Survey of the experiences in particular with the prototype of the CWD 2000 windmill at the Technical University Eindhoven from May 1983 until December 1985

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Ad v.d. NAT

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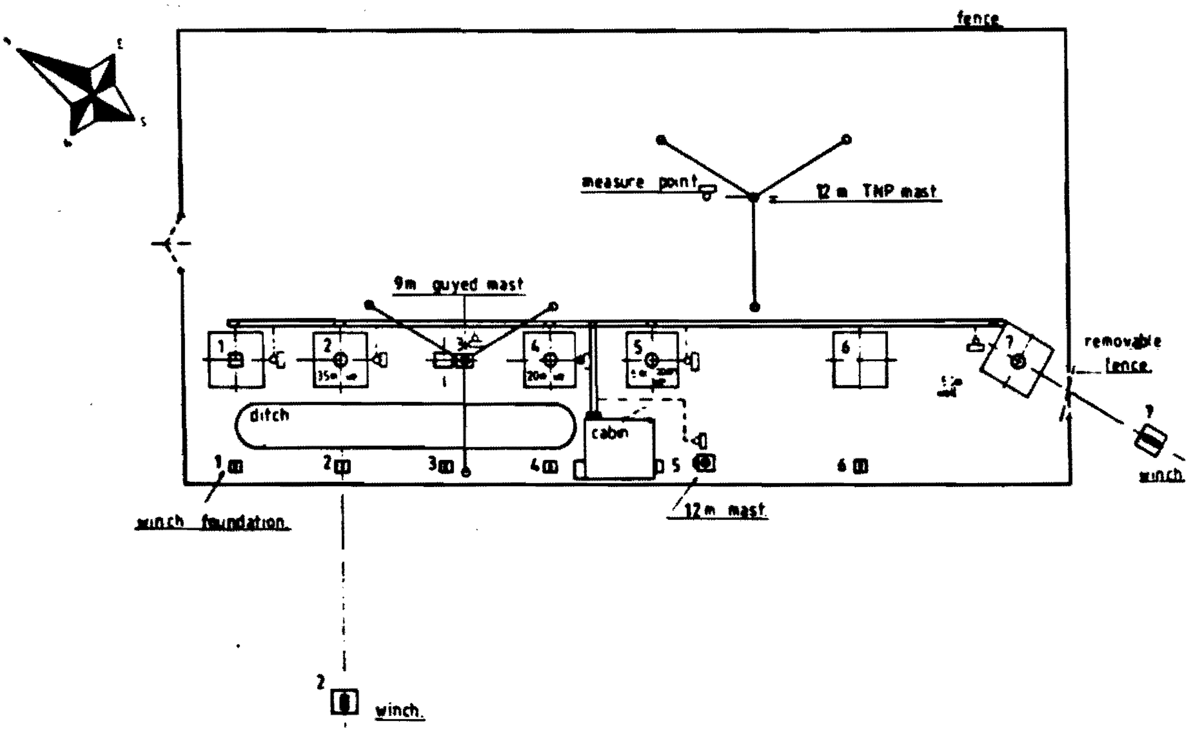
WIND ENERGY GROUP
Technical University Eindhoven
Faculty of Physics
Laboratory of Fluid Dynamics and Heat Transfer
P.O. Box 513, 5600 MB Eindhoven, the Netherlands

CONSULTANCY SERVICES WIND ENERGY DEVELOPING COUNTRIES
P.O. BOX 85
3800 AB AMERSFOORT
THE NETHERLANDS

CONTENTS

1. INTRODUCTION

In this report a survey is given of the experiences on the testfield at the Technology University Eindhoven.
The windmill testfield is illustrated in fig. 1.



A description of the mills presently installed on the Eindhoven testfield.

Location 1

No windmill has been installed at this moment.

Location 2

Name of the windmill	CWD 5000
Rotor diameter	5000 mm
Height of the tower	12 meter
Safety system	overspeed control by yawing, activated by means of side vane with manually activated furling device
Pump	single acting piston pump with a bore of 150 mm
Capacity	50 m^3/day at a wind speed of 4,5 m/sec and 20 meter lifting head
Stroke	80-110-140-170-200 mm
Design tip speed ratio	λ_d = 1,8
Number of blades	8
Depth of the well	30 meter
Capacity of the vessel	about 4 m^3

Location 3

Climbable THE mast. Height of the mast 10 meter, in use for installation of anemometer and wind vane and also pressure vessel.

Location 4

Name of the windmill	CWD 2740
Rotor diameter	2740 mm
Height of the tower	5,5 meter
Safety system	overspeed control by yawing activated by side vane and hinged tail vane with manually activated furling device
Pump	suction pump with a bore of 145 mm
Capacity	35 m^3/day at a wind speed of 4 m/sec and 10 meter lifting head
Stroke	adjustable from 0 to 60 mm
Design tip speed ratio	λ_d = 2
Number of blades	6
Depth of the well	20 meter

Location 5

Name of the windmill	CWD 2000
Rotor diameter	2000 mm
Height of the tower	6,5 meter
Safety system	overspeed control by yawing activated by eccentric rotor and hinged side vane
Pump	suction pump with a bore of 65 mm
Capacity	35 m^3/day at a wind speed of 3,5 m/sec and 5 meter lifting head
Stroke	25-50-75-100 mm

Design tip speed ratio	λ_d = 1,35
Number of blades	6
Depth of the well	open well, level varies with the ground water level between 1 and 2 meter

Location 6

Kaal van der Linden mast, climbable, height 12 meter, in use for testing: anemometers reed switch type at 6 m - 9 m - 12 meter; wind vane at 12 meter; temperature meter at 6 meter.
Also installed is the pressure vessel of the CWD 2000 windmill at 3,5 meter and the pressure vessel of the CWD 5000 HW windmill at 12 meter height.

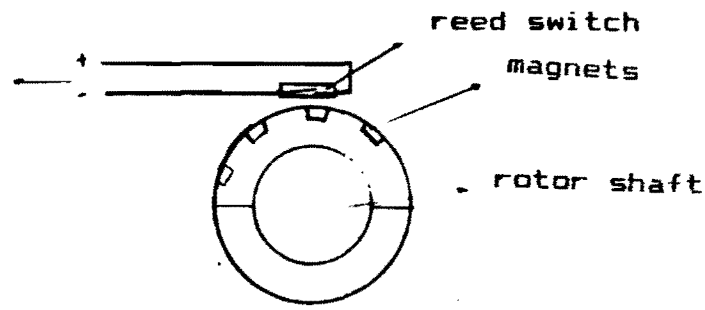
Location 7

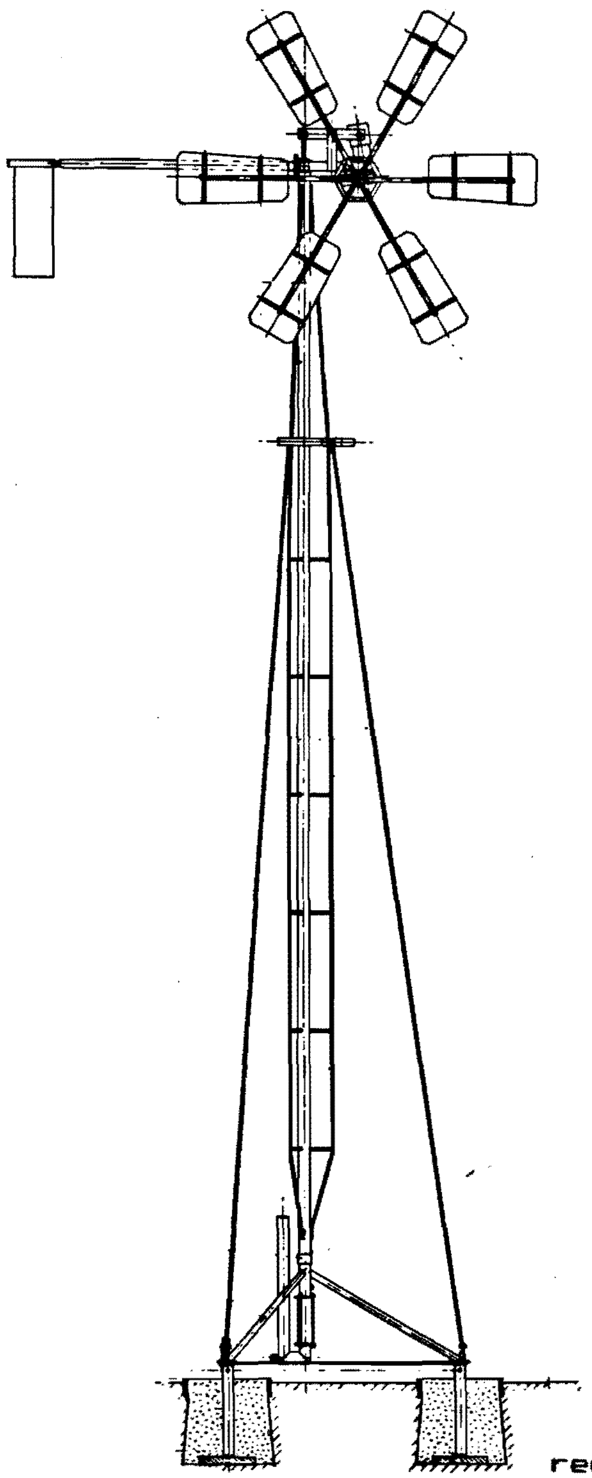
Name of the windmill	CWD 5000 HW
Rotor diameter	5000 mm
Height of the tower	6 meter
Safety system	overspeed control by yawing activated by side vane and ecliptic tail vane with manually activated furling device
Pump	single acting piston pump with a bore of 115 mm
Capacity	19 m^3/day at a wind speed of 4,5 m/sec and 54 meter lifting head
Stroke	adjustable from 0 to 120 mm
Design tip speed ratio	λ_d = 2
Number of blades	8
Depth of the well	50 meter

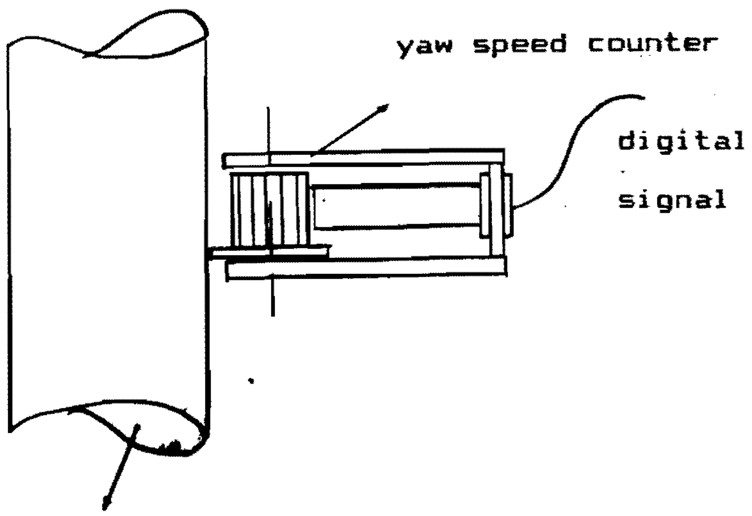
Location 8

Telescopic non climbable measuring mast (Natural Power) with a height of 12 meter in use for testing anemometers.

2. CWD 2000 INTRODUCTION

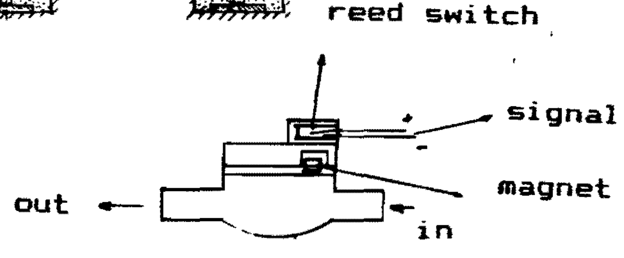






CWD 2000

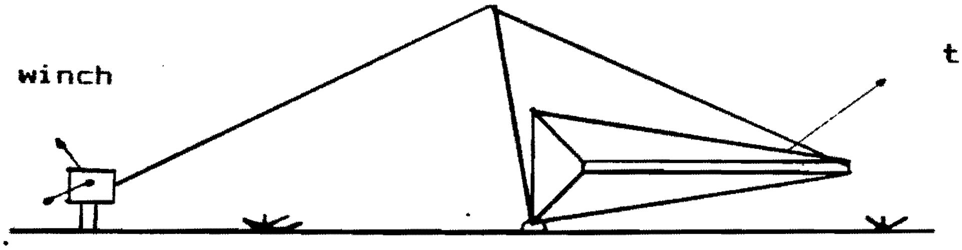
PURPOSE	: water lifting; designed for use in low and moderate wind regimes (yearly averages below 5 m/s)
ROTOR	: horizontal axis; kept in up wind position by balance of side vane and excentric rotor; rotor diameter 2 m; 6 blades of galvanized steel sheet; fixed pitch
TRANSMISSION	: direct drive crank mechanism with adjustable stroke and swing arm; strokes 25-100 mm; balanced pump rod weight
CONTROL SYSTEMS	: over speed control by yawing, activated by excentric rotor and hinged side vane system
PUMP SYSTEM	: single acting piston pump with starting nozzle and air chambers; nominal pump diameter 65 mm
TOWER	: steel tubular mast; height 6.5 m; can be lowered by means of hinges in the tower base
CAPACITY	: 25 m^3/day at 5 m static head and 3.5 m/s average wind speed.
OPERATING WIND SPEEDS	: -cut-in : 2.5 m/s -rated : 6 m/s -survival: 40 m/s
AERODYNAMIC PROPERTIES	: -λ (design): 1.5 -Cp (max): 0.3 -solidity: 0.36 -typical design wind speed: 3 m/s
WEIGHTS	: total (excl. foundation): ± 150 kg
COST	: materials ± US $ 180.- (in The Netherlands)



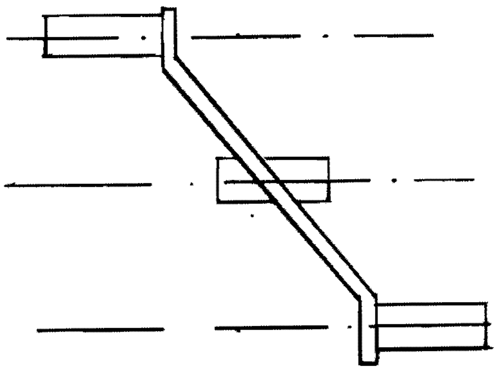
Water flow meter

3. SUMMARY OF FIELD EXPERIENCES WITH THE CWD 2000

Date 1983.05.11
The windmill has been erected (10 days) with the help of a winch.
See-drawing

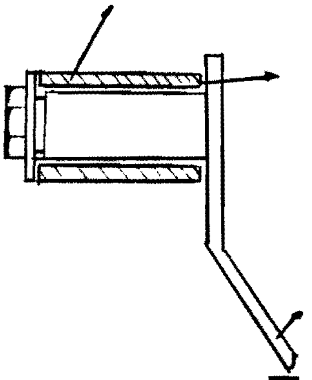


After erection it appears that the windmill has a bad starting behaviour.
The windmill starts at 4 m/sec but it should start at 2.5 m/sec.
The cause is probably friction in the wooden bearings of the rocker arm, pump rod and crank rod.
The cause of the friction is the incorrect manufacture of the rocker arm.
The axes of the rocker arm are not parallel.
See drawing.

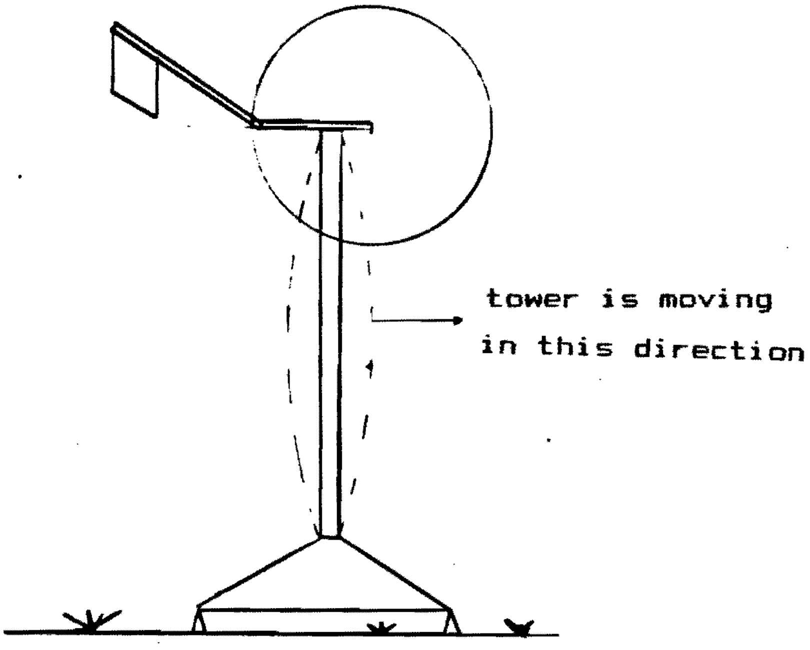


The axle lines are not parallel

Also the shaft taps are too short so the pump rod is clamping on the rocker arm.
See drawing.



When the windmill is running the tower is bending. For direction, of move; see drawing.



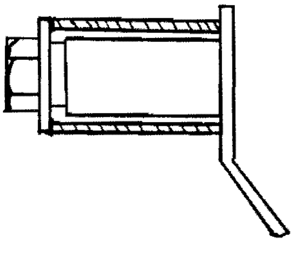
Pump has not been installed.

Date 1983.05.19

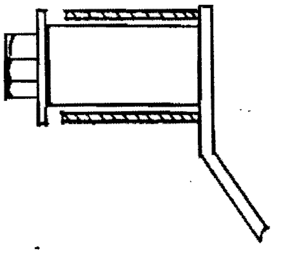
The pump has been connected now to the windmill.
However the starting behaviour is bad ± 4 m/sec.
Stroke maximum 100 mm.
Water level 1,60 meter below ground level.
No pressure height.

Date 1983.06.17

A smaller cup for the piston of the pump was made.
The old one had too much friction.
The cause of a bad starting behaviour is also the friction of the wooden bearings so the diameter was made a little larger and the length of the wooden bearings was shorted.
See drawing.

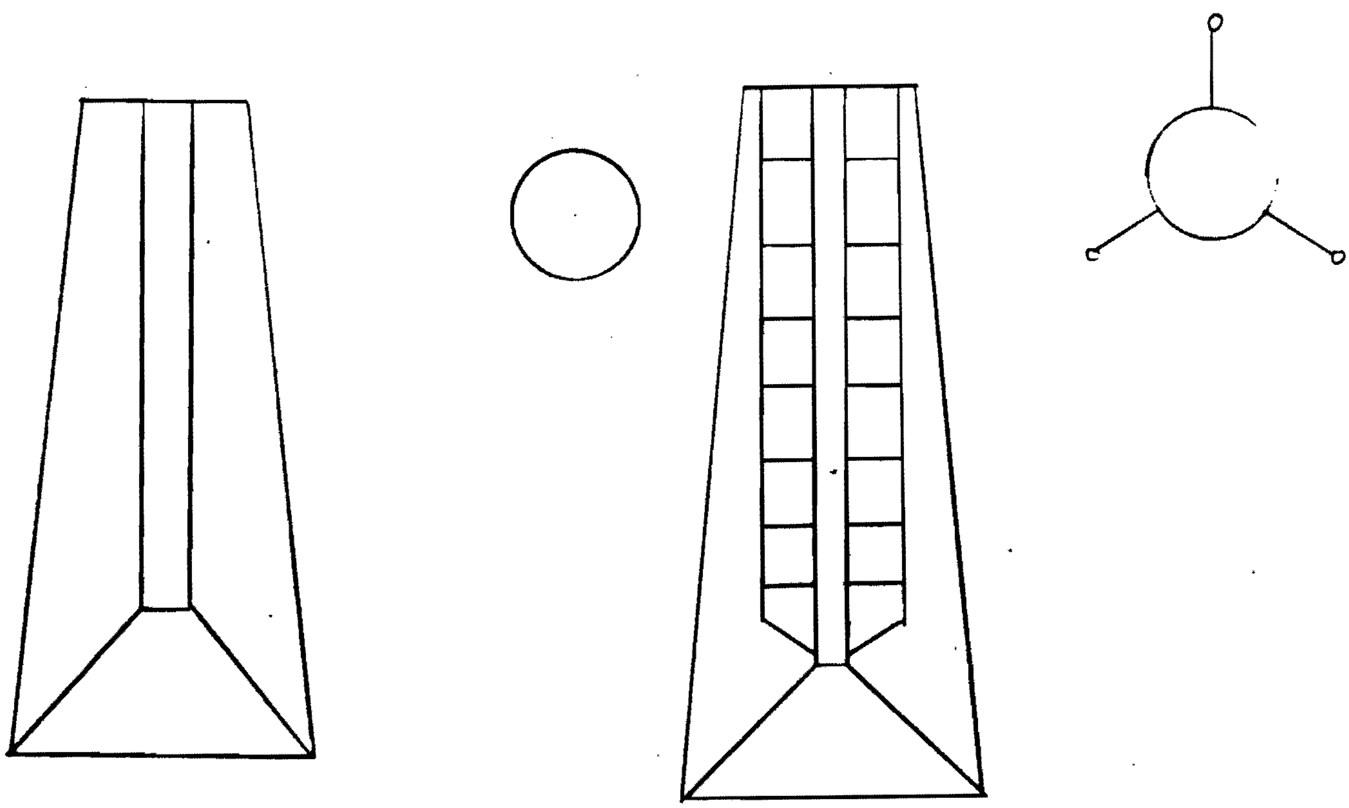


old situation



new situation

The starting behaviour is ok, now the windmill is starting at ± 2,5 m/sec. The tower was made more stiff now (see remark date 1983.05.11)
An other improvement is a climbable tower.
See drawing.



old tower new tower

water level 1,50 below ground level
stroke 50 mm
no pressure height

Date 1983.07.01

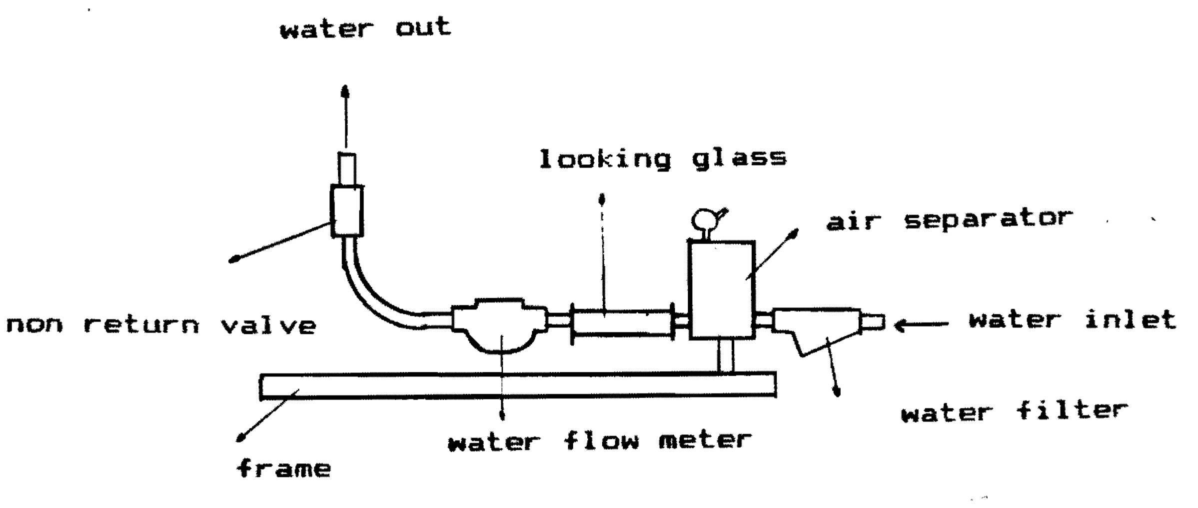
The starting behaviour of the windmill is ± 3,75 m/s which is too high.
The cause is too much friction of the wooden bearings of the rocker arm and pump rod.
The wood has soaked up water so the diameter has become smaller.
Water level 1,50 m
Stroke maximum 100 mm
No pressure height.

Date 1983.07.07

The stroke was changed from 100 mm to 50 mm so the windmill is starting at 2,5 m/s.
This means that the wooden bearings are running in.
Water level 1,50 m.
Stroke 50 mm.
No pressure height.

Date 1983.08.04

The water flow unit was connected to the windmill.
A pressure vessel was placed in the KvdL mast.
Pressure height is 3,50 meter.
Reading water flow meter 25 m^3.
Water level 2,10 m.
Stroke 50 mm.
See drawing.



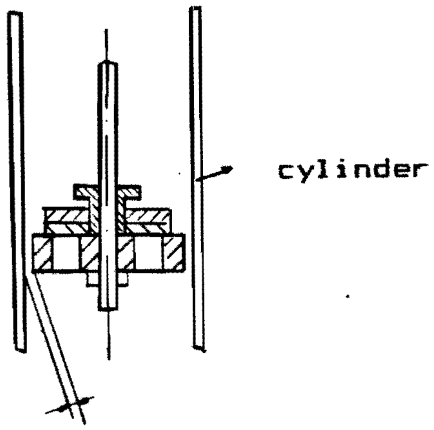
Date 1983.08.12

Suddenly the starting behaviour of the windmill became worse after inspection it appeared that the starting hole in the piston was stopped up by a little stone. After cleaning of the starting hole the windmill is running ok.

Starting at 2,5 m/sec.
Reading water flow meter 38 m³.
Water level 2 meter.
Pressure height changed from 3,5 m to 4 meter.

Date 1983.08.24

Experiment with piston without a leather cup.
The piston is made of synthetic material (teflon) the cylinder is made of brass. There is a slit between the piston and the cylinder which has the same function as the starting hole in the usual piston.
See drawing.



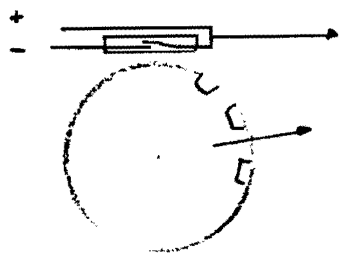
Water level 2,00 m.
Reading water flow meter 50 m³.
Pressure height 4 meter.
Stroke 50 mm.
However during testing of the pump it appeared that the piston sticked in the cylinder. The cause was an unroundness of the brass cylinder and/or probably the sucking up of water of the teflon piston.
Teflon can suck up water up to 5%.

Date 1983.09.01

The synthetic piston was made a little smaller so the sticking of the piston is over now. However, the slit between piston and cylinder is too large now.
The pump delivers too less water and the windmill is starting too early at ± 1,5 m/sec. It was decided to use the piston with a leather cup running in the brass cylinder.
Pressure height 4 meter.
Water level 1 meter.
Reading water flow meter 60 m³.
Stroke 50 mm.

Date 1983.10.05

Revolution counter was mounted on the rotor shaft.
See drawing.



Anemometer and wind direction meter have been mounted now.
Pressure height 4 meter.
Water level 1,60 meter below ground level.
Reading water flow meter 114 m^3.
Stroke 50 mm.

Date 1983.10.12

The pump is leaking water along the packings of the cylinder.
So air is coming on the suction side of the pump which gives a bad water output.
Pressure height 4 meter.
Water level 1,60 meter below ground level.
Reading water flow meter 123 m^3.
Stroke 50 mm.

Date 1983.10.26

Measurements with a pvc cylinder and usual piston were started.
Therefore a new pvc cylinder and a piston with a new leather cup have been mounted diameter Ø 63 mm.
The windmill starts now at ± 2,5 m/sec. and delivers 0,75 l/sec. at max. rpm which is ok.
Pressure height 4 meter.
Water level 1,60 meter below gound level.
Reading water flow meter 143 m^3.
Stroke 50 mm.

Date 1983.11.02

Because of frost the glass of the water flow meter has been broken.
After changing of the glass everything is working ok.
Pressure height 4 meter.
Water level 1,60 meter.
Reading water flow meter 154 m^3.
Stroke 50 mm.

Date 1983.11.11

The pump delivers no water. After priming of the pump it works again.
The cause probably was a leaking foot valve caused by dirt.
Pressure height 4 meter.
Water level 1,60 meter below ground level.
Reading water flow meter 157 m³.
Stroke 50 mm.

Date 1983.11.17

The suction and pressure line were removed from the CWD 2000 well and placed in the CWD 2740 well.
The meaning of this is to pump water from a closed well (no ground water). In order to protect the water flow meter against frost anti freeze was added to the water in the CWD 2740 well. (One part anti freeze to 10 parts water gives a protection till − 8°C.)
The pressure vessel was disconnected from the windmill so it is no longer possible that there is running water over the top of the tower.
Pressure height 0 meters.
Water level 2 meter below ground level.
Reading water flow meter 163 m³.
Stroke 50 mm.

Date 1983.11.24

The water level of the well has been changed.
The suction height is 4,5 m.
This to compensate the pressure height of 4 meters.
Pressure height 0 m.
Water level 4,5 m.
Reading water flow meter 179 m³.
Stroke 50 mm.

Date 1983.11.29

After standing still 3 a 4 hours the windmill delivered no water, the cause being a small hole in the suction line.
After sealing up it was ok.
It appeared that the counter mechanism of the water flow meter had been worn out completely.
The cause probably being sand from the well.
There was mounted an other water flow counter type 20 m.
Reading of this meter 1010 m³.
Pressure height 0 m.
Water level 4,5 m below ground level.
Reading water flow meter 1010 m³.
Stroke 50 mm.

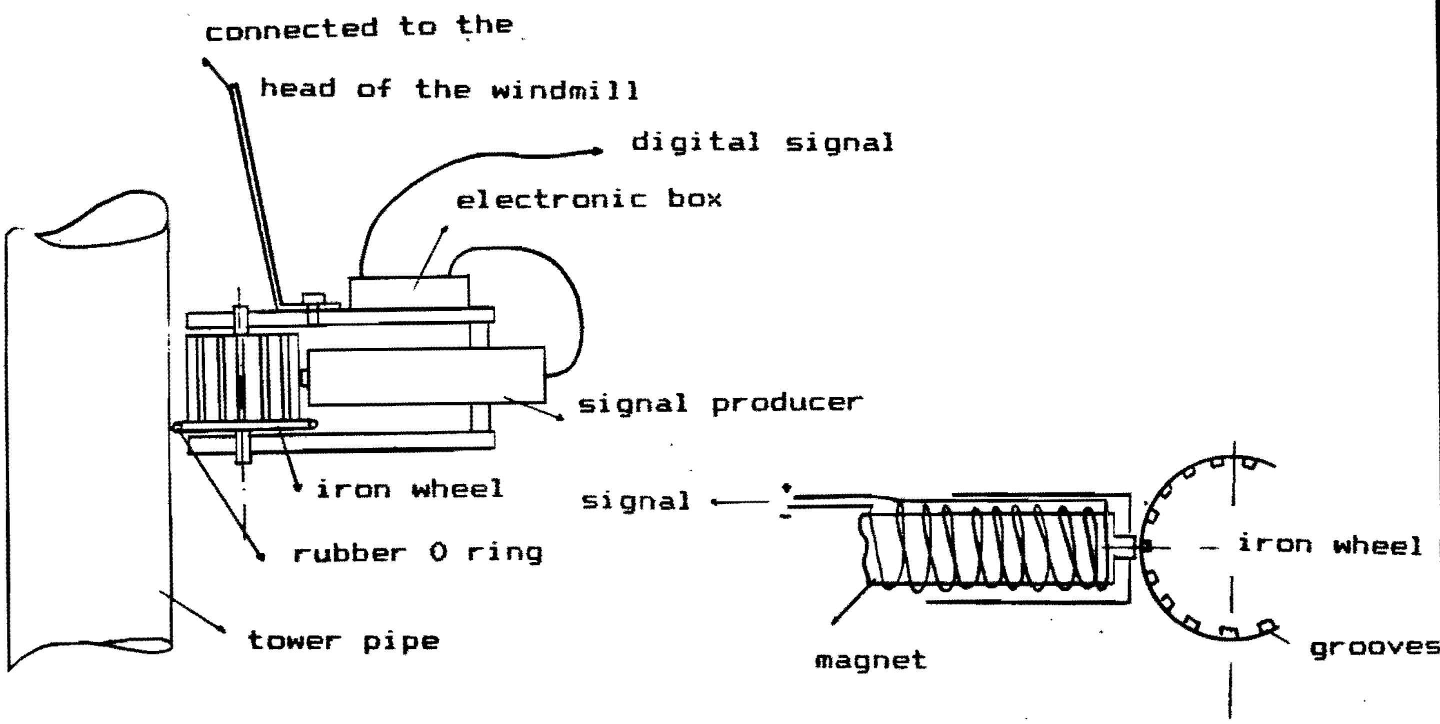
Date 1984.02.03

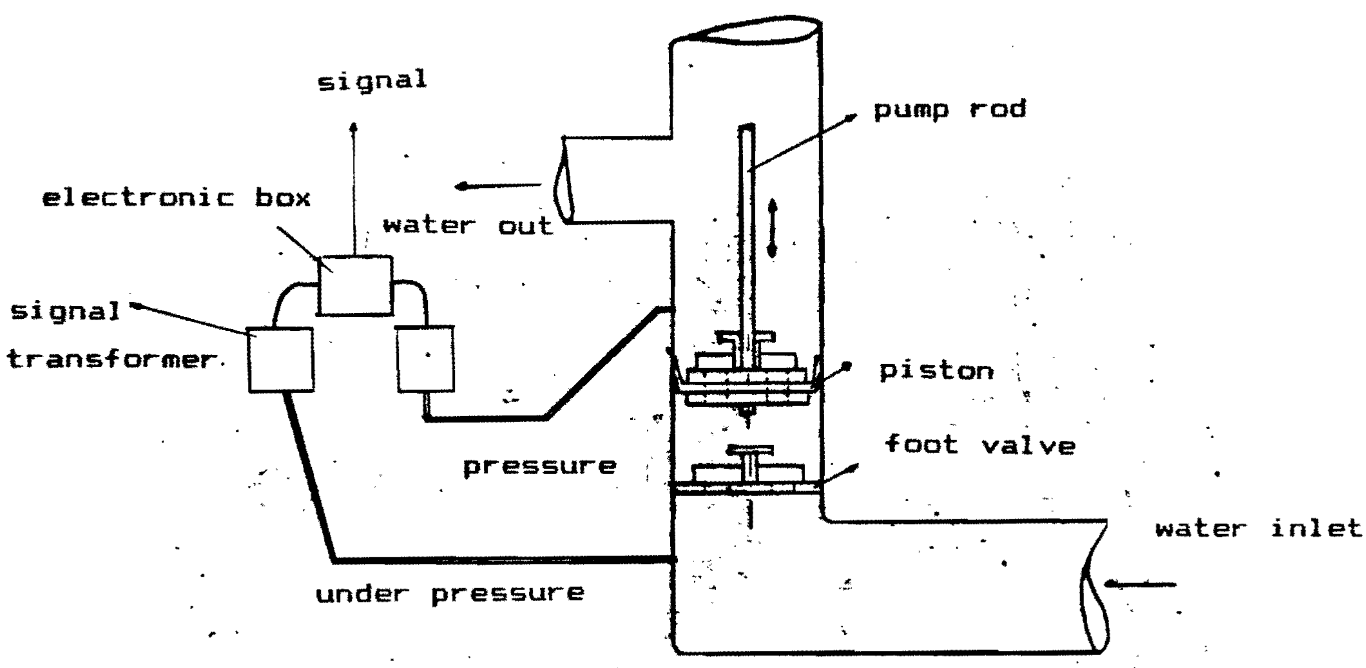
The reed switch of the rpm counter was broken. The cause being moisture and corrosion. After mounting a new one the rpm counter is working ok.
Pressure height 0 m.
Water level 4,5 m below ground level.

Reading water flow meter 2781 ?
Stroke 50 mm.
Remark the 2781 should be 1781.
The reading mechanism has been making a mistake.

Date 1984.02.10

A new cable was mounted from the head of the windmill to the central box on the ground.
Because the windmill had turned several times around his axis the cable was broken.
A yawing speed counter was mounted together with a pressure pick up for measurements of the dynamic pressure in the pump.
See drawing.





Pressure height 0 meter
Water level 4,5 meter
Reading water flow meter 2930 m^3.
Stroke 50 mm.

Date 1984.03.01

The suction line of the windmill was placed back in the open (ground water) well under the CWD 2000.
Pressure vessel was mounted again, pressure height is 5,5 meter now.
New flexible hoses have been mounted.
Pressure height 5,5 meter.
Water level 1,40 meter.
Reading water flow meter 2942 m^3.
Stroke 50 mm.

Date 1984.03.29

By high wind speed (up to 10 m/s) there was water running out of the tower top.
The cause probably being the pressure vessel and resistance of the water measuring system.
The counter mechanism of the water flow meter was cleaned.
Pressure height 5,5 meter.
Water level 1,60 meter.
Reading water flow meter 1989 m^3.
Stroke 50 mm.

Date 1984.04.26

The rotor shaft is running loose in its bearings so the excenter is running against the head frame of the windmill.
The result is a bad starting behaviour ± 4 m/sec. and a lot of noise.
The cause was the clamp rings in the ball bearing which are running loose caused by jamming of one of the ball bearings of the main shaft.
The cause of the jamming of the ball bearing was, that there was no grease in the bearing house.
Pressure height 5,5 meter.
Water level 1,60 meter below ground level.
Reading water flow meter 2095 m^3.
Stroke 50 mm.

Date 1984.05.10

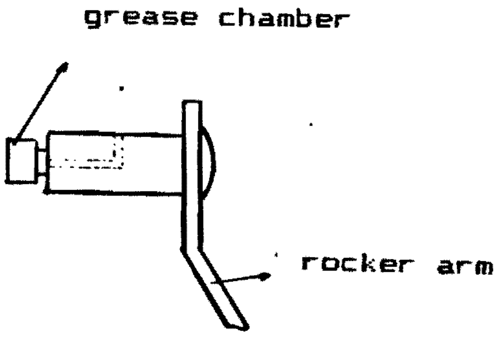
After dismounting of the windmill in order to paint it the following faults appeared.

a. The wooden bearings were complete worn out.
   The crank pins of the rocker arm are also worn out.
   The cause being defective lubrication by ineffective grease cups.
b. The rotor shaft bearings are worn out.
   The cause being defective lubrication by no grease in the bearing house.

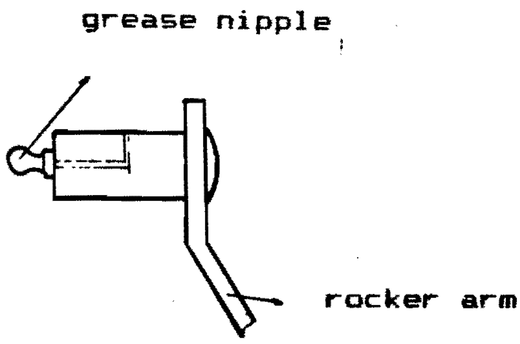
We manufactured new crank pins and made another lubrication system.

The grease cups were replaced by grease nipples.
See drawing

Old situation



New situation



Pressure height 5,5 meter.
Water level 1,80 meter.
Reading water flow meter 2118.
Stroke 50 mm.

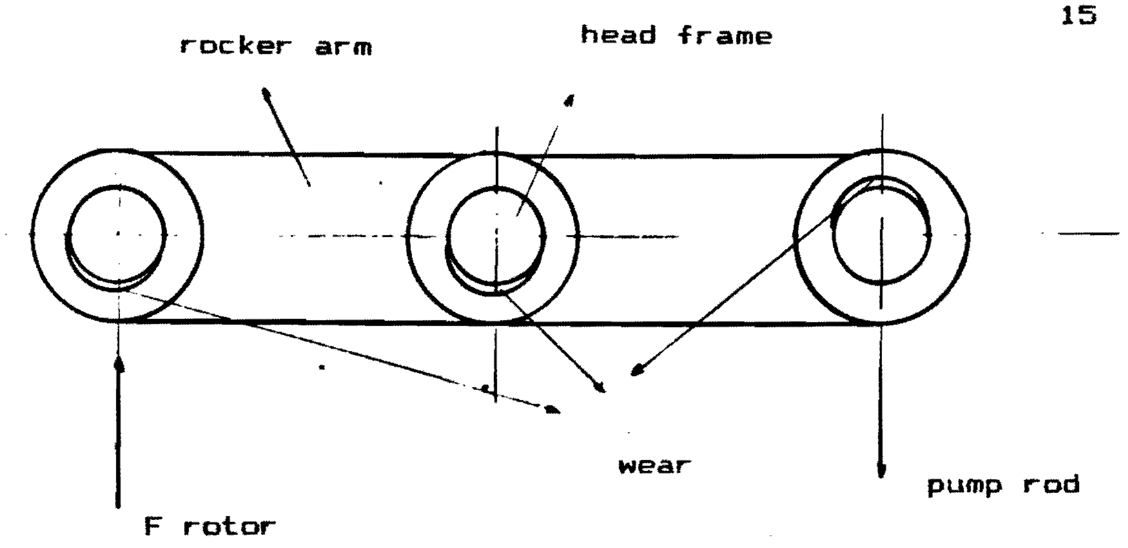
Summary repair CWD 2000

Reasons for overhaul

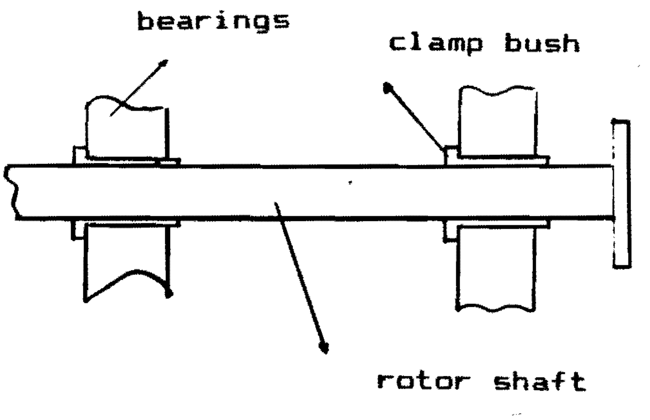
a. The bearings of the rocker arm were worn out.
b. The ball bearings of the rotor shaft were worn out.
c. The windmill needed painting.

Overhaul experiences

a. The wear of the rocker arm.
   See drawing

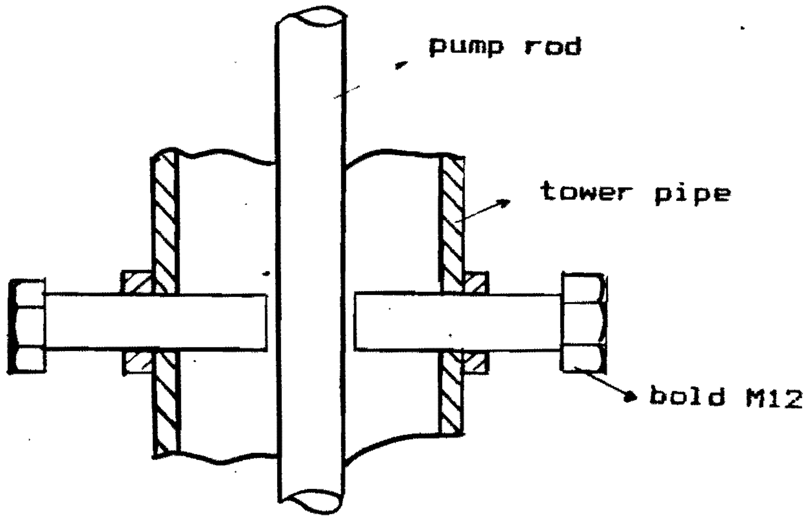


b. The wear of the rotor shaft.
   See drawing.



Note: The bearing house had not been filled with grease.

c. The ball bearing of the exenter had not been filled with grease.
   But this bearing has not been damaged.
d. The painting of the tower is still ok.
   We painted the windmill for reasons of estetics.
e. There was no wear on the pump rod guide.
   See drawing.

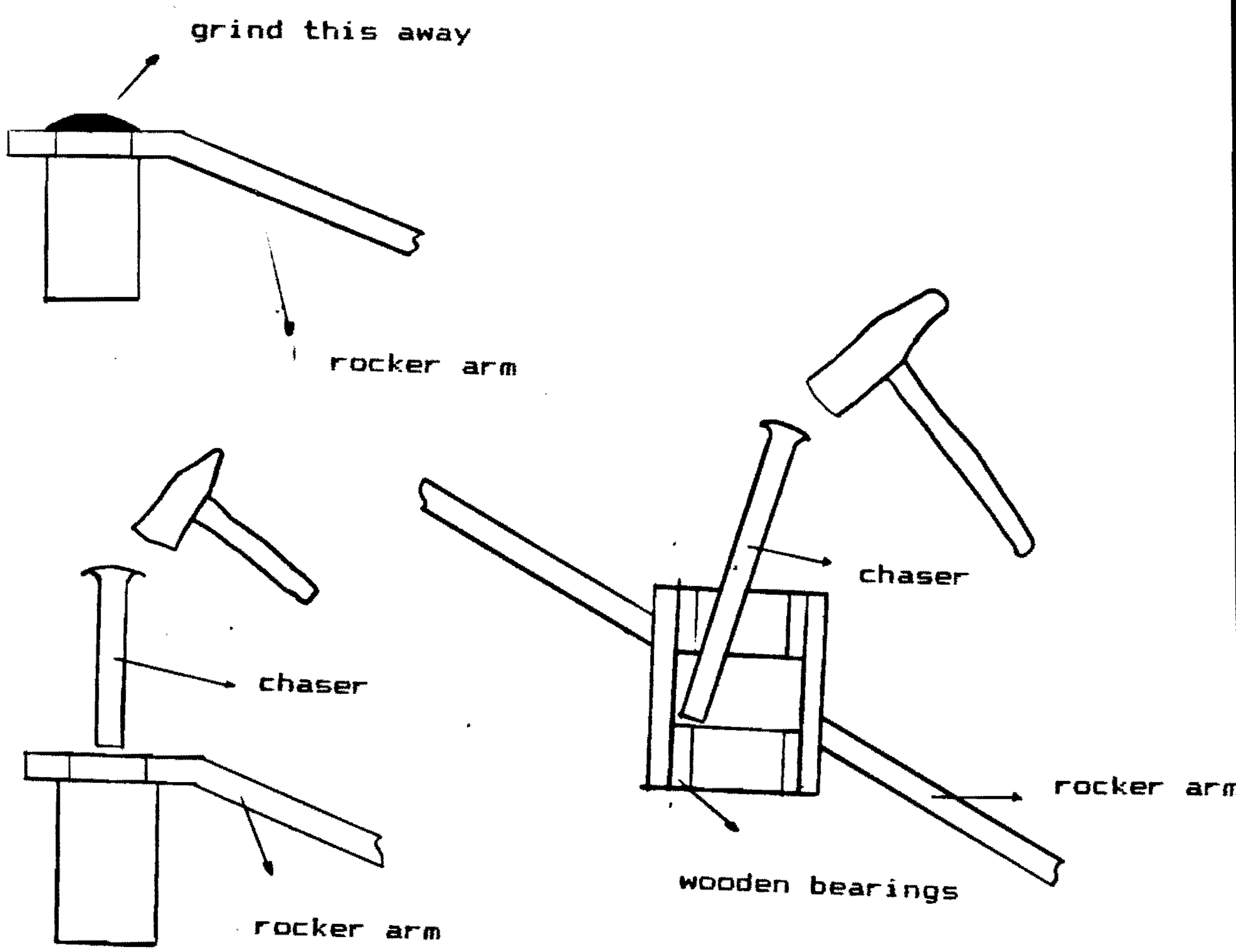


f. The condition of the piston and valves was ok.

Overhaul activities

a. Manufacturing of new crank pins for rocker arm and head frame.
b. Manufacturing of new wooden bearings for rocker arm and pump rod.
c. Manufacturing of new rotor shaft.
d. Removing of old crank pins from rocker arm head frame.

<u>See drawing</u>



e. Removing of wooden bearings.
f. Grinding of the windmill and spraying with correless paint, and Sikkens car paint (white).
g. Welding of new crank pins in to the rocker arm with special care to the parallism of the crank pins.
h. Pressing of new wooden bearings in rocker arm and pump rod, and making of bearings at the right size.
i. Mounting of the head frame and the bearing houses and filling of them with grease.
j. Manufacturing of new packings for the pump.
k. - Mounting of the pump under the windmill.
   - Mounting of the head frame on the windmill.
   - Mounting of the rotor.

Used materials at the overhaul

*ring spanner	10x11
	12x13
	16x17
	18x19
	32
	hammer
	drift
	grinding-machine
	welding-equipment
	scissors
	sanding paper
	paint + spray gun
	packing material

Date 1984.06.21

The overhaul has been finished now, windmill is running ok.
The windmill starts at 2,5 m/sec.
Mounted a new reed switch of the rpm counter the old one was broken.
Pressure height 5,5 meter.
Reading water flow meter 2132 m^3.
Water level 1,80 m.
Stroke 50 mm.

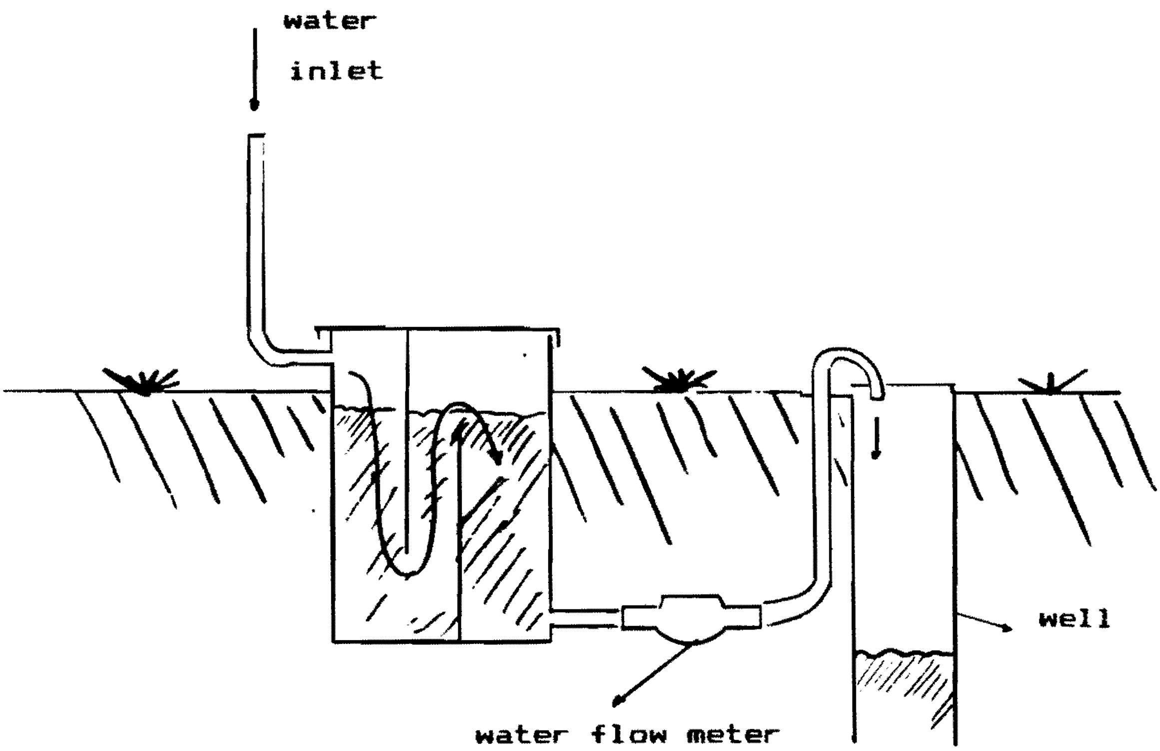
Date 1984.06.28

The windmill stows the water to the top of the tower where it is running over.
Cause being probably the resistance of the water flow meter.
The wooden bearings are running stuck.
Cause being swell of the bearings by the water from the top of the tower. Windmill starts now at 4,5 m/sec.
Pressure height 5,5 meter.
Water level 1,80 meter.
Reading water flow meter 2179 m^3.
Stroke 50 mm.

Date 1984.07.19

A collecting vessel has been installed in the return line.
The water flow meter in the pressure line has been removed.

This reduced the resistance of the pressure line.
See drawing.



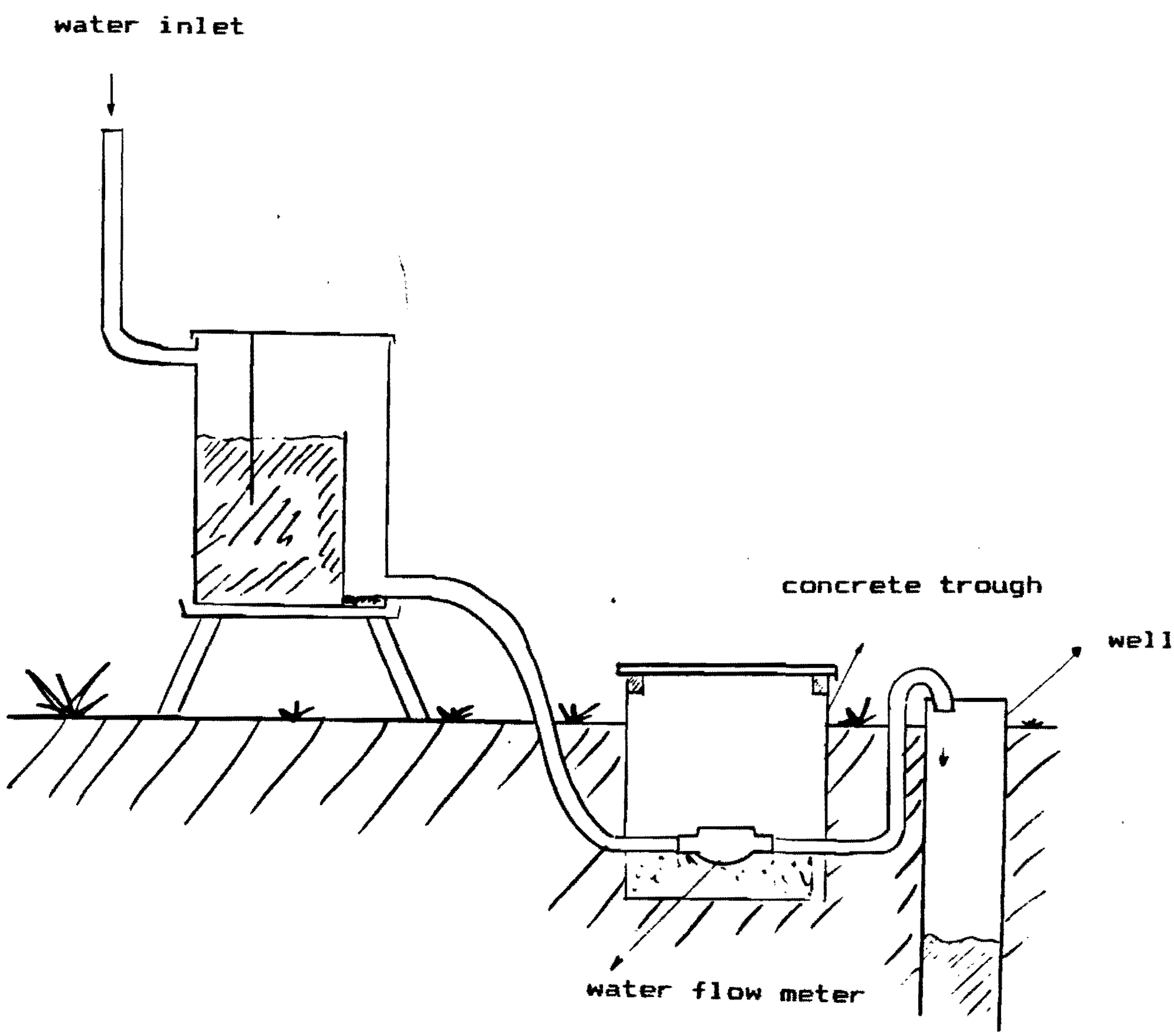
The advantage of this system
There is now resistance in the pressure line.
The system is not sensitive to frost.

The disadvantage of this system
There is a reaction time of ± 1 a 1 1/2 min. between delivery of water from the windmill and measuring of the water.

Date 1984.07.26

We have changed the water measuring system to reduce the time between delivery of water from the windmill and measuring of the water.

See drawing



Advantage of this system:
- Reaction time between delivery of water from the windmill to measuring of the water is now ± 30 a 45 sec. (There is more pressure over the water meter.)
- Water flow meter within better reach.

Pressure height 5,5 meter.
Water level 1,70 below ground level.
Reading flow meter -
Stroke 50 mm.

Date 1984.09.13

The windmill is starting at 4,5 m/sec. which is too high caused by the swell of the wooden bearings.

Date 1984.04.10

The windmill has been layed down to make the hole in the wooden bearings a little larger.
The clamping of the bearings should be over now.

Date 1984.10.11

The windmill has been erected.
Stroke is max. 100 mm.
However, by the large water flow the water is running over at the top of the tower. To prevent the running over of the water we decided to place the pressure vessel 0,5 meter lower.
Windmill starts at ± 2,5 m/sec.
Pressure height 5,0.
Water level 1,60 m.
Reading water flow meter -
Stroke 100 mm.

Date 1984.10.18

Water is still running over at the top of the tower of the windmill.
We decided to place the pressure vessel 0,5 meter lower.
Pressure height 4,5 meter.
Water level 1,60
Reading water flow meter
Stroke 100 mm.

Date 1984.11.01

The suction and pressure line have been placed in the well of the CWD 2740 windmill.
Now we can control the suction height.
Water is still running over the top of the tower (Probably the pressure line of 1" is too thin.)
We decided to place the pressure vessel 1 meter lower.
Pressure height 3,5 meter.
Water level 5,5 meter below ground level.
Reading water flow meter 1340 m^3 (new start)
Stroke 100 mm.

Date 1984.11.15

The windmill starts at ± 5 m/sec. which is too heigh.
Caused by the wooden bearings of the rocker arm.

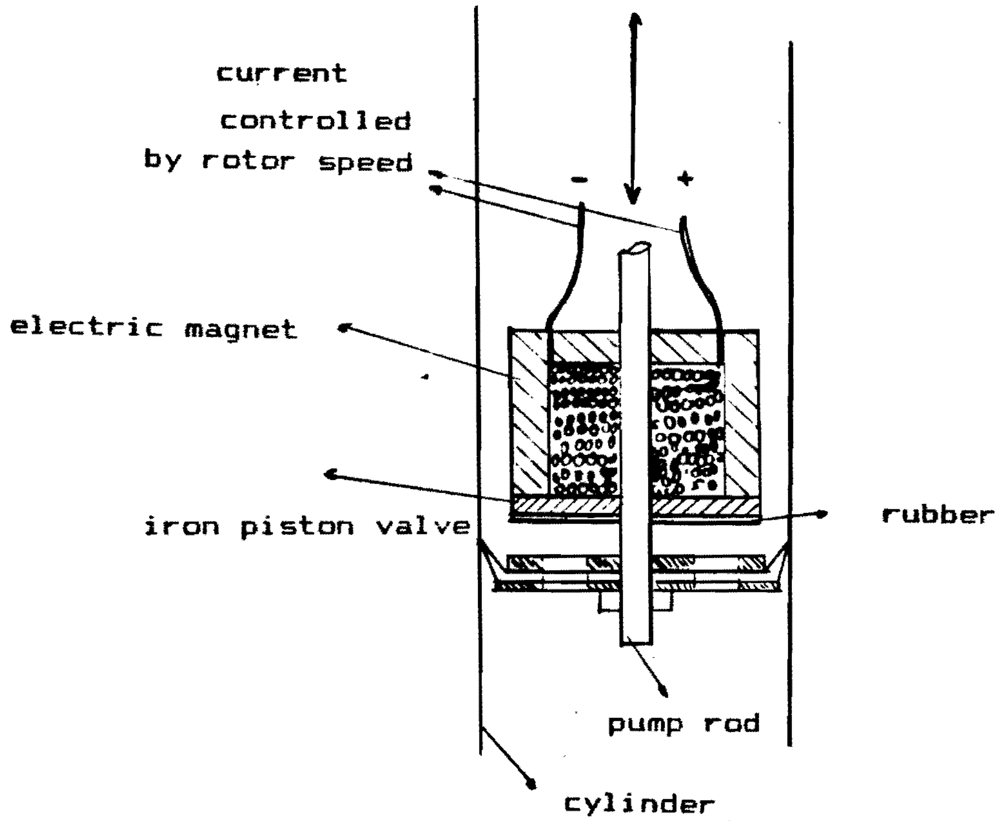
Date 1984.11.28

We have done an experiment to see where the friction, responsible for the heigh starting wind speed, is coming from.
The piston was replaced by a weight equal to the piston load.
The wooden bearings were cleaned and filled with grease.

A starting behaviour equal to the normal conditions was found. It was decided to do a test with an electric controlled piston valve to investigate if it would be possible to reduce the starting wind speed.

<u>The electric controlled piston valve</u>

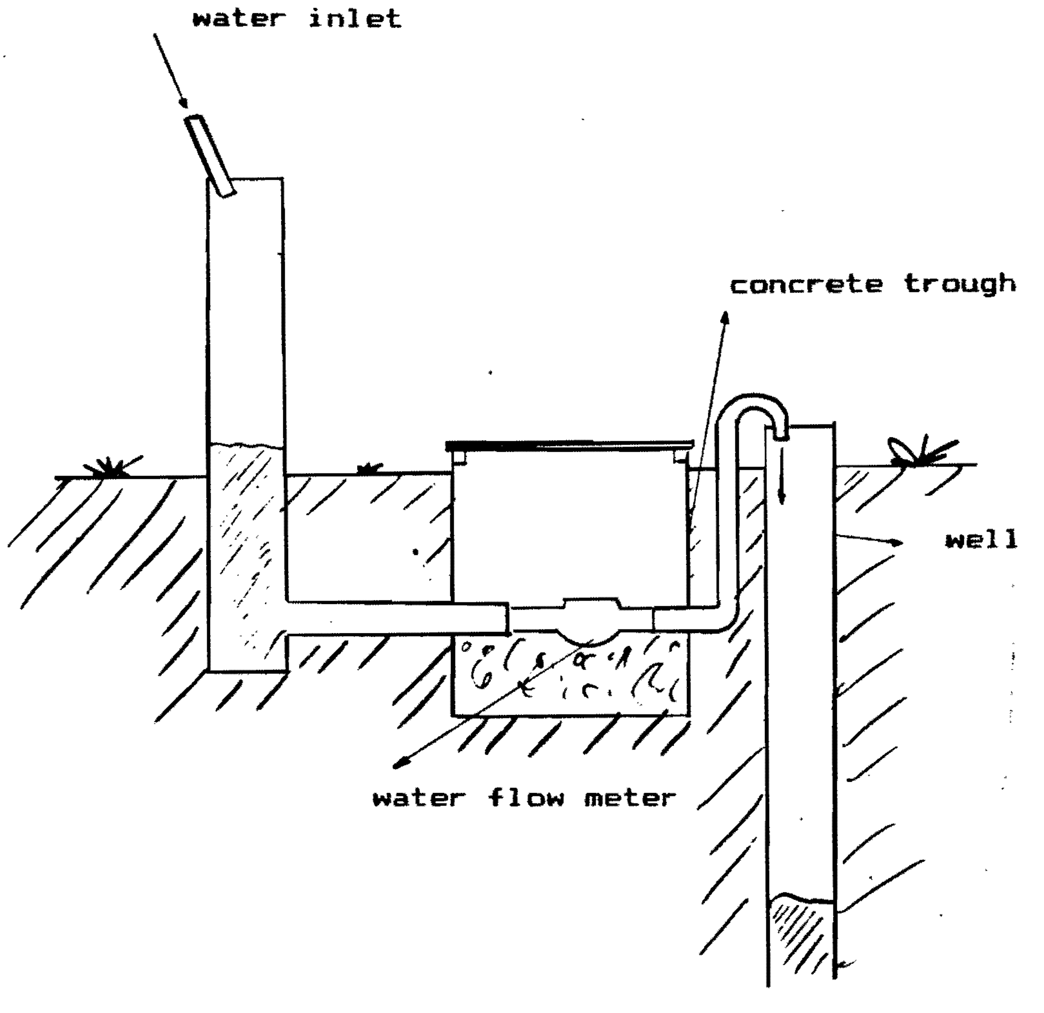
<u>See drawing</u>.



The electric magnet keeps the piston valve open until the rpm counter gives the sign to loose the valve.
Then the windmill starts to deliver water.
The starting wind speed of the windmill is ± 0,5 a 1 m/sec.
Pressure height 3,5 meter.
Water level 5,5 m^3 below ground level.
Reading water flow meter 1428 m^3.

Date 1984.12.07

We have changed the water measuring system.
See drawing.



Benefits of this system

- The time between pumping water and measuring water is reduced. Time is now ± 5 a 10 sec. (more pressure over the water meter).
- The total amount of water in the system is far less than the other system.

Date 1984.12.12

The filter in the return line is stopped up.
Water is running out the pressure vessel after cleaning it is ok.
Pressure height 3,5 meter.
Water level 5,5 below gorund level.
Reading water flow meter 1443 m^3.
Stroke 100 mm.

Date 1985.01.02

Because of frost the packing of the pump is broken.
After mounting new packings the windmill is working ok.
Pressure height 3,5 meter.
Water level 5,5 meter below ground level.
Reading water flow meter 1501 m^3.
Stroke 100 mm.

Date 1985.01.10

Because of heavy frost the windmill was complete frozen.
The pvc cylinder is frozen but not broken.

Date 1985.02.07

The wooden bearings of the rocker arm are clamping notwithstanding frequent lubrication.
After cleaning and new grease the wooden bearings are working ok.
Cleaned the well of the CWD 2740.
Pressure height 3,5 meter.
Water level 0,2 meter below ground level (temporal).
Reading water flow meter 1534 m^3.
Stroke 100 mm.

Date 1985.02.28

End of the frost period.
After mounting of the packings of the pump (they were pressed out by ice) the windmill is working ok.
Pressure height 3,5 meter.
Water level 0,2 meter below ground level.
Reading water flow meter 1637 m^3.
Stroke 100 mm.

Date 1985.03.27

A new and larger electric magnet is mounted to enlarge the attractive power to let the electric valve work in all conditions (high rpm).
After one cyclus of measurements the output seemed to have improved.
Measurements are going on (see report H. Oldenkamp, nr. R 765 D).
Pressure height 3,5 meter.
Water level 5,0 m. below ground level.
Reading water flow meter 1926 m^3.
Stroke 100 mm.

Date 1985.04.04

Replaced the reed switch of the rpm counter.
The old one was worne.
Pressure height 3,5 meter.
Water level 5,5 meter below ground level.
Reading water flow meter 2016 m^3.
Stroke 100 mm.

Date 1985.04.25

A stainless steel cylinder was mounted to investigate the influence of the friction between piston and cylinder.
Some experiments have been done with closing and opening of the piston valve with the help of the electric valve at preset times.
It is possible to find the max. cp eta curve.
(With the electric valve it is possible to close the piston valve at a suction rpm and to open the valve at an other rpm.)
Pressure height 3,5 meter.
Water level 5,5 meter below ground level.
Reading water flow meter 2218 m^3.
Stroke 100 mm.

Date 1985.06.06

The friction between piston and stainless steel cylinder was measured by dismounting the rocker arm and pulling up the pump rod loaded with the water column.
Pressure height 3.00 meter.
Water level 4,70 meter.
Reading water flow meter.
Stroke 100 mm.
Note: pressure height changed from 3,5 to 3 meter because there is running over water sometimes.
Probably the 1" diameter of the pressure line gives so much resistance.

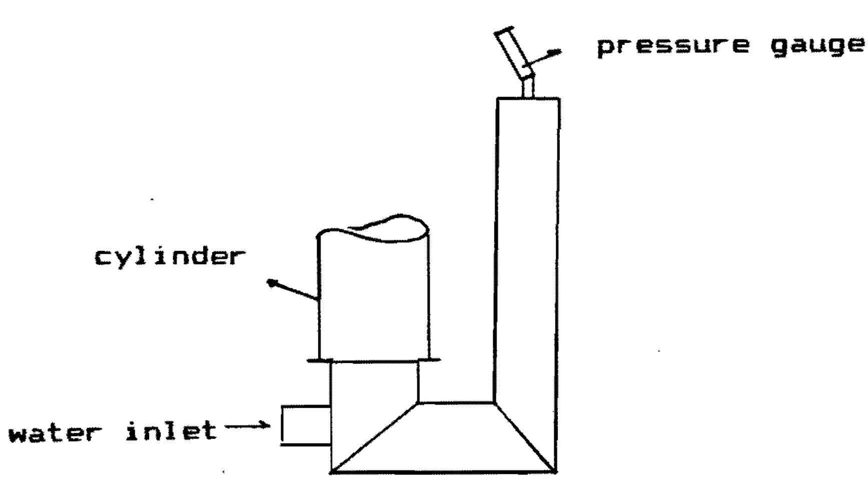
Date 1985.06.20

The stroke of the windmill was changed from 100 mm into 75 mm because of measurements with the electric valve.

Date 1985.06.27

A pressure gauge on top of the suction air chamber was installed to obtain the pressure and under pressure in the air chamber.

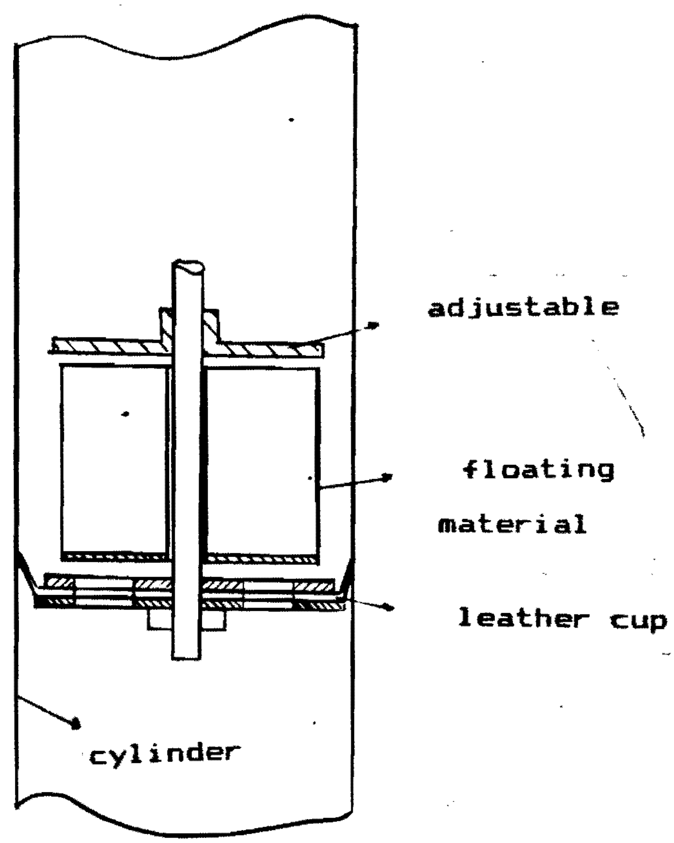
See drawing.



Pressure height 3,00 meter.
Water level 4,70 meter.
Reading water flow meter.
Stroke 75 mm.

Date 1985.08.08

The measurements were stopped for a period.
The pump was dismounted to remove the floating valve which was needed for measurements in the test rig at the laboratory of the CWD.
See drawing.



For exact specifications see drawing nrs. 8608-01.02.03.

The valve floats when the windmill is standing still.
There is no resistance in the pump when the windmill is starting.
At sufficient rpm of the rotor the water stream closes the valve by the under pressure caused by the water acceleration through the slit between piston valve and piston.
The under pressure moves the floating valve down to the piston.
Then the windmill starts to deliver water.

Date 1985.10.10

Measurements started with the floating valve in the windmill.
The wooden bearings of the rocker arm and pump rod were cleaned and greased.
Pump height 3,00 meter.
Water level 1,80 meter below ground level.
Reading water flow meter
Stroke 100 mm.

Date 1985.10.24

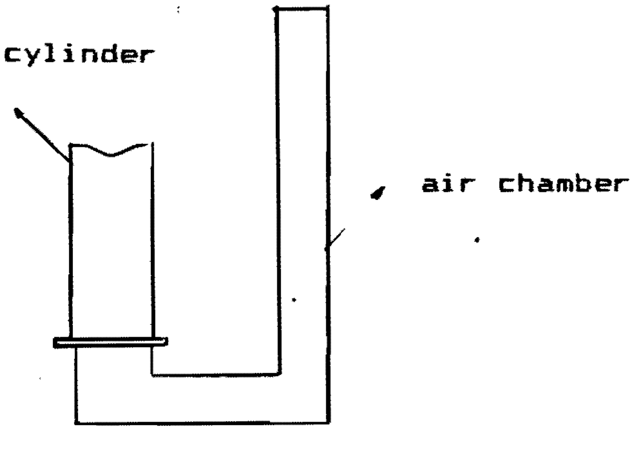
The measurements have been stopped because of overhaul of the measuring system at the testfield. (The signal cables of the windmills where damaged by rabbits.)

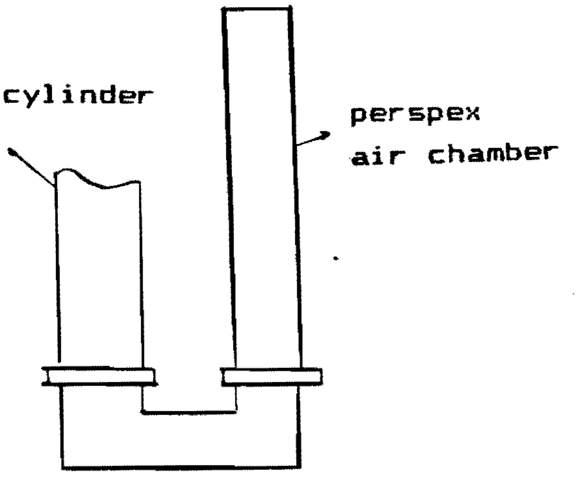
Date 1985.11.14

The measurements are started again.
A student is doing measurements on the dynamic behaviour of the windmill at several wind speeds.
The pump is working now with the floating valve.
The pressure vessel has been changed by a perspex one.
The pressure and suction line have been pulled back to the well of the
CWD 2000.
Pressure height 4 meter.
Water level 1,80 meter.
Reading water flow meter -
Stroke 100 mm.

Date 1985.12.07

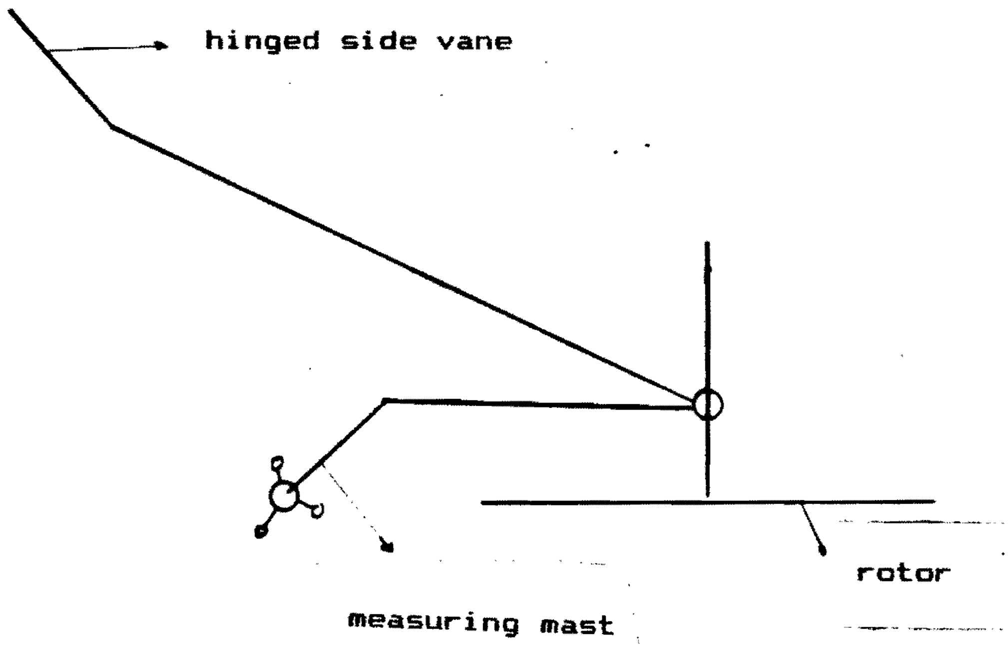
The suction air chamber is changed by a perspex one so we can see what is going on in the air chamber.
See drawing.





We have placed a measuring mast on the head of the windmill to measure:
- wind speed
- wind direction.

<u>See drawing</u>.



Pressure height 3,00 meter.
Water level 1,80 meter.
Reading water flow meter -
Stroke 100 mm.

Experiments are going on.

4. A FEW REMARKS

- One of the major problems of the CWD 2000 windmill is the wooden bearings of rocker arm and pump rod.
  They need a special care and that is not a guaranty they will work ok.
- The piston friction is a very important point for a small windmill (< 2,0 m).
  The influence on the starting behaviour is very high.
  (See report R 765 D.)
- Electric controlled piston valve.
  The experiment with the electric controlled piston valve (which) in its turn simulates the floating valve) gave promissing results with regard to pump starting at lower wind speeds.

5. CUMULATIVE MEASUREMENTS

- Not available.