

# TYPE APPROVAL CERTIFICATE

**This is to certify:****That the Ballast Water Management System**with type designation(s)  
**GloEn-Patrol 2.0 (model range P50-P6000)**

Issued to

**Panasia Co., Ltd.**  
**Busan, Republic of Korea**

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.279(70) - 2016 GUIDELINES FOR APPROVAL OF BALLAST WATER MANAGEMENT SYSTEMS (G8)****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 Guidelines contained in Resolution MEPC.279(70) 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 resolution MEPC.279(70), 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 GL, unless otherwise instructed by relevant Maritime Administrations.****Operating media:**Issued at **Høvik** on **2019-08-16**for **DNV GL**This Certificate is valid until **2024-08-15**.DNV GL local station: **Gimhae Station**Approval Engineer: **Qinglan Wu****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)

GloEn-Patrol 2.0

## Ballast water management system manufactured by

Panasia Co., Ltd.

## Place of production

Busan, Republic of Korea.

## Type and model designations

GloEn-Patrol 2.0: P50, P150, P150-Ex, P250, P250-Ex, P300, P300-Ex, P350, P350-Ex, P500, P500-Ex, P700, P700-Ex, P750, P750-Ex, P750-1, P750-1-Ex, P800, P800-Ex, P800-1, P800-1-Ex, P900, P900-Ex, P900-1, P900-1-Ex, P1000, P1000-Ex, P1000-1, P1000-1-Ex, P1200, P1200-Ex, P1200-1, P1200-1-Ex, P1500, P1500-Ex, P1500-1, P1500-1-Ex, P2000, P2000-Ex, P2000-1, P2000-1-Ex, P2500, P2500-Ex, P2500-1, P2500-1-Ex, P3000, P3000-Ex, P3000-1, P3000-1-Ex, P3500, P3500-Ex, P4000, P4000-Ex, P4500, P4500-Ex, P5000, P5000-Ex, P6000, P6000-Ex

## Equipment / assembly drawings

The GloEn-Patrol 2.0 BWMS shall be installed in accordance with the Operation Maintenance and Safety Manual (OMSM) and the documents as listed below.

| System Type designation | Description                               | Title  | Dwg Nr.     | Rev.              |
|-------------------------|---|--|-------------|-------------------|
| GloEn-Patrol 2.0        | Piping and instrumentation diagram (P&ID) | Piping & instrument diagram (P&ID) (all models) (in OMSM Appendix 4)       | PAD-USCG-03 | H<br>(2019-02-28) |
|                         | General Arrangement Drawings              | BWMS all model drawings (GA) (in OMSM Appendix 3)                          | PAD-USCG-02 | D<br>(2019-08-05) |
|                         | Drawings of components                    | Detailed drawings of all main components (in OMSM Appendix 2)              | PAD-USCG-02 | D<br>(2019-08-05) |
|                         | Electrical wiring diagram                 | GloEn-Patrol Ballast System Electrical wiring diagram (in OMSM Appendix 5) | PAD-USCG-05 | D<br>(2019-02-28) |
|                         | Bill of Material (BoM)                    | GloEn-Patrol Bill of Material (in OMSM Appendix 1)                         | PAD-USCG-01 | G<br>(2019-02-28) |

## Treatment Rated Capacity

50-6000 m<sup>3</sup>/h

## Product description

Treatment sequence:

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

After ballasting or de-ballasting operation, the system shall be cleaned through draining of remaining water from the filter and UV unit after operation.

## System design limitations / Water quality parameters

### Temperature & Salinity

Temperature and salinity of the ballast water are not limiting conditions for the ballast water management system.

## System design limitations / Operational parameters

### Holding time

GloEn-Patrol 2.0 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 system applies a UV dose controlled by flow and UV intensity. The low limit for UV intensity at full flow or half flow treatment is listed below. The system also includes UV-lamp power optimization control at higher UV intensity.

| UV-reactor size [m <sup>3</sup> /h] | UV intensity lower limit in marine or brackish water at full flow (TRC) <sup>1)</sup> | UV intensity lower limit in fresh water at full flow (TRC) <sup>2)</sup> | UV intensity lower limit in all salinities at half flow (50% TRC) <sup>3)</sup> |
|-------------------------------------|---|--|---|
| 50- 6000                            | 70 mW/cm <sup>2</sup>   | 90 mW/cm <sup>2</sup>  | 60 mW/m <sup>2</sup>  |

<sup>1)</sup> UV intensity set point for full flow treatment in marine and brackish water, corresponding to an UV transmission of approx. 55-60%. Below this UV intensity limit, ballast water will automatically be treated with a reduced flow of 50% TRC.

<sup>2)</sup> UV intensity set point for full flow treatment in fresh water, corresponding to an UV transmission of approx. 70%. Below this UV intensity limit, ballast water will be treated with a reduced flow of 50% TRC.

<sup>3)</sup> UV intensity set point for lower limit, corresponding to an UV transmission of approximately 50-55%. Below this UV intensity limit, the ballast water is not treated in accordance with this certificate and alarm will be triggered at  $\leq 59$  mW/cm<sup>2</sup>.

### Treatment Rated Capacity (TRC) of the BWMS

The Treatment Rated Capacities (TRC) of the designated GloEn-Patrol 2.0 BWMS models are listed in the table below. The table also specifies the major components that shall be installed for a specific GloEn-Patrol 2.0 BWMS model.

UV Reactors and filter units can be installed in parallel configuration to achieve higher flow capacities according to the design and installation guide and the table below.

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.

| Model name          | TRC                     | UV unit<br>(number of lamps) | Filter unit |
|---------------------|-------------------------|------------------------------|-------------|
| GloEn-P50           | 50 m <sup>3</sup> /h    | PU50 (2)                     | PF50        |
| GloEn-P150 (-Ex)    | 150 m <sup>3</sup> /h   | PU250 (6)                    | PF250       |
| GloEn-P250 (-Ex)    | 250 m <sup>3</sup> /h   | PU250 (8)                    |             |
| GloEn-P300 (-Ex)    | 300 m <sup>3</sup> /h   | PU250 (12)                   | PF500       |
| GloEn-P350 (-Ex)    | 350 m <sup>3</sup> /h   |                              |             |
| GloEn-P500 (-Ex)    | 500 m <sup>3</sup> /h   | PU500 (18)                   | PF750       |
| GloEn-P700 (-Ex)    | 700 m <sup>3</sup> /h   | PU500 (24)                   |             |
| GloEn-P750 (-Ex)    | 750 m <sup>3</sup> /h   | PU1000 (22)                  |             |
| GloEn-P750-1 (-Ex)  | 750 m <sup>3</sup> /h   | PU250 (8) + PU500 (18)       |             |
| GloEn-P800 (-Ex)    | 800 m <sup>3</sup> /h   | PU1000 (22)                  | PF900       |
| GloEn-P800-1 (-Ex)  | 800 m <sup>3</sup> /h   | PU250 (12) + PU500 (18)      | 2 x PF500   |
| GloEn-P900 (-Ex)    | 900 m <sup>3</sup> /h   | PU1000 (22)                  | PF900       |
| GloEn-P900-1 (-Ex)  | 900 m <sup>3</sup> /h   | 2 x PU500 (18)               | 2 x PF500   |
| GloEn-P1000 (-Ex)   | 1,000 m <sup>3</sup> /h | PU1000 (22)                  | PF1200      |
| GloEn-P1000-1 (-Ex) | 1,000 m <sup>3</sup> /h | 2 x PU500 (18)               | 2 x PF500   |
| GloEn-P1200 (-Ex)   | 1,200 m <sup>3</sup> /h | PU1250 (26)                  | PF1200      |
| GloEn-P1200-1 (-Ex) | 1,200 m <sup>3</sup> /h | 2 x PU500 (24)               | 2 x PF750   |
| GloEn-P1500 (-Ex)   | 1,500 m <sup>3</sup> /h | PU1500 (32)                  | PF1500      |
| GloEn-P1500-1 (-Ex) | 1,500 m <sup>3</sup> /h | 3 x PU500 (18)               | 3 x PF500   |
| GloEn-P2000 (-Ex)   | 2,000 m <sup>3</sup> /h | 2 x PU1000 (22)              | PF2000      |
| GloEn-P2000-1 (-Ex) | 2,000 m <sup>3</sup> /h | 3 x PU500 (24)               | 3 x PF750   |
| GloEn-P2500 (-Ex)   | 2,500 m <sup>3</sup> /h | 2 x PU1250 (26)              | PF2500      |
| GloEn-P2500-1(-Ex)  | 2,500 m <sup>3</sup> /h | 4 x PU500 (24)               | PF2500      |
| GloEn-P3000 (-Ex)   | 3,000 m <sup>3</sup> /h | 2 x PU1500 (32)              | PF3000      |
| GloEn-P3000-1 (-Ex) | 3,000 m <sup>3</sup> /h | 6 x PU500 (18)               | PF3000      |
| GloEn-P3500 (-Ex)   | 3,500 m <sup>3</sup> /h | 3 x PU1250 (26)              | 3 x PF1200  |
| GloEn-P4000 (-Ex)   | 4,000 m <sup>3</sup> /h | 3 x PU1500 (32)              | 3 x PF1500  |
| GloEn-P4500 (-Ex)   | 4,500 m <sup>3</sup> /h | 3 x PU1500 (32)              | 3 x PF1500  |
| GloEn-P5000 (-Ex)   | 5,000 m <sup>3</sup> /h | 4 x PU1250 (26)              | 2 x PF2500  |
| GloEn-P6000 (-Ex)   | 6,000 m <sup>3</sup> /h | 4 x PU1500 (32)              | 2 x PF3000  |

**NOTE:**

This table shows general system configuration as recommended by the manufacturer. A GloEn-Patrol 2.0 BWMS model may be used with a larger filter unit than specified above. The maximum TRC of any configuration is determined by either the maximum capacity of the UV unit or the filter unit, whichever is smaller.

**Pressure**

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

| <b>Filter type</b> | <b>Minimum inlet pressure (back-pressure)</b> | <b>Differential pressure triggering backflushing</b> | <b>Max operating pressure</b> |
|--------------------|---|--|-------------------------------|
| Panasia PF         | >1 Bar  | ≥ 0.1 Bar  | 10 Bar                        |

The GloEn-Patrol 2.0 BWMS filter and UV unit are classified as Pressure Vessel Class III. Certificate of the pressure vessel shall be provided for each installation according to class requirements.

**Control and monitoring equipment**

**Software version**

The GloEn-Patrol 2.0 BWMS is type approved with the system control software versions: V3.30. or V3.30.1 (when using alternative HMI TP1200 from SIEMENS). Any changes to the software are to be recorded as long as the system is in use onboard. Major changes in the software, as defined in the Software Quality Procedure Document PAR-SQ-01 (Rev A), require approval. Testing of the application functions of the revised software may be required.

**Safety measures**

The BWMS is type approved with the following instruments for monitoring the safe operation of the BWMS:

- Temperature transmitter (TT, mounted in UV unit)
- Pressure transmitter (PT, installed at the inlet and outlet of filter unit)
- Flow meter (mounted before or after each UV unit)
- Temperature switch for non-Ex-proof UV chamber (TS, mounted on surface of UV unit)
- Flow switch for Ex-proof UV chamber (FS, mounted in UV unit)
- In case of horizontal installation of UV chamber, a vent valve is installed on top of UV unit to release possible pressure if temperature inside UV chamber is too high.

**Electrical and electronic components**

The GloEn-Patrol 2.0 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 specified on the Bill of Material. Except for the components listed below, alternate models to the ones specified on the component lists 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 shall be used:

| <b>Component name</b>           | <b>Manufacturer</b> | <b>Model(s)</b>                                |
|---------------------------------|---------------------|--|
| Control panel                   | PANASIA             | PCP-8W<br>PCP-8S<br>PCP-14S                    |
| UV power supply panel           | PANASIA             | PBP-7XEB<br>PBP-10XEB<br>PBP14XEB<br>PBP-20XEB |
| Repeat panel for remote control | PANASIA             | PRP  |
| UV intensity transmitter        | IL Metronic         | SUV20.2 Y2 C                                   |

## **Hazardous area / Ex-proof**

The GloEn-Patrol 2.0 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, valves and flowmeters have Ex-certification and can be installed in hazardous area zone 1, gas group IIC and temperature class T4, but the electrical supply and control systems 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 is to be submitted for each BWMS installation:

- Piping and Instrumentation Diagram (P&ID) of the ballast system including the treatment system installation
- Power supply arrangement
- Interface description towards the ship's existing systems including alarms for failure
- Description confirming the arrangement of alarms for bypass of the BWMS system (as part of Ballast Water Management Plan)
- List of Ex equipment according to Pt.4 Ch.8 Sec.11 if the system is to be installed in hazardous zone

## **Type Approval documentation**

### **Biological test plan and test reports**

- Final Land-based Ballast Water Management Report According to USCG Final Rule - Panasia GloEn Patrol-250 BWMS, by Golden Bear Facility, US, 2017-12-19.
- Biological efficacy performance evaluation of Ballast Water Management System GloEn Patrol in land-based test, by DHI, Denmark, 2018-03-27.
- Biological efficacy performance evaluation of PANASIA GloEn Patrol Ballast Water Management Systems in shipboard test, by DHI, Denmark, 2018-03-28.
- Biological efficacy performance evaluation of Ballast Water Management System GloEn-Patrol in land-based test - Supplementary Study, by DHI, Denmark, 2019-03-04.
- TQAP GloEn P250 BWMS land-based test plan, by Golden Bear Facility, US, 2015-10-23.
- Test Plan - Biological efficacy performance evaluation of Ballast Water Management System GloEn Patrol in land-based test, by DHI, Denmark, 2017-03-20.
- Test Plan - Biological efficacy performance evaluation of PANASIA GloEn Patrol Ballast Water Management Systems in shipboard test, by DHI, Denmark, 2016-09-23.

### **Environmental test reports**

- Summary for environmental testing Doc No. STA R16 0001, by SGS, 2017-12-21, Rev02.
- Summary for environmental testing Doc No. STA R18 0001 (flow switch), by SGS, 2019-03-26 Rev.0.
- Report on additional environmental testing for IMO TA, PU1000 Environmental test, KOMERI-P-24-03(9) by KOMERI, 2014-01-16.
- Report on additional environmental testing for IMO TA, P1250, P1500 Environmental test reports, by SGS, 2015-12-24/2016-01-06.
- Test Report for Panasia PCP -14S, report No. SGS-R18-1520-EN00, by SGS, 2018-08-08.

- Test report for conductivity sensor and transmitter, report No. SGS-R19-1719-EN00, 1720-EN00, 1736-EN00, 1737-EN00, dated 2019-07-30; and SGS-E19-0049, 0050, 0057 and 0058; dated July 2019.

### **System descriptive documentation**

- GloEn-Patrol 2.0 Instruction manual PAD-USCG-07 (OMSM, Rev Q, 2019-07-15) by Panasia.
- ISO Management System Certificate by DNV GL, ISO 9001:2015, ISO 14001:2015 and OHSAS 18001:2007.
- GloEn-Patrol Functional Specification, Doc no. PAR-USCG-02, Rev G, dated 2019-02-28.
- UV lamp emission test report by Panasia, PA-ET-201905, dated 2019-06-11.
- CFD report 1 Performance analysis of UV sterilizer and design support of optimal layout for BWTS (60% and 75% UV transmittance) by KOMERI, dated 2015-07-23.
- CFD report 2 Performance analysis of UV sterilizer about transmittance changes and elbow pipe by KOMERI, dated 2015-11-20.
- CFD report 3 Analysis on irradiation of UV reactor (55% of transmittance) by KOMERI, dated 2016-02-19.
- CFD report 4 Analysis on irradiation of UV reactor (full flow at UVT=70% and half flow at UVT=55%) by KOMERI , dated 2018-02-27.
- Mathematical calculation for filter scaling, PAD-TP-06, Rev 1.1.

### **Commissioning procedures**

- Onboard test procedures, PAD-OTP-01, Rev. B-2, dated 2019-08-12, GloEn-Patrol Ballast Water Treatment System, Valid for GloEn-Patrol 2.0.

### **Tests carried out**

- Land-based testing using GloEn-P250 model with PF250 filter and PU250(8) UV reactor at GBF in accordance with Resolution MEPC.279(70) and USCG 46 CFR 162.060-26
- Land-based testing using GloEn-P250 model with PF250 filter and PU250(8) UV reactor at DHI Denmark in accordance with Resolution MEPC.279(70) and USCG 46 CFR 162.060-26
- Shipboard testing using GloEn-P1000 model with PF1200 filter and PU1000 UV reactor in accordance with Resolution MEPC.279(70) and USCG 46 CFR 162.060-28
- Function tests of the control and automation system witnessed by DNV GL
- Environmental testing in accordance with DNVGL-CG-0339 Standard for Certification Nov. 2015 "Environmental test specification for electrical, electronic and programmable equipment and systems", Resolution MEPC.279(70), USCG 46 CFR 162.060-30 and IACS E10
- Additional tests for validation of CFD model during land-based testing at DHI

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

Job Id: **262.1-031899-1**  
Certificate No: **TAP00001VN**

## **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 1: SUMMARY OF TESTING

### Summary of land-based testing for GloEn-Patrol BWMS

**Table 1** Test water conditions and operational data obtained during land-based testing of the GloEn-P250 BWMS with Pania PF250 filter with a 50 µm mesh size and PU250(8) UV reactor, performed in period October 2015 to August 2017 at the GBF in USA and at DHI in Denmark. All water quality data are inlet samples and operational data are from ballasting operations.

| Test cycle                        | Salinity (PSU) | Temp. (°C) | POC (mg/L) | DOC (mg/L) | TSS (mg/L) | UVT (%) | UVI range <sup>(1)</sup> (mW/cm <sup>2</sup> ) | Average flowrate (m <sup>3</sup> /h) |              | Holding time (days) |
|-----------------------------------|----------------|------------|------------|------------|------------|---------|--|--------------------------------------|--------------|---------------------|
|                                   |                |            |            |            |            |         |  | Before filter                        | After filter |                     |
| <b>Marine water test cycles</b>   |                |            |            |            |            |         |  |                                      |              |                     |
| KLB1                              | 25             | 19         | 6.8        | 5.4        | 59         | 59      | 53   | 260                                  | 250          | 3                   |
| KLB2                              | 25             | 19         | 7.5        | 7.2        | 57         | 59      | 56   | 260                                  | 250          | 3                   |
| KLB3                              | 25             | 18         | 6.7        | 6.1        | 66         | 60      | 59   | 260                                  | 251          | 3                   |
| KLB4                              | 25             | 18         | 7.9        | 7.2        | 65         | 59      | 57   | 260                                  | 247          | 3                   |
| KLB5                              | 25             | 16         | 8.1        | 7.1        | 60         | 61      | 54   | 260                                  | 250          | 3                   |
| KLB6                              | 25             | 16         | 10.6       | 12         | 66         | 50      | 52   | 200                                  | 178          | 3                   |
| KLB7                              | 24             | 14         | 7.8        | 7.6        | 98         | 58      | 65   | 260                                  | 249          | 3                   |
| KLB8                              | 24             | 14         | 6.8        | 6.7        | 88         | 59      | 67   | 260                                  | 249          | 3                   |
| M-1                               | 28             | 9.0        | 6.5        | 9.9        | 48         | 67      | 82-84  | 264                                  | 248          | 1                   |
| M-2                               | 28             | 9.4        | 6.5        | 9.9        | 48         | 67      | 87-88  | 266                                  | 247          | 1                   |
| M-3                               | 28             | 19         | 7.3        | 8.0        | 44         | 69      | 76-85  | 134                                  | 125          | 2                   |
| M-4                               | 27             | 19         | 7.3        | 8.0        | 44         | 69      | 76-82  | 134                                  | 126          | 2                   |
| <b>Brackish water test cycles</b> |                |            |            |            |            |         |  |                                      |              |                     |
| B-1                               | 17             | 5.3        | 8.3        | 8.0        | 68         | 71      | 94-96  | 280                                  | 245          | 1                   |
| B-2                               | 17             | 5.5        | 8.3        | 8.0        | 68         | 71      | 93-97  | 273                                  | 240          | 1                   |
| B-3                               | 19             | 7.6        | 7.4        | 8.3        | 67         | 62      | 96-100   | 263                                  | 243          | 1                   |
| B-4                               | 19             | 7.9        | 7.5        | 7.6        | 57         | 63      | 97-100   | 260                                  | 247          | 5                   |
| B-5                               | 19             | 8.0        | 7.5        | 7.6        | 57         | 63      | 95-99  | 260                                  | 249          | 5                   |
| B-6                               | 17             | 17         | 7.4        | 8.5        | 58         | 64      | 87-90  | 263                                  | 247          | 2                   |
| B-7                               | 18             | 17         | 7.3        | 11         | 56         | 58      | 63-70  | 129                                  | 122          | 2                   |
| B-8                               | 18             | 17         | 7.3        | 11         | 56         | 58      | 63-68  | 130                                  | 126          | 2                   |
| <b>Fresh water test cycles</b>    |                |            |            |            |            |         |  |                                      |              |                     |
| F-1                               | 0.4            | 16         | 5.8        | 7.2        | 59         | 49      | 65-68  | 134                                  | 125          | 5                   |
| F-2                               | 0.4            | 16         | 5.8        | 7.2        | 59         | 49      | 66-67  | 134                                  | 124          | 5                   |
| F-3                               | 0.4            | 18         | 6.6        | 6.8        | 71         | 47      | 59-61  | 140                                  | 122          | 5                   |

| Test cycle | Salinity (PSU) | Temp. (°C) | POC (mg/L) | DOC (mg/L) | TSS (mg/L) | UVT (%) | UVI range <sup>(1)</sup> (mW/cm <sup>2</sup> ) | Average flowrate (m <sup>3</sup> /h) |              | Holding time (days) |
|------------|----------------|------------|------------|------------|------------|---------|--|--------------------------------------|--------------|---------------------|
|            |                |            |            |            |            |         |  | Before filter                        | After filter |                     |
| F-4        | 0.4            | 16         | 5.8        | 6.0        | 69         | 52      | 58-69  | 140                                  | 124          | 2                   |
| F-5        | 0.4            | 16         | 5.8        | 6.0        | 69         | 52      | 59-67  | 139                                  | 125          | 2                   |
| F-6        | 0.4            | 17         | 5.6        | 6.4        | 64         | 52      | 58-64  | 139                                  | 126          | 5                   |
| F-7        | 0.4            | 17         | 5.6        | 6.4        | 64         | 52      | 58-62  | 139                                  | 125          | 5                   |

(1) For test cycles KLB1 to KLB8 performed at GBF, only average UV-I values are available from the test report; For the test cycles performed at DHI, the UV-I range measured and logged during stable ballasting operation conditions are reported.

**Table 2** Average densities of live organisms in inlet and treated discharge water during land-based testing of the GloEn-P250 BWMS with PF250 filter with a 50 µm mesh size and PU250(8) UV reactor. Live organisms ≥10 and <50 µm in inlet water were quantified based on CMFDA/FDA, and in discharge water based on MPN method. All counts of pathogenic bacteria (*E. coli*, *Enterococci* and *Vibrio cholerae*) in treated water were below the ballast water discharge standard. Tests were performed in period October 2015 to August 2017 at the GBF in USA and at DHI in Denmark.

| Test #                            | Organism densities in inlet water |                     | Organisms densities in discharge water |         |                     |                        |
|-----------------------------------|-----------------------------------|---------------------|--|---------|---------------------|------------------------|
|                                   | ≥50 µm (org/m <sup>3</sup> )      | ≥10-<50 µm (org/mL) | ≥50 µm (org/m <sup>3</sup> )           |         | ≥10-<50 µm (org/mL) |                        |
|                                   |                                   |                     | Treated                                | Control | Treated             | Control <sup>(1)</sup> |
| <b>Marine water test cycles</b>   |                                   |                     |  |         |                     |                        |
| KLB1                              | 171,313                           | 1,723               | 0.1                                    | 202,424 | <0.08               | 227                    |
| KLB2                              | 183,434                           | 1,360               | 0.1                                    | 202,424 | <0.08               | 227                    |
| KLB3 <sup>(2)</sup>               | 291,717                           | 1,064               | 3.8                                    | 77,677  | <0.08               | 91.7                   |
| KLB4 <sup>(2)</sup>               | 307,273                           | 1,230               | 5.6                                    | 77,677  | <0.08               | 91.7                   |
| KLB5                              | 144,949                           | 4,630               | 4.9                                    | 172,525 | 0.3                 | 329                    |
| KLB6                              | 197,879                           | 3,050               | 4.2                                    | 172,525 | 0.46                | 329                    |
| KLB7 <sup>(3)</sup>               | 102,626                           | 2,783               | 16                                     | 97,980  | 0.21                | 240                    |
| KLB8 <sup>(3)</sup>               | 135,960                           | 2,410               | 16                                     | 97,980  | <0.08               | 240                    |
| M-1                               | 152,892                           | 2,810               | 2.0                                    | 118,290 | 0.87                | 1,373                  |
| M-2                               | 195,800                           | 3,297               | 0.0                                    | 118,290 | <0.18               | 1,373                  |
| M-3 <sup>(4)</sup>                | 186,914                           | 1,146               | 0.0                                    | 21,877  | 0.19                | >1,600                 |
| M-4 <sup>(4)</sup>                | 197,417                           | 1,394               | 0.0                                    | 21,877  | <0.18               | >1,600                 |
| <b>Brackish water test cycles</b> |                                   |                     |  |         |                     |                        |
| B-1 <sup>(5)</sup>                | 96,947                            | 2,593               | 0                                      | 52,936  | <0.18               | 374                    |
| B-2 <sup>(5)</sup>                | 92,728                            | 2,693               | 0                                      | 52,936  | <0.18               | 374                    |
| B-3                               | 118,625                           | 1,320               | 0.3                                    | 36,906  | <0.18               | >1,600                 |
| B-4                               | 240,644                           | 1,186               | 0                                      | 70,355  | <0.18               | >1,600                 |
| B-5                               | 257,959                           | 1,188               | 0                                      | 70,355  | <0.18               | >1,600                 |
| B-6                               | 246,347                           | 1,072               | 0.7                                    | 164,600 | <0.18               | >1,600                 |

| Test #                         | Organism densities in inlet water |                     | Organisms densities in discharge water |         |                     |                        |
|--------------------------------|-----------------------------------|---------------------|--|---------|---------------------|------------------------|
|                                | ≥50 µm (org/m <sup>3</sup> )      | ≥10-<50 µm (org/mL) | ≥50 µm (org/m <sup>3</sup> )           |         | ≥10-<50 µm (org/mL) |                        |
|                                |                                   |                     | Treated                                | Control | Treated             | Control <sup>(1)</sup> |
| B-7                            | 284,514                           | 2,560               | 7.7                                    | 118,324 | <0.18               | 1,373                  |
| B-8                            | 425,972                           | 2,692               | 0.7                                    | 118,324 | <0.18               | 1,373                  |
| <b>Fresh water test cycles</b> |                                   |                     |  |         |                     |                        |
| F-1 <sup>(6)</sup>             | 421,222                           | 575                 | 4.7                                    | 265,099 | <0.18               | 1,147                  |
| F-2 <sup>(6)</sup>             | 463,070                           | 558                 | 0.0                                    | 265,099 | <0.18               | 1,147                  |
| F-3                            | 812,383                           | 1,864               | 0.3                                    | 469,261 | <0.18               | 540                    |
| F-4                            | 240,097                           | 1,596               | 0.3                                    | 243,572 | <0.18               | >1600                  |
| F-5                            | 224,958                           | 1,578               | 0.3                                    | 243,572 | <0.18               | >1600                  |
| F-6                            | 310,117                           | 1,206               | 0.0                                    | 213,662 | 0.56                | 377                    |
| F-7 <sup>(5)</sup>             | 304,889                           | 900                 | 0.0                                    | 213,662 | <0.18               | 377                    |

- (1) While for control discharge the MPN results are presented (except test cycles KLB1 to KLB8), the control discharge samples were also compliant (>100 organisms/mL) after enumeration with microscopy counting after staining with FDA/CMFDA. For test cycles KLB1 to KLB8, the results in FDA/CMFDA are presented (no MPN data are available for control discharge).
- (2) For test cycles KLB3 and KLB4, the organisms density in control discharge was 8% less than the required value of 100 org/mL for the ≥10 - <50 µm size class.
- (3) Test cycles KLB7 & KLB8 were performed with a filter differential pressure setpoint of 0.5 bar for activating backflushing, which is outside the System Design Limit (SDL). All the other test cycles were performed with a setpoint of 0.1 bar as specified in the final claim. Damage on filter screen was observed after the test.
- (4) Test cycles M-3 and M-4 were performed with a UV-I reading of 76 - 85 mW/cm<sup>2</sup> at a half flow, under a set point of 90 mW/cm<sup>2</sup> for flow reduction, which is higher than the final SDL of 70 mW/cm<sup>2</sup> for GloEn-Patrol 2.0.
- (5) For test cycles B-1 and B-2, the organisms density in inlet water was 3% and 7% less than the required value of 100,000 org/m<sup>3</sup> for the >50 µm size class. For test cycle F-7, the organisms density in inlet water was 10% less than the required value of 1000 org/mL.
- (6) For test cycles F-1 & F-2, the density of live organisms 10-50 µm in the inlet water was significantly below the required value of 100 org/ml, hence these test cycles were repeated and replaced by F-3 and F-4.

**Summary of additional land-based testing for GloEn-Patrol 2.0 BWMS**

**Table 3** Test water conditions and operational data obtained during additional land-based testing of the GloEn-P250 BWMS with Panasia PF250 filter with a 50 µm mesh size and PU250(8) UV reactor, performed in period September 2017 to July 2018 at DHI in Denmark. All water quality data are inlet samples and operational data are from ballasting operations.

| Test cycle                        | Salinity (PSU) | Temp. (°C) | POC (mg/L) | DOC (mg/L) | TSS (mg/L) | UVT <sup>(1)</sup> (%) | UVI range <sup>(1)</sup> (mW/cm <sup>2</sup> ) | Average flowrate (m <sup>3</sup> /h) |              | Holding time (days) |
|-----------------------------------|----------------|------------|------------|------------|------------|------------------------|--|--------------------------------------|--------------|---------------------|
|                                   |                |            |            |            |            |                        |  | Before filter                        | After filter |                     |
| <b>Marine water test cycles</b>   |                |            |            |            |            |                        |  |                                      |              |                     |
| M-5                               | 28             | 4.3        | 6.5        | 7.5        | 60         | 74                     | 107-109  | 281                                  | 246          | 1                   |
| M-6                               | 28             | 4.4        | 6.5        | 7.5        | 60         | 74                     | 106-108  | 282                                  | 246          | 1                   |
| <b>Brackish water test cycles</b> |                |            |            |            |            |                        |  |                                      |              |                     |
| B-9                               | 18             | 16         | 7.9        | 12         | 56         | 55                     | 66-70  | 257                                  | 252          | 1                   |
| B-10                              | 18             | 16         | 7.9        | 12         | 56         | 55                     | 66-69  | 253                                  | 243          | 1                   |
| B-11                              | 18             | 18         | 5.9        | 11         | 49         | 56                     | 64-70  | 275                                  | 248          | 1                   |
| B-12                              | 18             | 19         | 5.9        | 11         | 49         | 56                     | 67-69  | 277                                  | 248          | 1                   |
| <b>Fresh water test cycles</b>    |                |            |            |            |            |                        |  |                                      |              |                     |
| F-8                               | <1.0           | 15         | 6.4        | 7.9        | 66         | 54                     | 73-79  | 275                                  | 246          | 1                   |
| F-9                               | <1.0           | 15         | 6.4        | 7.9        | 66         | 54                     | 73-79  | 276                                  | 251          | 1                   |
| F-10                              | <1.0           | 9.2        | 6.8        | 6.3        | 57         | 58                     | 77-82  | 152                                  | 125          | 1                   |
| F-11                              | <1.0           | 9.3        | 6.8        | 6.3        | 57         | 58                     | 76-81  | 150                                  | 125          | 1                   |
| F-12                              | <1.0           | 22         | 7.2        | 7.8        | 65         | 52                     | 64-65  | 301                                  | 254          | 1                   |
| F-13                              | <1.0           | 22         | 7.2        | 7.8        | 65         | 52                     | 63-65  | 292                                  | 251          | 1                   |
| F-14                              | <1.0           | 21         | 6.1        | 7.7        | 56         | 63                     | 82-86  | 141                                  | 124          | 1                   |
| F-15                              | <1.0           | 21         | 6.1        | 7.7        | 56         | 63                     | 80-84  | 140                                  | 126          | 1                   |
| F-16                              | <1.0           | 22         | 8.0        | 7.0        | 69         | 55                     | 73-75  | 278                                  | 249          | 1                   |
| F-17                              | <1.0           | 22         | 8.0        | 7.0        | 69         | 55                     | 72-74  | 285                                  | 251          | 1                   |

(1) The UV-I range measured and logged during stable ballasting operation conditions are reported.

**Table 4** Average densities of live organisms in inlet and treated discharge water during additional land-based testing of the GloEn-P250 BWMS with PF250 filter with a 50 µm mesh size and PU250(8) UV reactor. Live organisms ≥10 and <50 µm in inlet water were quantified based on CMFDA/FDA, and in discharge water based on MPN method. All counts of pathogenic bacteria (*E. coli*, *Enterococci* and *Vibrio cholerae*) in treated water were below the ballast water discharge standard. Tests were performed in period September 2017 to July 2018 at DHI in Denmark.

| Test #                            | Organism densities in inlet water |                     | Organisms densities in discharge water |         |                     |                        |
|-----------------------------------|-----------------------------------|---------------------|--|---------|---------------------|------------------------|
|                                   | ≥50 µm (org/m <sup>3</sup> )      | ≥10-<50 µm (org/mL) | ≥50 µm (org/m <sup>3</sup> )           |         | ≥10-<50 µm (org/mL) |                        |
|                                   |                                   |                     | Treated                                | Control | Treated             | Control <sup>(1)</sup> |
| <b>Marine water test cycles</b>   |                                   |                     |  |         |                     |                        |
| M-5                               | 117,217                           | 1,188               | 0.0                                    | 90,878  | <0.18               | 1,600                  |
| M-6                               | 100,950                           | 1,263               | 0.3                                    | 90,878  | <0.18               | 1,600                  |
| <b>Brackish water test cycles</b> |                                   |                     |  |         |                     |                        |
| B-9 <sup>(2)</sup>                | 117,177                           | 1,170               | 519                                    | 76,422  | 9.2                 | >1,600                 |
| B-10 <sup>(2)</sup>               | 153,117                           | 1,216               | 634                                    | 76,422  | 1.9                 | >1,600                 |
| B-11                              | 394,672                           | 2,324               | 1.7                                    | 110,106 | 2.3                 | >1,600                 |
| B-12                              | 456,067                           | 2,322               | 0.7                                    | 110,106 | 1.9                 | >1,600                 |
| <b>Fresh water test cycles</b>    |                                   |                     |  |         |                     |                        |
| F-8 <sup>(3)</sup>                | 452,900                           | 1,214               | 19                                     | 178,185 | 4.0                 | 1,147                  |
| F-9 <sup>(3)</sup>                | 366,461                           | 1,254               | 47                                     | 178,185 | 2.7                 | 1,147                  |
| F-10                              | 158,722                           | 4,053               | 1.3                                    | 134,018 | 2.4                 | >1,600                 |
| F-11                              | 140,042                           | 3,731               | 0.3                                    | 134,018 | 3.0                 | >1,600                 |
| F-12                              | 974,361                           | 1,593               | 5.3                                    | 223,424 | 5.3                 | 1,373                  |
| F-13 <sup>(4)</sup>               | 790,000                           | 1,544               | 17                                     | 223,424 | 9.8                 | 1,373                  |
| F-14                              | 450,545                           | 1,927               | 2.0                                    | 205,335 | <0.18               | >1,600                 |
| F-15                              | 665,278                           | 2,038               | 0.0                                    | 205,335 | 0.67                | >1,600                 |
| F-16 <sup>(3)</sup>               | 936,750                           | 1,012               | 25                                     | 322,743 | 3.3                 | >1,600                 |
| F-17 <sup>(3)</sup>               | 752,889                           | 1,147               | 19                                     | 322,743 | 4.2                 | >1,600                 |

- (1) While for control discharge the MPN results are presented, the control discharge samples were also compliant (>100 organisms/mL) after enumeration with microscopy counting after staining with FDA/CMFDA.
- (2) During test cycles B-9 & B-10, the wiper for cleaning of UV lamp sleeves was operating continuously during ballasting, causing improper lower UV irradiation. This was due to an error in the setting of the software program. The error was corrected after these two tests cycles.
- (3) Test cycles F-8, F-9, F-16 & F-17 were performed outside the final SDL (UV-I of 90 mW/cm<sup>2</sup> for full flow treatment) in fresh water.
- (4) During the test cycle F-13, the BWMS stopped during ballasting due to fuel shortage on the power generator, leading untreated water entering test tank.

### Shipboard testing

**Table 5** Results from shipboard testing of GloEn-Patrol BWMS, model GloEn-P1000 on board WOYANG BANDERS in the period September 2016 to November 2017. Test conditions: salinity: 33–37 PSU, Temp: 14–30 °C, holding time: 1 day. Live organisms  $\geq 10$  and  $< 50 \mu\text{m}$  in discharge water were quantified based on FDA/CMFDA method.

| Test #               | UVT (%) | Flow rate <sup>(1)</sup> (m <sup>3</sup> /h) | UV-I (mW/cm <sup>2</sup> ) | Inlet density                               |   | Discharge density                           |   |                    |
|----------------------|---------|--|----------------------------|---|---|---|---|--------------------|
|                      |         |  |                            | $\geq 50 \mu\text{m}$ (org/m <sup>3</sup> ) | $\geq 10$ - $< 50 \mu\text{m}$ (org/mL) | $\geq 50 \mu\text{m}$ (org/m <sup>3</sup> ) | $\geq 10$ - $< 50 \mu\text{m}$ (org/mL) | $< 10 \mu\text{m}$ |
| No. 1 <sup>(2)</sup> | 98      | 1,011  | 74                         | 6,655                                       | 29                                      | 3.3   | 0.67                                    | Pass               |
| No. 2                | 71      | 995  | 93                         | 11,973                                      | 205                                     | 6.8   | 0.83                                    | Pass               |
| No. 3                | 92      | 1,005  | 97                         | 33,790                                      | 2,073                                   | 1.1   | 0.33                                    | Pass               |
| No. 4                | 92      | 1,011  | 115                        | 105,613                                     | 732                                     | 0.5   | 1.3                                     | Pass               |
| No. 5                | 92      | 1,008  | 108                        | 231,301                                     | 682                                     | 0.8   | 2.0                                     | Pass               |
| No. 6 <sup>(3)</sup> | 94      | 982  | 106                        | 25,281                                      | 92                                      | 8.6   | 1.3                                     | Pass               |

- (1) Average flow rate after filtration during ballast operation of treated water.  
 (2) The density of live organisms  $\geq 10$ - $< 50 \mu\text{m}$  in the inlet water was significantly below the validity criterion, hence the test cycle was repeated.  
 (3) For test cycle No.6, density of live organisms  $\geq 10$ - $< 50 \mu\text{m}$  in inlet water was 8% less than of the required value of 100 org/mL.

### Supporting data for evaluation of regrowth in marine water

**Table 6** Results from land-based testing of GloEn Patrol BWMS, GloEn-P250 at KOMERI in November 2015. Test cycles were performed with marine water quality and a hold time of 5 days. Test conditions: Temp: 30–33° C, salinity: 32 – 33 PSU, Live organisms  $\geq 10$  and  $< 50 \mu\text{m}$  in discharge water were quantified based on FDA/CMFDA method.

| Test # | UVT (%) | Flow rate <sup>(1)</sup> (m <sup>3</sup> /h) | UV-I (mW/cm <sup>2</sup> ) | Inlet density                               |   | Discharge density                           |   |                    |
|--------|---------|--|----------------------------|---|---|---|---|--------------------|
|        |         |  |                            | $\geq 50 \mu\text{m}$ (org/m <sup>3</sup> ) | $\geq 10$ - $< 50 \mu\text{m}$ (org/mL) | $\geq 50 \mu\text{m}$ (org/m <sup>3</sup> ) | $\geq 10$ - $< 50 \mu\text{m}$ (org/mL) | $< 10 \mu\text{m}$ |
| No. 1  | 53.2    | 235±9  | 64±12                      | 113,667                                     | 1,361                                   | 0±0.0                                       | 0.5±0.7                                 | Pass               |
| No. 2  | 51.5    | 238±5  | 51±1                       | 118,556                                     | 1,349                                   | 0±0.0                                       | 1.5±0.9                                 | Pass               |
| No. 3  | 47.8    | 233±4  | 46±1                       | 107,000                                     | 1,131                                   | 0±0.0                                       | 0.0±0.0                                 | Pass               |