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NEW VARIABLE SPEED COMPRESSORS FOR HOUSEHOLD AND LIGHT COMMERCIAL REFRIGERATION

E. ALBERA
EMBRACO

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Peter Buksar*, Enrico Albera**
*EMBRACO Slovakia sro, Odorinska Cesta 2, 052-01 Spisska Nova Ves, Slovakia
**EMBRACO Europe s.r.l., Via Pietro Andriano 12, 10020 Riva presso Chieri, Italy
peter.buksar@embraco.com, enrico.albera@embraco.com

Abstract

Embraco for many years is present as a one of the more successful companies in promoting hermetic compressors with variable capacity and with natural refrigerants in all continents. Apart of isobutane mainly used in household type of appliances, propane is becoming the main refrigerant in light commercial plug-in systems as R404A natural alternative.

Incoming Ecodesign (Lot 12) and Energy Labelling EU regulations for light commercial refrigeration will require significant reduction of energy consumption of those systems. Variable capacity solution together with use of natural refrigerants is a very powerful way to reach the new EU requirements and nowadays with continuous reduction of prices of power electronics is allowing very quick return of investment for inverter. New Embraco "Fullmotion" platforms are going to be presented with some case studies including their economical return evaluation.

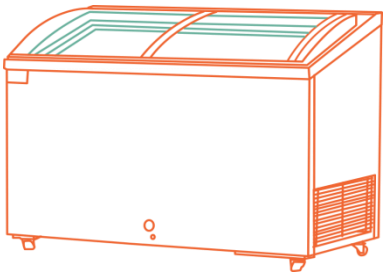
1. Introduction

Recently released "ECO directive" has raised a new demand to improve energy efficiency of commercial refrigeration equipment.

Effective from July 2016, many types of commercial refrigeration equipment (Lot 1) for EU market must display new energy labels in accordance with Ecodesign Directive known as ErP (Energy related Products) and MEPS (Minimum Energy Performance Standard). For second group of products (Lot 12) this obligation is coming soon. New Energy Standards will help EU in decreasing energy consumption and consequently reduce carbon emissions. Embraco have tested several variants of its product with target to help customers in reaching best possible energy performance by selecting proper refrigerant and compressor model.

Embraco for light commercial segment is recommending use of HC refrigerants in every product that allows its application, choosing between isobutane (R600a) and propane (R290). Several tests made with various models of compressors and different application types both with R600a and with R290 and results of some of them will be presented. Thanks to use of hydrocarbon, significant improvements were obtained, mainly due to their very good thermodynamic properties, but there is still space for improvement by using variable cooling capacity technology. This technology is well known and widely used in high efficiency A+++ rated household appliances, but its use is still limited in light commercial refrigeration segment. Thanks to new Embraco developments and FullMotion (VCC) range expansion, it is more and more likely to be applied also in this segment. Comparative testing of some types of commercial appliances with Embraco Fullmotion compressors will be presented as well as economical and environmental benefits of this choice.

2. Refrigeration Systems Specification



One of the leading articles that will be soon affected by above mentioned legislation is Ice Cream Freezer, which was used for comparative testing of on-off compressor vs. variable speed compressor solution and its results are presented in this paper. Its internal volume is 300 liters, contain skin condenser with forced air copper tube pre-condenser, sidewall insulation 60mm and double glass top sliding doors. As expansion device, a standard capillary tube is used. Compressors selected were EMC3121U (R290) and VESD9C (VCC R600a) in comparison to original configuration containing competitor's R600a compressor.

As second will be presented test results of household type refrigerator, which was tested with Embraco variable speed compressor.

The refrigerator is with two sections: 80lit freezer and 220lit fridge, stand alone, single compressor and regulation, wire on tube static condenser and A++ rating. Compressor selected was VEMX9C (R600a) in comparison to original configuration containing competitor's R600a on-off compressor. Control unit of both systems is standard electronic thermostat with temperature range from -10°C to -25°C.

3. Used Refrigerants

Both original systems were using refrigerant R600a. Substitute compressors were with R600a or R290. Both refrigerants are natural with minimum impact to environment and presents very good physical properties for this type of application. Basic physical properties are shown in table 1.

Refrigerant	Molecular formula	Boiling temperature	LFL	ODP	GWP 100y
R600a	C4H10	-11,7°C	1,8%	0,00	3
R290	C3H8	-42°C	2,1%	0,00	3

Table 1. Refrigerants – properties

4. Testing Methodology and Results

All tested configurations of refrigeration systems were almost identical, without any component change. Condenser, evaporator, piping, fans and all others components remained the same. The same thermostat can be used again as well. For this comparative testing, obviously compressors and filter dryers have been changed. Basic characteristics of compressors are given in table 2.

Model	Displacement (cc)	Refrigerant	RPM	Cooling capacity (W) at 55°C cond. Ashrae LBP				
				-30°C	-25°C	-20°C	-15°C	-10°C
EMC3121U	5,54	R290	2900	192	249	313	385	465
VESD11C	11,14	R600a	4500	199	254	325	422	554
VEMX9C	9,04	R600a	3000	162	216	280	356	446

Table 2. Basic characteristic of used compressors

In case of changing conventional on-off compressor, obviously, its electrical components (starting relay, run capacitor, overload protector) were changed as well. In case of changing conventional on-off compressor to variable speed compressor, the specifically selected inverter was applied. In both cases when VCC compressor was used, the inverter type was “Drop-in”. This option can be used for the systems with installed standard electro-mechanical thermostat. Control module of compressor inverter connected to standard thermostat will decide the best compressors RPM based on load on evaporator (which result to increased or decreased power input) to reach selected cabinet temperature. Both measurements of energy consumption were performed at 25°C ambient temperature and 60% relative humidity (45 ÷75% for HH refrigerator). Placement of the system has been always identical. As thermal load, it has been used testing package defined by the standard EN ISO 23953. Refrigeration systems have been tested in a climatic chamber. Temperature stability of the chamber has been ±0,5°C. Relative humidity during the testing has been ±3% from set point. Placement of the refrigeration system during the test has been defined by standard. Accuracy of the data acquisition system has been for temperature ±0,3°C, for pressure 0,2% and all electrical values have been measured with accuracy 1%. All results from measurements are listed in the table 3 and table 4.

Table 3. Results of Ice cream freezer testing

	HC	**HC**	**HC**
Compressor	Competitor	EMC3121U	VESD11C
Compressor type	recipro	recipro	VCC – recipro
Refrigerant	R600a	R290	R600a
Ambient temperature / Rel. humidity	25°C / 60%	25°C / 60%	25°C / 60%
Condensing temperature	34°C	35°C	30°C
Evaporating temperature	-33°C	-32.5°C	-30°C
Refrigerant charge	89g	76g	89g
Voltage	230V/50Hz	230V/50Hz	230V/50Hz
Power (before turn off of the compressor)	95W	115W	78W
Temperature warm package	-18°C	-18°C	-18°C
Energy consumption per 24 hours	1.37 kWh	1.35 kWh	1.00 kWh
Energy consumption - comparison	**Reference**	**-1,5%**	**-27,0%**

Table 4. Results of household refrigerator testing

	HC	**HC**
Compressor	Competitor	VEMX9C
Compressor type	recipro	VCC – recipro
Refrigerant	R600a	R600a
Ambient temperature / Rel. humidity	25°C / 45 ÷75%	25°C / 45 ÷75%
Condensing temperature	49°C	42°C
Evaporating temperature	-29°C	-26°C
Refrigerant charge	54g	66g
Voltage	230V/50Hz	230V/50Hz
Power (before turn off of the compressor)	81W	43W
Temperature	+5 / -18°C	+5 / -18°C
Energy consumption per 24 hours	0.892 kWh	0.667 kWh
Energy consumption - comparison	**Reference**	**-25,2%**

5. Estimated Cost Comparison for End User

	Refrigerant	Energy Consumption (kWh/year)	Price range Euro/kWh	Cost of energy in one year - Euro	Annual saving Euro
Ice cream freezer w/ original competitor compressor	R600a	1,37 x 365 = 500	0,1 – 0,3	50 - 150	Reference
Ice cream freezer with EMC3121U	R290	1,35 x 365 = 493	0,1 – 0,3	49 - 148	2
Ice cream freezer with VESD11C	R600a	1 x 365 = 365	0,1 – 0,3	37 - 110	12 - 38
	Refrigerant	Energy Consumption (kWh/year)	Price range Euro/kWh	Cost of energy in one year - Euro	Annual saving Euro
HH refrigerator w/ original competitor compressor	R600a	0,89 x 365 = 325	0,1 – 0,3	32,5 – 97,5	Reference
HH refrigerator w/ VEMX9C	R600a	0,667 x 365 = 243	0,1 – 0,3	24,3 – 72,9	8 - 25

Table 5. Analysis of operational costs

Data from measurements can be used to estimate energy costs of each specific system.

Full saving obtained by using VCC technology in systems presented in this paper should be calculated / multiplicated by number of years that are representative as life-time for given application.

6. Conclusions

From data presented above is possible to see significant saving of energy (25-27%) when using VCC technology in comparison to conventional on-off compressors. This saving is important in three aspects:

1. Saving energy and decrease general impact to environment
2. Reach energy standards
3. Save on energy cost

In general, it is recommended to use VCC technology for all refrigeration systems where applicable, of course, in combination with HC refrigerants.

At the moment it is still bringing significant increase in initial expense due to higher cost of compressor motor and inverter being applied, however, it is recommended to consider it as an investment with short-midterm return. Also fast evolution in the field of electronics is showing many opportunities to bring its cost to acceptable level, especially for smaller units with power input up to 300W.