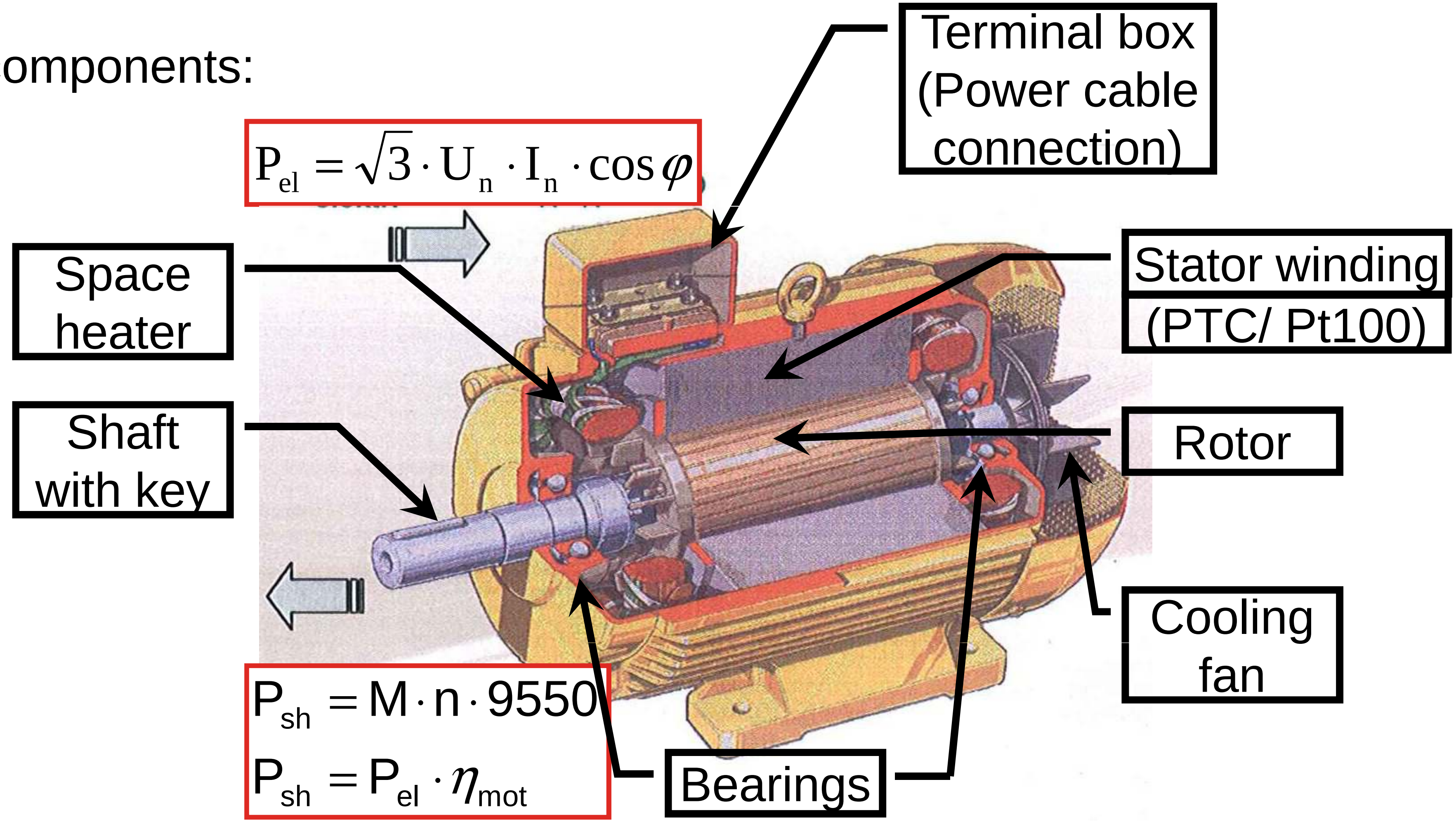
Electrical Motors

WITT & SOHN IGW Ventilatoren

Electrical Motors

Basic components:

$$P_{el} = \sqrt{3} \cdot U_n \cdot I_n \cdot \cos\varphi$$

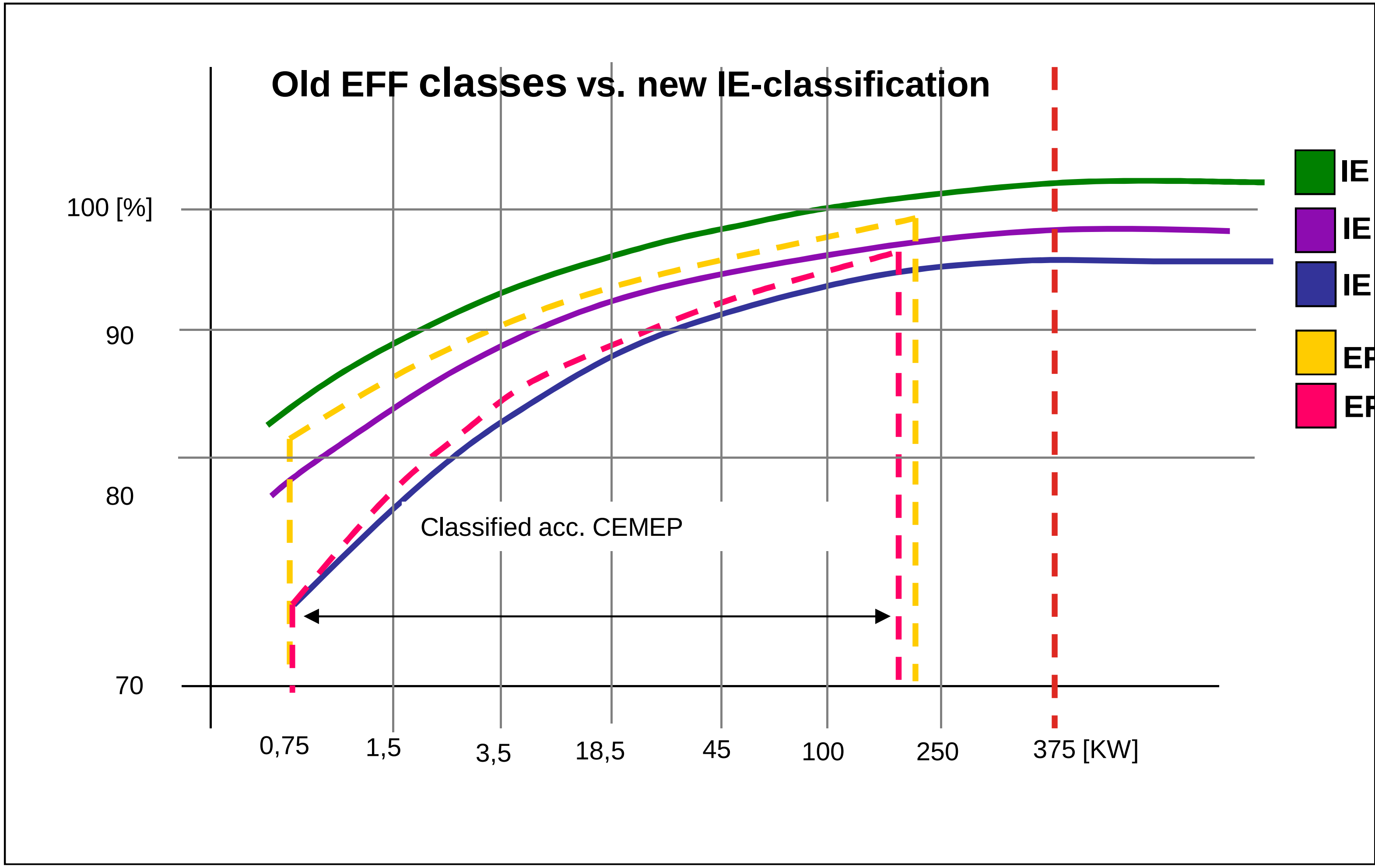


$$P_{sh} = M \cdot n \cdot 9550$$

$$P_{sh} = P_{el} \cdot \eta_{mot}$$

WITT & SOHN
IGW Ventilatoren

Efficiency classes:

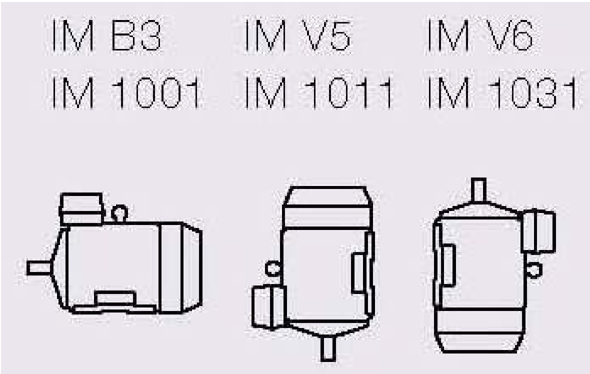


Source: International Electrotechnical Commission (IEC) and motor suppliers data.
*The efficiency of the new IE classes is slightly lower than those of EFF because P_{LL} losses have to be individual measured, instead of global deduction of 0,5% within EFF.

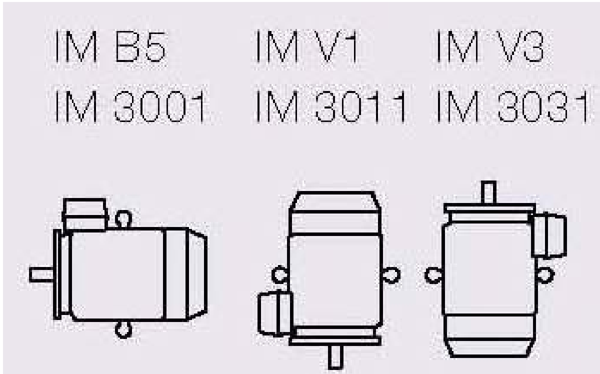
International mounting (IM) arrangements

→ common codes:

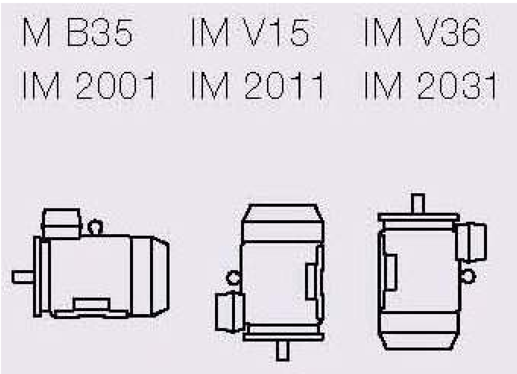
foot mounted



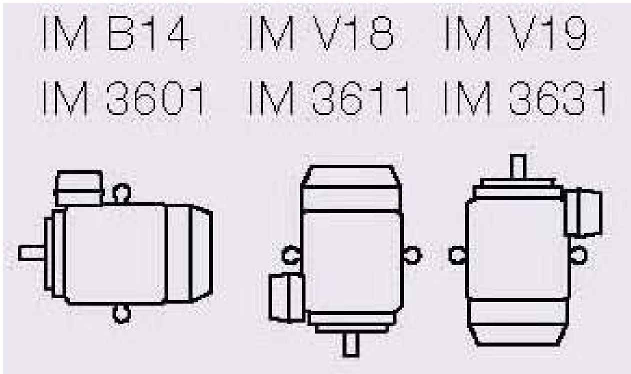
flange mounted (large)



foot- flange mounted



flange mounted (small)



WITT & SOHN
IGW Ventilatoren

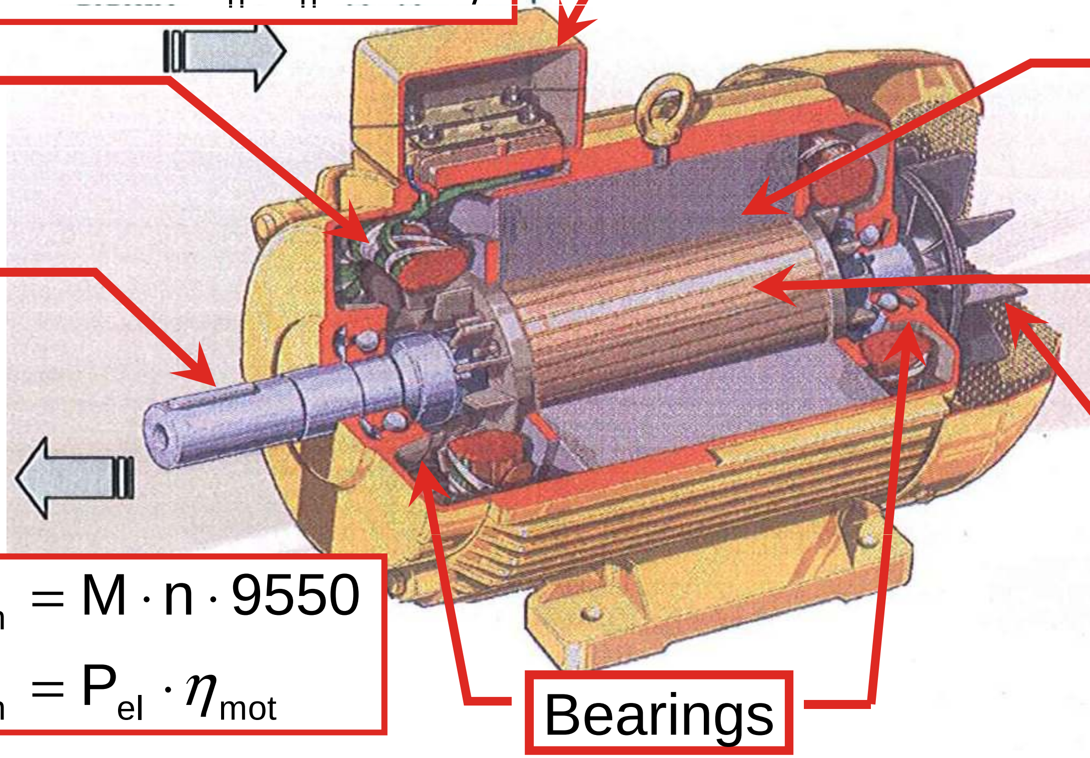
Electrical Motors

Insulation Classes

Basic components:

Stator Winding:

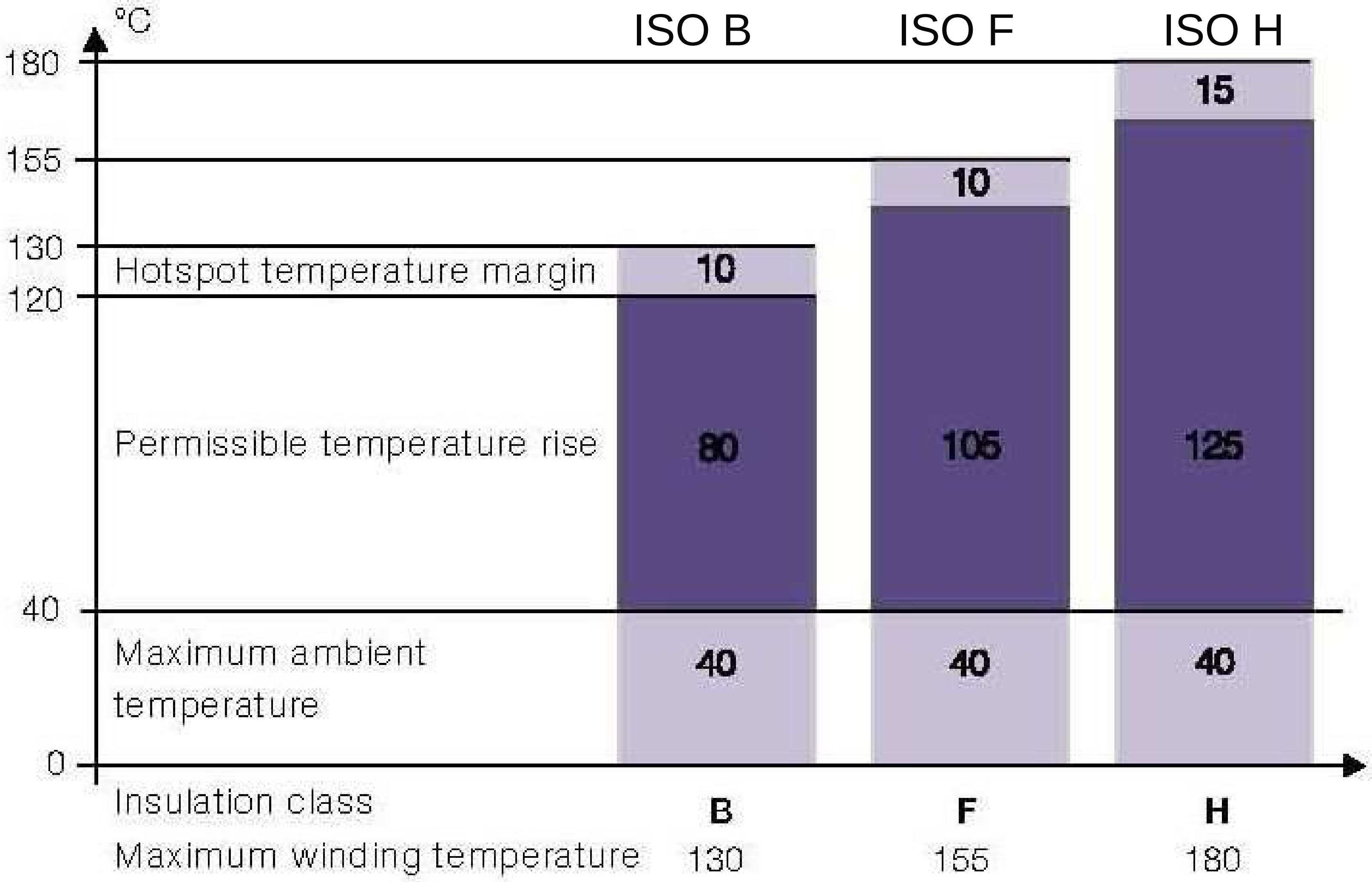
$$P_{el} = \sqrt{3} \cdot U_n \cdot I_n \cdot \cos\varphi$$



$$P_{sh} = M \cdot n \cdot 9550$$

$$P_{sh} = P_{el} \cdot \eta_{mot}$$

Insulation Classes



Insulation Classes

For heat resistant motors:

ISO H/ B → max. winding temperature capacity
→ max. used temperature level ISO B (for continous operation)

ISO H/ F → max. winding temperature capacity
→ max. used temperature level ISO F

ISO H/ FA → max. winding temperature capacity
→ max. used temperature level ISO F (with „air over“, i.e. cooling air speed >> 3m/s)

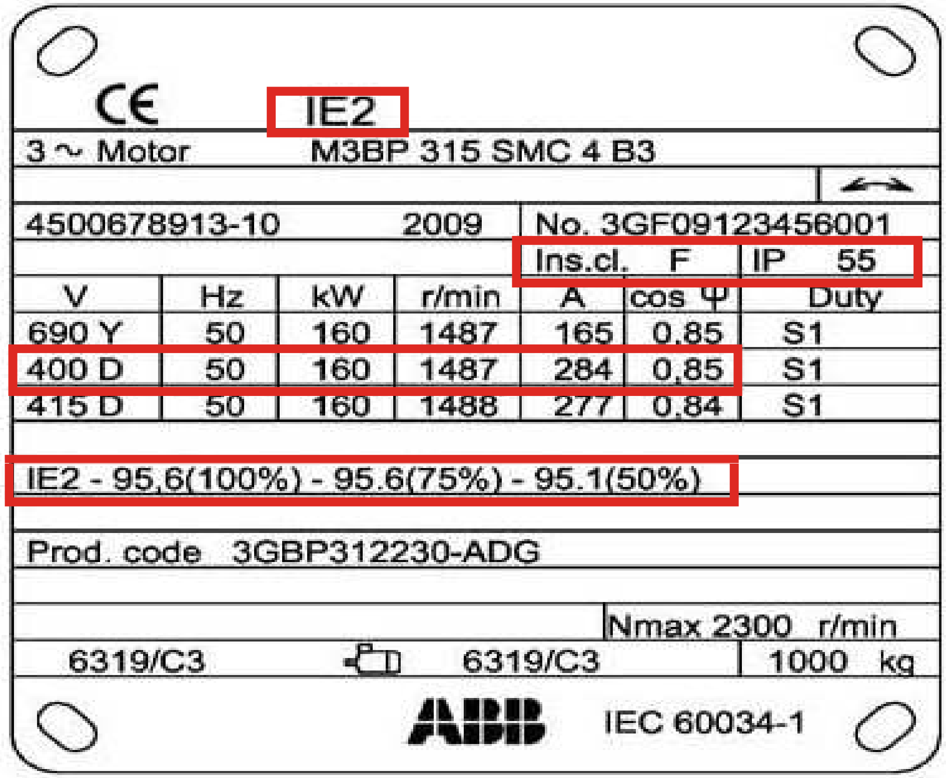
Electrical Motors

1. General
2. Insulation Classes
3. **Nameplate Rating vs. Real Performance**
4. Motor Power Cable
5. Motor Bearings
6. Space Heater
7. Sensors

Nameplate Rating:

- rated voltage
- rated current
- rated frequency
- rated speed
- rated **shaft** power (mech.)
- power factor
- efficiency class
- insulation class
- protection class

Motor sizes 280 to 450
Rating plate



Nameplate Rating vs. Real Performance

Nameplate data valid for rated conditions
(as per IEC 600 34-1):

- Installation height_{max} = 1000m a.s.l.
- Air cooling temperature_{max} = 40°C
- Duty cycle: S1 (continuous)
- Insulation class used
- Rated values at full load
- Air cooling air speed ~ $3^{m}/_{s}$

→ ANY CHANGE of these conditions will change rated nameplate data!

WITT & SOHN IGW Ventilatoren

Rating factors for motor power:

Altitude above sea level **ASL** in m	Coolant temperature in °C <30	30 – 40	45	50	55	60
1000	**1.07**	**1.00**	**0.96**	**0.92**	**0.87**	**0.82**
1500	1.04	0.97	0.93	0.89	0.84	0.79
2000	1.00	0.94	0.90	0.86	0.82	0.77
2500	0.96	0.90	0.86	0.83	0.78	0.74
3000	0.92	0.86	0.82	0.79	0.75	0.70
3500	0.88	0.82	0.79	0.75	0.71	0.67
4000	0.82	0.77	0.74	0.71	0.67	0.63

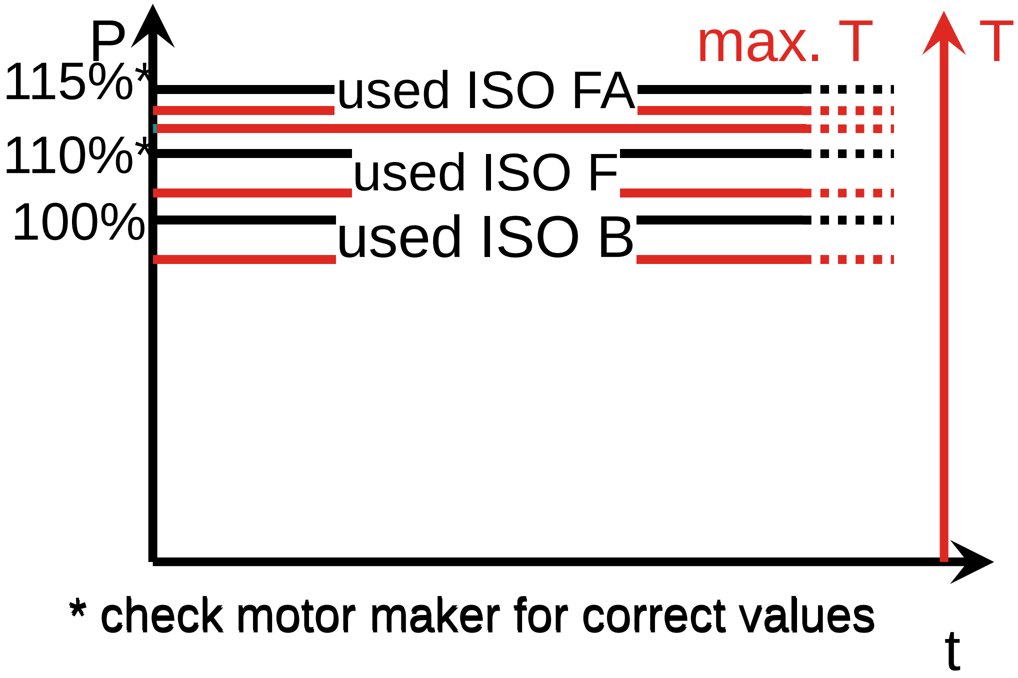
$$P_{shaft,actual} = P_{shaft,rated} \cdot f_{DG}$$

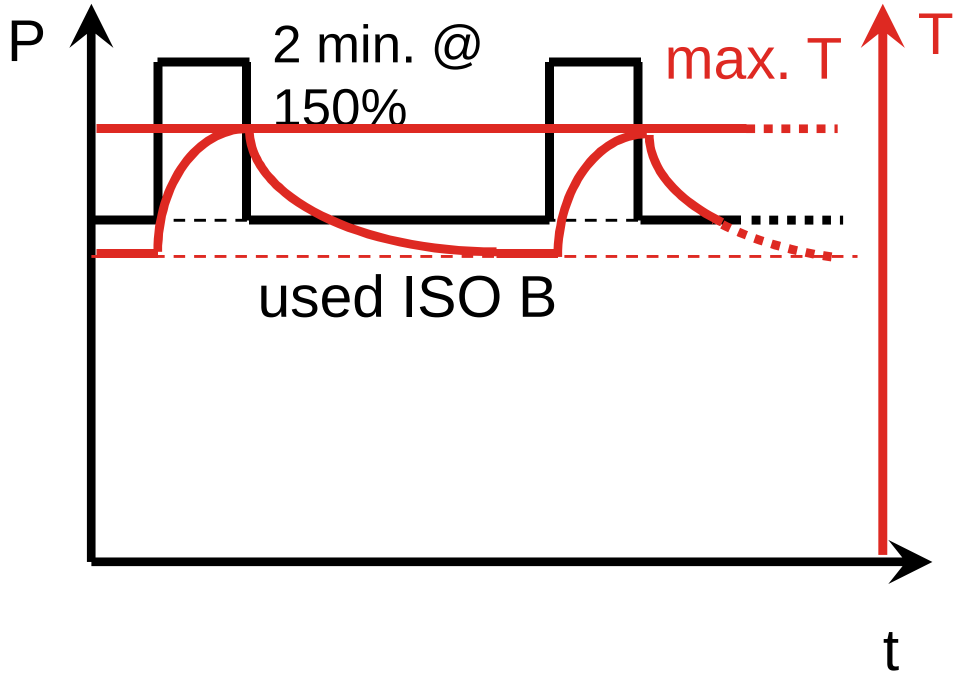
$$P_{shaft,55°C,2000m} = P_{shaft,rated} \cdot 0.82$$

f_{DG} = Degradation factor

Duty cycles (+ overloading):

<u>S1</u> (continuous) <u>other</u> (e.g. overload)





* check motor maker for correct values

use ISO classes > ISO B:
→ design life reduced!

→ short term overloading possible

WITT & SOHN IGW Ventilatoren

Rated Values vs. Real Values:

- Current

$$I_{actual} = I_{rated} \cdot \frac{U_{rated}}{U_{actual}} \cdot \frac{\cos \varphi_{actual,\ starting\ method}}{\cos \varphi_{rated,\ DOL}}$$

NOTE:

Actual power factor depends on

- starting method, i.e
  VSD operation → $\cos \varphi_{VSD} < \cos \varphi_{DOL}$
- ratio of actual load to rated load (partial load) →

Nameplate Ratings vs. Real Performance

Rated Values vs. Real Values:

- Efficiency

partial load — full load — over load

Part-load efficiency % at 1/4 of full load	1/2	3/4	4/4	5/4
93	96	97	**97**	96.5
92	95	96	**96**	95.5
90	93.5	95	**95**	94.5
89	92.5	94	**94**	93.5
87	91	92	**92**	91.5
86	90	91	**91**	90
85	89	90	**90**	89
84	88	89	**89**	88
80	87	88	**88**	87
79	86	87	**87**	86
78	85	86	**86**	85
76	84	85	**85**	83.5
74	83	84	**84**	82.5
72	82	83	**83**	81.5
70	81	82	**82**	80.5
68	80	81	**81**	79.5
66	79	80	**80**	78.5

- Power Factor

partial load — full load — over load

Part-load power factor at 1/4 of full load	1/2	3/4	4/4	5/4
[illegible]	[illegible]	0.90	[illegible]	[illegible]
0.65	0.85	0.89	**0.91**	0.91
0.63	0.83	0.88	**0.90**	0.90
0.61	0.80	0.86	**0.89**	0.89
0.53	0.76	0.84	**0.87**	0.87
0.51	0.75	0.83	**0.86**	0.86
0.49	0.73	0.81	**0.85**	0.86
0.47	0.71	0.80	**0.84**	0.85
0.45	0.69	0.79	**0.83**	0.84
0.43	0.67	0.77	**0.82**	0.83
0.41	0.66	0.76	**0.81**	0.82
0.40	0.65	0.75	**0.80**	0.81
0.38	0.63	0.74	**0.79**	0.80
0.36	0.61	0.72	**0.78**	0.80
0.34	0.59	0.71	**0.77**	0.79
0.32	0.58	0.70	**0.76**	0.78
0.30	0.56	0.69	**0.75**	0.78

WITT & SOHN IGW Ventilatoren

Rated Values vs. Real Values:

- Speed: load ↑ → speed ↓

Electrical Motors

1. General
2. Insulation Classes
3. Nameplate Rating vs. Real Performance
4. **Motor Power Cable**
5. Motor Bearings
6. Space Heater
7. Sensors

WITT & SOHN
IGW Ventilatoren

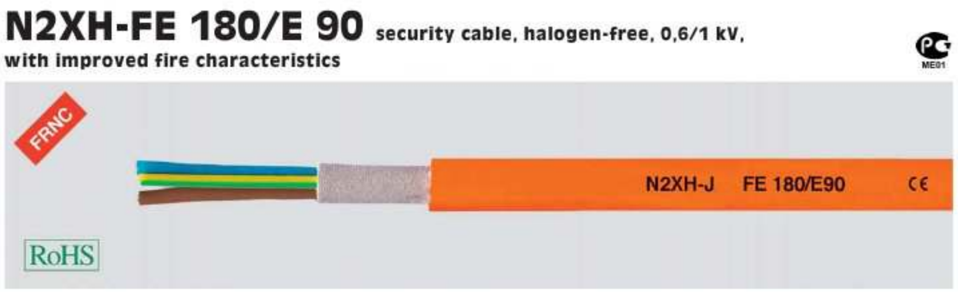
Heat-resistant Motor Cables - Selection:

- shielded (EMC)
- flameretardant (IEC 332-1/ 332-2)
- halogen free (IEC 60754-2)
- no fire propagation (IEC 60332-3)
- water-tight (protect versus electric shock!)
- DOL: 3 (phase) +1 (PE) lead
  Y-∆: 6 (phase) +1 (PE) lead
  → bundled by an outer shield!
- heat resistant acc. to requirement →

Heat-resistant Motor Cables – Samples:

- Certification for 250°C/2h:
  LAPP

- Certification for 400°C/2h:
  HELU



Motor Power Cable

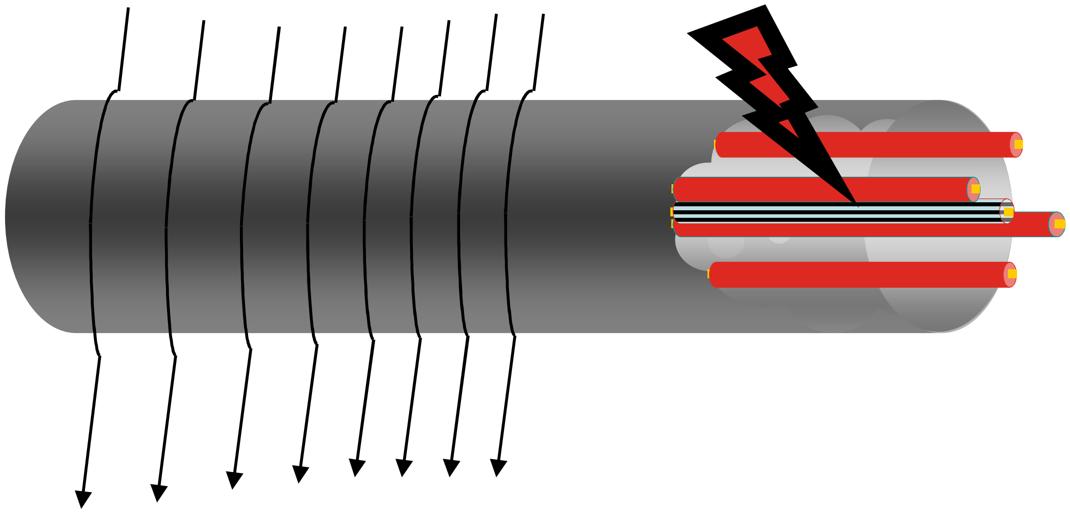
WITT & SOHN IGW Ventilatoren

Heat-resistant Motor Cables – Bad Samples:

- Outer shield impregnated fibre braiding: Omerin

- Single leads with metall tube might fail:

single lead



- during fire case
- fan operating
- outer sheath might get porous and disapears

→ Risk of short circuit!

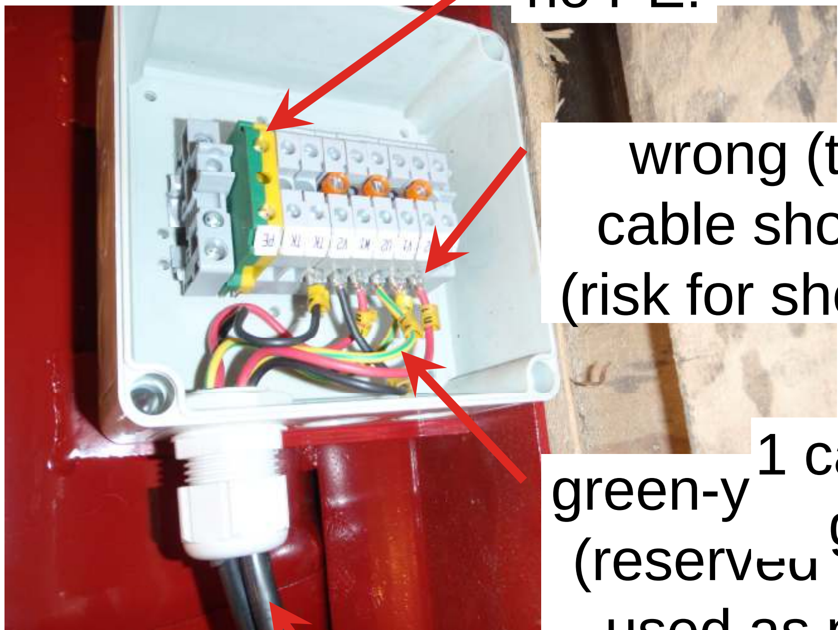
Heat-resistant Motor Cables:

- select correct cable cross section for rated current
- consider parallel cables for big cable cross sections
- apply reduction factors for those cables-sections located in elevated temperature areas

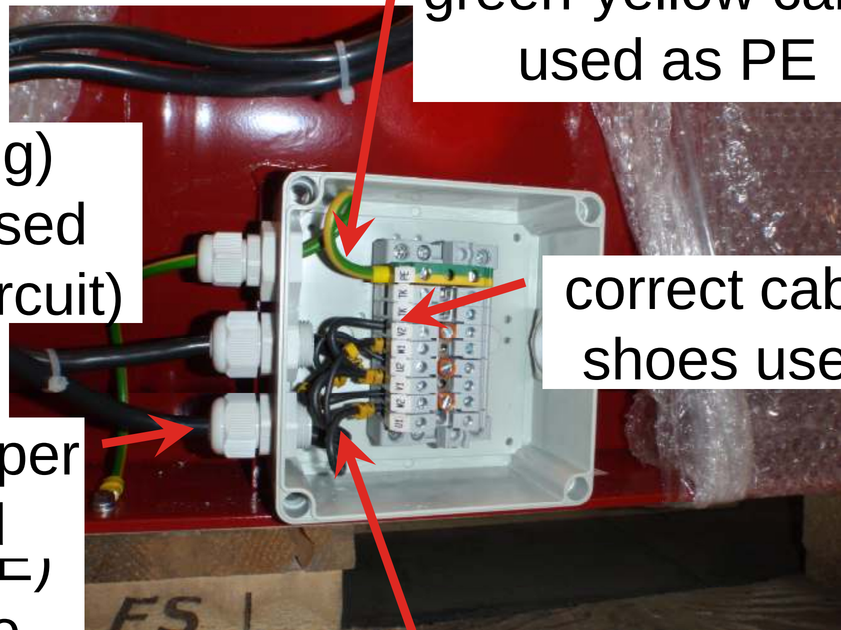
WITT & SOHN
IGW Ventilatoren

Cable Connection to Terminal Box:

- wrong

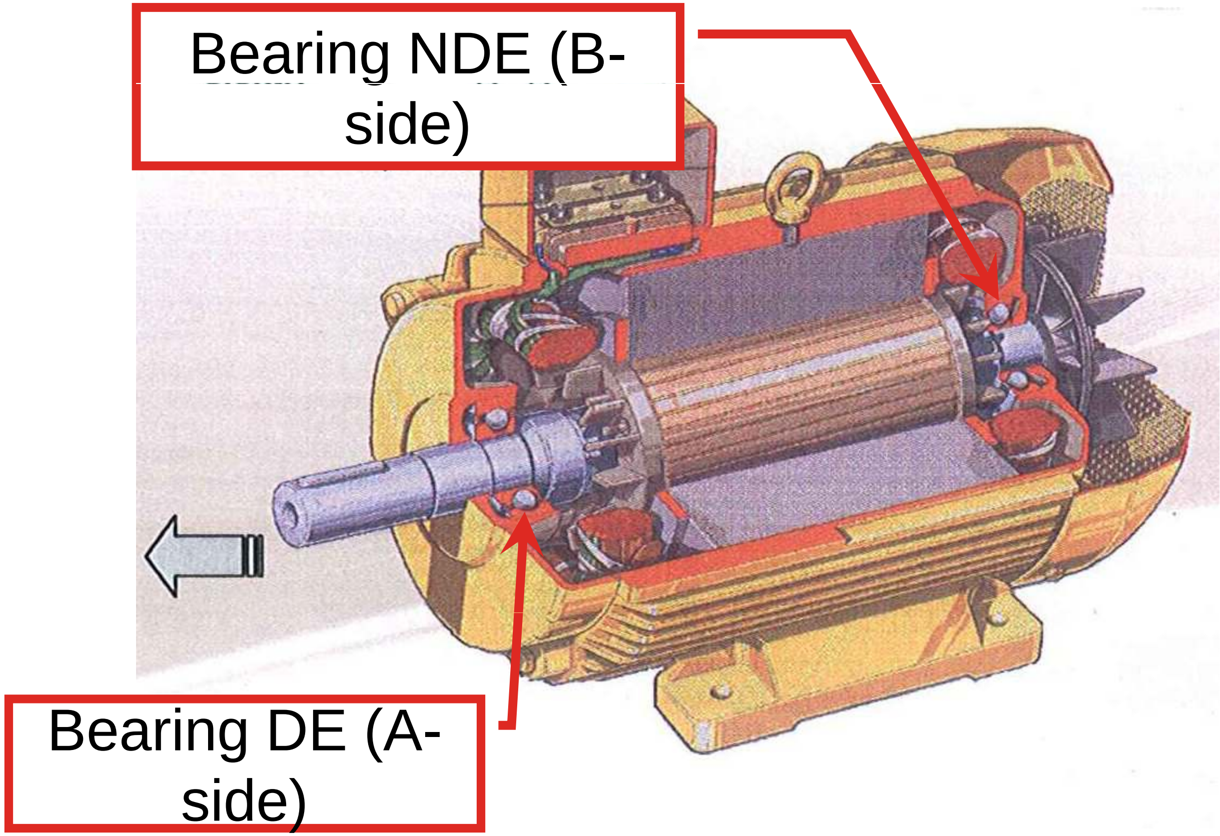


- correct



Electrical Motors

Basic components:



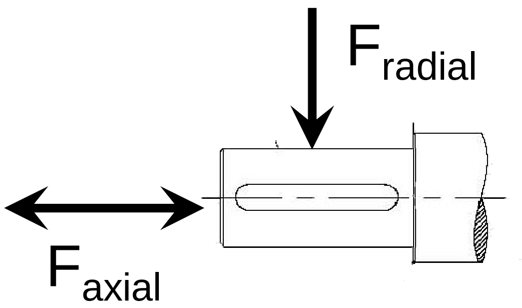
Bearing Life Time acc. to ISO 281

- Lh_{10}: - 10% of bearings allowed to fail in given time
- Lh_{50}: - 50% of bearings allowed to fail in given time
  - „average“
  - $Lh_{50} \sim 5x\ Lh_{10}$

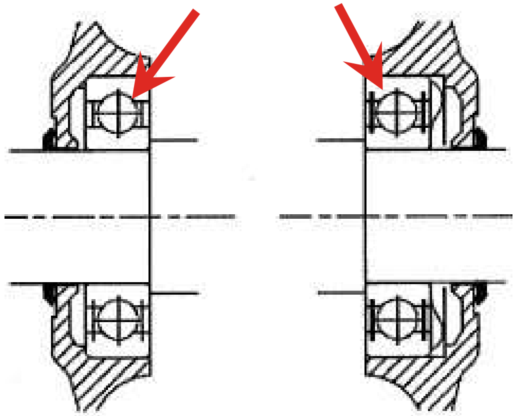
Motor Bearings

Selection of Bearings

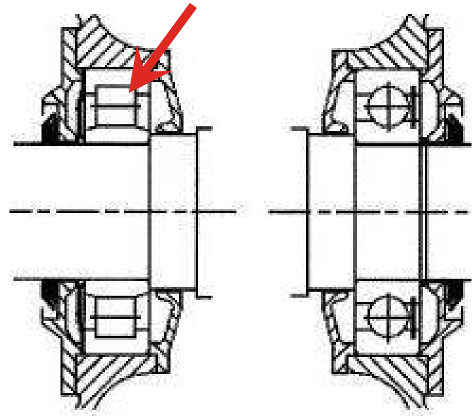
1. Self
   - check permissible loads
   - check fan actual loads
2. send motor inquiry sheet to motor makers



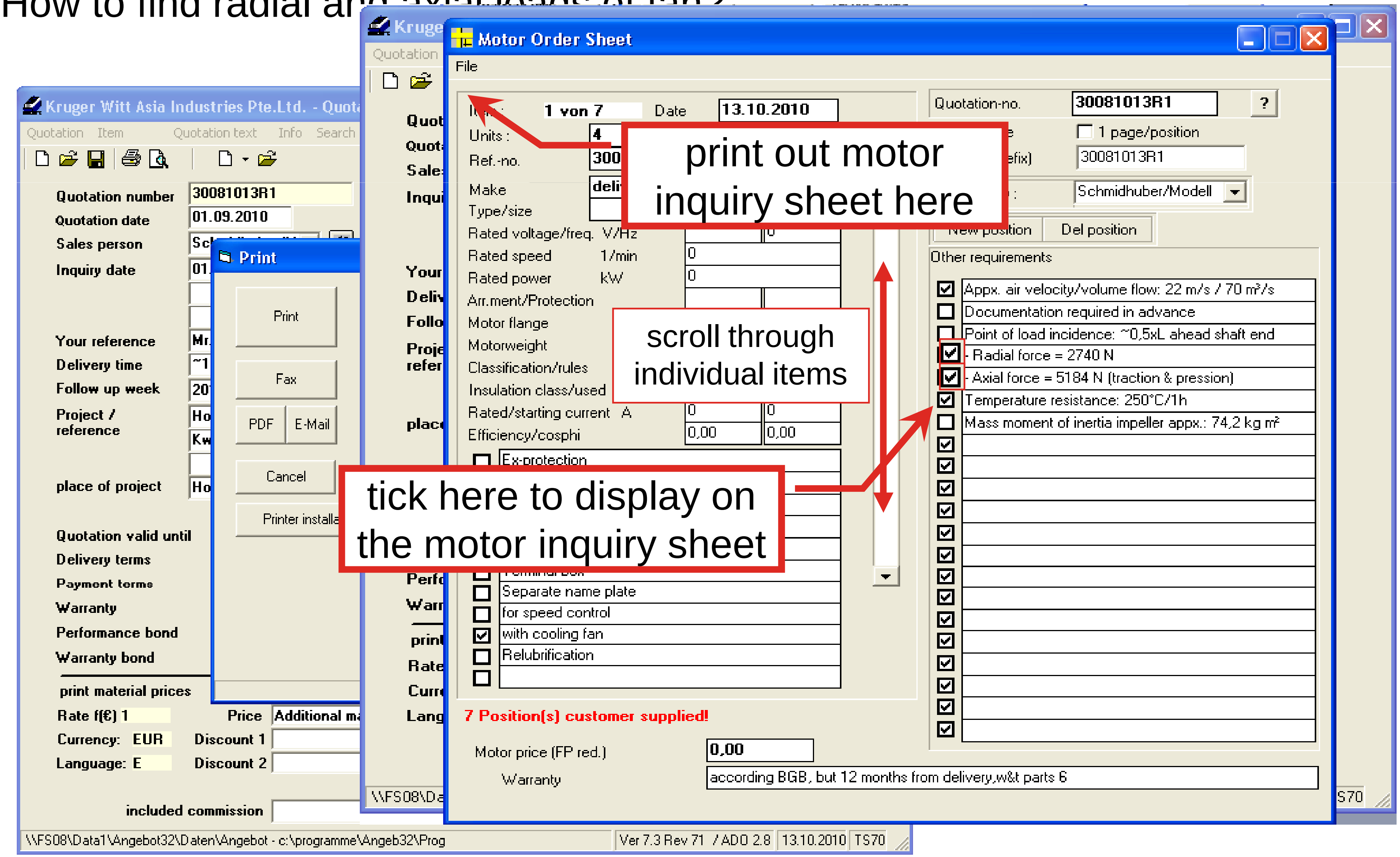
ball bearing
for direct driven fan



groove ball bearing
for belt driven fan



How to find radial and axial loads of fan?



Bearing Lubrification

Motor Grease/ Lubricant

→ soap grid emulsified with oil + special additives

1. Life lubricated bearings
   - → available only for smaller motors
   - → BEST solution:
     the less someone must interfere
     the less can go wrong

WITT & SOHN
IGW Ventilatoren

Bearing Lubrification

2. Regrease bearings through grease nipples
   → lubrification lines to external fan casing for comfort of maintenance
   → use always SAME grease!
   → follow STRICTLY relubrication intervals! (depends on load + load cycle)

   Read carefully the O&M manual of motor maker!

Consequences for wrong greasing:

Failure	Consequence 1	Consequence 2
Mixture of grease types	Chemical reaction of grease types	Grease and bearings destroyed
Too low amount	Bearings run dry	Bearings destroyed
Too high amount	Grease inside motor/ oil is „bleeding out“ of soap grid	Grease, bearings and motor destroyed

Motor Bearings

Consequences for wrong greasing:

→ High temperature grease
Good performance at high temperature only

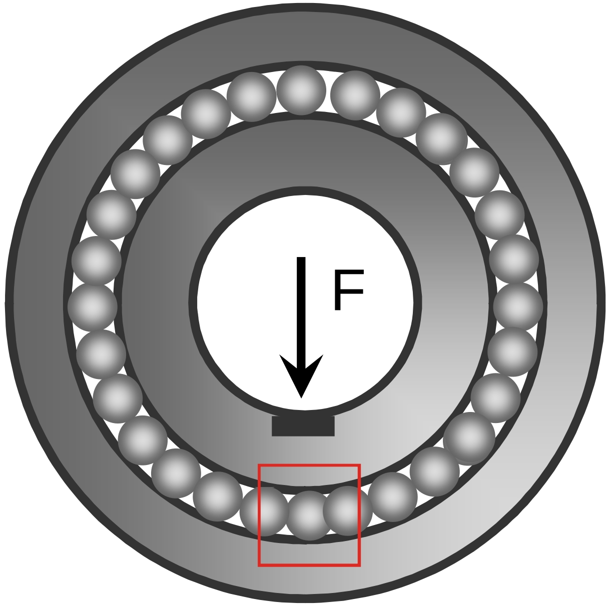
BUT fire once in life (<1%)
→ balanced time: normal temperature (>99%)
→ high viscosity
→ low grease performance
→ high screaming noise
→ bearings likely to be destroyed

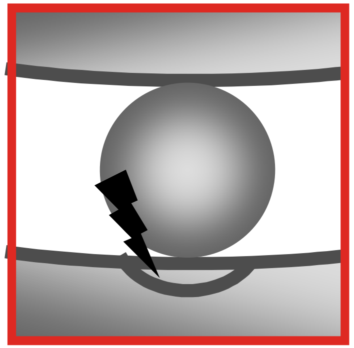
Recommendation:

→ use grease for normal temperature
with adequate performance for short term
heat application

Consequences for wrong operation:

→ Long time of standstill



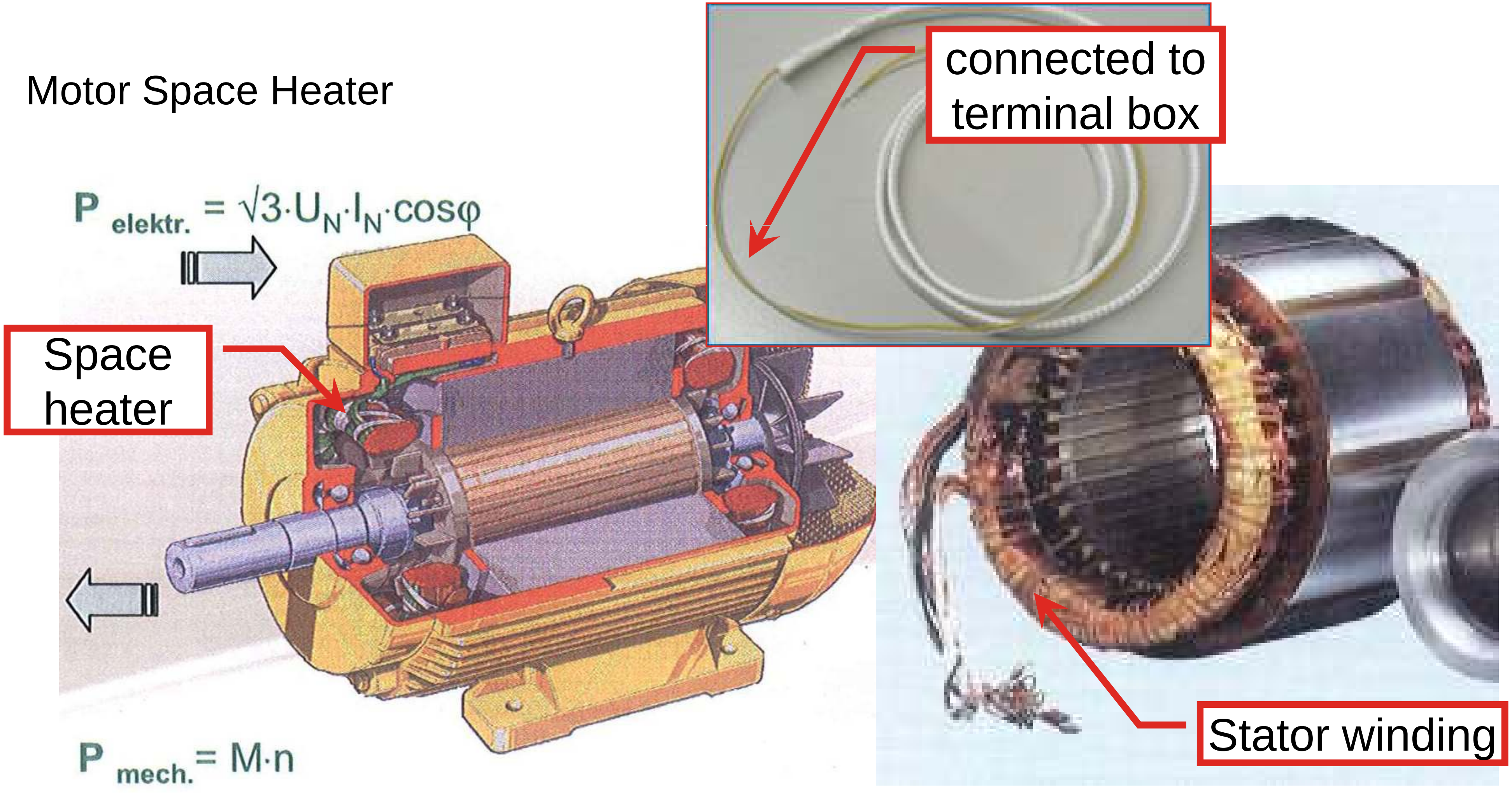


plastic deformation
of bearing ring
at point of contact
→ bearing destroyed

Pls. check O&M manual
Chapter 6 * Instruction for storage and prolonged downtime

Electrical Motors

Motor Space Heater



Motor Space Heater

WITT & SOHN
IGW Ventilatoren

Space Heater = Anti-Condensation Heater

Purpose:

→ Shall keep temperature inside of motor few degree K higher than outside

Operation:

→ To be switched on when motor stops
→ To be switched off when motor starts

Usage:

→ Ambient conditions with high fluctuation of temperature (e.g. day/ night)
→ Low ambient temperatures (< 0°C)

Electrical Motors

1. General
2. Insulation Classes
3. Nameplate Rating vs. Real Performance
4. Motor Power Cable
5. Motor Bearings
6. Space Heater
7. **Sensors**

WITT & SOHN
IGW Ventilatoren

Motor Sensors:

Temperature:

1. **P**ositive**T**emperature**C**oefficient (PTC)

2. Pt100

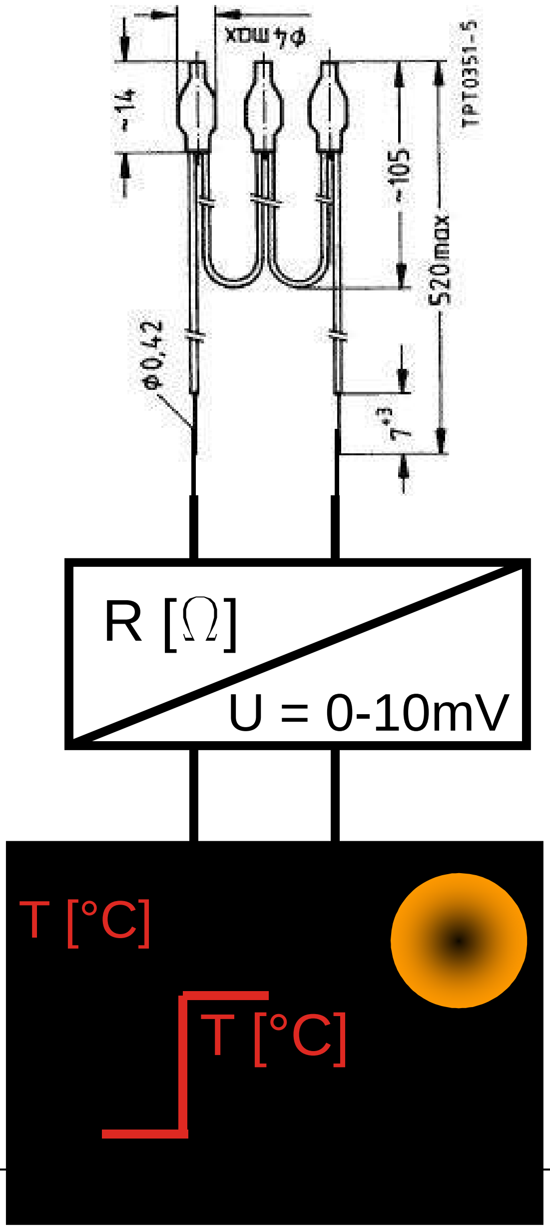
→ Locations:

- winding
- bearing

Positive**T**emperature**C**oefficient

- → cheap
- → triggers at a preset selected temperature
- → installed in series into the windings
  3 for shut off

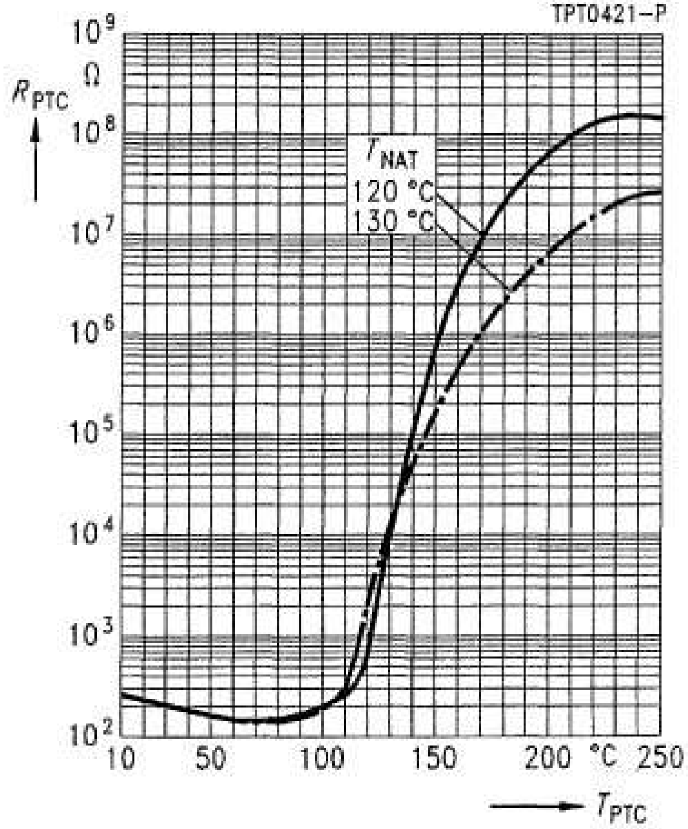
  or 2 x 3 for warning and shut off
- → characteristic:
  signal: Ω → mV

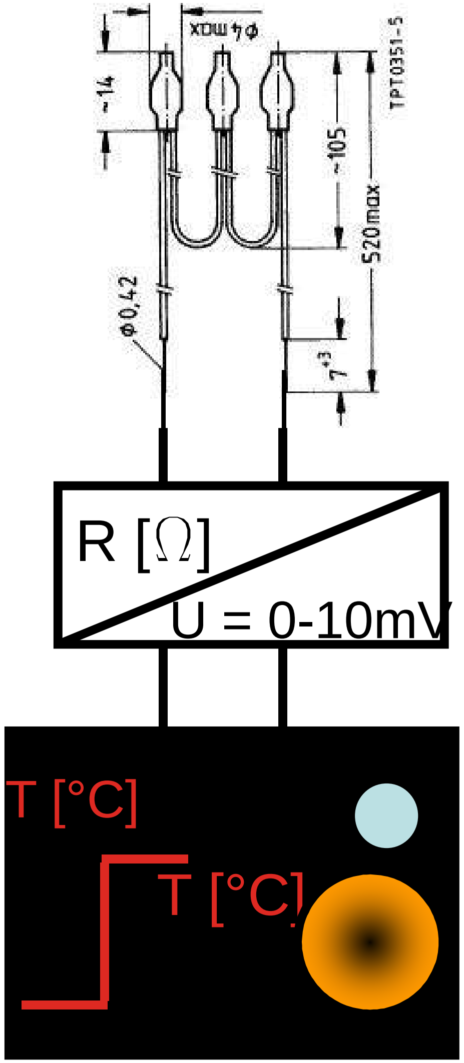


Sensors

Positive**T**emperature**C**oefficient

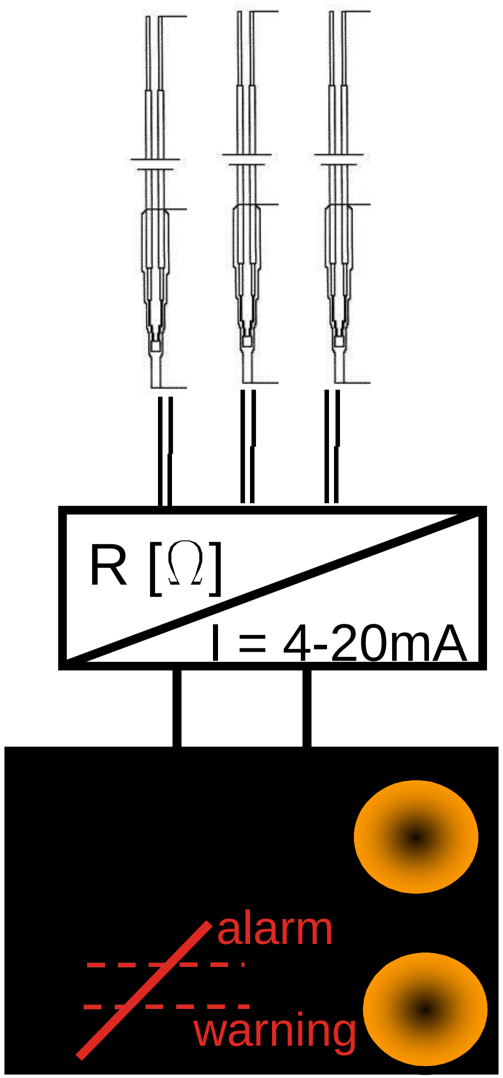
- → cheap
- → triggers at a preset selected temperature
- → installed in series into the windings
  3 for shut off
  or 2 x 3 for warning and shut off
- → characteristic:
  signal: Ω → mV





Pt100

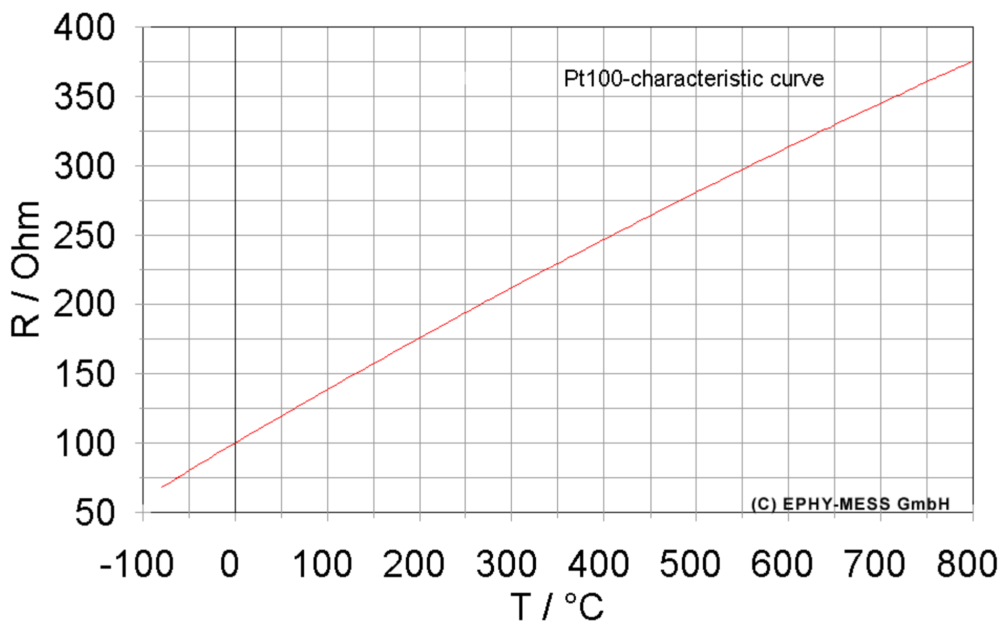
- → If temperature measurement is acquired (expensive solution (platinum))
- → provides continuous rising signal (0°C → 100Ω)
- → installed parallel into the windings
- → characteristic:
  signal:Ω → mA

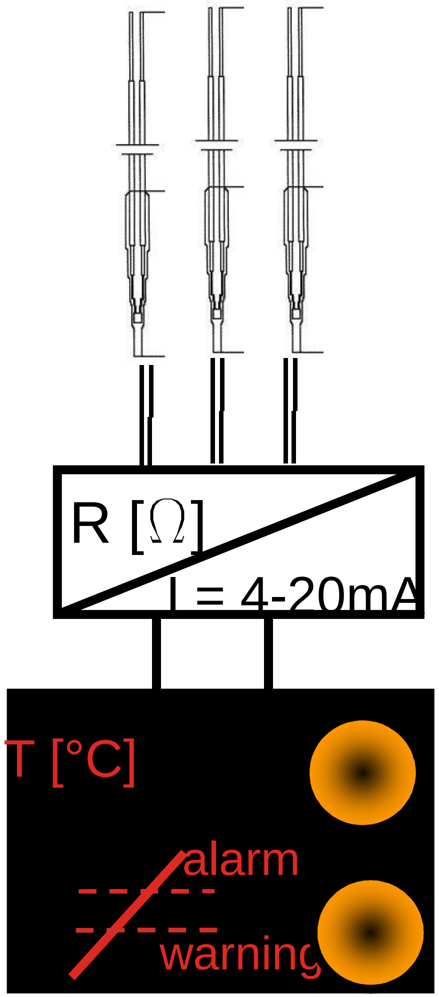


Pt100

- → If temperature measurement is acquired (expensive solution (platinum))
- → provides continuous rising signal (0°C → 100Ω)
- → installed parallel into the windings

- → characteristic:
  signal:Ω → mA



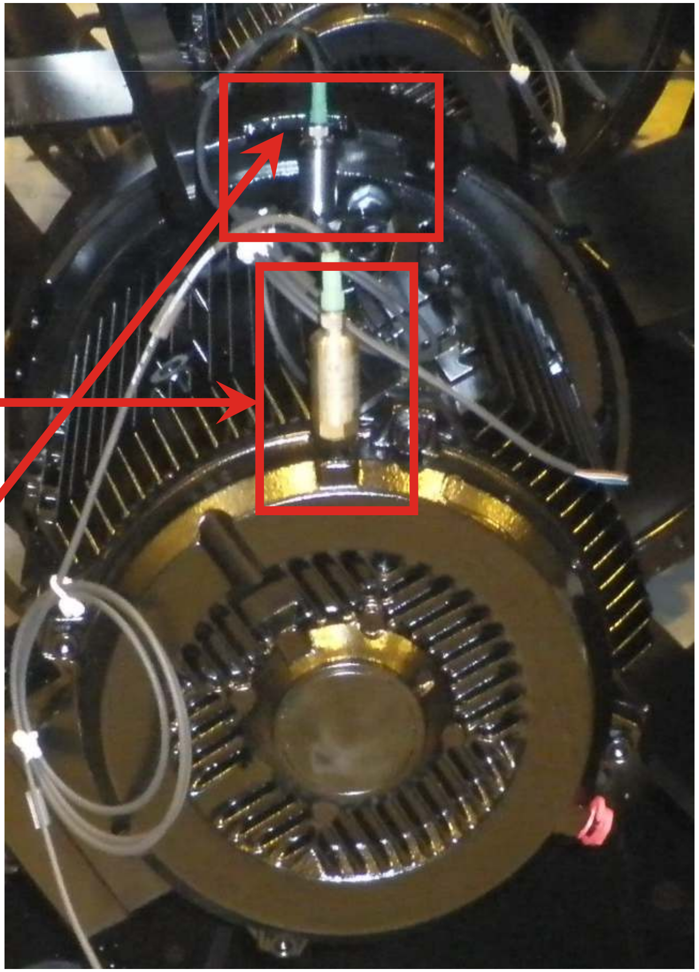


Motor Sensors:

Vibration:

→ Various types
  - wear&tear status
    → e.g. from SPM, but expensive + complex
  - vibration signal: mA

→ Location:
  - motor bearings



space allowance in motor support for sensor on DE side!

Summary

- Old efficiency classes such as eff1/eff2 have been replaced by IE1/IE2
- There are different kind of insulation classes.
- General motor ratings are based on 1000m a.s.l, 40°C ambient temperature, S1 duty cycle and insulation class used
- Motor rated data have to be downgraded for higher altitudes and higer ambient temperatures
- Motor efficiency and power factor decrease if motor is running at different speeds
- Special cables have to be used for heat resistant application
- Bearing life is calculated acc. to ISO281
- Correct grease has to used for regreasable bearings (acc. to manufacturers O&M manual)
- Fans being at standstill for a long time should be avoided.
- Optional parts for motors: PT100, PTC, Anti-condensation heaters

Cable size and costs

100% E90-cable (fire rated, 10m in fire zone) => e.g for axial fans

power [kW]	current [A]	**50** m			200 m			300 m			400 m			800 m		
			4x…²	€/50m		4x…²	€/200m		4x…²	€/300m		4x…²	€/400m		4x…²	€/800m
7,5	20	1 x	10	490	1 x	16	2.630	1 x	25	5.470	1 x	25	7.290	1 x	25	14.600
15	34	1 x	16	660	1 x	25	3.640	1 x	35	6.080	1 x	35	8.110	1 x	35	16.200
22	40,5	1 x	16	660	1 x	25	3.640	1 x	35	6.080	1 x	50	9.090	1 x	50	18.200
30	55	1 x	25	910	1 x	35	4.060	1 x	50	6.820	1 x	70	10.900	1 x	70	21.800
45	81	1 x	50	1.140	1 x	50	4.550	1 x	70	8.170	1 x	95	14.400	1 x	95	28.900
75	135	1 x	95	1.800	1 x	95	7.210	1 x	120	13.000	1 x	150	20.300	1 x	150	40.600
110	195	1 x	120	**2.170**	1 x	120	8.660	1 x	185	19.600	1 x	240	32.700	1 x	240	65.300
160	287	2 x	95	**3.610**	2 x	120	17.300	2 x	120	26.000	2 x	150	40.600	2 x	150	81.300
250	442	3 x	95	**5.410**	3 x	95	21.600	3 x	120	39.000	3 x	150	61.000	3 x	150	hä ?
315	550	3 x	120	6.500	3 x	120	26.000	3 x	150	45.700	3 x	185	78.300	3 x	185	hä ?

90% NYCWY-cable (70°C, under road level) +
10% E90-cable (fire rated, 10% in tunnel fire zone) => e.g. for jet fans

power [kW]	current [A]	100 m			200 m			300 m			**400** m			**800** m		
			4x…²	€/100m		4x…²	€/200m		4x…²	€/300m		4x…²	€/400m		4x…²	€/800m
7,5	20	1 x	10	300	1 x	10	610	1 x	16	1.130	1 x	25	2.200	1 x	25	4.390
15	34	1 x	16	380	1 x	16	750	1 x	25	1.650	1 x	35	2.590	1 x	35	5.190
22	41	1 x	16	380	1 x	25	1.100	1 x	35	1.950	1 x	50	2.950	1 x	50	**5.900**
30	55	1 x	25	550	1 x	35	1.300	1 x	50	2.210	1 x	70	4.110	1 x	70	**8.220**
45	81	1 x	70	1.030	1 x	70	2.050	1 x	70	3.080	1 x	95	**4.770**	1 x	95	9.540
75	135	1 x	120	1.420	1 x	120	2.850	1 x	120	4.270	1 x	150	**6.750**	1 x	150	13.500
110	195	1 x	150	1.690	1 x	150	3.380	1 x	185	6.400	1 x	185	8.530	1 x	185	17.100
160	287	2 x	120	2.850	2 x	120	5.690	2 x	120	8.540	2 x	150	13.500	2 x	150	27.000
250	442	3 x	120	4.270	3 x	120	8.540	3 x	120	12.800	3 x	150	20.300	3 x	150	40.500
315	550	3 x	150	5.060	3 x	150	10.100	3 x	150	15.200	3 x	185	25.600	3 x	185	51.200