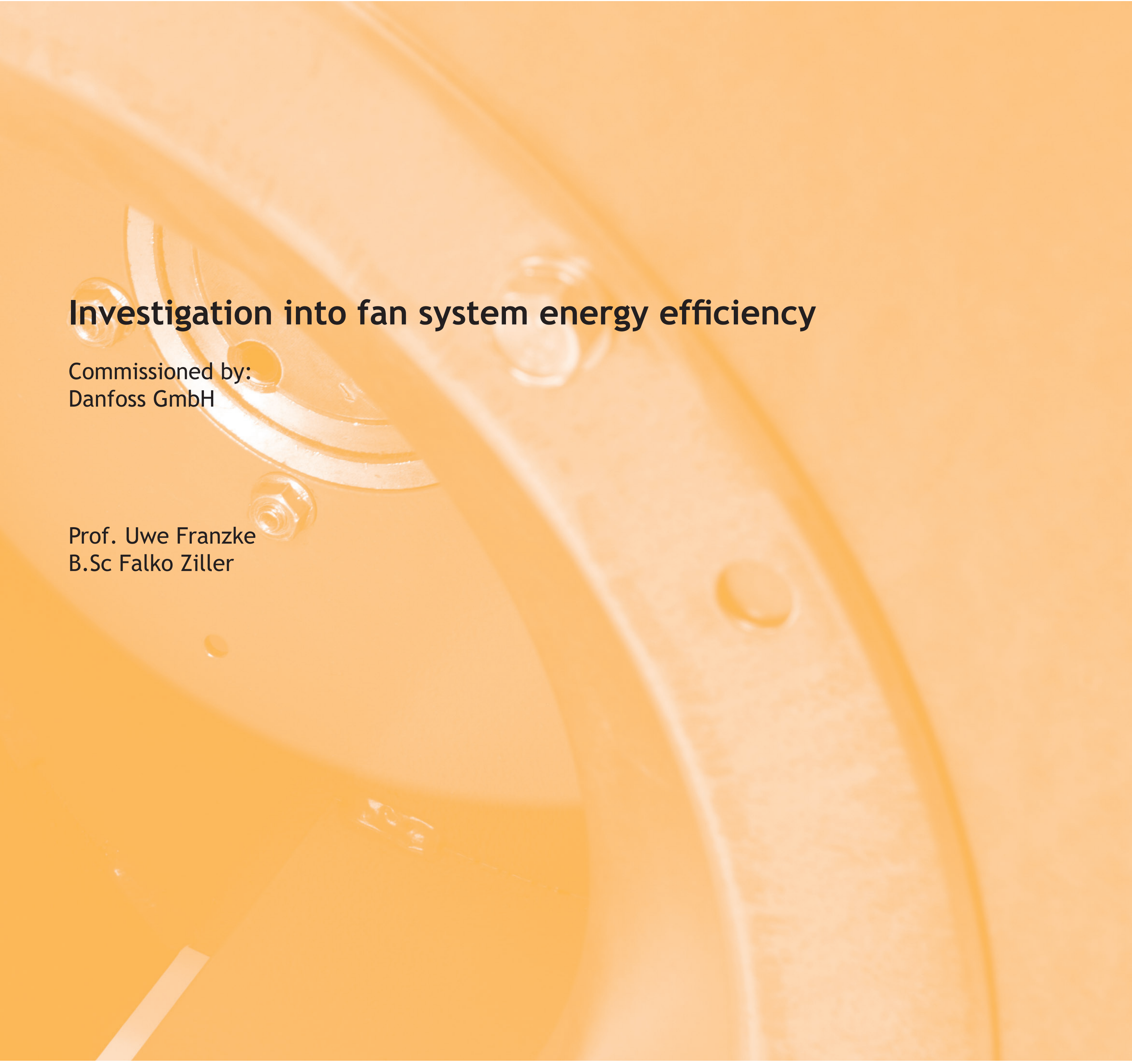
ILK Dresden

Technical report
ILK-B-31-13-3839
24/06/2013



Investigation into fan system energy efficiency

Commissioned by:
Danfoss GmbH

Prof. Uwe Franzke
B.Sc Falko Ziller

Institut für Luft- und Kältetechnik
Gemeinnützige Gesellschaft mbH
Bertolt-Brecht-Allee 20
01309 Dresden

Managing Director: Dr. Ralf Herzog, PhD
Authorised signatory: Prof. Uwe Franzke
Dresden district court HRB 6118
VAT ID no: DE140128898
Tax no: 203/124/00457

Table of Contents

1 Definition of task

A number of different fan-driven systems that are being promoted as energy efficient are currently available on the market. A study is to be conducted under application of the installation and operating conditions found in a HVAC device in order to determine and evaluate the energy efficiency of various fan-driven systems.

The following fan drive systems were observed:

· A permanent magnet motor with a frequency converter
· An EC fan with an integrated motor
· An asynchronous IE2 motor with a frequency converter
· An asynchronous IE3 motor with a frequency converter

2 Testing facility

2.1 Layout of testing facility

The measurements were obtained using an inlet-side chamber testing facility compliant with DIN EN ISO 5801 [1]. The testing facility essentially consists of the main components of a volume flow measurement facility, including the necessary inlet and outflow sections, a pressure-regulated supplementary fan, an inductor device as well as a rectifier and screen elements which precede the testing chamber. The clear dimensions of the facility‘s testing chamber are 1,400 mm x 1,600 mm. The facility allows characteristic fan measurements for a volume flow range between 11 m^3/h and 11,000 m^3/h at a maximum measurement deviation of 1% in relation to the respective reading. This testing facility enables characteristic measurements of resistance elements or fans to be made up to a test pressure of ± 5 kPa. The measurement deviation for test pressure within the measuring range (5 Pa to 5,000 Pa) is no greater than 0.3% in relation to the respective reading. The schematic layout of the testing facility is displayed in figure 1.

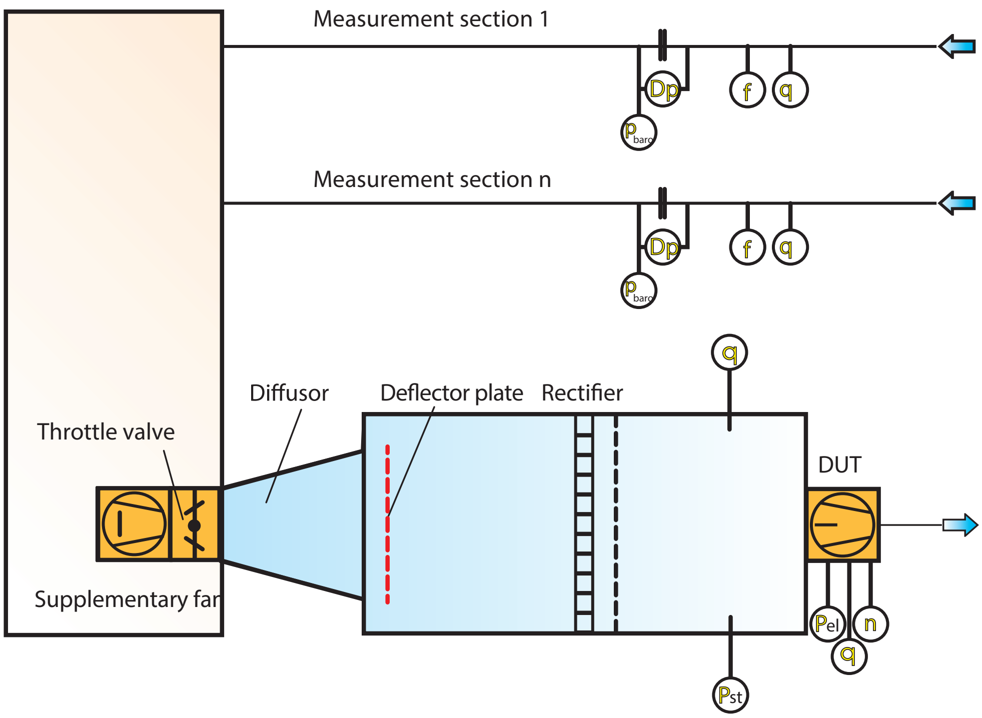


Figure 1
Schematic layout of the testing facility

2.2 Test setup

The influence of different motor systems on fan performance is to be investigated in order to measure their impact under HVAC operating conditions. As the surfaces of the device housing surrounding the fan have an impact on fan and energy efficiency characteristic measurements, the fan unit was enclosed inside a device housing. Furthermore, in order to limit the impact of air entering or exiting the device housing, inlet and outlet sections were created and a perforated metal plate with an open cross-sectional area of 35% was installed in the inlet area. This type of test setup (as displayed in figure 2) should serve to create the typical installation conditions of an HVAC device for the test procedure.

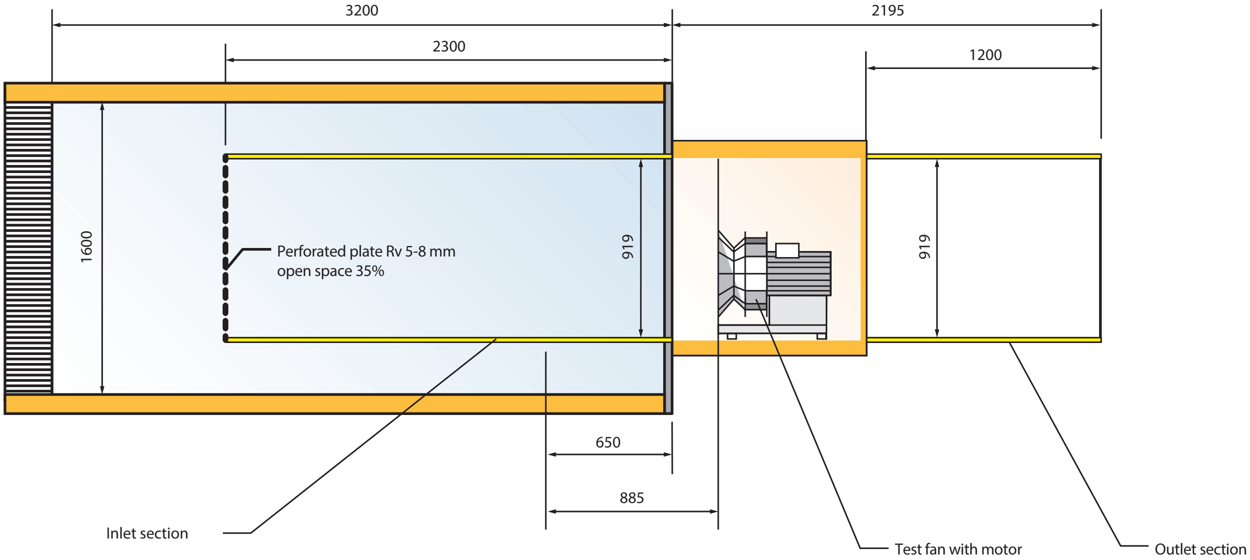
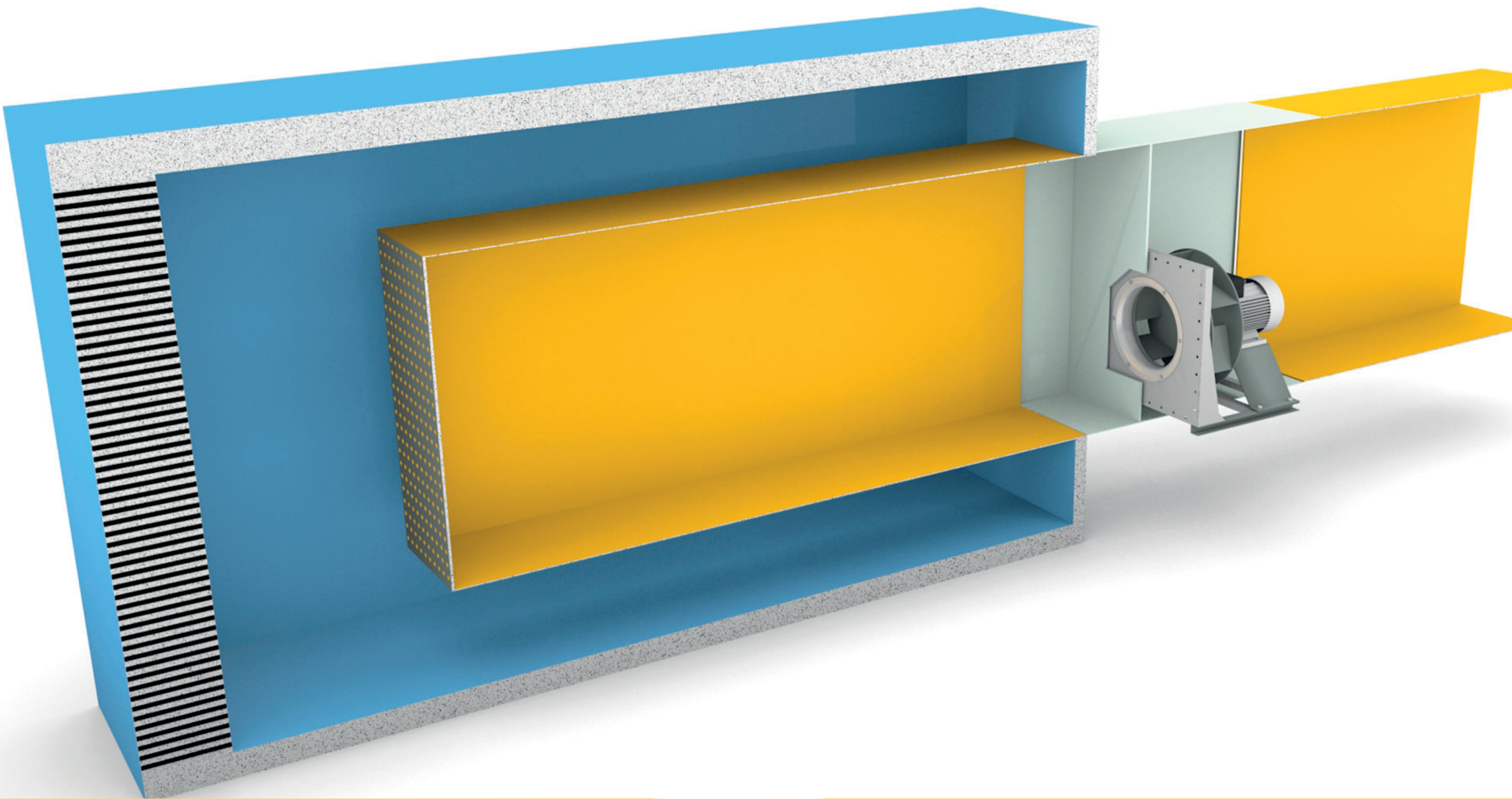


Figure 2
Installation conditions within chamber testing facility



3 Test systems

3.1 HVAC device module

A HVAC device housing with a pre-installed fan unit was provided by the commissioner for the purpose of testing.

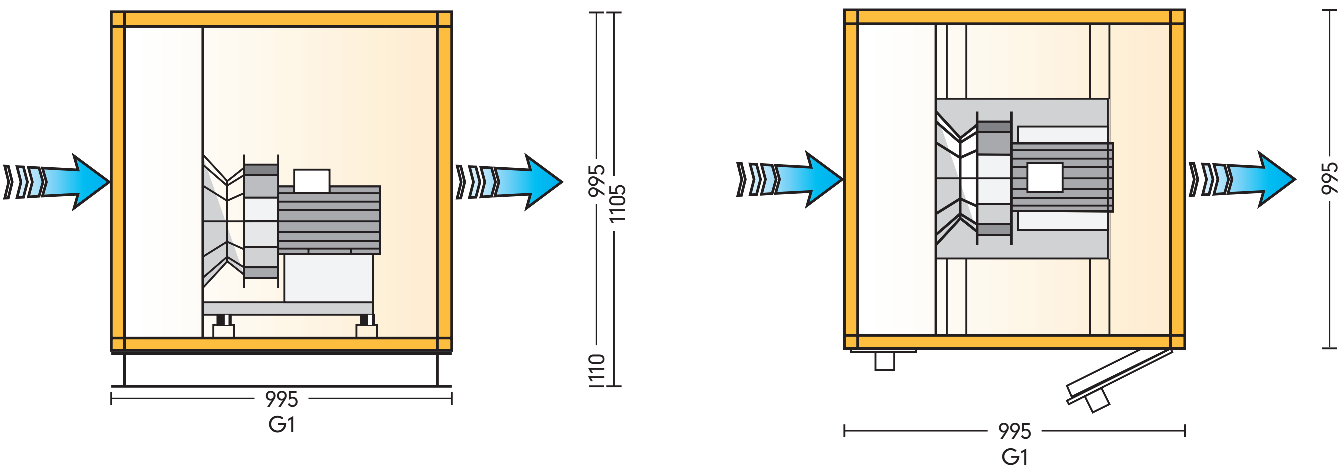


Figure 4
Graphic representation of device housing with integrated fan unit [2]

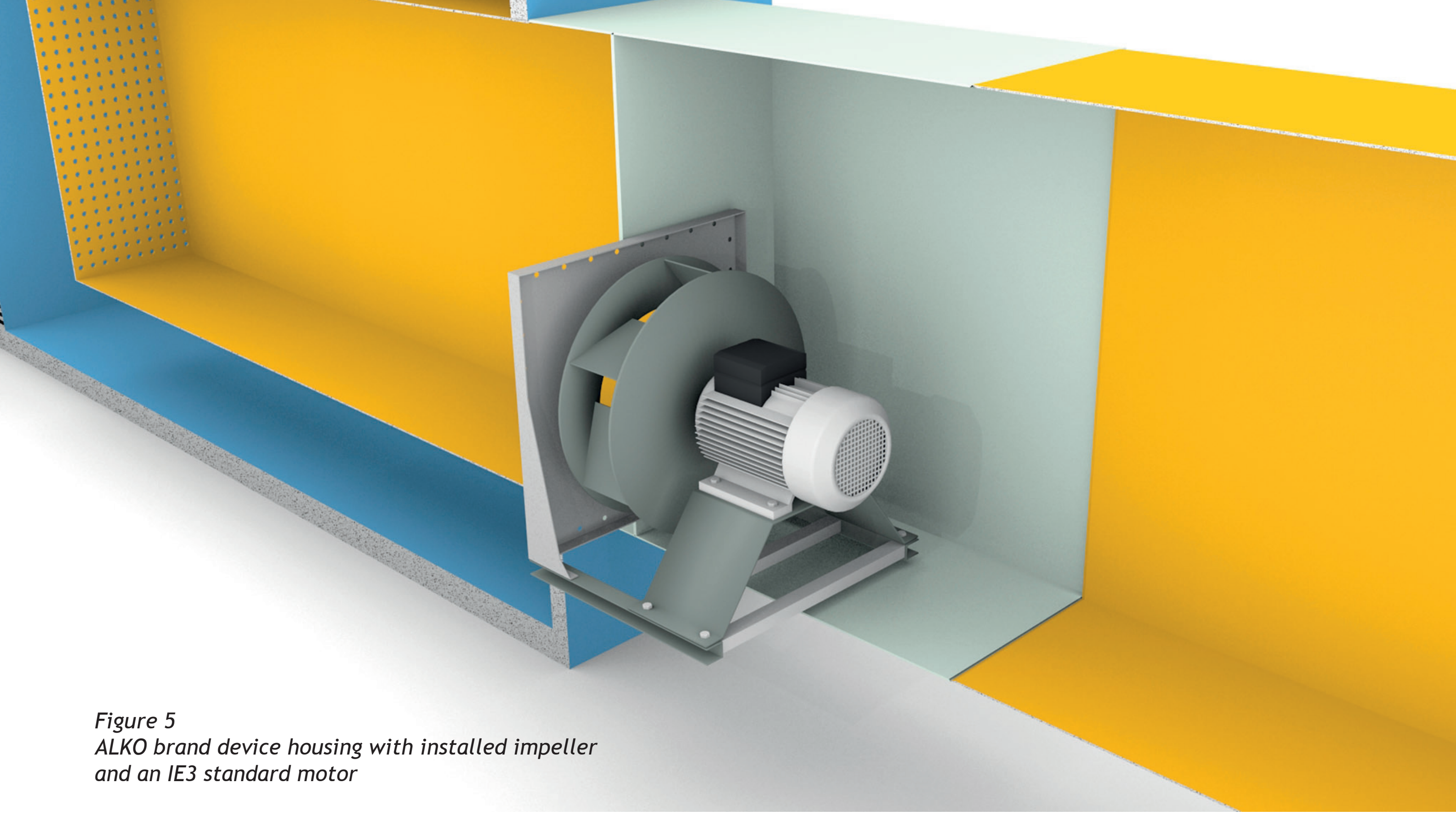


Figure 5
ALKO brand device housing with installed impeller and an IE3 standard motor

3.2 Test object 1 − centrifugal fan with PM standard IE4 motor

A fan impeller manufactured by Nicotra Gebhardt (model RLM E6-3540) was provided as a reference model for efficiency measurements. The fan is driven by a motor system which consists of a permanent magnet motor (PM motor) manufactured by Lafert and a frequency converter manufactured by Danfoss HVAC Drive.

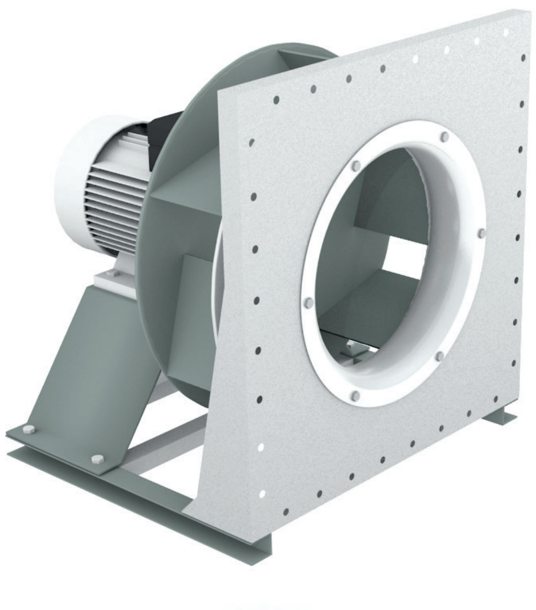


Figure 6
RLM E6 series fan impeller

AL-KO 89343 Jettingen

RLM E6-0400

DEVICE NO 150-950183-947740/1 YEAR OF MANUFACTURE 2012

FAN MOTOR					
n max.	= 2830	l/min	U N	= 400	V(D)
Density	= 1.2	kg/m3	f N	= 50	Hz
Tmax	= 40	°C	f B max	= 48	Hz
			I N	= 6.1	A
			n N	= 2905	l/min
			n max.	= 2830	l/min
			P N	= 3	kW
			T M max	= 40	°C
			Enclosure rating		IP 55
			Thermal class		F
			Type of current		3~

RLM E6-3540-2W-16-A3A

Figure 7
Nameplate for the fan module used for all measurements involving standard motors

LAFERT

Type HPS 90 3000 64 IEC 60034 3~Mot № 805973
Th.C1.F IP 55 S1 T.amb. 40° C Weight=12.0kg
B.E.M.F. 258V In=6,8A 3.0kW Mn=9.6 Nm
Speed=3000 min^{-1} Freq.=200Hz
R_{f-f}=0.98 Ohm L_{f-f}=11.0mH ke=0.82Vs kt=1.42Nm/Amp
REF.194812
Protector Type PTC 140°C 0611

Figure 8
PM motor nameplate

VLT® HVAC Drive
www.danfoss.com

T/C: FC-102P3K0T4Z55H1XGX1OXSXXXXAXBXCXXXXDX
P/N: 131U5081 S/N: 027402G043
3.0kW(400V) / 4.0HP(460V)
IN: 3x380-480V 50/60Hz 6.5/5.7A
OUT: 3x0-Vin 0-590Hz 7.2/6.3A
Type 12 / IP55 Tamb. 45°C/113°F
CE
MADE IN DENMARK
* 131U5081027402G043 *

Figure 9
Nameplate of the frequency converter used for all standard motor measurements

Figure 10
The applied frequency converter supplied by Danfoss

3.3 Test object 2 – centrifugal fan with standard IE3 motor

A 3 kW asynchronous motor manufactured by VEM was used as a reference device for efficiency measurements taken with an IE3 standard motor. The impeller and frequency converter outlined for test object 1 were used (with adjusted parameters).

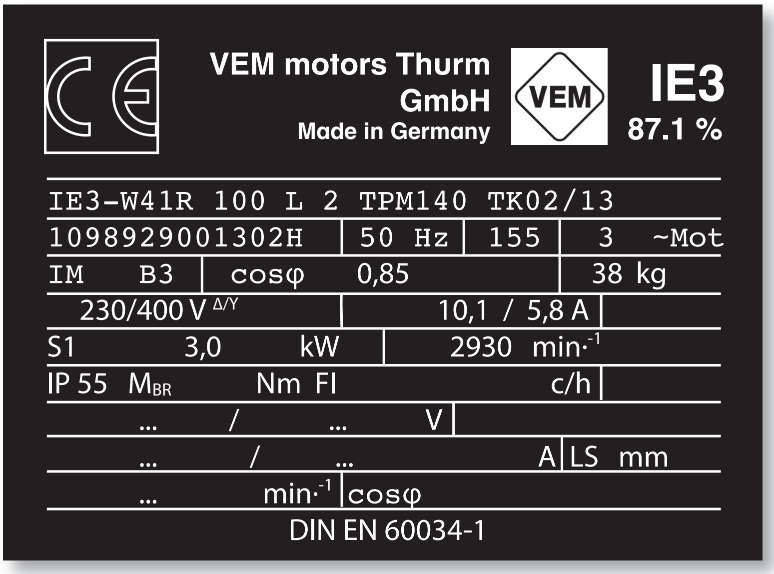


Figure 11
IE3 motor nameplate

3.4 Test object 3 – centrifugal fan with standard IE2 motor

A 3 kW asynchronous motor manufactured by SIEMENS was used as a reference device for efficiency measurements made using a IE2 standard motor. The impeller and frequency converter outlined for test object 1 were used (with adjusted parameters).

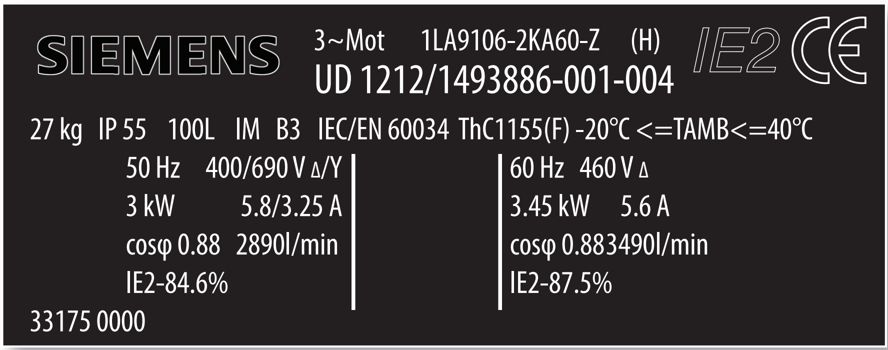


Figure 12
IE2 motor nameplate

3.5 Test object 4 – centrifugal fan with EC motor

A fan model manufactured by ebmpapst (model K3G400-AQ23) was provided as a reference device for efficiency measurements. The fan module consists of a unit with an integrated motor and speed control.

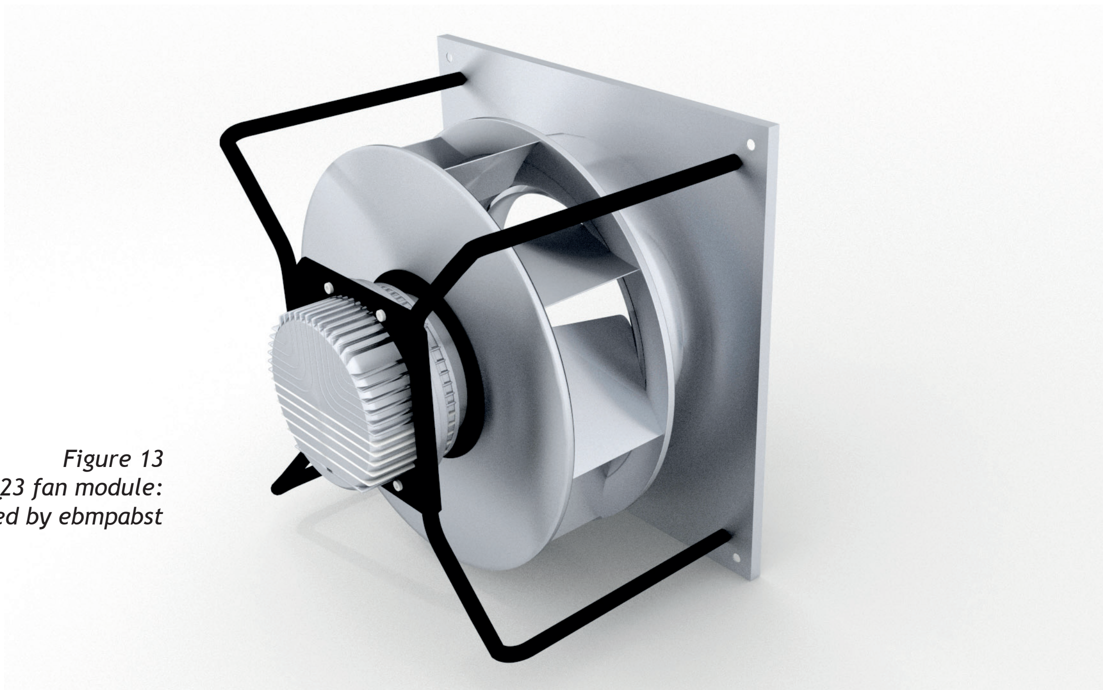


Figure 13
ebmpabst K3G400-AQ23 fan module:
manufactured by ebmpabst

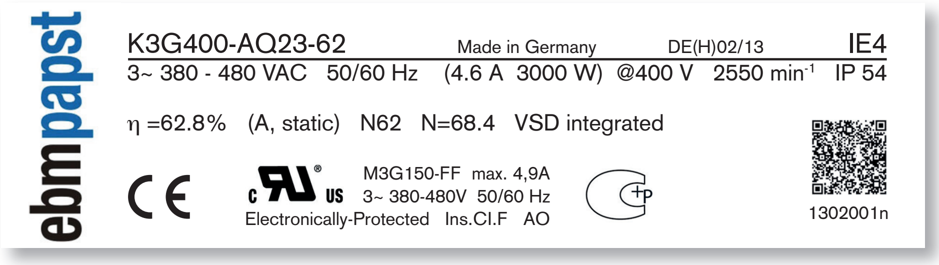


Figure 14
Nameplate of fan system with EC motor

3.6 Comparison of test objects

The described test objects differ in terms of their motor setup but also partly in terms of their fan geometry. Test objects 1 to 3 use the same fan impeller. This impeller has a slightly different geometry to the model used in test object 4.

On test object 4 a part of the motor protrudes through the fan impeller's support disc. Furthermore, the diameter of both the inlet pipe and the outlet width of the impeller are marginally larger in comparison to the test objects with a standard motor (test objects 1 to 3).

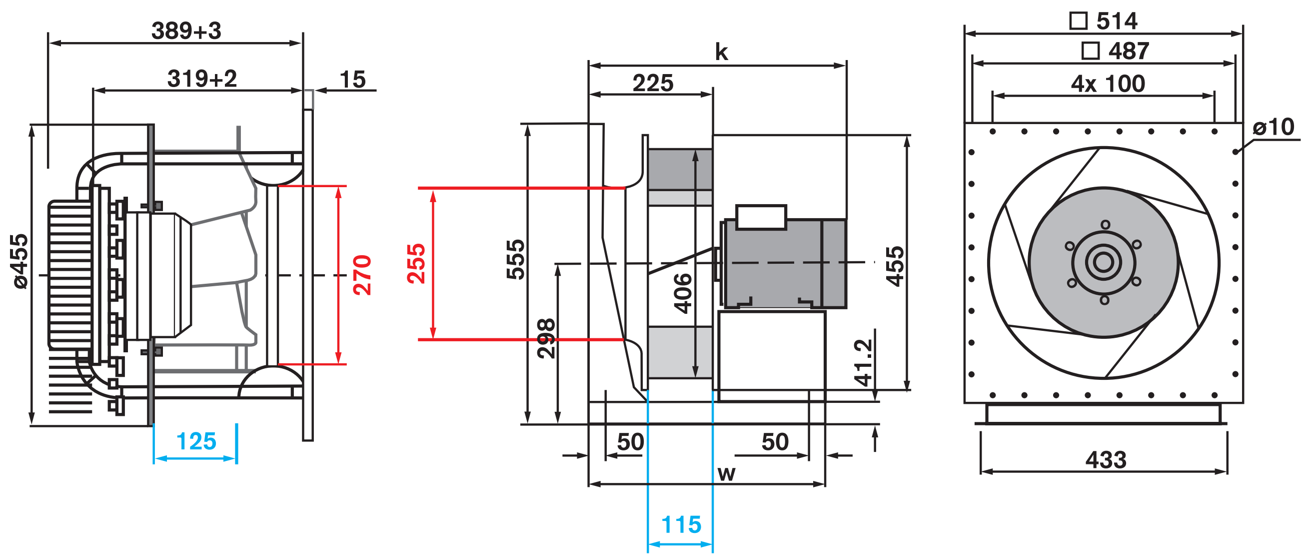


Figure 15
Dimensional drawing of fan systems under investigation [3] [4] including inlet pipe diameter and impeller width

Table 1 – mechanical dimensions of motors used for characteristics measurement (all 3 kW)			
IE class	Manufac-turer	Overall length without shaft	Diameter without base
IE 4	Lafert	260 mm	170 mm
IE 3	VEM	320 mm	190 mm
IE 2	Siemens	340 mm	190 mm

4 Measurement

The test objects were installed inside an inlet-side chamber testing facility compliant with DIN EN ISO 5801 and in accordance with the installation setup detailed on page 6. Each test object was operated for a minimum of 6 hours prior to measurement in order to avoid any impact caused by bearings not having been sufficiently broken in.
Furthermore, the partition inside the HVAC device housing located between the inlet and outlet sides of the fan was additionally sealed[1]. A series of measurements were recorded for each test object, starting with the nominal rated speed and finishing with a partial load of approximately 10% of the rated motor power.
The characteristics were measured using a virtually stationary procedure so that the standard deviation for the flow on each characteristic curve was no greater than 1%. Contingent upon thermal influences, the resulting measurement cycles lasted up to one hour for each individual characteristic curve.

Objects were measured in the following sequence:
· Test object 1 – RLM E6-3540 with permanent magnet motor and frequency converter
· Test object 4 – K3G400 with an EC motor and integrated speed control
· Test object 2 – RLM E6-3540 with an asynchronous IE2 motor and frequency converter
· Test object 3 – RLM E6-3540 with an asynchronous IE3 motor and frequency converter

The respective target speed for all fan models containing a standard motor was set manually using the frequency converter. For the EC fan, this was done by setting a voltage up to a maximum of 10 V. As the operating point appears to affect the actual speed of fans using EC motors, the speed setting signal was repositioned using an external PI controller for PM motor fans to ensure a fair characteristic comparison. The frequency converter was specially parameterised by the manufacturer in order to obtain a series of measurements for PM motor models. The relevant pre-set standard parameters were used and the motor data was entered for the series of measurements obtained using asynchronous motors. The obtained system efficiency maxima for each respective characteristic curve is displayed in table 2 and table 3 below.

[1] To ensure simple remodelling (so that comparative measurements could be made for different fan systems), the HVAC device manufacturer opted not to bond or seal the partition.

Table 2 – system efficiency maxima for measured characteristics for systems with PM and EC motors

Speed reference [1/min]	Maximum efficiency [%]	Volume flow (max eta) [m³/h]	Test pressure psF [Pa] (max eta)	Elec. power [W] (eta max)
PM motor/RLM E6-3540				
2851	63	6117	1202	3218
2560	63	5637	932	2315
2560	63	5689	924	2307
2280	62	4963	743	1649
2100	62	4558	640	1311
2050	62	4632	582	1212
1925	61	4097	547	1024
1800	60	3645	508	852
1650	58	3566	392	664
1500	56	3122	336	516
1200	51	2583	206	288
EC motor/K3G400-AQ23				
2550	59	6236	1027	2996
2550	59	5856	889	2444
2550	59	5778	865	2341
2200	58	5000	725	1718
2115	58	5349	677	1715
1680	56	4025	455	912
1500	54	3679	350	660
1350	53	3478	266	489
1250	51	2953	221	357
1200	51	3213	196	344

Table 3 – *System efficiency maxima for measured characteristic curves for systems with either an IE2 or IE3 motor*

Speed reference [1/min]	Maximum efficiency [%]	Volume flow (max eta) [m³/h]	Test pressure psF [Pa] (max eta)	Elec. power [W] (eta max)
		IE2 motor/RLM E6-3540		
2900	58	5905	1167	3265
2890	59	5884	1167	3240
2560	58	5514	862	2281
2280	56	4533	748	1675
2100	56	4291	632	1352
1925	55	3959	523	1048
1800	53	3950	425	872
1500	50	3197	305	542
1200	45	2630	186	304
		IE3 motor/RLM E6-3540		
2900	60	5952	1238	3387
2890	60	6287	1185	3420
2560	60	5270	950	2324
2280	58	4512	782	1670
2100	58	4358	632	1323
1925	57	3620	585	1036
1800	56	3720	466	864
1500	52	3105	322	532
1200	47	2468	205	296

5 Evaluation

Based on the efficiency maxima readings displayed in table 2 and table 3, figure 16 shows that out of all the examined device systems, the PM fan system (test object 1) demonstrated the highest level of system efficiency. Within the performance range between approx. 50% to 100% of rated power, the devices were ranked in the following order based on efficiency:

· Test object 1 – RLM E6-3540 with a permanent motor and frequency converter
· Test object 3 – RLM E6-3540 with an asynchronous IE3 motor and frequency converter
· Test object 4 – K3G400 with an EC motor and integrated speed control
· Test object 2 – RLM E6-3540 with an asynchronous IE2 motor and frequency converter

Furthermore, every system displayed an almost linear correlation between power and system efficiency once the power range increased above 1/3 of the rated power. Within this range, systems with PM and EC motors (test objects 1 and 4) presented a lower load-dependency in terms of system efficiency than was noted in systems with asynchronous motors (test objects 2 and 3).

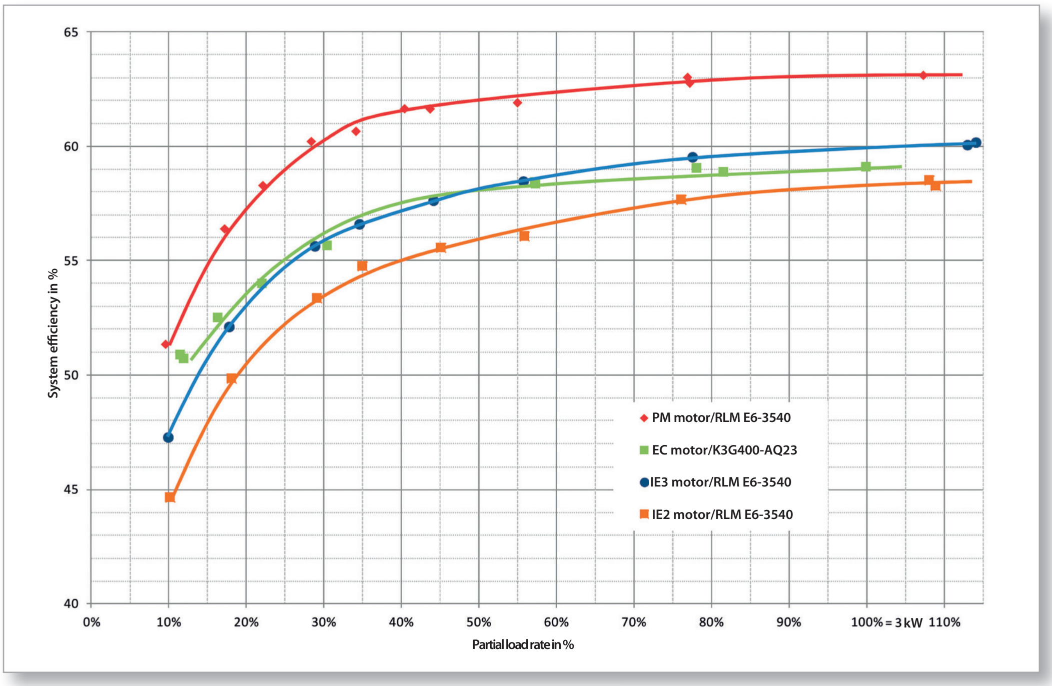


Figure 16
Optimum system efficiency for individual characteristic curves dependent upon power demand and fan motor system

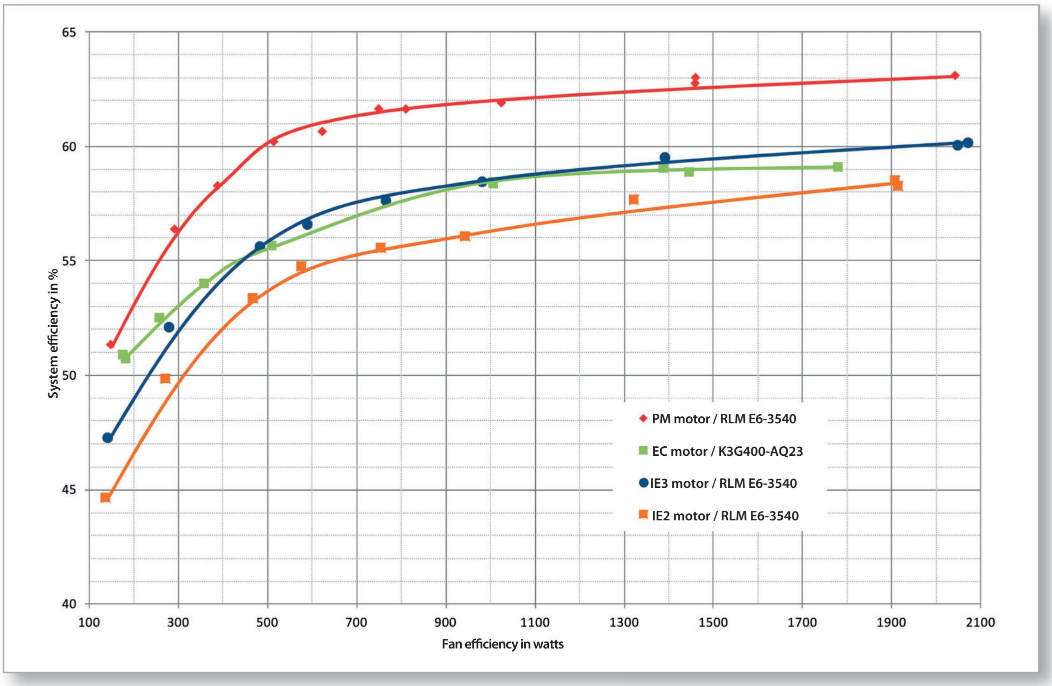


Figure 17
Optimum system efficiency for individual characteristic curves dependent upon real power of the respective fan system

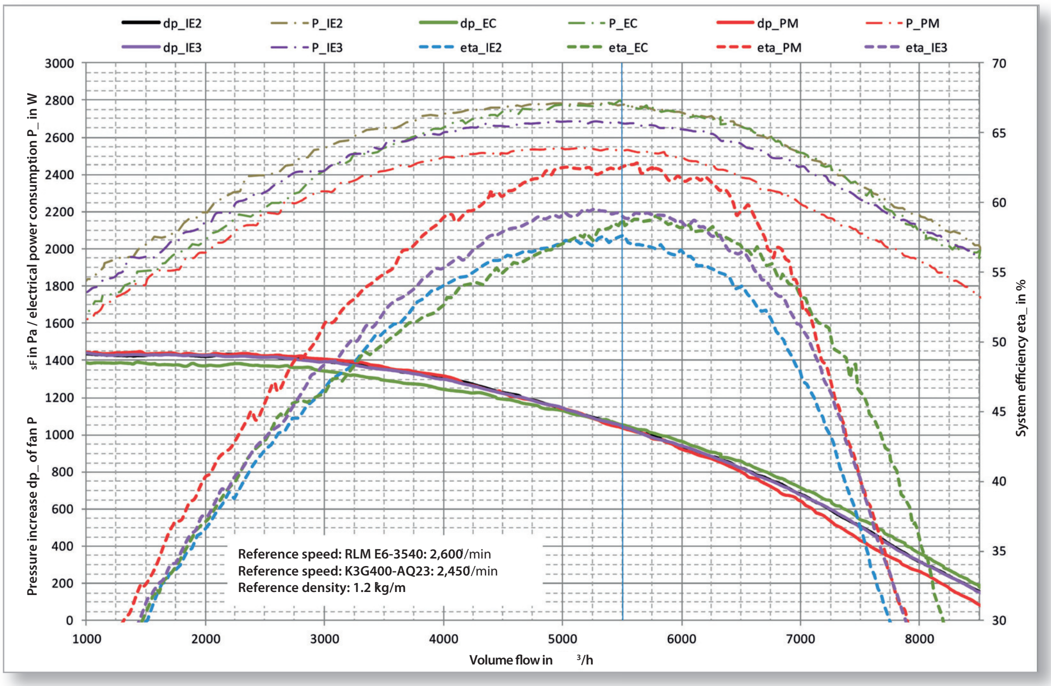


Figure 18
Standardised characteristic curves relating to an operating point of around 5,500 m^3/h

In order to allow for a direct comparison between the fan characteristics of the various systems, the characteristic curves were recalculated in accordance with the similarity rules outlined in DIN EN ISO 5801. Thus, the following reference figures were used: an air density of 1.2 kg/m^3 and a speed of 2,600 1/min for fan model RLM E6-3540 and a speed of 2,450 1/min for fan model K3G400.
Characteristic curves are displayed in figure 18 on page 20. Although it was possible to use the same fan impeller for systems containing a standard motor (test objects 1 to 3), no complete characteristic curve conformity was achieved. If a collective fan operating point of 5,500 m^3/h and 1,100 Pa is assumed, a significantly higher system efficiency can be noted for PM motors and thus the lowest

electricity demand. The EC motor system (test object 4) reached its system efficiency maxima at higher volume flow rates than test objects 1 to 3. It can be assumed that this is due to the constructive

design described in point 3.6 on page 12.
The experiments show that a fan system with a PM motor delivers the highest degree of system efficiency. EC fans and fans with an IE3 motor appear to show a system efficiency which is roughly 3% lower. At best, the performance of the system with an IE2 motor was approximately 5% below the system efficiency of the PM motor fan system. From an energy-efficiency perspective, the PM motor system and frequency converter (test object 1) is therefore the model favoured for use in HVAC devices. Furthermore, it is recommended that an economic assessment of the preferred fan system be carried out for specific application.

Bibliography

[1] DIN EN ISO 5801: 2011
Industrial fans − performance measurement on standardised testing facilities

[2] Product diagram of fan 400 with IE2 3 kW − 1 manufactured by AL-KO THERM GMBH

[3] Product documentation for fan module RLM E6 manufactured by Nicotra Gebhardt

[4] Product documentation for fan module K3G manufactured by ebm-papst

Study commissioned by:

AL-KO THERM GMBH
Hauptstraße 248 – 250 · 89343 Jettingen-Scheppach
Telephone +49 8225 39-0 · Fax +49 8225 39-2113
Email: info.therm@al-ko.de

Nicotra Gebhardt GmbH
Gebhardtstraße 19-257 · 4638 Waldenburg
Telephone +49 7942 101 0 · Fax +49 7942 101 170
Email: info@nicotra-gebhardt.com

Danfoss GmbH
VLT Antriebstechnik
Carl-Legien-Straße 8 · 63073 Offenbach/Main
Telephone +49 69 8902-0 · Fax +49 69 8902-106
Email: vlt@danfoss.de

DKDD.PB.414.A1.02

www.werbestudio-kombuechen.de – Produced by PE-MSMBM 2014.03