

SHORT FORM REPORT

SFR-MVK-001009

Boat Earthing / Anode Connection Test Report

Prepared By: JST Services Co. Ltd

Date: 7 September 2026

Location/Vessel	Ocean Marina Jomtien - MV Kaloda
Test date	4 September 2026
Recorded by	Pakpoom C.
Source record	Handwritten Notes - 4 September 2026
Condition 1	AC shore power supply connected
Condition 2	AC shore power disconnected; vessel operating from onboard power sources
Reference electrode type	Silver/silver chloride (Ag/AgCl)

1. Purpose

This report presents the measurements recorded during the boat earthing and sacrificial anode connection tests carried out on 4 September 2026. Boat-to-seawater AC and DC potentials were measured prior to connection of a single 30 kg zinc alloy sacrificial anode. The anode was subsequently connected to the boat's internal earthing bar and the resulting AC/DC current flow and boat-to-seawater potentials were measured under both shore-power and onboard-power operating conditions.

The primary purpose of the testing was to assess the electrical condition of the boat's internal earthing system relative to seawater, to evaluate the influence of the AC shore power connection, and to determine the response of the earthing system when a known external zinc sacrificial anode was deliberately connected directly to the internal earthing bar. The test was not intended to assume or demonstrate that the boat's existing transom-mounted zinc anodes were electrically connected to the internal earthing system.

2. Base Data

Parameter	Value
Sacrificial anode	30 kg zinc alloy sacrificial anode, approximately 1,000 mm long, trapezoidal cross-section with nominal maximum dimensions approximately 70 x 70 mm, incorporating a steel core and complete with approximately 35 m of 10 mm ² single-core copper cable tail.
Seawater resistivity (assumed)	25 $\Omega \cdot \text{cm}$
Calculated anode resistance	0.149 Ω
Indicative native potential - bare steel	approximately -0.60 V vs Ag/AgCl
Indicative native potential - naval brass	approximately -0.35 V vs Ag/AgCl
Approximate maximum anode output	3 A DC

3. Test Equipment

- 1 x Fluke 1797 multimeter
- 1 x Silvion silver/silver chloride (Ag/AgCl) reference electrode
- 1 x Hioki clamp meter (AC/DC)
- 1 x Standard test lead set

4. Test Arrangement and Methodology

The zinc sacrificial anode was placed in the seawater adjacent to the boat while the vessel was alongside the dock.

4.1 Test 1 - Anode Disconnected: As-Found Boat AC/DC Potentials to Seawater

Prior to electrically connecting the zinc sacrificial anode to the boat's internal earthing bar, the as-found boat-to-seawater DC potential was measured. The measurement was taken using a digital multimeter set to the DC voltage range, with the positive terminal connected directly to the boat's earthing bar and the negative terminal connected to a silver/silver chloride (Ag/AgCl) reference electrode immersed in the seawater adjacent to the boat.

Following completion of the DC potential measurement, the AC potential between the boat and seawater was measured using the same test connections, with the multimeter changed to the AC voltage range.

The recorded DC potential represented the as-found potential of the boat's electrically connected metallic structure relative to the Ag/AgCl seawater reference electrode prior to connection of the external zinc sacrificial anode. The AC measurement was taken to identify any alternating voltage present between the boat's earthing system and the surrounding seawater under the same test condition.

The DC and AC potential measurements were undertaken under two different operating conditions. The first set of measurements was recorded during the morning, prior to connection of the zinc sacrificial anode, while the boat remained connected to the AC shore power supply. A second set of measurements was recorded during the afternoon, immediately prior to reconnection of the sacrificial anode to the boat's earthing system, with the AC shore power supply disconnected and the boat operating solely from its onboard power sources.

These measurements provided a direct comparison of the boat-to-seawater electrical condition with and without the AC shore power supply connected. It should be noted that the external anode had been connected during the intervening morning test period; the afternoon DC reading should therefore be regarded as a pre-reconnection or as-found reading rather than a true fully depolarised native potential, as some residual polarisation may have remained.

4.2 Test 2 - Anode Connected: AC/DC Current Flow

The zinc sacrificial anode was then directly connected to the boat's internal earthing bar through the anode cable.

The DC current flowing between the zinc sacrificial anode and the boat was measured using a Hioki clamp meter set to the DC current range, with the clamp positioned around the anode connection cable.

Due to the relatively low level of AC current present in the anode cable, the clamp meter was unable to provide a stable or coherent AC current reading. The AC current was therefore measured using the digital multimeter connected in series between the boat's earthing bar and the exposed end of the anode cable tail. The multimeter was set to the AC milliamperes (mA AC) range so that the current flowing through the anode connection could be measured directly.

AC and DC current measurements were recorded under two operating conditions:

- with the boat connected to the AC shore power supply; and
- with the AC shore power supply disconnected and the boat operating solely from its onboard power sources.
- This allowed the influence of the shore power connection on both the DC galvanic current and any AC current flowing through the sacrificial anode circuit to be assessed.

4.3 Test 3 - Anode Connected: Boat AC/DC Potentials to Seawater

With the zinc sacrificial anode electrically connected to the boat's internal earthing bar, the boat-to-seawater DC and AC potentials were remeasured using the same test arrangement and methodology described for Test 1.

The DC potential was measured with the digital multimeter set to the DC voltage range, with the positive terminal connected to the boat's earthing bar and the negative terminal connected to the Ag/AgCl reference electrode immersed in the seawater adjacent to the boat. The AC potential was subsequently measured using the same connections with the multimeter set to the AC voltage range.

These measurements were used to determine the effect of connecting the external zinc sacrificial anode on the boat-to-seawater DC potential and on any AC voltage present between the boat's earthing system and the surrounding seawater.

5. Recorded Test Results and Assessment

5.1 Test 1 - As-Found Boat Potentials to Seawater (Anode Disconnected)

Period	Operating Condition	DC Potential	AC Voltage	Reference
Morning	Shore power connected	-0.981 V DC	0.072 V AC	Ag/AgCl
Afternoon	Shore power disconnected / onboard power	-0.984 V DC	0.004 V AC*	Ag/AgCl

* **Note:** The external anode had been connected during the intervening morning test period. The afternoon DC reading may therefore include residual polarisation.

The as-found DC potentials of approximately -0.98 V vs Ag/AgCl are substantially more negative than would normally be expected for freely corroding bare steel or naval brass in seawater. The results therefore indicate that submerged metallic components electrically connected to the boat's earthing system were already subject to cathodic influence prior to connection of the temporary external zinc anode.

The similarity between the morning and afternoon DC potentials indicates that disconnection of shore power did not materially affect the boat-to-seawater DC potential during the test period. The AC voltage, however, reduced from 0.072 V AC with shore power connected to approximately 0.004 V AC with shore power disconnected. This indicates a clear association between the shore power connection and the elevated AC voltage measured between the boat's earthing system and seawater.

5.2 Test 2 - Current Flow with Anode Connected

Condition	Power Supply	DC Current	DC Current Direction	AC Current
1	Shore power connected	79 mA	Earthing bar → Anode	0.33 mA AC
2	Onboard power only	65.5 mA	• Earthing bar → Anode	0.51 mA AC

The observed DC current flows under both operating conditions were low. For an otherwise unprotected steel structure, the recorded current would correspond to only a relatively small exposed steel area; however, the as-found potentials recorded during Test 1 indicate that the boat was already receiving cathodic protection or cathodic influence. The recorded DC current from the temporary anode should therefore be regarded as supplementary current applied to an already polarised system.

The measured conventional DC current direction in the metallic connection was from the boat earthing bar towards the zinc anode, consistent with electron flow in the opposite direction from the sacrificial anode towards the protected structure.

5.2.1 Theoretical Zinc Consumption from DC Current

At a continuous DC current output of 79 mA, the theoretical zinc consumption by Faraday's law is approximately:

$$m = (I \times t \times M) / (n \times F)$$

- $I = 0.079 \text{ A}$
- $M = 65.38 \text{ g/mol}$ for zinc
- $n = 2$
- $F = 96,485 \text{ C/mol}$
- $t = 31,536,000 \text{ seconds/year}$

The calculated theoretical zinc consumption due to the DC current flow is approximately **844 g/year (0.84 kg/year)**.

For a 30 kg zinc anode, this corresponds to approximately 2.8% of the nominal anode mass per year before allowance for utilisation, electrochemical efficiency and changes in current demand over time.

The calculated consumption rate applies to the temporary external zinc anode if it were to deliver 79 mA continuously. It should not be assumed to represent consumption of the existing transom-mounted zinc anodes, because previous on-site continuity testing undertaken by others reportedly found no electrical continuity between those anodes and the boat's internal earthing bar.

5.2.2 AC Current Assessment

The recorded AC current flows were very low, being less than 1 mA AC under both operating conditions. For the purpose of a deliberately conservative assessment, a hypothetical AC current of 5 mA has been adopted, which is substantially higher than either measured value.

Because AC reverses polarity during each cycle, the measured RMS AC current cannot be directly treated as an equivalent continuous corrosion current. The following calculation is therefore presented only as a hypothetical 100% DC-equivalent Faradaic upper bound.

Using Faraday's law:

$$m = (I \times t \times M) / (n \times F)$$

- $I = 0.005 \text{ A}$
- $M = 65.38 \text{ g/mol}$ for zinc
- $n = 2$
- $F = 96,485 \text{ C/mol}$

- $t = 31,536,000$ seconds/year

The calculated DC-equivalent zinc consumption is approximately **53.4 g/year**.

For the 30 kg temporary test anode, this represents approximately 0.18% of the nominal anode mass per year. Even under this deliberately conservative upper-bound assumption, the equivalent mass loss would be unlikely to produce a readily observable reduction in the physical dimensions of the temporary anode over a one-year period. This calculation should not be interpreted as evidence that the existing transom-mounted anodes are carrying the measured AC current.

Important qualification: 53.4 g/year is not the predicted actual AC corrosion loss. Actual metal loss caused by AC depends on the degree of electrochemical rectification and the proportion of the alternating current that produces net anodic dissolution.

5.2.3 Hypothetical Localised Steel Loss

A further conservative calculation can be made by assuming that the hypothetical 5 mA AC current is concentrated over a steel surface area of only 10 cm² and, again, treating the full current as a hypothetical 100% DC-equivalent Faradaic upper bound.

Equivalent current density = $5 \text{ mA} / 10 \text{ cm}^2 = 0.5 \text{ mA/cm}^2 = 5 \text{ A/m}^2$

Equivalent iron loss = approximately 45.6 g/year

Using a steel density of approximately 7.85 g/cm³, equivalent metal volume loss = **approximately 5.81 cm³/year**

If this loss were distributed uniformly over 10 cm², the equivalent penetration would be **approximately 5.8 mm/year**.

This value is a theoretical upper bound only. It should not be interpreted as the expected AC corrosion or pitting rate. Actual AC-induced metal loss depends on the waveform, frequency, current density, electrochemical conditions and degree of AC-to-DC rectification at the metal/seawater interface.

5.3 Test 3 - Boat Earthing Potential with Anode Connected

Condition	Power Supply	DC Potential	AC Voltage	Reference
1	Shore power connected	-1.003 V DC	0.0023 V AC	Ag/AgCl
2	Onboard power only	-1.003 V DC	0.0021 V AC	Ag/AgCl

- Connection of the external zinc sacrificial anode resulted in a small but measurable negative shift in the boat-to-seawater DC potential. Under shore-power conditions, the DC potential changed from approximately -0.981 V to -1.003 V vs Ag/AgCl, representing a negative shift of approximately 22 mV. Under onboard-power conditions, the pre-connection potential changed from approximately -0.984 V to -1.003 V vs Ag/AgCl, representing a negative shift of approximately 19 mV.
- The relatively small magnitude of these potential shifts is consistent with the indication from Test 1 that the boat was already cathodically influenced prior to connection of the temporary external anode.

A more significant effect was observed in the measured AC voltage. Under shore-power conditions, connection of the sacrificial anode reduced the measured boat-to-seawater AC voltage from 0.072 V AC to 0.0023 V AC. This represents a reduction of approximately 96.8%, or a reduction by a factor of approximately 31.

With shore power disconnected, the AC voltage reduced from approximately 0.004 V AC to 0.0021 V AC, representing a reduction of approximately 47.5%.

The results demonstrate that connection of the external sacrificial anode provided an additional electrically conductive path between the boat's earthing system and the surrounding seawater and substantially reduced the measurable AC voltage between the two, particularly while the vessel was connected to the AC shore power supply. The test does not, by itself, establish that all of the observed AC voltage was being discharged as corrosion current through the anode.

5.4 Existing Transom Zinc Anodes and Relationship to the Internal Earthing System

Previous on-site continuity testing undertaken by others reportedly found no electrical continuity between the existing transom-mounted zinc sacrificial anodes and the boat's internal earthing bar. On the basis of those reported measurements, the existing transom anodes cannot presently be assumed to form part of, or to be electrically bonded to, the internal earthing system.

Photographic evidence provided by the boat's Captain visually indicates only minimal apparent consumption of the existing transom zinc anodes. The photographs do not provide a quantitative measurement of anode mass loss or consumption rate; however, the limited visible wastage is consistent with the reported absence of electrical continuity and with the transom anodes not carrying a significant sustained current from the internal earthing system.

The temporary external zinc anode used for the 4 September 2026 test was deliberately connected directly to the internal earthing bar and therefore established a known electrical connection between the boat's earthing system and a zinc anode immersed in seawater. The measured DC current of 65.5-79 mA, together with the changes in boat-to-seawater DC and AC potentials, describe the response of the internal earthing system to that known temporary connection. They do not demonstrate that the permanently installed transom anodes are connected to the same earthing system.

Accordingly, the theoretical zinc-consumption calculations derived from the measured current through the temporary external anode should not be attributed to the existing transom anodes unless electrical continuity between those anodes and the internal earthing system is first demonstrated.

Until such continuity is positively confirmed, the existing transom-mounted zinc anodes should be treated as electrically separate from the internal earthing system for interpretation of the present test results. If the transom anodes are intended to provide cathodic protection to metallic components bonded to the internal earthing system, their bonding arrangement should be verified by direct low-resistance continuity measurements between each anode core or fixing arrangement and the internal earthing bar, together with inspection of associated bonding conductors and mechanical/electrical interfaces.

6. Conclusions

- The tests principally investigated the electrical behaviour of the boat's internal earthing system relative to seawater. The as-found DC potentials of approximately -0.98 V vs Ag/AgCl indicate that submerged metallic components electrically associated with the internal earthing system were already subject to cathodic influence before connection of the temporary external zinc sacrificial anode.
- Connection of the temporary external zinc sacrificial anode shifted the boat-to-seawater DC potential to approximately -1.003 V vs Ag/AgCl under both shore-power and onboard-power conditions. The additional

negative shift was relatively small, approximately 19-22 mV, indicating that the temporary anode provided supplementary cathodic influence rather than being the primary source of the existing negative potential.

- The temporary external anode delivered approximately 79 mA DC with shore power connected and 65.5 mA DC with shore power disconnected. These values represent low DC current demand and are consistent with an already substantially polarised system.
- The most significant difference between the two power configurations was the AC voltage measured between the boat's internal earthing system and seawater. With the temporary sacrificial anode disconnected, the AC voltage was approximately 72 mV with shore power connected and approximately 4 mV with shore power disconnected, indicating a clear association between the shore power connection and the elevated AC voltage.
- With the temporary external anode connected directly to the internal earthing bar, the shore-power AC voltage reduced from approximately 72 mV to 2.3 mV, a reduction of approximately 96.8% or a factor of approximately 31. This demonstrates that providing the earthing system with a known conductive connection to a zinc anode immersed in seawater materially reduced the measurable AC voltage between the earthing system and seawater.
- The measured AC current through the temporary anode circuit remained very low at 0.33-0.51 mA AC. Even using a deliberately conservative hypothetical value of 5 mA AC and treating it as a hypothetical 100% DC-equivalent Faradaic upper bound, the equivalent zinc consumption would be only approximately 53.4 g/year. The actual AC-driven zinc consumption would be expected to be lower and cannot be determined from RMS AC current alone.
- The results therefore do not support significant zinc-anode wastage being caused by the measured AC current through the temporary anode circuit. This is also consistent with the photographic evidence provided by the boat's Captain, which visually indicates minimal apparent consumption of the existing transom-mounted zinc anodes.
- Previous on-site continuity testing by others reportedly found no electrical continuity between the existing transom-mounted zinc anodes and the internal earthing bar. The present test does not contradict that finding: it demonstrates the response of the internal earthing system only when a separate temporary zinc anode is deliberately connected directly to it. The existing transom anodes should therefore not be assumed to be part of the internal earthing system, and the measured temporary-anode currents should not be attributed to them unless continuity is subsequently confirmed.
- Further investigation should therefore concentrate on: (i) confirming the electrical continuity or isolation of each existing transom zinc anode relative to the internal earthing bar; (ii) inspecting any associated bonding conductors, fasteners and interfaces; and (iii) reviewing the shore-power protective-earth and galvanic-isolation arrangements that are associated with the elevated boat-to-seawater AC voltage observed while shore power was connected.

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