User Organisation: Silesian University of Technology (SUT)
Institute of Thermal Technology

Project title: Velocity-Augmented Barriers for Tidal Turbines

Project acronym: VABTITUS

Project Reference Number 1716

UNIFI-LABIMA

Infrastructure Access Reports

Status: FINAL

Version: 05

Date: 10/Dec/2018

MaRINET2

ABOUT MARINET

The MaRINET2 project is the second iteration of the successful EU funded MaRINET Infrastructures Network, both of which are coordinated and managed by Irish research centre MaREI in University College Cork and avail of the Lir National Ocean Test Facilities.

MaRINET2 is a €10.5 million project which includes **39 organisations** representing some of the top offshore renewable energy testing facilities in Europe and globally. The project depends on strong international ties across Europe and draws on the expertise and participation of **13 countries**. Over 80 experts from these distinguished centres across Europe will be descending on Dublin for the launch and kick-off meeting on the 2nd of February.

The original MaRINET project has been described as a *"model of success that demonstrates what the EU can achieve in terms of collaboration and sharing knowledge transnationally".* Máire Geoghegan-Quinn, European Commissioner for Research, Innovation and Science, November 2013

MARINET2 expands on the success of its predecessor with an even greater number and variety of testing facilities across the offshore wind, wave, tidal current, electrical and environmental/cross-cutting sectors. The project not only aims to provide greater access to testing infrastructures across Europe, but also is driven to improve the quality of testing internationally through standardisation of testing and staff exchange programmes.

The MaRINET2 project will run in parallel to the MaREI, UCC coordinated EU marine project which aims to develop a business plan to put this international network of infrastructures on the European Strategy Forum for Research Infrastructures (ESFRI) roadmap.

The project will include at least 5 trans-national access calls where applicants can submit proposals for testing in the online portal. Details of and links to the call submission system are available on the project website www.marinet2.eu

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 731084.

Document Details		
Grant Agreement Number	1716	
Project Acronym	MaRINET2	
Title	Velocity-Augmented Barriers for Tidal Turbines	
Distribution	**Public**	
Document Reference	MARINET-TA1-VABTITUS – 1716	
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Infrastructure Accessed	CRIACIV_LABIMA - Wave Current Flume	
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Document Approval Record		
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Checked by	L. Cappietti, I. Simonetti, A. Esposito	05.11.2018 (2nd Draft) 21.11.2018 (4th Draft)
Approved by	L. Cappietti	10.12.2018

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1. Introduction & Background

1.1. Introduction

The use of arrays of turbines in parallel is quite common for the exploitation of tidal currents. An attractive solution is that of using vertical-axis turbines, installed with suitable two-dimensional devices for the enhancement of the stream velocity [1].

Actuator-disk models, based on the conservation of mass and momentum, have been developed [2] in order to predict the interaction with the free surface and the accelerated flow rate directed towards the turbine. The accuracy of actuator-disk models has been tested with towing experiments [3], and in similarity-scaled model tests performed in open flow channels [2].

The array of assemblies, each composed of convergent-turbine-diffuser, acts as a semi-permeable barrier representing a partial obstruction to the flow.

The existing models [2] deal with simple, non-ducted turbines. New models were developed which treat the whole assembly, i.e. convergent-turbine-diffuser. As a matter of fact, the choice of the correct contraction ratio of the convergent, together with the characteristic of the vertical-axis turbine, results from a compromise with the final goal of ensuring the maximum power output under given operating conditions.

The laboratory campaign at small scale performed within the VABTITUS project was aimed to experimentally measure the water flow behaviour in the proximity of an array of turbines. In the small-scale model, the turbines are embedded in a semipermeable barrier in which the turbines are simulated as an equivalent pressure loss (i.e. an actuator disk approach is adopted).

Similar tests were previously performed in the Wave-Current Flume (WCF) of LABIMA, demonstrating the soundness of the idea [4]. This new project was aimed at testing the model under a wider range of geometries and flow conditions, further developing the concept.

Tests were performed for different level of permeability of the barrier and for different flow conditions (i.e., Froude number was varied by modifying the flow velocity). The following quantities were measured: water free surface in different points, velocity profiles, pressure in different points.

The short-term objective of the VABTITUS project is to acquire a dataset of laboratory data to be used to validate the existing mathematical models.

The medium-term objective is to implement an accurate CFD model, validated by using the data acquired during the VABTITUS project, and to use such a CFD model to optimise the geometry of the barrier and the design of the ducted turbine (in terms of maximization of the power extracted from a given stream in a specified location and sea conditions).

The long-term objective is to use the expertise acquired during the VABTITUS project to get involved in a wide-scale international project aimed at supporting the development of an efficient tidal energy conversion system.

1.2. Development So Far

Previously completed: ✓

Planned for this project: ➲

STAGE GATE CRITERIA	Status
Stage 1 – Analytical model development	
Analytical model of the water behaviour within the flume with barrier	✓
Conference presentation of the model results	✓
Post conference publication of the model results [4]	✓
Stage 2 – First experimental campaign	
Preparing tests with permeable barrier and diffuser construction within the flume	✓
Experiment in the prepared flume	✓
Results collection	✓
Stage 3 – Second experimental campaign	
Preparing tests with semi - permeable barrier	➲
Experimental activities	➲
Data validation from experiment	➲
Publication based on comparing experiment with results from analytical model	
Stage 4 – Numerical (CFD) model development	
CFD model creation based on conducted experiments	
Results comparing from analytical model, CFD model and experiment	
Publication based on comparing experiment with results from analytical model - models validation	

1.3. Plan For This Access

The models for the barrier are scaled by using the Froude similarity. A foreseen positive effect induced by the installation of the barrier, in subcritical conditions (Fr<1), is a measurable local decrease of the water level downstream of the barrier. This determines a hydraulic head difference which could increase the performance of the turbine array.

The tests examine different flow velocities and two blockage configurations. The barrier model simulates the turbines as an equivalent pressure loss. The tests focus on quantifying the capability of the barrier of generating a local pressure head across the turbine assembly and on determining the vertical velocity profile before and after the assembly.

The equipment required and the measured parameters are described in detail in the next sections. In general, tests are performed at five different mass flow rates (all corresponding to values of the Froude number below unity).

The User Group members have been involved in the experimental activities of the VABTITUS project with the following roles and schedule:

1. Preparation for s-scale laboratory tests prepared by Silesian University of Technology + University of Florence (SUT+UNIFI): 09/2018
2. Test campaign: set up and experimental campaign (SUT+UNIFI): 09-10 2018
3. Interpretation of results (SUT+UNIFI): 10/2018
4. Model validation, writing the report and publishing of the results (SUT+UNIFI): 11/2018

The timing for access of the SUT team members at LABIMA has been as follows:

1. Marcin Nowak (MN): 14-23/09
2. Michał Stebel (MS): 22-30/09
3. Bartłomiej Melka (BM): 29/09-07/10

In Table 1 the simplified plan of the experimental research is presented. The day-by-day list of activities is reported in Section 6, Text Matrix.

Table 1 - Test duration and overview of the VABTITUS project activities

	Activity
Day 1-5	Preparation of the flume to the tests: measurement sensors mounting and calibration, run-up section preparation (elements increasing turbulence - roughness)
Day 6-10	Tests without the barrier within the flume: - configuration with the bottom roughness - configuration without the bottom roughness
Day 11-15	Tests with the barrier within the flume: - configuration with the bottom roughness - configuration without the bottom roughness

2. Outline of Work Carried Out

2.1. General experimental set-up

Tests have been done in the wave-current flume (WCF) of Florence University (LABIMA-WCF). The flume is a structure completely made of steel and glass side walls, with a total length of 3700cm and 80cm wide and high. A piston type wave maker is installed at one end of the flume and it has a stroke equal to 150cm driven by an electromechanical system with an absolute encoder of 0.01cm accuracy in position. The wave maker has not been used for the VABTITUS project (since wave generation was not required).

The WCF is also equipped with bi-directional recirculation system with maximum flow rate of 150l/s. The recirculation system was used during the tests in order to obtain different water mass flow rate in the WCF. Experiments were performed to measure the modification of the free surface profile induced by the installation of the barrier imitating the set of the horizontal axis water turbines. The barrier was mounted 15 cm above the WCF bottom and 21.78m far from the wave paddle (Figure 1).

Figure 1 - Barrier used to reproduce an array of vertical axis turbines

The WCF was instrumented with 2 ultrasonic and 5 resistive Wave Gauges (WGs), 3 Pressure Transducers (PTs) and 1 Vectrino. The position of the instruments is given in **Errore. L'origine riferimento non è stata trovata.**. The scheme of the barrier and measuring devices is presented in Figure 2 (top).

Table 2 - Distance of the sensors from the wave paddle

Sensors	Type of sensor	x (m)	y (m)	z (m)
WG1	Ultrasonic wave gauge	24.78	0.4	
WG2	Resistive wave gauge	23.78	0.4	
WG3	Ultrasonic wave gauge	22.78	0.4	
WG4	Resistive wave gauge	21.78	0.4	
WG5	Resistive wave gauge	21.75	0.4	
WG6	Resistive wave gauge	21.69	0.4	
WG7	Resistive wave gauge	21.63	0.4	
PT1	Pressure transducer	21.90	0.1	-0.3
PT2	Pressure transducer	21.74	0.04	-0.15
PT3	Pressure transducer	21.61	0.7	-0.3
Vectrino	Acoustic velocimeter	21.72	0.2	Variable

Barrier		21.78		-0.15

An array of bricks with a cubic shape (with lateral dimension L=12.2cm approximately) and two metallic nets with a 1cm mesh size are installed before the barrier in order to promote the development of turbulent flow conditions in the WCF.

A scheme of the installed roughness is presented in Figure 2 (bottom) and Figure 3. Overall, 8 lines of bricks are installed in the WCF, with a spacing (in the flow direction) of about 20cm. The assembly of the bricks covers an extension of about 2.4 m and is located 8.94 m before the location where the barrier is installed (see Figure 5).

The two metallic nets (Figure 3) ware located 1.2m and 2.4m downstream of the end of the brick assembly (Figure 5).

This whole assembly (bricks and nets) is hereafter referred to as *roughness*.

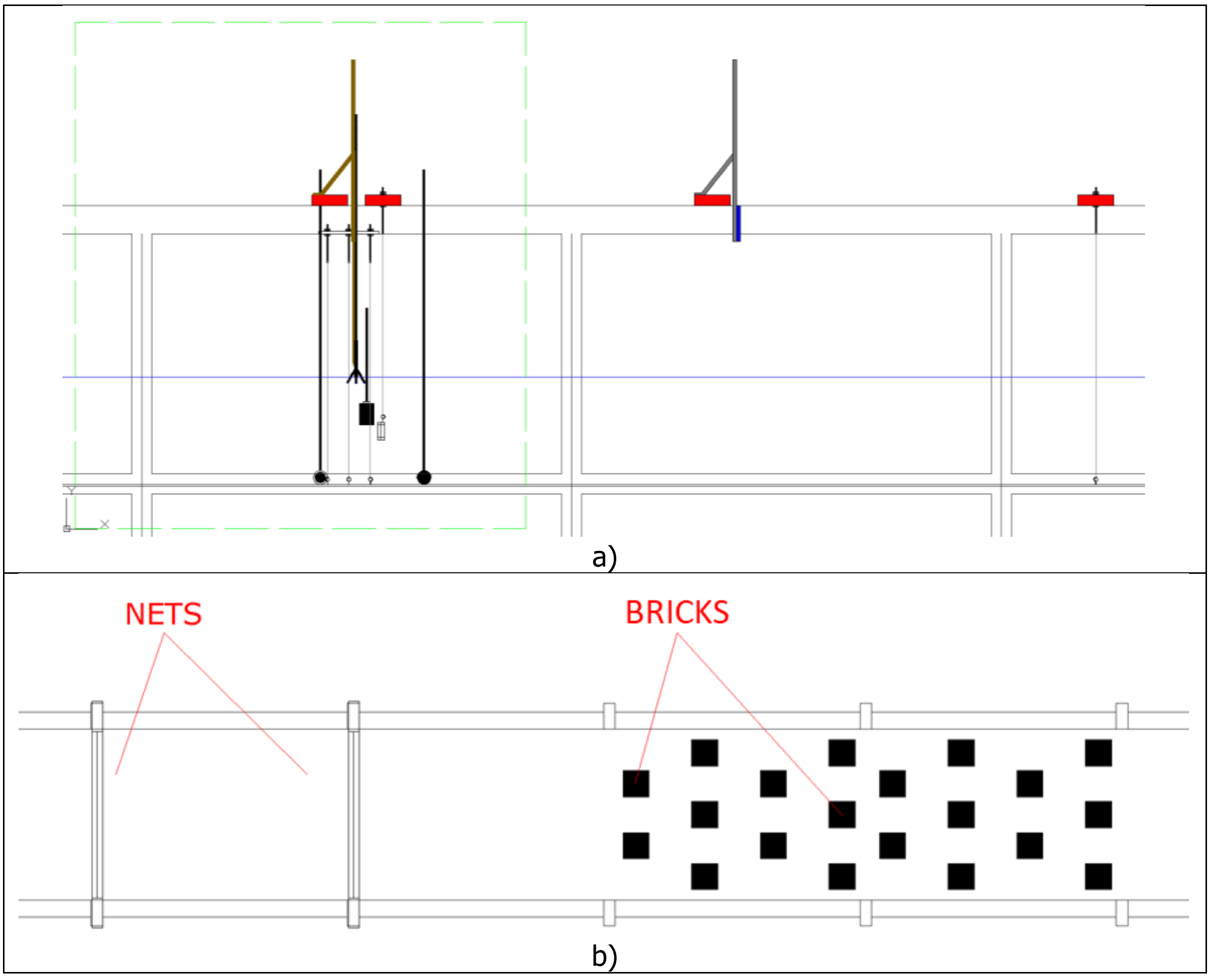

Figure 2 - Scheme of the test rig: a) Side view of the model section; b) Top view of the roughness installed in the WCF.

Figure 3 - Mechanism to promote the development of turbulence in the flow: a) bricks installed on the WCF bottom; b) net installed in a transversal section of the WFC

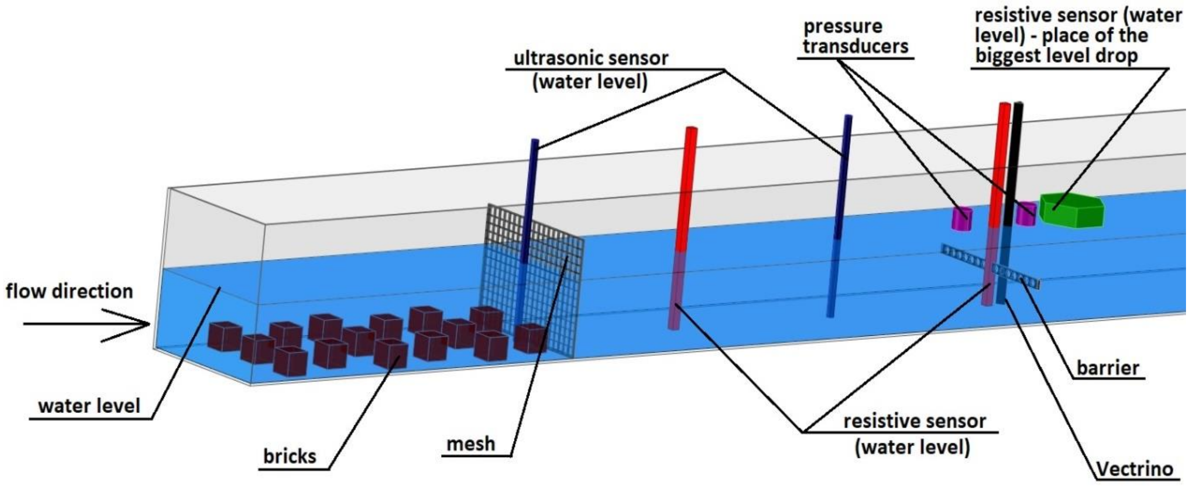

Figure 4 Simplified scheme of the flume configuration for the tests.

The following measurements were performed:

- water free surface level at specific locations:
  - before the barrier position
  - on the barrier
  - after the barrier position
- pressure level in specific at specific locations:
  - before the barrier position
  - immediately after the barrier position
  - after the barrier position
- velocity profile measured in several positions after the barrier.

Schemes of the whole WCF set-up are provided in Figure 4 and Figure 5. The detailed characterisation of the used measurement instrumentations is given in the following subchapters of the report (see *Section 2.3*).

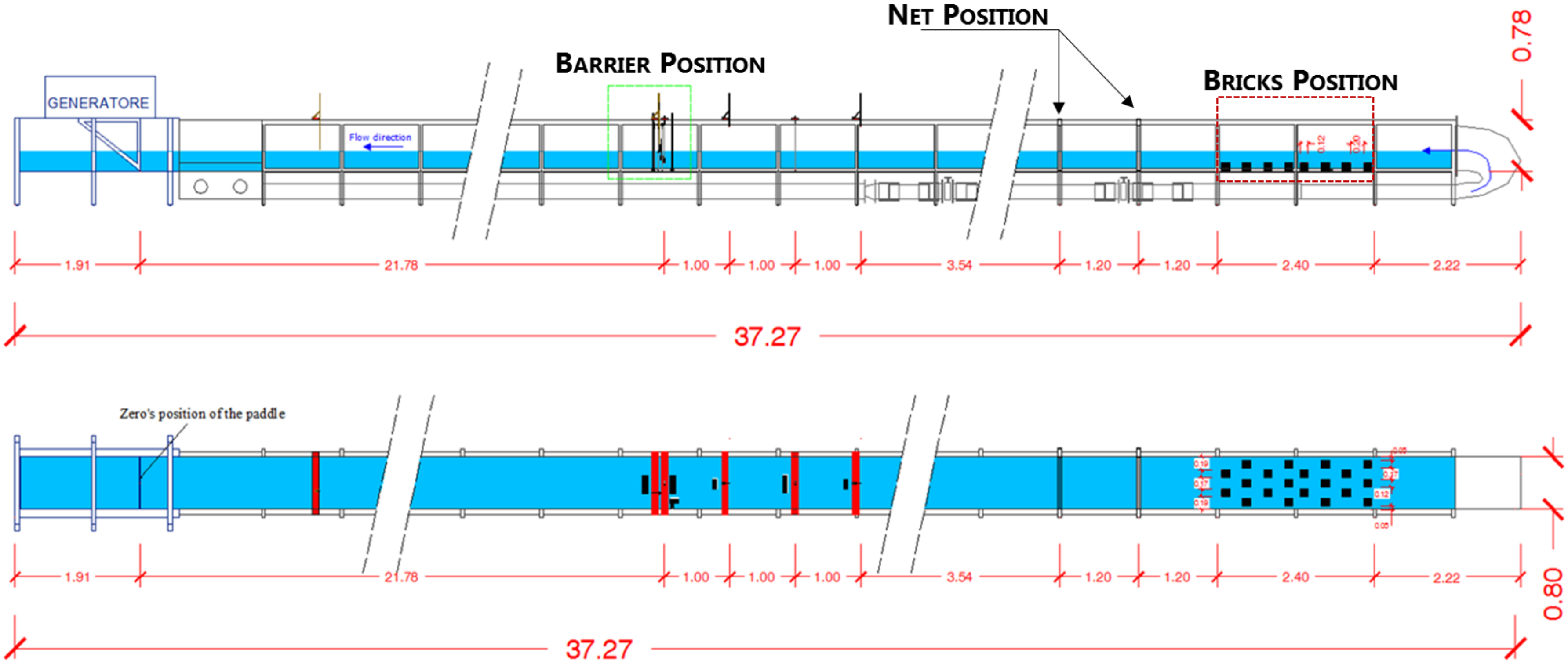

Figure 5 - Side view and top view of the installation

2.2. Tested configurations

Three different configurations were tested:

- Configuration 0 (C0): reference case, based on the measurements of the water behaviour in the WCF without the barrier.
- Configuration 1 (C1): barrier installed in the WCF and equipped with "Mesh #1", mounted at the position being exactly between the flume bottom and the water free surface.
- Configuration 2 (C2): barrier with the "Mesh #2", mounted in the same position as C1.

"Mesh 1" and "Mesh 2" where additional layers used to vary the permeability of the barrier. "Mesh #1" denotes a layer of metallic net, with a mesh size of 2mm, inserted in the central section of the barrier. "Mesh #2" denotes a layer of geotextile inserted in the central section of the barrier. "Mesh #2" was finer comparing to the previous one used during tests[1].

Moreover, configurations C0, C1 and C2 were tested in the variants with and without the roughness in the set-up section of the flume. Therefore, experimental activities were performed in the following variants:

(i) Configuration C0, C1 and C2 without roughness;
(ii) Configuration C0, C1 and C2 with roughness;

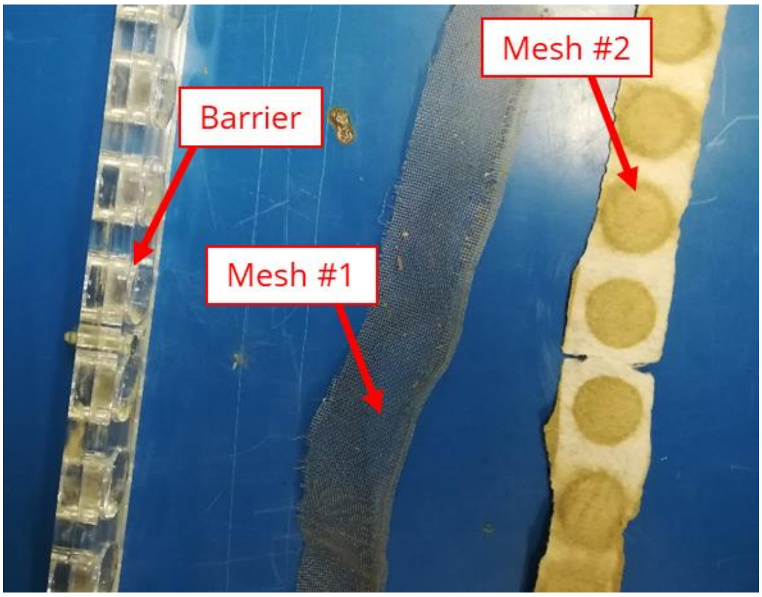

Figure 6 - Barrier, Mesh #1 and Mesh #2

[1] It is worth to note that, during the tests, sand was injected in the flume as a seed to ease the measurement of the acoustic doppler velocimeter (Vectrino). A decrease if the permeability of the layers located in the central section of the barrier is therefore expected during the tests, due to sand deposition.

2.3. Details of employed instrumentation

The following instrumentations were used during the tests:

- Vectrino acoustic velocimeter device, mounted 6cm behind the barrier at a fixed position but able to be moved up/down. The Vectrino was used to collect measurements at different height above the bottom of the WCF, in order to reconstruct a vertical profile of the velocity.

  Measurements with the Vectrino sensor were conducted on heights: 1.0, 1.5, 2.0, 2.5, 3.0, 4.0, 5.0, 6.0, up to 14 cm, 24 cm or 34 cm from the bottom of the flume for tests with water levels h=20 cm, h=30 cm and h=40 cm in the WCF respectively.

- Pressure transducers (PTs), to measure static pressure, installed in different location in the WCF:
  - 1 pressure sensor on the bottom of the channel, 12cm before the barrier, 10cm far from the left wall, sensor name: PT1 (see Table 2).
  - 1 pressure sensor on the left wall, immediately after the barrier and about 5cm far from the water level, sensor name: PT2 (see Table 2);
  - 1 pressure sensor on the bottom of the channel, 17 cm behind the barrier and 70cm far from the left wall, sensor name: PT3 (see Table 2).

- Pressure transducers (PTs), to measure the differential pressure between the point located in the middle opening of the barrier and point located on the bottom of the channel 15 cm behind the barrier (sensor name PT4)

- Resistive wave gauges (WGs), installed in different locations along the WCF:
  - 1 resistive wave gauge located 2m before the barrier (sensor name: WG2)
  - 1 resistive wave gauge located on the barrier (sensor name: WG4)
  - 3rd was located 3cm behind the barrier (sensor name: WG5);
  - 4th was located 9cm behind the barrier (sensor name: WG6);
  - 5th was located 15cm behind the barrier (sensor name: WG7).

- Ultrasonic distance sensors (WGs) for the water level measurement:
  - 1st was located 3 m before the barrier (sensor name: WG1);
  - 2nd was located 1 m before the barrier (sensor name: WG3).

2.3.1. Velocimetro ADV - Vectrino

The Vectrino Velocimeter (shown in Figure 7) measures the water velocity using the Doppler effect. According to the device specification, all three velocity vector components can be measured. The third one results from the two pairs of signal sensors; therefore, acquisition of this component is doubled. An example time series acquired by the Vectrino is given in Figure 8. The vectrino device specification is presented below:

- Water Velocity Measurement Range: ±0.01, 0.1, 0.3, 1, 2, 4 m/s (software selectable)
- Accuracy: ±0.5% of measured value ±1 mm/s
- Sampling rate (output) 1–25 Hz, 1–200 Hz (Vectrino + firmware only)
- Internal sampling rate: 200–5000 Hz
- SAMPLING VOLUME Distance from the probe: 0.05 m
- Diameter: 6 mm

- Height (user selectable): 3–15 mm
- DOPPLER UNCERTAINTY (noise) Typ. uncertainty at 25 Hz: 1% of the velocity range
- ECHO INTENSITY Acoustic frequency: 10 MHz
- Resolution: 0.45 dB Dynamic range: 60 dB
- SENSORS Temperature (thermistor embedded in the probe) Range: –4 ºC to 40ºC Accuracy/Resolution: 1 ºC / 0.1ºC
- Time response: 5 min
- Seed added to the water stream before the sensor: sand.

Figure 7 - Vectrino sensor

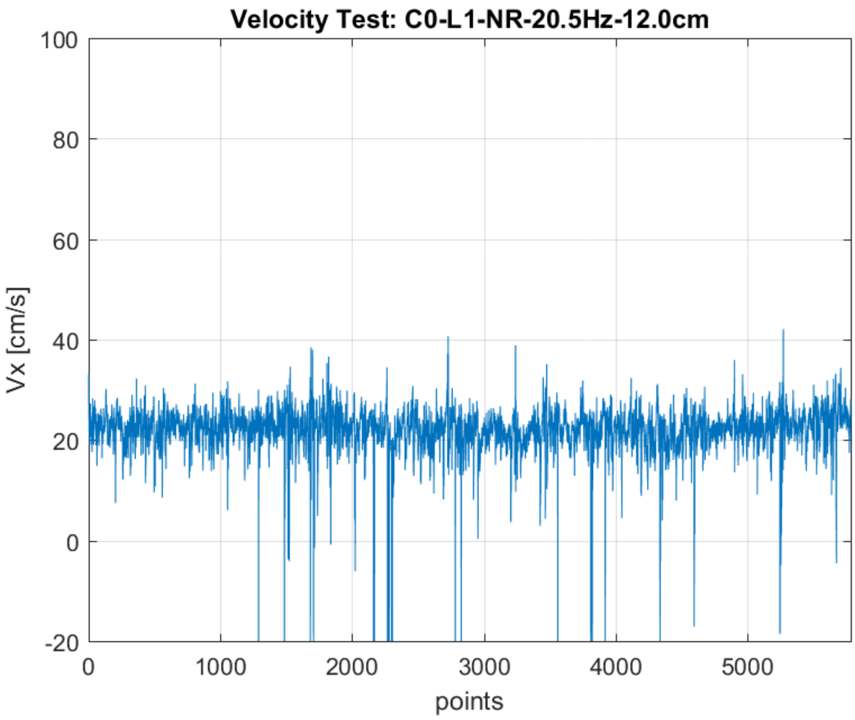

Figure 8 - Example of time series acquired by the Vectrino sensor

2.3.2. Ultrasonic wave gauges

To measure the incident and the reflected waves, two WGs are used (Series 943-M18-F4V-2D-1C0-330E by HONEYWELL). The adopted WGs measure the free surface displacement with an accuracy of 1mm at a distance from the sensor in the range 60-500mm (Figure 9).

Max. sensing distance:	500 mm
Min. sensing distance:	60 mm
Switching frequency:	100 ms
Repeatability:	0,2 % or ±1 mm

OUTPUT	TERMINATION	REFERENCE
0-10 V	Connector	943-F4V-2D-1C0-330E
0-10 V	Cable	943-F4Y-2D-1C0-330E
4-10 mA	Connector	943-F4V-2D-1D0-330E
4-20 mA	Cable	943-F4Y-2D-1D0-330E

Figure 9 - Ultrasonic wave gauges HONEYWELL Series 943-M18-F4V-2D-1C0-330E (left) and technical data sheet (right)

The sampling frequency of the ultrasonic wave gauges is 1 kHz. The calibration of ultrasonic wave gauges is done by measuring the distance between gauges and a horizontal plate which is located at a different distance away from the gauge head. The gauge results are well compatible with the measured distances. In Figure 10, the exemplary assembly of the ultrasonic wave gauges is presented on the test rig. An example acquisition of the signal from the ultrasonic wave gauge is presented in Figure 11.

Figure 10 - Ultrasonic wave gauges installed at LABIMA during the VABTITUS measurements

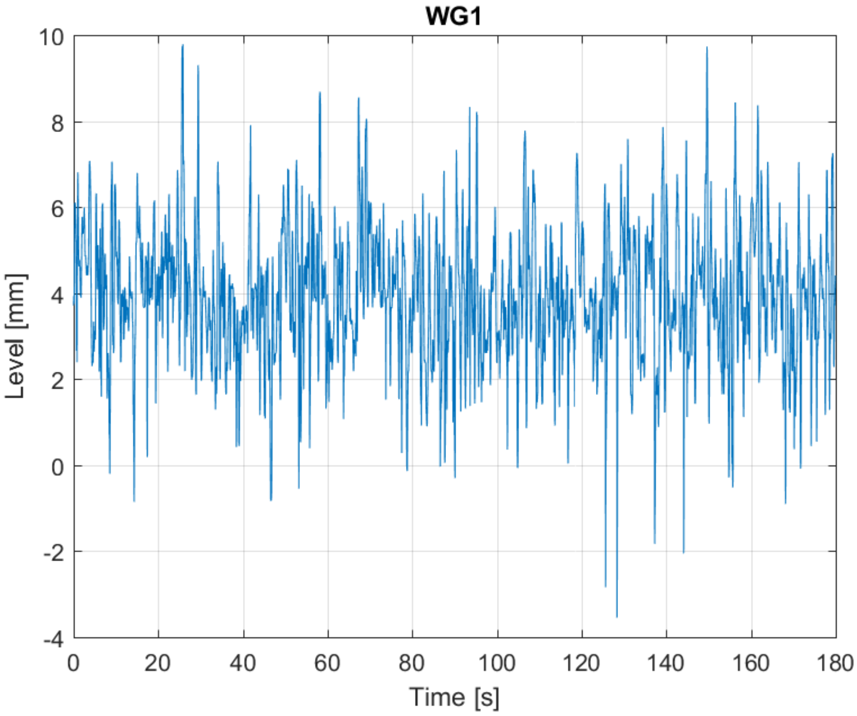

Figure 11 - Example of time series acquired by the ultrasonic wave gauge (WG1)

2.3.3. Resistive type wave gauges

Five resistive type wave gauges were installed in the flume to measure water level variation in the WCF during the tests (Figure 12). The sampling frequency of the resistive wave gauges is 1 kHz. Every day before the beginning of the tests, a calibration of the resistance sensors was conducted. The calibration was made for the water level heights: 0.27, 0.3 and 0.33m above the flume bottom. A linear correlation between the water level and the sensor signal was determined (Figure 13).

Figure 12 - The set of the resistive wave gauges on the barrier and after the barrier

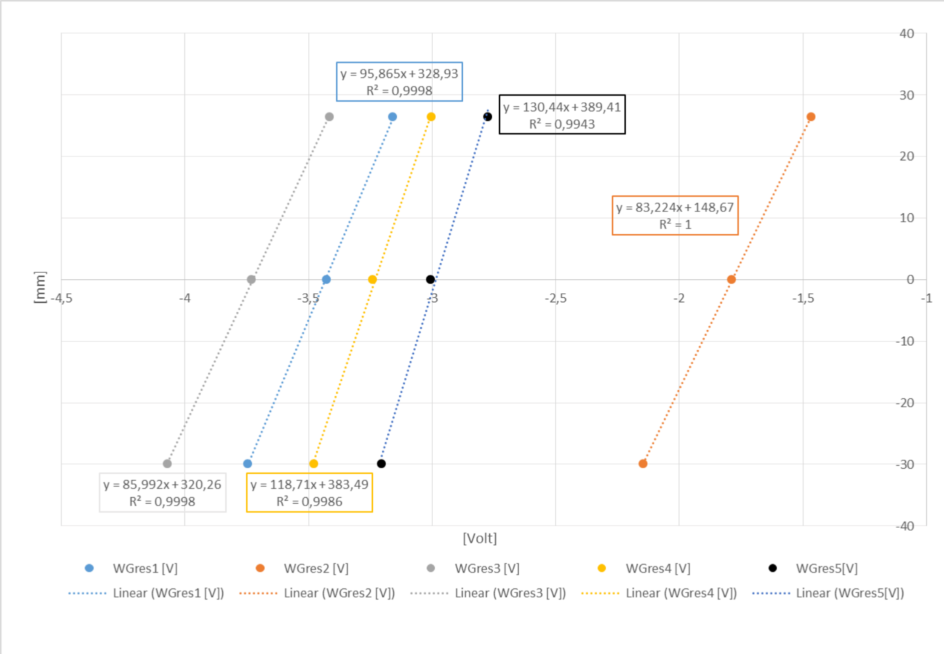

Figure 13 - Example of the resistive wave gauge calibration

2.3.4. Pressure transducers (PTs):

Pressure transducers (KELLER Series 46X, Figure 14) with a full scale (FS) of 100mBar and accuracy of ± 0.1%FS are used to measure pressure variations. The calibration of the PTs is shown in Figure 15.

An example time series acquired by pressure transducer PT1 is provided in Figure 16.

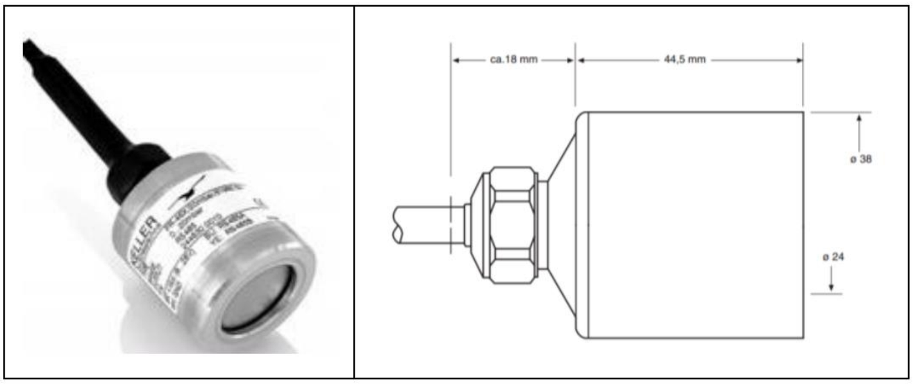

Figure 14 - Pressure transducer-KELLER Series 46X, picture and technical drawing.

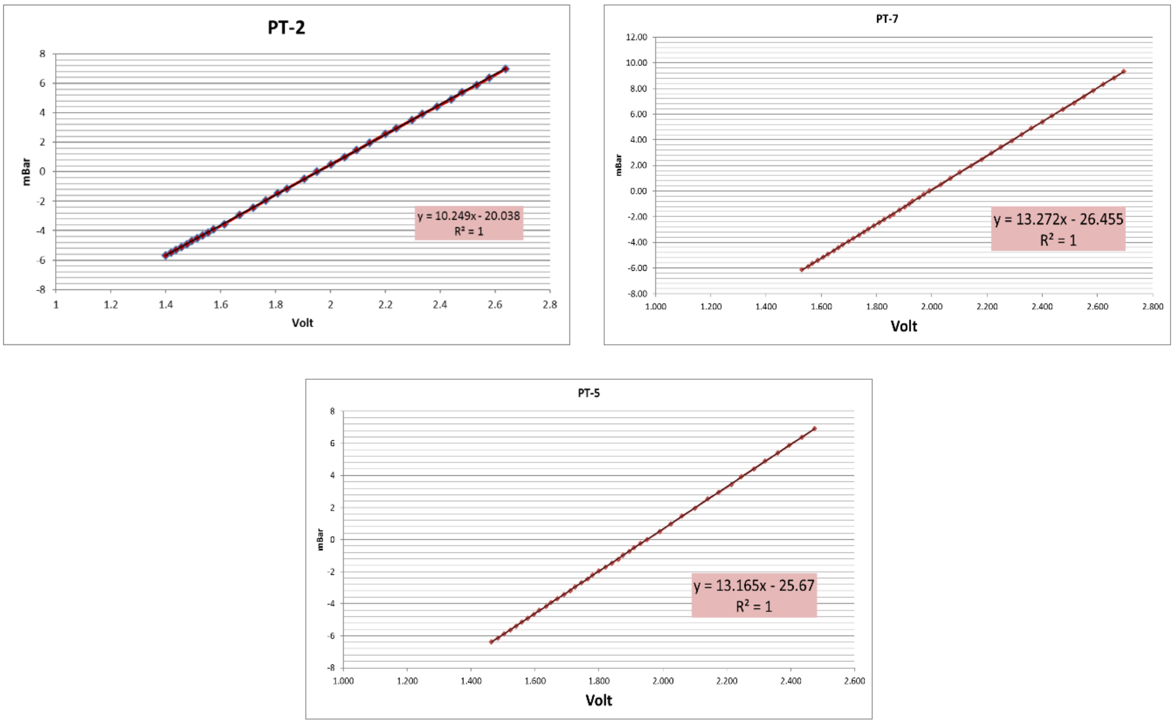

Figure 15 - Example of Pressure Transducers calibration

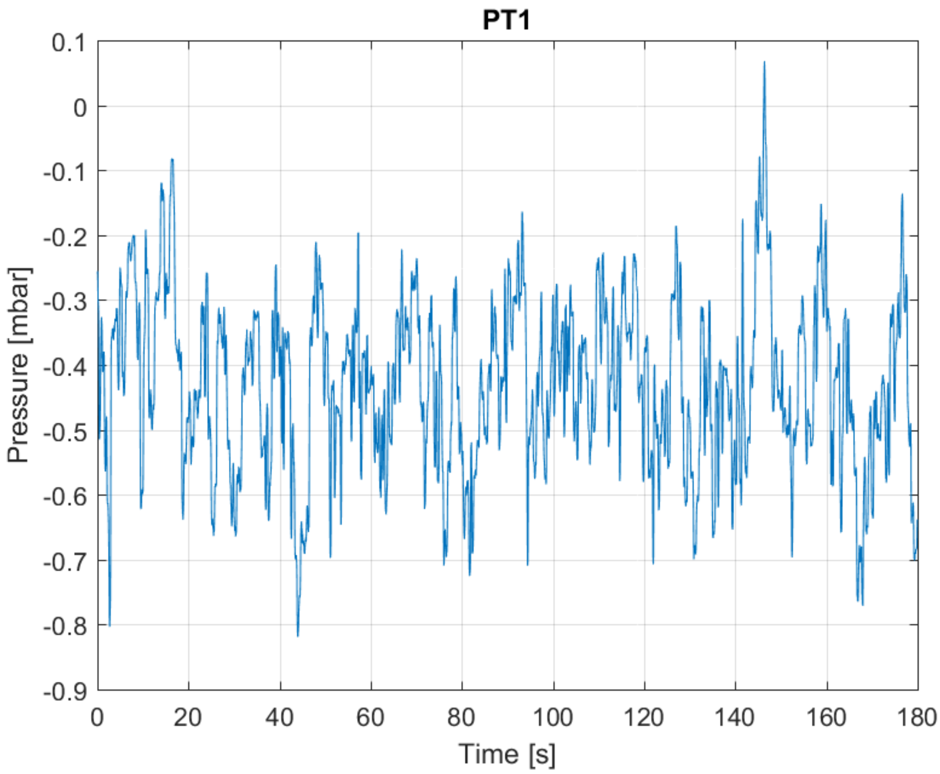

Figure 16 - Example of time series acquired by pressure transducer PT1

2.4. Tests

2.4.1. Hydrodynamic Conditions

The experimental tests were conducted with a constant value of the water depth in the flume, h=0.3m.

During the tests, 5 values of the mass flow rate were investigated for all configurations and variants described in the previous sections (i.e., Configuration C0, C1 and C2 with and without the bottom roughness as described in *Section 2.2*).

The range of Froude number (Fr) investigated in the tests varied between 0.1 and 0.275. The pump frequency and the resulting flow rate varied between 13.7 Hz and 37.6 Hz and 39 l/s and 112.5 l/s respectively.

Overall, the tabulated hydrodynamic conditions of the conducted tests are presented in Table 3.

Moreover, during the preliminary tests of characterization of the free WCF velocity profiles without the barrier installed (i.e. configuration C0), two further water levels h were tested, respectively 0.2m and 0.4m (Table 4).

Table 3 - Hydrodynamic conditions investigated during the tests of the VABTITUS project

Water level h [m]	Froude number Fr	Pump Frequency [Hz]	Discharge [l/s]
0.3	0.100	13.7	39.0
	0.150	20.5	59.6
	0.200	27.3	80.6
	0.250	34.3	102.0
	0.275	37.6	112.5

Table 4 - Hydrodynamic conditions investigated during the preliminary VABTITUS tests

Water level h [m]	Froude number Fr	Pump Frequency [Hz]	Discharge [l/s]
0.2	0.050	3.7	9.9
	0.075	5.6	15.0
	0.100	8.4	19.8
	0.125	9.3	25.4
	0.150	11.2	31.4
0.4	0.050	10.5	31.7
	0.075	15.8	45.5
	0.100	21.0	60.7
	0.125	26.3	78.0
	0.150	31.6	93.5

3. Results

The VABTITUS project had the main outcome to produce an extensive database containing significant variables related to the tested models and Configurations (i.e. water level, pressure and velocities).

The data acquired during VABTITUS project are stored in an online archive accessible via the link:

- https://www.labima.unifi.it/vp-172-vabtitus.html

3.1. Naming convention for the tests

The naming of the files is according to the following naming convention:

<Configuration><Water Level><Roughness><Frequency>.tsv

e.g. C0L1NR20.5Hz.tsv

where:

<Configuration> denotes the configuration tested, and can assume the following values:

Description	***<Configuration> code***
- No barrier	--> C0
- Barrier with mesh/net 1	--> C1
- Barrier with mesh/net 2	--> C2

<Water Level> denotes the water depth in the WCF, and can assume the following values:

Description	***<* Water Level *> code***
- 20.0cm	--> L0
- 30.0cm	--> L1
- 40.0cm	--> L2

<Roughness> denote the presence/absence of the bricks at the bottom and metal meshes in the flume:

Description	**<Roughness> code**
- No roughness	--> NR
- Roughness	--> R

<Frequency> denotes the frequency value [Hz] settled to the inverter in order to regulate the flow rate and therefore obtaining the desired Froude number:

Description	**<Frequency> code**
- Fr=0.050, L0	--> 3.7Hz
- Fr=0.050, L1	--> 6.8Hz
- Fr=0.050, L2	--> 10.5Hz
- Fr=0.075, L0	--> 5.6Hz
- Fr=0.075. L1	--> 10.2Hz

- Fr=0.075, L2 --> 15.8Hz
- Fr=0.100, L0 --> 8.4Hz
- Fr=0.100, L1 --> 13.7Hz
- Fr=0.100, L2 --> 21.0Hz
- Fr=0.125, L0 --> 9.3Hz
- Fr=0.125, L1 --> 17.1Hz
- Fr=0.125, L2 --> 26.3Hz
- Fr=0.150, L0 --> 11.2Hz
- Fr=0.150, L1 --> 20.5Hz
- Fr=0.150, L2 --> 31.6Hz
- Fr=0.200, L1 --> 27.3Hz
- Fr=0.250, L1 --> 34.3Hz
- Fr=0.275, L1 --> 37.6Hz

3.2. Database structure

The data acquired during the VABTITUS test campaign are stored in the online archive under two main directories:

(i) **RawData**, containing the output of the acquisition system "as it is", ordered chronologically and divided into subfolders corresponding to the date the tests were performed, according to the list contained in the file "ReadMe_Tests&datesList.docx";

(ii) **ValidatedData**, where the data are classified based on the test, preliminary checked and subjected to basic denoising and down-sampling operations (see *Section 3.3* for a detailed description of these operations).

For example, the '**RawData'** directory structure is as follow:

```
RawData
    04-10-18
        C1L1NR13.7Hz.tsv
        Level_0_C0L1NR13.7Hz.tsv
        ....
        Vectrino
            01.0cm.vno
            01.0cm.dat
            01.0cm.hdr
            01.0cm.pck
            ....
```

In the case of the directory '**ValidatedData**' the data are saved in '.dat' files under the "Table" folder. For each test, the related figures are under the "Figure" folder.
In the "Table" folder, each data file name has the same root of the test plus one more extension, to relate its content to the specific measurements:
<measurement> is the name of the measurement and it can be:
-Velocity.dat – Ultrasonic wave gauge number n
-Level.dat – Data from the load cells LCs

-Pressure.dat – Data from the pressure transducers PTs
"Vectrino" – Sub-folder containing the data from the Vectrino for the specific test. It contains a .dat file for each position where the measurement of the velocity was performed (the file is named after the coordinate of the point in which the measurement was collected, e.g. "**01.0cm.dat**" contains the measurements collected 1cm above the WCF bottom

Validated Data
- C0L0NR3.7Hz
  - Figure
    - C1L1NR13.7Hz-01.0cm-Velocity.bmp
    - ....
    - C1L1NR13.7Hz-VelocityProfile.bmp
    - C1L1NR13.7Hz-STD.bmp
    - C1L1NR13.7Hz-PT1
    - ....
    - C1L1NR13.7Hz-WG1
    - ....
    - C1L1NR13.7Hz-Level&Pressure
  - Table
    - C1L1NR13.7Hz-Velocity.dat
    - C1L1NR13.7Hz-Level.dat
    - C1L1NR13.7Hz-Pressure.dat
    - Vectrino
      - 01.0cm.dat
      - 01.5cm.dat
      - ....

3.3. Data validation

The following treatment was applied to the validated data (**Validated Data** dataset)

- Signals for the WGs are set to zero mean level at rest, filtered with a moving average filter and down sampled form 1000Hz to 20Hz;
- Signals for the PTs are set to zero mean level at rest, filtered with a moving average filter and down sampled form 1000Hz to 20Hz;
- No treatment is applied to the signals from the Vectrino, the data may require a specific filtering technique to eliminate eventual spikes.

4. Further Information

4.1. Website & Social Media

Website: https://www.labima.unifi.it/vp-172-vabtitus.html

References

[1] HydroGen Power Industries "Tidal power systems" http://www.h2oceanpower.com/index_htm_files/HydroGen%20Brochure%202%20up.pdf.

[2] J. I. Whelan, et al. "A free-surface and blockage correction for tidal turbines", J. Fluid Mech. (2009), vol. 624, pp. 281–291.

[3] B.K. Kirke, "Tests on ducted and barehelical and straight blade Darrieus hydrokinetic turbines", Renewable Energy 36 (2011) pp. 3013-3022

[4] D. Fiaschi, G. Manfrida, L. Talluri "A model for semi-permeable barriers with velocity-enhanced vertical-axis turbines for tidal streams", 9 th European Seminar OWEMES 2017

Test matrix

The following table offers the complete list of the tests performed, with the measurements acquired for each test.

Table 5 Complete test matrix VABTITUS

CODE	Velocity	Level	Pressure	Date
C0L0NR11.2Hz	✓			24/09/2018
C0L0NR3.7Hz	✓			25/09/2018
C0L0NR5.6Hz	✓			25/09/2018
C0L0NR8.4Hz	✓			25/09/2018
C0L0NR9.3Hz	✓			24/09/2018
C0L1NR10.2Hz	✓			24/09/2018
C0L1NR13.7Hz	✓			25/09/2018
C0L1NR17.1Hz	✓			25/09/2018
C0L1NR20.5Hz	✓			25/09/2018
C0L1NR27.3Hz	✓			09/10/2018
C0L1NR34.3Hz	✓			09/10/2018
C0L1NR37.6Hz	✓			09/10/2018
C0L1NR6.8Hz	✓			24/09/2018
C0L1R13.7Hz	✓			09/10/2018
C0L1R20.5Hz	✓			09/10/2018
C0L1R27.3Hz	✓			09/10/2018
C0L1R34.3Hz	✓			09/10/2018
C0L1R37.6Hz	✓			09/10/2018
C0L2NR10.5Hz	✓			20/09/2018
C0L2NR15.8Hz	✓			25/09/2018
C0L2NR21.0Hz	✓			25/09/2018
C0L2NR26.3Hz	✓			20/09/2018
C0L2NR31.6Hz	✓			20/09/2018
C1L1NR13.7Hz		✓	✓	03/10/2018
	✓			05/10/2018
C1L1NR20.5Hz		✓	✓	03/10/2018
	✓			05/10/2018
C1L1NR27.3Hz		✓	✓	03/10/2018
	✓			05/10/2018
C1L1NR34.3Hz		✓	✓	03/10/2018
	✓			05/10/2018
C1L1NR37.6Hz		✓	✓	03/10/2018
	✓			05/10/2018
C1L1R13.7Hz		✓	✓	03/10/2018
	✓			04/10/2018
C1L1R20.5Hz		✓	✓	03/10/2018
	✓			04/10/2018
C1L1R27.3Hz		✓	✓	03/10/2018
	✓			04/10/2018
C1L1R34.3Hz		✓	✓	03/10/2018
	✓			04/10/2018
C1L1R37.6Hz		✓	✓	03/10/2018
	✓			04/10/2018
C2L1R13.7Hz	✓			08/10/2018
		✓	✓	08/10/2018
C2L1R20.5Hz	✓			05/10/2018
		✓	✓	08/10/2018
C2L1R27.3Hz	✓			05/10/2018
		✓	✓	08/10/2018
C2L1R34.3Hz		✓	✓	08/10/2018
	✓			05/10/2018
C2L1R37.6Hz	✓			05/10/2018
		✓	✓	08/10/2018