OVERVIEW OF THE AIR LIQUIDE CRYOGENIC GROUND SPACE ACTIVITIES FOR LAUNCHERS AND SATELLITES

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Air Liquide has been involved since the end of the seventies in Space activities for the development of cryogenic equipment for rocket launching pads (Kourou for Ariane 4 and 5) and ground test benches (for thrusters, satellites,..).
Recently, Air Liquide has been in charge of the upgrade of the cryogenic installations of the ELA3 launching pads in Kourou for the latest version of ARIANE 5 launcher. An overview of theses activities will be briefly presented.
The use of subcooled (densification) propellant allows to increase the capacity of a launcher. Air Liquide has provided a specific liquid oxygen subcooling for a Vinci thruster bench at SNECMA. Process design and test results will be detailed.
The use of Xenon electrical propulsion thruster is a recent development in satellites technologies. Air Liquide has developed an original mobile high pressure (up to 150 bar) cryogenic thermal compressor for the filling of Xenon tanks on board satellites. Air Liquide also developed large pumping capacity cryopumps for Xenon trapping in thrusters test chambers. This specific development will be presented.

ON-SITE INSTALLATIONS

Launching pads for the Ariane rockets (Kourou)

The main functions of cryogenic installations for launching sites are production, storage, distribution and treatment of fluids used on launchers and thruster for the propelling (LH2 and LOX), pressurisation (Ghe), purge, inerting and cooling down (LN2, Lhe). The following equipment was supplied and installed by Air Liquide :

- An LH2 cold box for production on site production (33000 l/day)
- Fixed or mobile storage tanks from 10m^3 to 360m^3 for LH2, LOX, LN2 and LH2
- 250 bar compression station of GN2
- vacuum insulated flexible or rigid lines and valves boxes for liquid or gaseous fluids (O_2, H_2, N_2, He)

For the latest upgrade of the pad complex n°3 to be integrated in the Cryo-technical Upper (CSS) of ARIANE 5, study, manufacturing and assembly of the following equipment were carried out over the last 2 years :

- Fixed or mobile storage tanks from 10m^3 to 360m^3 for LH2, LOX, LN2 and LH2
- 1200 m of vacuum insulated lines for liquid and gaseous O_2, H_2, N_2 and He (Internal diameter from ½" to 4")
- 22 skids and panels with some 120 valves (among which 110 are cryogenic ones)
- 30 m^3 storage tank for LN2
- Vacuum insulated flexible elements and supports dedicated to the so-called “cryogenic arms”.

These Super Insulated flexible lines required some very specific development to comply with customer requirements presented above :

The main requirements are :

- high flexibility to limit the forces on the launcher interface (F<800 N)

- compatibility with kinematic of the arms
- compatibility with high temperature and aggressive chemical environment due to the booster (T>450°C)

Cryogenic arms

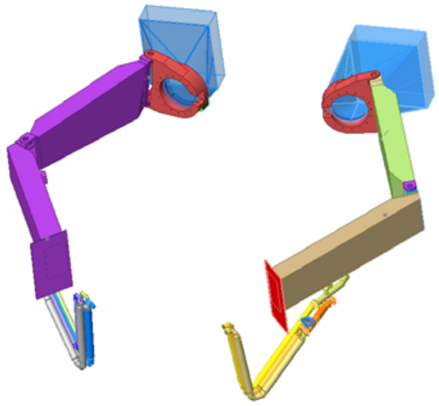

FIGURE 1 LO2 and LH2 arms

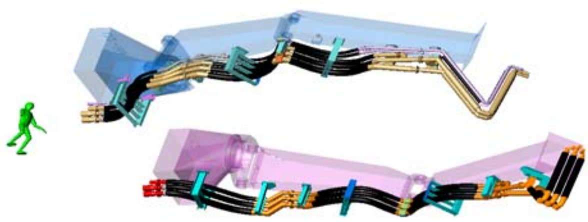

FIGURE 2 Cryogenic arm of Ariane 5

To achieve all the technical requirements, a first specific test campaign was carried out during the project in order to :

- measure the stiffness of double flexible envelop
- use these values for customed software modelisation to evaluate the forces on the launcher interface
- characterize the stiffness of manufactured vacuum insulated flexible pipes
- measure the resulting forces on the launcher equipment with the integrated overall system in a qualification step

A second test campaign test was carried out for validating the kinematic of the arms on a scale 1:1 dummy assembly.

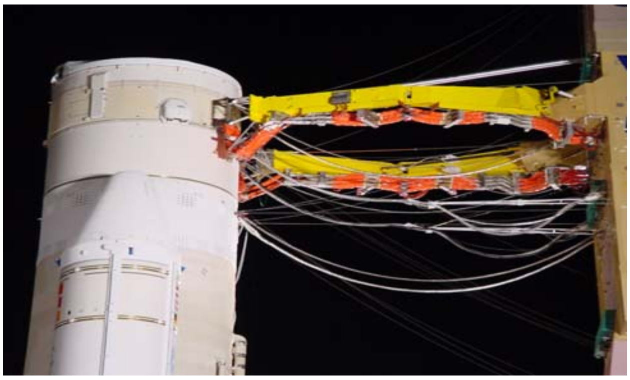

FIGURE 3 Cryotechnical Upper Stage arms

Specific covers were developed for protecting flexible elements against high temperature and aggressive chemical environment due to the booster. Some samples were tested during the launch of the Ariane 5 rocket.

All the requirements were fulfilled and validated during a final validation test campaign carried out by the customer for the first Ariane 5 Cryotechnical Upper stage.

TEST INSTALLATIONS

Cryogenic LH2/O_2 thruster test benches

Several Test benches are in operation in Europe for the qualification and the validation of Ariane motors. The main functions of cryogenic installations for test benches are similar to those for launch pads.

The Air Liquide last activities concern conception, fabrication and assembly of cryogenic sections to adjust test benches to the CSS requirements including also the limitation of resultant forces on thruster interface and specific equipments for filling tank storage with subcooled propellant.

The use of subcooled (densification) propellant allows to increase the capacity of a launcher. Air Liquide has designed and installed a specific liquid oxygen subcooling for Vinci motor test bench at SNECMA. A 20 m^3 storage tank is filled (1 to 2 l/s) at 88K with LO2 initially stored at 100K. The process design and test results are presented here after.

Development of a subcooler device for spatial application

In order to perform ignition tests of rocket motors in subcooled conditions, SNECMA needed a device which enables to fill O_2 tanks with a well controlled temperature fluid (T = 89 +0/-0.5K). As the liquid O_2 is delivered from mobile tankers at a temperature between 90 and 105 K, a process based on a by-pass principle was developed to produce the good conditions at the entry of the tank.

The figure 4 presents the process : the “hot O_2” (~2 kg/s) is separated in two flows. The main flow crosses a subcooler filled with liquid nitrogen at ambient pressure (T=77K) and the second one is by-passed. The two fluids are collected, cross a static mixer and are supplied to the tanker. The valve which controls the flow in the subcooler is regulated from the temperature measured just downstream the mixer. During the operation, the subcooler is fed continuously from a LN_2 mobile tank through a valve controlled by a level measurement.

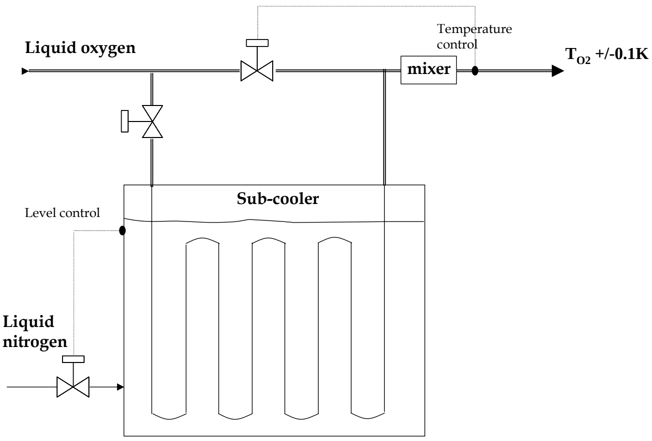

FIGURE 4 The subcooler process

FIGURE 5 The subooler

During the filling phase, the temperature of the O_2 flow was controlled with a 0.1 K precision. The device enables to produce subcooled O_2 liquid in the range [83-90K].

As the process is installed on a mobile skid, and the connection with the tank is flexible, it could be used in different locations on the customer’s site.

Simulation chambers

For Satellites tests, it is required to create space environment in simulation chambers. The Air Liquide is concerned about the supply of turn key cryogenic installations including equipments as cryopumps (from DN250 to DN1250), thermal panels (30KW at80 K) and thermal generators (4 kW at 100 K GN2), all compatible with 100 cleanliness class.

FIGURE 6 Thermal panels

Satellite instruments test bench

For the purpose of simulating the low temperature environment of IASI (meteorological and environmental satellite instrument) during ground tests, Air Liquide delivered to Alcatel Space two cryogenic loops:

- the first one, under operation at Alcatel Space Cannes, has a cooling capacity of 20 W @ 20 K,
- the second one, under operation at ESTEC, has a cooling capacity of 20 W @ 30 K

Each loop is based on the following principle:

- One cold box providing a gaseous helium flow of 4 g/s, and the refrigeration power (1 or 2 cold heads)
- A test panel, cooled by the helium flow, compatible with the cleanliness and vacuum requirements of space test chambers. It provides unique radiation capabilities at low temperature (absorbtivity better than 0,95 @ 20 K), thanks to the pyramid like shapes jointly developed by Alcatel Space Cannes and Air Liquide.

FIGURE 7 View of the test panel under mounting, courtesy of Alcatel Space Cannes

- Low temperature flexible transfer lines between the cold box and the test panel, with heat inputs lower than 0.1 W/m on the helium flow.

Operational advantages of this solution are: no liquid helium consumption, storage and waste, easy management of the test ("on-off" operation, limited training) and limited staff.

Xenon Cryopumping of the satellite motors testing benches

The xenon motors which are mainly designed to correct the position of satellites must be subjected to endurance testing before integration. These tests are performed in a vacuum chamber after cryopumping of the xenon gas ejected by the thruster. Air Liquide has studied and delivered two testing chambers with xenon cryupumps (dia 2,20 m) for 1300 W motors:at at CNRS Orléans and SNECMA Villaroche.

FIGURE 8 The Xenon motor

The following results were obtained

- Xe flow: m(Xe) = 5,4 mg / s
- Voltage supply: U = 300 V
- Output current : Id = 4,2 A
- Average electrical power :Pel = 1300W
- Total Xe pressure with motor ON:
  P (Xe) = 2,5.10-5 mb

In 2003, Air Liquide has studied an extension for these casings to be produced in 2005 for 6000 W motors.

The following performances must be obtained :

- Xe flow: m(Xe) = 20 mg / s
- Average electrical power: Pel = 6000 W
- Total Xe pressure with motor ON: P (Xe) = 2,5.10-5 mbar