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Limitations on halocarbon refrigerants trigger the question: why not ammonia?

Use of ammonia in civil air-conditioning applications

by Alessandro Sandelewski

Ammonia has been for decades the preferred refrigerant for industrial applications, thanks to its excellent thermodynamic properties and its low cost. However, its toxicity and flammability have until now limited the applicability of this otherwise excellent refrigerant. On the other hand, the limitations passed by many countries about the use of halocarbon refrigerants in these last few years have triggered a new interest in the use of ammonia for civil applications as well

Ammonia is an inorganic compound, produced naturally by living organisms (man, domestic animals, plants), and manufactured industrially prevalently as a fertilizer in agriculture. It is also used for the preparation of explosives such as TNT and nitroglycerin, as an alkaline acid neutralizing agent in liquid effluent treatment plants, and as an essential component in nitrogen and sulphur oxide abatement in large thermo-electrical power plants and industrial systems. Of the 100 million tonnes of ammonia produced annually, 80% is used in agriculture, 18% in the industry and only 2% as a refrigerant. The use of ammonia as a refrigerant in mechanical compression systems started to be considered towards the

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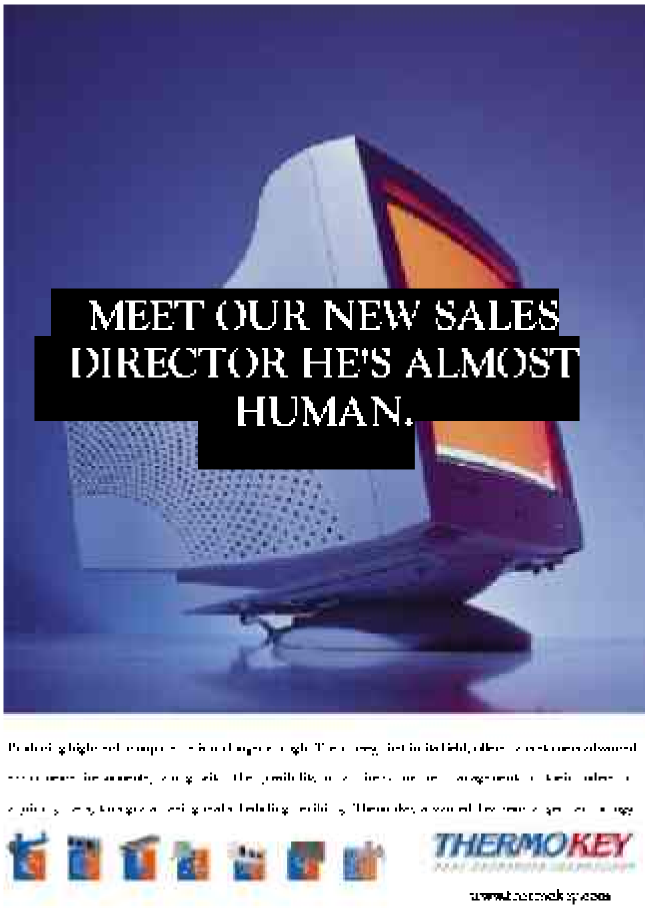

The Networked Company: a great opportunity for small enterprises

by Michele Coletti

Increasing competitive pressure forces firms to work closer with other companies. The revolution initiated by information and telecommunications technologies makes this a more affordable solution. Would you like to know the advantages of collaboration among enterprises and get some advice on it? Read on...

Managing a firm is a daunting task, particularly in the case of Small and Medium Enterprises (SMEs), because they typically suffer from a scarcity of financial, human and technological resources. However, there is increasing pressure to reach new markets, offer new products and services and imple-

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ment technologies or organizational changes that show up the inadequacy of the traditional short sighted, centralised and self-sufficient management approach within SMEs.
SMEs are, however, often led by entrepreneurs with quick and intuitive minds, able to read the market and grasp new opportunities.
The biggest change they have to cope with is the fact that the world is more and more interconnected and it is therefore no longer possible to work in isolation. It is therefore necessary to develop their ability to anticipate and react quickly.
Technological innovation and globalisation are the strong forces continuously reshaping the market. Many sectors have matured, so possibilities of growth are decreasing. In the consumer products sector, large distribution networks are using their might to put pressure on producers in terms of margins and market share. In several industries, the arrival of Asian competitors has added to price pressure on European and American firms.
In addition, purchasing managers are more skilled and competent than ever, forcing suppliers to lower prices. As a result, if the company is too small or isolated, its bargaining power may be too week to keep it profitable.
With investments in innovation rising continuously and their risk growing proportionally, it is only the larger entities that can bear the weight. Sharing the risks (and the rewards) is a wise strategy for innovation and investment.
Timing is another key issue. To be part of an alliance can mean the difference between survival and failure, and in a market where many are searching for good opportunities, it's the proverbial "early bird who catches the worm".
For all these reasons, from a strategic and organizational point of view, enterprise networks are a good answer to globalisation and technological innovation. As discovered by a recent study conducted in 1,600 manufacturing companies by the Fraunhofer Institute - ISI (based in Frankfurt, Germany), firms operating in partnership with others generate 14% more added value per employee than companies that are completely independent. When the market requires flexibility and low costs, forcing economies of scale; when there is a need of capital for large or risky investment, or tight integration (technological or organizational), is required or advisable, it is useful for the individual enterprise to consider some kind of cooperation with other companies.

How to cooperate

There are, of course, many forms of cooperation. Some are very loose and do not involve equity exchange or significant investments, and are usually narrow in scope or short in duration. Others, e.g. mergers and acquisitions, can be very binding or imply tight and detailed contracts.
It is certainly not easy to find the right kind of cooperation - many factors have to be considered. However, we shall try to give our contribution to the topic, starting with a description of some typical models and their main features (see Tab. 1).
The easiest and one of the most common forms of cooperation is *subcontracting* or *outsourcing*, i.e. the externalisation of some of the activities or processes previously executed internally. Outsourcing is growing, companies have realised that in order to compete they need to concentrate on their core capabilities (which are usually not too many), and acquire others externally. In this way, they can keep abreast of the latest technologies or changes in the market, while buying in from specialised firms as and when required, instead of maintaining expensive resources internally.
It is possible to outsource both primary and support processes, where the former add value for the customer (e.g. procurement, sales and production) while the latter are ancillary to operations (i.e. administration, facility management...). Nowadays, there are suppliers specialising in sub-components, maintenance, management of information systems, catering or whatever can assist their clients to cut costs and work more effectively. When subcontractors work very closely with their clients and have the capability to get involved in the development and design of new solutions, it is possible to define their relationship as *comakership*.
However, this is a relatively simple form of collaboration. A slightly more complex form is *franchising*, i.e. formal permission given by a *franchisor* to another party, called *franchisee*, to sell goods and services under certain conditions and control. In other words, the franchisee, in addition to the goods to be sold, enjoys the brand and support of the franchisor, for a fee. This formula has proved successful especially for b2c (business-to-consumer) activities, as customers benefit from the brand, image and consistency, while enabling the franchisor to increase sales points and the franchisee, making use of a valid business idea without having to develop it on its own.
Licensing is an agreement to transfer the right of exploitation of a patent, trademark or other kind of expertise for a specified period and area. If the transferred technology is still up-to-date, this is a viable option for the seller to earn money without additional investment, and for the buyer to acquire validated know-how without bearing the cost of development.
Other forms of collaboration are particular *contracts* through which products or services are exchanged under pre-established conditions - one can therefore place several orders during the year without having to negotiate every time. These are very useful for trading commodities or raw materials, where orders are recurrent - often the only variable to agree each time is price.
A *consortium* (or a temporary association of enterprises) is the usual agreement among partners for the implementation of a particular project (from the preparation of the bid to the delivery of the completed work). It may

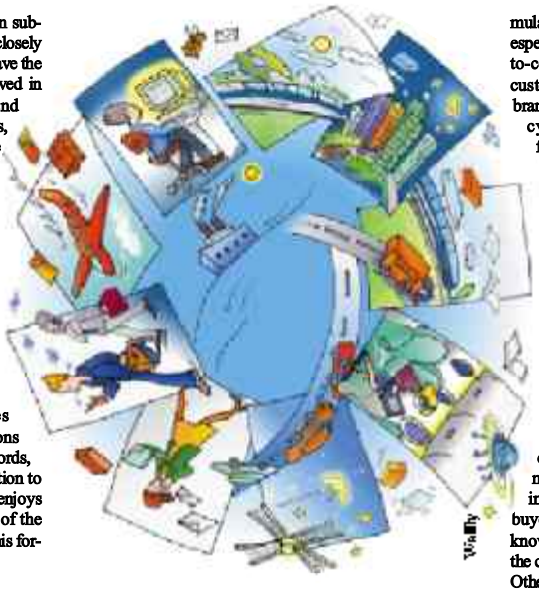

Table 1 - Forms of cooperation among enterprises

Type of co-operation	Object	Typical duration	Advantages	Disadvantages
Outsourcing, Subcontracting	Buy goods/services from specialised suppliers	Short-medium term	Lower costs and risks	Time and cost of supplier management
Licensing, Franchising	Transfer of technology, use of trademark, goods or services	Fixed, renewable	Acquisition of image, technologies and know-how	Costs and costraints of contracts
Contracts	Buy products/services under pre-established conditions	Medium term	Flexibility	Price volatility, narrow scope
Temporary association, consortium	Agreement among partners for the implementation of a particular project	Project duration	Synergies of competences and resources	Differentiation problems, teambuilding difficulties for lack of trust, limited duration
Strategic alliance, EEIG	Agreement among partners for the development of a particular product/market	Flexible	Access to new markets without heavy efforts	Operational and organisational complexity requires skillful management
Participation in equity	Share exchange, merger and acquisition	Long term	Acquisition of know-how and market shares	Integration may be difficult, risk of choking key success factors of the controlled enterprise
Joint-venture	New company owned and controlled by the partners	Long term	Complementarity of expertise, specialised managers	Diversity in stakeholders interests, cultural conflicts, high costs

Source: adapted from Tidd, Bessant and Pavitt

A framework for cooperation among firms: The European Economic Interest Grouping

We take the opportunity to interview Mr. Gennaro Aprea, an expert of international alliances and co-author of a recent book on the topic, with particular reference to Small and Medium Enterprises.

Q. Mr. Aprea, what is the European Economic Interest Grouping (EEIG) and what are its origins?
A. In the last twenty years or so the process of internationalisation first and then globalisation has involved enterprises of all sizes (especially thanks to the birth of a European Common Market). However, large firms could afford direct investments abroad, while others had to find and establish relationships without clear juridical tools. Therefore in 1985, based on the concept of the French GIE (Groupement d'Interêt Economique), the European Council issued a Regulation instituting the EEIG and its characteristics. The aim was to provide a legal framework for cooperation among European companies or individuals, and so far this is the only trans-national instrument of its kind.

Q. What are the advantages of the EEIG?
Above all flexibility: EEIGs are open to private and public companies, individuals and other bodies like Universities or Associations. The only limitation is that members shall be at least two and belong to a minimum two different EU countries. However, their activities must not be limited to the EU market. Wherever there is a need to develop or facilitate business, members of an EEIG put together their resources and can present themselves as one entity. Besides the obvious synergies, there is the possibility to tender for EU projects and other public bids with a greater and stronger structure, thus increasing the chances of success. Moreover, it is possible to apply for loans and other forms of financing and get better conditions, because the network of members is a guarantee of solidity.

Q. Which are the most appropriate conditions?
A not too big group of SMEs with a clear identification of scope and a significant mutual trust would be the ideal set to start with. Members take advantage of their partners in terms of organizational structure, capabilities, direct presence in other markets or segments, integration of products and services, not to mention the opportunity of learning from each other. Particularly suited are professional services - lawyers, engineers, tax consultants can establish an EEIG to serve their customers all over Europe. In this way, even an individual can provide services to a multi-national company thanks to its network, but there are also examples of EEIG involving large aircraft companies.

How many EEIG have been registered so far?
Despite the relatively short history of this kind of instrument, there have been a thousand EEIG registered in Europe, and more than 900 still operating. A quarter of them are based in Belgium (because of the presence of institutional bodies in Brussels), almost 200 hundred in France and more than 100 in the UK. In other countries such as Italy (less than 50), Greece (8), or Sweden (7), this instrument has apparently been less popular, but we have to consider that the

entail a significant cooperation, but it is fairly rigid and the partnership ends with the completion of the project. Similar agreements might be created to provide services to the members or to support them in the purchase or in sale of their products.

When a group of enterprises forms a new company and controls it, this is called a *corporate interest* (there are also *contractual* joint ventures, that do not imply a new firm) - a fairly demanding form of collaboration that can be advisable or compulsory if one wishes to establish manufacturing facilities in particular locations, such as China or Eastern Europe. In this case, the existence of a local partner, often a public body, with its knowledge of local culture and mechanisms, simplifies all activities, from administration to the recruitment of personnel. Hence, the other partner can concentrate on the areas in which is stronger, i.e. technology and finance. Joint ventures are a good way to enter new markets, although they can be difficult to manage due to the cultural and strategic differences between partners.

A further form of collaboration is the exchange of shares or, more extremely, the total or partial acquisition of a company by another company. When there is a *merger* between companies, only one of them continues with its business. A major driving force for these changes has been the willingness to integrate vertically (i.e. a firm with its supplier or with its customer) or horizontally (i.e. mergers between firms with similar products), in search of improved performance or economies of scale.

Criteria for partnerships

Although some scholars only consider formal forms of collaboration to be *strategic alliances*, we consider all types of cooperation with a strategic scope as an alliance, aware that sooner or later, some formal agreement will be written. A very flexible legal framework is the European Economic Interest Grouping, particularly suited to SMEs and professionals (see box).

Despite strong competition and rivalry, cooperation amongst firms has grown rapidly in the last two or three decades, as alliances have proliferated in one sector after another. Indeed, collaboration has created new types of competitors and generated new forms of rivalry, which now often exists between sets of allied firms, rather than between single firms.

This is particularly true in complex businesses undergoing rapid change and where collective competition dominates an industry, such as Information and Communication Technologies (ICT) and aircraft manufacturing. However, other industrial sectors have seen a proliferation of alliances in recent decades (e.g. the networks of companies working in the Italian industrial areas, the so called "Third Italy"), as have the service sectors (especially finance). Alliances alter rivalry in two ways: they create new units of competition that supersede firms, and introduce new patterns of competition, in which collaboration inside economic units affects their market behaviour.

Alliances also affect the way business strategies are approached. A constellation (the organization created by an alliance) must organize itself internally so as to maximize the benefits of collaboration, while minimizing conflicts among its members

It may be useful to introduce some criteria to help managers and entrepreneurs understand when search for some form of partnership: as demonstrated in the matrix of Fig. 1, when a product/service is easily identifiable and quite common, spot transactions or open contracts are acceptable. At the other end of the scale, for very specific and difficult-to-define goods, hierarchical arrangements like mergers or acquisitions are often the best option. In between, there is room for any form of partnership we have seen so far. In this case, other criteria such as management complexity and strategic relevance of the traded goods have to taken into account to select a suitable solution.

Fig. 1 - Criteria for co-operation

How to make it work

At the day-to-day level, partnerships usually involve more articulated interactions between companies: the exchange of information and goods becomes more frequent and rapid. New software such as Enterprise Resource Planning (ERP) and the Internet enable one to keep track and transfer data efficiently, saving money and time. From e-procurement to supply chain management, from co-design to digital markets, new technologies have been introduced to enable new business processes. Conversely, new business processes can be introduced because of the new technologies, up to the extreme point of the *virtual enterprise* a community of firms that, thanks to ICTs, can work and appear to its

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EEIG can be located independently from the nationality of its members. That means that usually they are established where they are better known and the administrative burden is lower, i.e. in relatively less bureaucratic countries.

What are usually the risks and benefits of an EEIG?

As costs of founding and managing an EEIG are very low (often less than the costs for a limited company registered in a single country), risks are relatively small. Nevertheless a real risk of the EEIG is the joint and several liability of the members, although only for the obligations rising from the activity of the Grouping (similarly to the liability of an individual businessman, i.e. a "sole trader", or a "società di persone" in Italy). However, it is always possible to enter into and to leave a Grouping. The benefits are that with a modest investment in capital and time, it is possible to become part of a stable international network of firms recognised by the EU institutions, while maintaining complete autonomy and independence and, whenever necessary, taking advantage of the flexibility and strength achieved by a group of well-chosen partners.

What things should be given careful consideration?

As the life of an EEIG is regulated by a contract among members, the first thing to carefully consider is the strategic reason for getting involved in a structured cooperation, and this must be clearly described in the articles of the formal agreement relating to the "scope". Then, a careful choice of partners and managers must be made (the role of the latter is generally to take care of administrative matters and to keep internal communications flowing); the expertise of a lobbyist if EU projects are the target; and, of course, a good and experienced consultant to help set up the Grouping and write the contract, and the manual of procedures necessary to rule it.

Mr. Aprea (aprea@gaa-consultnet.com) is the principal of G.A.&A. Ltd (www.gaa-consultnet.com), a strategic consultancy which is also member of an EEIG specialising in professional services.

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customer as a single organization.
However, the tighter the partnership, the more trust is needed - and trust should not based only on goodwill but also on reciprocal advantages. A good partnership makes it very costly to assume opportunistic behaviour. Other factors contributing to a successful collaboration are: the presence of a "champion" (supporter) to promote the alliance and a facilitator to coordinate it (they can be any of the members, but usually belong to the leader company); partners enjoying autonomy but prepared to offer their expertise to the group; significant benefits to each and every element of the group through fair sharing mechanisms, when compared to the cost of their membership; and last but not least, a common culture (if not a common language) to facilitate the exchange of information and knowledge, avoiding misunderstandings and interaction problems.

The future of the enterprise
Alliances among enterprises will be an increasingly important strategy for SMEs, not only to maximize profits, but also to develop knowledge and innovation - key issues for entrepreneurs striving to make their business sustainable (these may be debated at a later date). Companies will learn to forge alliances even with their competitors, when this is the case. The coexistence of these two seemingly opposing forces has sometimes been called "co-opetition". However, as can be observed in industrial districts, the social network is even more important for the purposes of business than the technological network - but it takes more time to grow and consolidate. Thus, successful partnerships are very much dependent on how well relationships among their members are managed. In conclusion, here are some thoughts from the experts to bear in mind:
Develop comprehensive partnership strategies, and nurture them throughout the lifecycle
Alliance instability should be not feared, but embraced.
Polygamy is often better than monogamy, but promiscuity is not. RW

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Useful Links
www.alliancestrategy.com offers resources and articles on alliance strategy and management. The site is maintained by Ben Gomes Casseres, author of The Alliance Revolution.
http://www.strategic-alliances.org is the site of the Association of Strategic Alliance Professionals (A.S.A.P.), with an interesting list of links.

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It's a cool Winter Meeting in Chicago

More than 50,000 people are heading to Chicago to attend the Ashrae Winter Meeting and/or AHR Expo.
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During the Meeting, the Ashrae Learning Institute will offer short courses and professional development seminars, including two new courses on project management and dedicated outdoor air systems.
The International Air-Conditioning, Heating, Refrigerating Exposition (AHR Expo) offers displays from more than 1,400 exhibitors.
New this year are the AHR Expo Innovation Awards being given to recognize the most innovative HVAC&R products showcased at the Expo.
It is intended to encourage innovation and to provide vocational school scholarships for HVAC&R students.
Winners of these annual awards will be selected by a panel of judges selected by Ashrae Journal for their knowledge of the industry and its products. Awards will be presented in seven product categories.
The Ashrae Technical Program and the social events (plenary session, welcome party, President's luncheon, Life Members' luncheon, reception and banquet) will take place at the Palmer House Hilton.
For more information about the winter meeting, visit www.ashrae.org/MEET/CH-MeetingInfo.htm
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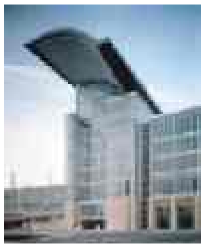
USE OF AMMONIA IN CIVIL AIR-CONDITIONING APPLICATIONS



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middle of the last century both in Europe and in the United States. The merit of having been the first to design and install actually working ammonia systems can be attributed ex aequo to the American David Boyle and to the German Karl von Linde. Linde's first new system was built in 1877 for the still existing Dreher brewery in Trieste, Italy, and worked effectively and efficiently until 1908, where it was transferred to the Technical Museum in Vienna. Since then, thanks to its excellent thermodynamic properties and low cost, ammonia became the universally adopted refrigerant for all medium to large refrigeration plants both in the civil and in the industrial sector. Ammonia machines of the beginning of the century rotated at a few hundred RPM, were extremely bulky, and, if properly maintained, could last for ever.
Supremacy of ammonia ended in the '40s when halogen refrigerants, odourless, nonflammable, nontoxic were developed, became standard in commercial refrigeration and air-conditioning. Ammonia, however, was, and still is, used extensively in industrial refrigeration, especially for food processing and conservation. A publication in 1988 estimated that 80% of refrigerated warehouses in USA and Canada used ammonia systems, while in Western Europe halogen refrigerants were slightly preferred.

The patent for the first refrigeration machine by Linde (1877)

NEW PERSPECTIVES

Given the present restrictions on production and use of halogen refrigerants, in particular with the outlawing of CFC-11 and 12 and the impending prohibition, in Europe at least, of HCFC-22, use of ammonia as an alternative refrigerant in sectors different from the traditional ones is considered with great interest. ASHRAE, in its Position Statement (1993), states that use of ammonia is necessary for food conservation and air-conditioning, and that the Society intends to promote a number of initiatives in order to maximize the economical benefits of its use, while reducing the associated risks to a minimum. In particular, diffusion of information shall be promoted by means of seminars and publications, research on application, operation and control of system emissions, development of guidelines and standards for design and application. Similar positions were expressed by other international organizations, such as the Australian Institute of Refrigeration (AIRAH), the International Institute of Refrigeration (IIR), and the German Institute of Refrigeration (DKV).

ADVANTAGES AND DISADVANTAGES

It seems interesting, at this point, to compare briefly the properties of ammonia with those of the most commonly used halogen refrigerants and propane, which is increasingly being used in Germany and other Western European nations as an alternative refrigerant. Table I summarizes the most important properties of these refrigerants:
If we wanted to briefly summarize advantages and disadvantages of ammonia, we could mention the following points in its favour:
Cost. Cost of ammonia per kg is more than six times lower than HCFC-22. Moreover, ammonia is favoured also by the low liquid density, which is half of HCFC-22. Since refrigerant is sold by the kg, but the amount necessary in a system depends from its volume, which is measured in litres, the cost of an ammonia charge, in volume terms, is 1/11 of HCFC-22. In systems where the amount of refrigerant used is great, such as that for the McCormick Center of Chicago which will be described later, the saving can amount to tens of thousands of dollars.

Thermodynamic efficiency. Table I shows that, with the same evaporation and condensation temperatures, ammonia offers the highest COP among all the refrigerants considered, even if the advantage against HCFC-22 is only 5%.
Heat transfer coefficient. Since the specific heat of ammonia, both liquid and vapour, is about four times, and latent heat of evaporation about six times, higher that HCFC-22, the heat transfer coefficient in evaporation and condensation of ammonia is between 1,6 and 4 times higher than HCFC-22. In practice, this means that the evaporator or the condenser of an ammonia chiller can be smaller than the same component in a HCFC-22 machine, or that, for the same heat exchange, evaporation temperatures can be higher and condensation temperatures lower, which translate in an evident advantage in COP terms.

Table 1 - Comparison of properties for some commonly used refrigerants

Parameter	Ammonia	R-12	R-22	R-134a	R-502	Propane
Ozone deployment potential (ODP)	0	0.93	0.05	0	0.38	0
Global Warming Potential (GWP)	none	3.2	0.4	0.31	5.62	none
Atmospheric life (years)	< 2 weeks	120	19	18	240	< 2 weeks
Operation in refrigeration, capacity 1760 kW, tevap = -17.8°C, tcond = 35°C						
Absorbed power (kW)	594	682	625	650	690	697
COP	2.960	2.580	2.814	2.707	2.550	2.523
Mass flow rate (kg/s)	1.631	15.938	11.302	12.337	18.203	6.765
Volume flow rate (l/s)	959	1,646	997	1,698	1,030	1,166