Wave Dragon
Development history and results achieved

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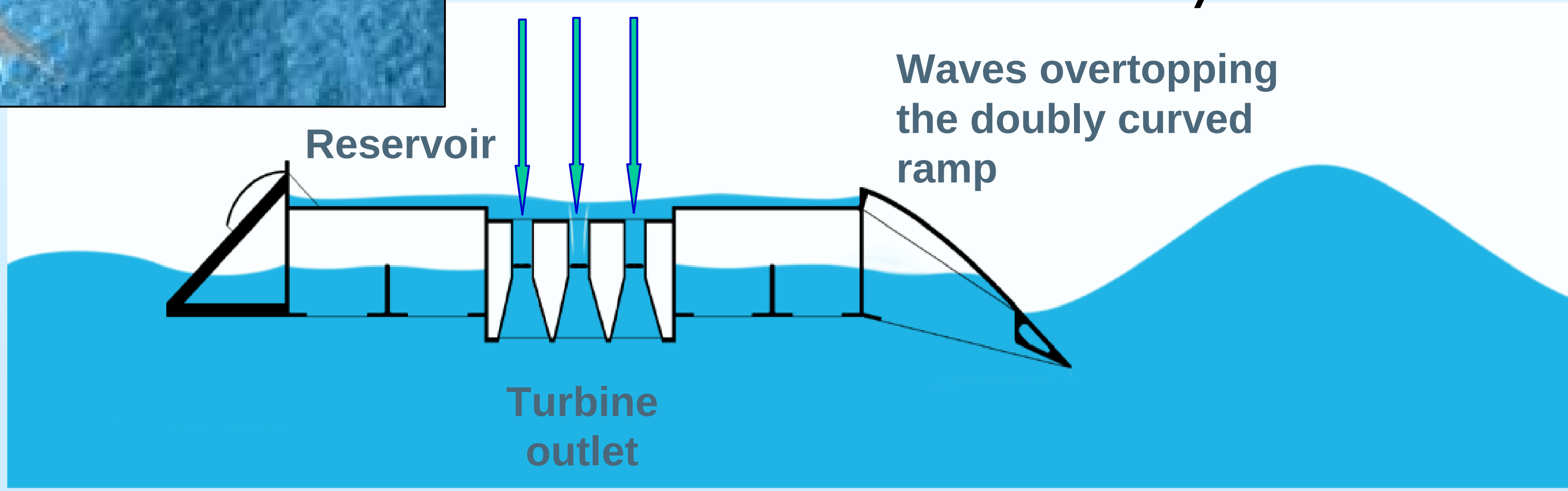
My story (focus om energy prod.)

- WD Technology
- Proto type testing
- History of operation
  35 % availability
- Instumentation
- Data analysis
  - Power production
- Yearly energy
  production 6.5 GWh

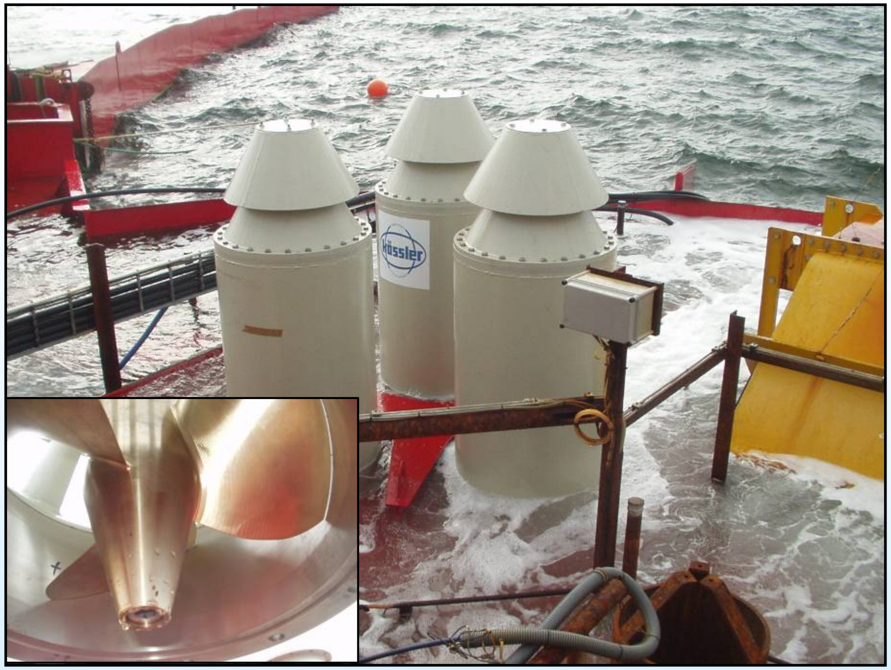
Wave Dragon Technology #1/5

The *Wave Dragon* is a slack-moored overtopping wave energy converter. It can be deployed alone or in parks where there is a sufficient wave climate and a water depth of more than 25 m.

Ressource	Power production
16 kW/m	6 GWh/y/unit
24 kW/m	12 GWh/y/unit
48 kW/m	35 GWh/y/unit



Wave Dragon Technology #2/5



Floating Platform

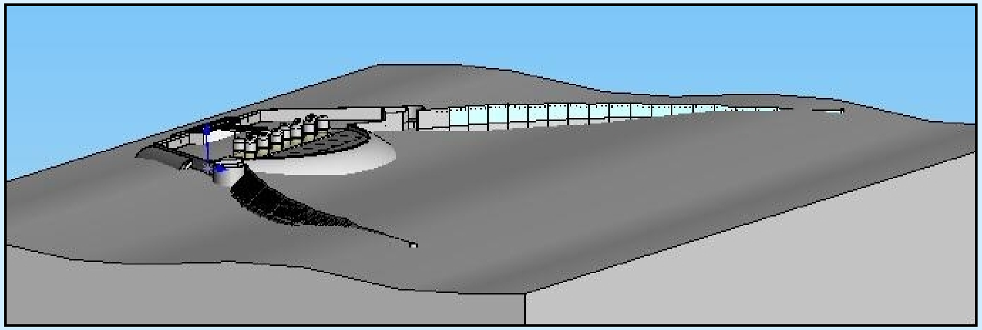
- Double curved ramp, crest level variable 1-4 m
- Reservoir storage

Hydro Turbines

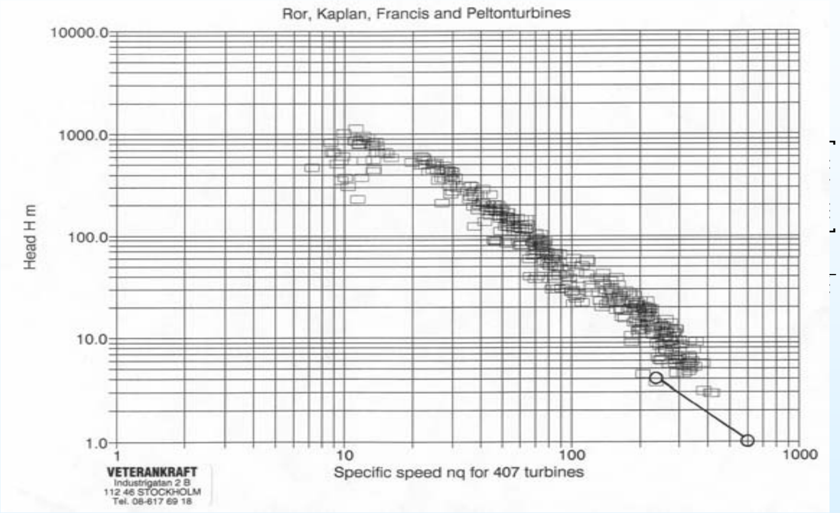
- Propeller turbines to produce electricity
- PM generators

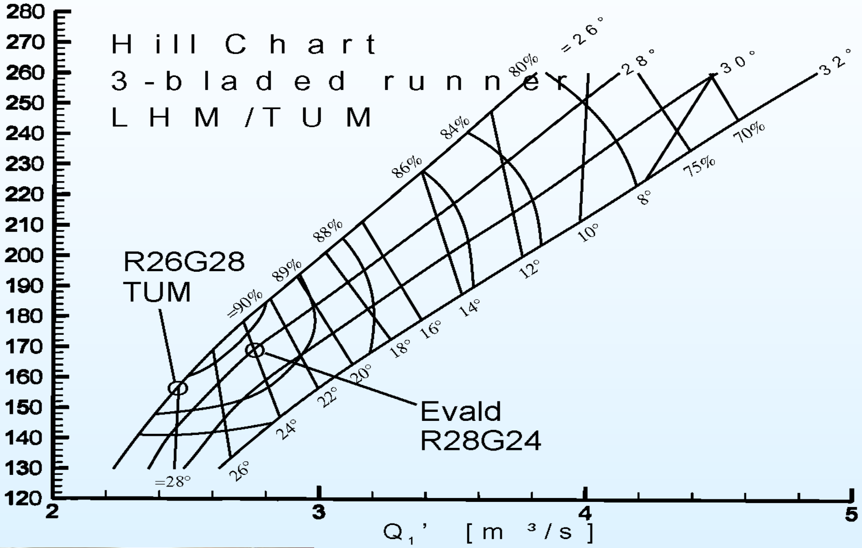
Wave reflectors

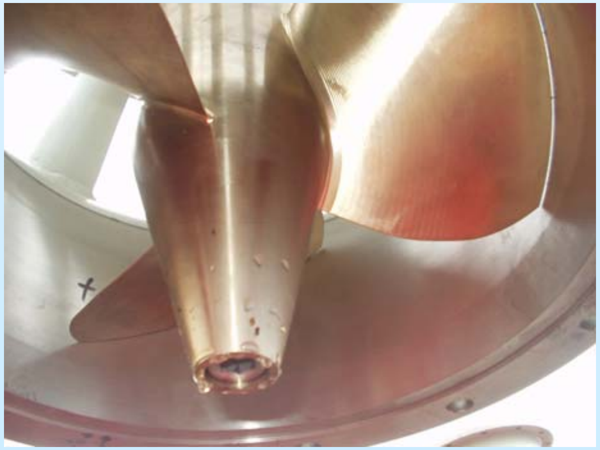
- Focused waves increase overtopping by up to 100%

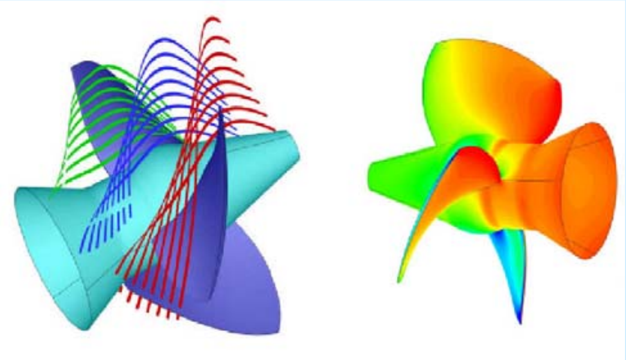


Wave Dragon Technology #3/5
Development of Ultra Low Head Propeller Turbine







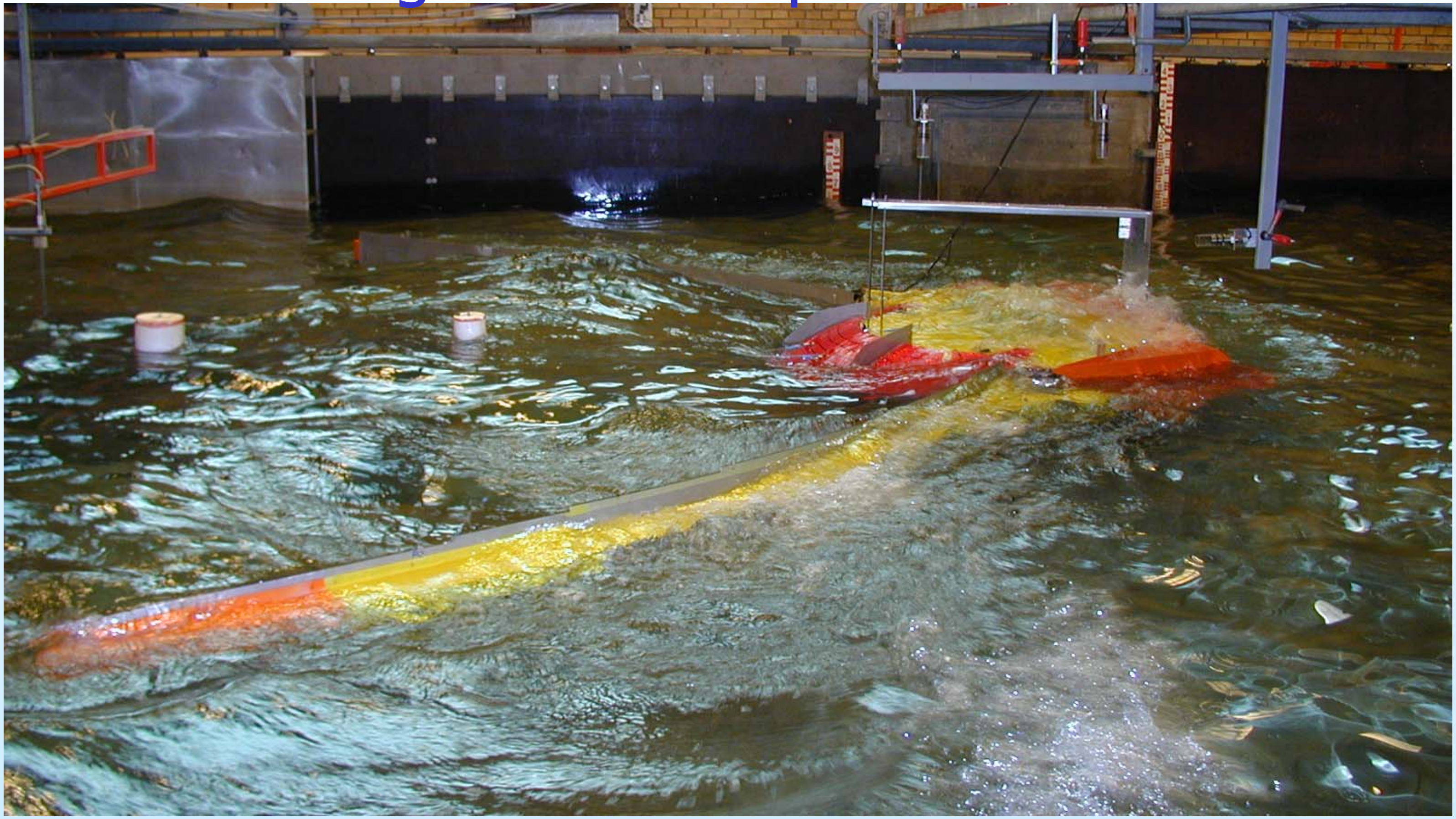


Wave Dragon Technology #4/5
Optimization of Overtopping Ramp

From single to double curved ramp

+5-15% energi

Wave Dragon Technology #5/5
Structural design – Most important: Survival Testing



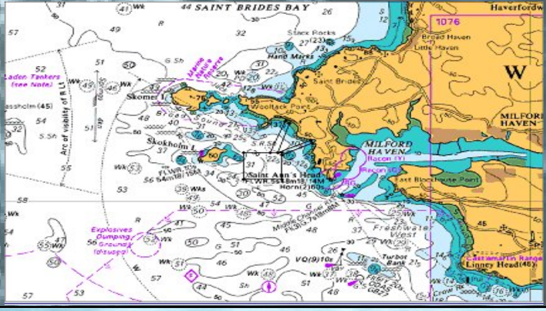
Scale 1:50 model in a 100 years storm event (EU CRAFT project, 2001)

Wave Dragon

- A Slack Moored Wave Energy Device of the Overtopping Type

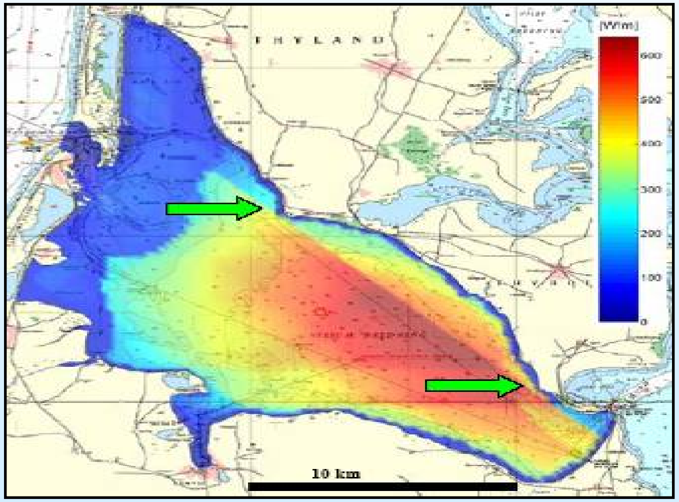
www.wavedragon.net

1:50 Model in Wave Tank	1:4.5 Protoype in Nissum Bredning	Full production unit near Wales



Prototype Testing #1/2 – History

- Nissum Bredning (From May 2003)
  - A benign site in Northern Denmark



- 1:4.5 scale prototype. Test Site 1, 2003–2005. Site 2, 2006-
- Grid connected, Full control system, Highly instrumented

Proto type testing #2/2
Demonstration of operation

History of operation - Availability

Production

- Automatic, grid connected

Testing

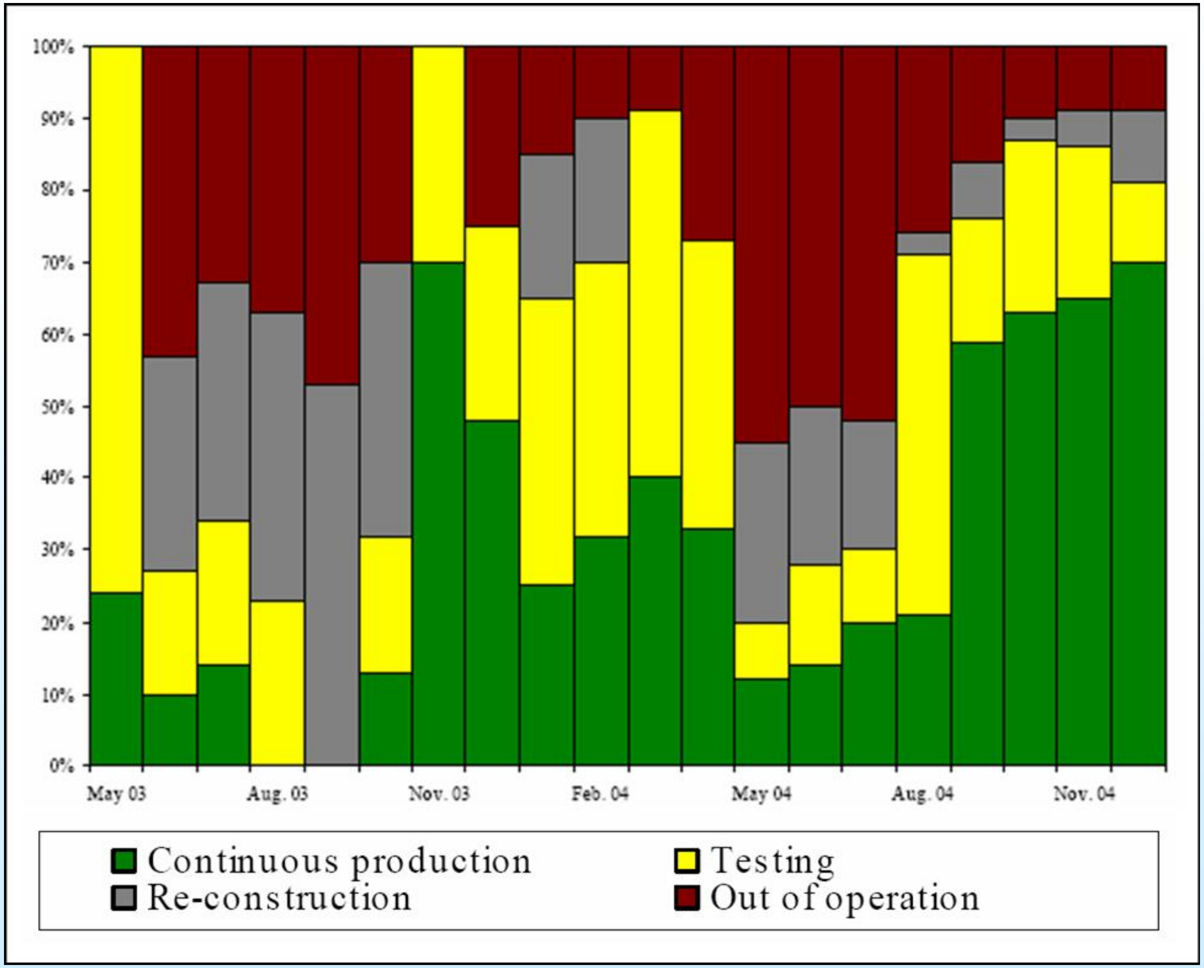
- Specific test of sub-systems, control/hydraulic response

Re-construction

- More major work; Planned out of operation periods

Out of Operation

- Fire safety system out of order
- Holiday Periods and non-planned out of operation.



Instrumentation #1

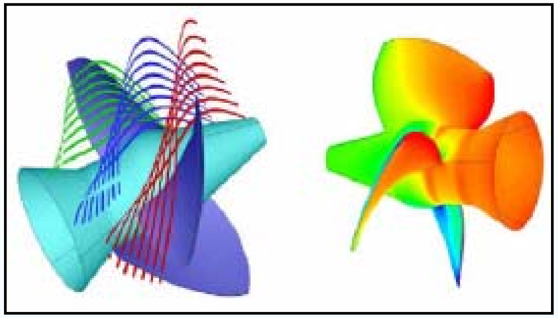
7 Propeller Turbines

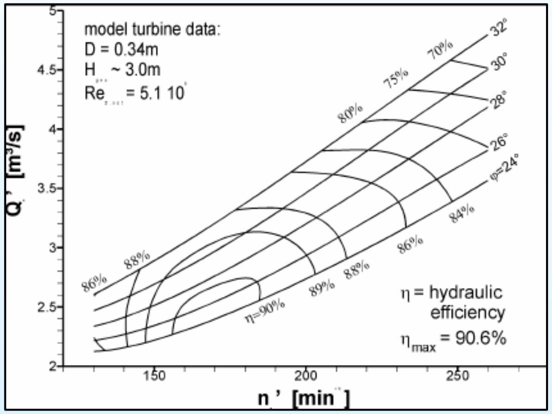
- On/Off controlled by cylider gate or Syphon
- Flow rate

  Q = Q(n, head)

PM generators

- Speed controlled by invertor

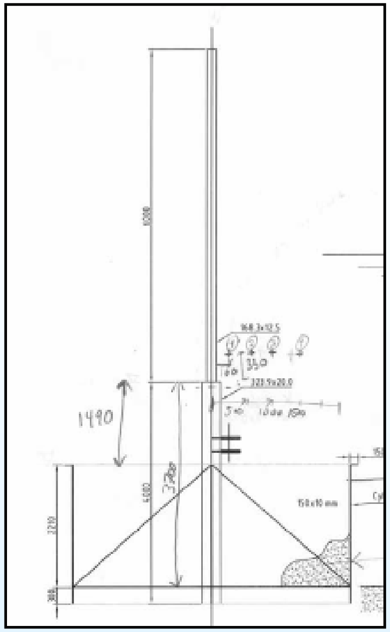




3 Dummy Turbines

- Calibrated on/off valve
- Flow rate Q = Q(head)
- Approximately twice the flow capacity of a propeller turbine
- No generator attached

Instrumentation #2



Incoming Waves

- Pressure Transducer mounted at pile
- Time record
- Wave statistics for sample and control of floating levels every 17 min.

Reservoir water level

- 3 Pressure Transducers on floor of reservoir

Floating level

- 3 Pressure Transducers beneath platform

Turbine Head calculated from water and floating levels

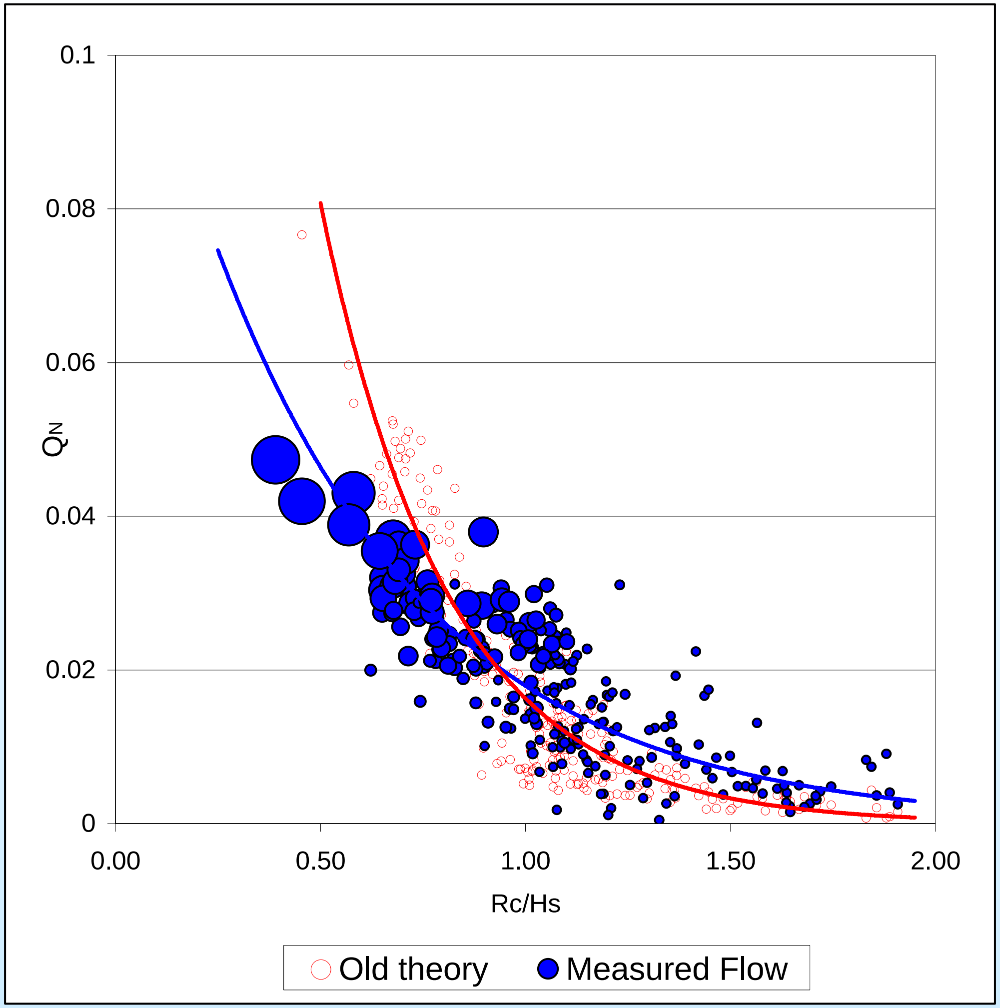
Strain gauges, movements ….etc

In total approx. 200.000.000.000 numbers plus video and web cameraes

Power production - data analysis

- Selection of good data sets
  - 4800 x 30 minute records taken over three months
  - 247 records chosen when high quality measurements, and enough waves to give some power production
- The results I will present today are:
  - Overtopping flow – to compare to the model results
  - Hydraulic energy – the potential energy of the water passing through the turbines
  - Actual Electricity generated by turbines
  - Estimated electricity – if dummy turbines produced as the propeller turbines
  - Estimated electricity – if PM-generators had had a decent efficiency (They have been working very badly)

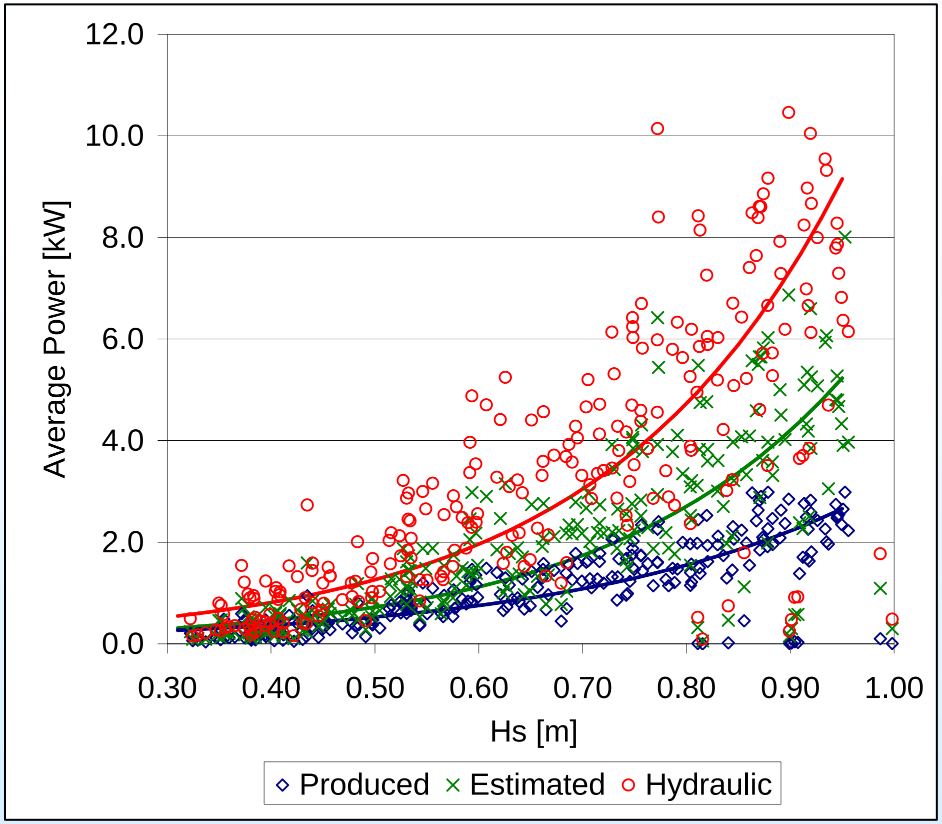
Overtopping



Comparison Tank to Prototype

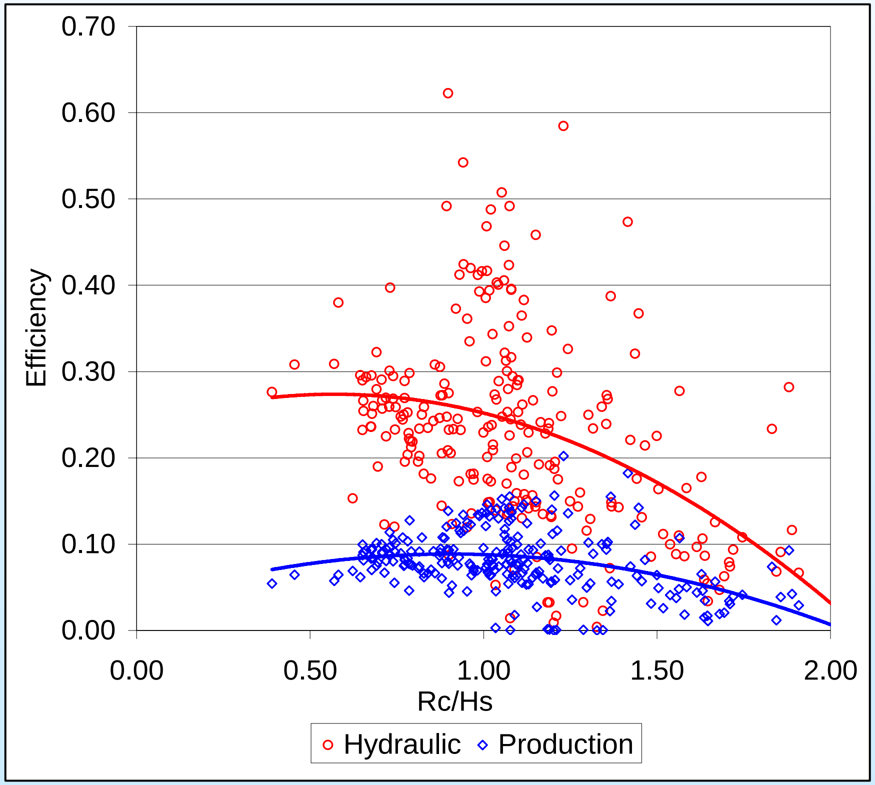
- Good agreement at higher relative floating levels
- A lot of spill in lower floating level
- Lack of capacity due to faults in turbines

Power and Efficiency



Optimal working point where Rc/Hs ≈ 0.7 not 1.0 as shown.

- Dummy turbines not included
- Low capacity gives considerable spill

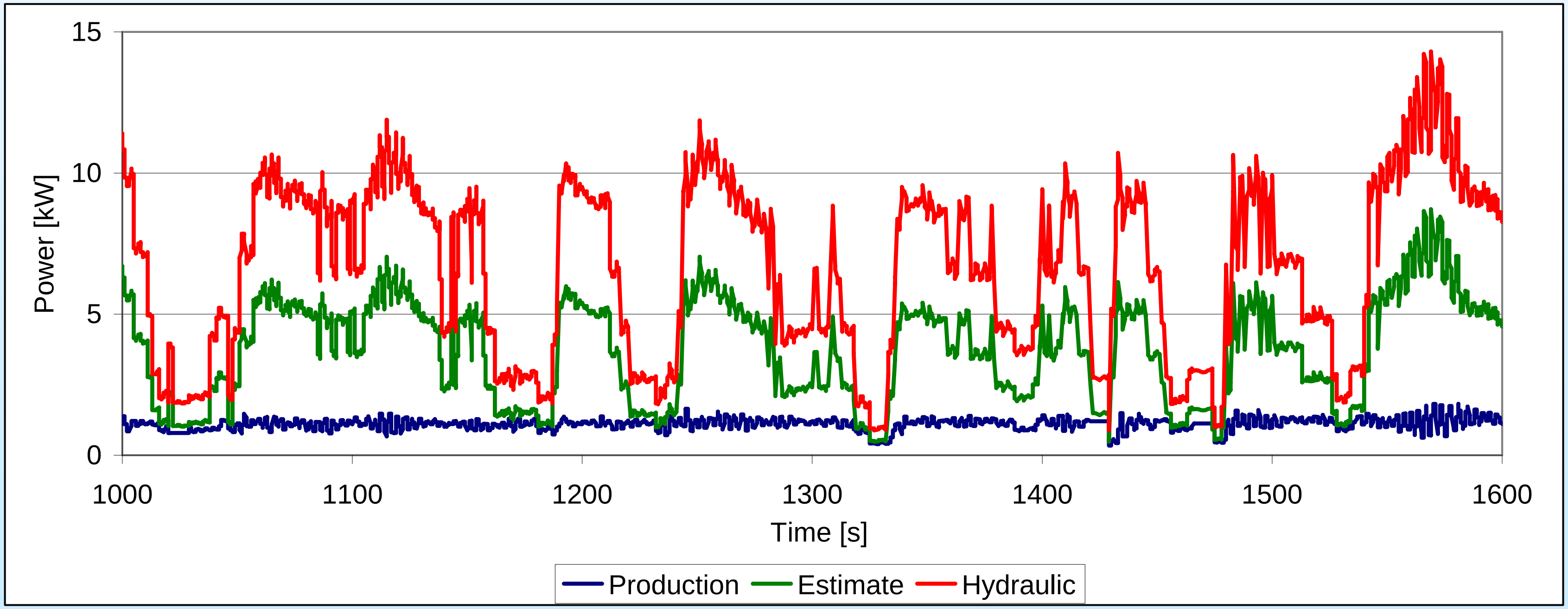


Efficiency relative to incoming wave energy toward width of ramp

Scatter due to different operation conditions, turbine control etc…

Typical Record

Date	16/12/2004, 9:00
Hs	0.62 m
Flow	3730 m^3/hr
Ave Elec Power	0.97 kW
Estimate Power	2.5 kW
Hydraulic Power	4.6 kW



Some conclusions

- Overtopping as predicted in tank tests. Maybe even slightly more in the Nissum Bredning
- Realised efficiency of reservoir plus PM-generator in the order of 0.2-0.4. Our guess (based on measurements) is an efficiency of the reservoir approx. 0.55, and an efficiency of the PM-generators approx 0.5.
- Availibility approx 35%
- Realised power more smooth than expected.

Yearly energy production ☺

- In 1 year the Wave Dragon Nissum Bredning has produced slightly less than 6.0 MWh
  Value approx. 250 euro ☺
- Scaling to North Sea conditions this means that we have produced approx. 1.1 GWh in 1 year
- Now, adjusting for the 35% availibility we find a yearly production approx. 3.2 GWh
- Assuming (indicated by tests) that the efficiency of generators and turbines can be increased to 60-80% we find an yearly production of 6.5 GWh. ☺
  Value off the Portuguise coast approx. 1.3 mill euro.

Conclusion

We believe (hope ☺) that a North Sea scale Wave Dragon placed in a wave climate with an average energy density of 16 kw/m will be able to produce

6.5 Gwh/year