

TYPE APPROVAL CERTIFICATE

This is to certify:**That the Ballast Water Management System**

with type designation(s)

Optimarin Ballast System 167/72BK3 – 3000/3100BK3 and 167/87FX2 – 3000/3000FX2

Issued to

**Optimarin AS
SANDNES, Norway**

is found to comply with

DNV GL rules for classification – Ships**DNV GL class programme DNVGL-CP-0209 – Type approval – Ballast water management systems****IMO Resolution MEPC.300(72) - Code for Approval of Ballast Water Management Systems (BWMS Code)****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 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 **2020-10-23**for **DNV GL**This Certificate is valid until **2025-10-22**.DNV GL local station: **Stavanger**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.

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Name of ballast water management system (BWMS)

Optimarin Ballast System (OBS), Optimarin Ballast System Ex (OBS Ex)

Ballast water management system manufactured by

Optimarin AS

Place of production

Sandnes, Norway

Type and model designations

OBS BWMS model designation: xxxx/yyyyBK3 and xxxx/yyyyFX2 where xxxx designates the below listed UV model and yyyy the below listed filter model of either the filter series manufactured by Boll & Kirch (BK3) or the filter series manufactured by Filtrex (FX2).

UV models: 167, 334, 500, 667, 834, 1000, 1167, 1334, 1500, 1667, 1834, 2000, 2167, 2334, 2500, 2667, 2834 and 3000

BK3 filter models: 72, 94, 204, 378, 518, 614, 1274, 1384, 2040 and 3100

FX2 filter models: 87, 135, 190, 225, 340, 515, 770, 1040, 1500, 2100 and 3000

A OBS BWMS model suitable for installation in hazardous area are designated with the suffix EX (e.g. xxxx/yyyyBK3EX).

Equipment / assembly drawings

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

Type	Title	Dwg No.	Rev.
Piping and instrumentation diagram (P&ID)	Flow Diagram	300000 ¹⁾	Rev 5/ 21.09.2020
	Flow Diagram EX		
	Flow Diagram (stripping with filter)		
	Flow Diagram (stripping without filter)		
Electrical wiring diagram	Wiring diagram with UV POWER CABINET TYPE ETA	500000 ²⁾	Rev 4/ 21.09.2020
	Wiring diagram with UV POWER CABINET TYPE NED MK3		
	Wiring diagram with UV POWER CABINET TYPE UVA		
General arrangement (GA) drawings	Filter BK3 (10 sizes): FILTER 72M ³ H DN80 PN10 TYPE BK MK3 to FILTER 3100M ³ H 600A 10K TYPE BK MK3	1xxxxx ³⁾	See, BOM

General arrangement (GA) drawings	Filters BK3 Ex (10 sizes): FILTER 72M³H DN80 PN10 IIB EX TYPE BK MK3 to FILTER 3100M³H 600A 10K IIB EX TYPE BK MK3		1xxxxx 3)	See, BOM
	Filters FX2 (11 sizes): FILTER 87M³H DN100 PN10 TYPE FX MK2 to FILTER FILTER 3000M³H DN600 PN10 TYPE FX MK2			
	Manifolds system 1 (13 sizes): MANIFOLD DN150 PN10 SYSTEM1-1 to MANIFOLD DN500 PN10 SYSTEM1-15			
	Manifolds system 2 (13 sizes) MANIFOLD DN200 PN10 SYSTEM2-2 to MANIFOLD 600A 10K SYSTEM2-18			
	UV chambers (8 variants): UV CHAMBER DN150 4 SOCKETS to UV CHAMBER DN150 4 SOCKETS WELDED EX MK2			
	Flow pressure valve (3 variants): FLOW PRESSURE VALVE DN100 PN10 TYPE GA to FLOW PRESSURE VALVE DN500 PN10 TYPE GA FLOW PRESSURE VALVE DN100 PN10 TYPE GA EX to FLOW PRESSURE VALVE DN500 PN10 TYPE GA EX FLOW PRESSURE VALVE DN100 PN10 TYPE BER to FLOW PRESSURE VALVE DN400 PN10 TYPE BER FLOW PRESSURE VALVE DN150 PN10 WAF or LUG TYPE ELT to FLOW PRESSURE VALVE DN600 PN10 WAF or LUG TYPE ELT FLOW PRESSURE VALVE DN150 PN10 WAF or LUG TYPE ELT EX to FLOW PRESSURE VALVE DN500 PN10 WAF or LUG TYPE ELT EX			
Bill of materials (BoM)	OBS complete BOM, rev1		-	Rev 1/ 14.10.2020
Operation, maintenance and safety manual (OMSM)	Operation, maintenance and safety manual for Optimarin Ballast System	Template OMS for BK3	4)	Rev 6/ 14.10.2020
		Template OMS for BK3 EX		
		Template OMS for FX2		

1) This is a template dwg no. Project specific P&ID will be numbered 3xxxxx. Each project specific document shall reference back to the template dwg no and rev as listed in this table.
 2) This is a template dwg no. Project specific electrical wiring will be numbered 5xxxxx. Number of cabinets in project specific may vary from template. Each project specific document shall reference back to the template dwg no and rev as listed in this table.
 3) All GA drawings have a unique sequence number (1xxxxx) automatically generated by the Optimarin PDM system.
 4) All project specific manuals will be indexed with a unique project number (3xxxx-xx-xx-xx) automatically generated by the ERP system. Revision of project specific manuals will start at rev. 1, and each manual will reference back to the template revision as listed in this table.

Other equipment manufactured by

The OBS BWMS applies one of the following selfcleaning screenfilters:

- 6.18.3 aquaBoll filter series with 25 µm mesh manufactured by Boll & Kirch (BK3)
- ACB filter series with 20 µm mesh manufactured by Filtrex (FX2)

Treatment Rated Capacity

- 72 – 3000 m³/h

Product description

Treatment sequence:

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

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 OBS BWMS has demonstrated performance to the discharge standard with a minimum holding time between uptake and discharge of 24 hours in land-based testing for the IMO mode. 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.

Operation mode	TRC [m ³ /h]	UVI lower limit at 24% of full flow [W/m ²]	UVI lower limit at full flow (TRC) [W/m ²]
IMO	167 per chamber	150 ⁽¹⁾	400 ⁽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 45-46%. UVT may vary depending on the water quality parameters, i.e. particles and dissolved organic carbon

(2) When targeting this UVI limit in land-based testing, the measured UVT was 54-56%.

The system also includes UV-lamp power optimization control based on measured UV-intensity. Lamp power can be reduced when UVI measures above 800 W/m².

The system has a USCG mode of operation which applies a higher UV dose than the described IMO mode above. This type approval therefore also applies to operation in USCG mode.

Treatment Rated Capacity (TRC) of the BWMS

The Treatment Rated Capacities (TRC) of the designated OBS BWMS models during ballasting is limited to either on the TRC of the UV system or the TRC of the selected filter model, whichever is lowest.

During deballasting, the TRC is limited to the TRC of the UV system only. The UV system is formed by several UV chambers installed in parallel configuration using specific manifolds with the TRCs as listed below. The TRC of the filter models, BK3 and FX2 are also listed in tables below. The minimum flow rate at which designated OBS BWMS model can be operated is the minimum flow rate of the selected filter model + (10m³/h*number of UV chambers).

The OBS 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.

Manifold model	Number of UV chambers	TRC [m ³ /h]		Manifold model	Number of UV chambers	TRC [m ³ /h]
Type 1, DN150	1	167		Type 2, DN200	2	334
Type 1, DN200	2	334		Type 2, DN250	3	500
Type 1, DN250	3	500		Type 2, DN300	4	667
Type 1, DN300	4	667		Type 2, DN300	5	834
Type 1, DN300	5	834		Type 2, DN350	6	1000
Type 1, DN350	6	1000		Type 2, DN400	7	1167
Type 1, DN400	7	1167		Type 2, DN400	8	1334
Type 1, DN400	8	1334		Type 2, DN400	9	1500
Type 1, DN400	9	1500		Type 2, DN500	10	1667
Type 1, DN500	10	1667		Type 2, DN500	11	1834
Type 1, DN500	11	1834		Type 2, DN500	12	2000
Type 1, DN500	12	2000		Type 2, DN500	13	2167
Type 1, DN500	13	2167		Type 2, DN500	14	2334
Type 1, DN500	14	2334		Type 2, DN500	15	2500
Type 1, DN500	15	2500		Type 2, DN500	16	2667
				Type 2, DN600	17	2834
				Type 2, DN600	18	3000

Filtrex ACB	Model designation	Flow range [m ³ /h]
ACB-906-100	87FX2	15 - 87
ACB-910-150	135FX2	25 - 135
ACB-915-150	190FX2	35 - 190
ACB-935-200	255FX2	35 - 255
ACB-945-200	340FX2	45 - 340
ACB-955-250	515FX2	50 - 515
ACB-985-300	770FX2	65 - 770
ACB-999-350	1040FX2	95 - 1040
ACB-9100-400	1500FX2	126 - 1500
ACB-9120-500	2100FX2	126 - 2100
ACB-9200-600	3000FX2	126 - 3000

Boll & Kirch 6.18.3/AquaBoll	Model designation	Flow range [m ³ /h]
aquaBoll 273	72BK3	19-72
aquaBoll 324	94BK3	19-94
aquaBoll 356	204BK3	24-204
aquaBoll 419	378BK3	33-378
aquaBoll 521	518BK3	33-518
aquaBoll 600	614BK3	34-614
aquaBoll 750	1274BK3	50-1274
aquaBoll 900	1384BK3	47-1384
aquaBoll 1000	2040BK3	47-2040
aquaBoll 1100	3100BK3	69-3100

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, FX2	1.5 bar	≥0.3 bar	10 bar
aquaBoll 6.18.3, BK3	1.5 bar	≥0.38 bar	10 bar

Control and monitoring equipment

Software version

The OBS BWMS is type approved with system control software version: 2.0x

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 Optimarin checklist, OM-C-59, require approval. Testing of the application functions of a revised software may be required.

Safety measures

The OBS 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 (TTxx) installed in each UV chamber
- Temperature switch (TSxx) installed in each UV chamber and arranged with safety function independent of BWMS control
- Pressure sensors (PT01) installed after the filter
- Flow meter (FM01) installed after the filter

Electrical and electronic components

The OBS 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&ID and as specified in the BOM. Except for the components listed in 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 ID	Description	Item	Manufacturer
+CP	CONTROL PANEL MK3	150876	Optimarin AS
+SCP	SUB-CONTROL PANEL MK3	152052	Optimarin AS
+FC	FILTER CONTROL MK3	150737	Optimarin AS
	FILTER CONTROL EX MK3	151199	Optimarin AS
	FILTER CONTROL EX MK3 MTL	152706	Optimarin AS
+SBx	SENSOR BOX 0VA MK3	151128	Optimarin AS
	SENSOR BOX 250VA MK3	151114	Optimarin AS
	SENSOR BOX 700VA MK3	151058	Optimarin AS
	SENSOR BOX MK3	151135	Optimarin AS
	SENSOR BOX 0VA EX MK3	151215	Optimarin AS
	SENSOR BOX 250VA EX MK3	151231	Optimarin AS
	SENSOR BOX 700VA EX MK3	151763	Optimarin AS
	SENSOR BOX EX MK3	151207	Optimarin AS
	SENSOR BOX 0VA EX MK3 MTL	152695	Optimarin AS
	SENSOR BOX 250VA EX MK3 MTL	152700	Optimarin AS
	SENSOR BOX 700VA EX MK3 MTL	152702	Optimarin AS
	SENSOR BOX EX MK3 MTL	152704	Optimarin AS
+EXIP	EX INTERFACE PANEL MK3	151142	Optimarin AS
+IP	INTERLOCK PANEL MK3	151859	Optimarin AS
+FWP	FRESH WATER PANEL MK3	151779	Optimarin AS
+ACP	ACTUATOR CONTROL PANEL 700VA MK3	151822	Optimarin AS
	ACTUATOR CONTROL PANEL 1600VA MK3	151813	Optimarin AS
	ACTUATOR CONTROL PANEL 3600VA MK3	151804	Optimarin AS
+PDP	POWER DISTRIBUTION PANEL SMALL MK3	152053	Optimarin AS
+GPS	GPS JUNCTION BOX MK3	152057	Optimarin AS
	GPS JUNCTION BOX 230VAC MK3	152058	Optimarin AS
+UVPxx	UV POWER CABINET TYPE NED MK3	145923	Nedap N.V.
	UV POWER CABINET TYPE ETA	145128	Eta plus electronic GmbH
	UV POWER CABINET TYPE UVA	150431	Uvantech AS
+TBxx	TERMINAL BOX MK3	148644	Optimarin AS
	TERMINAL BOX MK2 TYPE TRA	148540	R. Stahl Tranberg AS
	TERMINAL BOX MK2 EX TYPE TRA	145956	R. Stahl Tranberg AS
+EXJBxx	JUNCTION BOX EX TYPE TRA	148640	R. Stahl Tranberg AS
	JUNCTION BOX EX TYPE BAR	145466	Bartec Technor AS
UVxx	UV SENSOR 2300W_m2 TYPE ILM	117079	IL Metronic Sensortechnik GmbH
	UV SENSOR 2300W_m2 EX2C EX TYPE ILM	149352	IL Metronic Sensortechnik GmbH

Hazardous area / Ex-proof

The OBS Ex 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 chambers, valves, backflush pump, and flowmeters have Ex-certification and can be installed in hazardous area zone 1, gas group IIB 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



Job Id: **262.1-004395-16**
Certificate No: **TAP0000271**

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. All piping material shall be indicated and conform to class requirements.
- Commissioning procedure

Type Approval documentation

Biological test reports

NIVA, Land-based testing of OBS 334 Ballast Water Management system of Optimarin AS – Final Report, Report SNO 6921-2015, Final report v2.1, June 2016

NIVA, Shipboard testing of the Ballast Water Management System OBS1000 of Optimarin AS, Report SNO 7063-2016, Final report v2.0, June 2016

NIVA, Land-based testing of OBS 334 Ballast Water Management system of Optimarin AS – Final Report, Report SNO 7523-2020, Final report, August 2020

Environmental test reports

Applica EMC and Environmental testing of Gönzheimer Elektronik GmbH Control unit F850S and power supply for Optimarin AS, Report 20226, Rev. 1

Applica Technical Report Optimarin AS Environmental testing of Temperatures Switches, Report No. 21250 Rev 1

Applica Technical Report Optimarin AS Environmental testing of Sensor Box +EXSB01 and temperature transmitter TR-34, Report No. 21356 Rev 0

Applica Technical Report Optimarin AS Environmental testing, Report No. 20597 Rev 0

Applica Technical Report Optimarin AS Environmental testing of Environmental testing of TB (Terminal Boxes) Report No. 20984 Rev 0

Applica Technical Report Optimarin AS EMC and Environmental testing of new components to Optimarin BWMS, Report No. 30486 Rev 0

DNV GL Type Approval Certificate TAE000037U issued to UVANTECHAS for UV Power Cabinet Type UVA.

System descriptive documentation

Installation Manual for Optimarin Ballast System, Rev 6, Template dated 14/10/2020. This manual is specific to BK3 or FX2 or BK3EX filters

Optimarin, OM-C-59 Software maintenance and development checklist, Rev 3

Optimarin, UV chamber with instrumentation, Illustration for DNVGL dual safety layer requirement, Drawing No. 100000, Rev -

DNV GL report; flow balance calculation, Flow Distribution in Parallell UV chambers, 2015-0885, Rev. 1, 25.09.2015

DNV GL, Filter comparison of Boll & Kirch filter model 6.18.2 and 6.18.3, 385FIST130315-2

Optimarin, Filter Comparison Data TYPE BK, 2020

Optimarin, Filter Comparison Data TYPE FX, 2020

Optimarin, Flow pressure valve replacement report, Rev1

Commissioning procedure

Class survey checklist for Optimarin Ballast System, Rev. 2 Template dated 2.20.2018

Job Id: **262.1-004395-16**
Certificate No: **TAP0000271**

Tests carried out

- Land-based testing in accordance with Resolution MEPC.279(70) and 46 CFR 162.060-26 using Optimarin OBS model 334 and Boll & Kirch 6.18.2 filter with 40 µm mesh
- Shipboard testing in accordance with Resolution MEPC.279(70) and 46 CFR 162.060-28 using Optimarin OBS model 1000 and Boll & Kirch 6.18.2 filter with a 40 µm mesh
- Additional Land-based testing in accordance with Resolution MEPC.300(72) and 46 CFR 162.060-26 using Optimarin OBS model 334 and Boll & Kirch 6.18.3 aquaBoll filter with 25 µm mesh filter
- Additional Land-based testing in accordance with Resolution MEPC.300(72) and 46 CFR 162.060-26 using Optimarin OBS model 334 and Filtrex filter ACB 945-200 with 20 µm mesh
- Type tests of the control and automation system witnessed by DNV GL
- Testing in accordance with environmental test specification for instrumentation and automation equipment, DNVGL Standard for Certification no DNVGL-CG-0339 (December 2019) and Resolution MEPC.300(72) and 46 CFR 162.060-30
- Additional testing of Optimarin OBS model 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 (Jan, 2020) and Resolution MEPC.174(58)
- Type test of the control and automation system for optimized flow control, witnessed by DNV GL

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 always be carried onboard a vessel fitted with this ballast water management system. The annex containing the summary reports of the test results of land-based and shipboard tests should be available for inspection onboard the vessel.

ANNEX: SUMMARY OF TESTING

Land-based and shipboard testing were carried out with the OBS BWMS including a Boll&Kirch 6.18.2 self-cleaning filter with 40 µm mesh candles as per IMO requirements. Additional land-based testing for the type approval has been carried out with the OBS BWMS including two new filters; a Filtrex ACB filter with a 20 µm mesh screen (FX2) and aquaBoll 6.18.3 with 25 µm mesh (BK3). The 40 µm mesh filter is considered conservative compared with the new filters and therefore the test results are included in this annex, forming the basis for type approval of the Optimarin OBS with either FX2 or BK3.

Land-based testing

Table 1 Test water conditions and operational parameters in land-based testing of the Optimarin OBS BWMS (TRC of 334 m³/h) with a Boll & Kirch 6.18.2 filter (BK, 40 µm screen) and two UV chambers at the NIVA Test Facility in Drøbak, Norway, during the period of May 2015 to June 2016.

Test cycle/ salinity	Water temperature [°C]	Salinity [PSU]	UVT [%]	DOC [mg/L]	POC [mg/L]	TSS ¹⁾ [mg/L]	Holding time [hr]	UVI range at ballasting [W/m ²]	Average flow rate after filtration [m ³ /h]	
1	FW	10.2	0	61	5.4	5.8	36.6	69	381-400	333
3	FW	10.7	0	65.2	6.3	7.3	44.3	120	319-327	331
4	FW	11.6	0	65.9	6.4	5.8	35.5	119	290-294	333
6	FW	11.8	0	61.8	6.9	5.1	30.5	117	289-290	334
7	FW	13.8	0	67	6.9	4.9	28.3	118	263-264	337
8	FW	14.1	0	69.1	7.7	5.5	27.8	67	405-408	336
15	FW	13.8	0	90	6.8	7.8	36.3	74	1141-1206	328
16	FW	14.5	0	75.5	7.3	5.4	34.0	120	714-749	333
17	FW	16.0	0	73.5	7.2	6.9	33.9	120	641-674	332
10	BW	5.8	19.0	81.1	13.4	6.8	34.9	75	1115-1155	333
11	BW	7.1	19.3	77.1	8.1	4.8	31.1	75	932-971	332
12	BW	8.5	19.1	73.9	8.0	6.3	30.4	124	646-712	333
13	BW	7.5	19.1	71.4	7.7	6.3	33.2	124	713-637	333
14	BW	8.9	18.7	76.9	7.5	6.2	33.0	127	1199-1353	333
1	MW	14.3	31.3	69.5	6.3	5.7	29.5	70	718-738	334
2	MW	14.9	28.4	67.2	6.9	4.9	26.0	64	420-436	334
3	MW	13.0	28.5	63.7	6.7	4.4	28.6	117	362-375	338
4	MW	10.3	29.3	62.9	6.7	5.6	31.3	117	385-392	335
5	MW	12.2	27.6	65	5.9	4.9	27.0	119	434-446	333
6	MW	10.4	29.4	66.8	5.2	5.3	27.3	120	465-477	333
7	MW	9.8	28.1	70.6	6.0	4.9	26.0	117	617-631	333
8	MW	9.0	27.6	73.9	6.6	4.2	26.0	120	717-741	333
9	MW	8.2	28.2	83.5	6.7	4.7	27.0	120	1334-1377	333

1) Too low TSS in the prepared test water for all fresh and brackish water test cycles. The tests were therefore considered invalid, hence repeated with the upgraded filter from Boll & Kirch, type 6.18.3 aquaBoll with 25 µm screen (BK3). Although the marine water test cycles are valid test cycles, two additional marine water test cycles were performed using the BK3 with shorter hold time. See table 3.

Table 2 Average numbers of live organisms in inlet and treated discharge water during land-based testing of the Optimarin OBS BWMS with the filter BK1, 40 µm screen. Live organisms ≥10 and <50 µm were quantified by microscopy counting after staining with CMFDA/FDA. Treated samples and control discharge were also quantified by MPN+Motility for organisms in size group ≥10 and <50 µm. Results from using MPN+Motility was basis or determining a successful test. All counts of pathogenic bacteria (*E. coli*, Enterococci and *Vibrio cholerae*) in treated water were below the ballast water discharge standard.

Test cycle/ salinity		Organism densities in inlet water		Organisms densities in discharge water			
		Organisms ≥50 µm [organism/m ³]	Organisms ≥10-<50 µm (FDA/CMFDA) [organisms/mL]	Organisms ≥50 µm [organism/m ³]		Organisms ≥10-<50 µm [organisms/mL]	
				Treated	Control	Treated (MPN)	Control (MPN)
1	FW	129 427	1633	1.3	151 813	<0.06	2700
3	FW	166 940	3696	2.0	200 523	0.45	310
4	FW	155 992	3788	1.3	362 779	<0.06	330
6	FW	149 742	1729	1.3	355 650	0.27	790
7	FW	156 096	2471	2.0	354 263	<0.06	1100
8	FW	135 283	2420	0.5	260 075	0.78	350
15	FW	361 508	2004	0.3	371 437	<0.06	>2700
16	FW	362 175	2083	<0.3	272 674	0.2	930
17	FW	159 161	13917	<0.3	211 619	0.65	1300
10	BW	599 453	1813	<0.3	323 654	<0.06	15 ¹⁾
11	BW	289 113	1525	0.3	472 900	<0.06	310
12	BW	598 422	2179	<0.3	243 529	<0.06	67 ¹⁾
13	BW	813 679	1458	<0.3	777 958	<0.06	430
14	BW	308 857	2871	<0.3	667 444	<0.06	350
1	MW	161 917	1946	1.2	61 846	<0.06	430
2	MW	141 267	5008	3.7	7 875	<0.06	230
3	MW	94 133	3879	0.6	66 007	0.45	290
4	MW	115 308	3429	1.7	74 619	<0.06	230
5	MW	138 740	2104	<0.3	57 707	<0.06	290
6	MW	232 633	2146	1.4	111 792	0.06	>230
7	MW	145 239	3413	<0.3	162 222	<0.06	330
8	MW	159 883	1158	<0.3	117 139	<0.06	570
9	MW	136 033	1158	<0.3	70 171	<0.06	990

1) In BW Test Cycle no 10 and 12, the plankton community was dominated by *Thalassiosira nordenschioldii*. This algae species does not grow in the medium used in MPN method. The test results are considered invalid based on MPN, but valid based on FDA/CMFDA results which was <1 and 1 organism/ml respectively in the discharge and 1788 and 263 organism/ml respectively in the control discharge.

Table 3 Test water conditions and operational parameters in additional land-based testing of the Optimarin OBS BWMS (TRC of 334 m³/h) with a Boll & Kirch filter (BK3, 25 µm screen) and two UV chambers at the NIVA Test Facility in Drøbak, Norway, during the period of Oct 2019 to June 2020.

Test cycle ¹⁾	Water temperature [°C]	Salinity [PSU]	UVT [%]	DOC [mg/L]	POC [mg/L]	TSS [mg/L]	Holding time [hr]	UVI range at ballasting [W/m ²]	Average flow rate after filtration [m ³ /h]
1/1B	10	0	47	10	5	53	22.0	188-207	180
3/5B	9	0	46	11	5	58	22.5	157-173	88
25/5B	10	0	51	8	8	63	24.0	189-236	120
29/2B	14	0	53	10	6	64	23.0	424-456	330
31/1B	17	0	50	8	7	63	22.5	236-258	168
32/3B	15	0	51	8	6	62	119.5	268-284	199
33/4B	16	0	52	8	7	62	119.0	276-293	207
4/10B	9	18	48	8	7	66	23.5	230-251	162
5/8B	10	19	49	8	6	62	118.5	247-271	177
6/9B	10	19	49	8	5	66	118.0	242-266	174
7/7B	10	18	54	11	6	61	23.0	396-432	322
9/6B	9	19	46	8	5	57	23.5	158-175	90
11/11B	6	31	56	8	6	65	22.5	444-500	332
13/12B	7	30	55	8	7	66	23.5	426-482	327

1) Two consecutive valid successful tests were performed for all salinities in the USCG mode. Only results from test cycles in the IMO mode are shown here.

Table 4 Average numbers of live organisms in inlet and treated discharge water during additional land-based testing of the Optimarin OBS BWMS with the filter BK3, 25 µm screen.

Live organisms ≥10 and <50 µm were quantified by microscopy counting after staining with CMFDA/FDA. Treated samples and control discharge were quantified by MPN+Motility and CMFDA/FDA for organisms in size group ≥10 and <50 µm. Results from using MPN+Motility was basis or determining a successful test. All counts of pathogenic bacteria (*E. coli*, Enterococci and *Vibrio cholerae*) in treated water were below the ballast water discharge standard. Testing during the period Oct 2019 to June 2020.

Test cycle/salinity		Organism densities in inlet water		Organisms densities in discharge water			
		Organisms ≥50 µm [organism/m ³]	Organisms ≥10- <50 µm [organisms/mL]	Organisms ≥50 µm [organism/m ³]		Organisms ≥10-<50 µm [organisms/mL]	
				Treated	Control	Treated (MPN)	Control (MPN)
3/5B	FW	28,954 ¹⁾	3,067	<1	25 738	2.3	2 700
25/5B	FW	156,513	2,139	<1	144 279	0.29	1 300
29/2B	FW	149,895	2,506	3.2	134 937	<0.07	2 700
31/1B	FW	671,824	3,959	<1	415 497	<0.07	2000
32/3B	FW	1,392,036	1,204	<1	1 065 633	<0.07	190
33/4B	FW	1,298,360	1,100	0.3	1 065 633	<0.07	190
4/10B	BW	184,954	7,300	3.0	222 117	0.49	1 600
5/8B	BW	129,063	3,875	<1	96 654	<0.07	350
6/9B	BW	130,363	4,158	<1	96 654	<0.07	350
7/7B	BW	251,646	5,133	4.0	247 533	0.72	>2700
9/6B	BW	1,107,967	1,050	<1	499 033	<0.07	1300
11/11B	MW	140,388	1,800	0.7	192 250	<0.07	2 000
13/12B	MW	276,000	1,367	1.3	276 621	0.14	>2 700

1) For Test Cycle no 3/5B the inlet counts of organisms ≥50 µm was below target of 100,000 org/m³, hence the test was repeated as Test Cycle no 25.

Table 5 Test water conditions and operational parameters in additional land-based testing of the Optimarin OBS BWMS (TRC of 334 m³/h) with a Filtrex (FX2, 20 µm screen) and two UV chambers at the NIVA Test Facility in Drøbak, Norway, during the period of Oct 2019 to June 2020.

Test cycle/salinity ¹⁾		Water temperature [°C]	Salinity [PSU]	UVT [%]	DOC [mg/L]	POC [mg/L]	TSS [mg/L]	Holding time [hr]	UVI range at ballasting [W/m ²]	Average flow rate after filtration [m ³ /h]
28/2F	FW	13	0	53	11	6	66	23	419-448	330
30/1F	FW	16	0	49	8	6	62	22.5	232-253	164
36/2F	FW	20	0	60	7	8	58	23.5	472-501	332
8/4F	BW	10	18	53	10	6	62	23.5	395-428	323
10/3F	BW	9	19	46	9	5	55	23.5	154-173	85
12/5F	MW	6	31	56	8	6	66	22.5	451-508	331
14/6F	MW	7	29	55	8	7	64	23	436-493	330

1) Two consecutive valid successful tests were performed for all salinities in the IMO mode and three consecutive valid successful tests were performed for all salinities in the USCG mode. Only results from test cycles in the IMO mode are shown here.

Table 6 Average numbers of live organisms in inlet and treated discharge water during additional land-based testing of the Optimarin OBS BWMS with the filter FX2, 20 µm screen. Live organisms ≥10 and <50 µm were quantified by microscopy counting after staining with FDA/CMFDA. All counts of pathogenic bacteria (*E. coli*, Enterococci and *Vibrio cholerae*) in treated water were below the ballast water discharge standard.

Test cycle/salinity		Organism densities in inlet water		Organisms densities in discharge water			
		Organisms ≥50 µm [organism/m ³]	Organisms ≥10-<50 µm [organisms/mL(FDA/CMFDA)]	Organisms ≥50 µm [organism/m ³]		Organisms ≥10-<50 µm [organisms/mL]	
				Treated	Control	Treated (MPN)	Control (MPN)
28/2F	FW	172 651	2 478	3.1	134 937	160 ¹⁾	>2 700
30/1F	FW	650 300	5 283	<1	415 497	<0.07	2000
36/2F	FW	262 292	1 413	1.3	439 850	<0.07	1600
8/4F	BW	221 525	5 367	0.7	247 533	0.39	>2 700
10/3F	BW	1 437 675	1 042	0.3	499 033	0.39	1300
12/5F	MW	152 713	1 867	<1	192 250	<0.07	2000
14/6F	MW	230 646	1 413	<1	276 621	<0.07	>2700

1) The sample was contaminated, and further microscopic counts found that the sample including only 5.4 org./mL in the size above ≥10 µm. The test cycle was anyway repeated as Test Cycle no 36/2F.

Shipboard testing

Table 7 Test water conditions and operational parameters in shipboard testing with OBS BWMS (TRC of 1000 m³/h) including a Boll & Kirch 6.18.2 filter (BK1, 40 µm screen) and 6 UV chambers installed in parallel on board the ship Saga Future (IMO No. 9613836) during the period of October 2015 to June 2016.

Test cycle	Water temperature [°C]	Salinity [PSU]	UVT [%]	DOC [mg/L]	POC [mg/L]	TSS [mg/L]	Holding time [hr]	Average UVI at ballasting [W/m ²]	Average flow rate after filtration [m ³ /h]
1 ¹⁾	16.3	33.90	98	1.37	0.15	1.73	22	1652	991
3	11.2	30.30	67	1.43	0.81	41.93	28	473	995
6	31.6	32.4	94	1.70	0.05	17.33	35	1497	999
7	27.2	18.1	91	1.73	<0.1	6.27	45	801	997
8	29.7	33.1	95	1.50	<0.1	5.87	37	1882	997
10	31.9	31.6	96	1.80	<0.1	3.60	26	1589	992

1) Test Cycle no 1, 2, 4 and 5 are invalid tests due to low algae inlet counts and therefore some of these tests were aborted before all samples were analyzed. Test Cycle 9 was invalid due to a maintenance performed outside the specifications (filter damage).

Table 8 Average numbers of live organisms in inlet and treated discharge water during shipboard testing of the OBS BWMS (TRC of 1000 m³/h). Live organisms ≥10 and <50 µm were quantified by microscopy counting after staining with CMFDA/FDA in influent and treated water. 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 [organism/m ³]		Organisms ≥10-<50 µm [organisms/mL]	
	Influent water	Treated discharge	Influent water	Treated discharge
1	6 403	25 ²⁾	32 ¹⁾	1.7
3	57 250	7.2	138	0.2
6	12 118	2.6	95 ¹⁾	1.2
7	23 239	<1	121	5.7
8	20 498	0.17	120	<0.2
10	3 044	0.88	90.3 ¹⁾	<0.2

1) Test cycle 1, 2, 4 and 5 are invalid tests due to low algae counts at inlet. For Test cycle 6 and 10, the inlet count is between 90 and 95% of the test requirement which is considered an acceptable deviation.

2) In shipboard Test Cycle no 1 the number of organisms ≥50 µm in the treated discharge did not meet the discharge standard due to a leaking bypass valve which was replaced after Test Cycle no 5.