DNV·GL

Certificate No:
TAP000024G

TYPE APPROVAL CERTIFICATE

This is to certify:

That the Ballast Water Management System

with type designation(s)
PureBallast 3.2/3.2 Ex, PureBallast 3.2 Compact, PureBallast 3.2 Compact Flex

Issued to
Alfa Laval Tumba AB
Tumba, Sweden

is found to comply with
IMO Resolution MEPC.300(72) - Code for Approval of Ballast Water Management Systems (BWMS Code)
DNV GL class programme DNVGL-CP-0209 – Type approval – Ballast water management systems
DNV GL rules for classification – Ships Pt.6 Ch.7 Environmental protection and pollution control

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 the BWMS Code and DNV GL Rules stated above. This Certificate is valid only for the Ballast Water Management System referred to above.

For the compliance with the BWMS Code, the Certificate is issued on behalf of Transport Canada, Marine Safety & Security.

The Certificate is issued based on the Type Approval Certificate No. TAP000018Z Rev. 4 issued by DNV GL on behalf of the Norwegian Maritime Authority.
System Design Limitations / Limiting Operating Conditions imposed are described in this document.
Product(s) approved by this certificate is/are accepted for installation on all vessels classed by DNV GL, unless otherwise instructed by relevant Maritime Administrations.

Issued at **Høvik** on **2020-06-12**
This Certificate is valid until **2023-02-02**.
DNV GL local station: **Sweden CMC**

for **DNV GL**

Approval Engineer: **Tone Knudsen Fiskeseth**

Dag Sæle-Nilsen
Head of Section

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.

Name of ballast water management system (BWMS)

PureBallast 3.2

Ballast water management system manufactured by

Alfa Laval Tumba AB

Place of production

Alfa Laval Aalborg A/S, Aalborg, Denmark

Type and model designations

PureBallast 3.2: 250, 250HP, 300, 300HP, 300/600, 500, 500HP, 500/1000, 600, 600HP, 750, 750HP, 750/1500, 1000, 1000HP, 1000/2000, 1200, 1500, 1500HP, 1500/3000, 2000, 3000

PureBallast 3.2 Ex: 250, 250HP, 300, 300HP, 300/600, 500, 500HP, 500/1000, 600, 600HP, 750, 750HP, 750/1500, 1000, 1000HP, 1000/2000, 1200, 1500, 1500HP, 1500/3000, 2000, 3000

PureBallast 3.2 Compact: 85, 85HP, 135, 150HP, 170, 250, 300

PureBallast 3.2 Compact Flex: 85, 135, 170, 250, 300, 500, 600, 750, 1000

Equipment / assembly drawings

The PureBallast 3.2 BWMS shall be installed in accordance with the documents listed below.

System type designation	Description	Title	Dwg No.	Rev.
PureBallast 3.2	Piping and instrumentation diagram (P&ID)	Flow chart 250, 300, 500, 600, 750, 1000, 1500 300/600, 500/1000, 750/1500 HP 250, 300, 500, 750	9034854	3
		Flow chart 1200, 2000, 3000, 1000/2000, 1500/3000 HP 600, 1000, 1500	9034855	3
	Electrical wiring diagram	Electrical system layout 250-1200, 2000, 300/600, 500/1000, 1000/2000 HP 250-600, 1000, 2000	9037265	2
		Electrical system layout 1500, 3000, 750/1500, 1500/3000 HP 750, 1500, 3000	9037180	2
	Operation, maintenance and safety manual (OMSM) including list of components	System Manual PureBallast 3.2 Std	200000920	2

System type designation	Description	Title	Dwg No.	Rev.
PureBallast 3.2 Ex	Piping and instrumentation diagram (P&ID) for installation in hazardous area	Flow chart Ex 250,300,500,600,750,1000, 1500 , 300/600, 500/1000, 750/1000 Ex HP 250, 300, 500, 750	9034859	1
		Flow chart Ex 1200,2000,3000,1000/2000, 1500/3000 Ex HP 600,1000, 1500	9034860	1
	Electrical wiring diagram for hazardous area installation	Electrical system layout Ex 250-1200, 2000, 300/600, 500/1000,1000/2000 HP 250-600, 1000, 2000	9037266	4
		Electrical system layout Ex 1500, 3000, 750/1500, 1500/3000 HP 750, 1500, 3000	9037064	4
	Operation, maintenance and safety manual including list of components	System Manual PureBallast 3.2 Ex	200000921	2
	Component list for hazardous installation	Ex-certificate list	AWDOC-1-692	2
PureBallast 3.2 Compact	Piping and instrumentation diagram (P&ID)	Flow chart 85, 135, 170, HP 85	9034865	0
		Flow chart 250, 300, HP 150	9034866	0
	Electrical wiring diagram	Electrical system layout 85-300, HP 85-150	9037672	0
	Operation, maintenance and safety manual including list of components	System Manual PureBallast 3.2 Compact IMO/USCG	200000922	1
PureBallast 3.2 Compact Flex	Piping and instrumentation diagram (P&ID)	Flow chart 85 – 1000	9034867	1
	Electrical wiring diagram	Electrical system layout 85 – 1000	9035102	2
	Operation, maintenance and safety manual including list of components	System Manual PureBallast 3.2 Compact Flex IMO/USCG	200000887	1

Other equipment manufactured by

The PureBallast 3.2 BWMS applies the ACB self-cleaning screen filter series with 20 µm mesh manufactured by Filtrex.

Treatment Rated Capacity

85 – 3000 m^3/h

Product description

Treatment sequence:

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

After a treatment sequence and within 30 hours, the system shall be cleaned using the systems Cleaning in Place (CIP) function. Cleaning Liquid: Alpacon Descalant Offshore.

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 below parameters. 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.

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
600	210 W/m^2	480 W/m^2	410 W/m^2
1000	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%.

The system also includes UV-lamp power optimization control based on measured UV-intensity. Lamp power can be reduced by up to 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 the PureBallast design and installation guide and the table below.

The Treatment Rated Capacities (TRC) of the designated PureBallast 3.2 BWMS models are listed in the following table. The table also specifies the major components that shall be installed for a specific PureBallast 3.2 BWMS model.

BWMS model	TRC uptake [m³/h] (1)	TRC discharge [m³/h] (2)	Filter model Filtrex (3)	UV reactor size [m³/h]	PureBallast type designation (4)
85	85	85	ACB-906-100	1 x 170	Compact HP
85	85	170	ACB-906-100	1 x 170	Compact, Compact Flex
135	135	170	ACB-910-150	1 x 170	Compact, Compact Flex
150	150	150	ACB-935-200	1 x 300	Compact HP
170	170	170	ACB-915-150	1 x 170	Compact, Compact Flex
250	250	300	ACB-935-200	1 x 300	Compact, Compact Flex, Std., Ex,
				1 x 600	Std. HP, Ex HP
300	300	300	ACB-945-200	1 x 300	Compact, Compact Flex, Std., Ex
				1 x 600	Std. HP, Ex HP
300/600		600			Std., Ex
500	500	600	ACB-955-250	1 x 600	Compact Flex, Std., Ex,
		500		1 x 1000	Std. HP, Ex HP
500/1000		1000			Std., Ex
600	600	600	ACB-985-300	1 x 600	Compact Flex, Std., Ex,
				2 x 600	Std. HP, Ex HP
750	750	1000	ACB-985-300	1 x 1000	Compact Flex, Std., Ex,
		750		1 x 1500	Std. HP, Ex HP
750/1500		1500			Std., Ex
1000	1000	1000	ACB-999-350	1 x 1000	Compact Flex, Std., Ex,
				2 x 1000	Std. HP, Ex HP
1000/2000		2000			Std., Ex
1200	1200	1200	ACB-9100-400	2 x 600	Std., Ex,
1500	1500	1500	ACB-9100-400	1 x 1500	Std., Ex,
				2 x 1500	Std. HP, Ex HP
1500/3000		3000			Std., Ex
2000	2000	2000	ACB-9120-500	2 x 1000	Std., Ex
3000	3000	3000	ACB-9200-600	2 x 1500	Std., Ex

(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 3.2 BWMS model may be used with a larger filter unit than specified above, but the TRC will remain the same.

(4) The High Performance (HP) models applies UV reactor(s) with a rated capacity which is more than two times the filter rated capacity to avoid flow reduction when treating water with a low UV-transmittance in USCG mode.

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	≥0.5 bar	10 bar

Control and monitoring equipment

Software version
The PureBallast 3.2 BWMS is type approved with these system control software versions:

PureBallast 3.2: V3.2.3.zz
PureBallast 3.2 Ex: V.3.2.3.zz
PureBallast 3.2 Compact: V3.2.1.zz Compact
PureBallast 3.2 Compact Flex: V3.2.2.zz CFlex

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 3.2 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
- Temperature switch (TS201-60) installed in the UV reactor and arranged with safety function independent of BWMS control
- Pressure sensors (PT201-16; PT201-71 and/or-72) installed before and after the filter
- Flow meter (FIT201-1) installed after the filter

Electrical and electronic components
The PureBallast 3.2 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 component 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.

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 170, 300 and 600:* SUV 20.2 Y2 C40° 1000w/m2 MP
		UV-Technik, Speziallampen GMBH	*For UV reactor model 1000 and 1500:* SUV 20.2 Y2 C40° 3000w/m2 MP
CC	Control Cabinet for PB 3.2	Alfa Laval and Beijer	CC PB 3.2 HMI screen: Beijer X2 Marine 15
LDC	Lamp Drive Cabinet for PB 3.2	Alfa Laval	LDC PB 3.2
EC	Electrical Cabinet for PB 3.2 Compact and Compact Flex	Alfa Laval and Beijer	EC PB 3.2 HMI screen: Beijer X2 Marine 7
RCP	Remote Control Panel (optional)	Alfa Laval and Beijer	RCP 3.2 HMI screen: Beijer X2 Marine 15 or 7
LDC	Lamp Drive Cabinet for PB 3.2 Compact Flex	Alfa Laval	LDC 1
LDC	Lamp Drive Cabinet for PB 3.2 Compact Flex	Alfa Laval	LDC 2

Hazardous area / Ex-proof

The PureBallast 3.2 BWMS has been evaluated and found to be in compliance with DNV GL Rules Pt.4 Ch.8 Sec.11 for hazardous area installations. The filter, UV reactor, CIP unit, valves, backflush pump, optional ballast water booster pump and flowmeters have Ex-certification and can be installed in hazardous area zone 1, gas group IIC and temperature class T4. The cabinets are to be located in safe zone. Ex-certification is not covered by this certificate. Installation 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:

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

- Delta: EMC emission test of PureBallast 3.1, Report no: REC-E703866, July 2014
- Innventia: Control Cabinet, Mechanical test, Report no: 273 683 A, 30 May 2013
- Innventia: AOT Reactor, Mechanical test, Report no: 273 683 B, 21 August 2013
- Innventia: LDC, Mechanical test, Report no: 273 683 C, 4 June 2013
- Innventia: AOT Reactor, Control Cabinet and LDC, Climate testing, Report no: 273 705, 4 June 2013
- Innventia: LDC, Mechanical testing, Report no: 273 706 A, 28 May 2013
- Innventia: 273 706 B, LDC, Climate testing
- Applica: Technical Report, AlfaWall, EMC and Environmental testing of CC 3.1, Control Cabinet for BWTS, Report no: 20462, Rev. 1
- Delta: EMC test of Pure Ballast 3.0, Report no: E703512
- Applica: EMC and Environmental testing of CC 3.1 Control Cabinet for BWTS, Report no: 20462, March 2015
- Delta: Test for Marine Type Approval of PureBallast Electrical Cabinet, Project T209964 – Report no: DANAK 1915317

System descriptive documentation

- AW14-048 Verification of scaled unit PureBallast 3 Version 13
- AWDOC-1-646 Flow distribution calculation parallel configured reactors, Version 1.0
- ADSQAP-1-41 Software Quality Assurance Plan, Version 1.2

Document lists, including detailed drawings:

- AWDOC-1-464. Document list for Type Approval PureBallast 3.2 Version 4.0
- AWDOC-1-688. Document list for Type Approval PureBallast 3.2Ex Version 3.0

System manuals:

- System Manual PureBallast 3.2 – Book no. 200000920-2-EN-GB
- System Manual PureBallast 3.2 Ex – Book no. 200000921-2-EN-GB
- System Manual PureBallast 3.2 Compact – Book no. 200000922-1-EN-GB
- System Manual, PureBallast 3.2 Compact Flex – Book no. 200000887-1-EN-GB

Design and Installation guides:

- Design and Installation Guide PureBallast 3.2
- Design and Installation Guide PureBallast 3.2 Ex
- Design and Installation Guide PureBallast 3.2 Compact
- Design and Installation Guide PureBallast 3.2 Compact Flex

Commissioning procedures:

- Commissioning test form, PureBallast Ballast Water Treatment System, Valid for PureBallast 3.2 and 3.2 Ex dated 2020-02-28
- Commissioning test form, PureBallast Ballast Water Treatment System, Valid for PureBallast 3.2 Compact and Compact Flex dated 2020-02-28

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 GL
- 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 GL
- Type test of the control and automation system for the Compact Flex model, witnessed by DNV GL
- 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

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 GL 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 onboard 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 onboard the vessel.

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/m²]	Flow rate treated [m³/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 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 treated water were below the ballast water discharge standard.

Test cycle	Organisms ≥50 µm [org/m³]	Organisms ≥10 and <50 µm [org/mL]		Organisms ≥50 µm [org/m³]		Organisms ≥10 and <50 µm [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/m²]	Flow rate Treated [m³/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 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 treated water were below the ballast water discharge standard.

Test cycle	Organisms ≥50 µm [org/m³]	Organisms ≥10 and <50 µm [org/mL]	Organisms ≥50 µm [org/m³]		Organisms ≥10 and <50 µm [org/mL]	
		Inlet	Treated discharge	Control discharge	Treated discharge	Control discharge (1)
	Inlet	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 Hundested, 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/m²]	Average flow rate [m³/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/m³]	Organisms ≥10 and <50 µm [org/mL]	Organisms ≥50 µm [org/m³]		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 the 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 [m³/h]	UVT	UVI [W/m²]	Organisms ≥50 µm [org/m³]		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	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