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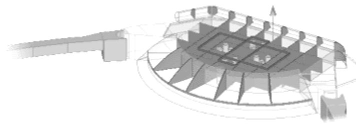

# Hydraulic Response of the Wave Energy Converter Wave Dragon in Nissum Bredning

Project:

*Determination of Hydraulic Response of the Wave Energy Converter Wave Dragon placed in Nissum Bredning*

according to Co-operation agreement between Wave Dragon Aps and Aalborg University, Dept. of Civil Engineering

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December, 2004

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# Hydraulic Response of the Wave Energy Converter Wave Dragon in Nissum Bredning

by

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December, 2004

# Table of contents

# 1. Introduction

This report deals with the hydraulic performance of the Wave Dragon, Nissum Bredning (WD-NB) prototype.

Six reports describing the progress of the work on WD-NB project has been issued by Dept. of Civil eng, Aalborg University. These are:

- Kofoed, J. P.: *Status rapport - Bygning af Wave Dragon, Nissum Bredning*. Hydraulics & Coastal Engineering Laboratory, Aalborg University, May 2003. In Danish. (Title in english: *Status report - Building of the Wave Dragon, Nissum Bredning*.)
- Kofoed, J. P.: *Status rapport - Instrumentering af Wave Dragon, Nissum Bredning*. Hydraulics & Coastal Engineering Laboratory, Aalborg University, May 2003. In Danish. (Title in english: *Status report - Instrumentation of the Wave Dragon, Nissum Bredning*.)
- Kofoed, J. P. and O'Donovan, E.: *Status report - First offshore experiences, Wave Dragon, Nissum bredning*. Hydraulics & Coastal Engineering Laboratory, Aalborg University, September 2003.
- Kofoed, J. P., Frigaard, P., Friis-Madsen, E., and Nimskov, M..: *Automatic Control of Freeboard and Turbine Operation - Wave Dragon, Nissum Bredning*. Hydraulics and Coastal Engineering No. 1, ISSN: 1603-9874, Dep. of Civil Eng., Aalborg University, February 2004.
- Kofoed, J. P., Riemann, S. and Knapp, W.: *Calibration and Validation of Measurement System - Wave Dragon, Nissum Bredning*. Hydraulics and Coastal Engineering No. 2, ISSN: 1603-9874, Dep. of Civil Eng., Aalborg University, March 2004.

Kramer, M. & Kofoed, J. P.: *Placering af trykmåler til bølgemåling - Wave Dragon, Nissum Bredning*. Hydraulics and Coastal Engineering No. 6, ISSN: 1603-9874, August 2004. In Danish. (Title in English: *Placement of pressure transducer for wave measurements - Wave Dragon, Nissum Bredning.*)

The current report aims at providing the latest available information on the hydraulic response of WD-NB up November 2004. This mainly includes:

- Wave measurements.
- Evaluation of turbine performance.
- Evaluation of overtopping rates.
- Forces in moorings.
- Wave induced motions.
- Connections between platform and reflectors.

These items are dealt with in individual chapters in the following.

# 2. Wave measurements

## *Instrumentation*

The task of carrying out continuous wave measurements in a real sea environment is by no means trivial. As already stated in Kofoed et al, 2004b, the cabling from the control room on board WD-NB to the pile where the pressure gauge, responsible for the wave measurements, is situated has been broken on more than one occasion. The cable was replaced with a robust offshore sea cable (supplied by Hydro Cable, Scotland)in the summer 2004. It was then discovered that the pressure gauge it self was malfunctioning and a replacement was put in place. Again, due to not too good experiences with the existing type of instrument, a different component was selected and installed. The new pressure gauge (PSL 4.1.1) is supplied by H. F. Jensen, Denmark.

Furthermore, a numerical study was performed in order to estimate the influence of the presence of the mooring caisson and pile on the wave measurements, and to study if less influence could be obtained by changing the location of the pressure gauge. It was found that less influence could be obtained by moving the pressure gauge further away from the pile (to 1 m horizontally from the center of the pile), but maintaining the level (4.03 m above the seabed). In this case the influence is max. 10 %, and typically less than 5 % in typical conditions. Furthermore, corrections factors to take the presence of the mooring caisson and pile into account into account have been found. See Kramer & Kofoed, 2004.

The new wave measuring equipment was ready ultimo Sept. 2004 and has been acquiring data continuously since then.

Figure 2.1: New pressure gauge on frame prior to installation on mooring pile.

## *Data analysis*

The data selected for this analysis covers the period 01.10.2004 to 24.11.2004. The data is selected from a much larger data material, and has been chosen as continuous data is available from a large number of the deployed instruments and the encountered wave conditions spans the relevant range of wave parameters.

The data is organized in half hour records with data sampled at 10 Hz, i.e. each record consists of 18,000 data samples from the pressure gauge. A total of 2,459 half hour records have been collected and processed from the period considered here. The period consists of a total of 2,582 half hours, i.e. the recorded data covers 95.2 % of the period.

The analyses of the wave data have been performed using the time series analysis tool in the in-house developed WaveLab 2.68 software (http://hydrosoft.civil.aau.dk/wavelab/). The transformation from measured pressures at the gauge placed 4.03 m above the seabed to surface elevations is taken care of by the software, using a density of water of 1,025 kg/m$^3$ and a cut-off of the transfer function when the value gets above 10 (in order to avoid artificial amplification of high frequency noise). A bandpass filter, using the limits 0.333 $f_p$ (peak frequency) and 3 $f_p$, has been applied to the surface elevation time series prior to the further analyses. Both a frequency and time domain analysis have been performed on each data record. In the frequency domain analyses at least 30 FFT sub blocks have been used, also using a taper width and overlap of 20 %.

No corrections have been done to take into account the presence of the mooring caisson. Furthermore, no wave reflection from the WD structure towards the measuring point has been assumed. Both items bias the results towards slight overestimation of the wave heights.

The results of the analyses are given below in figure 2.2 for the frequency domain analyses and 2.3 for the time domain analyses.

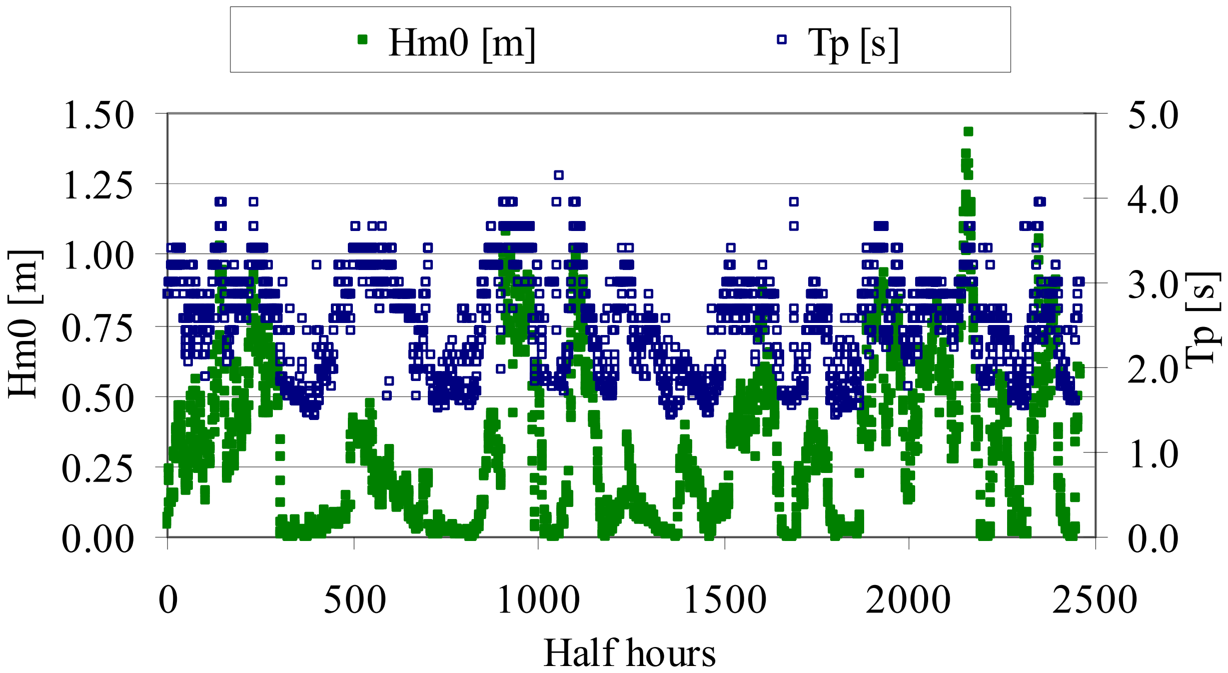



Figure 2.2. Results of the frequency domain analysis in terms of the frequency domain estimate of the significant wave height $H_{m0}$ and the peak period $T_p$.

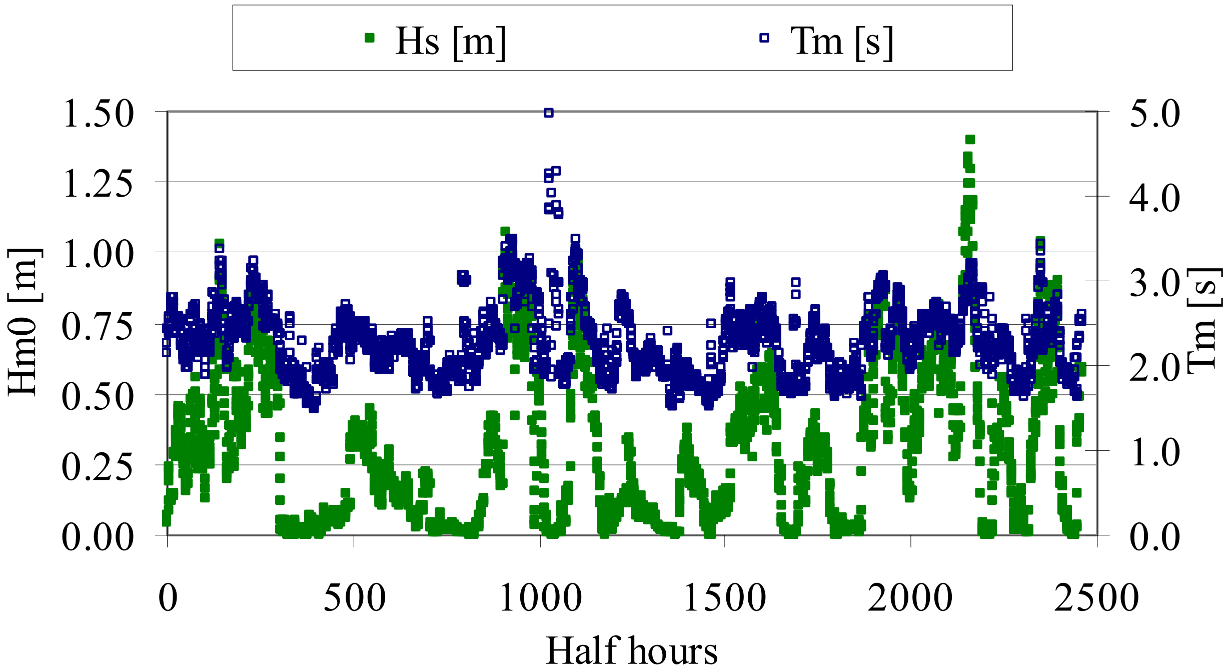



Figure 2.3. Results of the time domain analysis in terms of the significant wave height $H_s$ and the mean period $T_m$.

In table 2.1 and figure 2.4 the wave data is given in the form of scatter table and diagram of the frequency domain parameters.

An analysis comparing the wave data to the North Sea wave conditions defined by Bølgekraftudvalgets Sekretariat, 1999, has been performed. The results here of are given in table 2.2.

From here it is seen that the North Sea conditions in terms of wave heights scaled to Nissum Bredning are covered, but the corresponding wave periods generally are smaller.

Furthermore, the data has been compared to the calculated wave conditions at Helligsø Teglværk, Nissum Bredning, by Kerper and Jacobsen, 1998, see figure 2.4 and 2.5.

From this comparison it is seen that the WD data covers wave conditions exceeding the wave conditions calculated by Kerper and Jacobsen, 1998. One reason for this is that the WD cowers a limited period during one autumn, while the data by Kerper and Jacobsen, 1998, are overall average data. Since autumns generally are more windy than all year round averages it is not surprising the larger wave conditions are overrepresented in the WD data. However, the data by Kerper and Jacobsen, 1998, suggests that at a water depth of 5 m $H_s > 0.9$ m has almost zero probability, while the WD data shows that $H_s > 0.9$ m is almost frequently exceeded (> 3 %). As seen in figure 2.8 the water depths for the WD data are roughly 5 to 6 m.

| Hs \ Tp | 1.1 | 1.3 | 1.5 | 1.7 | 1.9 | 2.1 | 2.3 | 2.5 | 2.7 | 2.9 | 3.1 | 3.3 | 3.5 | 3.7 | 3.9 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **0.05** | 0.0% | 0.0% | 3.3% | 11.1% | 6.6% | 3.6% | 2.4% | 3.3% | 0.8% | 0.7% | 0.7% | 0.3% | 0.1% | 0.1% | 0.1% | **33.2%** |
| **0.15** | 0.0% | 0.0% | 0.0% | 1.6% | 2.2% | 1.4% | 0.6% | 0.8% | 1.4% | 1.7% | 1.5% | 0.8% | 0.4% | 0.0% | 0.0% | **12.4%** |
| **0.25** | 0.0% | 0.0% | 0.0% | 0.1% | 1.3% | 1.1% | 1.6% | 1.3% | 0.4% | 0.9% | 0.5% | 1.0% | 0.7% | 0.0% | 0.0% | **8.8%** |
| **0.35** | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.8% | 1.3% | 3.7% | 1.6% | 1.2% | 0.7% | 1.6% | 1.6% | 0.2% | 0.0% | **12.7%** |
| **0.45** | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.7% | 2.6% | 1.9% | 1.9% | 0.8% | 0.4% | 0.7% | 0.1% | 0.0% | **9.2%** |
| **0.55** | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 1.7% | 2.5% | 1.3% | 1.2% | 0.5% | 0.1% | 0.0% | 0.0% | **7.4%** |
| **0.65** | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.2% | 1.1% | 1.5% | 1.0% | 1.0% | 0.3% | 0.0% | 0.0% | **5.1%** |
| **0.75** | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.1% | 0.2% | 1.3% | 0.7% | 1.8% | 0.5% | 0.0% | **4.7%** |
| **0.85** | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.2% | 0.4% | 0.3% | 0.8% | 1.4% | 0.0% | **3.3%** |
| **0.95** | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.1% | 0.1% | 0.0% | 0.2% | 0.6% | 0.9% | **1.9%** |
| **1.05** | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.1% | 0.1% | 0.1% | 0.0% | 0.4% | 0.0% | **0.7%** |
| **1.15** | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.1% | 0.0% | 0.2% | 0.0% | **0.4%** |
| **1.25** | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | **0.1%** |
| **1.35** | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.2% | 0.0% | 0.0% | **0.2%** |
| **1.45** | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | **0.0%** |
| | **0.0%** | **0.0%** | **3.3%** | **12.8%** | **10.1%** | **7.0%** | **6.7%** | **13.6%** | **9.8%** | **9.8%** | **8.3%** | **6.9%** | **7.0%** | **3.7%** | **1.1%** | |

Table 2.1. Wave data presented as joint probability for given $H_s$ and $T_p$'s.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| North Sea | | | | | | | |
| Hs [m] | <0.5 | 1 | 2 | 3 | 4 | 5 | >5.5 |
| Tp [s] | | 5.6 | 7.0 | 8.4 | 9.8 | 11.0 | |
| Prob. [%] | 15.6 | 47.6 | 21.4 | 9.6 | 4.1 | 1.3 | 0.4 |
| Scaled to WD-NB (1:4.5 lengthscale) | | | | | | | |
| Hs [m] | | 0.22 | 0.44 | 0.67 | 0.89 | 1.11 | |
| Tp [s] | | 2.64 | 3.30 | 3.96 | 4.62 | 5.19 | |
| Measured data, WD-NB, test site 1, Oct. - Nov. 2004 | | | | | | | |
| Tp [s] | | 2.55 | 2.81 | 3.05 | 3.45 | 3.60 | |
| Prob. [%] | 34.9 | 23.7 | 21.5 | 12.2 | 6.3 | 1.1 | 0.3 |

Table 2.2. Comparison of standard wave conditions in Danish sector of the North Sea (Bølgekraftudvalgets Sekretariat, 1999) compared to measurements at WD-NB test site 1.

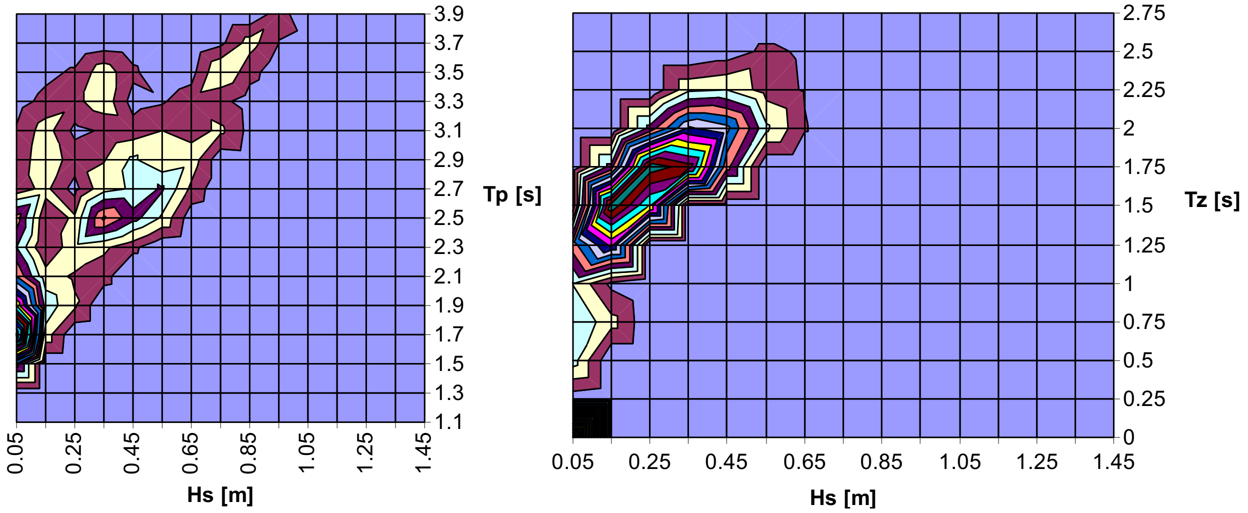



Figure 2.4. Left: Contour plot of the data given in table 2.1. Right: Results of calculation of wave conditions at 5 m water depth at Helligsø Teglværk, Kerper and Jacobsen, 1998 ($T_z$ is the average time domain wave period, typical $T_p/T_z$ ratio is ~1.25 for inner waters like Nissum Bredning).

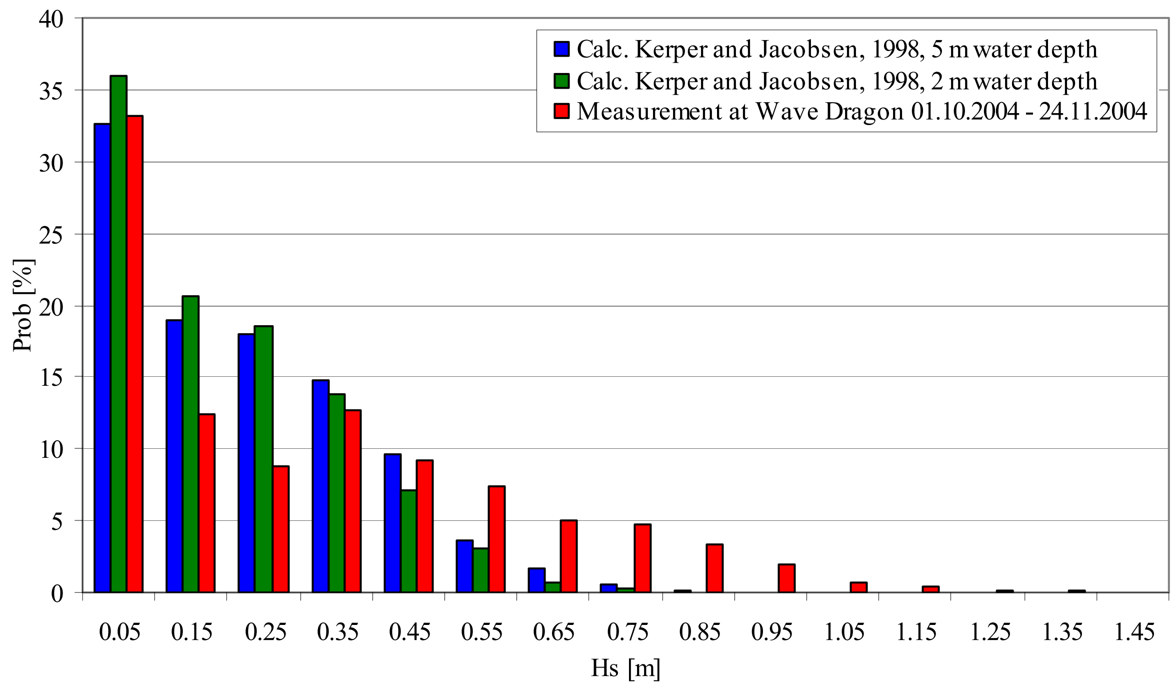



Figure 2.5. The wave height distribution for the wave conditions measured at WD and the calculated wave conditions at 5 and 2 m water depth at Helligsø Teglværk by Kerper and Jacobsen, 1998.

In figure 2.6 and 2.7 examples of measured wave spectra and wave height distributions are given. These shows reasonably shaped spectre and wave height distribution for a significant wave height of 1 m (no signs of significant wave breaking or higher order effects).

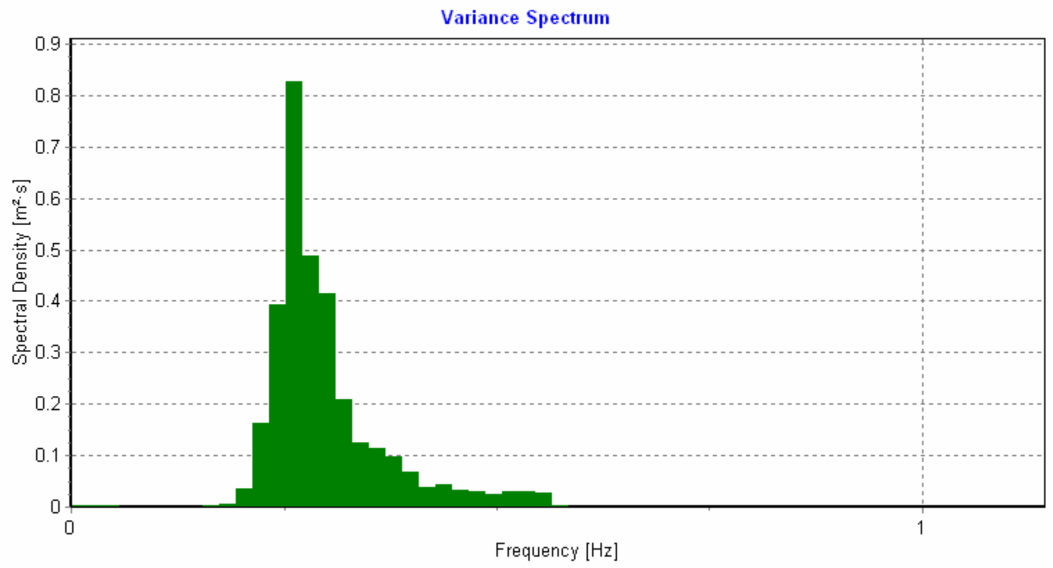



Figure 2.6. Variance spectrum for the measured waves from 25.10.2004 14.18-14.48.
$H_{m0}$ = 1.001 m, $T_p$ = 3.94 s.

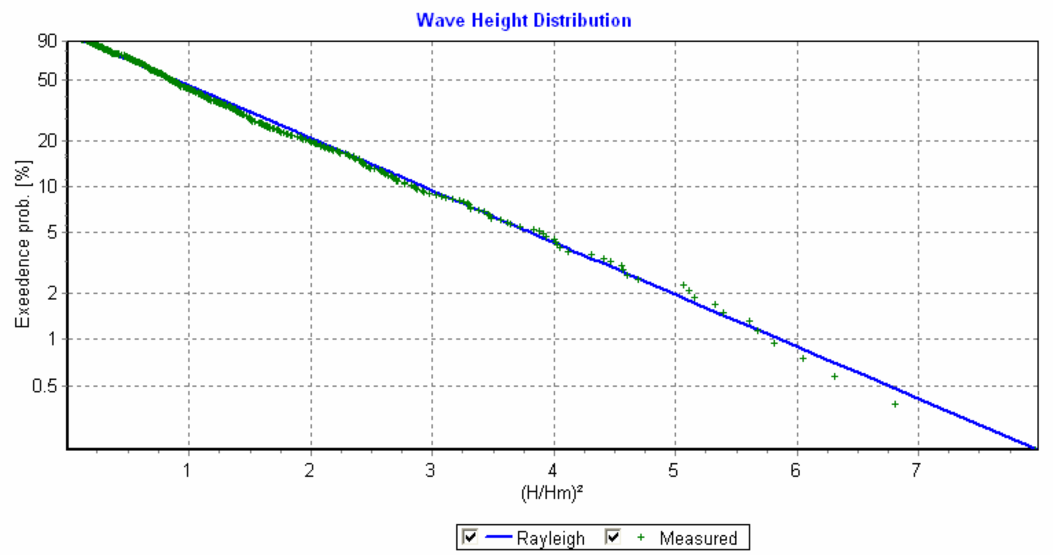



Figure 2.7. Wave height distribution for the measured waves from 25.10.2004 14.18-14.48.
$H_s$ = 0.992 m, $T_m$ = 3.38 s.

Also the water level variations at the location of the mooring pile have been extracted from the wave records as half hour averages of the water elevation signal. These are given in figure 2.8.

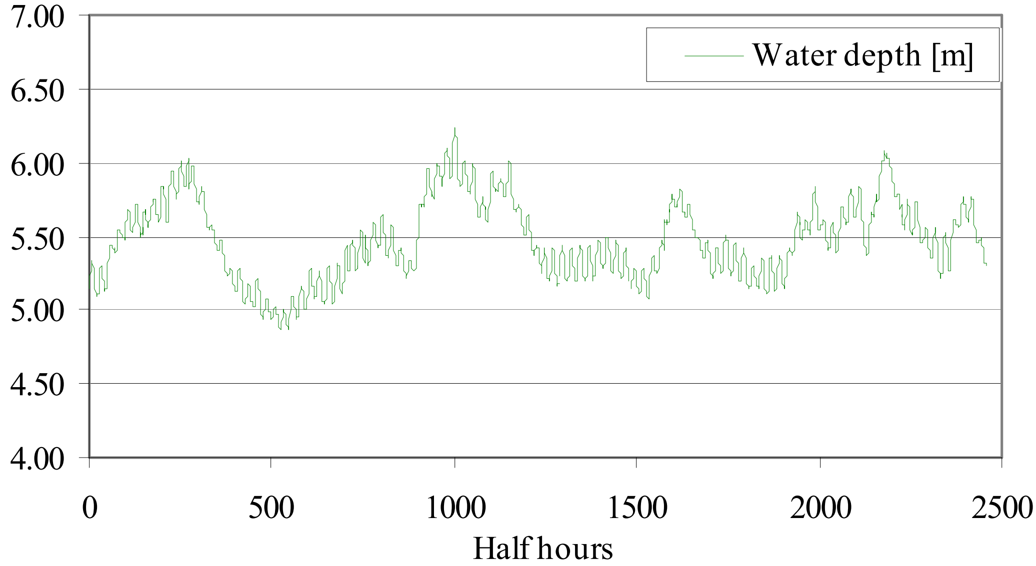



Figure 2.8. Water level variations at the location of the mooring pile during the period 01.10.2004 to 24.11.2004.

From these water level variations it is seen that the tide variation typically is up to 25 cm, while the larger variations (up to a little more than one meter) mainly is due to wind driven setup at the west coast, which enters into Nissum Bredning at Thyborøn.

# 3. Evaluation of turbine performance

Although turbine performance is not naturally a part of this report, it considered of importance to have a look at the subject, as the turbines are used as 'measuring devices' for the overtopping rates.

Before going into the details of the turbine performance a short overview of the evolvement of the turbine status:

The dummy turbines (TURB 8, 9, 10) were installed prior to the launch of WD-NB and have been working more or less since then. There have been, and still occasionally are, problems in opening and closing the turbines, as well as the adjustment of the end switches. The problems are mostly connected to the heavy corrosion of the dummy turbines, but with frequent treatment with grease they are kept running.

The siphon turbine (TURB 1) has also been in place from the beginning and was up and running in spring/summer 2003. However, at that time the automatic control system was not ready for continuous operation, and the turbine was only run when an operator was onboard. During the summer and autumn all attention was put on the structural problems, especially the problems with the fender systems in the connection between the reflectors and the platform, so serious attempts to run the turbine again did not happen until early 2004. At that time corrosion and ingress of salt water in the thrust bearing has made the turbine useless. The partners from TUM refurbished the turbine in May 2004 (see Knapp, 2004) and the turbine has been in an operational state since then. However, it has been experienced lately, that after longer time in standstill it needs a few manually forced turns to start running again. It is therefore important to operate the siphon frequently.

The cylinder gate turbines were installed autumn 2003, but the installation of the generators was not completed until February 2004, mostly due to bad weather conditions. When testing the turbines it was at first found there were problems with the electrical connection. Once this was sorted out it was found that the turbines did not deliver power as expected. Investigations later spring 2004 showed that there were severe problems with bearings in the cylinder gate turbines as well (see Knapp, 2004b). In July 2004 partners from TUM refurbished one of the cylinder gate turbines (TURB 5). In this process the thrust bearing was renovated, among other things (see Knapp, 2004c). This put TURB 5 in operational state. Based on the experiences from these refurbishment projects it was decided to refurbish the remaining 5 cylinder gate turbines. However, because of financial limitations this was split into two projects. It was also decided to discard the original thrust bearing design and install new bearings rather renovating the old ones. Refurbishment of TURB 2 and 4 was carried out in October 2004, and these turbines have been in an operational state since then (a report on this refurbishment is expected from TUM). The refurbishment of the remaining three cylinder gate turbines is currently postponed until the financial part of the problem has been solved.

The above means that real operational turbine data primarily exists in the period from last part of October 2004 to present (ultimo November 2004).

## *Power production*

When looking at power production focus has been on a shorter period in time, in order to limit the data handling. During this period the turbines 1, 2, 4 and 5 plus dummies, were in operation. However, no data giving the operation of the dummies are currently available on the MGC+ (status signals are planned to be made available from the PLC to the MGC+ via the CAN-bus), so whatever goes though these are at first neglected. The half hour average power produced during the period (see figure 3.1) has been obtain using six different procedures:

- NETPOWER – The power put onto the grid as reported from the West Control unit (averaged over half hour periods).
- POWERSUM – The sum of the power produced by the individual turbines (averaged over half hours periods).

- POWRSUM – The sum of power the individual turbines would have produced if they were following the characteristics given by project partner Veteran Kraft AB (VKAB), see table 3.1, based on the revolutions per minute ($n$ [RPM]) reported by the West Control unit (expression relating power ($P$ [W]) to n: $P = 0.0000183 \cdot n^{3.022}$ [W], by curvefitting to table 3.1).
- POWHSUM – The sum of power the individual turbines would have produced if they were running at the optimal $n$ at the given head, following the characteristics given in table 3.1, based on the turbine head ($h$ [m]) as calculated by the PLC (function of pressures in reservoir and under platform, and heel) (expression relating power to head: $P = 1000 \cdot (1.1457 \cdot h^2 + 1.6072 \cdot h - 0.1455)$). The fact that a change in the turbine speed $n$ will also change the flow rate $q$, and thereby also how often the turbines are running, is not considered. As the realized turbine speed typically is slightly lower than the optimal, POWHSUM will be slightly overestimating the power.
- HYDRTPOW - The power corresponding to the sum of the flow though the turbines and a turbine head as calculated by the PLC
- HYDRPOW – The power corresponding to the sum of the flow though the turbines and a head equal to the floating level as calculated by the PLC.

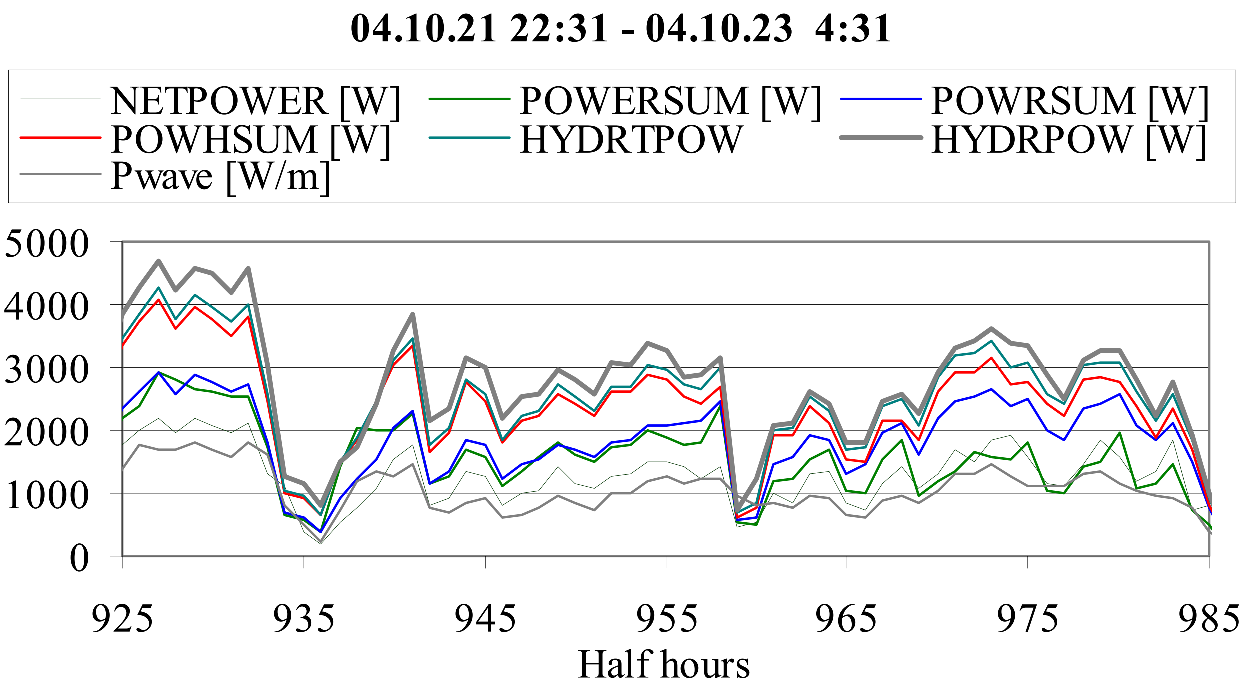



Figure 3.1. Power produced on board calculated in various manners.

Wave Dragon at Nissum Breding WAVDRNI1.wq1 STHLM 02-03-06

Speed-regulated on/off turbines: D = 0.34 m, Hn.max = 1. m
Working point: 4-bladed VKAB-runner, alfa=30 and gamma=18.5 deg.
3-bladed TUM-runner, alfa=28 and gamma=23.8 deg.
n11 = 170, Q11 = 2.75, Re-u-mod. = 5.2E6, Eta-mod = 89 %, t=10 grad C.

Model test at TU München: H=const.=3 m, D=0.34 m, t≈20 grad C
Eta-elect. = 100 %.

Hn = Tot.head at guide vane inlet - Tot.head at draft tube outlet,
for which the used model test data is valid.
H-gross=Hg = Level in storage basin - Average water surface level

| Hn m | n rpm | Q m3/s | Re-u*E-6 | d-Eta %-unit | Eta-tur % | in/out-loss m | Eta-Hg % | P-out kW |
|---|---|---|---|---|---|---|---|---|
| 1.600 | 632.5 | 0.40 | 2.9 | -1.1 | 87.9 | 0.061 | 84.6 | 5.336 |
| 1.450 | 602.1 | 0.38 | 2.8 | -1.2 | 87.8 | 0.055 | 84.5 | 4.599 |
| 1.300 | 570.1 | 0.36 | 2.7 | -1.3 | 87.7 | 0.049 | 84.4 | 3.899 |
| 1.150 | 536.2 | 0.34 | 2.5 | -1.4 | 87.6 | 0.044 | 84.3 | 3.240 |
| 1.000 | 500.0 | 0.32 | 2.3 | -1.5 | 87.5 | 0.038 | 84.2 | 2.623 |
| 0.875 | 467.7 | 0.30 | 2.2 | -1.6 | 87.4 | 0.033 | 84.0 | 2.144 |
| 0.750 | 433.0 | 0.28 | 2.0 | -1.8 | 87.2 | 0.028 | 83.9 | 1.698 |
| 0.675 | 410.8 | 0.26 | 1.9 | -1.9 | 87.1 | 0.026 | 83.8 | 1.448 |
| 0.500 | 353.6 | 0.22 | 1.6 | -2.2 | 86.8 | 0.019 | 83.5 | 0.920 |
| 0.375 | 306.2 | 0.19 | 1.4 | -2.5 | 86.5 | 0.014 | 83.2 | 0.596 |
| 0.250 | 250.0 | 0.16 | 1.2 | -2.9 | 86.1 | 0.009 | 82.8 | 0.323 |
| 0.200 | 223.6 | 0.14 | 1.0 | -3.2 | 85.8 | 0.008 | 82.6 | 0.230 |
| 0.150 | 193.6 | 0.12 | 0.9 | -3.5 | 85.5 | 0.006 | 82.2 | 0.149 |

Table 3.1. Turbine characteristics for turbines onboard WD-NB as provided by VKAB.

### *Efficiencies*

The corresponding efficiencies, based on the wave energy that passes between the reflector tips (width assumed to be 54 m) are given in figure 3.2.

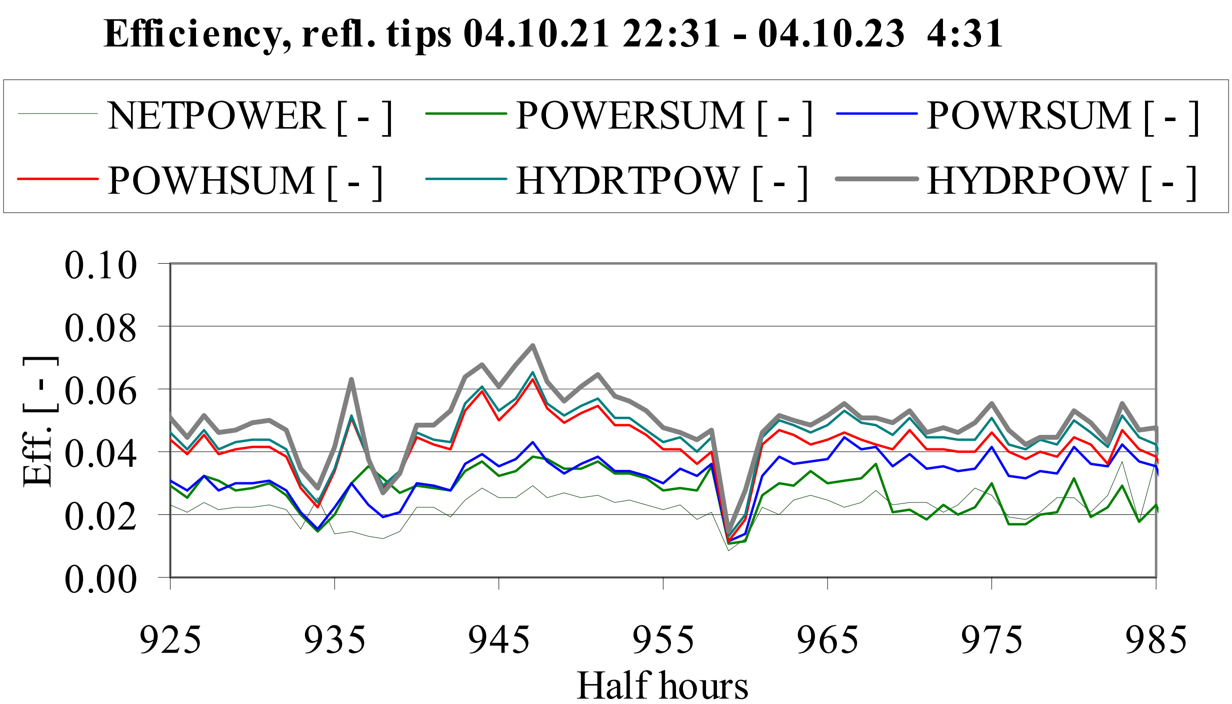



Figure 3.2. Efficiencies corresponding to the produced power given in figure 3.1.

### *Losses*

The losses in the different steps in the power take off (PTO) has been calculated and shown in figure 3.3 for a selected range in the analyzed period.

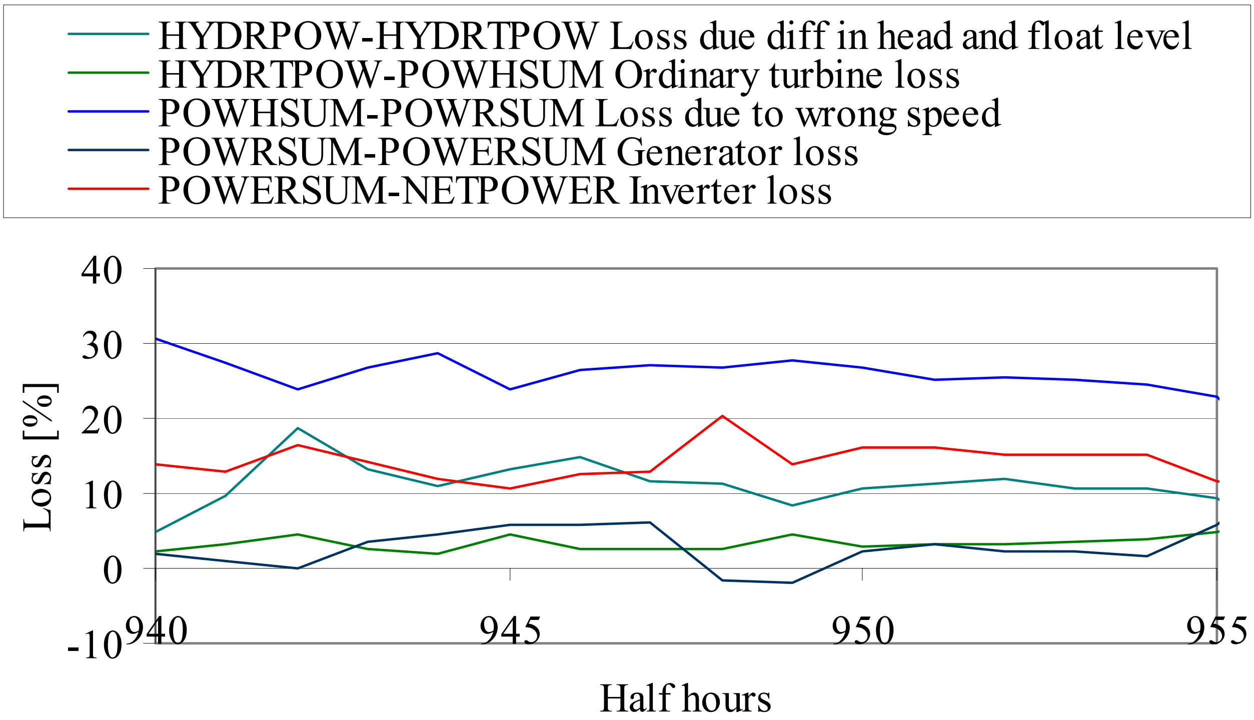



Figure 3.3. The various losses (in % of HYDRPOW) for a selected range of the analyzed period.

The average of the various losses (in % of HYDRPOW) in the selected range is given below:

- Loss due to difference in turbine head and floating level ((HYDRPOW-HYDRTPOW)/HYDRPOW): 11.4 %
- Ordinary turbine loss ((HYDRTPOW-POWHSUM)/HYDRPOW): 3.3 %
- Loss due to wrong speed ((POWHSUM-POWRSUM)/HYDRPOW): 26.2 %
- Generator loss((POWRSUM-POWERSUM)/HYDRPOW): 2.6 %
- Inverter loss ((POWERSUM-NETPOWER)/HYDRPOW): 14.3 %
- Total loss from HYDRPOW to NETPOWER: 57.8 %

It is seen that the losses due to the wrong speed of the turbines are the most severe ones, although figure 26.2 %, might be a little too high (for the above mentioned reason). This needs to be taken care of by modifications in the operation of the West Control unit. The ordinary turbine and generator losses seem to be too low – turbine losses around 10 %, and generator losses maybe down to 5 % at best, were anticipated. However, the given values are average values in a more or less arbitrarily selected range, so they should only be taken as rough estimates.

In figure 3.4 the half hour average values of the floating level (FLOATL), turbine head (TURBHEAD) and significant wave height ($H_{m0}$), as well as the ratio FLOATL/ $H_{m0}$, are given for the analyzed period.

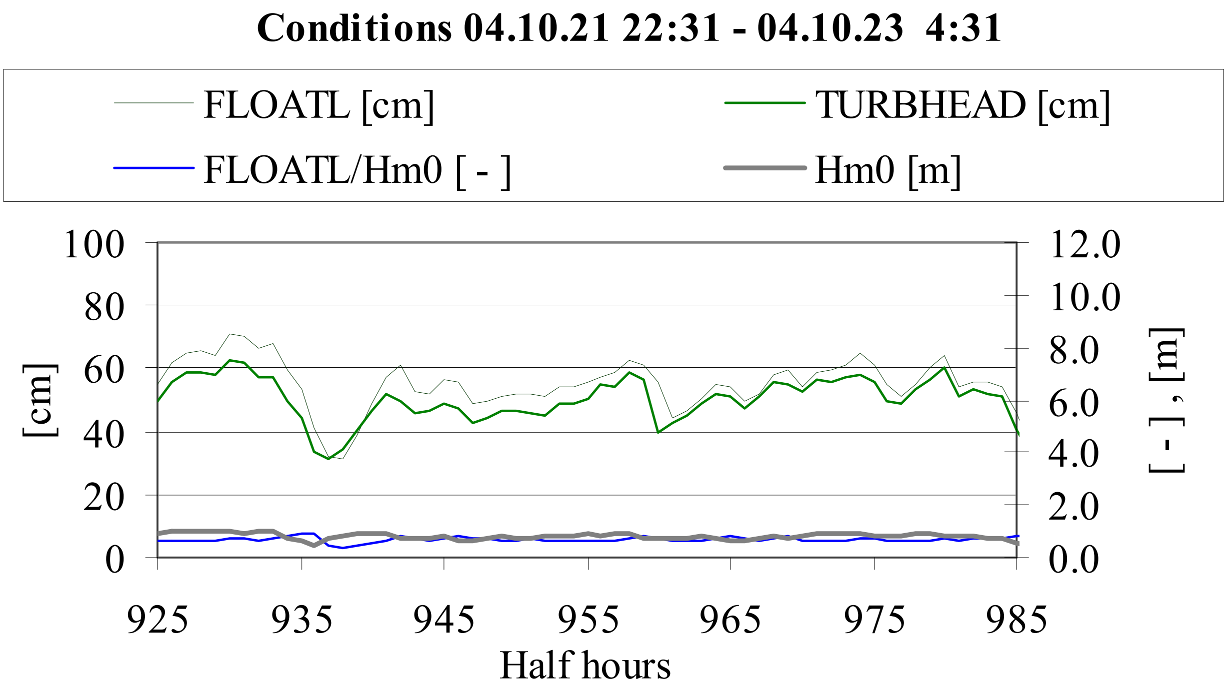
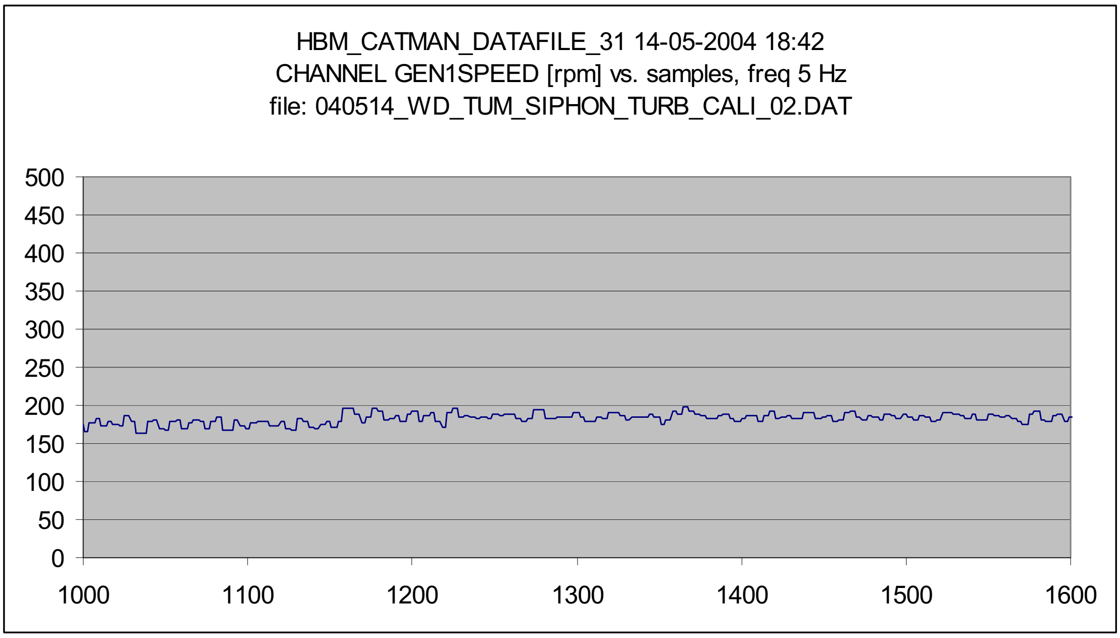



Figure 3.3. Important factors for the power production.

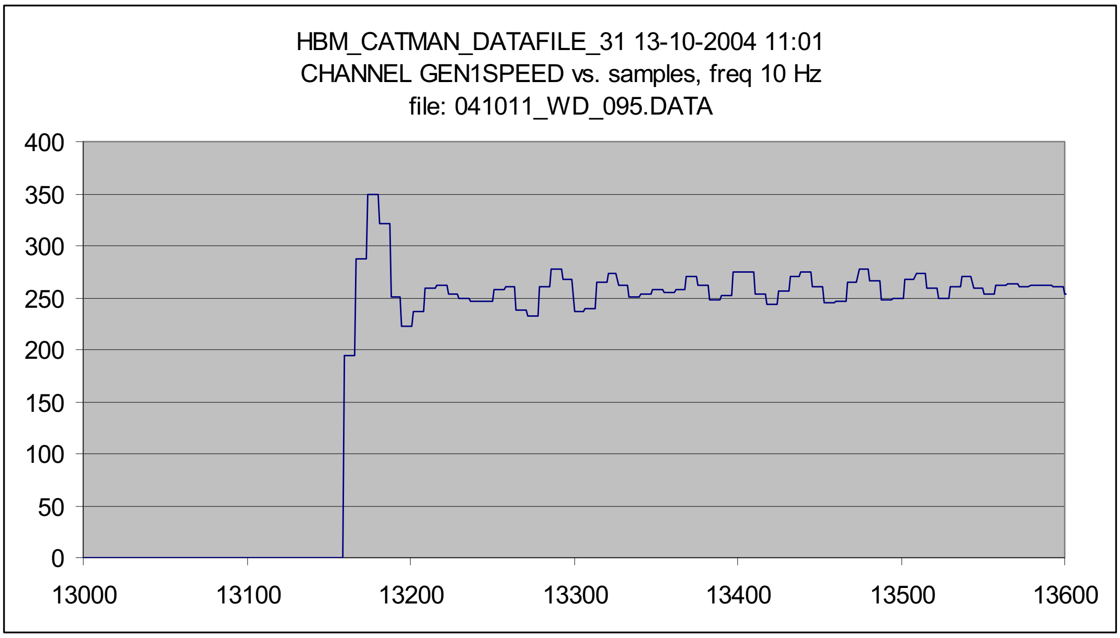
### *Oscillations in turbine speed*

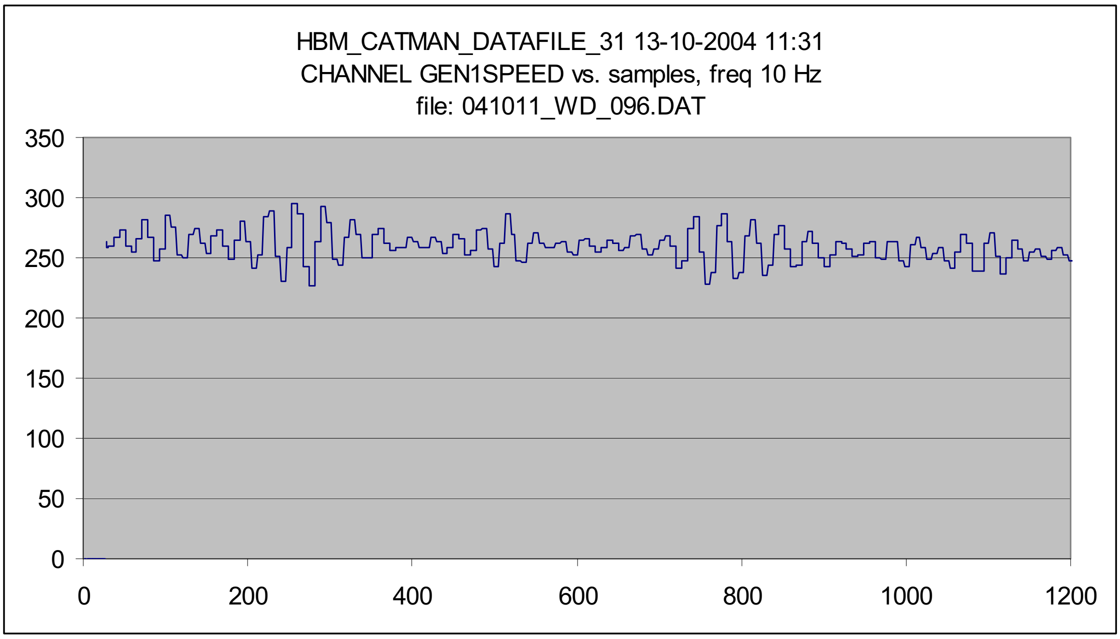
During the operation of the turbines after the refurbishments considerable oscillations in the turbines speeds has been seen. Below there are three figures with plots of turbine speed and pictures from the day.




webcam3_20040514s172411835.jpg webcam2_20040514173211000.jpg

Figure 3.4. Turbine calibration by TUM after restoration of TURB 1.

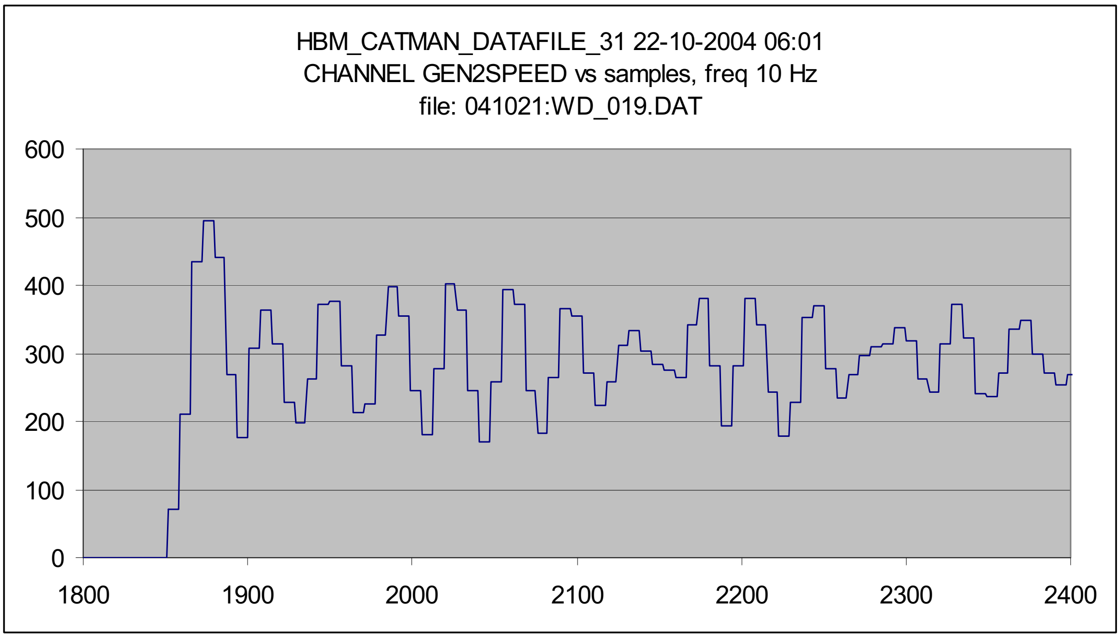


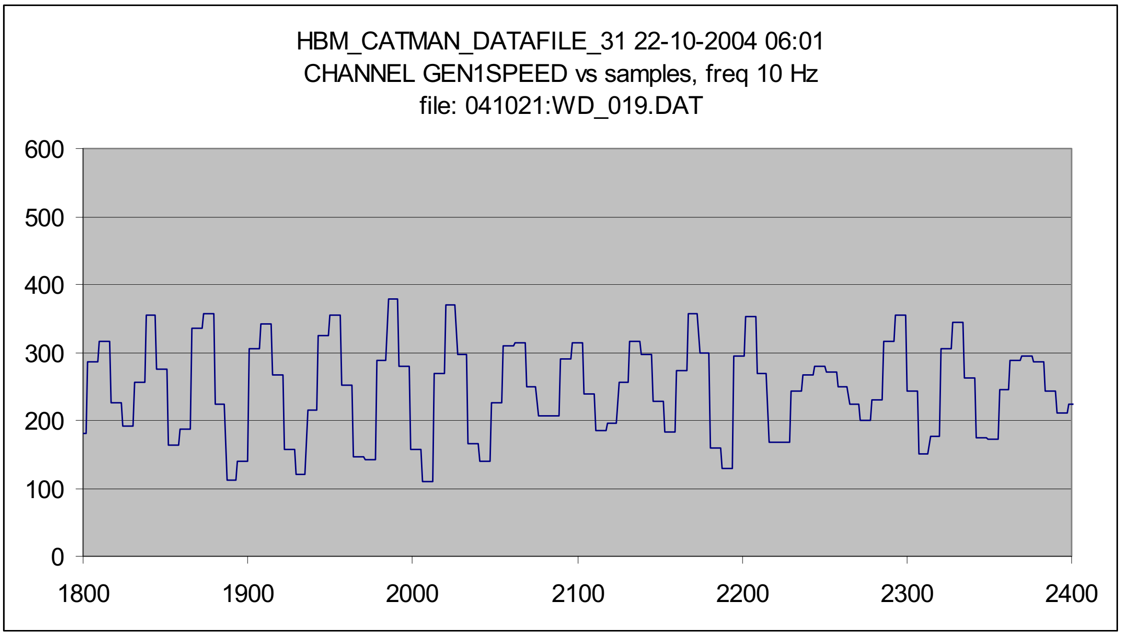




webcam3_20041013s110010757.jpg

webcam2_20041013120005500.jpg

Figure 3.5. Turbine testing by TUM after restoration of TURB 2 and 4.




webcam3_20041022s090010593.jpg webcam2_20041022080005812.jpg

Figure 3.6. Turbines running in good wave and power production conditions.

The change in the turbine speed oscillations are pronounced from figure 3.4 to 3.5 and 3.6. The period of the oscillations are not far from the wave periods, for what reason it seems fair to say that the oscillations are tricked by the changing turbine head due to waves propagating under the platform. West Control was at WD-NB in July 2004 to change some burned IGBT's (transistors) and at this time the EEPROMS containing the West Control programming of the inverters was also replaced. A change in the programming might be responsible for the increased sensitivity to oscillations in the turbine head. This item is currently being investigated.

# 4. Evaluation of overtopping rates

Based on the calculated flow through the turbines non-dimensional overtopping rate (Q*) has been calculated as a function of the non-dimensional crest freeboard (R*), here the floating level has been used as freeboard, neglecting any heel or trim. The data is compared to the overtopping expression below by Hald & Frigaard, 2001 based on 1:50 scale model tests.

$Q^* = 0.025 \exp(-40 R^*)$ where

$$Q^* = \frac{q\sqrt{s_{op}/2\pi}}{\sqrt{gH_s^3}L}$$

$$R^* = \frac{R_c}{H_s}\sqrt{\frac{s_{op}}{2\pi}}$$

$q$ = discharge due overtopping
$H_s$ = significant wave height
$T_p$ = Peak period
$L$ = ramp width
$R_c$ = Crest freeboard relative to MWL
$s_{op}$ = wave steepness, $s_{op} = H_s / L_{op}$
$L_{op}$ = deep water wave length, $L_{op} = \frac{g}{2\pi} T_p^2$

The results are shown in figure 4.1. From this figure it is clearly seen that, in opposition to previous findings, the overtopping rates falls significantly below the lab. results and the previous measurements on WD-NB. There can be a number of reasons for this:

- Dummies are not included in the overtopping rates in the new data. From graphs on the SCADA system (see figure 4.2 for the period corresponding to the power data given in figure 3.1, figure 4.3 the half hour period corresponding to the first data point in figure 3.1 and the red dots in figure 4.1) it can bee seen that there are quite frequent dummy turbine activity, and therefore significant amounts of water is 'lost' through these. For a single point, corresponding to the half hour shown in figure 4.3, the flow through the dummies are estimated to be 50 % of what goes through the other turbines (in average during the period).
- Spilling. From figure 4.2 - 4.3 it is also seen that the reservoir level is frequently above 100 %, ie. spilling occurs. Rough quantification of the spilling might be possible by calculation of the water level along the edges of the reservoir, comparing it to the crest height around along the edges, and then using an expression for the flow over an edge.
- Leaks. Earlier a leakage of up to 44 l/s has been seen, but this was primarily due to problems with the closing of the cylinder gates and recent observations shows fall of reservoir level of 6 – 10 cm an hour when no overtopping occurs, which corresponds to a leakage of 2.7 – 4.4 l/s (corresponding to 20 – 30 W at high floating level).
- Turbine calibration. In the calculations the original turbine characteristics have been used, as no other data is currently available. It is expected that TUM will provide updated turbine characteristics for the real turbines as well as the dummies. In the previous data set the characteristics from the first calibration tests of the dummies where used. These calibrations has later been questioned, as a later drain test showed as much as 30 % lower discharge, probably due to marine growth in the draft tubes.
- Bias in estimation of wave conditions. As mentioned in chapter 2 the presence of the mooring caisson and reflections from the WD structure towards the wave measuring point is not taken into account in the wave analyses. This will tend to result in slight overestimation of wave height, i.e. biasing the overtopping data points to fall below the prediction line.

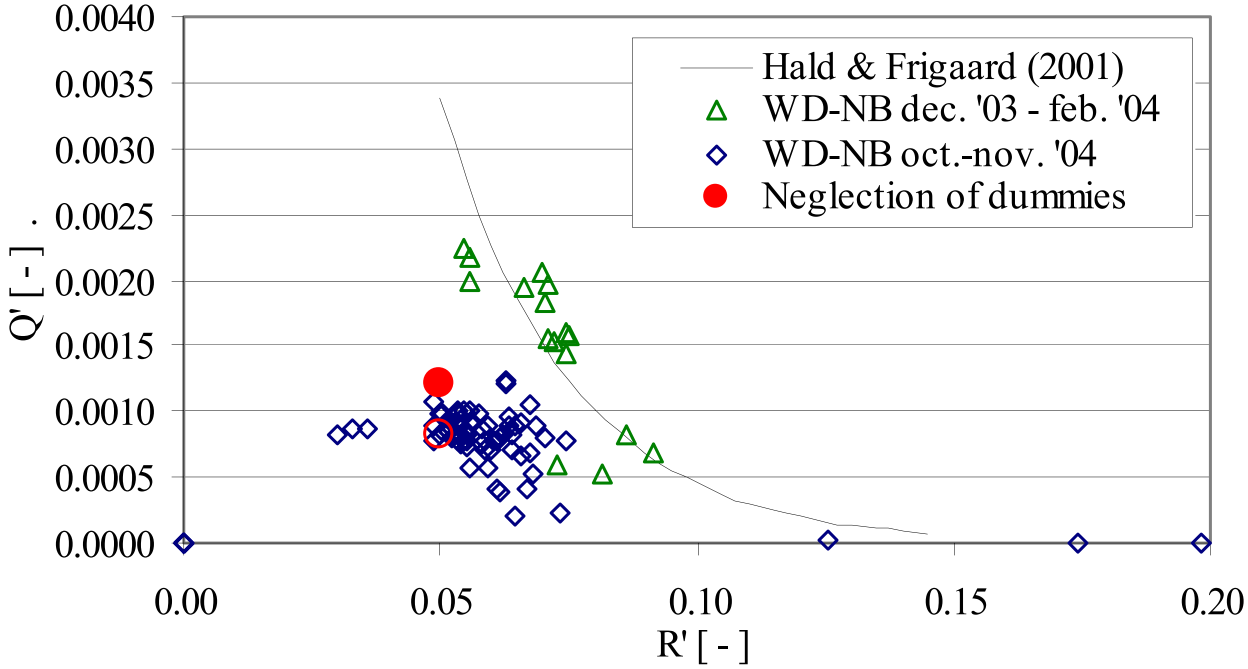



Figure 4.1. Non-dimensional overtopping rate as a function of the non-dimensional crest freeboard compared to lab. results and previous measurements at WD-NB. The effect of neglecting the dummy turbines exemplified in a single point based on observations in the SCADA system (all three dummies open 20 % of the time).

- Directionality of the waves. WD is able to align it self up against the waves as long as the wave direction is roughly +/- 60° from the middle position. Also the forcing from wind and current plays a role in the positioning of WD, and these are not always in line with the waves. Thus, although WD most of the time is facing towards the waves, this is not always the case and this then decrease the overtopping rate.
- Floating level used at crest freeboard. A different results might be achieved if the calculation was performed using the average position of the ramp, including heel, rather than the floating level, as the freeboard.
- The inclinometers measuring heel and trim have showed some drifting, which influences the position of the ramp and thereby the overtopping rate and the eventual spill back over the ramp.
- Uncertainty on floating level measurements. Some drifting in the measured pressures, used for the calculation of the floating level has been observed.

Furthermore, the overtopping process is highly non-linear and using an average over half an hour is therefore quite rough, taking into consideration the rather large motions, in especially heel, that typically occurs during such a half hour.

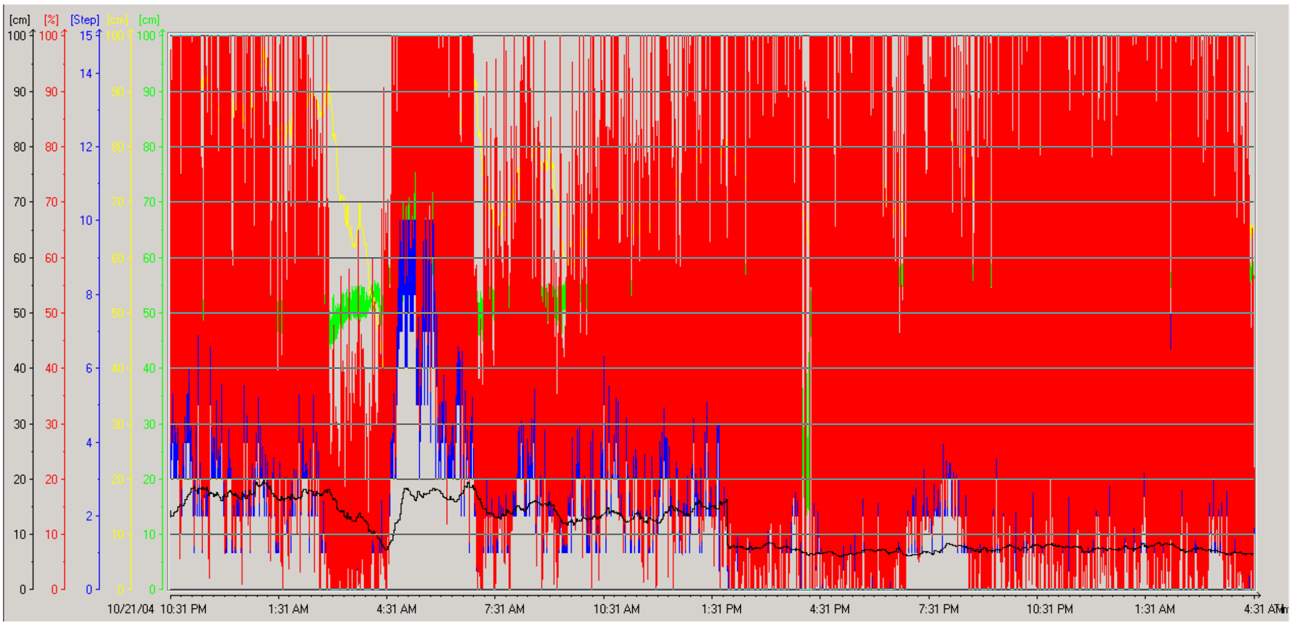



Figure 4.2. Screen dump from SCADA, graph 2, during the 30 hours period shown in figure 4.1.

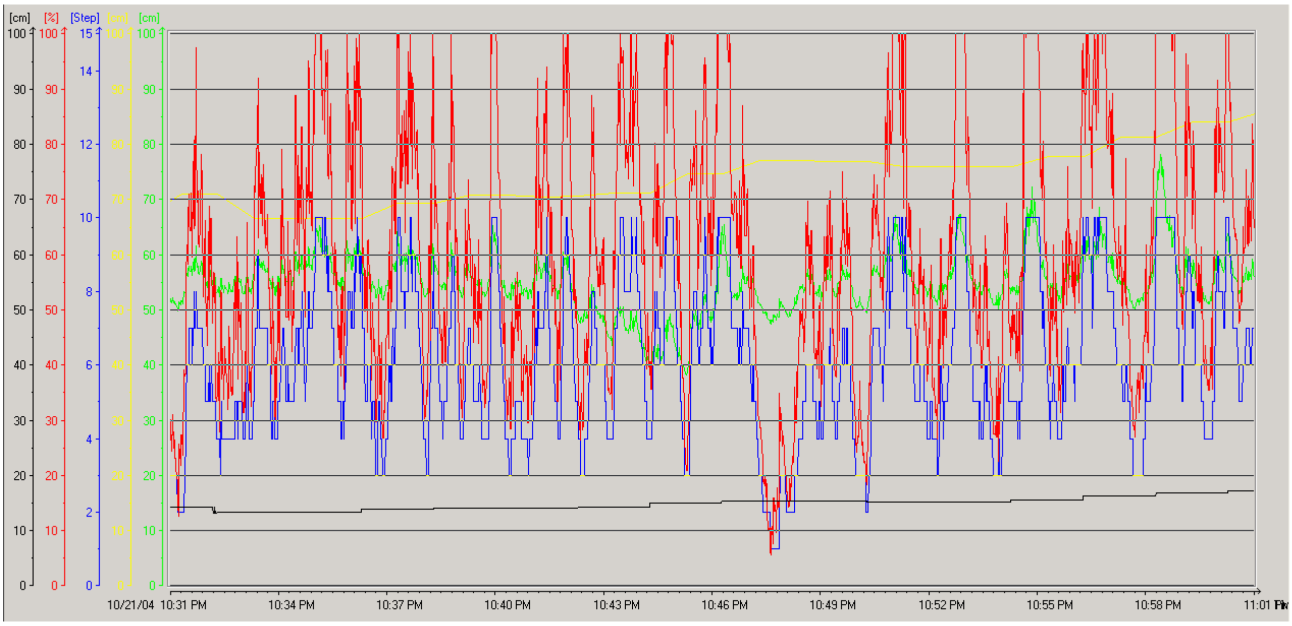



Figure 4.3. Zoom of figure 4.2, the first half hour.

An analysis of the overtopping rates, taking the heel into account, has also been performed, as described in Appendix B. The resulting overtopping rates are shown in figure 4.4. In these data the operation of the dummy turbines have been included.

Generally, as in figure 4.1 quite some scatter is seen and a large portion of the data points falls below the prediction line. The possible explanations for this are again the above mentioned points.

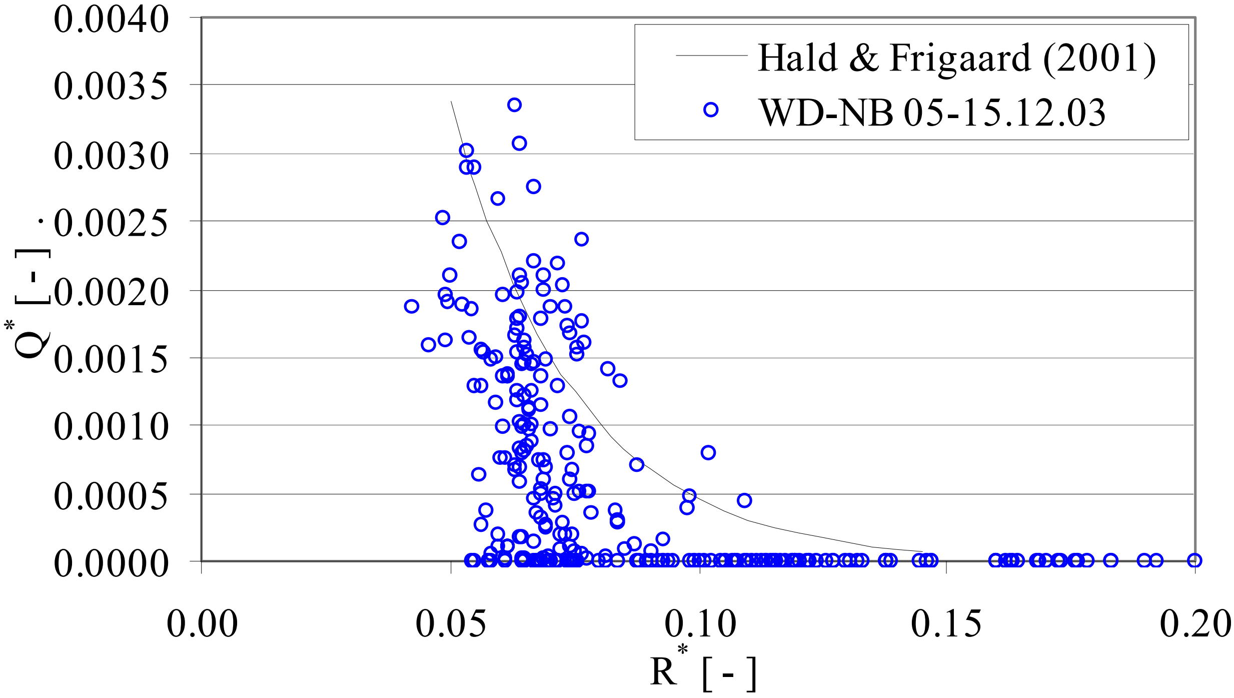



Figure 4.4: All the non-dimensional overtopping rates from Appendix B assembled in one graph. The data is also shown in figure 4.5.

In figure 4.5 the non-dimensional overtopping rates are plotted for one day at a time (6 days during the period 05-15.12.2003) along with half hour averages of the heel, crest freeboard (compensated using heel) and significant wave height. Below a few observations based on these graphs are given:

- Periods with heel close to 0 and $R_c$ close to $H_s$ seems to result in overtopping rates close to the prediction line.
- Significant oscillations in the heel seem to reduce the overtopping rates badly.

However, it is reassuring that some points are above the prediction line, as this could indicate that the overtopping expression under certain circumstances can be exceeded. Thus, the overall picture is that the overtopping expression is realistic in normal operation, i.e. the reservoir is level and not overflowed and WD is fairly aligned towards the waves.

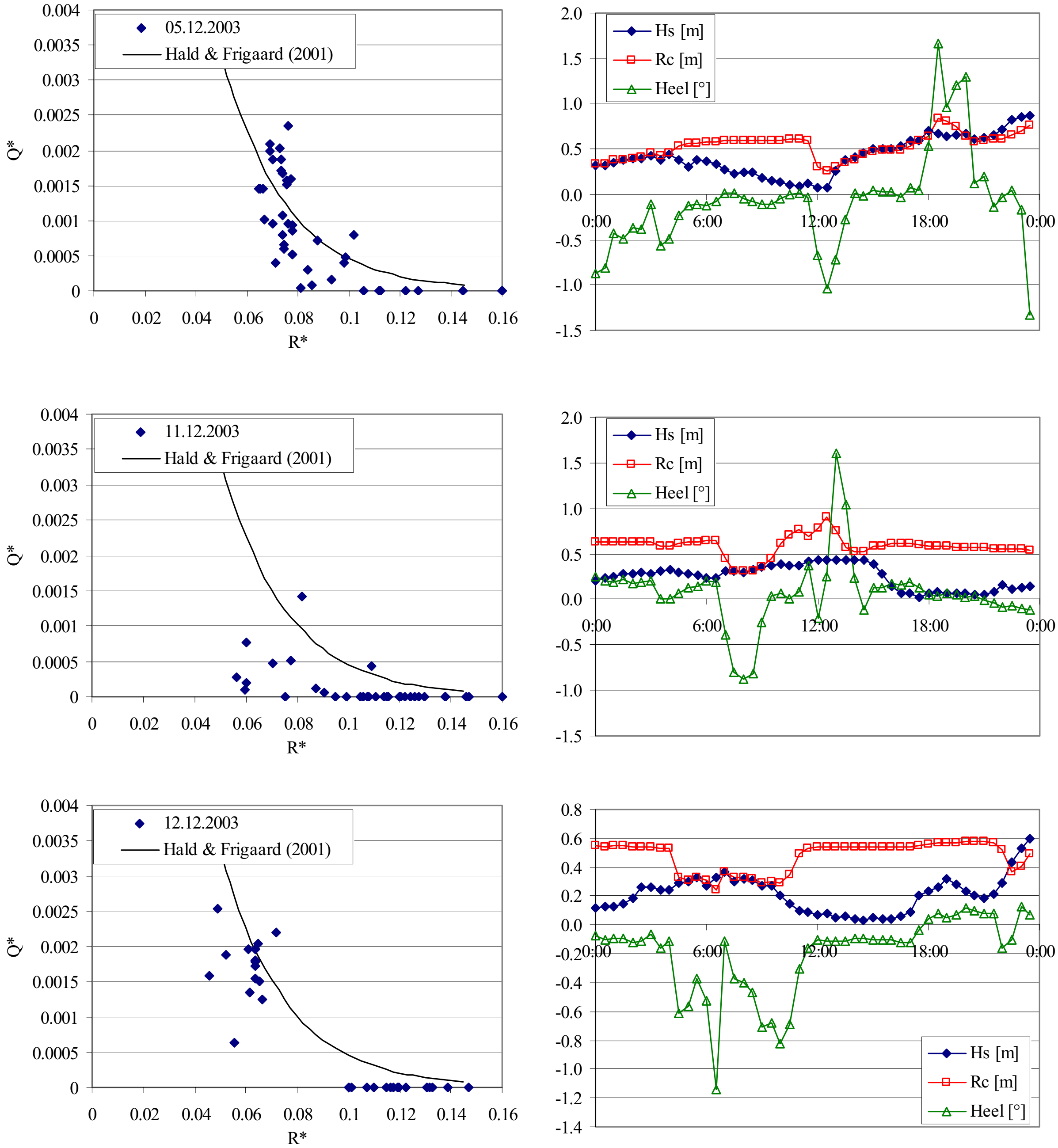



Figure 4.5a: Non-dimensional overtopping rates plotted for one day at a time (left) along with half hour averages of the heel, crest freeboard (compensated using heel) and significant wave height (right).

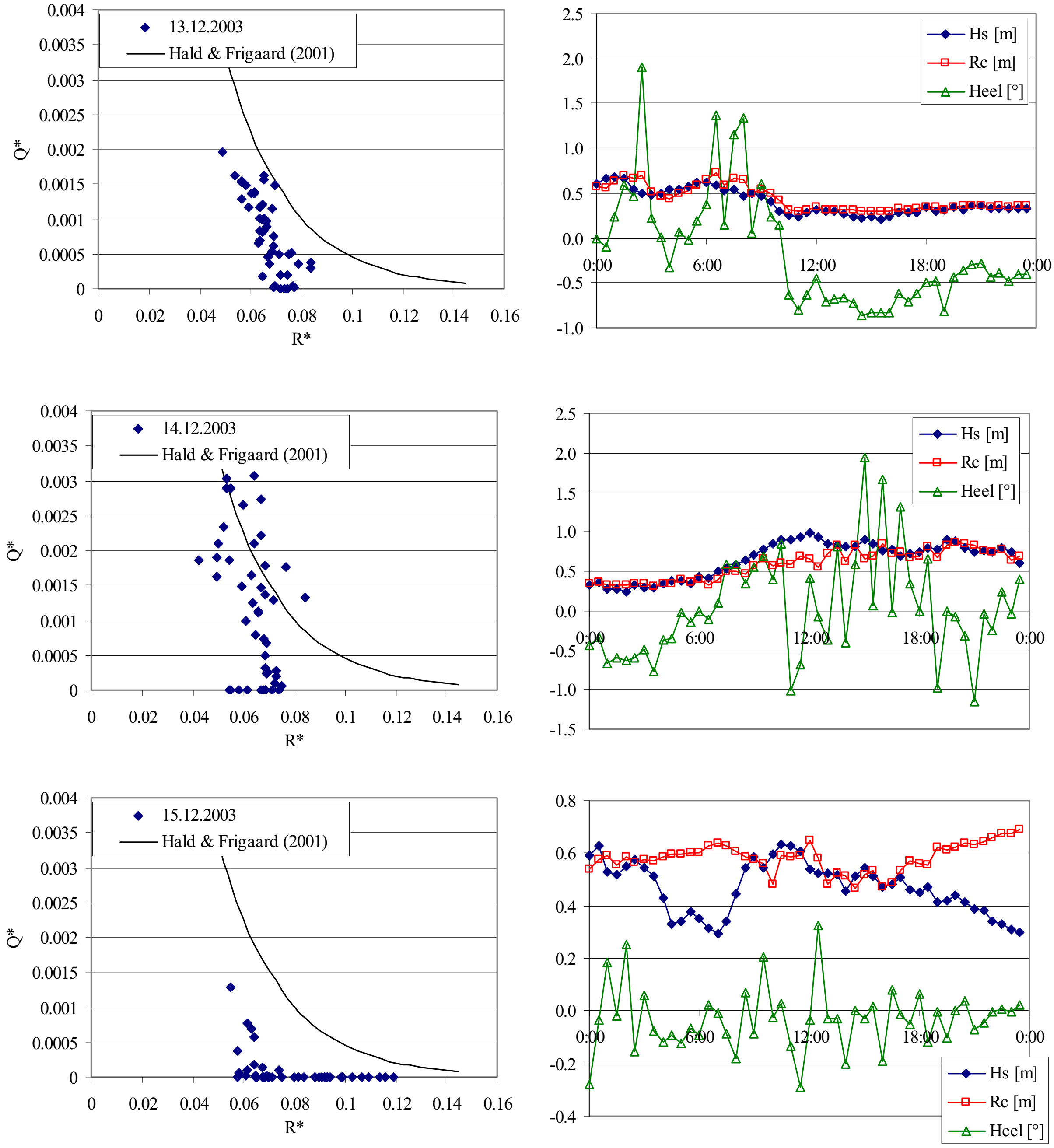



Figure 4.5b: Non-dimensional overtopping rates plotted for one day at a time (left) along with half hour averages of the heel, crest freeboard (compensated using heel) and significant wave height (right).

# 5. Forces in moorings

## *Instrumentation*

WD-NB was originally equipped with two force transducers in the mooring arrangement. One in the attachment point at the mooring pile, of the main mooring line and one in the attachment point on the port reflector, of the cross mooring line between the reflectors. The first transducer has been performing well since WD-NB was installed at test site 1, providing reliable data except in the periods were the signal cable from the pile to the platform has been broken. The second transducer was already ruined during the dislocation of the reflectors the first weekend after installation.

An attempt has been made to repair the transducer by re-installing a new signal cable from the transducer to the junction box and heavily reinforcing the support for the cabling, but it seems so far that the effort has been in vain. The fact that the cable connection across the port shoulder to the reflector has been disrupted more than once has not made the job of putting equipment on the reflector any easier.

Thus, the analyses of the forces in the mooring system are so far limited to looking at the forces in the main mooring line.

## *Data analysis*

The mooring forces in the main mooring line corresponding to the wave data given in chapter 2 are given in figure 5.1.

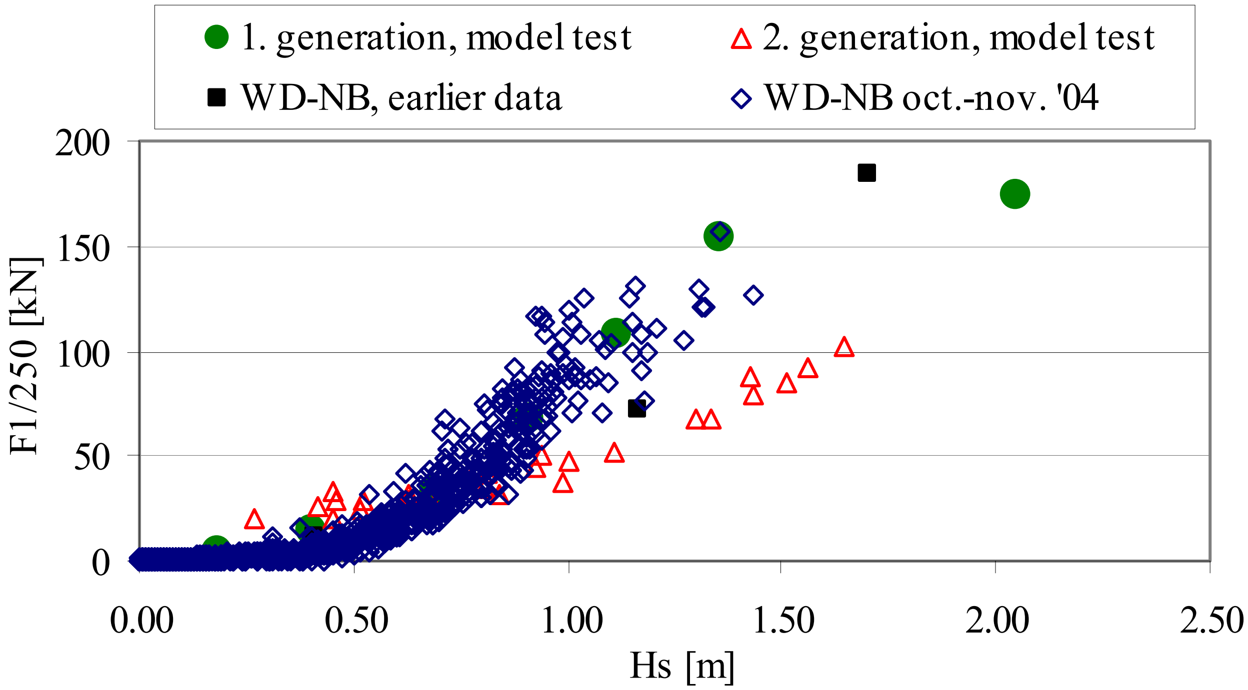



Figure 5.1. Mooring force in main mooring line attached to mooring pile in terms of $F_{1/250}$ (average of the 1/250 largest force peaks). The 'WD-NB, earlier data' is data observed at the SCADA system, ie. not really statistical data, but merely max points observed at the indicated single wave height.

From this figure it seems that the stiffness of the mooring system is too large – more like the situation as in the 1. generation model tests than in the 2.

# 6. Wave induced motions

## *Instrumentation*

The planned measurements of movements using accelerometers have largely been disrupted by the dislocations of the shoulder connections on more than one occasion. The signal cables to the accelerometers on the shoulders and the port reflectors was cut during the first dislocation immediately after installation of WD-NB at test site 1. Fortunately, the accelerometers on the reflector were not yet installed, as they in that case probably would have been submerged and thereby damaged. The signal connection to the port reflector has been restored and destroyed more than once, see Kofoed et al., 2004b. The installation of the accelerometers on the port reflector is expected to be carried out when time and weather allows it. The accelerometers on the shoulders are currently being re-installed after an overhaul – exchange of signal cable etc. They are expected to be in operation within weeks.

Thus, until present only two accelerometers have been available for measurements. These are the two situated inside the container on the platform, measuring horizontal and vertical accelerations of the platform. Combined with the two accelerometers on the shoulders, these should have been providing heave, surge, pitch and roll time-series of the platform by double integration of the accelerations. However, as only the two accelerometers in the container have operational the following calculations and analyses have been performed.

## *Data analysis*

The data from the accelerometers in the container on the platform have at first been integrated twice in order to obtain time-series of the motions of the points where they are placed. As an attempt to extract some information about the platforms motion in pitch and surge some assumptions have been made:

- LCG (longitudinal center of gravity) 5.509 m (forward from rear), given by Armstrong, 2003
- VCG (vertical center of gravity) 1.247 (above base), given by Armstrong, 2003
- ACC_P1: horizontal accelerometer in container, mounted on ceiling, on CL. Vertical distance to CG: roughly 3,5 m, depending of amount of water in reservoir.
- ACC_P2: vertical accelerometer in container, mounted on container wall towards reservoir, on CL. Horizontal distance to CG: roughly 5.5 m.
- If it is assumed the there is no heaving motion (probably not the case!) the pitch motion can be approximated as:
- pitch = arcsin(vertical motion from ACC_P2 / horizontal distance from ACC_P2 to CG).
- With a similar approach the motion in surge can be approximated as:
- surge = horizontal motion from ACC_P1 + sin(pitch)*vertical distance from ACC_P1 to CG.

Obviously these are rather rough assumptions and approximations which have to be kept in mind when evaluating the resulting data.

The results of these analyses for the period 04.10.20 17.50 - 04.10.24 22.01 are given in figure 6.1 and 6.2.

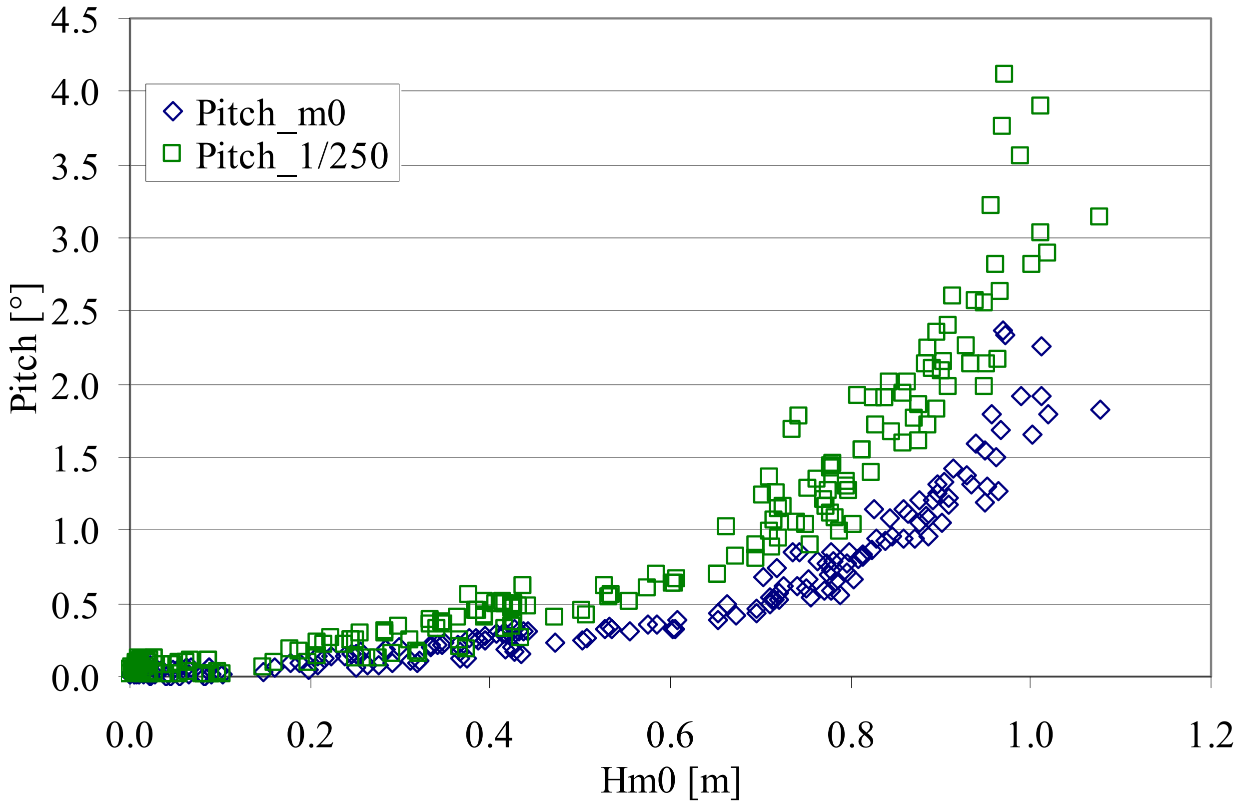



Figure 6.1. Motions in pitch, calculated corresponding to significant wave height (4 times the standard deviation), $pitch_{m0}$, and the mean of the 1/250$^{th}$ largest oscillations, $pitch_{1/250}$, both as a function of the significant wave height $H_{m0}$.

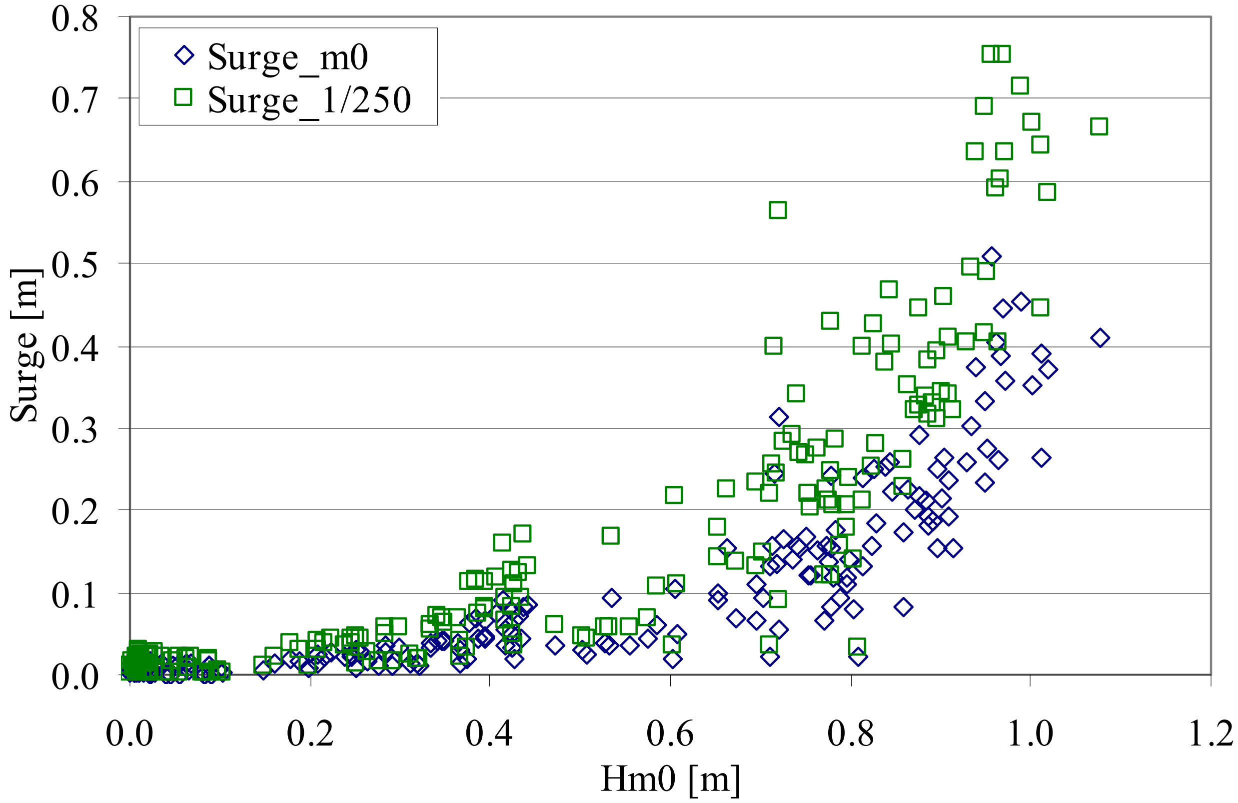



Figure 6.2. Motions in surge, calculated corresponding to significant wave height (4 times the standard deviation), $surge_{m0}$, and the mean of the 1/250$^{th}$ largest oscillations, $surge_{1/250}$, both as a function of the significant wave height $H_{m0}$.

# 7. Connection between platform and reflectors

## *Instrumentation*

Prior to installation of WD-NB at test site 1 preparations were made to mount two displacement sensors in the port shoulder connections. Due to the problems and work on getting the fender arrangement in the shoulder connection to perform as initially intended these displacement sensors have not been installed until now. Instead a webcamera has been installed looking down on the fender arrangements allowing observations of the shoulder connection even in serious sea conditions where it is not safe to be on board.

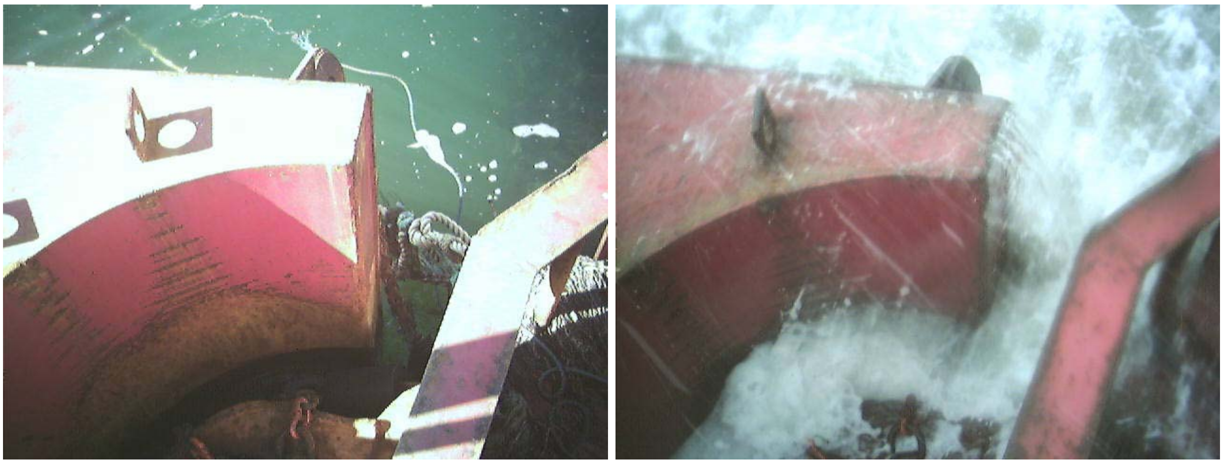
## *Observations*

In addition to work on the fender arrangement already mentioned by Kofoed and O'Donovan (2003) two major incidents during a little more than the last year:

Before repair of the port side fender arrangement planed in the autumn 2003 was carried out, heavy weather caused dislocation of the port reflector and consequently damage/puncture of the port side shoulder. This lead to flooding of a large buoyancy chamber. Further description is given in appendix A, date 03.10.08-09.

Between Christmas and New Year 2003 the starboard reflector was dislocated due failure of back rope between back of reflector and back corner of platform. The reflector was reinstalled the following day with calm weather, see figure 7.2.

webcam2_20040513090005585.jpg
webcam2_20040616170005773.jpg



webcam2_20040910120005484.jpg
webcam2_20040912160005390.jpg

Figure 7.1. Pictures captured by WebCam2 on the port shoulder.

Figure 7.2. Reinstallation of starboard reflector after dislocation, occurring between Christmas and New Year 2003.

Furthermore, the fenders and the chains holding them have continuously had problems. Both parts of the chains and fenders have been replaced in an attempt to maintain the connection. However, A durable long-term solution has not been found, and the layout of the connection most probably needs to be completely redesigned in order to obtain a solution that is applicable to a full-size structure.

Numerous problems with mooring lines have also been experienced, please refer to Appendix A for details.

# 8. Literature


Armstrong, 2003: Wave Dragon 1:4.5 Scale Prototype – Main Body Loading Conditions and Stability, Armstrong Technology, 1. April, 2003

Bølgekraftudvalgets Sekretariat, 1999: Bølgekraft – Forslag til forsøg og rapportering. Forslag til systematik i forbindelse med afprøvninger af bølgekraftanlæg. Rambøll, Marts, 1999. (In Danish.)

Hald, T. and Frigaard, P., 2001: *Forces and overtopping on 2. generation Wave Dragon for Nissum Bredning*. Phase 3 project, Danish Energy Agency. Project no. ENS-51191/00-0067. Hydraulics & Coastal Engineering Laboratory, Aalborg University.

Hald, T. and Friis-Madsen, E., 2001: *Strategy for regulating the crest freeboard of a floating wave energy converter*. Int. Conf. on Marine Renewable Energies, MAREC 2001, Newcastle.

Kerper, D. R. and Jacobsen, V., 1998: *Bølgeforhold ved Helligsø Teglværk, Nissum Bredning*, Dansk Hydraulisk Institut, Februar 1998.

Knapp, W and Riemann, S., 2003: *Measurements on Wave Dragon, Nissum Bredning on 24th of May 2003: Dummy turbine calibration*. Laboratorium für Hydraulische Maschinen, Technische Universität München, Germany.

Knapp, W., 2004: *Wave Dragon: Report on the refurbishment of the siphon turbine carried out 10.5. to 15.5.2004*. Laboratorium für Hydraulische Maschinen, Technische Universität München, Germany. May 2004.

Knapp, W., 2004b: *Problems with the cylinder gate turbines – informal intermidiate report*. Laboratorium für Hydraulische Maschinen, Technische Universität München, Germany. June 2004.

Knapp, W., 2004c: *Report on the repair and modification of cylinder gate turbine No. 5*. Laboratorium für Hydraulische Maschinen, Technische Universität München, Germany. August 2004.

Kofoed, J. P. 2003: *Status rapport - Bygning af Wave Dragon, Nissum Bredning*. Hydraulics & Coastal Engineering Laboratory, Aalborg University, May 2003. In Danish. (Title in english: *Status report - Building of the Wave Dragon, Nissum Bredning*.)

Kofoed, J. P., 2003b: *Status rapport - Instrumentering af Wave Dragon, Nissum Bredning*. Hydraulics & Coastal Engineering Laboratory, Aalborg University, May 2003. In Danish. (Title in english: *Status report - Instrumentation of the Wave Dragon, Nissum Bredning*.)

Kofoed, J. P. and O'Donovan, E., 2003: *Status report - First offshore experiences, Wave Dragon, Nissum bredning*. Hydraulics & Coastal Engineering Laboratory, Aalborg University, September 2003.

Kofoed, J. P., Frigaard, P., Friis-Madsen, E., and Nimskov, M., 2004: *Automatic Control of Freeboard and Turbine Operation - Wave Dragon, Nissum Bredning*. Hydraulics and Coastal Engineering No. 1, ISSN: 1603-9874, Dep. of Civil Eng., Aalborg University, March 2004.

Kofoed, J. P., Riemann, S. and Knapp, W., 2004b: *Calibration and Validation of Measurement System - Wave Dragon, Nissum Bredning*. Hydraulics and Coastal Engineering No. 2, ISSN: 1603-9874, Dep. of Civil Eng., Aalborg University, March 2004.

Kramer, M. & Kofoed, J. P., 2004: *Placering af trykmåler til bølgemåling - Wave Dragon, Nissum Bredning*. Hydraulics and Coastal Engineering No. 6, ISSN: 1603-9874, August 2004. In Danish. (Title in English: *Placement of pressure transducer for wave measurements - Wave Dragon, Nissum Bredning.*)

Nimskov, M., 2003: *Wave Dragon SCADA interface, User manual*. Balslev, December 2003.

# 9. Appendix A: Activity log

In the following pages the activity log recorded since Sept. 2003 is shown. The log from before Sept. 2003 is given by Kofoed and O'Donovan (2003). The format of the log has changed slightly during the period, and some log entries refers to smaller visit reports. These reports are given after the log.

The logs and reports are given in raw and unedited text. In the logging it has been attempted to include as much as possible, but not all partners have used the log systematically, so in some respects it is incomplete. Furthermore, some parts of the text appear in Danish. The quite substantial work done on refurbishing the turbine are only mentioned briefly in the log but documented thoroughly by Knapp (2004, 2004b, 2004c).

## Activity log

Last update 2003.11.20 by Jens Peter Kofoed

On this page the it is attempted to maintain an activity log of what has been going on at the Wave Dragon, i.e. who has ben there doing what. Please e-mail me if you have correction or additions.

| Date | Description | At site |
|---|---|---|
| 03.09.05 | Fishing fenders.<br>See '030905, Progress Report.pdf' | JPK, Eoin (AAU), BP (FC), Niels with father and brother (Diver) |
| 03.09.09 | Preparation of turbine installation.<br>See '030909, Progress Report.pdf' | JPK, Eoin (AAU), BP (FC), Leif, René (MTH) |
| 03.09.11-12 | Installation of cylinder gate turbines. | JPK (AAU), Lars C (SPOK), EFM (LOW), BP (FC), JP, Leif, René (MTH), 2 on Multisund (NH Svendbord Bugser), German TV team (2 people) |
| 03.09.15 | Maintenance of dummy turbines.<br>See '030915, Progress Report.pdf' | JPK, Eoin, Nik Flindt (AAU), Anders (Lindpro) |
| 03.09.17-18 | Moving pad eyes in shoulders, welding on walk way, putting in tubes for pressure trandsducers below structure. | Leif, René (MTH), BP (FC) |
| 03.09.29 | Preparation of fender mounting on port shoulder.<br>See '030929, Progress Report.pdf' | JPK, Eoin (AAU), BP (FC), Leif, René (MTH) |
| 03.10.07 | Installation of webcam, chain on port side bottum of W.<br>See '031007, Progress Report.pdf' | JPK, Eoin (AAU) |
| 03.10.09 | Rescue operation, port side damaged.<br>See '031009, Progress Report.pdf' | JPK, Eoin (AAU), BP & Niels (FC), Leif, other (MTH) |
| 03.10.12-17 | Repair after damages. Installation of hydraulics for cylinder gate turbines.<br>See '031017, Progress Report.pdf' | JPK, Eoin (AAU), BP & Niels (FC), Leif, René (MTH), Anders, apprentice (Lindpro), Torben (Danfoss), MN (Balslev), Niels (Diver), 3 persons (JH Dyk) |
| 03.10.30-31 | New steel wire ropes.<br>(In Danish)<br><br>d. 30 Oktober<br><br>1. Vi har afprøvet løftegalgen der skal bruges ved rep. af turbiner, Taljen skal understøttes for at kunne bære vægten af kappen .<br>2. Ny bagtros er monteret i venstre side.<br>3. Begge bagtrosse i begge sider er strammet op med 1,5 tons talje,<br><br>d. 31 Oktober<br><br>1. Nye H trosse er monteret<br>2. Nye inderste C trosse er monteret til knudepunkt i midten, højre trosse er også monteret til knudepunkt ved pullert. Venstre er ikke monteret til knudepunkt ved pullert, men er fastgjort med tov til arm.<br>3. Rigningen er strammet op som det var før monteringen af nye wire.<br>4. Alle øverste kuglehaner er indjusteret til næsten fuld åbning | BP (FC), Leif, Torben (MTH) |

| | | |
|---|---|---|
| | Skal udføres hurtigst muligt.<br><br>1. Begge bagtrosse skal beskyttes for gnavning mod IPE bjælke bag på platform. Platform må ikke sænkes før det er udført<br>2. Venstre C tros skal monteres færdig<br>3. Nye C trosse til midt på arm skal monteres.<br>4. Efter at C kæderne er monteret er det blevet meget svært at løfte rigningen ud af vandet, så der skal monteres flere olietønder på tømmerflåden.<br>5. Montering af styr på turbiner<br>6. Der mangler 5 stk. 30 mm sjækler for at kunne montere de sidste wire, hullet i kovsen på de nye wire er ikke stor nok til at de kan sættes på de store sjækler i knudepunkterne. | |
| 03.11.03 | Registration of hydraulic behavior, 031103, EFM WD-hydraulisk opforsel SCADA.pdf (in Danish) | EFM (LOW), JPK (AAU) |
| 03.11.05 | New boat, securing mooring line.<br>(In Danish):<br>- ny gummibåd leveret og fastgørelsessted på strand ved teglværk. Etableret.<br>- snørre bagtrosse. Gjort!<br>- dreje skulderkamera. Gjort!<br>- rekalibrere tryktransducere. Gjort!<br>- hænge hylde op. Gjort!<br>- sætte tønder op. Gjort!<br>- tage billeder. Gjort!<br>- pudse kameralinser. Gjort!<br>- checke om cyl gate turbiner er HELT lukkede. Gjort! Det er de.<br>- prøve at ansuge siphonturbinen. Slangen er IKKE forbundet! Kan ikke finde fittings.<br>- smøre dummyturbiner. Gjort med "entreprenørsmkinefedt".<br>- generatorkoblinger med retur. Er nu på vores værksted.<br>- strømforsyning til webcams. Etableret.<br>- pudse kameralinser. Gjort! | JPK, ND (AAU) |
| 03.11.07 | Guides mounted on cyl. gate turbines, GPS installed.<br>(In Danish)<br><br>GPS installeret. Fixpunkter indmålt.<br>- Hovedanker 56°41'24,27" 8°20'35,15"<br>- Baganker 56°41'25,77" 8°20'39,53"<br>- Testsite, platform 56°41'31,31" 8°20'44,63"<br>- Testsite, bro/strand 56°41'34,56" 8°20'50,70"<br><br>Checke at cyl. gate turbiner er HELT lukkede. Gjort - det ser de ud til at være!<br><br>Luftslange er IKKE forbundet forbundet til sifonturbine - skal gøres ved først givne lejlighed.<br><br>Tryktransducere rekalibreret (offset justeret), se billede.<br><br>HUSK til næste gang:<br>- WD40<br>- Pagaj<br>- Skævbidder | JPK (AAU), Leif, René (MTH) |

| | | |
|---|---|---|
| | - Opdrift til kamera<br>- Gardiner/persienner 70 x 70 cm<br>- Polysturenkugler eller andet opdriftsmiddel til 6 olietønder<br>- 750 kg talje fra HN<br>- vandtæt box til GPS<br>- USB forlængerledning samt repeater | |
| 03.11.12 | Remote controlled testing.<br><br>Bouyance and generators have now been running in automatic mode for several days without problems. The wave height has been low today, the reservoir has therefore a number of times been filled by use of the pump. Serious leaks in the reservoir have revealed themselves, as the volume of water in the reservoir falls about 20 m3 pr hour with all turbines stopped. The turbine gates are probably responsible for most of the leaks. It is necessary to mount some kind of soft gaskets on the gates.<br><br>During the day it has been verified that the lowest possible floating level with full reservoir is around 37 cm. This means that we 'lack' 37 - 22 = 15 cm. It is proposed to fill 2 x 10 m3 into the two watertight compartments (WTC2 P & S) in the center of the platform. This should bring the min. floating level down to app. 26 cm, which again means, that a heel around -0.5 degrees will lead to an average ramp freeboard of app 22 cm. This is OK for the moment - additional ballast should only be added, when the winter season is over.<br><br>To test the dummies setpoints of heel , work span etc. has been changed during the day. The setpoints are now:<br><br>TFL A: 1,00<br>TFL B: 0.00<br>TFL Min.: 37 cm<br>TFL Max.: 89 cm<br>BWS factor: 0,20<br>Turbine 8 step 1<br>Turbine 9 step 3<br>Turbine 10 step 5<br><br>See also picture/screendump from tests.<br><br>To be modified in SCADA by MON:<br>- Correct spelling of 'Buoyancy'.<br>- Specify BWS on the form Ax+B as it is done for TFL.<br>- Make it possible to adjust the time axis, or remove seconds and/or AM/PM - use 24 hours time format.<br>- Include automatic daily motioning of dummy turbines if they have not been used.<br><br>Furthermore, a list of what is done in the different buoyancy steps would be very welcome. | EFM (LOW), LC (SPOK), JPK (AAU) |
| 03.11.19 | Intro of Per and Martin (the new maintenance team;-)), repair of dummy turbines.<br>See '031119, Progress Report.pdf' | Per, Martin, Eoin, JPK (AAU) |
| 03.11.20 | Remote controlled leak test performed, see 031120, EFM Leak test.pdf (in Danish) | EFM (LOW), JPK (AAU) |
| | | |

YAHOO! Groups

# Table Name: Activity log

**Table Description: Log of activities onboard WD**

| Date / time | Comment | User | Attention | Acknowledged | Category |
|---|---|---|---|---|---|
| 999999 | IMPORTANT! Please use the following format when entering log entries: YY.MM.DD HH.MM. And please use '.' and not '-' or anything else as the seperators. This will help the sorting of the log a lot! | JPK | ALL | | Admin |
| 03.11.18 15:20 | Test, app. 3 h with heel = -1,0 and short periods with propellerpump in order to fill reservoir - turbine no. 9 is stuck in open position. | EFM | | | Testing |
| 03.11.19 12:00 | There seems to be a programmed upper limit to the TFL at 100 cm (in addition to the TFL max). This should be removed or set to 200. | JPK | MON | Done! 03.11.19 | SCADA |
| 03.11.19 19.00 | The login functions are now operational on the SCADA, users must use their login. | Morten | | | SCADA |
| 03.11.26 | Siphon turbine checked, light installed, raft modified, Oddesund harbour visited. See Files, Visit reports | JPK, Eoin (AAU) | | | Work on board |
| 03.11.26 10.00 | New alarm class introduced. The colour is blue and these alarms does not need nor can they be acknowledged | Morten | | | SCADA |
| 03.11.26 12:00 | UPS fault: mains rect. fault. Reset pressed. | JPK | | | Fault |
| 03.11.26 12:00 | Water pump 1 causes HPFI relay fallout on shore. | JPK | | | Fault |
| 03.11.26 17:00 | The new turbines are now activated (except no. 4 and 6) to keep the gates closed by the hydraulic cylinders. The turbines will however not operate untill step 10 - which at the present configuration most likely will not happen. | EFM + Morten | | | SCADA |
| 03.11.26 17:00 | It is possibel to switch the new 150 W lighs on/off by means of the SCADA system - Morten will tell JPK which contact to use. | EFM + Morten | JPK | JPK, connection 5.30 | Work on board |
| 03.11.26 18.30 | BWS A and BWS B now operational | Morten | | | SCADA |
| 03.11.28 | Steel ropes mounted, see Files, Visit reports | JPK, Eoin | | | Work on board |

Appendix A

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|---|---|---|---|---|
| | | (AAU) | | |
| 03.12.04 | Connected inclinometers, pump fault resolved. See Visit report in Files section. | JPK & Eoin (AAU) | | Work on board |
| 03.12.05 17:00 | Good wave conditions. Running in automatic mode. Only two dummy turbines enabled. Hs ~ 0.60 m | JPK & EFM | | Testing |
| 03.12.05 23.50 | Heavy conditions Hs ~ 0.90 m, WS ~ 20-21 m/s in Thyborøn. Hydraulic pump fault caused by heavy negative heel. Critical condition. See note in Files section. | JPK | EFM | Testing |
| 03.12.08 11:00 | TURB 4 (cyl. gate) half way open again. I have activated it and set it to run in step 10 in the generator control, in order to activly keeping it closed. To minimize the probability of of opening of it I have set BWS B has been changed from 0,0 to 0,1. | JPK | | SCADA |
| 03.12.11 | Siphon turbine repaired, End stops on cyl. gate turbines adjusted. See report for visit in the Files section. | JPK & Eoin (AAU) | | Work on board |
| 03.12.12 11:00 | The syphon turbine is not running even if it's set as turbine step. A manual start activates the water flow through the turbine, but there is no recording of the generator producing power. | EFM | | SCADA |
| 03.12.12 12:00 | TFL MAX is set to 67 cm to avoid unstability in high floating levels. When the regulation is fine tuned, the lmax level should be 87 cm. | EFM | | SCADA |
| 03.12.12 14:25 | Solenoids replaced in Dummy turb. 9, Siphon turb non-return valve cleaned & oiled, Oil changed in lub. bearing, end stops adj. in cyl. gate turb 4 & 6, coarse heel & trim inclinometer adj. | Eoin | | Work on board |
| 03.12.14 | Storm conditions with average WS up to 24 m/s. Problems with low water level in hydraulics. Does NOT seem to be cause by heavy backward heel. All dummy turbines opened and generator control switched to manual. Dummy turbine 10 can not close. | JPK | EFM, MON, LC | Testing |
| 03.12.14 22.50 | It seems that the buoyancy steps have been altered. However, it also seems like it is not done as suggested by EFM & JPK, see Excel sheet in Files, JPK notes. Please tell us what have been done. | JPK | MON | SCADA |
| 03.12.15 10:00 | Generators set in automatic mode. TURB10 can still not reach close end stop (has been closed as much as possible), so only TURB 8 & 9 are operating. Wave are coming almost directly from north. This induces heave movements of especially the port shoulder | JPK | | Testing |

Appendix A

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|---|---|---|---|---|
| 03.12.19 13:50 | Min floating level reset to 37 cm. To avoild "heeling":-) instabillity arising from constantly and fruitless attempts to adjust to high floating level . It worked. | Lars | | |
| 03.12.19 14:15 | Changed MAX bassin level from 60 to 65 cm. It seemed as if bassin level was not calibrated; showing higher level than could be seen at the web cam. | lars &efm | mon, jpk | Calibrating |
| 03.12.19 15:00 | TFL MIN adjusted to 32 cm and Basin max level adjusted to 70 cm due to incorrect calibration. | EFM | | SCADA/calibration |
| 03.12.19 15:25 | Trim SP changed to +0.5 due to mis calibration. | EFM | | SCADA/calibration |
| 03.12.22 15:45 | At the moment the platform is almost level in trim, when the measured value is +1.70 degrees - thus the set point is now set to this value. The heel set point is adjusted to +0.40. | EFM | JPK, Morten, Lars | SCADA set points |
| 03.12.23 13.43 | HEY - I found it!! I'll post commets here from now on. | monbalslev | all | |
| 03.12.23 13.44 | Both Trim and Heel from the MGC+ inclinometers are now the ones used by the program. | monbalslev | JP EFM | |
| 03.12.23 14.02 | Now that Trim and Heeling meassurements are reliable, Trim and Heeling SP's are set at 0,0. Basin max level is set at 60cm. | monbalslev | EFM, JP | |
| 03.12.23 14.30 | Floating level is unreliable. TFL_B has been set at 44cm, to compensate. Reason: At the ramp, it looked as if water level was at 2. line from top (FL=44cm) but meassurement said 79cm. | monbalslev | EFM, JP | |
| 03.12.23 14.30 | UPS TFL_B = 35.....! Why can't I edit my own records?? | monbalslev | EFM, JP | |
| 03.12.23 14.30 | Buoyancy sequence is now as suggested by JPK and EFM. | monbalslev | EFM, JP | |
| 03.12.23 14.45 | U4 is the problem for FL, so I've stopped using it for calculating FL. U3 is used instead. | monbalslev | EFM, JP | |
| 03.12.23 15.00 | TFL_MIN set at 45cm to prevent instability caused by inability to reach low FL. | monbalslev | EFM, JP | |
| 03.12.24 09.20 | Calculation of Hs has an error - it goes SKY high when waves are high. 999.0 is displayed in this case. I'll look into it later.... | monbalslev | EFM, JP | |
| 03.12.24 | | | | |

Appendix A

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|---|---|---|---|---|
| 17:20 | Dummy turbine no 8 restart | lars | jpk, efm | Maintenance? |
| 03.12.25 15:00 | Dummy 8 can open, but not close totally | EFM | JPK, Morten, Lars | |
| 03.12.26 00:30 | Graph 4 looks awfull! It seems like the force transducer is no longer giving any usable results, and the Hs measurements seems to be affected as well. This indicates a problem in the signal cable from pile. Not good! | JPK | EFM, MON, LC | Fault |
| 03.12.26 00:30 | Dummy turbine 8 restarted, but no effect. Some debrise is probably stuck in the turbine. | JPK | | Work on board |
| 03.12.26 00:30 | I5WDPC (the PC running the weather station etc.) seems to be down since the 23th (no uploads from it since then). I might try a remote reboot, but doing so also reboots the MGC+ and the WD_WINCC PC. | JPK | EFM, MON, LC | SCADA |
| 03.12.26 00:55 | Tried to reboot PC's and router via SMS. Got confirmation from unit that the PC's were turned back on, but never recieved confirmation on turning on the router. It seems that this has failed. This does VERY UNFORTUNATELY means we are without internetconnection from out there, and thus we can't see anything, I'm very sorry! I'll try and contact Bendy first thing tomorrow. | JPK | EFM, MON, LC | Fault |
| 03.12.26 01:55 | Confirmation for turning on router arrived. The router is up and running and so are the PCs. | JPK | EFM, MON, LC | Fault |
| 03.12.26 02:25 | What is ASP on the main page? Actual set point? | JPK | MON | SCADA |
| 03.12.26 02:35 | TFL changed from 1 to 0, TFL B set to 55. This is done as Hs changes from 2 to 999 just like that. | JPK | EFM, MON, LC | SCADA |
| 03.12.27 10:00 | Hydraulik pump restarted (water alarm). Dummy turrbines 8 and 10 cannot close due to stuck rubber fenders in the valves!!! I have sent a mail to Bendy in the hope that he can go out there today. The wave measurement seems to be o.k. at the moment so the floating level is set to follow the waveheigt. Constant floating level 55 cm will be set again when I leave the office around 16:00 | Erik | JPK, Morten, Lars | SCADA set points and turbine alarms |
| 03.12.27 24:00 | Automatic regulation stopped due to sudden heavy negative heel. The stacked grids have moved around on the deck. | Erik/Morten | JPK, Lars | Regulation |
| | | JPK, PF, Søren, | | |

Appendix A

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|---|---|---|---|---|---|
| 03.12.29 | Emergency work carried out. Starboard reflector displaced and capsized the night before yesterday. Reflector re-erected and put in place again. | Martin (AAU), EFM (LOW), Bendy, Niels (FC) | | | Work on board |
| 04-14.10.04 | Restauration of CGT's. TUM will make a complete report on this operation. | Thomas, Sven (TUM), Manfred (Kössler), LC (SPOK), JPK (AAU), Bendy (FC) | | | Work on board |
| 04.01.02 17.15 | Buoyancy sequence changed according to EFM/JPK wishes. Excel sheet uploaded to this site. I've tested the changes as much as possible. Still, I'll look at the dragon the next hours to detect malfunctions... | monbalslev | EFM, JP | | |
| 04.01.02 22.40 | ASP is "Artificial SetPoint" - the value the program aims for. The new version of the buoyancy program seems to work. I have "let it loose". Also I've set the generators in automatic running with T08-T10. | monbalslev | EFM, JPK | | |
| 04.01.02 22.41 | OOPS, the buoyancy is NOT let loose, the Hs calculation still doesnt work. TFL is at 45cm. | monbalslev | EFM, JPK | JPK, signal cable to pile heavily damaged/weared. Repair scheduled, replacement under consideration. | |
| 04.01.03 12.15 | I wondered why we couldn't make the shphon turbine run, and I found that I for some reason had turned off the communication alarm for the WDC. Anyway, the alarm is standing - the PLC cannot send succesfully to the WDC, and no telegrams are recieved. Either the cable is broken or there is an error in the WDC... | monbalslev | EFM, JPK | This requires contact to West Control. Can you talk to them? Maybe we can try 'rebooting' their units? /JPK I'm not at the office until feb. 1st. during the day time, so perhaps you can talk to them yourself? /MON | Fault |
| 04.01.04 | Last night I disabled the alarm for endswitches on the dummy turbines. | | | What seems to be the problem - anything stuck? Or is re-adjustment needed? /JPK I couldn't see if anything was stuck. But the | |

Appendix A

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|---|---|---|---|---|---|
| 19.45 | They should be enabled once the end switches are reliable. | monbalslev | JPK | readjustment is carried out WAY too often - perhaps something else than adjustment is needed........? /MON | SCADA |
| 04.01.05 16.00 | ACV2.2 T og ACV3.2 T changed to 70 seconds to stabilise heel regulation - see files, screndumps | EFM | | | |
| 04.01.05 21.15 | I just took out U1 from the FL calculation and used U2 instead. Something has to be done about the transducer problems - otherwise we'll soon find ourselves without ANY way of regulating anything! ;o) | monbalslev | all | I'll make an effort to put in a new pressure transducer in the tube situated near the crest at the center line. This will be removable, and thereby maintainable. Hopefully this can will help us. /JPK 04.01.06 12.44 | Fault |
| 04.01.06 11.00 | ACV2.2 T og ACV3.2 T changed back to 80 seconds as heel is pendling up to +- 2 degrees | efm | | | |
| 04.01.06 23.40 | I found the bug that caused the heavy heeling this afternoon. It affected steps 15 and 17 and is now fixed. Pr. request by EFM I have uploaded the source code for the buoyancy program to the board - feel free to have a look. Write me an email if you have any questions. For the programming nerds - the bugs were in lines 744 and 807, where it said "AN #EXH;" As you can see in the uploaded code the correct command is "O #EXH;" | monbalslev | EFM, JPK | Some of it seems to be understandable - at least the setting of the control of valves in the various steps. /JPK 04.01.07 10.15 | SCADA |
| 04.01.06 23.50 | Three new configuration values has been added to the config picture. ASP Factor: ASP = SP - (SP-PV)*(1-ASP Factor). Ext. Heel = abs(Extensive Heeling limit) Ext. Trim = abs(Extensive Trim limit) | monbalslev | EFM, JPK | | SCADA |
| 04.01.06 23.55 | I've had the buoyancy in automatic now for a while, and it looks as if the adjustable ASP Factor is a good idea. It's now at 0,3 but feel free to experiment (limits are 0,1-0,5). From my point of view it's OK to run in automatic again... but further test and verification would certainly be good. | monbalslev | EFM, JPK | | Buoyancy |
| 04.01.07 | I5wdpc (the pc running the weather station, gps, mgc+ software) is ill and has been since christmas. A new pc has been ordered. Data recovery is in progress. | JPK | | | Work on board |
| | | | | There does not seem to be | |

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| 04.01.07 07.10 | The hydraulic pump has tripped on high temperature during the night. Last night I saw that it started very often without any turbine action, this must be the reason for the high temp. At the next visit to WD the hydraulic system should be checked for leaks..... | monbalslev | EFM, JPK | any leaks - water level is almost at max mark. There must be a return valve that is leaking. /JPK 04.01.08 09.54 Have you called Danfoss? We won't be able to run the generators in automatic until this problem has been solved.... /MON 04.01.08 22.13 | Water Hydraulic |
| 04.01.07 10.15 | I'm running the bouyancy control in automatic to test under supervision. Test sequence: TFL 50 -> 80 cm, reservoir empty. TFL 80 -> 44 cm, reservoir empty. Reservoir filled, TFL maintained at 44 cm (system recovered lost floating level). TFL 44 -> 88, reservoir filled. | JPK | MON | | Testing |
| 04.01.09 | New mooring line 'E' installed to replace temporary ropes after last accident with loss of starboard reflector (between christmas and new year). New retractable pressure transducer mount in tube close to ramp crest and center line. Not yet connected. Once this is connected it should be use for the measurement of the freeboard, reporgramming of PLC needed. Light relay now connected, so light can be switched on from the SCADA software. | JPK & Nik, AAU | EFM, MON | | Work on board |
| 04.01.13 18.10 | As pr. request a seperate ASP factor has been introduced for Trim, Heel and FL. Please check if it's working properly.... | monbalslev | EFM, JPK | | Buoyancy |
| 04.01.15 12.00 | Testing of generator control, WCU. Temp. wire for one generator at a time is installed. Two out of 7 controller boards in WCU damaged. New pressure transducer for freeboard measurement connected to junction box. Hoses for ventilation of junction boxes with pressure transducers blown empty of water. Junction box in middle of turbine area contained water. Additional sealing applied. Water is dripping from ceiling in container (hole for wire for light, port side of container). Starboard line 'E' (from back side of reflector to aft reservoir corner) tightened. | Armin (West Control), Bendy, Thøger (FC), JPK, Martin, Per (AAU) | EFM | | Work on board |
| 04.01.16 06.50 | The generator data is now correct. I wonder why the values are not zero when the generators are not running.... | monbalslev | EFM, JPK | | Generators |
| 04.01.16 19.00 | JPK, could you please ask WestControl for a table explaining the values for: NETSTAT, NETFAULT, DRiveSTAT, DRiveFAULT... I haven't got the file from last year, and furthermore it seems to be outdated anyway. | monbalslev | JPK | | |

Appendix A

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|---|---|---|---|---|---|
| 04.01.18 18.00 | ASP Trim changed from 0,20 to 0,15. ASP Heel changed rom 0,40 to 0,30 to minimize pendling. Due to alarm ACV52 the trim adjustment is not verey good. Float Hyst changed from 3 to 5 cm due to inaccurate float calculation (only U2 and U3 are used) | EFM | Morten, JPK | | Configuration |
| 04.01.18 23.00 | ACV52 has been in alarm for not reaching end switch closed. At the next visit to WD the valve should be checked for adjustment and possibly lubricated | monbalslev | EFM, JPK | | |
| 04.01.19 | Bendy, an electrician and Hilligsø, Danfoss is working with the turbines all day. The platform is in high floating position. | EFM | | | |
| 04.01.21 | New prints for WDU, turbine 1 and 7, installed. Testing of generator control attempted. Transistor in circuit for turbine 7 exploded. Repair needed before turbine 7 can be tested. Remaining turbines not tested because of internet connection down (tests needed to be remote controlled). New pressure transducer PRES_FL connected to MGC+ - calibration/offset adjustment still needed. Work on protection of under neath container initiated. Work on signal cable connection across port shoulder continued. | Armin (West Control), Bendy, Thøger (FC), Per, Martin (AAU). On remote: JPK (AAU), EFM (LÖW) | | | Work on board |
| 04.01.22 | Turbines 6 and 7 has been operating this aftenoon. The configuration is now changed back to the dummies - se screndump in 'Files'. The Heel and Trim has been recalibrated - setpoints are now 0,00. | EFM | JPK, Morten, Lars | | SCADA set points |
| 04.01.22 | See visit report in 'Files' section. | Bendy (FC), Per, Morten & JPK (AAU) | | | Work on board |
| 04.01.23 15.20 | Buoyancy control modified so 'too' and 'much too' high/low floating level are all the same (all chambers are active). | JPK | MON, EFM | | SCADA |
| 04.01.23 18.00 | The Heel Hyst has been changed from 0,10 to 0,20. The ext. Hell has been changed from 1,00 to 0,80. The ext. Trim should be lowered somewhat, but it is not possible due to the actual limit on this parameter - the limit should be lowered to 0,1. | EFM | JPK, Morten, Lars | The purpose of the Ext. limits are purely to be a safeguard. If the normal operation cannot handle the Trim precisely enough, changes should be made here - not to the "safety function" /MON | SCADA set points |
| | Analouge output PQW578 is now ready for testing. At the config picture it is now possible to select which value is sent to the output. When a power | | | | |

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| 04.01.26 22.00 | signal is selected, the output is scaled from Value = 0-5000 => AO = 0-27648 and when a RPM signal is selected the output is scaled from Value = 0-1000 => AO = 0-27648. JPK: I haven't got the hardware drawings here, so I cannot tell you which terminals to connect to. When you are at WD or if you have a set of drawings give me a call..... | monbalslev | EFM, JPK | | |
| 04.02.02 02.00 | PRES_P seems to work fine. We get reasonable wave measurements. I have therefore changed TFL A from 0 to 1, TFL B from 66 to 0, and TFL min from 22 to 55. | JPK | EFM | TFL B has been changed to 55 cm to avoid heavy overtopping, as the top of turbine 3 is dismantled | SCADA |
| 04.02.03 17:00 | Ext. Heel has been changed from 0,80 to 1,00. This should be o.k. as the regulation now seems to be quite stable. Turbine calibration test has shown that heel is varying app. 2 degrees when the water level in the reservoir is changing 25 cm i.e. during normat turbine operation. | EFM | JPK, Morten, Lars | | SCADA set points |
| 04.02.04 18:00 | Trim SP changed to -0.5 - it is strange that the inclinometer has shifted 0.5 degree in 4 days. Trim Hyst raised from 0.1 to 0.15 and Heel Hyst raised from 0.2 to 0.3 to lower the number of regulation operations - for instance when changing the floating level. The floating level should ASAP be calculated from the measured value at the ramp crest to the center of the platform as it was before the trouble with some of the transducers. A screendump of the configuration sheet has been uploaded to 'Files' | EFM | Morten, JPK, Lars C. | | SCADA set points |
| 04.02.09 06.45 | JPK, regarding the CAN com; if you look in DB112, you'll see the data send to the gateway. It is transmitted every 1 second. I've enabled the alarm, so you will be able to see when the PLC is error-free on the com. | monbalslev | JPK | Will the error mess. MGCplus DP send disappear once it transmit the data properly to the UNIGATE? Or how should this error mess. be interpreted? 04.02.11 JPK - The alarm is acknowledged, so it should dissapear once the communication is OK. /MON 2004-02-24 | SCADA |
| 04.02.10 | AN attempt was done to get the Profi/CAN bus com. between PLC and MGC+ up and running. Not successfull so far, but the work is continued on remote. Furthermore, Loose bolts were fitted on the hood of the Flygt pump well (so the hood works as a non-return valve), so overtopping water is not | PF, JJ & JPK (AAU) | | | Work on board |

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|---|---|---|---|---|
| | lost into the well, but the pump can still be activated remotely. | | | |
| 04.02.10 11.15 | Power fall out (manual). Data in SCADA system seems to be bad a few hours back. | JPK | EFM | SCADA |
| 04.02.20 | Etablishing trash rag. WD placed in high floating level (automatic mode). | Lars | | |
| 04.02.21 | Trash rag establishing continued. With WD in high floating level. Late afternoon: TFL A=1 & TFL B=0 & BWS A=0.25 & BWS B=5cm. | Lars | | |
| 04.02.23 13.45 | Router/firewall reset by SMS. This seemed to remedy the VERY slow connection speed that has been seen the last days. | JPK | | Internet connection |
| 04.02.23 14.25 | A small time syncronizing piece of software (World Clock 3.0) have been installed on the PC's on board. Thus, the PC clock should be syncronized with an atomic clock every hour (provided internet connection is available): | JPK | LOW, BAL, TUM | Work on board |
| 04.02.24 11.00 | Dummy turbine 9 seems to be malfunctioning. No alarms are seen, but it is not openend when the step that should activate it is reached. It works in manual mode. This has probably been the situation since 04.02.20 at least, Which means that the measurements of overtopping during the weekend probably cannot be trusted. | JPK | MON | SCADA |
| 04.02.24 17.15 | As agreed with JPK, the turbines will not stop in case of end switch alarm. Alarms are displayed and the "block" representing the end switches will be flashing red. Furthermore, the max basin level is now corrected for negative heeling. The value used by the program cannot be seen on the screen. Finally, the FL is also corrected for heeling and should now be the correct floating level at the center line. The raw value from P_FLOAT can be seen on the overview screen. | monbalslev | JP, EFM | SCADA and PLC |
| 04.02.26 18.20 | Visit to WD. Starting up cyl. gate turbines. See visit report in 'Files' section, under 'visit reports' | JPK, MKR (AAU) | | Work on board. |
| 04.02.26 9.15 | Turbines taken out of operation, target FL set to 100 cm, target heel to -1 deg., for work on board. | JPK | EFM | Work on board |
| 04.03.01 9:45 | Hydraulics stopped during the night due to high temp. I tried restarting, but could hear that the security valve went of everytime the hydralic power pack was pumping. I think this valve needs to be adjusted before running the turbines in automatic again! | JPK | EFM, MON, LC | Fault |
| | WD has been without waves and set to try to obtain FL = Hs for two days. This means TFL has been 22 cm in this period. However, this cannot be | | | |

| | | | | |
|---|---|---|---|---|
| 04.03.09 10.00 | acheived, as we know - FL ends up around 66 cm. But anyway, it keeps trying, which leads to control induced oscillations in FL and heel, see uploaded screendump in 'files/SCADA' section. The pressure readings in the air chamber showed that there still is a little pressure in chamber 3 and quite some in chamber 1 (~32 mbar). I have now tried to take it out of automatic in bouyancy control, and opened all outlet valves to see how low it can go. I will then put i back into automatic to see if it then stabalizes at the same FL as before, or lower (which is what I exspect/hope). If the later is the case, maybe we need to put in some condition in the operation, that eg. when it has gone through 10 bouyancy adjustment cycles whitout getting as far down as wanted, it should open all outlet valves for 10 min. and then try again. | JPK | EFM, MON | SCADA |
| 04.03.14 17.05 | Wave measurements absurd - Basin work span and target floating level effected. I have set BWS to fixed value of 20 cm and TFL to a fixed value of 66 cm. No other changes. | JPK | EFM, MON, LC | SCADA / measurements |
| 04.03.14 18:45 | Jens Peter, you actually did'nt change BWS from 15 to 20 cm - I have left it as 15 cm because only 2 dummies are working. I have changed the turbine steps so now T8 is at step 2, T9 is at step8 and T10 is at step 5 | EFM | JPK, Morten | |
| 04.03.16 17.00 | Visit to WD. Demonstration for international students from AAU. Setting up new PTZ webcam. See visit report in Files/Visit reports section. | JPK | | Work on board |
| 04.03.19 | Heavy wave conditions. Measurements recorded by MGC+ but PRES_P not functioning properly. | JPK | | Testing |
| 04.03.22 | Turbine 8 and 10 endstpo error. Tried to open and close dummy turbines. no 8 couldn't open or close. No 10 could open but not close. | LC | | Turbien operation |
| 04.03.24 | Visit to WD, PTZ camera mounted on pile, see Visit Report in Files section | JPK | | Work on board |
| 04.03.28 | Per & Martin working on WD during the weekend, rust/paint jobs etc., see Visit report in Files section | Per & Martin, AAU | | Work on board |
| 04.04.01 | Pictures from the latest 4 visits to WD have been added to the partner site http://www.civil.auc.dk/~i5jpk/wd/partner/ pictures section | JPK | | Admin |
| 04.04.02 | Visit to WD, Check of amplifiers, see Visit report in 'Files' section | JPK | | Work on board |
| 04.04.04 | Rapid rise in wind/wave conditions at noon (from 4-6 m/s to 12-14 m/s from south within half an hour). Failure of hydraulics lead to VERY low floating level (9 - 12 cm). See picture in 'Photos' | JPK | | Fault / testing |

| | | | | |
|---|---|---|---|---|
| 04.04.13-14 | Meeting regarding EU WP 2.3 and 2.4 at WD. Minutes can be found in 'Files' section. Big problems getting out there, as outboard motors for boat was malfuntioning. Has been brought to Aalborg for repair. | Andreas and Tony, Niras, JPK, AAU | | Work on board / meeting in summerhouse |
| 04.04.19 1300 | Visit to WD. Work on communication between PLC and WCU. See visit report in 'Files' section. | JPK (AAU), Armin (West Control) | Wilfried (TUM), EFM (LOW), MON (BAL) | Work on board. |
| 04.04.21 15.00 | FWA (broadband internet) connection down. Sonofon is informed and will send a technician ASAP. | JPK | | Fault |
| 04.04.21 15.45 | FWA link up again. Sonofon will still send technician to check installation, thursday or friday. | JPK | | Fault corrected |
| 04.04.22 | Problem with lubrication of rubber bearing in cylinder. See note in 'JPK notes' in 'Files' section. | JPK | EFM, Kössler | Fault |
| 04.07.17 | Visit to WD. See report in 'Files' section. | Thomas, Søren Krogh, JPK, AAU and Xavier, FC | | Work on board |
| 04.08.13 | Visit to WD. Fan coil mounted, see Visit Report in 'Files' section. | EFM (LOW), JPK, Martin and Tim (AAU) | | Work on board |
| 04.08.21 12.55 | Checked SCADA system. The generator system seemed to have been left in automatic mode unattended since yesterday. Alarms on all dummies and the hydraulic pump had set out due to high temp yesterday around 18.00. It seems from inside temperature curve that the cooloing system stopped between 16 and 17 yesterday. I have set the generators in manual and tried to open the dummies. They don't open completely, but from webcam1 I can see they are almost open. | JPK | LC, EFM | Fault |
| 04.08.27 23.00 | Sihon turbine has been running in automatic mode all afternoon, unmanned. That is a premier! There is a lot of starting and stopping, but the waves are not very high compared to the freeboard. I have now switched turbine 1 and 5 in the generator setup to let turbine 5 run for a while. Only very seldom | JPK | | Testing |

| | | | | |
|---|---|---|---|---|
| | does both turbines run at same time. | | | |
| 04.08.30 12:00 | I have reduced the target floating level TFLB from 66 to 44 cm. The siphon turbine was running for very shot intervals. | Lars | | |
| 04.08.30 13:45 | Returned to TFLB = 66 cm. As the siphon turbine seems to have problems with the hydraulics, I have put turbine 5 in turbine step 1 and the siphon in step 5. | Lars | | |
| 04.09.09 11.25 | Offset of PRES_FL adjusted. Chanfed from 381 to 396 mbar, ie. the floating level has been recorded as 15 cm lower than real. | JPK | | Calibration |
| 04.09.10 | Reinstalled fender column on starbord shoulder. Added 30 cm small diameter fender in fender row on starbord shoulder. Replaced broken upper chain link in fender column number two. Hydraulics left off, due to leakage. Dummies open, rest closed. See Visit report in 'Files' section for further notes on activities at WD 04.09.08-10. | lch & efm | | Maintenance |
| 04.09.23 | Visit to WD. See visit report in 'Files' section. | JPK & NH (AAU) | | Work on board |
| 04.09.25 | Visit to WD. See visit report in 'Files' section. | TT Nautech, JPK (AAU) | | Work on board |
| 04.10.20 17.40 | Offset of PRES_FL, PRES_R1-3 adjusted, -3.5, -2.0, -4.0 and -4.0. | JPK | | Calibration |
| 04.10.25 14.08 | In order to avoid siphon turbine starting and stopping too frequently it is set at Step and Step 0->1 is set to 0.3 instead of 0.1. Thus, it will not start until step 4 is activated but stop is stil at Step 1->0 at 0.0. | JPK | EFM | SCADA |
| 04.12.03 21.05 | Trying out various CONSCALE values to get better generator/turbine performance. See note in 'Files' section. | JPK | EFM, WK (TUM) | Testing |

Wave Dragon Progress Report VI

Date: 5/9/2003

Location: Wave Dragon Test Site 1 (Nissum Bredning)

Present: Jens Peter Kofoed, Eoin O'Donovan, Bendy Poulsen, Nils (Diver) & aides

Report:

On this particular visit to WD:

- Bendy finished installing the submersible pumps in both port and starboard shoulders.
- The GSM internet connection was put back up and running again.
- In carrying on the work from 29/08/03, the rope from the mooring pile to the port reflector tip was reversed with a thimble placed at the designated length of 42m from the mooring pile. In addition, a 3m length of chain was attached to the starboard reflector/mooring pile line to increase it to the 42m length.
- The diver came and retrieved fenders noting that the fishtail plate on the starboard side has the bolt and retaining nut capped off. Ropes have been attached to the loose chains so that they can be retrieved next week.
- Due to time constraints, the diver did not get the opportunity to clean the transducers.

*Inventory of Fenders on WD*

| | *Within shoulder/reflector interface* | *Outside shoulder/reflector interface* |
|---|---|---|
| *Port side* | *4 Large*<br>*1 Small*<br>*1 ½* | *5 Large*<br>*9 Small*<br>*6 ½'s* |
| *Starboard side* | *5 Large*<br>-<br>*2 ½'s* | *5 large*<br>*4 Small*<br>*1 ½* |

Appendix A

Wave Dragon Progress Report VII

Date: 9/9/2003

Location: Wave Dragon Test Site 1 (Nissum Bredning)

Present:Jens Peter Kofoed, Eoin O'Donovan, Bendy Poulsen,Leif & Rene (Promecon)

Report:

On this particular visit to WD:

- Leif and Rene extended the floor bolts for the turbines and finished welding on the shoulder lips on the starboard side. Work is commencing on the lips on the port side.
- Leif cut up the old blinding plates to construct a pathway along the starboard of the main body.
- The Zywall 1 was replaced with a Zywall 10W Internet firewall.
- A method was agreed upon for installation of pipes for the pressure transducers under the structure.

Wave Dragon Progress Report VIII

Date: 15/9/2003

Location: Wave Dragon Test Site 1 (Nissum Bredning)

Present: Jens Peter Kofoed, Eoin O'Donovan & Nick (AAU), Anders (Lindpro)

Report:

- The main objective of Anders work was to make the Internet fiber connection operate correctly. As a result, the media converters that convert fiber to Ethernet communication were changed from 10 to 100 Megabit units. It is thought that the end filter installed by Siemens did not detect the 10 Megabit unit. In addition, the crossover cable between the media converter onshore and the filter installed by Siemens was changed.

- Some modifications were made to the web-cam settings and its online updating strategy. The Web-cam now updates at ~ 10 minute intervals and provides stationary shots illustrating conditions for the past ~ 2 hrs 40 mins. The online settings were also adjusted for compatibility with the broadband setup.

- The hydraulic cylinder that operates the Aer-ation valve is now operating again. However, all hydraulic cylinders, including those on the dummy turbines, need inspection (and most likely adjustment). A good opportunity to carry out this work may be to correspond with the installation of the systems on the 6 new Kössler turbines (Danefoss).

- Finally, some important maintenance work was carried out on the Dummy turbines. All 3 turbine shells were extracted individually before rust removal and treatment (Galvafroid and greased) was carried out. This allowed the shells to open and close effectively. In addition, the reconditioned hydraulic cylinder (bent ram) was installed on one of the dummy turbines. All 3 turbines now operate satisfactorily.

Wave Dragon Progress Report IX

Date: 29/9/2003

Location: Wave Dragon Test Site 1 (Nissum Bredning)

Present: JP Kofoed & Eoin O'Donovan(AAU), Bendy Poulsen(FC), Leif & Rene (Promecon)

Report:

- Leif and Rene proceeded to work on the port shoulder connection. On removing some of the fenders temporarily placed at the interface, it was noticed that the fishtail plate had been damaged in the same manner as the starboard side with the plate completely detached from the underside of the shoulder. On a more positive note, no more fenders or chains have been lost and all the material to carry out the modifications to the shoulder connection is available. The modifications to the port shoulder are due to be completed on 30/09/03.

- The buoy at the intersection of the mooring lines from the port shoulder and reflector, which had been ruptured on impact during high winds with an adjacent buoy, was also replaced.

- In other maintenance work, the dummy turbines were put operating again. However, despite recent treatment, two of the three turbines did not open/close properly. The root of the problem is, however, more related to the excessive "play" in the turbine shell causing it to be "off centre" than corrosion.
  Efforts need to be concentrated on improving the vertical guidance of the shells with a "self-centering" system preferred.

- As regards the on-line monitoring aspect, the Firewall was opened up allowing access from outside with a NetOp host providing remote control of the PC on board Wave Dragon. Another, freely downloadable, remote control host, "TightVNC", was installed.

- Finally, the fault with the pressure transducer was investigated and after some examination it was found that two of the connection wires in the electrical system panel were not secured in their appropriate terminals. These were promptly secured with the transducer giving pressure readings of the order anticipated.

Wave Dragon Progress Report X

Date: 7/10/2003

Location: Wave Dragon Test Site 1 (Nissum Bredning)

Present: JP Kofoed & Eoin O'Donovan(AAU)

Report:

On this particular visit to WD:

- The mooring line attached to the bollards on the port side was modified. 10 meters of chain was installed in place of the Nylon line to prevent wear at the shoulder window, which has been seen to be a problem. In turn, the Nylon rope was reduced to 8 meters to complete the mooring.

- Approx. $7m^3$ of water was pumped from the chamber in the port shoulder.

- In addition, a large rubber fender was placed in the port shoulder/reflector interface in view of the high winds expected over the coming days.

- A second (colour) webcam was placed on the left window of the container to monitor the port reflector. Currently, it only provides a black & white picture. The reason for this need to be investigated.

Wave Dragon Progress Report XI

Date: 9/10/2003

Location: Wave Dragon Test Site 1 (Nissum Bredning)

Present: JP Kofoed (AAU), Bendy & Nils (FC), Leif & Assistant (Promecon)

Report:

*Port Reflector disaster*

In light of the damage caused to the port shoulder of WD on impact from the misplaced reflector, it was necessary to pressurize the now flooded shoulder compartment. This was achieved by taking the air pipe from the Siphon turbine to the compartment, moving the pipe from the intake to the output side of the blower. With the blower left running, this had the effect of reducing the trim from 5 to 2.5 degrees.
In addition, some rubber fenders were added to the port side to prevent any damage from possible impacts of the reflector.

Wave Dragon Progress Report XII

Date: 12 - 17/10/2003

Location: Wave Dragon Test Site 1 (Nissum Bredning)

Present: JP Kofoed & Eoin (AAU), Bendy & Niels (FC), Leif & Rene (Promecon), Anders & Apprentice (Lindpro), Torben (Danfoss), Morten (Balslev), Nils (Diver), JH DYK Diving

Report:

*Shoulder/Reflector Interface*

- On Sunday, 12th Oct, Niels (FC) and his son (diver) visited test site 1 and recovered three small and one large of the rubber fenders which toppled off the port reflector arm when misplaced. Five further large fenders were reclaimed on Monday by diver Niels.
- Damage to the top of the port shoulder was welded up (Promecon) at which point it was also noticed that some further damage had been caused to the shoulder below water level.
- Water was pumped from the shoulder compartment using a high capacity submersible pump.
- To limit the extent of any possible future flooding of the shoulder section of the main body, on Tuesday, man-hole covers were fitted to close off the front shoulder compartment.
- JH DYK diving welded up the underwater damage to the port shoulder, recovered further fenders before assisting in installing the lower fishtail plate. The Diver also confirmed Niels finding of a ill-fitted starboard lower fishtail plate. It is thought that one of the small rubber fenders became caught on the underside of the shoulder when initially tensioning the chains.
- This problem was remedied by jacking out the starboard reflector, thus affording more room at the interface, and shortening (gas cutting) links from the appropriate fender chains.
- On Wednesday, the rubber fenders were re-fitted on the port side before moving the reflector into place.
- On Thursday, some piping was welded to the lower edge of the shoulder window to cover up the sharp edge that existed there, thus providing a smooth contact surface for the mooring chains attached to the shoulder bollards. In addition, vertical piping was welded from the base of the window to the rim of the main body, thus sectioning the shoulder window in two, to deflect the mooring from wearing on rubbing against the edge of the reflector.
- It was also noticed that the sounding pipes (vertical pipes to airtight compartments) are heavily corroded and are thus not competent in the event of bring hit by heavy debris that may be included in some overtopping waves. It is intended to weld galvanized pipe on the outside of the sounding pipes to prevent any flooding of the compartments.

- In repairing the damage to the signal cable, from the reflector to the container, at the port pile, it was decided to install two junction boxes (one on the shoulder, the other on the reflector) and install new cable in between. This will be also more convenient for detaching the reflector when towing to the next test-site.

*SCADA & Online Monitoring*

- On Monday and Tuesday Morten Nimskov, from Balslev, installed a new PC for the SCADA system making some modifications to the SCADA setup in turn, i.e. including the new cylinder gate turbines into the system. SCADA has now been confined to the new PC as there is no Profi-bus card on the original system.
- Wireless remote controlled WebCams (2) were installed on the staircase outside the container and on the pile over the port shoulder with remote control operation being made available to project partners.
- On Wednesday, the Firewall was upgraded to solve the problem with the FTP, *viz.* blocking LAN to WAN.

*Cylinder Gate Turbines*

- On Monday, Torben from Danfoss began fitting pipes for the cylinder gate turbine hydraulic system.
- It later emerged that some mistakes had been made which meant that the installation was more difficult that anticipated. These problems are outlined below:

    - The width and height of the brackets for attaching the upper end of the hydraulic cylinders to the turbine shell was incorrect. This was a design error as the specification for the cylinders was recorded as 48 mm dia., with the distance between the brackets being equal to 48 mm. The old brackets were cut off with new brackets being welded with a distance of 52mm between them. Furthermore, the min. length from eye to eye of the hydraulic cylinders appeared to be 15 mm longer than given in the specifications. Thus the brackets was also made higher to accommodate this.
    - Additionally, accommodation of the hydraulic hose from the upper end of the cylinder was not allowed for in the design of the top section of the cover of the turbine shell. This was remedied by extending the opening by gas cutting out some material there.
    - Finally, the window on the side of the turbine shell cover had to be extended downwards to avoid the lower edge of the window catching the hydraulic hose from the top of the cylinder during operation.

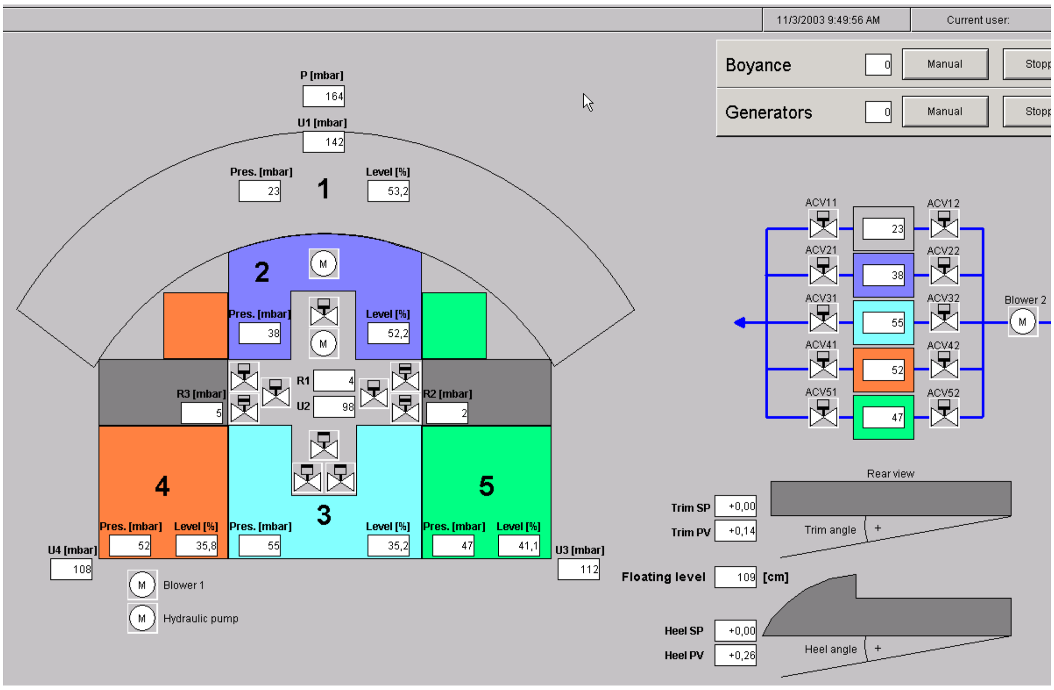
- On Thursday, Lindpro began installing the electrical system for the operation of the cylinder gate turbines.

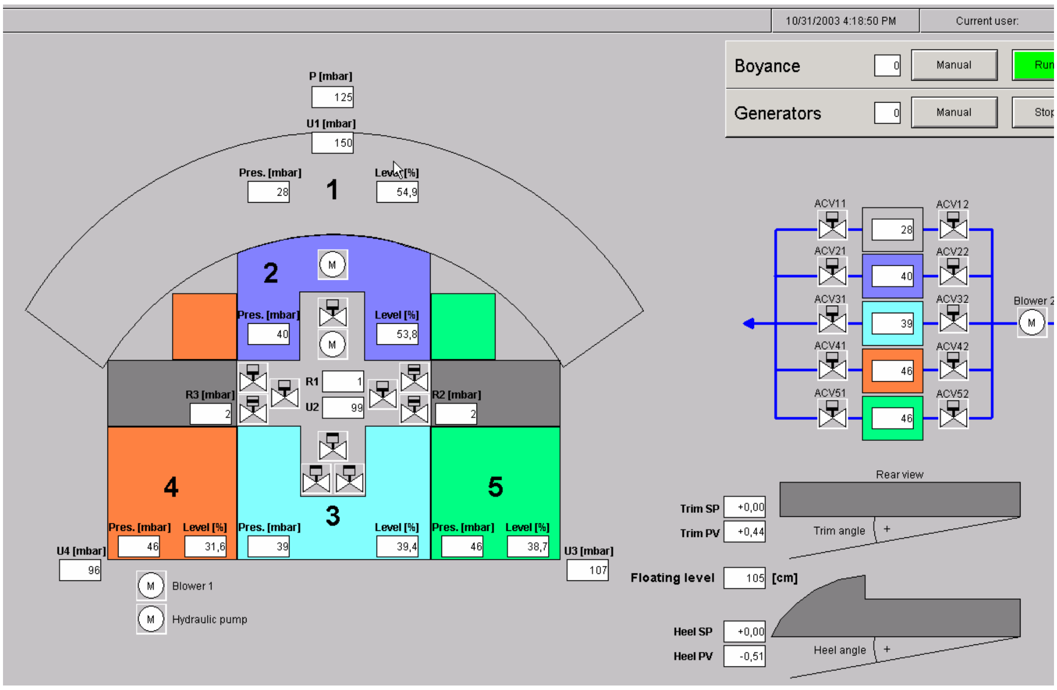
*Mooring Lines*

- Two pieces of 20 mm rope, each of length 26m, were prepared to attach from the centre of the 'W' to the tip of each reflector respectively using approx. 2.5m of chain from the tips, to maintain the geometry of the mooring lines in the case of no waves.
- In that operation, it was noticed that the wire rope mooring from the centre of the 'W' to the bottom of the 'W' on the starboard side was worn to ⅛ of the original diameter. To temporarily secure the line, a piece of chain was attached from the shackle and around the clasp forming the eye on the wire rope. New wire ropes with thimbles are necessary for the mooring comprising the 'W'.
- In the course of the port reflector disaster, the new shortened mooring line from the rear of WD to the reflector was cut from rubbing off the damper plate of the reflector when it was capsized. The older mooring line was still in place and has been shortened and reused.

Note:

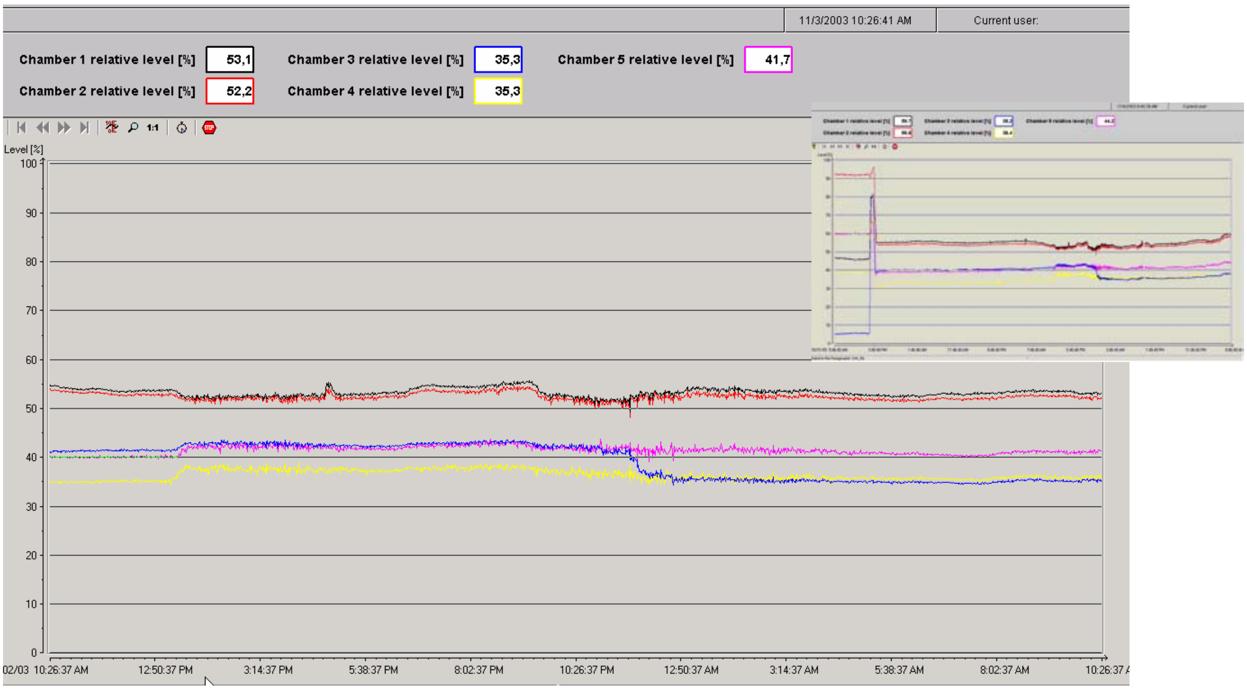
On Wednesday, the Canon digital Camera (DIGITAL IXUS $V^2$) and water-proof casing were lost. Despite best efforts, the diver could not find it on the sea bed.
He (Niels) did, however, find some more fenders and assisted installing the chain from bottom of the shoulder to the top of the port reflector (that prevents excessive vertical movement of the reflector).

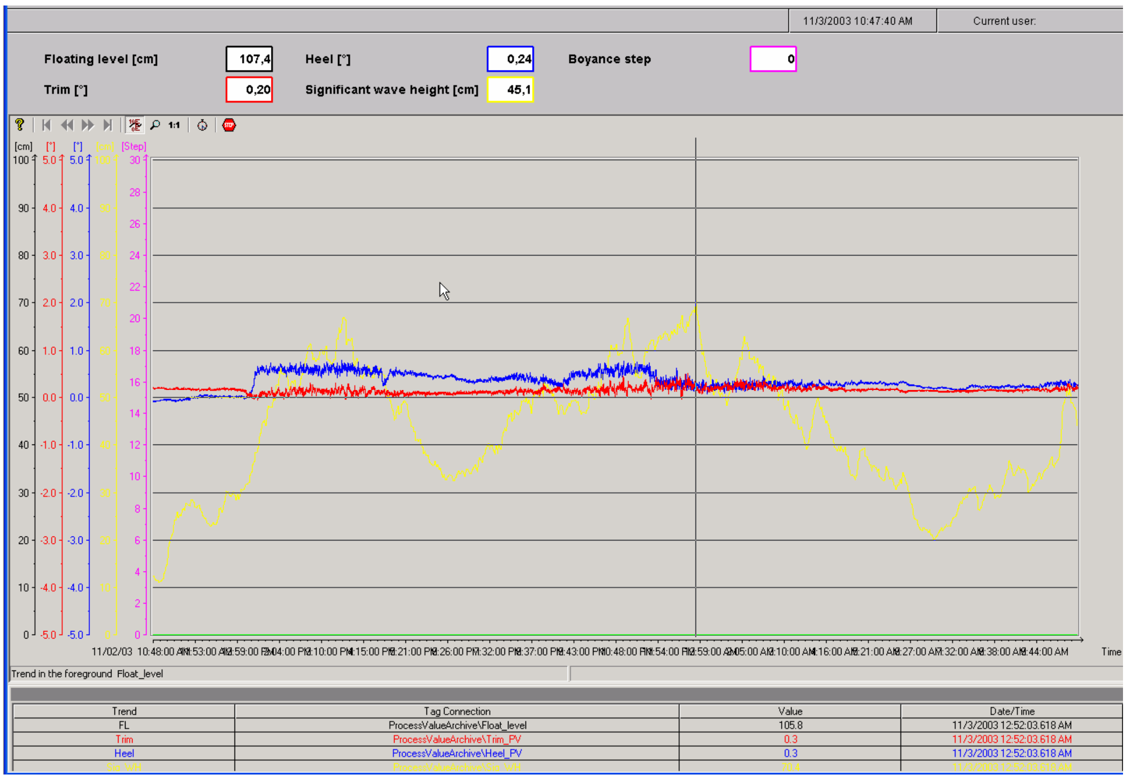



Automatikken har ikke været i drift i perioden mellem ovenstående screen dumps – d.v.s. i 65½ timer. Der har i perioden været bølgehøjder op til 0,7 m significant. Ved periodens start var ballastkamrene på dækket kun delvis fyldt, og der var væsentlig mere ballast i højre side.

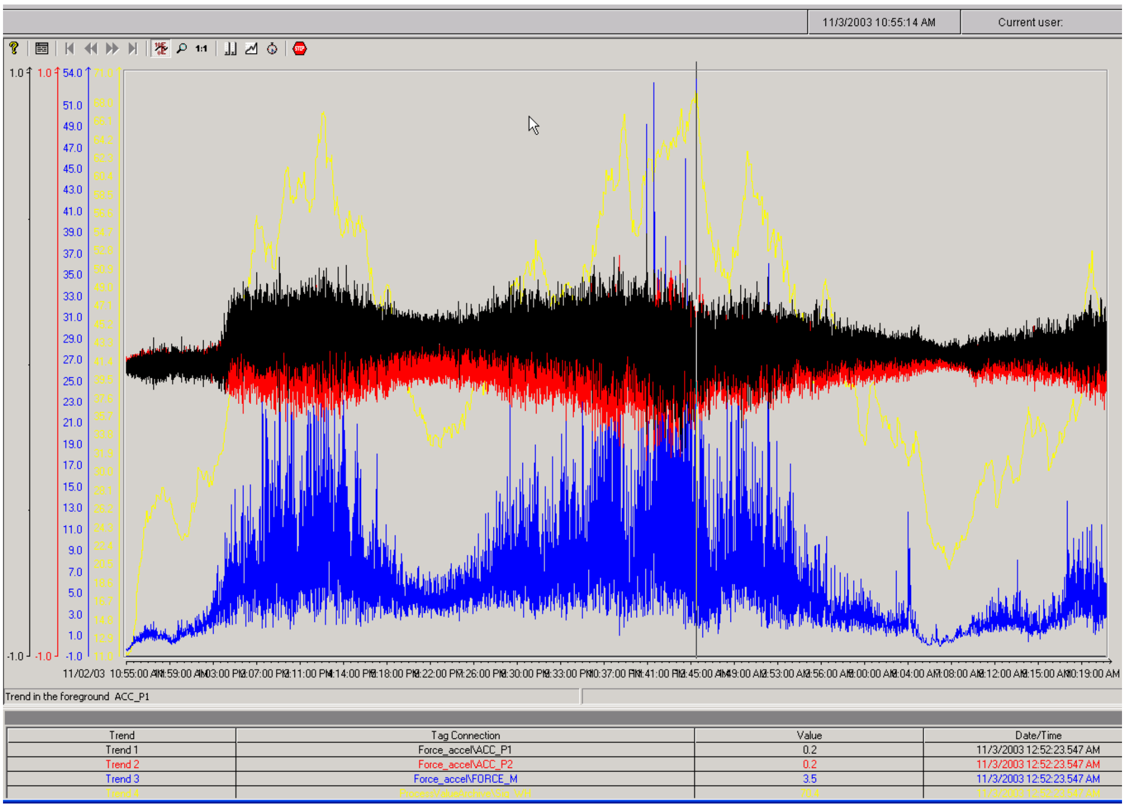
Det fremgår, at platformen i perioden er krænget 0,77° bagover (Heel), hvilket kan tilskrives fyldning af ballastkamrene på dækket. Samtidig ses det, at platformen har rettet sig o,3° op i tværretningen (Trim). Trykket i luftkamrene er ændret i god overensstemmelse hermed, d.v.s. luftmængderne i kamrene 1, 2 ,3 og 5 er stort set konstante. Imidlertid viser tryk-/level indikeringen, at der er tilført en vis luftmængde til kammer 3 - luftmængden er øget ca. 9%. Denne lufttilførsel kan kun stamme fra luft, der rives med i vandstrømmen gennem dummy turbinerne. Ved forholdsvis store opskylsmængder, som der her må have været tale om (på trods af, at flydehøjden har været 50% større end den største registrerede søtilstand) er der så stor inerti i vand-/luftblandingen, at noget af luften bevæger sig under skottene omkring dummyturbine-sektionen og op i kammer 3.



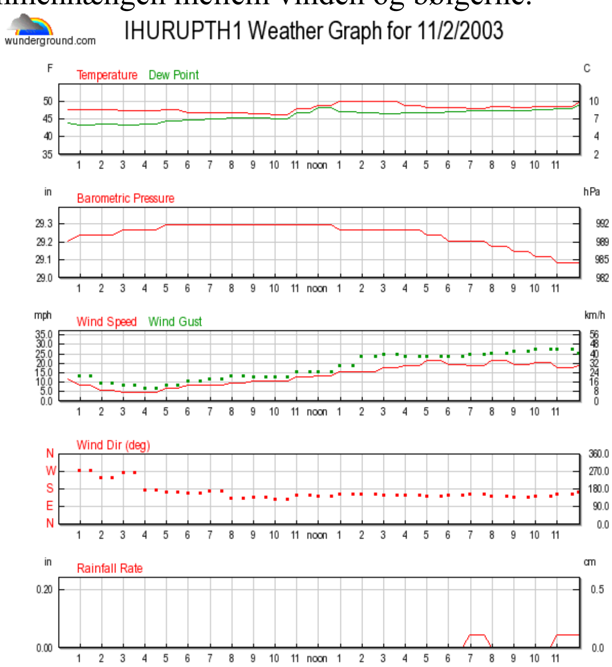

Det fremgår tydeligt af ovenstående skærm-dumps, at der ved den aktuelle flydehøjde bliver et så stort opskyl, når bølgehøjden overstiger ca. 0,3 m, at ballastkamrene fyldes og WD krænger lidt bagover. Denne krængning er en tilsigtet effekt af fyldningen af ballastkamrene/reservoiret og skyldes, at tyngdepunktet af vandet i reservoiret er placeret længere bagud end platformens tyngdepunkt. Det fremgår ligeledes, at den ovenfor omtalte tilførsel af luft til kammer 3 sker på et tidspunkt, hvor bølgehøjden er større end 0,6 m. I løbet af en halv time falder vandstanden i kammer 3 betydeligt, mens vandstanden og dermed luftmængden er næsten konstant i de øvrige kamre. Over en længere periode – her vist 4 døgn på det indsatte formindskede diagram – forsvinder ca. 10% af luftmængden i alle kamre bortset fra kammer 3. Denne reduktion svarer kun til halvdelen af iltindholdet i den friske luft. Det er således sandsynligt, at tabet af luft skyldes at en væsentlig del af ilten i luften forsvinder fra kamrene dels på grund af forrådnelsesprocesser dels på grund af korrosion af stålpladerne. Der bør foretages en iltmåling i kamrene for at få en bedre viden om dette forhold.

Appendix A




Denne skærm-dump viser accellerometrenes registreringer (platformens bevægelser) og kraften i ankertrossen. Det ses, at der er målt en kraft på 53 kN. Det skal bemærkes, at bølgehøjden beregnes ud fra målinger over et kvarter og derfor plottes senere end de tilhørende kraftmålinger etc.

Det er bemærkelsesværdigt, at der forekommer en markant stigning i bølgehøjden til mere end o,6 m significant med kulmination kl. ca 15.30, hvorefter bølgehøjden forholdsvis hurtigt igen falder. Registreringerne fra WD's vejrstation viser ikke en tilsvarende variation i vindhastigheden på dette tidspunkt, idet hastigheden var stigende indtil kl. 17.00. Derimod toppede den målte max, vindhastighed, "wind gust", allerede kl. 15.00. Vindretningen var næsten konstant. Sammenhængen mellem registreret vindhastighed og signifikant bølgehøjde er således ikke åbenbar. De målte vindhastigheder og vindretningen vil senere blive lagt ind i SCADA-systemet,  hvilket skulle giver et bedre overblik over sammenhængen mellem vinden og bølgerne.




Appendix A

Wave Dragon Progress Report XIII

Date: 19/11/2003

Location: Wave Dragon Test Site 1 (Nissum Bredning)

Present: JP Kofoed, Eoin O'Donovan, Martin & Per (AAU)

Report:

On this particular visit to Wave Dragon, the following tasks were carried out:

- The evacuation pipe, used to pump air to the port shoulder chamber in the time of storm damage (9.10.03), was reconnected to the siphon turbine.
- GPS receiver was moved from the container window to a fixed location on the roof with USB extension cord used to connect to the USB hub. This had the desired effect of attaining more satellites (currently a maximum of nine as opposed to five previously).
- As one of the dummy turbines had difficulty in operating, some examination revealed that the problem existed with one of the solenoids for activating the hydraulic piston. It seems that saltwater corrosion has caused this problem (previously experienced on 23.06.03). In response to this a solenoid switch was taken from the aeration valve with the siphon turbine operating satisfactorily again.
- Silicon was applied to the interface between the base of the centre section and the gate on one of the cylinder gate turbines (steel-steel contact) as a preliminary test to solve problems with leakage losses here. There is also a need to examine the possibility of reducing the closing/opening time for the cylinder gate turbines. Currently, there is a closing/opening time of 20-30 seconds, resulting in timeouts in the SCADA system.
- Blinds were installed on both container windows.
- Strain gauges on the port shoulder and the main beam of the main platform were connected to the MGC+. During this operation, it was also noticed that there are problems with the amplifier cards which must be examined further.
- The hole in the container floor, allowing for the exhaust from the evacuation pump for the siphon turbine, was sealed.
- The trace of the planned trash rack was checked for obstacles. Four problems was found, pictures taken.

## *Upcoming Tasks*

- Re-align Weather station.
- Re-arrange pressure transducer (on pile) wiring.
- Clean pressure transducer.
- Treat underneath of container.
- General rust & paint job.
- Implement Network Management Project (Morten and Jens).
- Replace signal cable from platform to mooring pile.

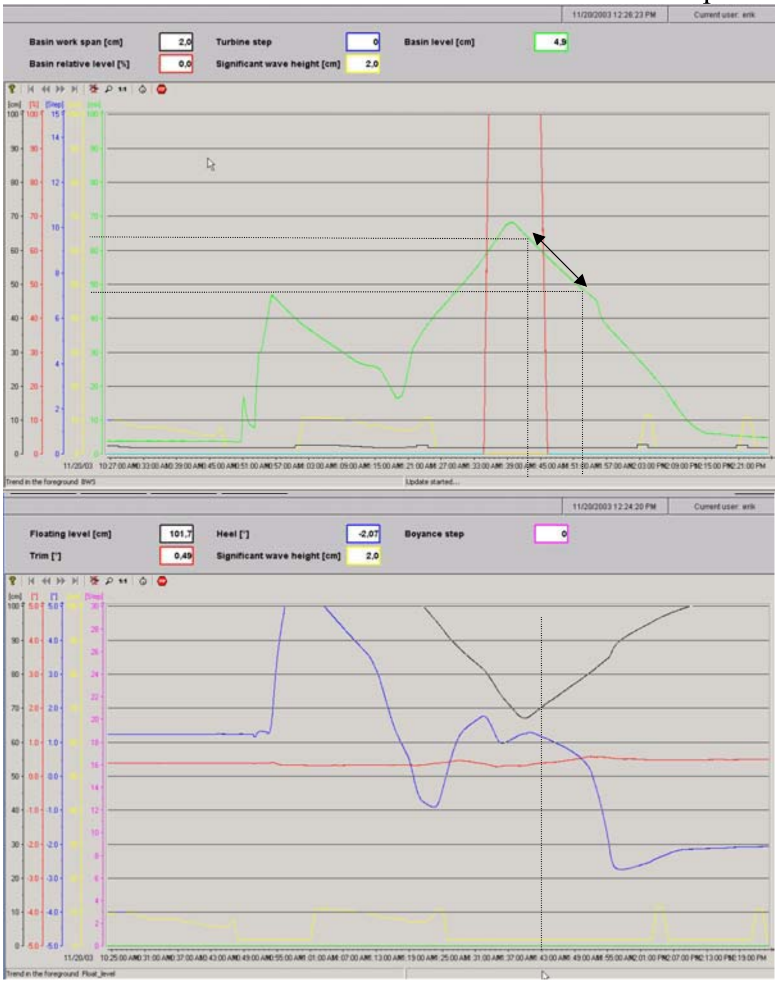
- Install accelerometers on port reflector.
- Install accelerometers on shoulders.
- Backup routines for data.
- Purchase some boxes for manuals.
- Organise electrical/hand tools more orderly in the container.
- Change the Belimo valves for air chamber or otherwise solve with stock valves.

### *SCADA system:*

- Implement default maintenance operation of valves.

**Læktest, 20. november 2003** **EFM**

Alle turbiner lukkede – en turbine tætnet med silicone på kanten af cylinderspjældet.




På 10 minutter (11:43 til 11:53) ses vandspejlet at falde med stort set konstant hastighed fra et niveau på 64 cm til 47,5 cm, d.v.s. 16,5 cm.

Idet netto bassinarealet er beregnet til at være 165,5 - 6 = 159,5 $m^2$ bliver læk tabet 2,63 $m^3$ svarende til 44 l/s eller en mistet elpoduktion på ca. 300 W ved højt flydeniveau.

Wave Dragon Progress Report XIV

Date: 26/11/2003

Location: Wave Dragon Test Site 1 (Nissum Bredning)

Present: JP Kofoed & Eoin O'Donovan (AAU)

Report:

On this particular visit to Wave Dragon, the following tasks were carried out:

- Efforts were made to turn the siphon turbine, however it seems that the lubricated bearing has been contaminated causing the oil in it to emulsify. This oil needs to be changed.
- Equipment manuals and project partner documents were filed separately and shelved.
- Some maintenance work was carried out on the raft with one of the drums moved from the rear to add buoyancy at the position of the hoist (front). Some of the timbers on the raft, which had become loose on hitting against WD, were also secured with extra screws.
- A halogen light was installed on the right container window to add visibility to the turbine area at night and also heat to the inside of the container. A second lamp will be installed in due course. A timer switch has been included in the operation of same.
- The remote controlled Web-cam's were cleaned and this will become part of the routine maintenance at each visit to WD.
- The pumps are activating the safety trip switch onshore. This problem needs to be investigated further.

Wave Dragon Progress Report XV

Date: 28/11/2003

Location: Wave Dragon Test Site 1 (Nissum Bredning)

Present: JP Kofoed & Eoin O'Donovan (AAU)

Report:

On this particular visit to Wave Dragon, the following tasks were carried out:

- The remaining modified wire rope mooring lines (with thimbles) of the 'W' were attached. These included the outer lines of the 'W' and the line on the port side of the centre of the 'W'.
- Force transducer was re-installed in the port cross-wire. In addition, some chain was included here to provide some additional security and prevent the transducer becoming the weakest link in the system. The latter needs to be wired to the junction box on the reflector arm.
- The weather station wind vane was re-calibrated based on GPS examination of WD location.
- Inclinometers to record heel and trim movements have been mounted on adjacent walls in the container. These need to be wired to the data acquisition port and power source respectively.

Wave Dragon Progress Report XVI

Date: 4/12/2003

Location: Wave Dragon Test Site 1 (Nissum Bredning)

Present: JP Kofoed & Eoin O'Donovan (AAU)

Report:

On this particular visit to Wave Dragon, the following tasks were carried out:

- A new bracket was mounted on the port shoulder pile for the remote Web-cam there.
- Work has begun on organizing the hand/electrical tools in the container. This job will be completed on the next visit to WD.
- Four plastic drums were delivered to the site for covering the valve chests for the siphon/cylinder gate/ dummy turbines. This work will be carried out at the next visit.
- The inclinometers for monitoring heel and trim were wired to the data acquisition ports and power source (24V) respectively. Some further calibration and examination needs to be carried out here to ensure readings are accurate and consistent.
- An electrician was called from Hurup Elektro to examine the problems experienced with the pumps (28/11/03). After some initial checks (for short circuits etc.), the pumps were activated and both were found to function without tripping the safety switch on-shore. Perhaps moisture in the junction box may have caused the problems initially. In light of this, some silicon gel should be applied to the junction box to absorb any moisture present.
  In any case, the small pump, for supplying water to the rubber bearing in the siphon turbine, was changed as a precautionary measure.

Wave Dragon Progress Report XVII

Date: 11/12/2003

Location: Wave Dragon Test Site 1 (Nissum Bredning)

Present: JP Kofoed & Eoin O'Donovan (AAU)

Report:

On this particular visit to Wave Dragon, the following tasks were carried out:

- Two Danfoss solenoids, which had shown significant saltwater corrosion and thus affected operation, were replaced in Dummy turbine 9.
- Checks were made to examine the fault with the siphon turbine. After careful examination, the non-return valve in the extension pipe was cited as the likely cause. The pipe was removed with the valve cleaned and oiled before checking the pipe for any blockages – none were found. The pipe was reassembled before flooding the reservoir and running the turbine. The latter was found to turn but at an extremely low rpm. However, it was noted previously (26/11/03) that the oil in the lubricated bearing had emulsified and needed changing. On draining the old oil from the bearing it was noticed that some swarf from cut threads has also contaminated the oil. This could be a serious obstruction to correct operation.
- The end stops were adjusted in cylinder gate turbines 4 and 6.
- Some further work was carried out in arranging the tools in the container. This will be completed by sorting the electrical tools on the far wall of same.
- In addition, some coarse zero adjustment of heel and trim was carried out on the inclinometers.

**040122, Visit report**

Bendy (FC), Per, Martin, JPK (AAU)

Wire from new pressure transducer Connected in PLC cabinet and to MGC+.
Repaired Dell PC (i5wdpc) setup and NetOp/VNC and Catman up and running. Re-install of weather station software needed.
Tried to install NetOp/VNC on new PC (i5wd2pc), but no success. The PC brought back home again.
Container treated under neath.
Worked signal wire connection via port shoulder.
Organized container.
Cleaned webcam lenses.
Checked temporary fix of signal cable to pile - look ok, but wave signal still ok.
Turbine 5 and 6 tested and put into operation. Was running fine and produced REAL wave energy for a couple of hours! Data from WCU regarding the power production, rpm etc. only arrives every few seconds - should be milliseconds.
Before departure the cylinder gate turbines was taken out of operation and the dummies activated. It is considered unsafe to have the generators running when WD is unmanned, as the automatic fire fighting system has not been installed yet.

**040226, Visit report**

TURB 9 sometimes stuck. Needs same treatment as TURB 8 by Wilfried et al. Not done today.

Growth in dummy turbine draft tubes. Moussels found on the lower 10-20 cm of draft tubes. Iron bar used for feeling the growth. Underwater cam with light needed for proper inspection.

Drilled holes in ballast cells filled with 'foam pipe' pieces - like ear plugs.

Testing of TURB 2, 3, 4 and 7. TURB 7 does not work - gives a DR_STAT=3. TURB 2 reports no RPM or Power, but by touching the runners with a small stick you could hear that the Runner on TURB 2 turned some thing doule as fast as TURB 3 (which works as expected - this also goes for TURB 4). This probably means that the generator in TURB 2 is not breaked at all.

It was also noted that no current was shown in the SCADA system for any of the turbines, although power was produced. By looking directly at the value coming from the WCU using Step7 it seemed that current values were transmitted from the WCU to the PLC.

It was observed that short wave period combined with high water level in NB resulted in extreme transfer values in the calculation of the Hs in the PLC. The matrix used needs to be checked.

'Struts' on back ropes. The struts produced in the workshop turned out to be made with a too small opening in the hook going through the hole in the knee. It is brought back to the workshop and will be modified.

Check measurering of trash rack. It was discovered that the reason for one of the rack plates seemed to be too short, as reported by Bendy, was actually caused by a mistake in the installation. The plate in front of the siphon turbine

New PC installed.

Solar cells for weather station inspected.

**040304-05, Visit report**

Present: JPK & Jens Jakobsen, AAU

Working on CAN-bus communication. New factory made cables connected, terminations checked, baud rates set. Found that MGC+, ML71 unit, works as expected. Detailed evaluation of signals on CAN-bus by using a scope. Do data, but network management data, from Unigate on CAN-bus. Verified through Step7 that data does arrived to the Unigate. However, no data is put on the CAN-bus by Unigate.

Work on the system entailed LARGE problems for the PLC. The profibus stopped working properly. Complete, simultanous close down of all units on the profibus necessary to get PLC and profibus up and running again.

Installation on PC's:
- GPS, Creative WebCam on i5wd2pc.
- Cyclic data acq. setup using Catman on i5wdpc.
- NetCam Watcher on i5wd2pc.

New strut on starboard back rope installed.

HC visited along with Taus and 3 potential investers friday at noon.

**040306-07, Visit report**

Visit by Per Bruun Madsen & Marting Thorsøe.

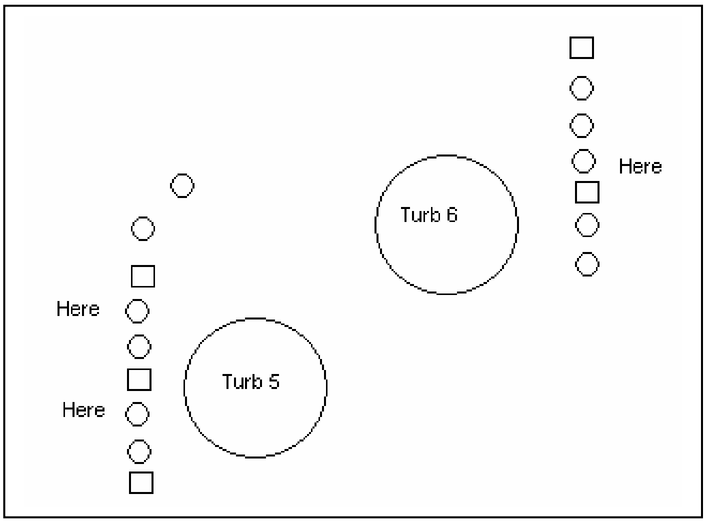
Painted the pipes on the platform and filled them with cement.
Modifyed TURB 9.
Exchanged halogen tube in starboard lamb on staircase.
Sealed leaks in reservoir.
Started rust and paint job at starboard side.

**Log for the weekend 24-25 March**

Saturday:
Sealed the holes in the fence round the turbine area using ion-mesh.
Removed pressure cylinder from turbine 8 and took it in for reappear.
Changed fittings for the turbines 9 and 10.

Removed white paint from pipes by ramp, the paint could be removed by rubbing. The pipes were painted last the 6/7 Marts 2004. Repainted the pipes with rust protecting paint.
Started to remove rust and paint at the fence around the container.

Sunday:
Tried to fill holes in the bottom of the turbine area, but had trouble making the filling stick in the holes. There was too much water in the turbine area. It is necessary to remove all the water from turbine area to be able to fill holes, but the wind was to strong to do so. Tree holes were filled as illustrated:




Moved box with chains and metal parts from the platform infront of the container to the roof of the container and secured it.
Removed rust and painted ventilation pipe by dummies in the turbine area.
Removed more rust and painted the fence around the container.

**040402, Visit report**

By JPK

Chain meant for keeping starboard reflector 'in the area' in case of joint failure, has failed (chain locks on reflector). Clearly it has not been long enough for low floating levels / large negative heel.

Endstop on TURB 9 closed adjusted.

SG amplifier boards in MGC+ checked. Only board 6 (boards 6 to 11 are SG amplifiers) are working.
- Back card (AP815's) 6 and 7 swapped, still only board 6 working - indicating the problem is not with the AP815's.
- Front boards (ML801's) 6 and 7 swapped, then slot 7 is working and 6 not. Indicates fault on ML801.
- ML801 from slot 5 (normally used with AP801 back card without problems) tested in slot 6 seems to work fine.
- ML815 from slot 8 tested in slot 6 - not working.
- ML815 from slot 6 tested in slot 8 - at first working, then not working.
- ML815 from slot 6 tested in slot 9 - not working.
- ML815 from slot 6 tested in slot 10 - not working.
- ML815 from slot 6 tested in slot 11 - not working.
- ML815 from slot 6 tested in slot 6 - not working. This work earlier. I'm afraid something is harming the ML801 cards! Could it be the the AP815's in slot 8 - 11?

ML801 in slot 1 - 5 are Hardware rev. 1.12, while 6 - 11 is rev 1.13. All have Software vers. P5.16.

All back and front cards in slots 6 - 11 are brought home to be send to supplier for repear.

Re-activation of CAN-bus after messing around with the MGC+ proved to be a little difficult. However, by the help of Jens J it is now working again. See mail from him for details on what to do.

I then tried to run the cyl gate turbines. Only TURB 3 seems to run without problems. By pushing the runner blades with a stick it was felt that the runners of TURB 4, 5, 6 are stuck. TURB 2 is not completly stuck but harder to turn than TURB 3 and 7.

TRIM zero adjusted in MGC+ by 0.07° - seems to be fine now. Target for trim set to 0 in SCADA.

Placement of fire fighting system. I think the only suitable place for both the bottle and electrical board is behind the entrance door. I will bring a wooden plate 1142 x 1398 mm for placing in the windows next to the door, so the tools can be moved to here.

## Working log from Wave Dragon 17-18.04.04

This log was written by Per Bruun Madsen and Martin Thorsøe, after working on Wave Dragon the weekend of the 17-18 April 2004.

**Saturday 17.04.04**

- **We had a lot of problems this day**. When we arrived we didn't have a key to unlock the boat and had to open it by force. When we got on the water the engine had a malfunction, to fix it we vent to a store in Agger. Therefore we didn't start the work before 2 in the afternoon.

- **Painting Drum.** We cleaned the painting drum, on platform. It had apparently been tilted during a storm and there was paint all over.

- **Painting job.** Continued the rust and painting job on the fence round the container.

**Sunday 18.04.04**

- **Fixed the raft**. We checked all the oil drums for leaks, none was found. Added 2 drums to the opposite side of the crane on the raft. When checking the drums for leaks we found that some of the ropes keeping the drums in place were broken, they were replaced. The broken moorings were replaced with new mooring lines and the raft is now secured by 4 mooring lines.

- **Filled water on the hydraulic pump**. We filled the hydraulic pump with distilled water, because it had been running dry. This wasn't enough to fix it though, so Bendy arrived and repaired it.

- **Put up antenna at bollard.** We in stored a new antenna at the pole (bollard) in front of the wave dragon, fastened the wire and connected the wire in the electrical box.

- **Painting job.** Continued the rust and painting job on the fence round the container.

For more information look at the pictures taken the weekend, they are located in the folder

**040419 Visit report**

By JPK

Out there: JPK (AAU), Armin (West Control)

Communication problem due to buffer overrun in WCU because hardware handshake not working.

Should not be a problem if data amount is reduced (from 48 to 17 bytes). This working fairly well. Data update rate 1.5 to 2 Hz.

Scale factor problem resolved. Was not enabled in WCU.
Test:

| | | | |
|---|---|---|---|
| Scale | 50 | 100 | 150 |
| RPM | 215 | 195 | 165 |
| W | 100 | 155 | 150 |

Mechanical problems with turbine 4, 5, 6 (not able to run, even in test mode). 4 and 6 could be turned by hand but very hard. 5 could not be turn by hand. 7 ended up running after som motioning by hand and running in test mode for a while.

Problem with hydraulics.

Solenoid on power pack failed. Permanent magnet used temporarely instead. TURB 2, 3, 9, 10 can not be operated.

A total of 13 old solenoids are on the valve blocks. They should be replaced by new model.

Measurements performed on siphon turbine for Wilfried. A+B = 350 mm, B = 31 mm, C = 16 mm.

**040717, Visit report**

Thomas, Søren Krogh, JPK (AAU) and Xavier (FC). Also 3 TUM working here, but not covered in this report.

Main mooring line inspected. Looks in good shape. New signal cable to pile attached to reserve main mooring line. New bouys attached as well. Steel wires from ramp inspected - no problems seen. New ropes from pile to tip of reflectors installed. Port side rope has a unworked length of 40 m, starboard side rope is 37 m plus 2 m of chain at reflector tip. Bouys have been attached to these ropes as well.

It was observed that the ropes previously installed from reflector tips to center bouy in front of ramp (to maintain geometry in periods with no loads) were there no more.

**040813, Visit report**

Present: JPK, Martin Thorsøe, Tim (AAU) and EFM (LOW).

Underwater inspections and video filming:
- Starboard lower fishtail not close to shoulder structure as it should be, approx. 25 cm room.
- Port side lower fishtail, port pad eye for chain holding the fishtail, broken off.
- Sandfill ind back and main anchors check. No significant change since last inspection (one year).
- Pressure transducer on pile dismounted. Tested by connecting directly in board in container, still not working. New pressure transducer ordered at H. F. Jensen (different type), shoulde arrive within 2-3 weeks.

Fan coil and pump for cooling installed. Not enough hose, so cooling on hydraulic power pack not installed yet, but both thermostats are in place.

Problem with hydraulic cylinder for activating butterfly valve on siphon turbine identified, pins in solenoid corroded. Sloenoid changed, problem fixed.

Similar problem for TURB8, should be fixed at next visit.

Wind anemometer and rain measuring device exchanged.

IP setting for wireless bridge at WebCam3 changed from 10.1.1.36 to 10.1.1.28 to get it out of the DHCP IP adress range.

Batteries in indoor thermometer exchanged.

New port side G rope mounted - however not in shackel at bouy, but in chain.

Distance from crest to pile checked in eastern wind (stretched back anchor chain) - 14.85 cm.

PRES_R2 checked - seems to be working ok. However, latter (040817 13.40) it was found not to working (constant value of -54).

Bring on next visit:
- 'Karabinhage' for boat.
- Plastic bags.
- Coffecups.
- Hobbyknifes.

**WD Visit report, 04.08.24**

Present: LC (SPOK), Tim, MKR, JPK (AAU)

Upgrade of LAN:
4 port 10 Mbit hub replaced by Linksys 8 port 100 Mbit switch.

WLAN access point integrated in ZyWall 10W disabled and replaced by Linksys WAP11 WLAN access point with external antenna. Antenna placed on container roof, point towards mooring pile. Loss of connection to WebCam3 should thus not happen anymore.

Wind anemometer:
Lately the wind speed has not been measured, although wind direction is. Various attempts to fix this were done by exchanging anemometer and/or transmitter – however, without success. Unfortunately, it seems like the equipment is not good enough for the rough conditions, so **a new instrument is needed**.

Reprogramming of level switch logic in siphon turbine:
Together with René Arnskov, Balslev (on remote access), the level switch logic in siphon turbine control was corrected. Now the lubrication pump starts when the siphon turbine is asked to start and the generator is not released until water is present at the level switch. If water is no longer present at the level switch the generator will brake after 60 s. However, the aeration valve does not open and as soon as there is water at the level switch again, the generator is released again. **It needs to be considered if the turbine should be completely shot down (the alarm then needs to be acknowledged manually before it starts again), or the very slow rotation (5-10 rpm) in braked mode is ok for the rubber bearing?**

Dummy turbines:
One solenoid for turbine 8 was malfunctioning. Getting it of was quite a job – force had to be applied! Finally, it was replaced. However, the general condition of the dummy turbines is poor. They very easily get stuck, primarily due to the heavy corrosion. A guiding system is badly needed. Heavy grease was applied to all three turbines, which did the job for the moment, but it is certainly not a solution in the long run.

Hydraulic power pack:
The release valve on the power pack proved to be malfunctioning. After talking to Torben Helligsø, Danfoss, another solenoid was tested, but that did not change anything. Neither did motioning of the adjustment screw while running. This should flush dirt in the valve if that was what was causing the problem. However, putting on a permanent magnet on the valve seemed to do the trick, however, it means that the hydraulic pressure cannot be released by the PLC. This points towards a bad electrical connection from the PLC to the solenoid, being the problem. This was not investigated further, **but needs to be taken care of soon**.
The water level in the power pack was low. The last 5 L which was available was filled in, but more is need – **order now and bring on next visit**.
It was also noted that the needle manometer next to the filter on the power pack was leaking.

Cooling system:
After the installation of the cooling system at last visit, it had been working fine for some days. However, Friday it was obvious that it was not cooling anymore. The reason was found to be that the hose had fallen of the pump, due to insufficient securing of the pump – the pump had been moved around by wave action. Therefore a more stable setup with a wooden pole was made, which seems to have solved the problem.

Underwater takes in turbine draft tubes:

A stick for mounting the underwater camera on had been prepared and brought out there, to enable inspection of the fouling inside the turbine draft tubes. However, it seems the camera was fixed to tightly to stick, resulting in crushing of the glace – and this was not seen until the camera stopped working as it was submerged!!! **New camera needed.**

SG's:
MGC+ and CatMan was setup to acquire data from SG's in addition to all other data. Now SG and all other available data is store continuously in half hour data sets.

**040910, Visit report**

040908: Per & Martin (AAU)
040909: Per & Martin (AAU), LC & EFM (LOW/SPOK)
040910: Leen & JPK (AAU), LC & EFM (LOW/SPOK)

040908:
Checked waterlevel in ballast tanks in both platform and reflectors, results are given in Excel sheet (on i5wdpc). Power (24V) made available for new pressure transducer on pile.

040909:
Submerged weight of moussles estimated - 15 kg pr. m^2, 10 - 15 cm thickness, underneath damping plate.

040910:
FORCE_C connected - however junction box on reflector contained water, again. Clips corroded.
Readings looks veird - 1800 - 5000 kN! Monday 040913 the reading was constant 17000 kN.
New pressure transducer from H. F. Jensen, type PSL 4.1.1 output 1-5V, was temporarely installed.
It is connected to channel 5-2 on the MGC+. Readings does not look right using the given (from H. F. Jensen) calibration constants, but there was no time to investigate. Will be check on next visit.
Internet connection faulty - proved to be a Sonofon problem, nation wide.
Problem with solenoid for TURB9. Lowest solenoid removed - a hole in the valve anchor was seen - hydraulic leak. New anchor ordered, as well as 'Safe Chill' - hydraulic fluid.

**040923, Visit report**

By JPK & NH (AAU)

Fractured 'anchor' in hydraulic valve block for Dummy turbine 9 changed. Hydraulics activated.

**040925, Visit report**

JPK (AAU), TT Nautech

Activated Signalix SMS messenging in case of grid fault, fire alarm and fire alarm fault.

WebCam1+2 and WLAN access point added to Q5, so they can be rebooted (together with i5wd2pc).

Ext. light can now be activated using Q8.

WCU can now be reset via Q7.

Attempt to activate wind measuring station - didn't work.

Setting up i5wd2pc after harddisk brakedown - map software still need to be installed for GPS to work.

Accelerometers on shoulders taken down and brought back home for repair.

WebCam1+2 wiped off.

Stainless steel plate fixed on siphon turbine, sheilding the coupling area.

**040930, Visit to WD**

Visit by Erik Grove Nielsen, Thomas Thøgersen (nautec), JPK (AAU)

Introduction of EGN to the WD and problems onboard. He thought he might be able to help talking care of solving the gnenrator control problem.

It was observed that bolts in connection between hydraulic cylinders and cylinder gates in dummy turbines where lost (in TURB8) and loose (TURB9) due to the more intensive use of the dummies during continous operation the last week. However, time had gone by before we got to fixing it. Locknuts (or contra nuts) where not used - have to be used in the future. Will be brought at next visit.

Due to the excellent weather conditions the priority of todays visit was put on getting the jobs at the pile done. Thus, time was not either found to fix a temporary level switch in the siphon turbine, check for growth in CGT's or to fix a thermometer in CGT no. 5. We have to take care of that at next visit - the restauration of additionally 2 CGT's next week.

All day was spend on mounting a new wind measuring station and a new pressure gauge for wave measurements at the pile. Wind speed (WINDSP) and direction (WINDDIR) sensors were mounted on a pipe on the top of the pile. The sensors where placed 3.05 m above the the top flange of the pile, ie. 13.05 m above the seabed.

The pressure sensor was installed on a rack, that can be retreived without diver assistance, positioning it at 4.03 m above the seabed, 1.0 m away from the pile - corresponding to point 3 in the report on 'Placement of pressure transducer for wave measurements at Wave Dragon.

24V DC supply to wind and wave sensors was taken in the PLC cabinet (top row clips to the right) and put on red (+) and blue (-) outer wires around the core in the newly installed signal cable to the pile.

WINDSP signal was put in clip 1 (+) and 2 (-) in JB on pile.
WINDDIR signal was put in clip 3 (+) and 4 (-) in JB on pile.

PRES_P2 signal was put in clip 13 (+) and 44 (-) in JB on pile.

For reference, underside of rack around stair on pile was measured to be 6.7 m above seabed.

# 10. Appendix B: Overtopping analysis including heel in crest freeboard calculation

An analysis has been performed where the crest freeboard has been calculated taking the motion in heel into consideration. This appendix are considering data from the period 05.12.2003 to 15.12.2003 and has primarily been prepared by a foreign student, Tim Florizoone, visiting Dept. of Civil Engineering, Aalborg University during August and September, 2004.

# 1. Introduction

During the last year lots of measurements have been done on board the Wave Dragon, Nissum Bredning (WD-NB) prototype.
All the available data were stored in CSV-files and collected day-by-day.
In order to interpret these data and work on it, the necessity to transfer it into a better-organized database became clear. A Matlab-program seemed to be the smoothest way to achieve this transfer.
This report explains in detail the working of that program, followed by a description of its practical use.

# 2. Program information

The program consists of 4 main parts: the files *lad.m*, *dataWD.m* and *range.m* and another 'run'-file. Dependent on the required result of the program (24-hour-data, figures,…) *run.m*, *runfig.m* or *stdev.m* can be chosen as possible 'run'-files.
What follows is a description of the structure of each of these M-files.

## 2.1.The file 'lad'

The data, imported directly from WD-NB, are available in a CSV- file. In this file the different values are separated by semi-colons and presented in the following way:

```
Date/Time;MS;Value
05-12-2003 00:00:00;384;13,8292512893677
05-12-2003 00:00:01;383;13,8292331695557
05-12-2003 00:00:02;384;13,8294906616211
```

At first sight the Matlab-command *csvread* looks to be the preferable way to import the data. Nevertheless, it appeared to recognize only the different values if they are comma-separated and if the decimal sign is denoted by a point. The string on line 1 cannot be recognized by *'csvread'* either. Therefore, the data should be imported as a text-file first. Hereby is chosen to make use of Matlab for the transformation, instead of adapting all the files separately with a time-consuming Wordpad *find and replace* command.

The Matlab-file *lad* imports all the available data and returns it into one matrix. This matrix contains 9 or 10 columns, dependent of the presence of Basin Level (BL) data ( BL can also be calculated based on Relative BL and BWS, cfr 2.2. remark (4)).
The file requires 2 input arguments:

- the exact point of time at which the data-collection starts in the following appearance: 'MM/DD/YYYY HH:MM:SS'
- 'y' or 'n': if the BL-data are available in a direct way or not
  The default BL-argument is set on 'n'.

The command *datevec* transforms the input string–argument into an array 'date'. The matrix substances are collected in 2 strings: 'dat1' en 'dat2', which are used later to construct the filenames of the CSV-files.
De string-array 'array' collects all the names of data imported from WD. While importing some of the data, we have remarked that both the names 'hill' and 'pitch' are used (same for 'trim' and 'roll'). To solve this inconsistency *load* recognizes which filename is used, via the Matlab-command *exist*.
The next for-loop saves the different components of the string array as separated variables 'word{i}'. This makes it possible to run through the different file-names when they are loaded further in the program.
The next step contains the veritable loading of the files. The text-files are read one by one using the command *textread('file','%q')*. In the next for-loop the comma-separated file is transformed into a matrix-column 'T(:,i)' using the following temporary variables and Matlab-commands:

- 'str': returns the string 's' in which every comma is changed into a point by means of the command *strrep*
- 'a': an array which returns all the possible positions of a semi-colon in the character array 'chararr' (command: *findstr(chararr,';')* )
- 'mem': returns the position of every second semi-colon

Knowing the position of the second semi-colon in every sentence, there is only a loop needed to return a character array with the required values. The command *str2num* converts the string 'temp' into a number.
The final output of the program is the 86340x9 double-matrix (or 86340x10 if BL-data are available) and a stopwatch timer. On a 2.40 GHz processor, the file-loading takes around 900s. This looks acceptable as this procedure has to be done only once. For all the following procedures the double matrix should be stored in the Matlab-workspace.

## 2.2. The file 'dataWD'

The M-file 'dataWD' needs 3 input arguments:
- The exact starting-date (as string) in the following form: 'MM/DD/YYYY HH:MM:SS'
- The loaded 'lad'-matrix
- The matrix 'Turbstep' which represents the used turbine numbers and the corresponding Turbine Steps (more precise description: cfr 2.2. remark (5))

The file returns a matrix, having the same number of rows as the 'lad'-matrix but containing more deduced data. The normal size is 86340x24. In Table 1 these are given together with its column-number, unit and (if necessary) its deduction.

| Nr. | Data | Unit | Formula | Remarks |
| --- | --- | --- | --- | --- |
| 1 | Date | - | O.d. | (1) |
| 2 | Time | - | O.d. | (2) |
| 3 | Significant Wave Height (Hs) | M | O.d. | (3) |
| 4 | Basin Level (BL) | M | O.d. | (4) |
| 5 | Floating Level (FL) | M | O.d. | |
| 6 | Head | M | *FL - (0.60 - BL)* | |
| 7 | Q Turbine | $M^3/s$ | $k_{Turb} \cdot A_{Turb} \cdot \sqrt{2\, g\, Head}$ | (5) |
| 8 | Turbine number | - | O.d. | |
| 9 | Power | kW | $g \cdot Q_{turb} \cdot Head \cdot 1.025$ | |
| 10 | Heel / Pitch | ° | O.d. | |
| 11 | Trim / Roll | ° | O.d. | |
| 12 | Relative Basin Level | - | O.d. | |
| 13 | Basin Work Span (BWS) | M | O.d. | |
| 14 | Crest Freeboard (CFb) | M | $FL + \sin\left(Heel.\pi/180\right) . 3,8$ | (6) |
| 15 | T-Waves | S | O.d. | (3) |
| 16 | L0p | M | $g . (T\text{-}waves . 1.2)^2 / (2 Pi)$ | |
| 17 | S0p | - | Hs / L0p | |
| 18 | R' | - | $\frac{CFb}{H_s}\sqrt{S0p/2.\pi}$ | (7) |
| 19 | Q' | - | $Q_{turb} \cdot \frac{\sqrt{S0p/2.\pi}}{\sqrt{g.(H_s)^3 .rampwidth}}$ | |
| 20 | P-wave | kW/m | $0.49 . 1,1 . T\text{-}Waves . H_s^3$ | |
| 21 | Eff. Reflection | - | $Power / Pwave.(Dist\_betw\_refl)$ | |
| 22 | Eff. Ramp | - | $Power / Pwave.(Rampwidth)$ | |
| 23 | Accumulated Turbine Volume | $m^3$ | O.d. out of 7 | |
| 24 | Accumulated Turbine Energy | kWh | O.d. out of 9 | |

Table 1

O.d.: Obtained directly

g = 9,82

rampwidth = 21,3

Dist_betw_refl = 0,147

**Remarks:**

(1) Date

This column represents the date as a number, f.e.: 20031224. To see this date properly in the Matlab-workspace, it's required to chose type 'long' in the Matlab-array editor.

(2) Time

The time is also represented as a number: HHMMSS. Same remark as above.

(3) Significant Wave Height & T-waves

These two data are only measured once a minute. Therefore a for-loop is added to show this minute-data 60 times during the whole minute.

(4) Basin Level

As mentioned before, the Basin Level data can be deduced directly or by means of BWS- and Relative BL – data. This last method is only used when the BL-data are not available (input-matrix 'lad' consists of 9 columns instead of 10): $0{,}60-\left(1-\frac{RBL}{100}\right)BWS$ .

It's important to observe that the measured and calculated Basin Level can differ (cfr. Fig 1). The higher the pitch, the bigger the departure. This deviation is neglected in this program although it can be quite significant.

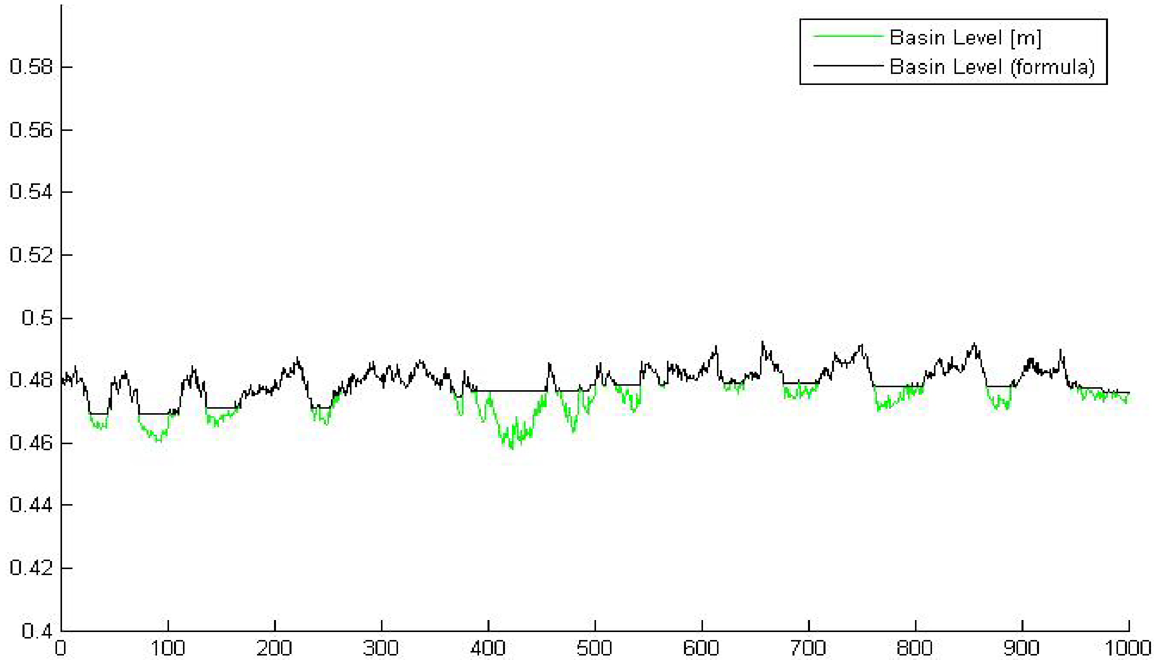



Figure 1

(5) Q $_{Turbine}$

The program is automated in such a way that it calculates Q, knowing only the vector 'TurbStep' and all the necessary k- and A-values. These values can be found in 'Calibration and Validation of Measurement System' and are summarized in the table below.

| Turbines | k | Turbine | A |
|---|---|---|---|
| 8 | 1,07 | 8 | 0.147 |
| 9 | 1,05 | 9 | 0.147 |
| 10 | 1,09 | 10 | 0.147 |
| 8+9 | 1,08 | | |
| 9+10 | 1,09 | | |
| 9+10 | 1,07 | | |
| 8+9+10 | 1,10 | | |

Table 2

'TurbStep' is a 3x2-matrix. The 2 columns contain the numbers of the turbines that are working and the steps associated with that numbers, respectively. The steps should be filled up in a rising order. If less than 3 steps are defined, 'Turbstep' should be filled up with zeros.

For example:

```
turbstep=[          8          2;
        9      5;
        10     8 ];
```

Because the program makes use of variable names as 'k_turb{**89**}', 'k_turb{**8910**}' instead of 'k_turb{**98**}' and 'k_turb{**1089**}' f.e., it's very helpful to use a program that picks the maximum or minimum value out of a number array. Normally the Matlab-function *min()* and *max()* can be used, but in some Matlab-versions there turned out to be some problems. Therefore it's needed to save the 2 files *mini.m* and *maxi.m*, as substitutes, in the same directory as 'dataWD.m'.
So far, the turbine numbers are limited to 8, 9 and 10 (see  Possible development of the program).

(6)  Crest Freeboard

(7)  R'
R' is calculated out of Crest Freeboard second-period-data and Hs-data, which is only measured once a minute. Making a minute average of the Crest Freeboard data turned out to be the most precise solution.

## 2.3. Range

This file picks out the desired data from the 24-hour data available. Hence, starting-hour and period are needed as input arguments, beside the 86340x24 matrix and the filename, returned by the *DataWD* -file. A fifth and sixth input argument indicate whether a plot, respectively an average calculation are needed.
The required input arguments, their description and type are summarized in Table 3.

| Input argument | Type | Description |
|---|---|---|
| start | String: 'MM/DD/YYYY HH:MM:SS' | Starting-point of data |
| period | Number | Period in seconds |
| data | Double array [1x _ ] | Desired data, called up by its number (cfr Table) |
| res | Matrix [86340x24] | One-day-data, returned by file 'dataWD' |
| figureonoff | 'y' / 'n' | Indicates whether a plot is desired or not |
| showaverage | 'y' / 'n' | Indicates whether average data should be displayed in the command window or not |

Table 3

The output of *range* consists of 2 matrixes:
- 'Result': Matrix that contains all the desired data, first column denotes the time. The data appear in the same order as called up in the array 'data'.
- Average: Matrix, collecting all the averages

The row-number, from where the data should be copied into the resulting matrix, is found by comparing the starting-point 'start' with the dates in the second column of the 'res'-matrix. If both dates are the same, the starting-number is known. Next step consists in copying all the required data during the desired period. These desired data are given by the input argument 'data'.

The remainder of the file is built up out of blocks with the following structure:

```
For i=1:t
  if data(1,i)==  data number
        if figureonoff=='y'                                              Plot
              h(counter)=plot(result(:,counter));                  Store plot in h-vector
               axis([0 period 0 1]);                                      Determine range of
               x- and y-axis   L{counter}='Significant Wave Height [m]';  Store legend-information in L-
               vector
              end
        sum=0;
              Average calculation
        [m,n]=size(result(:,counter));
        for j=1:m
              sum=sum+result(j,counter);                           Add all the data
        end
        aver=sum/m;
              Calculate average
        average(counter+extra)=aver;                        Store average in array 'average'('extra': cfr
                                                             remark 2)
         av=num2str(aver);                                               Show average value
on display
        if showaverage=='y'
              disp(['Average          :    ' av])
        end;
         counter=counter+1;
end
```

At the bottom of the file plot and legend information are collected. To improve overview an extra column, which shows time-information, is added in front.

**Remarks:**

(1) The if-construction on lines 13-16 is required due to a bug in Matlab: for some dates the command *datevec*, which transforms the different parts of a date-string into an array, fails to give the correct number. As this seems to be the case only when second-data switch from 59 to 0, the problem can be solved using a simple if-construction.
(2) In the case of the $Q_{turbine}$-calculation (i=7), the Q of the 3 turbine steps separately is calculated, just as the standard deviation. This explains the presence of the variable 'extra', added to 'counter' in the preceding program structure. In this way Q-data exist of 5 columns if it's called up in the 'data'-vector.
(3) The final-second-data of a file are sometimes missing. This incompleteness can result in negative values for accumulated volume and energy, because these are calculated as the difference between the ends of the matrix. To solve this problem while-loops are added on the following lines: 440-443 and 455-458.

## 2.4. The 'run' - files

### 2.4.1. The file *runfig*'

This file, like the other 'run'-files, is meant to deliver the input to the *range*-file. Table 1 can be used as explanation for the different variables. 'Runfig' contains the loaded matrix as input-argument and returns the required data. A default-function is added in case the *runfig*-file has no input arguments.

### 2.4.2. The file *run*

This file has the same function as the *runfig*-file, but is meant as a fluent means to gather average data of the whole day. A for-loop is running through the 24 hours in blocks of 30 minutes, which results in a matrix with 48 columns. The data are exported as an output of the file and is stored in an excel-file *Average Data.xls*. This file represents this data in a well-ordered way and should be stored in the same directory as the M-files before starting the run-file.

**Remarks:**

(1) Normally only the file-name and the 'turbstep'-matrix should be adapted in this file. Changing the order of the data-vector would cause some errors in the Excel-file.

(2) Sometime errors can appear in running through the first half an hour-data. The reason for this is that sometimes the first-minute-data are missing. Moving first-hour-data out of the loop appears to be an acceptable solution. In this way the starting-date can be adapted to 00:01:00 f.e..

(3) The command *xlswrite*, used to export data to the excel-sheet, is only available in Matlab 7.0. In earlier versions as Matlab 6.5 the data should be copied manually to the sheet.

(4) The command *strtok* on lines 32-33 and 37-38 is only added to reduce copy-work and has few importance.

### 2.4.3. The file 'stdev'

This file returns the average of the global Q, its standard deviation and the Q-averages of the separate turbine steps during a time-interval. All the variables are exactly the same as in the preceding files. Only the variable 'interval' is added. It denotes the length of the time-interval (in seconds) in which the average and standard deviation are calculated.
The main part of the file consists in finding a good way to represent the time, in order to pass it as the string-argument 'start' to the range file.

# 3) Practical use of the program

This chapter describes the successive acts need to be executed make the program work:

1) Save the 9 or 10 (with/without BL-data) CSV-files in the directory.
   Pay attention that the starting-date in the name of the file must be the same as the first point of time of which the data are measured.
   F.e.: if the data aren't collected from 11/12/2003 00:00:00 on exactly, but 1 minute later the filename should be: ProcessValueArchive_..._2003121100**01**00_20031211235959.

2) All the following Matlab-files should be stored in the same directory: *dataWD.m* , *laden.m* , *range.m* , *run.m* , *runfig.m* , *stdev.m* , *mini.m* and *maxi.m*.

3) Now the data should be transformed in a Matrix using the load-file.
   Example: L=load('12/05/2003 00:00:00','y'); if the basin level data are available and the data start at 00:00:00.

4) Variables mostly required to be adapted in the 'run-files':

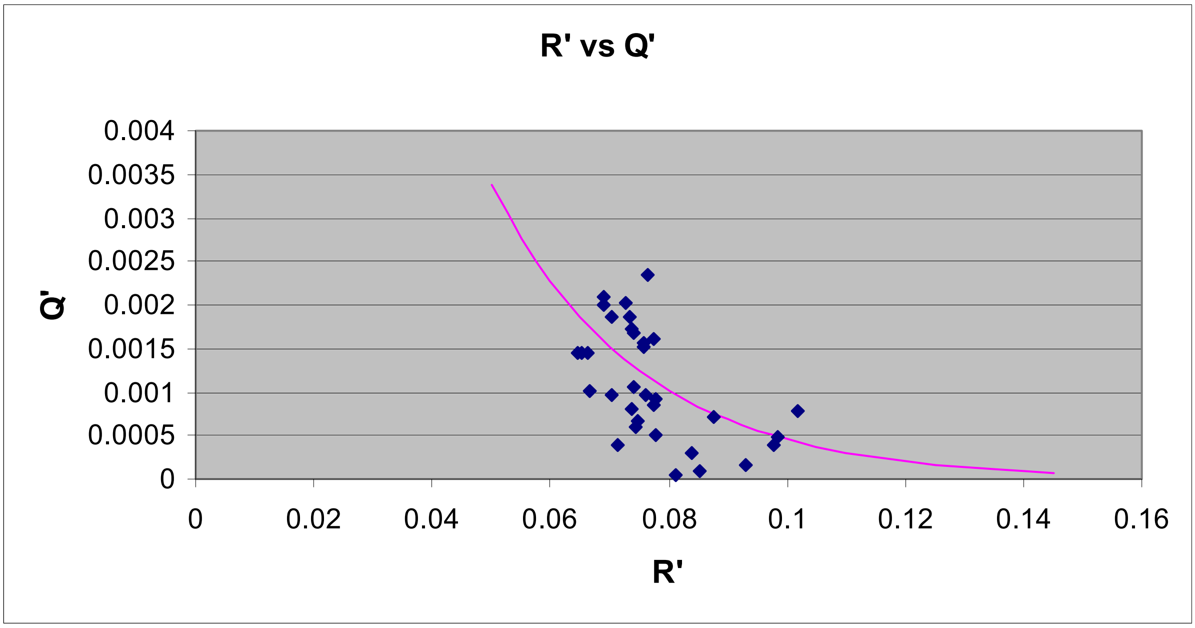
- run.m: file, turbstep
- runfig.m: file, turbstep, period, data and starting-hour (line 18)
- stdev.m: file, turbstep, period, interval

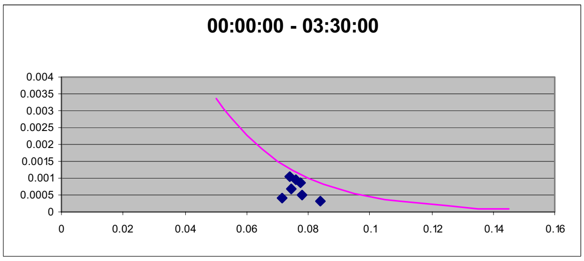
5) M=run(L)/M=runfig(L)/M=stdev(L) returns the required result.

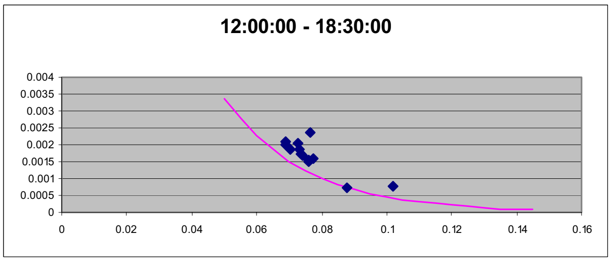
# 4) Results

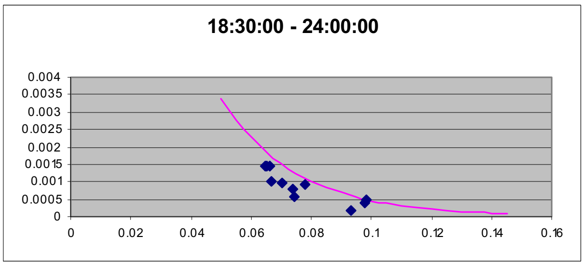
Underneath the R'-Q' diagrams are plotted, together with 24-hour-plot of Crest Freeboard and Heel.

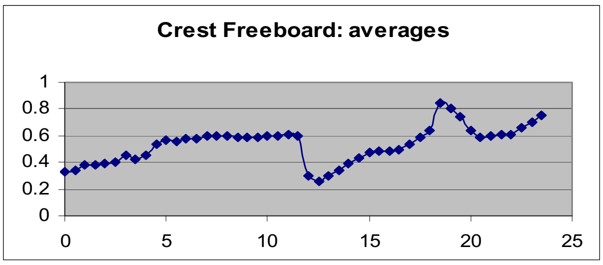
a) **05/12/2003**



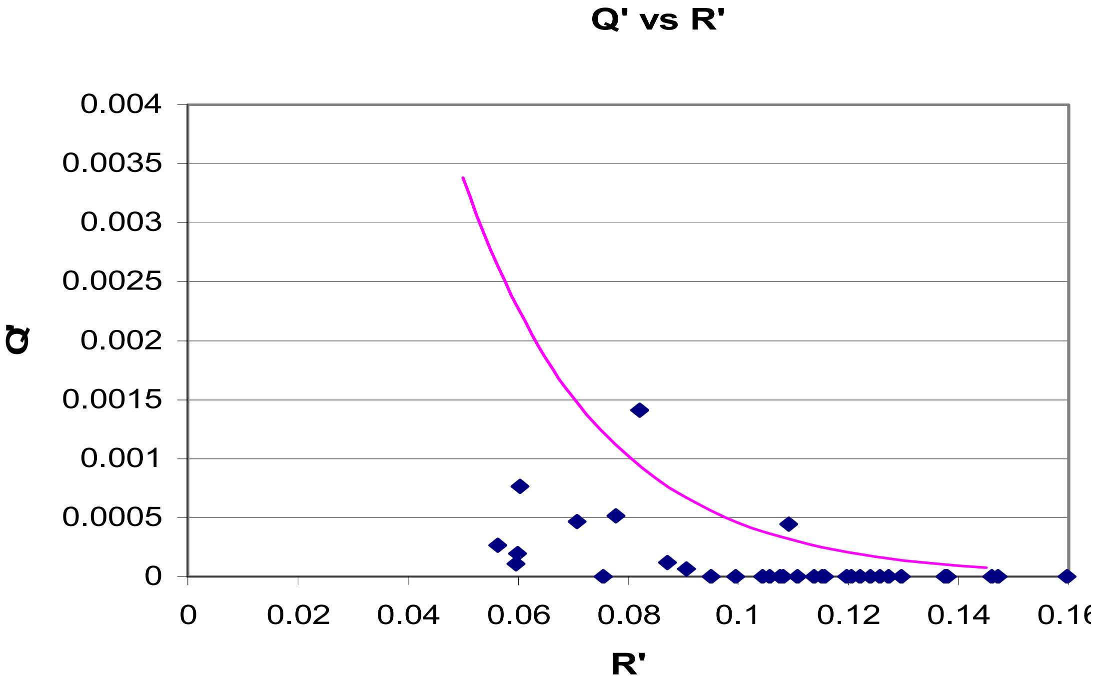



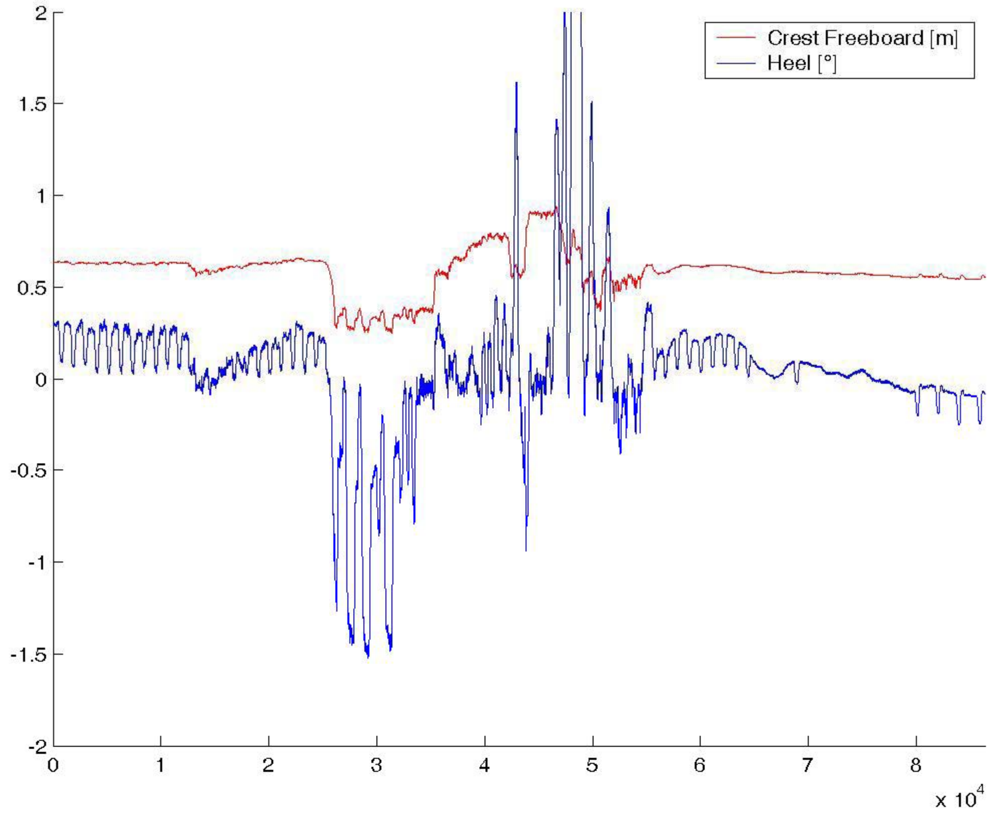



**b) 11/12/2003**

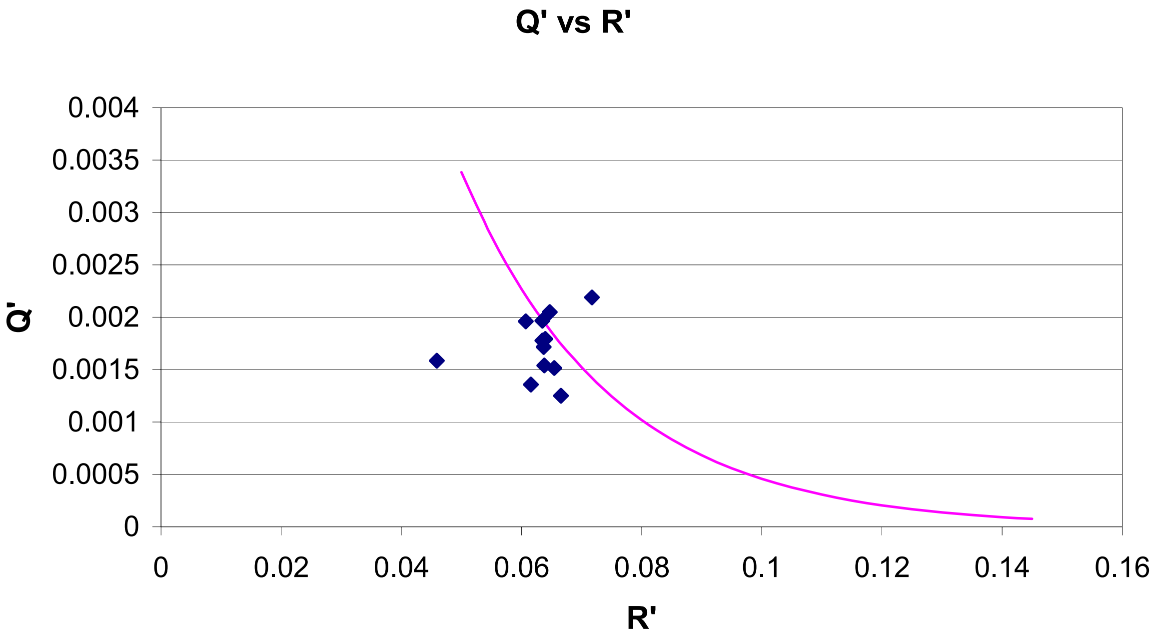


Q' vs R'
Q'
0.004
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
R'

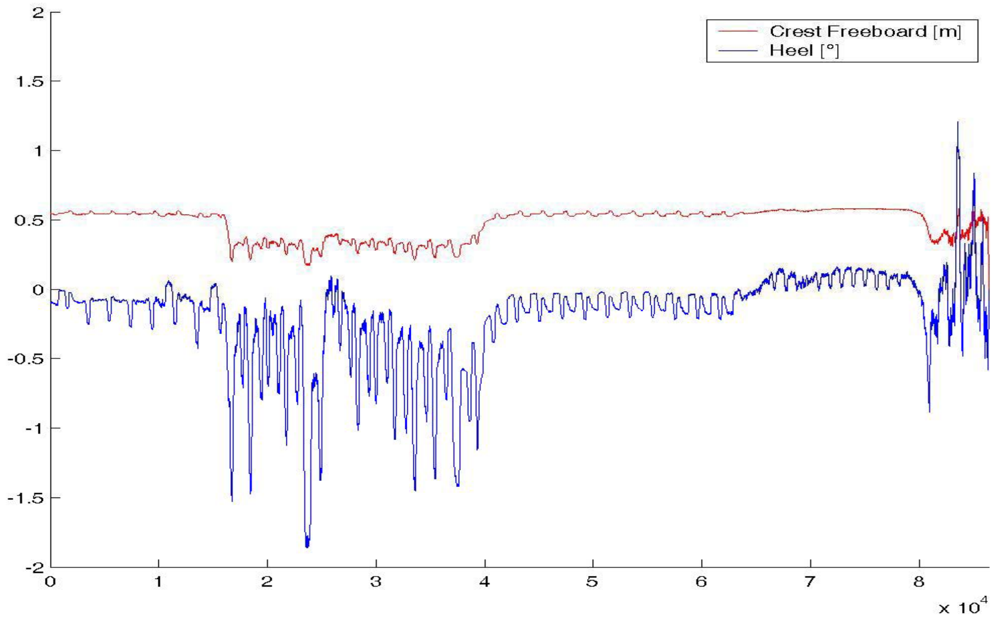



Crest Freeboard [m]
Heel [°]
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
0
1
2
3
4
5
6
7
8
x 10^4

c) 12/12/2003

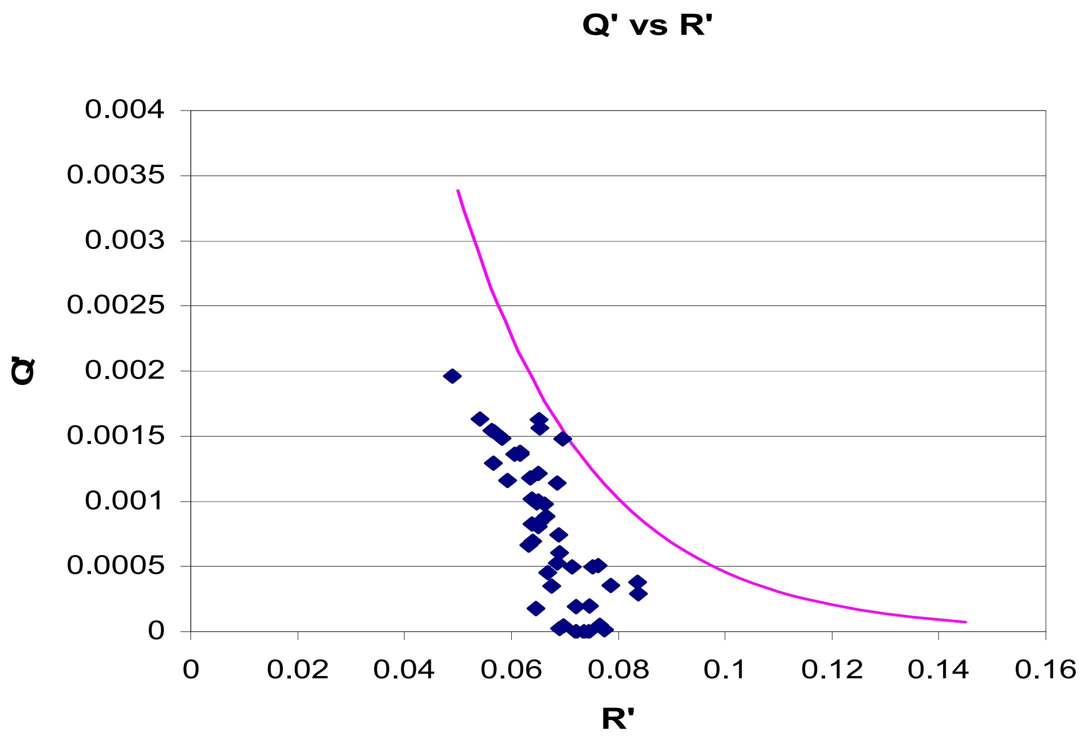


Q' vs R'
Q'
R'
0.004
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16

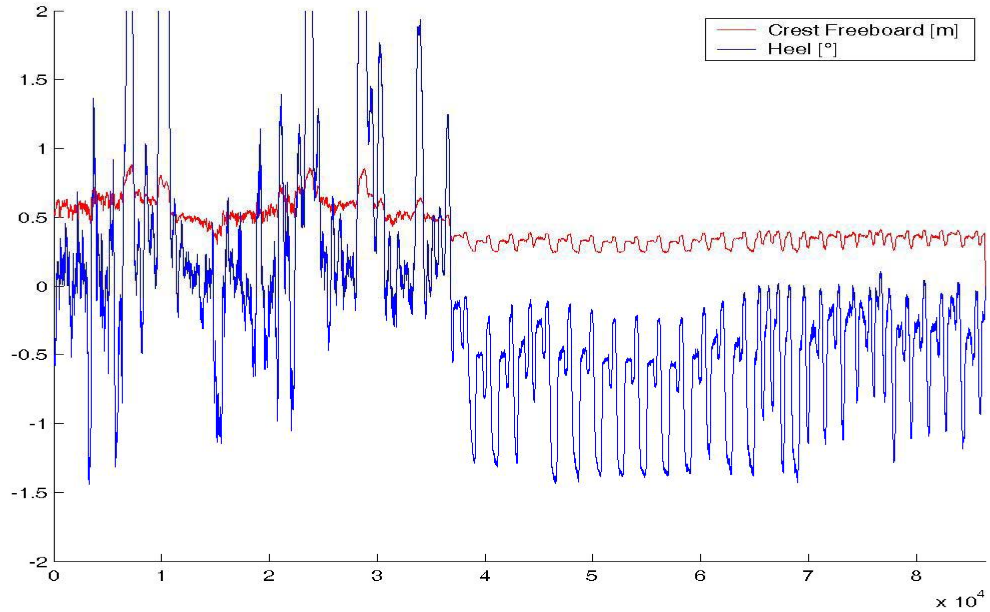



Crest Freeboard [m]
Heel [°]
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
0
1
2
3
4
5
6
7
8
x 10^4

**d) 13/12/2003**

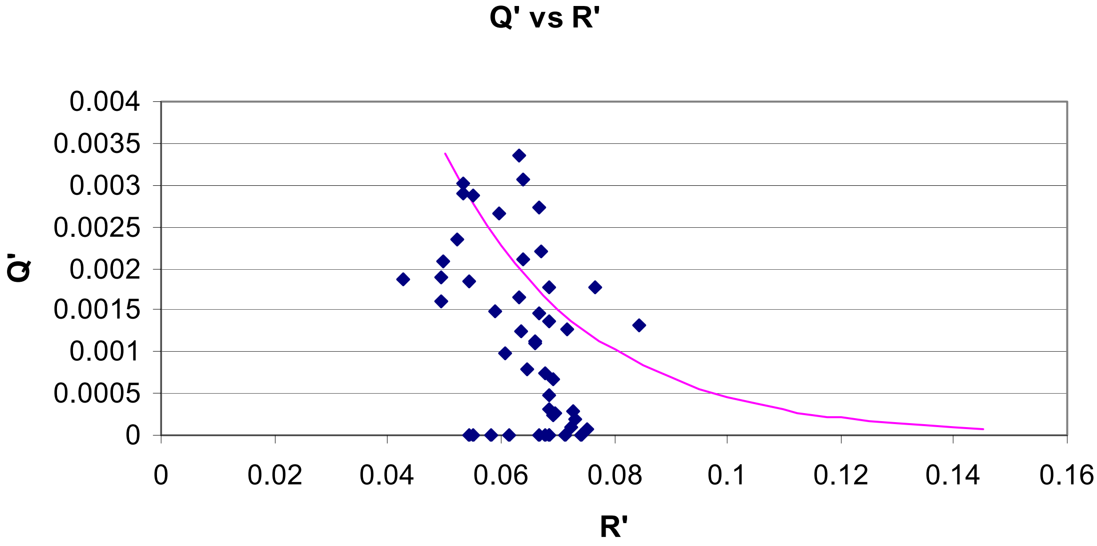


Q' vs R'
0.004
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
Q'
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
R'

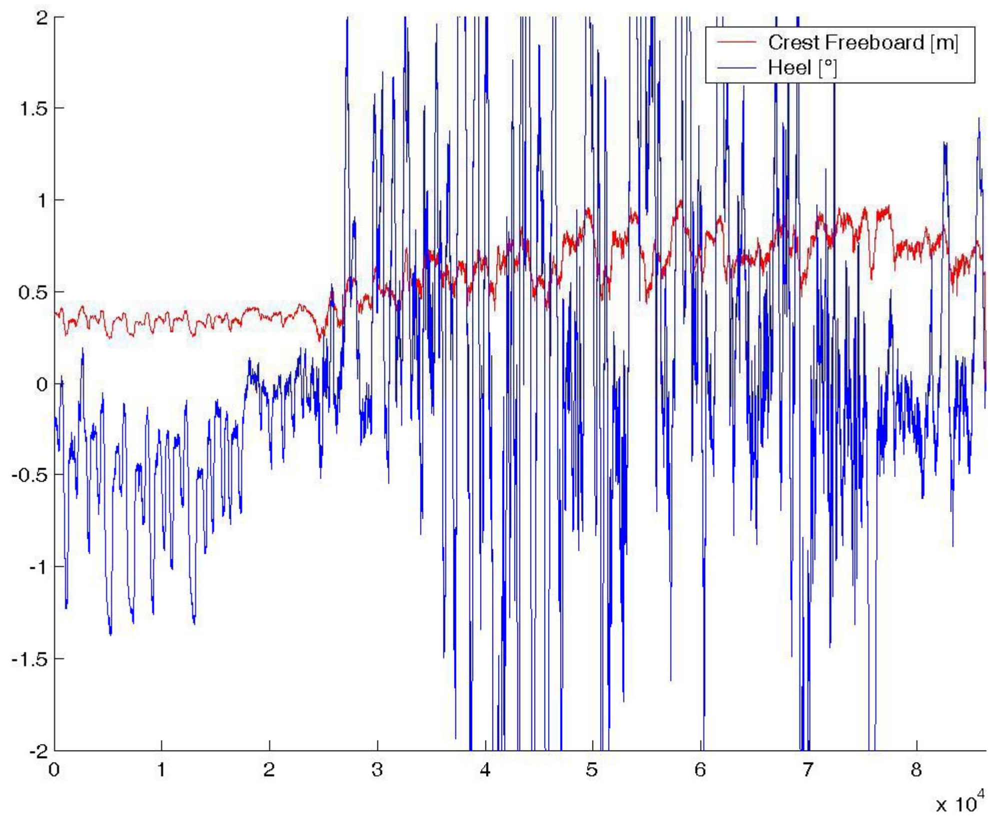



Crest Freeboard [m]
Heel [°]
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
0
1
2
3
4
5
6
7
8
x 10^4

**e) 14/12/2003**

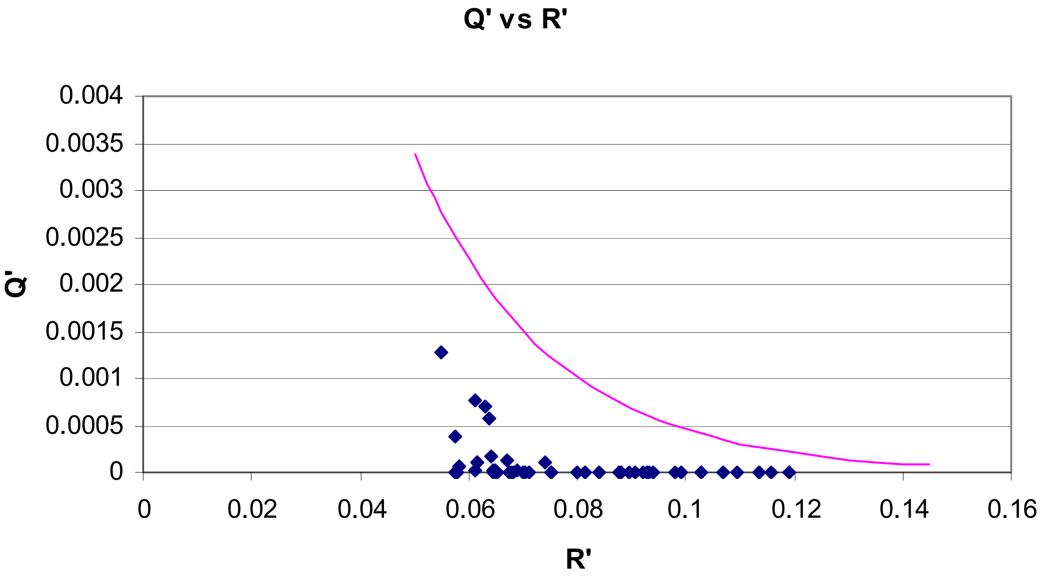


Q' vs R'
0.004
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
Q'
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
R'

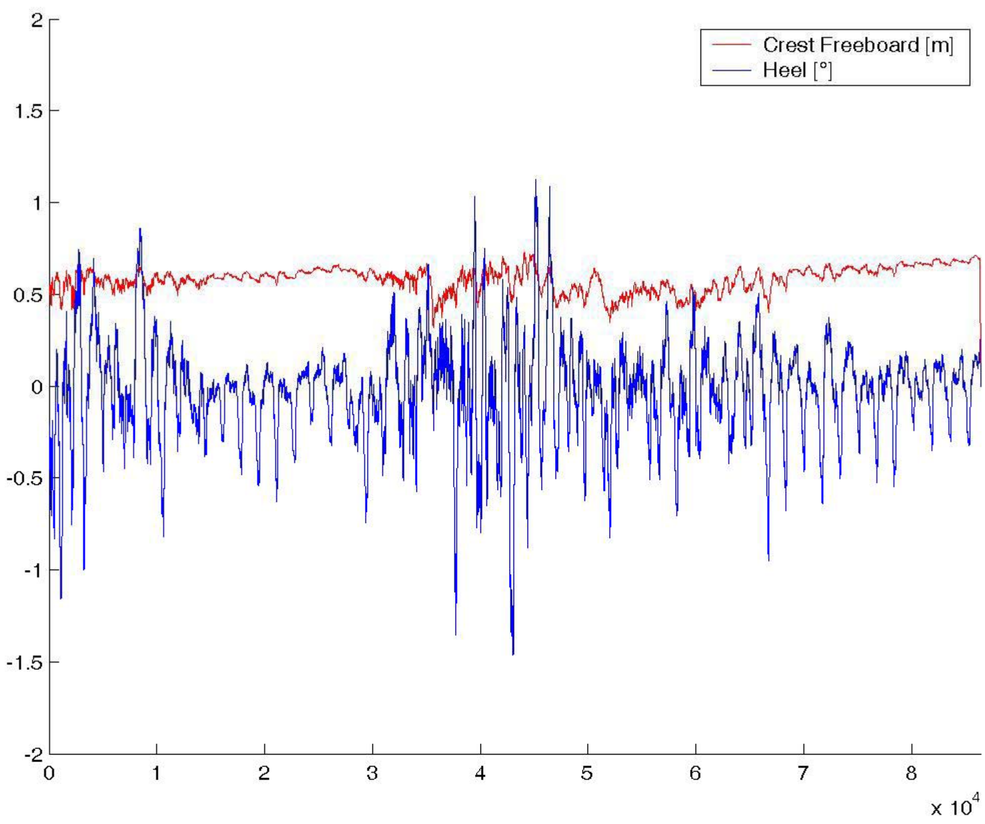



Crest Freeboard [m]
Heel [°]
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
0
1
2
3
4
5
6
7
8
x 10^4

**f) 15/12/2003**



Q' vs R'
0.004
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
Q'
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
R'

Crest Freeboard [m]
Heel [°]
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
0
1
2
3
4
5
6
7
8
x 10^4