 13.2.

At the factory: Factory Acceptance Test (FAT) shall be performed at the Contractor's site based on the procedure defined beforehand and submitted for CEA approval. If there were any remarks during the pre-acceptance

On the Site: Site Acceptance Test: SAT

Criteria for granting acceptance:

- Pre-shipment receipt at the supplier's factory
- Full delivery of the equipment
- The end of the installation and commissioning operations, with supplience of the hardware report
- The qualification checks and tests successfully passed
- EC conformity approval given by the body accredited by CEA.
- Supply of the documents stipulated in the "Documentation" paragraph 12

For control on the CEA site: any tests must be defined by the CEA and validated by the supplier (number of samples, sizes, shapes), number of tests)

All the procedures and taxes for export has to be assumed by the supplier and then included in its offer.

Acceptance tests are specified in the following sections.

13.1 Process specifications

Test Number	Test Description	Specifications
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Test 1	<i>Achieve at least the contractual production mass flow rate value</i>	<i>Production under the minimum value not acceptable</i>
Test 2	<i>Demonstrate that the equipment can achieve a mass flow rate of 0.1 kg/s (1,4 l/s) during the withdrawal with a downstream line having an overall pressure loss of 1 barg</i>	<i>Mass flow rate +/- 0.01 kg/s characterised with an adequate measuring technic (for exemple Coriolis massflowmeter calibrated with LH₂)</i>
Test 3	<i>No boil-off after 2.5 days (60 hours) with a storage tank starting with a tank full at 80 % of LH₂</i>	<i>No opening of the backpressure regulator during the test</i>

13.2 Equipment specifications

As for the production capacity, some values will be defined by the supplier and will become contractual as a minimum or maximum value.

Test number	Parameter description	Specification
Test 1	<i>Energetic efficiency without liquid nitrogen (kW / l/h @ 1.2 bara)</i>	<i>Measured value < to the value defined by the supplier</i>
Test 2 (if needed)	<i>Energetic efficiency with liquid nitrogen (kW / l/h @ 1.2 bara)</i>	<i>Measured value < to the value defined by the supplier</i>
Test 3	<i>Leak test on the vacuum vessels</i>	<i>< 10⁻⁸mbar.l/s</i>
Test 4	<i>Cooldown time from room temperature to a measurable level of liquid</i>	<i>Measured time < to the value defined by the supplier</i>
Test 5	<i>Automatic process from start-up to full tank filling. This must include all purging and inerting procedures</i>	<i>no human intervention during the process</i>
Test 6	<i>Automatic transfer of LH₂ from the liquefier to the experiment</i>	<i>no human intervention during the process</i>
Test 7	<i>Automatic process to stop the liquefier. Liquid will be kept in the tank</i>	<i>no human intervention during the process</i>
Test 8	<i>Automatic process for inerting the installation when the installation is liquid free but potential still cold</i>	<i>no human intervention during the process</i>

14. TRAINING

The description on how to use the equipment, how to perform the first and advanced level of maintenance have to be described in the documentation. All these information could be explained during the FAT and SAT.