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FINDING APPLICATIONS TODAY FOR TOMORROW'S TECHNOLOGY

by

Frédéric Touvard
Axane - Fuel Cell Systems (Air Liquide group)

September 26th, 2007
Report by Yves Breton
Translation by Rachel Marlin

Overview

The availability of energy and the reduction of pollution-causing emissions are very topical. In this context, hydrogen is returning as a potential energy solution mainly as fuel cells which have been in existence for a century. The European Community and the French national research agency are in favour of these new developments. Air Liquide, which has an obvious interest in the transportation market in which it may be involved in a few decades, has carried out research using hydrogen in particular applications. In this way, the company, by developing technology and taking into account users' needs while being aware of the dangers associated with the use of this combustible gas, hopes to be ready for the development of mass markets. However, this is a difficult balance to find because in order to achieve a profitable return on the initial investment to exploit this new energy source often requires the consumer to change his methods of consumption.

TALK : Frédéric Touvard

Having studied technology and science. I started my career in military defence engineering and subsequently worked for Axane, a company created by the Air Liquide group. Axane employs about sixty people and is located in a high-tech research centre in Sassenage, near Grenoble. I am in charge of a team of 25 people and I manage projects in order to define products, manufacture them and provide after-sales service.

This talk is based on the conclusions which Gilles Garel (a professor at the university of Paris-Est) and Rodolphe Rosier (a PhD student at the university of Paris-Est (Prism OEP) and a colleague at Axane) presented as a result of research which we carried out.

Axane

Air Liquide is a gas group. Hydrogen, including its manufacture, distribution and associated products, is one of the group's product areas. Air Liquide is naturally interested in fuel cells because they can function using hydrogen. Any discussion of fuel cells raises issues such as the dangers associated with their use (hydrogen can be a dangerous gas), as well as numerous other issues which concern energy in general. My talk will focus on how Axane developed technological possibilities for hydrogen cells and how it found new potential markets for them.

Hydrogen : a source of energy

There are three important challenges for the energy situation : these are the preservation of the global environment, the energy supply and its availability with respect to geopolitical situations, and the cost of energy which depends on the technology used. What are the available energy sources ? They are renewable energies (such as hydraulic energy), wind-generated energy, solar energy and biomass energy (based on fossil fuels such as petrol, coal and natural gas), and lastly, nuclear energy and other sources of energy including hydrogen. There is no one source which is definitely better than the others. Each source should be considered in relation to the others, according to the individual situation, the specific advantages, points for and against, difficulties, and so on.

Hydrogen

Where is hydrogen ranked in terms of its carbon dioxide emissions ? A hydrogen cell does not emit carbon dioxide apart from the emissions which result from the manufacture of its constituent materials. However, when one manufactures hydrogen, there are emissions. Research is currently being carried out and technological developments are being made with the aim of isolating carbon dioxide in the manufacture of hydrogen, and avoiding all possible emissions by using renewable sources instead. For example, in Canada, it is possible to produce hydrogen by electrolysis. The trend is therefore towards substantial reductions in these emissions.

What does the future hold for its usage ? At the moment the markets are at an early stage. A European view is that these markets will be followed in 2015 by other markets which, by 2030, will open the way for the transportation market.

My talk will focus my talk on the way in which we help to create this market by starting with niche markets, which concern important volumes less than single applications which require both development and management which is different to traditional marketing or mass marketing.

The fuel cell

The special feature of a fuel cell is that it does not contain its reagents – they come from the outside – unlike a battery where they are stored in the terminals of the electrodes. A hydrogen cell is fed by two fluids : hydrogen, which is supplied by a bottle outside the generator, and air (or pure oxygen) which is fed at the right moment to the right place. This system effectively separates power from energy which is an important aspect of a battery because if one wants to make it self-sufficient to the same degree as that of a generator, one merely has to add bottles of hydrogen, unlike a battery where one can only add the entire generator, in other words, both power and energy simultaneously.

The fuel cell versus the electricity generator

In an electricity generator, there is in addition fuel outside the thermal generator and the autonomy depends on the volume of fuel one has, but it is the technology which differs. The size of a generator does not have to be determined by a nominal horsepower but by a peak power value because it should not be suppressed in the early stages. This is not the case for a fuel cell. Therefore, for similar use at a normal rate, the fuel cell may be almost half as powerful. One can also carry out comparisons in terms of pollution and noise in order to identify, case by case, whether the fuel cell has a clear advantage compared to a solution based on the use of an electricity generator alone or together with batteries, as is the case, for example, in many hospitals.

The history of Axane

Axane's progress in its research on the hydrogen cell can be summarised into four important stages.

The technological approach

The first stage, from 1999 to 2002, was a preparatory phase using a technological approach in a series of projects with car manufacturers. During this period, car manufacturers were announcing innovative energy solutions to equip tens of thousands of vehicles over four to five years, but the date at which they should have been completed was put back each year by a year or two. In our innovation centre at Air Liquide, we took part in these projects by supplying hydrogen, fluids, and thermodynamic management, for tests on Renault PSA vehicles, objects of interest to the army, and electricity generators, in other words important examples of technology.

The first prototypes

Next, we completely mastered the technology of the hydrogen cell by building our own 'stack', in other words, a collection of active cells which constitute the core of the electrochemical reaction. This enabled us to launch two important projects in 2002 and 2003, the Polar Pac and the Roller Pac.

We intended to use the Polar Pac as a test even though it had also been devised to be used by a non-technician, Jean-Louis Étienne, during his three-and-a-half-month mission to the North Pole in 2002. A helicopter dropped him there in a capsule equipped with solar panels coupled with our fuel cell and lithium-ion batteries in order to generate energy for the length of his mission. The 350-watt cell functioned between 6 and 15 hours each day and served to recharge the batteries. Obviously, there were a number of surprises as a result of this hybrid set-up, a mixture of solar energy, fuel cells and batteries, because not a great deal is known about solar radiation at the North Pole. Since the ice-floe moves between 10 and 20 kilometres every day, eventually Jean-Louis Étienne found himself near Greenland, some 500 kilometres from where he had started. Nevertheless, he had been able to carry out a number of experiments such as measuring pollen and water levels, solar radiation and energy consumption.

A natural extension of the Polar Pac is the Roller Pac. This enabled the Axane team to gain credibility within the Air Liquide group and among fuel cell manufacturers. The Roller Pac is a generator which has a very attractive 'feminine' design unlike unsightly, square-shaped thermal generators which are often spattered with oil. The Roller Pac was awarded the 2003 '*Prix de l'Observeur du design'* prize and a special 'environment' award from the *Agence de l'environnement et de la maîtrise de l'énergie* (ADEME : French environment and energy management agency), as well as Siemen's 'Grand Prix for innovation' in 2004. The Roller Pac has a 2 kW-generator with integrated hybridisation which allows it to sustain peaks of 4 kW, thereby making it compare favourably with an electricity generator of the same strength. It has the added advantage of being silent and non-polluting. A rapid hydrogen hook-up, an 'on-off' button and a fuse key make it very simple to use.

Industrialisation

Between 2004 and 2005, we started to industrialise, and at the same time we looked for potential market openings. We soon realised that, from a purely marketing point of view, we lacked information because the users we approached expressed no need for our product. It was impossible to sell sections of our product, and obviously it was out of the question to manufacture a product which suited everyone. Consequently, we devised situations in which it could be used, for example, by imagining how a fireman might use our generator in the field. This helped us to learn lessons about the design and the modelling of the product, and subsequently to develop it by using both in-house know-how at Axane and through partnerships with suppliers. We finally manufactured prototypes and then mini-series of between 10 and 20 units on assembly lines giving us considerable flexibility.

This is the way in which, after initial discussions about the functions that our product might fulfil that the entire design team agreed on its creation in a very short space of time and in 'commando' fashion in order to test it in real situations and then to develop it. Clearly, we did not start everything from scratch every time because previously we had been concentrating our efforts on one object called Évopac. This is a standard, technological platform which can be found in various products with different packaging. It might be a large, fixed electricity board with one or two fuel cells and one or several compartments for storing hydrogen, or it might be a generator which is very compact and portable, making it easier to transport.

The deployment

In 2006 and 2007, the processes I have described continued, but the operation now involves multiple applications in a number of countries. For example, we have a partnership with Bouygues Télécom to supply a number of telephone antennas on a permanent basis which also means that from time to time we have to replace gas cylinders in order to avoid the generator coming to a complete standstill. This is made manageable by long-distance monitoring which enables us to check the on-site levels of hydrogen stocks from a distance and when necessary, to set in motion the delivery and installation of new cylinders.

There are several points which are of particular interest to us in this operation :
- hydrogen is recognised officially ; we are part of the regulatory body and we take part in committees which discuss standards ;
- costs which can be avoided ; this involves discussion with a potential user to discover which costs can be avoided by using our fuel cell rather than another technology ;
- recognising client needs ; analyses are carried out to determine what is really important for users and to revise current requirements in order to foresee the introduction of fuel cell technology ;
- technological reliability ; experience in the field often reveals surprises which are difficult for design teams to predict, or even impossible to spot in a laboratory setting ; it is necessary to take this into account when improving products ;
- additional equipment ; a single generator may not be sufficient for use in certain circumstances and therefore there is a need for accessories, such as trolleys (to transport the

generator or hydrogen cylinders) without which the commercial development of the product might be compromised ;
- capitalising on knowledge ; all the data concerning the manufacture – from the early design stages to the implementation of the product, as well as the various stages of the design itself – should be noted for future use.

A few examples

To illustrate the way in which we explore openings and develop our products, let me give some examples of our applications.

The cinema

A film was made at night in the 11th arrondissement in Paris by a team of between 20 and 40 people who were there for two or three nights. In view of the cost of such an operation, care was taken to organise the shooting so that as little time as possible was lost, and the equipment used was suitable and as reliable as possible.

For this sort of film-making, the energy necessary for lighting and for other equipment is usually provided by batteries installed near-by. These batteries only last about 20 minutes before they are recharged by an electricity generator which can be noisy and so must be located where it disturbs the least number of residents. One person has to be in charge of this generator and another has to remove the used batteries and install the newly charged ones. This is a hard and costly process.

We suggested replacing this system with a hydrogen cell. This appealed to the film crew because our silent and non-polluting generator could be located next to the equipment, used continuously, and merely required someone to check the hydrogen levels from time to time in order to replace a used hydrogen cylinder. The lighting director, who always installed black screens in order to reduce the lighting, learned to adjust the lighting power according to the capacity of the generator, having to put up with certain disadvantages in order to benefit from other advantages, in particular the quietness of the fuel cell which meant that the sound recording could be live.

As a result of this experience, we discovered the idea of silent energy ‘on request’, in other words, where only 5 or 10 seconds are needed to stop or restart the generator, unlike an electricity generator which one cannot stop in case it does not restart. This new concept can obviously have many other applications.

Public security

When a building collapses, for example after an earthquake, survivors have to be pulled out of the rubble. Such an operation requires both light and silence to locate the victims’ cries. It is impossible to hear anything if one uses electricity generators unless they are hundreds of metres away from the site. This creates problems of mobility in a situation where mobility is essential. The portable fuel cell can solve such problems as it can be installed in the centre of the site without causing any disruption.

Monitoring

Other more specific applications are possible, especially in the area of monitoring where there is a proven need for energy to be available over a period of weeks. Secret monitoring devices or listening devices, for example, installed in vehicles could benefit from this.

Some figures

Between 2002 and 2007, Axane grew :
- from 8 to 60 employees in the design team ;
- from 2 to 25 systems delivered each year for specific uses ;
- from 1 to 8 countries involved in the distribution ; and
- from 1 to 20 product configurations which all had different packaging from the standard Evopac.

Systems of innovation

A great deal of research is carried out on innovation, in particular at the École des mines' *Centre de gestion scientifique* (CGS : Centre of scientific management), the École polytechnique and the Paris-Est Marne-la-Vallée University. According to Gilles Garel[1], three systems of innovation can be identified :
- strengthening existing offers ;
- renewing offers for specific clients ; and
- 'exploration', or systems to identify users and to become aware of unknown or unstable technologies.

In terms of the work carried out at the CGS[2], strengthening and renewal can be qualified as 'organised design' where one extends the limits of an existing structure, whereas systems of identification are seen as 'innovative design' where one changes the structure and explores it differently.

System of exploration

The system of exploration requires innovative teams to research the possibilities of implementing new solutions different from those which are normally used. This means that it is necessary to understand the needs and develop new knowledge in order to achieve a result. How should one direct this development of knowledge ?

Situations of exploration not only serve to reveal a supposedly hidden and inaccessible reality but also to allow one to start afresh from initial questions which were badly phrased or badly constructed, concerning an idea which currently does not exist or where the available knowledge is limited or has not been used. These imperfect questions enable one to have a dialogue with the potential user regarding the problem and how to solve it by restructuring the question. This will give rise to knowledge which will allow, if it is possible, to provide a satisfactory solution to the problem. This approach can therefore be regarded as constructive.

In the exploration system, teams have to know how to deal with complex and uncertain situations without losing sight of the objective, which is to identify value and generate knowledge, in spite of all the ambiguities which exist in the unknown.

How to manage exploration

Exploration is clearly not an end in itself but a necessary means to achieve profitable applications in newly emerging markets. It requires a different methodology and organisation from those ordinarily used.

We consider the value of what is explored in order to direct our work around this value. This valuation is not only based on what potential users tell us but we must also understand their activity in order to reassess and reorganise the way they manage it. We show the potential

[1] Gilles Garel and Rodolphe Rosier (2007), *Gérer l'exploration, le cas des technologies à haut potentiel*, ASAC 2007 Conference *(Administrative Sciences Association of Canada)*, 2-7 June 2007, University of Ottawa, Telfer School of Management.
[2] Pascal Le Masson, Benoît Weil and Armand Hatchuel, *Les processus d'innovation, conception innovante et croissance des entreprises*, Hermès Lavoisier, (2006).

users, who are sufficiently forthcoming and who we can consider as our partners, our expertise with the help of prototypes in situ. In return, they help us to direct our product so that it corresponds well to their needs.

If the expected value proves to be wrong a few months later, we should be capable of reassessing it, and also the design work which has already been carried out. We regard such necessary reassessments as management principles.

Interface tools

We have adapted or developed interface tools to facilitate our work.

Specifications

The arrival of a future product at Axane concerns certain people in particular. These include the technical teams, the people in marketing and sales, as well the product manager who provides the link with the other professions. We decided to bring together their common views of the future object even though these views may change in the course of the design. We add our knowledge of the environment which defines the limits and we make our choices.

This information on the object is the equivalent of the specifications book, however it is neither too simple nor limiting, and remains open to changes in the environment. It encourages the adaptability and the flexibility which our exploratory approach requires.

Marketing tools

In order to choose our products, we use a very simple matrix which allows us to make notes on every case explored. These notes include a brief description of the product, where it is used, what was identified in the field as likely to satisfy a user, an assessment of the size of the potential market, and the position of the product in relation to all rival technologies. This matrix enables us to choose the targets and the time at which their potential value appears to be the greatest, and therefore to concentrate the work of the teams on the design of relevant products.

In order for the design to be in phase with the marketing, we use another matrix which has a very precise description of the intended use of the product, and all the criteria of technical design which are relevant to it, such as its mass, volume, sound level, and so on.

A final matrix allows us to find our place in relation to the competition both in fuel cells and in other technologies. It is here that we might be tempted to design a universal product which satisfies all the criteria, even the most restrictive. However, it is more realistic to aim for an overall compromise, even if it means presenting our ideas for future developments to users who are still hesitant about buying our products.

The management at Axane

We encourage innovation, which I consider to be more a state of mind than a function, by making sure that all the professions advance at the same rate and with many iterations. At Axane, this is an absolute management principle.

This is exemplified by the openness between the professions, in the detailed definition of the design criteria which are accepted by everyone. The aim is that the professions work together because no single profession can aspire to be the best. Such a relationship presupposes a mutual tolerance which allows each profession to develop itself within in its own area rather than feel insecure. At the same time, all those concerned should be put at ease so that the professions do not feel that they are being ignored.

In this process, we only immobilise the parameters which cannot wait, in other words, which find themselves at a given time on the critical design path. However, we remain flexible about the others. In addition, the prototyping and modelling methods are largely used within the organisation to show how the creation of the object takes form, and provides the opportunity for discussion about the choices taken or those about to be taken. It is one of the ways used in the design system to encourage an open and close communication, allowing us to organise ourselves and to react very quickly regarding the object : in the space of a week, quite important changes may take place. It is not a case of saying 'Here are the specifications ; see you again in a month's time.' The process of development takes place on a daily basis.

The kinds of organisation

I shall now discuss more generally the kinds of organisation and especially group cultures which can be seen in project management.

Culture of hierarchy

In Taylorism, a leader gives orders and the people carry them out. There is no going back. The power of the leader is absolute and subordinates lack autonomy.

Matrix culture

Projects are often organised in the form of a matrix with circuits, linked to procedures and standards within the professions. It is a treasure hunt with a well-organised process which has the advantage of being standardised, but which might discourage people from taking responsibility.

Polycellular or interactive culture

Sometimes, it is possible to observe polycellular or interactive organisations. Here, zones of influence or centres of gravity are created. This is the sort of entrepreneurial spirit which one finds in many start-ups or spin-offs, but which calls for a great deal of interpersonal regulation. The major inconvenience of these cultures is the disorganisation, chaos and disorder which results if they are not properly regulated.

The complexity of the proportions

It is difficult to bring together the three cultures and getting the balance right. In some cases, one needs the hierarchical model ; in others, the interactive one. One could integrate the management of the complexity into the 'I' of RID (Research, Innovation and Development) because in order to be efficient one has to position the method of functioning correctly according to the different stages. But if one wants to function in the interactive mode, one must take care in preparing all those involved beforehand, because it requires a common language, a degree of openness to change, and the sharing of values, clear objectives, issues, experiences and a recognition in terms of skills. If these conditions are not brought together, it will be very difficult to function in this mode.

Management of the issues at stake

It is very common to see a team tackling a problem by going straight into action rather than thinking initially about a work method, and only later on, about the issues at stake – in other words, the reasons for any action which has been taken. By not devising a work method beforehand, the team may find itself paralysed, faced with power games and preserving its territory simply because it is uncertain of its identity.

However, if one is able to identify the issues at stake and then work on the methodology, work can proceed normally because the necessary talents are present. The work can be carried out in a precise manner. Management in response to important issues or by a sequence of

issues, brings the teams together giving them a common vision. This will naturally modify the work in process because each individual identity is associated with issues specific to the group. This is how our team has managed to be efficient in the innovative sphere of exploration.

DISCUSSION

Question : *The ANR (Agence nationale de la recherche : National Research Agency) supports a programme*[3] *which devotes tens of millions of Euros to hydrogen. On a European scale, there is another project*[4] *concerning the same subject. However, if I have correctly understood what you have said, fuel cells are ready and you could deliver one to the École des mines immediately. But practically speaking, what would be the problems if hydrogen were used as a mass consumption product ?*

Frédéric Touvard : If I were to deliver a fuel cell to the École des mines, I would come up against the problem of regulations concerning combustible gases in public places because this fuel cell functions with hydrogen which is a combustible gas. However, between institutions, there may be different regulations in terms of safety levels concerning hydrogen. It is for this very reason that we have reached an agreement to use a fuel cell in one university because it is still the manager or owner who is responsible for the equipment and its safety on the premises. Next, I would have to determine the intended use of this fuel cell. Suppose that its purpose was to provide energy for a coffee machine. If this was the case, I would carry out tests on this machine, whose normal consumption would be about 1 kW, but which might have peaks of 5 or 6 kW when the machine is switched on : such peaks would be prohibitive. I might then suggest that a different model of coffee machine be installed which had a soft-start system which would allow the machine to remain within the energy limits of the generator when it is switched on. These are two important points which have to correct from the outset.

Is it profitable ?

Q. : *Can you give us some idea about prices ? For example, during the making of the film, was the generator cost effective ?*

F. T. : For the filming, we would have been priced out of the market if our generator had been compared to the electricity generator (all things bring equal), because our generator is much more expensive. On the other hand, because we can minimise costs, our technology can prove to be profitable, but this requires the client's co-operation in order to identify the hidden costs of rival technology. Another example : in telecommunications, the installation of antenna racks is accompanied by huge peaks in power consumption because their designers use the electricity network and are not particularly concerned with the consumption. So that our client can benefit from our offer, we encouraged him to adapt the starting sequence of their racks.

Q. : *You start with small specialised markets, but do these markets lead you to mass markets ?*

F. T. : It helps us to work on fleets of vehicles with hybrid architecture (vehicles such as those used at airports, by the post office, by local authorities and so on) in order to prepare us for mass markets since these hybrid vehicles demonstrate the technological constraints which could occur in practice. We also have research priorities for more powerful systems intended

[3] PAN-H (Plan d'action national sur l'hydrogène : National action plan for hydrogen and fuel cells), following a call for projects in 2006.
http://www.agence-nationale-recherche.fr/AAPProjetsOuverts?NodId=17&lngAAPId=55
[4] ERA-NET (European research area network) created following a call for projects in 2004
http://energie.wallonie.be/servlet/Repository/?IDR=1935

as back-ups for hospitals or transport vehicles such as buses. This preliminary work is part of our continuous research programme.

Q. : *I doubt that your company is profitable. How are you financed ?*

F. T. : The company is not yet profitable like many of our competitors, but some of our activities are financed by the ANR, or by the European Community, including an important project which represents a large part of our activity. This project involves hybrid vehicles, wheelchairs and commercial vehicles whose design, testing and distribution we guarantee over five years in four cities in Spain, Italy, Germany and France. This financing is very important because it helps us develop projects which correspond perfectly with our strategy.

Competition

Q. : *Do you have any rivals ?*

F. T. : We have lots of rivals in Canada and America.

Q. : *In these markets, many start-ups and spin-offs have a different approach to yours. Additionally, they have recourse to private financing, a very strong focus in some of your niches, and hundreds of installed systems. Some of these companies are quoted on the stock exchange and have announced huge losses despite increases in turnover. What do you think of this ?*

F. T. : It is true that these start-ups spread information about the fuel cell, but the number of systems which are deployed in the field and are seen by the public is very small. Of course, we would be very happy to discover a key application which we have not analysed which would justify a specific development in this type of market. One has to be very sure about the source of one's information.

Q. : *Do you consider the fact that you are in a group like Air Liquide to be a strength, or a hindrance regarding these start-ups ?*

F. T. : We regard it as a strength. Because our company has solid foundations, we are adding to our knowledge by becoming familiar with small targets in early-stage markets. I have only quoted a few applications, but there are many others. Some of our North American rivals have a very aggressive strategy based on dumping, but this is not our strategy. Our strategy is to build the initial markets brick by brick, then make them reliable, and refine our business model in the knowledge that we are not yet in a mass market.

The transport market

Q. : *I find the European hypothesis that the fuel cell will make a breakthrough in the transport sector by 2030 very optimistic. The aim of car manufacturers who launched into this sector was to replace existing engines with a fuel cell which was directly linked to the transmission. It was impossible to achieve this, not only because it was much too expensive to develop industrially, but also because hydrogen was not available in service stations. Perhaps there will be a very slow start made with the electric hybrid car, undoubtedly equipped initially with a small traditional thermal engine, which could be replaced in twenty years or more by a fuel cell.*

F. T. : The transport market will perhaps only be modified after 2030, but we concur with the European vision, according to which one must go through the transitional phase of early-stage markets, before tackling the mass transport market. I also share your analysis on the probable developments regarding the car. We are already developing a hybrid architecture on a small vehicle which is equipped with normal batteries and a cell, which is not only a hybrid of the engine, but may be used in order to prune a hedge, for example.

Q. : *In the aeronautical industry, the new generation of single-aisle airliners, intended to replace the Airbus A320 and the Boeing 737, will arrive between 2015 and 2017. Since aeroplanes are going to become increasingly electricity-driven, about 200 kW will be required to be supplied by a generator whose density is less than one kilogramme per kilowatt. In view of this, do you think that the aeronautical industry is a potential market for fuel cells ?*

F. T. : It is a matter of producing electricity when the aeroplane is on the ground and all the engines are switched off. At Axane, initial studies have been carried out on the replacement of the present turbine. However, as yet we do not have a very clear idea of the phases of power required before take-off, nor of the margins of compromise in terms of energy requirements. Of course, we could place our product with its non-polluting technology on the tarmac next to the aeroplane, but I do not think that the introduction of hydrogen in the aeroplane itself is currently acceptable.

The method of functioning

Q. : *You have not discussed planning. Is the time dimension a very 'elastic' concept in your management ?*

F. T. : At Axane, there is planning. It is not the tasks that we plan ahead, but the issues which are at stake, or the stages of issues which allow us to reach a final objective in 6 or 8 months' time. This mapping of the sequence of the issues is the result of an assessment which takes into account our potential, and the way in which this sequence might take place. Once this planning has been assessed and guaranteed, we start carrying out the work, and from that moment time margins become very limited.

Q. : *The way in which your team works seem impossible to me because it is too small. Since the relationship between the large company battalions and this small flexible and dynamic team might cause problems, surely its activity should be very strongly supported by top management ?*

F. T. : A team of between 40 and 50 people functions very intuitively but with more people, it would be important to formalise the culture and to ensure that the employees feel that they are part of a structured and organised team, making sure that the quality of relationships between people is preserved.

In the rest of the company, the methods of functioning and the culture are naturally different because the issues and the organisations are not the same. Therefore, particular care should be taken with the interface between the 'commando' team (ie. the management) and the majority of the troops.

As far as we are concerned, the Air Liquide group gives more than just support because it also has activities in service stations for demonstration cars and in the development of new logistics of production and of the conditioning of hydrogen. Of course, we are subject to severe constraints because we have to have profitable applications and we have to manage our budget, and take account of our activities. We have to deal with our profits and losses, and so on, just like any other structures and services of Air Liquide which are brought together to discuss the theme of 'hydrogen energy'.

Presentation of the speaker :

Frédéric Touvard : he began his career at Air Liquide in 1995 when the first installations for military purposes (such as the Charles de Gaulle aircraft carrier ; sub-marines) were launched. He became Project Manager when Axane was created and developed new methods of management for innovative projects. Today, he is the Director of projects and products for Axane and manages a team of twenty-five people. He is currently training to be a certified coach for *Coach & Team* (coaching and mentoring for CEOs)

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