Base for Fan selection
Static/ Total Pressure

Static/ Total Pressure

1. Definitions

2. Calculation of the required fan pressure

3. Use of Diffusers

Nomenclature:

Fan data sheet

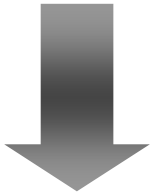
- Fan total pressure
- Fan static pressure
- Fan dynamic pressure (usually not directly shown)

Ventilation System

- System static pressure rise
- System total pressure rise
- System static pressure loss
- System dynamic pressure loss

Problem:

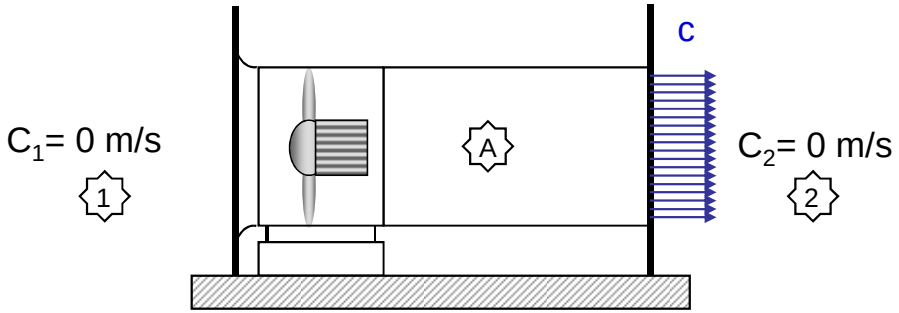
- Values depend on the fan /system arrangement!
- “fan” and “system” values differ from each other
- e.g. Fan static pressure not similar to static pressure rise in system



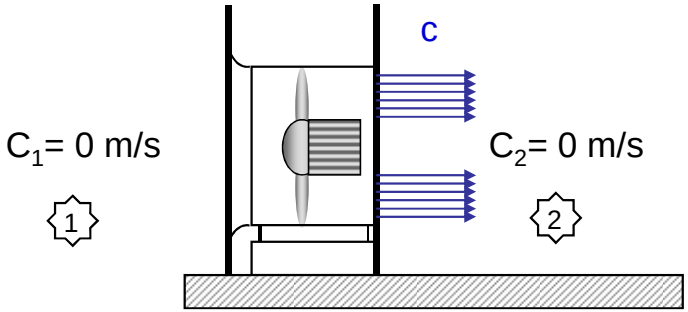
Confusion, wrong selections

Fan data sheet values

Outlet ducted



Free outlet



Base: No pressure losses in inlet and outlet

A Outlet tube to balance the air flow

$$p_{total} = p_{static} + p_{dynamic} \quad \text{with } p_{dynamic} = \frac{\rho}{2} \cdot c^2$$

$$p_{static} = p_{static2} - p_{static1}$$

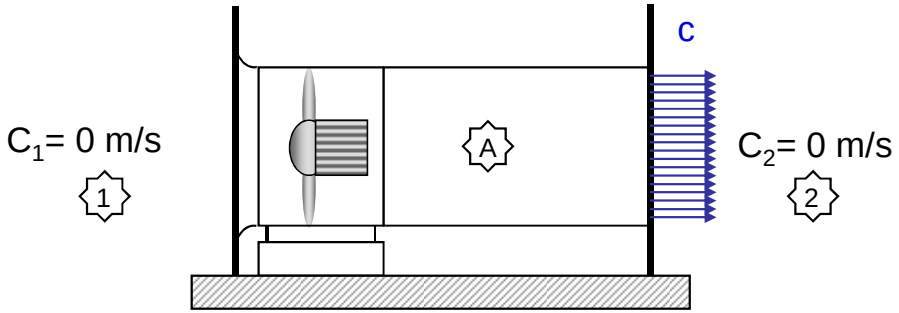
$$P_{shaft} = p_{total} \cdot \frac{Q}{\eta_{fan}} \quad \text{with } Q = A \cdot c$$

Attention:

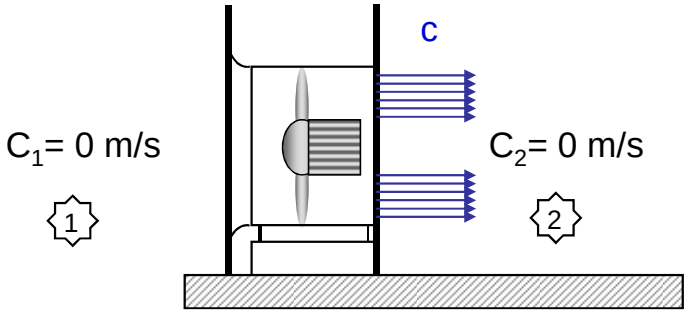
- Total pressure for outlet ducted is different than free outlet, the outlet tube is decreasing the total pressure
- Dynamic pressure for free outlet is higher than for outlet ducted, because the cross section is reduced

Fan data sheet values

Outlet ducted



Free outlet

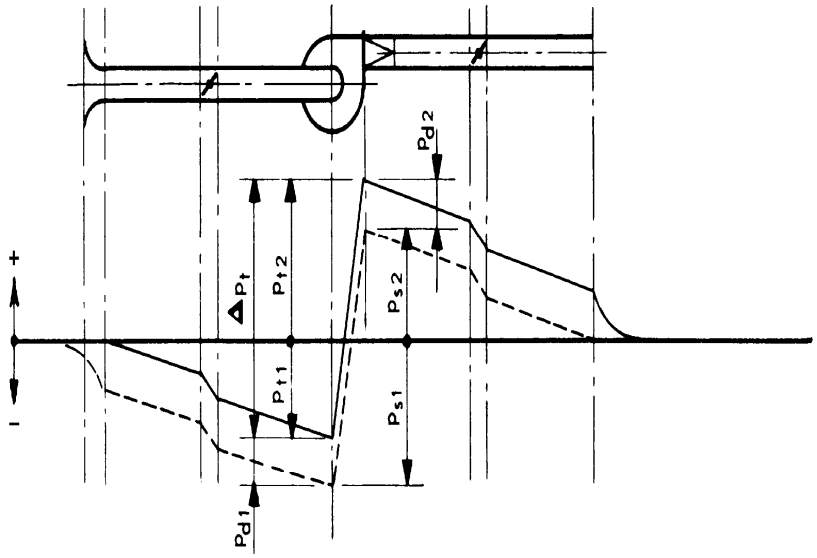


Base: No pressure losses in inlet and outlet

These are standard conditions but the real system is mostly different

Ventilation system values

Ducted in- and outlet



$$\Delta p_{total\ system} = \Delta p_{static\ system} = p_{total\ fan}$$

$$\Delta p_{static\ system} \neq p_{static\ fan}!!$$

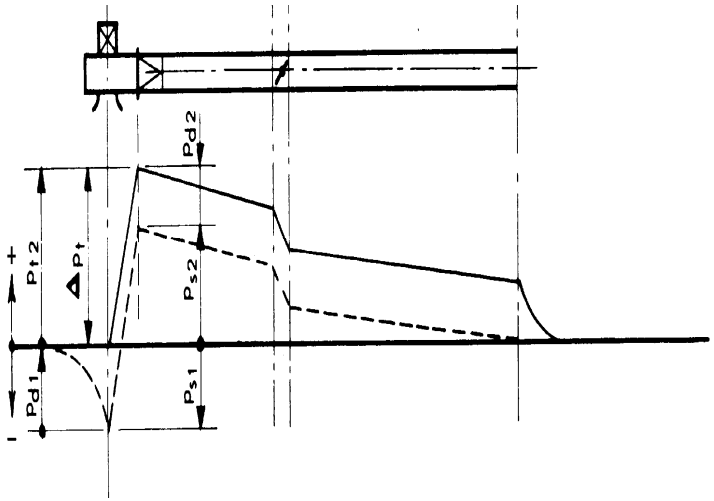
The static pressure rise in a ducted in- and outlet system is given by the fan total pressure

Selection of the fan with curves for outlet ducted arrangement

Base: Same cross section at inlet and outlet

Ventilation system values

Free inlet, ducted outlet



$\Delta p_{total\ system} = \Delta p_{static\ system} = p_{total\ fan}$

$\Delta p_{static\ system} \neq p_{static\ fan}$!!

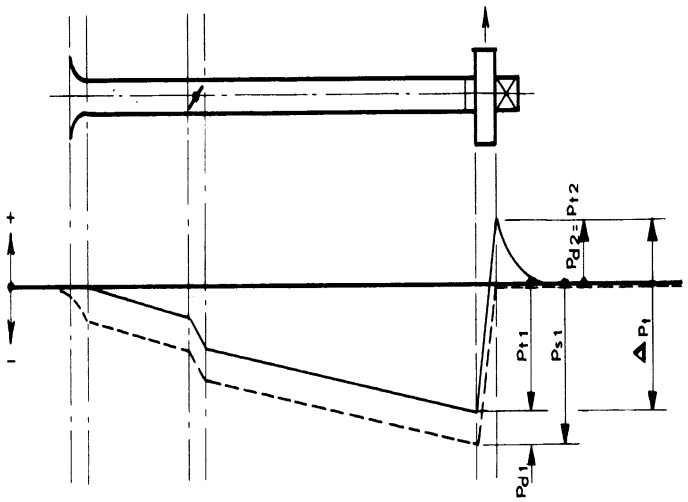
The static pressure rise in a free inlet and ducted outlet system is given by the fan total pressure

Selection of the fan with curves for outlet ducted arrangement

Base: Same cross section at inlet and outlet

Ventilation system values

Ducted inlet, free outlet



$\Delta p_{total\ system} = \Delta p_{static\ system} = p_{total\ fan}$

$\Delta p_{static\ system} \neq p_{static\ fan}$!!

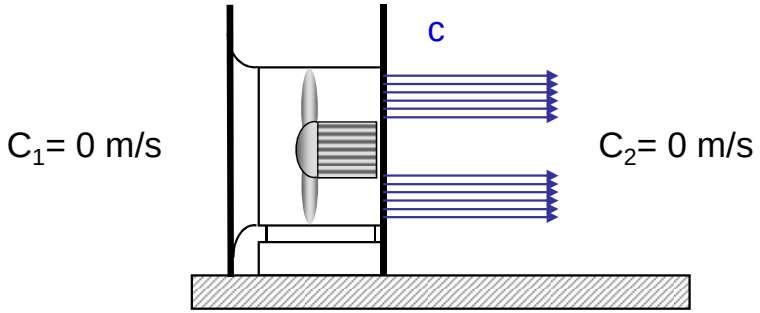
The static pressure rise in a ducted inlet system is given by the fan total pressure

Selection of the fan with curves for free outlet arrangement

Base: Same cross section at inlet and outlet

Ventilation system values

Free inlet, free outlet



$$\Delta p_{static\ system} = p_{static\ fan}!!$$

This is the only case, where the static pressure rise in the system is given by the fan static pressure.

Selection of the fan with curves for free outlet arrangement

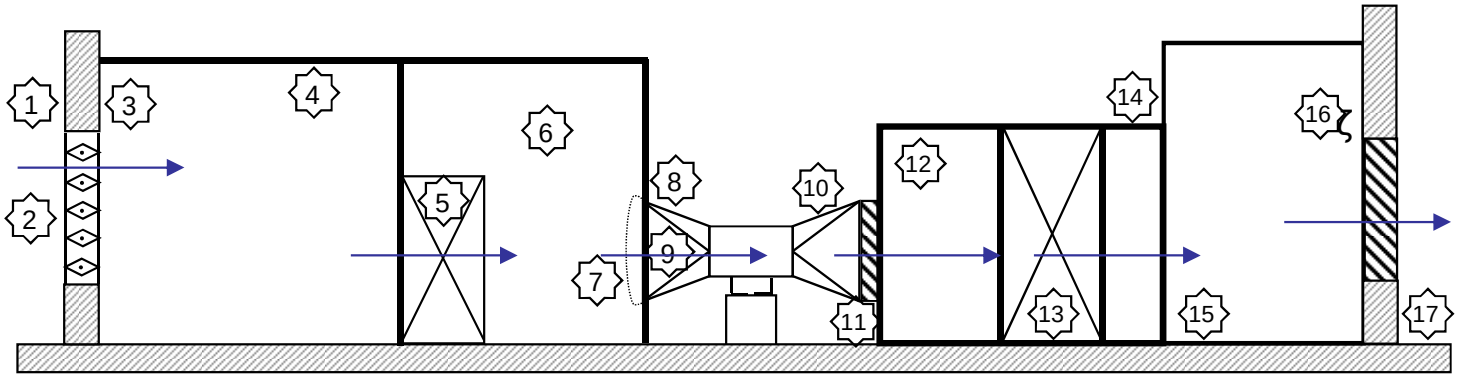
Static/ Total Pressure

1. Definitions

2. Calculation of the required fan pressure

3. Use of Diffusers

Calculation of the required fan pressure



System elements

1 inlet from tunnel

2 inlet damper

3 extension of cross section behind the damper

4 wall friction

5 silencers

6 velocity loss behind silencer

7 protection grill

8 inlet diffuser

9 diffuser inlet

10 diffuser outlet

11 fan isolation damper

12 velocity loss behind damper

13 silencer

14 velocity behind silencer

15 extension of cross section, velocity loss

16 weather protection grill

17 outlet to ambient

Fan has to generate enough pressure to overcome the looses of all elements. There're two types of losses:

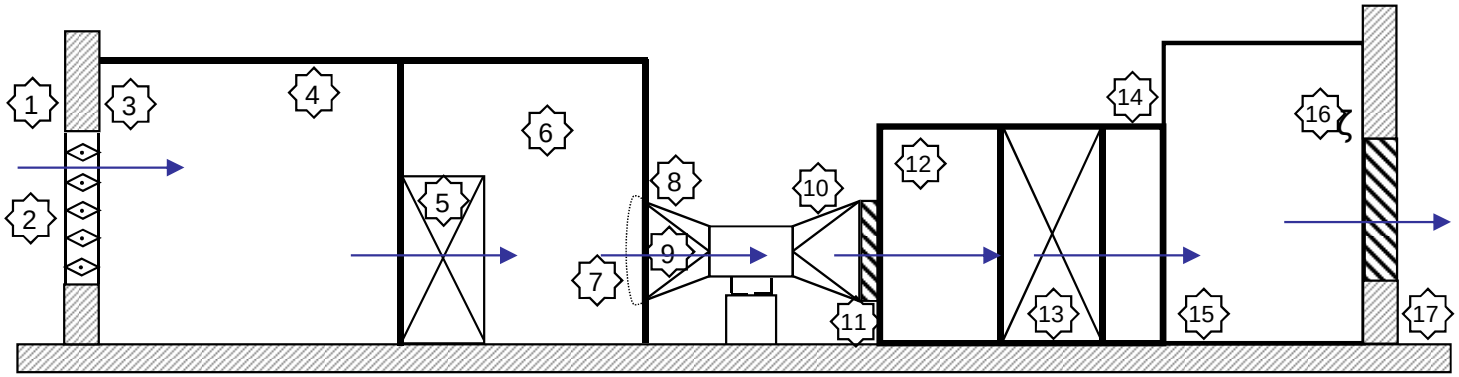
- Stactic pressure loss by obstacles as grills, dampers
- Dynamic pressure loss by deceleration of the air flow

Calculation is done in the same manner

$$p_{i\ loss} = p_{l\ dyn} \times \zeta_i$$

$$\mathbf{p_{l\ dyn} = 0{,}5 \times \rho \times c_i^2}$$

Calculation of the required fan pressure



If all the losses for all elements are calculated,
the required fan pressure will be:

$$p_{fan\ required} = \sum_{i=1}^{17} pi_{\ loss}$$

$p_{fan\ required} = p_{total\ fan}$!

Fan would be selected for total pressure with curves for ducted outled arrangement

System elements

1 inlet from tunnel

2 inlet damper

3 extension of cross section behind the damper

4 wall friction

5 silencers

6 velocity loss behind silencer

7 protection grill

8 inlet diffuser

9 diffuser inlet

10 diffuser outlet

11 fan isolation damper

12 velocity loss behind damper

13 silencer

14 velocity behind silencer

15 extension of cross section, velocity loss

16 weather protection grill

17 outlet to ambient

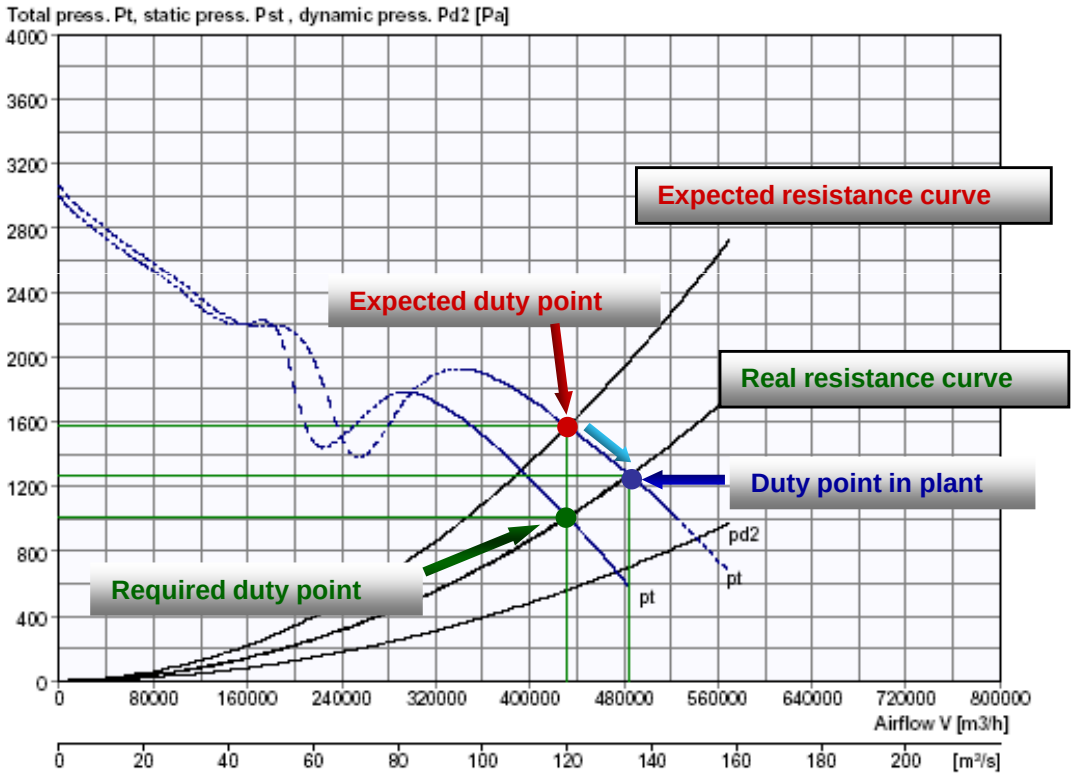
Calculation of the required fan pressure

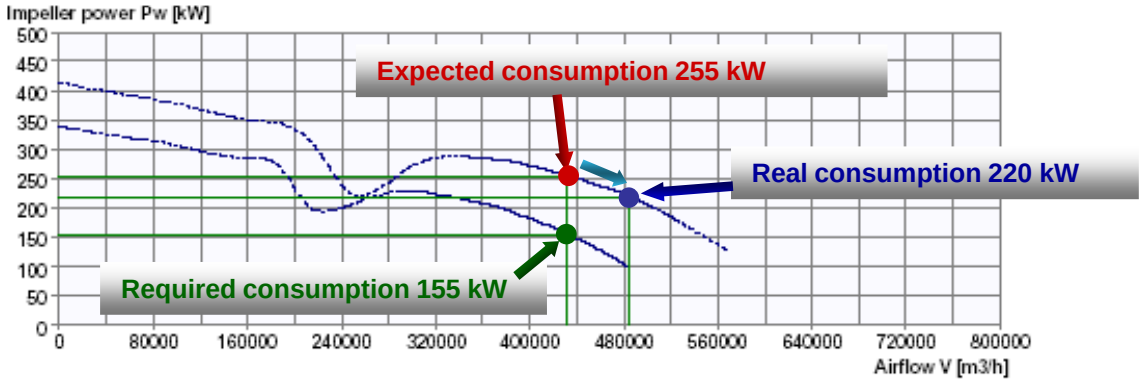
If Selection is done for “static pressure” instead of “total pressure”

Consequences:

- Oversized fans
- Oversized electrical system
- Waste of investment costs

- Fans would not be designed for the correct duty point
- Optimum efficiency at real duty point not assured,
- Waste of energy and operational costs





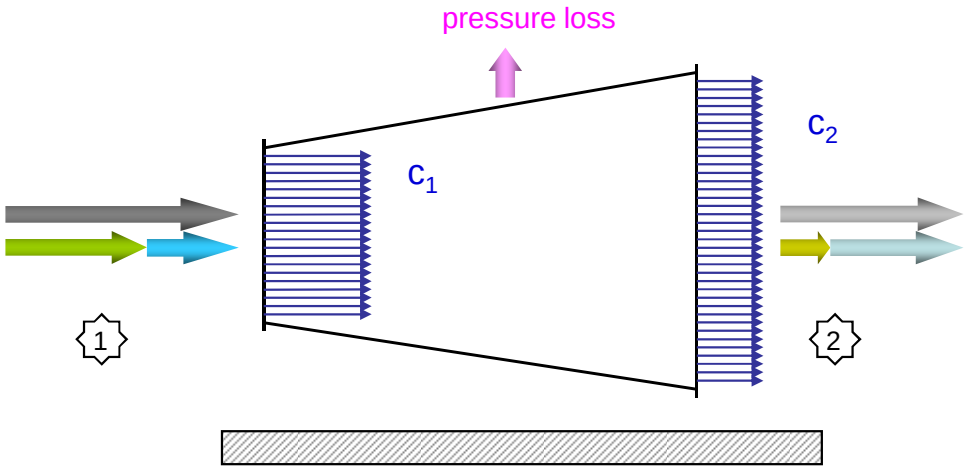
Static/ Total Pressure

1. Definitions

2. Calculation of the required fan pressure

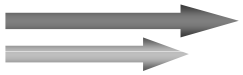
3. Use of Diffusers

Diffusers convert dynamic pressure to static pressure

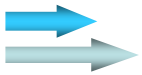


Diffusers are the most efficient way to decelerate air flow, but there'll always be a pressure loss depending on the diffuser design and the inlet conditions

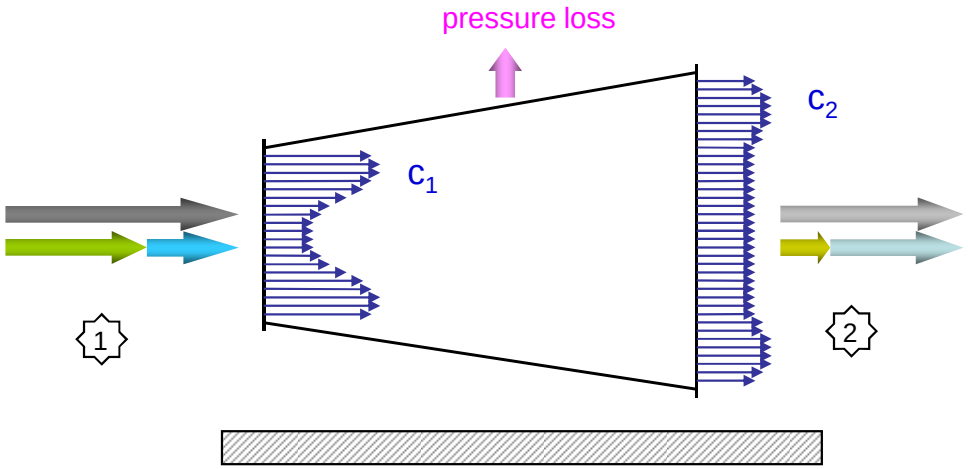
Consequences of the diffuser


Reduction of total pressure


Reduction of dynamic pressure

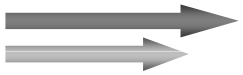

Increase of static pressure

Diffusers characteristics downstream of a fan



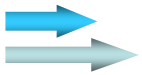
Downstream of a fan the velocities are not uniform. Standard literature to calculate the diffuser efficiency is not 100% accurate.

Consequences of the diffuser



Reduction of total pressure

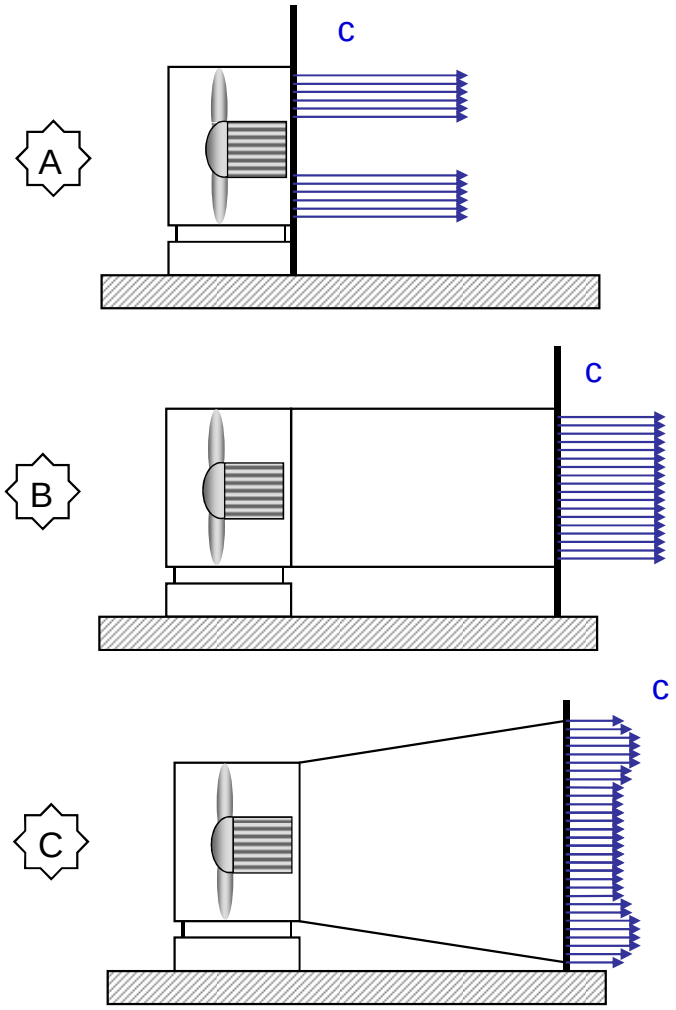
Reduction of dynamic pressure



Increase of static pressure

***WITT & SOHN* conducted tests to detect the performance curves of fan/diffuser units. Separate calculations of diffusers are not required!**

Case study, fan selection for static pressure



A: fan free outlet

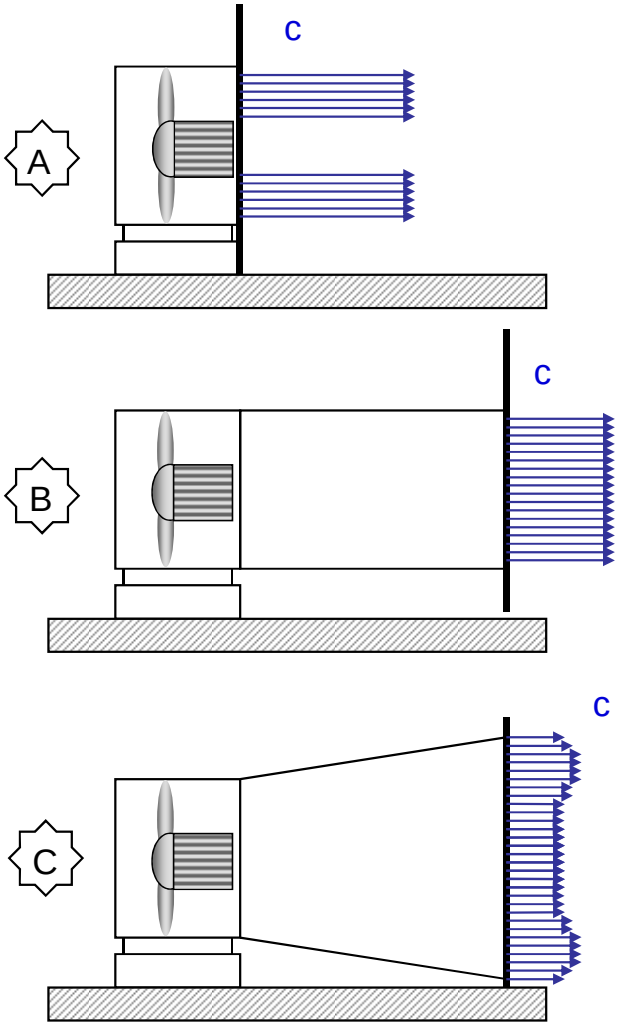
B: fan outlet ducted

C: fan with diffuser

- Maintain a diffuser angle of max. 7° to obtain optimum diffuser efficiency
- For reversible fans use always diffusers on both sides (otherwise stall operation in reverse!)

Case study, fan selection for static pressure

	Dimensions		Performance				
No. [1]	Size of impeller **(inlet)** [mm]	Size of diffuser/duct **(oulet)** [mm]	Q [m³/s]	Dp_{tot} [Pa]	Dp_{dyn} [Pa]	**Dp_{st}** [Pa]	P_{shaft} [kW]
A	**2000**		65	1201	401	**800**	118
B1	**2000**	**2000**	65	1057	257	**800**	97
B2	**1800**	**1800**	65	1192	392	**800**	108
C	**1800**	**2000**	65	1057	257	**800**	94

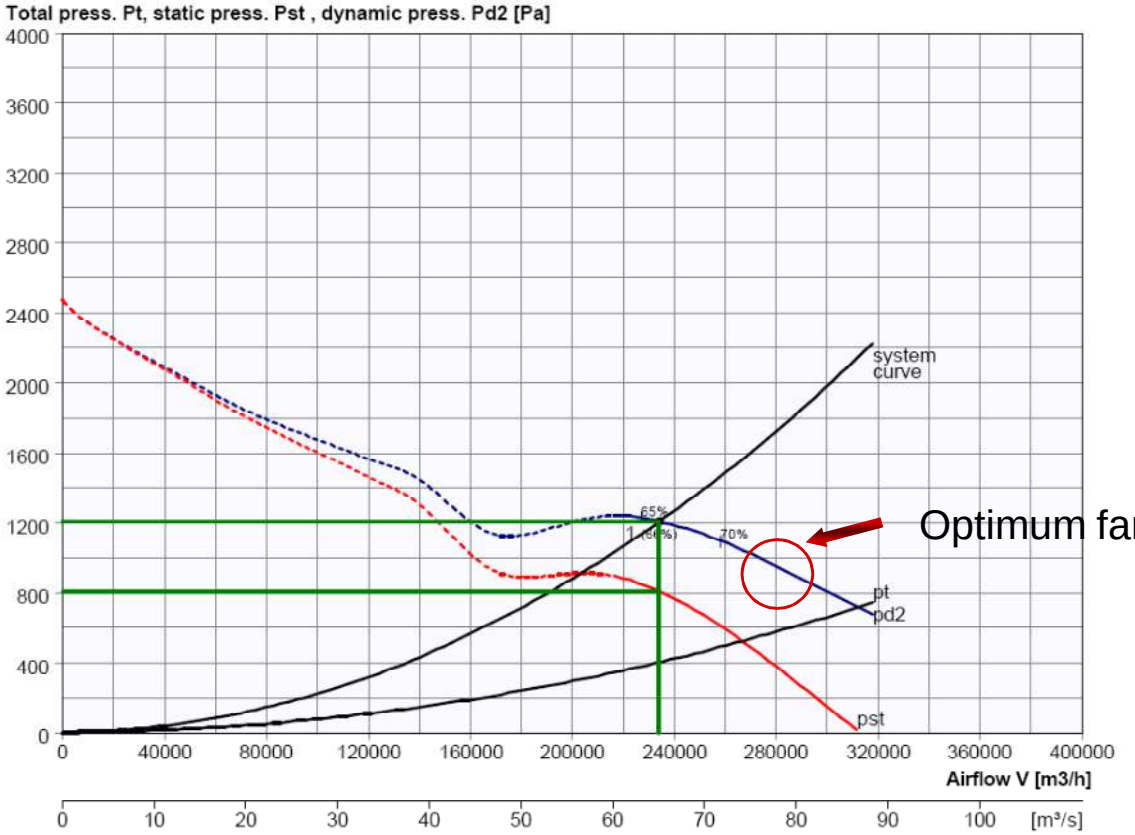


Optimum is solution C

- **low dynamic pressure,**
- **diffuser losses compensated, since fan is operated at optimum efficiency**

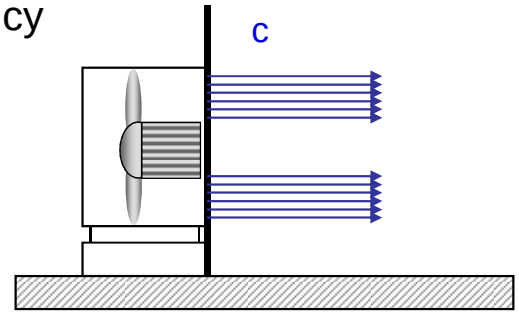
Case study, fan selection for static pressure

A: fan free outlet



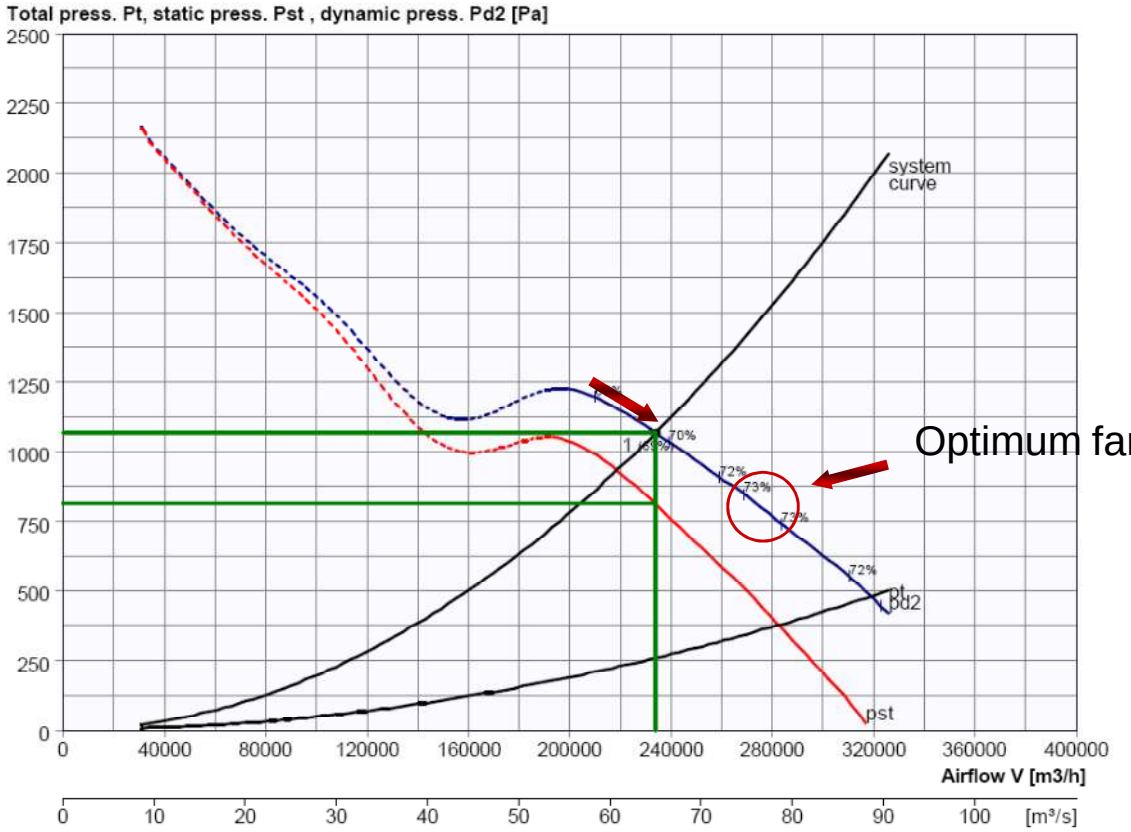
Operation point is very close to STALL. A smaller fan may help but as a consequence the air velocity, the pressure and the power consumption will increase.

Optimum fan efficiency



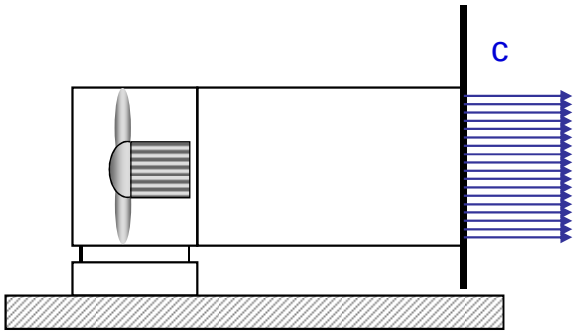
Case study, fan selection for static pressure

B: fan outlet ducted



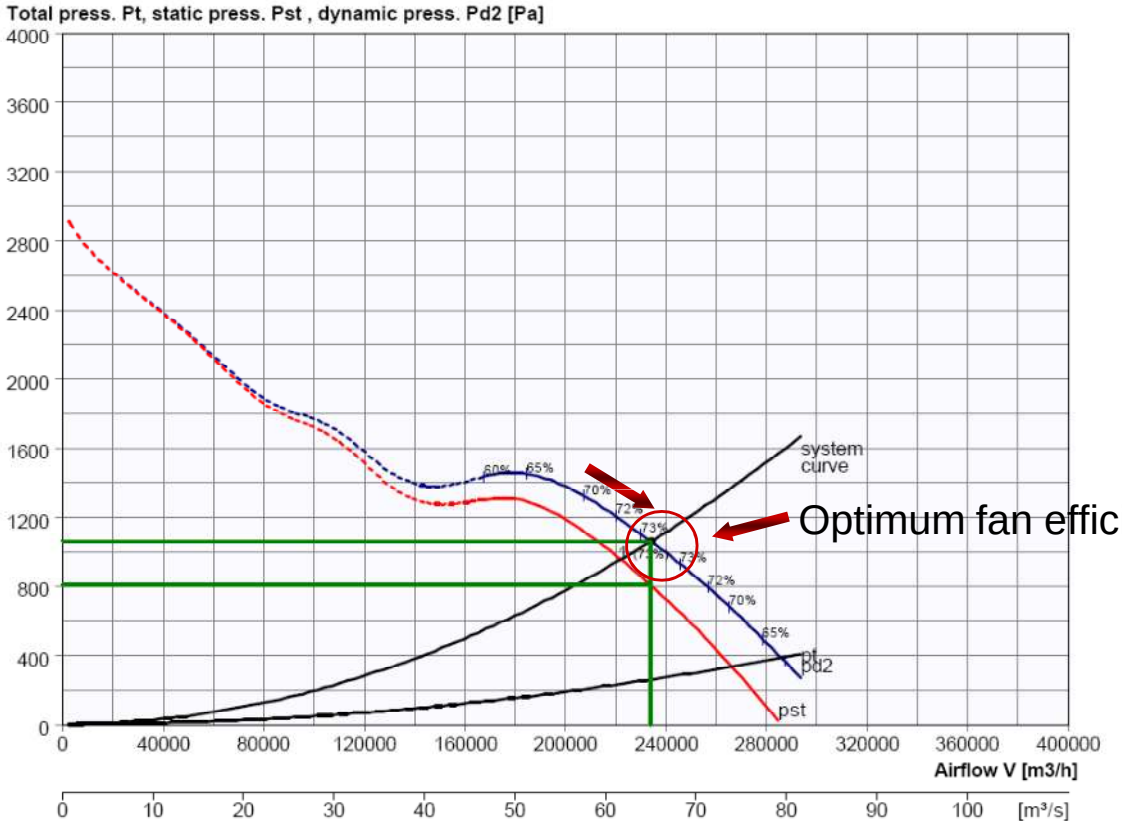
Optimum fan efficiency

Reduced total pressure distance to STALL enlarged but still not optimal. Fan is not operated at optimum efficiency



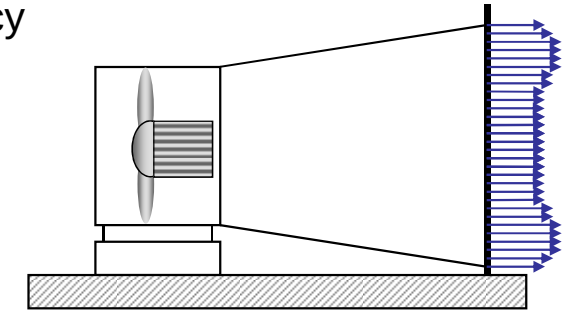
Case study, fan selection for static pressure

C: fan with diffuser



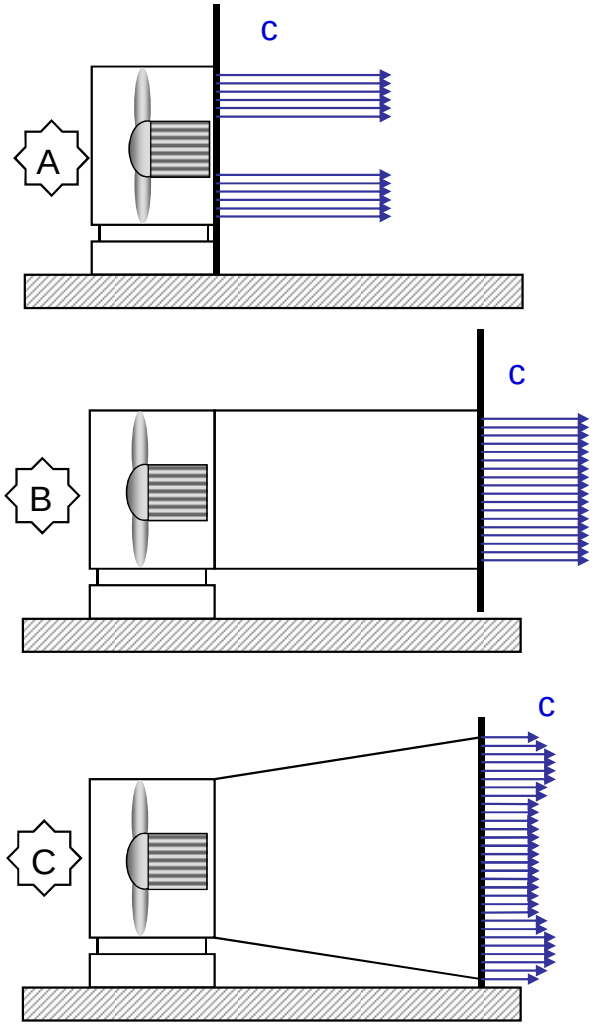
Large distance to STALL
Fan is operated at optimum efficiency

Recommended selection



Case study, final overview with cost

	Dimensions		Performance			Costs	
No.	Size of impeller [mm]	Size of diffuser / duct [mm]	Q [m³/s]	Dp_{st} [Pa]	P_{shaft} [kW]	Investment	Operation
A	**2000**		65	800	118	100,0%	121,6%
B1	**2000**	**2000**	65	800	97	100,0%	100,0%
B2	**1800**	**1800**	65	800	108	85,0%	111,3%
C	**1800**	**2000**	65	800	**94**	**85,0%**	**96,9%**



Optimum is solution C

- **Lowest investment and operation costs**
- **Best aerodynamic characteristics**

Summary

- Take care of the definitions, Fan static pressure not similar to static pressure rise in system
- **If pressure losses for all elements have been calculated, the fan selection has to be for total pressure**
- **Clients are often asking for fan static pressure although they require fan total pressure, there's a large potential to reduce costs**
- If fans have to be selected for fan static pressure **(mostly not needed!),** diffusers would reduce the fans cost (by reducing the fan size)
- The use of diffusers would reduce the risk of STALL
- Diffuser have to be designed correctly, max. angles have to be respected