TUNNELING VENTILATION

SWEDFAN - Experienced Underground Ventilation Specialists

SWEDFAN
Underground Ventilation System

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Complete Ventilation Systems

1 VENTILATION SYSTEM DESIGN

SWEDFAN design the entire ventilation system. Professional ventilation system design results in sufficient airflow for efficient tunneling and lowest possible number of installed fans. This means lowest possible investment and energy cost, generating the lowest total cost for the entire ventilation during the project.

2 HIGH PRESSURE FANS

SWEDFAN tunneling and mining fans are designed to reach highest possible pressure capacity which means airflow will be delivered at the tunneling face even though the ventilation distance is very long or the duct is installed in a very un-straight way.

3 FLEXIBLE DUCTING

SWEDFAN Flexible Ducting is manufactured inhouse from PVC-coated polyester fabric and is distinguished by the relatively low weight with kept high strength values which results in a very pliabel and easy to handle duct.

The importance of System Design

Energy costs for running the Ventilation System usually excced the investment cost of the entire Ventilation System.

WRONG VENT SYSTEM DESIGN

– WHAT ARE THE EFFECTS?

1

WRONG CHOICE OF AIR FLOW

Too low airflow leads to longer time to ventilate the blasting fumes which leads to slower tunneling speed. If the airflow is higher than required, this leads to higher investment costs of fans and higher running costs.

2

WRONG DUCT DIAMETER

The duct diameter determine the air flow velocity and the pressure inside the duct. The duct pressure determines the number of fans and/or kW rating of the fans, and the power load of the fans. The power load is directly proportional to the power costs to run the fans.

3

WRONG FAN

The fan should be chosen to meet the capacity according to the calculated duct pressure and airflow. Too low airflow means no efficient tunneling which results in lower profit for the project. Too high airflow cause higher duct pressure which increase the energy costs.

4

DUCT LEAKAGE

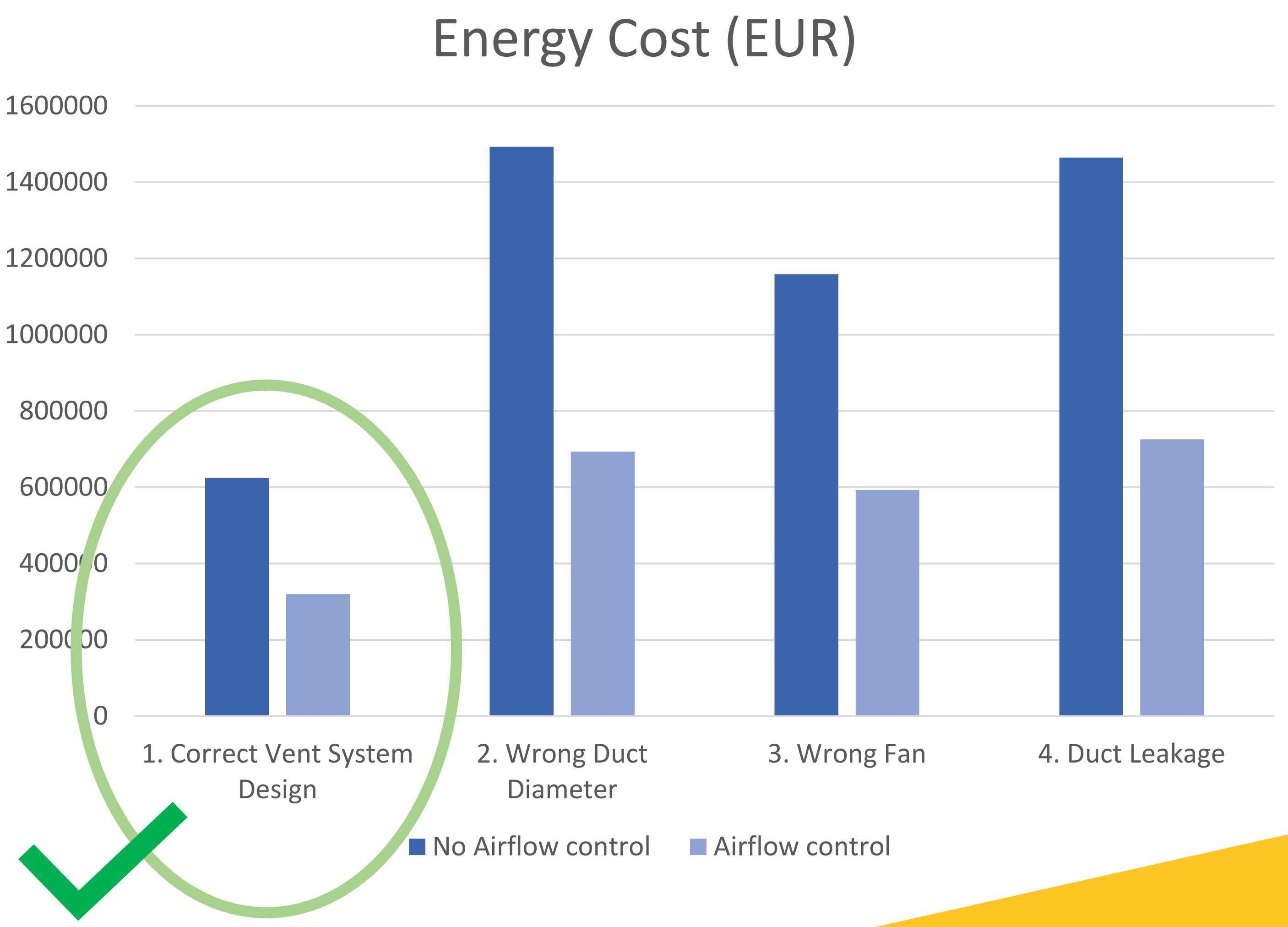
When calculating the required airflow delivered by the portal fan station in relation to the required airflow delivered to the tunneling front, a duct leakage must always be assumed. The leakage depends on how well the joints of each duct section are designed, the duct quality and how well damages are repaired.

5

NO AIRFLOW CONTROL

Normally, max airflow is required when ventilating the fumes after blasting and when mucking is executed. A reduced airflow can normally be accepted during works such as drilling, scaling, charging. With frequency inverters, a great energy cost saving is possible if the fan speed/airflow is controlled and regulated depending on what tunneling works are carried out.

Correct Vent System Design vs. common mistakes



1. Wrong choice of airflow

Airflow

If the airflow is too low, the effects are obvious: longer time to ventilate the blasting fumes which leads to slower tunneling speed. When diesel vehicles are used for mucking, with too low airflow the levels of toxic gases such as CO and NOX will exceed the limits and tunneling can not proceed as planned. At the end, this leads to reduced project profit or profit loss. If the airflow is chosen to be higher than required, this of course leads to higher investment costs of fans and higher running costs.

Example

To show what can go wrong, we take use of an “example tunnel” which we calculate with following data:

- Tunneling length 3.500 m (from the inlet portal to the outlet portal)
- Tunnel cross section area 70 m2
- Tunneling method drill & blast
- Total utilized diesel power of trucks and loader operating inside tunnel during mucking 1.200 kW
- Altitude of tunnel portal 200 m above sea level
- Lowest outside temperature +5 degree C
- Total time for excavation 20.000 hours (3 years)
- Cost of electric power 0,2 EUR/kWh

2. Wrong Duct Diameter

The diameter of the duct will determine what velocity the air inside the duct will flow at. The static duct pressure is in relation to the velocity in square which means higher velocity will have a great impact on the duct pressure. (Ex. Doubled air velocity cause 4 times higher duct pressure). The duct pressure determines the number and/or kW rating of the required fan(s) and the power load of the fans. The power load is directly proportional to the power costs to run the fan(s).

To the right, two alternative calculations are presented. One with the original duct diameter 2.200 mm, one with duct diameter 1.800 mm.

1. With dia 2.200 mm duct, the required fan station would be composed of a dual fan station, 2x160 kW and max power load 260 kW. The energy cost to run this fan station during three years would be 624.000 EUR if no airflow control would be utilized, 320.000 EUR if airflow control is utilized.

2. With all the tunnel data, airflow and other data kept identical, with dia 1.800 mm duct, the required fan station would be composed of a triple fan station, 3x250 kW and max power load 622 kW. The energy cost to run this fan station during three years would be 1.493.000 EUR if no airflow control would be utilized, 693.000 EUR if airflow control is utilized.

In this case, choosing a dia 1.800 mm duct instead of dia 2.200 mm, would increase the running costs by <u>**869.000/373.000 EUR**</u> and investment cost of ventilation system increased by approximately <u>**60.000 EUR**</u>.

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Calculating a suitable fan station for an example tunnel

This calculation is valid for 3600 m ducting of diameter 2200mm, air flow at heading 35 m3/s, assumed leakage 1,5%/100 m ducting.

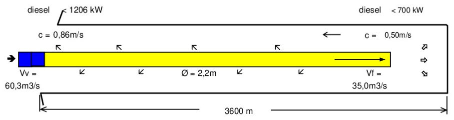
ORIGINAL - duct diameter 2.200 mm

Calculation ID:
Project:
Contractor:
Ref.:
Date: 2019-10-16

SITE:					
Lowest temperature	°C	5	Ventilation		forced
Altitude	m	200	Tunnelling method		D&B
Air density	kg/m3	1,24	Mucking		diesel trucks
Tunnelsection area	m2	70	Max diesel power at heading	kW	< 700
Tunnelling length	m	3500	Max total utilized diesel power inside tunnel	kW	< 1 206
VENTILATION:					
Lambda factor		0,0170	Air speed in tunnel at face	m/s	0,50
Duct diameter	m	2,2	**Air flow from fan**	**m3/s**	**60,3**
Length of duct	m	3600	Quotient L/D		1636,4
Air flow at face	**m3/s**	**35,0**	Air velocity in duct at entrance	m/s	15,9
Fan diameter	m	1,60	Air velocity in duct at end	m/s	9,2
Leakage per 100 m duct	%	1,5	Static pressure	Pa	2781
Zeta factor		0,2	Internal fan pressure	Pa	559
Addition. pressure	Pa	0,0	Additional pressure	Pa	112
Efficiency (÷)	%	80	**Total pressure**	**Pa**	**3451**
Nominal power	kW	160 x2	Power input	kW	260,1
Price of power	EUR/kWh	0,15	Duration of work	h	20 000
Total energy cost with one speed motor				**EUR**	**624 286**
Total energy cost with frequency inverter (*)				**EUR**	**319 868**

Hz: 50

Rekommended type of fan: **AVH-R160.160.8** **N° of fans:** 2 (in serie in one station)



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Calculating a suitable fan station for an example tunnel

This calculation is valid for 3600 m ducting of diameter 1800mm, air flow at heading 35 m3/s, assumed leakage 1,5%/100 m ducting.

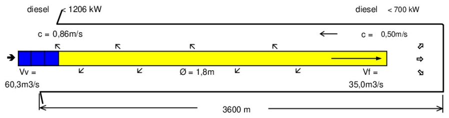
Calculation with duct diameter 1.800 mm

Calculation ID:
Project:
Contractor:
Ref.:
Date: 2019-10-16

SITE:					
Lowest temperature	°C	5	Ventilation		forced
Altitude	m	200	Tunnelling method		D&B
Air density	kg/m3	1,24	Mucking		diesel trucks
Tunnelsection area	m2	70	Max diesel power at heading	kW	< 700
Tunnelling length	m	3500	Max total utilized diesel power inside tunnel	kW	< 1 206
VENTILATION:					
Lambda factor		0,0170	Air speed in tunnel at face	m/s	0,50
Duct diameter	m	1,8	**Air flow from fan**	**m3/s**	**60,3**
Length of duct	m	3600	Quotient L/D		2000,0
Air flow at face	**m3/s**	**35,0**	Air velocity in duct at entrance	m/s	23,7
Fan diameter	m	1,60	Air velocity in duct at end	m/s	13,8
Leakage per 100 m duct	%	1,5	Static pressure	Pa	7584
Zeta factor		0,2	Internal fan pressure	Pa	559
Addition. pressure	Pa	0,0	Additional pressure	Pa	112
Efficiency (÷)	%	80	**Total pressure**	**Pa**	**8255**
Nominal power	kW	250 x3	Power input	kW	622,2
Price of power	EUR/kWh	0,15	Duration of work	h	20 000
Total energy cost with one speed motor				**EUR**	**1 493 330**
Total energy cost with frequency inverter (*)				**EUR**	**693 848**

Hz: 50

Rekommended type of fan: **AVH-R160.250.8** **N° of fans:** 3 (in serie in one station)



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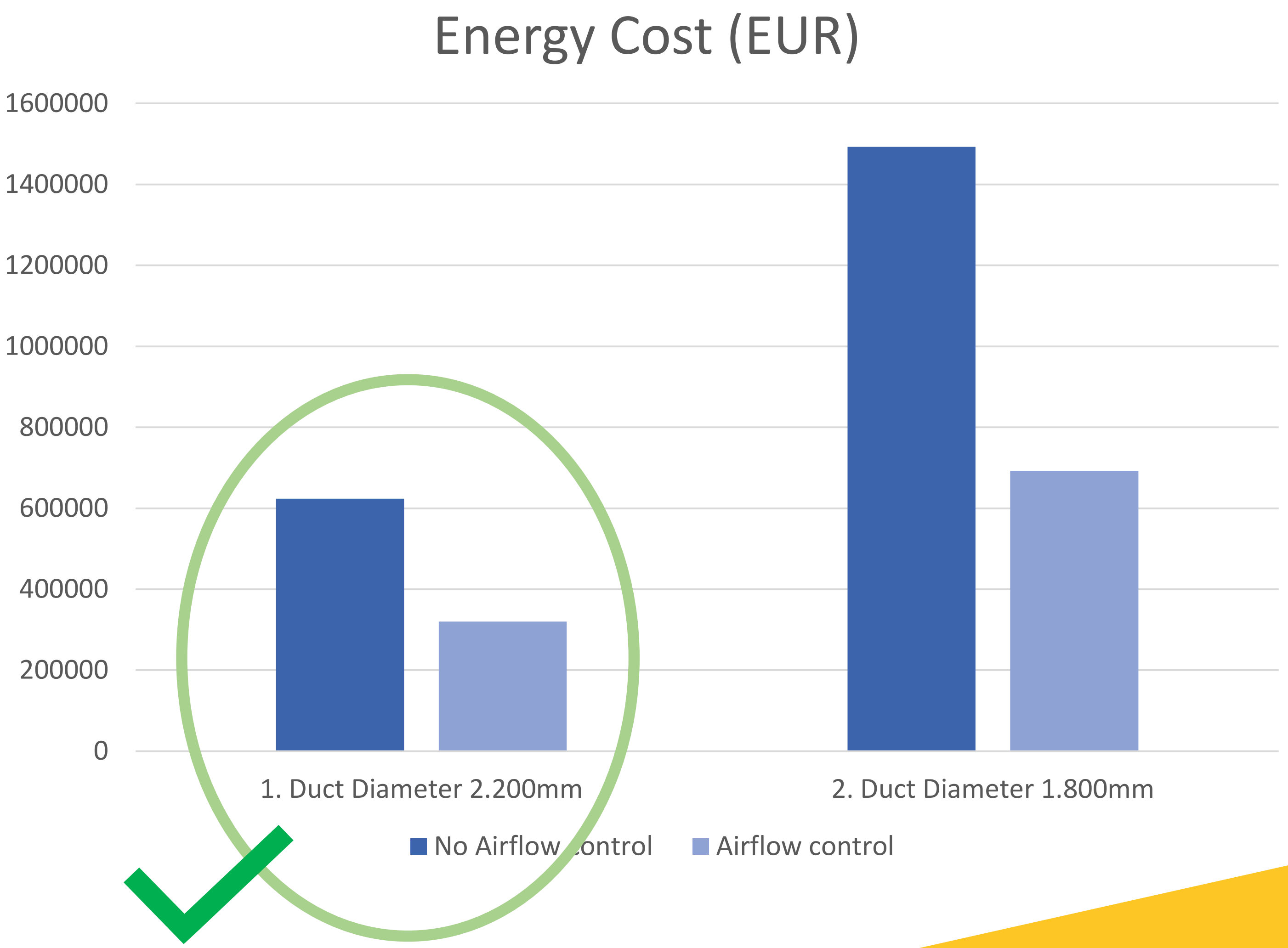
2. Wrong Duct Diameter



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3. Wrong fan

The fan should be chosen to meet the capacity according to the calculated duct pressure and airflow. It many times happens that the fan is chosen by “we have used fans in our warehouse”. This can cause either, not enough airflow to suit the tunneling job and/or to high airflow. Too low airflow means not efficient tunneling which results in lower profit for the project.
Too high airflow cause higher duct pressure which increase the energy costs.

To the right, two alternative calculations are presented. One with the fan chosen to fit the correct airflow calculated to give air return velocity at front min 0,5/s and to be sufficient for 1.200 kW utilized diesel power of vehicles during mucking. The other calculation with a larger fan “found in the warehouse”.

1. With fan chosen to fit the correct airflow, the required fan station would be composed of a dual fan station, 2x160 kW and max power load 260 kW. The energy cost to run this fan station during three years would be 624.000 EUR if no airflow control would be utilized, 320.000 EUR if airflow control is utilized.

2. With all the tunnel data, duct diameter and length and other data kept identical, with a larger fan 2x250 kW, the airflow from fan would be 74 m3/s which increase the duct pressure from 3.450 Pa to 5.200 Pa and max power load 483 kW. The energy cost to run this fan station during three years would be 1.158.000 EUR if no airflow control would be utilized, 593.000 EUR if airflow control is utilized.

In this case, a too large fan would increase the running costs by <u>**534.000/273.000 EUR**</u>. The investment costs would be lower using an existing fan, <u>**but the total costs would be higher**</u> **due to the higher energy costs.**

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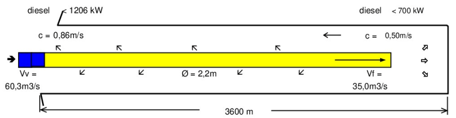
Calculating a suitable fan station for an example tunnel

This calculation is valid for 3600 m ducting of diameter 2200mm, air flow at heading 35 m3/s, assumed leakage 1,5%/100 m ducting.

ORIGINAL - duct diameter 2.200 mm

Calculation ID:
Project:
Contractor:
Ref.:
Date: 2019-10-16

SITE:					
Lowest temperature	°C	5	Ventilation		forced
Altitude	m	200	Tunnelling method		D&B
Air density	kg/m3	1,24	Mucking		diesel trucks
Tunnelsection area	m2	70	Max diesel power at heading	kW	< 700
Tunnelling length	m	3500	Max total utilized diesel power inside tunnel	kW	< 1 206
VENTILATION:					
Lambda factor		0,0170	Air speed in tunnel at face	m/s	0,50
Duct diameter	m	2,2	**Air flow from fan**	**m3/s**	**60,3**
Length of duct	m	3600	Quotient L/D		1636,4
Air flow at face	**m3/s**	**35,0**	Air velocity in duct at entrance	m/s	15,9
Fan diameter	m	1,60	Air velocity in duct at end	m/s	9,2
Leakage per 100 m duct	%	1,5	Static pressure	Pa	2781
Zeta factor		0,2	Internal fan pressure	Pa	559
Addition. pressure	Pa	0,0	Additional pressure	Pa	112
Efficiency (÷)	%	80	**Total pressure**	**Pa**	**3451**
Nominal power	kW	160 x2	Power input	kW	260,1
Price of power	EUR/kWh	0,15	Duration of work	h	20 000
Total energy cost with one speed motor				**EUR**	**624 286**
Total energy cost with frequency inverter (*)				**EUR**	**319 868**
		Hz: 50			
Rekommended type of fan:	**AVH-R160.160.8**		**N° of fans:**	2 (in serie in one station)	



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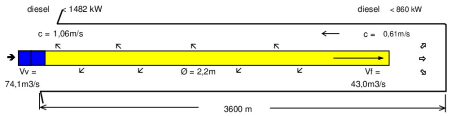
Calculating a suitable fan station for an example tunnel

This calculation is valid for 3600 m ducting of diameter 2200mm, air flow at heading 43 m3/s, assumed leakage 1,5%/100 m ducting.

Calculation with too large fan

Calculation ID:
Project:
Contractor:
Ref.:
Date: 2019-10-17

SITE:					
Lowest temperature	°C	5	Ventilation		forced
Altitude	m	200	Tunnelling method		D&B
Air density	kg/m3	1,24	Mucking		diesel trucks
Tunnelsection area	m2	70	Max diesel power at heading	kW	< 860
Tunnelling length	m	3500	Max total utilized diesel power inside tunnel	kW	< 1 482
VENTILATION:					
Lambda factor		0,0170	Air speed in tunnel at face	m/s	0,61
Duct diameter	m	2,2	**Air flow from fan**	**m3/s**	**74,1**
Length of duct	m	3600	Quotient L/D		1636,4
Air flow at face	**m3/s**	**43,0**	Air velocity in duct at entrance	m/s	19,5
Fan diameter	m	1,60	Air velocity in duct at end	m/s	11,3
Leakage per 100 m duct	%	1,5	Static pressure	Pa	4199
Zeta factor		0,2	Internal fan pressure	Pa	844
Addition. pressure	Pa	0,0	Additional pressure	Pa	169
Efficiency (÷)	%	80	**Total pressure**	**Pa**	**5212**
Nominal power	kW	250 x2	Power input	kW	482,8
Price of power	EUR/kWh	0,15	Duration of work	h	20 000
Total energy cost with one speed motor				**EUR**	**1 158 628**
Total energy cost with frequency inverter (*)				**EUR**	**593 627**
		Hz: 50			
Rekommended type of fan:	**AVH-R180.250.8**		**N° of fans:**	2 (in serie in one station)	



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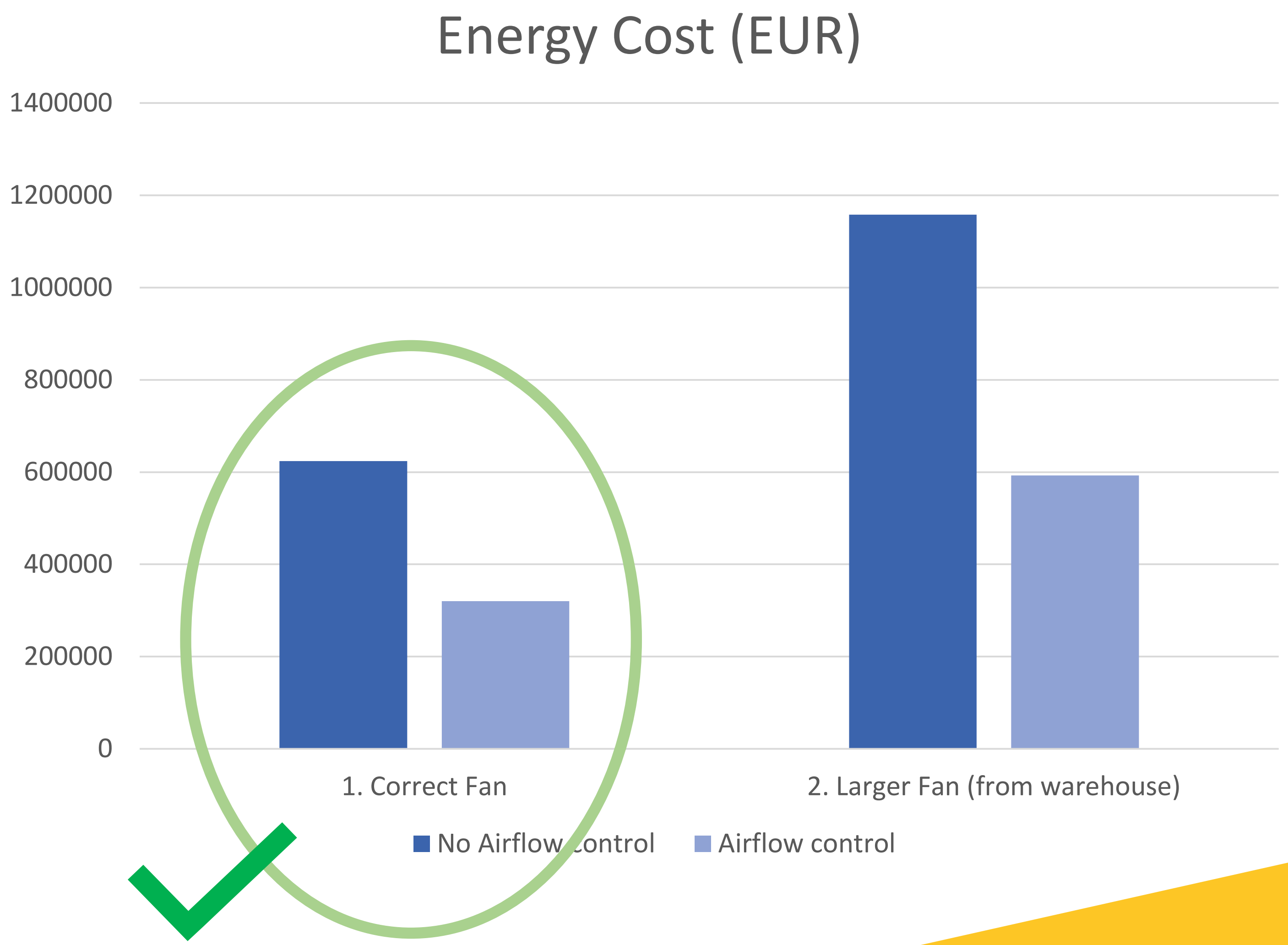
3. Wrong Fan



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4. Duct Leakage

When calculating the required airflow delivered by the portal fan station in relation to the required airflow delivered to the tunneling front, a duct leakage must always be assumed. The leakage can be caused by how well the joints of each duct section are designed (different types are offered from different manufacturers), the duct quality (with poorer quality, the more damages/holes will occur) and how well damages are repaired.

To the right, two alternative calculations are presented. One with the assumed leakage of 1,5%/100 m (which is to be considered as quite low but achievable if the duct is of a good quality with airtight joints and ducting quite well repaired from damages). The other calculation with assumed leakage 2,5%/100 m.

1. With leakage 1,5%/100 m, the required fan station would be composed of a dual fan station, 2x160 kW and max power load 260 kW. The energy cost to run this fan station during three years would be 624.000 EUR if no airflow control would be utilized, 320.000 EUR if airflow control is utilized.

2. With all the tunnel data, airflow and other data kept identical, with leakage 2,5%/100 m, the required fan station would be composed of a dual fan station, 2x315 kW and max power load 610 kW. The energy cost to run this fan station during three years would be 1.464.000 EUR if no airflow control would be utilized, 726.000 EUR if airflow control is utilized.

In this case, a poor quality duct and/or poorly maintained duct, would increase the running costs by <u>**840.000/406.000 EUR**</u> and investment cost of ventilation system increased by approximately <u>**50.000 EUR**</u>.

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Calculating a suitable fan station for an example tunnel

This calculation is valid for 3600 m ducting of diameter 2200mm, air flow at heading 35 m3/s, assumed leakage 1,5%/100 m ducting.

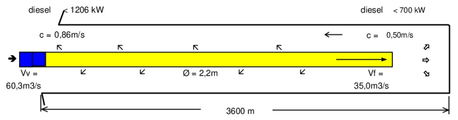
ORIGINAL - duct diameter 2.200 mm

Calculation ID:
Project:
Contractor:
Ref.:
Date: 2019-10-16

SITE:					
Lowest temperature	°C	5	Ventilation		forced
Altitude	m	200	Tunnelling method		D&B
Air density	kg/m3	1,24	Mucking		diesel trucks
Tunnelsection area	m2	70	Max diesel power at heading	kW	< 700
Tunnelling length	m	3500	Max total utilized diesel power inside tunnel	kW	< 1 206
VENTILATION:					
Lambda factor		0,0170	Air speed in tunnel at face	m/s	0,50
Duct diameter	m	2,2	**Air flow from fan**	**m3/s**	**60,3**
Length of duct	m	3600	Quotient L/D		1636,4
Air flow at face	**m3/s**	**35,0**	Air velocity in duct at entrance	m/s	15,9
Fan diameter	m	1,60	Air velocity in duct at end	m/s	9,2
Leakage per 100 m duct	%	1,5	Static pressure	Pa	2781
Zeta factor		0,2	Internal fan pressure	Pa	559
Addition. pressure	Pa	0,0	Additional pressure	Pa	112
Efficiency (÷)	%	80	**Total pressure**	**Pa**	**3451**
Nominal power	kW	160 x2	Power input	kW	260,1
Price of power	EUR/kWh	0,15	Duration of work	h	20 000
Total energy cost with one speed motor				**EUR**	**624 286**
Total energy cost with frequency inverter (*)				**EUR**	**319 868**

Hz: 50

Rekommended type of fan: **AVH-R160.160.8** **N° of fans:** 2 (in serie in one station)



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Calculating a suitable fan station for an example tunnel

This calculation is valid for 3600 m ducting of diameter 2200mm, air flow at heading 43 m3/s, assumed leakage 1,5%/100 m ducting.

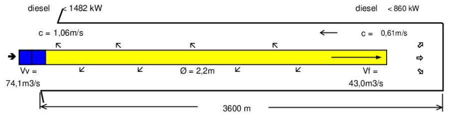
Calculation with too large fan

Calculation ID:
Project:
Contractor:
Ref.:
Date: 2019-10-17

SITE:					
Lowest temperature	°C	5	Ventilation		forced
Altitude	m	200	Tunnelling method		D&B
Air density	kg/m3	1,24	Mucking		diesel trucks
Tunnelsection area	m2	70	Max diesel power at heading	kW	< 860
Tunnelling length	m	3500	Max total utilized diesel power inside tunnel	kW	< 1 482
VENTILATION:					
Lambda factor		0,0170	Air speed in tunnel at face	m/s	0,61
Duct diameter	m	2,2	**Air flow from fan**	**m3/s**	**74,1**
Length of duct	m	3600	Quotient L/D		1636,4
Air flow at face	**m3/s**	**43,0**	Air velocity in duct at entrance	m/s	19,5
Fan diameter	m	1,60	Air velocity in duct at end	m/s	11,3
Leakage per 100 m duct	%	1,5	Static pressure	Pa	4199
Zeta factor		0,2	Internal fan pressure	Pa	844
Addition. pressure	Pa	0,0	Additional pressure	Pa	169
Efficiency (÷)	%	80	**Total pressure**	**Pa**	**5212**
Nominal power	kW	250 x2	Power input	kW	482,8
Price of power	EUR/kWh	0,15	Duration of work	h	20 000
Total energy cost with one speed motor				**EUR**	**1 158 628**
Total energy cost with frequency inverter (*)				**EUR**	**593 627**

Hz: 50

Rekommended type of fan: **AVH-R180.250.8** **N° of fans:** 2 (in serie in one station)



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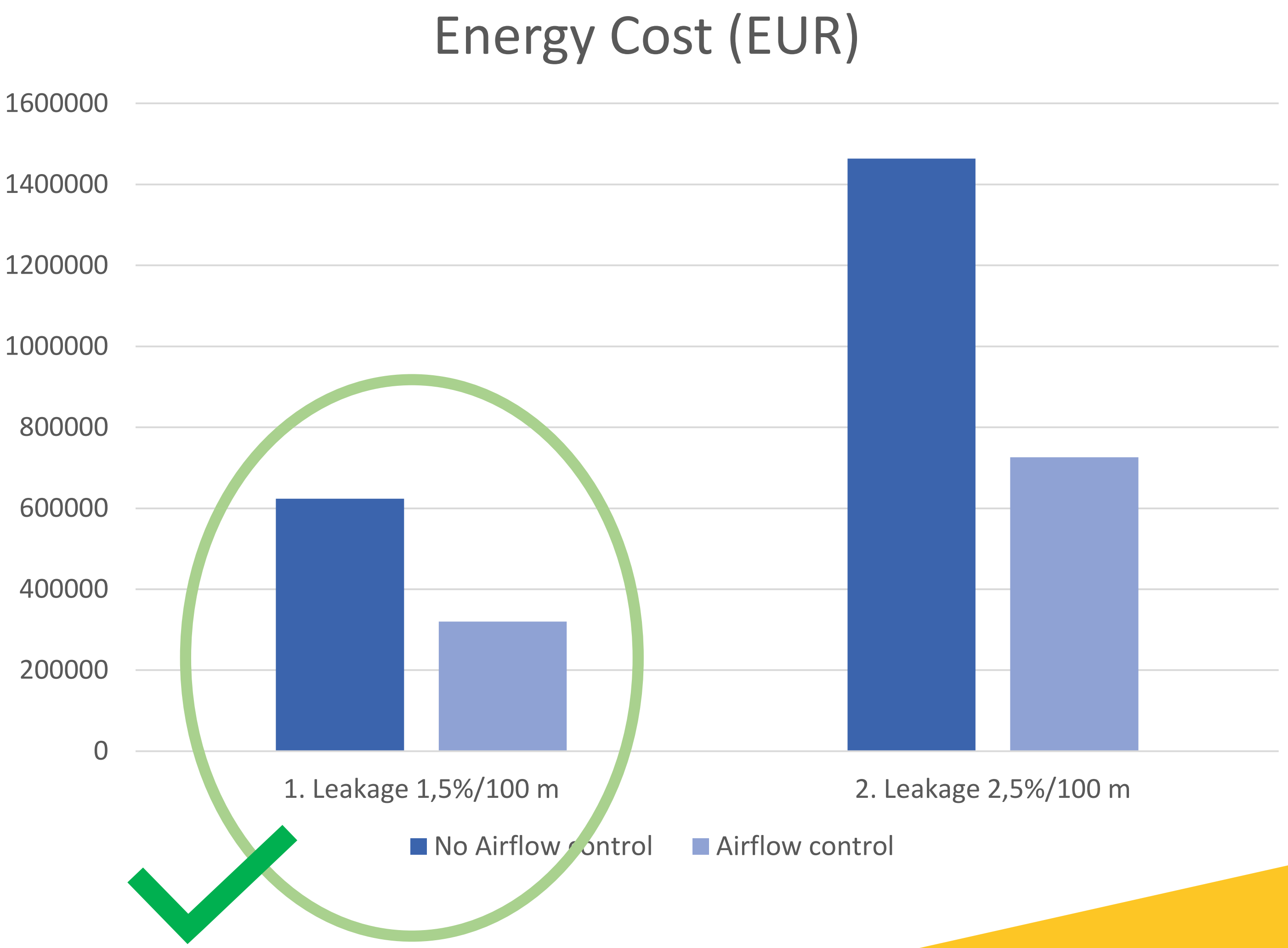
4. Duct Leakage



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No airflow control

Different tunneling works require different airflows. When ventilating the fumes after blasting and when mucking is executed, normally max airflow is required. During works such as drilling, scaling, charging, a reduced airflow can normally be accepted. With frequency inverters, the feeding power can have the frequency set from approx. 10 Hz up to 50 or 60 Hz. Consequently, the rpm of the fan can be set from 20% up to 100% speed.

The power load of a fan is related to the fan speed by cubed. The airflow is linearly related to the speed. As an example, if the power load of a fan in full speed is 100 kW, the power load at half speed is only 12,5% and airflow 50%. Therefore, a great energy cost saving is possible if the fan speed/airflow is controlled and regulated depending on what tunneling works are carried out.

In the example calculation to the right, the energy costs of with and without airflow control can be seen. This is valid for energy cost 0,2 EUR/kWh, total running time 20.000 hours (approx. 3 years) and assuming the fan will be used 50% in full speed and 50% in half speed. The energy cost to run this fan station would be 624.000 EUR if no airflow control would be utilized, 320.000 EUR if airflow control is utilized.

By controlling the airflow in this example case, the energy cost saving would be 304.000 EUR.

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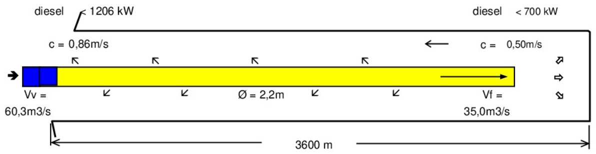
Calculating a suitable fan station for an example tunnel

This calculation is valid for 3600 m ducting of diameter 2200mm, air flow at heading 35 m3/s, assumed leakage 1,5%/100 m ducting.

ORIGINAL - duct diameter 2.200 mm

Calculation ID:
Project:
Contractor:
Ref.:
Date: 2019-10-16

SITE:					
Lowest temperature	°C	5	Ventilation		forced
Altitude	m	200	Tunnelling method		D&B
Air density	kg/m3	1,24	Mucking		diesel trucks
Tunnelsection area	m2	70	Max diesel power at heading	kW	< 700
Tunnelling length	m	3500	Max total utilized diesel power inside tunnel	kW	< 1 206
VENTILATION:					
Lambda factor		0,0170	Air speed in tunnel at face	m/s	0,50
Duct diameter	m	2,2	**Air flow from fan**	**m3/s**	**60,3**
Length of duct	m	3600	Quotient L/D		1636,4
Air flow at face	**m3/s**	**35,0**	Air velocity in duct at entrance	m/s	15,9
Fan diameter	m	1,60	Air velocity in duct at end	m/s	9,2
Leakage per 100 m duct	%	1,5	Static pressure	Pa	2781
Zeta factor		0,2	Internal fan pressure	Pa	559
Addition. pressure	Pa	0,0	Additional pressure	Pa	112
Efficiency (÷)	%	80	**Total pressure**	**Pa**	**3451**
Nominal power	kW	160 x2	Power input	kW	260,1
Price of power	EUR/kWh	0,15	Duration of work	h	20 000
Total energy cost with one speed motor				**EUR**	**624 286**
Total energy cost with frequency inverter (*)				**EUR**	**319 868**
		Hz: 50			
Rekommended type of fan:	**AVH-R160.160.8**		**N° of fans:**	2 (in serie in one station)	



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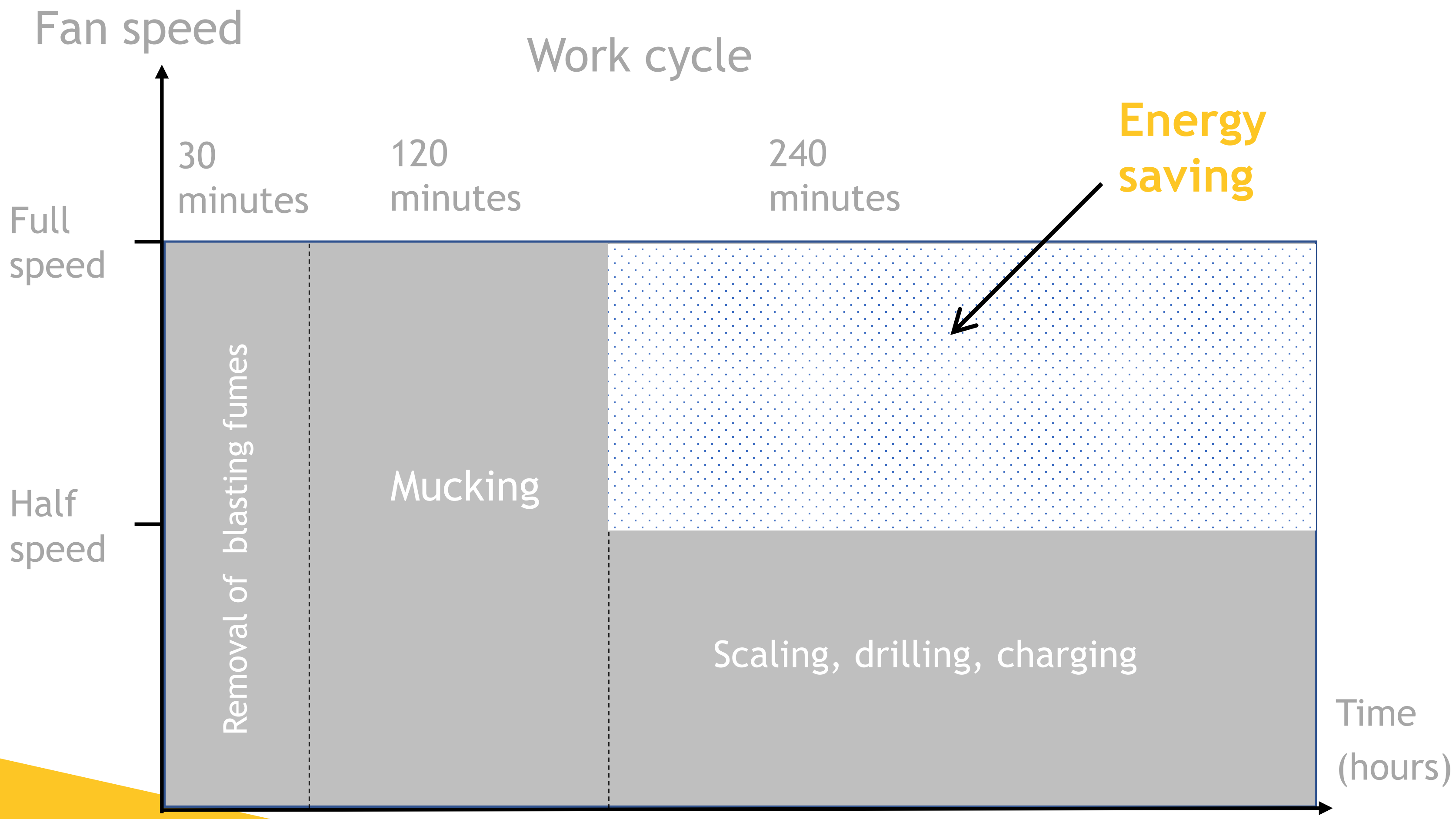
Example of airflow control during one blast cycle



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