**Introduction**

The term SFPv has been used in the Swedish ventilation industry for well over 20 years now. The calculation used by Swedish air handling unit manufacturers is based on a publication by Föreningen V from 1995. The latest update was made in 2000.

Föreningen V has become Svensk Ventilation so there is a need for a publication under the current organisation. There is also a need to update the content to include new requirements and European standards. In addition, there is a need for a definition for the term SFPe.

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# Definitions of SFP

Specific fan power (SFP) is the amount of electrical power consumed by the fans per volume of ventilation air. It is normally expressed in kW/m3/s or W/m3/s

SFP = $\frac{P\_{mains}}{q\_{v}}$ kW m-3 s

SFP can also be expressed as

SFP = $\frac{ΔP\_{stat}}{η}$

Electrical power is given by

 

Pmains is the useful power supplied from the mains in W

qv is the air volume flow through the fan in m3.s-1

ΔPtot  is the total pressure rise from the fan inlet to the fan outlet in Pa

ΔPstat is the static pressure rise from the fan inlet to the fan outlet in Pa

η tot is the total efficiency of the fan calculated using total pressure

η stat  is the total efficiency of the fan calculated using static pressure

Total efficiency means the product of the impeller, motor, transmission and control efficiencies. It relates to the power drawn from the power grid.

Various versions of SFP exist and some are defined in EN Standards

Specific fan power for an entire building: P SFP,B

Specific fan power of an individual air handling unit at design conditions: P SFP,E

Specific fan power of the internal components of a ventilation unit (VU): P SFP,int

Specific fan power of an individual air handling unit at clean filter conditions: P SFP,V

EN 16798-3 Energy performance of buildings - Ventilation for buildings - Part 3 defines the specific fan power for an entire building and for an individual air handling unit. The standard also defines load conditions as follows:

Reference load condition for air handling units is with clean filters, dry heat exchangers and with humidifiers at reference condition.

Design load condition is with the semi-dirty filter pressure drop and dry conditions.

It makes no mention of internal leakage or purging flows in this context.

# PSFP,B

*The PSFP,B is defined as follows: “The amount of electric power consumed by all of the fans in the distribution system divided by the total airflow rate through the building* ***under design conditions*** *, in [kW/ (m3/s)].”*



*Where*

*Psfp,B is specific fan power demand of the entire buildning in W.m-3.s*

*Pmains.SUP  is the total fan power of the supply air fans at the design air flow rate in W*

*Pmains.ETA is the total fan power of the extract air fans at the design air flow rate in W*

*Qv,max is the design exract air volume flow rate through the building in m3.s-1*

Note: *Psfp,B is defined with semi-clean filters and dry heat exchangers.*

EN 16798-3 also defines the specific fan power of individual air handling units:

*“To enable the designers of building projects to quickly determine whether a given air handling unit will positively or negatively meet the overall demands on energy efficiency, a PSFP,E for the individual air handling unit is defined. In some cases specific demands on power efficiency for each individual fan/air handling unit might have been stated in the project specification according to:*

**

*Note In case of disbalance, sometimes the maximum is used to calculate P SFP,E*

*Where*

*P SFP,E is specific fan power demand of the ventilation unit calculated with the individual air volume flows in W.m-3.s*

*P mains.SUP is the total fan power of supply air fans in the unit at the design air flow rate in W*

*P mains.ETA is the total fan power of extract air fans in the unit at the design air flow rate in W*

*Q v,SUP is the design supply air volume flow rate of the unit in m3.s-1*

*Q v,ETA is the design extract air volume flow rate of the unit in m3.s-1*

The note about “disbalance” is unfortunate. Firstly, it is not clear what “maximum” is refering to and secondly it has a significant effect on the calculation result.

EN 16798-3 does not give clear and detailed information about the conditions for the calculation.

We aim to clarify and regulate that later in this document.

# SFPint

SFPint is defined in EC Regulation 1253 and also in EN 13053 where a measurement method is also defined.

Internal specific fan power of ventilation components SFPint

ratio between the internal pressure difference of ventilation components and the fan efficiency, determined for the reference configuration

The internal specific fan power, for one air stream, results from:

 (11)

where

 (12)

where

 (13)

where

|  |  |
| --- | --- |
| *η*s,fan | is the overall static efficiency drive of the built-in fan (system losses considered) at the considered duty point of the unit. |
| *q*v | is the air flow rate expressed in m3·s−1 |
| *P*el | is the electrical power consumption of fan (input power shall include speed control device if existing) expressed in (W) |
| *P*el,int | is the electrical power consumption due to internal pressure differences of ventilation components (input power shall include speed control device if existing) expressed in (W) |
| Δ*p*s,int | is the internal pressure difference of ventilation components expressed in (Pa) |
| Δ*p*s,HRS | is the pressure difference over the heat recovery system expressed in pascals (Pa) |
| Δ*p*s,F | is the pressure difference over the clean filter expressed in pascals (Pa) |
| Δ*p*s,cas | is the pressure difference over the casing (inlets and outlets) expressed in pascals (Pa) |
| Δ*p*s,fan | is the static pressure difference of the fan expressed in pascals (Pa) |
| Δ*p*s,ext | are the external pressure losses (duct work) expressed in pascals (Pa) |
| Δ*p*s,add | are the additional pressure losses (e.g. cooler, silencer, humidifier) expressed in pascals (Pa). |

For air handling units with one air side:

 (15)

where

 (16)

gives

 (17)

where

|  |  |
| --- | --- |
| *SFP*int | is the internal specific fan power of ventilation components, expressed in W · m−3 · s; |
| Δ*p*s,ext | is the external static pressure difference of the unit from 5.4.2.2.1 b), expressed in Pa; |
| Δ*p*s,free,fan | is the static fan pressure of the stand-alone fan from 5.4.2.2.1 c), expressed in Pa; |
| *P*el | is the effective electric input of the fan drive (input power shall include speed control device if existing) from 5.4.2.2.1 a), expressed in Watts [W]; |
| *P*el,free fan | is the effective electric input of the fan drive (input power shall include speed control device if existing) of the stand-alone fan, expressed in Watts [W]; |
| *η*s,free,fan | is the overall static efficiency including motor and drive efficiency of the stand-alone fan |
| *q*v | is the air volume flow rate from 5.4.2.2.1 a), expressed in cubic meters per second (m3 · s−1). |

For air handling units with two air sides:

 (18)

where

|  |  |
| --- | --- |
| *SFP*int | is the internal specific fan power of ventilation components, expressed in watts per cubic metre per second (W · m−3 · s); |
| Indexes | SUP is the supply air stream and EHA is the exhaust air stream. |
| Δ*p*s,ext,xxx | is the external static pressure difference of the unit in the air stream of interest (xxx is SUP or EHA) from 5.4.2.2.1 b), expressed in pascals (Pa); |
| Δ*p*s,free,fan,xxx | is the static fan pressure of the stand-alone fan in the air stream of interest (xxx is SUP or EHA) from 5.4.2.2.1 c), expressed in pascals (Pa); |
| *P*el,xxx | is the effective electric input of the fan drive (including speed control device) of the air stream of interest (xxx is SUP or EHA) from 5.4.2.2.1 a), expressed in watts (W); |
| *q*v,xxx | is the air volume flow rate of the air stream of interest (xxx is SUP or EHA) from 5.4.2.2.1a), cubic meters per second (m3 · s−1). |

Note: 5.4.2.2.1 is the measurement procedure. See EN 13053 for details.

Briefly, it is the SFP for a ventilation unit (air handling unit with the esential components for ventilation) calculated using only the internal pressure drop. It is a legal requirement that manufacturers must fullfill under the EcoDesign Directive 2009/125/EG and European Regulation 1253.

# SFPv

SFPv is defined in V-skrift 1995:1 (rev 2000):

Specific fan power, SFPv, is the total electrical power of the fans in an air handling unit in kW divided by the largest of the supply air flow or the exhaust air flow (ie the ventilation flow and not the outdoor air or exhaust air flows) expressed in m3/s at load conditions prevailing when filters are clean.

SFPv = $\frac{P\_{gridSF} + P\_{gridEF}}{q\_{max}}$

SFPv = Ventilation unit specific fan power, kW/m3/s

PgridSF = Supply air fan total electrical power demand , kW

PgridEF = Extract air fan total electrical power demand , kW

qmax = The larger of the supply or extract air flow rates, m3/s

Note that units with run-around coil heat recovery systems are also included as supply and extract air handling units. This applies even where separated.

Separate supply or exhaust air units and individual fans

Specific fan power, SFPv is the electrical power of the fans in kW divided by the air flow rate expressed in m3/s at load conditions prevailing when the filters are clean and heat exchangers are dry.

SFPv = $\frac{P\_{grid}}{q\_{max}}$

SFPv = Air handling unit specific fan power, kW/m3/s

Pgrid = Fan power, kW

qmax = Airflow , m3/s

Calculation of Pgrid

The active power demand from the mains for each single-fan can be written:

Pgrid = $\frac{q\_{fl} . Δp\_{fl}}{η\_{tot }. 1000}$

Or

Pgrid = $\frac{P\_{fl}}{η\_{tr}.η\_{m}.η\_{r}}$

Pgrid = active power demand from the electrical power supply, kW

qfl = air flow rate through the fan, m3/s

Δpfl = Total pressure rise of the fan, Pa

Pfl = fan shaft power, kW

ηtot = ηfl . ηtr . ηm . ηr

ηfl = fan efficiency including any bearing losses

ηtr =mechanical efficiency of any transmission

ηm =efficiency of the motor including losses caused by speed control

ηr =the efficiency of the control equipment including its effect on motor losses.

*Note: Most fans today are direct driven and there are no bearings or transmission. The electric motor can contain built-in speed control.*

All values ​​apply to the air density 1.2 kg.m-3.

Δpfl = Total pressure rise of the fan, Pa, is the pressure increase needed to overcome the losses in both the air handling unit and the ventilation distribution system.

# SFPe

EN 16798-3 defines PSFP,B and PSFP,E  but the standard does not give the exact conditions regarding internal leakage, purging, condensation and filter status.

Therefore, we define here a new SFP value which we call SFPe

In this definition we use the mean value for the filter pressure drop and dry heat exchangers; which is the same as the definition of PSFP,E

Heat exchangers include both energy recovery devices and cooling coils. The ratio is intended to give a simple indicator of the total energy consumption over the year and heat exchangers tend to be dry for most of the running hours during the year in Nordic climate.

Specific fan power, SFPe is the sum of the electrical powers supplied to the fans in an air handling unit in kW divided by the larger of the supply or extract air flow rates ( i.e. the building ventilation flow rate and not the outdoor flow or exhaust flow) expressed in m3/s ath the design operating point with the design filter pressure drop and with dry heat exchangers.

SFPe = $\frac{P\_{gridSF} + P\_{gridEF}}{q\_{max}}$

SFPe = AHU specific fan power, kW/m3/s

PgridSF = Supply fan total electrical power demand, kW

PgridSF = Extract fan total electrical power demand, kW

qmax = The larger of the supply or extract air flow rates, m3/s

Note that units with run-around coil heat recovery systems are also included as supply and extract air handling units. This applies even where separated.

Separate supply or extract units and individual fans.

The specific fan power is the electrical power demand of the fan in kW divided by the airflow rate in m3/s at the condition using the dimensioning pressure drop for filters and the pressure drop for heat exchangers is at the dry condition.

The dimensioning pressure drop for filters (according to EN 13053 6.9.2, table 9)

Δp filter,dim = $\frac{Δp\_{filter,clean}+ Δp\_{filter,final}}{2}$

Δp filter,clean = The measured pressure drop of a new filter.

For ISO ePM1, ePM2.5, ePM10:

Δp filter,final = The lesser of [Δp filter,clean + 100Pa] or [Δp filter,clean x 3]

For ISO course:

Δp filter,final = The lesser of [Δp filter,clean + 50Pa] eller [Δp filter,clean x 3]

# Calculation of Pgrid

The active power demand from the grid for each fan is given by:

Pnät = $\frac{q\_{fl} . Δp\_{fl}}{η\_{tot }. 1000}$

Or

Pnät = $\frac{P\_{fl}}{η\_{tr}.η\_{m}.η\_{r}}$

Pnät = Active power demand, kW

qfl = airflow through the fan, m3/s

Δpfl = Total pressure rise in the fan, Pa

Pfl = axel power of the fan, kW

ηtot = ηfl . ηtr . ηm . ηr

ηfl = Efficiency of the fan including any bearing losses.

ηtr =Efficiency of any mechanical power transmission

ηm =Efficiency of the motor including the effects of speed control.

ηr =Efficiency of the speed control equipment at the operating point.

*Note: Most fans today are direct driven and there are no bearings or transmission. The electric motor can contain built-in speed control.*

All values ​​apply to the air density 1.2 kg.m-3.

Δpfl = Total pressure rise of the fan, Pa, is the pressure increase needed to overcome the losses in both the air handling unit and the ventilation distribution system.

In the calculation of the fan airflow, pressure, and electrical power demand the internal leakage flows (OACF and EATR), additional throttling and the purge flows in rotary heat exchangers shall be included.

Where there is a risk of leakage of extract air to the supply air additional throttling shall be included to ensure a pressure balance that prevents such leakage.

To calculate the SFP for an entire building the designer needs the electrical power

 (PSFP,B )for all fansin the building. See EN 16798-3 section 9.5.4

PSFP,B is the supply and extract fans electrical power demand in the SFPe calculation.

# Internal leakages

Internal leakages are defined by SS-EN 16798-3 and in the new pr EN 308.

Exhaust air transfer ratio (EATR, %)

Transfer of extract air into the supply air side. EATR provides information on the level of carry-over of extract air in the supply air. EATR is the ratio of the leakage flow to the supply air flow.

EATR = $\frac{q\_{SUP}-q\_{SUPnet}}{q\_{sup}}$

EN 308 provides a method for measurement and the definition is given in terms of tracer gas concentration:

EATR = $\frac{C\_{22}-C\_{21}}{C\_{11}-C\_{21}}$

C11 is tracer gas concentration of exhaust air inlet

C21 is tracer gas concentration of supply air inlet

C22 is tracer gas concentration of supply air outlet

Outdoor air correction factor (OACF)

Ratio of the entering supply air mass flow rate and the leaving supply air mass flow rate

Definition provided by EN 16798-3:2018:

OACF = $\frac{q\_{m,ODA,HR}}{q\_{m,SUP,HR}}$

Qm,ODA,HR =the air mas flow of outdoor air entering the heat exchanger

Qm,SUP,HR =the air mas flow of supply air leaving the heat exchanger

If OACF is greater than 1 then air is transfered from outdoor to extract. The amount of air passing through the outdoor air filter and other components in the outdoor air side before the heat exchanger; which will increase the pressure drop for the supply fan. In addition, the extract fan will need to operate at a higher flow rate that the required extract ventilation flow rate.

If OACF is smaller than 1 then air is transfered from extract to supply

# Presentation of data

SFPv and SFPe shall be calculated with the same airflow rate and shall be presented together in techncial data sheets.

Psfp,B shall be presented in a clear way so that it is not confused with the design power demand of the fans.

OACF and EATR shall be presented together and should be presented together with other data for the heat exchanger.

The necessary data required for checking the SFP values shall be presented as follows:

The following data shall be provided for each of the following:

the dimensioning point, the SFPv and the SFPe calculation cases:

* Supply and extract airflow rates, *qTF* and *qFF*, (m³/s)
* External static pressures given by the customer to the supplier (Pa)
* The pressure drops of filters, (Pa)
* The rotational speed of the fans, (r/m)
* Fan power, (kW)
* Total efficiency of the fans
* Duct connection dimensions

# Measuring SFPv and SFPe

**Prerequisites**

The air handling unit should normally be fitted with clean filters before you measure its SFPv. The air handling unit and ducting system should be free of impurities, that can give rise to a higher pressure drop.

A specific air density and a specific fan speed have been prerequisites in the design of the project. Since the airflow rate developed in the fan is highly conditional on these values, the measured data will have to be recalculated so that they will be comparable with the project design data as far as possible.

It is especially important to measure the speed under prevailing load conditions since this will affect the output to the third power. This rotational speed will not be equal to the project design speed. Moreover, it is not unusual that the design speed has been altered while the equipment was installed.

**Checks made in the air handling system**

It is generally more difficult to measure the performance of an air handling system on site than in a laboratory and the results of such checks are also more difficult to assess. If the external pressure drops cannot be adjusted to conform to the presupposed project design pressure drops in the air distribution system (after corrections have been made to compensate for speed of rotation and density), the duty point of the fans in the fan chart must then be identified in order to get some idea as to how the pressure, flow and performance deviate from the project design figures. No general conversion formulae are available for this case.

**Designations**

In the following presentation, all the project design values are designated by index “p”, the measured values by index “u” and the corrected values by index “k”. The values that refer to conditions at the fan inlet have been supplemented with index “fl”. Where there is a need for differentiating the data for the supply air and exhaust air fans respectively, “SA fan” and “EA fan” respectively have been added to the index.

All the measured data will be impaired by certain measurement errors that influence the accuracy of the results. The relative uncertainties due to these errors are designated by “m” together with a suitable index for each quantity.

Apart from measurement errors, the manufacturer should be permitted a certain tolerance for the data in his specifications. If no tolerance is specified, assume a tolerance of ±0.05 (5%) for both the air flow , SFPv and SFPe. The relative values of these permissible deviations are designated by “a” with a suitable index for each quantity.

|  |
| --- |
| **Determining the SFPv and SFPe of a Fan or an Air Handling Unit** |
|  |  | Project design | Measured |
| Quantity | Unit | Value | Permissible relative deviation | Value | Relative measurement error |
| Barometer reading | (hPa) | Bp=1013 |  | Bu | mB |
| Temperature where air flow is measured | (°C)(K) | tp=20.0Tp=293 |  | tuTu=273+tu | mT |
| Temperature at fan inlet | (°C)(K) |  |  | tuflTufl=273+tufl | mTfl |
| Density | (kg/m3) | ρp=1.20 |  | ρu | mρ |
| Total pressure drop outside AHU | (Pa) | ppext |  | puext | mpr |
| Pressure drop across filter | (Pa) | ppfil |  | pufil | mpr |
| Flow | (m3/s) | qp | aq | qu | mq |
| Speed of rotation | (rpm) | np |  | nu | mn |
| Power | (kW) |  |  | Pu | mP |
| SFPV value | (kW/(m3/s)) | SFPVp | aS | SFPVu | mS |
| SFPe value | (kW/(m3/s)) | SFPep | aS | SFPeu | mS |

**Measurements**

It is important to keep the doors of the unit closed while measuring the rpm of the fans so that the pressure and the flow conditions are correct.

The temperature, air flow rate and useful power demand can be measured under the prevailing air flow conditions. If a more accurate assessment is necessary, all of the external pressure drops and the filter pressure drop should be measured. If the barometer reading isn’t known, specify

1013 hPa and include it as an increased uncertain figure in an error estimate.

The temperature should be measured in the cross section of the ducting system where the air flow is measured as well as at the fan inlet. The temperature differential should not exceed 15 °C.

European standard EN 16211:2015 specifies methods for the measurement of airflows on site.

The calculation of SFPe requires measurements with the filters in the dimensioning pressure drop condition. The most convenient way to do that is to use clean filters and simulate the additional pressure drop by adding additional pressure in the external pressure on the inlet side of the filter. Note that the difference between SFPv and SFPe depends not only on the difference in pressure but also the difference in fan efficiency at the different operating points.

The measured useful power demands can then be recalculated to apply to an air density of ρ = 1.2 kg/m3 and at the project designed fan speed. Then compute the corrected specific fan power, SFPvk and SFPek. These values can then be compared with those specified by the air handling unit supplier.

The useful power should always be directly measured with an output meter and not indirectly by measuring voltage and amperes.

If the unit includes a frequency converter, the measurements should be carried out on the mains power supply side of the frequency converter. Use an instrument that indicates the true output (TRMS) and has a wide band.

***Warning! Never carry out measurements between the frequency converter and motor. Doing so may endanger your life!***

**Calculation process and assessment.**

The basis for forming an assessment is that an air handling unit at least meets the project design air flow rate and that its power consumption doesn’t exceed the max permissible rate in the project design specifications. This is expressed as the SFPV. Applicable tolerances and deviations have been taken into consideration.

The computation and assessment below are divided into two steps. Step 2 involves a more complex management in which corrections and comments are entered to ensure a correct assessment.

The measured values should be corrected taking the air density into account.

The expressions to the right of each equation indicate how the probable errors in the computed values are due to errors in each of the measurements.

**Air density**

The air density must be taken into consideration in all cases. Normal variations can be a matter of 10% for changes in temperature, 4% for changes in pressure (at sea level) and 1% for changes in moisture content.

The temperature readings must therefore always be made. A barometer reading of 1013 hPa can be used for an initial assessment (Step 1). The relative error can then be 0.04 (4%). As a rule, the influence of variations in the moisture content of the air is negligible.

**Step 1 Basic assessment**

In this step, it is assumed that the air flow rate has been accepted. The speed of the fans is not taken into consideration.

 

Bu = Bpand *mB* = 0.04 (4%) if the barometer pressure is not measured.

 

*qumax* = The highest from measured supply air or exhaust air flow of the air handling unit (m³/s)

If the following condition is met, the air handling unit can be accepted, if not, proceed to step 2.



**Step 2 Detailed assessment**

The duty point of the air handling system is assumed to be quadratic in the following equations wherein the laws of affinity of a fan are applicable. The measured values can be recalculated to corrected values (indicated by index ”k”), which are applicable to the design fan speed and standard air density.

The airflow volume through a fan is not affected by changes in air density. The airflow volume in ducts of various cross section may however change with regard to changes in air density (constant mass flow). Hence an airflow reading should be corrected with regard to temperature.

Enter the design fan speed for clean filters in the formulae below.

 

 

The SFPVk can be computed using corrected measured values according to the previous formulae. The following expressions are thus applicable to an air handling unit with both supply air and exhaust air fan:

 

**Necessary air flow condition to be met:**

qk . (1 + mqk )  qp . (1 - aq )

If the condition above cannot be met, this may be because the flow resistance in the air handling system is more than anticipated or that the filters do not conform to the initial design pressure drop. Measure the external pressure drop and the filter pressure drop while examining the system to determine the cause of this inconsistency.

**Necessary corrected SFPV condition to be met:**



The air handling unit can be accepted if the necessary conditions of both the air flow and for the SFPVk have been met. If not, get in touch with the air handling unit supplier before not accepting the unit, if this action is to be taken.

The same process applies to SFPe

Examples

The following air handling unit readings have been taken on a clear day.

Bu = 1045 hPa ±1%. tu = 18 °C ±3°. Tu = 291 K ±1%. tufl = 5 °C ±3°.

Tufl = 278 K ±1%. nu = 1030 rpm ±0.5%. qu = 8.3 m3/s ±8%. Pu = 9.8 kW ±3%.

The air handling unit has been designed into a project calling for qp = 8.0 m3/s under normal conditions. Under the given load conditions, the supplier has specified np = 1000 rpm and an SFPV of 1.0 kW/(m3/s).

The supplier is allowed a ±5% tolerance on the data he has specified. Can the air handling unit be accepted?

Without corrections, the SFPV would be 9.8/8.3 = 1.18 kW/(m3/s), which appears to be far from the goal. The other data does not differ so much from what might be expected.

By considerable corrections, the following can be obtained instead:

 

 

 

Flow :  **OK**

SFPVk :  **OK**

# Relevant Standards

EN 13053:2019

Ventilation for buildings – Air handling units – Rating and performance for units, components and sections.

EN 16798-3: 2018

Energy performance of buildings – ventilation for buildings – Part 3: For non-residential buildings

EN 308

Heat Exchangers – Test procedures for establishing performance of air to air and flue gases heat recovery devices.

EN 16211:2015

Ventilation for buildings – Measurement of air flows on site - Methods

# Figures



Figure 1: Pressure conditions in the ducting system (external pressure drop)



Figure 2: Pressure conditions inside the air handling unit

# Appendix 1

**How to calculate the extra throttling pthrottle on exhaust air side of the rotary heat exchanger necessary for ensuring the correct air leakage direction.**



To ensure that the leakage across the rotary heat exchanger will be from the supply air to the exhaust air, the pressure p3 must be lower than the pressure p2 as illustrated above.

pext o in the illustration = pext u in the equations, where u denotes a measured value.

Hence: p3  p2

p2 = -[pext u + pahu s]

p3 = -[pext e + pthrottle + pfil]

If p2 = p3 then:

pthrottle = pext u + pahu s - pext e - pfil

specify pext e + pext a = pext ea thus

pthottle = pext u + pahu s - pext ea + pext a - pfil

The supplier of the air handling unit must calculate the pahu and pfil used in the equations above.

The external pressure drops of the supply air, pext us and the external pressure drop of the exhaust air, pext ea is specified in the program documents. On the other hand, pext o and pext a are seldom specified. In order to carry out a consistent calculation of pthrottle, the following settings can be assumed:

if pext us > 150 Pa set pext u = 50 Pa, otherwise set pext u = pext us / 3

if pext ea > 150 Pa set pext a = 50 Pa, otherwise set pext a = pext ea / 3

The smallest degree of extra throttling required, pthrottle can then be calculated from the formula above.

The pressure drop, pfil, refers to a unit with clean filters.

Negative pthrottle means that no extra throttling is necessary.