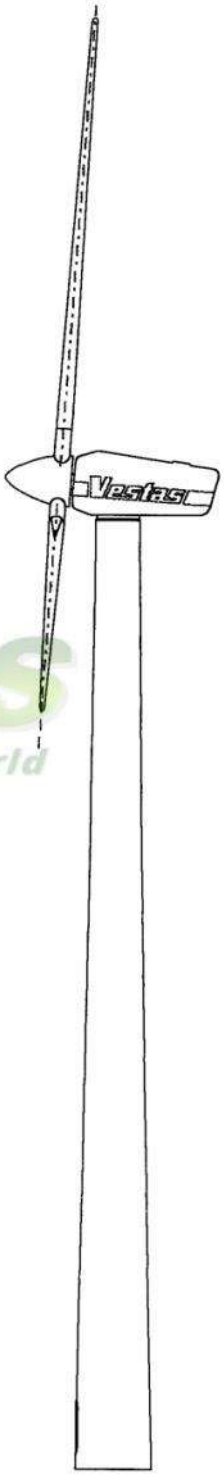
GENERAL SPECIFICATION



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VESTAS V29 - 225 kW
50 Hz Wind Turbine

ITEM no. 941521.R3

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1. Introduction

The VESTAS V29 turbine is based and developed on the experiences gained with the V27-225 kW wind turbine.

VESTAS V29 is a pitchregulated upwind wind turbine with active yaw and a high speed rotor with three blades.

The blades are made of glassfibre reinforced polyester each consisting of two bladeshells, glued on a supporting beam. By special glued in threadrods the blades are fastened to a blade steel root which is mounted in two bearings. The bearings are mounted in a blade bearing console which is bolted to the blade hub.

Through an independently supported main shaft, the power is transmitted to the generator through a two stage gearbox. The generator is changeable between 8 poles as "the little generator" and 6 poles as "the big generator". The generator is asynchronous and is directly connected to the grid. The rotor has two different speeds depending on which number of poles, there are connected. This is done to achieve a maximum performance both at low and high wind speeds.

From the gearbox to the generator the power is transmitted through a transmission shaft. Braking of the turbine is done by full feathering. Emergency stop activates the hydraulic disc brake, which is fitted to the high speed shaft of the gearbox.

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All functions of the turbine are monitored and controlled by a microprocessor based control unit, and variations in the bladeposition are performed by a hydraulic system, which also delivers pressure to the brake system.

Yawing is done by two yawing motors, which meshes with a big toothed wheel mounted on the top of the tower. The system is a slide system with built-in friction.

The nacelle is fully closed in a glassfibre reinforced nacelle cover. There is access through a central opening independent of the orientation of the nacelle in relation to the tower.

The tower is delivered metallized and painted. The tower can be delivered in one, two or three sections. The tower is delivered with an internal ladder. The lattice tower is delivered galvanized.

2. Type Approvals

The windturbine is designed in accordance with IEC 1400-1 (Draft), DS472 ("Teknisk Grundlag"), "Germanisher Lloyd Rules and Regulations IV- None-marine Technology Part 1 - Wind energy" and NEN 6096/2.

3. Climate Conditions

The wind climate for a given site is normally specified by a Weibull wind distribution described by an A and a C factor. The A factor is proportional to the mean wind speed and the C factor defines the shape of the Weibull distribution or in other words long term variations of hours at different wind speeds. Turbulence is the factor which describes short term variation/fluctuations. In the table below the design wind conditions for the Vestas V29-225 kW kW wind turbine is listed.

Mean wind speed	Turbulence
Max. 8,5 m/s	Max. 17%

Wind speed and turbulence at hub height.

The stop wind speed is a design parameter. The maximum wind speeds also are important for the loads on the wind turbine. The maximum allowable extreme windspeeds are listed below:

Max. 10 min. mean	Max. 3 sec. mean	Gust max. acc.	Stop wind speed / Restart wind speed
52,2 m/s	67 m/s	10 m/s^2	25 m/s / 20 m/s

3.1 Stop wind speed / restart wind speed

The turbine stops for high wind speed when the exponential mean wind speed averaged during 100 seconds, is above the stop wind speed level.
The turbine restarts when the exponential mean wind speed averaged during 100 seconds, is below the reset wind speed, and stay below for 10 minutes.

3.2 Site specific loads

The turbines can be placed under various climatic conditions: where the air mass density, turbulence intensity and the mean wind speed are the parameters to be considered. If the turbulence intensity is high, the turbine loading increases and the turbine lifetime decreases, contrary the loading will be reduced and the lifetime extended, if the mean wind speed is low. Therefore, the turbines can be placed on sites with high turbulence intensity if the mean wind speed is suitable.

Vestas has to examine the climatic conditions if the prescribed is exceeded.

3.3 Low Temperature version

The Vestas V29-225kW turbines are also available as a Low Temperature version.

This version is equipped with special heat treated steel components when necessary, and the nacelle has built in heaters. Also the wind vane and anemometer are heated. Other modifications have also been necessary to enable this version to operate down to -30°C. This version is designed for a temperature range from -30° to +40°C. (Standard -20°-+40°C).

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4. Power curve and yearly production

See enclosure 1, power curve.

4.1 V29 - Power curve

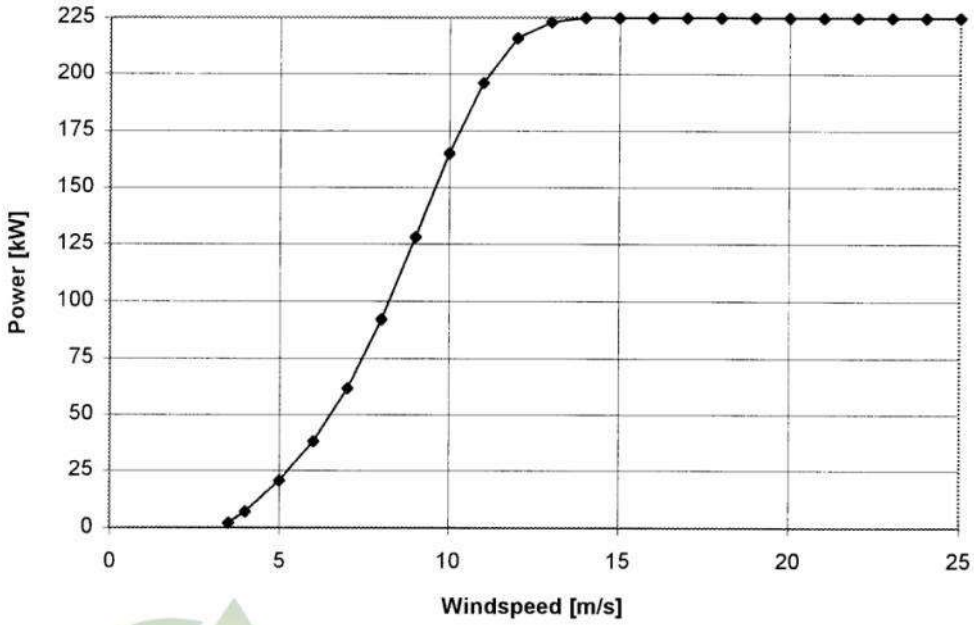
Power curves calculated on basis of NACA63.200.

Parameters for calculated curves:	50 Hz/60 Hz
Rotordiameter:	29 m
Rotor RPM:	41/30,8 RPM/min.
Tip angle:	Pitchregulated.
Turbulence:	10 %.

EL-power [kW] as a function of wind speed [m/s] and air density [kg/m^3]:

V_{10}	1,225	1,06	1,09	1,12	1,15	1,18	1,21	1,24	1,27
3,5	2,1	1,0	1,5	1,6	1,7	1,9	2,0	2,2	2,3
4	7,1	5,6	5,9	6,1	6,4	6,7	7,0	7,2	7,5
5	20,5	17,2	17,8	18,4	19,0	19,6	20,2	20,8	21,4
6	38,3	32,7	33,7	34,7	35,8	36,8	37,8	38,8	39,8
7	61,9	53,2	54,8	56,4	58,0	59,5	61,1	62,6	64,2
8	92,2	79,3	81,7	84,0	86,3	88,7	91,0	93,4	95,8
9	128	110	113	116	120	123	126	130	133
10	165	142	147	151	155	159	163	167	171
11	196	174	179	183	188	191	195	198	201
12	216	200	204	207	211	213	215	217	218
13	223	216	218	220	221	222	223	223	224
14	225	223	224	224	224	225	225	225	225
15	225	225	225	225	225	225	225	225	225
16	225	225	225	225	225	225	225	225	225
17	225	225	225	225	225	225	225	225	225
18	225	225	225	225	225	225	225	225	225
19	225	225	225	225	225	225	225	225	225
20-25	225	225	225	225	225	225	225	225	225

Wind speed: 10 minutes average value, at hub height and orthogonal to the rotor plane.



The V29-225 kW power curve is based on measurements performed by WindTest, Tripod and Vestas. The power curve is calculated with a mean density of 1.225 kg/m^3 and a turbulence of 10 %. The curve will vary at other values of turbulence and air density.

4.2 Annual output

(Terrain-classes calculated in accordance with Beldringe-Site, DK)

Roughness class 0:	870.000 kWh
Roughness class 1:	571.000 kWh
Roughness class 2:	464.000 kWh
Roughness class 3:	314.000 kWh

5. Noise emission

See enclosure 2, noise résumé

Sound power level LWA,rev.: 98 dB(A)

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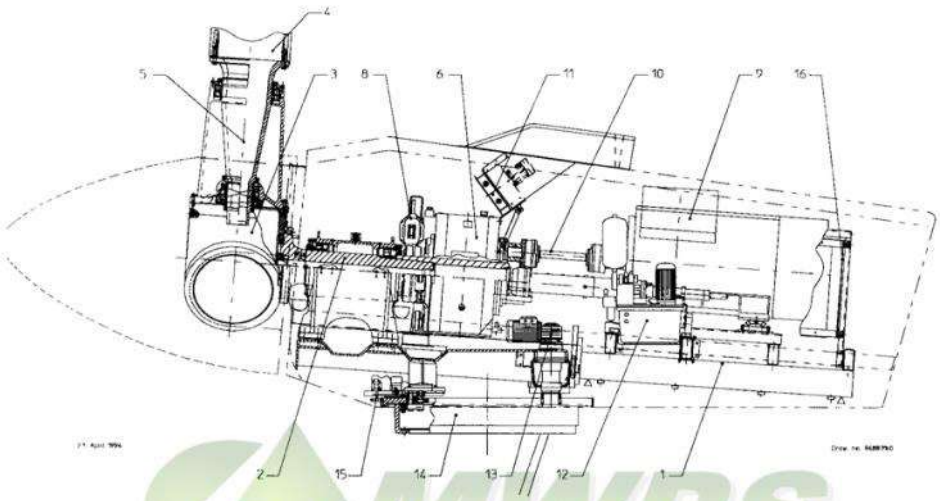
6. General Specification

6.1 Structure of machinery



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1. Nacelle bed plate
2. Main shaft
3. Blade hub
4. Bade
5. Blade bearing
6. Gearbox
7. Torque arm system
8. Disc brake
9. Generator
10. Transmission shaft
11. Hydraulic unit
12. Gear oil system
13. Yaw gears
14. Yaw ring
15. Yaw control
16. VMP-top control unit

6.2 Rotor

Diameter:	29 m
Swept area:	661 m2
Rotational speed, Main Generator:	41 rpm
Rotational speed, Small Generator:	30,8 rpm
Rotational direction:	Clock wise (front view)
Orientation:	Up wind
Number of blades:	3
Airbrake:	Full feathering

6.2.1 Blades

Profile:	NACA 63.214-63235
Length:	13 m
Width:	1,3/0,5 m
Twist	13^0
Weight:	650 kg/pcs.

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6.3 Tower

Tubular tower

Height: (Approx.)	31 m
Diameter top:	1,4 m
Diameter bottom:	2,4 m

6.3.1 Lattice tower

Height: (Approx.)	31 m

6.4 Weights and Heights (Approx. weights)

Tower excl. foundationsbolts:	12,000 kg
Nacelle excl. rotor:	9,000 kg
Rotor (incl. hub, bladebearing and blade):	5,000 kg
TOTAL:	26,000 kg

Lattice tower:	9,000 kg
Hub height:	32.0 m
Free height:	17.5 m
Highest point:	46.5 m

6.5 Operational data

Cut-in wind speed:	4.0 m/s
Rated wind speed (225 kW):	14 m/s
Cut-off wind speed:	25 m/s
Survival wind speed:	52.2 m/s

7. Components of the Wind Turbine

7.1 Rotor

7.1.1 Blades

Manufacturer:	VESTAS
Material:	GRP
Principle:	Supporting beam with glued on shells
Bolt connection:	Threadrods

7.1.2 Blade bearing

Manufacturer:	SKF, FAG or corresponding
Type:	Double bearing system

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7.1.3 Blade hub

Manufacturer:	VESTAS
Type:	Casted
Material:	SG - iron

7.2 Main shaft

Manufacturer:	VESTAS
Material:	34CrNiMo6
Type:	Forged with flange
Shaft/hub connection:	Bolts 10.9

7.3 Bearing housing

Manufacturer:	VESTAS
Type:	Casted construction
Material:	GGG 40.3

7.4 Main bearings

Manufacturer:	SKF or corresponding
Type:	Spherical roller bearing

7.5 Machinefoundation

Manufacturer:	VESTAS
Type:	Tubular construction
Material:	Steel 44.2 DIN 17100

7.6 Yaw System

Manufacturer:	VESTAS
Type:	Slideblocksystem with build in friction

7.6.1 Yaw gear, 2 units

Type:	Planet and worm gear
Rated torque:	2 x 500 Nm
Manufacturer:	Bonfiglioli-Transmittal, or corresponding

7.6.2 Yaw motors

Rotational Speed:	950 RPM
Rated power:	0.55 kW

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7.7 Tower

Type:	Conical tubular
Height:	31 m
Manufacturer:	VESTAS
Surface treatment:	Metallized + painting
Weight:	12,000 kg

7.7.1 Paintsystem, outside

Sandblasting:	SA3 (ISO 8501)
Metallizing:	DSI/ISO 2063 Zn 80
Epoxy coating:	Min. 120 µ (2 layers)
Polyurethane coat:	UV resistant min. 40 µ (1 layer)

7.7.2 Paintsystem, inside

Sandblasting:	SA2.5 (DS8501)
Zinciferous first coat:	Min. 50 µ (1 layer)
Epoxy coating:	Min. 100 µ (1 layer)

7.7.3 Lattice tower

Type:	Lattice
Height:	31 m
Manufacturer:	VESTAS
Surface treatment:	Hot galvanized

7.8 Gearbox

Nominal power:	450 kW
Ratio:	1:24,6
Type:	Two stage, parallel shafts
Oil quantity:	53 l
Slowspeed shaft:	Hollow shaft
Manufacturer:	Valmet or corresponding

7.9 Couplings

7.9.1 Main shaft gear

Type:	Conical shrink disc

7.9.2 Gear - Generator

Type:	Transmission shaft

7.10 Generator

Type:	Doublewinding, asynchronous	
Manufacturer:	Siemens corresponding	
Rated power, 6 poles:	225 kW	
Voltage:	3x690 V	
Frequency:	50 Hz	
Class of insulation:	F	
Rotational speed (225 kW):	1016 RPM	
Rated current:	390A/225A	
Power factor:	0.83	
Reactive power no load:	95 kVAr	
Power Factor correction:	100 kVAr	
Resulting power factor at:	1/1 load:	0.98
	3/4 load:	0.99
	1/2 load:	0.99
	1/4 load:	1.00
Resulting power at full load:	333/193 A	
Rated power, 8 poles:	50 kW	
Voltage:	3x690 V	
Frequency:	50 Hz	
Class of insulation:	F	
Rotational speed (50 kW):	760 RPM	
Rated Power:	98A/57A	
Power factor:	0,74	
Reactive power no. load:	34 kVAr	
Power factor correction:	37,5 kVAr	
Resulting power factor at:	1/1 load	0.99
	3/4 load	0.99
	1/2 load	1.00
	1/4 load	0.99
Resulting current:	73A/42A	

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7.11 Brake unit

Type:	Disc brake
Diameter:	600 mm
Callipers:	2 hydraulic activated
Manufacturers Callipers:	Brembo
Disc materiel:	SG-iron

7.12 Hydraulic unit

Pump capacity:	4.5 l/min.
Max. pressure:	100 bar
Brake pressure:	25 bar
Pressure switches:	Piezolectrical
Oil quantity:	30 l

7.13 Anemometer

Type:	Optoelectrical
Manufacturer:	VESTAS

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7.14 Wind vane

Type:	Optoelectrical
Manufacturer:	VESTAS

7.15 Control unit

Manufacturer:	VESTAS

7.15.1 Heavy current

Frequency:	50 Hz
Voltage:	3x400V/3x690V
Lockabale circuit breaker:	ABB 56N 630
Power supply for light:	1x10 A/230 V
Generator cut in:	Via Thyristors
Power factor correction:	2 stages, 62.5 + 37.5 kVAr

7.15.2 Computer

CPU:	2 x8086
Programming language:	Modula-2
Configuration:	Modules
Operation:	Numeric keyboard + functionskeys
Display:	4x40 characters

7.15.3 Top processor

Supervision/Control:	Yawing Hydraulic Surroundings (Wind-Temp.) Rotation Generator Pitch system

7.15.4 Bottom processor

Supervision/Control	Grid Power factor correction Thyristors

7.15.5 Operator panel

Information:	Operating data Production Operation log Alarm log
Commands:	Operation/Pause Man. yaw start/stop Maintenance routine
Remote supervision	Possibility of connection of serial communication

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7.16 Measuring device

	Can be delivered for build together with the control unit.
Measuring type:	Production measurement or Sale/Purchase measurement

8. Installation

8.1 Terrain:

If the terrain within a 100 m radius of the turbine has a slope of more than 10° or 18% particular considerations may be necessary.

8.2 Climatic conditions:

The turbine is designed for an ambient temperature range from -20°C up to +40°C, (10 min. average). The temperature range for the LT-version is -30° up to +40°C (10 minutes average). Outside these temperatures the turbine will stop and particular considerations may be necessary.

Regarding the wind the turbine is designed in accordance with Danish conditions (roughness class 0,1, 2 and 3)

The turbine can be placed in wind farms with a distance of 4 rotor diameters (120 m) between turbines in a row, and 5 rotor diameters (150 m) between rows (along predominant wind direction).

The wind turbine is designed for a mean air density of 1.23 kg m3. Operational data and the power curve are given at this air density. If the man air density differs from this value the data as well as the power curve will be changed.

The humidity can be 100%, (max. 10% of the time). Corrosion protection according to corrosion class 3 outside, a 1 to 2 inside, (DS/R 454).

For operation under different conditions please contact VESTAS.

8.3 Grid connection:

Intermittent or rapid power fluctuations of utility grid frequencies may cause serious damage to the wind turbine. Steady variations within +1/-3 Hz are acceptable. The nominal voltage 400V/690V may have a variation of +6%/-10% as the highest.

The short circuit power must in most cases e at least 10 times the rated power of the generator in order to fulfil the above.

Grid drop-outs must only take place once per week as an average over the lifetime of the turbine.

A ground connection of max. 10 Ω must be present.

In the case of small independent grids it is necessary to check the actual conditions.

Furthermore please see the electric installation instruction VESTAS V29.

9. General reservations

Periodic operation disturbances may occur with a combination of e.g. high wind, low voltage and high temperature.

In general it is recommended that the grid voltage is as close to the nominal as possible.

In connection with grid drop-out and very low temperatures, a certain time of heating-up before the turbine restarts after re-establishing the grid must be expected.

Due to continuous development and updating of our products, we reserve the right to change the specifications.

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10. Enclosure 1, Power Curve Measurement

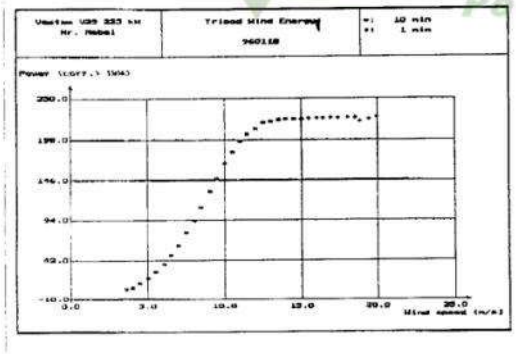
Power curve measurement on V29-225 kW wind turbine

1. The measurement is carried out by:

   Tripod Wind Energy Aps
   Gladsaxe Møllevej 21
   2860 Søborg
   Phone +45 39666622
   Fax: +45 39666699

   Tripod Wind Energy is approved by "Energistyrelsen" in Denmark to carry out power curve measurements and basic tests for type approvals of wind turbines.

2. This resumé is made on April 23, 1996 by Vestas Wind Systems A/S
3. The measurements are reported in "TWE-report 960114-1", which is dated January 1996 The measurements are carried out in the period April 27, 95 till December 19, 95. The reported measurement period is from October 11-95 till December 19, 95.
4. The Windturbine type is: VESTAS V29-225 kW.
5. The measurement was performed according to the "Recommandation for wind turbine power curve measurements", 1st edition 1992.
6. Results of the measurements:



The measured power curve is corrected to a standard air density of 1.225 kg/m^3

TRIPOD WIND ENERGY : 18/1-1996 9:23 (4.fin)

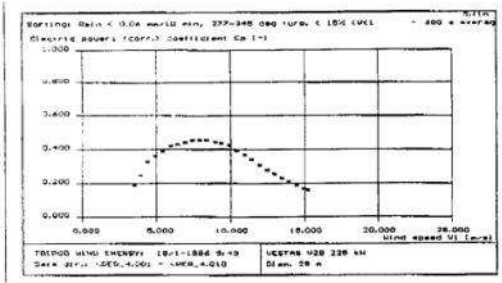
Object of bin-analysis : Sorting: Rain < 0.06 mm/10 min,
277-345 deg turb. < 15% (V<1
: VESTAS V29 225 kW
: Diam. 29 m
Data directories : \PER_4.001 - \PER_4.010
Basic averaging time : 60.00 secs
Final averaging time : 600.00 secs

X-axis (bins) : Wind speed V1 [m/s]
Y-axis (binned) : Power1 Corrected [kW]

X bin	# data	mean(Y)	rms(Y)	min(Y)	max(Y)
3.61	12	3.52	1.03	1.52	5.72
3.99	25	6.49	1.72	3.51	10.34
4.47	24	11.92	2.26	7.44	15.50
4.99	31	17.99	2.33	11.77	23.69
5.51	11	26.19	2.99	20.83	30.44
6.04	30	37.23	5.74	28.63	54.86
6.52	34	47.94	5.14	38.49	69.32
6.99	45	61.11	6.20	44.87	77.19
7.50	20	77.37	10.46	59.77	97.80
7.98	29	93.31	10.01	73.82	119.64
8.44	23	110.26	8.20	93.19	126.25
9.04	26	131.09	9.01	108.24	149.01
9.46	30	147.92	12.57	127.87	174.56
10.01	31	168.09	9.97	140.37	187.19
10.51	34	182.83	8.38	159.08	202.58
11.00	49	196.22	5.91	184.52	208.15
11.47	39	205.21	4.82	193.90	212.30
11.99	29	212.13	3.35	191.91	220.75
12.50	32	219.33	2.57	213.96	224.80
12.98	23	221.40	2.25	210.06	224.41
13.49	19	223.18	1.78	217.33	224.71
13.93	10	224.37	0.44	223.44	225.00
14.48	7	224.12	0.87	222.90	224.80
14.98	4	223.93	0.87	222.71	224.76
15.40	2	224.83	0.02	224.80	224.85
Total	616				

1 min:

14.49	119	224.33	2.39	207.62	228.61
14.95	69	224.66	1.53	218.85	227.64
15.47	50	224.89	1.40	220.31	227.64
15.99	26	224.58	2.29	215.43	227.15
16.41	21	225.03	1.49	221.78	227.64
16.91	10	225.34	1.43	223.73	228.61
17.41	5	224.48	1.14	223.24	226.17
17.99	3	224.61	0.92	224.71	226.66
18.50	3	225.52	1.40	223.73	227.15
18.80	1	223.78	0.00	223.78	223.78
19.30	1	223.73	0.00	223.73	223.73
19.92	1	226.66	0.00	226.66	226.66



The annual energy output is calculated on the assumption that the availability is 100% and that the stop wind speed is 25m/s. The annual energy output is calculated for a Weibull distribution in the 4 Danish roughness classes and a Rayleigh distribution with an annual mean wind speed of 5 - 10 m/s.

```
TRIPOD WIND ENERGY      :  18/1-1996 9:43   (5.tin)

Object of bin-analysis  :  Sorting: Rain < 0.06 mm/10 min,
                           277-345 deg turb. < 15% (V<1
                        :  VESTAS V29 225 kW
                        :  Diam. 29 m
Data directories        :  \PER_4.001 - \PER_4.010
Basic averaging time    :  60.00 secs
Final averaging time    :  600.00 secs

X-axis (bins)           :  Wind speed V1 [m/s]
Y-axis (binned)         :  Electric power1 (corr.) coefficient Cp [-]

   X-bin   # data   mean(Y)    rms(Y)    min(Y)    max(Y)
    3.61      12    0.184     0.049     0.091     0.287
    3.99      25    0.245     0.043     0.159     0.351
    4.47      24    0.323     0.038     0.229     0.395
    4.99      31    0.358     0.037     0.260     0.443
    5.51      11    0.386     0.034     0.333     0.440
    6.04      30    0.415     0.046     0.346     0.574
    6.52      34    0.427     0.034     0.375     0.540
    6.99      45    0.441     0.036     0.356     0.521
    7.50      20    0.450     0.039     0.363     0.533
    7.98      29    0.452     0.036     0.381     0.564
    8.44      23    0.453     0.025     0.403     0.498
    9.04      26    0.439     0.029     0.367     0.494
    9.46      30    0.431     0.028     0.370     0.502
   10.01      41    0.414     0.020     0.359     0.458
   10.51      34    0.390     0.015     0.355     0.418
   11.00      40    0.365     0.012     0.341     0.393
   11.47      39    0.336     0.012     0.308     0.350
   11.99      29    0.304     0.011     0.285     0.329
   12.50      32    0.278     0.007     0.265     0.291
   12.98      23    0.250     0.007     0.240     0.261
   13.49      19    0.224     0.006     0.214     0.236
   13.93      10    0.205     0.005     0.196     0.211
   14.48       3    0.182     0.006     0.175     0.190
   14.98       4    0.165     0.002     0.162     0.168
   15.30       2    0.155     0.001     0.154     0.156
  Total      516
```

MWPS Powering The World

Raleigh distribution

Yearly mean wind speed	Production/year	Uncertainty	
[m/s]	[MWh]	[MWh]	[%]
5	320.2	12.6	3.9
6	504.5	15.0	3.0
7	688.3	16.3	2.4
8	856.2	16.8	2.0
9	1000.5	16.8	1.7
10	1117.2	16.3	1.5

The Annual Energy Output in the 4 roughness classes is calculated by Vestas Wind Systems A/S. The uncertainties are estimated from the above mentioned uncertainties, which is calculated by Tripod Wind Energy Aps.

Weibull distribution in the 4 Danish roughness classes:

Roughness classes	Production/year	Diffidences of measurement	
[-]	[MWh]	[MWh]	[%]
0	870.7	16.8	1.9
1	571.9	15.5	2.7
2	464.7	14.5	3.1
3	313.4	12.5	4.0

11. Encl. 2, Noise résumé of Vestas V29 -225 kW wind turbine

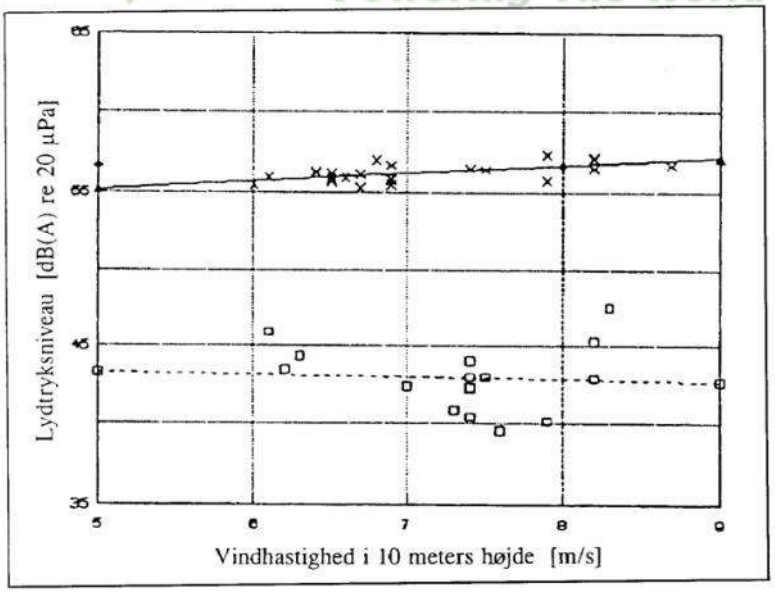
1. The measurement has been done under accreditation, registration no. 134, from DANAK by:

   Acoustica as
   Sohngårdsholmvej 2
   DK 9000 Aalborg
   Phone 45 98 113011
   Fax 45 98 117374

   Tripod Wind Energy is authorised by the Danish Ministry of Energy to carry out power curve measurements and type testing in accordance with the Danish system for approval of wind turbines.

2. This resume is made August 15, 1996 by Vestas Wind Systems A/S
3. The measurements are reported in "Acoustica-report P8.005.94", which is dated June 1994. The measurements are carried out on June 9, 1994.
4. The Windturbine type is: VESTAS V29.225 kW
5. The measurement was performed according to the "Recommendation for wind turbine power curve measurements [Risø-I-745(EN), November 1993]".
6. Results of the measurements:

6a.



The sound power level (L_{Aeq}) can be calculated from the sound pressure level, using the following expression:

$$L_{wa} = L_{Aeq} * 10 * \log\left(4 * \pi * \left(d^2 + h^2\right)\right) - 6\ dB$$

Where, d = distance from the base of the wind turbine to the measurement (d= 56 m).
h = hub height (h = 32 m).

6b. The measurements show the following results at a wind speed of 8 m/s. The measurements are given respectively, as the A-weighted sound pressure level $L_{Aeq,ref}$ and the A-weighted sound power level $L_{WA,ref}$.

Frequency	Sound pressure $L_{Aeq,ref}$ [dB(A)]	Sound Power $L_{WA,ref}$ [dB(A)]
1/1 octave 63 Hz	35.2	76.4
1/1 octave 125 Hz	42.5	83.7
1/1 octave 250 Hz	47.3	88.5
1/1 octave 500 Hz	52,1	93.3
1/1 octave 1 kHz	51.1	92.3
1/1 octave 2 kHz	48.4	89.6
1/1 octave 4 kHz	40.4	81-6
1/1 octave 8 kHz	29.8	71.0
A-weighted, total	56.6	97.8

According to statoturial order no. 304 of May 14, 1991, from the Danish Ministry of the Environment, the degree of accuracy on the results is ±2 dB.

6c. An analysis of the noise in a distance of 56 meter show that the noise from the turbine contains no clearly audible tones or impulses. The analysis has been pre-formed according to guideline no. 6/1984, "Noise from Industrial Plants", from the Danish Ministry of the Environment.

6d.

