Plenum Fan & Multiple Fan System

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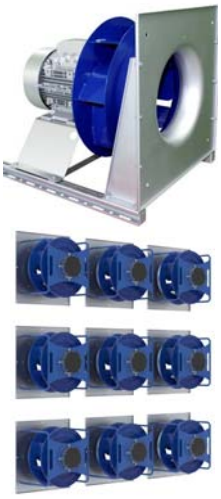
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Learning Objectives

- Plenum Fan
- Multiple Fan System

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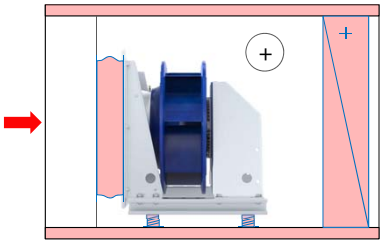
- Plenum Fans
  - What is a plenum fan?
  - Test setup
  - Evolution of plenum fans
  - Advantages of plenum fans
  - Installation effects
- Multiple Fan System
  - Benefits of multiple fan system
  - Mounting recommendations
  - Failure of a fan
  - Airflow measurement

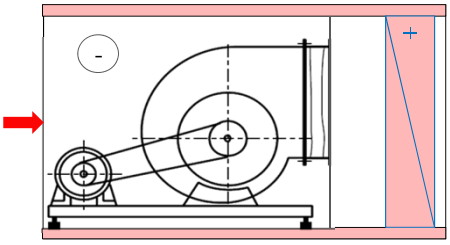


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What is a Plenum Fan?

- The fan wheel pressurizes the entire surrounding air plenum in which the fan is installed, allowing air ducts from any direction to be directly connected to the air handling unit enclosure.

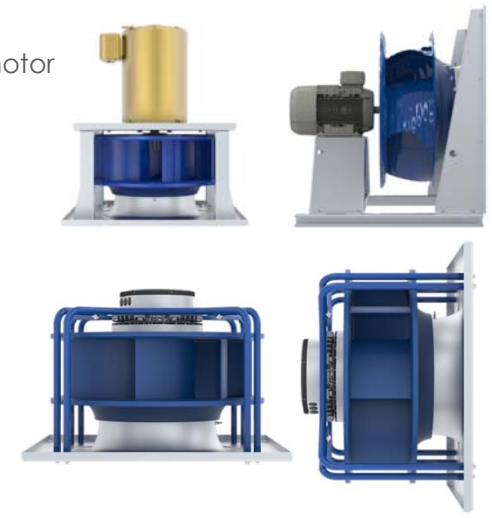




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What is a Plenum Fan?

- Plenum Fan with standard motor or EC motor
  - horizontal mounting
  - vertical mounting



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Test Setup for Plenum Fans

AMCA 210 and AMCA 300

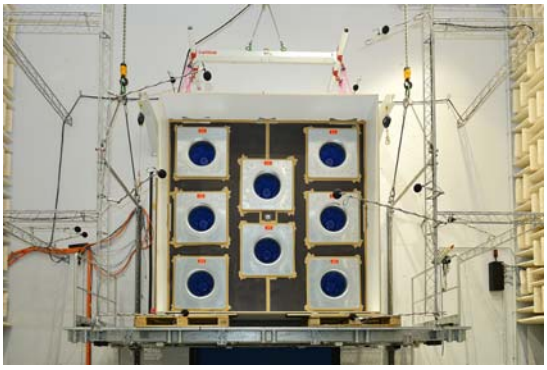
- Air Performance according AMCA 210
- Sound according AMCA 300 in reverberation room
- Sound Measurement according ISO 13347 in anechoic room



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Test Setup for Plenum Fans

AMCA 210





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Evolution of impellers for plenum fans

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Evolution of Impeller and System Efficiency

14% increase of efficiency during the past 20 years! η



- 1997
- backward curved
- ηimpeller 69%
- IE1
- ηsys 58%



- 2003
- rotating diffusor
- ηimpeller 73%
- IE1
- ηsys 61%

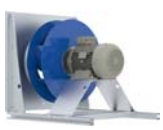


- 2011
- profiled blade
- ηimpeller 75%
- IE2
- ηsys 63%



- 2017
- bionic 3D blade
- ηimpeller **79%**
- IE4
- ηsys **70%**









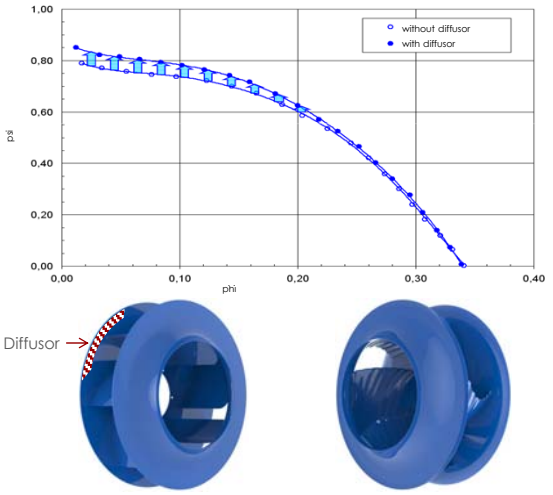
21% increase of system efficiency η

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System Efficiency

Optimized fan geometry

- Rotating divergent diffusor
  - conversion of dynamic into static pressure
  - increase static efficiency
- Bionic 3D blade
  - stabilization of blade flow condition
  - wider range of optimum efficiency
  - less turbulences reduced noise
  - twisted blade to reduce flow separation

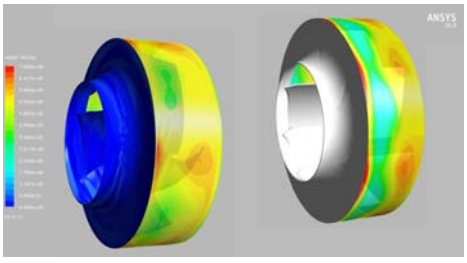


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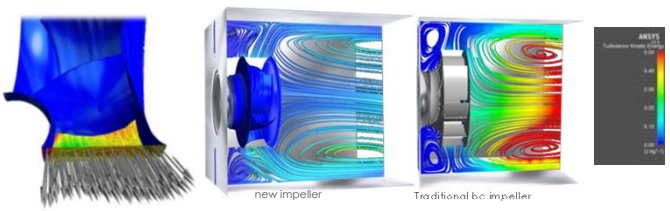
Optimized Fan Geometry

Angular discharge

- Flow-optimized blade design with improved velocity distribution at outlet
- Reduced impulse losses in installation situations
- Significantly reduced swirls behind the wheel for optimum airflow to the next components



new design traditional design



new impeller

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Advantages of Plenum Fans

- High system efficiency → Energy saving

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System Efficiency Comparison



Plenum fan
with direct drive



Backward curved
centrifugal fan
with belt drive



Forward curved
centrifugal fan
with belt drive

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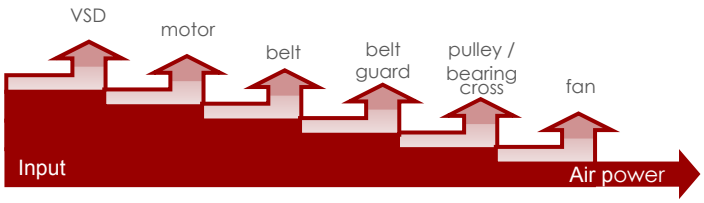
System Efficiency Comparison

Scroll fan - belt driven





$\eta_{sFSys} = \eta_{VFD} * \eta_{motor} * \eta_{belt} * \eta_{beltguard} * \eta_{pulley} * \eta_{fan}$



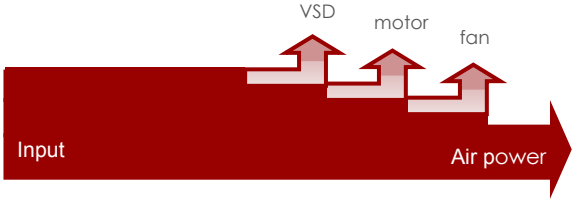
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System Efficiency Comparison

Plenum fan – direct driven



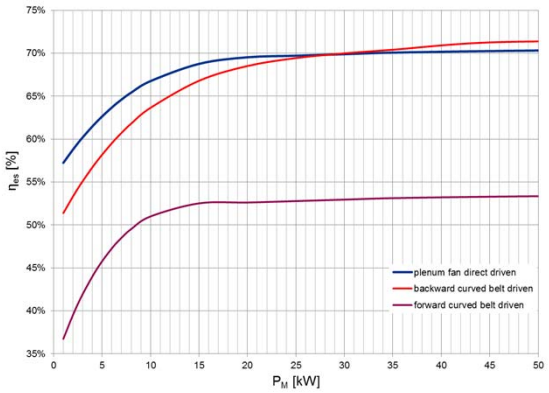
$\eta_{sFSys} = \eta_{VFD} * \eta_{motor} * \eta_{fan}$



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System Efficiency Comparison

Plenum fan direct drive vs. bc/fc scroll fan belt drive



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Advantages of Plenum Fans

- High system efficiency → Energy saving
- No belts and pulleys → Very low maintenance costs

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Belt Driven Fans – Maintenance

Many components to service

- Inspection of V-belt
- Maintenance of belt tension
  → often belt replacement!
- High loads on the motor bearings
  → shorter lifetime
- Further 2-4 components to servicing
- Additional filter
  → higher pressure drop







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Advantages of Plenum Fans

- High system efficiency → Energy saving
- No belts and pulleys → Very low maintenance costs
- Speed control by internal electronics or VFD → High potential to save energy

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Speed Control by Internal Electronics or VFD

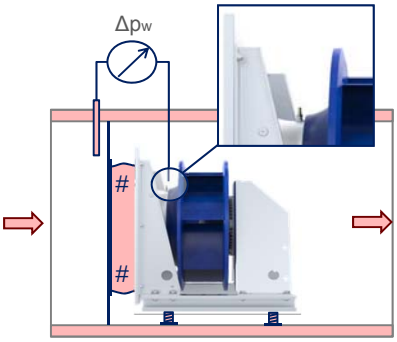
- Easy monitoring of fan operation
- Offers air performance flexibility
- Ability to maintain constant air flow despite filter contamination
- Simplified start-up
- Huge potential for energy saving
  → Shaft power changes proportionately by the 3rd power of the speed of fan



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Speed Control by Internal Electronics or VFD

Exact and simple determination of airflow by measuring device





0-10 V signal output

$q_V = k * \sqrt{\Delta p_W / \rho}$

k = inlet cone calibration factor
Δp_W = differential pressure across inlet cone
ρ = air density

- k-factor established experimentally by test
- accuracy 5-8%
- pressure tap on suction side should be placed 90° to air flow direction at area free of turbulences
- single pressure tap sufficient at unobstructed fan inlet

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Advantages of Plenum Fans

- High system efficiency → Energy saving
- No belts and pulleys → Very low maintenance costs
- Speed control by internal electronics or VFD → High potential to save money
- Smaller footprint → Saves space

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Space and Cost-saving Construction

Example: 60.000 m³/h @ 1500 Pa

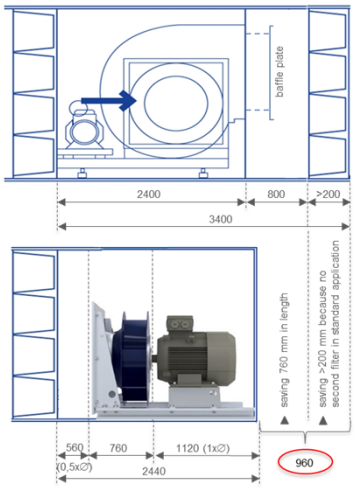
Double inlet bc centrifugal fan:

Size 1000 mm / motor 37kW
→ Length 3400 mm

Plenum fan:

Size 1120 mm / motor 37kW
→ Length 2440 mm

→ **Saving 960 mm = 28% in length**



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Advantages of Plenum Fans

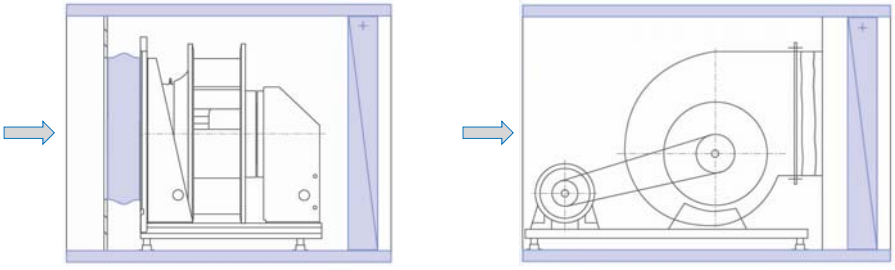
- High system efficiency → Energy saving
- No belts and pulleys → Very low maintenance costs
- Speed control by internal electronics or VFD → High potential to save money
- Smaller footprint → Saves space
- Ideal intake and discharge airflow conditions → Better usage of down streamed components

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Ideal Airflow Conditions

Inlet

- Favorable intake airflow conditions → reduced flow losses
- No pulley obstruction and belt guard equipment

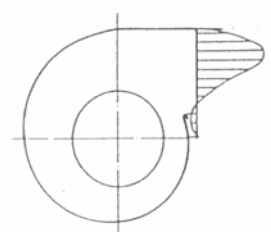


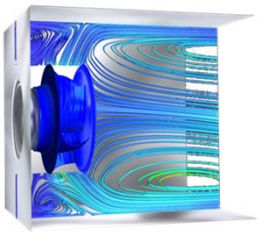
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Ideal Airflow Conditions

Outlet

- Versatility of discharge directions
- Uniform exhaust flow profile with plenum fans → no baffle plate needed
- Better approaching flow conditions for down streamed components





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Cons of Plenum Fans

- Limited static pressure
- Plenum needed to generate pressure
- Motor change requires disassembly of impeller
- VFD needed

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Installation Effects

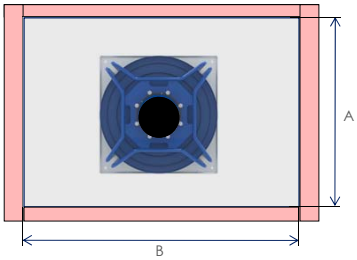
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Wall Distances

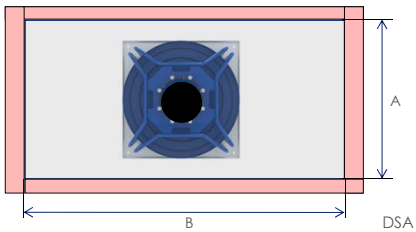
Housing wall distances

- Installation has an effect on air performance and sound of a fan

square cross section
A = B ≥ 1,8 x DSA



rectangular cross section
$\frac{A + B}{2} \geq 1{,}8 \times DSA$



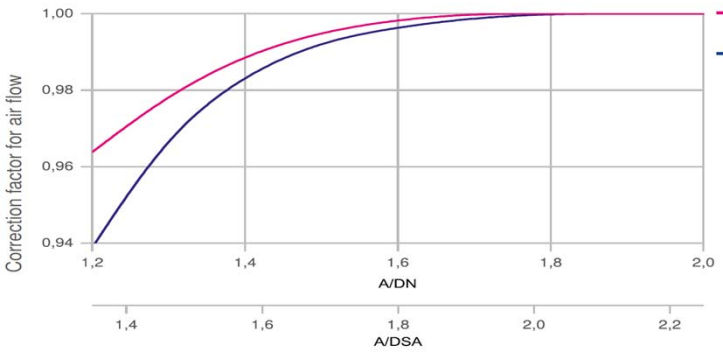
DSA = blade diameter

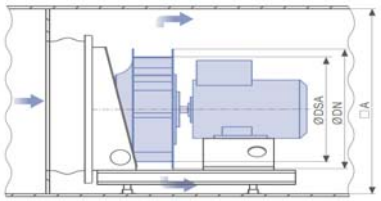
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Wall Distances

Housing wall distances

- Installation has an effect on air performance and sound of a fan





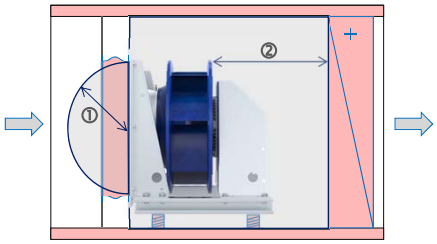
DSA = blade diameter
DN = outer diameter diffusor

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Straight Airflow Direction

Distance to components in front of and behind the fan

- The performance depends on distance to components
- Suction side ① ≥ 0.5 x DSA
- Pressure side ② ≥ 1.0 x DSA, abs. minimum ② ≥ 0.7 x DSA (exemption: cooling coil or humidifier behind the fan)

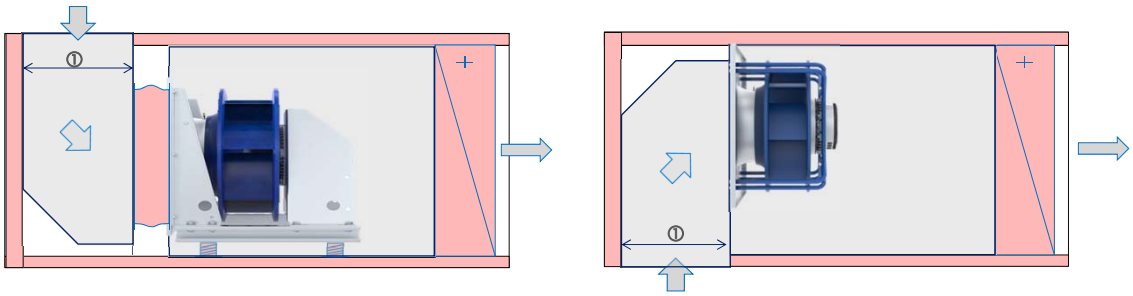


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Change of Airflow Direction at Intake

Distance to components in front of and behind the fan

- A change of air stream direction in front of the fan can create massive turbulences, it can reduce the air flow performance
- Suction side ① ≥ 1.0 x DSA, with guide vanes it can be reduced to ① 0.7 x DSA, otherwise increased sound and drop of performance

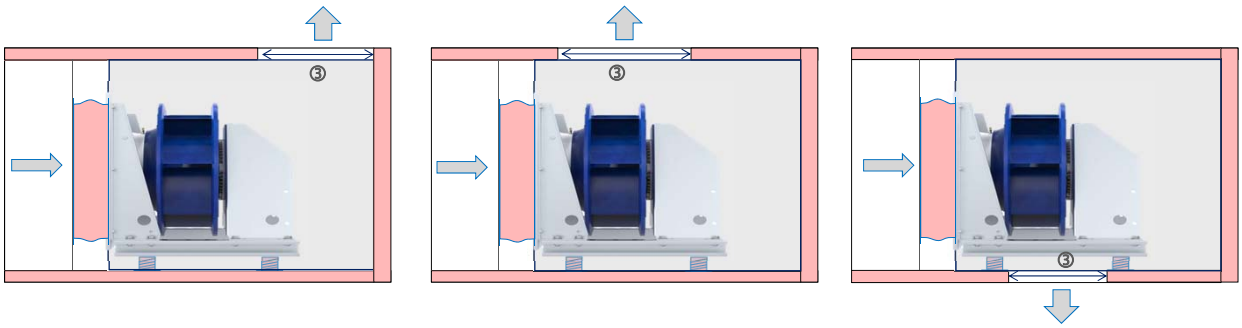


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Change of Airflow Direction at Discharge

Distance to components and dimension of exhaust

- The opening can be above or underneath the fan and should be ③ ≥ 0,8 x DSA
- Opening should be across entire width of unit

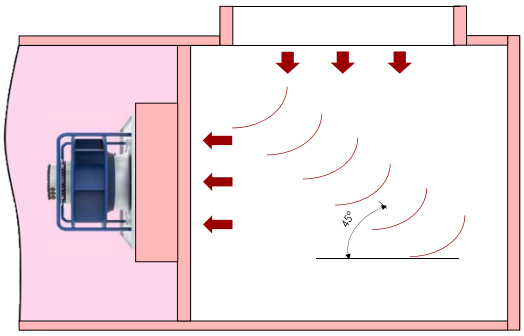


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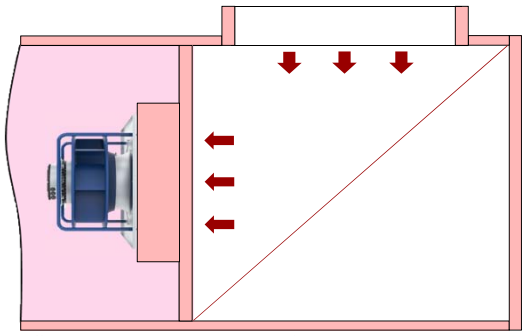
Inlet Conditions | Optimization Potential

Installation with 90° change of direction before the intake

- Additional baffle plates must be fitted in the suction chamber



Baffle plates as quadrants

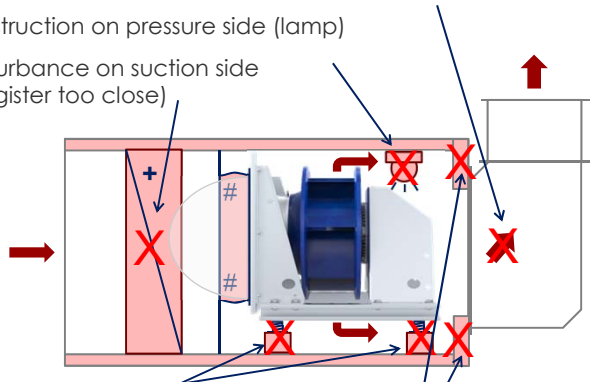


Baffle plate as a sheet metal mounted in an angle

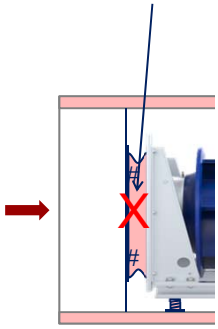
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Failures at Installation

- 90° change of airflow direction with reduction of cross section
- Obstruction on pressure side (lamp)
- Disturbance on suction side (Register too close)



- Obstruction on suction side (compressed flexible connector)



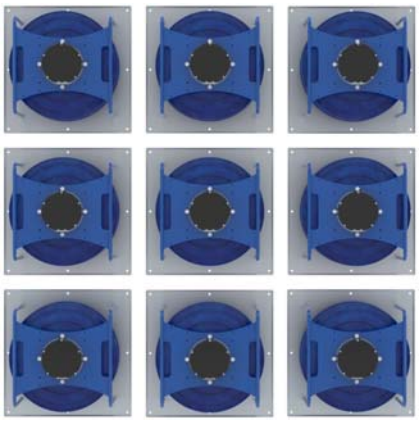
- Obstruction on pressure side (high rails)
- Contraction at device exhaust/connection

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Multiple Fan System

Multiple Fan System | Benefits

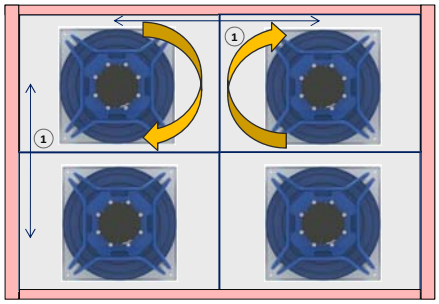
- Redundancy – more operational reliability
- Easy service/replacement
- Simplified handling
- Reduced cost for operation
- Shorter HVAC unit (fan, distances, silencer, costs)
- Less space required
- Ideal for retrofit

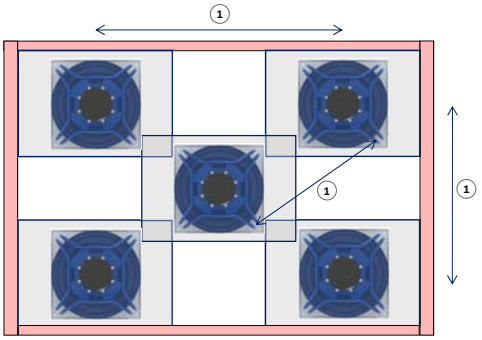


Multiple Fan System | Mounting Recommendations

Multi-Fan Arrangement

- Distance between fan axis / Diagonal distance ① ≥ 1,8 x DSA without separation plate



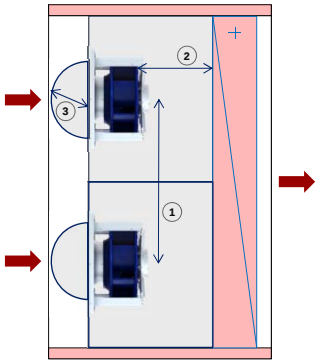


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Multiple Fan System | Mounting Recommendations

Installation inside AHU

- Distances to other components



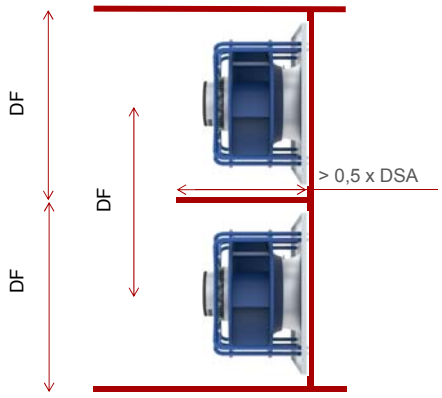
① ≥ 1.8 x DSA
② ≥ 1.0 x DSA
③ ≥ 0.5 x DSA

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Multiple Fan System | Mounting Recommendations

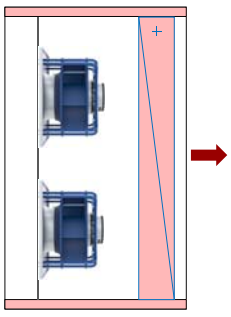
Distance between centre of fan DF (times the impeller diameter DSA)

- DF > 1,8 x DSA
  - no sensible influence on suction and pressure side
- DF = 1,8 – 1,6 x DSA
  - no influence on suction side, a separation wall reduces the acoustics on pressure side (compared without separation wall)
- DF = 1,6 – 1,4 x DSA
  - little influence on suction side, on pressure side a separation wall is necessary to optimize the air flow and acoustics
- DF < 1,4 x DSA
  - significant influence, no practical design

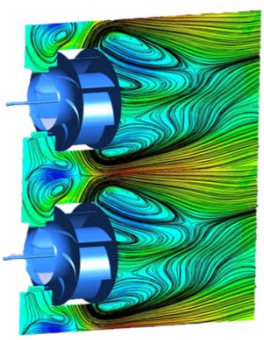


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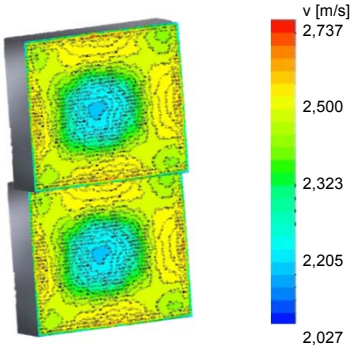
Multiple Fan System | Mounting Recommendations



1x DSA behind the fans



1x DSA behind the next component (coil)



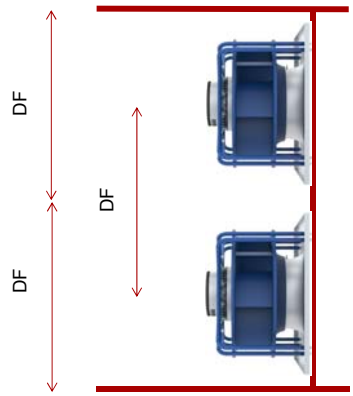
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Multiple Fan System | Challenge

Distance < 1,6 x DSA

Short Distances without separation plate can cause:

- influence (shock impulse)
- vibration
- increase of tonal noise



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Multiple Fan System | Solution

Distance < 1,6 x DSA

Improvements:

- cube around fan
- higher efficiency
- better acoustic
- reliable data

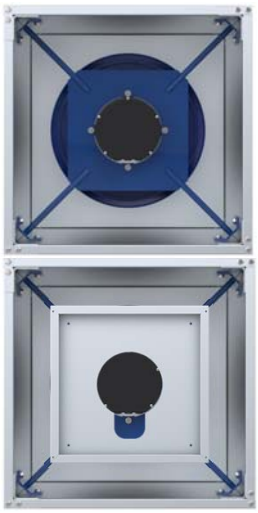


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Cube with Optimizer

Functionality

- Considerable improvement of product performance
  - more air performance
  - higher efficiency
  - reduced noise
- Reason: Prevention of backstream

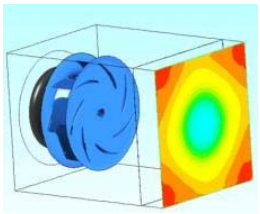


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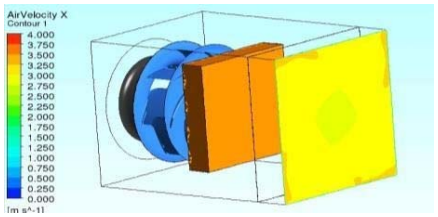
Cube with Optimizer

Flow Pattern

Without Optimizer



With Optimizer



Heavy improved flow pattern at exhaust

- Considerable lower deviation of air velocity
- Uniform inflow for downstream component
  → Reduced distance possible

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Multiple Fan System | Failure of a Fan

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Multiple Fan System | Failure of a Fan

Example of a multiple fan system with 4 fans

- Duty point
  - 14410 m³/h @ 1190 Pa
  - approx. 3600 m³/h per fan
  - 2785 rpm
- All fans are running at the same speed

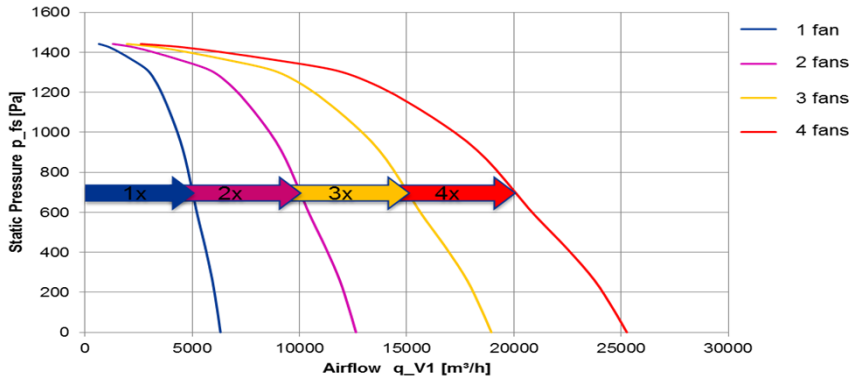


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Multiple Fan System | Failure of a Fan

Operation of 4 fans

- Parallel operation of fans is an addition of airflow, static pressure would be constant
- Duty point of single fan multiplied with number of fans [$q_{V1\ all} = n \times q_{V1\ single}$]

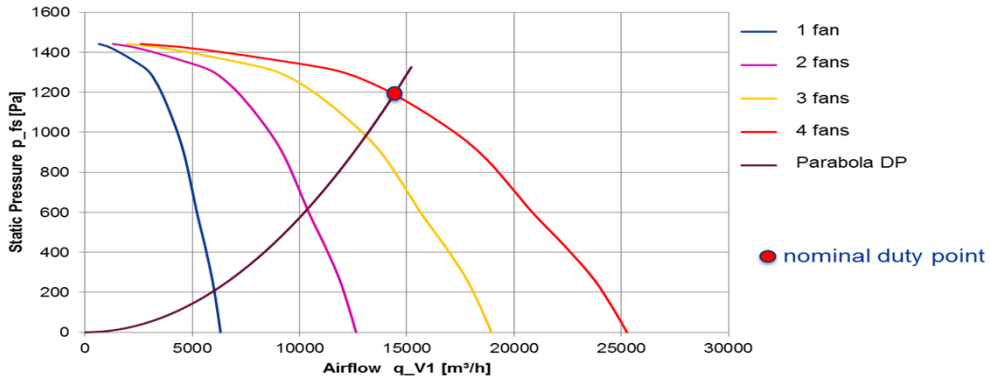


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Multiple Fan System | Failure of a Fan

All Fans running

- Duty point 14410 m³/h @ 1190 Pa at 2785 rpm under normal conditions

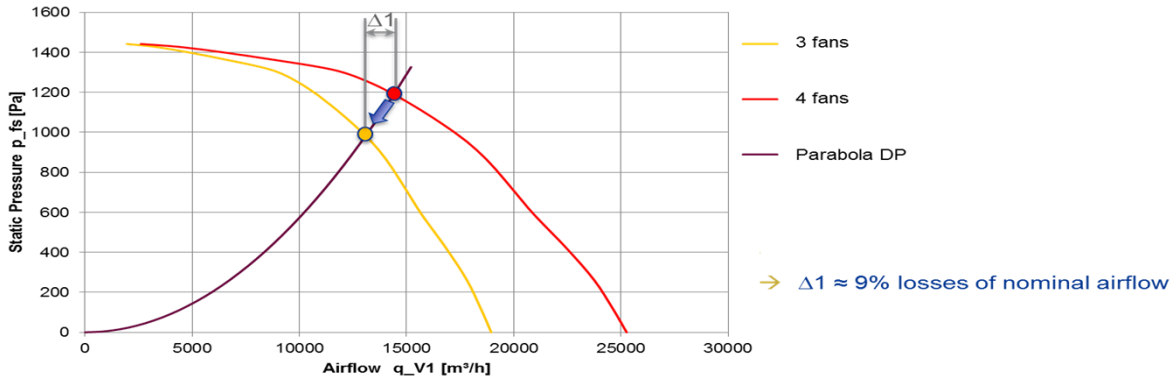


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Multiple Fan System | Failure of a Fan

1 fan failed (closed nozzle)

- Duty point follows the parabola towards the curve of 3 fans (n-1)



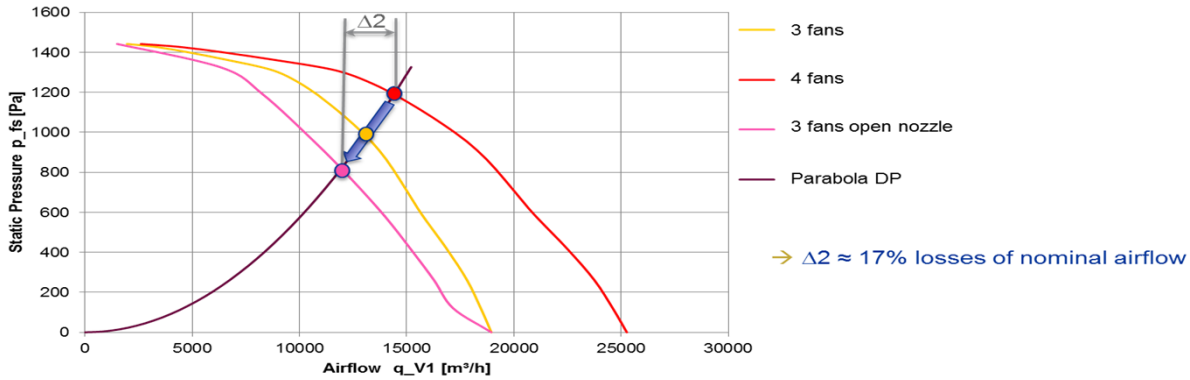
→ Δ1 ≈ 9% losses of nominal airflow

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Multiple Fan System | Failure of a Fan

1 fan failed (open nozzle)

- Duty point follows parabola below the fan curve of 3 fans due to additional losses through open nozzle



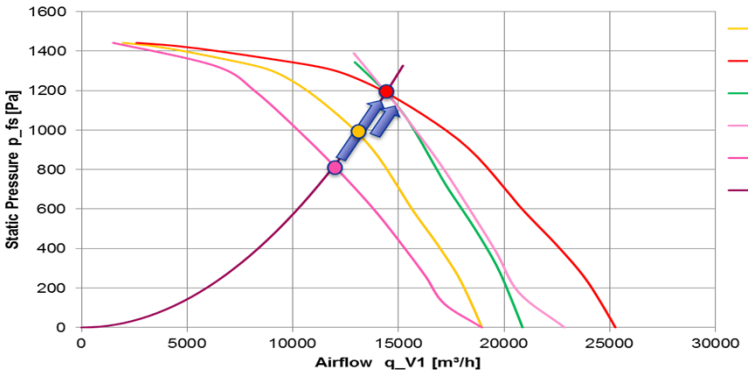
→ Δ2 ≈ 17% losses of nominal airflow

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Multiple Fan System | Failure of a Fan

1 fan failed (open nozzle)

- For compensation of the losses these 3 running fans have to increase the speed



- Back to the nominal duty point
- Power +28,4% with open nozzle

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Multiple Fan System | Failure of a Fan

Measurement Results

- To achieve the nominal duty point, with closed nozzle 10%, with open nozzle 20% more speed required

	Situation	Airflow q_V1_sum [m³/h]	Pressure p_fs [Pa]	Speed n [rpm]	Sys. Power P_ed [W]
	Nominal duty point 4 fans running	14410	1190	2783	7906

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Multiple Fan System | Failure of a Fan

Important for full redundancy

- Recommendation
  - Selection at optimum efficiency and good acoustic
  - With more fans there is higher chance to select fan close to peak efficiency
  - Safety margin at selection for full redundancy is lower with increased number of fans



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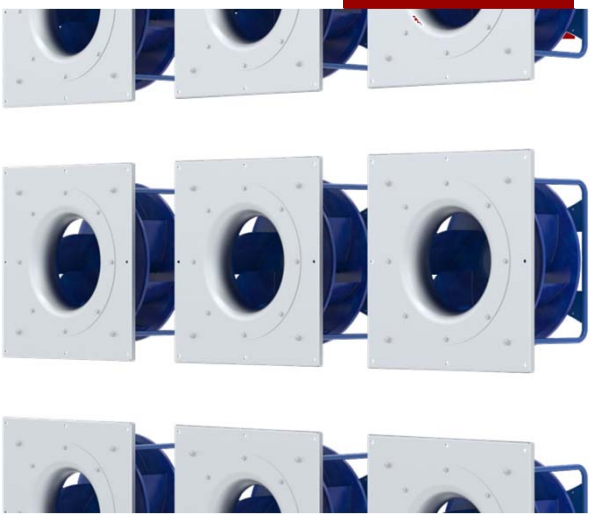
Airflow measurement

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Multiple Fan System | Airflow Measurement

Basics

- Physical basics
  - Airflow of single fan multiplied with number of fans
  - Static pressure of a single fan analog for all fans
- For airflow measurement
  - Based on differential static pressure measurement
  - Measurement of one fan analogues result for each fan of the multiple fan system

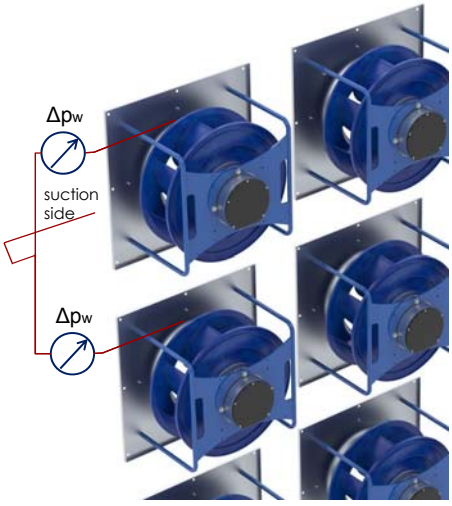


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Multiple Fan System | Airflow Measurement

Possibilities for airflow measurement

- 1 fan as reference, result multiplied with number of fan ► simple solution
- 2 fans parallel measured with separate measurement unit, average multiplied ► if one of them fails, result for the other running fans still ensured
- All fans measured parallel with one measurement unit, multiplied ►good result (average of pressure)



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Thank you and see you again at ZIEHL-ABEGG