EUROVENT / CECOMAF

EUROVENT 1/4

TERMINOLOGY OF FAN AIR PERFORMANCE PARAMETERS AND OPERATING CHARACTERISTICS

EUROVENT 1/4

TERMINOLOGY OF FAN AIR PERFORMANCE PARAMETERS AND OPERATING CHARACTERISTICS

EUROVENT 1/4

Published by EUROVENT/CECOMAF
15 rue Montorgueil
F-75001 PARIS
Tel 33 1 40 26 00 85
Fax 33 1 40 26 01 26

1 - PURPOSE

The purpose of this document is to define the principal quantities required for the expression of the fan performance characteristics.

2 - INSTALLATION CATEGORIES

It is at present recognized that the fan performance is influenced by the ducts connected to the fan at its inlet or outlet. Four test installation categories are defined :

Category A : free inlet and free outlet
Category B : free inlet and ducted outlet
Category C : ducted inlet and free outlet.
Category D : ducted inlet and ducted outlet

As the fan characteristics obtained on different test installations are not the same, it is necessary to add a subscript to the symbols (for instance Y_A represents the fan work obtained by a test on installation category A).

3 - DEFINITIONS

1 - Mass flow rate q_m $[kg \cdot s^{-1}]$

Time averaged value of the fluid mass passing through the fan per unit of time.

2 - Fan inlet area A_1 $[m^2]$

The fan inlet plane should be taken as that surface bounded by the upstream extremity of the air moving device casing.
The inlet area is, by convention, taken as the gross area in the inlet plane inside the casing.

3 - Inlet temperature θ_1 [K]

Mean absolute temperature at fan inlet.

4 - Stagnation inlet temperature θ_{st1} [K]

Mean stagnation temperature at fan inlet given by

$$\theta_{st1} = \theta_1 \left[1 + \frac{\kappa - 1}{2} \alpha_{A1} M_{a1}^2\right]$$

where

κ Isentropic exponent

M_{a1} Mach number of flow through the inlet area

α_{A1} Kinetic energy factor at fan inlet

By convention α_{A1} is considered equal to 1.

For a free inlet fan the stagnation temperature is equal to the mean temperature upstream of the fan inlet.

5 - Inlet static pressure p_{e1} [Pa]

Mean static pressure at fan inlet relative to atmospheric pressure.

6 - Inlet pressure p_1 [Pa]

Mean absolute pressure at fan inlet given by

$$p_1 = p_{e1} + p_{a0}$$

where

p_{e1} inlet static pressure

p_{a0} atmospheric pressure at the mean altitude between fan inlet and outlet.

7 - Inlet density ρ_1 $[kg.m^{-3}]$

Mean density at fan inlet given by

$$\rho_1 = \frac{p_1}{R\theta_1}$$

where R is mass constant of wet air on the inlet side.

8 - Stagnation inlet density ρ_{st1} $[kg.m^{-3}]$

Mean stagnation density at fan inlet given by

$$\rho_{st1} = \rho_1 \left[\frac{\theta_{st1}}{\theta_1}\right]^{\frac{1}{\kappa-1}}$$

For a free inlet fan it is equal to the upstream density corrected if necessary for mean altitude.

9 - Inlet volume flow rate q_{v1} $[m^3.s^{-1}]$

Volume flow rate given by

$$q_{v1} = \frac{q_m}{\rho_1}$$

10 - Inlet stagnation volume flow rate q_{vst1} $[m^3.s^{-1}]$

Volume flow rate given by

$$q_{vst1} = \frac{q_m}{\rho_{st1}}$$

11 - Inlet mean velocity V_{m1} $[m.s^{-1}]$

Mass flow divided by the product of the density at the fan inlet and the fan inlet area

$$V_{m1} = \frac{q_m}{\rho_1 A_1}$$

12 - Inlet dynamic pressure p_{d1} $[Pa]$

By convention, dynamic pressure at fan inlet given by

$$p_{d1} = \frac{1}{2} \rho_1 V_{m1}^2$$

13 - Inlet total pressure p_{t1} $[Pa]$

Total pressure at fan inlet given by

$$p_{t1} = p_{e1} + p_{d1}$$

14 - Stagnation inlet pressure p_{st1} $[Pa]$

Stagnation pressure at fan inlet given by

$$p_{st1} = p_1 \left[\frac{\theta_{st1}}{\theta_1}\right]^{\frac{\kappa}{\kappa - 1}}$$

15 - Fan outlet area A_2 $[m^2]$

The fan outlet plane should be taken as that surface bounded by the downstream extremity of the air moving device casing.

The outlet area is, by convention, taken as the gross area in the outlet plane inside the casing.

16 - Outlet temperature θ_2 $[K]$

Mean absolute temperature at fan outlet

17 - Stagnation outlet temperature θ_{st2} $[K]$

Mean stagnation temperature at fan outlet given by

$$\theta_{st2} = \theta_2 \left[1 + \frac{\kappa - 1}{2} \alpha_{A2} M_{a2}^2\right]$$

where

κ Isentropic exponent
M_{a2} Mach number of flow through the outlet area
α_{A2} Kinetic energy factor at fan outlet

By convention α_{A2} is considered equal to 1.

18 - Outlet static pressure p_{e2} [Pa]

Mean static pressure at fan outlet

19 - Outlet pressure p_2 [Pa]

Mean absolute pressure at fan outlet

it is given by

$$p_2 = p_{e2} + p_{a0}$$

with

p_{e2} outlet static pressure

p_{a0} atmospheric pressure at the mean altitude between fan inlet and outlet.

20 - Outlet density ρ_2 [$kg.m^{-3}$]

it is given by

$$\rho_2 = \frac{p_2}{R\theta_2}$$

where $R = \frac{R_o}{M}$ is mass constant of wet air on the inlet side.

21 - Stagnation outlet density ρ_{st2} [$kg.m^{-3}$]

it is given by

$$\rho_{st2} = \rho_2 \left[\frac{\theta_{st2}}{\theta_2}\right]^{\frac{1}{\kappa-1}}$$

22 - Outlet mean velocity V_{m2} $[m.s^{-1}]$

Mass flow divided by the product of the density at the fan outlet and the fan outlet area.

$$V_{m2} = \frac{q_m}{\rho_2 A_2}$$

23 - Outlet dynamic pressure P_{d2} [Pa]

it is given by

$$P_{d2} = \frac{1}{2} \rho_2 V_{m2}^2$$

24 - Outlet total pressure P_{t2} [Pa]

it is given by

$$P_{t2} = P_{e2} + P_{d2}$$

25 - Stagnation outlet pressure P_{st2} [Pa]

it is given by

$$P_{st2} = P_2 \left[\frac{\theta_{st2}}{\theta_2} \right]^{\frac{K}{K-1}}$$

26 - Fan pressure p_F [Pa]

Pressure difference induced by the fan and used for fans of categories B and D.

a - Rigorously it is given by :

$$p_F = p_{st2} - p_{st1}$$

It is strictly valid even for high mean velocities.

b - When the compressibility effect can be neglected it is given by

$$p_F = p_{t2} - p_{t1}$$

The difference between two definitions of fan total pressure does not exceed 0.3 % if Mach number does not exceed 0.1.

27 - Fan static pressure p_s [Pa]

Pressure difference induced by the fan and used for fans of categories A and C.

a - Rigorously it is given by

$$p_s = p_2 - p_{st1}$$

It is strictly valid even for high mean velocities.

b - When the compressibility effect can be neglected it is given by

$$p_s = p_{e2} - p_{t1}$$

28 - Mean density ρ_m $[kg.m^{-3}]$

Arithmetic mean value of inlet and outlet densities

$$\rho_m = \frac{\rho_1 + \rho_2}{2}$$

29 - Fan work per unit mass y $[J.kg^{-1}]$

That part of the increase of the mechanical energy per unit mass of the fluid passing through the fan which is available to the user.It depends on the installation category and the appropriate letter A, B, C or D should be mentioned as a subscript (for instance y_A for the fan work per unit mass measured with installation category A).

With the convention adopted for the definition of p_1 and p_2 , the variation of altitude is taken in account.

Fan work per unit mass is given by :

Category A : free inlet and free outlet

$$y_A = \frac{p_2 - p_1}{\rho_m} - \alpha_{A1} \frac{v_{m1}^2}{2}$$

Category B : free inlet and ducted outlet

$$y_B = \frac{p_2 - p_1}{\rho_m} + \alpha_{A2} \frac{v_{m2}^2}{2} - \alpha_{A1} \frac{v_{m1}^2}{2}$$

Category C : ducted inlet and free outlet

$$y_C = \frac{p_2 - p_1}{\rho_m} - \alpha_{A1} \frac{v_{m1}^2}{2}$$

Category D : ducted inlet and ducted outlet

$$y_D = \frac{p_2 - p_1}{\rho_m} + \alpha_{A_2} \frac{v_{m2}^2}{2} - \alpha_{A_1} \frac{v_{m1}^2}{2}$$

α_{A_1} and α_{A_2} are always taken equal to 1. For A and C installation categories, the whole fluid kinetic energy at the outlet is considered as not available to the user. For B and D installation categories the kinetic energy of the swirling flow at the outlet is also considered as not available to the user ; the same applies to the part of the kinetic energy of the axial flow which is in excess of the value for the same flow rate with α_{A_2} equal to 1.

30 - Fan air power P_F [W]

Product of mass flow and work per unit mass

$$P_F = q_m \cdot y$$

The appropriate letter of referred installation category should be mentioned as a subscript :

$$P_{FA} = q_m \cdot y_A$$
$$P_{FB} = q_m \cdot y_B$$
$$P_{FC} = q_m \cdot y_C$$
$$P_{FD} = q_m \cdot y_D$$

31 - Fan impeller power P_R [W]

Mechanical power supplied to the fan impeller.

32 - Fan shaft power P_A [W]

Mechanical power supplied to the fan shaft.

33 - Motor output power P_M [W]

Shaft power output of the motor or other prime mover.

34 - Motor input power P_E [W]

Electrical power supplied at the terminal of an electric motor drive.
With other forms of drive, it is not usual to express the input to the prime mover in terms of power. The consumption of fuel or steam is generally given.

35 - Angular velocity ω [rad.s^{-1}]

Angular velocity of the fan impeller.

36 - Rotational frequency n [rev.s^{-1}]

Number of revolutions of the fan impeller per unit of time.

37 - Rotational speed N [rev.min^{-1}]

Number of revolution of the fan impeller per minute.

38 - Tip speed U [m.s^{-1}]

Peripheral velocity of the impeller blade.

39 - Impeller power fan efficiency η_R

Fan air power divided by the fan impeller power

$$\eta_R = \frac{P_F}{P_R}$$

The appropriate letter of referred installation category should be mentioned as a subscript.

$$\eta_{RA} \,/\, \eta_{RB} \,/\, \eta_{RC} \,/\, \eta_{RD}$$

40 - Shaft power fan efficiency η_A

Fan air power divided by the fan shaft power

$$\eta_A = \frac{P_F}{P_A}$$

The appropriate letter of referred installation category should be mentioned as a subscript.

41 - Motor output fan efficiency η_M

Fan air power divided by the motor output power

$$\eta_M = \frac{P_F}{P_M}$$

The appropriate letter of referred installation category shall be mentioned as a subscript.

42 - Overall fan efficiency η_E

Fan air power divided by the motor drive input power for a fan and motor combination

$$\eta_E = \frac{P_F}{P_E}$$

The appropriate letter of referred installation category should be mentioned as a subscript.

43 - Compressibility factor K_ρ

Fluid density at the fan inlet divided by the mean density in the fan given by

$$K_\rho = \frac{\rho_1}{\rho_m} = \frac{2\rho_1}{\rho_1 + \rho_2}$$

44 - Compressibility factor deviation ΔK

Difference between unity and compressibility factor given by

$$\Delta K = 1 - K_\rho = \frac{\rho_2 - \rho_1}{\rho_1 + \rho_2} = \frac{\frac{\rho_2}{\rho_1} - 1}{\frac{\rho_2}{\rho_1} + 1}$$

45 - Fan density ratio r_ρ

Fluid density at the fan outlet divided by fluid density at the fan inlet given by

$$r_\rho = \frac{\rho_2}{\rho_1} = \frac{2 - K_\rho}{K_\rho} = \frac{1 + \Delta K}{1 - \Delta K}$$

46 - Fan inlet density ratio $r\rho_1$

Fan inlet density divided by stagnation inlet density.

$$r\rho_1 = \frac{\rho_1}{\rho_{st1}}$$

47 - Peripheral Mach number M_U

Impeller peripheral velocity divided by the speed of sound at fan inlet given by

$$M_U = \frac{U}{\sqrt{\kappa . R \theta_1}}$$

In the case of a perfect gas with :

κ isentropic exponent

R mass constant

$$R = \frac{\kappa - 1}{\kappa} Cp$$

48 - Transfer coefficient m

Square of ratio of peripheral Mach numbers for reference and test conditions : coefficient m takes into account the effect of Mach number changes and allows for transfer of fan performances from test conditions to reference conditions.

For a perfect gas,

$$m = \left(\frac{U_r}{U_t}\right)^2 \frac{(\kappa R \theta_1)_t}{(\kappa R \theta_1)_r}$$

49 - Kinetic energy factor for an area A_i traversed by fluid flow α_{A_i}

Time averaged flux of kinetic energy per unit mass through the considered area A_i divided by kinetic energy per unit mass corresponding to the mean air velocity through this area given by

$$\alpha_{A_i} = \frac{\iint_{A_i} (\rho \cdot v_n \cdot v^2)\, dA_i}{q_m \cdot v_{m1}^2}$$

where

v is the local absolute flow velocity

v_n is the local velocity normal to the cross section

50 - Inlet kinetic index

Kinetic energy per unit mass through the fan inlet divided by the fan work per unit mass given by

$$i_{K1} = \frac{v_{m1}^2}{\alpha_{A1} \cdot 2y}$$

where $\alpha_{A1} = 1$

51 - Mach number of flow through the inlet area M_{a1}

Mean fan inlet velocity v_{m1} divided by the speed of sound for inlet conditions given by

$$M_{a1} = \frac{v_{m1}}{\sqrt{\kappa \cdot R \cdot \theta_1}} = \frac{q_m}{A_1 \sqrt{\kappa \cdot p_1 \cdot \rho_1}}$$

52 - Discharge kinetic index i_{K2}

Kinetic energy per unit mass through the fan outlet divided by the fan work per unit mass given by

$$i_{K2} = \alpha_{A2} \frac{v_{m2}^2}{2y}$$

where $\alpha_{A2} = 1$

53 - Mach number of flow through the outlet area M_{a2}

Fan outlet mean velocity divided by the speed of sound for outlet conditions given by

$$M_{a2} = \frac{v_{m2}}{\sqrt{\kappa . R . \theta_2}}$$

54 - Fan equivalent orifice area O_F $[m^2]$

Area of a circle through which a uniform steady flow of an isochoric fluid of the density ρ_m would run with the same mass flow rate and a kinetic energy equal to the fan work per unit mass given by

$$O_F = \frac{q_m}{\rho_m . \sqrt{2y}}$$

55 - Fan equivalent orifice diameter D_F $[m]$

$$D_F = \sqrt{\frac{O_F . 4}{\pi}}$$

4 - QUANTITIES : SYMBOLS AND UNITS

Specific heat capacity at constant pressure	C_p	$J.kg^{-1}.K^{-1}$
Isentropic exponent	κ	
Mass constant of a gas	R	$J.kg^{-1}.K^{-1}$
Mean static pressure at fan inlet	p_{e1}	Pa
Mean absolute pressure at fan inlet	p_1	Pa
Mean dynamic pressure at fan inlet	p_{d1}	Pa
Mean absolute temperature at fan inlet	θ_1	K
Density at fan inlet	ρ_1	$kg.m^{-3}$
Stagnation temperature at fan inlet	θ_{st1}	K
Mean total pressure at fan inlet	p_{t1}	Pa
Fan inlet stagnation pressure referred to mean altitude	p_{st1}	Pa
Stagnation density at fan inlet	ρ_{st1}	$kg.m^{-3}$
Mean static pressure at fan outlet	p_{e2}	Pa
Mean absolute pressure at fan outlet	p_2	Pa
Mean dynamic pressure at fan outlet	p_{d2}	Pa
Mean absolute temperature at fan outlet	θ_2	K

Density at fan outlet	ρ_2	$kg.m^{-3}$
Stagnation temperature at fan outlet	θ_{st2}	K
Mean total pressure at fan outlet	p_{t2}	Pa
Fan outlet stagnation pressure referred to mean altitude	p_{st2}	Pa
Stagnation density at fan outlet	ρ_{st2}	$kg.m^{-3}$
Mean density in the fan $\frac{\rho_1+\rho_2}{2}$	ρ_m	$kg.m^{-3}$
Compressibility factor $\frac{\rho_1}{\rho_m}$	K_ρ	
Compressibility factor deviation $1-K$	ΔK	
Fan pressure	p_F	Pa
Fan static pressure $p_s = p_2 - p_{st1}$	p_s	Pa
Kinetic energy factor in the section A_1	α_{A1}	
Mass flow rate	q_m	$kg.s^{-1}$
Inlet volume flow rate	q_{v1}	$m^3.s^{-1}$
Inlet stagnation volume flow rate	q_{vst1}	$m^3.s^{-1}$
Fan work per unit mass	y	$J.kg^{-1}$
Fan air power $= q_m \cdot y$	P_F	W
Fan impeller power	P_R	W
Fan shaft power	P_A	W

Motor output power	P_M	W
Motor input power	P_E	W
Angular velocity	ω	$rad.s^{-1}$
Rotational frequency	n	$rev.s^{-1}$
Rotational speed	N	$rev.min^{-1}$
Tip speed	U	$m.s^{-1}$
Impeller diameter	D	m
Impeller power fan efficiency	η_R	
Shaft power fan efficiency	η_A	
Motor output power fan efficiency	η_M	
Overall fan efficiency	η_E	
Density ratio $\frac{\rho_2}{\rho_1}$	$r\rho$	
Fan inlet density ratio $\frac{\rho_1}{\rho_{st1}}$	$r\rho_1$	
Peripheral Mach number	Ma_u	
Fan inlet area	A_1	m^2
Fan inlet mean velocity	v_{m1}	$m.s^{-1}$
Fan inlet kinetic energy factor	α_{A1}	

Fan inlet kinetic index	i_{K1}	
Fan inlet Mach number	M_{a1}	
Fan outlet area	A_2	m^2
Fan outlet mean velocity	V_{m2}	$m.s^{-1}$
Fan outlet kinetic energy factor	α_{A2}	
Fan outlet kinetic index	i_{K2}	
Fan outlet Mach number	M_{a2}	
Transfert coefficient	m	
Fan equivalent orifice area	O_F	m^2
Fan equivalent orifice diameter	D_F	m
Mean altitude of fan inlet	Z_1	m
Mean altitude of fan outlet	Z_2	m
Mean altitude of the fan.	Z_m	m

LIST OF THE MEMBER ASSOCIATIONS

BELGIUM
FABRIMETAL
21 rue des Drapiers -
B-1050 BRUXELLES
Tel. 32/2/5102518 - Fax : 32/2/5102563

GERMANY
FG ALT im VDMA
Postfach 710864 - D-60498 FRANKFURT/MAIN
Tel. 49/69/66031227 - Fax : 9/69/66031218

SPAIN
AFEC
Francisco Silvela, 69-1°C - E-28028 MADRID
Tel. 34/1/4027383 - Fax : 34/1/4027638

FINLAND
AFMAHE
Etaläranta 10 - FIN-00130 HELSINKI
Tel. 358/9/19231 - Fax : 358/9/624462

FINLAND
FREA
PL 37
FIN-00801 HELSINKI
Tel : 358/9/759 11 66 - Fax : 358/9/755 72 46

FRANCE
UNICLIMA (Syndicat du Matériel Frigorifique, Syndicat de l'Aéraulique)
Cedex 72 -
F-92038 PARIS LA DEFENSE
Tél : 33/1/47176292 - Fax : 33/1/47176427

GREAT BRITAIN
FETA (HEVAC and BRA)
Sterling House - 6 Furlong Road - Bourne End
GB-BUCKS SL 8 5DG
Tel : 44/1628/531186 or 7 -
Fax : 44/1628/810423

ITALY
ANIMA - CO.AER
Via Battistotti Sassi, 11 - I-20133 MILANO
Tel : 39/2/73971 - Fax : 39/2/7397316

NETHERLANDS
NKI
Postbus 190 - NL-2700 AD ZOETERMEER
Tel : 31/79/3531258 - Fax : 31/79/3531365

NETHERLANDS
VLA
Postbus 190 - NL-2700 AD ZOETERMEER
Tel. 31/79/3531258 - Fax : 31/79/3531365

NORWAY
NVEF
P.O.Box 850 Sentrum - N-0104 OSLO
Tel. 47/2/413445 - Fax : 47/2/2202875

SWEDEN
KTG
P.O. Box 5510 - S-11485 STOCKHOLM
Tel. 46/8/7820800 - Fax : 46/8/6603378

SWEDEN
SWEDVENT
P.O. Box 17537 - S-11891 STOCKHOLM
Tel : 46/8/6160400 - Fax : 46/8/6681180

TURKEY
ISKID
Büyükdere Cad. No: 108 Kat.
10 Oyal Ishani Esentepe - ISTANBUL
Tel + Fax : 90/212 272 30 07