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CO2LD: AN EDUCATIONAL INNOVATION PROJECT FOR ADVANCED VOCATIONAL TRAINING IN REFRIGERATION

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Abstract

Refrigeration is one of the technology sectors that has suffered the most changes in the last twenty years, because of the negative impact of the fluids used in the refrigeration cycles, i.e., refrigerants, due to their impact on the ozone layer and their contribution to global warming. As a result of their negative effects, the European Union has established several directives to restrict the use of refrigerant fluids, and the sector therefore needs to adapt to the new regulations.

This process of adaptation of the refrigeration sector to the new regulations must be carried out by all the agents involved, including those engaged in the training and education of the future refrigeration technicians. To allow this to be accomplished, a project called CO2LD was developed to introduce the future technology in High Degree Professional Training in Refrigeration. The objective of the project consisted in introducing more efficient and more sustainable refrigeration systems, namely R134a/CO_2 cascade cycles, into the Advanced Vocational Training in Refrigeration studies, and in creating a collaborative framework among students, secondary schools, refrigeration technicians, refrigeration companies, and the University in order to facilitate the transfer of know-how. This paper presents the objectives of the project, describes its development, and analyzes its main conclusions.

Keywords – advanced vocational training, refrigeration, cascade cycles, low GWP refrigerants

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1 INTRODUCTION

Refrigeration, or the production of “artificial cold”, is a technology that is essential to guarantee the welfare of our society, for example in air-conditioning, refrigerated transport, refrigeration for preservation of perishables, industrial processes, and so forth. Thus, refrigeration has spread to all areas of our lives. In fact, in 2007 the electrical energy consumption of the refrigeration sector, including air-conditioning, accounted for 15% of the total electrical energy produced in the world (International Institute of Refrigeration, 2007). Moreover, in some applications, such as supermarkets, refrigeration and HVAC represent around 50% of the electrical energy consumption (Tassou, Ge, Hadawey & Marriott, 2011).

Achieving sustainable development is a global objective all around the world and, accordingly, increasing energy efficiency and using more environmentally friendly technologies is needed for any activity or process, both in industry and for domestic uses. The refrigeration sector must deal with both perspectives, since its energy consumption is continuously increasing with the spread of this technology in all human activities, and because the most common refrigerants are greenhouse gases. First, the electricity demanded by the refrigeration plants represents important emissions of the greenhouse gas CO_2, known as the ‘indirect effect’ of refrigeration plants. Second, the most widespread refrigerants belong to the HFC family, which are classified as one of the six types of greenhouse gases (United Nations, 1997) and have a Global Warming Potential (GWP) thousands of times that of CO_2. The emission of these refrigerants into the atmosphere corresponds to the 'direct effect', representing another problem for the environment (Figure 1). Therefore, the use of low-GWP refrigerants must be considered.

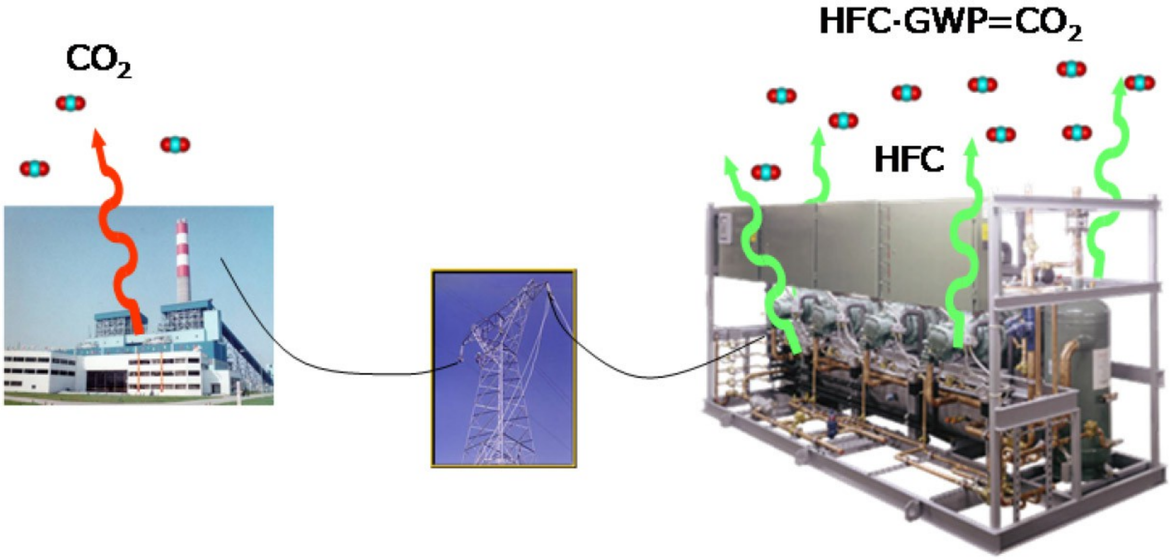

Figure 1. Outline of the environmental issues of refrigerating systems

In Europe legal measures have been introduced to restrict the use and emissions of fluorinated gases (like refrigerants with fluorine), such as Regulations CE-1484/2007, CE-842/2006, CE-40/2006 and CE-0189/2003, which were focused on limiting the use of refrigerants with high GWP values (above 150) in air-conditioning or refrigeration appliances. Additionally, the European Commission has presented the proposal of regulation COM/643/2012 (2012) on the regulation of fluorinated greenhouse gases, which include strong limitations on the use of HFC refrigerants. That proposal will mainly affect the refrigerants used in commercial refrigeration, i.e., R404A and R507A, as of the year 2020.

This last proposal for regulation, if approved, will call for a profound renewal of refrigeration technology and its refrigerants in order to achieve the following goals:

- Use of more environmentally friendly refrigerants. Among these refrigerants CO_2 stands out above the rest because of its environmental properties (ODP=0, GWP=1), its safety characteristics (non-toxic, non-inflammable, non-explosive) and its thermophysical properties (high heat transfer coefficients).
- Implementation of more energy-efficient refrigeration systems. In this line, in refrigeration at medium and low evaporating temperatures, double-stage refrigeration systems, either as compound (Torrella, Llopis & Cabello, 2009), booster (Mumanachit, Reindl & Nellis, 2012) or cascade systems (Dopazo & Fernández-Seara, 2011; Getu & Bansal, 2008), are being used more and more frequently. This project focuses on the application of cascade systems with low-GWP refrigerants.

To comply with the above objectives a number of important barriers need to be surmounted (McMullan, 2002), among which we could highlight the need for education, training, and awareness of the use of new refrigerants and the new technologies associated with them, which differ greatly from those currently in use. To overcome these barriers, the main objective of the project entitled '*CO2LD: New vapour compression refrigeration technologies using CO_2 and R134a to replace the current fluorinated refrigerants (HFC)*' was to introduce these new refrigeration systems and the new refrigerants in the 'Advanced Vocational Training in Refrigeration' and at the same time create a collaborative framework among the instructors, the sector companies, and the University to facilitate the implementation of these refrigeration systems. Each part of the framework performed a vital role in ensuring the success of the project: the University carried out a process of technology transfer, the companies provided the technology, and the high school teachers were instructed so as to be able to teach the future technicians in refrigeration.

2 PROJECT APPROACH

To fulfill the goal of the project mentioned in Section 1, the project was organized in such a way as to allow the following sub-objectives to be fulfilled:

- Achieve a common forum to allow knowledge to be transferred among all the parts involved in the project. To accomplish this, collaboration between the University and the Companies was established in order to attain a process of knowledge transfer to the instructors and students of the Advanced Vocational Training.
- Design, build, and develop a refrigeration system in each participating school. The plants were based on the cascade technology, the selected fluids being CO_2 and R134a, since their combination was one which provided a low GWP solution and, at the same time, high energy efficiency.
- Provide measurement devices and a data acquisition system in each plant in order to be able to evaluate the energy performance of their operating cycle. This was absolutely necessary to complete the process of instructing the future technicians.
- Build and launch a website and a virtual classroom to make the results and development of this project, including the equipment that was implemented, knowledge and results, accessible to other educational institutions that are related with refrigeration but were not able to participate in this project.
- Embody all the project results and the process of knowledge transfer in educational documentation to be used as a support for the practical and theoretical lessons that are taught in the high schools.
- Instruct the advanced vocational training teachers about automation, measurement, regulation, and control techniques of complex refrigeration plants. Furthermore, they were also to be instructed about new refrigeration methods which are being introduced in the industrial field.
- Disseminate the project results through specialized means of communication in the refrigeration sector, both from the point of view of education and from the point of view of industry. A good, strong involvement on the part of the sector companies in the results of the project is essential.

3 PROJECT METHODOLOGY

To achieve the objectives of the project, the methodology used, and summarized in Figure 2, was the following:

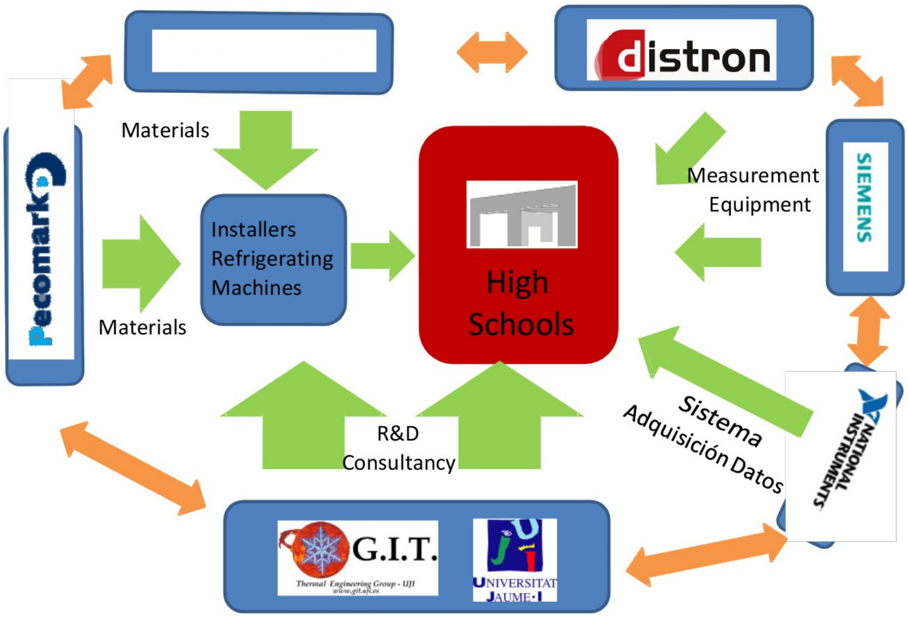

Figure 2. Map of the collaboration among agents involved in the project

The Thermal Engineering Research Group (www.git.uji.es) from the Universitat Jaume I of Castellón planned and designed the cascade refrigeration system, with the support of the companies Frost-Trol S.A. (www.frost-trol.com) and Pecomark S.A. (www.pecomark.com). All the components of the refrigeration system were provided by Pecomark Levante and Pecomark Andalucía, and Frost-Trol S.A. supplied the refrigerated cabinets to provide the system with the refrigeration load.

The companies Distron S.L. (www.distron.es) and Suelcasa S.A. (www.suelcasa.com) supplied the electrical components and measurement devices to monitor the refrigeration plants. Those components, together with the data acquisition systems provided by National Instruments (spain.ni.com), comprised the Data Acquisition System used to monitor the plants. Furthermore, the Thermal Engineering Research Group developed a data acquisition system based on LabView to be able to analyze the energy performance of the plants.

The refrigeration plants, with the measurement devices, were built by Pecomark and sent to the refrigeration installers to complete the whole refrigeration system in each participating school (IES Rascanya-Antonio Cañuelo, Valencia; IES Salvador Victoria, Monreal del Campo, Teruel; IES el Valle, Jaén; IES Pou Clar, Ontinyent, Valencia).

Throughout the whole of the project, the University, companies, and school staff collaborated in all the phases of the project, establishing a thematic network to analyze the advances being made in the project. Periodically, congresses and specific seminars were held in order to achieve knowledge transfer among all the agents involved.

4 PROJECT DEVELOPMENT

The project started in November 2011 and ended in October 2012, the main activities being the following:

- An initial training week to deal with the possible consequences of the modifications to the regulations, to instruct the participants in the use of CO_2 in refrigeration plants, and to study several energy efficiency techniques in refrigeration plants (Figure 3). This training week was held in December 2011 at the IES Rascanya, in Valencia, Spain. The conferences were open to installers, students, and everybody participating in the project.

Figure 3. Conference leaflet about refrigeration fundamentals, regulation, and refrigerant fluids

- A second training week, held in March 2012 at the IES Rascanya, Valencia, about the energy monitoring of refrigeration plants. This week covered sensors, data acquisition systems, automation systems, and the software needed to handle all the information received by the measurement devices.
- A third training week, held in April 2012 in the laboratories of the Thermal Engineering Research Group in Castellón, Spain, and at the IES Rascanya, was about research methodologies with refrigeration plants and their automation.
- In parallel with the training sessions, the cascade refrigeration systems were designed, their schematic outline being that presented in Figure 4.

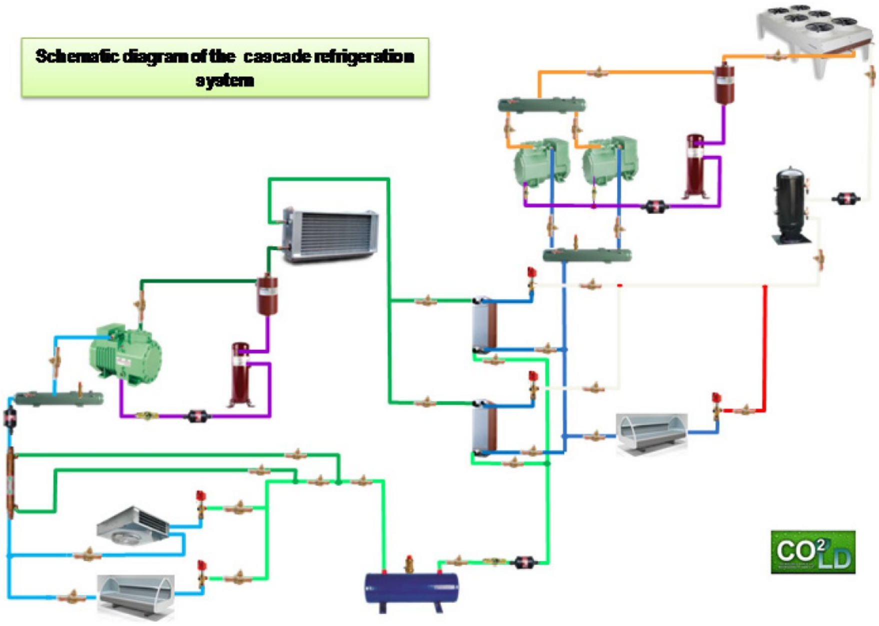

Figure 4. Schematic diagram of the design of the cascade refrigeration systems

- Technical visits to the participating companies. A visit to Pecomark Industrial in Barcelona and a visit to Bitzer in Germany were arranged (Figure 5).

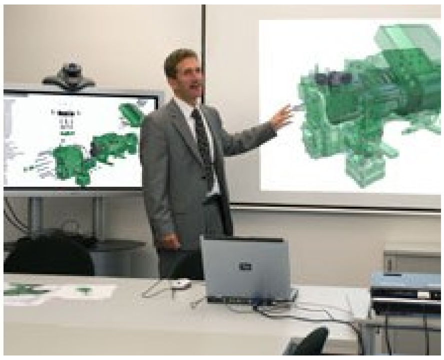

Figure 5. Visit to Pecomark Industrial in Barcelona (left) and to Bitzer in Stuttgart, Germany (right)

- Before the school's refrigeration plants were finished, some previous technical issues were tested in an experimental CO_2/R134a cascade in the laboratories of the Thermal Engineering Research Group, in Castellón (Figure 6). Accordingly, several technological solutions were tested successfully and were then implemented in the other cascade plants.

Figure 6. Experimental CO2/R134a cascade at the Universitat Jaume I

- Once the refrigeration plants were finished at Pecomark's plant, they were sent to each participating school to be installed by the refrigeration installers (Figure 7). The refrigeration plants were connected to the refrigerated cabinets and to the air condenser, the electrical box, and all the elements were connected and the data acquisition system was installed (Figure 8).

Figure 7. Arrival of the cascade refrigeration plant

Figure 8. Refrigerated cabinet (left), electrical box (center), DAQ system (right)

- The next fundamental activity was performed by the Thermal Engineering Research Group of Castellón, and consisted in developing the software for the real-time monitoring of the plants. This software, developed with LabView, was able to represent the operating thermodynamic cycle of the plants as they were running (Figure 9).

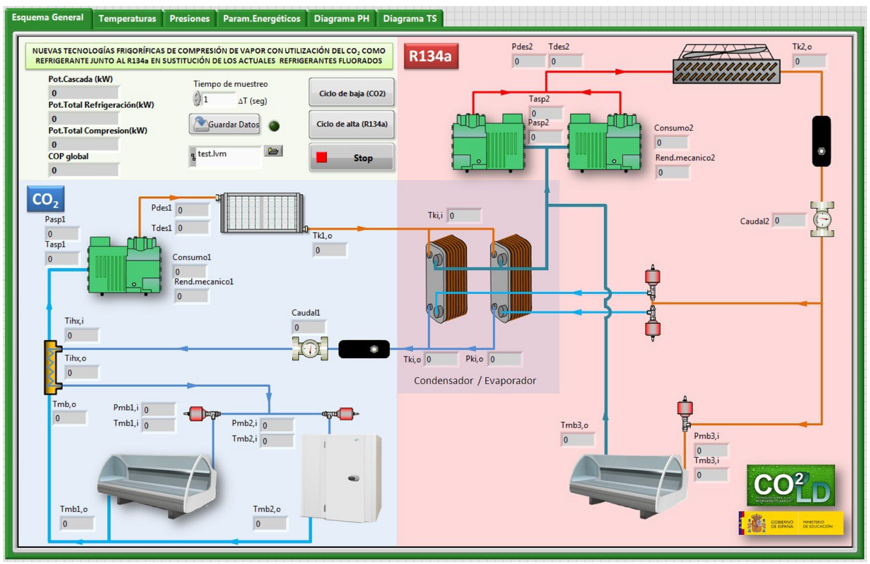

Figure 9. Front end of the DAQ system

- And finally, the last main activity was to launch each cascade facility in each school. This consisted in another process of collaboration, where all the people involved were present and helped with the launching of the plants.

Figure 10. Launching of the cascade refrigeration systems. (Top-left: IES el Valle, Jaén; Top-right: IES Salvador Victoria, Monreal del Campo, Teruel; Bottom-left: IES Pou Clar, Ontinyent, Valencia; Bottom-right: IES Rascanya-Antonio Cañuelo, Valencia)

5 PROJECT RESULTS AND CONCLUSIONS

Although the project has been under way for more than a year and there have been a lot of activities, the main results or conclusions from the project can be summarized as follows:

- The training given to the teachers of Advanced Vocational Training in Refrigeration included the following subjects:
  - Cascade refrigeration plants.
  - Regulation of the compressors of refrigeration plants by using variable-speed drives.
  - Condensing pressure regulation, methods, and energy involvement.
  - Handling and use of fluorinated refrigerants.
  - Defrosting methods in refrigeration plants.
  - Technology of cascade refrigeration systems.
  - Use and applications of CO_2 as a refrigerant.
  - Energy analysis of refrigeration plants. Sensors, data acquisition systems, and data analysis.
  - Energy optimization techniques and control of refrigeration plants.
- About technology transfer from University to the industrial sector: The Thermal Engineering Research Group already had some years of experience in the use of CO_2 as a refrigerant. This knowledge was transferred to the industrial companies and to the teachers and students, mainly based on new refrigeration technologies and new refrigerants.
- About the integration and business collaboration: With the project, a collaborative framework including all the agents involved in refrigeration has been achieved. It extends to cover secondary

school students, the University, the installer companies, and also the manufacturers of refrigeration products. A collaboration forum was created within the framework, where the knowledge flowed from one side to another. And more important, students have been approached by companies in the refrigeration sector.

- And finally, concerning the tangible results, one of the main objectives of the project was to provide the schools with refrigeration plants to be able to practice with them. Furthermore, apart from the plants, a lot of written material has also been created and distributed to the schools, thus enabling them to continue with their training objectives. Moreover, a collaboration platform was set up among the schools, University and companies.

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