



TYPE APPROVAL CERTIFICATE

Certificate No:
TAP0000218
Revision No:
2

This is to certify:

That the **Ballast Water Management System**

with type designation(s)
Wärtsilä Aquarius UV BWMS - Model range AQ-50-UV(X) to AQ-1000-UV(X)

Issued to
Wartsila Water Systems Ltd
Poole, Dorset, United Kingdom

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

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 (MEPC.300(72))** and **DNV GL 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**.

Operating media: N/A

Issued at **Høvik** on **2021-04-30**

for **DNV**

This Certificate is valid until **2025-03-19**.

DNV local station: **Southampton**

Approval Engineer: **Michael Lehmann**

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.

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 300,000 USD.



Name of ballast water management system (BWMS)

Wärtsilä Aquarius UV BWMS

Ballast water management system manufactured by

Wartsila Water Systems Ltd

Place of production

Wartsila Water Systems Ltd, Merchants House, Poole, Dorset BH15 1PH, United Kingdom

Wartsila Suzhou Ltd, 77, Hongxi Road, New District of Suzhou, 215151, P.R. China

Type and model designations

Wärtsilä Aquarius UV BWMS AQ-50-UV, AQ-80-UV, AQ-125-UV, AQ-180-UV, AQ-250-UV, AQ-275-UV, AQ-300-UV, AQ-375-UV, AQ-410-UV, AQ-430-UV, AQ-500-UV, AQ-550-UV, AQ-750-UV, AQ-850-UV and AQ-1000-UV

Wärtsilä Aquarius UV BWMS models suitable for installation in hazardous area are designated with the suffix X (e.g. AQ-1000-UVX).

Equipment / Assembly drawings

The Wärtsilä Aquarius UV BWMS shall be installed in accordance with the documents listed below.

| Type | Drawing no. | Description |
|--|--|--|
| Operation, maintenance and safety manual (OMSM) | Wärtsilä Aquarius UV AQ-xxxx-UV Operational Maintenance & Safety Manual (OMSM 162.060-38) Ballast Water Management System Designed for Compliance with USCG rule 33CFR part 151 and 46CFR part 162 IMO MEPC 300 (72) {G8} Revision 6 – 25 th January 2021 | Operational Maintenance & Safety Manual |
| Piping and instrumentation diagram ⁽¹⁾ (P&ID) | UV-T-001-171 | Single System |
| | UV-T-002-171 | Multiple System |
| | UV-T-004-171 | EX Single System |
| | UV-T-005-171 | EX Multiple System |
| | UV-T-006-171 | EX Single System, Submerged Pump |
| | UV-T-007-171 | Single System Loose Supply Scope |
| | UV-T-008-171 | Single System Skidded |
| | UV-T-009-171 | EX Single System Loose Kit |
| | UV-T-010-171 | Single System, Filter & UV Chamber Skidded, Power & Control Panels Loose |
| | UV-T-011-171 | Single System, Loose Filter |
| UV-T-016-171 | Single Filter, Multi Chamber | |
| Bill of materials (BoM) | BD00410 (Rev. 7) | Generic BoM |
| General arrangement (GA) drawings ⁽¹⁾⁽²⁾ | H0050FK-xxx-171 to H0180FK-xxx-171, H0250FK-xxx-191 to H1000FK-xxx-191 | Standard Filter Kits |
| | H0050FXK-xxx-171 to H0180FXK-xxx-171, H0250FXK-xxx-191 to H1000FXK-xxx-191 | Standard Ex Filter Kits |
| | H0050FCK-xxx-171 to H0180FCK-xxx-171, H0250FCK-xxx-191 to H0500FCK-xxx-191 | Compact Filter Kits |
| | H0050FCXK-xxx-171 to H0180FCXK-xxx-171, H0250FCXK-xxx-191 to H0500FCXK-xxx-191 | Compact Ex Filter Kits |
| | H0500FCK-SP-xxx-191 to H1000FK-SP-xxx-191 | Super Turbo Filter Kits |
| | H0500FCXK-SP-xxx-191 to H1000FXK-SP-xxx-191 | Super Turbo Ex Filter Kits |
| | H0125UVK-xxx-201 to H1000UVK-xxx-201 | UV Kits |
| | H0125UVXK-xxx-201 to H1000UVXK-xxx-201 | Ex UV Kits |
| AQ0050-SP-002 to AQ1000-SP-002 | Sample Points | |

| | | |
|--|---------------------------------|---------------------------------------|
| | 6742000100 to 6742000107 | UV Power Supply 440V 60Hz |
| | 6742000108 to 6742000115 | UV Power Supply 400V 50Hz |
| | 6742000116 | UV Power Supply 440V 60Hz ATEX |
| | 6742000117 | UV Power Supply 400V 50Hz ATEX |
| | BWCP-GA-01 | UV Control Panel |
| Electrical wiring diagram ⁽³⁾ | BWCP10001 to BWCP10015 | Standard UV Control Panel (440V/60Hz) |
| | BW15001 to BWCP15015 | Standard UV Control Panel (400V/50Hz) |
| | BWCP30001EX to BWCP30015EX | Ex UV Control Panel (440V/60Hz) |
| | BWCP35001EX to BWCP35015EX | Ex UV Control Panel (400V/50Hz) |
| | BWCP70051, BWCP70053, BWCP70055 | Remote UV Console |

- (1) -171 (or -191,-201) represents the revision number of the P&ID or GA drawings. For any revision resulting in a change of this revision number, the revised P&ID or GA drawings are to be forwarded to DNV for evaluation.
- (2) The listed GA drawings are generic and are not used for specific installations. The orientation and voltage/frequency of each installation will be determined to allow for the relevant GA drawing to be created, replacing -xxx with the specific type code. Each GA drawing will reference back to the generic GA drawing number listed in this table. Any significant changes to the BWMS leading to a new generic drawing being created with a new model version number requires submission of that new generic drawing to DNV.
- (3) Drawing numbers for specific installations may include the installation contract number for traceability purposes (e.g. BWCPxxx-50xxx). Each drawings will reference back to the electrical drawing number listed in this table.

Other equipment manufactured by

The Wärtsilä Aquarius UV BWMS applies filter models (in standard, turbo and super-turbo configurations) of the BS series and BS e-series with a 40 µm Smartweave™ sintered filter screen designed by Filtersafe but manufactured by Wartsila under license.

The UV chamber models BWT IL are manufactured by Hanovia.

Treatment Rated Capacity

50 – 1000 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 & salinity

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

System design limitations / Operational parameters

Holding time

The Wärtsilä Aquarius UV BWMS has demonstrated performance to the discharge standard with a minimum holding time between uptake and discharge of 24 hours in land-based testing in brackish and marine water. 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 BWMS for treating brackish or marine water.

A minimum holding time of 72 hours is required by the BWMS for treatment of fresh water. Salinity of the water will have to be measured by the crew for compliance.

UV dose

The Wärtsilä Aquarius UV BWMS evaluates the water quality through measurements of UV intensity. To ensure adequate UV dose at lower UV-T levels, the system automatically applies four discrete flow reduction steps reducing the flow rate to either 75%, 50%, 25% or 15% of TRC based on the measured UV intensity as listed below.

| Model | TRC [m ³ /h] | UV intensity (UVI) operating envelope [W/m ²]: | | | | |
|------------|-------------------------|--|-----------------------|-----------------------|-----------------------|--------------------------------------|
| | | Flow rate @100% of TRC | Flow rate @75% of TRC | Flow rate @50% of TRC | Flow rate @25% of TRC | Flow rate @15% of TRC ⁽¹⁾ |
| AQ-50-UV | 50 | ≥494 | 371≤UVI<494 | 247≤UVI<371 | 124≤UVI<247 | 74≤UVI<124 |
| AQ-80-UV | 80 | ≥791 | 593≤UVI<791 | 395≤UVI<593 | 198≤UVI<395 | 119≤UVI<198 |
| AQ-125-UV | 125 | ≥1235 | 926≤UVI<1235 | 618≤UVI<926 | 309≤UVI<618 | 185≤UVI<309 |
| AQ-180-UV | 180 | ≥139 | 104≤UVI<139 | 69≤UVI<104 | 35≤UVI<69 | 21≤UVI<35 |
| AQ-250-UV | 250 | ≥193 | 145≤UVI<193 | 96≤UVI<145 | 48≤UVI<96 | 29≤UVI<48 |
| AQ-275-UV | 275 | ≥258 | 193≤UVI<258 | 129≤UVI<193 | 64≤UVI<129 | 39≤UVI<64 |
| AQ-300-UV | 300 | ≥281 | 211≤UVI<281 | 140≤UVI<211 | 70≤UVI<140 | 42≤UVI<70 |
| AQ-375-UV | 375 | ≥307 | 230≤UVI<307 | 154≤UVI<230 | 77≤UVI<154 | 46≤UVI<77 |
| AQ-410-UV | 410 | ≥342 | 256≤UVI<342 | 171≤UVI<256 | 85≤UVI<171 | 51≤UVI<85 |
| AQ-430-UV | 430 | ≥358 | 269≤UVI<358 | 179≤UVI<269 | 90≤UVI<179 | 54≤UVI<90 |
| AQ-500-UV | 500 | ≥511 | 383≤UVI<511 | 255≤UVI<383 | 128≤UVI<255 | 77≤UVI<128 |
| AQ-550-UV | 550 | ≥252 | 189≤UVI<252 | 126≤UVI<189 | 63≤UVI<126 | 38≤UVI<63 |
| AQ-750-UV | 750 | ≥343 | 257≤UVI<343 | 172≤UVI<257 | 86≤UVI<172 | 51≤UVI<86 |
| AQ-850-UV | 850 | ≥426 | 320≤UVI<426 | 213≤UVI<320 | 107≤UVI<213 | 64≤UVI<107 |
| AQ-1000-UV | 1000 | ≥502 | 376≤UVI<502 | 251≤UVI<376 | 125≤UVI<251 | 75≤UVI<125 |

(1) A UVI below the lower limit implies that the ballast water is not treated in accordance with this certificate. The Wärtsilä Aquarius UV BWMS has demonstrated performance to the discharge standard at low UV-T in the range of 52-55% when operating at flow rate of 15% of TRC.

Treatment Rated Capacity

The Treatment Rated Capacities (TRC) of the designated Wärtsilä Aquarius UV(X) BWMS models are listed below. The list also specifies the filter and UV chamber that shall be installed for a specific model. A Wärtsilä Aquarius UV BWMS model may be used with a larger filter than specified below.

A Wärtsilä Aquarius UV BWMS model may also be installed with a larger UV chamber model than specified below. For such installations referred to as High Rate Discharge arrangements, the TRC for ballast water uptake is as specified below for the specific Wärtsilä Aquarius UV(X) BWMS models, while the TRC for ballast water discharge will be equal to the largest TRC specified below for the relevant installed UV chamber model.

| Wärtsilä Aquarius UV model | TRC [m ³ /h] | Filter model ⁽¹⁾ | UV chamber model |
|----------------------------|-------------------------|--|------------------|
| AQ-50-UV(X) | 50 | BS-025H/V-03 or BS-031H/V-03 | BWT IL +125 |
| AQ-80-UV(X) | 80 | BS-050H/V-04 | |
| AQ-125-UV(X) | 125 | BS-050H/V-06 or BS-061H/V-T-06 | |
| AQ-180-UV(X) | 180 | BS-070H/V-06 or BS-061H/V-T-06 | BWT IL +250 |
| AQ-250-UV(X) | 250 | BS-100H/V-08 or BS-101(e)H/V-08 | |
| AQ-275-UV | 275 | BS-100H/V-T-08 | BWT IL +300 |
| AQ-300-UV | 300 | BS-101(e)H/V-T-08 | |
| AQ-375-UV(X) | 375 | BS-150H/V-10 or BS-151(e)H/V-10 | BWT IL +375 |
| AQ-410-UV(X) | 410 | BS-150H/V-T-10 | BWT IL +430 |
| AQ-430-UV(X) | 430 | BS-151(e)H/V-T-10 | |
| AQ-500-UV(X) | 500 | BS-200H/V-12 or BS-201(e)H/V-12 or BS151(e)H/V-ST-12 | BWT IL +500 |
| AQ-550-UV(X) | 550 | BS-200H/V-T-12 or BS-201(e)H/V-T-12 | BWT IL +750 |
| AQ-750-UV(X) | 750 | BS-300(e)H/V-14 | |
| AQ-850-UV(X) | 850 | BS-300(e)H/V-T-14 | BWT IL +1000 |
| AQ-1000-UV(X) | 1000 | BS-400(e)H/V-14 or BS-300(e)H/V-ST-14 | |

(1) H/V symbolises filters for horizontal or vertical installation. (e) symbolises filters of the BS e-series range.

The BWMS automatically controls the flow rate with a flow control valve targeting TRC or the relevant discrete flow reduction when treating ballast water with lower UV-T levels.

Pressure

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

| Wärtsilä Aquarius UV model | Minimum ballast water inlet pressure ⁽¹⁾ | Maximum ballast water operating pressure | Differential pressure triggering backflushing |
|------------------------------|---|--|---|
| AQ-50-UV(X) to AQ-1000-UV(X) | 1.6 bar | 6 bar | 0.5 bar |

(1) Minimum pressure required when using a backflush pump to enable effective filter cleaning.

Control and monitoring equipment

Software version

The Wärtsilä Aquarius UV BWMS is type approved with the system control software version R12XX. In the revision number R12XX the "1" represents the major revision number of the software and the "2" represents the hardware revision number. XX represents the minor revision number.

Any changes to the software are to be recorded as long as the system is in use onboard. Records of any major software changes or any changes to the hardware are to be forwarded to DNV for evaluation. Major software changes include any change to the control and operating philosophy of the BWMS, which can alter the performance of the system.

Testing of the application functions of the revised software may be required.

Safety measures

The Wärtsilä Aquarius UV 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:

- Pressure transducers PT1 and PT2 before and after the filter
- Flow meter FIT1
- Water sensor capacitance probe CP1 in the UV chamber
- UV chamber temperature sensor UVT
- UV chamber temperature switch (arranged with safety function independent of BWMS control)

Electrical and electronic components

The Wärtsilä Aquarius UV 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 specified on the BoM. Except for the components listed below, alternate models to the ones specified on the BoM 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 a 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 only the models specified in the BoM shall be used:

| Tag No. | Component name | Manufacturer | Model(s) |
|---------|----------------------|---|--------------------------|
| MCP1 | Main control panel | CMR or Wartsila Suzhou (designed by Wärtsilä) | BWCP1xxxx or BWCP3xxxxEx |
| | UV remote console | CMR or Wartsila Suzhou (designed by Wärtsilä) | BWCP7xxxx |
| | HMI | Beijer Electronics | T7A or X2Pro7 |
| UVI | UV intensity monitor | IL Metronic | SUV 20 |
| UVPS1 | Power supply | Hanovia | BWT |

Hazardous area / Ex-proof

Both the Ex version of the filter module and the Ex version of the UV treatment module (except the UV chamber BWTL IL +300) of the Wärtsilä Aquarius UV BWMS have been found to be in compliance with DNV GL rules for classification of ships Pt.4 Ch.8 Sec.11 and may be installed in hazardous areas. All other units of the BWMS must be located in non-hazardous areas.

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. Ex-certification is not covered by this certificate.

Documents approval

The following documentation is to be submitted for approval for each BWMS installation:

- Piping and Instrumentation Diagram (P&ID) of the ballast system including the treatment system installation
- Commissioning procedure
- Interface description towards ship's existing systems including alarms for failure
- List of Ex-equipment according to DNV GL rules for classification of ships Pt.4 Ch.8 Sec.11 if the system is to be installed in hazardous area zone

Type approval documentation

Test plan and reports:

- DHI Denmark: Biological efficacy performance evaluation of Ballast Water Management System Wärtsilä Aquarius AQ-250-UV in land-based test - Land-based test report (Final test report of 18 October 2018)
- DHI Denmark: Biological efficacy performance evaluation of Wärtsilä Aquarius AQ-1000-UV Ballast Water Management System in shipboard test - Shipboard test report (Final test report of 17 October 2018)
- PHOENIX TESTLAB: Test report (Report Number: U171715E1) - Equipment under Test (EUT): Ballast Water Management System Project Aquarius UV (Rev. 6 of 18 October 2018)
- PHOENIX TESTLAB: Test report (Report Number: U180038E1) - Equipment under Test (EUT): UV-Lamps (BWMS Project Aquarius) (Rev. 2 of 1 October 2018)
- PHOENIX TESTLAB: Test report (Report Number: U180038E1) - Equipment under Test (EUT): UV-Lamps (BWMS Project Aquarius) (Rev. 2 of 13 February 2018)
- PHOENIX TESTLAB: Test report (Report Number: U181132E1) - Equipment under Test (EUT): 6000 and 6500 Series Purge Unit (Rev. 3 of 12 October 2018)
- PHOENIX TESTLAB: Test report (Report Number: U170239E1) - Equipment under Test (EUT): Ballast Water Management System Project Aquarius EC (Rev. 3 of 11 June 2018)

System documentation:

- Wartsila Water Systems Ltd.: Wärtsilä Aquarius UV AQ-xxxx-UV - Operational Maintenance & Safety Manual (OMSM 162.060-38) Ballast Water Management System Designed for Compliance with USCG rule 33CFR part 151 and 46CFR part 162 IMO MEPC 300(72) {G8}, rev. 6
- Wartsila Water Systems Ltd.: Wärtsilä Aquarius UV BWMS Generic BOM's - USCG (BD00410), rev. 7
- Wartsila Water Systems Ltd.: Wartsila AQUARIUS UV BWMS Operator User Guide (BD00409), rev. 2
- Wartsila Water Systems Ltd.: Aquarius UV Installation Instructions (BD00198), rev. 6
- Wartsila Water Systems Ltd.: Aquarius UV Ballast Water Management System Alarm and Function Test Procedure (R12** Software) (BD00441), rev. 1
- Wartsila Water Systems Ltd.: Wärtsilä Aquarius UV BWMS Sizing Document USCG (BD00294), rev. 4
- Wartsila Water Systems Ltd.: Wärtsilä Aquarius UV BWMS control and operating philosophy (BD00292), rev. 2)
- Wartsila Water Systems Ltd.: Aquarius UV PLC Alarm & Trip Summary (BD00308), rev. 11
- Wartsila Water Systems Ltd.: Aquarius UV Control System Software Functional Description (BD00320), rev. 8
- Wartsila Water Systems Ltd.: Wartsila AQUARIUS UV BWMS Control System Options (BD00356), rev. 3
- Wartsila Water Systems Ltd.: Wärtsilä Aquarius UV BWMS all system TRC performance claim (BD00398), rev. 4
- Wartsila Water Systems Ltd.: Wartsila Water Systems Ltd.: Wärtsilä Aquarius UV BWMS basis of process design and scale-up (BD00427), rev. 1

- Wartsila Water Systems Ltd./Hanovia: BWT-Scaling-Using-CFD report (BD00451), rev. 1
- Wartsila UK Ltd.: Wärtsilä Aquarius UV Temperature Assessment (BD00492), rev. 1
- Wartsila UK Ltd.: UV Shipboard Testing Summary (Revised IMO G8) (BD00490), rev. 1
- Wartsila Water Systems Ltd.: Wärtsilä Aquarius UV BWMS Alternative Arrangement Descriptions (BD00419), rev. 3
- DNV GL: Evaluation report - Equivalence of new 'e' type BS filter series with old BS filter series by Filtersafe (Report No.: A0803585-001), Rev. 0

Tests carried out

- Land-based testing with Wärtsilä Aquarius UV BWMS AQ-250-UV (TRC of 250 m3/h) with a standard Filtersafe filter (BS-100H, 40 µm screen) and a BWT IL +250 UV chamber in accordance with Resolution MEPC.279(70)
- Shipboard testing with one of the two Aquarius UV BWMS AQ-1000-UV (TRC of 1000 m3/h) with a standard Filtersafe filter (BS-400H, 40 µm screen) and a BWT IL +1000 UV installed in parallel on board the bulk carrier MV Paolo Topic (IMO No. 9726256) in accordance with Resolution MEPC.279(70)
- Function tests of the control and monitoring system witnessed by DNV
- Environmental testing in accordance with DNV GL class guidelines for Environmental test specification for electrical, electronic and programmable equipment and systems (DNVGL-CG-0339) and Resolution MEPC.279(70)

Marking of product

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

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

Revision history of this certificate

| Revision No. | Date of issuance | Description |
|--------------|------------------|---|
| - | 2020-03-20 | Initial certificate |
| 1 | 2020-06-12 | Inclusion of BS e-series filters by Filtersafe |
| 2 | 2021-04-30 | Change of manufacturer name from Wartsila UK Ltd to Wartsila Water Systems Ltd. and approval of alternate capacitor and transformer for UV power supply |

ANNEX: SUMMARY OF TESTING

Land-based testing

Table 1 Test water conditions and operational parameters in land-based testing of the Wärsilä Aquarius UV BWMS AQ-250-UV (TRC of 250 m³/h) with a standard Filtersafe filter (BS-100H, 40 µm screen) and a BWT IL +250 UV chamber at the DHI Maritime Technology Evaluation Facility in Hundested, Denmark, during the period of August 2017 to June 2018.

| Test cycle | Water temperature [°C] | Salinity [PSU] | UV-T [%] | DOC [mg/L] | POC [mg/L] | TSS [mg/L] | Holding time | Average UV-I at ballasting (± standard deviation) [W/m ²] | Average flow rate after filtration [m ³ /h] |
|--------------------|------------------------|----------------|----------|------------|------------|------------|--------------|---|--|
| F-1 | 11 | 0.41 | 58 | 6.6 | 6.6 | 60 | 5 days | 48 ± 2 | 46 |
| F-2 | 17 | 0.4 | 55 | 6.9 | 5.56 | 61 | 72 hours | 36 ± 2 | 37 |
| F-3 | 19 | 0.36 | 52 | 7.7 | 6.1 | 54 | 5 days | 28 ± 1 | 37 |
| F-4 | 20 | 0.39 | 55 | 6.7 | 6.8 | 58 | 72 hours | 36 ± 1 | 37 |
| F-5 | 19 | 0.37 | 55 | 7.6 | 6.1 | 53 | 72 hours | 31 ± 0.8 | 37 |
| B-1 | 19 | 17 | 66 | 8.1 | 7.3 | 55 | 24 hours | 111 ± 2 | 179 |
| B-2 | 19 | 18 | 65 | 7.8 | 7.3 | 54 | 5 days | 117 ± 2 | 179 |
| B-3 | 19 | 18 | 65 | 7.8 | 7.3 | 54 | 5 days | 116 ± 2 | 183 |
| B-4 | 15 | 18 | 58 | 10 | 9 | 60 | 72 hours | 48 ± 1 | 74 |
| B-5 | 12 | 18 | 54 | 13 | 7.3 | 65 | 72 hours | 24 ± 1 | 49 |
| B-6 | 20 | 18 | 67 | 7.5 | 8 | 77 | 24 hours | 123 ± 5 | 122 |
| M-1 | 16 | 29 | 70 | 7.6 | 5.8 | 51 | 72 hours | 147 ± 2 | 243 |
| M-2 | 16 | 29 | 70 | 7.6 | 5.8 | 51 | 72 hours | 145 ± 2 | 245 |
| M-3 ⁽¹⁾ | | | 64 | | | | | | |
| M-4 | 8.3 | 28 | 65 | 8 | 9.4 | 59 | 5 days | 94 ± 1 | 122 |
| M-5 | 8.3 | 28 | 65 | 8 | 9.4 | 59 | 5 days | 94 ± 2 | 122 |
| M-6 | 8.6 | 28 | 69 | 7.7 | 7 | 48 | 72 hours | 120 ± 2 | 182 |
| M-7 | 5 | 28 | 72 | 7.2 | 6.2 | 44 | 24 hours | 134 ± 2 | 180 |
| M-8 | 5 | 28 | 72 | 7.2 | 6.2 | 44 | 24 hours | 134 ± 3 | 189 |
| M-9 | 8.3 | 28 | 73 | 7.3 | 6.7 | 45 | 24 hours | 157 ± 3 | 187 |
| M-10 | 18 | 29 | 71 | 7.4 | 5.7 | 60 | 24 hours | 144 ± 4 | 149 |

(1) Marine water test cycle M-3 was cancelled due to the BWMS operating outside its performance claim.

Table 2 Average numbers of live organisms in inlet and treated discharge water during land-based testing of the Wärtsilä Aquarius UV BWMS AQ-250-UV. Live organisms ≥ 10 and $< 50 \mu\text{m}$ were quantified 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 | Organism densities in inlet water | | Organisms densities in discharge water | | | |
|--------------------|---|---|---|---------|---|---------|
| | Organisms $\geq 50 \mu\text{m}$ [organism/m ³] | Organisms ≥ 10 - $< 50 \mu\text{m}$ (FDA/CMFDA) [organisms/mL] | Organisms $\geq 50 \mu\text{m}$ [organism/m ³] | | Organisms ≥ 10 - $< 50 \mu\text{m}$ (FDA/CMFDA) [organisms/mL] | |
| | | | Treated | Control | Treated | Control |
| F-1 | 358,578 | 4,998 | 0 | 152,074 | 1.4 | 1,898 |
| F-2 | 344,806 | 1,967 | 0.67 | 281,841 | 0.11 | 1,626 |
| F-3 | 502,778 | 1,934 | 0 | 355,981 | 2.8 | 909 |
| F-4 | 208,606 | 2,888 | 1 | 75,556 | 1.6 | 2,097 |
| F-5 | 869,306 | 1,655 | 1.3 | 253,566 | 4.6 | 947 |
| B-1 | 634,611 | 1,289 | 0.33 | 246,367 | 6.7 | 1,242 |
| B-2 ⁽¹⁾ | 139,495 | 1,718 | 0 | 18,233 | 1.2 | 384 |
| B-3 ⁽¹⁾ | 132,500 | 1,467 | 0 | 18,233 | 0.33 | 384 |
| B-4 | 290,764 | 1,274 | 0.67 | 50,597 | 0 | 628 |
| B-5 | 309,989 | 1,451 | 1 | 118,914 | 1.5 | 2,679 |
| B-6 | 728,539 | 1,942 | 0 | 212,749 | 1 | 496 |
| M-1 ⁽¹⁾ | 210,333 | 1,004 | 0.33 | 114,543 | 0.83 | 1,063 |
| M-2 ⁽¹⁾ | 239,208 | 1,068 | 0 | 114,543 | 0.5 | 1,063 |
| M-4 ⁽¹⁾ | 346,542 | 1,376 | 0.33 | 138,714 | 1.2 | 1,598 |
| M-5 ⁽¹⁾ | 247,306 | 1,978 | 0 | 138,714 | 3 | 1,598 |
| M-6 | 191,776 | 2,436 | 1.7 | 100,530 | 8.7 ⁽²⁾ | 1,471 |
| M-7 ⁽¹⁾ | 252,552 | 1,689 | 0.33 | 105,331 | 9.8 ⁽²⁾ | 1,334 |
| M-8 ⁽¹⁾ | 246,311 | 1,760 | 0.33 | 105,331 | 18 ⁽²⁾⁽³⁾ | 1,334 |
| M-9 | 275,333 | 1,698 | 23 ⁽⁴⁾ | 113,302 | 2.7 | 229 |
| M-10 | 204,556 | 1,873 | 5.3 | 68,028 | 0.33 | 1,436 |

- (1) Tests cycles B-2 & B-3, M-1 & M-2, M-4 & M-5 and M-7 & M-8 were performed on the same day using the same control water tank.
- (2) Test cycles where the number of false positives was determined and subtracted from the result obtained on the corresponding treated discharge sample. Live algae were also quantified by measuring the growth of the algae by use of a most probable number assay (MPN assay). The MPN assay results for test cycles M-6, M-7 and M-8 were < 0.18 , 0.18 and 0.19 organism per mL, respectively.
- (3) Test cycle M-8 did not meet the discharge standard for organisms ≥ 10 - $< 50 \mu\text{m}$ when live organisms were quantified by microscopy counting after staining with CMFDA/FDA, but met the discharge standers when using MPN assay (0.19 organism per mL). The test cycle was also considered invalid because no stable flow rate could be obtained during uptake.
- (4) Test cycle M-9 was the only test cycle that did not meet the discharge standard for organisms $\geq 50 \mu\text{m}$. All other test cycles confirmed sufficient biological efficacy for organisms $\geq 50 \mu\text{m}$ by filtration and subsequent UV treatment of the BWMS. The 23 motile organisms per m³ that were detected in the treated discharge appeared to be in the process of dying and would have been dead and no longer motile if analysed at a later point of time.

Shipboard testing

Table 3 Test water conditions and operational parameters in shipboard testing with one of the two Wärtsilä Aquarius UV BWMS AQ-1000-UV (TRC of 1000 m³/h) with a standard Filtersafe filter (BS-400H, 40 µm screen) and a BWT IL +1000 UV installed in parallel on board the bulk carrier MV Paolo Topic (IMO No. 9726256) during the period of July 2017 to June 2018.

| Test cycle | Water temperature [°C] | Salinity [PSU] | UV-T [%] | DOC [mg/L] | POC [mg/L] | TSS [mg/L] | Holding time [hr] | Average UV-I at ballasting [W/m ²] | Average flow rate after filtration [m ³ /h] |
|------------|------------------------|----------------|----------|------------|------------|------------|-------------------|--|--|
| 1 | 23 | 34 | 89 | 1.5 | 0.72 | 14 | 64 | 538 | 997 |
| 2 | 29 | 33 | 93 | 0.89 | 0.46 | 41 | 320 | 393 | 1,002 |
| 3 | 27 | 35 | 75 | 1.1 | 0.81 | 30 | 49 | 157 | 999 |
| 4 | 29 | 32 | 82 | 0.94 | 1.2 | 106 | 39 | 344 | 999 |
| 5 | 28 | 30 | 89 | 0.76 | 0.51 | 7.9 | 35 | 503 | 1,001 |
| 6 | 9.7 | 34 | 88 | 1.2 | 0.19 | 52 | 37 | 486 | 996 |
| 7 | 14 | 0.07 | 86 | 1.8 | 0.19 | 8.9 | 37 | 347 | 995 |
| 8 | 30 | 34 | 97 | 0.89 | 0.19 | 26 | 41 | 802 | 981 |

Table 4 Average numbers of live organisms in inlet and treated discharge water during shipboard testing of the Wärtsilä Aquarius UV BWMS AQ-1000-UV. Live organisms ≥10 and <50 µm were quantified 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 [organism/m ³] | | Organisms ≥10-<50 µm (FDA/CMFDA) [organisms/mL] | |
|------------|---|-------------------|---|-------------------|
| | Influent water | Treated discharge | Influent water | Treated discharge |
| 1 | 17,340 | 32 ⁽¹⁾ | 343 | 0.5 |
| 2 | 19,371 | 13 ⁽¹⁾ | 117 | 1.2 |
| 3 | 36,091 | 10 ⁽¹⁾ | 232 | 1.3 |
| 4 | 7,055 | 0.61 | 568 | 0.33 |
| 5 | 34,158 | 0 | 101 | 0 |
| 6 | 5,358 | 0 | 504 | 1.3 |
| 7 | 29,411 | 0 | 1,080 | 0.17 |
| 8 | 16,125 | 0.18 | 183 | 1.7 |

(1) In the first three shipboard test cycle the number of organism ≥50 µm in the treated discharge did not meet the discharge standard. The detailed analysis of the result of these shipboard test cycles indicated contamination of the ballast water tanks due to sediments in the tank. Disinfection of the ballast water tanks used for shipboard testing was conducted after the first shipboard test cycle. However, significant deposits of silt in the ballast water tanks were still found after shipboard test cycles 2 and 3, and Wärtsilä performed further cleaning of the ballast water tank used for shipboard testing before further shipboard test cycles were conducted.