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THE CRYOSCOPE

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Cryogenics helps electricity distribution

Small nitrogen liquefiers for inaccessible sites

How do you provide a steady supply of liquid nitrogen to cool the sensors of an observatory located at 3,000 m in the Sierra Nevada, the highest point in Spain? By frequently shipping barrels of nitrogen via 4 x4 vehicle or snowmobile? That would be hazardous, difficult, unpredictable, costly… For this reason, Air Liquide-Spain contacted Advanced Technologies to provide an automous nitrogen liquefier, known as an LNP or Liquid Nitrogen Plant, that automatically produces, 24/7, 98% pure nitrogen purity from ambient air. *"The system filters the air, compresses it, dries it, then passes it through membranes that separate nitrogen from the air,* explains Thierry Trollier, manager of the Cryocoolers and Cryostats Center. *Nitrogen-enriched air is then sent to a cryogenic cooler. Thus, once it has been liquefied, the nitrogen is stored in a 160-liter isolating tank, or dewar, with a three-day capacity for cooling the observatory's sensors."* After this initial experience, Advanced Technologies's autonomous liquefier won over new clients. For example: *"We have just delivered an LNP with a daily capacity of 60 liters to Pointe-à-Pitre, Guadeloupe, to supply liquid nitrogen for the island's dermatologists and hospital complex,* notes Thierry Trollier. *The range of possible applications is extremely vast and demand is high."*

The LNP particularly contains a cryogenic coolant based on Gifford-MacMahon technology produced by Cryomech (Syracuse, New York).

Pure-aC™, serving the next generation of semiconductor processes

A reliable and safe acetylene purifier.

The world leader in electronic equipment manufacturers, Applied Materials, has just launched a new generation of semiconductor coating machines that run with acetylene. Acetylene is a compound that is highly inflammable and very unstable unless it is dissolved in a solvent such as acetone. However, this solvent, that is found in acetylene distribution, is harmful for semiconductor processes. *"We were thus contacted by Applied Materials,* said Régis Zils, project manager, *to design an acetylene purifier capable of removing acetone and delivering a gas that was sufficiently pure. With the Air Liquide Group's expertise, we developed a reliable, safe purifier that we have patented: Pure-aC™."* The first acetylene purifier to leave the Advanced Technologies workshops was delivered to Applied Materials in Santa Clara, in Silicon Valley in the U.S. The electronic equipment manufacturer already expects that, by 2010, it will have sold 30 - 50 acetylene coating machines worldwide. And for each of these machines, Applied Materials will recommend exclusive use of the Pure-aC™.

An unlimited supply of oxygen for field hospitals

An example of a medical-surgical power unit deployed by the French Army Health Services.

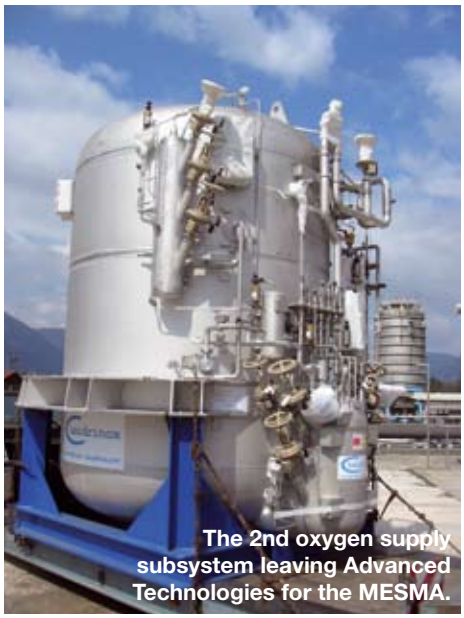
Advanced Technologies has signed a contract with the French Army Health Services to develop and supply seven oxygen generator units for the French army's field hospitals. The objective is to do away with the complex logistics involved in storing and transporting conventional oxygen cylinders. *"The first unit, scheduled to be delivered in August 2009, is a prototype,* explains Régis d'Hérouville, the program's manager. *It will undergo a series of tests (temperature, altitude, extreme shipping conditions, etc.) to ensure its robustness and reliability in every type of environment."* These units, currently being designed by Advanced Technologies, use the same oxygen generation technology found in aeronautics. They are built into containers in order to fit into the standard logistics chains of the Health Service. By providing an endless supply and guaranteed quality of oxgen, these units will guarantee the supply required for field hospitals.

MESMA : 1, 2, 3… Tested

"In 2007, we delivered an oxygen supply subsystem (SSA-O_2) to DCNS to run the MESMA** propulsion system in a Pakistani submarine, and to meet the crew's needs for breathing oxygen,"* recalls Jean-Marie Gaillard, 'Marine Products' manager (cf. *The Cryoscope* No. 37, p. 2). *"In 2008, we performed the oxygen qualification test for a second SSA-O_2. And today, a third one enters the test phase."*

Testing of SSA-O_2 No. 2 was performed at Advanced Technologies's cryogenic testing center, safely, in view of the 22 m^3 of oxygen involved. Remotely controlled in a bunker in order to protect the technicians, the tests were performed in a special room, on a special test bench, so as to simulate the actual conditions of use of the SSA-O_2 in the submarine.

"The battery of tests performed over two months on the oxygen supply subsystem has been completed, notes Samuel Trompezinski, test engineer. *Tests of the liquid oxygen fill squences, performance tests on the cryogenic pumps under actual conditions, verification of thermal performances, inspection of active and passive safety devices, breathable air supply functional tests, tank draining tests, etc."* The expected performance levels were met. *"We finished up this second battery of tests by draining all of the oxygen out of the entire system in order to inert the tank with nitrogen. The system can now go to its port of call at the DCNS in Cherbourg without any risk involved."*



The 2nd oxygen supply subsystem leaving Advanced Technologies for the MESMA.

*DCNS (Department of Naval Systems Construction) is the French naval defense system manufacturer.
**MESMA is an anaerobic propulsion system that produces electricity for the submarine to provide greater autonomy in dive mode.

"The Advanced Technologies Cryogenic Award"

Catherine Candela, Advanced Technologies Director and Pascale Dauguet, recognizing the best publication at ICEC.

On the occasion of the 100th anniversary of the liquefaction of helium at the ICEC Conference (International Cryogenics Engineering Conference) in Seoul (July 21 to 25, 2008), Alain Ravex, Director of Technologies and Innovations, and Pascale Dauguet, Research Contracts manager, selected, on behalf of Advanced Technologies, the award winner for the best paper at the event. *"We received no fewer than 120 publications,"* reports Pascale Dauguet, *'all absolutely top notch.' We finally decided on the paper by the team that designed the ITER* cryogenic system. In fact, we wanted to award innovation and highlight the macroscopic vision offered by this publication."*

*"Conceptual Design of the Cryogenic System for ITER" *by Luigi Serio, Michel Chalifour, Vladimir Kalinin, Denis Henry (ITER Cadarache), Manel Sanmarti (Fusion for Energy, Barcelona, Spain), Biswanath Sarkar (ITER India, Bhat, Gandhinagar).*

A perfect start for the SSRF's cooling unit!

Mission accomplished: The HELIAL 2000 supplied by Advanced Technologies for the Shanghai Synchrotron Radiation Facility (SSRF) particle accelerator has kept its promises. The cooling unit, which has just been commissioned, effectively met Advanced Technologies's customer's requirements through its robustness and flexibility of use, serving two functions within the synchrotron. By cooling to 4.5 K with a cooling capacity of 650 W, it serves to "chill" the superconducting resonant chambers and to provide the cooling capacity required to perform the research experiments.

"With this HELIAL, **commented Simon Crispel, project engineer,** ***we supplied a 2000-liter dewar*, a cryogenic transfer and distribution line, three compressors to power the refrigeration unit, an oil extraction system, a gas analyzer, etc. Everything was delivered in one go! We were thus able to help the client assemble the installation and ensure it started properly."***

Pierre Roux and the SSRF clients.

In order to work for the Chinese synchrotron, Advanced Technologies succeeded in adapting its work organization. Thus, to comply with pressure-vessel regulations (AQSIQ), DTA teamed up with a contractor that had Chinese certification. ***"With this new supplier,*** **reports Pierre Roux, project manager,** ***everything went very smoothly. The liaison role fulfiled by Liu Shuang, from Air Liquide Advanced Technologies in China, facilitated negotiations and the start-up phase."***

*Isolating storage tank.

SUPERCONDUCTIVITY

Cryogenics helps electricity distribution

As in the LIPA project, the liquid nitrogen cooling and distribution system developed by Air Liquide's Advanced Technologies is of interest to many companies in the market for electric power transmission via superconducting cable.

An electrically conducting material is said to become superconducting when, below a critical threshold temperature, its electrical resistance drops to zero. It can then be used to transmit very large electric currents without any energy dissipation. Clearly, in order to prevent the conductor from overheating, the cable should be kept in a temperature range of 70 to 80 K, i.e. around 200 °C. The world leader in cryogenics, with its knowledge base on ultra-low temperatures[1] in Sassenage, Air Liquide was contacted to be a partner in the construction of the longest and most powerful superconducting cable in the world to date. In June 2008, it was hooked up to the commercial power transmission system of Holbrook (New York) by the Long Island Power Authority (LIPA) and American Superconductor.

A first on Long Island!

The goal of the LIPA project was to demonstrate the use of a high-voltage superconductor cable on an electric power distribution network. To undertand

KEY FIGURES

This 600-meter-long cable can supply up to 300,000 homes with electricity. It carries up to 2,400 amperes, i.e. a power level of 574 million volt-amperes at a voltage of 138 kV. Capacity of the Air Liquide cooling system: 6 KW at 65 K and 17 bars.

Air Liquide's Advanced Technologies also delivered and installed six terminal cryostats to connect the resistive system and the superconductor cable.

In June 2008, for the first time world-wide, on Long Island (New York), a high-voltage electric power distributon superconductor was connected toan electric power grid. The Air Liquide Advanced Technologies cooling unit is located near the station, used to connect the resistive overhead grid to the superconductor system.

This 20 kVA cryostat delivered to Budapest is made of composite material (epoxy glass). A second one of 100 kVA will soon be completed.

the importance of this project, it should be noted that this cable carries more power than all of the previous HTS (high-temperature superconductor) demonstration cables. In the American market, in large urban areas where power grids sometimes reach saturation, this demonstration offers promising opportunities for the various partners in the project[2]. In effect, in order to relieve the power grid, superconductor cables can be used to replace conventional cables or overhead lines. Four times the energy with the same cable cross-section! This makes it possible to increase the amount of electric power distributed under ground significantly. Its low impact in terms of construction means this technology is particularly suitable for urban areas. Moreover, satisfied with the outcome, the partners in the LIPA project are now set on designing and building and even more powerful installations (see inset). In Europe, a similar project is being studied in Germany. At present, funding has been found to build a prototype superconductor cable, 30 m in length, in Bilbao[3], but it will not be connected to any power grid. For this project known as Super 3C, Advanced Technologies delivered a cooling unit with a capacity of 1.5 kW in 2007.

Safety

In Budapest, another European project – Slimformer – is the focus of attention from Advanced Technologies in terms of superconducting[4]. In this case, it is not necessary to cool a superconductor but rather to design and produce a fault current limiter in a substation that contains resistive sections and supercoducting sections. Thus, in the event of a short-circuit, since the electric power passes through superconducting coils, they will lose their "super" quality and then act as safety switches. Advanced Technologies must design and produce the cryostats intended to contain the coils but, given their environment, they cannot contain any metallic parts. A 20 kVA prototype made of composite materials gave full satisfaction. A second 100 kVA cryostat is due to be completed soon. As all of these projects show, cryogenic cooling is critical for the use of superconductivity. Air Liquide's Advanced Technologies is developing innovative technology solutions that will allow it to be used tomorrow on an industrial scale.

In Bilbao, Air Liquide Advanced Technologies delivered a cooling unit used to cool the Super 3C cable, shown here in the workshop with the two cryostats at either end.

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(1) For example: the supply of liquid helium for the LHC's superconductor chambers at CERN.

(2) This project includes the American Department of Energy (DOE), Nexans, a world leader in the cable industry, and AMSC (American Superconductor, Boston).

(3) With Air Liquide, this project brings together Nexans, EHTS, EON from Germany, and Labein and ICMAB from Spain.

(4) With Air Liquide, this project brings together Nexans, EHTS, Areva UK, Ganz and Budapest University of Technology and Economics.

LIPA 2: to be continued…

With the planned cable measuring 10 km in length, the scale of the LIPA 2 project will be even bigger… At the request of DOE, this time it will involve industrializing a cooling system currently designed only for use in research.

The goals are to reduce the cost, electric power consumption and maintenance, and to make the system simpler and more reliable, as well as increase its service life. This will require a technological leap…

The idea is to eliminate all friction and the use of oil. Instead of a lubricated screw compressor, a centrifugal compressor will be mounted on magnetic bearings and driven by a high-speed electric motor.

The compressed gas will pass through the "cold box" and then, to obtain refrigeration, will be expanded in a centipetal cryogenic turbine. A turbo version of the eternal Brayton cycle! *"It's the same principle as a jet plane engine"* as Fabien Durand put it in brief. Watch this space.

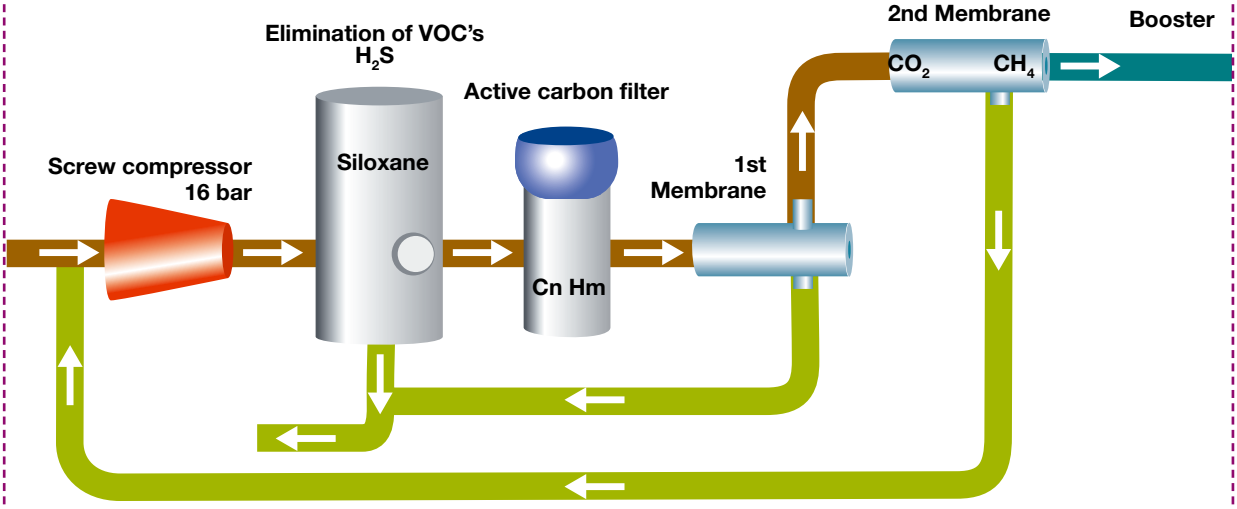
BIOMETHANE

From waste to green energy

Air Liquide's Advanced Technologies is developing an industrial system designed to purify the biogas that comes from sanitary landfills or digesting plants. The objective is to produce enriched methane that can be commercialized in compliance with sustainable development/growth criteria.

Biogas is produced by the decomposition of organic matter in an oxygen free atmosphere (anaerobic fermentation). This natural phenomenon can be found in swamps or compost heaps. It can also be controlled in digesting plants supplied with organic waste. Comprised mainly of methane and carbon dioxide (see *Key Figures* on page 7), biogas is a major greenhouse gas and a potent renewable energy source. Today, it is flared off or collected through a pipeline grid to power plants producing heat and electricity. Driven by the context of fossil fuel scarcity, biogas, through decontamination and enrichment, is finding new valorization processes. Thus, for a country such as France, which imports more than 90% of its gas, it is estimated that biogas could eventually provide 10% of the nation's consumption.

Biogas solution mechanism



A promising market

In the United States, thanks to the role played by its subsidiary, Medal*, Air Liquide has, for two years now, had ten facilities in operation and has three more under construction. With its concern for sustainable development, the European market will soon follow suit. Already, especially in northern countries, Advanced Technologies's sales teams have made contact with a number of sanitary landfills, bio-digesters, digesting plants, and even regional institutions and manufacturers of vehicles that use methane as fuel.
Our strategy is to offer them a technology that meets ever more stringent environmental criteria. In the context of irreversibly rising energy costs and of dependence on fossil fuel imports, the advantages are undeniable: a simple, robust technology providing biomethane enriched to 99%, with low operating costs, etc. This is accompanied by the assurance that the waste valorization circuit being set up does not itself generate any environmentally harmful by-products.

From biogas to methane

By combining several technological blocks, Air Liquide is developing a global solution that includes all of the stages involved, from the collection of biogas to the compression or liquefaction of biomethane. Before purification begins, the first stage consists of compressing the biogas supplied at atmospheric pressure. To do so, Air Liquide is proposing to set up a lubricated screw compressor, a proven technology. The second stage is intended to remove corrosive compounds from the biogas, meaning hydrogen sulphide and volatile organic compounds (VOCs). At

On the left: the double-stage membrane system serving to eliminate carbon dioxide. In the centre: the PSA (Pressure Swing Adsorption) module. On the right: the two columns of activated charcoal used to eliminate VOCs, siloxanes and hydrocarbons.

this point, the technologies required are PSA (Pressure Swing Adsorption) and trapping by activated carbon bed. The next stage consists in the separation of the two main components of biogas: methane and carbon dioxide. To do so, Medal* has developed an innovative process based on the use of polymer membranes. Air Liquide has patented the "methane recovery process" system it designed. While biogas is produced by an anaerobic process (methane generator), biomethane purity turns out to be nearly 100%. In addition, in the case of sanitary landfills, if the biogas is sucked out, it will still contain some nitrogen and oxygen. In order to separate them from the methane, the fluid is passed through a distillation column.

Lastly, the final stage may vary depending on the commercial end-use specified by the client. A compression stage may serve as input for a pipeline network or a vehicle filling station. A second option is liquefaction, where the objective is to store the biomethane in the Liquefied Natural Gas state. To this end, Air Liquide employs a technique commonly used by Advanced Technologies, especially for hydrogen and helium applications: the Brayton cycle.

An industrial solution

Developed for prototypes and applications where the amount of gas to be processed is relatively low, these technologies are currently being combined on an industrial scale. Thanks to a modular, upgradeable system, Advanced Technologies can meet needs ranging from 100 to 10,000 m^3 of processed biogas per hour.

Medal has already set up major industrial plants: in Johnstown, Pennsylvania, the installation for Keystone Renewable Energy (32 extraction wells) has a capacity of 3,600 m^3/h, and the capacity at Energy System Group in Johnson City, Tennessee, is 4,100 m^3/h. In addition to the reliability of the technology and the fact that no manual operation is required – the man-machine interface provides easy operation of the equipment – the reduced overhead is a notable benefit.

In fact, thanks to the reduced number of rotary machines and the limiting of contaminating effluents, maintenance is kept to a minimum and basically involves the compressor placed at the head of the chain…

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KEY FIGURES

An example of the composition of biogas produced by a Processing Unit

42% methane, 38% carbon dioxide, 13% nitrogen, 4% water, 3% oxygen and a few mg/Nm^3 of hydrogen sulphide, siloxane VOCs and overall VOCs.

Power equivalence

1 m^3 of methane is equivalent to 8,570 kcal, i.e.: 0.94 m^3 of natural gas, 1.15 liters of gasoline, 1.7 liters of industrial alcohol, 1 liter of heating fuel, 1.3 kg of coal and 9.7 kW/h of electricity.

**Medal is Group member company, affiliated with Alatus (Air Liquide Advanced Technologies, United States).*

A400M: OBOGS cleared for take-off!

Following months of testing, Air Liquide Advanced Technologies's on board oxygen generating system (OBOGS*) is now ready for take-off: it has received "flight readiness" for use in the future Airbus European strategic military transport plane, the A400M. Jean-Michel Cazenave, expert at Air Liquide, relates the various stages leading up to this success.

Before anything else, tell us about the A400M. What are the special features of this new military transport plane?

Designed in the late 1990s by Airbus Military Company, the A400M was officially presented on June 26, 2008. It is a highly flexible military aircraft, intended both for transporting troops, for medevac missions, in-flight fueling and remote basing. It was the first in an order for 192 units for the armies of seven EU member countries (Germany, the UK, Spain, Belgium, France and Luxembourg), one NATO country (Turkey) and two countries outside of Europe (South Africa and Malaysia). Delivery should start in 2010.

But before that, the A400M will make its maiden flight in late 2008. It was precisely for this flight under realistic conditions that our OBOGS received its flight readiness.

How did you come to be part of the A400M program?

Around the holiday period of 2004, our OBOGS was selected by Airbus. What a wonderful gift!

For this new development, we drew on our experience with the Rafale and A380 programs. Nevertheless, the A400M's oxygen generator is really a unique case. In particular, as it is intended to meet the oxygen needs of a crew of five to seven people, the OBOGS in the A400M is twice as large as those found in fighter planes (for two pilots) and three times smaller than the one in the A380 (for 200 passengers). But above all, it is equipped with very advanced technology with a digital electronic control, programmable components, continuous monitoring… Even better: the system has an output flow regulator valve that makes it possible to manage automatic selection of the oxygen supply system – tanks or OBOGS – without the risk of an interruption in supply. It's very safe!

What types of testing did the OBOGS undergo before obtaining its «flight readiness»?

Three OBOGS systems were subjected to a full battery of tests required by Airbus to ensure their safety on A400M flights. We provided a fourth OBOGS directly to the aircraft manufacturer for the qualification tests performed on its own benches. On the Sassenage site and in specialized laboratories, we were thus able to demonstrate that our OBOGS systems achieve the specified performance levels - both at low temperatures (-15 °C) and at high temperatures (+70 °C), that they can withstand the most extreme stress in terms of vibrations (given that the A400M is powered by four turboprops and that the oxygen generators are located near the propellers), that they are compatible with the electrical system and the aircraft's other equipment (radar systems, for example), and that they do not generate any electromagnetic interference… We even went further by conducting acceleration tests and crash resistance tests and also by determining the limits of our equipment. Thus, by demonstrating that our OBOGS makes it possible to guarantee the safety of A400M flights, we won over the confidence of Airbus.

**On Board Oxygen Generating System.*

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Jean-Michel Cazenave and his team passed every test to obtain "flight readiness" for the OBOGS.

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