Howden Netherlands

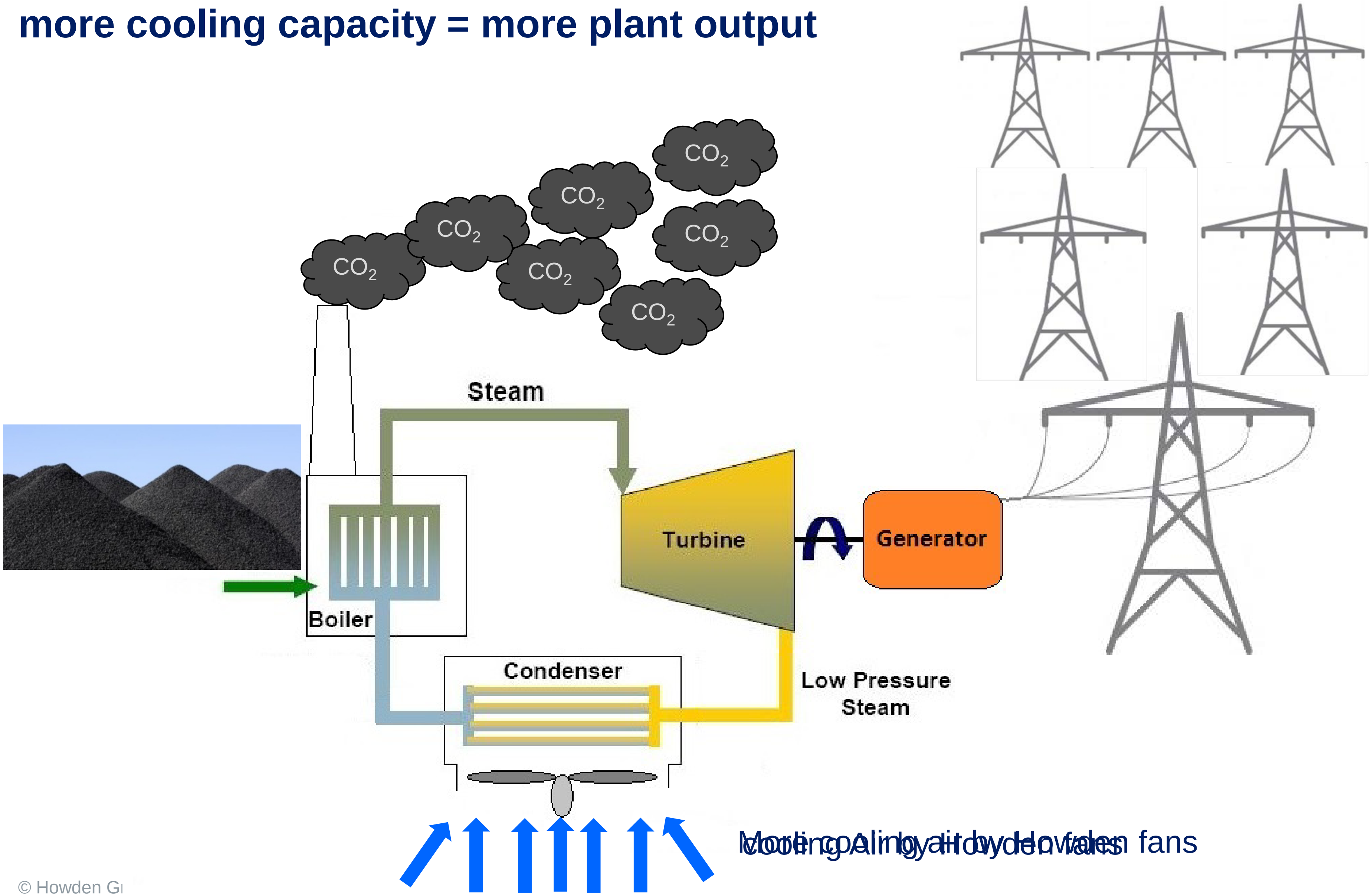
A closer look to air side condenser performance

Revolving Around You

Air side condenser performance

Cooling capacity in relation to plant output

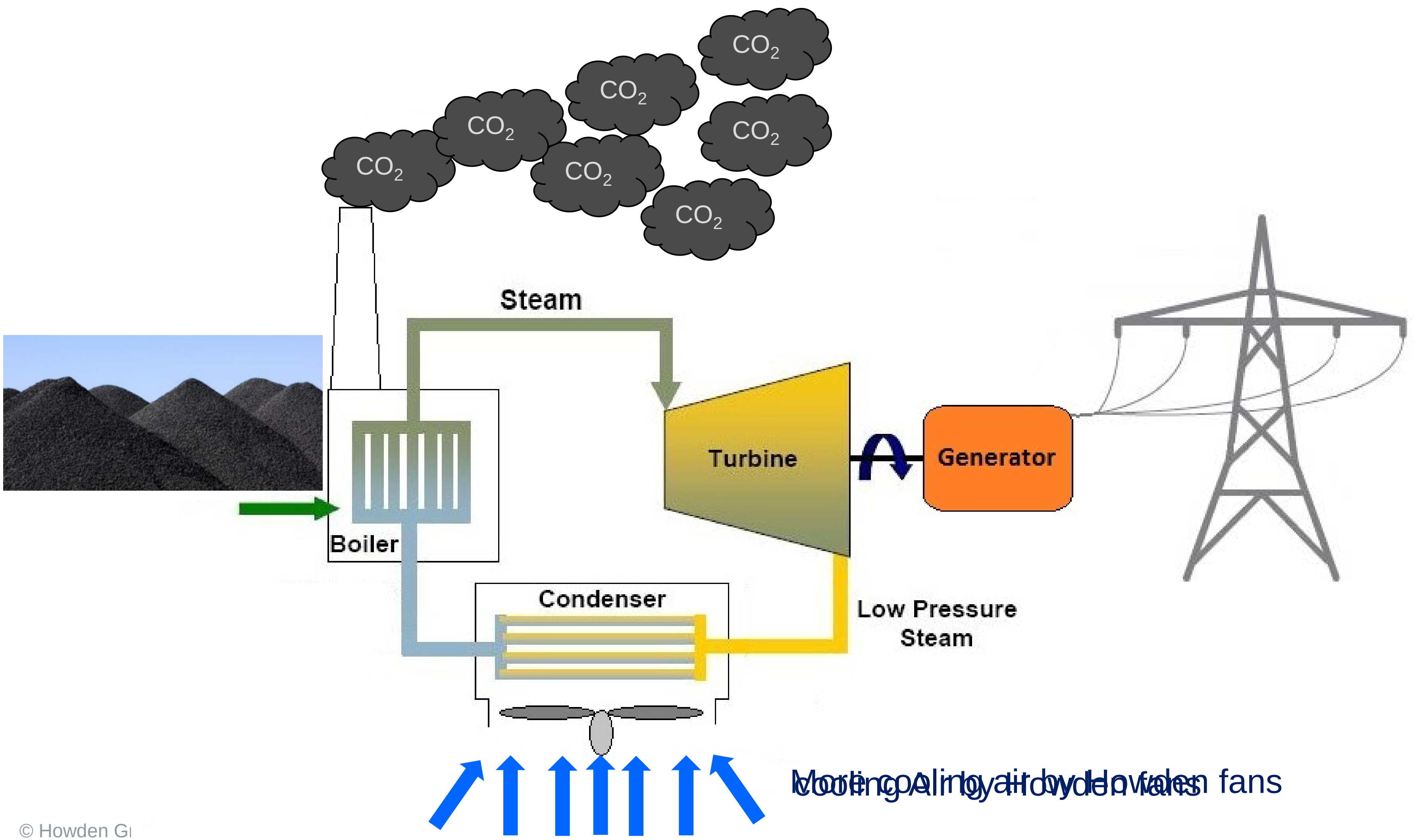
more cooling capacity = more plant output



Air side condenser performance

Cooling capacity in relation to cost reduction

more cooling capacity = more process efficiency = cost reduction

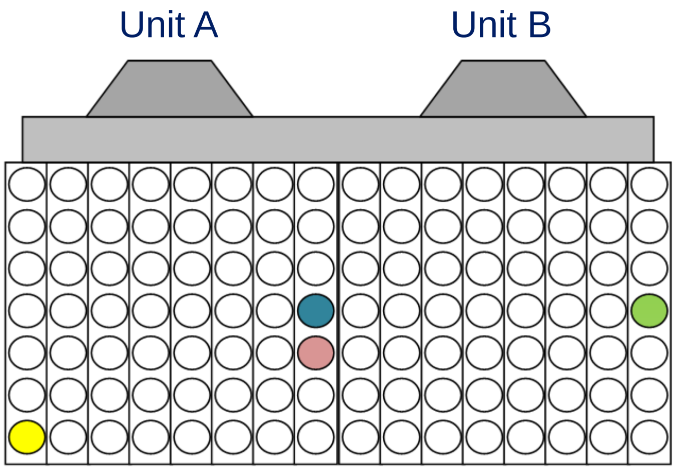


Air side condenser performance

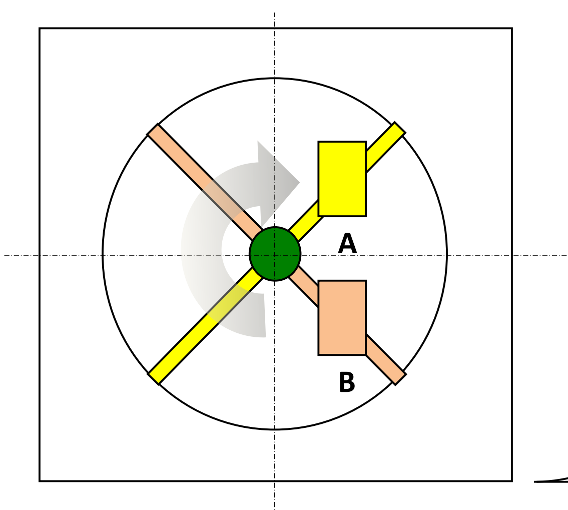
Site assessment

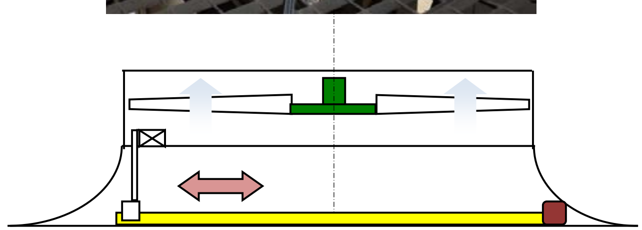
Air side condenser performance

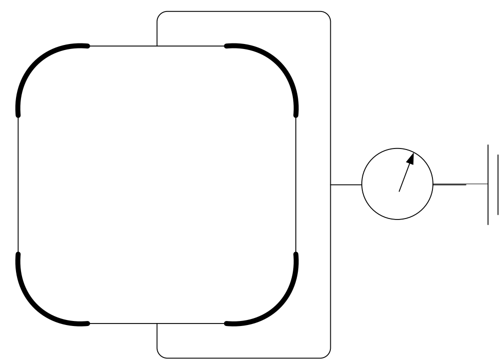
Site assessment: Volume, Pressure, Temperature – System resistance curve



Top view of ACC with measured fans.

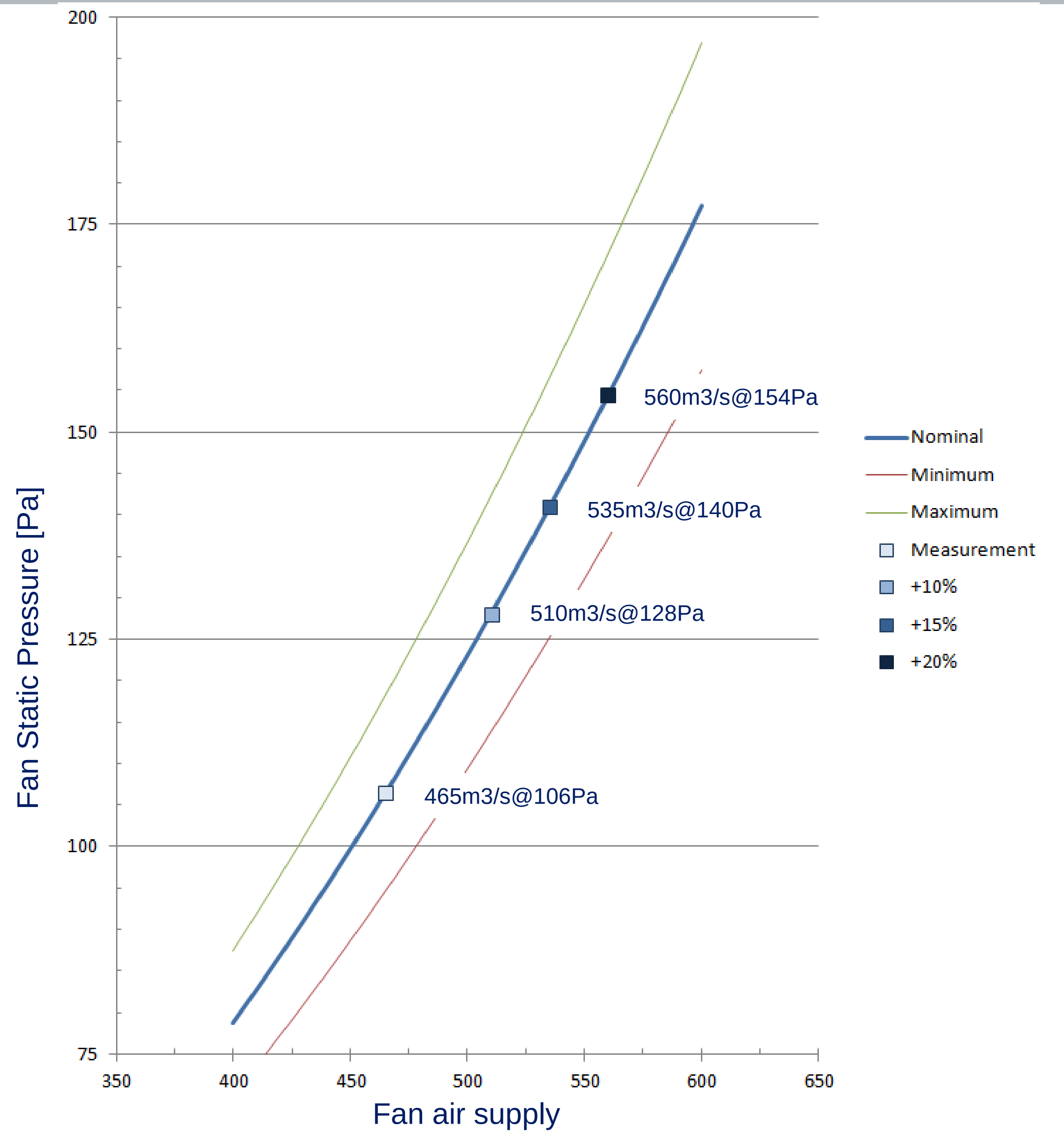






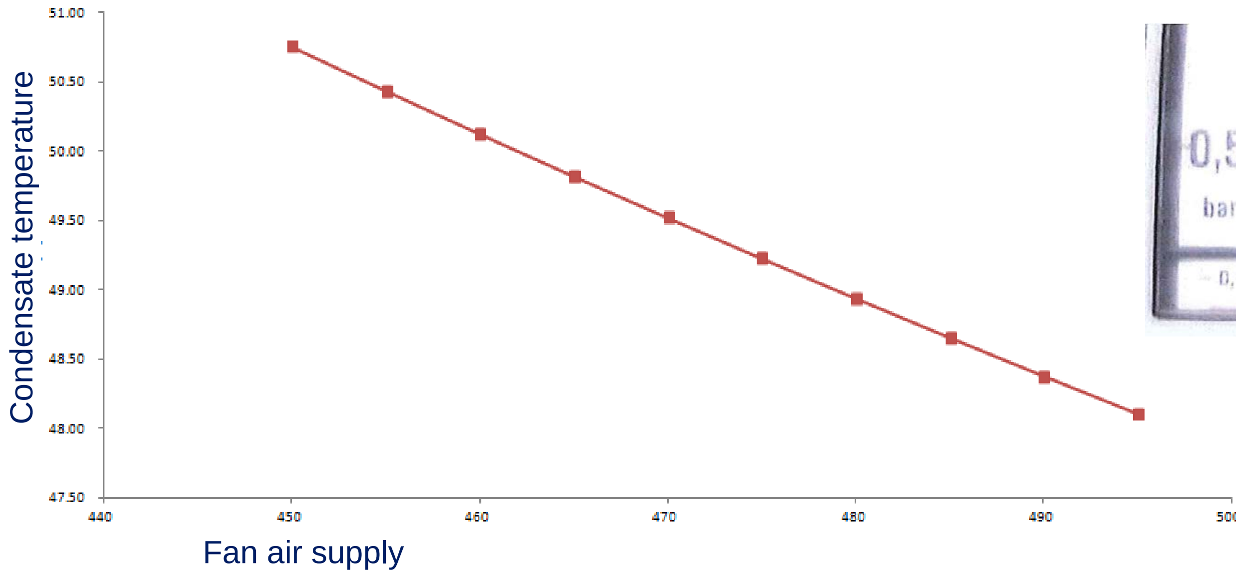
Air side condenser performance

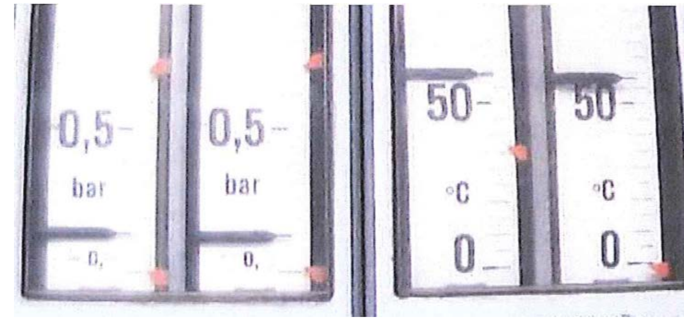
Increased air side performance

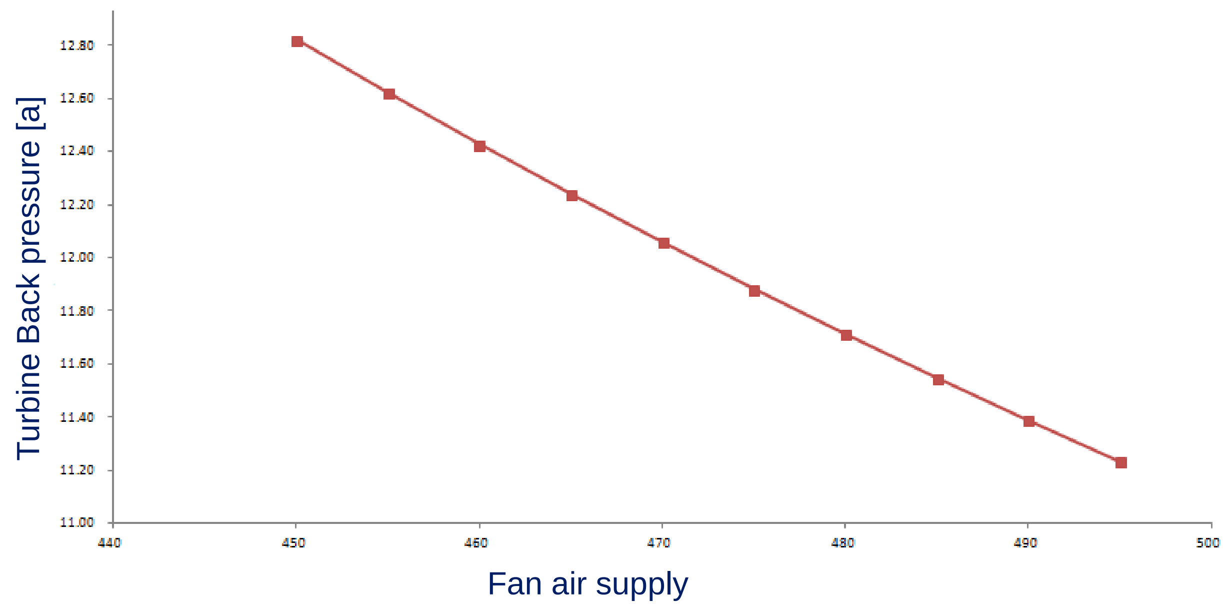


Air side condenser performance

Condensing data in relation to fan air supply

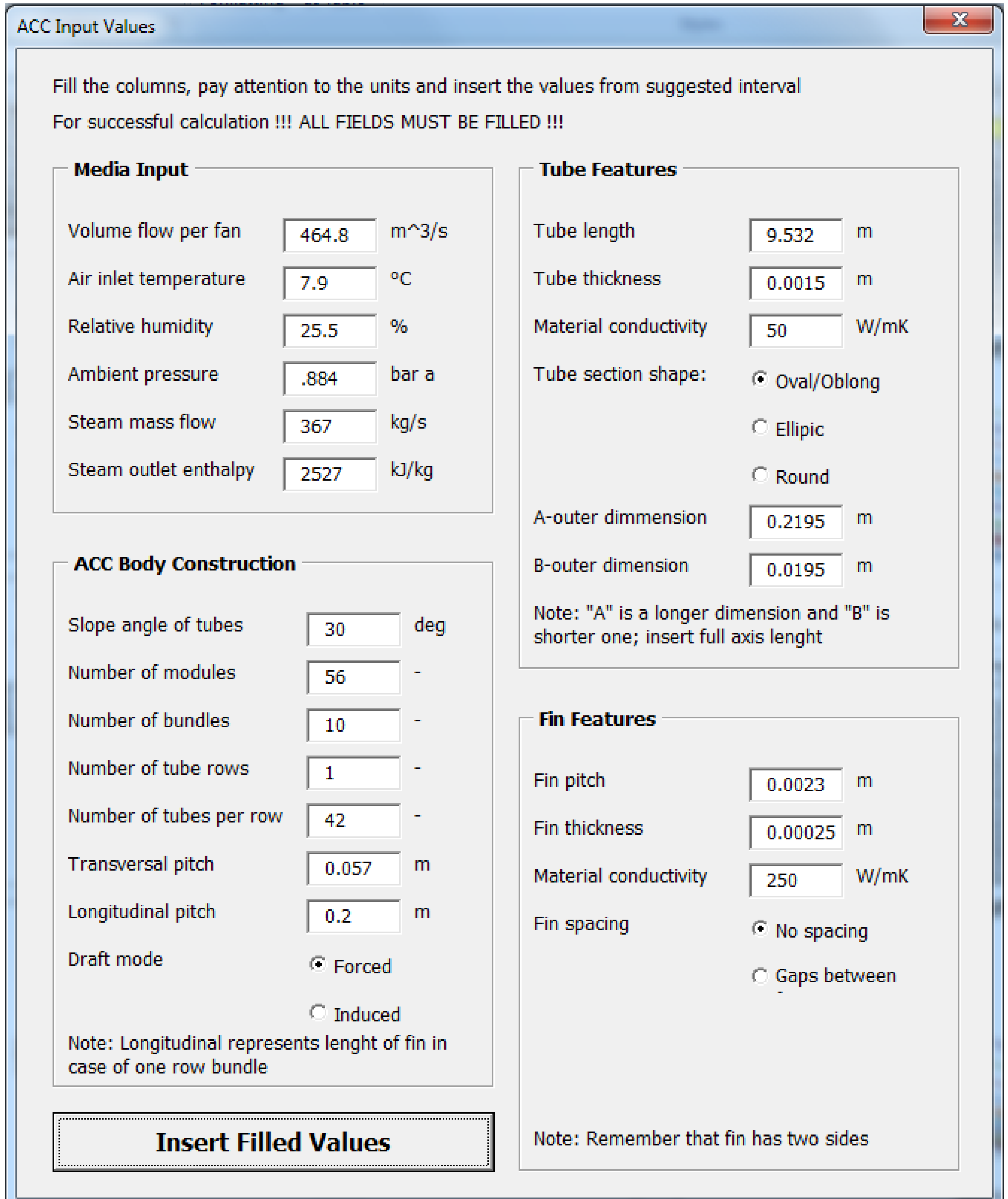






Air side condenser performance

Process data estimation



ACC Input Values

Fill the columns, pay attention to the units and insert the values from suggested interval

For successful calculation !!! ALL FIELDS MUST BE FILLED !!!

Media Input

Volume flow per fan	464.8	m^3/s
Air inlet temperature	7.9	°C
Relative humidity	25.5	%
Ambient pressure	.884	bar a
Steam mass flow	367	kg/s
Steam outlet enthalpy	2527	kJ/kg

ACC Body Construction

Slope angle of tubes	30	deg
Number of modules	56	-
Number of bundles	10	-
Number of tube rows	1	-
Number of tubes per row	42	-
Transversal pitch	0.057	m
Longitudinal pitch	0.2	m
Draft mode	(•) Forced / ( ) Induced	

Note: Longitudinal represents lenght of fin in case of one row bundle

Insert Filled Values

Tube Features

Tube length	9.532	m
Tube thickness	0.0015	m
Material conductivity	50	W/mK
Tube section shape:	(•) Oval/Oblong / ( ) Ellipic / ( ) Round	
A-outer dimmension	0.2195	m
B-outer dimension	0.0195	m

Note: "A" is a longer dimension and "B" is shorter one; insert full axis lenght

Fin Features

Fin pitch	0.0023	m
Fin thickness	0.00025	m
Material conductivity	250	W/mK
Fin spacing	(•) No spacing / ( ) Gaps between	

Note: Remember that fin has two sides

Air side condenser performance

Process data estimation

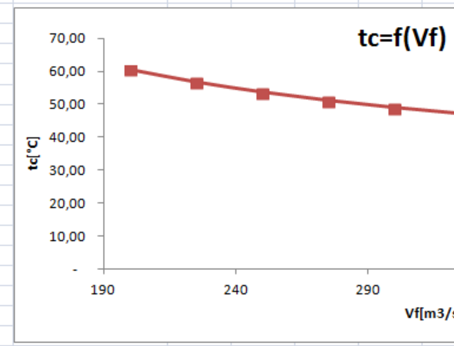
Stand_alone_version_V2-datong - Microsoft Excel

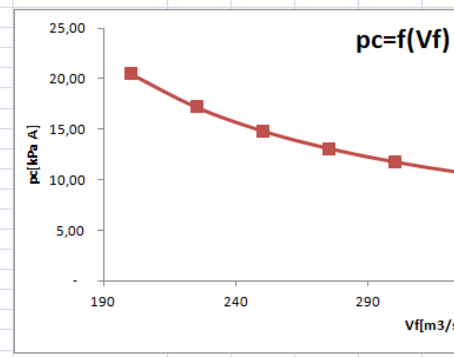
F133

	A	B	C	D
1		Cells legend		
2	Start		do not touch	
3			change by hand	
4			important cells	
5		xxx	must be equal	
6	**Input table overview**			
7	Media Input			
8	volume flow per fan	V f	m3/s	535,2
9	air inlet temperature	t ai	°C	7,4
10	relative humidity	φ	-	25,0
11	ambient pressure	p b	bar a	0,890
12	steam mass flow	m s	kg/s	367,000
13	steam outlet enthalpy	i s1	kJ/kg	2527,0
14	expected condensation temperature	t c	°C	40,388
15				
16	ACC Body Construction			
17	half of top point angle	θ	deg	30
18	modules	n m	-	64
19	bundles per module	n b	-	10
20	number of rows	n r	-	1
21	tubes per row in bundle	n t	-	42
22	transversal pitch	P t	m	0,057
23	longitudial pitch	P l	m	0,200
24				0,000
25	Tube Features			
26	tube length	l t	m	9,5
27	tube thickness	t t	m	0,002
28	tube thermal conductivity	k t	W/mK	50,0
29	A-outer characteristic dimension	a t	m	0,220
30	B-outer characteristic dimension	b t	m	0,020
31				
32	Fin Features			
33	Fin pitch	P f	m	0,00230
34	Fin thickness	t f	m	0,0003
35	Fin thermal conductivity	k f	W/mK	250,000
36	Fin area per fin pitch(without tf)	A fp	m2	0,015
37	Fin circumference	L fp	m	0,875
38				
39	Fan			
40	Forced/Induced Draft	D	-	1
41	Fan overall efficiency	η f	%	55
42				
43	Turbine			
44	Power output from turbine	E t	MW	290,000

	F	G	H	I
1	**Calculation**			
2	tube inner circumference	L ti	m	0,461
3	tube outer circumference	L to	m	0,452
4	tube inner section	A ti	m2	0,004
5	tube outer section	A to	m2	0,004
6	tube inner characteristic dimmension	d ri	m	0,030
7	tube outer characteristic dimmension	d ro	m	0,041
8	Fin characteristic dimension	d f	m	0,080
9	minimum free flow area per fin pitch	A afp	m2	7,688E-05
10	partial water vapor pressure	p v"	Pa	1029,8842
11	water in air	w	kg/kg	0,0018046
12	dry air density	ρ ai	kg/m3	1,1050369
13	wet air density	ρ awi	kg/m3	1,1038284
14	dry air inlet specific heat capacity	c pai	J/kgK	1006,4341
15	wet air specific heat capacity	c pawi	J/kgK	1007,9878
16	water vapor inlet specific heat capacity	c pvi	J/kgK	1868,9275
17	dry air dynamic viscosity	μ ai	Pa s	1,756E-05
18	wet air dynamic viscosity	μ awi	Pa s	1,755E-05
19	water vapor inlet dynamic viscosity	μ vi	Pa s	9,453E-06
20	dry air dynamic conductivity	k ai	W/mK	0,0247022
21	wet air dynamic conductivity	k awi	W/mK	0,0246844
22	water vapor inlet dynamic conductivity	k vi	W/mK	0,0175107
23	air mass flow	m a	kg/s	37812,203
24	wet inlet air Prandtl	Pr ai	-	0,7164969
25	mass velocity of air	G ai	kg/m2s	4,4153119
26	wet air inlet Reynolds	Re 1	-	10268,498
27	formula 5.5.1 Brigs+Young	h a1	W/m2K	31,651719
28	formula 49 Schmidt	h a2	W/m2K	28,139151
29	formula 50 VDI Heat atlas	h a3	W/m2K	34,858647
30	critical speed in the narrowest place	vc	m/s	3,9999983
31	vc+row effect coeficient	h nr	-	0,7982597
32	forced draft mode factor	h/h6	-	1,15
33	induced draft mode factor	h/h6	-	0,7
34	HTC air overall average	h ae	W/m2K	28,962711
35	air exposed area of condenser	A a	m2	1774187
36	rib area	A f	m2	1671001
37	tube inner area	A i	m2	118184,38
38	corresponding air mass flow over one hal	m at	kg/s	0,703352
39	condensate enthalpy	i c	kJ/kg	169,16279
40	condensate density	ρ c	kg/m3	992,18651
41	condensate thermal conductivity	k c	W/mK	0,6315699
42	condensate dynamic viscosity	μ c	Pa s	0,0006466
43	HTC on condensate side	h c	W/m2K	12331,691
44	ribbing efficiency	Ω	-	0,8961223

	K	L	M	N	O	P
1	Input table	1	2	3	4	
2	V f [m3/s]	200	225	250	275	3
3	m s [kg/s]	210	210	210	210	2
4	t c [°C]	60,65	56,87	53,80	51,24	49,0
5	p c [kPa A]	20,55	17,23	14,87	13,13	11,8
6	Δp S [Pa]	23,79	26,96	30,19	33,45	36,7
7	E f [MW]	0,433	0,552	0,686	0,836	1,0





Functions | Calculation | List of signs

Ready

Air side condenser performance

Process data

			Measurement
Nom. air flow per fan	Q_{air}	m^3/s	465
Nom. fan static pressure	p_{Static}	Pa	106
Fan shaft power	P_{Fan}	kW	82
Generated output	E_{turb}	MW	293
Steam mass flow per unit	$\dot{m}_{steam}$	kg/s	367
Condensing temperature	t_C	°C	49,9
Condensing pressure	t_p	bar a	0,123
Condensate enthalpy	h_c	kJ/kg	207,5
Turbine inlet enthalpy	h_{turb}	kJ/kg	3395
Required fuel energy	$\mathbf{E_{fuel}}$	**MJ/s**	**1170**

$E_{fuel} = (h_{turb} - h_c) \times \dot{m}_{steam}$

Air side condenser performance

Estimated savings when increasing airflow

			Measurement		+10%	
Nom. air flow per fan	Q_{air}	m^3/s	465	→	510	
Nom. fan static pressure	p_{Static}	Pa	106		128	
Fan shaft power	P_{Fan}	kW	82		108	
Generated output	E_{turb}	MW	293		293	
Steam mass flow per unit	$\dot{m}_{steam}$	kg/s	367		364,2	
Condensing temperature	t_C	°C	49.9		47	
Condensing pressure	t_p	bar a	0,123		0,103	
Condensate enthalpy	h_c	kJ/kg	207,5		195,6	
Turbine inlet enthalpy	h_{turb}	kJ/kg	3395		3395	
Required fuel energy	E_{fuel}	MJ/s	1170		1165,2	$E_{fuel} = (h_{turb} - h_c) \times \dot{m}_{steam}$
Saving	ΔE_{fuel}	MJ/day			407331	
Heat density coal		MJ/kg	25			
Coal saving per day	$\Delta Coal_{Cons}$	ton/day			**16,3**	$3{,}667 = \frac{44\text{ kg [1kgmol } CO_2]}{12\text{ kg [1kgmol C]}}$
Estimated carbon content	C_{coal}	%	70			
CO_2 saving per day	ΔCO_2	ton/day			**41,8**	$\Delta CO_2 = 3{,}667 \times \Delta Coal_{Cons} \times C_{coal}$

Air side condenser performance

Estimated savings when increasing airflow

			Measurement	+10%		+15%		+20%
Nom. air flow per fan	Q_{air}	m^3/s	465	510		535		560
Nom. fan static pressure	p_{Static}	Pa	106	128		140		154
Fan shaft power	P_{Fan}	kW	82	108		125		143
Generated output	E_{turb}	MW	293	293		293		293
Steam mass flow per unit	$\dot{m}_{steam}$	kg/s	367.0	364.2		362.7		361.9
Condensing temperature	t_C	°C	49.9	47		45.7		44.8
Condensing pressure	t_p	bar a	0.123	0.103		0.100		0.0949
Condensate enthalpy	h_c	kJ/kg	207.5	195.6		189.9		186.3
Turbine inlet enthalpy	h_{turb}	kJ/kg	3395	3395		3395		3395
Required fuel energy	E_{fuel}	MJ/s	1170.0	1165.2		1162.5		1161.2
Saving	ΔE_{fuel}	MJ/day		407331		644924		753895
Heat density coal		MJ/kg	25					
Coal saving per day	$\Delta Coal_{Cons}$	ton/day		16.3	→	25.8	→	30.2
Estimated carbon content		%	70					
CO2 saving per day	ΔCO_2	ton/day		41.8	→	66.2	→	77.4

Air side condenser performance

Estimated savings when increasing airflow

			Measurement	+10%	+15%	+20%
Nominal air flow per fan	Q_{air}	m^3/s	465	510	535	560
Required fuel energy	E_{fuel}	MJ/s	1170	1165,2	1162,5	1161,2
Saving	ΔE_{fuel}	MJ/day		407331	644924	753895
Heat density coal		MJ/kg	25			
Coal saving	$\Delta Coal_{Cons}$	ton/day		16,3	25,8	30,2
Price black coal / ton		RMB	400			
Saving in black coal/year		RMB		2.380.000	3.770.000	4.410.000
		Euro		332.000	526.000	616.000

Air side condenser performance

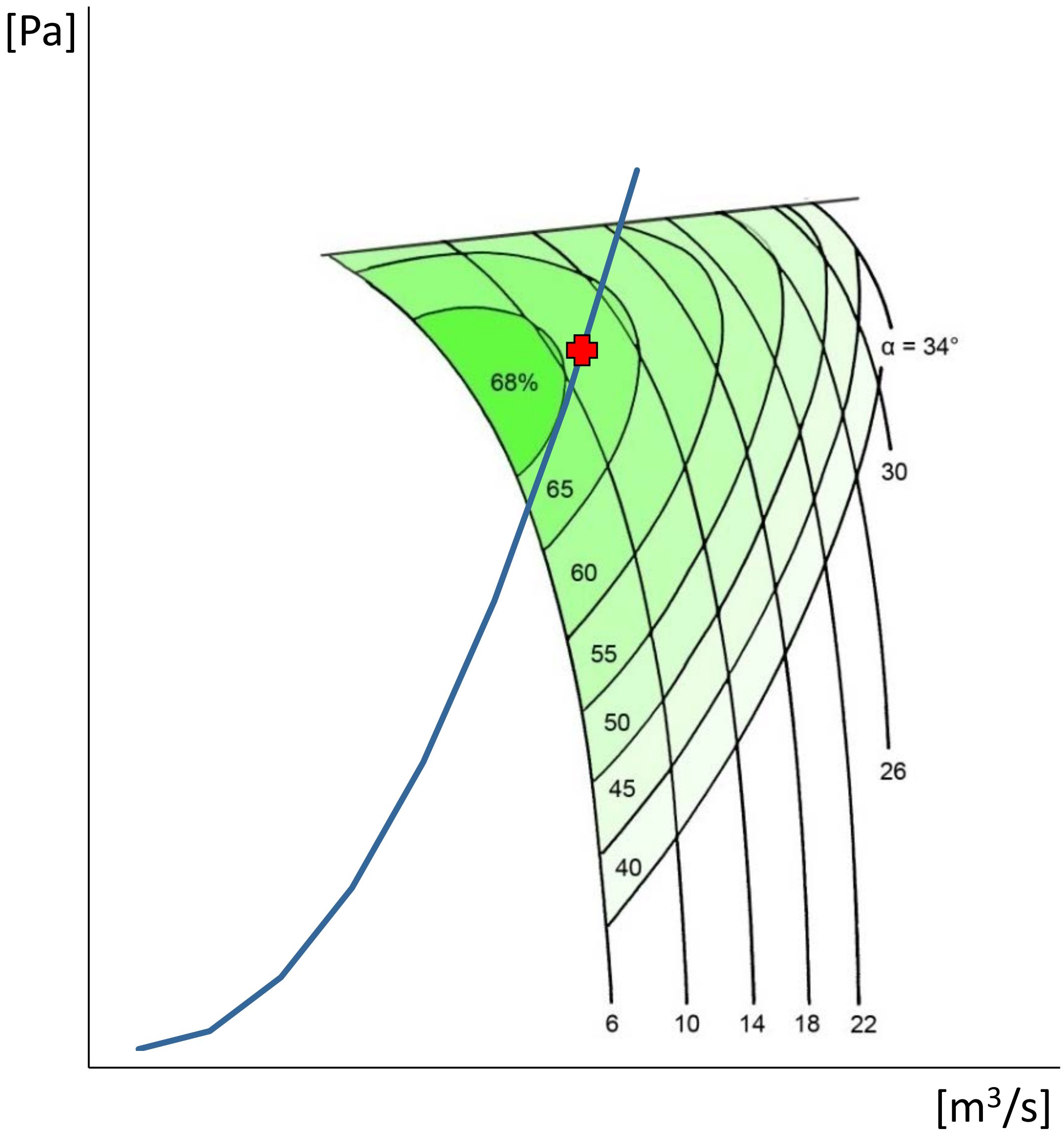
Estimated savings when increasing airflow

			Measurement	+10%	+15%	+20%
Nominal air flow per fan	Q_{air}	m^3/s	465	510	535	560
Coal saving per day	$\Delta Coal_{Cons}$	ton		16,3	25,8	30,2
Estimated carbon content	C_{coal}	%	70			
CO2 saving per day	ΔCO_2	ton/day		41,8	66,2	77,4
Costs CO2 emission per ton		RMB	25			
Saving in CO2 emission/year		RMB		382.000	604.000	706.000
		Euro		53.000	85.000	99.000

		+10%	+15%	+20%
Total savings/year	RMB	2.762.000	4.374.000	5.116.000
	Euro	385.000	611.000	715.000

Air side condenser performance

Increased air supply – Blade angle

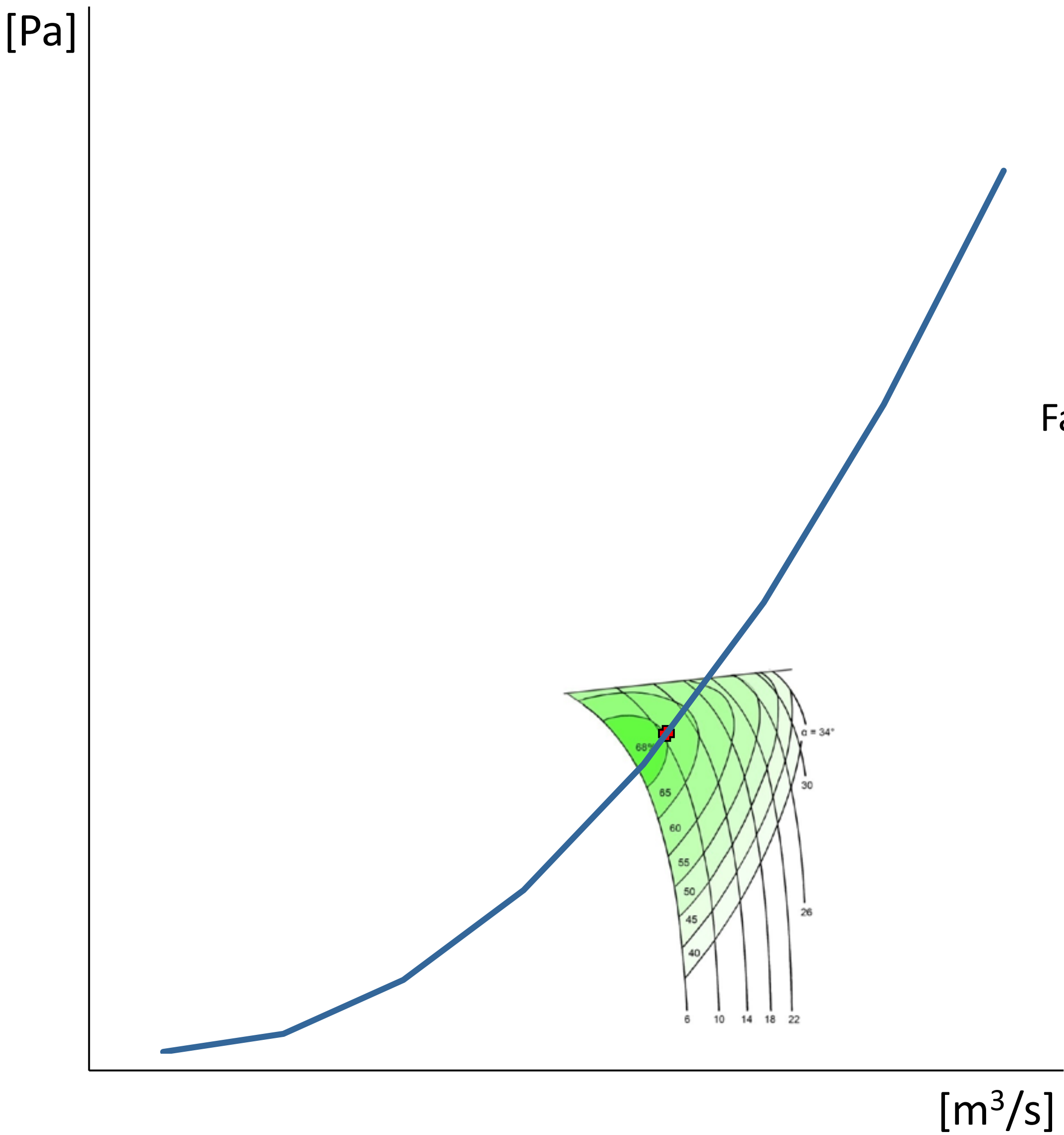


- Increased power consumption to compensate reduced efficiency.
- Increased risk of stall due to reduced pressure margin.

Air flow %	∆ PWL db(A)
120	2.4
115	1.8
110	1.2
105	0.6
100	0.0
95	-0.7
90	-1.4
85	-2.1

Air side condenser performance

Increased air supply – Higher fan speed



Air flow volume: $$\frac{Q_2}{Q_1} = \frac{n_2}{n_1}$$

Fan static pressure: $$\frac{p_2}{p_1} = \left(\frac{n_2}{n_1}\right)^2$$

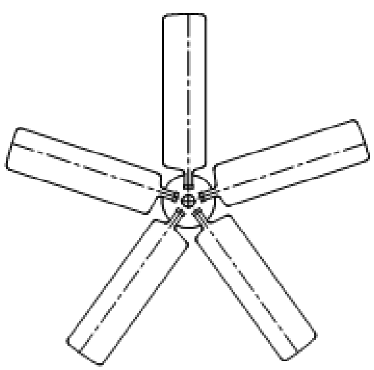
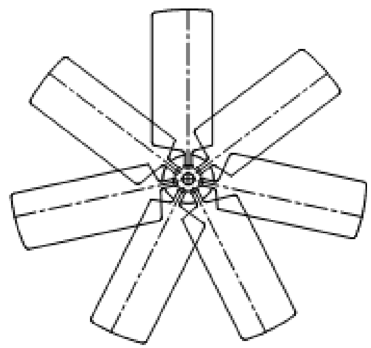
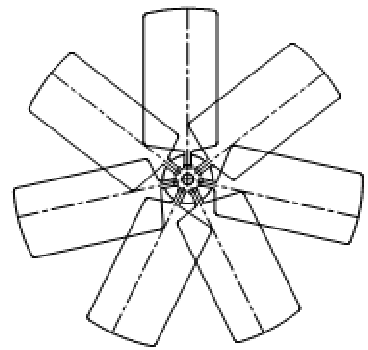
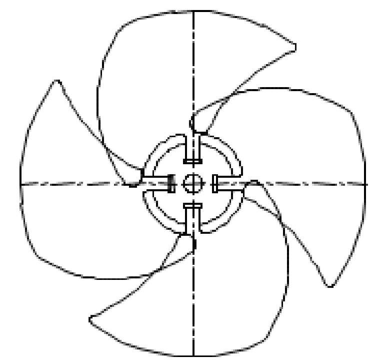
Absorbed power: $$\frac{P_{Fan2}}{P_{Fan1}} = \left(\frac{n_2}{n_1}\right)^3$$

Noise: $$\Delta PWL = 60 LOG\left(\frac{n_2}{n_1}\right)$$

Air side condenser performance

Increased air supply – Noise level

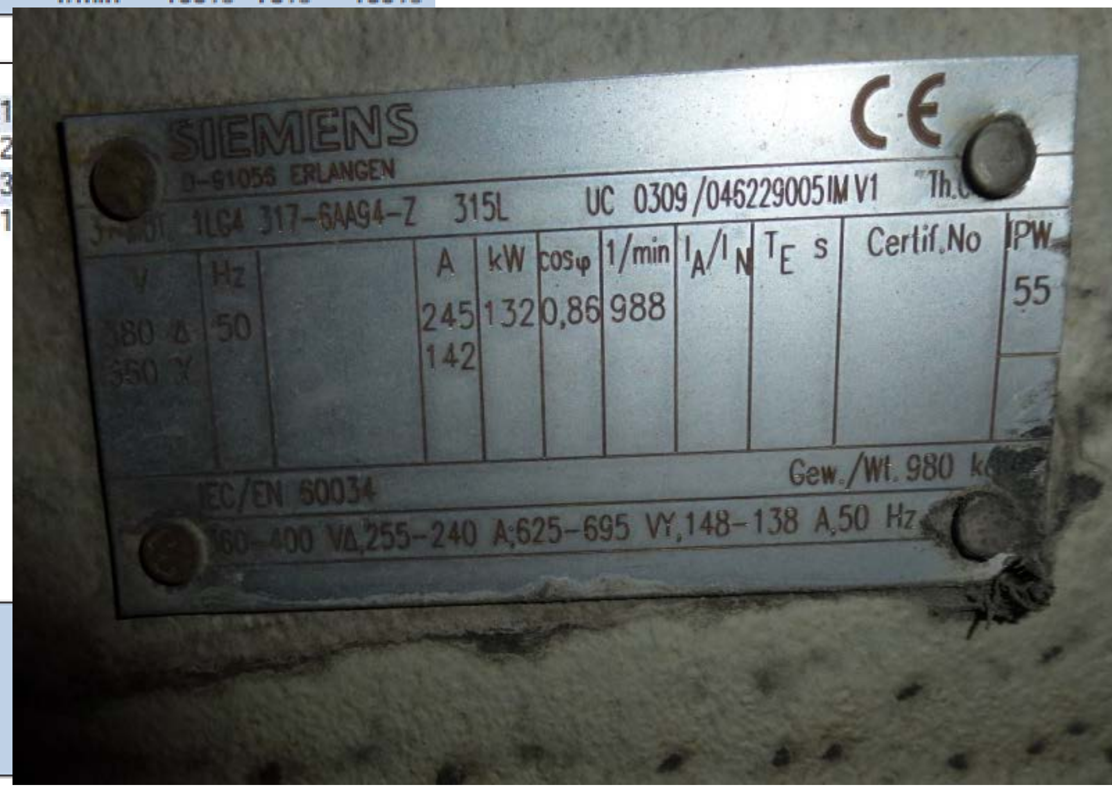
Basic formula: $$PWL_{Fan} = C + 30 LOG\, U_{Tip} + 10 LOG P_{Aero} - 5 LOG D_{Waaier} + \Delta dB$$

	ENF / DNF	ELF / DLF	ELFA / DVF	SX / FPX
Shape				
Noise Classification	 Standard	 Low-noise	 Very low-noise	 Ultra low-noise

Air side condenser performance

Retrofit – Extrapolating a new fan duty

Output kW	Motor type		Product code		Speed r/min	Efficiency Full load 100%	Efficiency 3/4 load 75%	Power factor cos φ 100%
1000 r/min = 6-poles								
75	M3BP	315 SMA	3GBP	313 21				
90	M3BP	315 SMB	3GBP	313 22				
110	M3BP	315 SMC	3GBP	313 23				
132	M3BP	315 MLA	3GBP	313 41				



Output kW	Motor type		Product code		Speed r/min	Efficiency Full load 100%	Efficiency 3/4 load 75%	Power factor cos φ 100%
1500 r/min = 4-poles					**400 V 50 Hz**			
110	M3BP	315 SMA	3GBP	312 210-••G	1487	95.6	95.4	0.86
132	M3BP	315 SMB	3GBP	312 220-••G	1487	95.8	95.7	0.86
160	M3BP	315 SMC	3GBP	312 230-••G	1487	96.0	95.9	0.85
200 [2]	M3BP	315 MLA	3GBP	312 410-••G	1486	96.2	96.2	0.86

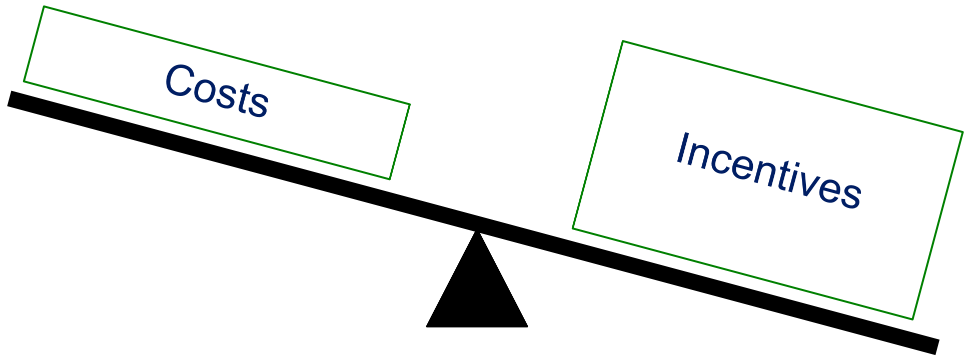
Air side condenser performance

Retrofit – Extrapolating a new fan duty

$$P = \frac{T \times n}{9550}$$

Air side condenser performance

Return On Investment



f.e. 20% improvement:	56 x 30ELF fans	RMB 6.500.000
	56 x 160kW E-Motor	RMB 2.800.000
	Installation costs	RMB 3.000.000
	Total costs	RMB 12.300.000

Savings per year: RMB 5.116.000 (Pay back time ≈ 2,5 years)

Air side condenser performance

Resume

Site assessment:
- knowledge of the actual air side performance
- reliable prediction of the improvement

Why increase air side performance?
- more plant output against same fuel consumption and CO_2 emission
- same plant output, but less fuel consumption and CO_2 emission

How increase air side performance?
- Blade angle
- Increase fan speed
- Increase motor power
- Replace fan
- and many combinations

Benefits
- Relative low investment
- Short pay back time
- Not only “end of life time replacement” but PROCESS IMPROVEMENT

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Time for questions

Revolving Around You