



Certificate no.:
TAP0000313

TYPE APPROVAL CERTIFICATE

This is to certify:

that the **Ballast Water Management System**

with type designation(s)

PureBallast 3.5 Ultra (85-3000), PureBallast 3.5 Ultra Ex (300-3000)

issued to

Alfa Laval Technologies AB
Lund, Skåne Län, Sweden

is found to comply with

IMO Resolution MEPC.300(72) – Code for Approval of Ballast Water Management Systems (BWMS Code)
DNV rules for classification – Ships Pt.6 Ch.7 Sec.1 Ballast water management – BWM
DNV class programme DNV-CP-0209 – Type approval – Ballast water management systems
DNV class guideline DNV-CG-0339 – Environmental test specification for electrical, electronic and programmable equipment and systems

Application:

This is to certify that the **Ballast Water Management System** listed above has been examined and tested in accordance with the requirements of the specifications contained in **BWMS Code** and **DNV Rules** stated above. This Certificate is valid only for the **Ballast Water Management System** referred to above.

System design limitations / Limiting Operating Conditions imposed are described in this document.

For the compliance with the **BWMS Code**, the Certificate is issued on behalf of the **Norwegian Maritime Authority**.

Product(s) approved by this certificate is/are accepted for installation on all vessels classed by **DNV**, unless otherwise instructed by relevant **Maritime Administrations**.

Issued at **Høvik** on **2025-08-26**

This Certificate is valid until **2030-08-25**.

for **DNV**

DNV local unit: **Sweden CMC**

Approval Engineer: **Ingrid Sigvaldsen**

This Certificate is subject to terms and conditions overleaf. Any significant change in design or construction may render this Certificate invalid. The validity date relates to the Type Approval Certificate and not to the approval of equipment/systems installed.

LEGAL DISCLAIMER: Unless otherwise stated in the applicable contract with the holder of this document, or following from mandatory law, the liability of DNV AS, its parent companies and their subsidiaries as well as their officers, directors and employees ("DNV") arising from or in connection with the services rendered for the purpose of the issuance of this document or reliance thereon, whether in contract or in tort (including negligence), shall be limited to direct losses and under any circumstance be limited to USD 300 000.

Name of ballast water management system (BWMS)

PureBallast 3.5 Ultra

Ballast water management system manufactured by

Alfa Laval Technologies AB

Place of production

Alfa Laval Aalborg A/S, Aalborg, Denmark

Alfa Laval Qingdao Ltd, China

Type and model designations

PureBallast 3.5 Ultra: 85, 135, 170, 300, 300, 500, 600, 800, 1000, 1200, 1500, 2000, 3000

PureBallast 3.5 Ultra Ex: 300, 500, 600, 800, 1000, 1200, 1500, 2000, 3000

Equipment / assembly drawings

The PureBallast 3.5 Ultra BWMS shall be installed in accordance with the documents listed below.

System type designation	Description	Title	Dwg No.	Rev.
PureBallast 3.5 Ultra	Piping and instrumentation diagram (P&ID)	Flow chart 85, 135, 170, 300, 500, 600, 800, 1000, 1200, 1500	9066442	4
		Flow chart 2000, 3000	9068123	4
	Electrical wiring diagram	Electrical system layout 85, 135, 170, 300, 500, 600	9066625	5
		Electrical system layout 800, 1000, 1200, 1500	9068595	5
		Electrical system layout 2000	9068587	6
		Electrical system layout 3000	9070955	6
	Operation, maintenance and safety manual (OMSM) including list of components	System Manual PureBallast 3.5 Ultra	200015857-1-EN-GB	1
	Design and Installation Manual	PureBallast 3.5 Ultra Design and Installation manual	Size specific version	-
PureBallast 3.5 Ultra Ex	Piping and instrumentation diagram (P&ID) for installation in hazardous area	Commissioning test form PB3.5 Ultra and 3.5 Ultra Ex	200015938	1
	Electrical wiring diagram for installation in hazardous area	Flow chart Ex 300, 500, 600, 800, 1000, 1200, 1500	9068124	3
		Flow chart Ex 2000, 3000	9068125	3
		Electrical system layout 300-600	9068656	5
		Electrical system layout 800-1500	9069423	5
		Electrical system layout 2000	9069424	6
		Electrical system layout 3000	9070956	6
	Operation, maintenance and safety manual including list of components	System manual PureBallast 3.5 Ultra Ex	200015860-1-EN-GB	1
	Design and Installation Manual	PureBallast 3.5 3000 Ultra Ex Design and Installation manual	Size specific version	-
	Commissioning procedure	Commissioning test form PB3.5 Ultra and 3.5 Ultra Ex	200015938	1

Other equipment manufactured by

The PureBallast 3.5 BWMS applies the ACB self-cleaning screen filter series with 20 µm mesh manufactured by Filtrex (available in variants standard, X and L).

Treatment Rated Capacity

85 – 3000 m³/h

Product description

Treatment sequence:

- Ballast water uptake: Filtration and UV treatment
- Ballast water discharge: UV treatment

After a treatment sequence the system shall be cleaned using the system's Cleaning in Place (CIP) function. (Cleaning Liquid: Alpacon Descalant Offshore or Alpacon Descalant Offshore II).

System design limitations / Water quality parameters

Temperature and Salinity

Temperature and salinity of the ballast water are not a limiting condition for the ballast water treatment system.

System design limitations / Operational parameters

Holding time

The PureBallast 3.2 BWMS has demonstrated performance to the discharge standard with a minimum holding time between uptake and discharge of 24 hours in land-based testing. UV treatment is instant and does not require any hold time in a ballast tank to render organisms inviable. Therefore, holding time is not found to be a limiting condition for the ballast water management system.

Dosing

The BWMS has demonstrated performance to the discharge standard when the UV intensity (UVI) and flow rate is measured above the parameters below. Note that the UVI limits correspond to a UV transmission (UVT) of the water, but this corresponding UVT may vary depending on the water quality parameters, i.e., particles and dissolved organic carbon.

The system also includes UV-lamp power optimization control based on measured UV-intensity. Lamp power can be reduced by up to 50%.

UV-reactor size [m ³ /h]	UVI lower limit in marine and brackish water (1)	UVI lower limit in fresh water at full flow (TRC) (2)	UVI lower limit in fresh water at half flow (3)
170	210 W/m ²	480 W/m ²	410 W/m ²
300	210 W/m ²	480 W/m ²	410 W/m ²
500	210 W/m ²	480 W/m ²	410 W/m ²
600	210 W/m ²	480 W/m ²	410 W/m ²
800	252 W/m ²	576 W/m ²	492 W/m ²
1000	252 W/m ²	576 W/m ²	492 W/m ²
1300	252 W/m ²	576 W/m ²	492 W/m ²
1500	252 W/m ²	576 W/m ²	492 W/m ²

(1) UVI below lower limit implies that the ballast water is not treated in accordance with this certificate. When targeting this UVI limit in land based testing, the measured UVT was 42%.

(2) When targeting this UVI limit in land-based testing, the measured UVT was 54%.

(3) The system includes flow control in fresh water with a flow reduction of up to 50% of rated flow. UVI below lower limit implies that the ballast water is not treated in accordance with this certificate. When extrapolating between the lowest and highest UVT measured during land-based testing, this UVI limit corresponds to a UVT between 48% and 50%.

Treatment Rated Capacity (TRC) of the BWMS

The BWMS controls the flow rate in the ballast water line by using a flow control valve to ensure that flow rates are kept within the TRC of a specific model. To achieve higher flow capacities, the UV reactors can be installed in parallel configuration according to the PureBallast design and installation guide and the table below.

The Treatment Rated Capacities (TRC) of the designated PureBallast 3.5 Ultra BWMS models are listed in the following table. The table also specifies the major components that shall be installed for a specific PureBallast 3.5 Ultra BWMS model.

BWMS model	TRC uptake [m ³ /h] ⁽¹⁾	TRC discharge [m ³ /h] ⁽²⁾	Filter model Filtrex 20 µm ⁽³⁾	Filter flow range [m ³ /h]	UV reactor size [m ³ /h]
85	85	170	ACB-906-100X	15-87	1 x 170
135	135	135	ACB-910-150X	25-135	1 x 170
170	170	170	ACB-915-150X	35-190	1 x 170
300	300	300	ACB-940-200X	42-300	1 x 300
500	500	500	ACB-955-250X	47-515	1 x 500
600	600	600	ACB-960-250X	54-600	1 x 600
800	800	800	ACB-990-300X	73-800	1x800
1000	1000	1000	ACB-999-350X	94-1040	1 x 1000
1200	1200	1300	ACB-9050-350X	108-1200	1 x 1300
1500	1500	1500	ACB-9100-400 ACB-9100-400L	126-1500	1 x 1500
2000	2000	2000	ACB-9120-500 ACB-9120-500L	126-2010	2 x 1000
3000	3000	3000	ACB-9200-600 ACB-9200-600L	126-3000	2 x 1500

(1) TRC is the net flow out of the treatment system, a net flow exceeding the given value implies that the ballast water is not treated in accordance with this certificate.

(2) During ballast water discharge, the size and number of UV reactors limits the systems TRC.

(3) This table shows general system configuration as recommended by the manufacturer. The PureBallast 3.5 BWMS model may be used with a larger filter unit than specified above, but the TRC will remain the same.

Pressure

The minimum and maximum system operating pressure and the differential pressure triggering backflushing are listed below.

Filter type	Minimum inlet pressure (back-pressure)	Differential pressure triggering backflushing	Maximum operating pressure
Filtrex Type ACB	1 bar	0.3 - 0.5 bar	6 bar

Control and monitoring equipment

Software version

The PureBallast 3.5 Ultra BWMS is type approved with the system control software version V3.5.0.01.

Any change to the software is to be recorded as long as the system is in use on board. Major changes in the software, as defined in the Software Quality Assurance Plan ADSQAP-1-41, require approval. Testing of the application functions of a revised software may be required.

Safety measures

The PureBallast 3.5 BWMS is type approved with the following instruments for monitoring the safe operation of the BWMS and for activating, as necessary, an automatic shutdown of the BWMS:

- Temperature sensor (TT201-33) installed in the UV reactor and arranged with safety function independent of BWMS control
- Level switch (LS201-50) installed in the UV reactor
- Pressure sensor (PT201-16) on the UV reactor
- Flow meter (FIT201-1) installed after the filter

Electrical and electronic components

The PureBallast 3.5 Ultra BWMS is type approved with the electrical and electronic components (including the above listed instruments for monitoring safe operation of the BWMS) indicated on the P&IDs and as specified in the lists of main components given in the OMSM. Except for the components listed in the OMSM and the table below, alternate models may be used provided that information regarding the selected components is part of the documentation related to the specific installation, by providing either a reference to valid type approval certificate or technical documentation demonstrating that the selected component was subject to environmental testing as per IACS UR E10, revision 7 (or later).

For the following electrical and electronic components, the models specified in the table below shall be used:

Tag No.	Component name	Manufacturer	Model(s)
QT201-50	UV sensor	UV-Technik, Speziallampen GMBH	For UV reactor model size 170 to 600: SUV 20.2 Y2 C40° 1000 W/m2 MP
		UV-Technik, Speziallampen GMBH	For UV reactor model size 800 to 1500: SUV 20.2 Y2 C40° 3000 W/m2 MP
-	UV lamp	Alfa Laval	Medium pressure UV lamp, - 3kW Article. no.: 582034 80 - 6kW Article. no.: 9007810 80
-	UV-lamp sleeve	Alfa Laval	Quartz sleeve - 3kW Article. no.: 9070612 01 - 6kW Article. no.: 9070612 02
EC	Electrical Cabinet for PB 3.5	Alfa Laval	EC PB 3.5 HMI screen B&R T80, 10,1"
LDC	Lamp Drive Cabinet for PB 3.5	Alfa Laval	LDC PB 3.5 (for UV-R 800 – 3000)
LDC2	Lamp Drive Cabinet for PB 3.5	Alfa Laval	LDCS PB 3.5 (for UV-R 2000 & 3000)
LDC2S	Lamp Drive Cabinet for PB 3.5	Alfa Laval	LDCS PB 3.5 (for UV-R 3000)
RCP	Remote Control Panel (optional)	Alfa Laval and Beijer	RCP 3.5 HMI screen: B&R, T80, 10.1"

Hazardous area / Ex-proof

The PureBallast 3.5 Ultra BWMS models 300-3000 has been evaluated and found to be in compliance with DNV Rules Pt.4 Ch.8 Sec.11 for hazardous area installations. The filter, UV reactor, CIP unit, valves, backflush pump and flowmeter have Ex-certification and can be installed in hazardous area zone 1, gas group IIC and temperature class T4. Installations in a hazardous area are to be approved in each case according to the Rules and Ex-certification / Special Condition for Safe Use, listed in a valid Ex-certificate issued by a notified/recognized Certification Body.

Documents approval

The following documentation are to be submitted for each BWMS installation:

Interface description towards the ship's existing systems including alarms for failure

- List of Ex equipment according to Pt.4 Ch.8 Sec.11 if the system is to be installed in hazardous area zone
- Piping and instrumentation diagram (P&ID) of the ballast system including the treatment system. The P&ID shall include connection to/from CIP unit. All piping material shall be indicated and conform to class requirements.
- Commissioning procedure

Type Approval documentation

Biological test reports

- DHI Denmark: Performance evaluation in land-based test facility, PureBallast 3.0, Advanced oxidation technology with two mechanical filter options, Hydac AutoFilt RF10 and Boll & Kirch 6.18.3, Final Report, December 2013
- DHI Denmark: Biological efficacy performance evaluation of Ballast Water Management System in shipboard test, Final Report v2, March 2015
- DHI Denmark: Performance evaluation in land-based test facility, PureBallast 3.0, UV treatment with two mechanical filter options, Hydac AutoFilt RF10 and Filtrex ACB, Final Report v2, March 2016
- DHI Denmark: Performance evaluation of PureBallast 3.1 Ballast Water Management System in land-based test, land-based test report, Final Report, February 2018

Environmental test reports

- Innventia: AOT Reactor, Mechanical test, Report no: 273 683 B, 21 August 2013
- Innventia: AOT Reactor, Control Cabinet and LDC, Climate testing, Report no: 273 705, 4 June 2013
- Applica: EMC testing of Electrical cabinet type EC & Lamp drive cabinet type LDC for PureBallast 3.5 Ultra, Report no: 31636-1 rev. 02, January 2025
- Applica: Environmental testing of PureBallast 3.5 Ultra – Ballast Water Management System, Report no: 31636-2 rev. 02, May 2025
- Delta: EMC test of Electrical cabinet EC10 for PureBallast 3.5 Ultra, Report no: 624-20353-10-R0, February 2025

System descriptive documentation

- AW14-048 Verification of scaled unit PureBallast 3, Version 1.3
- AWD0C-1-646 Flow distribution calculation parallel configured reactors, Version 1.0
- AWD0C-1029828768-1581 UVR Standardization – a revised design of the UV reactor Version 4.0
- ADSQAP-1-41 Software Quality Assurance Plan, Version 1.3

Document lists, including detailed drawings:

- AWD0C-1029828768-2261. Document list PureBallast 3.5, Version 3.0

System manuals:

- PureBallast 3.5 Ultra System Manual– Doc.no. 200015857-1-EN-GB
- PureBallast 3.5 Ultra System Manual Ex – Doc.no. 200015860-1-EN-GB

Design and Installation guides:

- Design and Installation Guide PureBallast 3.5 Ultra, one for each system size

- Design and Installation Guide PureBallast 3.5 Ultra Ex, one for each system size

Commissioning procedures:

- 200015938 rev1 Commissioning test form PB 3.5 Ultra and 3.5 Ultra Ex

Tests carried out

- Land-based testing in accordance with Resolution MEPC.279(70) and 46 CFR 162.060-26 using PureBallast 3.0 with UV reactor size 300 and Hydac filter RF-10 with a 50 µm mesh filter
- Land-based testing in accordance with Resolution MEPC.279(70) and 46 CFR 162.060-26 using PureBallast 3.1 with UV reactor size 300 and Filtrex filter ACB 945-200 with a 20 µm mesh filter
- Additional land-based testing in accordance with Resolution MEPC.279(70) using PureBallast 3.2 with UV reactor size 300 and Filtrex filter ACB 945-200 with a 20 µm mesh filter
- Shipboard testing in accordance with Resolution MEPC.279(70) and 46 CFR 162.060-28 using PureBallast 3.0 with UV reactor size 1000 and Hydac filter RF-10 with a 50 µm mesh filter
- Type tests of the control and automation system witnessed by DNV
- Testing in accordance with environmental test specification for instrumentation and automation equipment, DNV Standard for Certification No. 2.4 (April 2006) and Resolution MEPC.279(70) and 46 CFR 162.060-30
- Additional testing of PureBallast 3.1 in accordance with environmental test specification for instrumentation and automation equipment, DNVGL-CG-0339 Environmental test specification for electrical, electronic and programmable equipment and systems (November 2016) and Resolution MEPC.174(58)
- Type test of the control and automation system for flow 170, witnessed by DNV
- Type test of the control and automation system for PureBallast 3.5 Ultra BWMS, witnessed by DNV
- Type test of the control and automation system for the Compact Flex model, witnessed by DNV
- Scaling validation land-based testing in accordance with the IMO Circular, BWM.2/Circ.33 Rev.1 using the PureBallast 3.1 with the UV reactor size 170
- Comparison testing for approval of alternative UV lamp and Quartz sleeve manufacturer

A summary of the test results from land-based and shipboard tests are given in an annex to this certificate.

Marking of product

For traceability of this type approval, each treatment system is to be marked with:

- Manufacturer's name or trade mark
- Type designation
- Serial number

Periodical assessment

For retention of the Type Approval, DNV Surveyor shall perform periodical assessments to verify that the conditions of the TA are not altered since the certificate was issued.

The scope of periodical assessment includes:

- Review of the TA documentation and verification that the documentation is still used as basis for the production
- Review of possible changes in design, material and performance of the product
- Verification of the company's production and quality systems ensuring continued consistent production of the type approved products to the required quality
- Verification that the product marking for identification and traceability to the TA Certificate is not altered

Copy of type approval certificate

A copy of this type approval certificate should be carried on board a vessel fitted with this Ballast Water Management System at all times. A reference to the test protocol and a copy of the test results should be available for inspection on board the vessel.

Revision history of this certificate

Revision No.	Date of Issuance	Description
-	2025-08-26	Initial certificate The PureBallast 3.5 Ultra BWMS is an updated version of the previously approved PureBallast 3.2 BWMS (DNV type approval certificate no. TAP000018Z). The basis for approval of the PureBallast 3.5 Ultra BWMS is the land-based and shipboard testing performed with the PureBallast 3.0, 3.1 and 3.2 BWMS.

Annex: Summary of testing

Land-based testing

Table 1 Test water conditions and operational parameters in land-based testing of the Alfa Laval AB, PureBallast 3.0 with a TRC of 300 m³/h including the UV reactor size 300 and Hydac RF-10 filter with a 50 µm mesh screen at the DHI Maritime Technology Evaluation Facility in Hundested, Denmark, during the period from October 2012 to June 2013.

Test cycle	Sample	TSS [mg/L]	POC [mg/L]	DOC [mg/L]	Temp. [°C]	UVT ⁽¹⁾ [%]	Salinity [PSU]	UVI [mW/m ²]	Flow rate treated [m ³ /h]	Holding time [day]
B-1	Inlet	49	6.7	10	13	48	17	312	307	5
B-2	Inlet	49	6.7	10	13	48	17	310	311	5
B-3	Inlet	62	6.8	5.8	10	53	18	486	301	5
B-4	Inlet	62	6.8	5.8	11	53	18	484	296	5
B-5	Inlet	60	7.1	6.5	10	53	19	471	283	5
B-6	Inlet	60	7.1	6.5	10	53	19	477	277	5
M-1	Inlet	42	6.3	8.2	10	56	34	421	300	5
M-2	Inlet	46	7.8	7.3	7.0	57	32	470	301	5
M-3	Inlet	46	7.8	7.3	7.1	57	32	470	303	5
M-4	Inlet	49	8.2	7.3	7.7	58	36	459	280	5
M-5	Inlet	49	8.2	7.3	7.9	58	36	459	250	5

(1) The tested UVT is lower than the required UVT as validated in accordance with paragraph 2.4.21 of the annex in MEPC.279(70).

Table 2 Average numbers [three replicates] of live organisms in inlet and treated discharge water during land-based testing of the Alfa Laval AB, PureBallast 3.0 during the test period from October 2012 to June 2013. Viable organisms of size class ≥ 10 and $< 50 \mu\text{m}$ were quantified by a most probable number assay (MPN) after discharge. Inlet samples were analysed for live organisms of size class ≥ 10 and $< 50 \mu\text{m}$ by microscopy counting after staining with CMFDA/FDA. All counts of pathogenic bacteria (E. coli, Enterococci and Vibrio cholerae) in treated water were below the ballast water discharge standard.

Test cycle	Organisms $\geq 50 \mu\text{m}$ [org/m ³]	Organisms ≥ 10 and $< 50 \mu\text{m}$ [org/mL]		Organisms $\geq 50 \mu\text{m}$ [org/m ³]		Organisms ≥ 10 and $< 50 \mu\text{m}$ [org/mL]	
		Inlet		Treated discharge	Control discharge	Treated discharge	Control discharge ⁽¹⁾
	Inlet	MPN	CMFDA/FDA			MPN	MPN
B-1	243,672	>16,000	1,334	9.0	62,217	0.30	>1,600
B-2	243,672	>16,000	1,334	10.3 ⁽²⁾	62,217	0.57	>1,600
B-3	598,982	>16,000	2,970	2.7	157,065	0.18	>1,600
B-4	598,982	>16,000	2,970	1.7	157,065	<0.18	>1,600
B-5	333,520	16,000	2,232	0	42,134	0.25	1,373
B-6	333,520	16,000	2,232	0.67	42,134	<0.18	1,373
M-1	168,553	13,733	1,715	0.33	48,907	0.66	1,147
M-2	187,007	3,133	1,508	1.0	13,283	<0.18	830
M-3	187,007	3,133	1,508	0.33	13,283	<0.18	830
M-4	232,600	3,133	1,221	0.33	60,757	<0.18	1,373
M-5	232,600	3,133	1,221	1.0	60,757	<0.18	1,373

(1) While control discharge results are presented with MPN only, the control discharge samples were also compliant (>100 organisms/mL) after enumeration with microscopy counting after staining with CMFDA/FDA.

(2) UVI was 310 mW/m² which is outside the borders of the system design limitation

Table 3 Test water conditions and operational parameters in land-based testing of the Alfa Laval AB, PureBallast 3.1 with a TRC of 300 m³/h including the UV reactor size 300 and Filtrex ACB 945-200 with a 20 µm mesh screen at the DHI Maritime Technology Evaluation Facility in Hundested, Denmark, during the period of April to June 2014 for brackish and fresh water and during the period July to August 2015 for marine water.

Test cycle ⁽¹⁾	Sample	TSS [mg/L]	POC [mg/L]	DOC [mg/L]	Temp. [°C]	UVT ⁽²⁾ [%]	Salinity [PSU]	UVI [mW/m ²]	Flow rate Treated [m ³ /h]	Holding time [day]
F-1	Inlet	56	8.3	8.0	7.5	45	0.37	362-366	304	5
F-3	Inlet	61	6.4	8.2	13	45	0.35	303-308	306	5
F-4	Inlet	61	6.7	9.5	13	42	0.36	260-262	303	5
F-5	Inlet	54	6.2	11	16	42	0.37	207-210	307	5
F-6	Inlet	54	6.2	11	16	42	0.37	211	304	5
B-9	Inlet	56	7.7	11	19	45	17	238-241	302	5
B-10	Inlet	58	8.0	10	18	44	18	272-273	308	5
B-11	Inlet	58	8.0	10	19	44	18	271-273	300	5
M-8	Inlet	39	9.3	11	19	46	33	236-238	308	5
M-9	Inlet	44	9.0	11	18	46	33	228-231	307	5
M-10	Inlet	44	9.0	11	19	46	33	229-231	303	5

(1) Only three consecutive valid successful tests were performed for this filter in marine and brackish water salinity as this was identified as an additional filter.

(2) The tested UVT is lower than the required UVT as validated in accordance with paragraph 2.4.21 of the annex in MEPC.279(70).

Table 4 Average numbers [three replicates] of live organisms in inlet and treated discharge water during land-based testing of the Alfa Laval AB, PureBallast 3.1 during the period of April to June 2014 for brackish and fresh water and during the period July to August 2015 for marine water. Viable organisms of size class ≥ 10 and $< 50 \mu\text{m}$ were quantified by a most probable number assay (MPN) after discharge. Inlet samples were analysed for live organisms of size class ≥ 10 and $< 50 \mu\text{m}$ by microscopy counting after staining with CMFDA/FDA. All counts of pathogenic bacteria (*E. coli*, *Enterococci* and *Vibrio cholerae*) in treated water were below the ballast water discharge standard.

Test cycle	Organisms $\geq 50 \mu\text{m}$ [org/m ³]	Organisms ≥ 10 and $< 50 \mu\text{m}$ [org/mL]	Organisms $\geq 50 \mu\text{m}$ [org/m ³]		Organisms ≥ 10 and $< 50 \mu\text{m}$ [org/mL]	
	Inlet	Inlet	Treated discharge	Control discharge	Treated discharge	Control discharge ⁽¹⁾
		CMFDA/FDA			MPN	MPN
F-1	279,837	5,732	2.0	99,349	0.19	1373
F-3	288,278	10,289	1.3	97,019	<0.18	1247
F-4	288,278	10,289	1.0	97,019	<0.18	1247
F-5	348,870	3,302	0.67	175,287	1.4	440
F-6	348,870	3,302	0.67	175,287	0.68	440
B-9	393,511	1,802	0.33	114,512	3.4	276
B-10	625,241	1,778	2.7	55,068	0.60	667
B-11	625,241	1,778	1.3	55,068	1.0	667
M-8	167,650	1,494	3.0	24,208	2.4	1600
M-9	237,994	2,642	2.3	79,520	3.5	1600
M-10	237,994	2,642	2.0	79,520	9.5	>1600

(1) While control discharge results are presented with MPN only, the control discharge samples were also compliant (>100 organisms/mL) after enumeration with microscopy counting after staining with CMFDA/FDA.

Table 5 Test water conditions and operational parameters in land-based testing of the Alfa Laval AB, PureBallast 3.2 with a TRC of 300 m³/h including the UV reactor size 300 and Filtrex ACB 945-200 with a 20 µm mesh screen at the DHI Maritime Technology Evaluation Facility in Husted, Denmark, during the period of March to September 2017.

Test cycle	Temp. [°C]	Salinity [PSU]	UVT (1) [%]	DOC [mg/L]	POC [mg/L]	TSS [mg/L]	UVI [W/m ²]	Average flow rate [m ³ /h]	Holding time [day]
F-5	15	0.37	54	5.2	6.3	70	508-511	304	1
F-6	15	0.37	54	5.2	6.3	70	503-508	307	1
B-1	5.8	19	46	11	9.5	63	269-296	305	1
B-2	5.9	19	46	11	9.5	63	233-249	313	1
M-1	6.2	29	71	7.3	7.5	45	597-870	306	1
M-2	6.2	29	71	7.3	7.5	45	597-884	302	1

(1) The tested UVT is lower than the required UVT as validated in accordance with paragraph 2.4.21 of the annex to G8.

Table 6 Average numbers [three replicates] of live organisms in inlet, treated and control discharge water during land-based testing of the Alfa Laval AB, PureBallast 3.2 during the period of March to September 2017. Viable organisms of size class ≥10 and <50 µm were quantified by a most probable number assay (MPN) after discharge. Inlet samples were analysed for live organisms of size class ≥10 and <50 µm by microscopy counting after staining with CMFDA/FDA. All counts of pathogenic bacteria [E. coli, Enterococci and Vibrio cholerae] in the test cycles were below the ballast water discharge standard.

Test cycle	Organisms ≥50 µm [org/m ³]	Organisms ≥10 and <50 µm [org/mL]	Organisms ≥50 µm [org/m ³]		Organisms ≥10 and <50 µm [org/mL]	
		Inlet	Treated discharge	Control discharge	Treated discharge	Control Discharge ⁽¹⁾
	Inlet	CMFDA/FDA			MPN	MPN
F-5	840,561	1,147	5.2	261,717	<0.18	>1,600
F-6	715,203	1,102	3.0	261,717	0.47	>1,600
B-1	219,283	2,983	1.0	132,471	<0.18	303
B-2	190,272	2,738	6.7	132,471	<0.18	303
M-1	153,236	3,196	0	80,179	0.48	377
M-2	137,125	3,321	0	80,179	0.30	377

(1) While control discharge results are presented with MPN only, the control discharge samples were also compliant (>100 organisms/mL) after enumeration with microscopy counting after staining with CMFDA/FDA.

Shipboard testing

Table 7 Test water conditions, operational data, and organism density counts in shipboard testing of the Alfa Laval AB, PureBallast 3.0 using Hydac RF-10 filter with a 50 µm mesh screen during the period from December 2012 to October 2014. Viable organisms of size class ≥10 and <50 µm in the discharge were quantified by both most probable number assay [MPN] and live organisms in the inlet and discharge were quantified by microscopy counting after staining with CMFDA/FDA. All counts of pathogenic bacteria [E. coli, Enterococci and Vibrio cholerae] in the test cycles were below the ballast water discharge standard.

Test cycle	Average flow rate during ballast operation [m ³ /h]	UVT	UVI [W/m ²]	Organisms ≥50 µm [org/m ³]		Organisms ≥10 and <50 µm [org/mL] Algal re-growth + CMFDA/FDA-stained motile organisms		
				Inlet	Discharge	Inlet CMFDA/FDA	Discharge CMFDA/FDA	Discharge MPN
No. 1 ⁽¹⁾	356	96	1,815-1,820	6,429	1.5	70	0.53	<0.18
No. 2	889	96	1,710-1,805	8,490	0	1,102	2.8	0.27
No. 3	950	96	1,280-2,100	2,100	0	787	0.75	<0.18
No. 4	950	90	1,175-1,403	23,603	1.9	103	0.67	<0.18
No. 6	998	60	497-563	7,537	7.0	175	6.4	<0.18
No. 9	893	99	1,168-1,187	20,272	4.6	128	0.17	<0.18

(1) Test 1 was concluded invalid due to insufficient organisms in the inlet water. The low flow rate was also lower than TRC because one of the ship ballast pumps was unable to operate during the test.