Numerical evaluation of the impact of some design parameters of centrifugal fans on their energy efficiency. Corresponding algorithm in the Python language.

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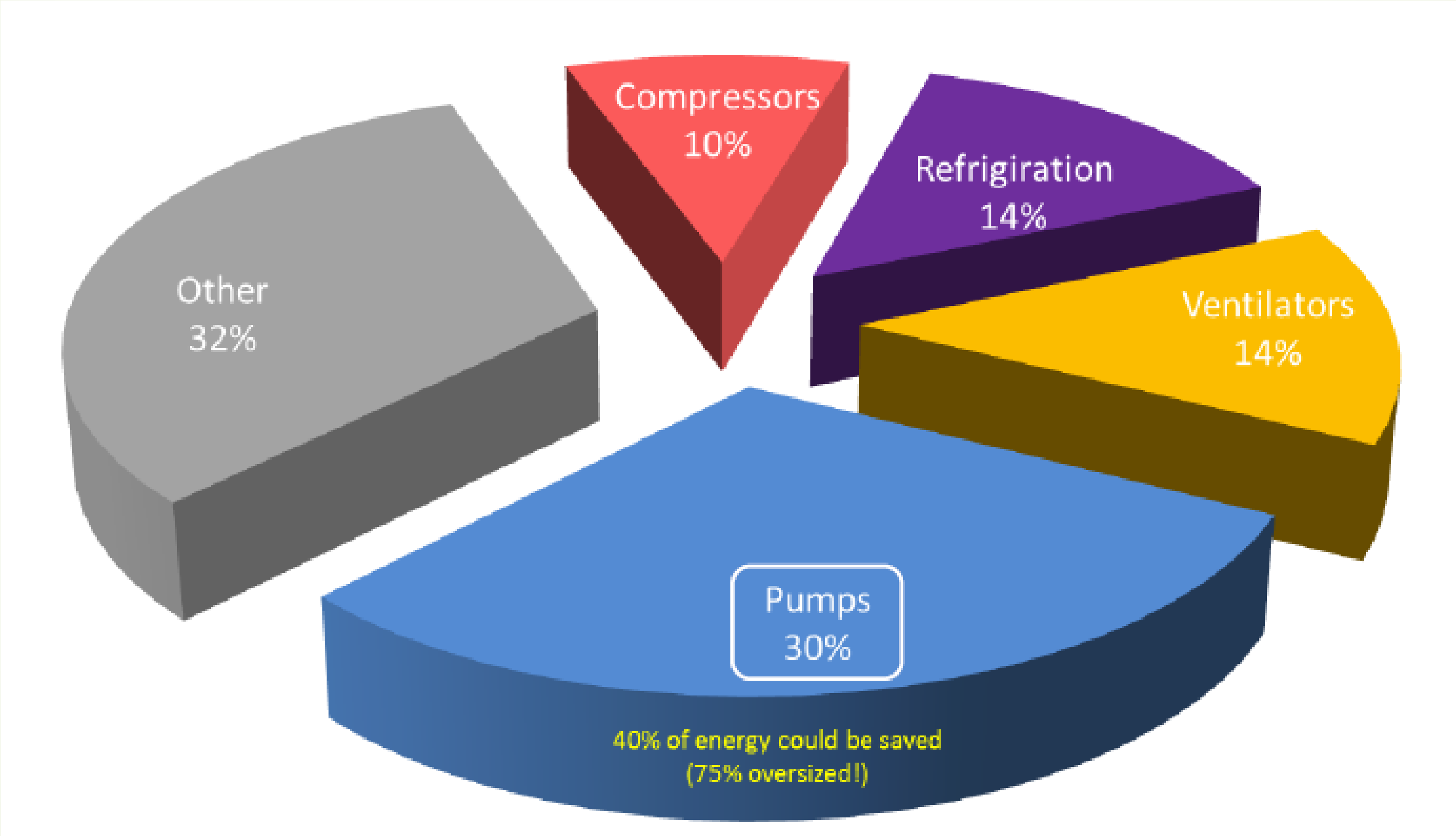
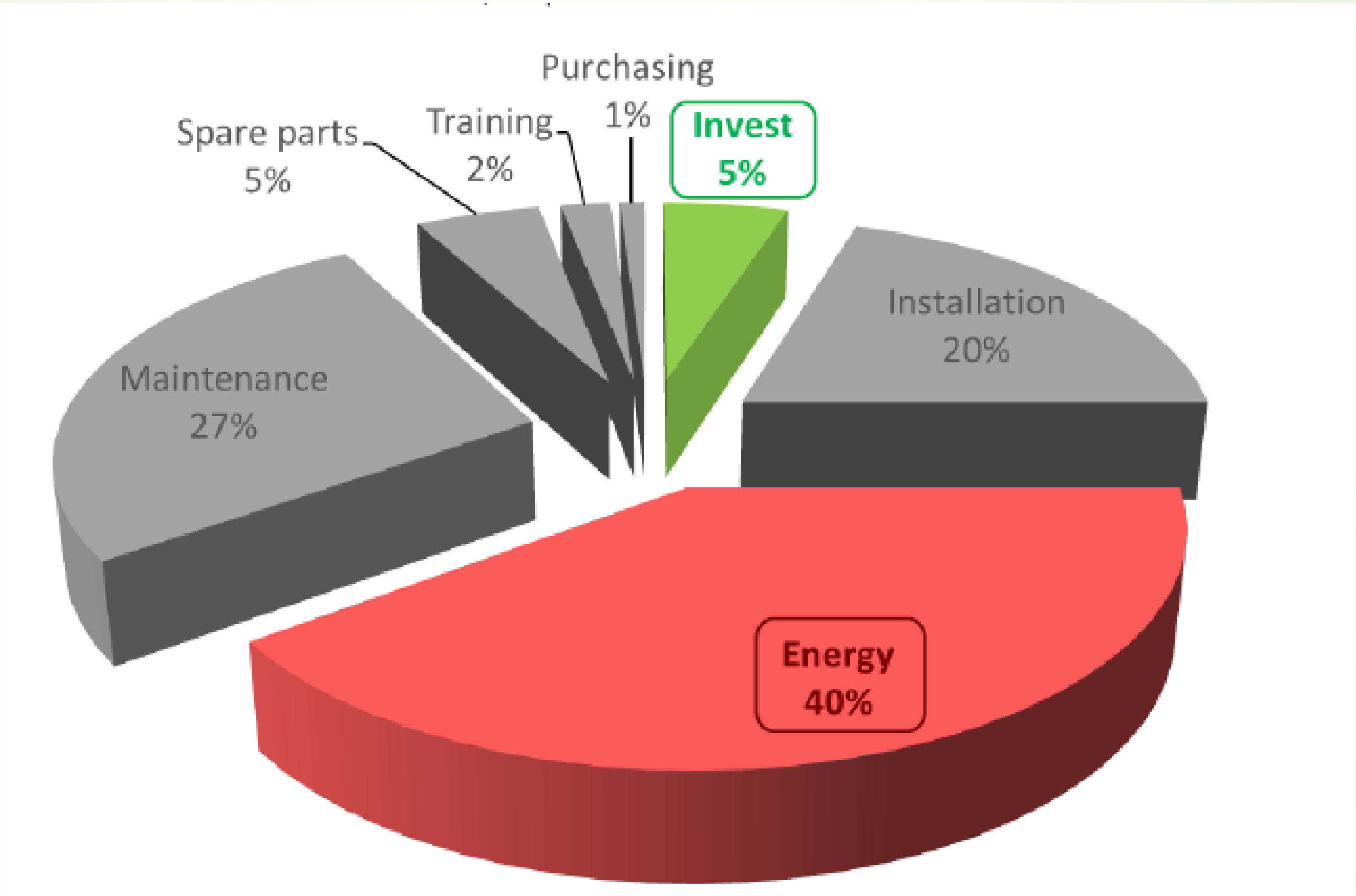
Consumed Electricity of Motor Driven System (EU)



Live-cycle cost(LCC)of a medium sized fan in a chemical plant



Introduction

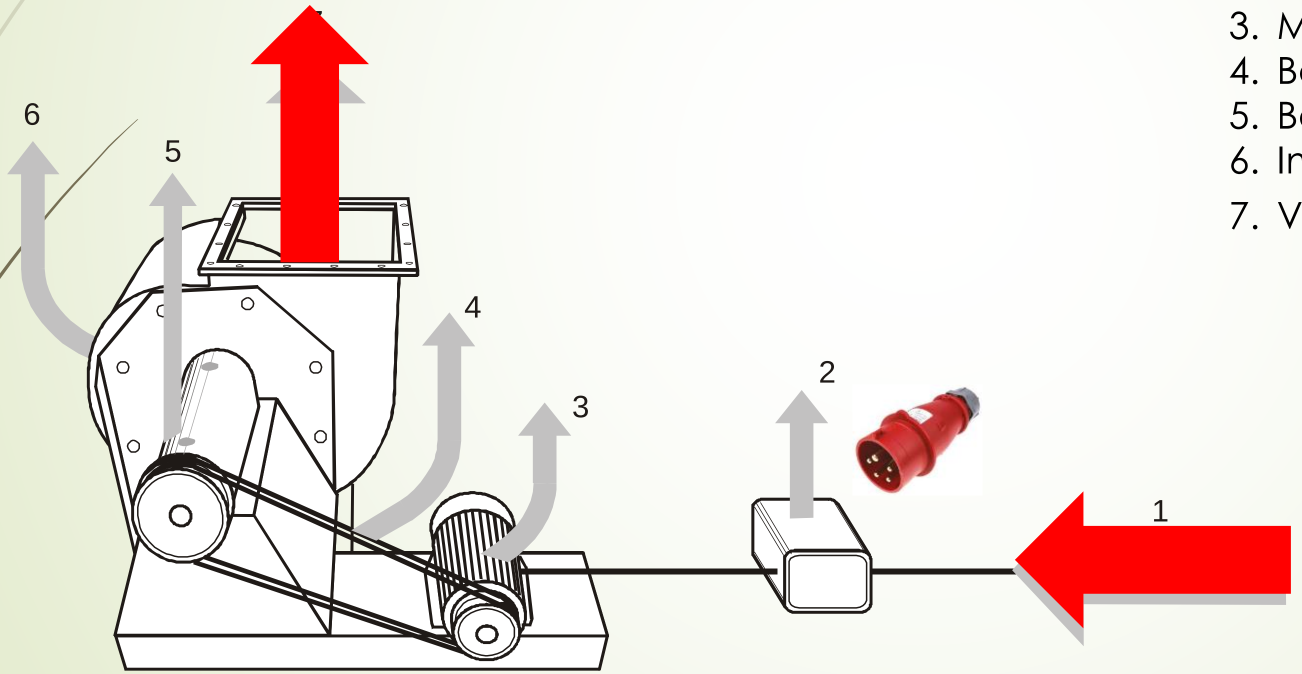
History

EN ISO 5801

The ISO Suite of Standards

Standards

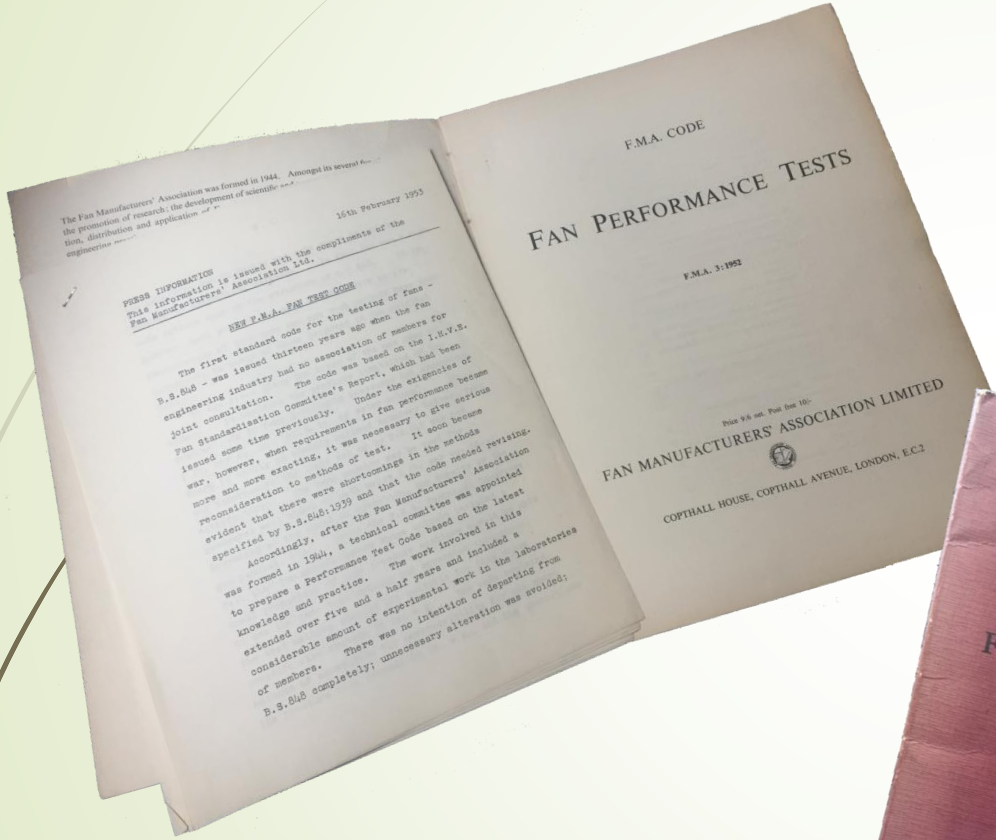
Introduction

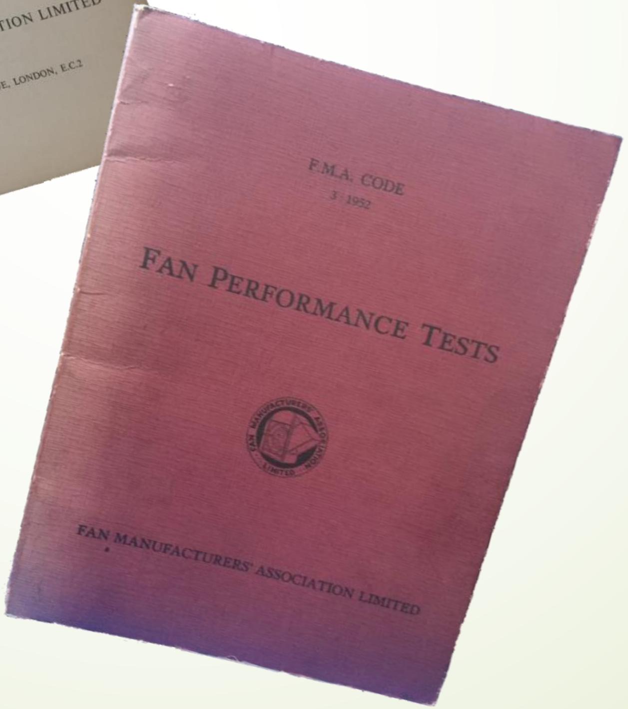


Key

1. Electrical input power P_{ed}
2. Variable speed device loss (heat)*
3. Motor losses (heat)
4. Belt losses (heat)
5. Bearing losses (heat)
6. Impeller and casing aerodynamic losses (heat)
7. Volume flow and pressure Pu (Air Power)

History





1920- Standardisation Committees

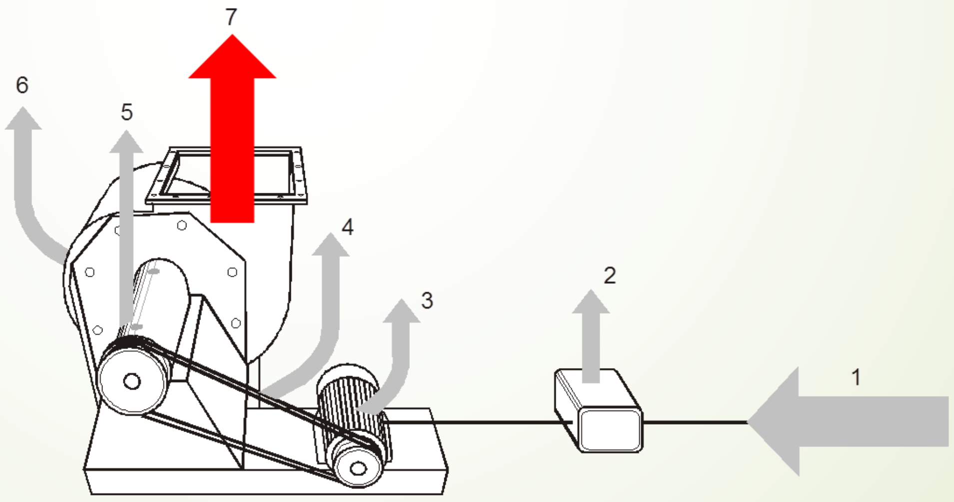
1925-1996- National Fan Standards

1963- ISO Technical Committee 117 (ISO TC 117)

1997- 1st Ed ISO 5801

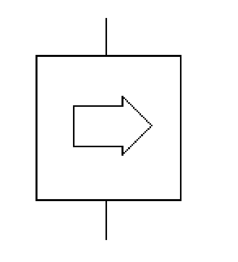
ISO 5801 Air Performance

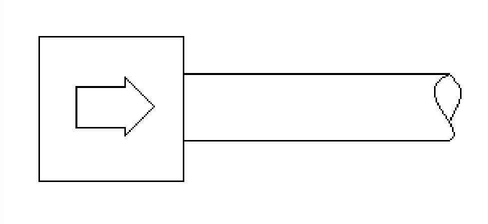
- Reverting back to the three main points for fan characteristics. Air Performance is probably the most critical element, this has been addressed in ISO 5801.



EN ISO 5801

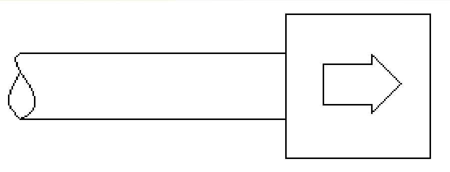
- **Standard Test Configurations**
- **Flow measurement devices:**



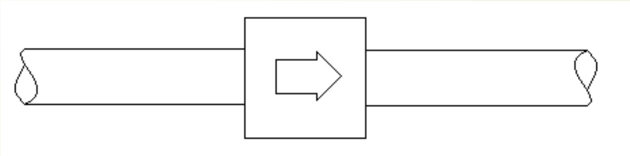


fan outlet

C. Ducted on fan inlet

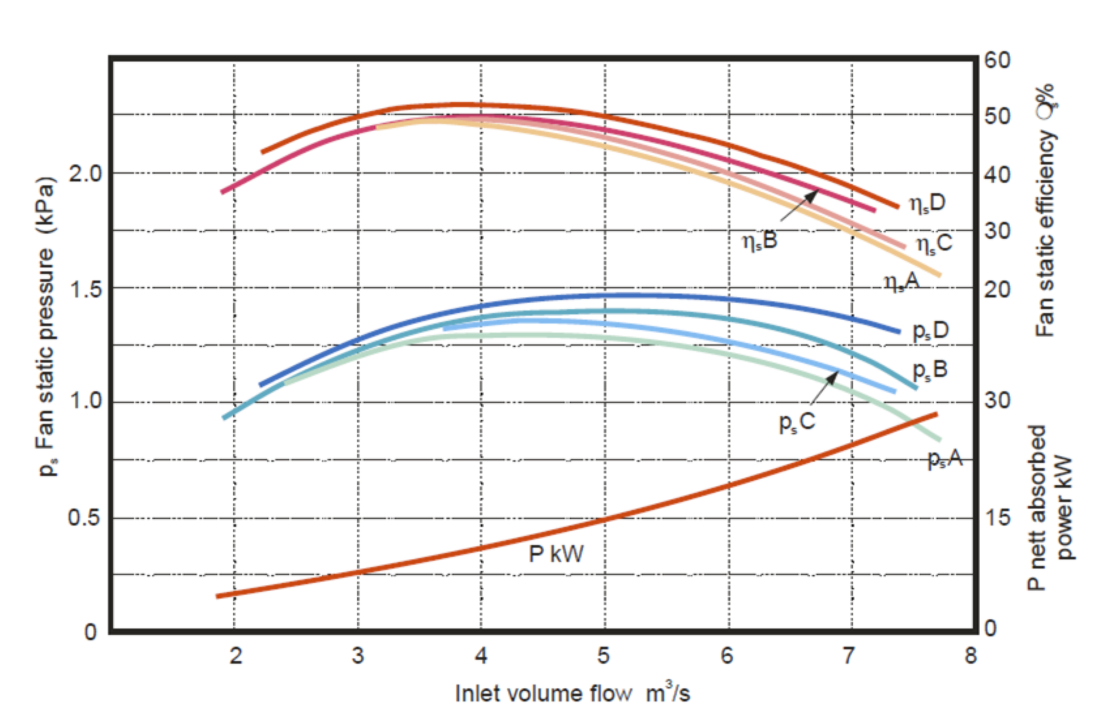



D. Ducted on the fan inlet and outlet



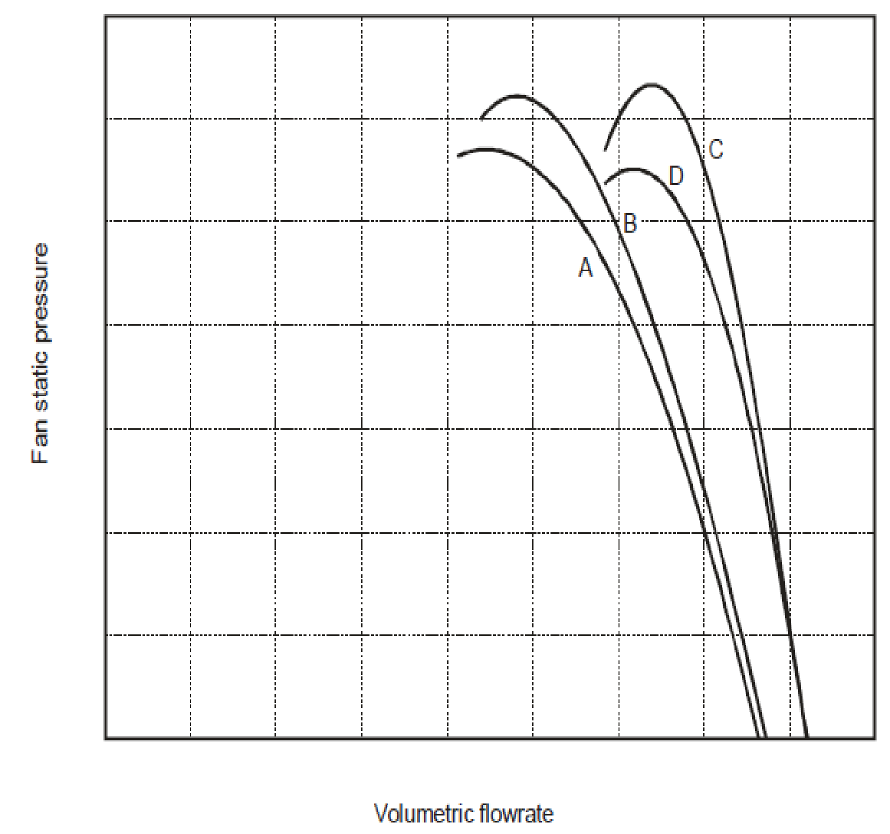

EN ISO 5801

- Typical Performance curves for a forward curved centrifugal fan to different installation categories

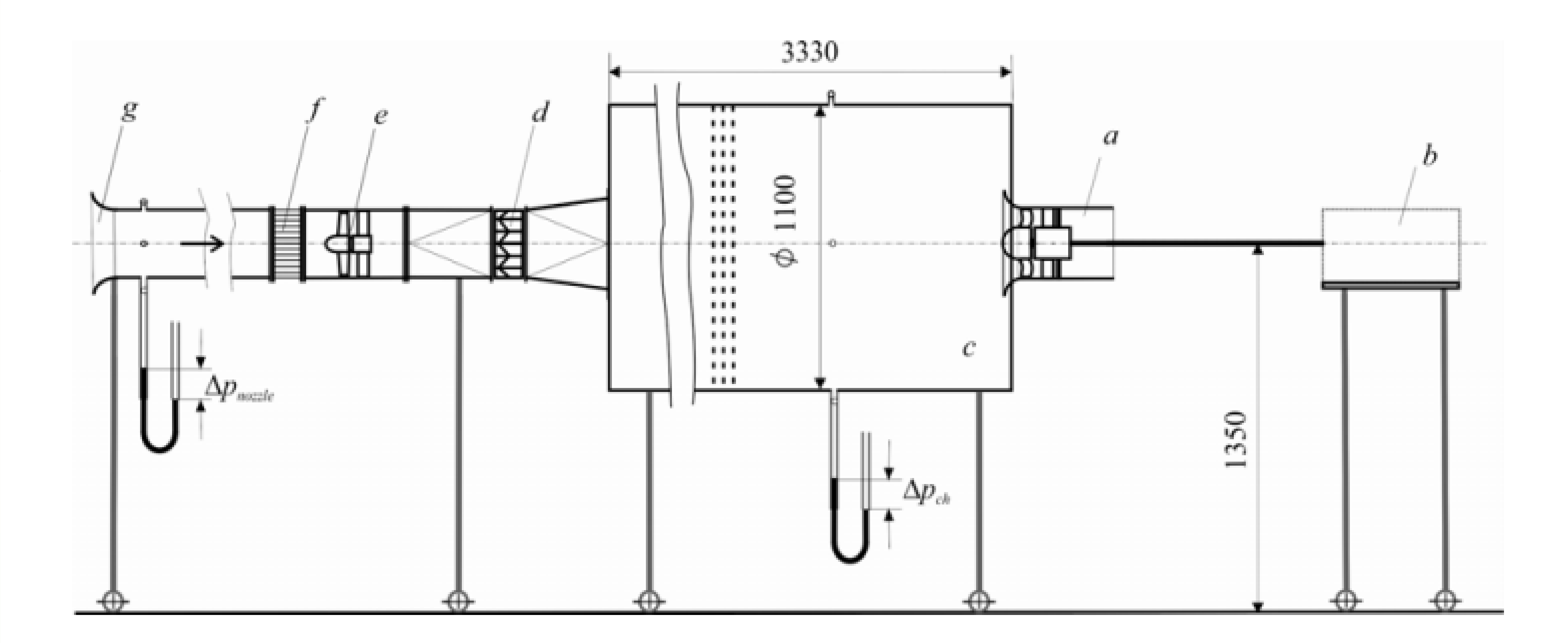


EN ISO 5801

- Typical performance curves for a tube axial fan to different installation categories

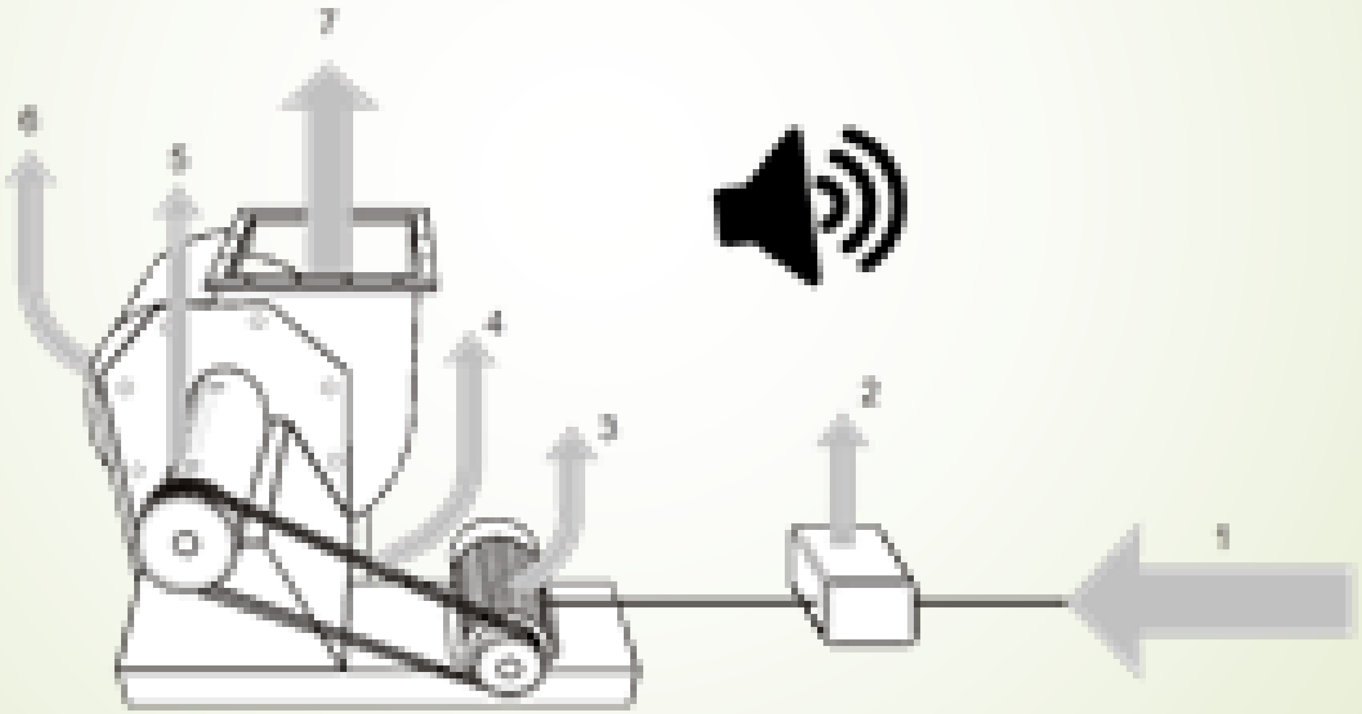


ISO 5802: 2001 Industrial Fans- Performance Testing Testing Proof



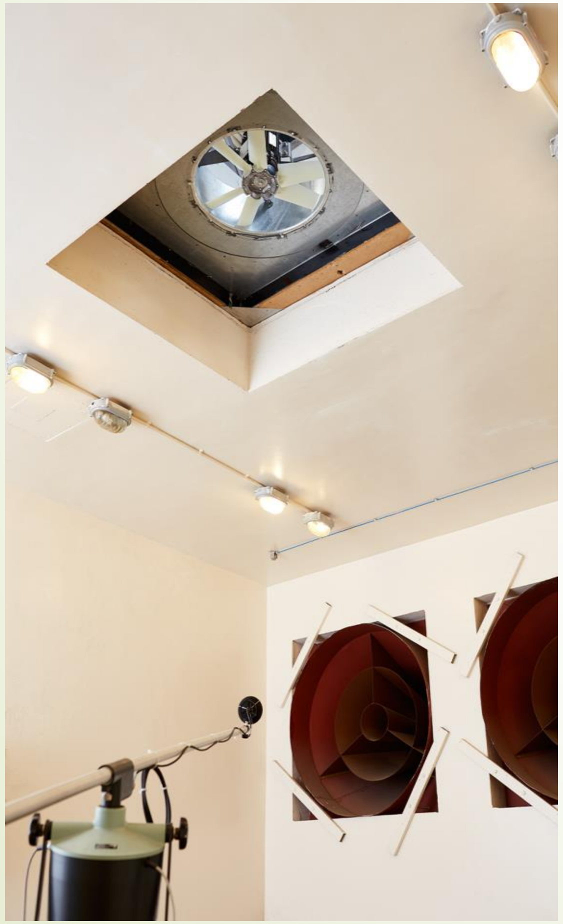
ISO 13347 Sound Measurement

Reverting back to the three main points for fan characteristics . Sound is the next characteristic of fans, which I will cover now with ISO 13347.



ISO 13347

Reverberant Sound Cell



Standard

- ISO 13348 – Tolerances, methods of conversion and technical data presentation
- EN ISO 12759- FANS- Efficiency Classification for Fans
- EU 327/2011
- COMMISSION REGULATION (EU) No 327/2011 of March 2011
- Implementing Directive 2009/125/EC of the European Parliament and of the council with regard to the eco-design requirements for fans driven by motors with an electric input power between 125 W and 500kW
- EU 1253-Implementing directive 2009/125/EC of the European Parliament and of the council with regard to eco-design requirements for ventilation units


EFFICIENT WORK
TIRANA TEKNOLOGJI
According ErP
MOTOR TYPE
ENERGY REQUIRED
ENERGY SAVE
EC BRUSHLESS IE4 + VSD
+++
45%
AC IE3 + VSD
++
35%
AC IE3
+
5%
AC IE2
0%
AC – –
EFFICIENT WORK
TIRANA TEKNOLOGJI

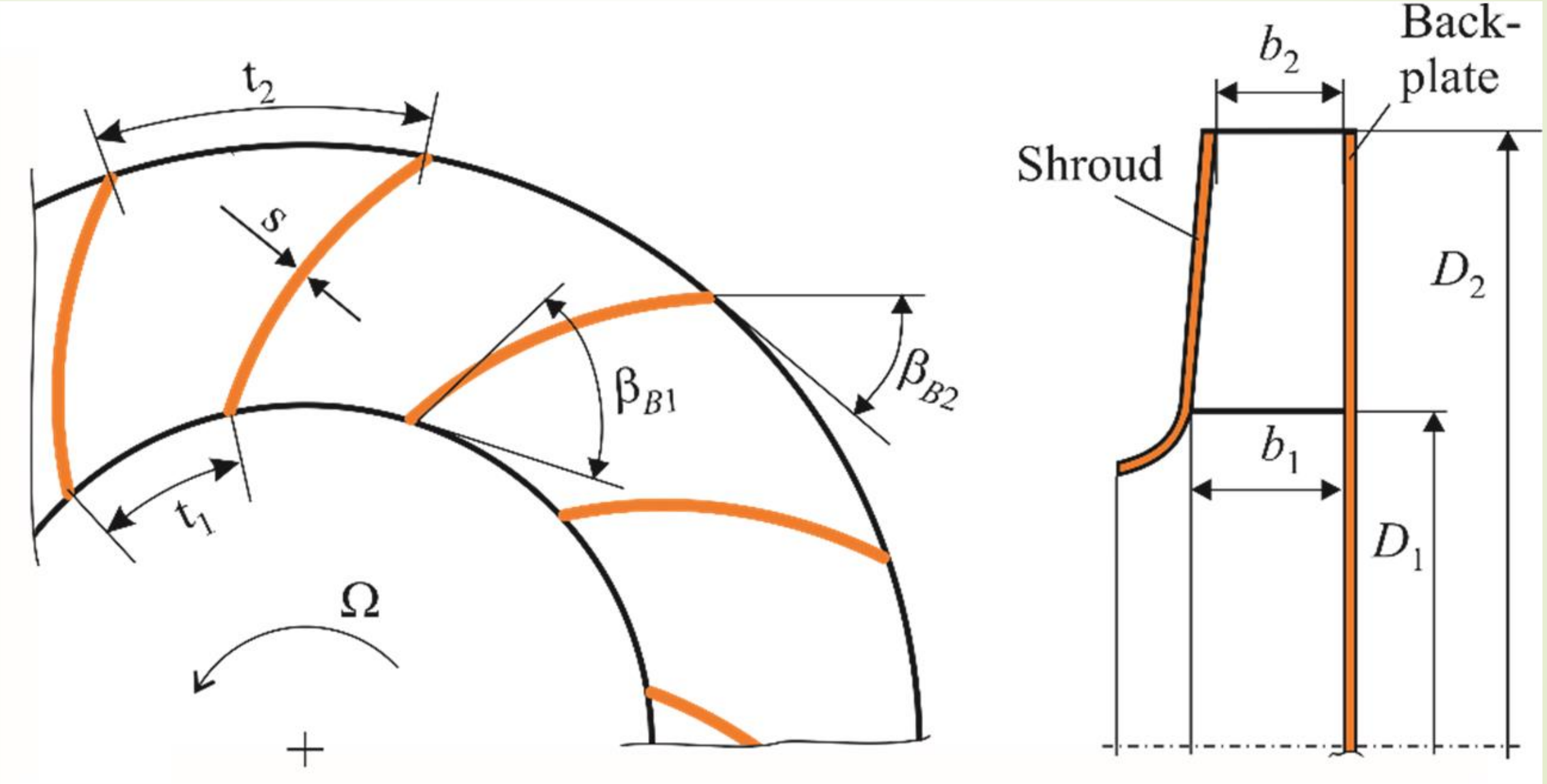
What is ErP?

- ErP (Energy-Related Products) - Products related to energy means products that use energy. In order to fulfill the objectives of the EU Package for Climate and Energy, in 2005 the EuP directive "energy-using products" was issued, which was then replaced by the ErP directive 2009. This directive specifies the rules for establishing requirements regarding energy, related products, including electric fan motors.
- The main purpose of this directive is to increase the efficiency of fan units by 20%. This directive also fulfills the objectives set in the EU package for climate and energy, which defines the reduction of greenhouse gas emissions up to 20%, with the simultaneous increase in the use of renewable energies in the EEA area (European Economic Area) by 20% up to in 2020.
- Pursuant to regulation 327/2011 with some exceptions, it is foreseen that all fans equipped with an electric motor with power between 0.125 kW and 500 kW sold or imported from the EU must meet the conditions of the ErP directive.

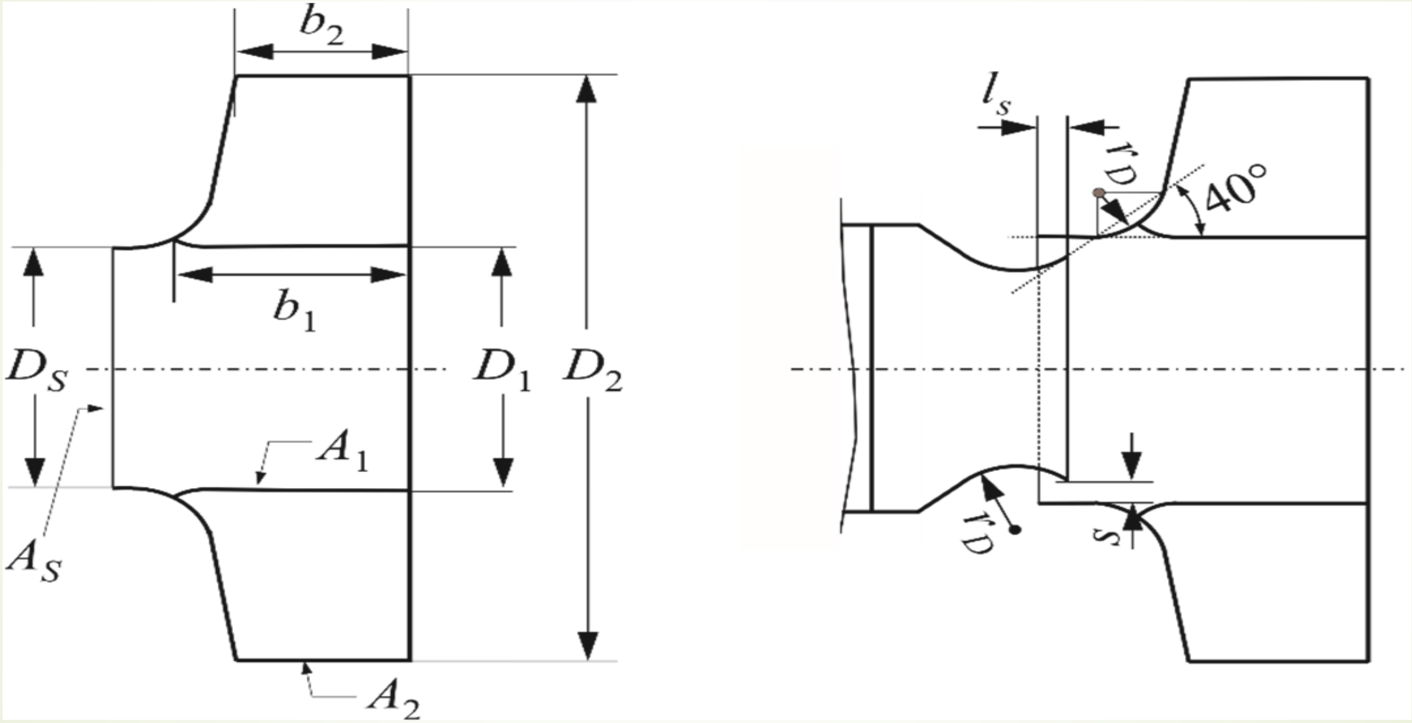
Case study in Tirana Technology

- 1137 restaurants with 1137 ventilators were studied. Their real consumption is 2235 kWh. These fans have electric motors of type IE3+VSD and IE4+VSDIE3 and IE4 fans save 35%-45% electricity compared to that of the usual standard IE2 and IE3. Energy consumption for electric motors will be:IE3+VSD and IE4+VSD is 2235 kWh since they consume 40% lessIE2 and IE3 would be 3276 kWh; So the real energy saving for one working hour is 1490 kW.A restaurant keeps the hood working for at least 10 hours in 365 days of the yearThe energy saved will be 1490kWhx10 hours x365 days a year = 5 438 000 kWh = 645,186 Euro = 550 Euro/year for each restaurant

Nomenclature of the centrifugal impeller.



Geometry parameters of the centrifugal impeller with backward curved blades and the inlet nozzle



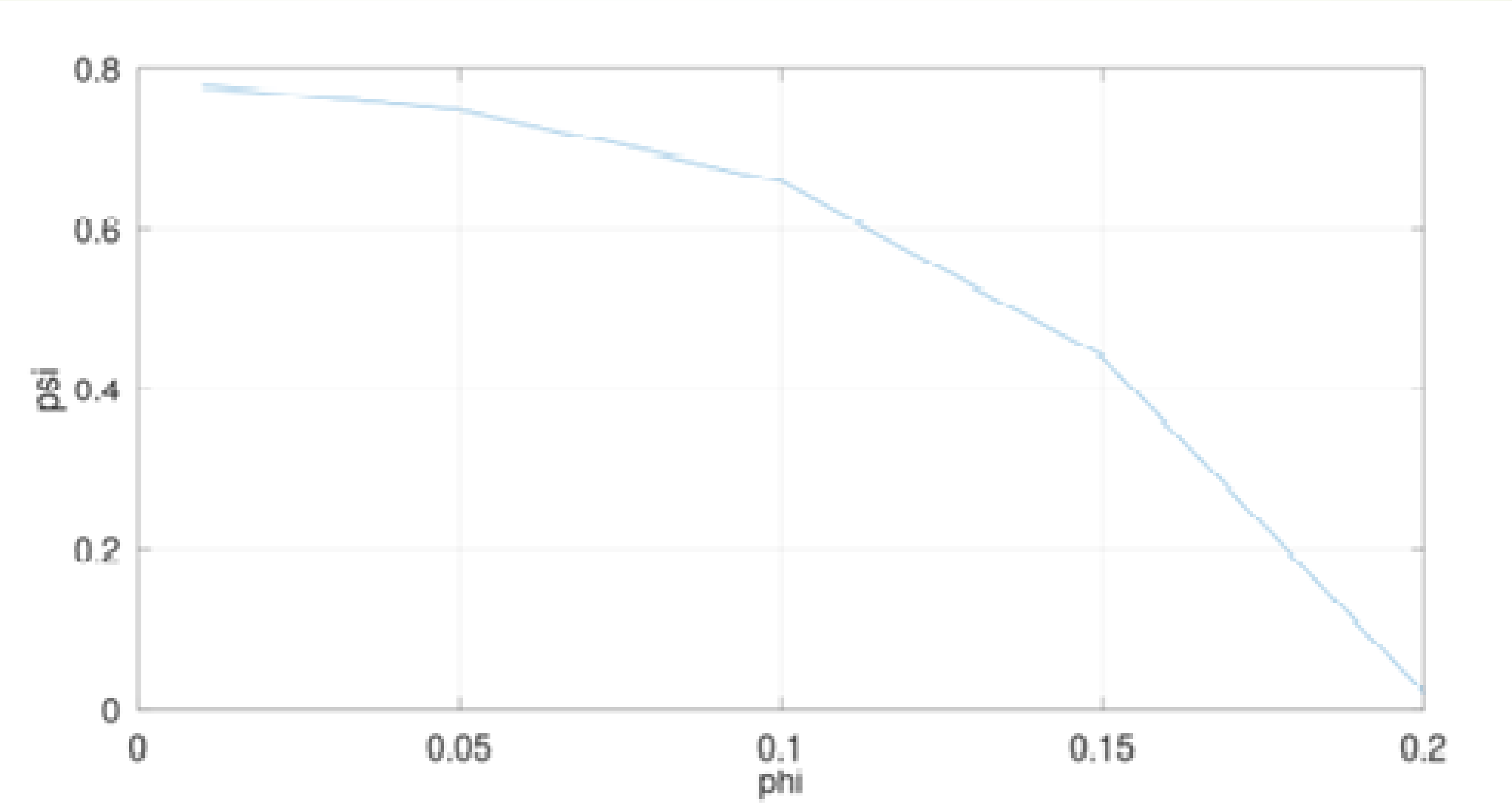
Axial gap overlap ls given by **Carolus Th**, :

- Blade shape backwards curved — $0\text{-}0.08\ D_1$
- Blade shape forward curved — Axial gap permissible up to 0.03 D2

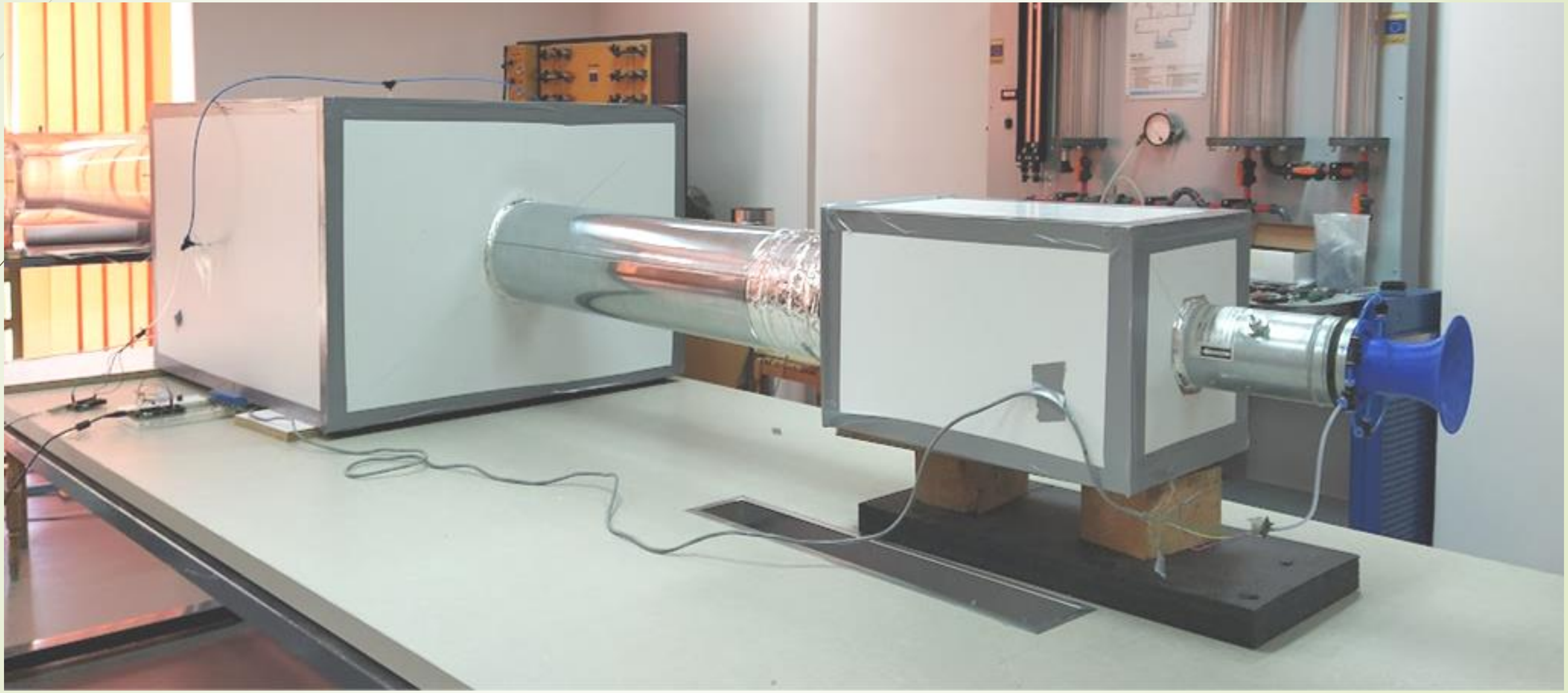
Non-dimensional parameters

Designation	Definition
Volume flow rate coefficient	$\phi = \frac{\dot{V}}{\frac{\pi^2}{4} \cdot D^3 \cdot n}$
Pressure rise coefficient	$\psi_t = \frac{Y_t}{\frac{\pi^2}{4} \cdot D^2 \cdot n^2}$
Power coefficient	$\lambda = \frac{P_s}{\left(\frac{\pi^4}{8}\right) \cdot \rho \cdot D^5 \cdot n^3}$
Specific speed	$\sigma = \frac{n}{(2 \cdot \pi^2)^{-\frac{1}{4}} \cdot Y_t^{\frac{3}{4}} \cdot \dot{V}^{-\frac{1}{2}}}$
Specific diameter	$\delta = \frac{D}{(8/\pi^2)^{\frac{1}{4}} \cdot Y_t^{-\frac{1}{4}} \cdot \dot{V}^{\frac{1}{2}}}$
Overall efficiency	$\eta = \frac{\dot{m}}{P_s} Y_t = \frac{\dot{V} \cdot \Delta p_t}{M_s \cdot 2\pi n}$

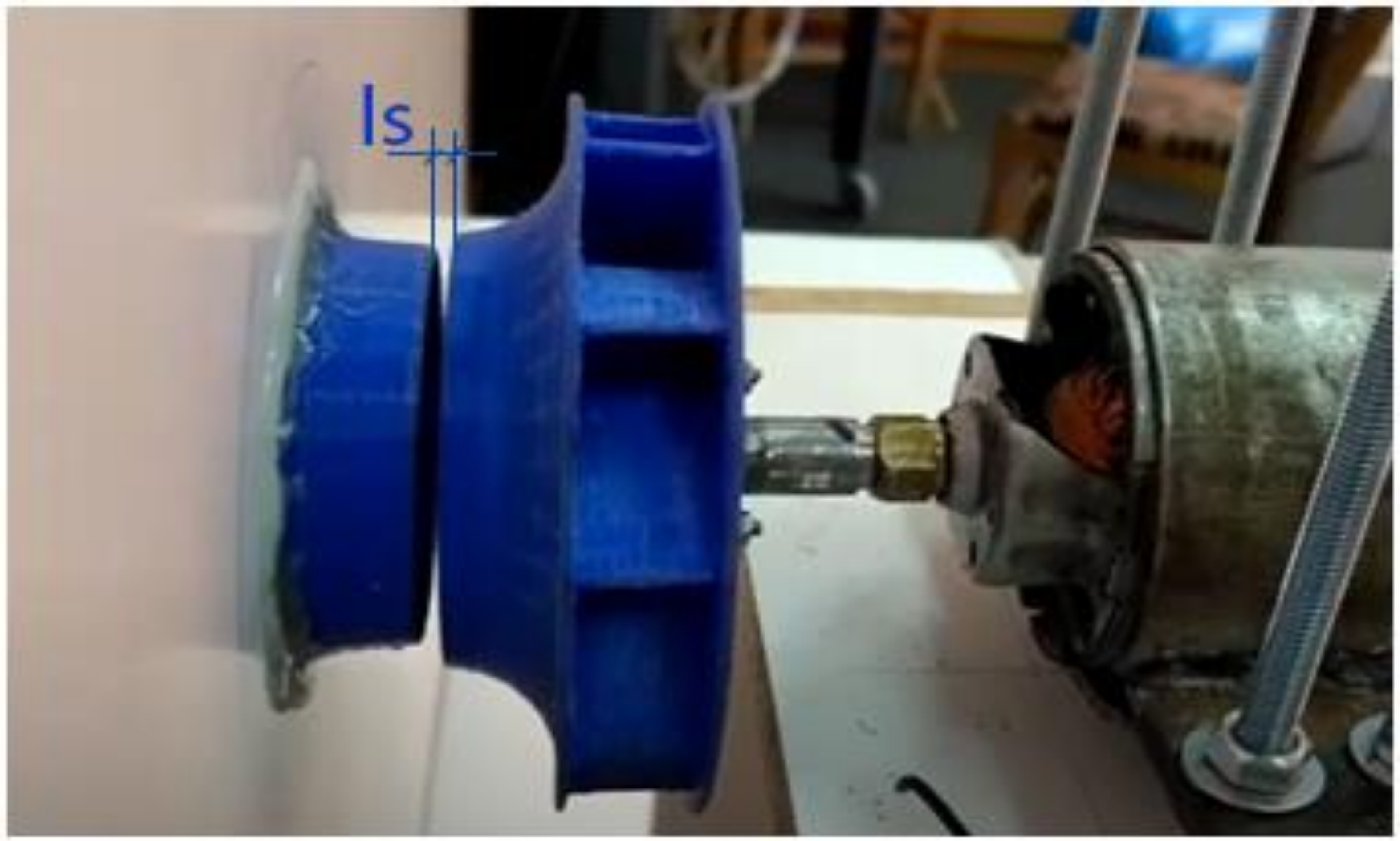
The dimensionless characteristic of the fan LR V3.1 CMV pro 200 $(\varphi = f(\phi))$



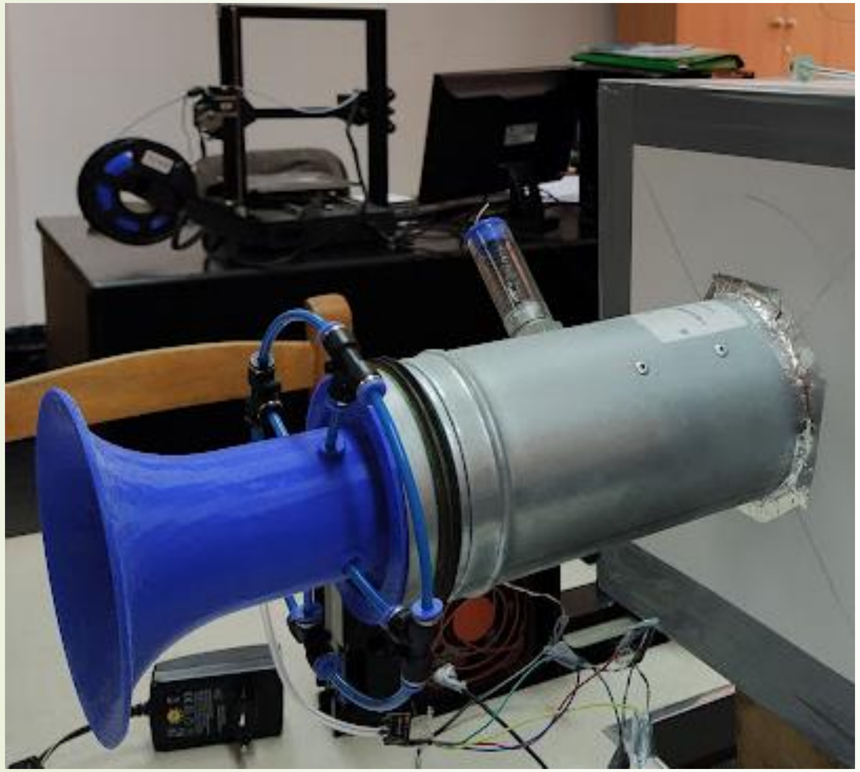
Fan characteristic testing device. Laboratory of thermofluidic machines PUT



The fan in the test device. Gap ls



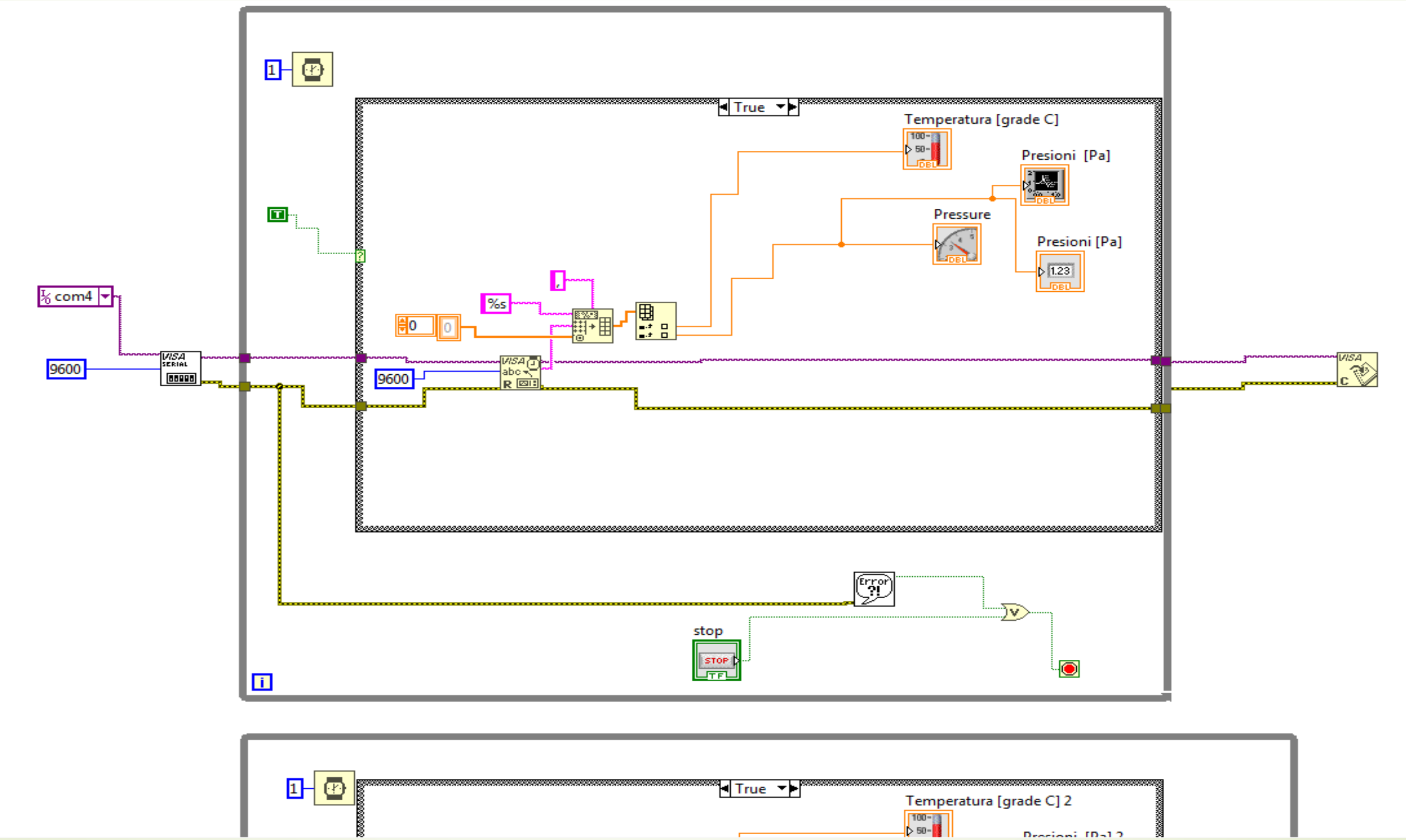
Flow rate valve located at the entrance of the experimental device



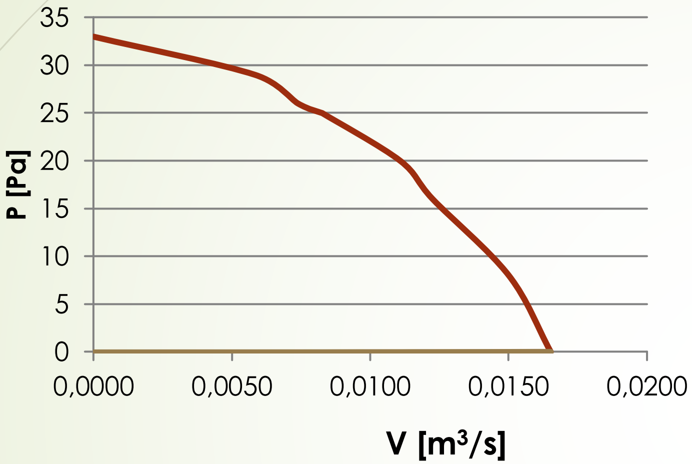
The grid, placed in the device to linearize the air flow before the measurement by the pressure sensor.

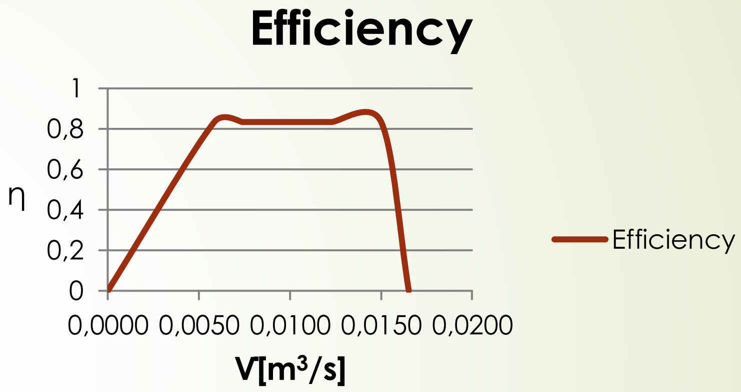
The arduino Uno programmable device and the sensor used for pressure measurement .

The program design in LabView for measuring pressure and flow



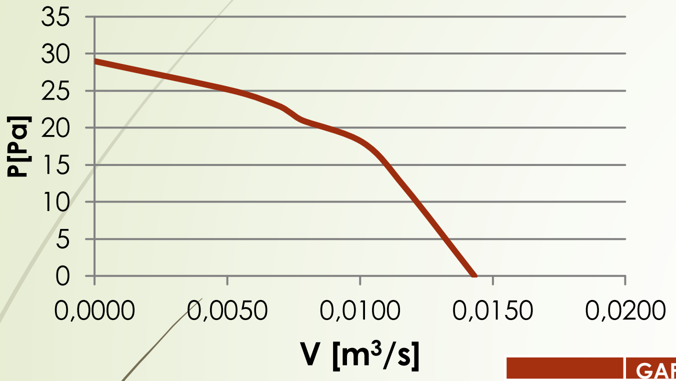
The results obtained for the value of the gap ls=0.25mm and impeller shaft speed 1337 rrot/min

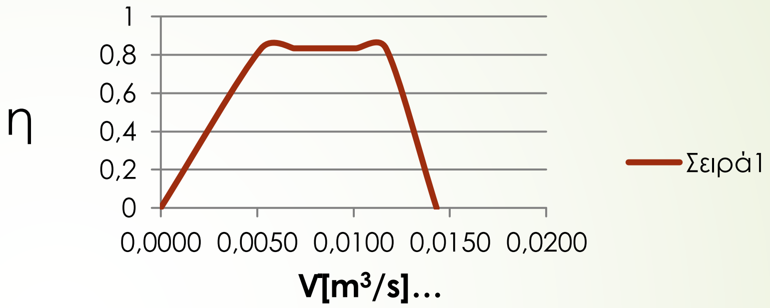




	GAP= 0.25 mm		1337 rot/min						
Opening %	P [Pa]	Axial Fan	Q[m3/s]	P [pa]	λ	k*Q^2	φ	ψ	Efficiency
	Nozzle			Box					
0%	0	OFF	0.0000	33	0	0.000000	0	3.85	#DIV/0!
10%	1	OFF	0.0026	31	0.2	0.000008	0.06	3.61	0.28
20%	4	OFF	0.0052	30	0.5	0.000033	0.11	3.50	0.67
25%	5	OFF	0.0058	29	0.51	0.000041	0.13	3.38	0.83
50%	8	OFF	0.0074	26	0.58	0.000066	0.16	3.03	0.83
75%	10	OFF	0.0083	25	0.63	0.000082	0.18	2.91	0.83
100%	10	OFF	0.0083	25	0.63	0.000082	0.18	2.91	0.83
100%	18	ON (I)	0.0111	20	0.67	0.000147	0.24	2.33	0.83
100%	22	ON (II)	0.0123	16	0.59	0.000180	0.27	1.86	0.83
100%	25	ON (III)	0.0131	14	0.55	0.000205	0.28	1.63	0.78
100%	29	ON (IV)	0.0141	10	0.43	0.000238	0.30	1.17	0.65
100%	33	ON (V)	0.0150	8	0.36	0.000270	0.32	0.93	0.26
100%	40	ON (VI)	0.0165	0	0	0.000328	0.36	0.000	#DIV/0!

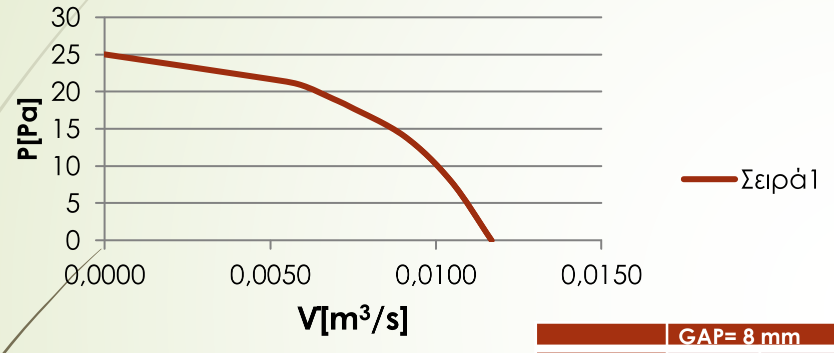
The results obtained for the value of the gap ls=2,5mm and impeller shaft speed 1337 rrot/min

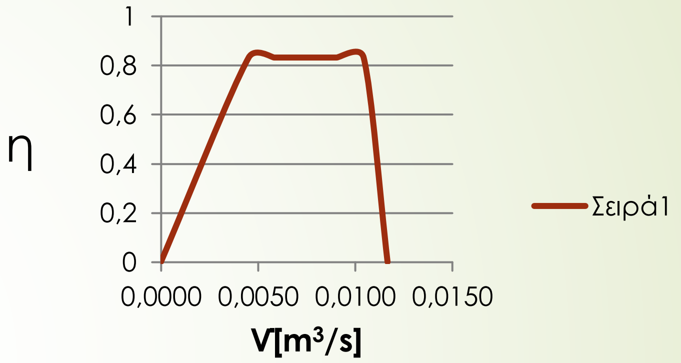




	GAP= 2.5 mm		1337 rot/min						
Opening %	P [Pa] Nozzle	Axial Fan	Q[m3/s]	P [pa] Box	λ	k*Q^2	φ	ψ	Efficiency
0%	0	OFF	0.0000	29	0	0	0	3.38	#DIV/0!
10%	1	OFF	0.0026	28	0.2	0.000008	0.06	3.26	0.524
20%	2	OFF	0.0037	27	0.3	0.000016	0.08	3.15	0.675
25%	4	OFF	0.0052	25	0.40	0.000033	0.11	2.91	0.833
50%	7	OFF	0.0069	23	0.48	0.000057	0.15	2.68	0.833
75%	8	OFF	0.0074	22	0.49	0.000066	0.16	2.56	0.833
100%	9	OFF	0.0078	21	0.50	0.000074	0.17	2.45	0.833
100%	15	ON (I)	0.0101	18	0.55	0.000123	0.22	2.10	0.833
100%	19	ON (II)	0.0114	17	0.59	0.000156	0.25	1.98	0.833
100%	21	ON (III)	0.0120	12	0.43	0.000172	0.26	1.40	0.712
100%	28	ON (IV)	0.0138	6	0.25	0.000229	0.30	0.70	0.270
100%	30	ON (V)	0.0143	0	0	0.000246	0.31	0	#DIV/0!

The results obtained for the value of the gap ls=8mm and impeller shaft speed 1337 rrot/min

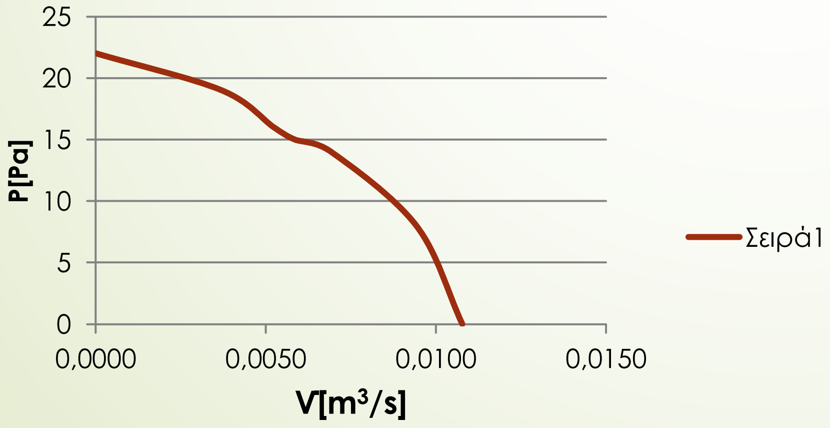


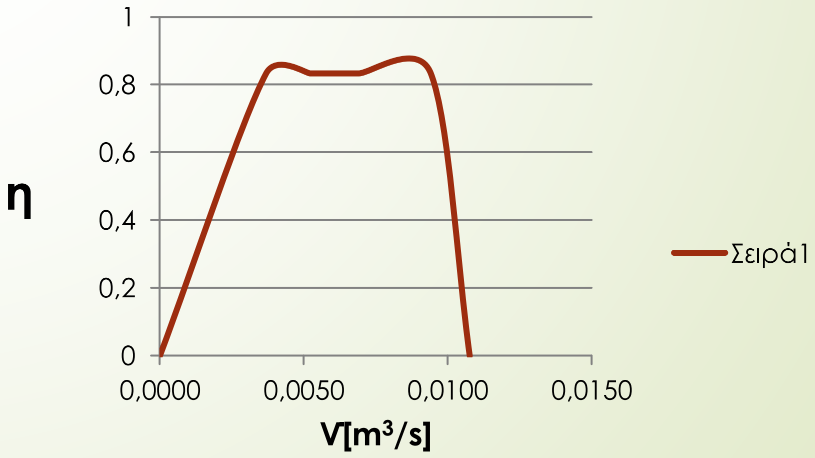


	GAP= 8 mm		1337 rot/min						
Opening %	P [Pa]	Axial Fan	Q[m3/s]	P [pa]	λ	k*Q^2	φ	ψ	Efficiency
	Nozzle			Box					
0%	0	OFF	0.0000	25	0	0	0	2.91	#DIV/0!
10%	0.5	OFF	0.0018	24	0.1	0.000004	0.04	2.80	0.22
20%	2	OFF	0.0037	23	0.3	0.000016	0.08	2.68	0.71
25%	3	OFF	0.0045	22	0.30	0.000025	0.10	2.56	0.83
50%	5	OFF	0.0058	21	0.37	0.000041	0.13	2.45	0.83
75%	7	OFF	0.0069	19	0.40	0.000057	0.15	2.21	0.83
100%	8	OFF	0.0074	18	0.40	0.000066	0.16	2.10	0.83
100%	12	ON (I)	0.0091	14	0.38	0.000098	0.20	1.63	0.83
100%	16	ON (II)	0.0105	8	0.25	0.000131	0.23	0.93	0.83
100%	17	ON (III)	0.0108	6	0.20	0.000139	0.23	0.70	0.74
100%	18	ON (VI)	0.0111	4	0.13	0.000147	0.24	0.47	0.30
100%	20	ON (V)	0.0117	0	0	0.000164	0.25	0	#DIV/0!

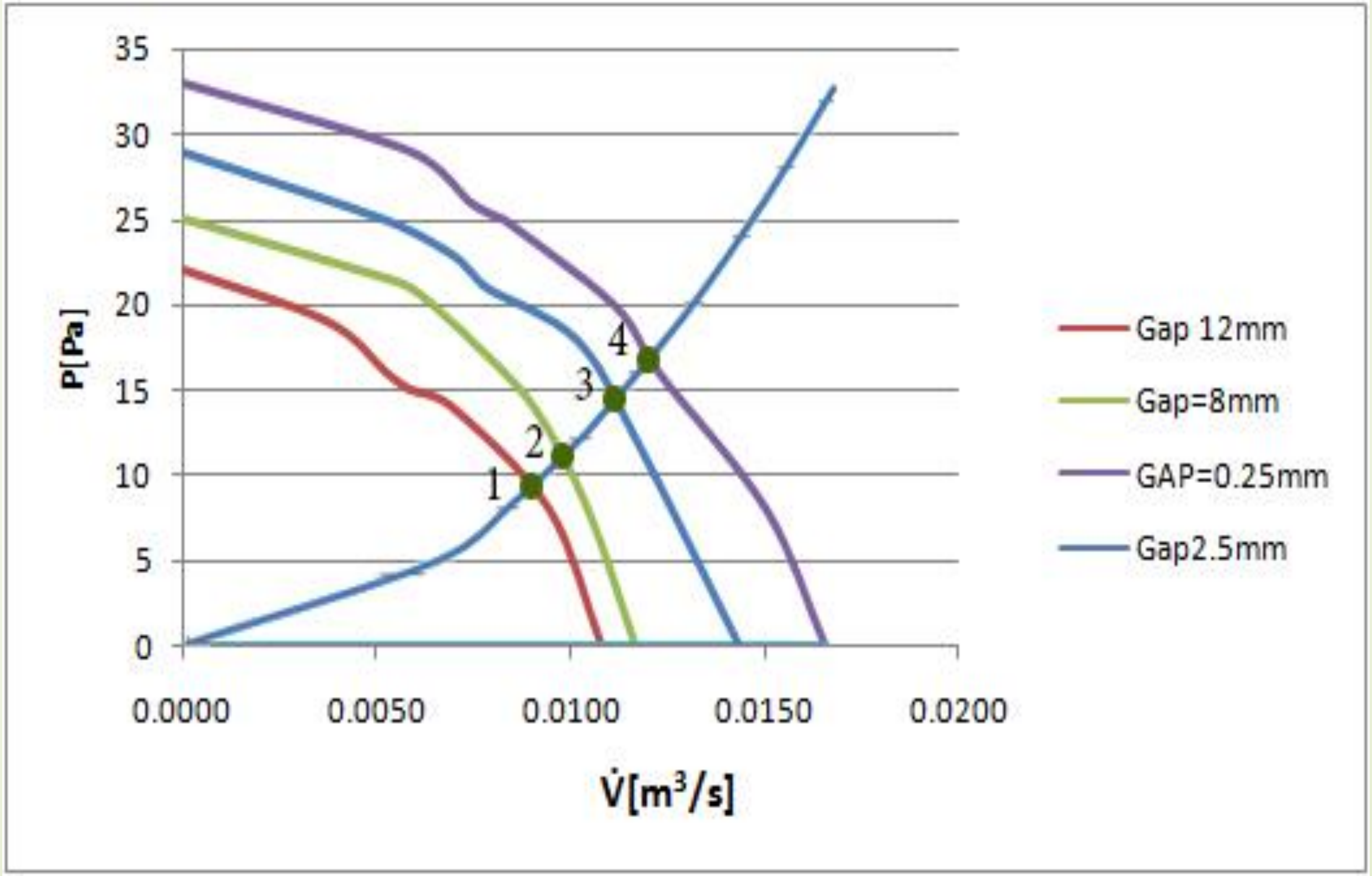
The results obtained for the value of the gap ls=12mm and impeller shaft speed 1337 rrot/min

	GAP= 12 mm		1337 rot/min						
Opening %	P [Pa] Nozzle	Axial Fan	Q[m3/s]	P [pa] Box	λ	k*Q^2	φ	ψ	Efficiency
0%	0	OFF	0.0000	22	0	0	0	2.56	#DIV/0!
10%	0.5	OFF	0.0018	21	0.1	0.000004	0.04	2.45	0.35
20%	1	OFF	0.0026	20	0.2	0.000008	0.06	2.33	0.58
25%	2	OFF	0.0037	19	0.21	0.000016	0.08	2.21	0.833
50%	4	OFF	0.0052	16	0.25	0.000033	0.11	1.86	0.833
75%	5	OFF	0.0058	15	0.27	0.000041	0.13	1.75	0.833
100%	7	OFF	0.0069	14	0.29	0.000057	0.15	1.63	0.833
100%	13	ON (I)	0.0094	8	0.23	0.000107	0.20	0.93	0.833
100%	14	ON (II)	0.0098	6	0.18	0.000115	0.21	0.70	0.710
100%	15	ON (III)	0.0101	4	0.12	0.000123	0.22	0.47	0.520
100%	17	ON (VI)	0.0108	0	0	0.000139	0.23	0	#DIV/0!

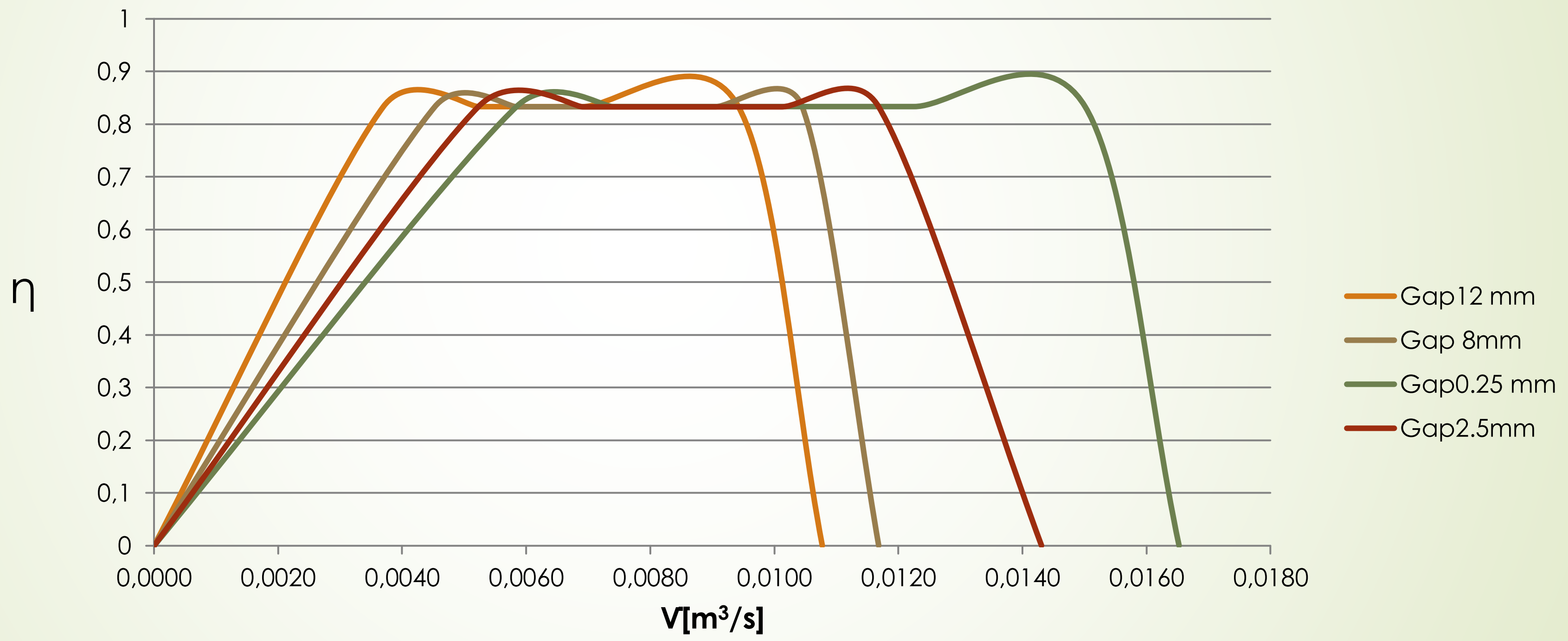




The characteristic's of the fan for the diferent value of gap



Overlay of graphs of fan's efficiency for different gap values 0.25mm, 2.5mm, 8 mm dhe 12 mm.



Conclusions

1. if the value of ls is within the recommended values , the maximum value of efficiency is almost constant.
2. The operating point of the system with the increase of the gap ls moves to the lower left in the direction of decreasing the flow and pressure of the fan. So, from ls 0.25 mm to ls = 8 mm. The pressure and flow of the fan will decrease respectively working point (from point 4 to point 1) this will be accompanied by a decrease in the efficiency of the fan.
3. For increased values of the gap, outside the recommended values, the maximum value of the efficiency remains almost constant , but the working area with maximum efficiency is significantly reduced. Thus, for a gap value of 0.25 mm, the working area with maximum efficiency is in the range of 0.0050 m3/s to 0.0155 m^3/s, while for a gap value of 12 mm, the working area with maximum efficiency is in the range of 0. 0040 m^3/s to 0.0011 m^3/s, so it decreases by about 9% .

Thank you for staying awake for those who managed it ☺