

# application note



A scientific  
approach applied  
to intuition

## where

### Laboratory tests

- Carter Retail Equipment (UK)

### Field tests

- Eurospar supermarket in Azzano X (ITA)

## what

### Comparison between proportional and PWM electronic expansion:

- Control quality
- Energy saving

## why

- To compare the different control features of these two expansion devices in quantitative and qualitative terms, with practical field and laboratory tests

## E<sup>2</sup>V & PWM:

comparison between proportional and pulse width modulating expansion valves

Expansion valves are used in commercial refrigeration to supply the evaporators on showcases and in cold rooms.

The task of the expansion device is to guarantee correct superheat at the evaporator outlet.

It's easy to understand how better control precision can bring advantages in terms of energy saving, control quality and stability/safety of the entire refrigerant circuit.

To demonstrate such assumption with scientific rigour, CAREL has brought together a series of data and observations to help understand the true positive effects of proportional control compared to pulse width modulating.

This document reports the results measured in our laboratories, on real working installations and with the help of tests conducted independently by third party organisations.



## E<sup>2</sup>V stepper valve continuous flow modulation

- The electronic valve driver sends the valve a low voltage signal to rotate the rotor clockwise or anticlockwise
- The drive mechanism converts the rotation into axial movement of the pin
- The position of the pin changes the area of opening for refrigerant to flow through;
- Refrigerant flow is modulated precisely and continuously.

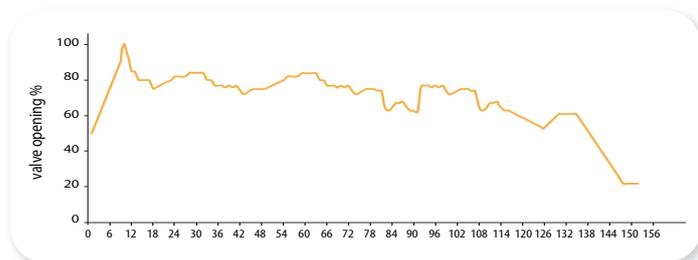
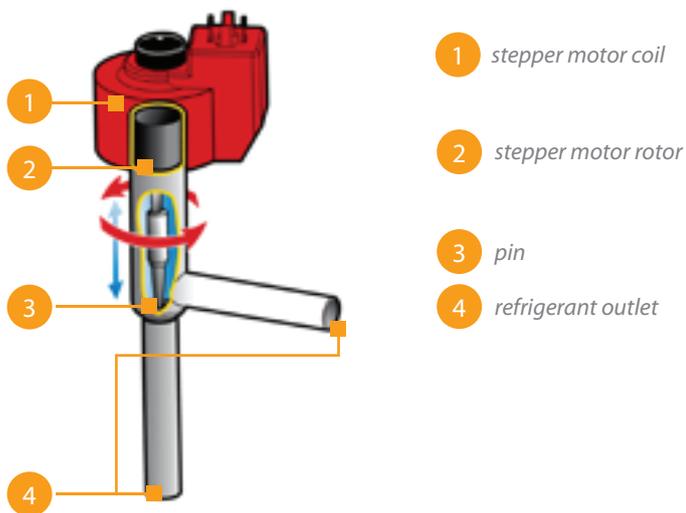


Diagram of the operating principle of a generic proportional expansion valve. The main plus of CAREL E<sup>2</sup>V proportional valves is axial rather than rotary movement of the control pin. Stepper valves can precisely and continuously modulate refrigerant flow based on the quantity needed by the system at any given time.

## PWM valve (Pulse Width Modulation) pulsating flow modulation

- The driver sends the winding a voltage signal to modulate the duration of the pulses (seconds)
- The magnet moves when the winding is energised
- The closing mechanism connected to the magnet either completely opens or completely closes the opening
- "Average flow" modulation is performed by adjusting the duration of the opening and closing times

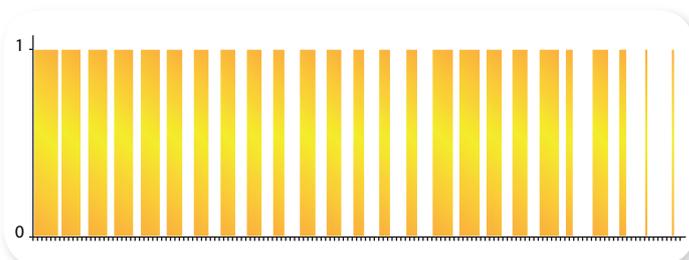
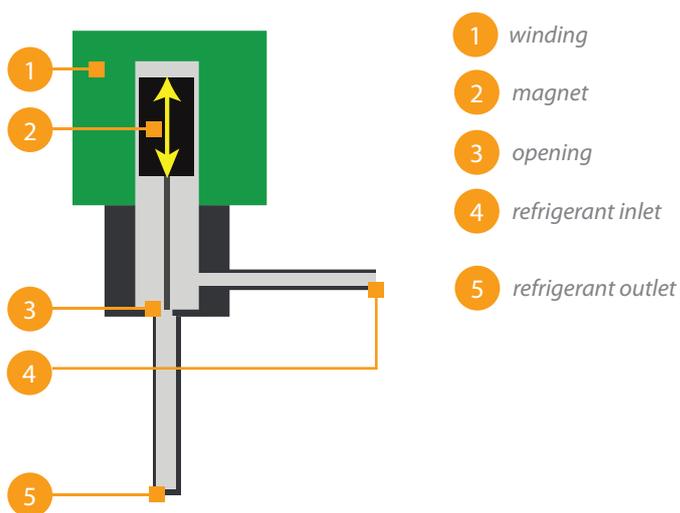


Diagram of the operating principle of a generic PWM expansion valve. PWM valves can only achieve a variation in the "average flow" over a period of several seconds. Instant flow can only be 100% or 0%.

### Advantages of proportional control



more stable superheat control: units can operate with lower set points, thus achieving better evaporator efficiency. This implies possible higher evaporation pressures, consequently saving compression energy;



wider range of control: a proportional EEV can better respond to changes in condensing and evaporation pressure and adapt to variations in load. The same model of valve can work on units with different capacities and different refrigerants, making the selection and replacement processes less complicated;



less vibrations in the pipes: PWM valves may create vibrations in the piping and in the refrigerant flow that can also lead to breakages or system malfunctions, or that require thicker and more expensive pipes to be used, with special anchoring;



no noise in the installation: unlike PWM valves, there is no noise created during normal operation;;



low operating voltages: less precautions needed for maintenance or if ice forms.

## Laboratory tests

Carter Retail Equipment conducted laboratory tests to compare a CAREL E2V18 proportional valve with a PWM valve. The tests were performed using a medium temperature upright showcase, especially modified so as to allow expansion by the two valves alternately: when one valve is selected, the branch the other is installed on is bypassed by a solenoid valve. This guarantees perfectly identical test conditions.

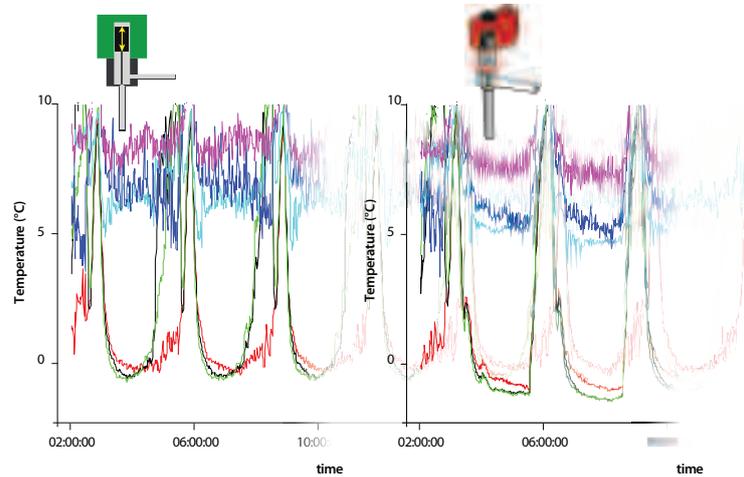
The purpose of the tests was to measure the extraction factor for the same product temperature. This is equivalent to measuring the cooling efficiency required to achieve the same effect on the product stored at low temperature, or alternatively equivalent to the amount of refrigerant required to achieve the same cooling effect. The tests were conducted by operating the showcase with the proportional valve and the PWM valve alternately every 24 hours. Refrigerant flow was measured using a mass flow meter.



refrigeration unit used for tests at the CARTER Refrigeration laboratories

### Ice formation

Records show different behaviour in air temperature that is due to probable different ice formation on the coil. During operation with the proportional valve, no drift nor increases in the controlled temperature or defrost times were noted.

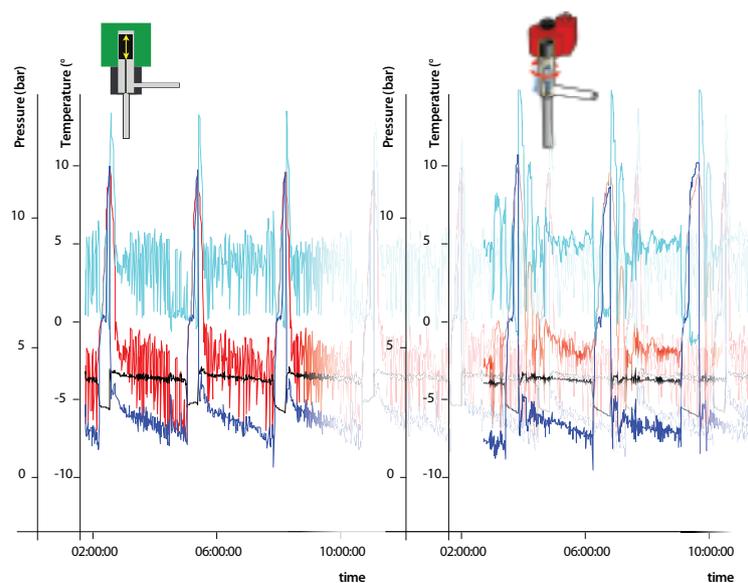


Red	Air off left	Black	Air off center	Green	Air off right
Cyan	Air on left	Blue	Air on center	Purple	Air on right

### Stable superheat control

The proportional valve is able to maintain stable superheat without wide fluctuations.

This is due to steady refrigerant flow, and ensures good control of showcase temperature and efficiency

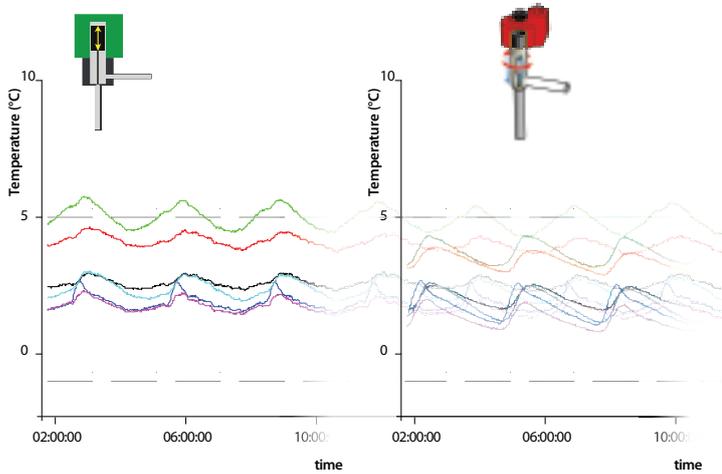


Red	suction temperature	Black	suction pressure
Cyan	superheat	Blue	evaporator temperature



## Product storage temperature

The graph highlights how with proportional control the average product temperatures in the showcase are within the range of optimum control



■	Air off left	■	Air off center	■	Air off right
■	Air on left	■	Air on center	■	Air on right

## Analysis of results

Description	PWM	CAREL E2V-18
Maximum product temperature	6.2 °C	6.4 °C
Extraction factor	2.59 kW	2.34 kW
Evaporation temperature	-6.6 °C	-6.7 °C
Power consumption (100%= PWM)	100%	90%
<b>Saving with E<sup>2</sup>V</b>	<b>10%</b>	

These laboratory tests show higher efficiency of the proportional valves compared to PWM valves in the specific tests conditions. Moreover, they provide an interesting basis for assessing the type of control and the quality of control for the storage of foodstuffs.

## Field tests

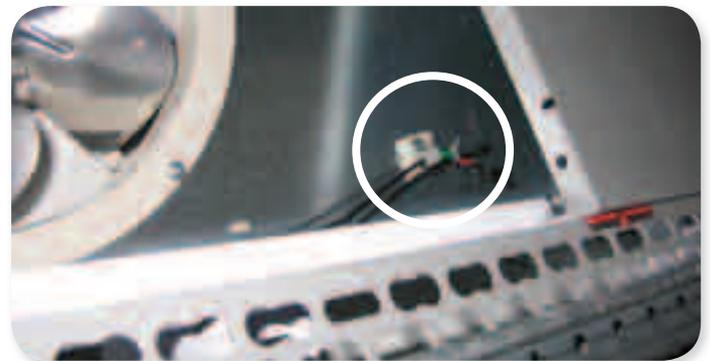
In order to evaluate the different behaviour of the CAREL E<sup>2</sup>V proportional valve and a PWM valve, a “dual technology” system was installed in a real working supermarket.

The ASPIAG store in Azzano X (PN) covers a surface area of 1500 m<sup>2</sup>, has 100 kW of medium temperature and 50 kW of low temperature cooling capacity installed, with 21 medium and 13 low temperature units.

Tests were conducted by alternating the expansion valve used on a daily basis, with the same conditions both outside and inside the store.



*parallel installation of the E<sup>2</sup>V and PWM valves*



*all probes were duplicated to measure the same temperature/pressure value*



*the electrical panel was fitted to manage the changeover in technology between PWM and E<sup>2</sup>V manually or via PlantVisorPRO*

In order to acquire perfectly comparable results, the branch where the expansion valve was installed was duplicated. Two solenoid valves managed via PlantVisorPRO alternately bypass one of the two branches, thus changing the expansion technology used. Each showcase was installed with the probes needed for each of the two valve drivers, in adjacent positions so as to avoid possible incongruities in the measurements. Each showcase was thus fitted with the following pairs of probes:

- outlet air temperature;
- return air temperature;
- defrost temperature;
- suction pressure;
- suction temperature.

#### Test method

The tests were carried out so as to acquire comparable data. All the valve driver parameters were set coherently (set point, alarms, defrosts) so as to guarantee operation in similar conditions. The compressor rack control parameters were kept identical during operation with each type of technology. The technology used was switched at 24 hour intervals, so as to guarantee the closest possible climatic conditions. Data was sampled every 5 minutes.

#### Eurospar supermarket (ASPIAG) in Azzano X

##### Site specifications

- Surface area: 1500 m<sup>2</sup>
- Medium temperature showcases: 15
- Low temperature showcases: 11
- Medium temp. cold rooms: 6
- Low temperature cold rooms: 2

##### Medium temperature rack:

- 3 compressors in total
- 1 inverter-driven compressor (35 – 100%)
- Total capacity 100 kW
- Condenser coil with 6 inverter driven fans

##### Low temperature rack:

- 3 compressors in total
- 1 inverter-driven compressor (35 – 100%)
- Total capacity 50 kW
- Subcooling heat exchanger
- Condenser coil with 4 inverter driven fans

##### CAREL controllers

Compressor racks: pRack pR100  
 showcases/cold rooms: MPXPRO step3  
 expansion valves: E2V  
 supervisor: PlantVisorPRO Touch Hyper



## Test method

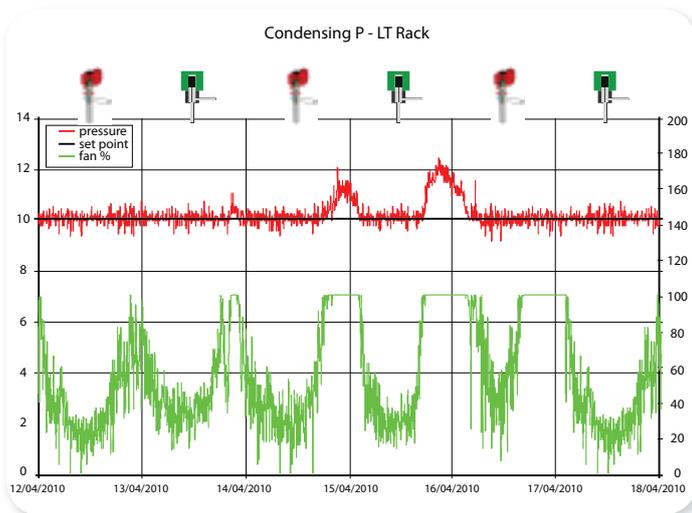
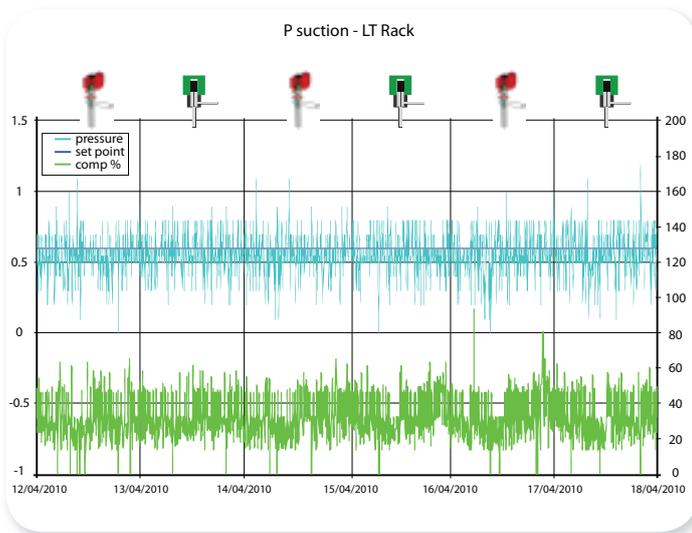
The tests at the supermarket in Azzano X lasted a total of ten months, some of which time was dedicated to the comparison between E2V and PWM valves.

Nonetheless, the graphs correspond to one of the tests lasting several days in which the climatic conditions were practically constant.

## Comparable test conditions

The graph shows how the pressure conditions remain practically identical on the days when the PWM and the E2V were operating.

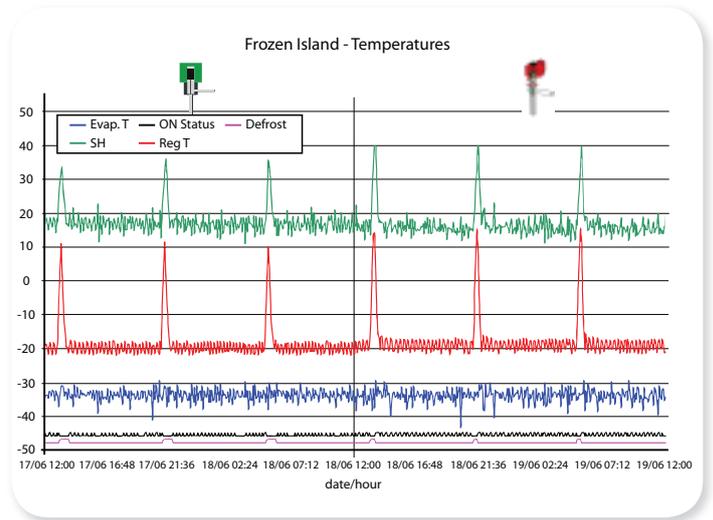
The trend in compressor and fan power consumption was likewise stable over the various days.



## Parameters

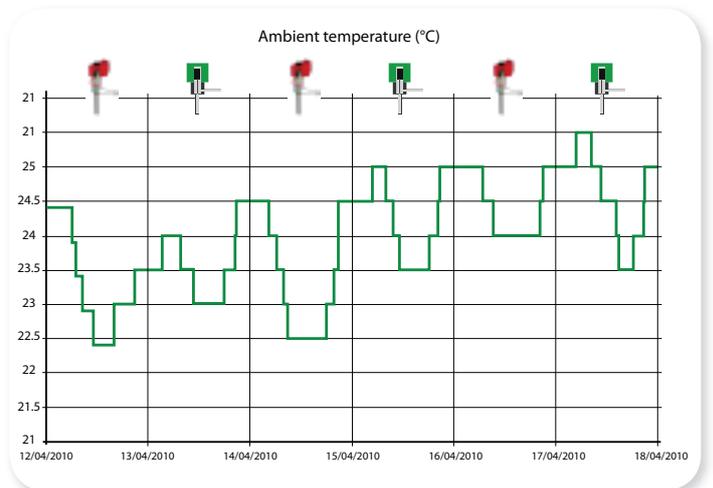
The graph clearly shows how the corresponding showcase outlet air and superheat set points were kept identical in the E2V and PWM valve drivers.

It can also be seen that the defrost times were unchanged using the two types of technology.



## Temperature

Over the interval in question it can be observed that the average temperature remained practically constant.



### Test results

To achieve comparable data, only the period of time in which the outside temperature was sufficiently stable was considered.

Data corresponding to periods in which other types of tests were performed were also neglected (see Success story Azzano X).

Analysis of the data leads to general confirmation of the results achieved by Carter Refrigeration in the laboratory.

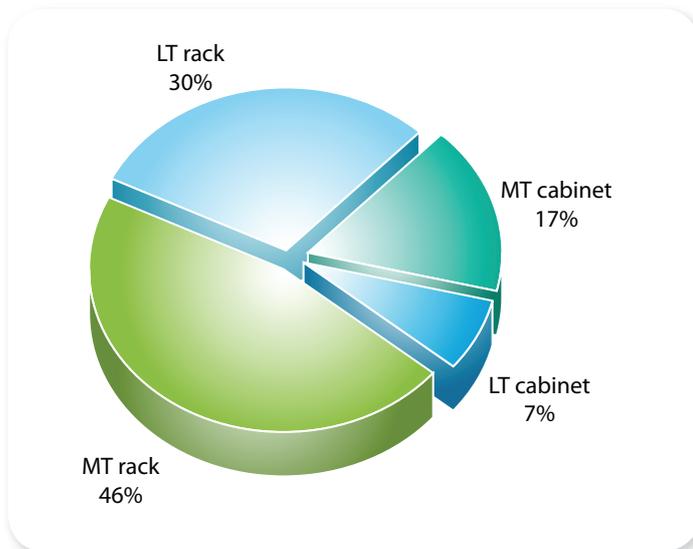
More precise and continuous control of flow-rate in the evaporators reduces inefficiencies and means less refrigerant is used for the same cooling effect.

Precision and continuity of flow control mean more efficient use of refrigerant, with energy saving of around 5% in the system in question.

This has a direct influence on compressor rack power consumption, as can be easily seen from the pie chart.

Total system power consumption/ Hours of operation		Energy saving
E <sup>2</sup> V	PWM	
33,5 kW	35,1 kW	-4,5%

4.5% energy saving: distribution



## Conclusions

The laboratory tests (Carter Refrigeration) and field tests (Interspar Azzano X) lead to the conclusion that proportional valves are generally to be preferred over PWM valves in commercial refrigeration applications.

As well as the advantages relating to range of control, lower noise and better quality superheat control, there are also benefits in terms of energy saving, quantified in the tests analysed in this document.

PWM valves cannot always guarantee the refrigerant flow required by the unit to maintain the correct superheat, probably because control is pulsating by nature.

This means a higher extraction factor, that is, more refrigerant is used to generate the cooling effect. The E<sup>2</sup>V valve, on the other hand, controls the flow-rate of refrigerant continuously, instant-by-instant.



## CAREL retail sistema solutions for proportional superheat control

CAREL proportional expansion technology can be used with our new generation of controllers and valves, the result of years of fine-tuning aspects including usability.

### MPXPRO STEP3 with Ultracap technology

Continuous modulation now also available in commercial refrigeration, without the need for solenoid valves or external power supply.



### EVD EVO

The power of modulating control with a stand-alone solution.



### E<sup>2</sup>V SMART

The new generation of E<sup>2</sup>V proportional valves up to 40 kW now also including sight glass and internal mechanical filter for even simpler installation and maintenance.



### EXV sistema simulator

For a practical demonstration of differences in control. Available at our stand at the main trade exhibitions or at your nearest CAREL subsidiary. The simulator is a simple refrigerant circuit fitted with transparent heat exchangers and three different expansion valves: E<sup>2</sup>V, PWM and mechanical thermostatic. The different results achieved by the action of the valves can be seen on the monitor or directly in the transparent heat exchangers, including effects on superheat and unit operation.



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