“ENVIRONMENTALLY-FRIENDLY” HEAT EXCHANGERS: LU-VE PROPOSALS FOR THE REDUCTION OF ENERGY CONSUMPTION AND REFRIGERANT CHARGE

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Pressure has been building up considerably over the last few years to develop solutions which enable the reduction of energy consumption and the quantity of refrigerant in cooling circuits.

This article focuses on two solutions recently developed by LU-VE. The first applies to unit coolers in cold rooms; it consists of an innovative control system which can be installed on board the unit cooler itself and is therefore capable of operating correctly in a cold (down to -30°C), damp, environment, with the presence of ice. This controller drives the electronic expansion valve which feeds the unit cooler itself. The system combines the efficiency of the electronic valve with the simplicity of a plug-and-play solution, from which it derives its name, Plug&Save. Having a system already fitted to the unit cooler greatly simplifies installation, facilitates setting up the plant and encourages the more widespread use of electronic valves which significantly save energy; indeed, the greater precision of the valve allows the overheating of the evaporator to be contained and therefore to raise evaporating temperature, while the wide operating range of the valve makes it possible to work with floating condensing thus reducing the evaporating temperature in cold periods.

The second solution on the other hand, is for condensers; this paper presents the results of the development of a new, compact, finned-tube geometry, 20x17.32mm. The technology employs 5.0mm diameter copper tubes and advanced louvered fins for condenser applications. First, the fin geometry development process and the definition of the new grooved tube generation is illustrated; the basis of development is CFD analysis of heat exchanger performance which is able to find the optimum compromise from several geometric parameters in order to maximize the heat transfer coefficient and minimize air pressure drop. Theoretical outcomes are compared with an extensive testing campaign. The main advantages of the new technology are lower refrigerant charge combined with high performance overall. These characteristics allow the design of product with low life cycle costs and help to reduce plant refrigerant charge, as required by the current strict European standardization. The article later compares the new geometry with traditional finned tube technology heat exchanger with geometry 25x21.65 m and 9.52mm diameter copper tubes and Micro Channel tube heat exchanger with extruded aluminium tubes and corrugated fins.

1. PLUG&SAVE system for electronic expansion valves

Recently electronic expansion valves are greatly increasing their spread in refrigeration, however their potential is still largely untapped, indeed nowadays many installers still rely on traditional thermostatic expansion valve, despite the electronic valve has lot of advantages especially regarding the energetic performance of the systems where they are installed.

Among these advantages we can mention the possibility of having a floating condensation, able to adapt to ambient conditions, this allows the cycle to move to a lower condensing pressure when ambient temperature moves from the design one (usually the most severe), leading to a decrease in the compression work and hence to an increase in the COP of the whole cycle. In Figure 1 is presented a test on a cell for meat storage, in this test both standard valves standard and electronic proportional valves were tested.

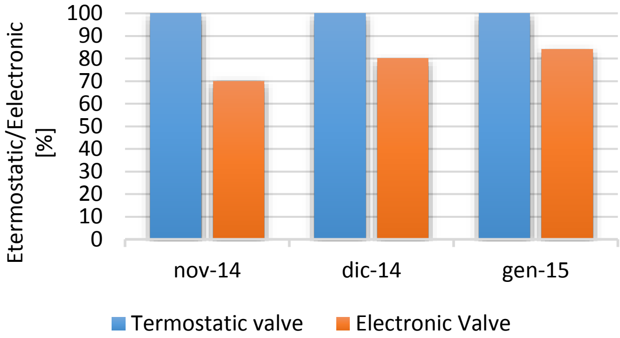

Figure 1: Comparison between electronic valve and traditional valve, winter period.

As the graph outlines, which presents the seasons during which ambient temperatures are lower, the possibility of using a system with a floating condensation leads to a drastic reduction to the energy consumption, which in the case studied is at about 25%. In addition to this advantage, the electronic valve allows a more precise superheat control bringing to a raise in the evaporation temperature. Finally, an electronic valve has a wider working range compared to a standard valve, moreover its higher capacity to adapt to load changes [1] leads to a reduction in the time for making the system working in full-operation (pull-down), thus improving the ability of quickly cooling the goods to be preserved.

For these reasons LU-VE has developed (with the aid of CAREL Spa) an innovative system called *PLUG&SAVE* which consists in the assembly of the valve and the controller directly on board of the evaporator for cold rooms.

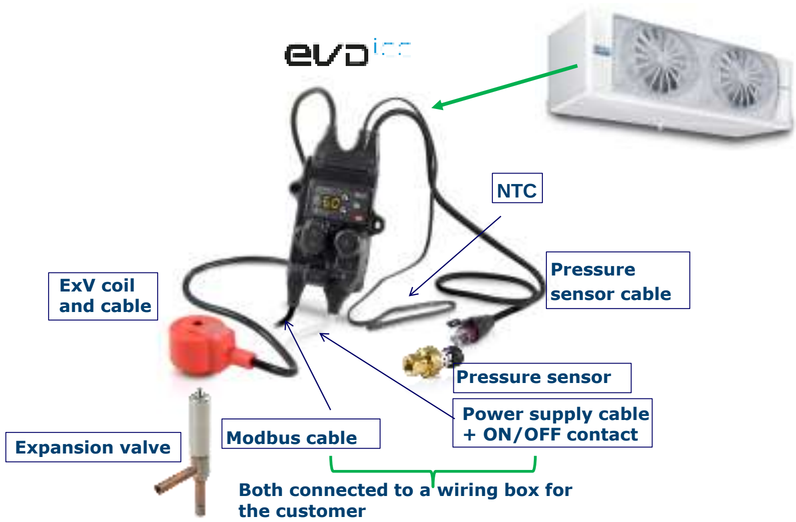

Figure 2: PLUG&SAVE system scheme.

The system is quite simple, as can be seen in Figure 2 it is composed of the following parts:

1. Controller: PCB constructed using the overmoulding technology in order to work well in wet and icy rooms (with temperatures down to -30 C); The PCB manages all the main

parameters of the valve and contains preset programs for the operation of the evaporator in cold rooms, minimizing on-field set-up operations.

2. Temperature and pressure probes: fit at the evaporator discharge (header) to allow the evaluation of the superheating degree.

3. Electronic proportional valve.

The system is very simple to be installed as it is easy to perform all the necessary wirings, indeed it must also be remembered that the PCB is powered directly from the 230V grid, removing the need of an auxiliary transformer. Furthermore, the setting of the device is very simple: it is only need to define the type of fluid (the PCB is equipped with a database of 24 different refrigerant fluids) and the system is fully functional. Furthermore, a "Modbus" cable is equipped to allow another communication with a supervision and control system.

2. New geometry with 5mm tube

Always in the scope of limiting the environmental impact, a very important topic is the reduction of the refrigerant charge in refrigeration devices; since heat exchangers are typically those components where the greatest part of the fluid is contained, it becomes very important to develop units having an internal volume as low as possible. LU-VE was the first company to propose a geometry with a 5mm tube diameter.

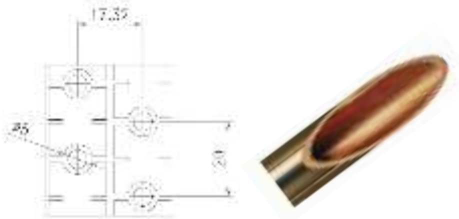

Figure 3: New geometry developed by LU-VE

The geometry is characterized by louvered fins and micro-finned tubes (which increase the inner surface of the tube) in order to have very high heat transfer performance.

Table 1: Comparison between standard LU-VE solution, Micro-channel and 5mm tube.

Model	**SHVN 19/0**	**Special 5mm tubes**	**Special multichannel**
Capacity [kW]	19,6	20,2	19,5
Tube diameter [mm]	9,52	5,0	multichannel 30 x 2
Tubes volume [dm3]	5,15	2,04	1,90
Header volume [dm3]	0,36	0,36	0,91
Total coil internal volume [dm3]	5,51	2,41	2,81
Header diameter [mm]	22	22	38
Internal volume difference	100%	43,6%	50,9%
Internal volume difference		100%	116,7%

Furthermore, the header can be chosen without particular mechanical constraints, therefore, the volume of the heat exchanger can be greatly reduced. Indeed, as Table 1 outlines, the heat exchanger volume and therefore the refrigerant charge is smaller for the new solution compared to the standard tube with 9.52 mm diameter and is slightly less than that of a heat exchanger made with the Micro-Channel technique at the same capacity and equal external dimensions.

Computational fluid dynamics (CFD) was extensively used for the development of the new solution. Indeed, if in the past the definition of the main characteristics of the heat exchanger were based mainly on a technical and economic optimization combined with experimental tests [2,3], nowadays we can no longer forbear a detailed study of the fluid-dynamics especially when the geometry of the fin gets complex as in the present cases (presence of micro-grooves).

The approach used in CFD LU-VE [4] was validated on an intensive experimental campaign, in this way the results of the numerical models are very reliable and able to describe with a good accuracy the performance of the heat exchanger. Over 30 solutions were tested at a numerical level, for example by changing the number of notches and the design of the louvered pattern: once a first selection we passed to the experimental analysis (based on test at the tunnel) in order to obtain a 'further validation of the performance of the heat exchanger. Moreover, the performance of different fin spacing and different fin thickness have been investigated in order to obtain a better characterization of the exchanger.

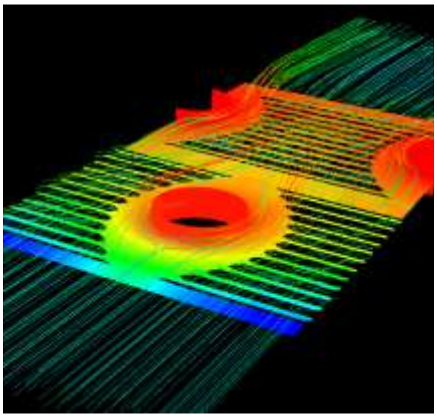

Figure 4: Temperature contour and pathlines along the fin.

In addition to the heat transfer performance and external fluid dynamics analysis using experimental test and CFD different types of tube were tested. The study was not focused only on tubes currently available on the market but a further optimization was studied, obviously in this study also the supplier of the tube was directly involved.

This kind of solution challenges directly heat exchangers made entirely of aluminum with the "Micro-Channel" technology. Here a comparison between the two technological solutions is proposed.

Table 2: Technological comparison between LU-VE solution and Micro-channel

	LU-VE Solution	Micro-channel	Comment
Installation	+	-	Installer has to solder copper pipe has usual in both cases but MC has joint Cu-Al rather fragile that can be easily damaged and reparation is difficult.
Cost			Influenced by production lot, however till 50 pieces the 5mm solution is surely competitive.
Reliability	+	-	MC has shown more problems.
Flexibility	+	-	MC has a very rigid production, it is difficult to provide special circuiting or enlarged coils. 5mm is very flexible as the actual technology shows.
Weight	=	=	Very similar values.
Recicling	-	+	Il MC has the advantage of the single material construction.
Fouling	+	-	MC actually has a 1,3mm fin spacing [5, 6], fouling is quicker.
Cleaning	-	+	MC is stronger, cleaning is quicker and easier without damage risk.

Table 2 shows that the main advantages of the tube to 5mm ("Minichannel" made with copper-aluminum than "Microchannel" of only aluminum) are mainly related with the lower fouling, the greater production flexibility, and the better reliability. Finally, this solution fits very well to the natural fluids such as CO2 (which is characterized by very low pressure drops and so does not suffer the usage of a small diameter tube) and hydrocarbons that for reasons related to the maximum refrigerant charge of refrigerant (linked to their flammability) require volumes as small as possible [7].

3. Conclusion

In this article the strategies of LU-VE for the production of environmentally friendly heat exchangers have been outlined. The first solution is the PLUG & SAVE system thet with an electronic valve allows an improvement in the energy performance thanks to a better control of the superheating degree and of the condensing temperature. The second consists in the "Mini-Channel" technology which allows a reduction of the refrigerant charge and that behaves well with natural fluids characterized by a low GWP.

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