Data Storage Report

Project: Hy+_HSVA-01

Experimental study on wave propagation in ice and the combined action of waves and ice on structures

"Loads on Structures – Waves propagating in Ice"
LS-WICE
LIMB - Hamburg Ship Model Basin

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Author: Andrei Tsarau,
Norwegian University of Science and Technology,
Trondheim, Norway

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1st user group contact (name/email)	Andrei Tsarau, andrei.tsarau@ntnu.no
2nd user group contact (name/email)	Hilde Benedikte Østlund, Hilde.Benedikte.Ostlund@kvaerner.com
1st provider contact (name/email)	Karl-Ulrich Evers, evers@hsva.de
2nd provider contact (name/email)	Peter Jochmann,jochmann@hsva.de
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Document objective

This data storage plan describes the experimental program and how tests should be performed. When all data has been obtained, the data storage plan is updated to a data storage report. In the data storage report, the data is described so that others can use them.

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Contents

1 Objectives

The proposed study comprises the following objectives:

- Determination of the dampening effect of ice on wave propagation;
- Analysis of the motion behaviour of ice floes in waves;
- Analysis of ice-breaking due to waves;
- Measurement of combined ice and wave loads on a structure.

2 Experimental setup

2.1 General description

The test setups are shown below as they were for the Attenuation tests (Series 2000-3000) and for the tests with the structure (Series 4000). The setup for the break-up test (Series 1000) was similar to the setup in Figure 2.1, except the unbroken ice cover. The sensor positions in the open-water tests with the structure (Series 5000) were the same as in Figure 2.2.

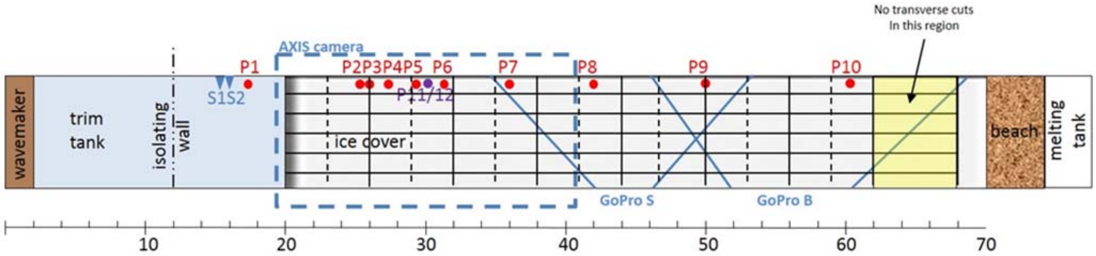


Figure 2.1: Experimental setup for test series 2000-3000. Location of instruments: P1 – P10 are single pressure sensors, P11/12 – a double pressure sensor, S1 and S2 – ultrasound sensors, continuous blue lines – fields of view of GoPro cameras, dashed blue lines – field of view of the AXIS camera, continuous black lines – locations of longitudinal and transverse cuts for the first series of tests, dashed black lines – locations of transverse cuts for the second series of tests, yellow rectangle – region, where no transverse cuts are done during the tests.

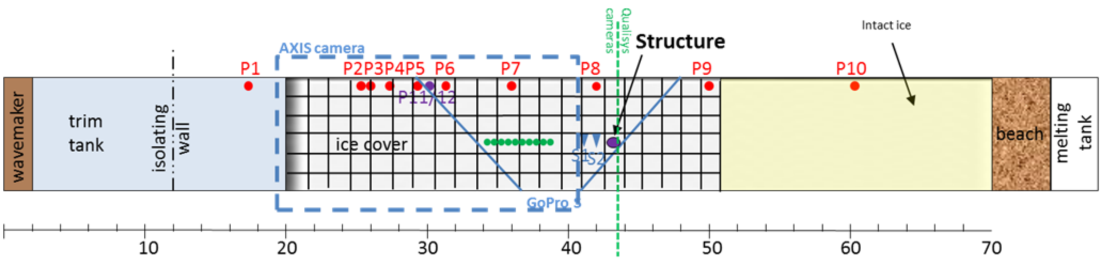


Figure 2.2: Experimental setup for test series 4000. Location of instruments: P1 – P10 are single pressure sensors, P11/12 – a double pressure sensor, S1 and S2 – ultrasound sensors, continuous blue lines – fields of view of GoPro camera, dashed blue lines – field of view of the AXIS camera, continuous black lines – locations of longitudinal and transverse cuts for the first series of tests, yellow rectangle – region, where no transverse cuts are done during the tests, green points – location of Qualisys markers, dashed green line – approximate location of Qualisys cameras and IMU units.

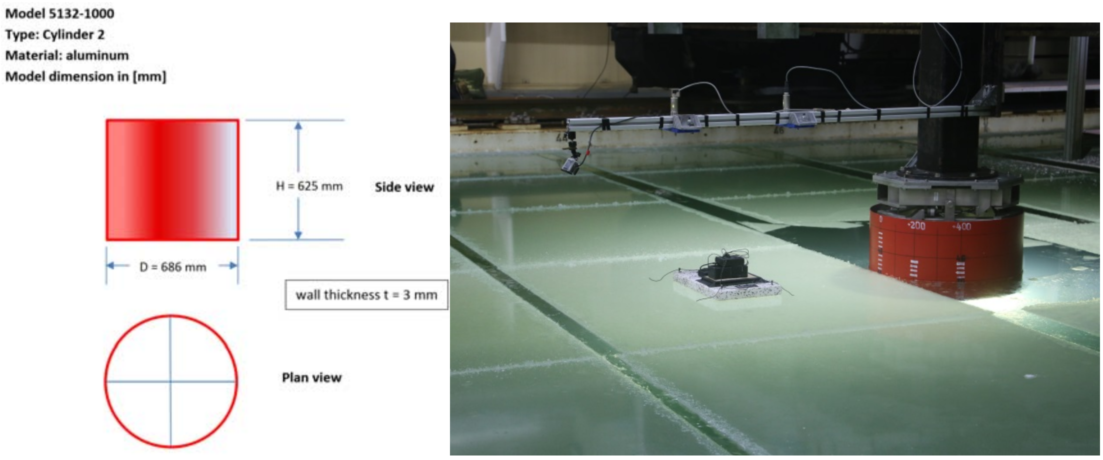


Figure 2.3: Structure model.

Comments to the setup:

- The cylindrical structure was installed on the transverse carriage at the rear end of the main carriage.

2.2 Definition of the coordinate system

Figure 2.4: Coordinate system used by the Qualisys (the wave maker is to the left).

2.3 Relevant fixed parameters

Target ice parameters (model scale):

- Ice sheet thickness: nominal thickness = (35 ± 5) mm.
- Density = (920 ± 5) kg/m3.
- Flexural strength = (60 ± 20) kPa.
- Elastic modulus E 16 – 76 MPa.
- Shear modulus G - ?

See the mechanical property tests in the daily reports (Appendix G) for the exact values.

Target wave parameters:

- Wave period from 1 to 2 s.
- Open water region ~15 m for the wave maker to setup regular waves. Wave maker run duration ~90 s to ensure waves travel the entire length of the wave tank for each test run.
- Low wave steepness to satisfy linear theory. Sufficiently high wave height to enable signal strength. wave maker

See the wave properties in the daily reports (Appendix G) for the exact values.

Water depth

Test series 1000	w= 2.48 m
Test series 2000	w= 2.47 m

Test series 3000 w= 2.45 m
Test series 4000 w= 2.48 m
Test series 5000 w= 2.48 m

3 Instrumentation and data acquisition

3.1 Instruments

Wave-in-ice sensors:

- Pressure sensors: 10 from HSVA (P1-P10) and 2 from Users (P11-P12). See Appendix A for details.
- Ultrasound sensors: 2 ultrasonic probes (Appendix B)
- Qualisys Motion Capture System to allow the determination of deflections and motions.
- Crane camera & image processing tools to obtain floe size distribution in the basin.

Sensors on the structure

- Force transducers to measure loads in both the longitudinal and lateral directions.
- 2 ultrasound sensors 0.5 and 1 m upstream from the structure.
- Bow video camera to capture ice floes that are in contact with the structure.
- Underwater camera.

Table 3.1: Sensors and equipment from HSVA

Name	Number required	Type	Unit	Resolution	Accuracy	Range	Sampling frequency	Cable length	Acquisition & Storage
Pressure sensors	10	Append. A				1 m			
Ultrasound sensors	2	USS13-HF Append. B	mm	0.36 mm	+/- 1 mm	200-1200 mm	50/100 Hz	10 m	
Amplifier for ultrasonics	2 (2*4 channels)	UltraLab ULS Advanced							
Crane camera for floe size distribution	1								
Qualisys	2-9 markers								
Force transducer			N						

Table 3.2: Additional sensors brought by Users (may be used or not)

Name	Number	Type	Unit	Sampling frequency	Acquisition & Storage	Responsible*
Inertial Measurement Unit (IMU)	2	ADIS16364 See App. F	m/s^2	50-100 Hz	Internal memory	NTNU
Video cameras	2	GoPro4	-	-	Internal memory	NTNU
Top cameras (to film ice-cover dynamics)	1	AXIS			NAS at HSVA	NTNU

Positions of the pressure sensors

See daily reports.

- The positions of pressure sensors in the tank are chosen based on a range of T=1-2s, and assuming no need to change the positions of the sensors from one T to another.

- Two considerations are used to determine the sensor locations: phase speed and attenuation. To measure phase speed two consecutive sensors need to be less than half the wavelength. To measure weak attenuation sensors need to be far apart. Estimates of the range of phase speed and attenuation guide the placement of these sensors.
- The two sensors in the open-water area are needed to capture the reflection. wave maker
- It was proposed to install the transducers at a depth of about 40 cm below calm water level. The transducers will be fixed in a distance of about 50 cm from the tank wall towards the center-line of the ice tank.

Positions of the ultrasound sensors

See daily reports.

Comments:

- There is no experience with these ultrasound sensors in ice.
- Ice crystals may affect the performance of ultrasound sensors.
- Ultrasound sensors will be considered as additional sources of data (supplementary to the pressure sensors).

Qualisys Motion Capture System

Qualisys markers are installed at the geometrical centres of minimum 2 and up to 9 interacting ice floes to capture 3DOF motions. Also used in the Breakup test.

3.2 Definition of time origin and instrument synchronization

For each test run the systems were started in the following order:

- Measurements start (starts the Data Acquisition System, all sensors except the IMUs and Qualisys);
- Qualisys start (sync signal received by the Data Acquisition System)
- Video sync lamp start (the lamp is on and its voltage is recorded by the Data Acquisition System);
- Wave maker start (start signal received by the Data Acquisition System)
- The fixed video cameras (shown in the setup) were either operating continuously or were started before the sync lamp was switched on.

The Data Acquisition System files are marked with local Hamburg time when the System was started (see Appendix D). However, the time in each file starts from 0.

The overlay clock on Axis video files was loosely synced with the Data Acquisition System (i.e., the same local Hamburg time was manually set on Axis); however for a better synchronization the sync lamp should be used.

The GoPro files are not synchronized and therefore the sync lamp should be used for further post pocessing.

The IMUs are neither synced with each other nor with the Data Acquisition System. For syncing the IMU data during post processing the following files can be used:
…\LS-WICE\data\2016-11-03\sensor data\IMU data\IMU6_3100_3200\ ADIS-11-45-31@3.11.2016 and
..\LS-WICE\data\2016-11-03\sensor data\IMU data\IMU2_3100_3200 \ADIS-11-46-6@3.11.2016.
Both files contain the acceleration data while the two sensors were shaken together (see Figure 3.1).

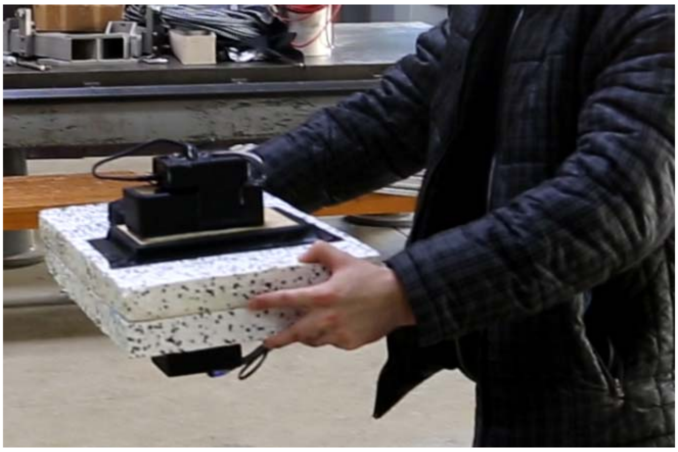


Figure 3.1: Synchronization of the IMUs.

IMU 6 can be synchronized with the Data Acquisition System by using the data from Test Run 4000 where the structure hit the ice floe with the IMU on it.

The time in the metafiles created by personal video/photo cameras may or may NOT show the local Hamburg time when the picture/video was taken; thus no synchronisation with the Data Acquisition System should be assumed.

NB: Local time was changed from daylight saving to normal on 29 Oct.

3.3 Measured parameters

See Appendix D and Appendix E.

4 Experimental procedure and test programme

4.1 Test programme

The test programme comprises three major groups of tests: Ice Breakup Tests, Wave Attenuation Tests and Tests to determine Ice/Wave Loads on Structure. Open Water Tests were also performed with and without the structure.

Table 4.1: Test matrix Open Water Tests

Run No.	Wave height	Wave period	Wave length	Duration of Test Run*	Remarks
[-]	[m]	[s]	[m]	[min]	[-]
1	0.05	1	1.56	1.5	Stop for 5 min each test or longer depend on how long the disturbance will last.
2	0.1	1	1.56	1.5	Also, we may sweep period first, then move to a higher amplitude, in that order.
3	0.05	1.2	2.25	1.5	
4	0.1	1.2	2.25	1.5	
5	0.05	1.4	3.05	1.5	
6	0.1	1.4	3.05	1.5	
7	0.05	1.6	4.00	1.5	Skip
8	0.1	1.6	4.00	1.5	Skip
9	0.05	1.8	5.05	1.5	Skip
10	0.1	1.8	5.05	1.5	Skip
11	0.05	2	6.24	1.5	Skip
12	0.1	2	6.24	1.5	

*Note: duration of test run means the time the wave maker operated; the data were recorded for a longer time period

Table 4.2: Test matrix Test Series 1000 (Breakup Tests)

Run No.	Wave height	Wave period	Wave length	Duration of Test Run*	Remarks
[-]	[mm]	[s]	[m]	[min]	[-]
1100	10.0	2.0		1.5	no breaking observed
1200	10.0	1.6		1.5	no breaking observed
1300	10.0	1.2		1.5	no breaking observed
1400	20.0	2.0		1.5	no breaking observed
1410	30.0	2.0		1.5	no breaking observed
1420	40.0	2.0		1.5	no breaking observed
1430	50.0	2.0		1.5	no breaking observed
1440	70.0	2.0		1.5	the first major crack developed (approx. at x = 44 m, see Fig. 3a)
1450	90.0	2.0		(1.5)	major breaking; measurement continued for several minutes, until no further breaking occurred (Fig. 3b)
photos from the crane camera for FSD					
1500	50.0	1.6		1.5	no breaking observed
1510	70.0	1.6		(1.5)	major breaking; measurement continued for several minutes, until no further breaking occurred (Fig. 3c)
photos from the crane camera for FSD					

*Note: duration of test run means the time the wave maker operated; the data were recorded for a longer time period

Table 4.3: Test matrix Test Series 2000 (Attenuation Tests)

Run No.	Wave height	Wave period	Floe length	Duration of Test Run*	Remarks
[-]	[mm]	[s]	[m]	[min]	[-]
2410	50.0	2.0	6.0	1.2	a few cracks (in floes neighboring the left wall + around bending-test sites)
2420	50.0	1.8	6.0	1.2	further cracks close to the ice edge and the left wall)
2460	10.0	0.9	6.0	1.2	very strong attenuation (already by the first floe); very noisy pressure measurements due to small amplitude
2450	20.0	0.9	6.0	1.2	strong overwash at the ice edge, weaker seen also between ice floes; new cracks only very close to the ice edge
2440	20.0	1.2	6.0	1.2	no further breaking
2430	40.0	2.0	6.0	1.2	no further breaking
photos from the crane camera for FSD					
2610	25.0	2.0	1.5	1.2	no breaking
2620	25.0	1.8	1.5	1.2	no breaking
2630	25.0	1.6	1.5	1.2	no breaking
2640	25.0	1.4	1.5	1.2	no breaking
2650	25.0	1.2	1.5	1.2	no breaking ; strong overwash within 10-15m from ice edge
2660	25.0	0.9	1.5	1.2	no breaking; very strong attenuation; strong overwash within 4-5m from ice edge
photos from the crane camera for FSD					
2710	25.0	2.0	0.5	1.2	no breaking

2720	25.0	1.8	0.5	1.2	-||-
2730	25.0	1.6	0.5	1.2	-||-
2740	25.0	1.4	0.5	1.2	-||-
2750	25.0	1.2	0.5	1.2	-||-
2760	25.0	0.9	0.5	1.2	-||-
photos from the crane camera for FSD					

*Note: duration of test run means the time the wave maker operated; the data were recorded for a longer time period

Table 4.4: Test matrix Test Series 3000 (Attenuation Tests)

Run No.	Wave height	Wave period	Floe length	Duration of Test Run	Remarks
[-]	[mm]	[s]	[m]	[min]	[-]
3110	25.0	2.0	3.0	1.2	many floes are frozen to each other (ice behaves like a continuous sheet)
3120	25.0	1.8	3.0	1.2	-||-
3130	25.0	1.6	3.0	1.2	after this test: re-cutting of ice from the walls and from each other in the region in front of the main carriage
3140	30.0	1.5	3.0	1.2	some breaking of floes close to the ice edge
3150	30.0	1.4	3.0	1.2	
3160	30.0	1.1	3.0	1.2	
photos from the crane camera for FSD					
3210	25.0	2.0	1.5	1.2	no breaking
3220	25.0	1.8	1.5	1.2	-||-
3230	25.0	1.6	1.5	1.2	no breaking; transverse re-cutting of some ice floes in the beach region after this test
3240	30.0	1.5	1.5	1.2	no breaking
3250	30.0	1.4	1.5	1.2	-||-
3260	25.0	1.1	1.5	1.2	-||-
photos from the crane camera for FSD					
3310	25.0	2.0	0.5	1.2	no breaking
3320	25.0	1.8	0.5	1.2	-||-
3330	25.0	1.6	0.5	1.2	-||-
3340	30.0	1.5	0.5	1.2	-||-
3350	30.0	1.4	0.5	1.2	-||-
3360	30.0	1.1	0.5	1.2	-||-
3370	25.0	2.3	0.5	1.2	-||-
3380	25.0	2.2	0.5	1.2	-||-
3390	25.0	2.1	0.5	1.2	-||-
photos from the crane camera for FSD					

Table 4.5: Test matrix Test Series 4000 (Loads on Structure)

Run No.	Approx. start/finish time	Wave height	Wave period	Floe length	Duration of Test Run	Remarks
[-]		[mm]	[s]	[m]	[min]	[-]
4000						IMU synchronization with other sensors. The main carriage was driven with the speed of 1 cm/s towards the closest ice floe

4110	14:20/14:24	25.0	2.0	1.5	2	- gaps/ regions with open water between the floes after cutting and structure installation - after several impacts between the ice floe and structure, the floe moved from the structure and not impacts were observed - after this run all the floes were pushed close to each other and the structure
4120	14:43/14:64	25.0	1.8	1.5	2	-More impacts and less floe drift from the structure - Significant vibrations of the beam with attached ultrasound sensors S1 and S2 and Go Pro camera
4130	14:52/14:54	25.0	1.6	1.5	2	- floe/structure impacts. More frequent at the beginning of the run
4140	15:00/15:04	25.0	1.5	1.5	2	-//-
Doubled amplitude						
4210	15:08/15:12	50.0	2.0	1.5	2	Floe/structure impacts
4220	15:19/15:25	50.0	1.8	1.5	2	
4230	15:29/15:33	50.0	1.6	1.5	2	the structure-floe contact area increased (arc contact zone)
4240	15:43/15:46	50.0	1.5	1.5	2	After completing test group 4300 the floes no 2, 4, 5, 6, 7, 8,9, 11 in the row with the structure were split
4310	16:08/16:12	75.0	2.0	1.5	2	After the first structure/floe impact the floe adjacent to the structure on the sided side rotated. This floe blocked possibility for impact with the floe in front of the structure
4320	16:18/16:20	75.0	1.8	1.5	2	IMU started to float and was removed Breakage of the ice but only transverse to the structure
4330	16:26/16:28	75.0	1.6	1.5	2	
4340	16:32/16:36	75.0	1.5	1.5	2	Significant increase in structure-floe contact area
4430	16:42/16:44	100.0	1.6	1.5	2	The floe closest to the structure is splitted
4530		200.0	1.6	1.5	2	Major breaking of the floes in random pieces Flooding on the back side of the trim tank

Table 4.6: **Test matrix Test Series 5000 (Open Water with Structure)**

Run No.	Approx. start/finish time	Wave height	Wave period	Duration of Test Run	Remarks
[-]		[mm]	[s]	[min]	[-]
Decay tests. The structure was hit by the hammer approximately at the water level, both in X and Y direction.					

5002	11:04:00 11:05:00 11:05:30				Hit in Y direction. The sampling rate was 100 Hz. After checking the data it was realized that the sampling rate should be increased.
5001	11:12:30 11:13:00 11:14:00				Hit in X direction (3 times). Sampling frequency increased to 600 Hz
5002	11:15:00 11:15:30 11:16:00				Hit in Y direction (3 times) Sampling frequency increased to 600 Hz
Open water tests					
5110	11:33/11:35	25.0	2.0	2	
5120	11:42/11:44	25.0	1.8	2	
5130	11:50/11:53	25.0	1.6	2	
5140	11:57/12:02	25.0	1.5	2	
Doubled amplitude					
5210	12:07/12:10	50.0	2.0	2	
5220	12:117/12:20	50.0	1.8	2	
5230	12:26/12:29	50.0	1.6	2	
5240	12:35/12:38	50.0	1.5	2	
5310	13:49/13:52	75.0	2.0	2	
5320	13:59/14:02	75.0	1.8	2	
5330	14:09/14:12	75.0	1.6	2	
5340	14:19/14:21	75.0	1.5	2	
5430	14:29/14:31	100.0	1.6	2	

4.2 Preparation of broken ice

The preparation of ice floes in the ice tank is done manually by cutting the parental level ice sheet into pieces of required size and shape (Figure 4.3).

In the setup in Figure 2.1:

- Rectangular floes were produced by cutting the ice sheet first into 1.6-m-wide strips with the help of 5 people standing on the motor-driven carriage and holding ‘ice knives’ and then cutting these strips into L-m-long rectangles.
- Changing floe size means decreasing floe length (L) only.

Figure 4.3. Preparation of ice floes.

4.3 Ice property tests

For each newly grown ice sheet mechanical tests were typically performed in the morning before the experiments. The daily reports (Appendix G) provide the values for the measured ice properties, which includes Flexural strength, Modulus of elasticity and Ice density. The procedures for these mechanical tests are described in Appendix C.

5 Data post-processing

No numerical filtering was performed, only raw data are stored. These post-processed data will be published in archieved literature.

6 Organization of data files

Description of the data files:
- format (ASCII or binary)
- column separator (in case of ASCII)
- type of data (video of measurement data)
- units of data
- structure of file content
- organization of files in directories]

The data files are stored in directories as shown in Figure 6.1:

2016-10-25	OW tests
2016-10-27	Test Series 1000
2016-11-01	Test Series 2000

2016-11-03 Test Series 3000
2016-11-08 Test Series 4000
2016-11-09 Test Series 5000.

Folders “photos” contain:

- Photos taken by Users with their personal hand-held cameras.
- These folders may also contain video files taken by personal cameras.
- For Test Series 1000-3000 photos were taken also by HSVA’s crane camera for a later analysis of floe-size distribution.
- For test Series 4000 the underwater video files are also stored in “/photos/Evers” to make it more confusing for those who want to find them.

Folders “videos” contain:

- Video files by Axis camera (see the setup in Figure 2.1);
- Video files by GoPro Silver (see test setup);
- Video files by GoPro Black (see test setup);
- May also contain videos by personal hand-held cameras.

Folders “sensor data” contain:
ASCII files for most of the sensors (see data description in Appendix D)
Qualisys files (see data description in Appendix E)
IMU data for Test Series 3000 and 4000 (see data description in Appendix D)

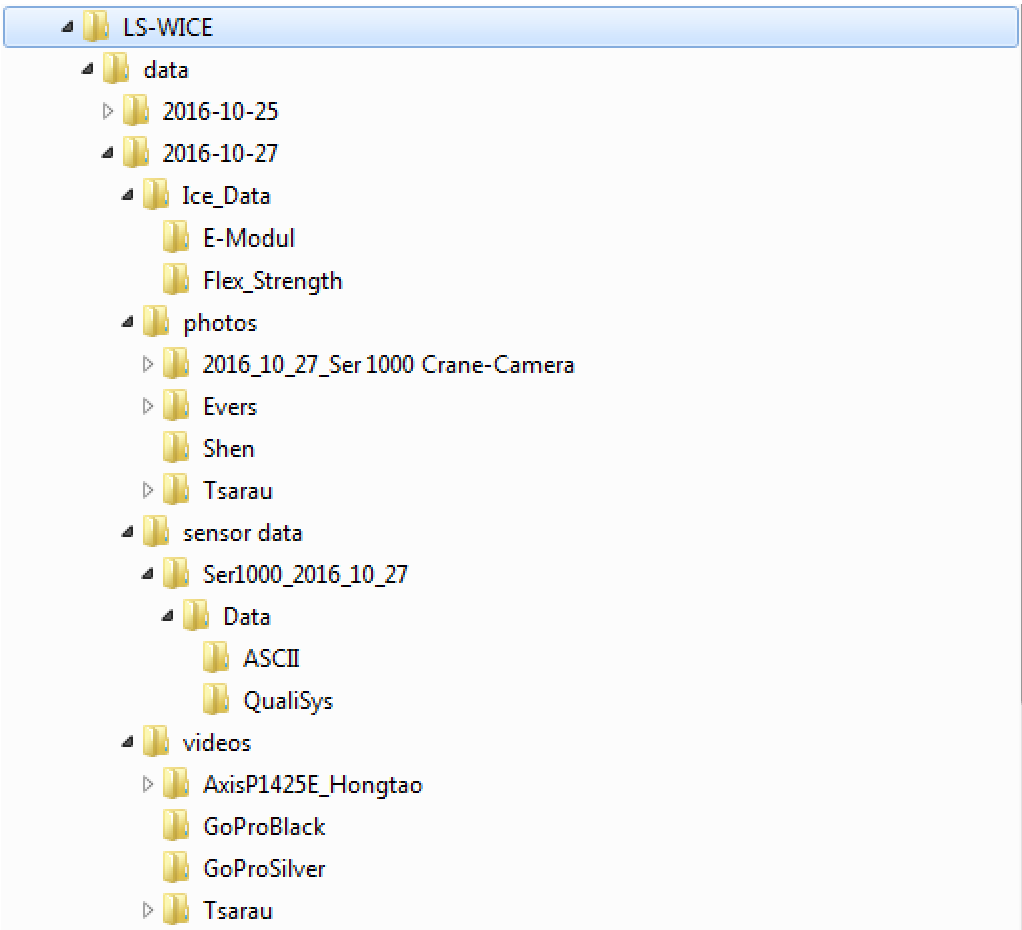


Figure 6.1. Directories for data files.

7 Remarks

. Temperature data should be here if available…

8 Appendices

Appendix A: Pressure sensors

HSVA sensors (P1-P10)

The data with the HSVA pressure sensors (P1...P10) type BD LMP307 were measured in the unit metres [m]. The maximum end value is 1 meter water column.

LMP 307

Stainless Steel Probe

Technical Data

Input pressure range														
Nominal pressure gauge	[bar]	0.1	0.16	0.25	0.4	0.6	1	1.6	2.5	4	6	10	16	25
Level	[mH_2O]	1	1.6	2.5	4	6	10	16	25	40	60	100	160	250
Overpressure	[bar]	0.5	1	1	2	5	5	10	10	20	40	40	80	80
Burst pressure ≥	[bar]	1.5	1.5	1.5	3	7.5	7.5	15	15	25	50	50	120	120

Output signal / Supply	
Standard	2-wire: 4 ... 20 mA / V_S = 8 ... 32 V_{DC} SIL-version: V_S = 14 ... 28 V_{DC}
Option Ex-protection	2-wire: 4 ... 20 mA / V_S = 10 ... 28 V_{DC} SIL-version: V_S = 14 ... 28 V_{DC}
Options 3-wire	3-wire: 0 ... 20 mA / V_S = 14 ... 30 V_{DC} 0 ... 10 V / V_S = 14 ... 30 V_{DC}
Performance	
Accuracy	standard: nominal pressure < 0.4 bar: ≤ ± 0.5 % FSO nominal pressure ≥ 0.4 bar: ≤ ± 0.35 % FSO option 1: nominal pressure ≥ 0.4 bar: ≤ ± 0.25 % FSO option 2: for all nominal pressures: ≤ ± 0.1 % FSO
Permissible load	current 2-wire: R_{max} = [(V_S – V_S min) / 0.02 A] Ω current 3-wire: R_{max} = 500 Ω voltage 3-wire: R_{min} = 10 kΩ
Influence effects	supply: 0.05 % FSO / 10 V load: 0.05 % FSO / kΩ
Long term stability	≤ ± 0.1 % FSO / year at reference conditions
Response time	2-wire: ≤ 10 msec; 3-wire: ≤ 3 msec
[1] *accuracy according to IEC 60770 – limit point adjustment (non-linearity, hysteresis, repeatability)*	
Thermal effects (Offset and Span)	
Nominal pressure P_N [bar]	< 0.40 ≥ 0.40
Tolerance band [% FSO]	≤ ± 1 ≤ ± 0.75
in compensated range [°C]	0 ... 70
Permissible temperatures	
Permissible temperatures	medium: -10 ... 70 °C storage: -25 ... 70 °C
Electrical protection [2]	
Short-circuit protection	permanent
Reverse polarity protection	no damage, but also no function
Electromagnetic compatibility	emission and immunity according to EN 61326
[2] *additional external overvoltage protection unit in terminal box KL 1 or KL 2 with atmospheric pressure reference available on request*	
Electrical connection	
Cable with sheath material [3]	PVC (-5 ... 70 °C) grey PUR (-10 ... 70 °C) black FEP[4] (-10 ... 70 °C) black TPE-U (-10 ... 70 °C) blue (with drinking water certificate)
[3] *cable with integrated air tube for atmospheric pressure reference* [4] *do not use freely suspended probes with an FEP cable if effects due to highly charging processes are expected*	
Materials (media wetted)	
Housing	stainless steel 1.4404 (316L)
Seals	FKM EPDM (with drinking water certificate) others on request
Diaphragm	stainless steel 1.4435 (316L)
Protection cap	POM-C
Explosion protection (only for 4 ... 20 mA / 2-wire)	
Approvals DX19-LMP 307	**IBExU 10 ATEX 1068 X / IECEx IBE 12.0027X** zone 0: II 1G Ex ia IIC T4 Ga zone 20: II 1D Ex ia IIIC T 85°C Da
Safety technical maximum values	U_i = 28 V, I_i = 93 mA, P_i = 660 mW, C_i = 0 nF, L_i = 0 µH, the supply connections have an inner capacity of max. 27 nF to the housing
Ambient temperature range	in zone 0: -20 ... 60 °C with p_{atm} 0.8 bar up to 1.1 bar in zone 1 or higher: -20 ... 70 °C
Connecting cables (by factory)	cable capacitance: signal line/shield also signal line/signal line: 160 pF/m cable inductance: signal line/shield also signal line/signal line: 1µH/m
Miscellaneous	
Option SIL[5] 2 application	according to IEC 61508 / IEC 61511
drinking water certificate	According to DVGW W 270 and UBA KTW (With order please indicate if her device must be certificated for drinking water.)
Current consumption	signal output current: max. 25 mA / signal output voltage: max. 7 mA
Weight	approx. 200 g (without cable)
Ingress protection	IP 68
CE-conformity	EMC Directive: 2014/30/EU
ATEX Directive	2014/34/EU
[5] *not in combination with the accuracy 0.1%, only for 4...20mA / 2-wire*	

User's sensors (P11 – P12)

Name	Model	S/N	Label
Omega pressure transducer	PX437 2psi	1200877	P12
Omega pressure transducer	PX438 2psi	1206731	P11

SUBMERSIBLE WATER LEVEL TRANSMITTERS

MEASURE 0 to 1.5 m (5') TO 0 to 210.3 m (690') OF WATER

Desiccant included.

PX439-010GI, shown with PX430-TRAP moisture trap (included) and DP41-E meter, sold separately.

Shown actual size.

Three Accuracies
4 to 20 mA Output
PX437 0.1%
PX438 0.25%
PX439 0.5%

Series Submersible Transmitters
0-1.5 m (5') to 0-210.3 m (690') Water
0-2 to 0-300 psi

1 YEAR WARRANTY CE RoHS

- **Designed for Complete Submersibility**
- **Unique Molded-Cable Seal System Ensures Watertight Integrity**
- **High Static Accuracy and Repeatability**
- **100% Computer Tested, Calibrated, and Serialized**
- **Calibration Sheet Provided**
- **Fully Temperature Compensated**
- **Moisture Trap Included as Standard Feature**

Typical Applications

- **Well Monitoring**
- **Slug Tests**
- **Pump Control**
- **Groundwater Monitoring**
- **Soil Remediation**
- **Oceanographic Research**
- **Lift Stations**
- **Level Control**
- **Surface Water Monitoring**

OMEGA's PX437, PX438, and PX439 Series submersible water level transmitters are designed to meet the rigorous environments of applications such as well monitoring, pump tests, lift stations, chemical tank levels, groundwater and surface water measurement, and process control. They provide repeatable, precision depth measurements under the most adverse conditions. These transmitters use a silicon pressure cell fitted into a stainless steel housing with an integral welded 316 stainless steel barrier diaphragm. The nose cap is made of Delrin®.

The supplied calibration sheet specifies input and output data that reflects the unit's static accuracy and thermal characteristics.

Each transmitter is shipped with a trap that prevents moisture from entering the vent tube. Replacement moisture traps are available as accessory items.

B-281

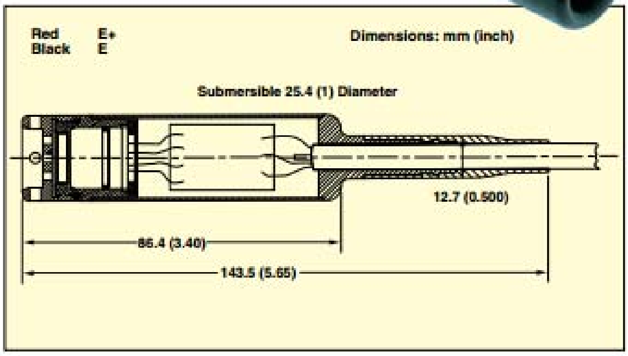
SUBMERSIBLE WATER LEVEL TRANSMITTERS

SPECIFICATIONS

Excitation: 9 to 30 Vdc, reverse polarity protected
Output: 4 to 20 mA DC, 2 wire, short circuit protected
Input Current: 20 mA maximum
Zero Offset: ±0.12 mA maximum
Insulation Resistance: 100 MΩ at 50 Vdc
Accuracy:
PX437: 0.10% FS BFSL
PX438: 0.25% FS BFSL
PX439: 0.50% FS BFSL
(includes linearity, hysteresis and repeatability)
Response Time: 2 ms
Operating Temperature: -10 to 60°C (15 to 140°F)
Compensated Temperature: 0 to 50°C (32 to 120°F)
Combined Thermal Effect: ±0.05% full scale/°C (zero and span) 0.1% full scale/°C for 2 and 5 psig ranges
Proof Pressure: 150%
Burst Pressure: 200%
Wetted Parts: 316 stainless steel, acetal, polyurethane cable FKM or FFKM
Fill Fluid: Silicone oil
Mounting Provisions: Suspended by cable. For turbulent conditions, specify optional mounting clamp.

Electrical Connections: Submersible cable terminating in pigtail leads
Cable: Polyurethane jacketed shielded cable with polyethylene vent tube and Kevlar® tension members, 90 kg (198 lb) pull strength. Conductors are 22 AWG.
Weight: 200 g (7 oz) transducer 79 g/m cable (0.8 oz/ft) cable weight

PX437-002GI, shown actual size.



To Order

RANGE			0.10% FS ACCURACY	0.25% FS ACCURACY	0.50% FS ACCURACY	LENGTH m (ft)
psig	bar	ftH2O	MODEL NO.	MODEL NO.	MODEL NO.	
0 to 2	0 to 0.14	5	PX437-002GI	PX438-002GI	PX439-002GI	6 (20)
0 to 5	0 to 0.34	11.5	PX437-005GI	PX438-005GI	PX439-005GI	6 (20)
0 to 10	0 to 0.69	23.1	PX437-010GI	PX438-010GI	PX439-010GI	12 (40)
0 to 15	0 to 1.0	34.6	PX437-015GI	PX438-015GI	PX439-015GI	15 (50)
0 to 30	0 to 2.1	69.2	PX437-030GI	PX438-030GI	PX439-030GI	27 (90)
0 to 50	0 to 3.4	115	PX437-050GI	PX438-050GI	PX439-050GI	41 (135)
0 to 100	0 to 6.9	230	PX437-100GI	PX438-100GI	PX439-100GI	76 (250)
0 to 150	0 to 10.3	345	PX437-150GI	PX438-150GI	PX439-150GI	111 (365)
0 to 200	0 to 13.8	460	PX437-200GI	PX438-200GI	PX439-200GI	146 (480)
0 to 250	0 to 17.2	575	PX437-250GI	PX438-250GI	PX439-250GI	181 (595)
0 to 300	0 to 20.7	690	PX437-300GI	PX438-300GI	PX439-300GI	216 (710)

Comes complete with PX430-TRAP moisture trap and operator's manual.
***Ordering Example: PX439-010GI**, submersible transmitter with 0.5% FS accuracy, 0 to 10 psig (23.1 ftH2O) and a 12 m (40') cable.*
*Order extra **PX430-TRAP**, vent filter/water vapor trap. Add **"-009"** to model no. for lightning-protection option and add additional cost to price.*

CUSTOM RANGES

PX43____-____GI-____

Enter "7" for 0.1%, "8" for 0.25%, "9" for 0.5% Accuracy
Enter psi Range
Enter cable length (Additional cost/ft)

ACCESSORIES

MODEL NO.	DESCRIPTION
PX430-TRAP	Replacement vent filter/water vapor trap
PX430-CLAMP	Mounting clamp

Appendix B: Ultrasound sensors and amplifier

11 TECHNICAL SPECIFICATIONS

Instrument model	*UltraLab ULS Advanced*
Sensors	USS13-HF, IP 65, M30x1.5
Parameter setting	Virtual com-port via Ethernet (LAN)
Measuring range	From 200 mm up to 1200 mm
Technical resolution	0.36 mm
Accuracy	+/- 1 mm
Sample rate	50Hz/100 Hz switchable (optional interpolated output of 100Hz by a sample rate of 50Hz)
Data readout	RS232/LAN via ASCII data telegram
Electric power supply	230 VAC, 250 mA (110 VAC optional)
Chassis	ca. 330 / 120 / 260 mm width / height / depth IP 50
Temperature range	-20 ...+70°C
Delivery package (fully equipped)	*UltraLab ULS Advanced* instrument, 12 pc. ultrasound sensors USS13_HF, 12 pc. 10m sensor cable, 1 reference sensor REF-300 including calibrated distance unit, 1 reference sensor cable, RS232 cable, 1 Ethernet cable, 1 power supply cable, 1 User Manual

Appendix C: Determination of ice properties

Flexural strength

The flexural strength of model ice is usually determined by measuring the strength using *in situ* cantilever beams (Figure below).

Preliminary tests on the influence of the width to thickness ratio on the apparent flexural strength of the ice indicate that strength is not a strong function of this ratio (Timco, 1981). It would thus seem that for tests on model ice, the length to thickness ratio of the cantilever beams should be of the order of 5-7, and the width to thickness ratio should be 1-2.

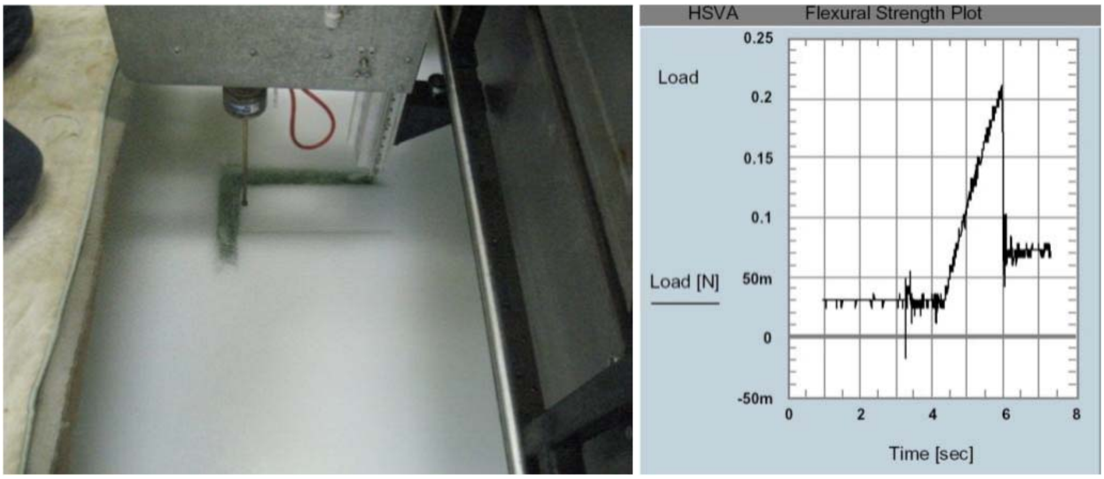


Figure D1. In-situ cantilever beam loading (downward loading); load vs. time plot.

Modulus of elasticity

Similar to the ice strength, the strain (apparent elastic) modulus E must be scaled by the geometric scaling factor of the tests. Since the proper scaling of this parameter in model tests is important, an acceptable test must be defined to measure this property. Basically, it can be measured using either static or dynamic techniques (Timco, 1981). In the static method, the strain modulus can be determined using either a beam or plate approach.

In the former, the modulus is determined by measuring both the load and deflection characteristics of a cantilever beam during loading to failure, whereas in the latter the modulus is determined by monitoring the deflection of the ice sheet as it is loaded with a known increasing load. In ice tanks which measure the strain modulus, the latter technique is usually preferred since it integrates over a large area of the ice sheet and is both simpler and quicker to perform.

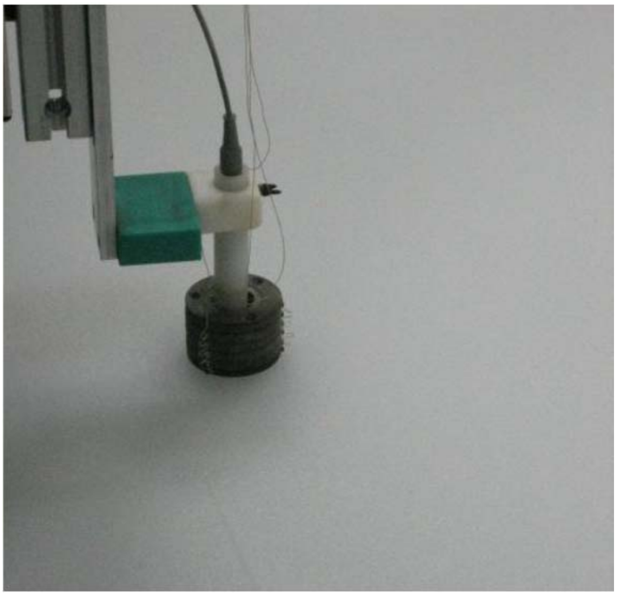


Figure D2. Determination of strain modulus (plate approach)

Ice density

Ice samples (120 mm * 120 mm * ice thickness) are sampled from the model ice sheet at locations where cantilever beam tests are carried out and stored in a plastic bowl filled with tank water in order to avoid any drainage.

The specimen is submerged and the displaced water volume is collected and weighed. The buoyancy force is measured.

Figure D4. Test setup for ice density tests at HSVA

Appendix D: Sensor data description

Introduction

This document lists the different files logged during the LS-WICE project in Oct-Nov 2016. The data description given below includes units and synchronisation. Qualisys data are described in a separate file.

Data files

File name	Format	Content
*.TST *.TSX	TXT	Measurement start time on the PC (local Hamburg time); sample rate
*.bin	BIN (HBM Catman Software)	All time series from the pressure sensors, the ultrasound sensors and the load cells on the structure; synchronisation signals for Qualisys, video and the wave makerwave maker
*.ASC	ASCII	All time series from the pressure sensors, the ultrasound sensors and the load cells on the structure; synchronisation signals for Qualisys, video and the wave maker
ADIS-*.csv	CSV	Acceleration data from IMU

Data description for the *.ASC files

This file contains data from all pressure sensors, the ultrasound sensors, the load cells on the structure; synchronisation signals for Qualisys, video and the wave maker

Column	Parameter	Unit
Zeit 1 - Standardmessrate [s]	Timestamp (starts from 0)	[s]
F_IV_1 [N] (F_II_1 [N])	Force component (not in use)	[N]
F_IV_2 [N] (F_II_3 [N])	Force component (not in use)	[N]
F_IV_3 [N] (F_II_4 [N])	Force component (not in use)	[N]
F_IV_4 [N] (F_II_5 [N])	Force component (not in use)	[N]
F_IV_5 [N] (F_II_6 [N])	Force component (not in use)	[N]
F_IV_6 [N] (F_II_2 [N])	Force component (not in use)	[N]
s_x [m]	Carriage position (back edge)	m
Sync_1 [Volt]	Video lamp sync signal	
Sync_2 [Volt]	Qualisys accusation start	

MGCplus_1 NTP Zeit 1 (Me?rate 1) [s]	Not in use	
Zeit 2 - Standardmessrate [s]	Not in use	
P9 [m]	Pressure at P9	[m]
P10 [m]	Pressure at P10	[m]
h_wave_1 [m]	Ultrasound sensor S1 (surface elevation)	[m]
h_wave_2 [m]	Ultrasound sensor S2 (surface elevation)	[m]
P11 [m]	Clarkson pressure sensor	[m]
P12 [m]	Clarkson pressure sensor	[m]
Sync_3 [Volt]	Wave maker start	
MX840A_1 NTP Zeit 1 (Messrate 1) [s]	PC time	
Zeit 3 - Standardmessrate [s]	Not in use	
P1 [m]	Pressure at P1	[m]
P2 [m]	Pressure at P2	[m]
P3 [m]	Pressure at P3	[m]
P4 [m]	Pressure at P4	[m]
P5 [m]	Pressure at P5	[m]
P6 [m]	Pressure at P6	[m]
P7 [m]	Pressure at P7	[m]
P8 [m]	Pressure at P8	[m]
MX840B NTP Zeit 1 (Messrate 1) [s]	Not in use	
Fx []	Force on structure X direction	[N]
Fy []	Force on structure Y direction	[N]
Fz []	Force on structure Z direction	[N]

IMU data description (ADIS-*.csv files)

Column	Parameter	Unit
PROD_ID	system data/ not in use	
SYSTEM_STAT	system data/ not in use	
POWER_SUP	system data/ not in use	
X_ACCL	surge acceleration $[m/s^2]$	$[m/s^2]$
Y_ACCL	sway acceleration $[m/s^2]$	$[m/s^2]$
Z_ACCL	heave acceleration [m/s2]	$[m/s^2]$
X_GYRO	not in use	
Y_GYRO	not in use	
Z_GYRO	not in use	
X_TEMP	not in use	
Y_TEMP	not in use	
Z_TEMP	not in use	
YEAR	time stamp	

MONTH	time stamp	
DATE	time stamp	
HOUR	time stamp (not synced with other sensor data)	
MINUTE	time stamp (not synced with other sensor data)	
SECOND	time stamp (not synced with other sensor data)	
MILLISECONDS	time stamp (not synced with other sensor data)	
RUNNUMBER	Sample number from start	

Appendix E: Qualisys data description

Introduction

This document describes the structure of files produced by the Qualisys Motion Capture System. They can be found in the “sensor data\QualiSys” folder. The data is available in both ASCII and Matlab format, as described below.
Detailed documentation can be found in QTM-user-manual_V_2014_letzte XP.pdf.

Data structure

Note 1: the number of entries in the files is in general not equal to the number of markers that were placed on the ice (due to the presence of other reflecting objects in the field of view of the cameras). This means, the user has to identify useful data and disregard the rest.
Note 2: the order of entries is different in different files, even if the same set of markers was used (like, e.g., in subsequent tests belonging to the same test series). Thus, the only way to identify markers is by their relative position in space (in the case of LS-WICE experiments: by the x coordinate).

Matlab files

The data is organized in a structure `qtm_xxxx` (where `xxxx` is the ID of the test series (e.g. 1100) with fields:

Field name	Description	Example content
File	file name	C:\Users\Qualisys\Documents\Hydralab\Data\1100.qtm
Timestamp	time when measurement was started	2016-10-27, 16:47:59
StartFrame	the first entry	1
Frames	number of entries (i.e., length of time series)	26206
FrameRate	frequency (1/s)	100
Trajectories	marker trajectories	[1×1 struct]

The time series with the positions of the markers are stored in the structure `Trajectories` with three fields: `Labeled`, `Unidentified`, and `Discarded`. Each of them contains information about the number of markers (field `Count`). If `Count` is greater than zero, they also contain field `Data`, which is a 3D matrix of size `Count` × 4 × `Frames`, i.e., there are 4 time series for each marker, containing:

- the x, y, z coordinates of the marker,
- the average residual (i.e., average of residuals in x, y and z directions) of the marker position.

All data are in mm.
Attached is a Matlab function read_qualisys.m that reads the *.mat files and extracts from them “cleaned” marker data (i.e., it removes “fake” markers and sorts the remaining ones according to their position).

ASCII files

The ASCII files contain a header with the following structure:

```
NO_OF_FRAMES        26206
NO_OF_CAMERAS       6
```

```
NO_OF_MARKERS      5
FREQUENCY          100
NO_OF_ANALOG       0
ANALOG_FREQUENCY   0
DESCRIPTION        --
TIME_STAMP         2016-10-27, 16:47:59    30466.87331265
DATA_INCLUDED      3D
MARKER_NAMES
```

The first four lines contain information about: the length of the time series, the number of cameras and markers, frequency (in 1/s). The content of lines 5-7 is irrelevant for the Qualisys setup used in LS-WICE. The time stamp corresponds to the first entry in the record. The data table contains `NO_OF_MARKERS` × 3 number of columns and `NO_OF_FRAMES` number of rows. For each marker, the three columns contain its x, y, z coordinates in mm.

Appendix F: IMU data sheet

SPECIFICATIONS

T_A = 25°C, VCC = 5.0 V, angular rate = 0°/sec, dynamic range = ±300°/sec ± 1 *g*, unless otherwise noted.

Table 1.

Parameter	Test Conditions/Comments	Min	Typ	Max	Unit
GYROSCOPES					
Dynamic Range		±300	±350		°/sec
Initial Sensitivity	Dynamic range = ±300°/sec	0.0495	0.05	0.0505	°/sec/LSB
	Dynamic range = ±150°/sec		0.025		°/sec/LSB
	Dynamic range = ±75°/sec		0.0125		°/sec/LSB
Sensitivity Temperature Coefficient	−20°C ≤ T_A ≤ +70°C		±50		ppm/°C
Misalignment	Axis-to-axis		±0.05		Degrees
	Axis-to-frame (package)		±0.5		Degrees
Nonlinearity	Best fit straight line		±0.1		% of FS
Initial Bias Error	±1 σ		±3		°/sec
In-Run Bias Stability	1 σ, SMPL_PRD = 0x0001		0.007		°/sec
Angular Random Walk	1 σ, SMPL_PRD = 0x0001		2.0		°/√hr
Bias Temperature Coefficient	−20°C ≤ T_A ≤ +70°C		±0.01		°/sec/°C
Linear Acceleration Effect on Bias	Any axis, 1 σ (MSC_CTRL[7] = 1)		0.05		°/sec/*g*
Bias Voltage Sensitivity	VCC = 4.75 V to 5.25 V		±0.3		°/sec/V
Output Noise	±300°/sec range, no filtering		0.8		°/sec rms
Rate Noise Density	f = 25 Hz, ±300°/sec range, no filtering		0.044		°/sec/√Hz rms
3 dB Bandwidth			330		Hz
Sensor Resonant Frequency			14.5		kHz
Self-Test Change in Output Response	±300°/sec range setting	±696	±1400	±2449	LSB
ACCELEROMETERS	Each axis				
Dynamic Range		±5	±5.25		*g*
Initial Sensitivity		0.99	1.00	1.01	m*g*/LSB
Sensitivity Temperature Coefficient	−20°C ≤ T_A ≤ +70°C		50		ppm/°C
Misalignment	Axis-to-axis		0.2		Degrees
	Axis-to-frame (package)		±0.5		Degrees
Nonlinearity	Best fit straight line		0.1		% of FS
Initial Bias Error	±1 σ		8		m*g*
In-Run Bias Stability	1 σ		0.1		m*g*
Velocity Random Walk	1 σ		0.12		m/sec/√hr
Bias Temperature Coefficient	−20°C ≤ T_A ≤ +70°C		0.05		m*g*/°C
Bias Voltage Sensitivity	VCC = 4.75 V to 5.25 V		2.5		m*g*/V
Output Noise	No filtering		5		m*g* rms
Noise Density	No filtering		0.27		m*g*/√Hz rms
3 dB Bandwidth			330		Hz
Sensor Resonant Frequency			5.5		kHz
Self-Test Change in Output Response	X-axis and y-axis	140		570	LSB
TEMPERATURE SENSOR					
Scale Factor	Output = 0x0000 at 25°C (±5°C)		0.136		°C/LSB
ADC INPUT					
Resolution			12		Bits
Integral Nonlinearity			±2		LSB
Differential Nonlinearity			±1		LSB
Offset Error			±4		LSB
Gain Error			±2		LSB
Input Range		0		3.3	V
Input Capacitance	During acquisition		20		pF

Appendix G: Daily reports

HSVA	**Arctic Technology**	2016-10-25
hydralab+	**Loads on Structure and Waves in Ice LS-WICE**	
Order Nr.: 62 7074/524	**Daily Report**	**No:** …………………
Prepared by: ……………………..	**Checked by:** ………………..	**Approved by:** ……………..

Participant	**Institution**
1. 2. 3. 4. … …	

All time in this report is the Hamburg local time (note, local time change from daylight saving to normal on 29 Oct.)

1. Kick off

(EXAMPLE): 8-13 local time shake down, camera, sensor cables, synchronization discuss…

2. Open water test

(EXAMPLE): Open water test

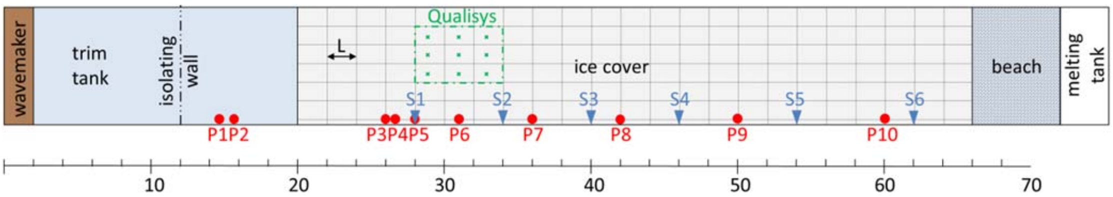
Run No.	Wave height	Wave period	Wave length	Duration of Test Run*	Remarks
[-]	[m]	[s]	[m]	[min]	[-]
1	0.05	1	1.56	1.5	Stop for 5 min each test or longer depend on how long the disturbance will last.
2	0.1	1	1.56	1.5	Also, we may sweep period first, then move to a higher amplitude, in that order.
3	0.05	1.2	2.25	1.5	
4	0.1	1.2	2.25	1.5	
5	0.05	1.4	3.05	1.5	
6	0.1	1.4	3.05	1.5	
7	0.05	1.6	4.00	1.5	Skip
8	0.1	1.6	4.00	1.5	Skip
9	0.05	1.8	5.05	1.5	Skip
10	0.1	1.8	5.05	1.5	Skip

11	0.05	2	6.24	1.5	Skip
12	0.1	2	6.24	1.5	

*Note: duration of test run means the time the wave maker operated; the data were recorded for a longer time period

Table 8.3: Positons of the pressure sensors in the basin

Name	Position [m]	Comment
P1	15	Wave reflection from the ice edge
P2	15.5	Wave reflection from the ice edge
P3	26	Wave speed
P4	26.5	Wave speed
P5	28	Attenuation
P6	31	Attenuation
P7	36	Attenuation
P8	42	Attenuation
P9	50	Attenuation
P10	60	Attenuation
P11	~31	Wave number, not connected
P12	~31	Wave number, not connected
US1	15	
US2	15.5	



Notes:

1. At P10 the wave basin drops by ~2.5m deeper from the rest of the tank.
2. Water depth on 2016-10-25 was 2.51m deep.
3. Water specific gravity 1.0055. Measured in the cold room.

3. Camera installation

……………. and so on ……

Participant	**Institution**
1. 2. 3. 4. … …	

All time in this report is the Hamburg local time (note, local time change from daylight saving to normal on 29 Oct.)

4. Measurements of ice properties

- Young modulus
- Beam tests of ice strength
- Ice thickness (in front of the isolating wall, close to the beach, along the tank walls)
- Ice density (samples from the region close to the isolating wall)
- Ice salinity (samples from the region close to the isolating wall)

Ice thickness			
x (m)	h_right (mm)	h_left (mm)	h_center (mm)
15	34.5	–	–
20	32.5	–	–
25	33.5	–	–
30	33.0	–	–
35	35.5	–	–
40	37.0	–	–
45	38.5	–	–
50	36.0	–	–
55	33.0	–	–
60	34.5	32.5	31.5
65	35.0	36.5	33.5

Density	Specific density (-)	Density (water dens. = 1005g/m^3)
Test 1	0.916	921.038
Test 2	0.912	917.016
Salinity	PSU	
Test 1	3.55	@ 13.5°C
Test 2	3.50	@ 14.5°C
Young's modulus	16 MPa	conditions: X=17m, Y=5m, h=27.5mm, σ_F=67.1kPa, time 07:40

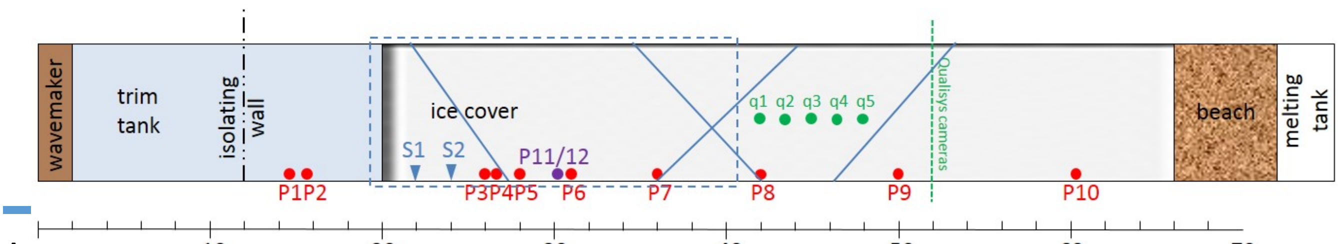
Beam tests (from ice removed later)				
sigma (kPa)	F (N)	L (mm)	B (mm)	H (mm)
(at x = 13.5 m, i.e., close to the "future" ice edge)				
36.4	1.25	175	60	24.5
43.7	1.51	175	60	24.5
44.3	1.45	175	55	24.5
(at x = 66 m, i.e., close to the beach; Y = 5 m)				
65.8	3.40	180	60	30.5
68.4	3.42	180	60	30.0
67.2	3.08	180	55	30.0

5. Cutting and positioning of the ice sheet

- Cutting the ice across the tank close to the isolating wall (x = 14 m) and close to the beach
(x = 65 m)
- Cutting the ice along the side walls (~10 cm from the walls)
- Repositioning of the ice sheet towards its final position by shifting it ~6 m towards the beach (ice edge at x = 20 m)

6. Camera installation and calibration

- Installation of the GoPro cameras + recording of images required for calibration (a rope with markers spanned across the tank every 2m)
- Installation of the AXIS camera on the ceiling (position: x = 16 m, y = 5 m, z = 5 m)
- Setup of the Qualisys cameras and markers
- synchronization of the cameras: during the experiment (with a lamp)



Ar

Fig. 1. Location of instruments: P1 – P10 are single pressure sensors, P11/12 – a double pressure sensor, S1 and S2 – ultrasound sensors, q1 – q5 – Qualisys markers, continuous blue lines – fields of view of GoPro cameras, dashed blue lines – field of view of the AXIS camera

7. Test setup, position of equipment

- All locations are measured relative to the corner of the tank shown in Fig. 2

Qualisys marker positions (m)
42.0
43.5
45.0
46.5
48.0
Cameras roughly at 52 m

9 Single pressure sensors are located approx. 0.6m from the wall of the tank. For the double sensor: the top one is 0.6m and the bottom one 0.765m from the wall. US1 and US2 are 0.65m from the wall.

Position of sensors		
Sensor	Rel. pos. (m)	Abs. pos. (m)
P1		15.200
P2	0.605	15.805
ice edge		19.910
US1		22.305
US2	1.795	24.100
P3	1.865	25.965
P4	0.625	26.590
P5	1.210	27.800
P11/12		30.185
P6	0.605	30.790
P7		36.195
P8		41.610
P9		50.065
P10		60.583

Fig. 2. Coordinate system used by the Qualisys

8. Tests series 1100 – 1500

Run No.	Wave height	Wave period	Wave length	Duration of Test Run*	Remarks
[-]	[mm]	[s]	[m]	[min]	[-]
1100	10.0	2.0		1.5	no breaking observed
1200	10.0	1.6		1.5	no breaking observed
1300	10.0	1.2		1.5	no breaking observed
1400	20.0	2.0		1.5	no breaking observed
1410	30.0	2.0		1.5	no breaking observed
1420	40.0	2.0		1.5	no breaking observed
1430	50.0	2.0		1.5	no breaking observed
1440	70.0	2.0		1.5	the first major crack developed (approx. at x = 44 m, see Fig. 3a)
1450	90.0	2.0		(1.5)	major breaking; measurement continued for several minutes, until no further breaking occurred (Fig. 3b)
photos from the crane camera for FSD					
1500	50.0	1.6		1.5	no breaking observed
1510	70.0	1.6		(1.5)	major breaking; measurement continued for several minutes, until no further breaking occurred (Fig. 3c)
photos from the crane camera for FSD					

*Note: duration of test run means the time the wave maker operated; the data were recorded for a longer time period

9. List of data collected

- ice properties, air and water temperature
- time series from pressure sensors
- time series from ultrasound sensors
- 3D motion of Qualisys markers
- videos from AXIS and GoPro cameras
- after test 1450 and 1510: photographs of the entire tank surface from the crane camera
- photos and videos from hand-held cameras done by a number of experiment participants

10

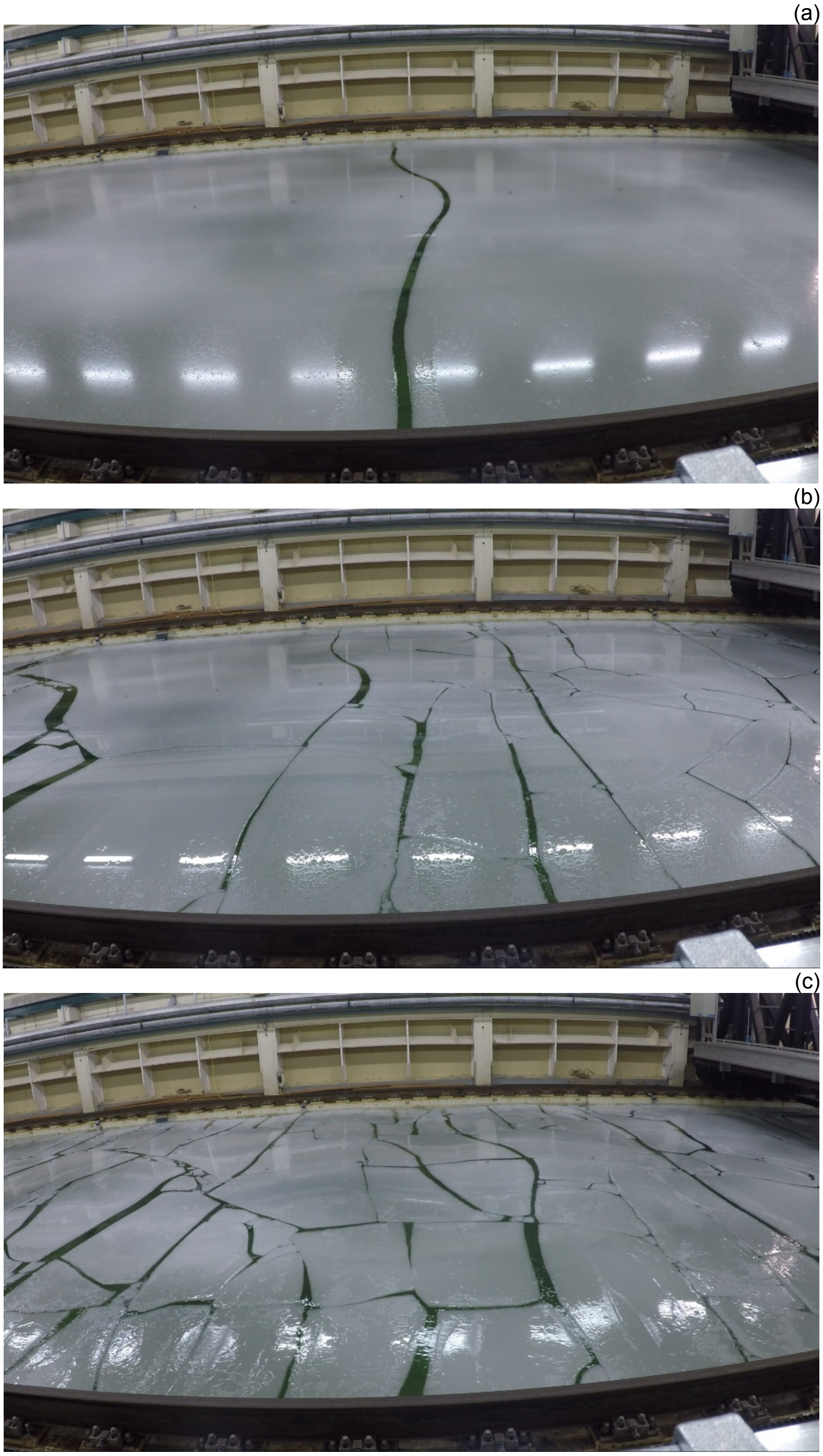


Fig. 3. Uncorrected snapshots from GoPro Silver after test 1440 (a), 1450 (b) and 1510 (c).

HSVA	Arctic Technology	2016-10-28
hydralab+	**Loads on Structure and Waves in Ice LS-WICE**	
Order Nr.: 62 7074/524	**Daily Report**	**No:** ……………………

Prepared by: ……………………..	**Checked by:** ………………..	**Approved by:** ……………..

Participant	**Institution**
1. 2. 3. 4. … …	

All time in this report is the Hamburg local time (note, local time change from daylight saving to normal on 29 Oct.)

10. Axis camera calibration

Images of reference points in the tank are taken for further image processing. They are stored in the folder 'data' from 28.10.2016.

11. Ice tank preparation

Ice melt, water filtering, etc.

HSVA	Arctic Technology	2016-11-01
hydralab+	**Loads on Structure and Waves in Ice LS-WICE**	
Order Nr.: 62 7074/524	**Daily Report**	**No:** ……………………

Prepared by: Agnieszka Herman	**Checked by:** ………………..	**Approved by:** ……………..

Participant	**Institution**
1. 2. 3. 4. … …	

All time in this report is the Hamburg local time (note, local time change from daylight saving to normal on 29 Oct.)

12. Measurements of ice properties

- Young modulus
- Beam tests of ice strength
- Ice thickness (along the centerline of the tank)
- Ice density
- Ice salinity

Ice thickness (time: 07:45)	
x (m)	h_center (mm)
16	34.0
20	37.0
26	35.0
32	36.5
37	38.0
43	37.0
49	38.0
55	34.5
60	36.0
66	36.5

$$\text{Ice density } = \frac{\text{W2}}{\text{W3}} \times \text{Water density}$$

Density	W2 (g)	W3 (g)	Specific density W2/W3 (-)	Water Density (kg/m^3)	Ice Density (kg/m^3)
Test 1	455	493	0.9155	1005.5	920.53
Test 2	503	549	0.9162	1005.5	921.25
Test 3	487	545	0.9103	1005.5	915.29

Salinity	PSU	

Test 1	3.7	@ x=16, y=1.5
Test 2	3.8	@ x=43, y=1.5
Test 3	3.7	@ x=66, y=1.5

Young's modulus	E_{mean} (MPa)	E_{mean}/σ_F	Conditions
Test 1	28.6	390	Time: 07:20, position: x = 16m, ice thickness = 34.7mm, σ_F = 73.50 kPa
Test 2	26.0	420	Time: 07:30, position: x = 43m, ice thickness = 39.0mm, σ_F = 62.80 kPa
Test 3	34.6	513	Time: 07:40, position: x = 66m, ice thickness = 37.7mm, σ_F = 67.50 kPa

Beam tests					
	sigma (kPa)	F (N)	L (mm)	B (mm)	H (mm)
Time: 08:30	(at x = 16.0 m)				
	68	4.40	232	74	35
	76	4.36	235	70	34
	77	4.79	230	70	35
Time: 08:40	(at x = 43 m)				
	69	6.54	240	90	39
	57	5.42	225	84	39
	62	4.89	237	74	39
Time: 08:50	(at x = 66 m)				
	65	5.05	241	80	37.5
	73	5.36	240	75	37.5
	65	4.72	240	73	38.0

13. Cutting and positioning of the ice sheet

- Cutting the ice along the side walls (13 cm from the right wall and 12 cm from the left wall)
- Cutting the ice across the tank at x = 20, 26, 32, 38, 44, 50, 56, 62, 68, and 71 m (Fig. 1);
  removing the ice from the trim tank; final ice edge position **~19.8m**
- Cutting the ice along the tank (average strip width: 1.62 m; Fig. 1)

14. Test setup, position of equipment

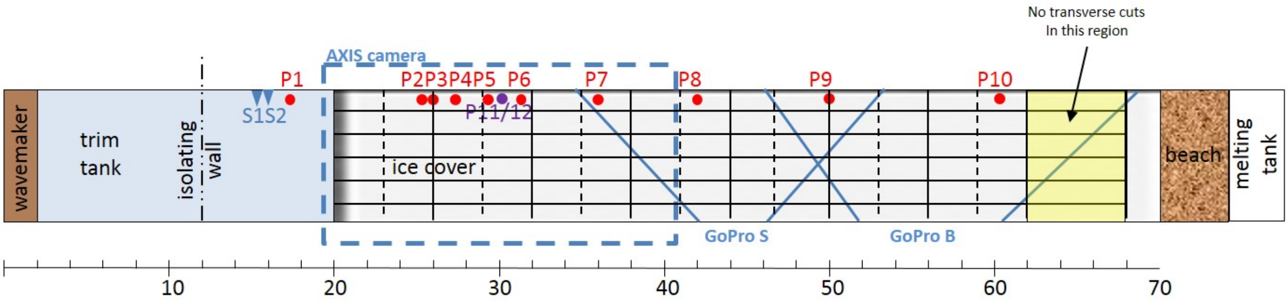


Fig. 1. Location of instruments: P1 – P10 are single pressure sensors, P11/12 – a double pressure sensor, S1 and S2 – ultrasound sensors, continuous blue lines – fields of view of GoPro cameras, dashed blue lines – field of view of the AXIS camera, continuous black lines – locations of longitudinal and transverse cuts for the first series of tests, dashed black lines – locations of transverse cuts for the second series of tests, yellow rectangle – region, where no transverse cuts are done during the tests. The table shows x-coordinates of the pressure and ultrasound sensors.

Position of sensors		
Sensor	Rel. pos. (m)	Abs. pos. (m)
US1		15.182
US2	0.50	15.682
P1	1.385	17.067
ice edge		19.80
P2		25.285
P3	1.2	26.485
P4	0.595	27.08
P5		29.083
P11/P12	0.6	29.683
P6	1.193	30.876
P7		36.108
P8		41.687
P9		49.985
P10		60.59

Single pressure sensors are located approx. 0.6m from the wall of the tank. For the double sensor: the top one is 0.6m and the bottom one 0.765m from the wall. US1 and US2 are 0.65m from the wall.

15. Tests series 2000

Run No.	Wave height	Wave period	Floe length	Duration of Test Run*	Remarks
[-]	[mm]	[s]	[m]	[min]	[-]
2410	50.0	2.0	6.0	1.2	a few cracks (in floes neighboring the left wall + around bending-test sites)
2420	50.0	1.8	6.0	1.2	further cracks close to the ice edge and the left wall)
2460	10.0	0.9	6.0	1.2	very strong attenuation (already by the first floe); very noisy pressure measurements due to small amplitude

2450	20.0	0.9	6.0	1.2	strong overwash at the ice edge, weaker seen also between ice floes; new cracks only very close to the ice edge
2440	20.0	1.2	6.0	1.2	no further breaking
2430	40.0	2.0	6.0	1.2	no further breaking
photos from the crane camera for FSD					
2610	25.0	2.0	1.5	1.2	no breaking
2620	25.0	1.8	1.5	1.2	no breaking
2630	25.0	1.6	1.5	1.2	no breaking
2640	25.0	1.4	1.5	1.2	no breaking
2650	25.0	1.2	1.5	1.2	no breaking ; strong overwash within 10-15m from ice edge
2660	25.0	0.9	1.5	1.2	no breaking; very strong attenuation; strong overwash within 4-5m from ice edge
photos from the crane camera for FSD					
2710	25.0	2.0	0.5	1.2	no breaking
2720	25.0	1.8	0.5	1.2	-‖-
2730	25.0	1.6	0.5	1.2	-‖-
2740	25.0	1.4	0.5	1.2	-‖-
2750	25.0	1.2	0.5	1.2	-‖-
2760	25.0	0.9	0.5	1.2	-‖-
photos from the crane camera for FSD					

*Note: duration of test run means the time the wave maker operated; the data were recorded for a longer time period

11 Note: the previously planned tests 2100, 2200, 2300, as well as the whole test series 25xx, have been cancelled. In the table above, the tests in the 24xx group are provided in chronological order.

16. List of data collected

- ice properties, air and water temperature
- time series from pressure sensors
- time series from ultrasound sensors
- videos from AXIS and GoPro cameras
- after test 2430, 2660 and 2760: photographs of the entire tank surface from the crane camera
- photos and videos from hand-held cameras done by a number of experiment participants

<table>
<tr><td>HSVA</td><td colspan="2">Arctic Technology</td><td>2016-11-03</td></tr>
<tr><td>hydralab+</td><td colspan="3">Loads on Structure and Waves in Ice
LS-WICE</td></tr>
<tr><td>Order Nr.:
62 7074/524</td><td colspan="2">Daily Report</td><td>No:
……………………</td></tr>
<tr><td>Prepared by: Agnieszka Herman</td><td colspan="2">Checked by:
………………..</td><td>Approved by:
……………..</td></tr>
<tr><td>Participant</td><td colspan="3">Institution</td></tr>
<tr><td>1.
2.
3.
4.
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</table>

All time in this report is the Hamburg local time (note, local time change from daylight saving to normal on 29 Oct.)

17. Measurements of ice properties

- Young modulus
- Beam tests of ice strength
- Ice thickness (along the centerline of the tank)
- Ice density
- Ice salinity

Ice thickness (time: 06:23-06:40)	
x (m)	h_center (mm)
16	35.2
43	36.0
66	37.2
Ice thickness (after all tests)	
66	42

$$\text{Ice density} = \frac{\text{W2}}{\text{W3}} \times \text{Water density}$$

Density	W2 (g)	W3 (g)	Specific density W2/W3 (-)	Water Density (kg/m^3)	Ice Density (kg/m^3)
Test 1	475	522	0.9100	1005.5	915
Test 2	501	551	0.9093	1005.5	914
Test 3	511	560	0.9125	1005.5	918

Salinity	PSU	
Test 1	4.0	@ x=16, y=1.5

Test 2	4.0	@ x=43, y=1.5
Test 3	4.2	@ x=66, y=1.5

Young's modulus	E_{mean} (MPa)	E_{mean}/σ_F	Conditions
Test 1	51.5	617	Time: 06:23, position: x = 16m, ice thickness = 35.2mm, σ_F = 83.50 kPa
Test 2	41.0	481	Time: 06:33, position: x = 43m, ice thickness = 36.0mm, σ_F = 85.90 kPa
Test 3	76.8	968	Time: 06:40, position: x = 66m, ice thickness = 37.2mm, σ_F = 79.40 kPa

Beam tests					
	sigma (kPa)	F (N)	L (mm)	B (mm)	H (mm)
Time: 08:32	(at x = 16.0 m)				
	83	5.65	210	70	35
	81.5	5.06	220	65	35.5
	86.1	5.59	220	70	35
Time: 07:03	(at x = 43 m)				
	86	6.8	205	75	36
	85.8	6.6	205	73	36
Time: 07:07	(at x = 66 m)				
	70.1	5.60	200	70	37
	92.5	7.39	200	70	37
	75.5	6.19	200	70	37.5

18. Cutting and positioning of the ice sheet

- Cutting the ice along the side walls
- Cutting the ice across the tank into 3m-long floes (Fig. 1);
  removing the ice from the trim tank; final ice edge position **20.0m**
- Cutting the ice along the tank (average strip width: 1.62 m; Fig. 1)

19. Test setup, position of equipment

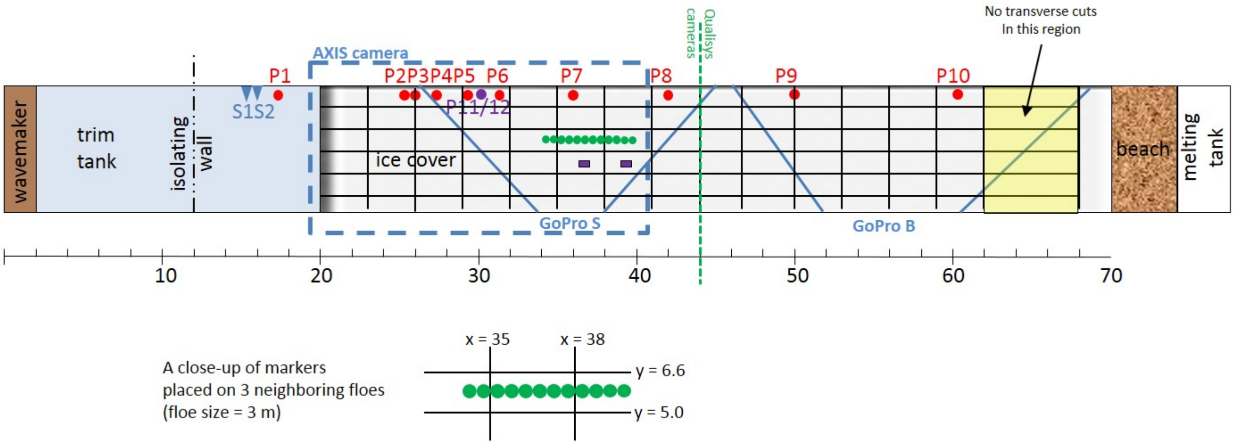

Fig. 1. Location of instruments: P1 – P10 are single pressure sensors, P11/12 – a double pressure sensor, S1 and S2 – ultrasound sensors, continuous blue lines – fields of view of GoPro cameras, dashed blue lines – field of view of the AXIS camera, continuous black lines – locations of longitudinal and transverse cuts for the first series of tests, yellow rectangle – region, where no transverse cuts are done during the tests, green points – location of Qualisys markers, dashed green line – approximate location of Qualisys cameras, violet rectangles – location of IMU units.

Position of sensors		
Sensor	Rel. pos. (m)	Abs. pos. (m)
US1*		15.01
US2*		15.61
P1		17
ice edge		20.00
P2		25.158
P3	1.125	26.283
P4	0.645	26.93
P5		29.035
P11/P12	1.125	30.16
P6	0.605	30.765
P7		36.23
P8		41.63
P9		50
P10		Not used

Single pressure sensors are located approx. 0.6m from the wall of the tank. For the double sensor: the top one is 0.6m and the bottom one 0.765m from the wall. US1 and US2 are 0.65m from the wall.
*Note: the ultrasound sensors were deinstalled and reinstalled after each group of tests. The positions in the table were measured before the test group 3300

Qualisys marker positions	
x (m)	y (m)
34.25	5.8
34.75	5.8
35.25	5.8
35.75	5.8
36.25	5.8
36.75	5.8
37.25	5.8
37.75	5.8

38.25	5.8
38.75	5.8
39.25	5.8
39.75	5.8

Note: additionally, in test groups 3100 and 3200, two IMU units were used on selected ice floes parallel to the Qualisys markers, as shown in Fig.1. The position of IMU units was changed between test groups 3100 and 3200, so that both were located approximately in the middle of an ice floe.
For test group 3100, the position was: x = 36.75, y = 4.2 m; x = 39.75 m, y = 4.2 m.
For test group 3200, the position was: x = 37.25, y = 4.2 m; x = 38.75 m, y = 4.2 m.

20. Tests series 3000

Run No.	Wave height	Wave period	Floe length	Duration of Test Run	Remarks
[-]	[mm]	[s]	[m]	[min]	[-]
3110	25.0	2.0	3.0	1.2	many floes are frozen to each other (ice behaves like a continuous sheet)
3120	25.0	1.8	3.0	1.2	-||-
3130	25.0	1.6	3.0	1.2	after this test: re-cutting of ice from the walls and from each other in the region in front of the main carriage
3140	30.0	1.5	3.0	1.2	some breaking of floes close to the ice edge
3150	30.0	1.4	3.0	1.2	
3160	30.0	1.1	3.0	1.2	
photos from the crane camera for FSD					
3210	25.0	2.0	1.5	1.2	no breaking
3220	25.0	1.8	1.5	1.2	-||-
3230	25.0	1.6	1.5	1.2	no breaking; transverse re-cutting of some ice floes in the beach region after this test
3240	30.0	1.5	1.5	1.2	no breaking
3250	30.0	1.4	1.5	1.2	-||-
3260	25.0	1.1	1.5	1.2	-||-
photos from the crane camera for FSD					
3310	25.0	2.0	0.5	1.2	no breaking
3320	25.0	1.8	0.5	1.2	-||-
3330	25.0	1.6	0.5	1.2	-||-
3340	30.0	1.5	0.5	1.2	-||-
3350	30.0	1.4	0.5	1.2	-||-
3360	30.0	1.1	0.5	1.2	-||-
3370	25.0	2.3	0.5	1.2	-||-
3380	25.0	2.2	0.5	1.2	-||-
3390	25.0	2.1	0.5	1.2	-||-
photos from the crane camera for FSD					

21. List of data collected

- ice properties, air and water temperature
- time series from pressure sensors

- time series from ultrasound sensors
- videos from AXIS and GoPro cameras
- time series of marker locations from the Qualisys system
- time series of accelerations from the two IMU units
- after test 3160, 3260 and 3390: photographs of the entire tank surface from the crane camera
- photos and videos from hand-held cameras done by a number of experiment participants

12

HSVA	Arctic Technology	2016-11-08
hydralab+	**Loads on Structure and Waves in Ice LS-WICE**	
Order Nr.: 62 7074/524	**Daily Report**	**No:** ……………………
Prepared by:	**Checked by:** ………………..	**Approved by:** ……………..

Participant	**Institution**
1. 2. 3. 4. … …	

All time in this report is the Hamburg local time (note, local time change from daylight saving to normal on 29 Oct.)

22. Measurements of ice properties

- Young modulus
- Beam tests of ice strength
- Ice thickness (along the centerline of the tank)
- Ice density

Young's modulus	E_{mean} (MPa)	E_{mean}/σ_F	Time [hh:mm]	Tank position		Time [hh:mm]
				X [m]	Y [m]	
Test 1	41.5	633	06:33	16	5	06:33
Test 2	30	353	06:39	43	5	06:39
Test 3	49.6	666	06:49	66	5	06:49

Beam tests					
	sigma (kPa)	F (N)	L (mm)	B (mm)	H (mm)
Time: 08:00 – 08:04	(at x = 16.0 m)				
	60.3	3.52	190	65	32
	63.1	3.40	190	60	32
	73.6	3.65	200	60	31.5
Time: 08:10 -08:14	(at x = 43 m)				
	78.7	5.23	200	65	35
	76.0	4.90	200	65	34.5
	96.6	6.23	200	65	34.5
Time: 08:15 – 08:17	(at x = 66 m)				
	75.7	4.2	200	65	32
	73.3	3.72	205	65	31

23. Cutting and positioning of the ice sheet

- Cutting the ice along the side walls
- Cutting the ice across the tank into 1.5 m-long floes (Fig. 1); removing the ice from the trim tank; final ice edge position **21.5m**
- Cutting the ice along the tank (average strip width: 1.63 m; Fig. 1)

24. Test setup, position of equipment

NB1 Fig.1 is schematic location of the ice edge is 20.5 m (21.5 m after first test), structure position 43.7 m, IMU sensor = 43 m. Ultrasound sensors: S1 – closest to the structure and the distance between S1 and S2 is 50 cm. Distance from S1 to the closest point on the structure is 50 cm
IMU mass = 1.214 kg

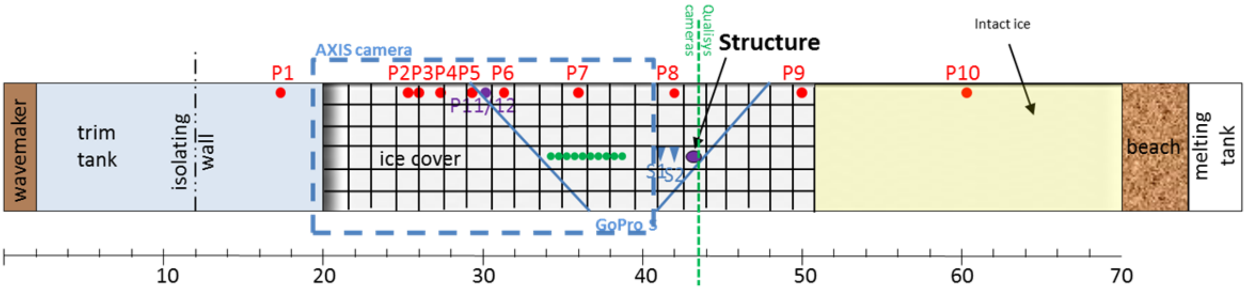

Fig. 1. Location of instruments: P1 – P10 are single pressure sensors, P11/12 – a double pressure sensor, S1 and S2 – ultrasound sensors, continuous blue lines – fields of view of GoPro camera, dashed blue lines – field of view of the AXIS camera, continuous black lines – locations of longitudinal and transverse cuts for the first series of tests, yellow rectangle – region, where no transverse cuts are done during the tests, green points – location of Qualisys markers, dashed green line – approximate location of Qualisys cameras, IMU units.

Position of sensors		
Sensor	Rel. pos. (m)	Abs. pos. (m)
P1		17.08
ice edge		20.50 initial (21.50*)
P2		25.28
P3	1.205	26.49
P4	0. 59	27.08
P5		29.09
P11/P12	0.60	29.69
P6	1.195	30.88
P7		36.11
P8		41.70
US1*		Ca. 43 m
US2*		Ca. 42.5
P9		50
P10		60.53

Single pressure sensors are located approx. 0.6m from the wall of the tank. For the double sensor: the top one is 0.6m and the bottom one 0.765m from the wall. US1 and US2 are 0.65m from the wall.

* US1 and US2 y position is ca. 4.2 m
On three ice floes: no. 9 , 10 and 11 (counting from the ice edge in X) qualisys markers were installed.

Floe no.*	**Qualisys** marker positions

	x (m)	y (m)
9	33.25	4.20
	33.75	4.20
	34.25	4.20
10	34.75	4.20
	35.25	4.20
	35.75	4.20
11	36.25	4.20
	36.75	4.20
	37.25	4.20

IMU unit was installed on the floe no.15 (counting from the ice edge and e) and used in test groups 4100 and 4200 and in test runs 4310, 4320 and 4330 (started to float), so that both were located approximately in the middle of an ice floe. The center of the ice floe no. 15 was x = 43.00 m, y = 4.2 m.

25. Tests series 4000

IMU synchronization between IMU and Go-Pro: at 11:18.

Run No.	**Approx. start/finish time**	**Wave height**	**Wave period**	**Floe length**	**Duration of Test Run**	**Remarks**
[-]		**[mm]**	**[s]**	**[m]**	**[min]**	**[-]**
4000						IMU synchronization with other sensors. The main carriage was driven with the speed of 1 cm/s towards the closest ice floe
4110	14:20/14:24	25.0	2.0	1.5	2	- gaps/ regions with open water between the floes after cutting and structure installation - after several impacts between the ice floe and structure, the floe moved from the structure and not impacts were observed - after this run all the floes were pushed close to each other and the structure
4120	14:43/14:64	25.0	1.8	1.5	2	-More impacts and less floe drift from the structure - Significant vibrations of the beam with attached ultrasound sensors S1 and S2 and Go Pro camera
4130	14:52/14:54	25.0	1.6	1.5	2	- floe/structure impacts. More frequent at the beginning of the run
4140	15:00/15:04	25.0	1.5	1.5	2	-//-
Doubled amplitude						
4210	15:08/15:12	50.0	2.0	1.5	2	Floe/structure impacts
4220	15:19/15:25	50.0	1.8	1.5	2	
4230	15:29/15:33	50.0	1.6	1.5	2	the structure-floe contact area increased (arc contact zone)

4240	15:43/15:46	50.0	1.5	1.5	2	After completing test group 4300 the floes no 2, 4, 5, 6, 7, 8,9, 11 in the row with the structure were split
4310	16:08/16:12	75.0	2.0	1.5	2	After the first structure/floe impact the floe adjacent to the structure on the sided side rotated. This floe blocked possibility for impact with the floe in front of the structure
4320	16:18/16:20	75.0	1.8	1.5	2	IMU started to float and was removed Breakage of the ice but only transverse to the structure
4330	16:26/16:28	75.0	1.6	1.5	2	
4340	16:32/16:36	75.0	1.5	1.5	2	Significant increase in structure-floe contact area
4430	16:42/16:44	100.0	1.6	1.5	2	The floe closest to the structure is splitted
4530		200.0	1.6	1.5	2	Major breaking of the floes in random pieces Flooding on the back side of the trim tank

26. List of data collected

- ice properties, air and water temperature
- time series from pressure sensors
- time series from ultrasound sensors
- videos from AXIS and GoPro cameras, underwater camera
- time series of marker locations from the Qualisys system
- time series of accelerations from the IMU unit
- photos and videos from hand-held cameras done by a number of experiment participants

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hydralab+	**Loads on Structure and Waves in Ice LS-WICE**		
Order Nr.: **62 7074/524**	**Daily Report**		**No:** ……………………
Prepared by:		**Checked by:** ………………..	**Approved by:** ……………..

Participant	**Institution**
1. 2. 3. 4. … …	

All time in this report is the Hamburg local time (note, local time change from daylight saving to normal on 29 Oct.)

27. Open water tests with the structure

Structure is the cylinder with the diameter of 680 mm and the height of 620 mm, shown in Fig.1:

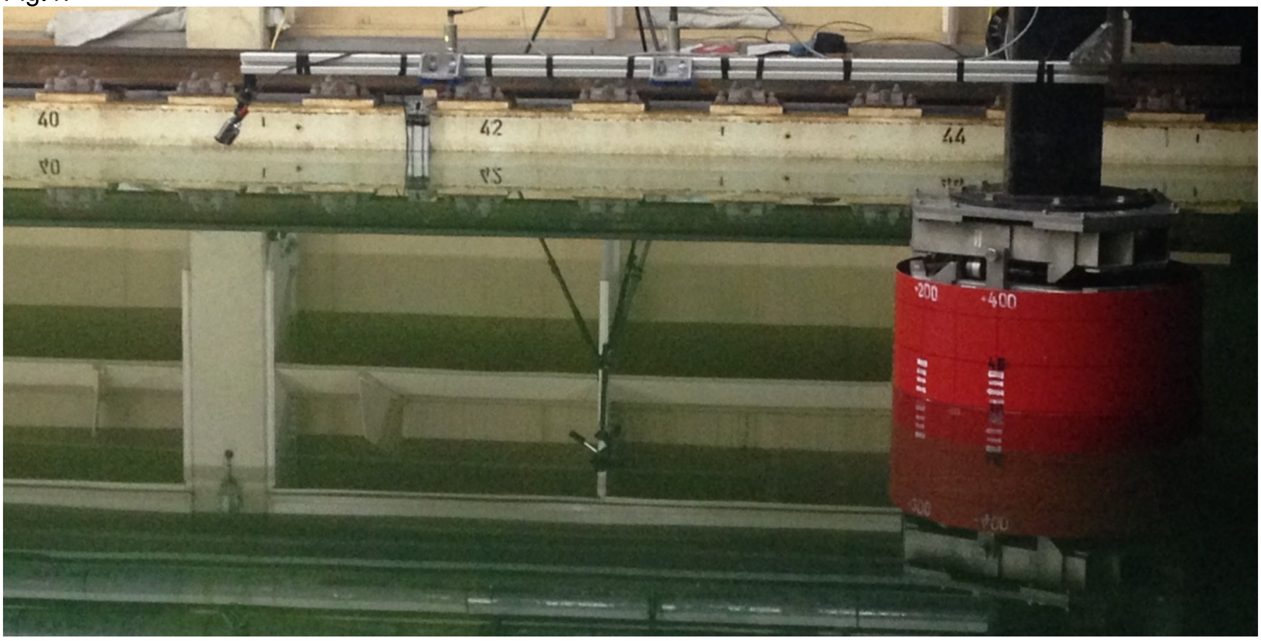

Fig. 1. The structure before open water tests.

28. Test setup, position of equipment

Ultrasound sensors: S1 – closest to the structure and the distance between S1 and S2 is 50 cm. Distance from S1 to the closest point on the structure is 50 cm

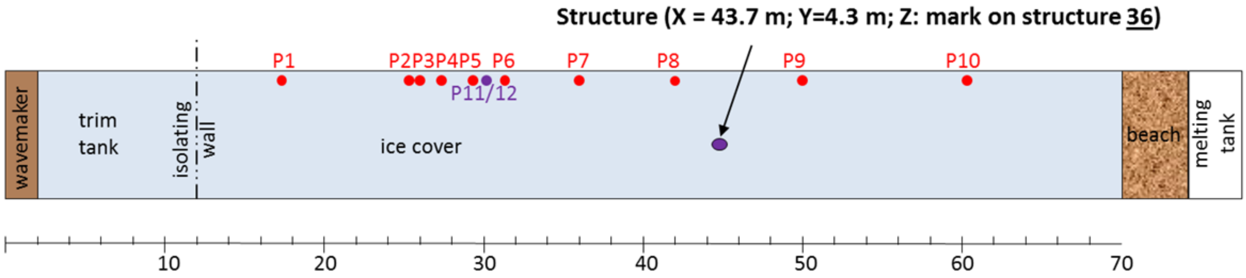

Fig. 2. Location of instruments: P1 – P10 are single pressure sensors, P11/12 – a double pressure sensor.

Position of sensors		
Sensor	Rel. pos. (m)	Abs. pos. (m)
P1		17.08
P2		25.28
P3	1.205	26.49
P4	0. 59	27.08
P5		29.09
P11/P12	0.60	29.69
P6	1.195	30.88
P7		36.11
P8		41.70
US1*		Ca. 43 m
US2*		Ca. 42.5
P9		50
P10		60.53

Single pressure sensors are located approx. 0.6m from the wall of the tank. For the double sensor: the top one is 0.6m and the bottom one 0.765m from the wall. US1 and US2 are 0.65m from the wall.

* US1 and US2 y position is ca. 4.2 m
The load cells had a capacity 5 kN, and the accuracy 0.1% (from the capacity).

29. Tests series 5000

Run No.	Approx. start/finish time	Wave height	Wave period	Duration of Test Run	Remarks
[-]		[mm]	[s]	[min]	[-]
Decay tests. The structure was hit by the hammer approximately at the water level, both in X and Y direction.					
5002	11:04:00 11:05:00 11:05:30				Hit in Y direction. The sampling rate was 100 Hz. After checking the data it was realized that the sampling rate should be increased.
5001	11:12:30 11:13:00 11:14:00				Hit in X direction (3 times). Sampling frequency increased to 600 Hz
5002	11:15:00 11:15:30 11:16:00				Hit in Y direction (3 times) Sampling frequency increased to 600 Hz
Open water tests					
5110	11:33/11:35	25.0	2.0	2	
5120	11:42/11:44	25.0	1.8	2	
5130	11:50/11:53	25.0	1.6	2	
5140	11:57/12:02	25.0	1.5	2	
Doubled amplitude					
5210	12:07/12:10	50.0	2.0	2	
5220	12:117/12:20	50.0	1.8	2	

5230	12:26/12:29	50.0	1.6	2	
5240	12:35/12:38	50.0	1.5	2	
5310	13:49/13:52	75.0	2.0	2	
5320	13:59/14:02	75.0	1.8	2	
5330	14:09/14:12	75.0	1.6	2	
5340	14:19/14:21	75.0	1.5	2	
5430	14:29/14:31	100.0	1.6	2	

30. List of data collected

- time series from pressure sensors
- time series from ultrasound sensors
- time series from load cells (6 components)
- videos from AXIS and GoPro cameras, underwater camera
- photos and videos from hand-held cameras done by a number of experiment participants