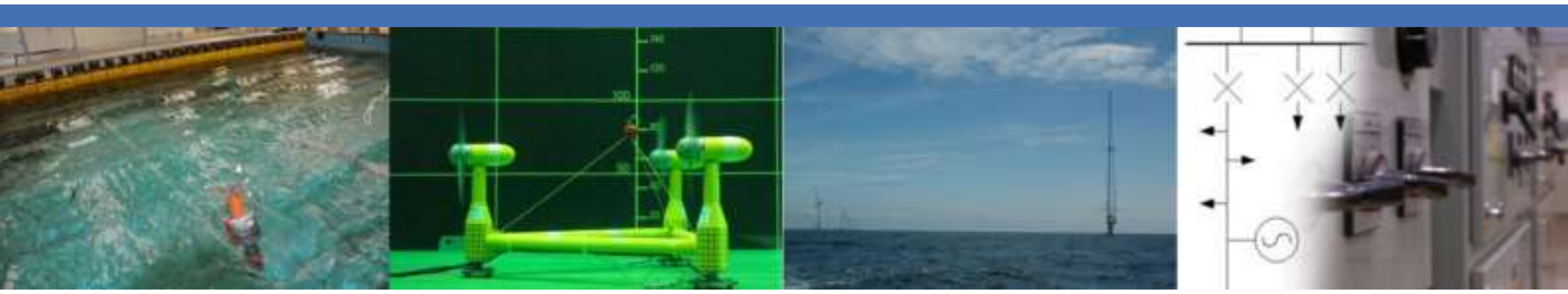
MARINET

Marine Renewables Infrastructure Network



Infrastructure Access Report

Infrastructure: UCC-HMRC Ocean Wave Basin

***User-Project*: Wave Pump**

Wave Pump Optimisation Study

Gangolf Jobb

Status: Final
Version: 01
Date: 01-Apr-2014

EC FP7 "Capacities" Specific Programme
Research Infrastructure Action

ABOUT MARINET

MARINET (Marine Renewables Infrastructure Network for emerging Energy Technologies) is an EC-funded network of research centres and organisations that are working together to accelerate the development of marine renewable energy - wave, tidal & offshore-wind. The initiative is funded through the EC's Seventh Framework Programme (FP7) and runs for four years until 2015. The network of 29 partners with 42 specialist marine research facilities is spread across 11 EU countries and 1 International Cooperation Partner Country (Brazil).

MARINET offers periods of free-of-charge access to test facilities at a range of world-class research centres. Companies and research groups can avail of this Transnational Access (TA) to test devices at any scale in areas such as wave energy, tidal energy, offshore-wind energy and environmental data or to conduct tests on cross-cutting areas such as power take-off systems, grid integration, materials or moorings. In total, over 700 weeks of access is available to an estimated 300 projects and 800 external users, with at least four calls for access applications over the 4-year initiative.

MARINET partners are also working to implement common standards for testing in order to streamline the development process, conducting research to improve testing capabilities across the network, providing training at various facilities in the network in order to enhance personnel expertise and organising industry networking events in order to facilitate partnerships and knowledge exchange.

The aim of the initiative is to streamline the capabilities of test infrastructures in order to enhance their impact and accelerate the commercialisation of marine renewable energy. See www.fp7-marinet.eu for more details.

Partners

Ireland
University College Cork, HMRC (UCC_HMRC)
Coordinator
Sustainable Energy Authority of Ireland (SEAI_OEDU)

Denmark
Aalborg Universitet (AAU)
Danmarks Tekniske Universitet (RISOE)

France
Ecole Centrale de Nantes (ECN)
Institut Français de Recherche Pour l'Exploitation de la Mer (IFREMER)

United Kingdom
National Renewable Energy Centre Ltd. (NAREC)
The University of Exeter (UNEXE)
European Marine Energy Centre Ltd. (EMEC)
University of Strathclyde (UNI_STRATH)
The University of Edinburgh (UEDIN)
Queen's University Belfast (QUB)
Plymouth University(PU)

Spain
Ente Vasco de la Energía (EVE)
Tecnalia Research & Innovation Foundation (TECNALIA)

Belgium
1-Tech (1_TECH)

Netherlands
Stichting Tidal Testing Centre (TTC)
Stichting Energieonderzoek Centrum Nederland (ECNeth)

Germany
Fraunhofer-Gesellschaft Zur Foerderung Der Angewandten Forschung E.V (Fh_IWES)
Gottfried Wilhelm Leibniz Universität Hannover (LUH)
Universitaet Stuttgart (USTUTT)

Portugal
Wave Energy Centre – Centro de Energia das Ondas (WavEC)

Italy
Università degli Studi di Firenze (UNIFI-CRIACIV)
Università degli Studi di Firenze (UNIFI-PIN)
Università degli Studi della Tuscia (UNI_TUS)
Consiglio Nazionale delle Ricerche (CNR-INSEAN)

Brazil
Instituto de Pesquisas Tecnológicas do Estado de São Paulo S.A. (IPT)

Norway
Sintef Energi AS (SINTEF)
Norges Teknisk-Naturvitenskapelige Universitet (NTNU)

DOCUMENT INFORMATION

Title	Wave Pump Optimisation Study
Distribution	**Public**
Document Reference	MARINET-TA1-Wave Pump
User-Group Leader, Lead Author	Gangolf Jobb gangolf.jobb@treefinder.de
User-Group Members, Contributing Authors	
Infrastructure Accessed:	UCC-HMRC Ocean Wave Basin
Infrastructure Manager (or Main Contact)	Florent Thiebaut

REVISION HISTORY

Rev.	Date	Description	Prepared by (Name)	Approved By Infrastructure Manager	Status (Draft/Final)
01					

ABOUT THIS REPORT

One of the requirements of the EC in enabling a user group to benefit from free-of-charge access to an infrastructure is that the user group must be entitled to disseminate the foreground (information and results) that they have generated under the project in order to progress the state-of-the-art of the sector. Notwithstanding this, the EC also state that dissemination activities shall be compatible with the protection of intellectual property rights, confidentiality obligations and the legitimate interests of the owner(s) of the foreground.

The aim of this report is therefore to meet the first requirement of publicly disseminating the knowledge generated through this MARINET infrastructure access project in an accessible format in order to:

- progress the state-of-the-art
- publicise resulting progress made for the technology/industry
- provide evidence of progress made along the Structured Development Plan
- provide due diligence material for potential future investment and financing
- share lessons learned
- avoid potential future replication by others
- provide opportunities for future collaboration
- etc.

In some cases, the user group may wish to protect some of this information which they deem commercially sensitive, and so may choose to present results in a normalised (non-dimensional) format or withhold certain design data – this is acceptable and allowed for in the second requirement outlined above.

ACKNOWLEDGEMENT

The work described in this publication has received support from MARINET, a European Community - Research Infrastructure Action under the FP7 "Capacities" Specific Programme.

LEGAL DISCLAIMER

The views expressed, and responsibility for the content of this publication, lie solely with the authors. The European Commission is not liable for any use that may be made of the information contained herein. This work may rely on data from sources external to the MARINET project Consortium. Members of the Consortium do not accept liability for loss or damage suffered by any third party as a result of errors or inaccuracies in such data. The information in this document is provided "as is" and no guarantee or warranty is given that the information is fit for any particular purpose. The user thereof uses the information at its sole risk and neither the European Commission nor any member of the MARINET Consortium is liable for any use that may be made of the information.

EXECUTIVE SUMMARY

The Wave Pump is a novel wave energy conversion device combining the principles of an Oscillating Water Column (OWC) and an overtopping device. It is a wave-driven water pump with no moving parts. The pumped water can be used to silently drive a water turbine.

The Wave Pump has a stack of specially shaped basins, overtopping trays, along which an oscillating air pressure causes water to climb upwards. An OWC-type wave chamber acts as the intermediary energy transfer mechanism from the ocean waves to the overtopping trays. The Wave Pump has the potential for energy storage in a reservoir at the level of the highest tray, which can allow either a smoother instantaneous output from the turbine or for energy generation during times of low wave conditions.

The Wave Pump is like a ten storey apartment block in which the water goes up two stairs with each wave. The air acts on all the storeys simultaneously. The Wave Pump can be fabricated from concrete and is initially designed as a fixed device for shallow water applications.

Before the MARINET supported testing at the HMRC, several prototypes had been built and tested with real waves at beaches. Videos had been produced which show that the principle of the concept is valid and that the Wave Pump is capable of pumping water. However, there had not been any systematic measurements of performance in terms of flow rates and power output so the efficiency of the device was not known.

For the testing at the HMRC, a Wave Pump prototype was constructed with a strongly inclined wave chamber. This is suitable for the use in shallow water where the horizontal component of the water movement is predominant. Older prototypes have had vertical wave chambers, which reflected too much of the horizontally arriving wave energy at the beaches where they were tested.

Four series of experiments in the ocean wave basin at the HMRC have shown that the Wave Pump works both with monochromatic waves as well as with panchromatic waves. Compared with other wave energy converters, its measured CWR is lower than average, but this can be acceptable because the technology is cheap. Taking into account the losses by overflow, which can be resolved, one can assume there is a big potential for improvement. Only a small part of the planned Wave Pump optimisation could be done due to insufficient financial resources.

CONTENTS

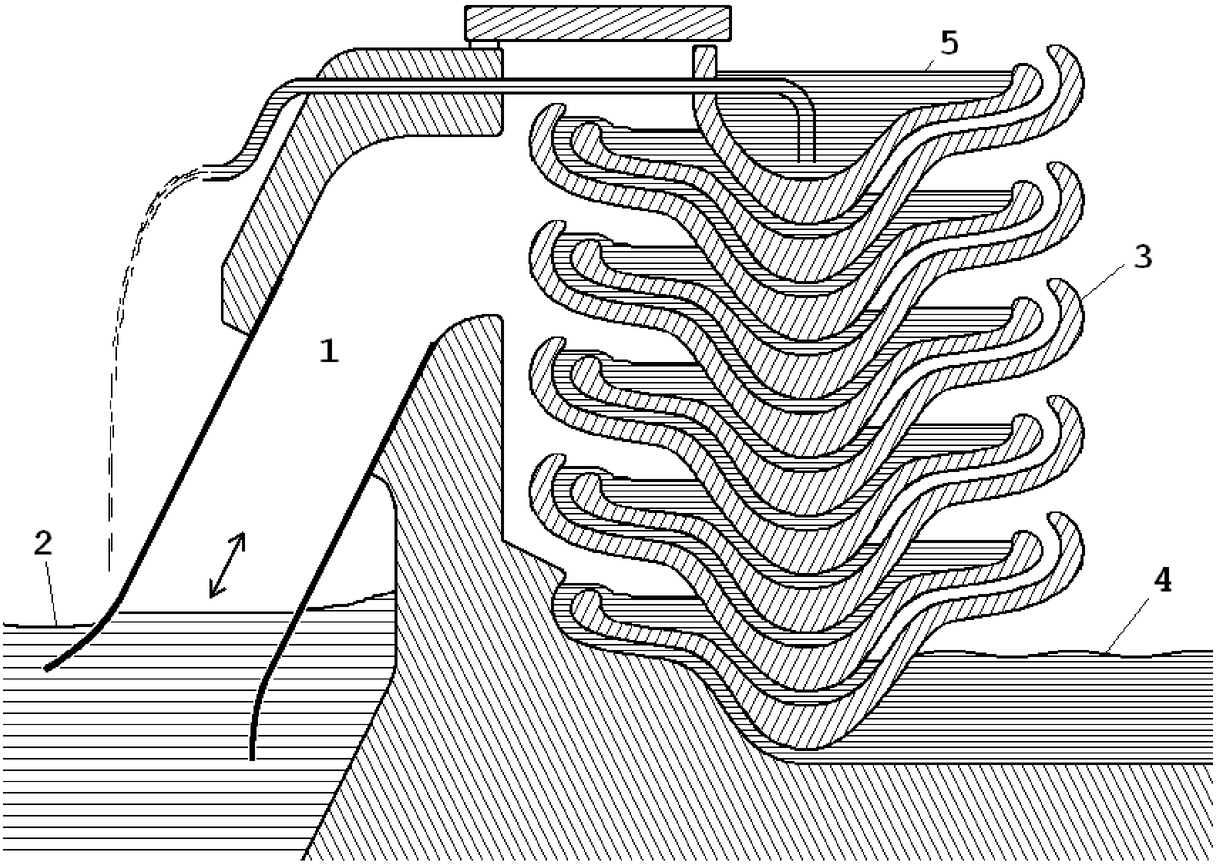
1 INTRODUCTION & BACKGROUND

1.1 INTRODUCTION

The Wave Pump is a novel wave energy conversion device combining the principles of an Oscillating Water Column (OWC) and an overtopping device. It is a wave-driven water pump with no moving parts. The pumped water can be used to silently drive a water turbine.

The Wave Pump has a stack of specially shaped basins (3), overtopping trays, along which an oscillating air pressure causes water to climb upwards. An OWC-type wave chamber (1) acts as the intermediary energy transfer mechanism from the ocean waves to the overtopping trays. The figure below illustrates the concept. On the trough of the incident sea wave (2), the OWC creates a negative pressure in the system, thus taking the water to be pumped (4) into the base tray and also squeezing water from all trays on the right side one level up to their respective following tray on the left side. On the crest of the wave, the OWC creates a positive pressure in the system, thus squeezing water from all of the trays on the left side up to those on the right. This process continues from the first tray level to the second tray level etc. Theoretically, the device may have an infinite number of trays but losses within the system will limit the overall number.

The Wave Pump also has the potential for energy storage in a reservoir at the level of the highest tray (5), which can allow either a smoother instantaneous output from the turbine or for energy generation during times of low wave conditions.



The Wave Pump is like a ten storey apartment block in which the water goes up two stairs with each wave. The air acts on all the storeys simultaneously. The Wave Pump can be fabricated from concrete and is initially designed as a fixed device for shallow water applications.

1.2 DEVELOPMENT SO FAR

Several prototypes have already been built and tested with real waves at beaches. Videos were produced which show that the principle of the concept is valid and that the Wave Pump is capable of pumping water.

However, before the MARINET supported testing of the Wave Pump at the Hydraulics and Maritime Research Centre (HMRC) in Cork, Ireland, there have been no systematic measurements of performance in terms of flow rates and power output so the efficiency of the device was not known.

It was envisaged that the testing at the HMRC provides the necessary clarification to determine whether the concept has merit and is worth pursuing to more advanced stages of development.

The objectives of the testing were as follows:

1. Verification of the concept of the wave pump on a quantitative basis
2. Determination of interrelationship between a number of key parameters (flow rates, power output, efficiency, number and size of trays, width of flow gaps, size and shape of wave chamber, etc.) for a variety of wave conditions
3. Obtain the limits of operation of the concept
4. Produce power matrix such that to allow an economic evaluation
5. Optimization of the design by the testing of various model configurations

A first week of testing took place from 28th October to 1st November 2013.

A second week of testing was planned, but then cancelled, because there was no more possibility to build prototypes.

2 OUTLINE OF WORK CARRIED OUT

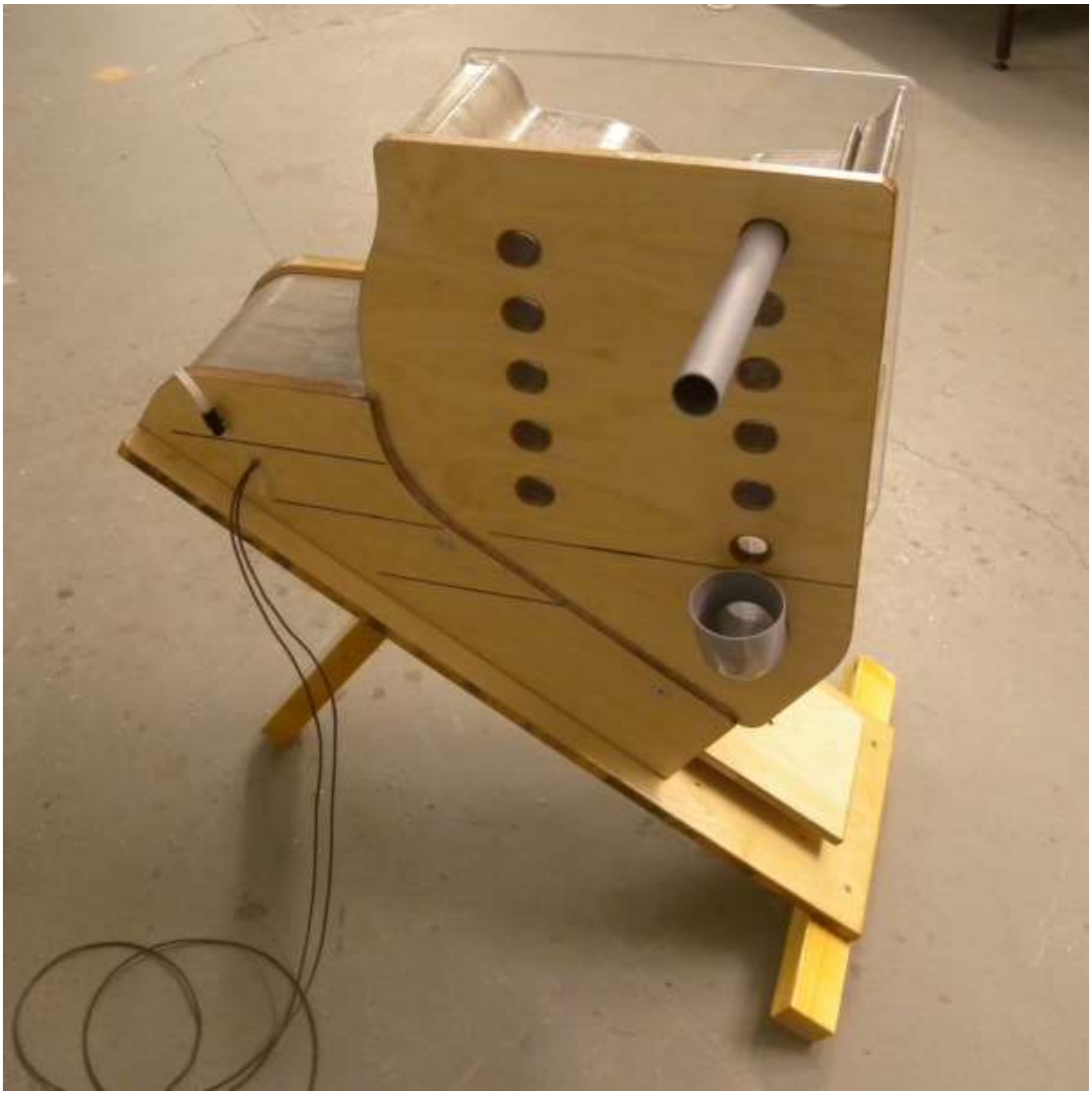
2.1 MODELS

The model used in the first week of testing is shown in the following pictures.

This prototype was designed with a strongly inclined wave chamber, which is suitable for the use in shallow water where the horizontal component of the water movement is predominant. Older prototypes have had vertical wave chambers, which reflected too much of the horizontally arriving wave energy at the beaches where they were tested.

The trays were cast of concrete using moulds of milled polystyrene foam, and they were coated with epoxide resin to improve their smoothness. The side walls are of plywood, which is also thoroughly coated with resin. The front window is of polycarbonate and allows to observe what happens inside the model.

On the inclined wave chamber bottom there is a removable plywood plate, fixed on a spacer, which allows to vary the wave chamber size for the tests.

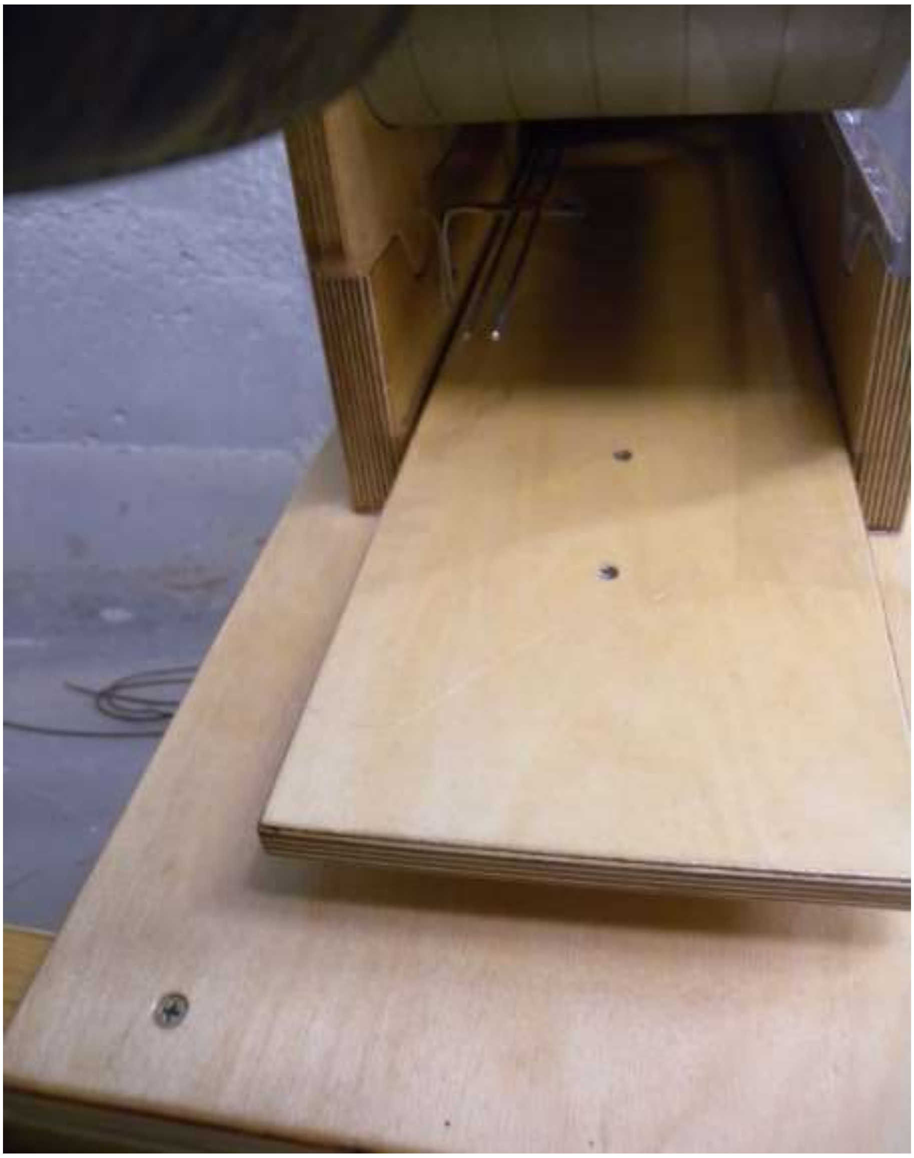


The middle black line indicates the average water level in the test basin, to which the model must be adjusted. The other black lines indicate the maximum and the minimum height of the expected water level inside the wave chamber, respectively. Outside the model, the waves may be bigger.

The grey plastic tubes are the inlet and the outlet for the water to be pumped, which is to be taken from the test basin in this case. The inlet tube has its rim 30 mm above the average water level, which requires that the test waves must have an amplitude of more than 30 mm. The height difference between inlet and outlet, the pump height, is 300 mm in the shown model configuration.

There are transparent windows in the plywood wall, which let light shine into the trays to make observation easier. Some of these windows can be used to plug the outlet tube into an alternative position so that one can explore the effect of varying the number of trays.

The cable comes from a resistive wave probe inside the wave chamber, for measuring the water level and the volume of water pushed in by the waves, and there is a tube plug for measuring the air pressure.



Here is a view into the wave chamber from the front: one can see the two parallel wires of the wave probe as well as the removable plywood plate fixed onto the wave chamber bottom.

2.2 Test Procedure

The model was installed in the middle of the test basin, standing with its three feet on a pile of bricks on the basin floor.

There were probes and sensors installed and connected to a data logger. Time series of the following parameters were recorded while the model was exposed to waves:

1. The water surface elevation outside the model.
2. The water surface elevation inside the model's wave chamber.
3. The air pressure inside the model's wave chamber.
4. The load of the pumped water.

The pumped water was collected at the Wave Pump's outlet tube and then pumped away from there with an electric pump, into a bucket fastened at a load cell, because there was not enough space to weigh the water directly at the outlet tube.

Before each test run, the Wave Pump was filled with water to ensure the same starting conditions.

In this manner, four series of experiments were done trying different design options and different wave conditions.

Monochromatic waves were used in the first three series of experiments to establish the basic operating criteria of the device with height and periods chosen being typical of energy levels along the Atlantic coastlines. Each of the

first three series tried a different model configuration, varying the size of the wave chamber and the number of tray levels.
After this, in the fourth series of experiments, wave spectra of various shapes were also tested in order to assess the ability of the Wave Pump to transfer energy from panchromatic incident waves through the trays to the outlet. This was done with the same model configuration that was used in the first series of experiments, because a first look at the data had suggested it was the best. However, after a more thorough analysis it does now look like as if the second model configuration might have been better.

2.3 Data Analysis

The text files containing the time series were read, plotted and visually checked. Then, the power output was calculated from the curves.
The pump power Pp in W (Watts) was obtained as the average slope in the energy-vs-time plot, examples of which are shown in the results section, with Ep denoting the potential energy in J (Joules) of the pumped water collected in the bucket. Also calculated was the wave power absorbed by the wave chamber, Pa. This was done by integrating the area in the pressure-vs-volume diagram, with p denoting the air pressure in the wave chamber, measured in mmH2O (water column in millimeters), and V denoting the volume of air displaced by the wave in ml (milliliters). The volume, in turn, was calculated from the data of the wave probe inside the wave chamber. The integration was done over the whole duration of the experiment. The green and the red dot in the example plots shown in the results section indicate the beginning and the end of integration, respectively.
The power of the incident waves Pw is:

$Pw = b * 1.0 * \left(\frac{Hw}{1000}\right)^2 * Tw$ for monochromatic waves,

$Pw = b * 0.42 * \left(\frac{Hs}{1000}\right)^2 * Tp$ for panchromatic waves.

Hw is the wave height in mm (millimeters) and Tw is the wave period in s (seconds), and b is the breadth of the model in mm. In the panchromatic case, Hs is the significant wave height in mm and Tp is the peak period in s. Once obtained Pp and Pw, the capture width ratio CWR of the model was calculated as:

$$CWR = Pp/Pw$$

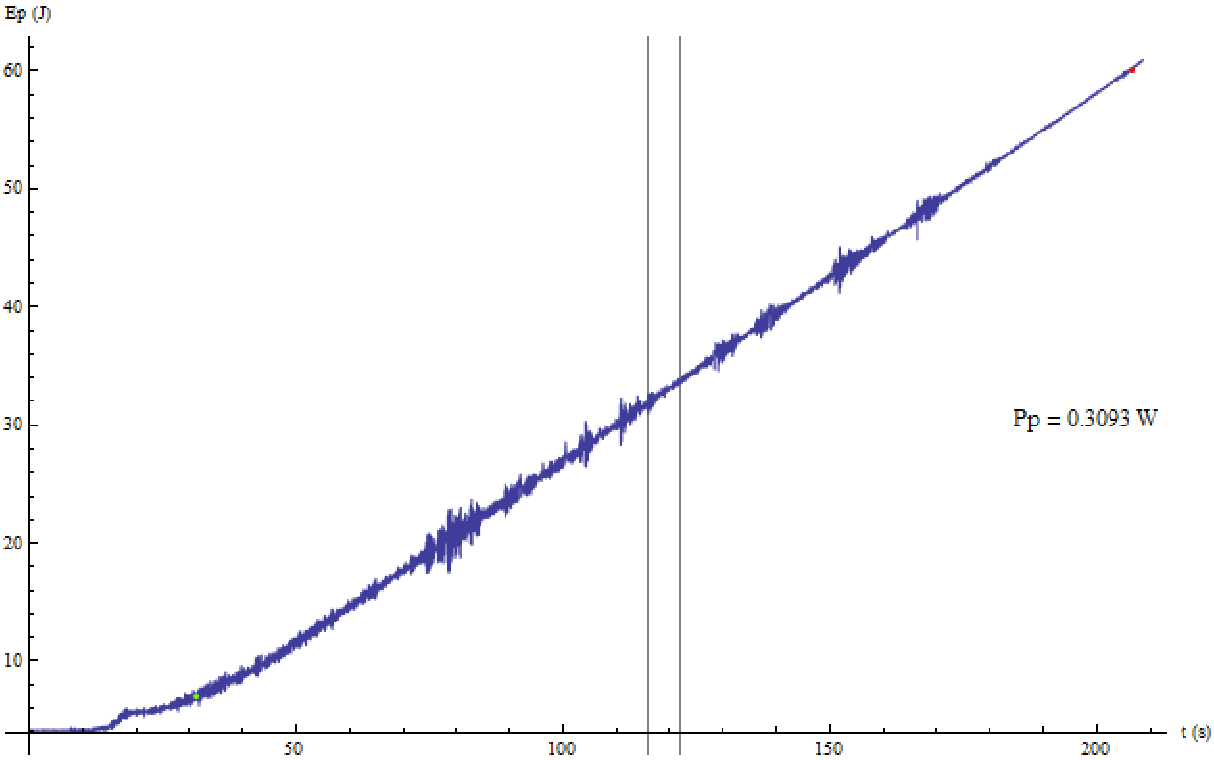
3 RESULTS

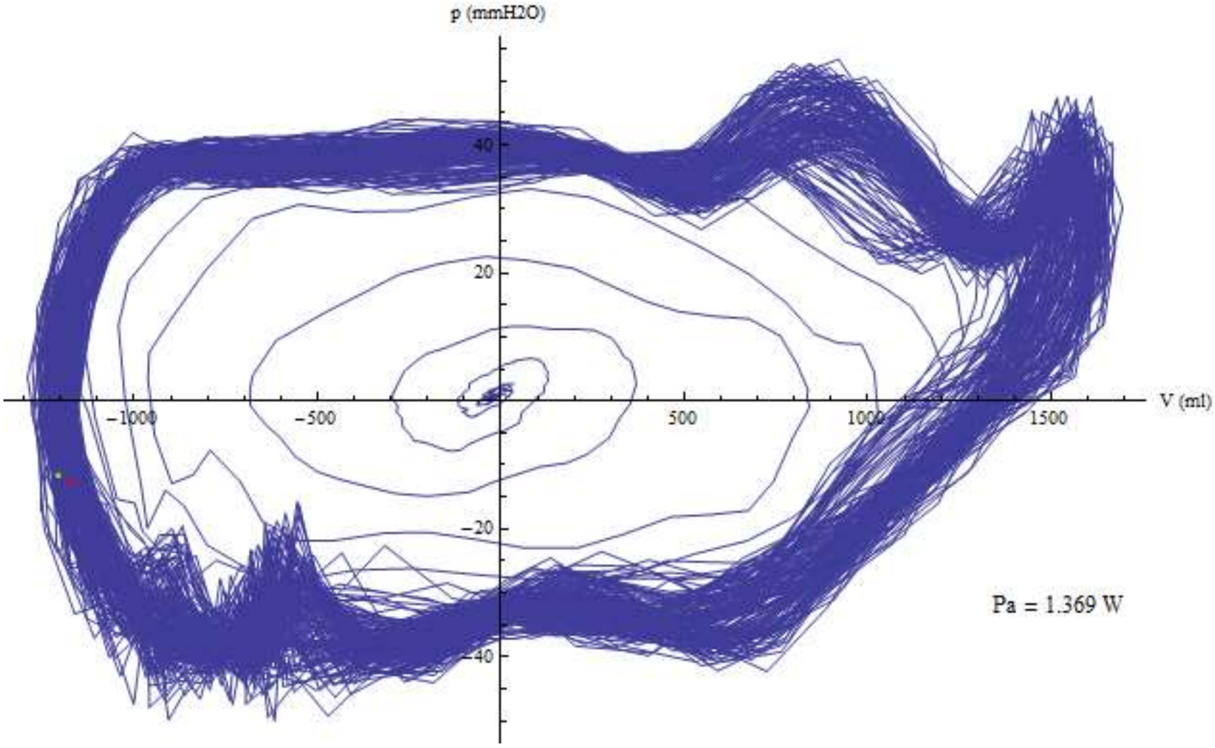
3.1 First Week of Testing

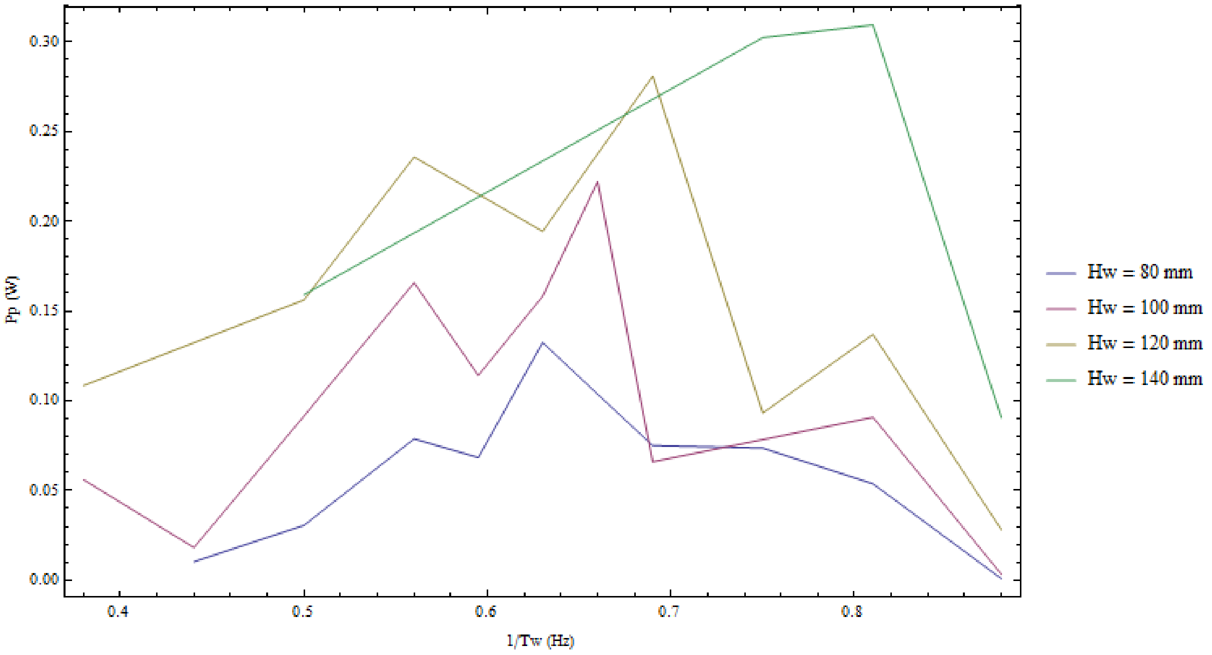
3.1.1 First Series of Experiments

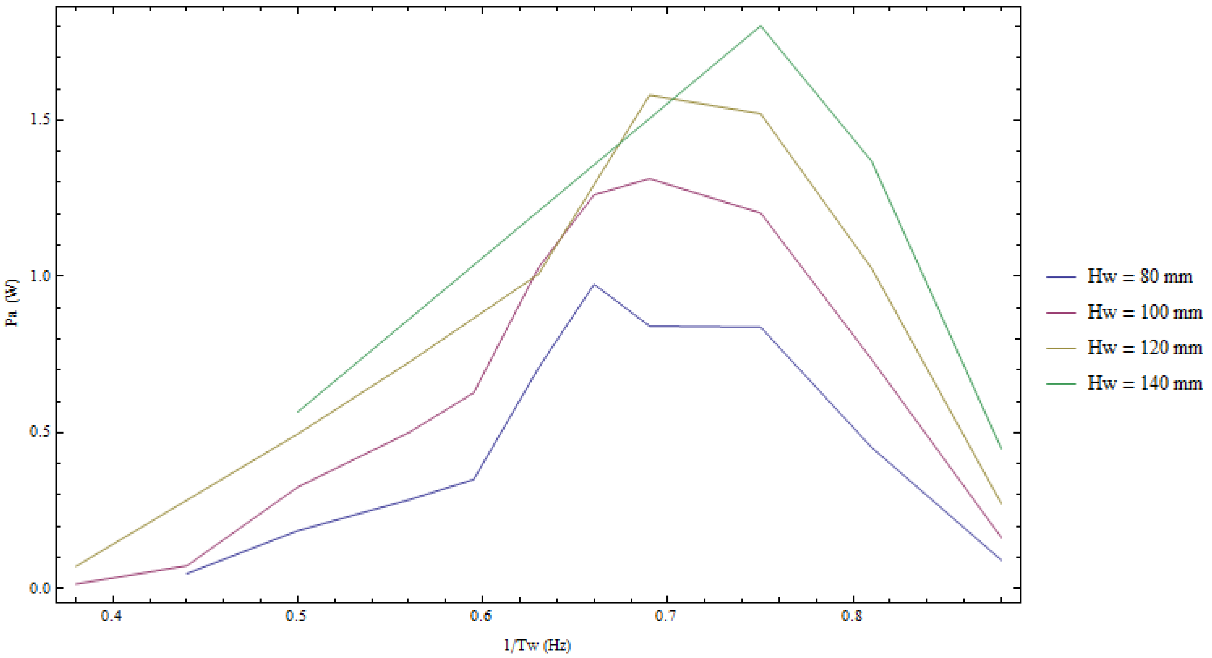
The model configuration was: 10 tray levels, diminished wave chamber. The waves were monochromatic.

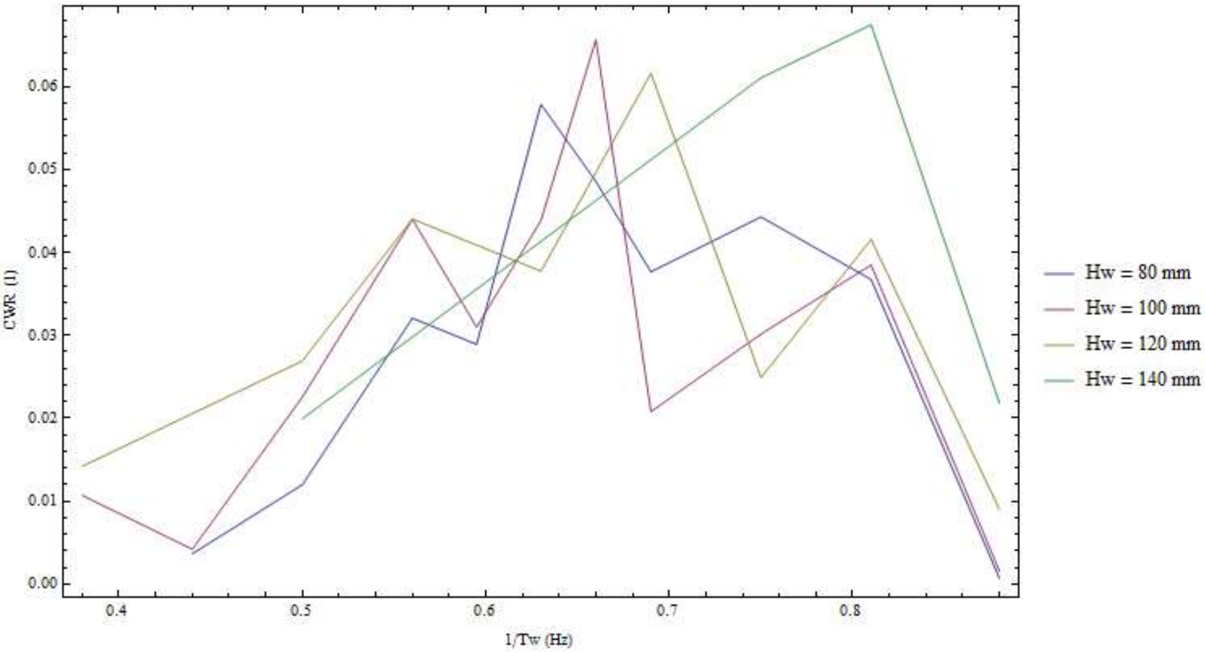
	1/Tw [Hz]	Hw [mm]	Pp [W]	Pa [W]	Pw [W]	Pp/Pw [1]
F0H80	0,44	80	0,010363	0,049311	2,836364	0,003654
F0H100	0,44	99	0,018234	0,074304	4,343625	0,004198
F1H80	0,5	81	0,030676	0,186638	2,55879	0,011988
F1H100	0,5	102	0,091521	0,326535	4,05756	0,022556
F-1H100	0,38	101	0,056016	0,015975	5,234724	0,010701
F1H120	0,5	122	0,156236	0,496527	5,80476	0,026915
F-1H120	0,38	122	0,108526	0,072093	7,637842	0,014209
F1H140	0,5	143	0,159103	0,566811	7,97511	0,01995
F2H80	0,56	84	0,078793	0,285292	2,457	0,032069
F2H100	0,56	104	0,165726	0,500531	3,766286	0,044003
F2H120	0,56	124	0,235797	0,725415	5,354143	0,04404
F3H80	0,63	86	0,132478	0,7074	2,289238	0,05787
F3H100	0,63	108	0,158255	1,028817	3,610286	0,043834
F3H120	0,63	129	0,194397	1,007498	5,150786	0,037741
F4H80	0,69	84	0,075091	0,841183	1,994087	0,037657
F4H100	0,69	106	0,066058	1,312843	3,175391	0,020803
F4H120	0,69	127	0,28079	1,580462	4,558196	0,061601
F5H80	0,75	80	0,073673	0,837743	1,664	0,044275
F5H100	0,75	100	0,078401	1,203145	2,6	0,030154
F5H120	0,75	120	0,093244	1,52076	3,744	0,024905
F5H140	0,75	138	0,302292	1,802125	4,95144	0,061051
F6H80	0,81	78	0,053795	0,452644	1,464667	0,036729
F6H100	0,81	99	0,09081	0,734428	2,3595	0,038487
F6H120	0,81	117	0,136973	1,0257	3,2955	0,041564
F6H140	0,81	138	0,30934	1,368722	4,584667	0,067473
F7H80	0,88	78	0,000916	0,09231	1,348159	0,00068
F7H100	0,88	99	0,003344	0,16442	2,171813	0,00154
F7H120	0,88	119	0,028147	0,273254	3,137949	0,00897
F7H140	0,88	137	0,090608	0,448948	4,15904	0,021786
F25H80	0,595	85	0,068447	0,350254	2,367857	0,028907
F25H100	0,595	106	0,114144	0,627974	3,682387	0,030997
F35H80	0,66	85	0,103675	0,975085	2,134659	0,048567
F35H100	0,66	107	0,22209	1,26148	3,382659	0,065655


Ep (J)
60
50
40
30
20
10
50
100
150
200
t (s)
Pp = 0.3093 W


p (mmH2O)
40
20
−20
−40
−1000
−500
500
1000
1500
V (ml)
Pa = 1.369 W


0.30
0.25
0.20
0.15
0.10
0.05
0.00
Pp (W)
0.4
0.5
0.6
0.7
0.8
1/Tw (Hz)
Hw = 80 mm
Hw = 100 mm
Hw = 120 mm
Hw = 140 mm

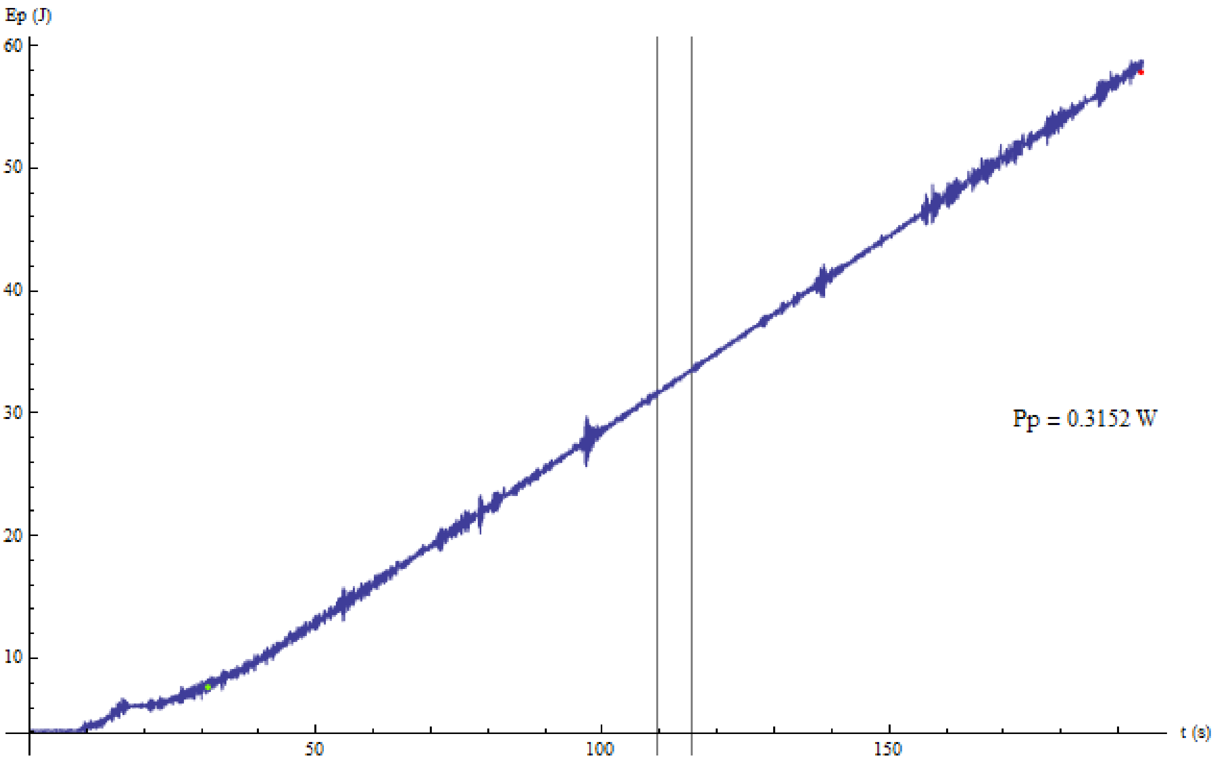

1.5
1.0
0.5
0.0
Pa (W)
0.4
0.5
0.6
0.7
0.8
1/Tw (Hz)
Hw = 80 mm
Hw = 100 mm
Hw = 120 mm
Hw = 140 mm

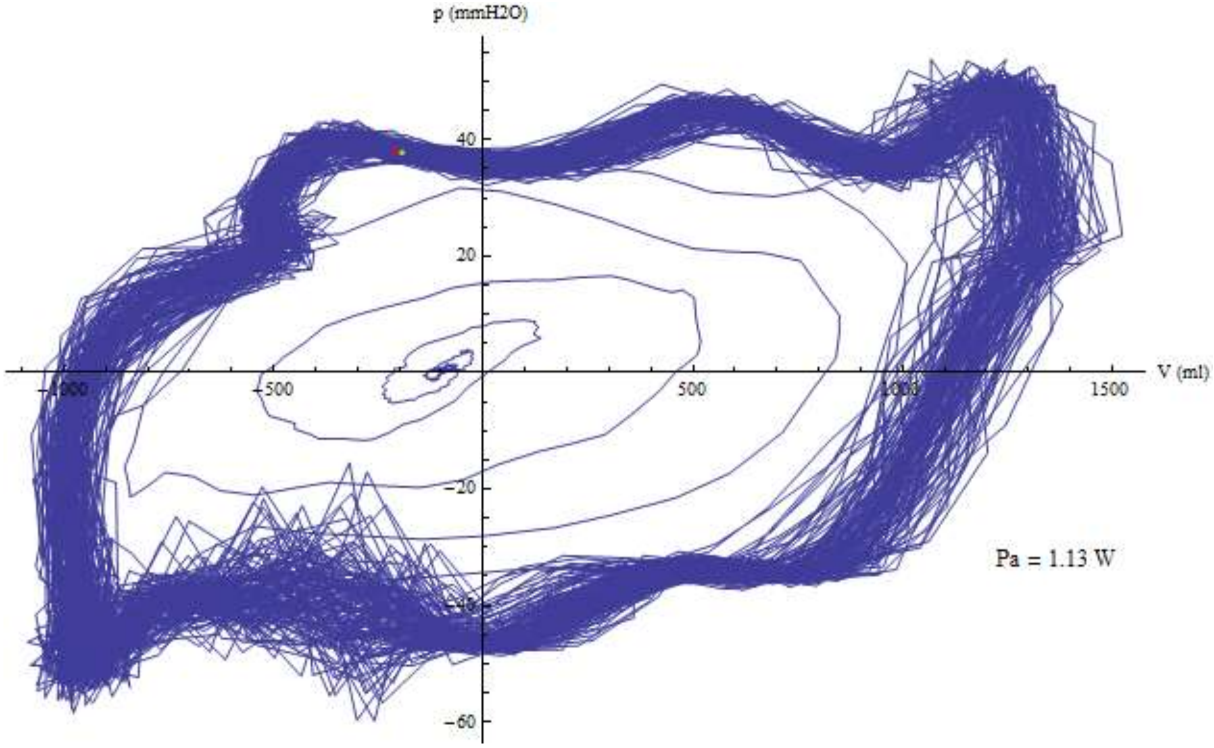


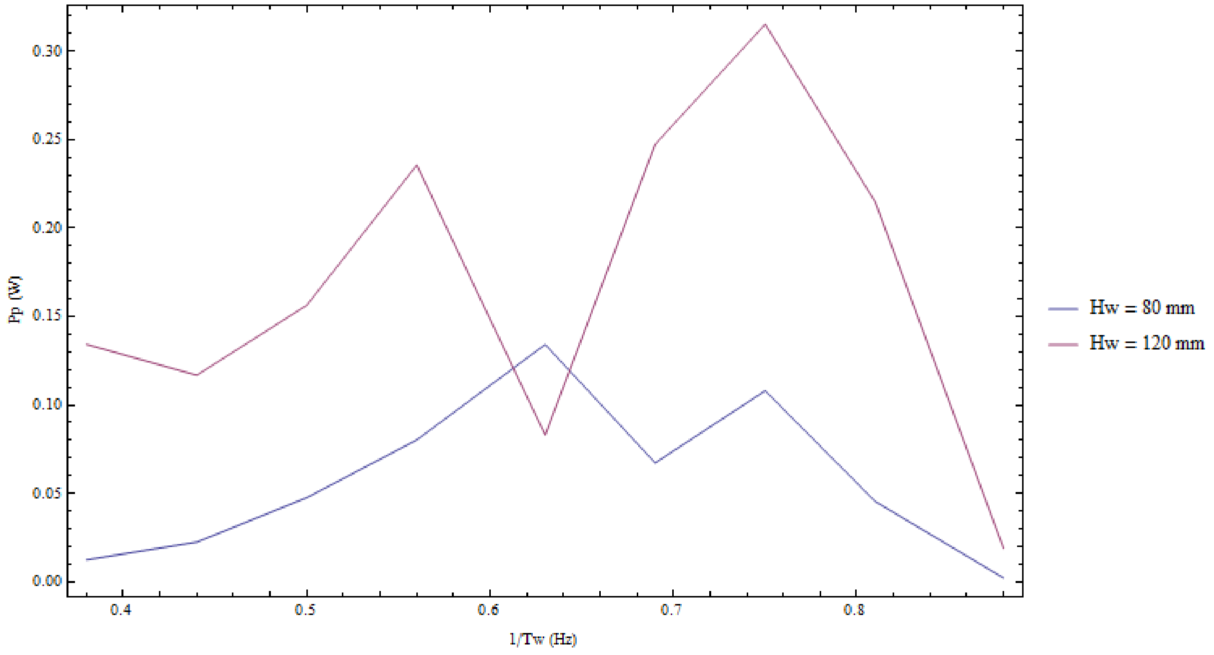
3.1.2 Second Series of Experiments

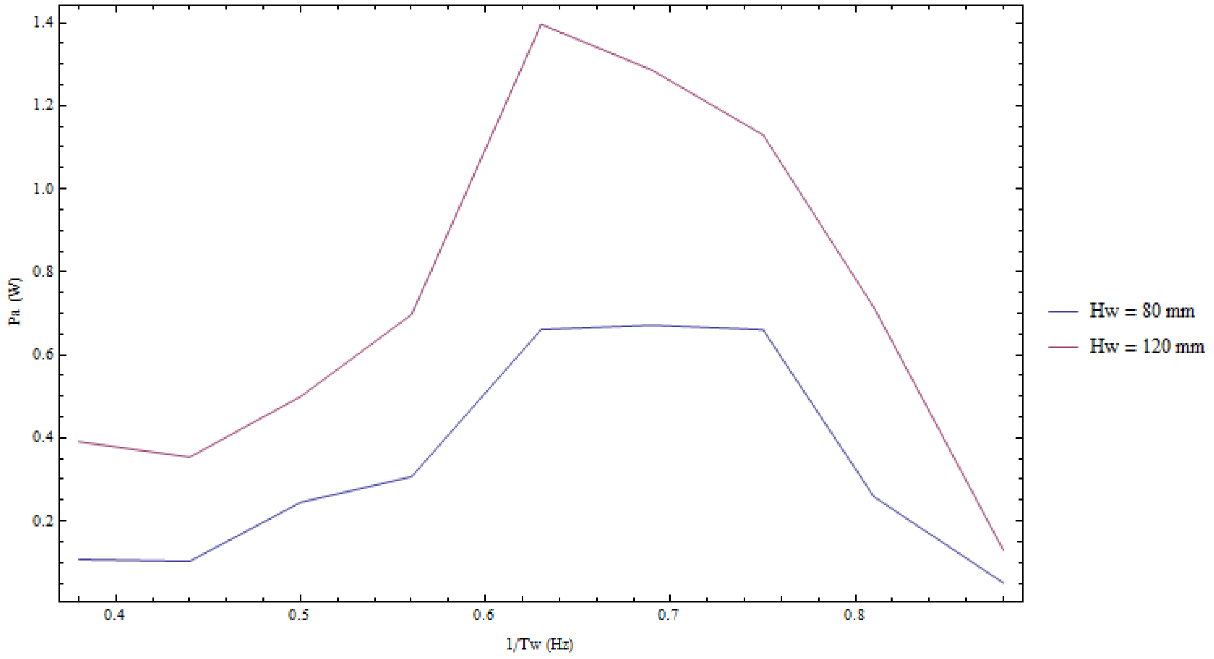
The model configuration was: 10 tray levels, full wave chamber. The waves were monochromatic.

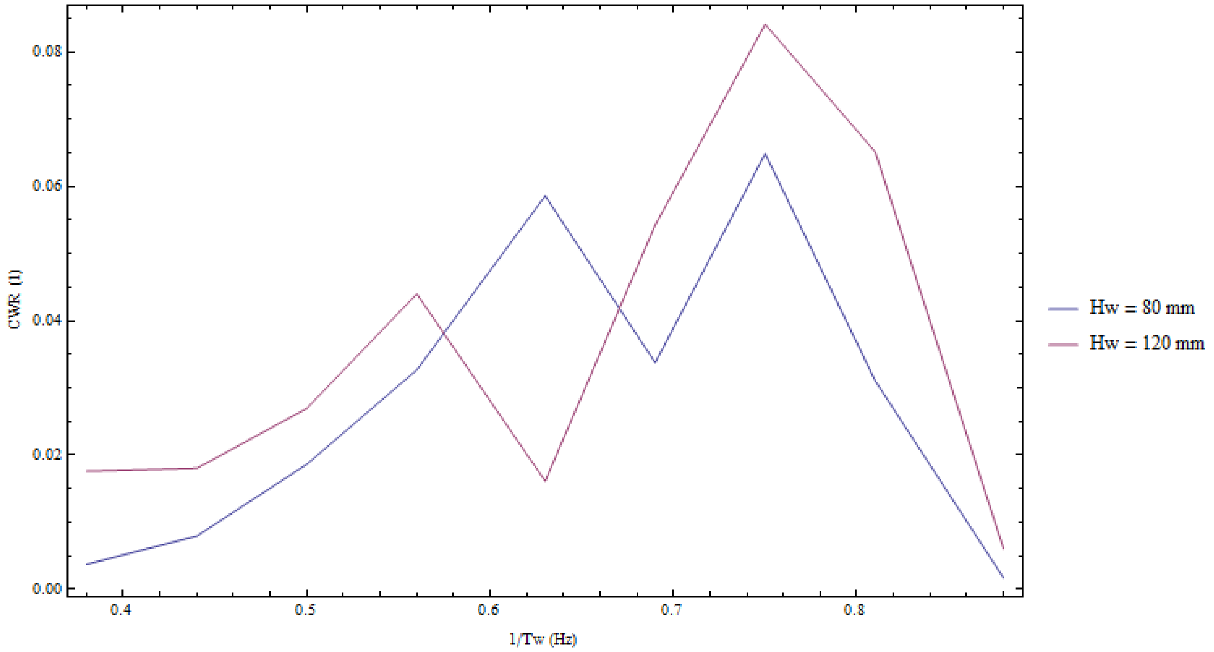
	1/Tw [Hz]	Hw [mm]	Pp [W]	Pa [W]	Pw [W]	Pp/Pw [1]
F0H80	0,44	80	0,022488	0,10302	2,836364	0,007928
F0H120	0,44	121	0,116837	0,353789	6,488625	0,018006
F1H80	0,5	81	0,047621	0,244912	2,55879	0,018611
F-1H80	0,38	81	0,012506	0,10755	3,366829	0,003715
F1H120	0,5	122	0,156368	0,499758	5,80476	0,026938
F-1H120	0,38	122	0,134228	0,391075	7,637842	0,017574
F2H80	0,56	84	0,080269	0,306673	2,457	0,03267
F2H120	0,56	124	0,235597	0,697325	5,354143	0,044003
F3H80	0,63	86	0,134156	0,660992	2,289238	0,058603
F3H120	0,63	129	0,083002	1,396284	5,150786	0,016114
F4H80	0,69	84	0,067311	0,671813	1,994087	0,033755
F4H120	0,69	127	0,247281	1,286027	4,558196	0,05425
F5H80	0,75	80	0,108005	0,660635	1,664	0,064907
F5H120	0,75	120	0,315171	1,129941	3,744	0,08418
F6H80	0,81	78	0,045472	0,258482	1,464667	0,031046
F6H120	0,81	117	0,214684	0,713901	3,2955	0,065145
F7H80	0,88	78	0,00227	0,050952	1,348159	0,001684
F7H120	0,88	119	0,018925	0,129105	3,137949	0,006031


Ep (J)
60
50
40
30
20
10
50
100
150
t (s)
Pp = 0.3152 W


p (mmH2O)
40
20
−20
−40
−60
−1000
−500
500
1000
1500
V (ml)
Pa = 1.13 W


0.30
0.25
0.20
0.15
0.10
0.05
0.00
Pp (W)
0.4
0.5
0.6
0.7
0.8
1/Tw (Hz)
Hw = 80 mm
Hw = 120 mm

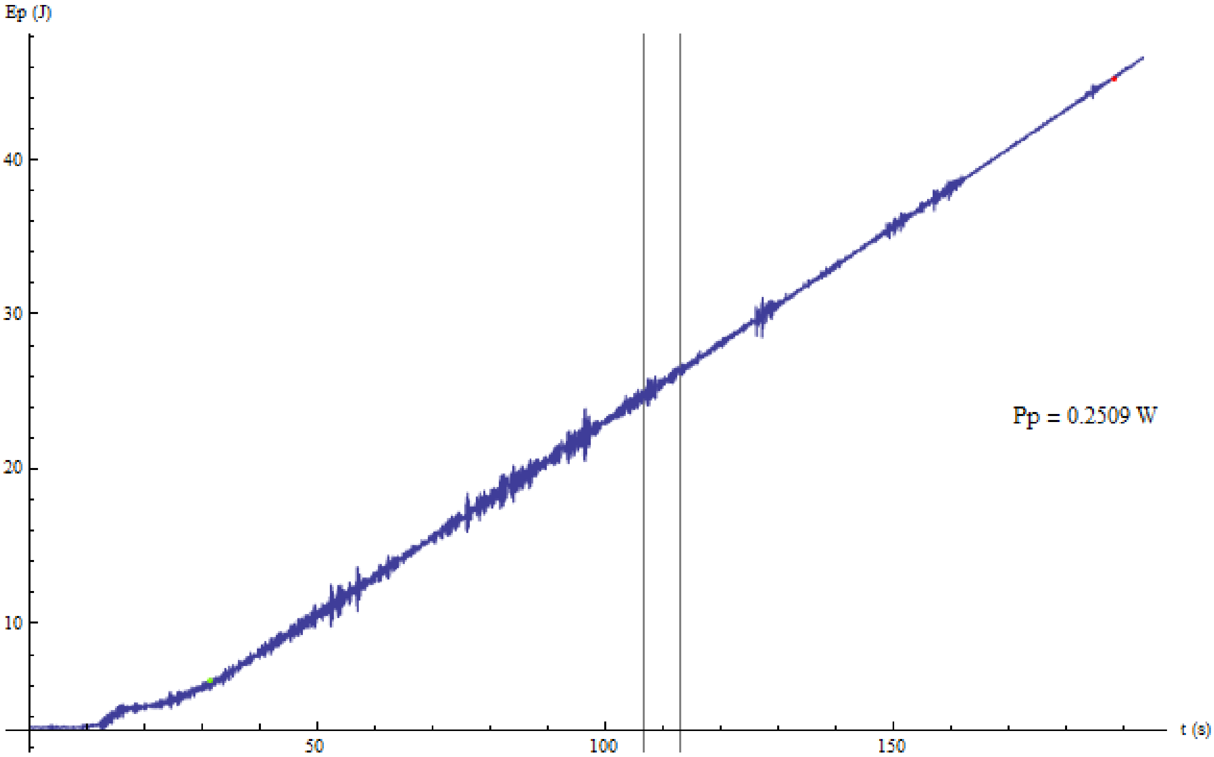

1.4
1.2
1.0
0.8
0.6
0.4
0.2
Pa (W)
0.4
0.5
0.6
0.7
0.8
1/Tw (Hz)
Hw = 80 mm
Hw = 120 mm

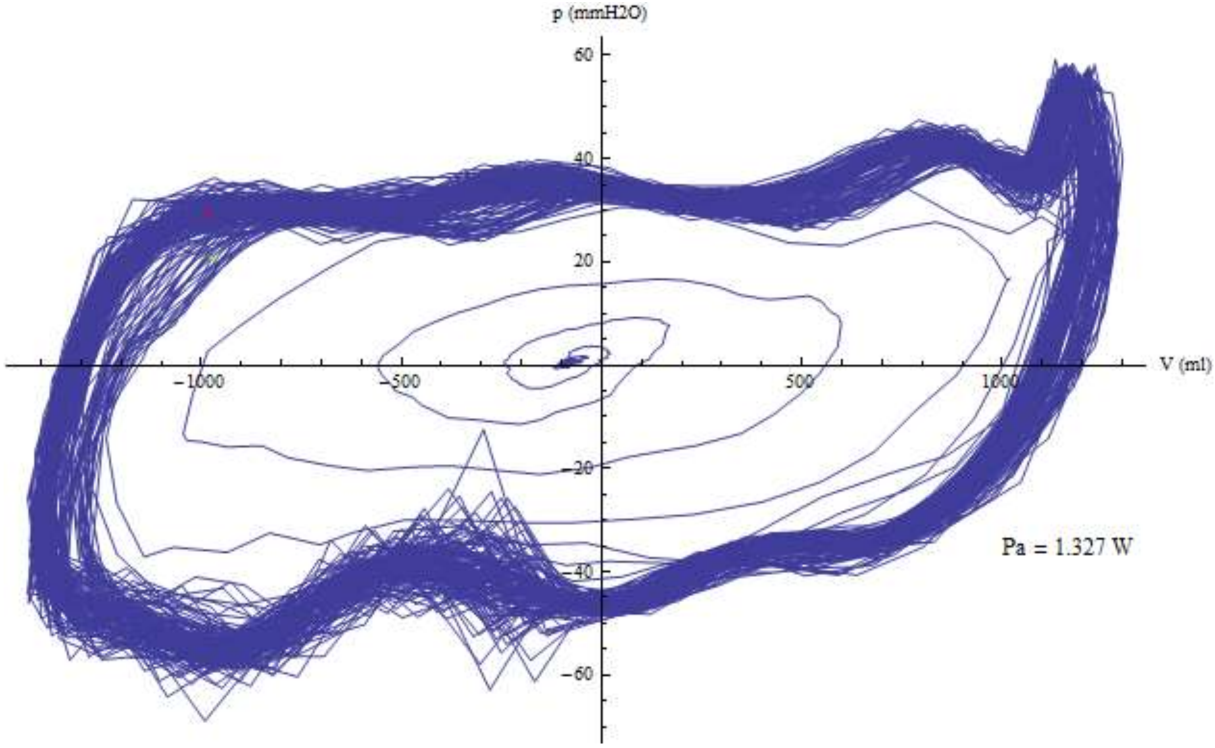


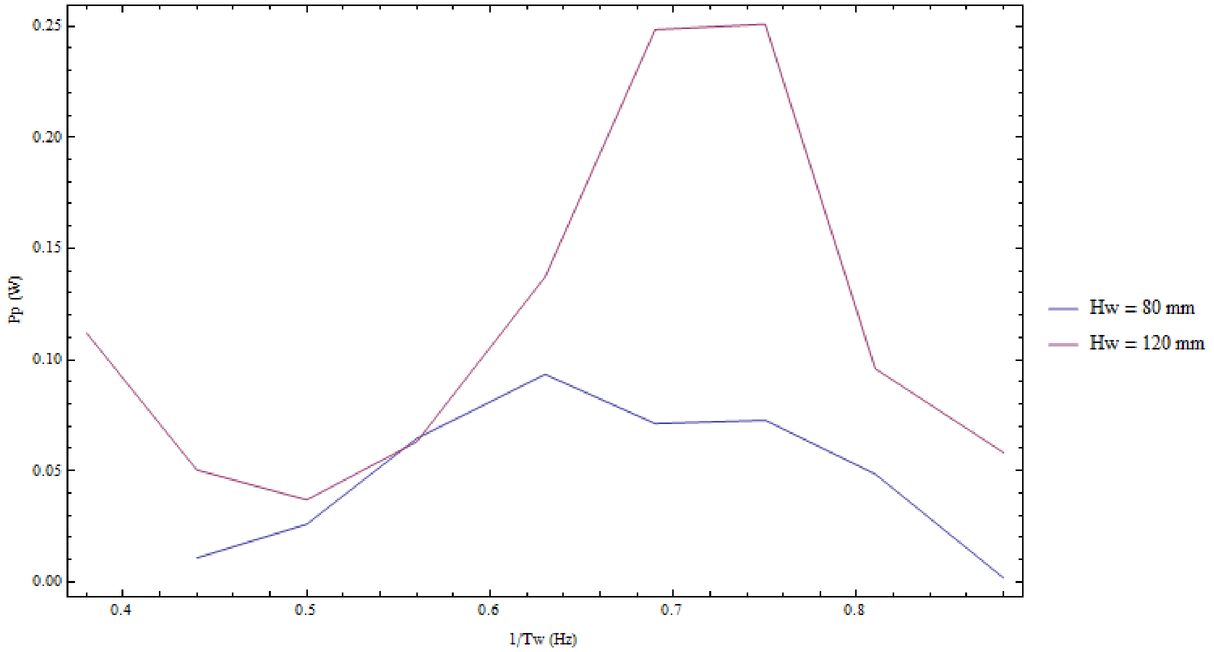
3.1.3 Third Series of Experiments

The model configuration was: 8 tray levels, diminished wave chamber. The waves were monochromatic.

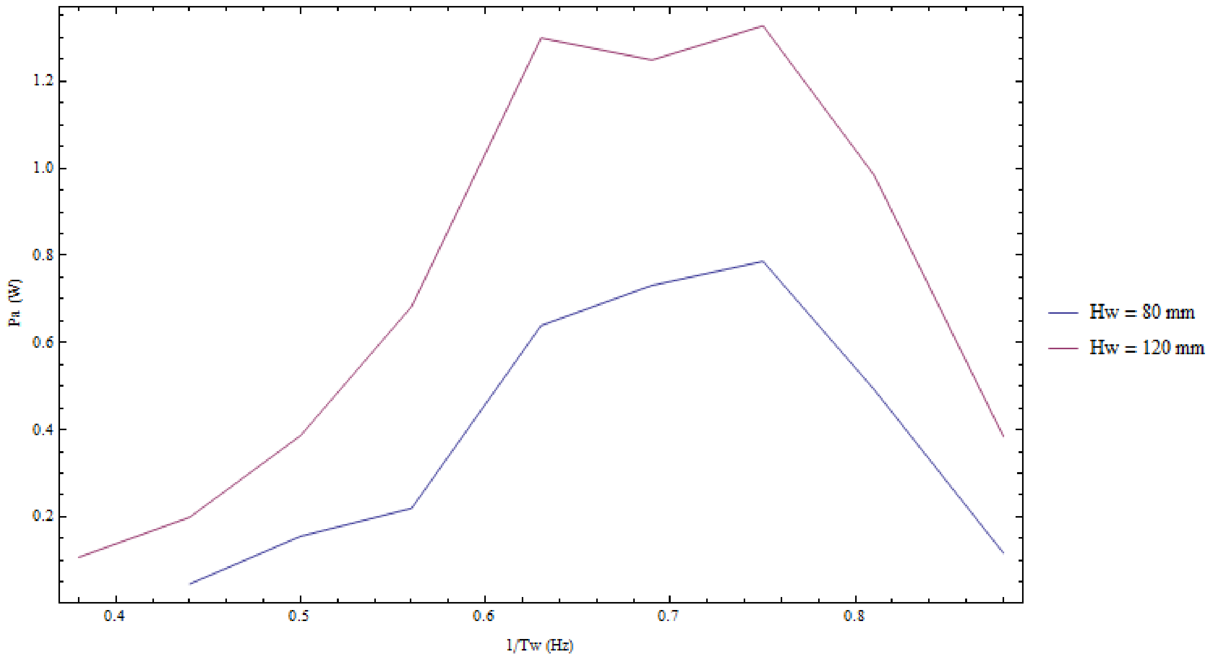
	1/Tw [Hz]	Hw [mm]	Pp [W]	Pa [W]	Pw [W]	Pp/Pw [1]
F0H80	0,44	80	0,010766	0,046012	2,836364	0,003796
F0H120	0,44	121	0,050403	0,199237	6,488625	0,007768
F1H80	0,5	81	0,025992	0,155472	2,55879	0,010158
F1H120	0,5	122	0,036922	0,386833	5,80476	0,006361
F-1H120	0,38	122	0,111958	0,107322	7,637842	0,014658
F2H80	0,56	84	0,064562	0,219642	2,457	0,026277
F2H120	0,56	124	0,063054	0,682874	5,354143	0,011777
F3H80	0,63	86	0,093375	0,639298	2,289238	0,040789
F3H120	0,63	129	0,13725	1,29948	5,150786	0,026646
F4H80	0,69	84	0,071239	0,731464	1,994087	0,035725
F4H120	0,69	127	0,248403	1,248562	4,558196	0,054496
F5H80	0,75	80	0,072731	0,786708	1,664	0,043709
F5H120	0,75	120	0,250856	1,327366	3,744	0,067002
F6H80	0,81	78	0,048542	0,492875	1,464667	0,033142
F6H120	0,81	117	0,095922	0,985084	3,2955	0,029107
F7H80	0,88	78	0,001826	0,116864	1,348159	0,001354
F7H120	0,88	119	0,058167	0,384265	3,137949	0,018537


Ep (J)
40
30
20
10
50
100
150
t (s)
Pp = 0.2509 W

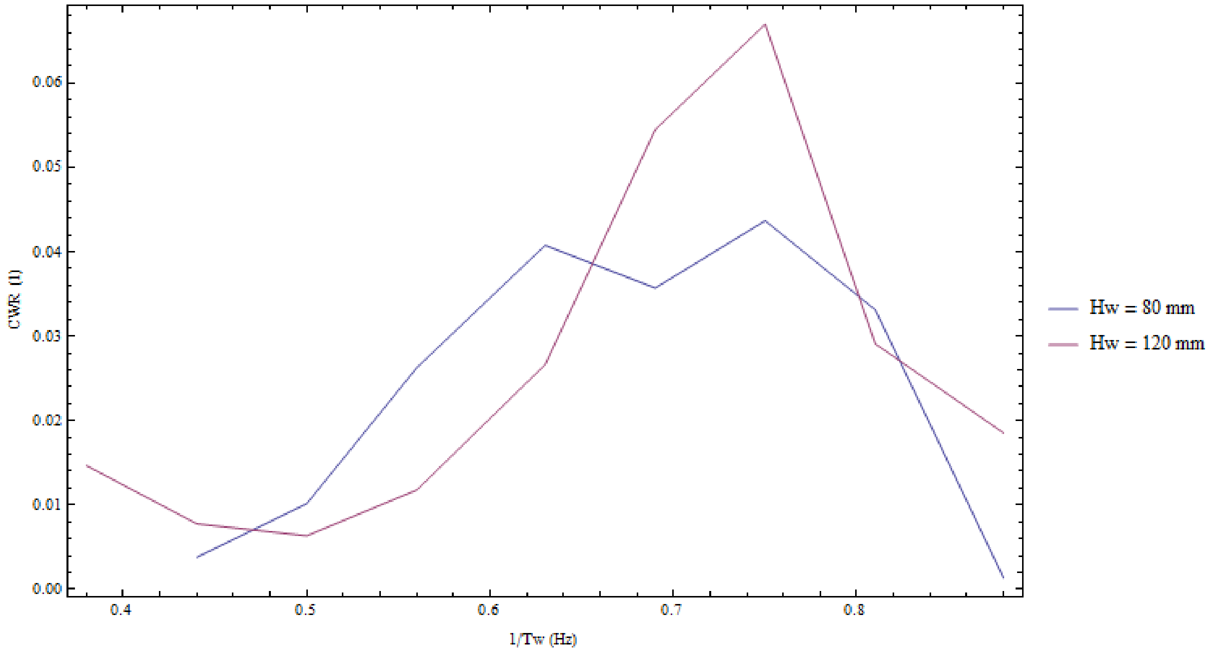

p (mmH2O)
60
40
20
−20
−40
−60
−1000
−500
500
1000
V (ml)
Pa = 1.327 W



Pp (W)
0.25
0.20
0.15
0.10
0.05
0.00
0.4
0.5
0.6
0.7
0.8
1/Tw (Hz)
Hw = 80 mm
Hw = 120 mm



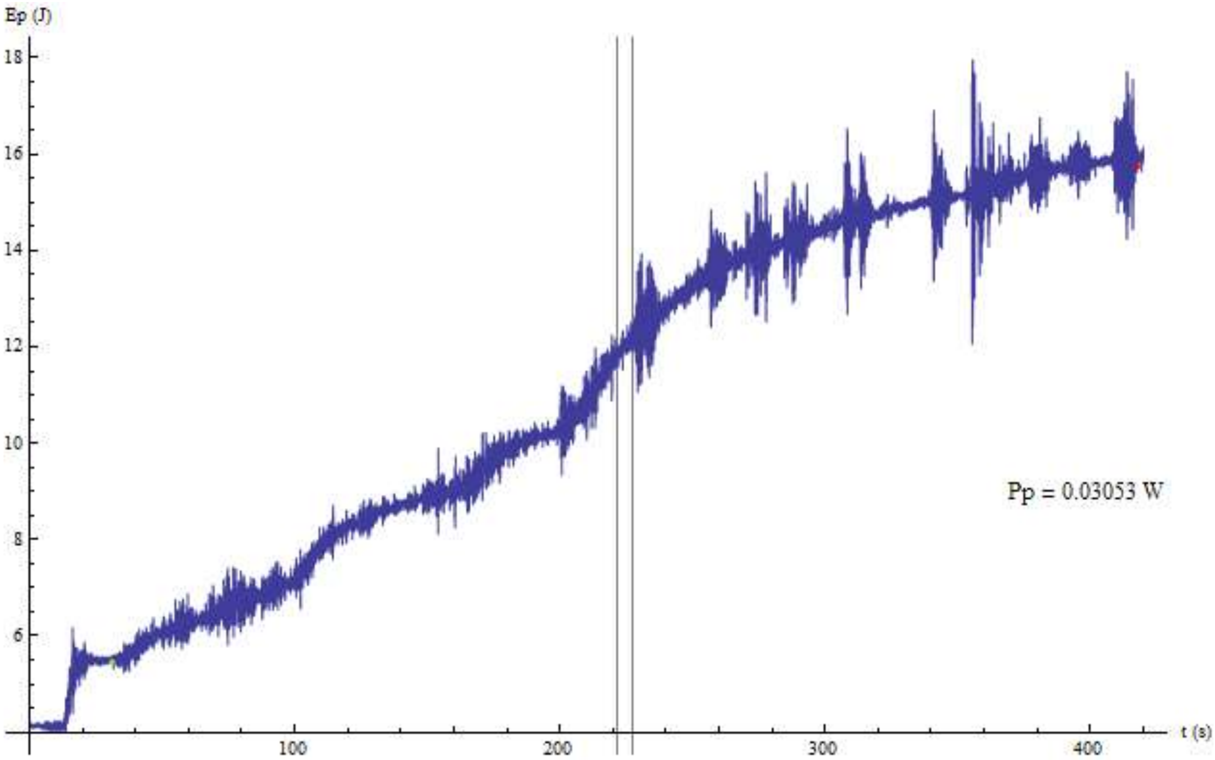
Pa (W)
1.2
1.0
0.8
0.6
0.4
0.2
0.4
0.5
0.6
0.7
0.8
1/Tw (Hz)
Hw = 80 mm
Hw = 120 mm

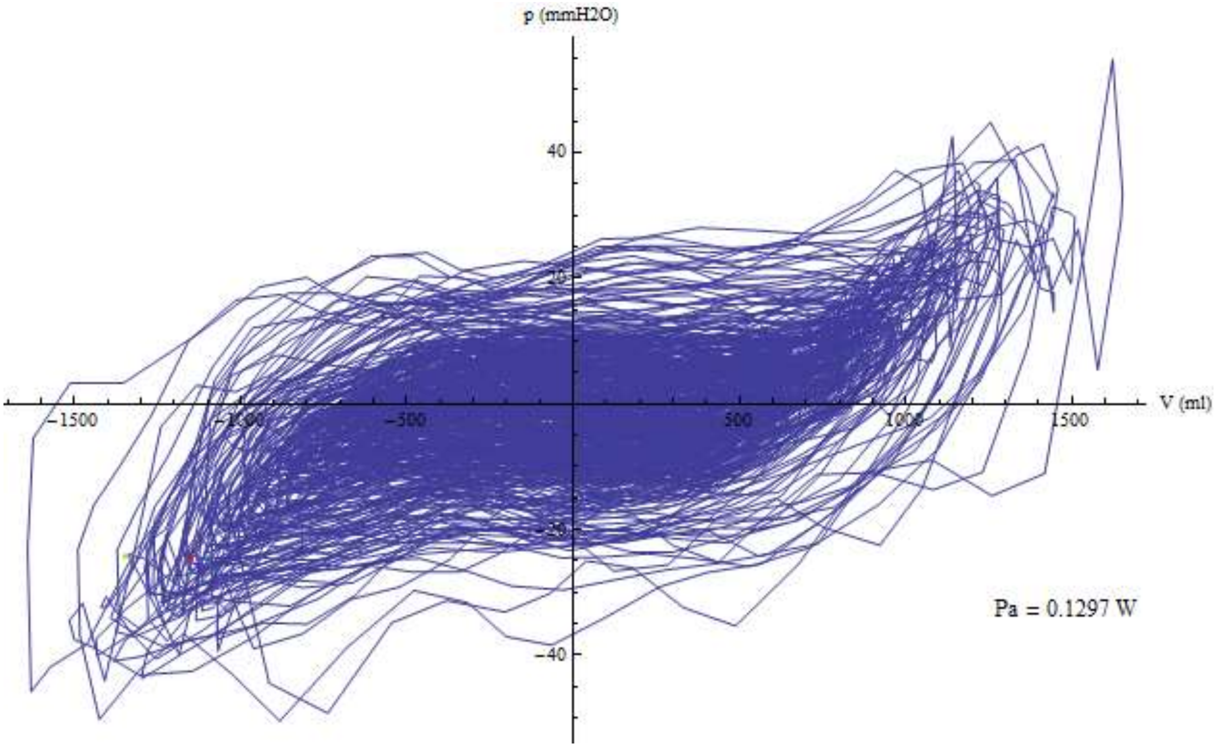


3.1.4 Fourth Series of Experiments

The model configuration was: 10 tray levels, diminished wave chamber. The waves were panchromatic.

	1/Tp [Hz]	Hs [mm]	Pp [W]	Pa [W]	Pw [W]	Pp/Pw [1]
B4	0,806452	65,7	0,009372	0,065402	0,438365	0,021379
B4cos2	0,806452	65,7	0,010872	0,063904	0,438365	0,024802
B5	0,775194	102,5	0,045205	0,201577	1,109996	0,040725
B5cos2	0,775194	102,5	0,050451	0,215403	1,109996	0,045452
B6	0,662252	65,7	0,0282	0,137041	0,533816	0,052828
B6cos2	0,662252	65,7	0,03053	0,129733	0,533816	0,057193
B7	0,666667	108	0,059655	0,334154	1,432922	0,041632
B7cos2	0,666667	108	0,068766	0,358107	1,432922	0,04799
B8	0,641026	154	0,111005	0,714095	3,030051	0,036635
B9	0,555556	109	0,059617	0,340185	1,751497	0,034038
B9cos2	0,555556	109	0,067375	0,36038	1,751497	0,038467
B10	0,546448	165,2	0,106794	0,811339	4,090299	0,026109
B12	0,502513	65,3	0,025588	0,112177	0,694966	0,036819
B12cos2	0,502513	65,3	0,027241	0,107636	0,694966	0,039198
B14	0,5	170,3	0,076884	0,818751	4,750542	0,016184
B15	0,411523	106,5	0,053426	0,184681	2,257301	0,023668
B15cos2	0,411523	106,5	0,056688	0,201345	2,257301	0,025113





3.1.5 Overflow Problem

Under many of the tested wave conditions, especially with the bigger waves, one can observe that a considerable part of the pumped water gets lost by overflow and does not arrive at the outlet. The following picture was extracted from a video.

3.2 SECOND WEEK OF TESTING

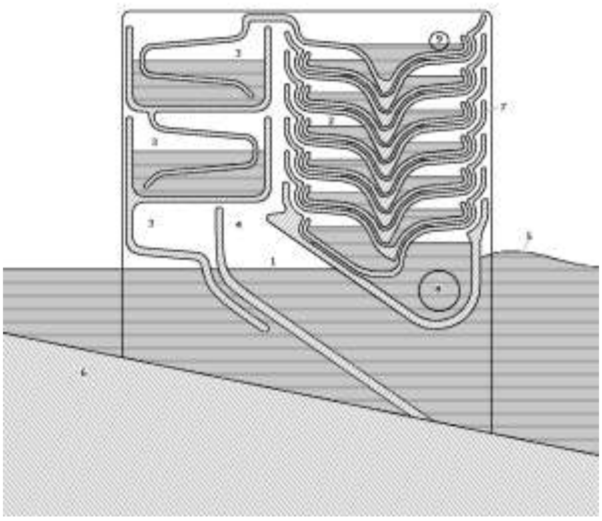
The second week of testing was cancelled.

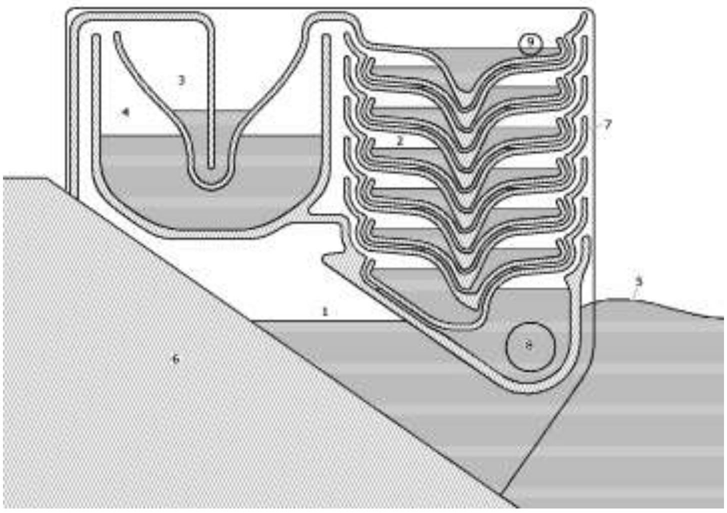
4 MAIN LEARNING OUTCOMES

The Wave Pump works both with monochromatic waves as well as with panchromatic waves. Compared with other wave energy converters, its measured CWR is lower than average, but this can be acceptable because the technology is cheap. Taking into account the losses by overflow, which can be resolved, one can assume there is a big potential for improvement.

The goal to build and test up to eight different prototypes and then select the best could not be achieved due to insufficient financial resources and, most importantly, lack of space. Most of the planned optimisation of the wave pump was not done. It is likely that, if more prototypes had been tested, at least one of them would have shown better results.

After the first week of testing, a solution for the overflow problem was developed and a patent application was filed (DE102013020209). The idea was to add one or more non-linear air buffers, which would limit the air pressure or the air volume coming out of the wave chamber, or both. Unfortunately, there was no more possibility to build any further wave pump prototypes and test this idea. Drawings of the improved wave pumps are shown below.





5 FURTHER INFORMATION

5.1 WEBSITE

Website: www.treefinder.de/ideas.html