

# Canada & the World of Ocean Renewable Energy Symposium

## Development of Ocean Energy in Denmark

Kim Nielsen, Ramboll

[www.ramboll.dk](http://www.ramboll.dk)

[www.ca-oe.org](http://www.ca-oe.org)

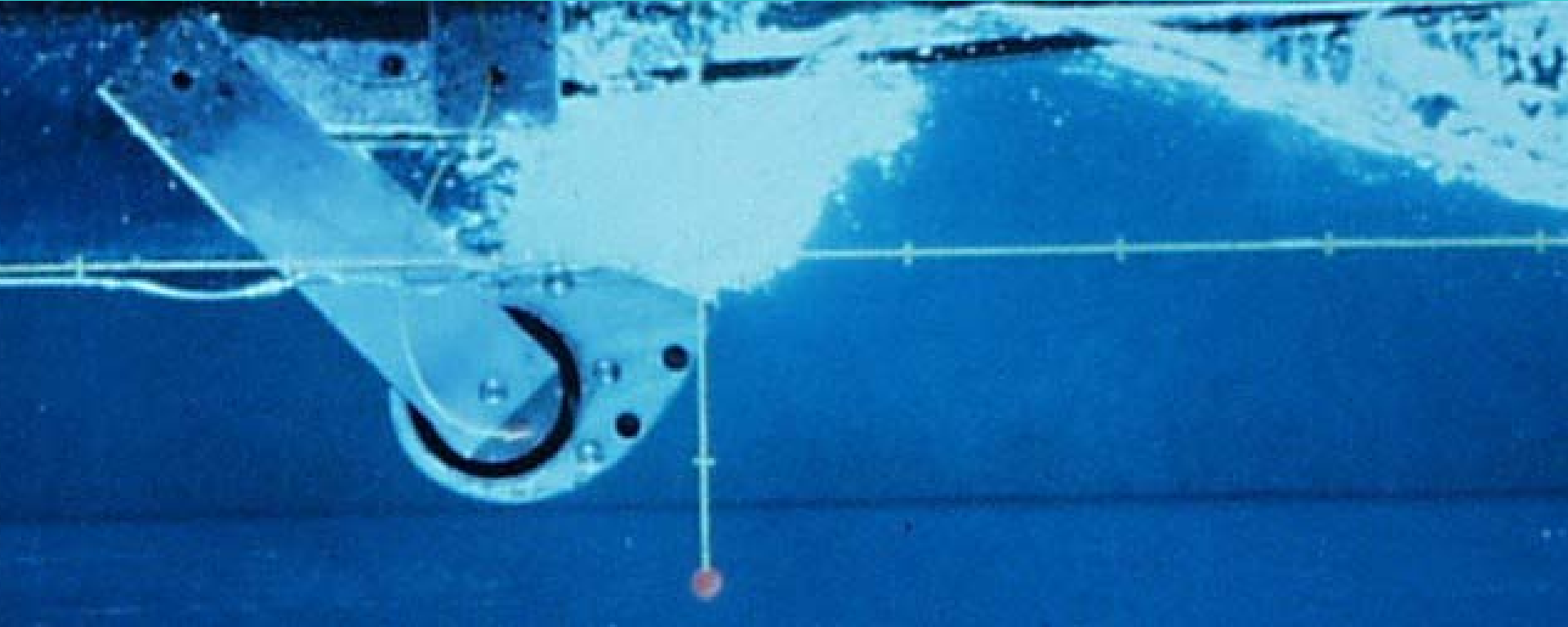
Royal BC Museum, Victoria, BC, May 4-5, 2006



# Graduation & PHD Project DTU 1977-82



# Salters Duck, UK



# Kaimai, Jamstec, Japan

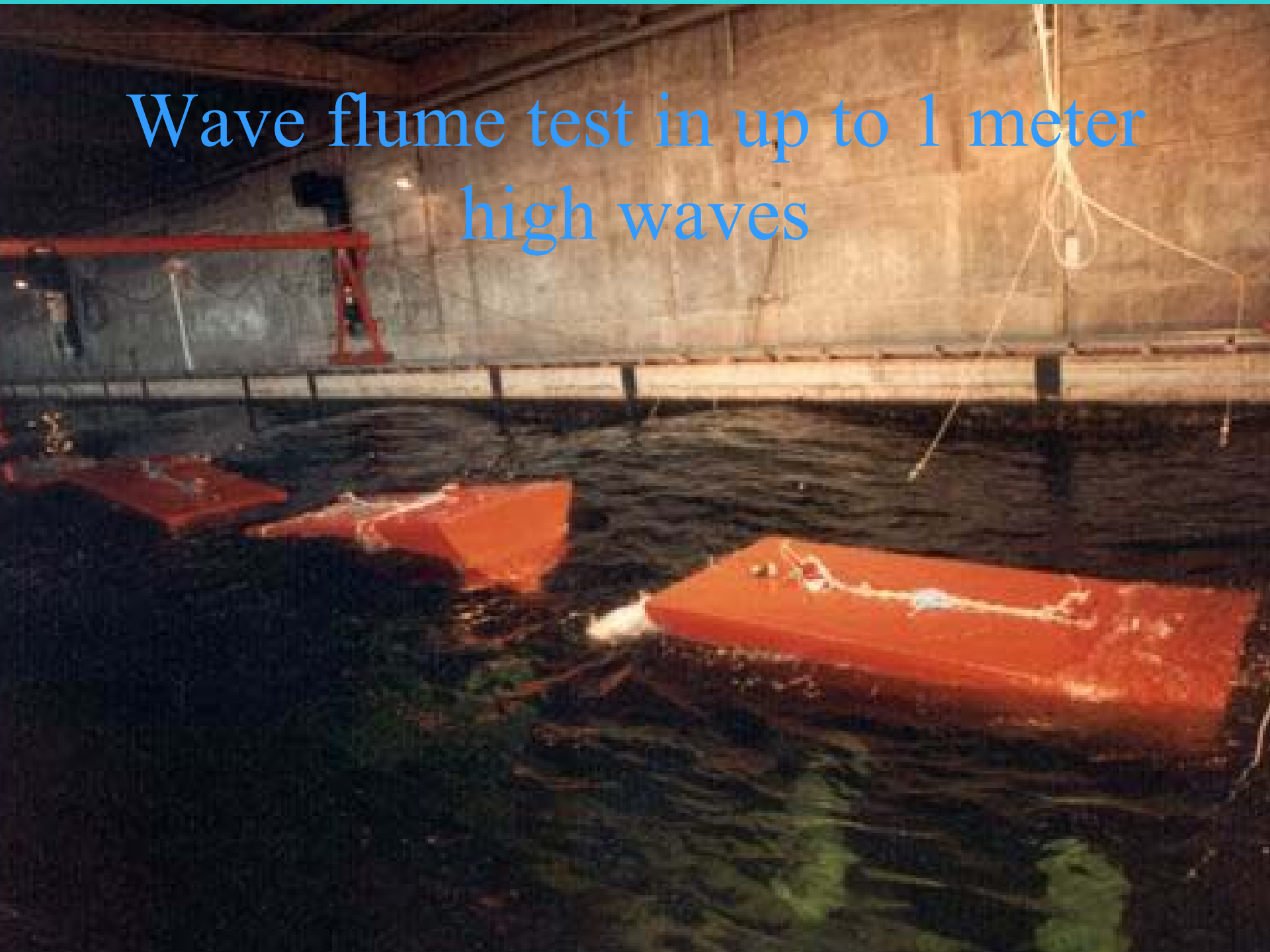


# Post PHD project 1983-86

## Test at DMI



Wave flume test in up to 1 meter  
high waves



# Turborg Harbor 1985



# Espergærde 1986

- Water depth 5 meter
- Maximum  $H_s = 1\text{m}$



# Test data obtained 1986

A photograph of an offshore test facility in the ocean. The facility consists of several vertical poles and a larger structure on the right. The water is dark and choppy, and the sky is overcast.

- Permit for installation
- Wind speed & direction
- Wave rider data
- Current speed & dir
- Electrical production

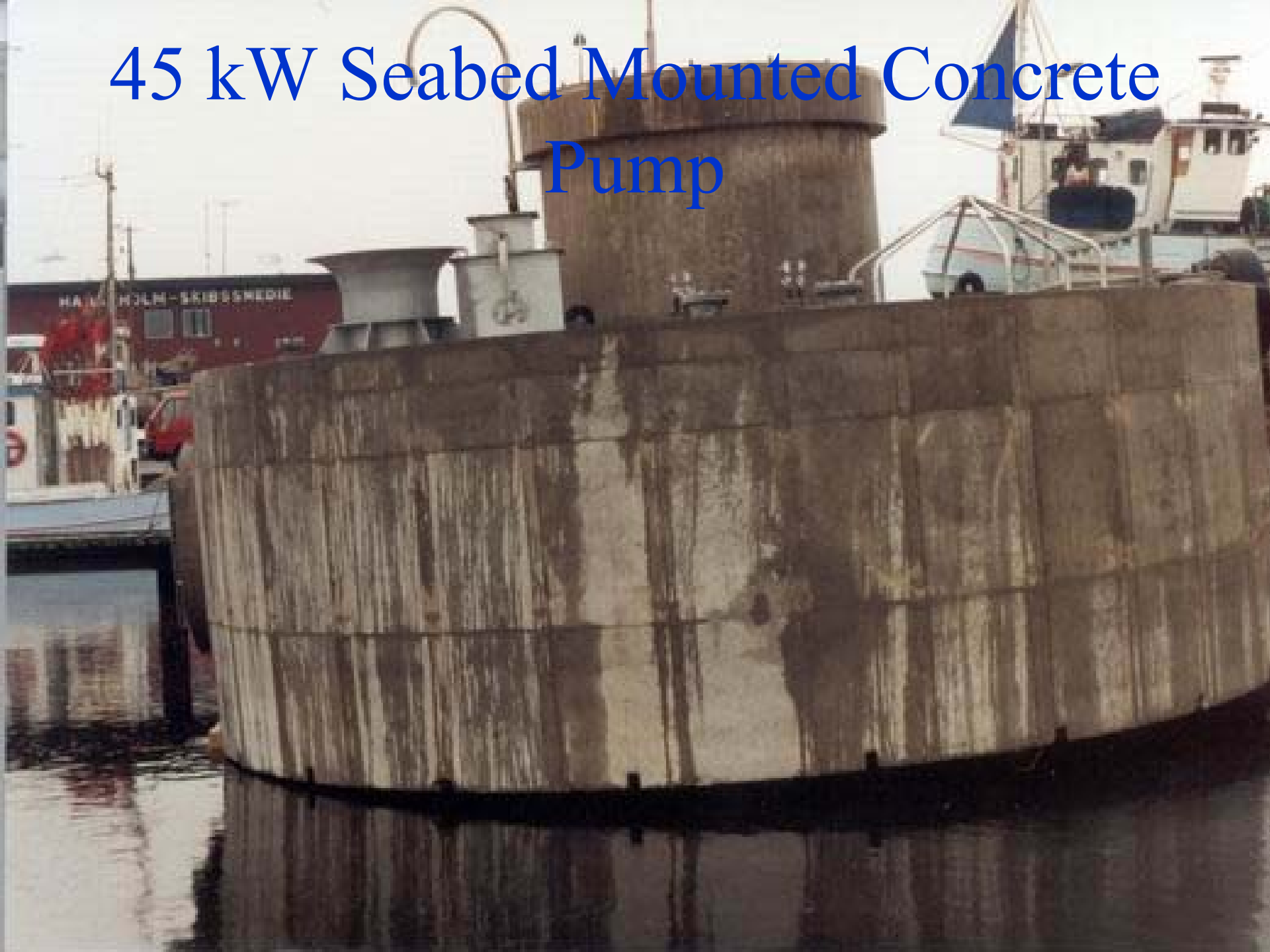
# Hanstholm 1987 - 90

## Danish Wave Power Aps

- Højlund Rasmussen
- Flygt Pumper
- NKT Cables
- Højgaard & Schultz



# 45 kW Seabed Mounted Concrete Pump



45 kW prototype



# Concrete/steel Piston

- Diameter 2.2 m
- Trumpet design for fiber rope connection
- Sliding bearings



Does it fit?





Fatal flap valves



# Installation barge designed by H&S

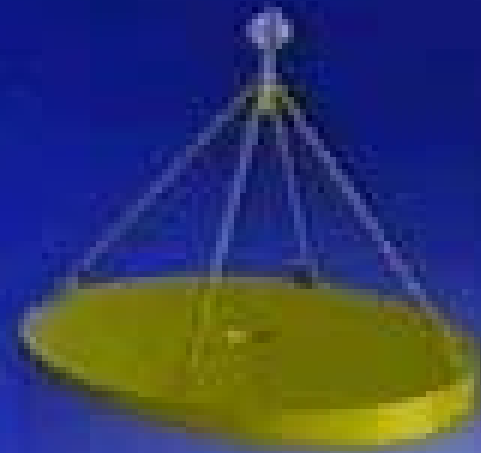


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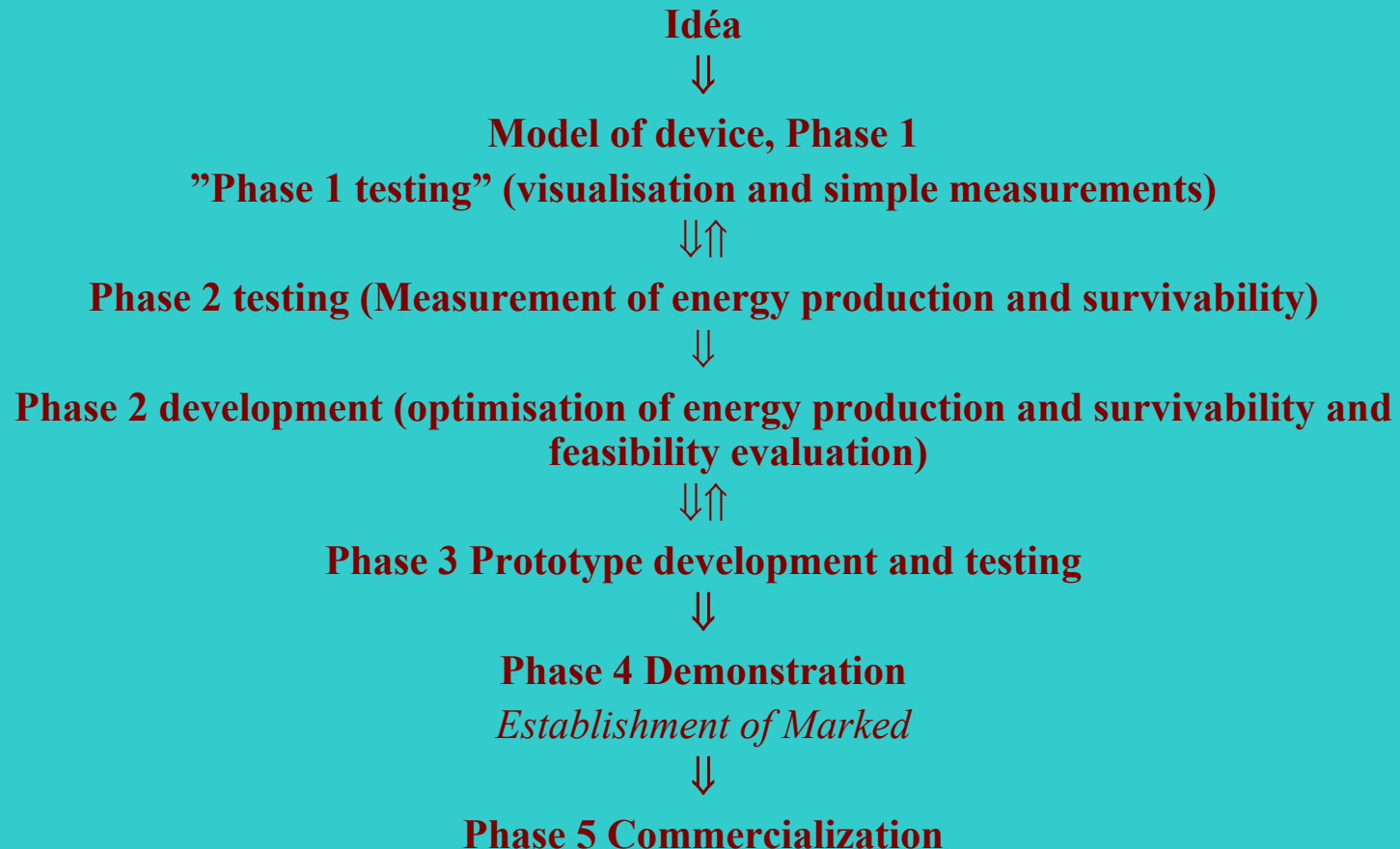
European Cooperation OWEC 1  
1993 - 96



# Hanstholm phase II, 1994-96



# Danish Wave Energy Programme 1997-2002 40 mio. DDK



# Wave Dragon scale test Aalborg University 2000



# Tusindben



# Point absorber 1998 – 2001

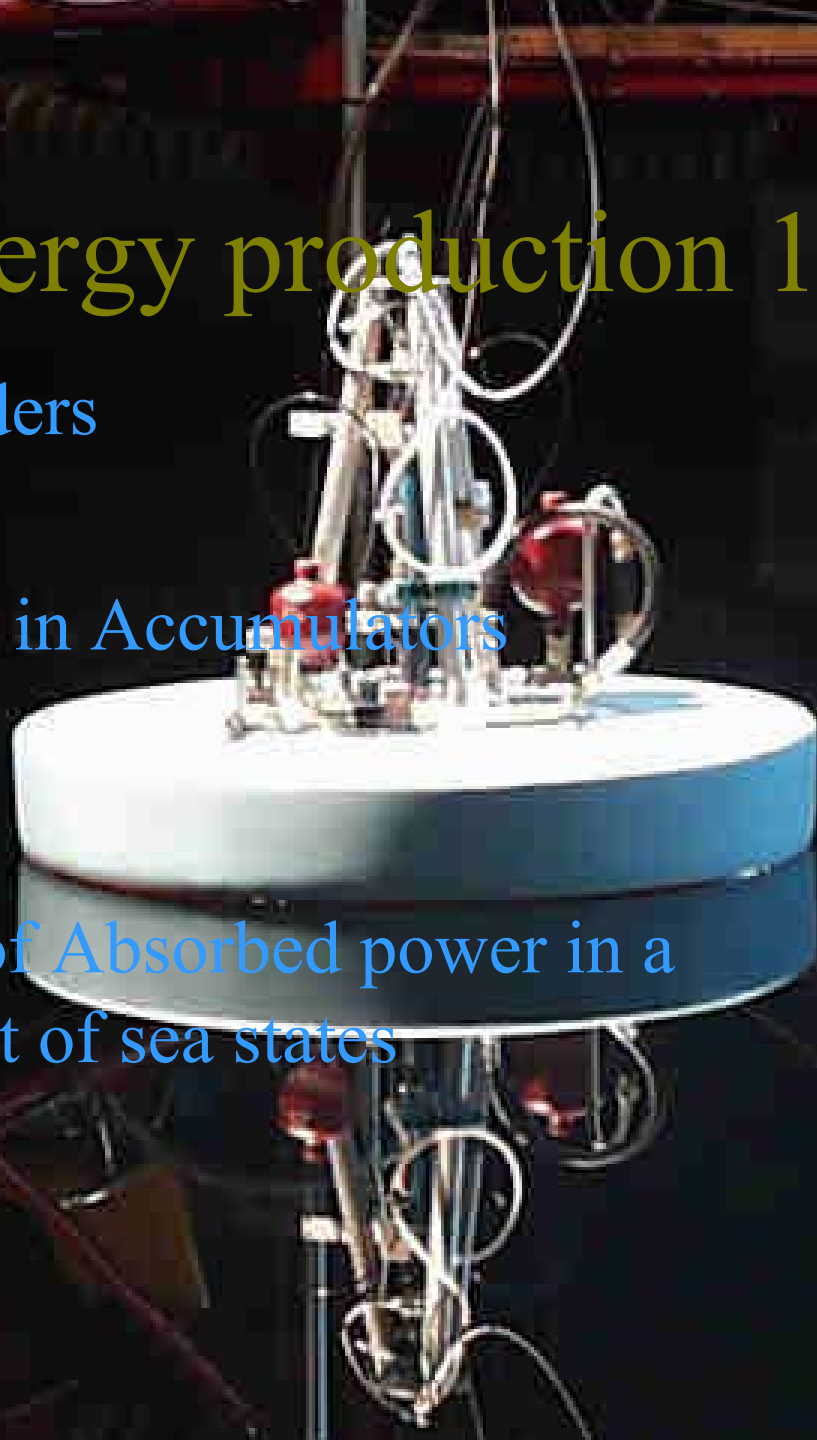
## Scale 1:40

- HP Hydraulics
- Power take-off
- on float



# Energy production 1:10

- Hydraulic cylinders
- Closed system
- Energy storage in Accumulators
- Measurement of Absorbed power in a standardised set of sea states



# Sheltered test site Nisum Bredning, 1999



Survived the winter storm  
December 1999



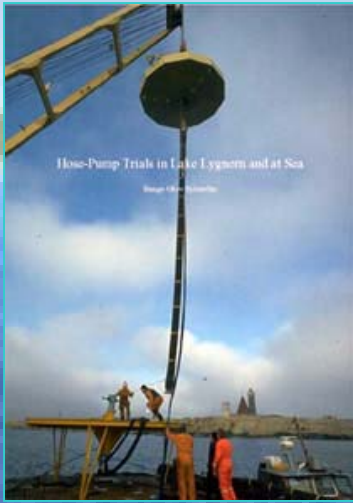
# Testing Power Take-off Scale 1:4 DMI 2001

- Rated Power 1 kW
- Hydraulic power
- Mechanical power
- Electrical power



# IEA Ocean Energy Systems ExCo Committee and observers 2004





# AquaBuOY

## AquaEnergy



# Wave Dragon



# Wave Dragon



# WAVE STAR



# **WAVE STAR**

**April 2006**  
**Nissum Bredning**  
**[www.waveenergy.dk](http://www.waveenergy.dk)**

