

White Paper

Boost in Performance as well as Capability of Drop-In-Replacement

Three examples for setting new standards with EC motor technology

Hans-Jürgen Withopf, Dipl.-Ing. (FH)

Product Manager Home Appliance Industry / ebm-papst Landshut GmbH

Content

Introduction.....	1
Cold, hot and wet appliances	1
EC motor technology determines the pace.....	1
Efficiency approach	2
<i>ErP framework in European Union</i>	2
<i>Energy conservation standards in the US</i>	2
Refrigerators and freezers.....	3
shaded-pole motor:	3
EC motor:.....	3
Kitchen hoods.....	4
Motorized impellers:	4
Dual inlet blower:.....	5
washer-dryers.....	5
Forward curved wheels	7
Backward curved wheels.....	7
Summary.....	7

Introduction

Cold, hot and wet appliances

Large household appliances could be categorized into three main groups: cold, hot and wet appliances. *COLD* includes all appliances keeping perishable goods fresh or stored for a longer period of time or chilling food stuff or liquids before consumption. *HOT* deals with elevated temperatures. Any kind of oven, steamer, cook top as well as cooker hood or microwave oven belongs to this category. Last but not least *WET* contains two major applications: laundry care and dish care equipment. They are characterized either by the requirement of water as a process media or by the removal of humidity from textiles. Products associated to this category are e. g. dishwashers, washing machines, washer-dryers or tumble dryers.

EC motor technology determines the pace

These major home appliances are a wide field for the usage of electric motors and fans in general and in large scale.

While in ovens they keep the surfaces cold or the temperature homogenous inside the cavity in other appliances like refrigerators they make for example the manual defrost obsolete or keep perishable food fresh for a long period of time within the 0° chamber or fresh food compartment.

While in the past EC motor technology (EC = electronically commutated) has been something to be used just by appliance manufacturers focusing on a premium market segment or following the philosophy of being a driver of innovation within its market segment, in the meantime EC technology determines as well the pace when talking about the usage of motor and fan technologies in mass volume markets.

To illustrate this in more detail the focus in the next chapters is on three specific products for major appliances:

- DE 20 motor for domestic refrigerators, freezers or refrigerator-freezers,
- VHD 0146 double side suction blower for cooker hoods / range hoods,
- R3G radial fans respectively G3G radial blowers for washer-dryers.

Efficiency approach

The conservation of energy in the white goods industry is driven by continued legal requirements on minimum efficiency grades. The specific requirements on an international level vary a lot depending on the laws, rules and directives in place.

ErP framework in European Union

In Europe e. g. this process has been enforced by implementing the directive 2005/32/EC through the European Parliament in July 2005 as a framework for the setting of ecodesign requirements for energy-using products (EuP) which has been extended to energy-related products (ErP)¹ in general by directive 2009/125/EC in October 2009.

Within this so called ErP process different product groups became subject of an assessment with regard to their environmental footprint. Meanwhile the third working plan is in progress. Several regulations of the European Commission have been the result of it setting minimum efficiency grades. For the above mentioned appliances the following regulations have been enacted:

- household refrigerating appliances – Commission Regulation (EC) No 643/2009
- household tumble driers – Commission Regulation (EU) No 932/2012
- domestic ovens, cook tops – and range hoods – Commission Regulation (EU) No 66/2014
- professional refrigerated storage cabinets, blast cabinets, condensing units and process chillers – Commission Regulation (EU) 1095/2015

Furthermore there is a draft document available concerning possible requirements for non-household washing machines, non-household textile dryers and non-household dishwashers.

The end user or consumer could identify the efficiency level of a distinct appliance by consulting an energy efficiency label which is put visibly onto the appliances. With colored bars it classifies the appliances in A, B, C, D, F and G efficiency categories. Sometimes – e. g. refrigerators – the A category is divided into A, A⁺, A⁺⁺ and A⁺⁺⁺ categories.²

Energy conservation standards in the US

Since its amendment in 1979 the Energy Policy and Conservation Act (EPCA) constitutes the basis for energy saving standards in the US. Minimum efficiency standards for household appliances were established in 1987 (National

¹ Different from energy using products (EuP) energy related products (ErP) haven't to consume electricity by themselves. Insulation materials which help to reduce the consumption of electricity are also within the scope of ErP framework.

² At the moment the European Union is working on an up-date of the energy labeling system to eliminate A⁺, A⁺⁺ and A⁺⁺⁺.

Appliance Conservation Act). The Department of Energy (DOE) is in charge of reviewing and updating these standards and supports the Environmental Protection Agency ENERGY STAR Program and the Federal Trade Commission ENERGY GUIDE labeling.

The following examples are among these rule-makings for energy conservation standards:

- residential refrigerators 76 FR 57516 – final standard
- consumer clothes dryers 78 FR 49608 – final standard
- residential refrigerators - ice making final standard / *compliance mandatory as of 1st January 2018*
- miscellaneous residential refrigeration rule-making in progress
including wine chillers final determination, pre-publication status

On the latest agenda of DOE rule makings under the appliance standards program are e. g. clothes dryers or refrigerators and freezers. In the first case a standard and a test procedure is foreseen for September 2017 and in the second case a test procedure rule making started and a request for information on possible standards amendments is expected in September 2017.

Like in the European Union a label was also introduced in the US to provide consumers information about energy consumption, efficiency and operating cost. This label is called ENERGY GUIDE. Besides that another voluntary one exists with the ENERGY STAR label. It sets more stringent requirements on energy saving than the ENERGY GUIDE.

Refrigerators and freezers

The prime example of the successful implementation of EC technology and product placement of small EC motors in white goods applications are refrigerators and freezers. As these appliances are permanently operated to store perishable goods for a reasonable period of time they are among the major domestic appliances with the highest consumption of electricity. Therefore they have been always in a primary focus of energy conservation policies.

Gaskets, compressors, controllers and other components have been improved to maximize efficiency. Vacuum panels started to be used as an alternative insulation, LED lighting was introduced in high-end and premium products and especially EC motors became very popular increasing the efficiency of evaporator and condenser fan units whereupon mains supply driven ones permitted an easy drop-in replacement of the commonly used C-frame shaded-pole motors with axial impellers.

Electric motors are used in different areas of a refrigerator. Driving an impeller they circulate the air inside the refrigerator compartment or within specific temperature controlled devices like a 0° chamber or they move the “warm” and humid air within a freezer over an evaporator to make it dry and cool it down before it enters the freezing chamber again. Outside the refrigerator compartment they assist in the socket area the vaporization of condensed water collected in a small tank placed on top of the compressor or they are used to cool the condenser coil.

shaded-pole motor:

C-frame shaded-pole motors were the back bone of this refrigerator cycle. The EM 2513LN motor platform for refrigerators and freezers used in the late 1990's for optimizing the power consumption and material impact and providing an extended life expectancy. Over the last 20 years these motors have been steadily substituted in Europe by EC motors due to energy labeling requirements. Nevertheless C-frame shaded pole motors are still in use in significant volumes in several markets where the requirements on energy efficiency haven't been that stringent. But following the trends to continuously tighten the requirements on energy efficiency and to provide to the end user more comfort and functionality of a refrigerator or freezer, shaded-pole motors continue to be replaced.

EC motor:

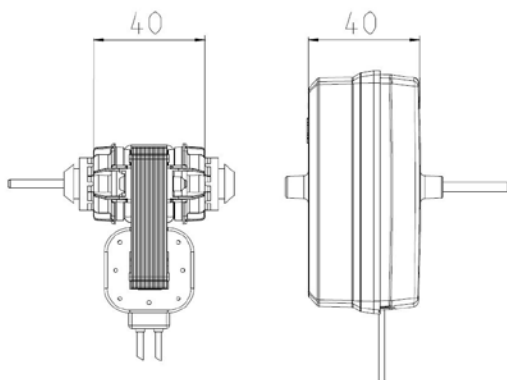
Since around the year 2000 EC technology found its way into refrigerators and freezers and could be seen as a common standard. Such EC motors are either used to drive axial or radial impellers and they pioneered the design of integrated

fan units with an increased level of efficiency while reducing in parallel the space requirements.

DE 20 is a new member to the brushless direct current motors' family which combines the advantages of its predecessors: light weight, robust and easy to implement providing the typical shape and mounting arrangement. It keeps the widely used axial mounting distance of 40 mm and has on both sides of the plastic housing two domes for the assembly of two rubber grommets to be used for fixing the motor within a support and act as a soft suspension. The soft suspended assembly together with its smooth running have a positive effect on the overall acoustic performance. Furthermore it is not necessary to place it into a separate encasing as the motor is already fully encased in a plastic box.



Picture 1: DE 20 evaporator fan motor



Picture 2: mounting arrangement of EM 2513LN (left) versus DE 20 (right)

With its basic design the **DE 20** provides a typical fixed speed of 2500 rpm or alternatively of 2200 rpm combined with a four blade axial impeller of 100 mm diameter. With the possibility to connect it directly to mains supply of e. g. 230 V 50 Hz it permits an easy drop-in-replacement of the old-fashioned shaded-pole motors in evaporator units.

For a more advanced use alternatively a 12 VDC version could be selected with or without speed control by using an analog input signal of 0 to 10 V.

Kitchen hoods

Besides a nice appearance in the kitchen due to some exceptional design features a range hood has to provide sufficient suction capability to fulfill its operational duties and to do so at an acceptable noise level.

Depending on the specific design of a cooker hood different types of fans and blowers are used. They could be described with the two categories mentioned hereafter.

Motorized impellers:

This is the most basic design. It consists of a motor on which either a forward curved or a backward curved centrifugal impeller is mounted. In the past AC motor driven fans were most commonly used in cooker hoods. An environment determined by energy labeling and by a demand of increased electrical efficiency is making EC technology more popular for use with motorized impellers.

Fans with backward curved impellers don't require a specific scroll housing and are easy to implement. They are typically found in substructure extractor hoods or outside wall blowers. Depending on the application the impeller is placed in a ducted system which is designed in round, square, or spiral form. Systems equipped with such blower wheels could be easily switched from exhaust to circulating air.

Forward curved impellers do need a specific scroll housing. They are typically found in flat-screen, intermediate installation and built-in extractor hoods. Compared to a single-motor hood, a dual-motor hood design offers the same air performance at considerably lower noise levels.



Picture 3: VHD 0146
with integrated guard grill

Dual inlet blower:

Compared to motorized impellers dual inlet blowers could be considered as an advanced design. These forward curved dual inlet centrifugal blowers are widely used in applications featuring so-called wall and island area chimneys as well as in built-in hoods that are equipped with a fan module. The blower consists not just of a motor and an impeller but also of a complete scroll housing. Even with high air performance this range performs at extremely low acoustics. Due to their specific housing design with standardized overall dimensions and mounting interfaces they can be easily mounted into the application. Furthermore, exhaust air pipes and reducers can be attached without any problem.

Different from other large white goods' appliances, cooker hoods had to be marked the first time with an energy label within the European Union as of 1st January 2015 following the requirements of Commission Regulation (EU) N° 66/2014. This regulation foresees as stepwise

elimination of the energy efficiency classes G, F and E while new classes with A⁺, A⁺⁺, A⁺⁺⁺ find their way into the labeling system and their declaration becomes mandatory. This process will be completed as of 1st January 2020. The increasing demand on energy efficiency consequently impacts the cooker hood design and the requirements of the blower.

Within this environment the new **VHD 0146** platform of a dual inlet centrifugal blower targets on simplicity and versatility. The credo is having one blower for almost everything:

- With an airflow of 800 m³/h at free air it covers a wide range in performance.
- With a PWM interface to adjust the speed to the required working points for a maximum of convenience to the end user it provides the engineer a high degree of freedom in design. The necessary boost in efficiency is already built-in through the use of a one core EC motor.
- Combined with an optimized aerodynamics and assembly concept the sound level can be kept at comfortable levels.
- Above all its versatility is given by
 - two guard grills integrated into the blower housing together with
 - an integrated bayonet for the fixation of round activated carbon filters on the left and right side of the dual suction area and
 - the possibility to fix a flap to the outlet.



Picture 4: VHD 0146
assembled with
activated carbon
filter^{*)} and flap^{*)}

^{*)} not scope of supply

washer-dryers

"Bigger, faster, wider". Performance is often described with such attributes. But is "bigger" really an indicator of more performance?

When we look to washer-dryer appliances we could note that the load capacity of the drum has increased throughout the years. While in the past the typical drum capacity has been between 5 to 6 kg it increased nowadays to 8 up to 15 kg. As a result the size of the drum increased significantly. From this point of view "bigger" or "wider" are attributes of power and strength. Nevertheless the outer dimensions of the appliance remained the same as they are set as a kind of a standard by the kitchen cabinet makers.

When the drum becomes bigger and the size of appliances itself remains the same the free space for the system components within the appliance becomes less and less. One such system component is the **process fan** which is

needed to bring the hot air into the drum for drying the clothes inside of it.

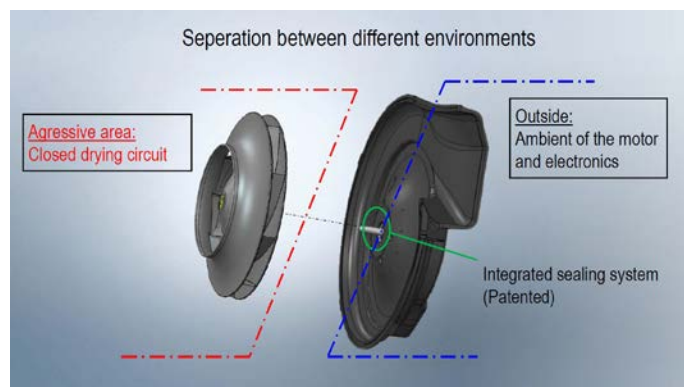
In washer-dryers typically radial blowers are used. The main reason is the ratio between air performance and back pressure. The process air is heated up either by heating elements or the condenser coil of heat pump unit and induced into the drum. Within the drum the hot air absorbs the humidity from the clothes. After having left the drum the humid air is lead to the cross-flow heat exchanger unit of the washer-dryer where the humidity is condensing before the dry air returns to the heater again.

Driven by the target to increase further the energy efficiency of the appliances new technologies entered washer-dryer appliances. When comparing combination washer-dryers with standalone unvented tumble dryers which are commonly used in Europe it could be stated that heat pump technology became a commonly used technology platform besides condenser technology while combination washer-dryers were typically based on condenser technology. In 2013 the first washer-dryer was presented to the market using a heat pump system for generating the hot air. As a result an evaporator unit had to be integrated additionally besides the condenser unit requiring its own space.

Several consequences raised from these above described trends for the **process fan**:

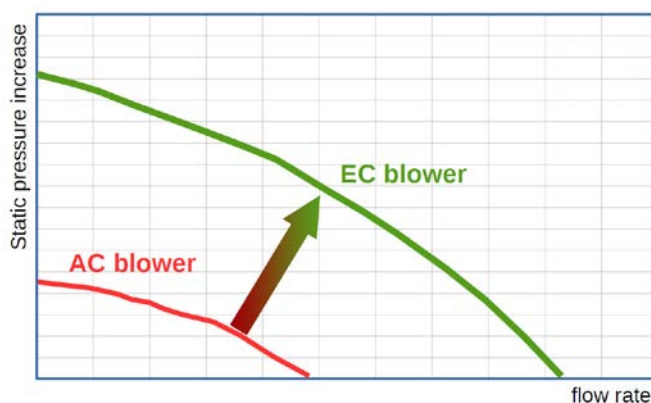
1. demand of an increased air performance
2. requirement of an increased electrical efficiency of the fan
3. necessity of a highly integrable and compact process fan unit

The first criterion is simply defined by the bigger load of the washer-dryer: If more clothes are inside the drum more clothes will be dried during one cycle. The second one is linked to energy efficiency standards. To reach a good energy efficiency labeling the power consumption of the appliance is restricted to certain efficiency grades. And last but not least



Picture 5: washer-dryer process fan - constructional provisions to operate in an aggressive environment

the third consequence is the result of the reduced free space.



Picture 6: Air performance - EC blower versus AC blower

And here we are back with our first question: *Is "bigger" really an indicator of more performance?* In this context the simple answer is: NO! "Bigger" is not an indicator of more performance. To the contrary, it would be even a disqualifying criterion. A process fan unit has to become smarter not bigger.

But how do we meet an increased demand in air performance when the blower is not allowed to become bigger and while being confronted with the requirement to become even more compact? Traditionally the process fan was driven by an AC shaded-pole (low performing solutions) or AC

capacitor motor (high performing solutions). At 50 Hz (60 Hz) operations they are limited by the boundary of the

synchronous speed of 3000 at 50 Hz (3600 at 60 Hz) rpm. Using EC technology in the new range of **R3G** respectively **G3G** process fans and blowers it has been possible to go beyond these limits and significantly increase the performance.

In addition to the electrical efficiency of the fan unit and the size of it, the acoustic performance helps to classify a smart process fan. The energy label with its A+++ to D scale which is commonly used within the 28 member states of the European Union requires also the declaration of the noise emissions of the appliance itself.

Forward curved wheels

Fans and blowers with forward curved wheels could be seen as a common standard in washer-dryer appliances. Commonly accepted is a wheel made of sheet steel. Such radial ventilators are either used as a process fan or as a cooling fan.

While the cooling fan blows cold air through the cross-flow heat exchanger of the condenser unit the process fan forwards the hot air – which has been heated up either within an electrical heater unit or within the heat exchanger of heat pump system – into the drum.

Backward curved wheels

Driven by the demand on compactness, higher efficiency and improved acoustics backward curved impellers offer an alternative approach to the traditional forward curved wheels. As the radial impellers are done from injection molding they allow more flexibility in construction and design. With a higher efficiency than forward curved impellers the backward curved wheels high performing solutions at minimum size can be realized. Ventilators equipped with such impellers could be integrated into complex system structures while occupying just a little space.

Summary

EC motor technology has become more commonplace in appliances such as domestic refrigerators and freezers, cooker hoods and washer-dryers. With its high electrical efficiency, the EC motor technology helps meet appliance-specific regulations on eco-design and market requirements for convenience and function. In keeping the same basic mechanical interfaces it is easy to substitute AC with EC motor driven products. Besides exceeding AC motors' performance limits given by the grid frequency, they allow an integrative and compact design.