Survey of the experiences on the testfield at the Eindhoven University of Technology in particular for the WEU 1-3 windmill from April 1983 until May 1985

SURVEY OF THE EXPERIENCES ON THE TESTFIELD AT THE EINDHOVEN UNIVERSITY OF TECHNOLOGY IN PARTICULAR FOR THE WEU 1-3 WINDMILL from April 1983 until May 1985

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CONTENTS

I INTRODUCTION

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

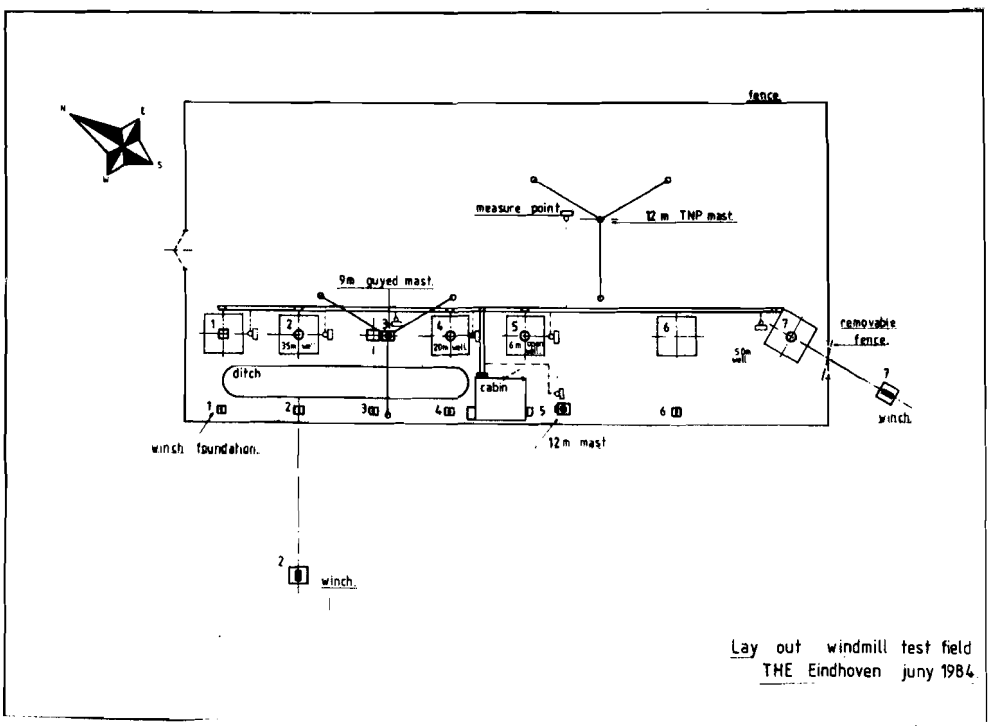


Fig. I

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

Location 1

Name of the windmill	Weu 1-3
Rotor diameter	3000 mm
Height of the tower	9 meter
Safety system	overspeed control by yawing, activated by means of side vane and hinged main vane with manually activated furling device

Pump	suction pump with a bore of 150 mm
Capacity	42 m^3/day at a wind speed of 4 m/sec and 10 m lifting head
Stroke	adjustable from 0 to 120 mm
Design tip speed ratio	$\lambda_d = 2$
Number of blades	6
Depth of the well	no well
Capacity of the vessel	about 4 m^3

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 and hinged tail vane with manually activated furling device
Pump	single acting piston pump with a bore of 150 mm
Capacity	50 m^3/day at a windspeed of 4,5 m/sec and 20 meter lifting head
Stroke	80-110-140-170-200 mm
Design tip speed ratio	$\lambda_d = 1,8$
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 windspeed of 4 m/sec and 10 meter lifting head
Stroke	adjustable from 0 to 60 mm
Design tip speed ratio	$\lambda_d = 2$
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 windspeed of 3,5 m/sec and 5 meter lifting head
Stroke	25-50-75-100 mm
Design tip speed ratio	$\lambda_d = 1,35$
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	$\lambda_d = 2$
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.

II SUMMARY OF FIELD EXPERIENCES WITH THE WEU 1-3 WINDMILL SINCE APRIL 1983

19.04.1983 The tower is placed on the testfield and the head is mounted. No rotor and no pump are mounted. The tower is erected using a Tirfor winch.

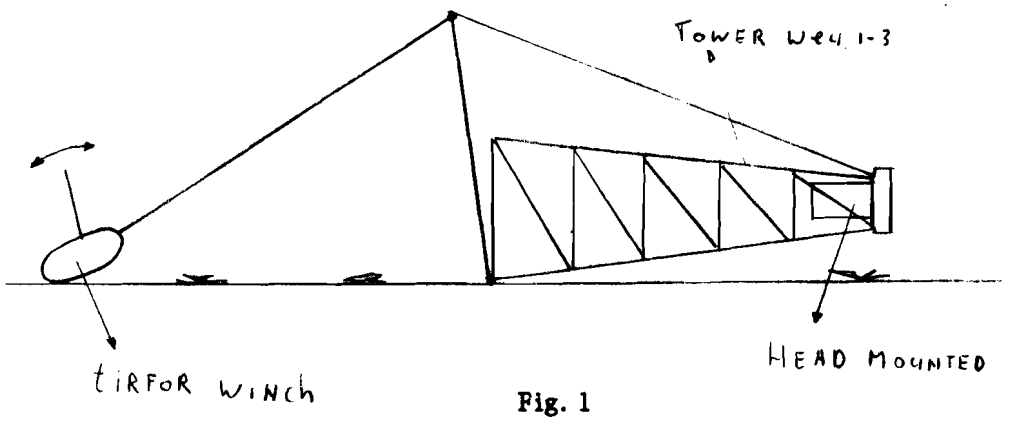


Fig. 1

21.04.1983 The rotor and the vanes are mounted. The windmill is running unloaded. No pump has been mounted yet.
Everything is working o.k..

25.04.1983 The pump is mounted and the windmill is running, however the delivery air chamber is leaking, the cause being a porous welded seam.

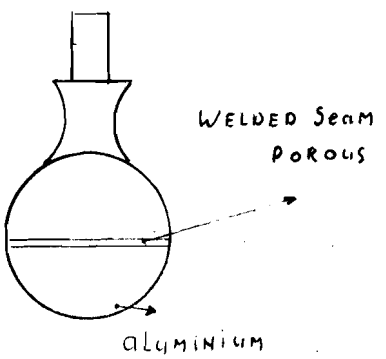


Fig. 2

A spare delivery air chamber is installed, this one is o.k.
The counter piston is leaking a little: about 10 cc per stroke.
The pump foundation is too light so when the windmill is running it is moving up and down. The solution for this problem is to make the foundation heavier by adding 50 kg of concrete.

Original foundation:

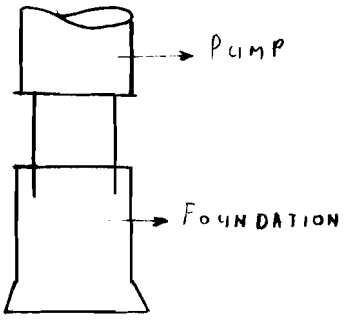


Fig. 3

Modified foundation:

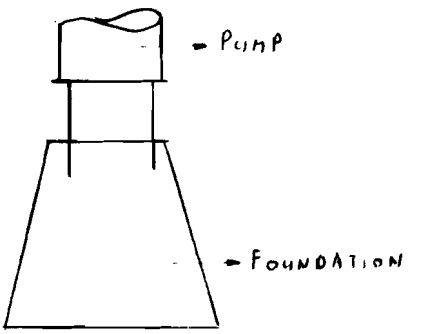


Fig. 4

29.04.1983 The waterflowmeter, (type 20 m) is installed in the pressure pipe. Reading is 520 m^3.
The stroke of the windmill is 150 mm.
There is no pressure height.
The delivery air chamber is leaking, the cause being a porous welded seam. A spare one is mounted.

06.05.1983 The crankshaft bearing housing is broken. The cause is probably working loose of a nut due to a soft spring washer.

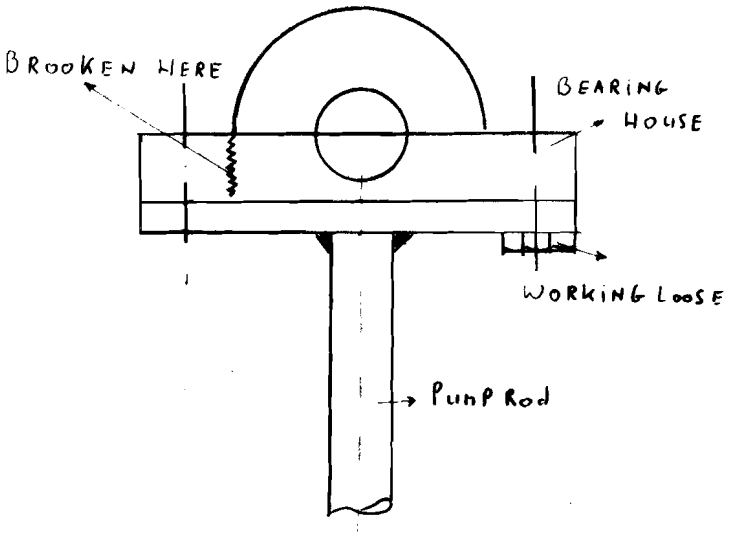


Fig. 5

A new bearing housing is mounted, using a good quality spring washer.

19.05.1983 The furling system is broken, probably during the storm on 12.5.1983.. The wind gives too strong a force on the connection of the furling mechanism to the side vane arm.

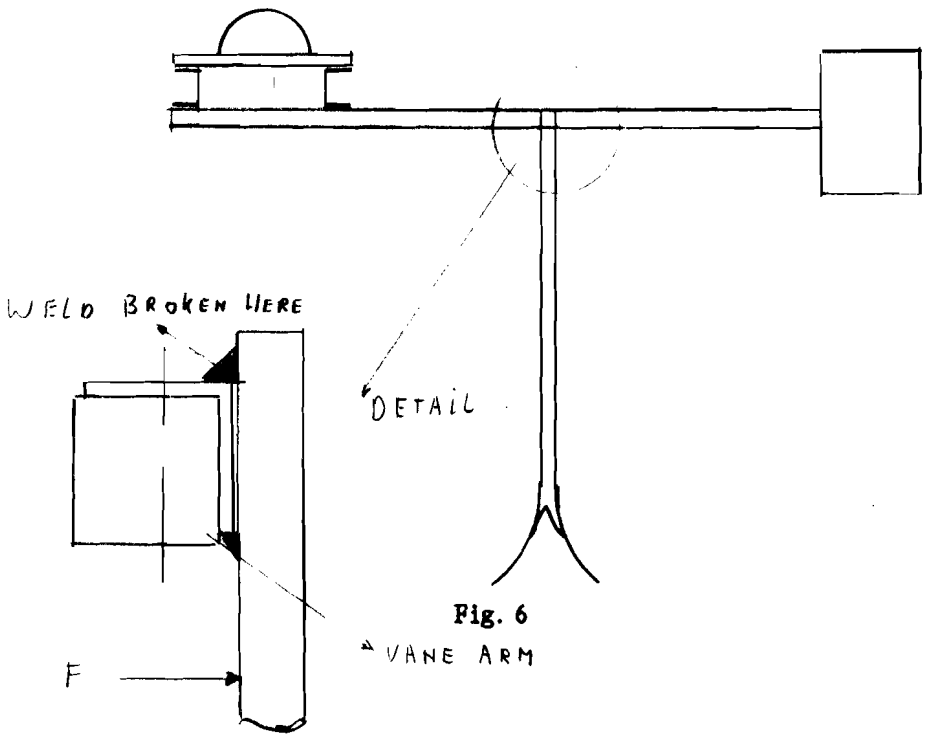


Fig. 6

02.06.1983 The furling system is repaired and mounted.
The suction and delivery air chamber are painted on the inside with coal tar to be sure that they are tight. They are not leaking anymore.

10.06.1983 The filter and foot valve at the beginning of the suction line are frequently blocked by leaves in the ditch. After removing the leaves the windmill is running o.k.
Reading waterflowmeter: 735 m^3.
Stroke: 150 mm.
No pressure height.

23.06.1983 We have mounted an extra air chamber to the suction line and the delivery line because the volume of one air chamber is 8 liter and it should have been 15 liter (according to calculations).
The windmill is running more smoothly now.

07.07.1983 There is a clear click when the windmill is running. When the number of revolutions increases the clicking noise stops. After a check of the windmill it appears theat one of the blades is loose due to a nut of a U bolt that has worked loose. After a check of the other blades it appears that it is necessary to tighten the U bolts as well.
The cause is probably working loose of the nuts due to soft spring washers.
Reading waterflowmeter: 766 m^3.
Stroke: 150 mm.
No pressure height.

14.07.1983 Waterflow measuring unit is installed now. The same waterflowmeter is used as before on the WEU 1-3.

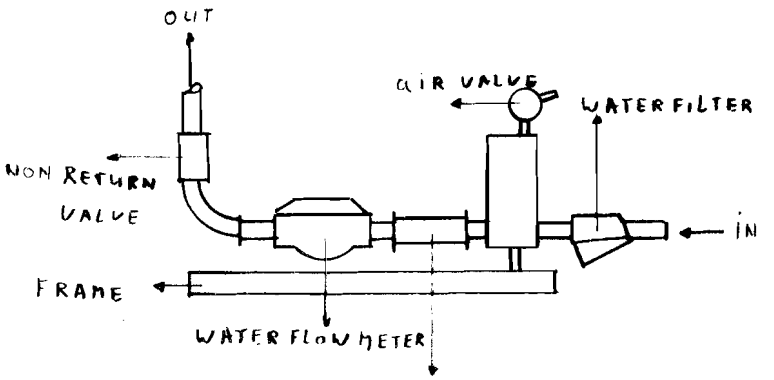


Fig. 7 Loking Glass

Reading waterflowmeter: 803 m^3.
Stroke: 150 mm.
No pressure height.

12.08.1983 The sieve of the waterflowmeter is broken by dust that has passed through the waterfilter.
Then the counting mechanism is wearing fast.
The counting mechanism is removed, in order for the water to pass through the waterflow unit with minimum resistance.

21.09.1983 The pump delivers no water. After dismounting the pump it appears that the leather cup is torn away from the piston.
Probably it is torn away by too high pressure by a blocked waterflowmeter.

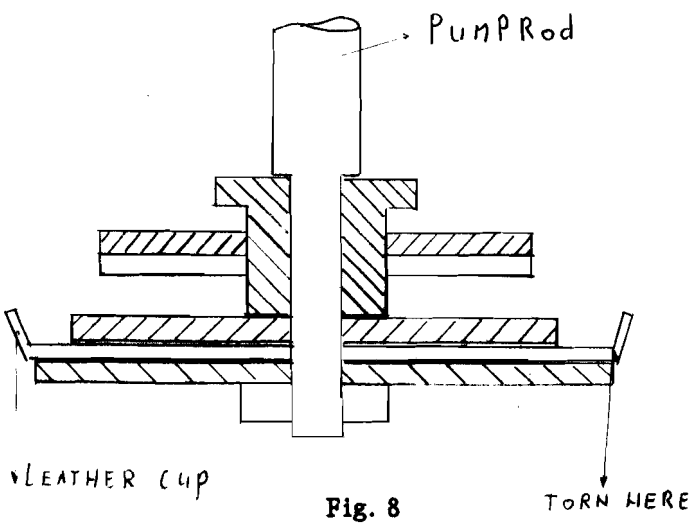


Fig. 8

A new cup is made and the pump is mounted again. The pump is working again.
The counting mechanism of the waterflowmeter is repaired now and is working again.
Reading flowmeter: 610 m^3.
Stroke: 150 mm.
No pressure height.

12.10.1983 The pumprod is broken below the crankshaft bearing housing.
The cause is high pressure forces in the pumprod.
The pumprod is buckled.

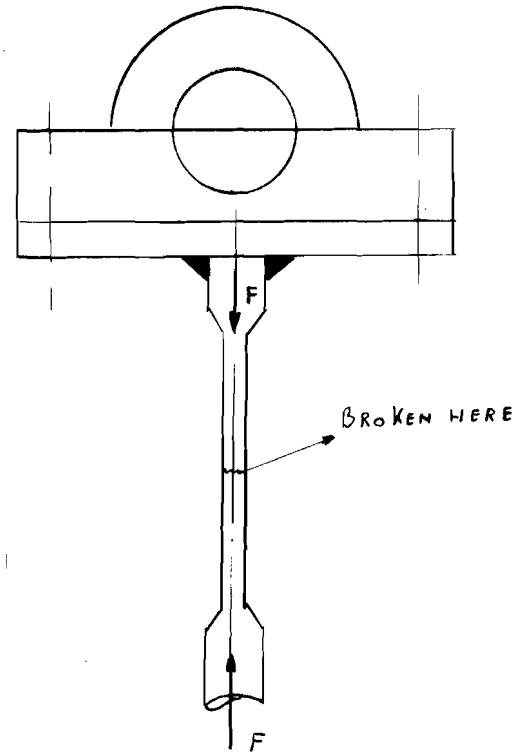


Fig. 9

A new pumprod of the same size as the old one is made.

Reading waterflowmeter: 662 m^3.

Stroke: 150 mm.

No pressure height.

26.10.1983 The waterfilter was blocked by leaves from the ditch.
This resulted in high pressure in the delivery air chamber. The delivery air chamber has exploded. The cylinder of the counter piston is also broken. We decided to make new air chambers of pvc tube.

17.11.1983 Air chamber new type:
New air chambers are mounted and the counter cylinder is repaired. The water measuring unit is dismounted because it gives too many problems with the dirt in the ditch. The filter in the unit has been blocked many times. At this moment no reading of waterflowmeter.
Reading: 710 m^3.
Stroke: 150 mm.
No pressure height.

13.12.1983 Furling mechanism has broken. The cause is probably too high a force on the connection of the furling mechanism to the side vane by the wind.
Furling stiffened and mounted again.

Old situation:

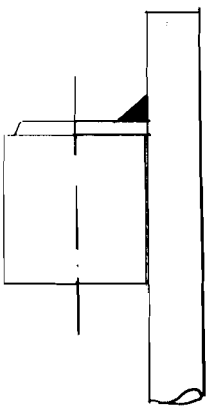


Fig. 10

New situation:

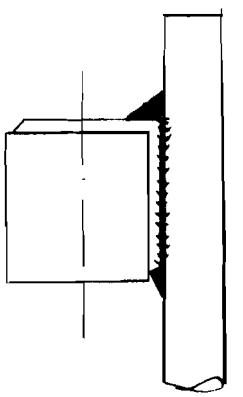


Fig. 11

06.01.1984 The swivel point of the pumprod has broken. The cause is too high a pumprod force.

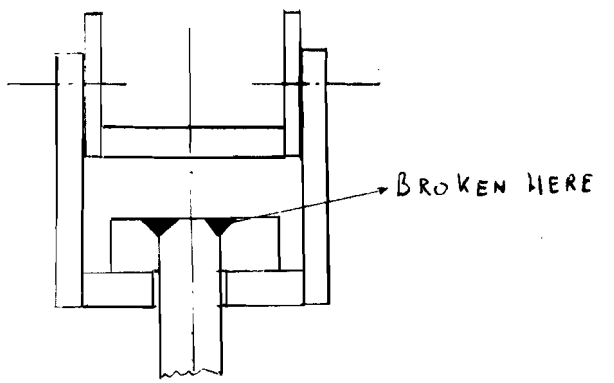


Fig. 12

Swivel point is repaired and mounted again.

Old situation:

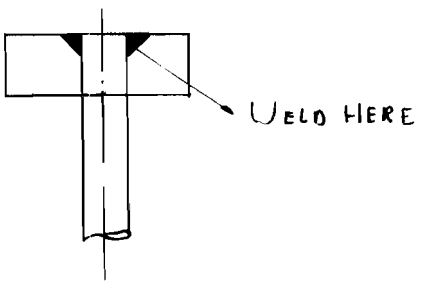


Fig. 13

New situation:

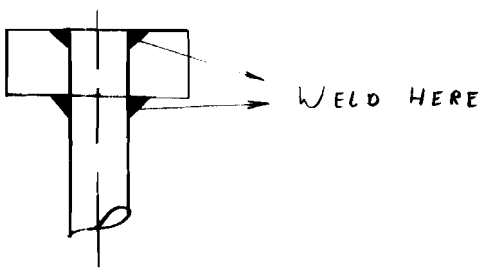


Fig. 14

The cause of the high forces in the pumprod is among others a play of ± 5 mm in the swivel point, so there is a shock load on the pumprod.

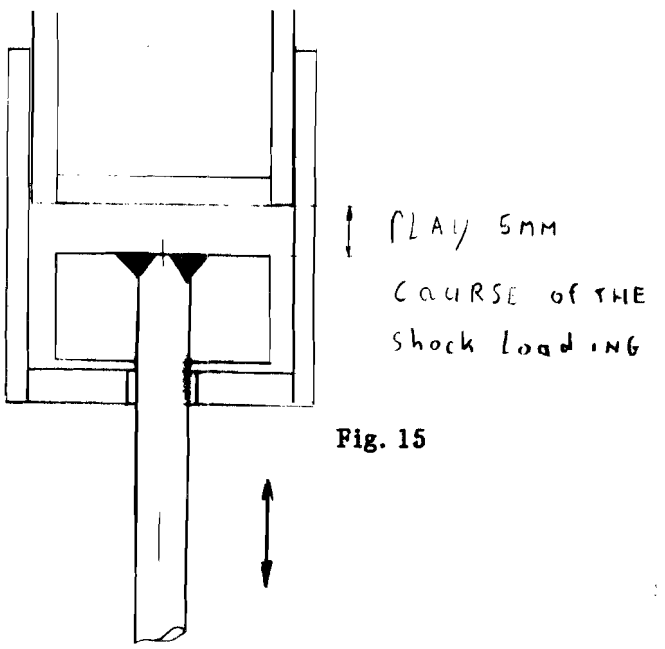


Fig. 15

19.01.1984 During a heavy storm, it appears that the head of the windmill is lifted up by the pumprod ± 5 cm just before it turns out of the wind, which causes high forces on vanes and rotor.

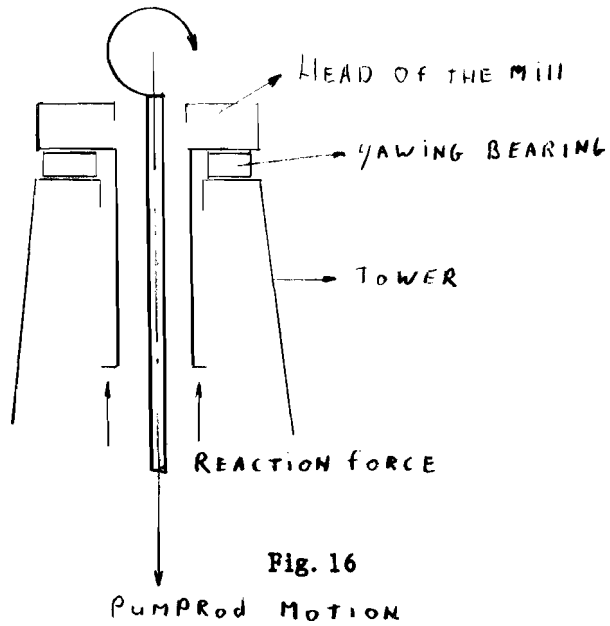


Fig. 16

A large suction filter is mounted at the beginning of the suction line to be sure there are no leaves coming in the pump.

27.01.1984 A pressure vessel is mounted at a height of 6 meter in the tower of the WEU 1-3.
Reading waterflowmeter: 412 m^3.
Stroke maximum: 150 mm.
Pressure height: 6 meter.

03.02.1984 Of the main shaft bearing housing at the back of the head frame the bolts are running loose. The cause is probably soft sparing washers.
The pumprod has broken at the flattened part.

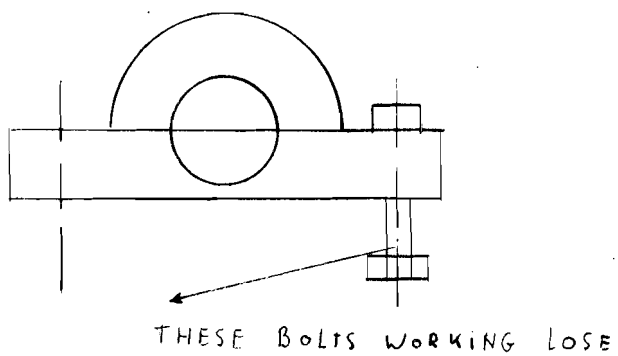


Fig. 17

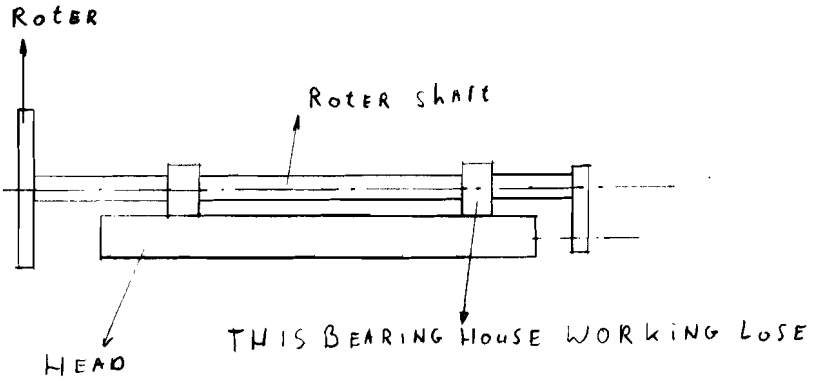


Fig. 18

Reading flowmeter: 630 m^3.
Stroke maximum: 150 mm.
Pressure height: 6 meter.

17.02.1984 A measuring mast is placed on the WEU 1-3 windmill.
Measured are now:
* wind direction
* wind speed
* rotor speed
* yawing speed
* waterflow.

01.03.1984 The pumprod has broken again at the flattened part.

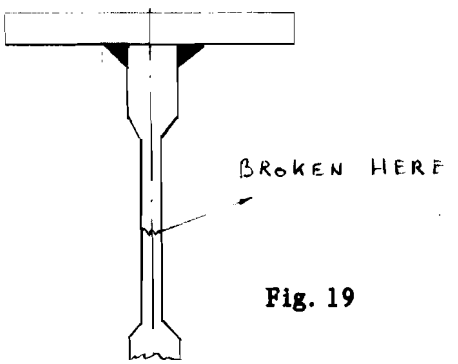


Fig. 19

It is decided to make this part of the pumprod stronger.
The 1" flattened tube is replaced by a ϕ 16 mm rod.

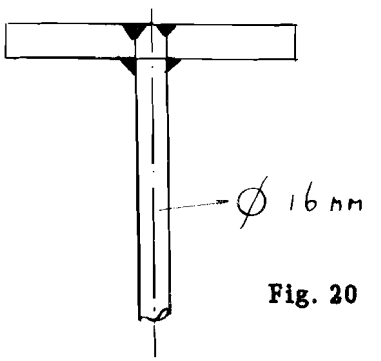


Fig. 20

08.03.1984 The clamp couplings of the pumprod can not take the maximum pump-rod force.
At maximum RPM of the rotor one of the clamp couplings is pulling loose.

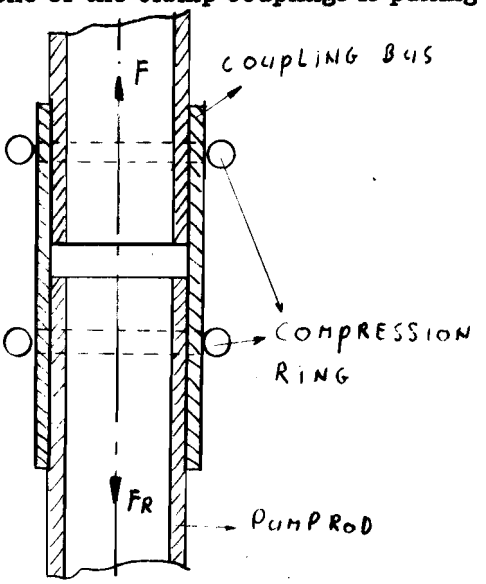


Fig. 21

The pumprod forces are reduced by changing the stroke.
Stroke is now: 75 mm.
Reading flowmeter: 838 m^3.
Pressure height: 6 meter.

29.03.1984 Suction and delivery pipes are replaced by flexible tubes and new fittings, because old ones were clumsy in use.
The wind direction meter has broken. The cause is probably the play of the bottom head pipe bearing. The measuring mast is making a large movement (see drawing).

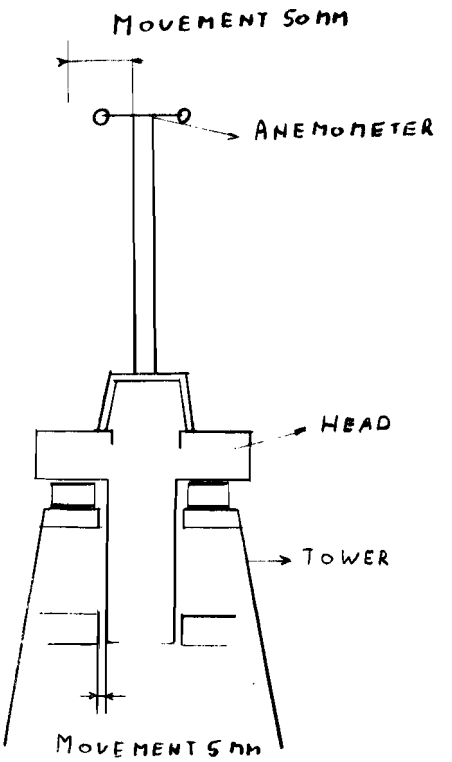


Fig. 22

Waterflowmeter is cleaned and counter mechanism is replaced by a clean counter mechanism.
Reading flowmeter: 2001 m^3.
Stroke: 75 mm.
Pressure height: 6 meter.

26.04.1984 The play in the bottom head pipe bearing is reduced by spacing shims.

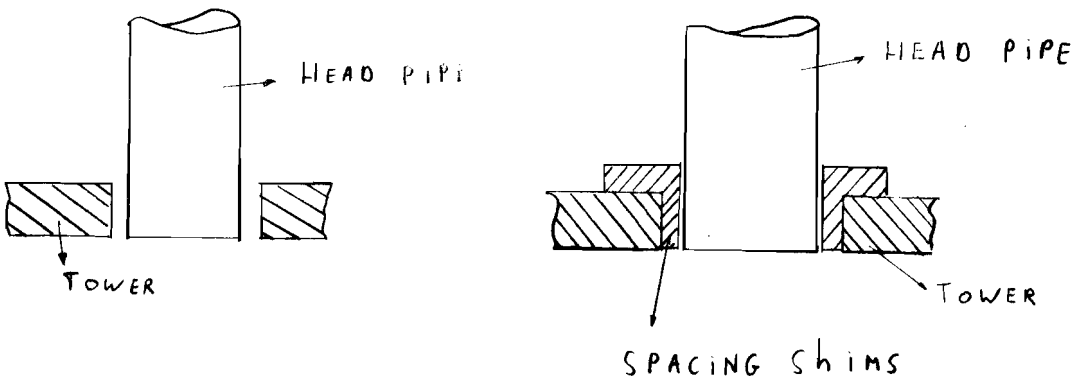


Fig. 23

Some experiments with the puls counter of the flowmeter are performed.
Original:

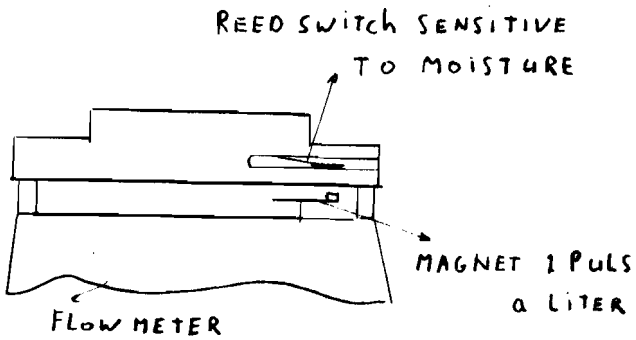
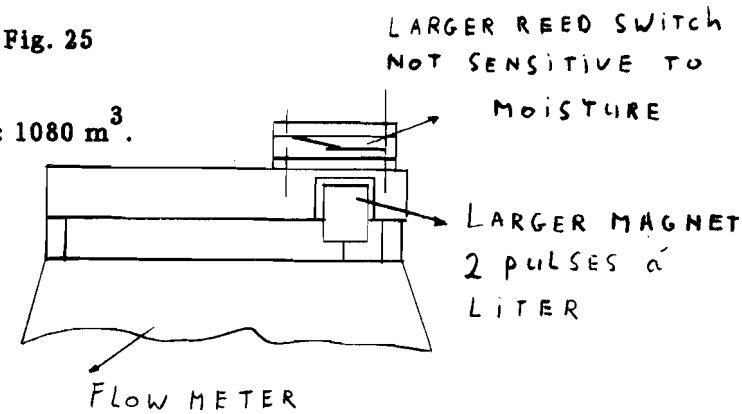


Fig. 24

Experiment:

Fig. 25



Reading waterflowmeter: 1080 m^3.
Stroke: 75 mm.
Pressure height: 6 meter.

14.06.1984 The wind direction meter gives wrong information.
Upon inspection it appears that the wind vane is working loose. The cause probably being the play in the under tower pipe bearing.

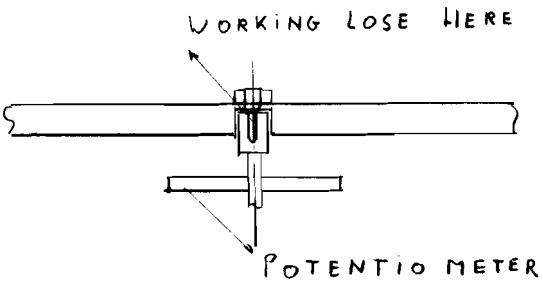


Fig. 26

After mounting everything works o.k..

21.06.1984 The signal cable is broken, probably by a rabbit. After repairs o.k. again.
Reading flowmeter: 1694 m^3.
Stroke: 75 mm.
Pressure height: 6 meter.

12.07.1984 A general inspection reveils that there are hair cracks in the rotor plate.

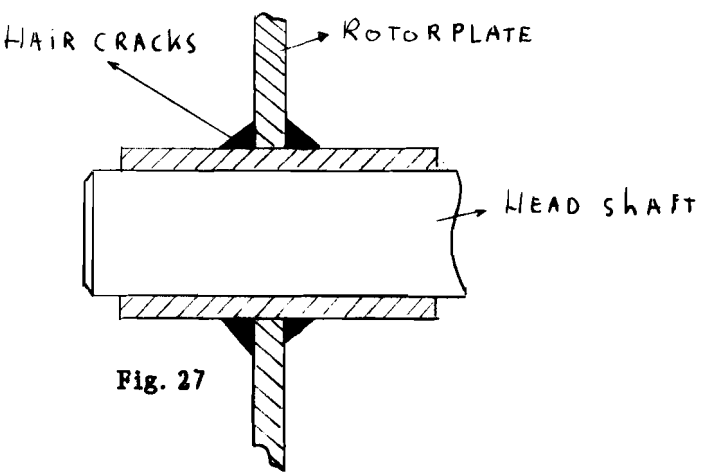


Fig. 27

Stroke: 75 mm.
Pressure height: 6 meter.

19.07.1984 The hair cracks in the rotor plate are the same size as on 12.07.1984.
The water measuring unit is replaced by an other type.

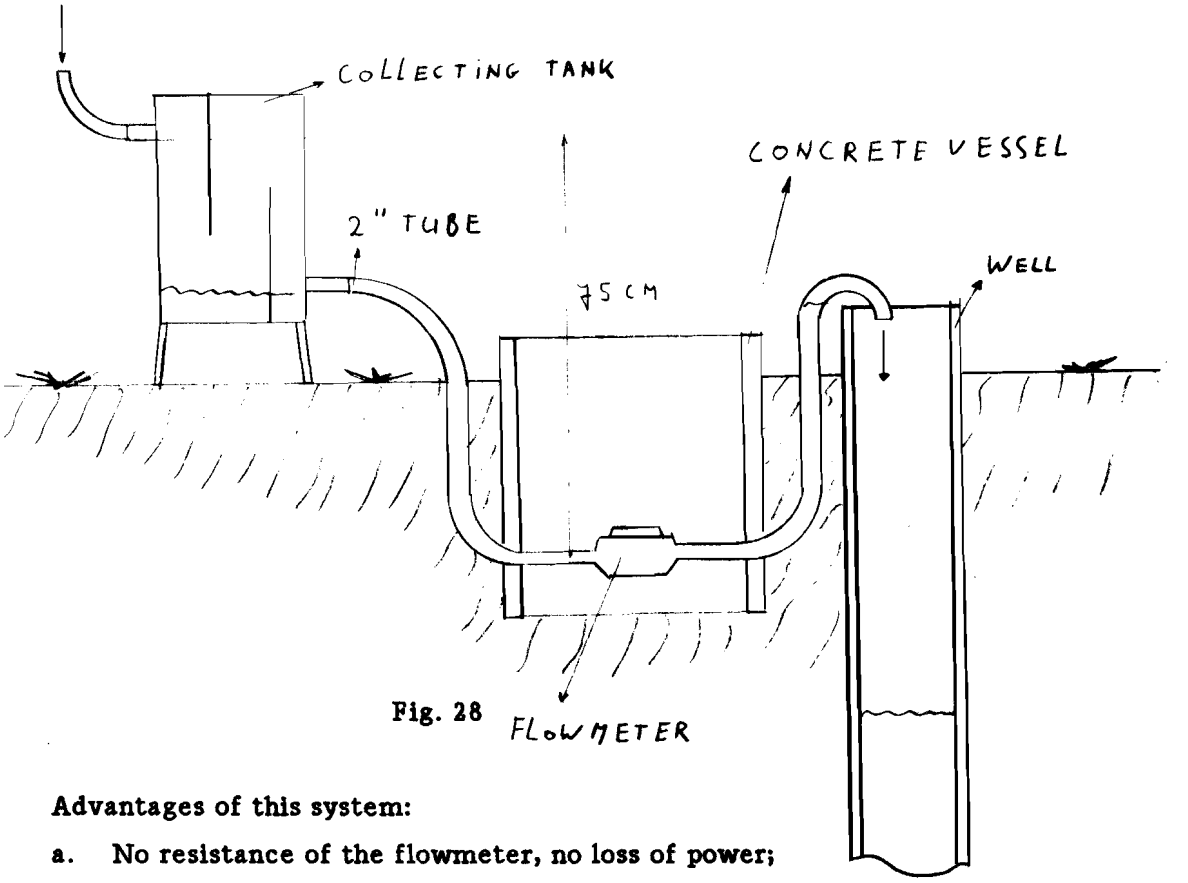


Fig. 28

Advantages of this system:

a. No resistance of the flowmeter, no loss of power;
b. Waterflowmeter protected against frost;
c. Dirt in the water can sink to the bottom of the collecting tank.

16.08.1984 The hair cracks in the rotor plate are the same size as on 12.07.1984.
The wind direction meter is broken again. We decided to mount no new wind direction meter because we have enough measurements.

30.08.1984 The windmill is running unloaded. The ditch is filled with sand and replaced by a water vessel.
The hair cracks in the rotor plate are larger as on 16.08.1984 (about half the diameter) of the rotor plate tube.

06.09.1984 The windmill is connected to the water vessel and is running loaded.
The pump is leaking a little at the counter piston.
The pump is running dry. After priming it works o.k..

13.09.1984 Hair cracks are the same size as on 30.8.1984.
The pump is running dry. The cause is not clear: all the fittings are tight.
The yawing speed counter gives unclear information, probably a broken signal cable.

20.09.1984 The crank pin is broken and the windmill is stopped. Upon inspection it appears that the crank pin plate is 7 ½ mm thick. It should be 10 mm, according to the drawings.

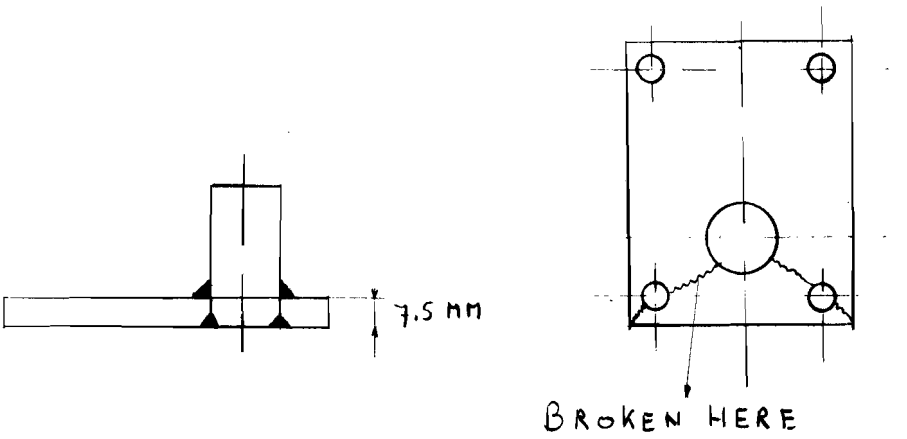


Fig. 29

27.09.1984 Reinforcing ribs are welded to the hub plate.

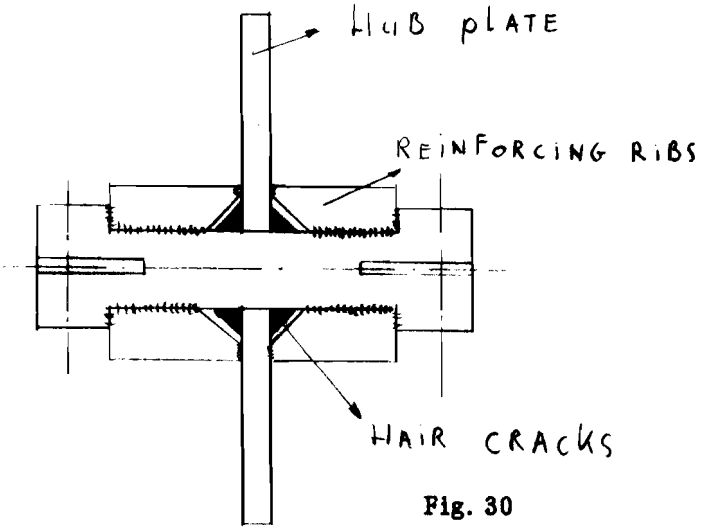


Fig. 30

Windmill is not running because the crank pin is still broken.

04.10.1984 Crank pin repaired and stroke is adjusted to 150 mm. Crank pin has new bearings. The old ones were worn; the cause is not clear.
The windmill has play in the following points:

A. Head pipe bearings ± 6 mm bottom head pipe bearing ± 3 mm top head pipe bearing.

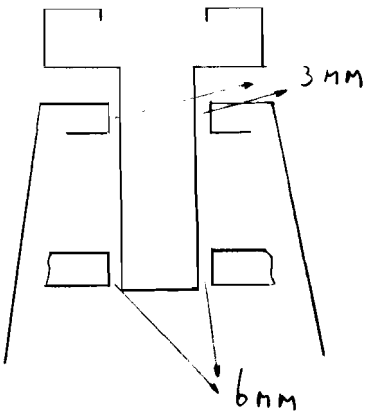


Fig. 31

B. The pumprod guides have ± 3 mm play.

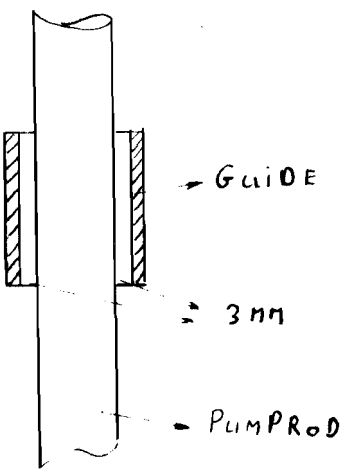


Fig. 32

C. The swing arm hinge has a play of 1 ½ mm.

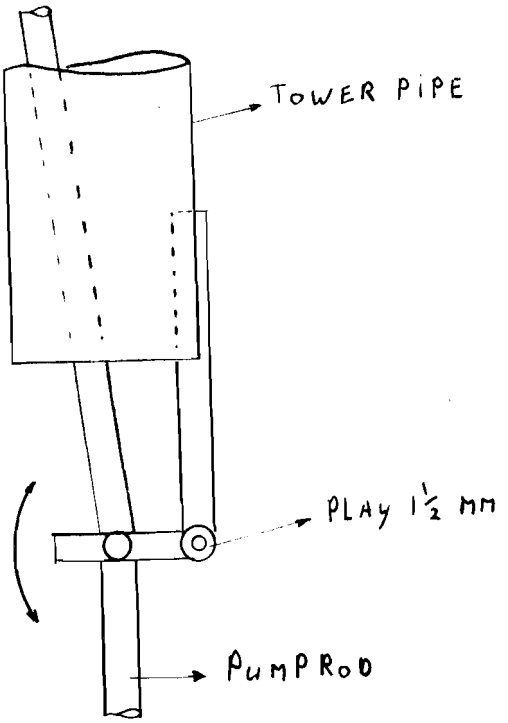


Fig. 33

D. The main vane bearing has a play of a few mm.

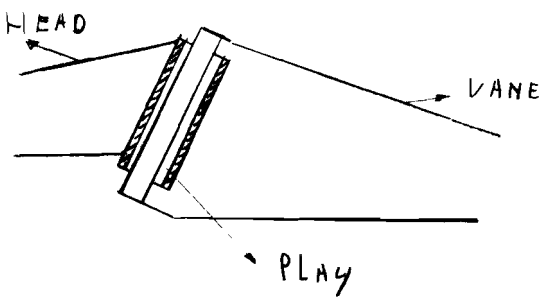


Fig. 34

11.10.1984 The windmill is running dry 2 to 3 times a week. The cause probably being a leaking footvalve.
The yawing speed counter gives no signal and has been demounted.

18.10.1984 The waterflow measuring system has been modified.

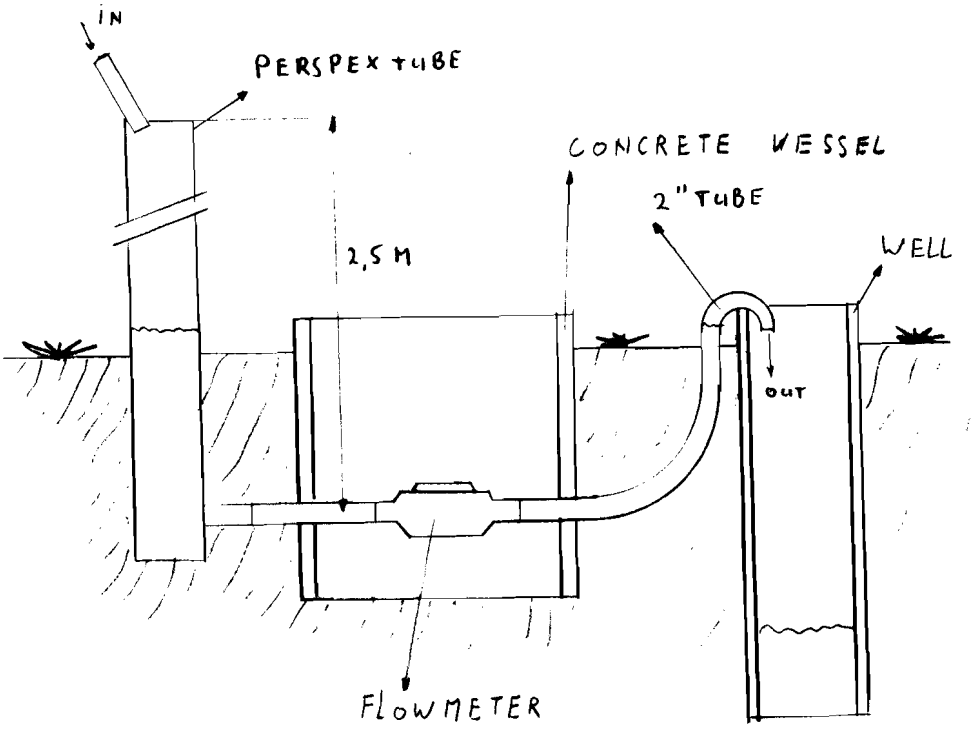


Fig. 35

Advantages of this system:

a. The same as mentioned on 19.07.1984;
b. The pressure drop over the flowmeter is larger (2,5 meter water column against 0,75 meter for the other system) so the reaction time between delivering water from the windmill and measuring the water is shorter (see drawing 19.7.'83):

System 19.07.1984 about 1 - 1 ½ minute;
System 18.10.1984 about 5 - 10 seconds.

08.11.1984 A new signal cable for the yawing speed counter is mounted. It was biten by a rabbit. After mounting a new cable o.k.
We have installed a frost protection.

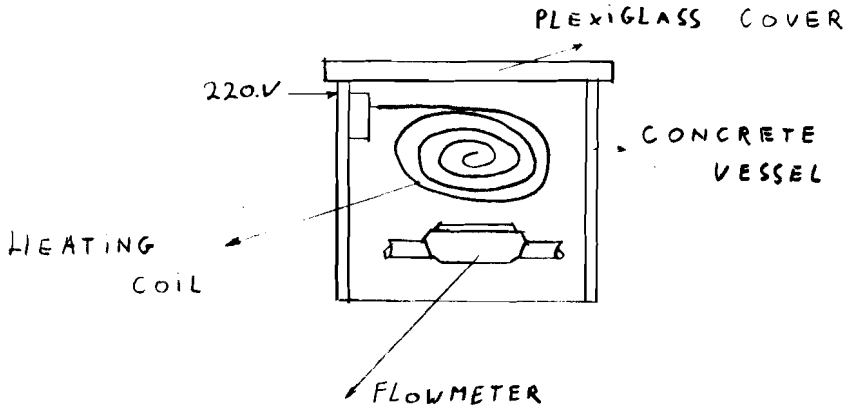


Fig. 36

28.11.1984 After dismounting the pump appears to be the cause of the priming necessity.
The bolt in the footvalve has gone so there is a hole of 9 mm. So the foot valve does not open when the windmill is running.

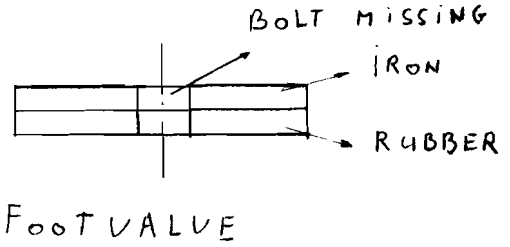


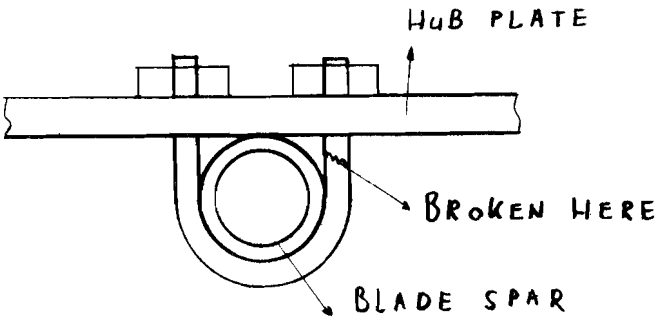
Fig. 37

After repairing and mounting, the pump is working o.k..
Mounted a new wind direction meter.

06.12.1984 Mounted a non-return valve in the delivery hose.
Now it is no more possible for the water to leak back into the water vessel.

20.12.1984 There is a clicking noise when the windmill is running. After inspection of the mill it appears that one of the rotor blades is loose. Bolts are tightened again.
The magnet of the flowmeter is loose; mounted a spare waterflow-meter.

02.01.1985 There is a rotor blade partly broken due to a broken U bolt.
One of the rotor blades is stuck in the tower.



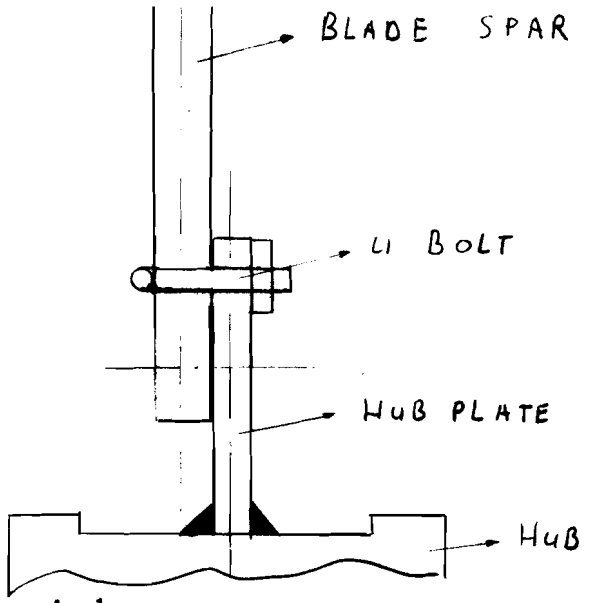


Fig. 38

24.01.1985 Due to severe frost, the rotor is not repaired.
One rotor blade has fallen down and the rotor runs with 5 blades.
The main vane has fallen down due to the unbalance in the rotor.

31.01.1985 From the point of view of safety the other 5 rotor blades are demounted and also the side vane and main vane.

16.05.1985 We decided to dismantle the WEU 1-3 because there are enough measurements.

III A FEW ADDS AND REMARKS

One of the major problems with the WEU1-3 were that many parts have broken during its operation time.
The cause is probably the safety system allowing too high a rotor R.P.M. and yawing speed (see report H. Oldenkamp, February 1985, R-709-D).

One of the other problems are the spring washers, being too weak, so many bolts are running loose when the windmill is running.

A general comment concerning the WEU 1-3 is that many details are not according to specifications (e.g. welds) and also the finish is not up to the required standards.

IV CUMULATIVE MEASUREMENTS

There are no cumulative measurements available of the WEU 1-3 windmill.