CRYO SCOPE

THE AIR LIQUIDE ADVANCED TECHNOLOGIES MAGAZINE #57

20 years!

eMag

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AIR LIQUIDE

Creative Oxygen

editorial

EXPLORATION

From the infinitely large to the molecular level;
from outer space to inside our homes, Air Liquide is constantly developing new technologies, exploring new territories at the crossroads of new usages – in perpetual exploration.

Exploration today: our business is increasingly oriented towards the general public. Taxis that run on hydrogen, planes fitted with first aid oxygen, delivery trucks' refrigeration units that run on nitrogen...
There is also biomethane that powers vehicles and supplies homes and industries with electricity...
Concrete solutions for our daily lives.

Xavier VIGOR
CEO of Air Liquide advanced Technologies

Exploration tomorrow: the ITER program with its cryogenic system that matches the scale of the project, the Exomars mission for the exploration of Mars. De-polluting airports by using hydrogen as a source of energy. Projects that echo the challenges raised by COP21. We are improving and consolidating our knowledge; our advanced technologies are serving new markets... The range of possibilities is constantly growing!

Pierre-Étienne FRANC
Vice President, advanced Business and Technologies, Air Liquide

**Discover the 2016 version of Cryoscope print and enriched digital versions.
For its 20th anniversary, Cryoscope is beginning a new chapter, but it is still at the heart of Air Liquide, whose business philosophy can be summarized in one word: exploration.**

IN BRIEF

COP21

Air Liquide present at the Solutions COP21 exhibition

While COP21 brought together politicians and experts in search of a global accord on the climate, December 4 to 10, 2015, the Grand Palais hosted the Solutions COP21 climate experience.

In the interest of putting forth specific ideas, the organizers brought together more than 500 bodies working to promote the energy transition: non-profits, scientific organizations, institutional players, and businesses. Under the famous glass canopy, Air Liquide demonstrated its commitment to the energy transition, presenting its solutions in the areas of hydrogen energy, biomethane, and refrigerated transport.

Recharged at the first Air Liquide station installed in Paris, the hydrogen-powered electric taxis, launched in the French capital for this occasion, illustrated the group's efforts to promote clean transport. Biogas solutions designed to make biomass a renewable source of energy could replace fossil fuel gases and reduce greenhouse gas emissions. Visitors to the Grand Palais were able to become acquainted with the Air Liquide approach, from the purification of the biogas released by methanation plants to its enhancement as methane, injected into the gas grid or vehicle fuel.

The third innovation showcased was *Blueeze*. Concept: decrease the consumption of fossil fuels used by refrigerated trucks by fueling their cooling units with cryogenic nitrogen, while also lowering CO_2 emissions and noise pollution. Here too, Air Liquide proposes an integrated solution that encompasses the fueling station, the cooling unit for the trucks, and related services.

The COP21 Solutions exhibition attracted 42,000 visitors. Taking part in it and meeting people who are looking for effective solutions for the planet was fulfilling and galvanizing.

COP21

Using hydrogen to make aviation more sustainable

Because aviation already accounts for 2% of global emissions of CO_2, and forecasts suggest that this figure could rise to anywhere from 3 to 5% by 2050, the Solutions COP21 initiative wanted to start a conversation about the issue.

On December 9, the roundtable discussion *"Towards more sustainable aviation"* brought together several players with solutions designed to mitigate or adapt. Air Liquide, represented by Pierre Crespi, Head of Innovation at Air Liquide advanced Technologies, spoke alongside panelists from KLM, Safety Line, Aerospace Valley, Evolution Energie, and the University of Utrecht. The debate, which covered technological economic, and organizational aspects, was moderated by representatives from Climate-KIC, the principal public-private partnership in Europe promoting innovations related to climate.

Pierre Crespi presented the hydrogen-based solutions explored by the group. *"Aircraft require more and more electricity. The question is how to generate it? Using its reactors and kerosene is far from optimal, especially on the ground. Airplane and parts manufacturers are considering the use of fuel cell systems, a promising solution on many levels. During the roundtable discussion, we talked at length about an example of how using a fuel cell system could substantially decrease CO_2 emissions and cut down on kerosene by 5-10%: power the airplane by electrical engines. At the Frankfurt Airport, this innovation allowed medium haul flights alone to save almost 50 tons of fuel daily now and 100 tons in 2035! To ensure the success of these projects, the first challenge is to fly using a fuel cell system.*

The second challenge is to deploy the hydrogen infrastructure in airports by building mobile charging stations capable of fueling airplanes with gas or liquid hydrogen. These stations could also fuel some ground vehicles or generators. Air Liquide is the only player in aeronautics that masters the entire hydrogen value chain, from the fuel cell system to the hydrogen charging station, not to mention the onboard tank and the supply of gas. The road to innovation is a long one. In aviation, this is all the more so in that, in addition to the technological and logistical obstacles, safety must be guaranteed. This roundtable discussion did show that a community fighting against global warming is active in this area. In addition, Air Liquide, in partnership with several of the sector's industrial players, is working on several projects that will see the light of day this year."

"The first challenge is to fly using a fuel cell system."

VIDEO AVAILABLE ON-LINE
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HYDROGEN

Air Liquide hosts a delegation from IPHE

On December 2, 2015, the Sassenage site had the pleasure of hosting a delegation from IPHE (International Partnership on Hydrogen and Fuel Cells in the Economy), which traveled to Grenoble to hold its annual colloquium. Established in 2003, IPHE now counts 18 member countries. It works to accelerate the transition to a hydrogen economy. The 40 invited guests began their visit by learning more about Air Liquide's hydrogen and biogas activities. Under the winter sun, the tour then took them to other sectors in which Air Liquide is invested: cryogenics, aeronautics and space. Thanks to this encounter, the delegation from IPHE came away with an appreciation for the diversity and technological value of the various businesses of the group.

FIRST

The first hydrogen charging station in Paris: *go* for clean taxis running on hydrogen

Since December 2015, Parisians have the option of getting around in a taxi that runs on a clean and renewable energy: hydrogen!

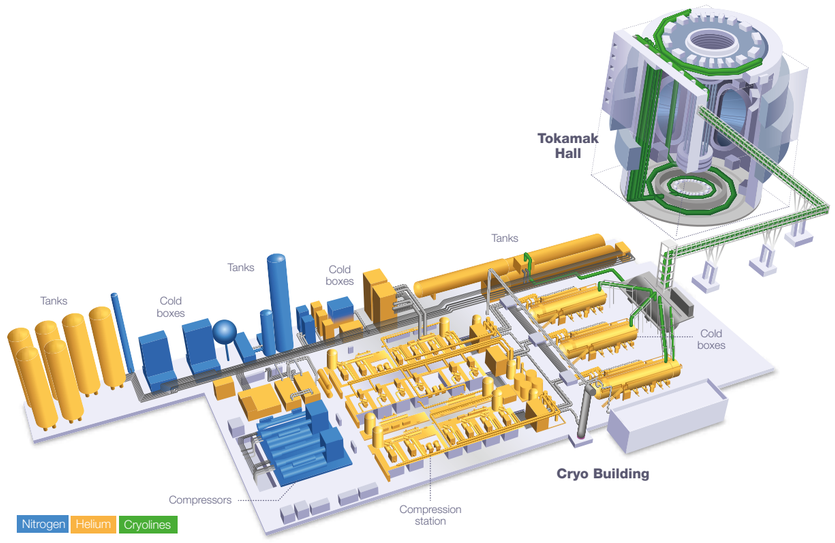
Recharged in 5 minutes at the hydrogen charging station at the Pont de l'Alma parking garage, these brand new electric taxis from the hype fleet can go for 500km. At the origin of this novelty is the project carried out by the start-up STEP - for Société du Taxi Électrique Parisien – and the first hydrogen charging station in Paris inaugurated by Air Liquide in time for COP21. The fleet, which was launched with 5 cars, should have 70 by the end of 2016 and several hundred in 5 years. In parallel, the supply network provided by Air Liquide will increase as demand rises.

The hydrogen is used to fuel the car's onboard fuel cell system. Combined with oxygen from the air, it produces electricity and generates only water as a byproduct. Mastering the entire supply chain for hydrogen, the Air Liquide group is participating actively in the effort to win broad acceptance of this clean fuel. To date, Air Liquide has already designed and installed 75 hydrogen charging stations around the world. On the occasion of this Paris premiere, François Darchis, member of the Air Liquide Executive Committee supervising innovation, noted: "*This project further illustrates Air Liquide's commitment to the deployment of hydrogen technologies that support both sustainable mobility and environmental protection*". Aboard, clients said they were delighted with the comfortable, silent ride that was non-polluting to boot. This environmental aspect also won over the Paris Mayor's Office, which is supporting the project.

ITER : the energy of tomorrow

AIR LIQUIDE AND ITER, AT THE BORDER BETWEEN INDUSTRY AND SCIENTIFIC RESEARCH

ITER will explore the possibility of using fusion as a source of energy. The contributions of Air Liquide to this ambitious project reaffirm its expertise in state-of-the-art cryogenics. More fundamentally, these contributions consolidate its position as a preferred partner for large-scale global scientific projects and for the development of the energy solutions of tomorrow.



VIDEO AVAILABLE ON-LINE

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The Cadarache cryogenic factory,
the world's largest, will be three times bigger than the biggest one, which was built by Air Liquide. It will be composed of three helium refrigerators, two nitrogen refrigerators, with their own dedicated storage, and 19 cryolines.

ITER stands for International Thermonuclear Experimental Reactor. In Latin, the word ITER means path or way. Last but not least, ITER is one of the avenues chosen by scientists to try and respond to the challenge of supplying humanity with sustainable energy. Against a backdrop of steadily rising energy needs, the exhaustion of non-renewable resources, and the likely indelibility of our negative environmental impact, ITER is exploring a sustainable, non-polluting solution to this challenge. The ITER program, carried by 7 members, where 35 states collaborate, is aimed to demonstrate the scientific and technological feasibility of fusion power for energy purposes. Nearly 30 years after the beginning of the international scientific collaboration, the reactor's construction began in 2010, in Cadarache (France). The world's biggest tokamak[1] – with a plasma volume of 840 m^3 – must still be assembled before the experiment actually launches, which is planned within the next ten years. The ITER program also integrates a Broader Approach, via complementary experimental projects outside of Cadarache, in order to make fusion a viable source of energy for humanity.

Cryogenics: expertise at the service of fusion

Extremely cold temperatures are required to create very strong electromagnetic fields, indispensable for the conditions of fusion. Air Liquide has substantial expertise in the area of very low temperatures. In addition, the company possesses recognized savoir-faire in the design, fabrication and installation of large capacity gas liquefaction and refrigeration systems. It has already completed impressive cryogenic installations, notably for the CERN's Large Hadron Collider in Switzerland, which is the world's largest liquid helium production unit, in Qatar, and the South Korean tokamak known as KSTAR. Thanks to the magnitude of these achievements and to the company's earlier experiences in the field of fusion, the ITER project called on Air Liquide. First mission: provide ITER with a centralized helium cryogenic plant… the largest ever designed. Other requests followed, for cryogenic lines, or on behalf of the project's Broader Approach. All in all, this adds up to an important acknowledgement of the industrial expertise of Air Liquide and the talents of its development teams.

On average, the helium refrigeration units will provide a global cooling capacity of 75kW to 4.5K, which translates into a maximum liquefaction rate of 12,300 liters/hour. They will be completed by two nitrogen units (LN_2). The 11 helium and nitrogen gas storage units - with a total capacity of 3,700 m^3 (of which 3,300 m^3 for the helium) - will help to optimize the recovery of fluids in the various operational phases of the tokamak.

With high tech cryolines

Air Liquide's experience on the CERN project led the ITER project to call on the company for another facet of the project. ITER-India, responsible for the successful execution of the project by India and responsible for the management of the corresponding equipment, asked Air Liquide to design and fabricate 19 cryogenic lines, which will complete the Cadarache cryogenic plant by distributing the cooling power needed for the ITER equipment to run. Dedicated to helium, this 1.6km long network will link the cryogenic plant to the tokamak between 2017 and 2019. Since some of the lines will need to function at temperatures close to absolute zero, the elaboration of a system like this requires a sophisticated design and the implementation of high tech fabrication processes.

State-of-the-art technology for state-of-the-art science

Projects of this scale demand innovations on the part of Air Liquide and its subsidiaries, both in terms of equipment design and in terms of their industrial production. François Darchis, member of the Air Liquide Executive Committee supervising Innovation, states: "*The contribution of Air Liquide to the ITER program illustrates the level of confidence in the expertise and know-how of our teams in the area of very low temperatures, but also in the design and fabrication of large-capacity cryogenic units. The involvement of all the Group teams invested in ITER has already enabled us to pass the first milestones successfully.*"

Helium cold box

[1] Tokamak: this Russian acronym means toroidal chamber with magnetic coils and designates an experimental machine designed to harness the energy produced through fusion. At the heart of the tokamak, a ring-shaped chamber houses the plasma, confined and controlled by very powerful magnetic fields, created by the extreme cooling of the superconductors.

[2] Plasma: fourth state of matter, where the atoms of a gas separate into electrons and neutrons, achievable at very high temperatures.

[3] Deuterium, Tritium: isotopes of hydrogen, each with one proton, but with one and two neutrons, respectively. Deuterium is widely available in nature. Naturally occurring tritium, which is radioactive, is relatively rare on Earth but is produced by reactions used in nuclear power plants. Its radioactivity only poses a danger if it is inhaled or ingested and, à priori, only to the cells that it penetrates.

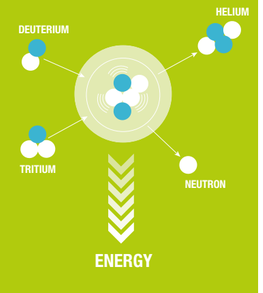
Cooling 10,000 tons of superconducting magnets that will control ITER's plasma, is crucial to the success of this ambitious scientific challenge. Air Liquide will contribute to this success by providing some of the highly technical equipment.

The largest cryogenic plant

Cooling 10,000 tons of superconducting magnets that will confine the energy generating plasma[2] is indispensable to the proper working of the ITER tokamak. The cryogenic factory dedicated to this end is a request from the ITER Organization and Fusion For Energy (F4E), the EU organization managing the European contribution to the ITER project. Its design, mobilizing more than 100 employees of Air Liquide, began in 2013 and is now in the fabrication phase. The Cadarache installation is scheduled for 2017. This impressive centralized cryogenic refrigeration system will be composed of helium (He) and nitrogen (N_2) refrigeration units and dedicated storage, functioning in a closed loop. Helium, which is capable of reaching a temperature of close to absolute zero (-269°C, or 4.5K), will be used to cool magnets, vacuum pumps and certain diagnostic systems. Nitrogen, whose temperature (-196°C, or 77K) is not quite as low, will contribute, among other things, to the cooling of the heat shield and the pre-cooling of the helium refrigeration unit and the helium loops. The site's three helium units (LHe) will occupy 3,000 m^2 of the 5,400 m^2 set aside for the ITER cryogenic unit. LHe is composed of several compression stations and 3 large cold boxes, which weigh 135 tons each, measure 21 meters in length, and have a diameter of 4.2 meters.

Fusion

In nature, fusion is the energy source that fuels the stars. It results from collisions of hydrogen nuclei, which, under these extreme pressure and temperature conditions, free up a lot of energy. Under experimental conditions, fusion is carried out with hydrogen's cousins, deuterium and tritium[3]. The goal is to recover at least 10 times the energy consumed ($Q \geq 10$). To do so, three conditions must be met: a temperature of around 150 M°C, great particle density, and long confinement of the energy. Fusion thus requires that gas be transformed into plasma. This is done inside a tokamak, where this hot plasma is confined and controlled by strong magnetic fields created by superconducting magnets. It is to ensure a temperature of close to absolute zero, indispensable for these superconductors, that ITER needs state-of-the-art cryogenics. About 80% of the energy released, carried by the neutron, is absorbed by the walls of the tokamak. This creates heat, which will produce steam, which in turn will be converted into electricity using turbines and alternators.



Name: ITER

ITER is one of the world's most ambitious energy projects. The experiment is expected to demonstrate the scientific and technological feasibility of fusion as a source for producing electricity that does not release CO_2 and that can be used on a large scale.

PLACE:
In France, Cadarache, Saint Paul-lez-Durance, Bouches-du-Rhône.

MISSIONS:

1. Produce 500 MW of fusion power, with a Q ratio of 10, a record never before reached.
2. Pave the way for the industrial demonstrators of the future.
3. Produce a self-sustaining deuterium-tritium plasma, unlike the current combustion-sustaining plasma.
4. Experiment with the production of tritium.
5. Demonstrate the safety of a fusion system and the absence of impact on people and the environment.

Dr. Biswanath. Sarkar, Project Manager, ITER-India

"The cryogenic system of ITER is, after CERN, one of the most complex systems known to date. ITER India teams are happy to be associated with Air Liquide teams in this technological and scientific adventure, to provide the cryogenic lines that will deliver helium at different temperatures from the cryogenic plant to the tokamak, and bring it to the necessary conditions for the realization of the plasma."

Jean-Marc Filhol, Head of ITER Department, Fusion for Energy

"The collaboration between F4E and Air Liquide is pushing back the frontiers of science and technology, and is making European industry more competitive. Thanks to the expertise of Air Liquide and the involvement of F4E, Europe will supply the additional equipment needed to enable the unprecedented cryogenic cooling and distribution system for ITER to function."

Heads of helium tank

4 questions to…

Sergio Orlandi, Head of Department Plant Engineering - ITER Organization

Could you explain in few words the ITER program?

ITER is the way to re-create the energy of the sun on the earth; this represents our major challenge. We are going to test the fusion reaction in order to produce approximately 500MW of power to attain an amplification factor of Q > = 10. This is a challenge that I am sure is achievable. It is for this reason that the plant has a complex configuration: nothing is usual, even the simplest things. Everything we do on ITER surpasses the current technological knowledge that we have collectively. We are achieving an important level of progress for humanity.

What is a tokamak? What is the cryogenics system interaction with the tokamak?

The tokamak is a Russian-origin technology using magnetic fields to confine fusion. The plasma reaction happens at 150 Millions°C, so the plasma reaction is confined in the center of the vacuum vessel. The ITER magnets will be cooled with helium at 4.5K (-269°C) in order to operate at the high magnetic fields necessary for the confinement of the plasma. They will be surrounded by a large cryostat and a thermal shield with a forced flow of helium at 80K (-193°C). A cryoplant on the ITER Platform will produce the required cooling power, and distribute it through a complex system of cryolines and cold boxes. All this is done by the cryogenics system.

Why have you selected Air Liquide as a supplier?

We were looking for a company that could assure, in the long term, the necessary assistance and capacity to manage such a complex system, ensuring the required flexibility – and that would also have an understanding of the variables that could change during the completion of the system design. We were also looking for a reliable partner in terms of financial solidity and technical knowledge and experience. Furthermore, the chosen company has to have the continuous flexibility to adapt to system changes and client's requirements, as the cryogenic system is intended for the most important system of this plant being the magnets.

Could you talk about your partnership with Air Liquide?

Air Liquide is the major industrial partner that we have in ITER for the cryogenics system. Air Liquide's team is fully involved in the design, procurement, installation and commissioning of the liquid helium system. It has been selected as an industrial partner also by Fusion For Energy for the nitrogen unit and auxiliary systems up to installation and commissioning. We are discussing the possibility of an integrated strategy for installation and how to manage properly the commissioning to assure proper operation of the system. For ITER, Air Liquide is an industrial partner and not just a supplier. We have succeeded in creating a very fruitful cooperation, which at the end we believe will bring solutions and positive results.

Broader approach

JT-60SA
Air Liquide advanced Technologies contributes to the JT60SA, project, result of a collaboration between japan and Europe, on behalf of the CEA (the French Alternative Energies and Atomic Energy Commission) by supplying a helium refrigeration unit for the Japanese tokamak that should be done by the end of the year. Baptized JT-60SA, Japan Torus - Super Advanced, this tokamak is designed for the optimization of the performances, the control, and the duration of the plasma phases. It is paving the way for the pre-industrial reactor DEMO, the successor to ITER. The challenge is to satisfy Japanese standards pertaining to seismicity.

IFMIF EVEDA
IFMIF (International Fusion Materials Irradiation Facility), currently in the EVEDA (Engineering Validation and Engineering Design Activities) phase, is one of the three pillars of the broader approach between Europe and Japan. This source of neutrons, located in Rokkasho (Japan), generated by an accelerator, was designed to test the materials under conditions simulating what actually happens inside a tokamak. Thus, it completes the ITER approach, preparing for the exploitation of fusion. Air Liquide provides the helium refrigerator that is indispensable to the success of this experiment.

AURÉLIEN MOUREAUX, on another planet

Aurélien is a product manager at Air Liquide. His universe is the Universe. Outer space. For 3 years, the ExoMars mission has been at the center of his work. The goal is to mobilize technical competencies and business specific know-how in order to eventually analyze the gases collected. It's true that Aurélien sometimes sees red. Like the planet of the same name. But the cause is a worthy one: ExoMars is a demanding and exciting subject.

How long have you been working on this project?

Air Liquide has been working in partnership with LISA (Laboratoire Interuniversitaire des Systèmes Atmosphériques) on ExoMars since 2008. Given that outer space exploratory missions are tentacular and that development times are measured in decades, this is a short deadline for developing products driven by innovative technology. During this period, the project has undergone numerous evolutions. So it is a huge challenge.

What exactly is Air Liquide's mission?

Its mission is twofold. First, fabricate innovative, high-performing components on the instrument of the gas chromatograph[4]. As for helium management, we are producing a storage tank, flow regulation valves, and on/off valves. Our second mission is business specific. We provide the expertise for the development and fabrication of other components of the chromatograph. Traps and heated tubes, with integration assistance (soldering and welding). We also do prototypes, testing and qualification. At Air Liquide, several teams work fulltime on these subjects.

How is the collaboration with your customer going?

With respect to these technologies, we are growing at the same pace as the customer. In addition, we write the specifications together. Interaction and exchanges are very important and the complex elements are eventually mastered. We are developing together, and adapting to changing needs. For example, we suggested miniaturizing the heated tubes, which brought into play expertise that went beyond the customer's initial expectations.

"You can't imagine the issues related to a simple on/off valve!"

What problems were encountered?

The first technical glitch we ran into was that the on/off valves were using too much electricity. In outer space, electricity consumption is limited by solar panels, which means the same is true for a rover, which is a moving probe. Mars rotates and the panels are not always lit. With so many instruments running, the energy constraints are considerable. We had to adapt.

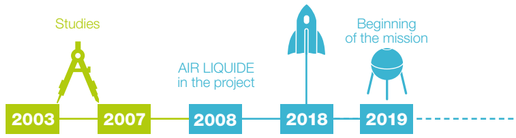
How has the project evolved to date?

Today, the qualification models of our 3 components (storage tank, flow regulation valves, and on/off valves) have been fabricated. They are strictly similar to the flight models and will undergo the same life cycle and uses as the final models. They will vibrate as they would vibrate if they were in the rocket at liftoff. They will be pressurized and they will cycle in temperature at the level of both hot and cold, as they would during a Martian day or night. Then the flight models will be fabricated and tested to ensure they are in good working order. After that, the spare model – identical to the flight model – will be made, though it will remain on Earth. It will be used to help us resolve from here any problems that come up there. The fabrication of the spare model this spring will mark the end of the project for us.

What is the schedule for the ExoMars mission?

The launch will take place in 2018. The actual voyage out will take about nine months, followed by a few orbits around Mars, the separation, and the descent. Then we will get the rover rolling. We won't be using the instruments before mid to late 2019: lots of verifications will be carried out before then.

A FEW DATES ABOUT EXOMARS PROJECT



The impact will certainly go beyond the ExoMars mission…

The components developed will be reused in other contexts. In particular, the helium flow regulator, which will be adapted for electrical thrust. If there is one thing I dream about at night, it is that every satellite launched into orbit has this component on board!

What's your current state of mind?

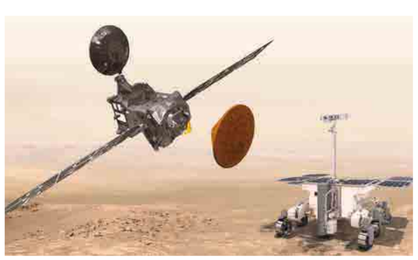
I have several projects going in parallel under my project leader hat, but this one is coming to an end. So the phase we are in right now is… intensive! We are finally seeing the outcome of all our work. For me, this is the most exciting project at the moment.

For more information on the ExoMars mission: exomars.cnes.fr

THE ROVER EXOMARS

- **310 kg**
- **9** SCIENTIFIC INSTRUMENTS
- **2** METERS subsurface drill capacity

1 YEAR ON MARS = **687** EARTH DAYS



[4] An apparatus that is used for the separation of the constituents of volatile gas mixtures.

OXYGEN FOR AERONAUTICS

AIR LIQUIDE IN THE SOLAR IMPULSE ADVENTURE: creativity around oxygen

For human beings, oxygen is life. The Solar Impulse pilot flies his plane at an altitude of more than 3,000 meters. Making sure he has oxygen thus becomes vital. Air Liquide puts its savoir-faire to work.

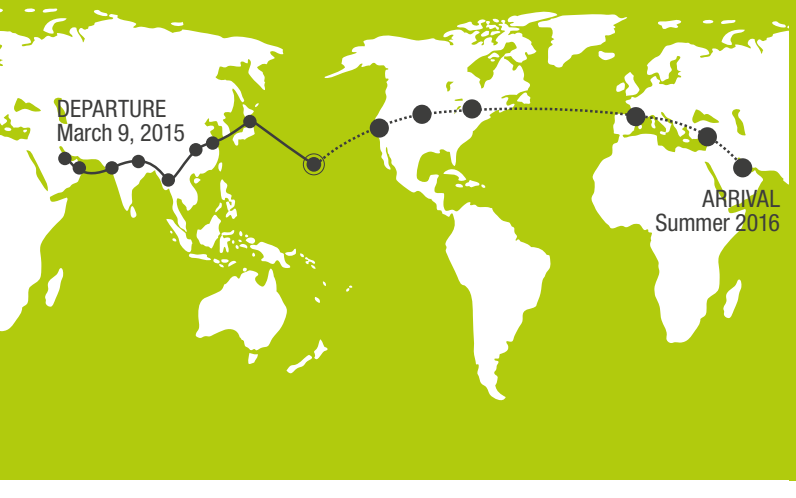
An adventure whose aim is to show that clean technologies can change the world, Solar Impulse brings numerous technologies together to serve a vision. Founded by two Swiss pioneers, this project's fascinating draw comes both from the spirit of exploration and science of the Piccard family, which produced Chairman Bertrand Piccard, and the managerial, technophile and humanist strand of its CEO, André Borschberg. The idea for this aircraft, which would fly nonstop around the world without fuel, began to develop in the mind of Bertrand Piccard in 1999, just after he had successfully flown around the Earth in a hot air balloon, the tank running on empty. The two founders got together in 2002. The project took off. The first prototype, Solar Impulse 1 (Si1), came to light in 2009 and completed its maiden night flight in 2010, demonstrating the validity of clean and renewable technologies.
With the support of several major companies and strong partnerships, the project solidified and a series of successes ensued: after European flights in 2011 and in Morocco in 2012, in 2013 it flew over the United States. Proof of Concept was near. Starting in 2011, the team got to work to design a successor to the Si1. The Si2 took off for the first time in 2014. The tests were conclusive.
The adventure took on the dream of Bertrand Piccard: to fly around the world. In 2015, the plane made it to Abu Dhabi, its departure point.

VIDEO AVAILABLE ON-LINE

www.cryoscope.airliquide.com

A preferred partner in aviation, Air Liquide has been an official supporter of Solar Impulse since 2013.

By supplying vital oxygen to the pilot, the company is taking part in a societal project and reaffirming its commitment to clean, sustainable technologies.



A two-step trip around the world

On March 9, 2015, Si2 took off from Abu Dhabi. In eight legs, it reached Hawaii. Though it had completed almost half of the distance, successfully tested a number of its technological equipment, and flown for 117 hours, a constraint was discovered: overheating of the batteries. Since June of 2015, repairing them has kept the plane grounded in Honolulu.
The adventure should resume in April 2016, in 6 legs, crossing the United States, Europe, and the Middle East, before touching down where it began, in Abu Dhabi, in the summer of 2016.

Solar Impulse 2, a flying laboratory

Solar Impulse gets its energy from the Sun and must be able to fly for 5 days – and nights! – to cross over oceans unassisted. And doing so will mean a genuine test bench for clean technologies. 269.5 m^2 of solar panels covering the wings generate energy. Charged during the day, the batteries take over when darkness falls. In order to navigate during 14 hours of darkness, the flight's cycle was studied and adapted: Solar Impulse can climb as high as 9,000 meters during the light phase and thus gain 4 hours of gliding, with the engines throttled down. Only when the plane reaches an altitude of 1,500 meters does it begin to use the energy stored during the day. Lastly, it is impossible to talk about Solar Impulse without mentioning its feather weight: 2.3 tons fully loaded, which is the weight of a van! Yet it has to be robust in the face of wind, rain, pressure, light, and temperature. The cockpit was a real challenge as well. Its unheated and non-pressurized 3.8 m^3 must house instruments, provisions, and survival gear while providing the pilot a functional and ergonomic living space, since he may be spending up to 6 days there! And above 3,000 m of altitude, oxygen is also needed.

Aboard, a pilot

A partner of choice for the aviation industry for many decades, Air Liquide is an expert in onboard oxygen systems. So it was natural that the company became the official supporter of the project in 2013, lending its expertise to this endeavor. Both Air Liquide and Solar Impulse wanted to install an OBOGS (On Board Oxygen Generating System). This equipment, standard in some aircraft, produces oxygen onboard by removing nitrogen from the air, an unlimited source, while optimizing mass. But there was a constraint: the system had to be adapted to Solar Impulse and cleared for use prior to takeoff. Despite satisfactory tests conducted in Switzerland in April of 2014, it was a race against the clock and Si2 had to take off without its OBOGS. But the system was completed by Air Liquide, which now has valuable experience that can be used to develop equipment of this type for non-military applications. For Solar Impulse, the alternative was found in aeronautic oxygen. Very pure, like its therapeutic counterpart, it is also very dry. Usually a disadvantage – because dry oxygen is less comfortable – here this is an advantage. There is no risk of freezing despite the conditions that may prevail in the Si2 cockpit. Going forward, all eyes are on the end of the trip around the world for Solar Impulse, which is expected to begin in late April. In light of the current fluctuations in weather conditions, the planned flight path is now more flexible. While New York and Abu Dhabi will certainly be maintained, the other stops each have up to four alternatives.
Now it is up to Air Liquide to prepare the correct loads of aeronautic oxygen – in all, several thousand liters – and to make sure stopping points are provisioned.
The team, proud to be part of this great adventure, is sprouting wings.

CRYOSCOPE

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