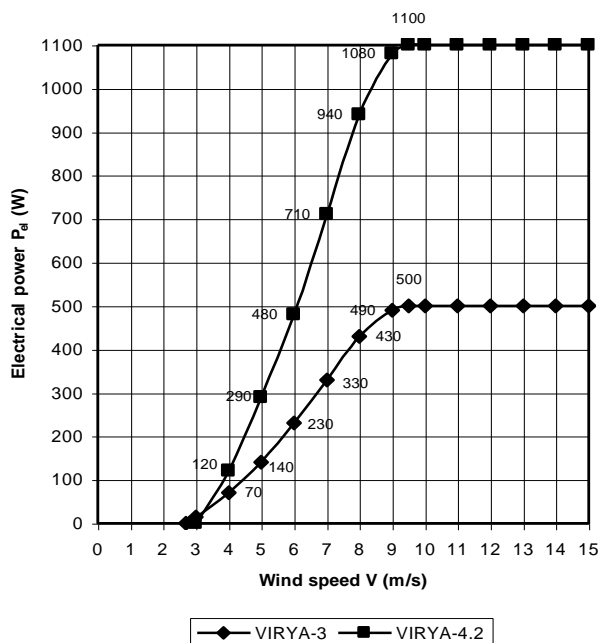


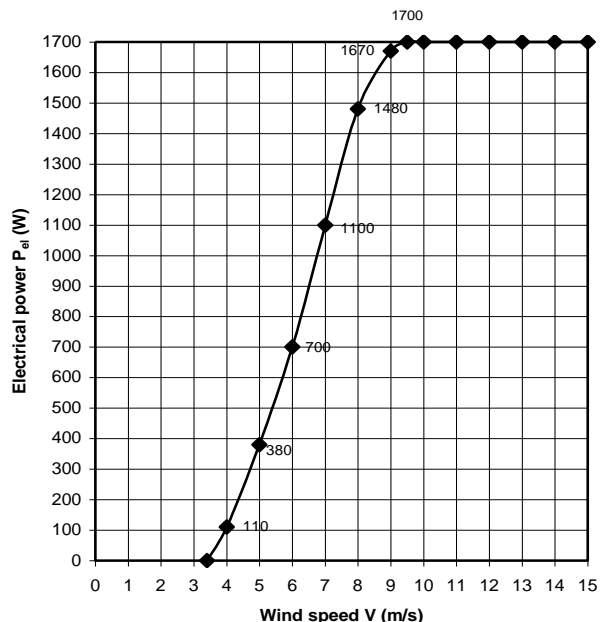
Licence for manufacture and sale of windmills  
**VIRYA-3, VIRYA-3B3, VIRYA-4.2 and VIRYA-4.6B2**  
 April 2015

**$P_{el}$ -V curve VIRYA-3 and VIRYA-4.2 windmills**



**VIRYA-4.2**

**$P_{el}$ -V curve VIRYA-4.6B2 windmill**



**Former VIRYA-3.3**

**Kragten Design**

Kragten Design (KD) is a one man engineering office founded in 1989 and specialises in designing windmills and wind energy consultancy (see separate folder). Up to now eighteen windmills with rotor diameters from 1 to 4.6 metre haven been developed and more than 580 KD-reports haven been written. Adriaan Kragten, B.Sc., worked for fifteen years in the Wind Energy Group, Faculty Physics of the University of Technology Eindhoven, one of the parties in the former CWD (Consultancy services Wind energy Developing countries). The address of KD is:

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## Description of the VIRYA-3, the VIRYA-3B3, the VIRYA-4.2 and the VIRYA-4.6B2 windmills

These four VIRYA windmills are designed especially for manufacturing in developing countries. The VIRYA-3, the VIRYA-4.2 and the VIRYA-4.6B2 have 2-bladed rotors. 2-bladed rotors are easier to manufacture and to balance and can even be transported completely mounted. The VIRYA-3B3 has a 3-bladed rotor and the rotor and head looks very much the same as the old VIRYA-3.3 (see photo). The  $P_{el}$ -V curve of the VIRYA-3B3 is the same as that of the VIRYA-3. The rotor blades are made of hard wood and have a constant chord and no twist. The rotor geometry, the rotor characteristics and the  $P_{el}$ -V curve have been calculated in report KD 241 for the VIRYA-3, in KD 484 for the VIRYA-3B3, in KD 218 for the VIRYA-4.2 and in KD 584 for the VIRYA-4.6B2.

The generator of the VIRYA-3 is mechanically the same as the generator of the VIRYA-2.68 but has a modified winding. The generator of the VIRYA-4.2 is almost identical to the generator of the former VIRYA-3.6 but the shaft diameter has been enlarged from 30 mm to 35 mm. The generator of the VIRYA-4.6B2 is almost identical to the generator of the former VIRYA-5A but the shaft length is shorter. The generators of the VIRYA-3, the VIRYA-3B3 and the VIRYA-4.2 have been measured (see report KD 78 and KD 200). The generator of the VIRYA-4.6B2 has not yet been measured but measurements of the former VIRYA-5A generator (see report KD 82) were used to determine the  $P_{el}$ -V curve. All windmills have generators based on standard rotary current motors. This motor is modified with a permanent magnet armature with neodymium magnets and a stainless steel shaft. The windmill rotor is mounted directly to the tapered shaft of the generator and the rpm range is much lower than the nominal motor rpm. The VIRYA-3 and the VIRYA-3B3 make use of a modified 115/200 V winding in star for 24 V battery charging. For the VIRYA-4.2, the standard 230/400 V winding in star can be used for 48 V battery charging. The VIRYA-4.6B2 makes use of the standard 400/690 V winding in star for 96 V battery charging and a modified 200/345 V winding in star for 48 V battery charging.

The generator can be used as a brake by short-circuiting the winding. The batteries are protected against over charging by one 27.6 V battery charge controller for the VIRYA-3 and the VIRYA-3B3. The VIRYA-4.2 and VIRYA-4.6B2 have two 27.6 V battery charge controllers and two dump loads in series and can therefore be used for both 24 V and 48 V electrical equipment. A prototype of the VIRYA-4.2 is tested by Kragten Design from 2004 up to 2006. Drawings and manuals of the VIRYA-3, the VIRYA-3B3 and the VIRYA-4.6B2 are ready but prototypes will not be tested by Kragten Design.

The mills are provided with a "hinged side vane safety system" to limit rotor rpm and thrust at high wind speeds. The rotor axis is offset from the tower axis. The vane juts out along the rotor and the vane blade is connected to the vane arm using hinges. At low wind speeds the vane blade hangs in almost vertical position and the rotor is perpendicular to the wind. At wind speeds higher than about 6 m/s the rotor starts to turn gradually out of the wind. At very high wind speeds the rotor turns out of the wind by about 75° and the vane blade is in almost horizontal position. The behaviour of this system is very stable and the rotor speed is well controlled. A description of this safety system with all formulas for calculation of the  $\delta$ -V curve for the VIRYA-4.2 is available (report KD 213).

The tower of the VIRYA-3 + the VIRYA-3B3 is identical to the tower of the VIRYA-3.3D and the VIRYA-3.8. This tower has a 3 m upper part made of pipe and two 3.5 m parts made of angle iron. Both the VIRYA-4.2 and the VIRYA-4.6 make use of the same tower which is almost identical to the tower of the former VIRYA-3.3 which has been tested for 12 years. The VIRYA-4.2 and VIRYA-4.6B2 have a 12 m, three legs lattice tower made of pipe and horizontal strips. The tower consists of two 6 m sections which are bolted together (the former VIRYA-3.3 tower has only one 12 m section but the geometry is the same). The lowest section of both towers is connected to the foundation by hinges. The head bearings are waterproof and the mills are almost maintenance free.

A prerequisite for manufacture of these VIRYA windmills is that a well equipped workshop is available and that one should be able to import some of the materials and standard parts. Kragten Design cannot supply materials and parts such as bearings, generator housings, permanent magnets, electronics et cetera. The required workshop skills are sawing, drilling, turning, milling and welding.

### Specification

	<b>VIRYA-3</b>	<b>VIRYA-3B3</b>	<b>VIRYA-4.2</b>	<b>VIRYA-4.6B2</b>
Diameter	D = 3 m	D = 3 m	D = 4.2 m	D = 4.6 m
Number of blades	B = 2	B = 3	B = 2	B = 2
Design tip speed ratio	$\lambda_d = 7$	$\lambda_d = 6.5$	$\lambda_d = 8$	$\lambda_d = 7.75$
Rotor eccentricity	e = 0.26 m	e = 0.26 m	e = 0.42 m	e = 0.44 m
Total tower height	$H_{tot} = 9.5$ m	$H_{tot} = 9.5$ m	$H_{tot} = 12.2$ m	$H_{tot} = 12.2$ m
Total mass	$m_{tot} = 165.7$ kg	$m_{tot} = 166.2$ kg	$m_{tot} = 315.7$ kg	$m_{tot} = 361.4$ kg
Starting wind speed	$V_{start} = 3.3$ m/s	$V_{start} = 2.7$ m/s	$V_{start} = 3.4$ m/s	$V_{start} = 3.3$ m/s
Cut in wind speed (if started)	$V_{cut\ in} = 2.7$ m/s	$V_{cut\ in} = 2.7$ m/s	$V_{cut\ in} = 3$ m/s	$V_{cut\ in} = 3.4$ m/s
Rated wind speed	$V_{rated} = 9.5$ m/s	$V_{rated} = 9.5$ m/s	$V_{rated} = 9.5$ m/s	$V_{rated} = 9.5$ m/s
Survival wind speed	$V_{surv} = 35$ m/s	$V_{surv} = 35$ m/s	$V_{surv} = 35$ m/s	$V_{surv} = 35$ m/s
Nominal battery voltage	U = 24 V DC	U = 24 V DC	U = 24 and 48 V DC	U = 24 and 48 V DC
Power at rated wind speed	$P_{rated} = 500$ W	$P_{rated} = 500$ W	$P_{rated} = 1100$ W	$P_{rated} = 1700$ W

### Drawings and manuals

A set of drawings consists of a main assembly drawing of the whole mill, sub-assembly drawings of rotor, generator, head, tower, dump load and tools and detailed drawings of all parts. Lists of parts to be manufactured and of standard parts are also included. In the manual several aspects are explained in detail including the safety system, manufacture of parts, mounting and installation. The battery charge controller is described in a separate manual.

### Licence conditions

A licence for manufacture and sale is available only for professional manufacturers or trading companies. For details about the licence, ask Kragten Design. Because only the VIRYA-4.2 has been tested by Kragten Design, a prototype of the VIRYA-3, the VIRYA-3B3 and the VIRYA-4.6B2 has to be tested by the licensee before serial production is started. The licensee will be informed about important modifications and can ask Kragten Design for support (at the normal hourly fee). Although all four windmills have been designed carefully, no responsibility is accepted for the operation of a mill neither as a whole, nor for any of its separate parts.