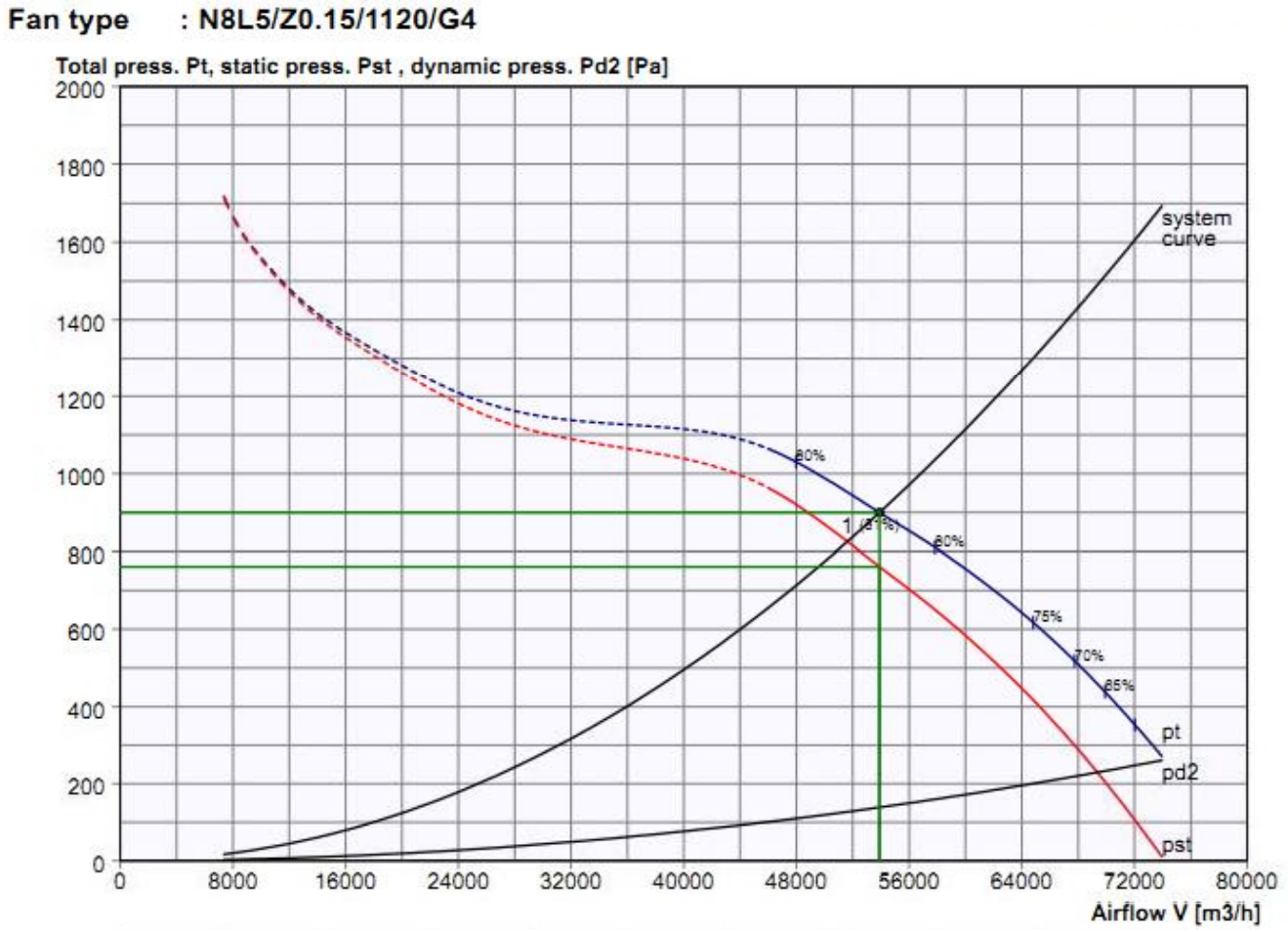
Maximum achievable fan motor efficiency taking into account application specific losses

(axial flow fans only)

Discussion paper

WITT & SOHN AG

Standard axial flow fan curve (15% Pd)



Source: ***Witt & Sohn AG*** analysis

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Application specific losses and compensation factors

Design specific losses	Delta Pd loss		Efficiency reduction*	Compensation factor**
Anti stall	15%	30%	2% - 4%	0,95 - 0,97
External shaft motor	40%	70%	6% - 10%	0,87 - 0,92
Externally cooled motor	20%	40%	3% - 5%	0,93 - 0,96
Free form fan blades	15%	40%	2% - 5%	0,93 - 0,97
Heavy duty design	15%	40%	2% - 6%	0,92 - 0,97
Increased air gap	20%	50%	3% - 7%	0,91 - 0,96
Large terminal box/ extra thick cables	15%	40%	2% - 5%	0,93 - 0,97
Light/ occasional dust load (> exclusion)	10%	60%	2% - 8%	0,89 - 0,97
Reverse flow (100%)	30%	50%	4% - 7%	0,91 - 0,95
Reverse flow (80%)	20%	40%	3% - 5%	0,93 - 0,96
Shock/ earth quake resistant	35%	60%	5% - 8%	0,89 - 0,93
Star- delta motor / 2 speed motor (cables)	10%	15%	1% - 2%	0,97 - 0,99
Temperature motor	15%	20%	2% - 3%	0,96 - 0,97
V-belt drive	35%	60%	5% - 8%	0,89 - 0,93
Swing out type/ Access door/ 2 part fan	10%	20%	2% - 3%	0,96 - 0,97
High pressure	40%	60%	6% - 8%	0,87 - 0,93
Decontaminable			1% - 3%	0,96 - 0,99
High pressure blower (high hub ratio)			2% - 6%	0,92 - 0,97
Shaft seals			2% - 3%	0,96 - 0,97
*Assuming 15% dynamic pressure at BEP				
**Assuming a 75% aerodynamic efficiency				

Source: ***Witt & Sohn AG*** analysis

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Efficiency reduction & compensation factors for different applications

Application	Efficiency red.	Comp. Factor	Application	Efficiency red.	Comp. Factor
Wind mill generator cooling	**11%**	**0,85**	**Military fan (bomb shelter)**	**15%**	**0,80**
- heavy duty design	4%		- schock/ earth quake resistant	8%	
- increased air gap	7%		- increased air gap	7%	
Mining fan/ steel mill	**14%**	**0,81**	**Smoke extract fans**	**12%**	**0,84**
- heavy duty design	4%		- increased air gap	5%	
- shaft seal	2%		- reverse flow	4%	
- V-belt drive	8%		- high temperature motor	3%	
Pulp & paper/ cement (small)	**10%**	**0,87**	**Pulp & paper/ cement (large)**	**13%**	**0,83**
- externally cooled motor	5%		- V-belt	8%	
- shaft seal	2%		- shaft seal	2%	
- heavy duty construction	2%		- heavy duty construction	2%	
- star/ delta motor (cables)	1%		- star/ delta motor (cables)	1%	
Wind tunnel	**12%**	**0,84**	**Atex blower (zone 1, infrequent gas)**	**13%**	**0,83**
- reverse flow	4%		- increased air gap	7%	
- externally cooled motor	5%		- heavy duty design	2%	
- free form fan blades	3%		- large terminal box	4%	
Nuclear	**11%**	**0,85**	**Fan with stand by motor (gas turbine)**	**10%**	**0,87**
- schock/ earth quake resistant	8%		- heavy duty design	2%	
- decontaminable	3%		- external shaft	8%	
Very cold climate ventilation fan	**13%**	**0,83**	**Food industry**	**14%**	**0,81**
- free form fan blades (- 50°C)	3%		- externally cooled motor	5%	
- reverse flow	5%		- shaft seal	2%	
- heavy duty design	2%		- increased air gap	3%	
- anti stall	3%		- high pressure (filters)	4%	

Source: ***Witt & Sohn AG*** analysis

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Minimum 10 % aerodynamic losses

Base aerodynamic losses inside the fan:

- friction on the walls of the fan,
- losses in the air gap,
- impulse loses on the blades and the hub,
- friction across the fan blade,
- friction across the motor
- impulse/ friction losses on the motor support
- friction losses from the cables from the motor
- losses from the rotational energy (perpendicular to the air stream)

IEC 60034-30 defines the minimum efficiency levels of the motors

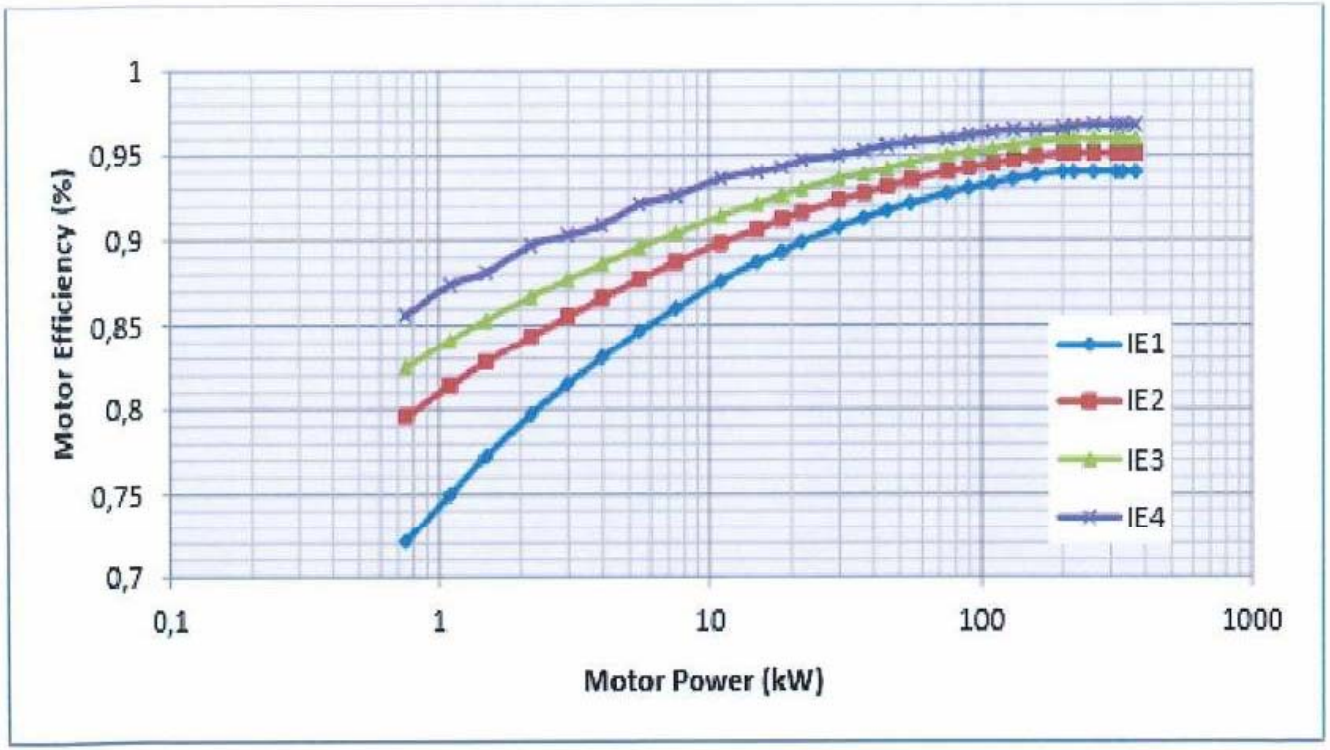
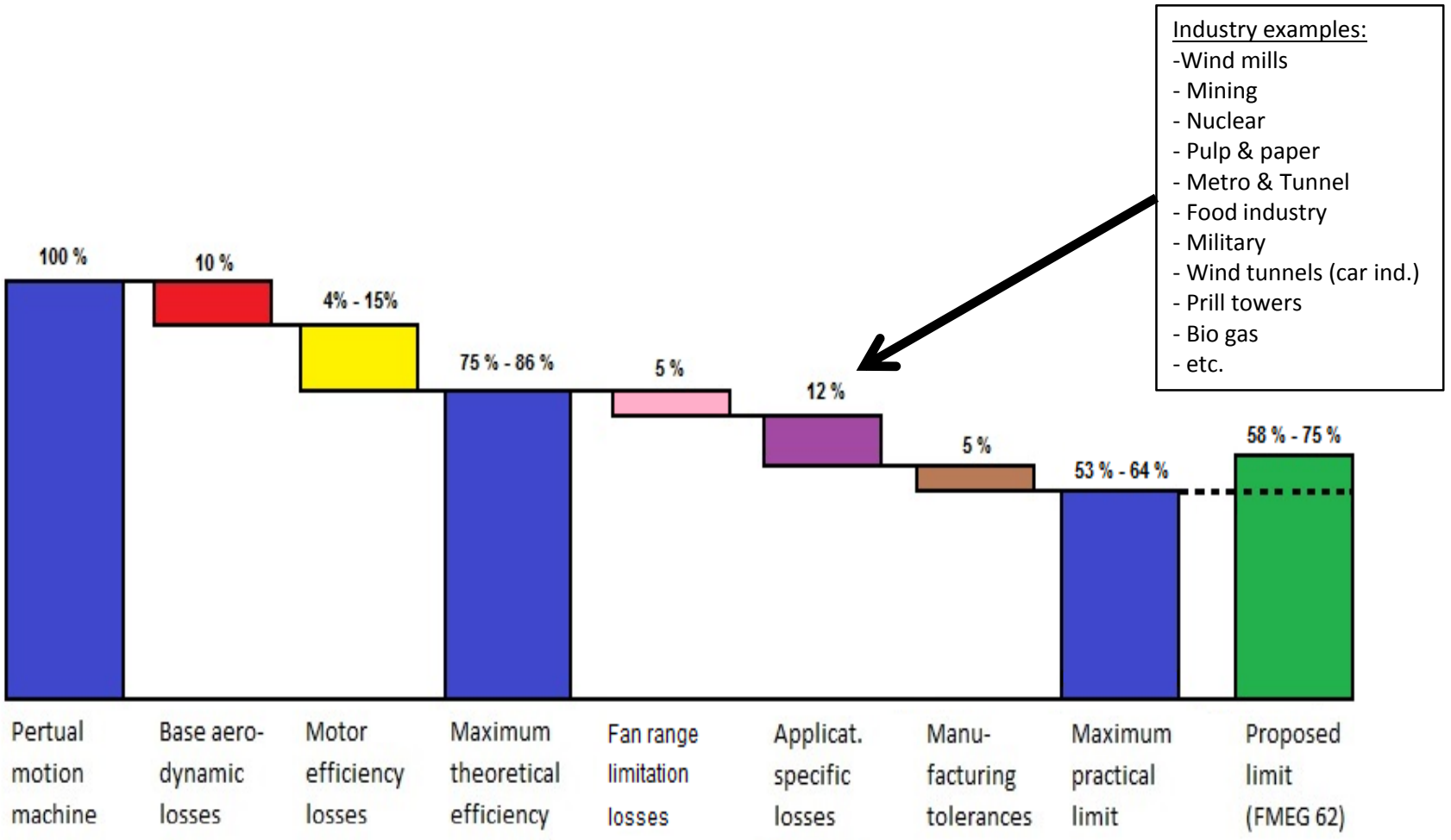


Figure 1-2. IE1, IE2 and IE3 efficiency levels in the IEC 60034-30 standard for 4 poled motors [6] and the new IE4 proposed in the IEC 60034-31 standard [12].

Source: IEC 60034-31

Cascade of losses for industrial axial flow fans (1 kW⁺)



Source: ***Witt & Sohn AG*** analysis

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Minimum 5% manufacturing tolerances must be recognized

Table 2 — Manufacturing tolerance grades

Parameter	Tolerance grade (air and noise) AN1	AN2	AN3	AN4	Additional information
Volume flow rate, q_V	± 1 %	± 2,5 %	± 5 %	± 10 %	$\Delta_{q_V} = t_{q_V} \cdot q_V$
Fan pressure p_F	± 1 %	± 2,5 %	± 5 %	± 10 %	$\Delta_{p_F} = t_{pF} \cdot p_F$
Power, P_r [a, b]	+ 2 %	+ 3 %	+ 8 %	+ 16 %	$\Delta_P = t_P \cdot P_r$ Negative deviations are permissible. For small fans, P, shall be the motor input power.
Efficiency, η	− 1 %	− 2 %	− 5 %	− 12 %	$\Delta_\eta = t_\eta$ i.e. the value of t_η is identical with the permissible tolerance of the efficiency. Positive deviations are permissible.
A-weighted sound power level, L_{WA} [c]	+ 2 dB	+ 3 dB	+ 4 dB	+ 6 dB	$\Delta_{L_{WA}} = t_{L_{WA}}$ The value of $t_{L_{WA}}$ is a permissible tolerance of the sound power level. Negative deviations are permissible.

NOTE Sound pressure levels are dependant on the environment. Tolerances will be higher due to wave length effects, local resonances, directional factors, room effects, etc. In particular, sound pressure levels measured close to fan casings are heavily influenced by "near-field" effects and, as such, great care should be taken when using sound pressure measurements. As a guide the tolerances, given above for sound power may have to be doubled.

[a] The power should be clearly defined: i.e. whether it is impeller power, shaft power (including bearing losses), overall fan power (including transmission losses, e.g. coupling or vee-belt drive losses), or motor input power (applicable especially to small fans). See also ISO 5801, ISO 13349 and IEC 60034-2.

[b] The power measurement of electric motors shall be carried out with a sinusoidal supply on nominal frequency and voltage. The voltage from frequency converters could give higher power values due to additional losses within the motor.

[c] The measuring uncertainty of octave or one-third octave band sound power levels increases significantly, while universal scaling rules are not accepted. (see 7.2.3.1). It is therefore recommended that tolerance band levels not be included in contractual terms.

Source: ISO 13448

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Commercial design constraints amount to at least 5 %

- Losses from specific fan designs
  - Only vane axial flow fans
  - No tube axial flow fans
  - No propeller flow fans
  - No allowances included for those type of fans

- Fans come with discrete
  - sizes,
  - fan speeds
  - blade angles
  - casing length
  - Motor sizes
  - Stall avoidance
  - Minimum 5% allowance

A FMEG of 62 is the real benchmark for axial fans

Conclusion

- Maximum practical efficiency limit for FME is **53% - 64% (58% - 69%** without manufacturing tolerances)
- The suggested EVIA limit (62) is **58% - 75%**
- Compensation factors are not loopholes due to much higher cost
- FMEG 62 is above the maximum possible without compensation factors