Analysis of three systems of air conditioning the production facility

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Abstract. *As a basic foundation for this study, expenses of exploitation are used, as well as general costs and expenses in the present market in Serbia. To improve energy efficiency of similar facilities, the author of this study wanted to present the various investment possibilities concerning energy saving, and to clarify some doubts concerning variable flow in perforated ducts.*
In order to analyze objectively, three systems were designed in one typical production facility. This analyze can be apply on any other facility with similar requirements: Building height, ventilation, configuration and so on.
Idea was to clarify real energy savings, mentioned on web sites of different producers. Generally, the story about energy saving through variable flow is highlighted. This analysis prove is it true or just a commercial.
Not only design was done but also BoQ with current prices on Serbian market, which can be applied across Europe with proportional factor.
Cooling and heating calculations have been done using HAP software (Hourly Analysis Program).

Keywords*: perforated ducts, variable air flow, boosting airflow, energy savings, economic analysis*

1. INTRODUCTION

Air conditioning of any space with perforated ducts is present on the market more than 20 years. My first installation was done successfully back in 2014. Even I was suspicious about proposed solution, after careful study and design I was surprised with the result. We got temperature difference within the facility less than 1.5 ºC. Installation height was 10m from the ground. During commissioning we have done few experiments playing with the flow to see the result. The AHU was equipped with frequency drive fan. Conclusion was that you can decrease flow in winter regime for 20%, not more, and you can increase flow by 5-15%, not more due to the reserve in fan power in AHU.

With the construction industry of high facilities there was a need for a solution in heating period because warm air was always going up, due to density difference. In order to save space in ceiling and installation costs, perforated ducts came on market as one of the solution. During time this application was more and more present.

What is principle of perforated ducts? High induction factor. This phenomenon could also have called as entrainment. On small orifice pressure drop is several times (up to the 12 times) bigger than in the duct, so the uniform air distribution is obtaining according to same pressure drop through the orifice.

Picture 1Visible example of bigger local pressure drop in fluid flow

High velocity on the exit from the duct secure high induction factor, so the airflow reaches the floor from the bigger heights, even 20m. Due to bigger pressure drop on the orifice, airflow is evenly distributed along the duct even on lengths above 50m. Some manufacturers have stated that there are no limits on lengths. That must be checked on site after implementation.

Ideal air velocity on the beginning of the perforated duct should not be bigger than 7.5m/s. Dynamic pressure drop is proportional with square of velocity.

For smaller heights, velocity at the beginning of perforated duct could be in a range of even 2-3m/s. This value is also connected with generic noise created within the duct. All aspects must be taken into account when designing such a system. Recommendation: always check with duct manufacturer for specific project following values: air throws, winter, summer regime, noise pressure loss.

Diagram bellow explain ratio.

Figure 1 recommended velocity at the beginning of the duct

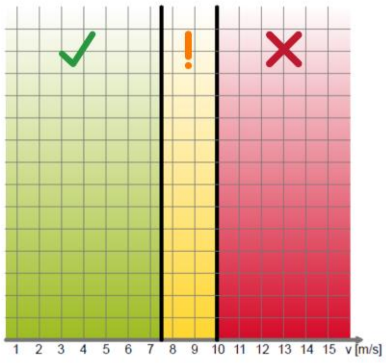


Figure 2 Installation height (H) – launch distance (L) ratio

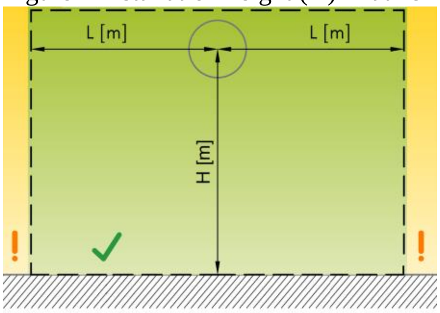
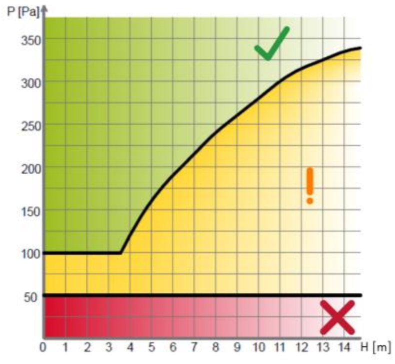


Figure 3 Pressure (P) – installation height (H) ratio



Shown values should be considering as guidelines. On different manufacturers web sites, those values naturally vary, but the differences are not significant.

Figures were taken from https://www.oneair.it/configurator/#dimensionamento

2. THEORETICAL BASES FOR CALCULATIONS

Nomenclature

AHU	Air Handling Unit
h	enthalpy, *kJ/kg*
$\dot{m}$	mass flow, *kg/s*
Q	heat flow, *kW*
$c_{p,w}$	specific heat of water, *kJ/kgK*

$\boldsymbol{P_{el}}$	electric power output, *kW*
$\boldsymbol{\eta_{el}}$	the electrical efficiency
CPU	Central Process Unit
$\boldsymbol{t_{oa}}$	temperature of outside air, ºC
$\boldsymbol{t_{wb}}$	wet bulb temperature, ºC
$\boldsymbol{t_{in}}$	inlet temperature, ºC
$\boldsymbol{t_{o}}$	outlet temperature, ºC

To be able to compare three systems we will shortly explain designs and their differences in theoretical and practical manner.

Production facility dimensions:

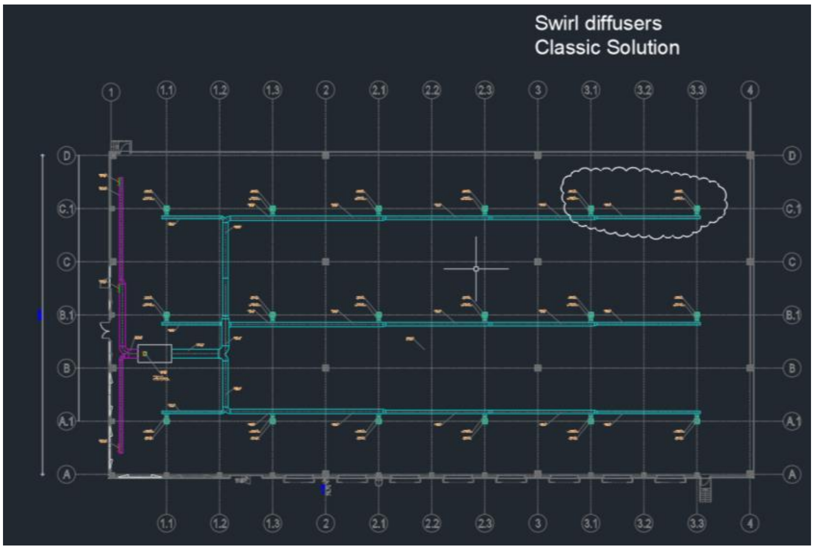
Length: 76m
Width: 33m
Height: 14m
Duct installation height: 11m

Ventilation System
Airflow 33.000m3/h, of which 1440m3/h is fresh outside air (OA)
Heating loss: 120kW
Cooling gains: 50kW
Indoor conditions:
Summer: 26-28 ºC , no humidity requirements
Winter: 18 ºC
Supply Air conditions:
Summer: min 16 ºC, max 26 ºC
Winter: min 18 ºC, max 28 ºC
The drawings of all systems are shown as appendix 1 of this paper

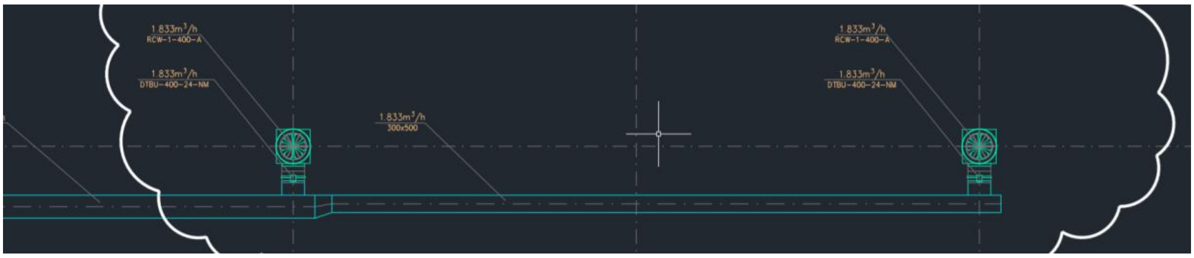
2.1 Solution 1

Air distribution with swirl diffusors

Dwg 1.1



Dwg 1.2



System is consisted of square insulated ducting with swirl diffusers.

There are 18 diffusers in the facility, each with 1833m3/h.

During calculation of diffusers, maximal throw was determined as 8.6m with DT=10 ºC for size 400. With air velocity of 0.2m/s. For the DT=5 ºC air throw is 10.9m which is quite convenient due to low temperature difference between room indoor temperature and supply air temperature. Reaching those 10m, we could assume that the temperature difference would be less than 0.1 ºC due to induction and air mixing.

Recommended height for the diffuser would be 10m. that implicates that each diffuser should be lower by 1m from the duct installation. That is not the problem if there is no obstacle in the facility at that height, which would be probably the case. Designed diffuser were RCW-1-400-A. At 75º blades setup for maximal air throw pressure drop is 45Pa, and for the 45 º pressure drop is 65Pa. In order to have a control of blades all diffusers are equipped with Belimo motors, 24V 0-10V regulated. Diffusers must be equipped with motors in order to change regime according to needs in the facility.

In order to have a uniform air distribution on all diffusers motorized dampers were designed on each diffuser branch. Type DTBU-400-24-NM.

Recirculation ducting was also designed in order to have as much uniform temperature in the facility. Those recirculation ducting could be avoided as well, but this is better. We could have only damper on the AHU recirculation side. Pressure drop in ducting was calculated, and results are:

Recirculating ducting: 118Pa

Supply ducting: 276Pa, with diffusers with blades on 45 º.

All together 394Pa, with some reserve the external pressure for the AHU should be 450Pa

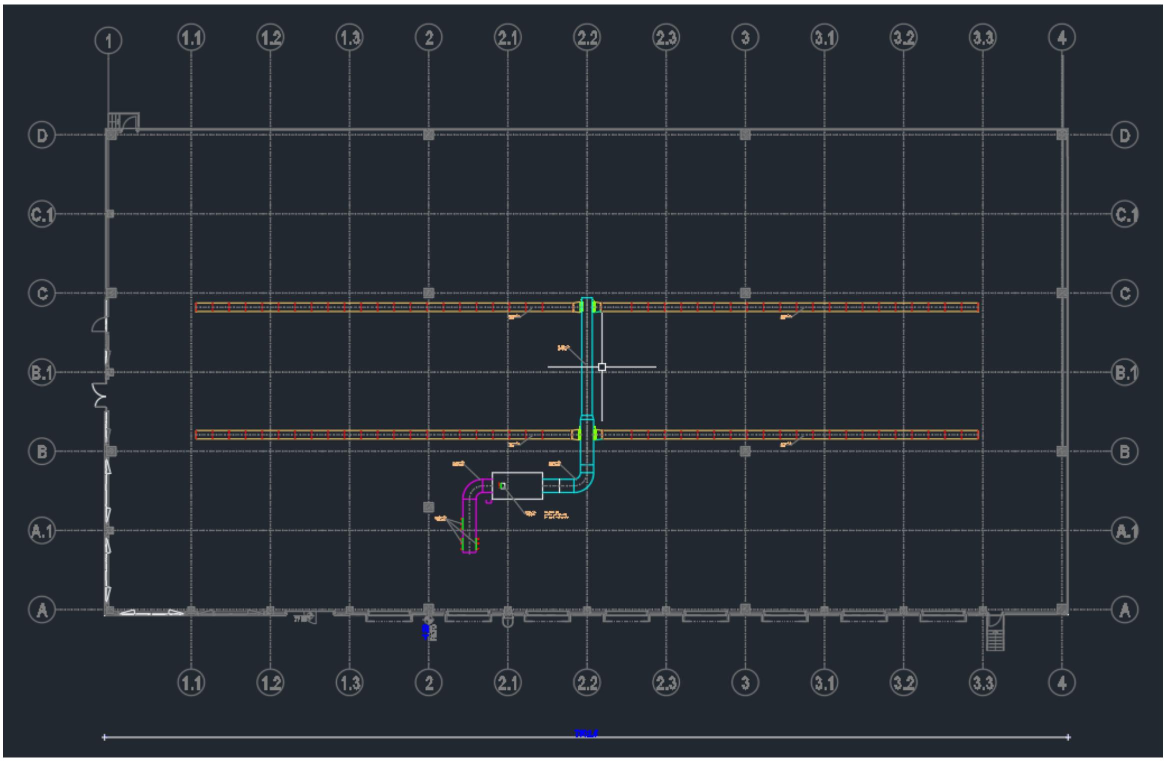
Picture 1 Installation example

2.2 Solution 2

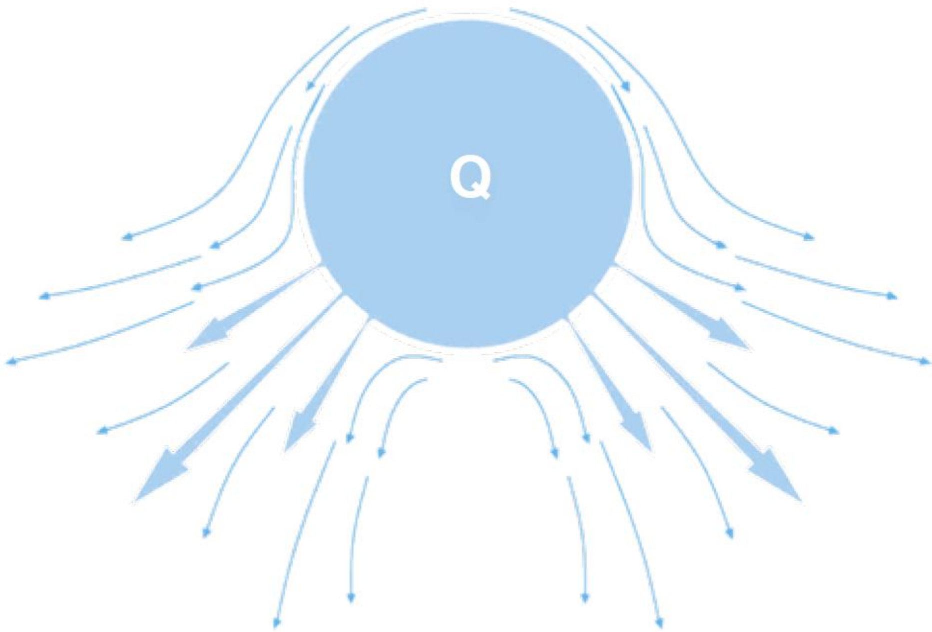
Perforated ducts with constant flow or minimal flow variation

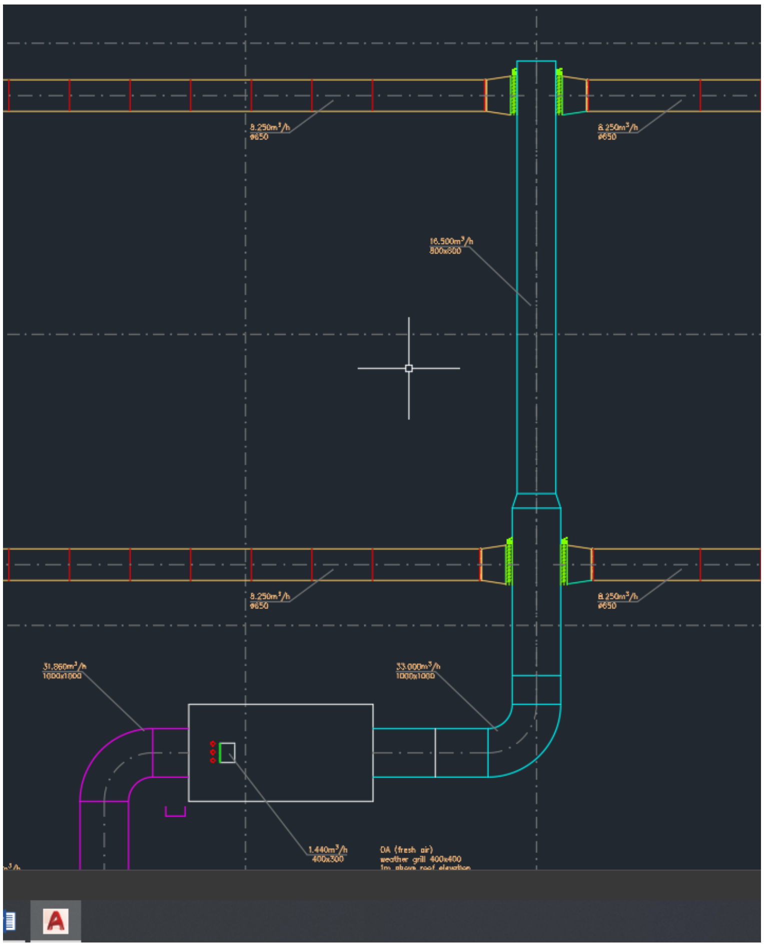
Air distribution with perforated ducts

Dwg 2.1



Picture 1.1 Induction effect with air stream in perforated ducts



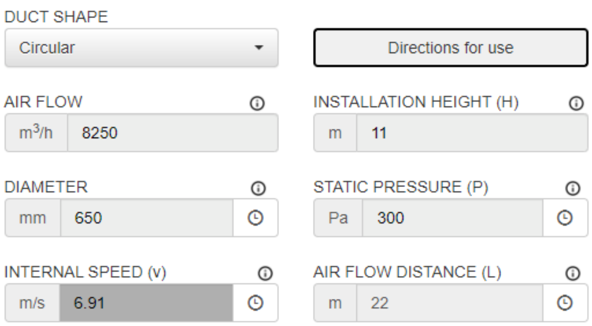


Dwg 2.2

There are 4 equal ducts placed 12.7m from the walls towards center of the facility. Each duct is dimensioned as DN650 round perforated duct.

Air velocity at the beginning of the PED is 6.91m/s. Optimal pressure for the functioning is 300Pa.

Airflow distance is 22m which allows the absolute uniform temperature gradient all over the conditioned space.



Example of dimensioning perforated ducts,
picture donloaded from site:
https://www.oneair.it/configurator/#dimensionamento

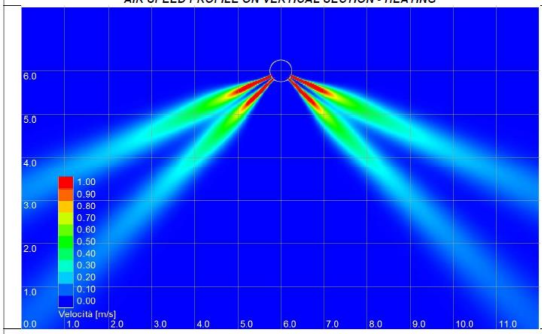
Pressure drop on the beginning of the duct is only 30Pa, while the rest static pressure loss is on the perforations.

Each manufacturer of perforated ducts is using special software for simulation. During project design, it is a must to check with certain manufacturer for help.

During calculation the results will be similar to those shown bellow

AIR THROW DIAGRAMS

AIR SPEED PROFILE ON VERTICAL SECTION - HEATING

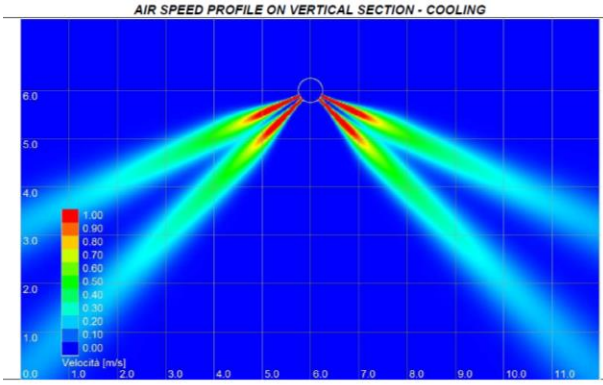


RESULTS OF THE CALCULATION

Description	U.M.	Value
Duct entrance speed	[m/s]	7.074
Maximum speed at 1.600 m above the ground	[m/s]	0.123

AIR THROW DIAGRAMS

AIR SPEED PROFILE ON VERTICAL SECTION - COOLING



RESULTS OF THE CALCULATION

Description	U.M.	Value
Duct entrance speed	[m/s]	7.074
Maximum speed at 1.600 m above the ground	[m/s]	0.201

Solution 2 was checked with OneAir.

What will happen if the nominal airflow is decreased? Duct and the installation height must stay constant.
In next two pictures calculations are shown.
Calculations could be done in software from various manufacturers.
Results will be similar, with slight difference

Table 1 Pressure drop changing in correlation with airflow fluctuation in range of -+40%.

	Airflow	width	height	Eq. diameter	Section Area	Velocity	Section length	Unit pressure drop	Linear pressure drop	Local resistance coeff.	Local press. drop	Total press. drop
	L	a	b	(d_e), d	F	w	l	R	R x l	$\Sigma\zeta$	Z	Rl + Z
	m^3/h	mm	mm	mm	m^2	m/s	m	Pa/m	Pa	-	Pa	Pa
	supply air											
100%	2.0	6		6	0.000	19.6	0.0007	1298.00	0.9	1.20	278.0	278.9
nominal	8,250	650		650	0.332	6.9	2	0.64	1.3	0.40	11.4	12.7
	16,500	800	800	875	0.640	7.2	9	0.48	4.4	0.80	24.6	29.0
	33,000	800	800	875	0.640	14.3	9	1.74	15.7	0.80	98.5	114.1
	extraxt, return air											
	10,520	400	1000	674	0.400	7.3	3	0.68	2.0	0.30	9.6	11.7
	21,040	700	1000	911	0.700	8.3	1	0.61	0.6	0.40	16.7	17.3
	31,560	1000	1000	1093	1.000	8.8	5	0.54	2.7	0.40	18.4	21.2
												484.9
-10%	1.8	6		6	0.000	17.7	0.0007	1082.42	0.8	1.20	225.2	225.9
	7,425	650		650	0.332	6.2	28	0.53	14.8	0.40	9.3	24.1
	14,850	800	800	875	0.640	6.4	9	0.40	3.6	0.80	19.9	23.5
	29,700	800	800	875	0.640	12.9	9	1.43	12.9	0.80	79.8	92.6
	extraxt, return air											
	9,900	400	1000	674	0.400	6.9	3	0.61	1.8	0.30	8.5	10.3
	19,799	700	1000	911	0.700	7.9	1	0.55	0.5	0.40	14.8	15.4
	29,699	1000	1000	1093	1.000	8.2	5	0.49	2.4	0.40	16.3	18.8
												410.7
-20%	1.6	6		6	0.000	15.7	0.0007	883.75	0.6	1.20	177.9	178.5
	6,600	650		650	0.332	5.5	28	0.43	12.0	0.40	7.3	19.3
	13,200	800	800	875	0.640	5.7	9	0.32	2.9	0.80	15.8	18.7
	26,400	800	800	875	0.640	11.5	9	1.15	10.4	0.80	63.0	73.4
	extraxt, return air											
	8,800	400	1000	674	0.400	6.1	3	0.49	1.5	0.30	6.7	8.2
	17,599	700	1000	911	0.700	7.0	1	0.44	0.4	0.40	11.7	12.1
	26,399	1000	1000	1093	1.000	7.3	5	0.39	2.0	0.40	12.9	14.9
												325.1
-30%	1.4	6		6	0.000	13.8	0.0007	702.48	0.5	1.20	136.2	136.7
	5,775	650		650	0.332	4.8	28	0.34	9.4	0.40	5.6	15.0
	11,550	800	800	875	0.640	5.0	9	0.25	2.3	0.80	12.1	14.3
	23,100	800	800	875	0.640	10.0	9	0.90	8.1	0.80	48.3	56.3
	extraxt, return air											
	7,699	400	1000	674	0.400	5.3	3	0.39	1.2	0.30	5.1	6.3
	15,399	700	1000	911	0.700	6.1	1	0.35	0.3	0.40	9.0	9.3
	23,098	1000	1000	1093	1.000	6.4	5	0.31	1.5	0.40	9.9	11.4
												249.4
-40%	1.2	6		6	0.000	11.8	0.0007	539.17	0.4	1.20	100.1	100.4
	4,950	650		650	0.332	4.1	28	0.25	7.1	0.40	4.1	11.2
	9,900	800	800	875	0.640	4.3	9	0.19	1.7	0.80	8.9	10.6
	19,800	800	800	875	0.640	8.6	9	0.68	6.1	0.80	35.4	41.5
	extraxt, return air											
	6,599	400	1000	674	0.400	4.6	3	0.29	0.9	0.30	3.8	4.7
	13,199	700	1000	911	0.700	5.2	1	0.26	0.3	0.40	6.6	6.8
	19,798	1000	1000	1093	1.000	5.5	5	0.23	1.2	0.40	7.3	8.4
												183.7

	Airflow	width	height	Eq. diameter	Section Area	Velocity	Section length	Unit pressure drop	Linear pressure drop	Local resistance coeff.	Local press. drop	Total press. drop
	L	a	b	(d_e), d	F	w	l	R	R x l	Σζ	Z	Rl + Z
	m^3/h	mm	mm	mm	m^2	m/s	m	Pa/m	Pa	-	Pa	Pa
10%	2.2	6		6	0.000	21.6	0.0007	1530.09	1.1	1.20	336.3	337.4
	9,075	650		650	0.332	7.6	28	0.76	21.4	0.40	13.9	35.3
	18,150	800	800	875	0.640	7.9	9	0.58	5.2	0.80	29.8	35.0
	36,300	800	800	875	0.640	15.8	9	2.08	18.7	0.80	119.1	137.8
	extraxt, return air											
	12,100	400	1000	674	0.400	8.4	3	0.88	2.6	0.30	12.7	15.4
	24,199	700	1000	911	0.700	9.6	1	0.79	0.8	0.40	22.1	22.9
	36,299	1000	1000	1093	1.000	10.1	5	0.70	3.5	0.40	24.4	27.9
												611.7
20%	2.4	6		6	0.000	23.6	0.0007	1778.32	1.2	1.20	400.3	401.5
	9,900	650		650	0.332	8.3	28	0.90	25.1	0.40	16.5	41.6
	19,800	800	800	875	0.640	8.6	9	0.68	6.1	0.80	35.4	41.5
	39,600	800	800	875	0.640	17.2	9	2.44	22.0	0.80	141.8	163.8
	extraxt, return air											
	13,200	400	1000	674	0.400	9.2	3	1.03	3.1	0.30	15.1	18.2
	26,399	700	1000	911	0.700	10.5	1	0.93	0.9	0.40	26.3	27.3
	39,599	1000	1000	1093	1.000	11.0	5	0.83	4.1	0.40	29.0	33.2
												727.1
30%	2.6	6		6	0.000	25.5	0.0007	2042.37	1.4	1.20	469.8	471.2
	10,725	650		650	0.332	9.0	28	1.04	29.0	0.40	19.3	48.4
	21,450	800	800	875	0.640	9.3	9	0.78	7.1	0.80	41.6	48.7
	42,900	800	800	875	0.640	18.6	9	2.83	25.5	0.80	166.4	191.9
	extraxt, return air											
	14,300	400	1000	674	0.400	9.9	3	1.20	3.6	0.30	17.8	21.3
	28,599	700	1000	911	0.700	11.3	1	1.08	1.1	0.40	30.9	32.0
	42,899	1000	1000	1093	1.000	11.9	5	0.96	4.8	0.40	34.1	38.9
												852.4
40%	2.8	6		6	0.000	27.5	0.0007	2321.97	1.6	1.20	544.8	546.5
	11,550	650		650	0.332	9.7	28	1.19	33.3	0.40	22.4	55.7
	23,100	800	800	875	0.640	10.0	9	0.90	8.1	0.80	48.3	56.3
	46,200	800	800	875	0.640	20.1	9	3.25	29.3	0.80	193.0	222.3
	extraxt, return air											
	15,400	400	1000	674	0.400	10.7	3	1.37	4.1	0.30	20.6	24.7
	30,800	700	1000	911	0.700	12.2	1	1.24	1.2	0.40	35.9	37.1
	46,199	1000	1000	1093	1.000	12.8	5	1.10	5.5	0.40	39.5	45.0
												987.6

The simplifier table could be shown as system pressure drop curve

Airflow	Total press. drop		Airflow	Dp/Dp nom
m^3/h	Pa			
19,800	183.7		60%	37%
23,100	249.4		70%	50%
26,400	325.1		80%	65%
29,700	410.7		90%	82%
33,000	501.6		100%	100%
36,300	611.7		110%	122%
39,600	727.1		120%	145%
42,900	852.4		130%	170%
46,200	987.6		140%	197%

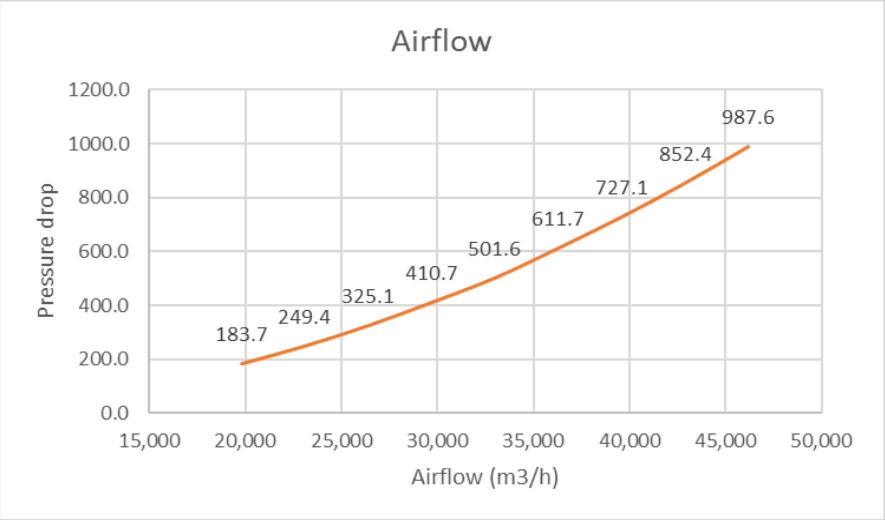


Figure 1: Pressure drop curve

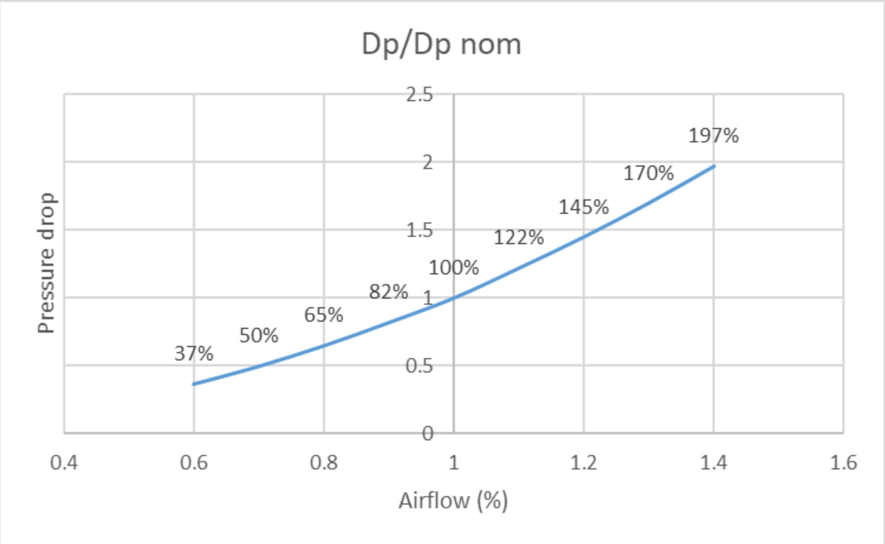


Figure 2: Pressure drop curve (as function of airflow deviation shown in percentages)

Calculation and Figures are showing exactly what we could expect, that pressure drop will increase with airflow.

Increasing airflow doesn't make any sense because we will need much bigger fan in AHU. So we can increase airflow for 5-10% only if there is enough reserve power in AHU fan selection. Increasing airflow in any case is not recommended, or even not possible at all.

How much airflow can be decrease?

With decreasing airflow, the induction on the perforated ducts are dramatically decreasing because the velocity is decreasing and a dynamic pressure drop is decreasing as well. However, ratio between local pressure drop on orifice and total system pressure drop remains in the stabile borders, between 1.79 and 1.83, which can be adopted as constant. Decreased airflow is directly reflected on air throw. No matter what simulation software is used, only exact data can be seen after commissioning with all furniture and machines are installed in the facility.

Indoor temperature is better to regulate with constant flow and decreasing supply temperature during winter period. When heat loss is less than 50% of nominal, the airflow can be decrease by 30% because the difference between supply and indoor air is less and the air throw will be more like isothermal flow. Recommendation is to keep constant flow until the temperature difference reach 50% of nominal.

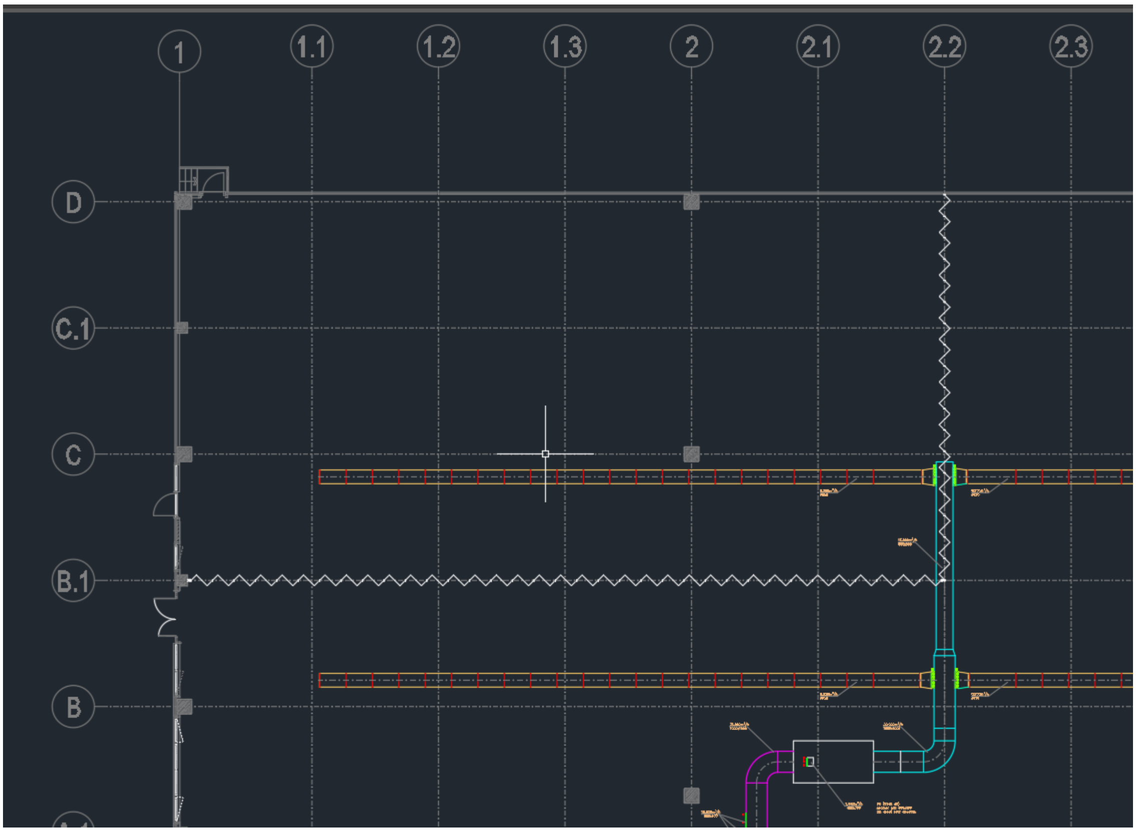
In cooling period, regulation can be obtain in the same principle, but the bench mark could be 40% temperature difference instead 50%, which means airflow can be decreased earlier.

One of the features of system with perforated ducts is the uniform temperature gradient across the entire space. Does the client need this? Well, no. The occupant zone is 1.8m above ground, so actually the client doesn't need uniform temperature across the space. However, if there is a need for drug storage, according to GMP, uniform temperature is a requirement. As a result of high induction, this feature is present in any case, consider it good or not necessary, it is there, and it can't be changed. Another advantage of uniform temperature across the space is less heat exchange between air mass within the space, which means that in winter period less air will move up due to

This type of installation is much quicker than system with ducts.

Also, commissioning is very simple, everything is done in AHU.

The space can be divided in equal parts. In this example in four equal parts, and one of them could be excluded from the conditioning simple by closing one damper. Of course, fan must be reduced to frequency for the new set point.

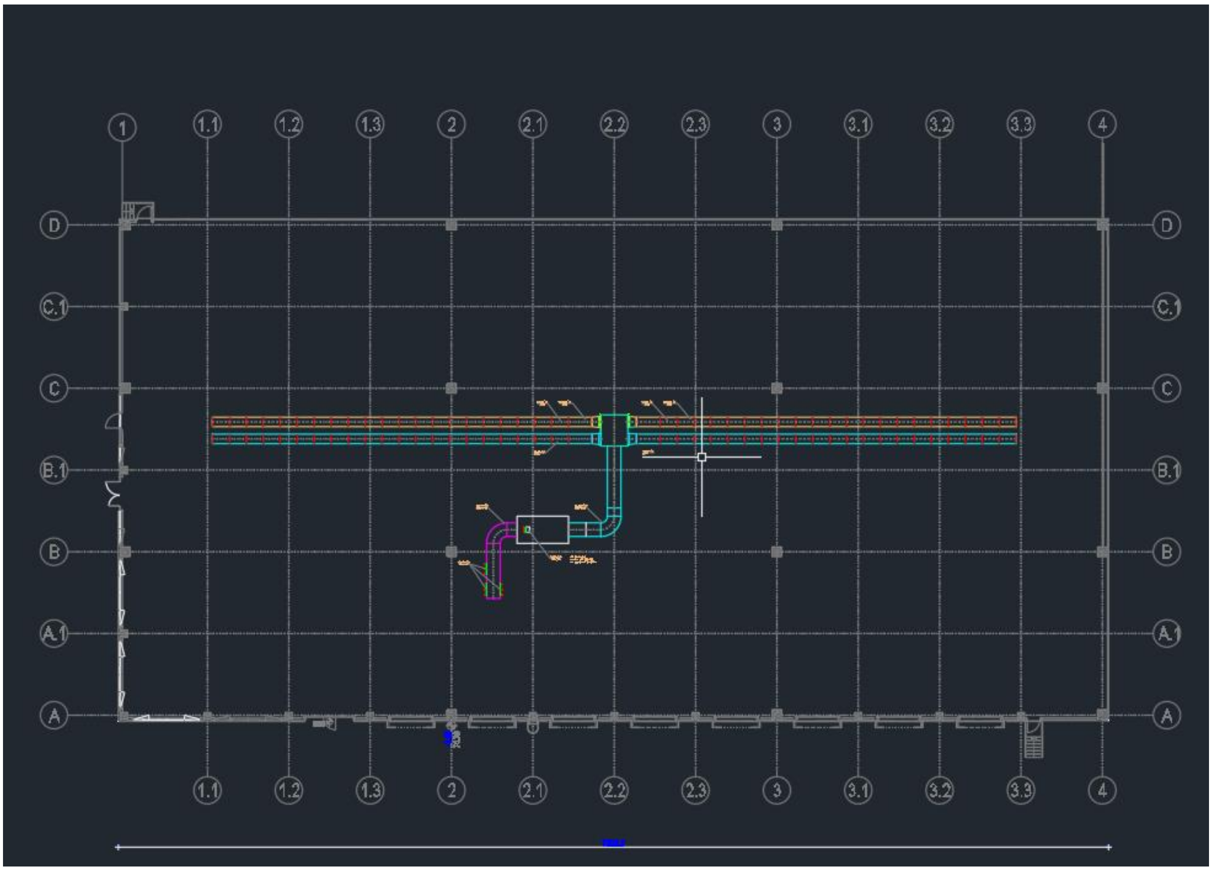


Dwg 2.3.

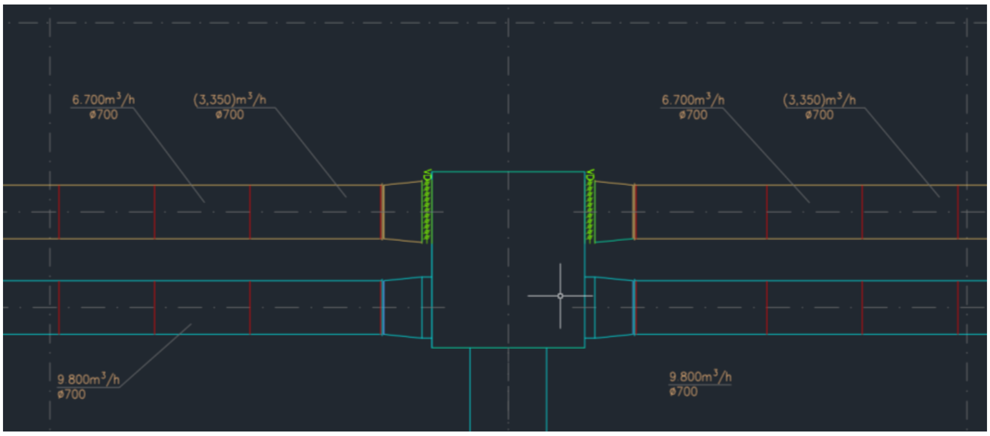
2.3 Solution 3

Perforated ducts with variable airflow

Solution 3 is often called improved perforated duct air conditioning. Typical solution would be with “pulser system”
Principle of design is following: two parallel ducts close to each other. However, the airflow is not equal. It is divided in ratio 1.4-1.5:1.



Dwg 3.1



Dwg 3.2

Company Sintra has patented this solution, according to their website:
http://www.mix-ind.com/perforated-ducts/

From previous experience with Sintra airflow could be defined as follows:

Primary duct 9800m3/h, Secondary duct :6700m3/h.

Primary duct is for air conditioning, while secondary duct helps the induction and doesn't disturb function of primary duct. Secondary ducts have dampers on the beginning and can be closed in certain point. Even the airflows are different, dimensions of the ducts are the same. According to increased flow in primary duct, the dimension must be increased.

As the secondary duct, or "Secondary Pulser" function only as support to primary duct that means that holes are different. Air throw from secondary duct is minimal and has no impact to occupant area bellow, only on the air around ducts, to increase induction. In my opinion for that purpose smaller duct could be used, in this case for 6700m3/h duct with diameter 600 could be used with throw of 5m. This is just my suggestion, Sintra has patented this solution and any further comments on this subject will not be placed here.

Duct of 700 is suitable for the airflow of 9800m3/h.

In normal regime the necessary pressure of the beginning of the perforated duct must be at least 350Pa. However, in booster regime, available pressure must be 500Pa.

Av. Static Pressure	
Standard	Boost
350 Pa	500 Pa

Part of a calculation sheet from Sintra Mix ind technology.

What is booster regime?

According to manufacturer, this regime allows the end user to heat up or cool down the space in shorter time. And to save energy with this process because the fans will run shorter.

In this paper, this case will be analyzed as well.

In standard regime, pressure drop for the whole ductwork should be 546Pa. In the solution 2, pressure drop of ductwork was 501Pa.

In booster regime, minimum available pressure on the duct beginning must be 500Pa. Fact that secondary duct is closed, bigger pressure head is necessary. In that case pressure drop of the system is 720Pa. Result of significant air velocity increase result in pressure drop increase. This is expected, and well known fact. Also shown on figure 2.

For this solution AHU 3 must be determined with external available pressure of 750Pa. That is the fact. In order to "boost" a space in shorter period of time, bigger fan in AHU is a must.

In another words, if the client wants fast heated or cooled space, bigger fan must be implemented. That fan will run on lower speed most of the exploitation period, but it is bigger.

Another comparation, you buy a car with 200HP, but you will drive it 120km/h most of the time. Only once per day you will run a car on full speed for few minutes. Do you really need a car with 200HP engine? Same effect you will achieve if you have a car with 120HP but you start 10 minutes earlier.

	Sintra											
	supply air											
100%	2.6	6		6	0.000	25.9	0.0007	2097.06	1.5	1.20	484.3	485.8
nominal	16,500	700		700	0.385	11.9	28	1.60	44.8	0.40	34.0	78.8
	33,000	800	800	875	0.640	14.3	9	1.74	15.7	0.80	98.5	114.1
	extraxt, return air											
	10,520	400	1000	674	0.400	7.3	3	0.68	2.0	0.30	9.6	11.7
	21,040	700	1000	911	0.700	8.3	1	0.61	0.6	0.40	16.7	17.3
	31,560	1000	1000	1093	1.000	8.8	5	0.54	2.7	0.40	18.4	21.2
												728.9

In this example usual reserve in fan pressure (15-20%) was not taken in consideration. With a reserve, the difference between solutions 2 and 3 would be bigger.

3. AHU selection for three systems

For all three systems the same AHU configuration shall be used.
Difference in AHU is in available external pressure.
All three AHU has same dimensions and same heating and cooling capacities. The case size is 39HQ 14.12. Fan type is ER90C, directly driven, suitable for frequency drive.
Detail selection of the AHU is shown in appendix 2 of this paper.

Table 3. Fan characteristics for AHU

	External static pressure (Pa)	Total static pressure (Pa)	Shaft power (kW)	Installed motor power (kW)	Current (A)	unit shaft power/maximal shaft power
AHU 1	450	961	12.68	15	30.2	78.1%
AHU 2	550	1064	13.85	15	30.2	85.3%
AHU 3	750	1270	16.24	18.5	36.7	100.0%

Derivation of prices of those units are in range of 5-7%.
The result is expected, just confirmation of previous data and Figures.

Usually, any booster system is a system which provide additional pressure to any fluid system at single point, either it is fan, or a pump.

AHU is equipped with sensors and damper motors. In this project I have used Belimo dampers as a reliable one. Not so long ago, Belimo has sensors as well, and experience is the same. Temperature sensors placed in recirculation and supply duct, also in the AHU. Length of a sensor probe is important issue; measurement is more accurate with the longer probe. Price difference between longer probe and smaller one is very small, with in few percents. More information could be found on: http://www.belimo.rs/sensors/
Information on damper motors could be found on: http://www.belimo.rs/air-solutions/damper-actuators-without-emergency-function/
There is no need for emergency function in this case.

4. Cost

For all systems BoQ was done. It can be shown upon a request to the author.
Few reasons are for this decision.
Sometimes manufacturers offer for the same product different price for different projects. That comes with marketing policy of each manufacturer and project location.
At this particular moment, September 2022, situation on the market is far from stabile, so any price breakdown won’t be realistic in future.
Anyway, at this moment I can state following price wise: The cheapest solution is solution No.2.
Difference in budget was within the margin of 20-25%.
This project was done for space 76x33x14. Not so big facility.
Bigger the space, bigger the savings.

5. CONCLUSIONS

Analysis of three systems for air conditioning of a production facility can be applied on any other facility with similar shape and requirements: storages, manufacturing, reparation facilities, drug storages etc.

It was shown that conventional system with ducts and swirl diffusers for high spaces can be replaced with perforated duct system. Advantages are: lower initial cost, quicker installation and commissioning. Yet, system with swirl diffusers allow the division of spaces in more sections (for rental purposes for example).

Perforated ducts system with variable flow and booster system require AHU with bigger fan, there is no energy savings what so ever and the system is most expensive. High induction with perforated ducts allow the relatively short heating up period. Variable heat loss and heat gain over the year should be regulated with variable temperature of supply air until heat loss or gains reach 40-50% of nominal values. Then could be applied variable flow reduction in amount of 40%. This way of control provides maximum energy saving over the exploitation period.

If there is a necessity of point heat exhaust or moving machine with in the space, system with swirl diffusers can provide such requirements with slight change in installation. Also, system with swirl diffusers can be moved on z axis (height can be changed). This system has generally biggest flexibility in exploitation period, can be adapt. AHU for those systems has minimal shaft power on the fan.

System with perforated ducts require less maintenance and there is no necessity for duct cleaning after certain period of time. Those systems can be also adapting to the new configuration of requirements due to the fact that ducts are manufactured in length of 1,2m. easily can be moved to new position.

Systems with perforated ducts has better acoustic reduction.

Final recommendation to investors: systems with perforated ducts without boosting system is the best solution for production facilities and the cheapest at this moment.

Energy wise you can always ask yourself simple question: When is a lowest fuel consumption? When the car is driven on stable, approximately constant velocity without fast accelerations. Simple.

It is wise to analyze few possible solutions for each project before final decision is made. It could help you save the investment cost, and the operational cost as well.

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