NTNU	TEP 4175: Design of a Wind Turbine
Department of Energy and Process Engineering	Laboratory Work – The Generator Handed out: 2016-10-03 Edited: 2017-08-24

CONTENTS

DESCRIPTION OF THE GENERATOR TEST RIGS

A generator is generally driven by a turbine or a motor coupled to the same shaft as the generator rotor. To be able to test only the generator, the drive will be a motor with adjustable speed. In your project you will be given the task to design either an axial flux generator or a radial flux generator. The groups designing a radial flux generator may choose if they wish to make a single-phase or a three-phase generator. The groups designing an axial flux generator should make it single-phase.

Axial Flux Generator

The magnetic flux lines of this generator is in the axial direction. For that reason, the generator is called an axial flux generator.

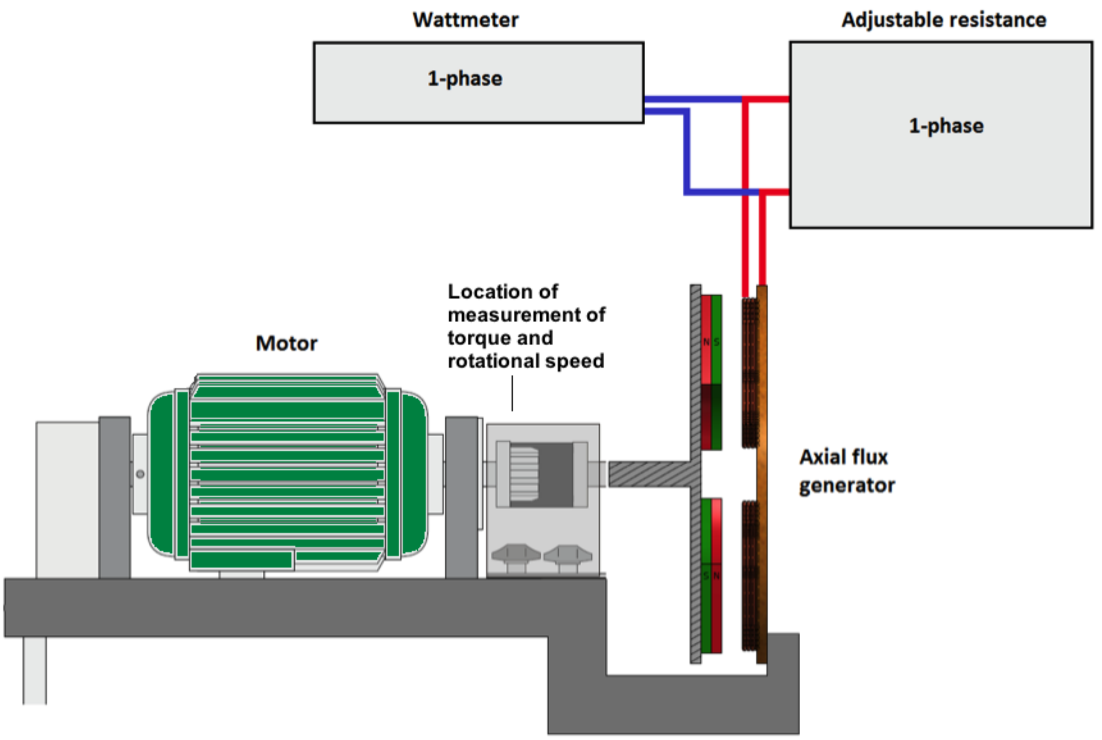


Figure 1: Test rig for the axial flux generator.

Detailed drawings of the axial flux generator are given in Appendix A.

Radial Flux Generator

The magnetic flux lines of this generator is in the radial direction. For that reason, the generator is called a radial flux generator.

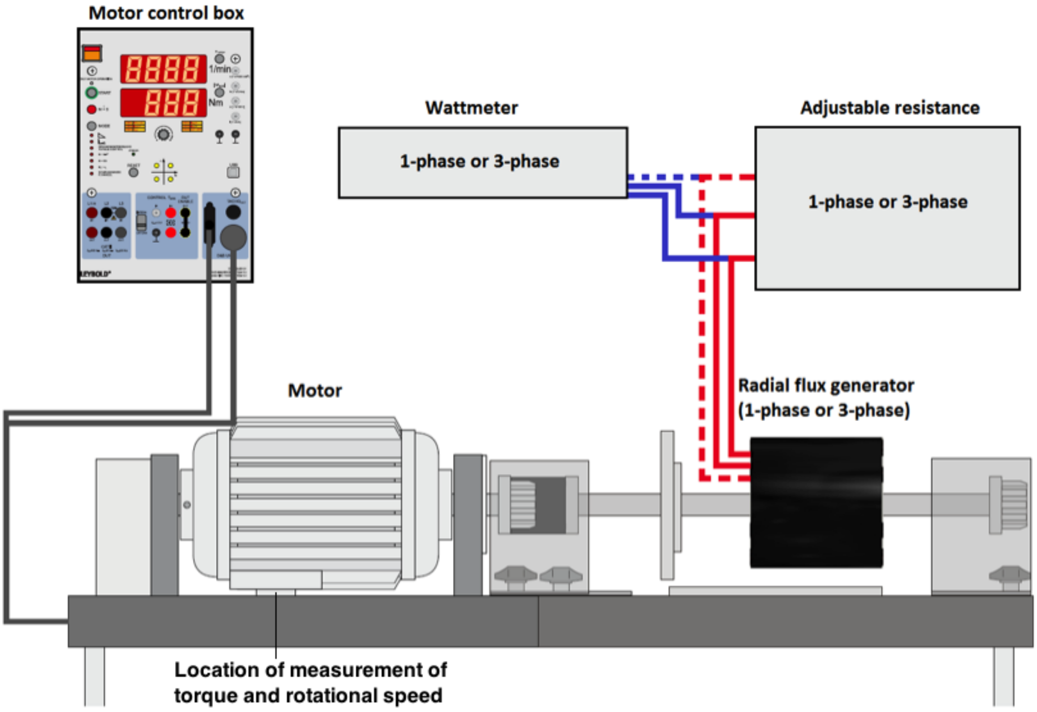


Figure 2: Test rig for the radial flux generator.

Detailed drawings of the radial flux generator are given in Appendix B.

GENERATOR PARAMETERS

A generator is generally driven by a turbine or an engine coupled to the same shaft as the generator rotor. In wind power installations a turbine is designed to rotate at a certain nominal speed delivering a specified nominal power. The design of the generator should be optimized at the point described by these nominal values. When the power and angular velocity is specified, the torque delivered by both the turbine blade and the generator is given by:

$$P = \omega_m \cdot T \quad [W] \tag{1}$$

$$T = \frac{P}{\omega_m} \quad [Nm] \tag{2}$$

Where P is power, T is torque, and ω_m is the mechanical angular speed. (Not to be confused with the electrical angular speed, i.e., the angular speed of the magnetic field, $\omega_e = \frac{P}{2} \cdot \omega_m$, where P is the number of poles of the generator rotor.) To obtain the constant nominal speed, the net torque on the shaft connecting the turbine blade and the generator must be zero. Otherwise, the speed of the turbine would accelerate or decelerate. The turbine blade imposes a driving torque and the generator imposes a braking torque when connected to a load.

The equivalent circuit of a single-phase generator connected to a resistive load is given in Figure 3.

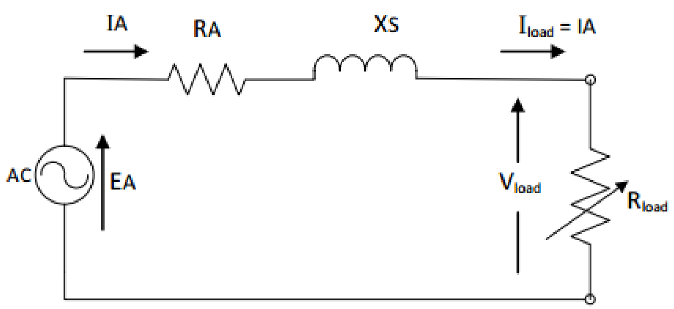


Figure 3: Equivalent circuit of single-phase generator connected to resistive load.

The components of the equivalent circuit:

- E_A is the induced voltage in the generator stator. This must be measured at the no-load condition, i.e., R_{load} is infinite.
- I_A is the current flowing through the stator and the load, when the load is connected. The current is always the same through all components of a closed circuit.
- R_A is the resistance of the stator coils, i.e., the resistance of the copper windings. Also called armature resistance.
- X_S is the reactance of the stator coils. The changing magnetic field through the coils induces a counter-acting current, which in this equivalent circuit is represented by a voltage drop across X_S.
- R_{load} is the adjustable load resistance.
- V_{load} is the voltage over the load, also called terminal voltage.

All the different parameters of the generator are described more thoroughly in Table 1.

Table 1: Important generator parameters.

Parameter			Description	Numerical value	Comments
Name	**Symbol**	**Unit**			
Induced voltage	E_A	[V]	**The induced voltage is a function of:** - Flux density at the surface of the permanent magnet (B_r) - Distance from magnet surface to the mid-level of the coil - Flux density distribution in space - Shape and area of the coil - Rotational speed of the rotor (i.e. of the magnetic field) - Effective number of turns of the coil ($k_w = k_p * k_d$)	To be measured at no-load condition for the generator at different rotational speeds.	The induced voltage is not affected by the armature current (i.e. the load of the generator). k_w = 0.9 could be used in the calculations (design phase).
Peak flux density	B_p	[T]	**The peak flux density (at coil level) is a function of:** - Flux density at the surface of the permanent magnet (B_r) - Distance from magnet surface to the mid-level of the coil - Shape of permanent magnets - The material on which the magnet is mounted (e.g. steel back plate)	To be calculated, based on manufacturer data for the magnets.	Equations and links to permanent magnet flux density calculators is given in the section below on flux density. Manufacturer data for the permanent magnets is given in Appendix C.
Rotational speed	ω	[rad/s]	**The rotational speed depends on:** - Operating point defined by turbine and generator torque	To be measured.	Used as a parameter for various curves/characteristics.

Armature resistance	R_A	[Ω]	**The armature resistance is a function of:** - Area of the wire used for making the armature coil - Total length of the wire for each coil - Number of series-connected coils - Specific resistance of the conductor material (copper) - Temperature - Skin effect (for AC machines) - Proximity effect (for AC machines) - Additional resistance in connection terminals, etc.	To be measured with special instrument. The instrument is handled by service personnel from Department of Electric Power Engineering.	The temperature at which R_A is measured should be stated in the report. For an assumed conductor temperature of approx. 50 °C, a correction factor of approx. 1.1-1.2 could be used, which takes into account the temperature and skin effects.
Synchronous reactance	X_S	[Ω]	**The synchronous reactance is a function of:** - magnetic leakage (X_{al}) - armature reaction (X_{ar}) - inductance L_S of the coil ($X_S = \omega_e * L_S$) - frequency (in this case proportional to rotational speed)	To be calculated – based on measurements.	Values for X_S is to be calculated based on measured load current I_L, induced voltage E_A, etc. – with reference to pertaining electrical rotational speed ω_e.
Synchronous inductance	L_S	[H]	**The inductance of the stator coil is a function of:** - Number of turns of the coil - Area (and shape) of the coil - Length of the coil (in axial direction) - Magnetic conditions (e.g. magnetic saturation)	To be calculated – based on measurements, via calculated values for X_S and rotational speed.	Estimated values of L_S will be given as a function of load current I_L, pertaining to certain rotational speed ω and number of turns N for stator coil(s) – for design purposes $L_S = L_{S0} \cdot \left(\frac{N}{N_0}\right)^{\beta} \quad \beta \approx 1.0 - 1.5$
Terminal voltage	V_{load}	[V]	**The terminal voltage is a function of:** - Induced voltage E_A - load current $I_L = I_A$ (amplitude and phase angle) - synchronous reactance X_S - armature resistance R_A	To be measured for different load situations at different rotational speeds.	Curves are to be presented with current and/or load power P_L as independent variable.

Efficiency of generator	η_{gen}	[-]	**The generator efficiency is a function of:** - Input power (shaft power) (P_{in}) - Output power (load power) (P_{out}) - *Losses* ($P_{gen,loss}$)	To be calculated – based on measurements, at different rotational speeds. For design purposes the copper losses in the stator windings should be calculated, and the other losses estimated (see next row).	Generator efficiency: $\eta_{gen} = \frac{P_{out}}{P_{in}} \cdot 100 = \frac{P_{in} - P_{gen,loss}}{P_{in}} \cdot 100 = \left(1 - \frac{P_{gen,loss}}{P_{in}}\right) \cdot 100 \ [\%]$ Curves are to be presented with current and/or load power P_L as independent variable
Generator losses	$P_{gen,loss}$	[W]	**The generator losses consist of:** - Rotational losses (P_{mech}) - Core losses (P_{core}) - Additional losses (P_{add}) - Stator copper losses (P_{Cu})	To be calculated/ estimated – based on measurements, at different rotational speeds. For design purposes: $P_{mech} + P_{core} + P_{add} \approx 10 - 30$ W	Stator copper losses (P_{Cu}) are found via: $P_{Cu} = R_A \cdot I_A^2$ per phase. Other losses are to be estimated, based on P_{in}, P_{out} and P_{Cu}.

Coil Inductance

The following estimates of the value of the coil inductance L_S could be used as a starting point for the design of your generator. (**NOTE!** There is some uncertainty regarding these estimates):

Table 2: Typical values for the coil inductance in a three-phase, 4-pole, radial flux generator. The number of turns per coil were N_0 = 28 turns.

Load current [A]	Inductance per phase L_{S0} [H]
0 - 3	0.00300
> 3	0.00800

Table 3: Typical values for the coil inductance in a single-phase, 4-pole, radial flux generator. The number of turns per coil were N_0 = 28 turns.

Load current [A]	Inductance per phase L_{S0} [H]
0-3	0.00290
> 3	0.00150

Table 4: Typical values for the coil inductance in a single-phase, 4-pole, axial flux generator. The number of turns per coil were N_0 = 40 turns.

Load current [A]	Inductance per phase L_{S0} [H]
0 – 3	0.00580
> 3	0.00334

Flux Density

The following estimates of the value of the peak flux density B_p at the stator coil level could be used as a starting point for the design of your generator. (**NOTE!** There is some uncertainty regarding these estimates):

Table 5: Flux density.

Generator type	Flux density [T]
Axial flux generator	0.18
Radial flux generator 4-pole	0.21

The peak flux density at the stator coil level is a function of the geometric shape of the permanent magnets. An online calculator for flux density can be found here:
https://www.dextermag.com/resource-center/magnetic-field-calculators

A formula[1] for calculating the peak flux density of a rectangular permanent magnet at a distance x from the pole surface (surface of the permanent magnets) is also given in one of the lectures, and repeated here:

$$B_p = \frac{B_r}{\pi} \cdot \left(\tan^{-1} \frac{A \cdot B}{2 \cdot X \cdot \sqrt{4 \cdot X^2 + A^2 + B^2}} - \tan^{-1} \frac{A \cdot B}{2 \cdot (L + X) \cdot \sqrt{4 \cdot (L + X)^2 + A^2 + B^2}} \right) \quad [Gauss] \tag{3}$$

NOTE! For a magnet mounted on a steel back plate, substitute 2L for L in equation 3.

See Figure 4 for the variables A, B, L and X.

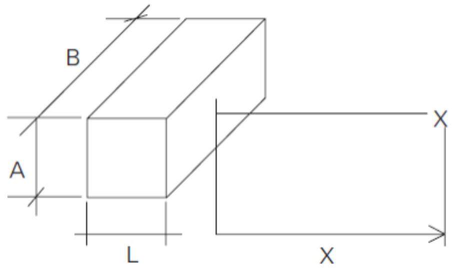


Figure 4: Calculation of the flux density on a magnet's central line X when the magnet is mounted on a steel structure.

Note! When using equation 3 to calculate the peak flux density, the unit of the flux density is given in Gauss and all angles are in radians. 1 Tesla = 10 000 Gauss.

Technical data for the permanent magnets of both the axial flux generator and the radial flux generator are given in Appendix C.

Copper Wire for Stator Winding

You may choose between the following copper wires for the stator winding:

Table 6: Resistance in copper wires.

Diameter [mm]	Resistance [Ω/m at 20°C]
1.2	0.015110
1.5	0.009756

[1]Catalogue from company Magnet Sales & Manufacturing Inc.: «High performance permanent magnets – 7». Copyright © 1995. http://www.magnetsales.com/

NOTE! Make sure you do not use more copper wire than needed when in the laboratory. When you finish the design of your generator you can collect **ONLY** the length given by the design of your stator windings. The copper wire can be collected in the laboratory where you work on your generators.

DESIGN OF THE GENERATOR

The main objectives are:

- Design a generator with the highest possible efficiency at the design point given by the nominal speed of the turbine blade n. (n_{max} = 1600 rpm.) At this point the net torque on the shaft from the turbine blade and generator should be zero, so that maximum energy from the wind is transferred to mechanical energy in the turbine blade, and again to electric energy in the generator at a constant rotational speed.
- Design a generator with a power output that corresponds to the power output from the turbine blade at the design point.

Now that you are familiar with the main objectives for the design and the different generator parameters, you may begin the design procedure. An outline of the process is given here:

1. Decide the turbine blade performance, $P_{turbine}$. This will be given from the design of the turbine blade. Design criteria for the turbine blade:
    a. Maximum Tip Speed Ratio, TSR_{max} = 7.5
    b. D = 0.9 m
    c. n_{max} = 1600 rpm
    d. V = 10 m/s
2. The generator performance, $P_{el-output}$ may then be estimated from the relationship:
   $$P_{el-output} = P_{turbine} \cdot \eta_{generator} \tag{4}$$
3. Decide the mechanical rotational speed, ω_m. This is given from the design criteria for the turbine blade:
   $$TSR = \frac{\omega_m \cdot R}{V} \tag{5}$$
   In equation 5, the maximum design tip speed ratio, TSR = 7.5, R = 0.45 and V = 10 m/s.
4. Decide the turbine torque, $T_{turbine}$ from equation 1 on page 4. The generator braking torque, $T_{generator}$, should be equal but opposite in direction to the turbine torque.
5. Use the software Ashes and enter given and estimated design parameters as user input, and vary the optional parameters (such as number of turns per coil, etc.) until the generator torque and power corresponds to the values found in step 1 and 2. (The formulas used in Ashes can be found in the spreadsheets uploaded on Blackboard called *TEP4175 PMSG Generator Axial Design,* or *TEP4175 PMSG Generator Radial Design.)*

EQUIPMENT FOR LABORATORY WORK

All the groups will be given slot times in the laboratory in order to complete the generator. Each group will be given a box with necessary equipment, marked with group number. Additional tools that will be available:

- Nails
- Screws
- Wooden planks
- Saw
- Nippers
- Screwdriver
- Drill
- Hammer
- File

NOTE!

- Make sure you clean up your workspace after EVERY session.
- Mark your generator CLEARLY with a note stating **group number, year, copper wire dimension, number of turns per coil and measured armature resistance R_A.**

TEST PROCEDURE FOR THE GENERATOR

When the generator is built, you should test it in the laboratory before the final test in the wind tunnel with the turbine blade as the driving force. For the generator tests in the laboratory, the driving force will be a motor. See Figure 1 and 2 for an illustration of the test setup. Student assistants will be available to assist you in the lab.

You should measure different parameters and record all of them (so that they may be compared with estimated and simulated values) in one of the following tables:

a) Generator Measurements and Calculations - Single-phase
b) Generator Measurements and Calculations - Three-phase

When the test setup is ready, this is what you should do:

1) Measure the armature resistance R_A per coil.
2) Measure the total armature resistance R_A with an ohmmeter with connections and wires attached. The temperature of the coils should be low.
3) Vary the rotational speed with an open circuit (no-load). Note the corresponding induced voltages, E_A. Test for at least five different rotational speeds, ranging from 500 to 1600 rpm or higher if possible. **You should of course also test at your design speed.**
4) Connect the generator to a resistive load and measure the terminal voltage, current and power for different rotational speeds and resistive load values. **OBS! You must use the same rotational speeds as you did in 3). If not you will not be able to perform all calculations**. (Tip: Start the test at a low load (i.e. high resistance) and gradually increase the load (i.e. decrease the resistance) to get several measured points for each rotational speed.)
5) Use the oscilloscope to get graphs of the measured voltage at selected operating scenarios (e.g. no-load and high load).

Remember:

$$R_{load,1-phase} = \frac{V_{phase}}{I_{phase}} = \frac{V_{load}}{I_{load}} = \frac{V_{line-line}}{I_{load}}$$

$$R_{load,3-phase,\ \ per\ phase} = \frac{V_{phase}}{I_{phase}} = \frac{V_{phase}}{I_{load}}$$

For a symmetrical, 3-phase, Y-connected generator the relationship between line-voltage and phase-voltage is as follows:

$$V_{phase} = \frac{V_{line-line}}{\sqrt{3}}$$

6) Measure the total armature resistance R_A with an ohmmeter with connections and wires attached. The temperature of the coils should be high.

ANALYSIS OF THE GENERATOR TEST DATA

1) Create the following tables:
   a. Tables of measurement results and calculations as found on Blackboard:
      - *Generator Measurements and Calculations - Single-phase* or
      - *Generator Measurements and Calculations - Three-phase*
   b. Table 7 given on page 14 of this document.
   c. Estimated versus calculated flux density, B_p, at the stator coil level for selected rotational speeds. (Must be calculated from the measured value of E_A and other parameters.) May be added to the tables in 1a.

2) Create the following graphs:
   a. Induced voltage E_A as a function of the rotational speed, n. (Based on the open circuit measurements.)
   b. Estimated versus calculated coil inductance L_s as a function of load current, I_L, and rotational speed, n.
   c. Estimated versus calculated generator efficiency, $\eta_{generator}$, as a function of generator output power.
   d. Calculated synchronous reactance, X_S, as a function of load current, I_L and rotational speed, n.
   e. Terminal voltage, V_{load}, as a function of output power, P_{load}.

3) Include the following in your final report:

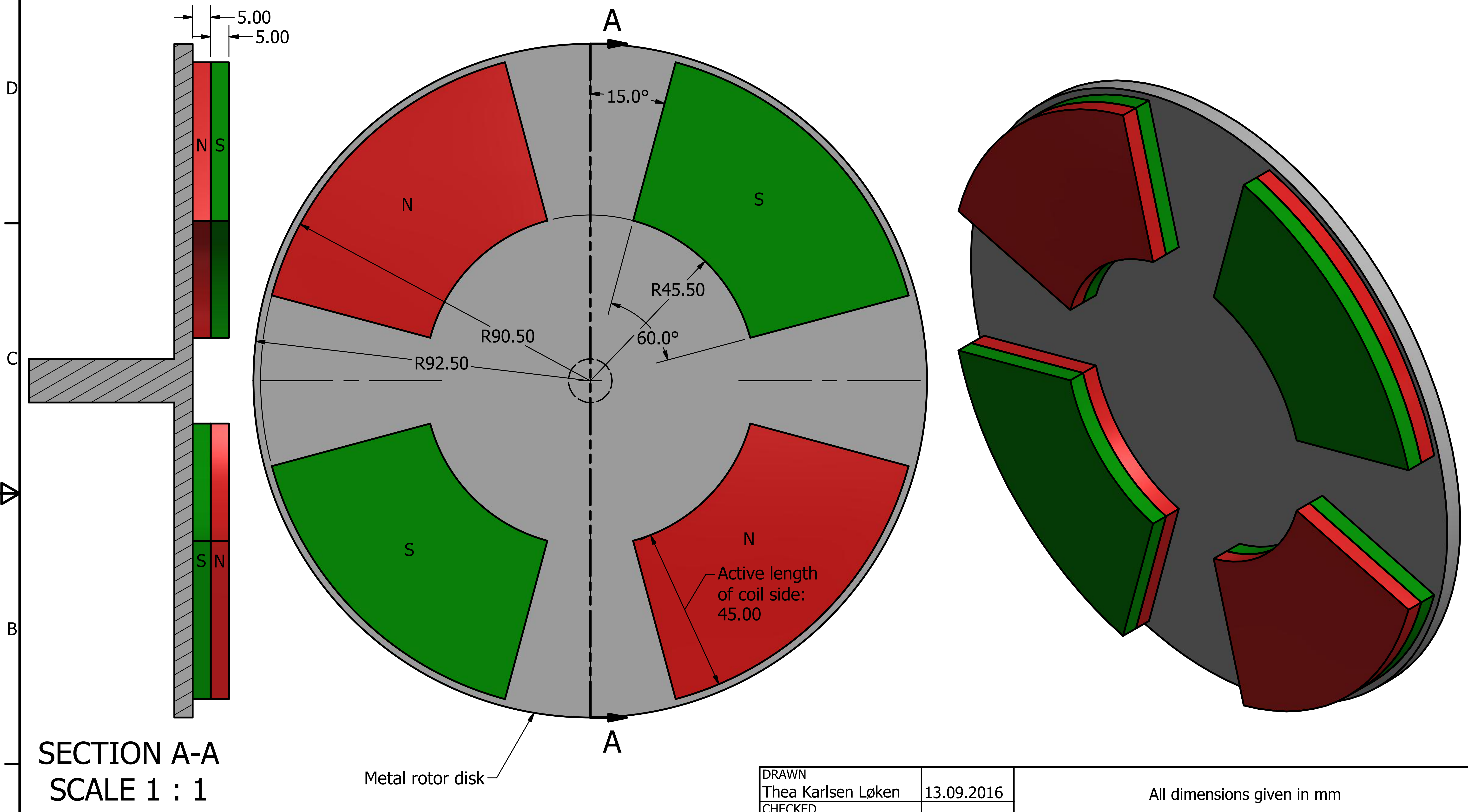
   a. All the tables as described above (1a – 1c).
   b. All the graphs as described above (2a – 2e).
   c. Dimension and measured resistance of the copper wire used.
   d. Number of turns in your coils.
   e. Graphs of measured voltage from the oscilloscope at selected operating scenarios (e.g. at no-load and high load).

Table 7: Structured compilation of design and test data. When applicable, give all values at the design speed of your generator.

Type of machine					
Number of phases					
Number of poles					
Parameter		**Unit**	**Design value**	**Measured/ calculated value**	**Comments**
Name	**Symbol**				
Optimum rotational speed	n	rpm			Design value for wind turbine.
Optimum angular velocity (mech.)	ω_m	rad/s			Calculated: $\omega_{mech} = \frac{2\pi n}{60}$
Optimum electric power output	P_{el}	W (Watt)			The measured value here is the value achieved in the tests performed on the generator only at the optimum rotational speed.
Number of turns per coil	N	[-]			
Stator coil inductance (per phase)	L_S	H (Henry)	Specify rotational speed	Specify rotational speed	Calculated, based on calculated value of X_S (for which calculation is based on measurements).
Stator coil reactance (per phase)	X_S	Ω (Ohm)	Specify rotational speed	Specify rotational speed	Calculated: $X_S = \omega_e \cdot L_S = \frac{P}{2} \cdot \omega_{mech} \cdot L_S$
Armature resistance	R_A	Ω (Ohm)			To be measured with precision instrument. Ambient temperature must be specified.
Peak flux density	B_p	T (Tesla)	Specify rotational speed	Specify rotational speed	Must be calculated from the measured values.
Induced voltage	E_A	V (Volt)	Specify rotational speed	Specify rotational speed	Phase voltage 3-phase generator. Line-Line voltage for 1-phase gen.
Terminal voltage (per phase)	V_T	V (Volt)	Specify rotational speed	Specify rotational speed	To be specified with reference to a load resistance R_L and a load current I_L.
Efficiency of generator	η_{gen}	[-]	Specify rotational speed	Specify rotational speed	To be specified with reference to a load resistance R_L, a load current I_L and load power P_L.
Stator copper losses	P_{Cu}	W (Watt)	Specify rotational speed	Specify rotational speed	Stator copper losses (P_{Cu}) are found via: $P_{Cu} = R_A \cdot I_A^2$ (per phase)
Generator losses	$P_{gen,loss}$	W (Watt)	Specify rotational speed	Specify rotational speed	Total losses: To be specified with reference to a load resistance R_L, a load current I_L and load power P_L.

APPENDIX A

Drawings of Axial Flux Generator

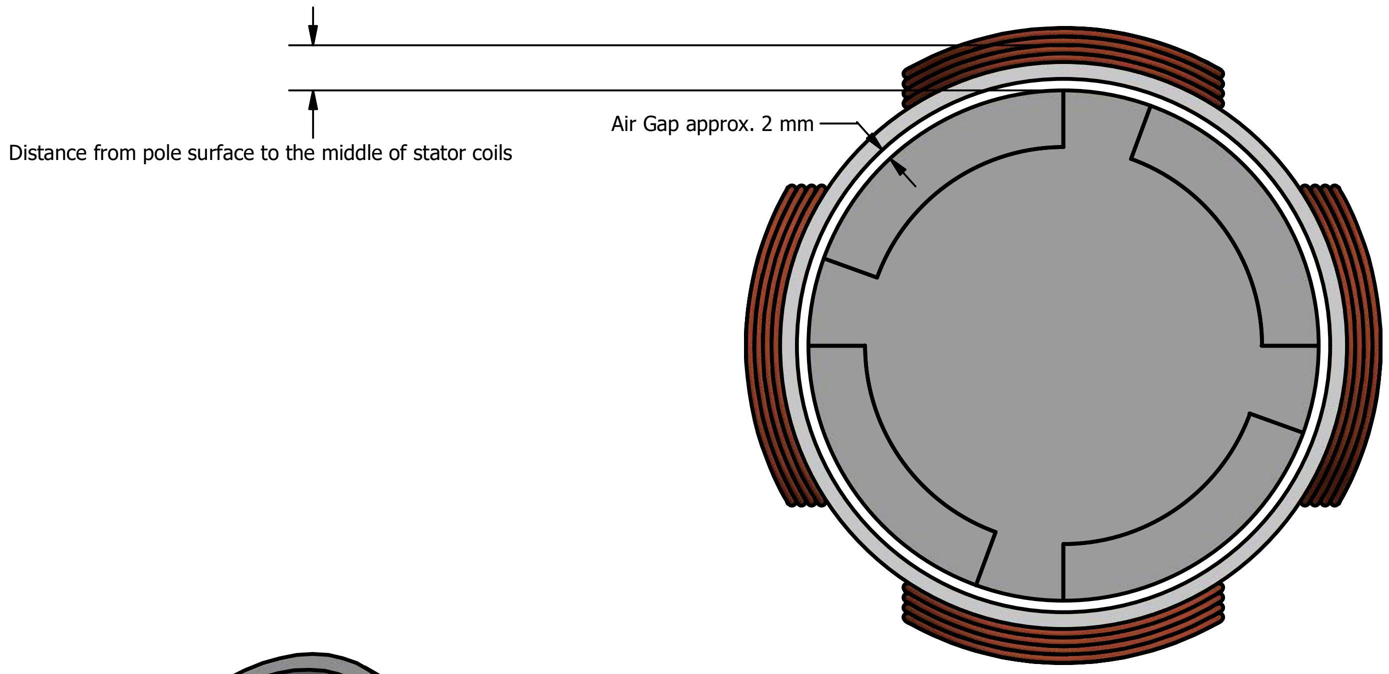


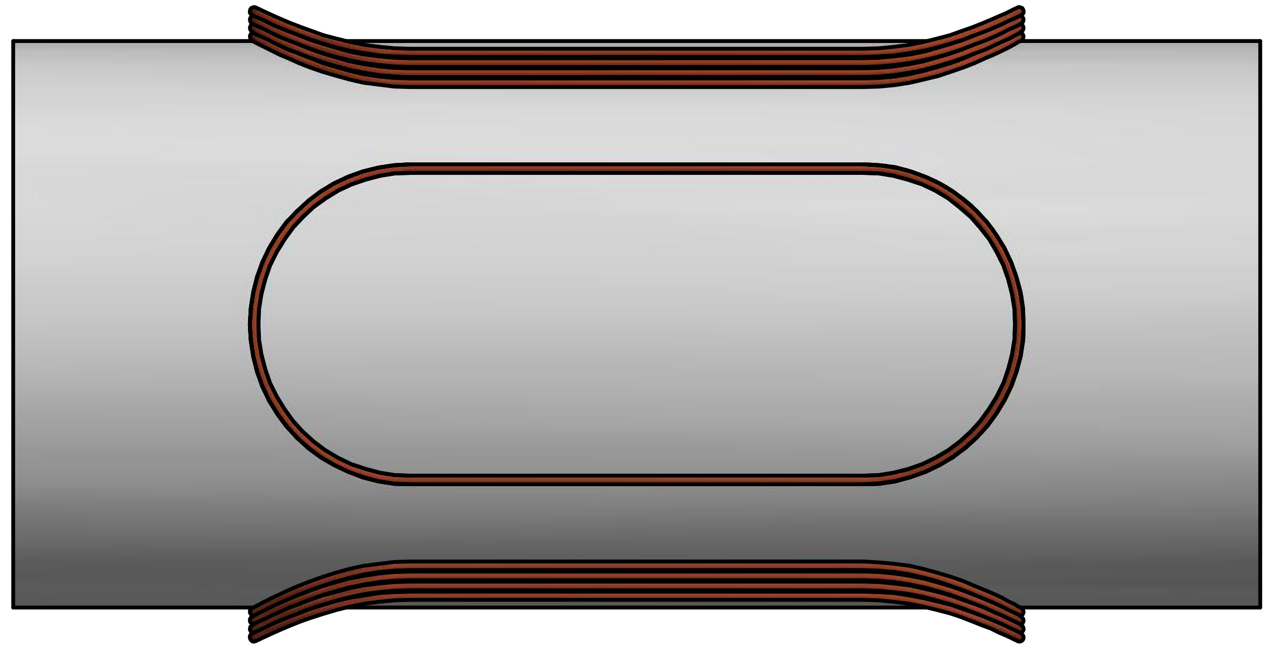
DRAWN Thea Karlsen Løken	13.09.2016	All dimensions given in mm
CHECKED		TITLE
QA		Axial Flux Rotor with 4 poles
MFG		
APPROVED		
		SIZE A3 · DWG NO Axial Flux Rotor · REV
		SCALE 1:1 · SHEET 1 OF 1

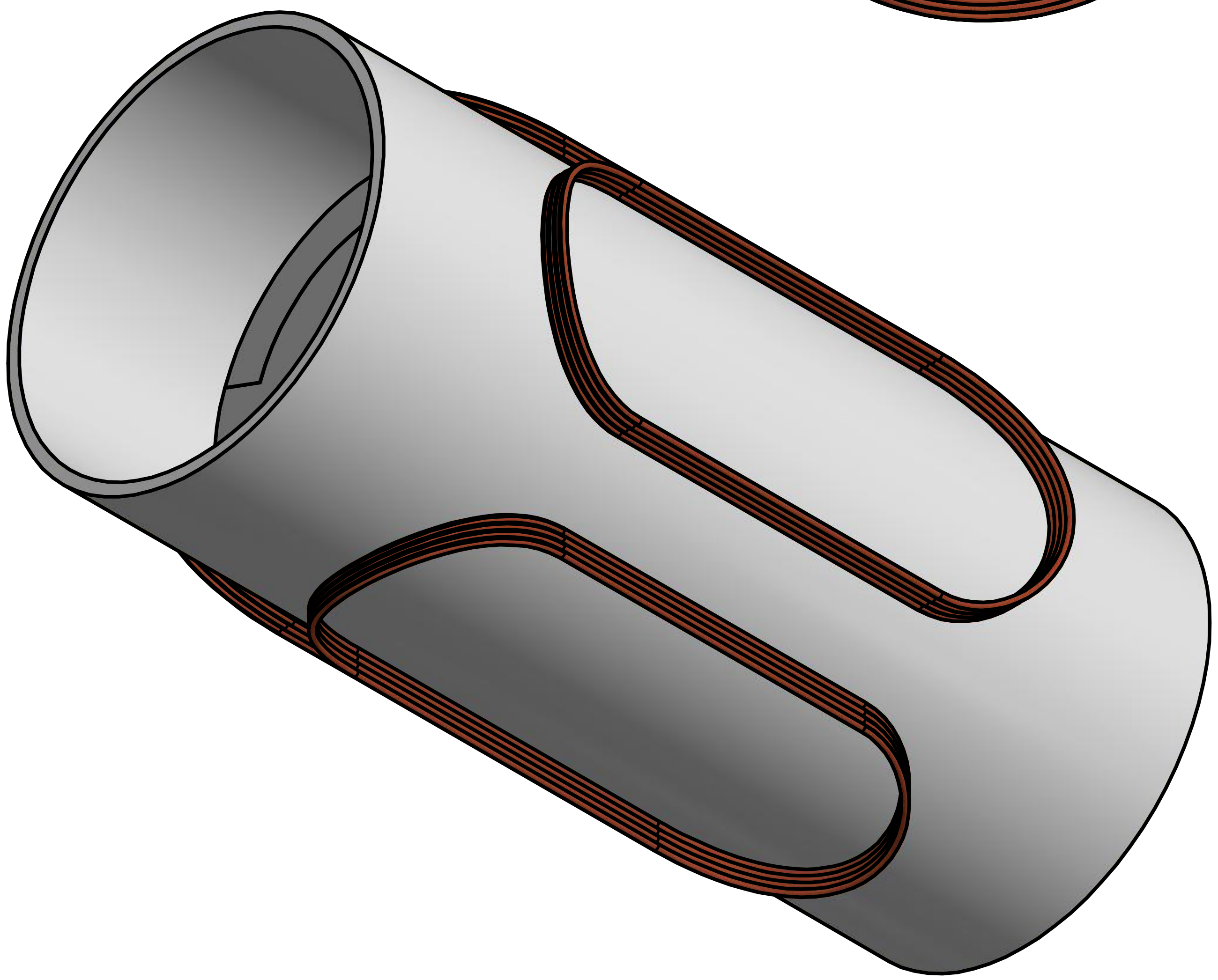
DRAWN Thea Karlsen Løken	13.09.2016	All dimensions given in mm
CHECKED		TITLE Axial Flux Stator 4 coils (Single-phase)
QA		
MFG		
APPROVED		SIZE A3 / DWG NO Axial Flux Stator / REV
		SCALE 1:1 / SHEET 1 OF 1

APPENDIX B

Drawings of Radial Flux Generator







DRAWN Thea Karlsen Løken	26.07.2017	All dimensions given in mm
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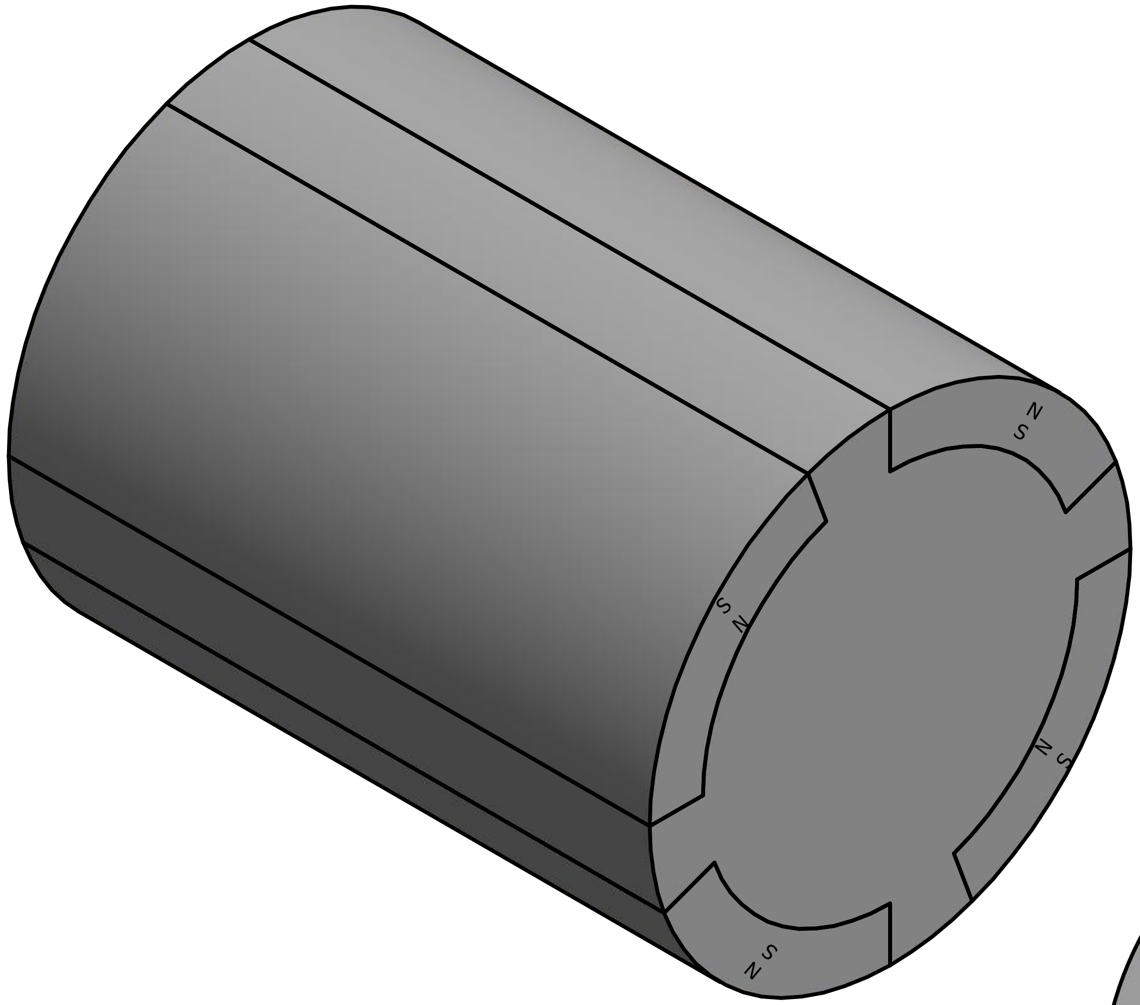
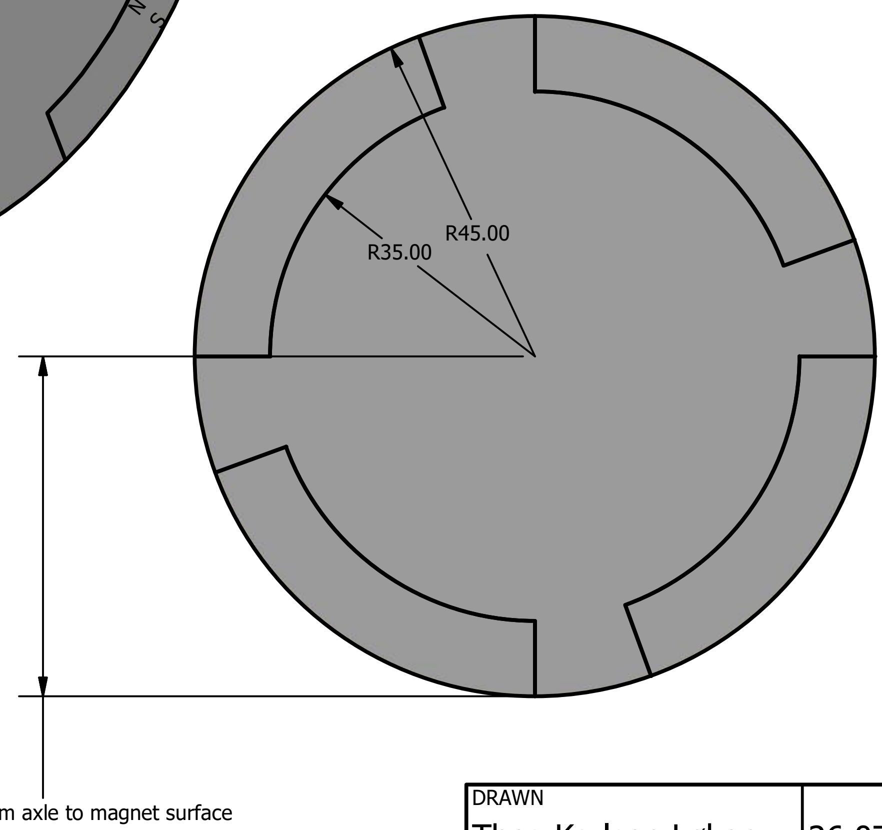
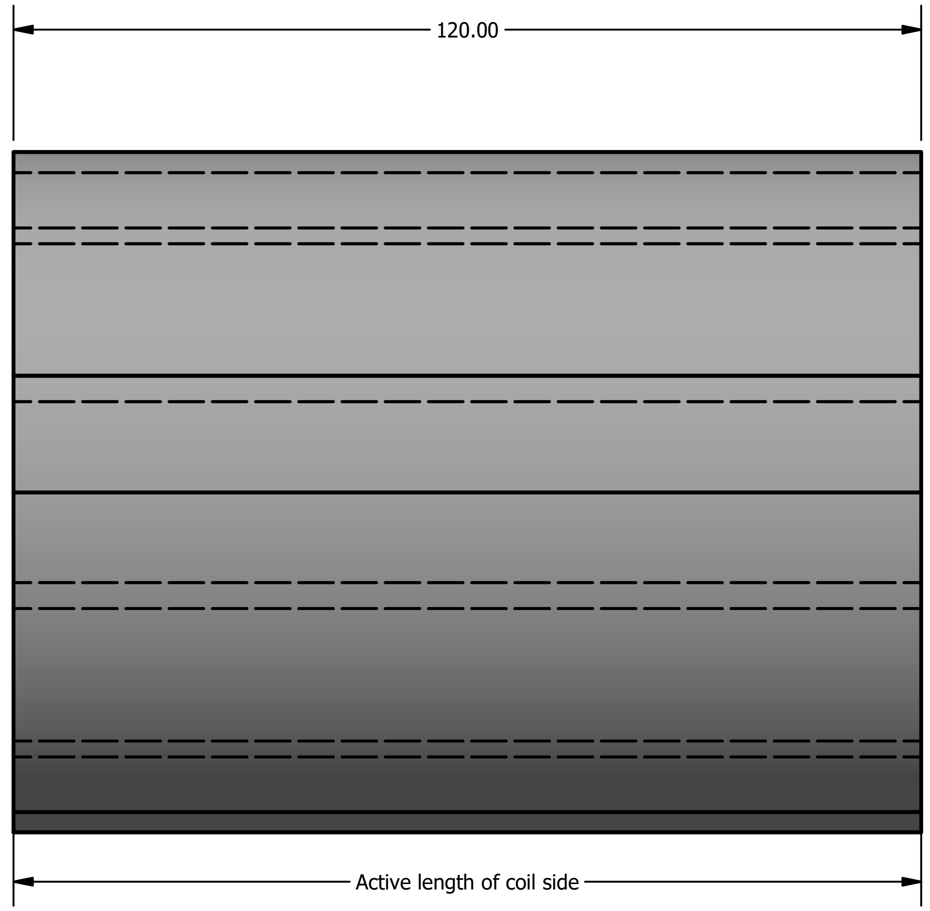
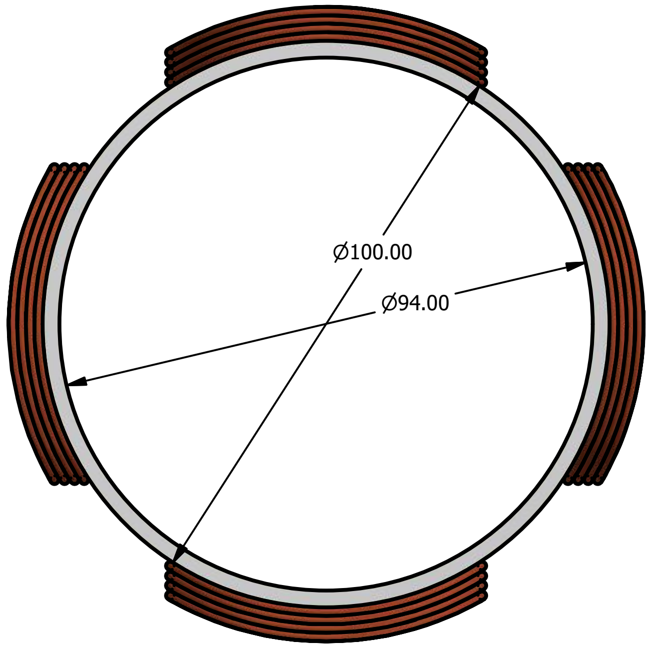
QA		
MFG		
APPROVED		SIZE A3 · DWG NO Radial Flux 4pole Generator Assemb · REV
		SCALE 1:1 · SHEET 1 OF 1

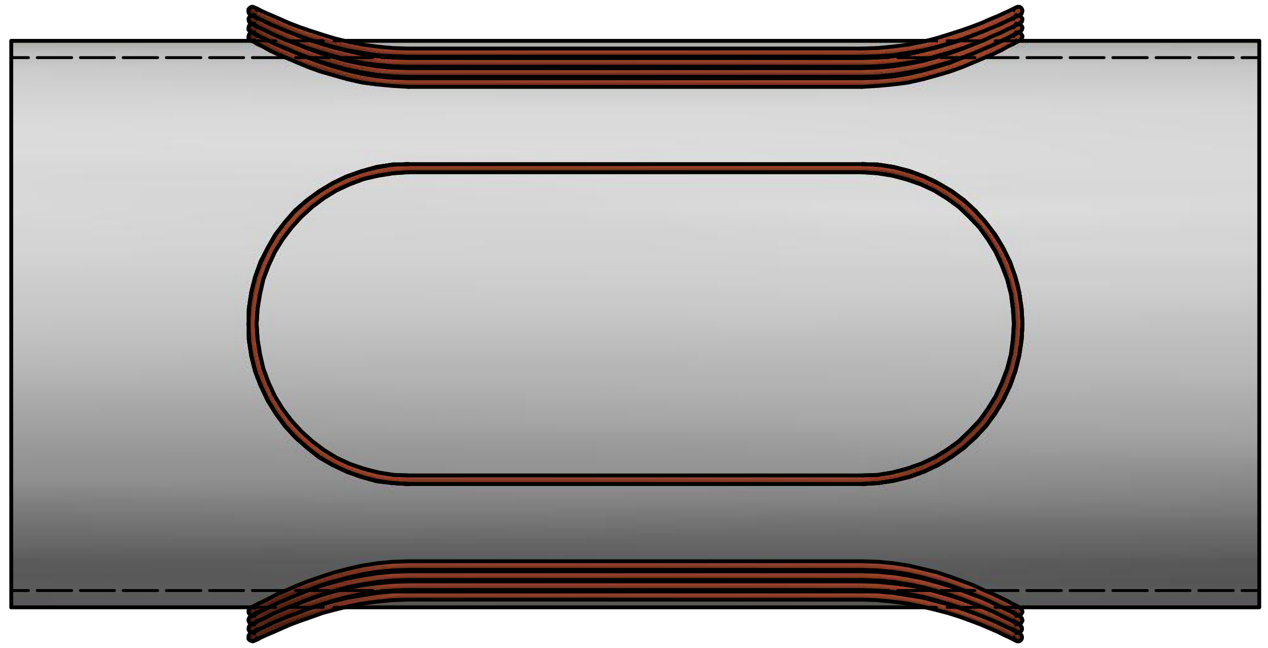


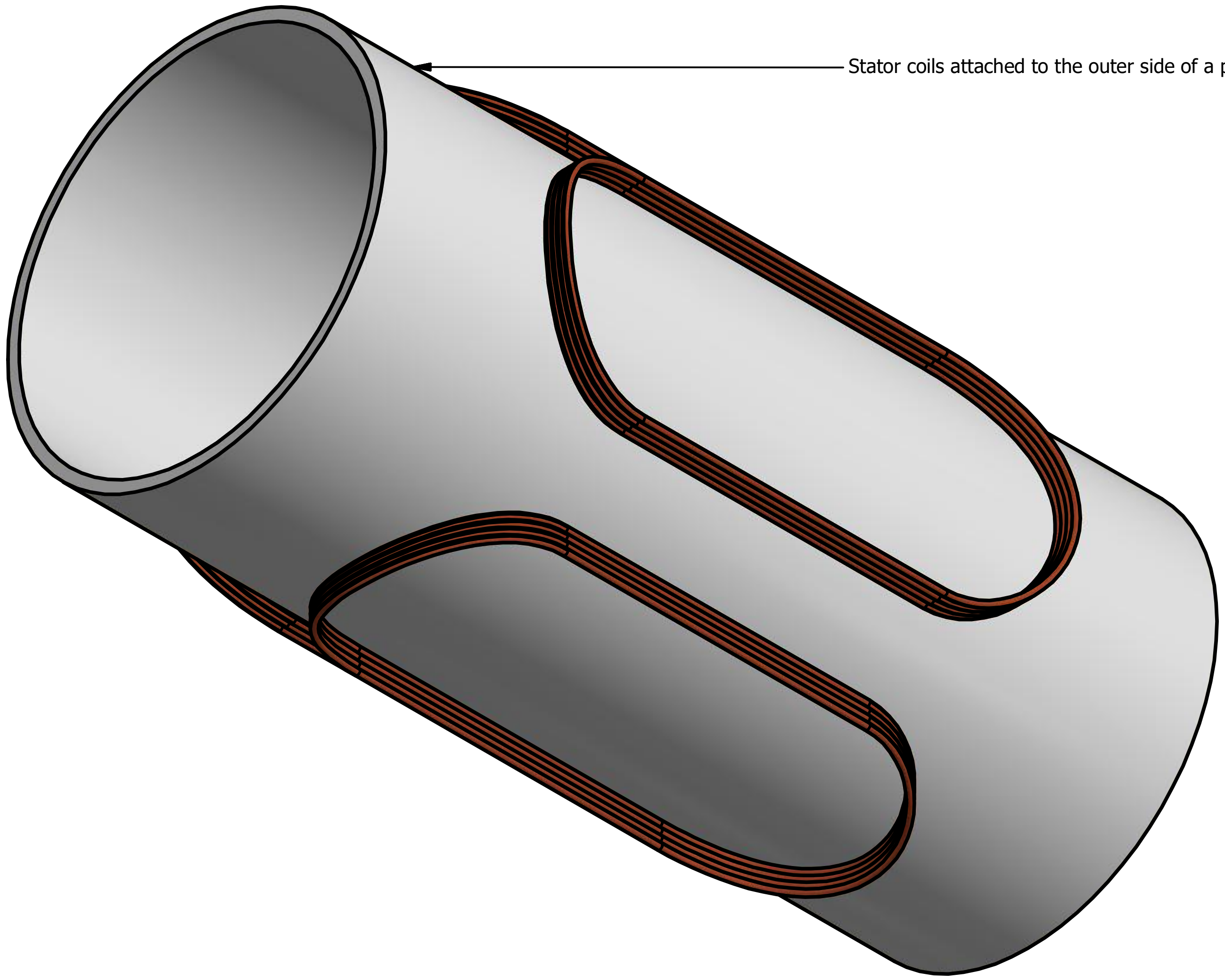




DRAWN Thea Karlsen Løken	26.07.2017	All dimensions given in mm
CHECKED		TITLE Radial Flux Rotor 4 poles
QA		
MFG		
APPROVED		SIZE A3 · DWG NO Radial Flux Rotor 4pole · REV
		SCALE 1:1 · SHEET 1 OF 1







DRAWN Thea Karlsen Løken	26.07.2017	All dimensions given in mm
CHECKED		TITLE Radial Flux Stator 4 poles (Single-phase)
QA		
MFG		
APPROVED		SIZE: A3 · DWG NO: Radial Flux Stator 4pole · REV
		SCALE 1:1 · SHEET 1 OF 1

APPENDIX C

Technical Data for the Permanent Magnets

A member of VAC group

QUOTATION 14782

9.9.2014

NTNU Vannkraftlaboratoriet Alfred Getz' vei 4 7034 Trondheim Norway	Bård Aslak Brandåstrø bard:brandastro@ntnu.no

ITEM 1.

Dimensions:	OD180, ID90, α 60°, 10 (a) mm, similar to emailed drawing
Magnetic properties:	Br >= 1,24T, jHc > 1400 kA/m
Magnetization direction:	10 mm
Magnetization:	Yes
Coating:	Ni 10 µm
Quantity:	20 pcs
Weight:	0,242 kg/pc
Price EUR/pc (VAT 0%):	75,00

Note:

Delivery terms:	CPT Trondheim, Norway (Incoterms 2010)
Delivery time:	6-8 weeks
Payment terms:	30 days net
Validity of quotation:	Until 17.10.2014

Kind regards,

Olli Naukkarinen
NEOREM MAGNETS OY

Our prices will be adjusted based on the raw material prices and exchange rates at the time of order. Our prices will also be adjusted quarterly based on the raw material prices and exchange rates.

The seller retains ownership until full payment is received. Interest rate on overdue payment is 8%. The "Terms and Conditions for the Supply of Goods and Services" of Neorem Magnets Oy shall apply. These Terms and Conditions are available on our internet page www.neorem.fi.

Data sheet article Q-40-20-10-N

Technical data and application safety

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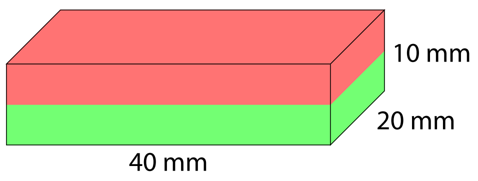
Fax: +49 7731 939 839 9

www.supermagnete.de
support@supermagnete.de

1. Technical information

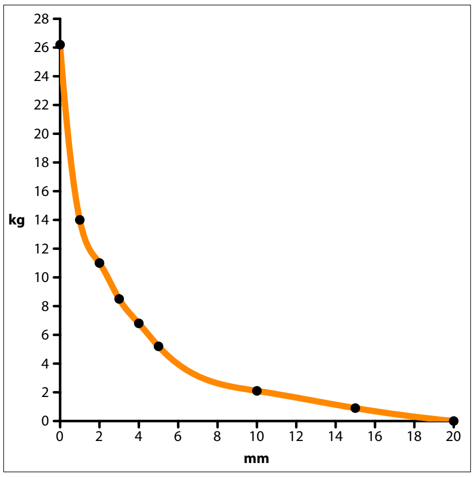
Article	Q-40-20-10-N	
Shape	Block	
Side 1	40 mm	
Side 2	20 mm	
Side 3	10 mm	
Tolerance in size	+/- 0,1 mm	
Direction of magnetisation	parallel to side 3	
Pole faces	40 x 20 mm	
Material	NdFeB (Neodymium Iron Boron)	
Type of coating	Nickel (Ni-Cu-Ni)	
Strength	approx. 25 kg	approx. 245 N
Weight	60,8 g	
Manufacturing method	sintered	
Magnetisation (Grade)	N42	
Max. working temperature	80°C	
Curie temperature	310 °C	
Residual magnetism Br	12900-13200 G	1.29-1.32 T
Coercive field strength bHc	10.8-12.0 kOe	860-955 kA/m
Coercive field strength iHc	≥12 kOe	≥955 kA/m
Energy product (BxH)max	40-42 MGOe	318-334 kJ/m^3



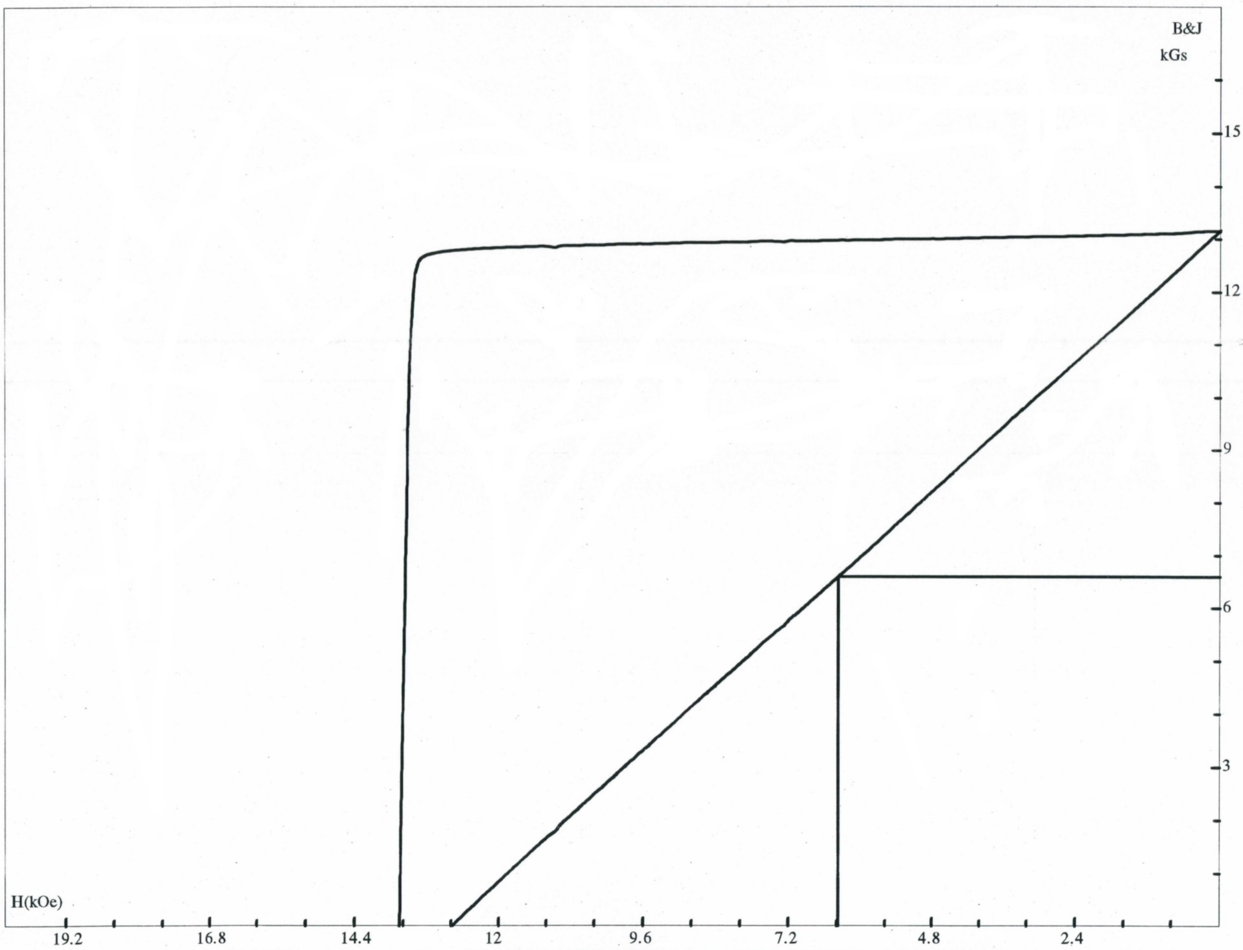
Pollutant-free according to RoHS Directive 2011/65/EU.
Exempt from registration according to REACH.

2. Adhesive force diagram

Adhesive force in relation to the air gap between magnet and steel plate.



3. Demagnetisation curve N42



4. Safety tips

Warning	Contusions
	Big magnets have a very strong attractive force. • Unsafe handling could cause jamming of fingers or skin in between magnets. This may lead to contusions and bruises. • Powerful, very large magnets could cause bone fractures. Wear heavy protective gloves when handling larger magnets.

Warning	Pacemaker
	Magnets could affect the functioning of pacemakers and implanted heart defibrillators. • A pacemaker could switch into test mode and cause illness. • A heart defibrillator may stop working. • If you wear these devices keep sufficient distance to magnets: www.supermagnete.de/eng/faq/distance • Warn others who wear these devices from getting too close to magnets.

Warning	Heavy objects
	Too heavy loads, symptoms of fatigue as well as material defect could cause a magnet or magnetic hook to loosen from the surface that is was attached to. Falling objects could lead to serious injuries. • The indicated adhesive force applies only to ideal conditions. Allow for a high safety cushion. • Don't use magnets in places where people could sustain injuries in case of material failure.

Warning	Metal splinters
	Neodymium magnets are brittle. Colliding magnets could crack. Sharp splinters could be catapulted away for several meters and injure your eyes.
	• Avoid the collision of magnets. • Wear safety glasses when handling larger magnets. • Make sure that nearby people are also protected or keep their distance.

5. Handling and storing

Caution	Magnetic field
	Magnets produce a far-reaching, strong magnetic field. They could damage TVs and laptops, computer hard drives, credit and ATM cards, data storage media, mechanical watches, hearing aids and speakers.
	• Keep magnets away from devices and objects that could be damaged by strong magnetic fields. • Please refer to our table of recommended distances: www.supermagnete.de/eng/faq/distance

Caution	Combustibility
	When machining magnets, the drilling dust could easily ignite.
	Stay away from machining magnets or use appropriate tools and sufficient cooling water.

Caution	Nickel allergy
	Many of our magnets have coatings that contain nickel. • Some people have an allergic reaction when they come into contact with nickel. • Nickel allergies could develop from constant contact with nickel-plated objects.
	• Avoid constant skin contact with nickel-plated magnets. • Avoid contact with magnets if you already have a nickel allergy.

Notice	Influence on people
	According to the current level of knowledge, magnetic fields of permanent magnets do not have a measurable positive or negative influence on people. It is unlikely that permanent magnets constitute a health risk, but it cannot be ruled out entirely.
	• For your own safety, avoid constant contact with magnets. • Store large magnets at least one metre away from your body.

Notice	Splintering of coating
	Most of our neodymium magnets have a thin nickel-copper-nickel coating to protect them from erosion. This coating could splinter or crack due to collision or large pressure. This makes them vulnerable to environmental influences like moisture and they could oxidise.
	• Separate big magnets, especially spheres, with a piece of cardboard. • Avoid collisions of magnets as well as repeated mechanical exposure (e.g. blows, bashes).

Notice	Oxidation, corrosion, rust
	Untreated neodymium magnets oxidise quickly and disintegrate. Most of our magnets have a nickel-copper-nickel coating to protect them from corrosion. This coating provides some protection against corrosion, but it is not robust enough for continuous outdoor use.
	• Use magnets only in the dry indoors or protect them against environmental influences. • Avoid damages to the coating.

Notice	Temperature resistance
	Neodymium magnets have a maximum working temperature of 80 to 200 °C. Most neodymium magnets lose part of their adhesive force permanently at a temperature of 80 °C.
	• Don't use magnets in places where they are exposed to extreme heat. • If you use an adhesive, don't harden it with hot air.

Notice	Mechanical treatment
	Neodymium magnets are brittle, heat-sensitive and oxidise easily. • When drilling or sawing a magnet with improper tools, the magnet may break. • The emerging heat may demagnetise the magnet. • The magnet will oxidise and disintegrate due to the damaged coating.
	Stay away from mechanical treatment of magnets if you do not possess the necessary equipment and experience.

6. Transportation tips

Caution	Airfreight
	Magnetic fields of improperly packaged magnets could influence airplane navigation devices. In the worst case it could lead to an accident.
	• Airfreight magnets only in packaging with sufficient magnetic shielding. • Please refer to the respective regulations: www.supermagnete.de/eng/faq/airfreight

Caution	Postage
	Magnetic fields of improperly packaged magnets could cause disturbances in sorting machines and damage fragile goods in other packages.
	• Please refer to our shipping tips: www.supermagnete.de/eng/faq/shipping • Use a large box and place the magnet in the middle surrounded by lots of padding material. • Arrange magnets in a package in a way that the magnetic fields neutralise each other. • If necessary, use sheet iron to shield the magnetic field. • There are stricter rules for airfreight: Refer to the warning notice "Airfreight".

7. Disposal tips

Small amounts of used neodymium magnets can be thrown out with the regular trash. Larger amounts of magnets need to be recycled as scrap metal.

8. Statutory provisions

Neodymium magnets are not intended for sale/export to the United States of America, Canada or Japan. You are strictly prohibited from directly or indirectly exporting the neodymium magnets that you received from us or the end products that you produced from those magnets to the countries mentioned above.

TARIC-Code: 8505 1100 99 0

Origin: China

For more information about magnets please review
www.supermagnete.de/faq.php.

Last update: 23/11/2011