HYDROCARBONS, HEAT PUMP, HOME LAUNDRY DRYER: ENVIRONMENT FRIENDLY APPLIANCE

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Abstract: As consequence of Global Warming concern, the developed nations must reduce the level of green-house gases emissions. Both direct effect of low GWP refrigerant and indirect effect of reduced energy consumption must be taken in account.
Isobutane (R600a) is dominating in household european market, while propane (R290) is well consolidated in low temperature commercial application, like ice cream chest freezers. On the other hand, the use of heat pumps in dryers, tap water heaters and similar applications becomes to be diffused, and R134a is the preferred refrigerant till today.
The combination of heat pump energy efficiency with hydrocarbons green properties is opening a wide range of new opportunities with a lower environmental impact.
A commercially available heat pump laundry dryer, using R134a, and its evolution towards R290 application is presented in this article.
Dryer working conditions, compressor reliability and energy efficiency comparison with standard equipments using electrical heaters are discussed, and some experimental results are shown.

1. INTRODUCTION

After the ban of the CFCs related to ozone depletion, the concern of the public opinion is now focused on Global Warming. The European Community has already decided actions to phase out HCFC and HFC refrigerants, because of their high contribution to green-house effect. The use of R134a in mobile air conditioning will be forbidden in 2011 and restrictions on use of HFC in refrigeration systems have been put in place in some countries. Also some large end users of refrigeration systems have declared their intention of phasing out HFCs in favour of natural refrigerants.
In household refrigeration the process of substitution of R134a with R600a is already in place, while in commercial refrigeration the use of propane in substitution of R404A is well consolidated on ice cream chest freezers.

TEWI, Total Equivalent Warming Impact, can be considered as a good parameter to evaluate the impact on environment caused by a refrigerating system. It is considering both the direct effect related to refrigerant leakage in the atmosphere and the indirect effect related to energy consumption of the appliance.

$$TEWI = GWP*L*n + GWP*m*(1-\alpha) + n*E*\beta$$

Direct effect:
L – leakage rate [Kg/year]
n – life time [years]
m – refrigerant charge [Kg]
α – recycling factor [%]

Indirect effect:
E – energy consumption [KWh/year]
β – emission on energy generation [$KgCO_2$/KWh]

For plug-in appliances using hermetic compressors the leakage rate is negligible and also refrigerant charge is reduced, so the energy consumption effect is prevalent, representing till 95% of the total contribution. For large size installations and mobile air conditioning the direct effect of refrigerant leakage represents a larger contribution.
Emission on energy generation is strongly dependent on the tecnology used to produce electricity: higher for coal, oil and gas, lower for hydroelectric, nuclear, wind and solar.
Energy consumption is related to the type of application and its level of efficiency; some typical values are 30 KWh/month for a household combined refrigerator, 120 KWh/month for a 200 litres chest freezer, 400 KWh/month for an ice cream display case.

A complete action to reduce environmental impact of the refrigeration should include:
- High GWP refrigerants replacement
- Energy efficiency improvement
- Refrigerant leakage reduction
- End of life refrigerant recovery improvement
- Change of energy generation mix

As compressor manufacturer, Embraco is strongly committed in efficiency improvement, introduction of natural refrigerants with lower GWP value and good thermodynamic performances and development of special models suitable for heat pump application.

2. HOME LAUNDRY DRYER TECNOLOGIES

Wet laundry to dry in fresh air, to zero cost, is still better for portmoney and environment, but if the wheater is usually cold or a large balcony is not available, a home laudry dryer is well appreciated.
Fig. 1 is showing the traditional condensation dryer on the left and the new heat pump technology on the right.
Conventional dryer is using electrical resistances to heat up a primary air flow (process air), that is drying the clothes, while a secondary air flow (cooling air) is cooling down the processing air inside a heat exchanger, causing the humidity to condense. This warmed up air escapes then into the setting up area. In absence of an open window or wall break-through, it is introducing moisture and heat in the house.
Heat pump dryer is using a refrigerating system that is heating up the process air for drying the laundry and then is cooling it down to extract the moisture and to recover energy. The extracted energy remains into drying process and the energy need is reduced. Additionally, the secondary air flow is not present so that no exhaust air is introduced inside the house.

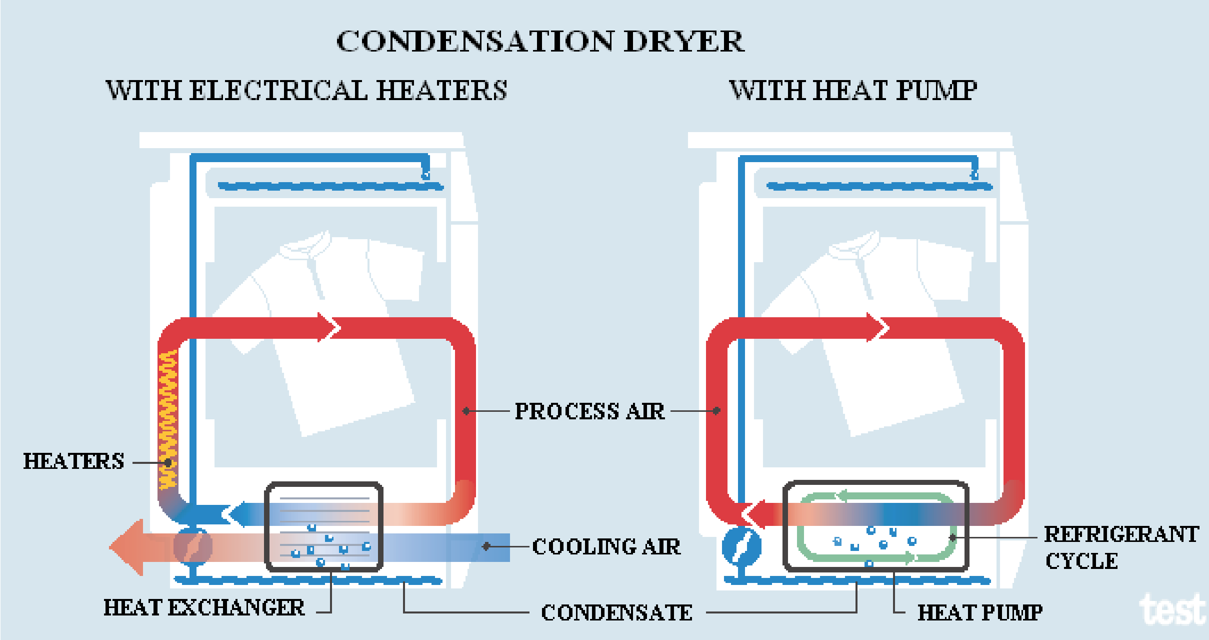

Fig. 1

Fig. 2 is showing the main components of the heat pump dryer. Condenser is used to heat up at high temperature the air that is blown inside the rotating drum containing the wet clothes. The exhaust warm air flows then through the evaporator that is collecting the humidity and recovering energy.

The water is collected in a plastic tray to empty after each drying cycle or can be derived into the discharge over a hose.

The hermetic reciprocating compressor is similar to those used in light commercial refrigeration, but with special features, due to the particularly severe working conditions.

Control element is simply a capillary tube, while the refrigerant used in presently market available appliance is R134a.

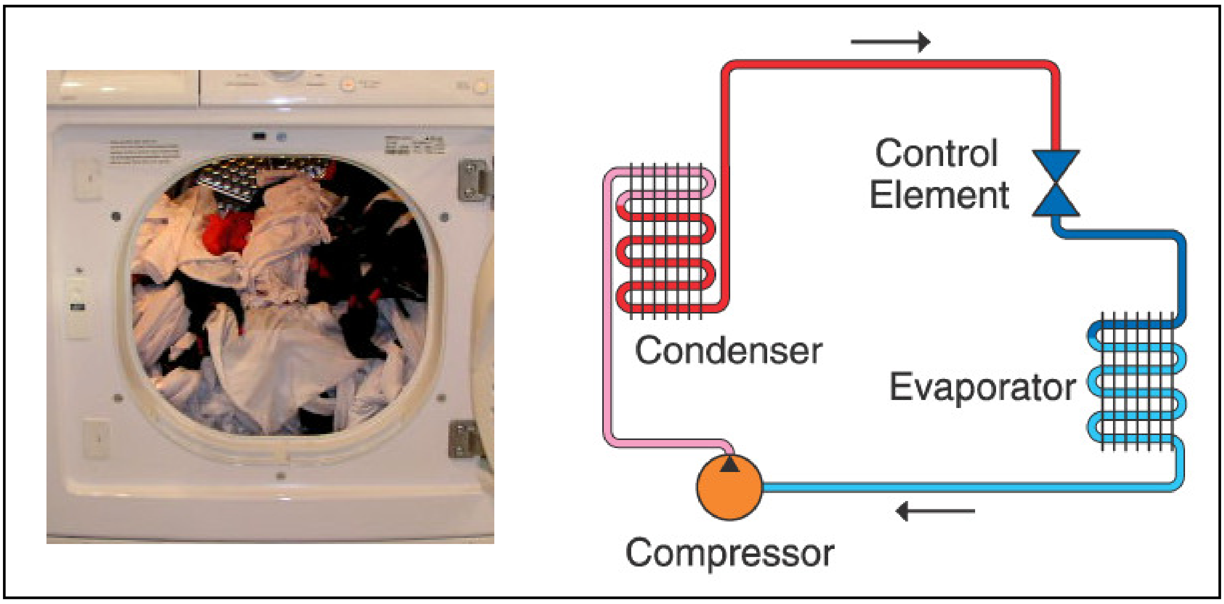

Fig. 2

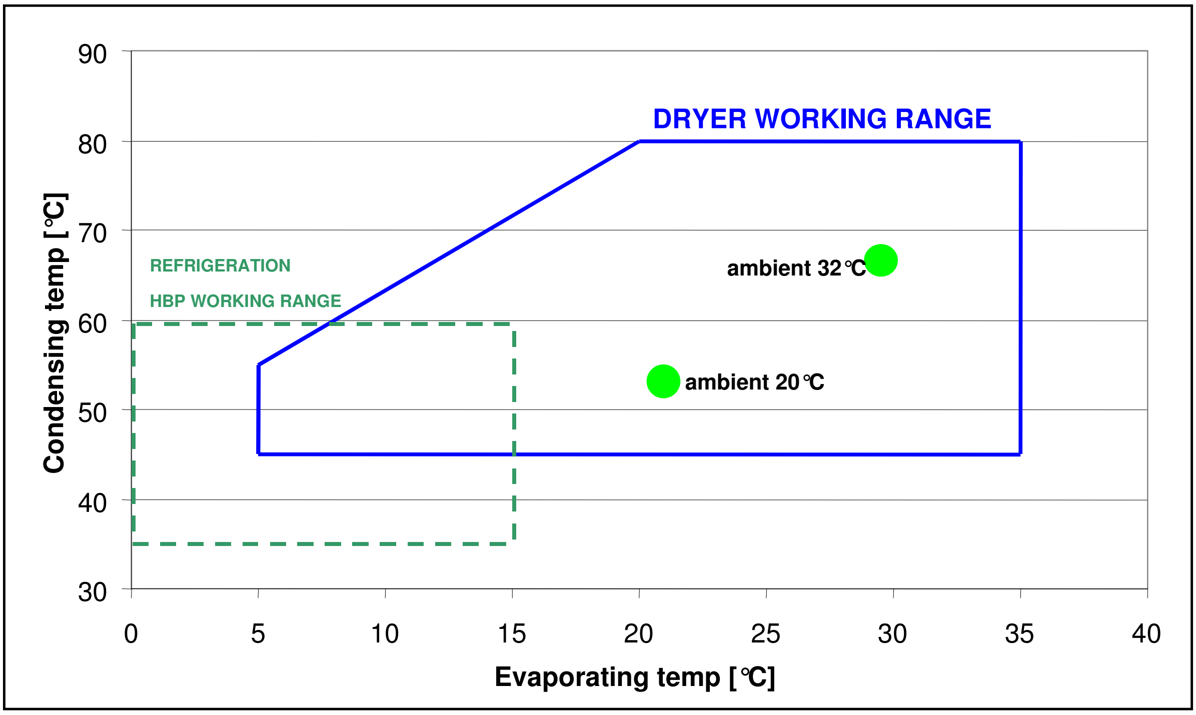

Fig. 3

Working conditions are more severe than in standard HBP refrigeration (dotted green square in fig. 3), because condensing temperature can reach 80°C, while evaporating temperature is till to 35°C. In fact it is necessary to reach high values of air temperature in order to have an effective drying action, while evaporator recovers energy from the exhaust air, that is warm and full of moisture. The green points are showing working conditions for two different temperatures, with ambient 20°C and 32°C, condition that can occur when application is operating inside a small room. Conditions become even worse when the filters protecting heat exchangers are partially obstructed by the dirty produced by the clothes friction and air flow is reduced.

Compressor must be specifically designed for such severe working conditions and is characterized by robust mechanical design and strong motor.

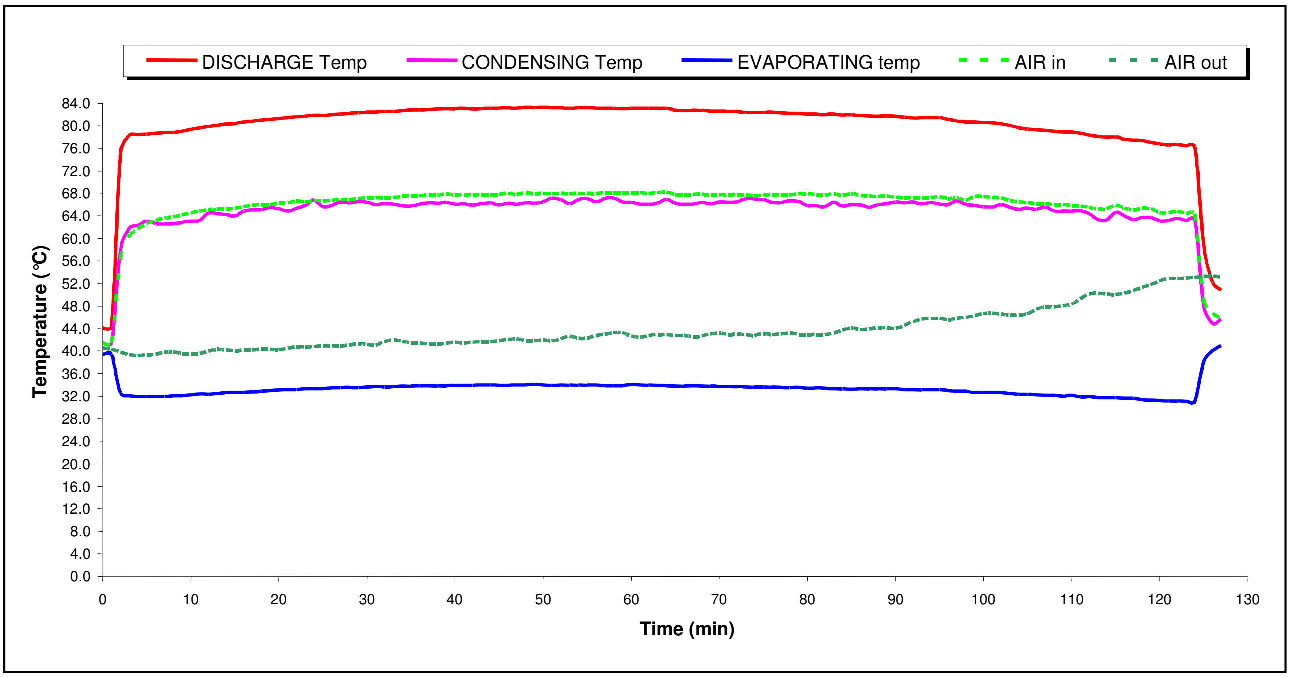

Fig. 4

In the standard testing cycle, shown in fig. 4, 6 Kg of cotton clothes are impregnated with 4,2 kg of water and application takes a couple of hours to complete the job. Condensing temperature (pink line) is around 65°C while evaporating temperature (blu line) remains near 32°C. Drum inlet air (light green line) has almost same temperature of condensing, because the superheated refrigerant at the beginning of the condenser is around 80°C (red line). At drum outlet the air (dark green line) is higher than 40°C and full of moisture so that energy recovery in the evaporator is very effective.

3. HEAT PUMP DRYER - ENERGY SAVING

In october 2006 the German consumers magazine Stiftung Warentest has performed a comparative test among the most diffused models in local market, 6 conventional and 8 heat pump laundry dryers. The energy saving obtained with the heat pump technology is higher than 40%. On the other side, 40% is also the typical price increasing of the appliance, so that several years are needed before recovering the money with the saving on electricity bill.
A public institutions intervention should encourage the diffusion of such environment friendly applications, because the social benefit is evident.

4. HEAT PUMP DRYER - PROPANE EVOLUTION

The dryer today available on the marked is equipped with R134a compressor; a propane compressor has been used in substitution and refrigerant charge and capillary have been determined in order to reproduce same working conditions. The charge is 400 grams for R134a compressor and 200 grams for propane. Condensing, evaporating and air temperatures are similar to R134a application, as well as drying time.
In the various different tested conditions with R290 compressor has been obtained an energy saving between 8% and 12%. Internal temperatures of the compressor are 5°C lower than using R134a.

5. CONCLUSIONS

Hydrocarbons are representing a good solution for HFC replacement in light commercial refrigeration.
Their positive environmental impact is related not only to low GWP value but also to favourable thermodynamic characteristics that ensure reduced energy consumption of the application.
Impact on industial processes of compressor and appliances manufacturers is minimized, if we compare with other natural refrigerants like CO_2.
The use of isobutane in household refrigeration and propane in ice cream freezer is already well consolidated on european market.
Propane and isobutane are even suitable in high temperature application, also with very severe working conditions, as described in this article.
The combination between green properties of hydrocarbons and energy efficiency of heat pump is matter of diffused interest and will lead to a great variety of environment friendly new applications.

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