Manual of

electricity generating windmill

VIRYA-1.36

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1 Introduction

In this manual the 2-bladed VIRYA-1.36, electricity generating windmill, is described. This windmill is provided with an 8-pole, 3-phase axial flux generator and is meant for 12 V battery charging after star rectification of the winding. The design calculations of the generator, the rotor and the head geometry are given in report KD 571 (ref. 1). It is expected that, together with the detailed drawings, the windmill can be manufactured in a good workshop. The drawings of the VIRYA-1.36 windmill are numbered 1407-00 up to 1407-06. All drawings are made on A3 format and are reduced to A4 format. The scanned reduced drawings are incorporated in chapter 7 of this manual.

Drawing 1407-00 is the main assembly and gives a top and front view of the whole windmill. The sub assembly rotor + generator is mentioned as (01) and the sub assembly head + tower pipe is mentioned as (04) referring to the relevant drawing numbers.
Drawing 1407-01 is the sub assembly of rotor + generator and also contains a list with standard parts (indicated with --N) which are required to connect all parts together.
Drawing 1407-02 gives a detailed drawing of the rotor blade (01), the core + coil (02), the bearing housing (03) and the distance bush (04).
Drawing 1407-03 gives a detailed drawing of the armature sheet (05) and the stator disk (06).
Drawing 1407-04 is the sub assembly of head + tower pipe and also contains a list with standard parts (indicated with --N) which are required to connect all parts together.
Drawing 1407-05 gives a detailed drawing of the vane arm assembly (01), the tower pipe (02) and the head bearing housing (03).
Drawing 1407-06 gives a detailed drawing of the vane blade (04), the vane blade stop (05), the clamp (06) and the threaded rod (07).

For the stainless steel blades of other VIRYA-windmills, hydraulic blade presses were developed. The small blades of the VIRYA-1.36 rotor need a much lower pressing force and therefore a simpler, lighter and cheaper blade press can be used. This blade press and the tools to twist the blades are not yet drawn but can be derived from the blade press and the tools which were designed for the VIRYA-1.04 windmill. The drawings of the VIRYA-1.04 windmill are given in a public manual (ref. 2) which can be copied from my page on the web site of Bidnetwork. The length of the blade press should be increased from 400 up to 500 mm. One has to do some test to find the correct radius of the pressing block for a 1.5 mm stainless steel blade. One has to make a 3° jig and a 11° jig to verify the correct twist and blade angles.

The maximum power of the VIRYA-1.36 windmill is expected to be about 70 W at a maximum charging voltage of 14 V. So the maximum charging current is about 5 A. It is assumed that no voltage controller and dump load are required to limit the charging voltage if a normal lead acid battery of large enough capacity is used (at least 50 Ah). Such battery can have a charging current of 5 A for a certain time even if it is full. However, the battery has to be removed from the windmill if substantial gas production has started.

The VIRYA-1.36 is designed by

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Although the VIRYA-1.36 windmill has been designed carefully, no responsibility is assumed for the operation of the windmill as a whole, nor for any of its separate parts.

2 Specification

Diameter	D = 1.36 m
Number of blades	B = 2
Design tip speed ratio	$\lambda_d = 5$
Gear ratio	i = 1
Rotor eccentricity	e = 0.12 m
Tower height for tower pipe only	H = 2 m
Mass including 2 m tower pipe	m = 13.6 kg
Starting wind speed	V_{start} = 2.4 m/s
Survival wind speed	V_{surv} = 30 m/s
Cut in wind speed (if started)	$V_{cut\ in}$ = 2.5 m/s
Rated wind speed	V_{rated} = 10 m/s
Nominal voltage	12 V DC
Power at rated wind speed	P = 80 W

3 The safety system (see report KD 571 chapter 9)

The safety system was developed by A. Kragten in 1982. It is used in all VIRYA windmills developed by Kragten Design, in the water pumping windmill CWD 2000 and in some other windmills. A detailed description of the system for rotors with 7.14 % cambered blades can be found in the report KD 223 (ref. 3). Checking of the head geometry is given in chapter 9 of report KD 571 (ref. 1). Here only the use and working of the system in general will be explained.

At low wind speeds, the vane blade hangs in an almost vertical position and the moment of the horizontal component of the aerodynamic force on the vane N cos θ around the tower axis is in balance with the moment of the thrust on the rotor F_t (see KD 571 figure 8). The head and vane geometry are chosen such that the rotor is about perpendicular to the wind for low wind speeds. If the wind speed increases, the vane blade turns from an almost vertical to an almost horizontal position, because the moment of the aerodynamic force around the vane axis must be in balance with the moment of the weight G of the vane blade.

The horizontal component of the aerodynamic force on the vane blade at a certain wind speed is much smaller for the vane in the horizontal position than for the vane in the vertical position. This effect becomes dominant if the wind speed is higher than about 6 m/s and will result in yawing of the rotor of about 30° out of the wind as the wind speed increases from 6 m/s up to 10 m/s. At higher wind speeds, the vane blade is lifted more and more and will be in a nearly horizontal position at wind speeds of about 30 m/s. At this wind speed the rotor is turned about 75° out of the wind. The rotor speed will be about constant for wind speeds between 10 m/s and 30 m/s. These are the values for a 2 mm aluminium vane blade.

The behaviour of this system is very stable and it has the following advantages:

1. The vane blade is in the undisturbed wind speed and is therefore not hindered by turbulence of the rotor wake.
2. The eccentricity between rotor shaft and tower axis is adequately high (e = 0.088 D). Therefore, the moment which turns the head out of the wind is mainly determined by the thrust on the rotor. Other unfavourable forces like the side force on the rotor, the so called self-orientating moment and the head bearing friction have only a minor effect.
3. As the vane arm is a part of the head, it makes the moment of inertia of the head around the tower axis very large. This results in slow rotation of the head. This reduces the gyroscopic moment in the rotor blades and the generator shaft.
4. At high wind speeds only small changes in the angle between the rotor axis and the wind direction are necessary to come to a new balance of moments.
5. Simple and cheap door hinges can be used for the hinges of the vane blade.

4 Manufacture of the parts

4.1 General

The information necessary to manufacture the separate parts is given on the drawings given in the appendix. The standard parts are indicated with N. The description for connecting material like bolts and nuts and electronics is in accordance with the description, code number and DIN standard of the Fabory catalogue and the Farnell catalogue. In this manual, only parts are described of which it is thought that it is necessary to give additional information.

4.2 Rotor (drawing 1407-02)

A rotor blade (01) is made from a stainless steel strip size 1.5 * 625 * 125 mm. 40 blades can be made out of a standard sheet of 1.25 * 2.5 m without waste material. Normally a standard sheet is some mm longer than the nominal value so the tolerance of the width of 125 mm of the last strip should be checked. The two blade strips of one rotor must be identical to prevent blade imbalance.

First the hole spacing is made in the blade root. The hole spacing must be made very accurate to prevent rotor imbalance. It is possible to drill two blades together. Accurate drilling requires a milling machine or hardened drilling jigs. Next the radius R = 2 mm is made on all four corners. The whole outline is rounded with R = 0.3 mm.

Next the 7.14 % camber is made over a length of 500 mm by cambering the blade with R = 220 mm. This can be done using a modified blade press of the VIRYA-1.04 given on drawing 1302-01. The radius of the pressing block has to be found by try and error by using a strip of the used stainless steel and bend it around cylinders of different diameter until the correct radius is found. The radius of the pressing block must be much smaller than 220 mm because the blade bends back in the elastic region.

After cambering, the blade has to be twisted 3° right hand in between cross section A and cross section F. Tools to do this are given for the VIRYA-1.04 at drawing 1303-01. Two identical torsion levers item 01 and torsion strips item 02 are used. One torsion lever is clamped in a vice with the hollow side upwards. The blade is clamped in between item 01 and item 02 by means of two screws item 02 N such that the free blade length is 490 mm. The other set of tools is clamped around the blade tip. The blade is twisted about 5° right hand and is then twisted back until the correct angle of 3° is gained. The correct angle can be verified by item 05 of drawing 1303-01 which must have an angle of 3° for the VIRYA-1.36. As the torsion tools have a thickness of 10 mm, the blade is twisted effectively over a length of 480 mm in stead of 500 mm but this is no problem.

Next the blade is twisted 11° in between cross section F and the flat inner side of the blade which has a length of 24 mm. The outer set of torsion tools is removed. Two flat strips item 07 are slightly clamped around the blade root by two screws 01N. These strips are clamped in a vice such that the blade points upwards. The blade is twisted by turning the first set of torsion tools about 13° left hand and is then twisted back until the correct angle of 11° is gained. The correct angle can be verified by the jig item 04 of drawing 1303-01 which must have an angle of 11° for the VIRYA-1.36. One has to be alert that the blade is only twisted and not bent forwards or backwards. This can be checked by placing a water-level on the torsion lever.

4.3 Coil + core (drawing 1407-02)

At the date of writing this provisional manual, a complete generator has not yet been measured. But tests have been performed to determine the wire thickness and the number of turns per coil. The wire thickness is 0.8 mm and the number of turns per coil is 130. The procedure how this was done is given in chapter 10 of KD 571.

The two coils of one phase have to be made together to eliminate soldering points. The winding direction of both coils is the same. The 9 mm chamber for the connecting screw M5 * 16 must point to the front side for both cores at mounting of the cores against the stator sheet.

The coil cores are made of polyacetal (or POM) and have a central hole with a diameter of 5 mm. So the winding thorn must have a shaft with a diameter of 5 mm at the cores. It is assumed that the left side of winding thorn has a diameter of 15 mm and that this side is clamped in a driving unit which can be the head stock of a lath for the prototype. The 5 mm shaft has M5 thread at the end. Three brass disks with a central hole of 5 mm, an outer diameter of 56 mm and a thickness of 4 mm are also used.

First a brass disk is shifted over the shaft. Next the left core is placed with the 9 mm chamber to the left. Next the second brass disk is placed. Next the right core is placed with the 9 mm chamber to the left. Next the last brass disk is placed. Everything is clamped together by a nut M5. If the 9 mm chambers are pointing in the same direction on the winding thorn, the winding direction will be the same for both coils if the cores are mounted to the stator sheet.

One needs a driving unit with variable speed to drive the winding thorn. The number of revolutions has to be counted by a counter. If the number of turns per coil and the wire thickness are determined correctly, it means that the outside coil diameter is just 58 mm for 130 turns per coil and 0.8 mm enamelled copper wire. The last layer is covered by some epoxy lacquer to prevent that the last layer unwinds when the winding thorn is disconnected. Hardening of the epoxy lacquer will take some time, so one needs at least three winding thorns to continue production for the coils of the other two phases.

4.4 Armature sheet (drawing 1407-03)

Eight neodymium magnets size 25.4 * 25.4 * 12.7 mm have to be glued to the back side of the armature sheet in such a way that four north poles and four south poles are created. For correct positioning it is advised to make a Teflon sheet size 156 * 156 * 4 mm which can be bolted to the armature sheet. The Teflon sheet should have eight square holes size 25.5 * 25.5 at the correct pitch circle and the correct position. Eight magnets are piled together with isolation sheets in between them. Arrows are placed at all four free sides of each magnet in the same direction. First four magnets are glued by epoxy to the armature sheet and the arrows on these first four magnets are pointing upwards. Next four magnets are glued in between the first four ones and the arrows on these second four magnets are pointing downwards.

4.5 Vane arm assembly (drawing 1407-05)

Drilling of the hole ϕ 8 in the pin item 01/02 from one side requires a special long drill. It is also possible to drill the hole (on a lathe) from two sides, but this will probably result in some non-concentricity in the middle which is acceptable if there are no sharp edges.

During milling of the hole ϕ 16 in the ¾” gas pipe, the 45° plane for the generator bracket must be parallel to the axis of the cutter. This situation is accomplished if the 45° plane is perpendicular to the bed of the milling machine which can be checked with a carpenters square. The flat side of the strip (01/03) must be perpendicular to the axis of the hole ϕ 16. The flatness of the generator bracket (01/04) must be checked after welding. Some straightening might be necessary. The pin has an edge at 35 mm from the top. The ¾” gas pipe has to touch this edge during welding. Prevent that welding drips fall on the bearing seats. Use stainless steel electrodes for all welding.

4.6 Tower pipe (drawing 1407-05)

The stainless steel tower pipe (06) has a length of 2 m. The inside of the top has to be machined accurately for fitting of the head bearing housing. One needs a lath which has a central hole in the head stock with a diameter of at least 35 mm. Four clamps (06) and four threaded rods M8 (07) are used for connection of the tower pipe to a hard wood square pole with sides of 65 mm and a length of about 3 m. The wooden pole isn’t drawn. The pole is connected to a solid structure by two bolts or threaded rods M12 at a pitch of about 0.6 m.

4.7 Head bearing housing (drawing 1407- 05)

Be alert that the two bearing seats A and B are made with the required concentricity other wise the head pin will clamp in the bearings.

5 Mounting and installation

The maximum torque level of the generator might be too low to stop the rotor by making short-circuit in the winding like it can be done for all other VIRYA-windmills which have generators made of asynchronous motors. This means that the rotor of the VIRYA-1.36 will always turn except at very low wind speeds. So installation of the VIRYA-1.36 windmill should only be done at very low wind speeds! The VIRYA-1.36 has a low total mass (about 13.6 kg) so it is possible to install the complete windmill without special lifting tools. Only a ladder is needed.

The vane blade (04) is connected to the head pipe by means of two hinges (06N) in the workshop. The head bearings (07N) and (08N) are pressed in the tower pipe in the workshop using a tool given left of item 05 on drawing 1407-06. The head pin of the vane arm assembly is mounted in the head bearing housing in the workshop using the outer retaining ring (05N).

The mounting sequence of the generator and the rotor is given in chapter 5 of KD 571. The rotor blades (01) can be mounted to the generator in the workshop. Don’t forget to balance the rotor. Mounting of the assembly of rotor + generator to the vane arm assembly and of the vane arm assembly to the tower pipe is done at the site where the windmill is placed.

The 2 m long tower pipe is probably too short to mount it against a solid structure like the wall of a shed. It is assumed that a 3 m long hard wooden pole size 65 * 65 mm is mounted to the wall by two bolts M12 at a pitch of at about 600 mm. The top of this pole should be bevelled 30° and painted with epoxy to prevent entrance of water. The drawing of the pole isn’t given. Four 8 mm holes are drilled in the pole at a vertical hole spacing of 300 mm and a horizontal hole spacing of 45 mm. One must use the washers (04N) to prevent deformation of the wood and an extra nut M8 (03N) in between the clamp and the pole.

Next only the tower pipe is connected to the wooden pole using the four clamps (06) and the four threaded rods (07). The tower pipe should be vertical within 1°.

Next the generator + rotor assembly is connected to the head assembly by four bolts M8 (02N) .

Next the electricity cable 2 * 1.5 mm^2 (01N) is pushed upwards to the central hole in the head pin and connected to the 3-phase rectifier of the generator by two crimp terminals (15N).

Next the bottom part of the electricity cable is guided through the top of the tower pipe.

Next the assembly of rotor, generator and head is lifted by one hand and placed on the tower pipe. One should be alert that the cable is guided further downwards and that is isn’t clamped during this action.

Next the electricity cable is connected to a minimum 60 Ah battery (not specified) such that the plus of the wire corresponds to the plus of the battery.

It is expected that the VIRYA-1.36 windmill will need only little maintenance as is it almost made completely out of stainless steel. It is advised to lubricate the vane hinges with some oil if they start creaking. The water level in the battery should be checked regularly, especial at places with high wind speeds.

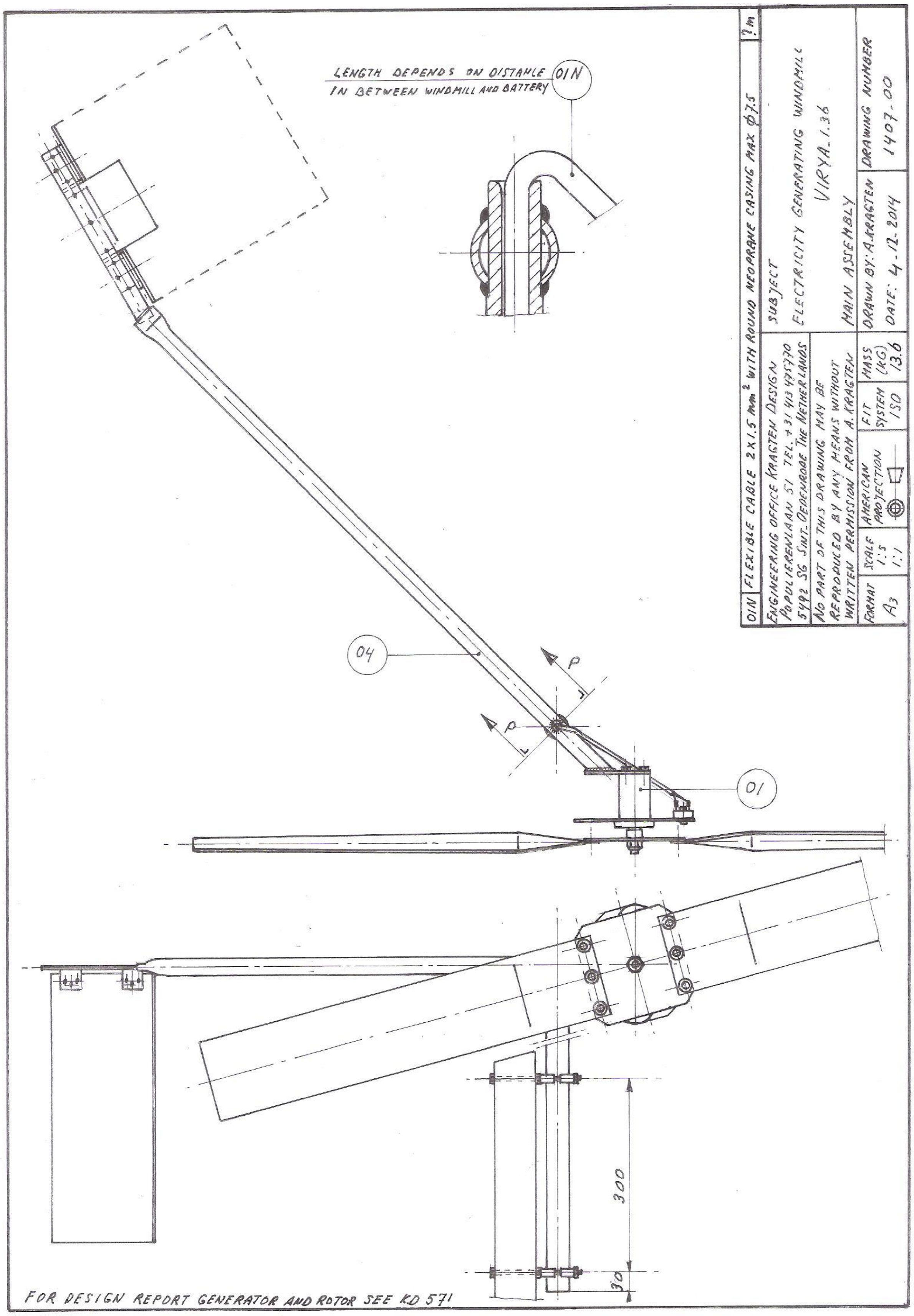
6 References

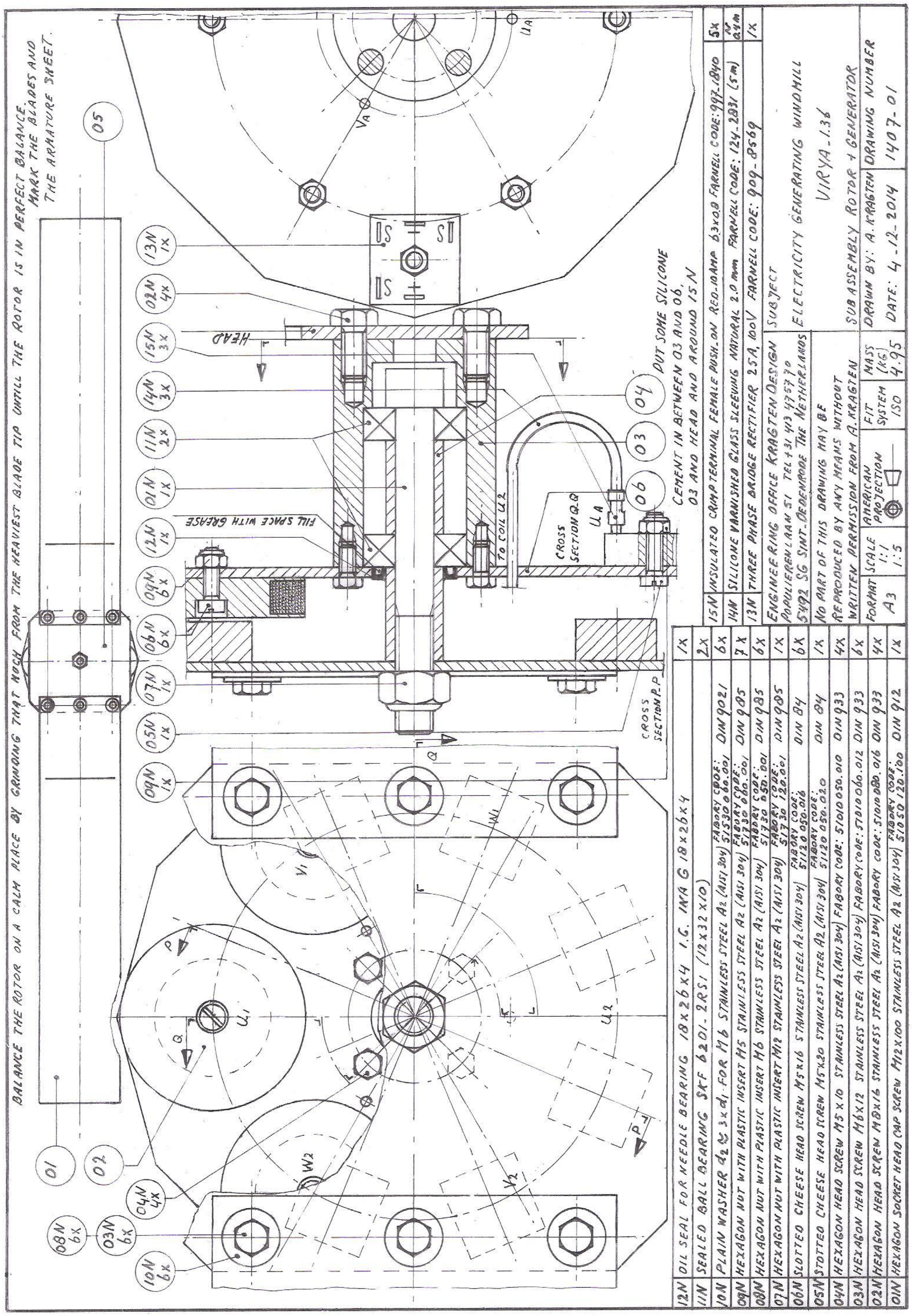
1 Kragten A. Development of an 8-pole, 3-phase axial flux permanent magnet generator for the VIRYA-1.36 windmill using 8 neodymium magnets size 25.4 * 25.4 * 12.7 mm. Design report of the rotor (λ_d = 5, B = 2, stainless steel blades), November 2014, reviewed December 2014, free public report KD 571, engineering office Kragten Design, Populierenlaan 51, 5492 SG Sint-Oedenrode, The Netherlands.

2 Kragten A. Manual of electricity generating windmill VIRYA-1.04, February 2013, reviewed May 2013, engineering office Kragten Design, Populierenlaan 51, 5492 SG Sint-Oedenrode, The Netherlands. Can be copied for free from my website.

3 Kragten A. Method to check the estimated δ-V curve of the hinged side vane safety system and checking of the δ-V curve of the VIRYA-3.3D windmill (7.14 % cambered steel blades), February 2005, public report KD 223, nett price € 30, engineering office Kragten Design, Populierenlaan 51, 5492 SG Sint-Oedenrode, The Netherlands.

7 Appendix: Drawings of VIRYA-1.36




BALANCE THE ROTOR ON A CALM PLACE BY GRINDING THAT MUCH FROM THE HEAVIEST BLADE TIP UNTILL THE ROTOR IS IN PERFECT BALANCE. MARK THE BLADES AND THE ARMATURE SHEET.
HEAD
FILL SPACE WITH GREASE
TO COIL U2
CROSS SECTION Q-Q
CROSS SECTION P-P
PUT SOME SILICONE CEMENT IN BETWEEN 03 AND 06, 03 AND HEAD AND AROUND 15N
15N INSULATED CRIMPTERMINAL FEMALE PUSH-ON RED-10AMP 63x08 FARNELL CODE: 997-1840 5x
14N SILICONE VARNISHED GLASS SLEEVING NATURAL 2.0 mm FARNELL CODE: 124-2831 (5m) 0.4m
13N THREE PHASE BRIDGE RECTIFIER 25A, 100V FARNELL CODE: 909-8569 1x
12N OIL SEAL FOR NEEDLE BEARING 18x26x4 I.C. INA G 18x26x4 1x
11N SEALED BALL BEARING SKF 6201-2RS1 (12x32x10) 2x
10N PLAIN WASHER FOR M6 STAINLESS STEEL A2 (AISI 304) FABORY CODE: 51530 060.001 DIN 9021 6x
09N HEXAGON NUT WITH PLASTIC INSERT M5 STAINLESS STEEL A2 (AISI 304) FABORY CODE: 51730 060.001 DIN 985 7x
08N HEXAGON NUT WITH PLASTIC INSERT M6 STAINLESS STEEL A2 (AISI 304) FABORY CODE: 51730 050.001 DIN 985 6x
07N HEXAGON NUT WITH PLASTIC INSERT M12 STAINLESS STEEL A2 (AISI 304) FABORY CODE: 51730 120.001 DIN 985 1x
06N SLOTTED CHEESE HEAD SCREW M5x16 STAINLESS STEEL A2 (AISI 304) FABORY CODE: 51120 050.016 DIN 84 6x
05N SLOTTED CHEESE HEAD SCREW M5x20 STAINLESS STEEL A2 (AISI 304) FABORY CODE: 51120 050.020 DIN 84 1x
04N HEXAGON HEAD SCREW M5 x 10 STAINLESS STEEL A2 (AISI 304) FABORY CODE: 51010 050.010 DIN 933 4x
03N HEXAGON HEAD SCREW M6x12 STAINLESS STEEL A2 (AISI 304) FABORY CODE: 51010 060.012 DIN 933 6x
02N HEXAGON HEAD SCREW M8x16 STAINLESS STEEL A2 (AISI 304) FABORY CODE: 51010 080.016 DIN 933 4x
01N HEXAGON SOCKET HEAD CAP SCREW M12x100 STAINLESS STEEL A2 (AISI 304) FABORY CODE: 51050 120.100 DIN 912 1x
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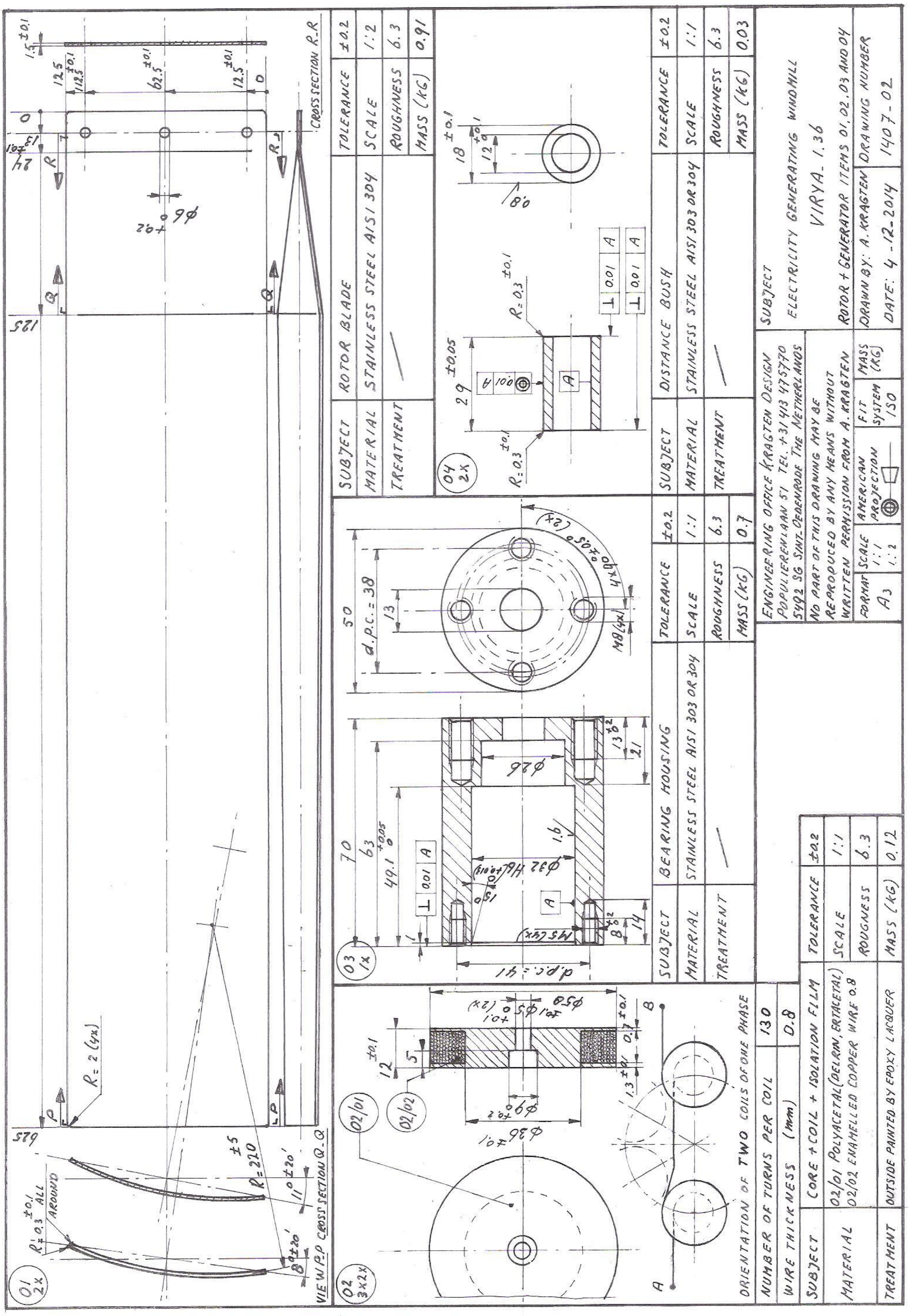
5492 SG SINT-OEDENRODE THE NETHERLANDS
NO PART OF THIS DRAWING MAY BE REPRODUCED BY ANY MEANS WITHOUT WRITTEN PERMISSION FROM A. KRAGTEN
SUBJECT
ELECTRICITY GENERATING WINDMILL
VIRYA-1.36
SUBASSEMBLY ROTOR + GENERATOR
FORMAT A3
SCALE 1:1 1:5
AMERICAN PROJECTION
FIT SYSTEM ISO
MASS (KG) 4.95
DRAWN BY: A. KRAGTEN
DATE: 4-12-2014
DRAWING NUMBER 1407-01


ROTOR BLADE
STAINLESS STEEL AISI 304
TOLERANCE ±0.2
SCALE 1:2
ROUGHNESS 6.3
MASS (KG) 0.91
CROSS SECTION R-R
VIEW P-P CROSS SECTION Q-Q
BEARING HOUSING
STAINLESS STEEL AISI 303 OR 304
TOLERANCE ±0.2
SCALE 1:1
ROUGHNESS 6.3
MASS (KG) 0.7
DISTANCE BUSH
STAINLESS STEEL AISI 303 OR 304
TOLERANCE ±0.2
SCALE 1:1
ROUGHNESS 6.3
MASS (KG) 0.03
ORIENTATION OF TWO COILS OF ONE PHASE
NUMBER OF TURNS PER COIL 130
WIRE THICKNESS (mm) 0.8
CORE + COIL + ISOLATION FILM
02/01 POLYACETAL (DELRIN, ERTACETAL)
02/02 ENAMELLED COPPER WIRE 0.8
OUTSIDE PAINTED BY EPOXY LACQUER
TOLERANCE ±0.2
SCALE 1:1
ROUGNESS 6.3
MASS (KG) 0.12
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ELECTRICITY GENERATING WINDMILL
VIRYA-1.36
ROTOR + GENERATOR ITEMS 01, 02, 03 AND 04
DRAWN BY: A. KRAGTEN
DATE: 4-12-2014
DRAWING NUMBER 1407-02