

SPECIAL TECHNICAL SPECIFICATIONS

PUBLIC CONTRACT FOR GENERAL SUPPLIES AND SERVICES

Mobile hydrogen liquefier with vacuum pump

1. Background

In order to structure its projects in the fields of education and research and to achieve an overall hydrogen (H₂) vision at ISAE-SUPAERO, the Department of Aerodynamics, Energetics and Propulsion (DAEP) intends to acquire a deployable hydrogen liquefier that can be operated at a test site.

2. Technical specifications

2.1 Liquefaction system

- **Liquefaction rate:**
 - Minimum 20 L/day, maximum 50 L/day (with liquid nitrogen pre-cooling – LN₂)
 - Minimum 10 L/day, maximum 50 L/day (without liquid nitrogen pre-cooling – LN₂)
- **Dewar capacity (storage):** minimum 100 L
- **Typical electrical consumption and voltage range:**
 - Compatible with 50 Hz: 380/415 V AC / 3-phase
- **Gaseous hydrogen requirements:**
 - H₂ with minimum purity of 99.995% (grade 4.5)

The H₂ gas storage used @ ISAE-SUPAERO is B50 metallic bottles pressures at max 200 bar when completely full.

- **System dimensions (L × W × H):**
 - Maximum: standard 20-foot container (6.06 m × 2.44 m × 2.59 m)
- **Certification:**
 - The liquefier must be CE-certified.
- **Transport:**

The complete hydrogen liquefaction system must be transportable and mobile. This requirement implies that the entire system can be loaded onto a truck and moved to a test site. Ideally, all equipment should be integrated into a container. This condition implies that the assembled equipment must fit within the container and that only electrical power and hydrogen gas cylinders (pressurized to a maximum of 200 bar) are required for operation. All subsystems related to cooling, air supply, and energy management must be included and integrated within the system.

- **LH₂ storage:**
 - The system must provide storage of at least 100 liters of liquid hydrogen, including a subsystem that integrates active cooling of the boil-off gas. This requirement implies that the boil-off gas must not be vented but instead re-liquefied.
 - A study of the safety valve system for the storage tank under rapid/severe evaporation conditions (loss of vacuum) is required and must be included in the proposal.
- **Safety:**

The liquefaction system must integrate a safety device allowing the shutdown of all electrical power sources in the event of hydrogen leak detection. This requirement implies the mandatory presence of a hydrogen gas detection system integrated into the entire liquefier. Hydrogen sensors must be installed at all potential locations where accumulation

due to hydrogen leaks could occur. From a detectable threshold of 1000 ppm of H_2 , the complete system must automatically shut down and must not supply any energy capable of igniting the leaking hydrogen.

- **Mobility:**

This aspect concerns operational requirements at any test site. Minimal external support is required for operation of the liquefaction system. It shall only require a supply of gaseous hydrogen in the form of cylinders (filled to 200 bar and containing 750 g of H_2 per cylinder) and an electrical power supply. All other subsystems required for liquefaction must be integrated within the system and the transportable container.

- **External connections and components:**

In addition to the liquefaction system, the supplier must provide all insulated piping and connections required to fill small embeddable tanks used for drones or refueling stations. The details of these connections will be defined during the negotiation phase. The supplier shall provide:

- All external connections and components required for hydrogen transfer to the refueling station, compatible with a 3-inch Johnston-Cox and Linde female coupling for liquid hydrogen.
- The fittings, piping, and pressure regulation required for the supply of gaseous hydrogen at a maximum pressure of 200 bar must also be provided with the system.

2.2 Vacuum pump

The objective is to be able to evacuate (create vacuum) for maintenance and operation all cryogenic storage tanks owned by ISAE-SUPAERO, including small tanks of 5 to 20 L, large filling stations of 50 to 250 L, as well as liquefier storage vessels of 80 to 200 L.

2.2.1 Pumping system requirements

The pumping system must allow:

- The creation of primary vacuum followed by secondary vacuum down to the high-vacuum range,
- A sufficient pumping speed for evacuating volumes on the order of 10–100 L,
- Compatibility with cryogenic environments (low temperatures, condensation risks, N_2/LH_2 atmosphere).

The system must be supplied in a compact configuration, integrating:

- A turbomolecular pump,
- A dry or oil-sealed backing pump,
- An integrated control and command module.

2.2.2 Interfaces

To ensure compatibility of the vacuum pump with all cryogenic tanks and vacuum lines of the system, the following interfaces must be provided with the equipment:

Mandatory ISO-K flange interface

The system must be able to connect to:

- DN63 ISO-K (main pumping interface on cryogenic tanks).

The following components must be provided or be compatible:

- ISO-K DN63 adapter flange,
- Appropriate clamping rings / claw clamps,
- ISO-K O-ring seal.

The overall architecture must allow rapid assembly and disassembly for maintenance operations.

ISO-KF (QF) compatibility

The system must also allow direct connection or connection via adapter to the following flanges:

- KF16,
- KF25,
- KF40.

These interfaces are required for pumping operations:

- On instrumented lines,
- On small vacuum-insulated volumes,
- During testing or maintenance operations.

The equipment must include:

- KF ↔ DN63 adapters,
- Centering rings,
- KF clamps.

ConFlat (CF) compatibility for hydrogen atmospheres

The system must be compatible, at least via adapters, with:

- CF40,
- CF63.

These interfaces may be required for:

- High-purity hydrogen lines,
- Enclosures requiring metal-to-metal sealing,
- High-vacuum operations (10^{-7} mbar and below).

The adapters must include:

- Appropriate copper gaskets,
- The necessary bolts and clamp hardware.

2.2.3 Vacuum performance requirements

The equipment must achieve:

- Final pressure $\leq 1 \times 10^{-5}$ mbar under standard operation,
- Pressure $\leq 1 \times 10^{-6}$ mbar with assisted backing pump operation,
- Sufficient pumping speed to reach these levels within a reasonable time for cryogenic volumes (typically < 10 h for 50–80 L, with no strict requirement).

No specific architecture is imposed (turbomolecular, hybrid, etc.), but performance must be verifiable through documentation.

2.2.4 Electrical and control requirements

- Mandatory local control interface (integrated screen / panel).
- Emergency stop capability.
- Operation on single-phase 230 V power supply or equivalent available on site.
- Automatic startup and coordination between the backing pump and the high-vacuum pump.

2.2.5 Required accessories set

The supplier must provide or guarantee the availability of the following items:

- Adapters for all KF, ISO-K, and CF flanges described above,
- O-ring seals and copper gaskets in sufficient quantities,
- KF and ISO-K clamping hardware,
- Power and control cables,
- Complete technical manual.

3. Deliverables

Liquefier and vacuum pump that meet the technical requirements described in this document.

Equipment **delivery and unloading** at ISAE-SUPAERO.

The storage, packaging and transport of supplies are the responsibility of the contractor, including customs formalities in the event of shipment from a country outside the European Union.

The quality of the packaging must be appropriate for the conditions and methods of transport and is the responsibility of the contractor. The packaging remains the property of the contractor.

Transport is carried out under the contractor's responsibility to the installation site. Packaging, loading, stowage and unloading are carried out under the contractor's responsibility.

Commissioning:

Installation, complete assembly, and the initial liquefaction demonstration shall be carried out at the time of equipment delivery.

Documentation:

The system must be delivered with the corresponding manuals covering operation,

maintenance, and filling services, including schematics of the system's electrical, pneumatic, and hydraulic subsystems.

Training:

Training of ISAE-SUPAERO personnel (maximum 10 people) is required. This training shall enable operational autonomy over the entire liquefaction system, including all aspects related to safety and maintenance.

COURTESY TRANSLATION