PRODUCT DATA SHEET

ADVANCE TECHNOLOGY

ProNode™

ALUMINUM ALLOY SACRIFICIAL ANODE

PRODUCT DESCRIPTION

Aluminum alloy sacrificial anodes are primarily used for cathodic protection of metallic structures in seawater environments, such as offshore oil and gas platforms, offshore wind turbine foundations, bridge and wharf steel piles, and ship ballast tanks, as well as the internal surfaces of crude oil storage tanks. This anode material provides excellent electrochemical performance and high current output capacity, approximately three times that of zinc anodes and twice that of magnesium anodes. In seawater and other chloride-containing media, it delivers reliable performance and strong self-regulating current output.

PRODUCT PERFORMANCE

Electrochemical Performance Compliance

- Electrochemical properties and chemical composition are designed and controlled with reference to applicable international standards, including GB/T 4948, DNV-RP-B401, EN 12496, and NACE SP0387, ensuring stable and reliable anode performance.

Environmental Adaptability

- Alloy composition and performance can be optimized according to seawater temperature, salinity, water depth, and other environmental conditions to support effective long-term cathodic protection performance.

PRODUCT FEATURES

Standards & Certification

- Product quality is verified through recognized industry testing and certification processes, including DNV and CCS certification, as applicable.

Custom Engineering Capability

- Alloy grades can be selected in accordance with applicable standards or customized for specific service environments, with performance verified through pre-production qualification testing (PQT).

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Reference	Title
DNV-RP-B401	CATHODIC PROTECTION DESIGN
NACE SP0387	METALLURGICAL AND INSPECTION REQUIREMENTS FOR CAST GALVANIC ANODES FOR OFFSHORE APPLICATIONS
EN 12496	GALVANIC ANODES FOR CATHODIC PROTECTION IN SEAWATER AND SALINE MUD
NACE TM0190	IMPRESSED CURRENT LABORATORY TESTING OF ALUMINUM ALLOY ANODES
NACE SP0492	METALLURGICAL AND INSPECTION REQUIREMENTS FOR OFFSHORE PIPELINE BRACELET ANODES

PRODUCT QUALITY

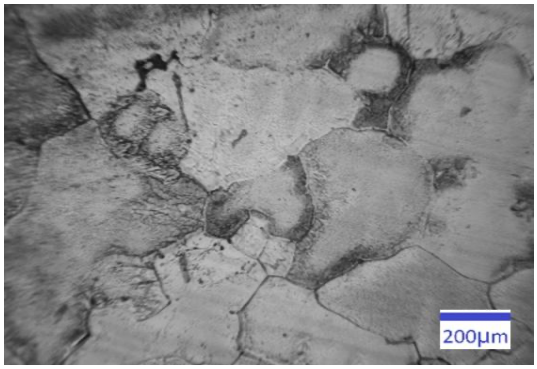
Strict Manufacturing Control

Advance Technology ensures the stable performance and consistent quality of its sacrificial anodes through strict raw material control and optimized casting processes.

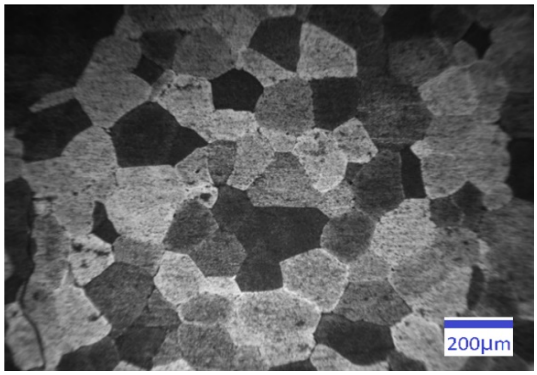
Raw material purity directly affects impurity levels and the accuracy of the anode alloy composition, both of which are critical to anode performance. Advance Technology uses high-purity raw materials and strictly inspects, accepts, labels, and stores each batch of raw materials in accordance with established quality control requirements.

In addition to precise control of each alloying element, casting parameters for aluminum alloy sacrificial anodes, such as pouring temperature, mold temperature, and holding time, have a significant impact on the anode's metallographic structure. This structure, including element distribution and grain size, directly influences anode performance.

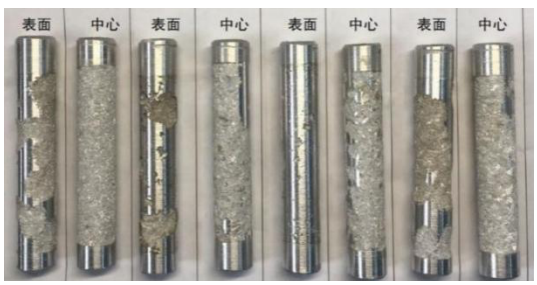
The following comparison shows the dissolution morphology of sacrificial anodes with the same alloy composition but different casting process controls, based on DNVGL-RP-B401, Appendix B. Compared with anodes produced using less controlled casting processes, Advance Technology sacrificial anodes are manufactured with refined casting control, resulting in finer and more uniform grains, denser grain packing, and more uniform dissolution morphology. During long-term service, uneven dissolution may lead to localized corrosion, anode body detachment, and reduced utilization. Advance Technology anode products are designed to effectively reduce this risk and support reliable long-term performance.



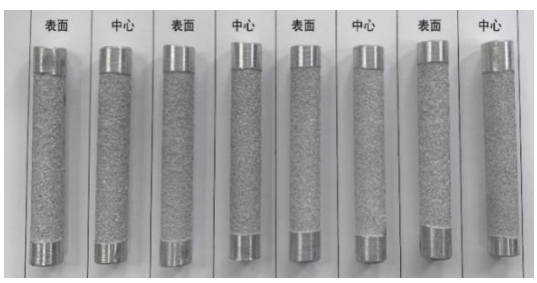
Coarse and nonuniform grains



Fine and uniform grains



Nonuniform electrochemical dissolution morphologies



Uniform electrochemical dissolution morphologies

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Standardized Quality Control Process

Advance Technology has established a rigorous quality management system in accordance with ISO 9001 requirements. For sacrificial anodes, a series of quality control procedures has been implemented, including but not limited to:

- Manufacturing Process Specification (MPS)
- Inspection and Test Plan (ITP)
- Production Record Sheet

These quality control procedures are developed in accordance with customer requirements and project specifications, and are verified through pre-production qualification testing (PQT) before full-scale production to help ensure the stable performance and consistent quality of our sacrificial anodes.

Customized Inspection & Testing

Our sacrificial anode inspection and testing methods are conducted in accordance with applicable international standards, including DNV-RP-B401, EN 12496, and NACE SP0387, as well as customer requirements and project specifications.

Chemical composition and electrochemical performance testing can be performed using samples taken from the melt at the start, middle, or end of each heat, or from finished anodes. Physical inspection and testing can be carried out through either random batch inspection or 100% inspection, depending on project requirements.

TECHNICAL INNOVATION

Advance Technology offers a wide range of sacrificial anode products and has developed dedicated anode solutions for different project requirements and service environments.

Deep-Sea Aluminum Alloy Anode

Early offshore projects were mainly developed in coastal areas, where most offshore structures were installed at water depths of approximately 30 meters or less. With the continuous development of the offshore oil, gas, and energy industries, offshore projects have gradually expanded into deeper waters. As water depth increases, cathodic protection systems that require frequent replacement or maintenance become increasingly impractical. As a result, the development of effective, long-term cathodic protection systems has become increasingly important.

Field test data indicate that several environmental factors can affect deep-sea cathodic protection systems, including temperature, dissolved oxygen content, salinity, pH, seawater flow rate, and marine biological activity. Among these factors, temperature and dissolved oxygen content are particularly important because they directly affect the electrochemical performance of aluminum alloy sacrificial anodes. In deep-sea environments, low temperature and low dissolved oxygen content may cause aluminum alloy sacrificial anodes to exhibit degraded dissolution morphology, reduced current efficiency, and a positive shift in closed-circuit potential. These changes may lead to premature cathodic protection system failure and reduced service life of offshore structures.

In response to the environmental conditions of deep-sea engineering projects, Advance Technology has developed aluminum alloy anodes suitable for low-temperature and low-dissolved-oxygen environments. The following figures show the temperature-dependent changes in closed-circuit potential and electrochemical capacity of various aluminum alloy anodes under dissolved oxygen conditions of 0.6–0.8 ppm. Under these test conditions, Advance Technology’s aluminum alloy anodes achieved a closed-circuit potential of -1.1 V and an electrochemical capacity of 2,580 Ah/kg, representing an approximately 7% improvement in electrochemical performance compared with other aluminum alloy anodes.

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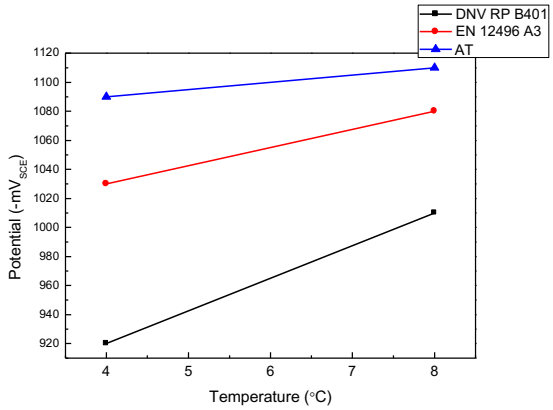
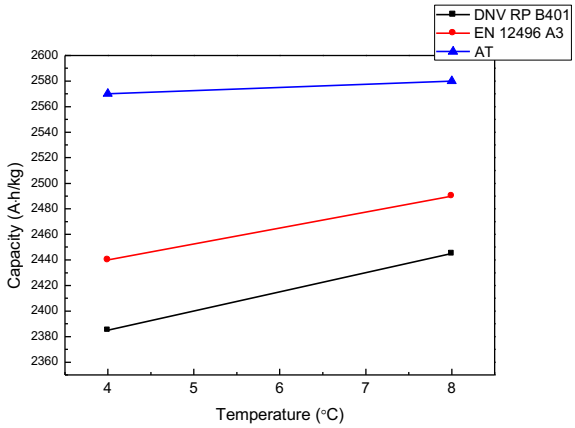


Closed-Circuit Potential–Temperature Curves of Aluminum Alloy Anodes



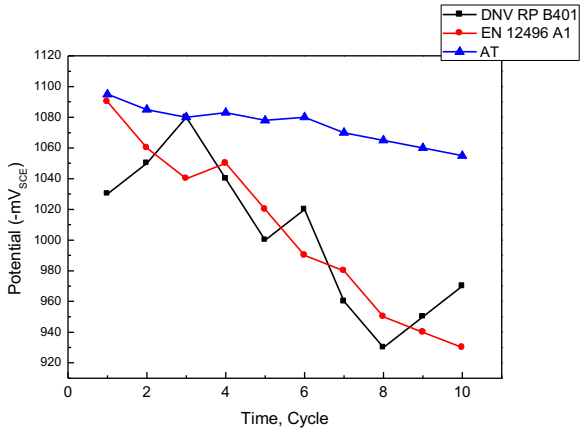
Electrochemical Capacity–Temperature Curves of Aluminum Alloy Anodes

Marine Aluminum Alloy Anode

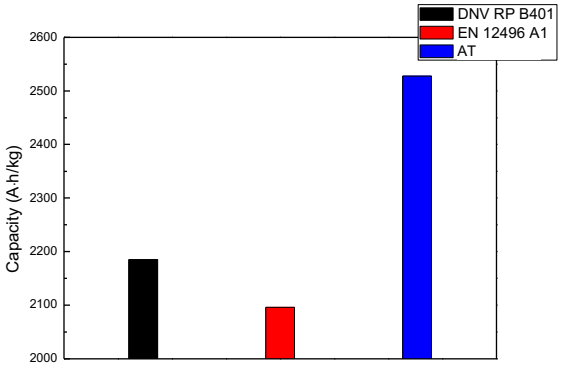
Cathodic protection has proven to be an effective method for controlling corrosion on ships and marine structures. When properly designed and implemented, cathodic protection can achieve a hull protection rate of over 90%, while ballast tank protection rates can reach approximately 50% to 70%, effectively reducing corrosion risk. Among sacrificial anodes used for ship cathodic protection, aluminum alloy anodes are among the most widely used and consumed.

Sacrificial anodes may be used in alternating wet and dry environments, such as ballast tanks and seawater-wetted hull areas subject to periodic exposure. In these corrosive wet–dry conditions, corrosion products on the anode surface can dehydrate during air exposure and form a hard oxide layer. As wet–dry cycling continues, these corrosion products may accumulate and develop into a dense surface layer, reducing the effective contact area between the anode and seawater and ultimately leading to anode failure. Electrochemically, this may be reflected by a positive shift in closed-circuit potential, reduced anode activity, and a significant decrease in current efficiency.

In response to the wet–dry cycling conditions commonly encountered in marine engineering applications, Advance Technology has developed aluminum alloy anodes suitable for such environments. The following figures show the changes in closed-circuit potential and electrochemical capacity of different aluminum alloy anodes with increasing wet–dry cycles. After 10 wet–dry cycles, Advance Technology's aluminum alloy anode achieved a closed-circuit potential of -1.05 V and an electrochemical capacity of 2,530 Ah/kg, representing an approximately 10% improvement in electrochemical performance compared with other aluminum alloy anodes under the stated test conditions.



Closed-Circuit Potential–Wet–Dry Cycle Curves of Aluminum Alloy Anodes



Electrochemical Capacity of Aluminum Alloy Anodes After Wet–Dry Cycling

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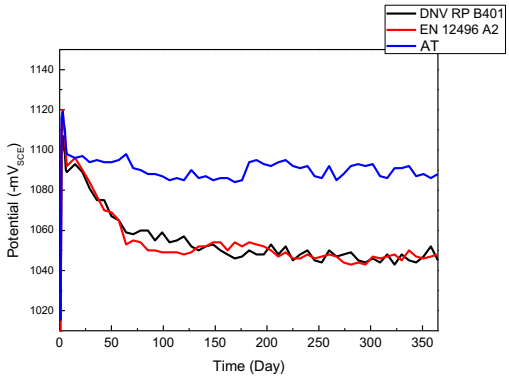
Brackish Water Aluminum Alloy Anode

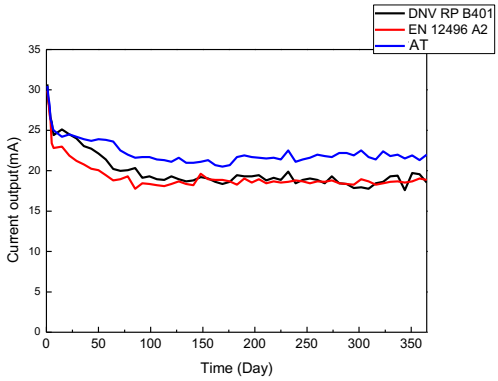
Many docks and bridges supported by steel pipe piles are constructed in coastal areas. Sacrificial anodes are commonly used to protect the submerged and mud-zone areas of these piles. In practical applications, sacrificial anodes are typically installed on steel pipe piles after pile driving, either by underwater welding or by clamping. Due to their high electrochemical capacity and low density, aluminum alloy sacrificial anodes are well suited for underwater installation and are widely used for cathodic protection of docks, bridges, and similar marine structures.

Corrosion products generated by aluminum alloy sacrificial anodes can adhere to the anode surface. In brackish water environments, such as river estuaries, the reduced activity of the electrolyte may slow the corrosion process. As a result, corrosion products on the anode surface may not detach readily, creating a shielding effect. This can inhibit the dissolution and redeposition of anode-activating elements on the working surface, leading to localized corrosion, such as pitting and cratering, and reducing current efficiency.

Advance Technology has developed aluminum alloy anodes suitable for brackish water environments. The following figures show the time-dependent changes in closed-circuit potential and current output of various aluminum alloy anodes under brackish water conditions with a resistivity of 70–80 Ω·cm. During one year of free-running operation, Advance Technology's aluminum alloy anode achieved an average closed-circuit potential of -1.09 V and an electrochemical capacity of 2,520 Ah/kg, calculated based on the measured output current. This represents an approximately 10% improvement in electrochemical performance compared with other aluminum alloy anodes under the stated test conditions.



Closed-Circuit Potential–Time Curves of Aluminum Alloy Anodes in Brackish Water



Current Output–Time Curves of Aluminum Alloy Anodes in Brackish Water

Marine Sediment Aluminum Alloy Anode

With the continuous development of offshore engineering, marine sediment environments have become an important service area for many offshore steel structures, such as subsea tunnels, oil and gas pipelines, and bridge pile foundations. Aluminum alloy sacrificial anodes are installed to help protect these submerged steel structures from corrosion throughout their design service life. In certain silting environments, rising mud levels may also cause aluminum alloy sacrificial anodes originally designed for seawater exposure to become buried in sediment, requiring them to operate under mud-buried conditions.

Conventional sacrificial anode design and installation may not fully account for the effects of sediment burial. When aluminum alloy sacrificial anodes designed for seawater environments are used in marine sediment, the higher resistivity of the sediment can reduce their current output capacity, resulting in insufficient protection for steel structures buried in the mud.

Advance Technology has developed aluminum alloy anodes specifically designed for marine sediment environments. The following figures show the open-circuit potential, closed-circuit potential, and electrochemical capacity of various aluminum alloy anodes in marine sediment. In this environment, Advance Technology's aluminum alloy anode achieved an open-circuit potential of -1.13 V, a closed-circuit potential of -1.08 V, and an electrochemical capacity of 2,280 Ah/kg, representing an approximately 10% improvement in electrochemical performance compared with other aluminum alloy anodes under the stated test conditions.

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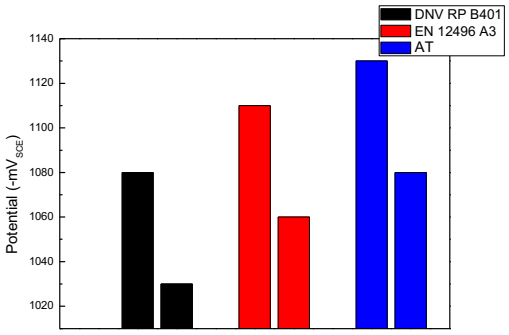
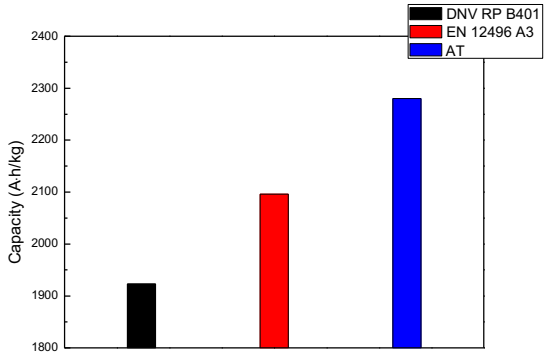


Open-Circuit and Closed-Circuit Potentials of Aluminum Alloy Anodes in Marine Sediment

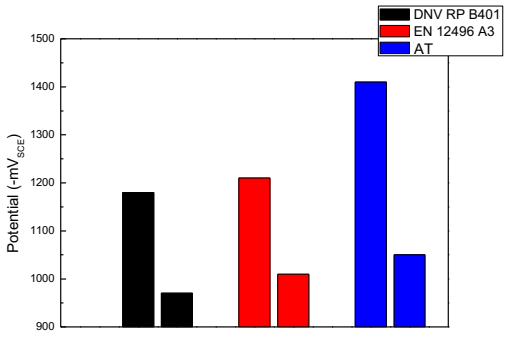


Electrochemical Capacity of Aluminum Alloy Anodes in Marine Sediment

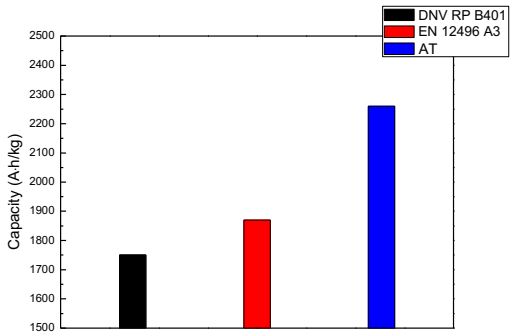
High-Temperature Aluminum Alloy Anode

In the petroleum and chemical industries, aluminum alloy sacrificial anodes are widely used in high-temperature, water-containing environments, including oily water and certain oil and gas well applications. Conventional aluminum alloy sacrificial anodes can corrode uniformly at ambient temperature, with current efficiencies exceeding 80%. However, as the operating temperature increases, the surface of the aluminum alloy sacrificial anode becomes more susceptible to passivation. The shielding effect of the passivation film can prevent the activating elements from continuously activating the sacrificial anode, resulting in a positive shift in closed-circuit potential and a decrease in current efficiency.

Advance Technology has developed aluminum alloy anodes suitable for high-temperature environments. The following figures show the open-circuit potential, closed-circuit potential, and electrochemical capacity of different aluminum alloy anodes in 70°C oily water. Under high-temperature test conditions, Advance Technology's aluminum alloy anode achieved an open-circuit potential of -1.41 V, a closed-circuit potential of -1.05 V, and an electrochemical capacity of 2,260 Ah/kg, representing an approximately 20% improvement in electrochemical performance compared with other aluminum alloy anodes under the stated test conditions.



Open-Circuit and Closed-Circuit Potentials of Aluminum Alloy Anodes Under High-Temperature Conditions



Electrochemical Capacity of Aluminum Alloy Anodes Under High-Temperature Conditions

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PRODUCT PARAMETERS

Chemical Composition

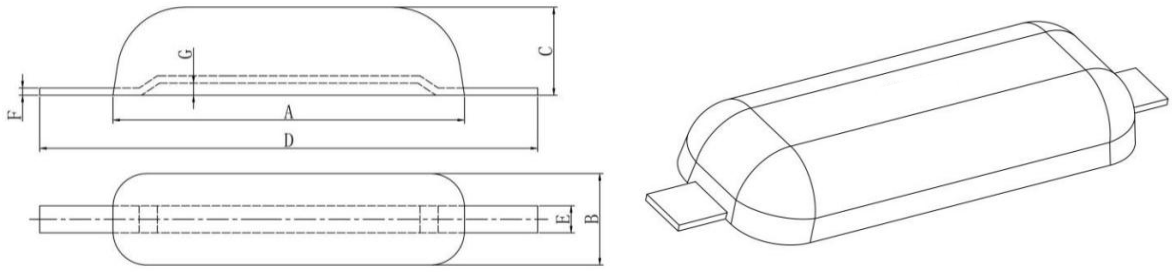
Model	Alloy Element %									Al
	Zn	In	Cd	Sn	Mg	Ti	Si	Fe	Cu	
DNV-RP-B401	2.50-5.75	0.015-0.040	≤0.002	-	-	-	≤0.12	≤0.09	≤0.003	Remainder
EN 12496 A1	2.0-6.0	0.010-0.030	≤0.002	-	-	-	≤0.12	≤0.12	≤0.006	Remainder
EN 12496 A2	3.0-5.5	0.016-0.040	≤0.002	-	-	-	≤0.10	≤0.09	≤0.005	Remainder
EN 12496 A3	4.75-5.75	0.016-0.020	≤0.002	-	-	-	0.08-0.12	≤0.06	≤0.003	Remainder

Electrochemical Properties

Model	Environment	Closed potential -V, SCE	Electrochemical capacity A.h/kg	Current efficiency %	Anode consumption rate kg/A.y
DNV-RP-B401	Seawater	≥1.05	≥2500	≥85	3.5
	Marine sediments	-	-	-	-
EN 12496 A1	Seawater	≥1.09	≥2500	≥85	3.5
	Marine sediments	≥1.05	≥2000	≥70	4.4
EN 12496 A2	Seawater	≥1.09	≥2500	≥85	3.5
	Marine sediments	≥1.05	≥2000	≥70	4.4
EN 12496 A3	Seawater	≥1.09	≥2500	≥85	3.5
	Marine sediments	≥1.05	≥2000	≥70	4.4

MODELS AND SPECIFICATIONS

Hull Anode (Single Core)



Model	Size / mm	Core Size /mm				Net Weight /kg	Gross Weight /kg
	A×B×C	D	E	F	G		
AT-AL-H-1	800×140×60	900	45	6	10	14.4	16.2
AT-AL-H-2	800×140×50	900	45	6	8	12.3	14.1
AT-AL-H-3	800×140×40	900	45	6	6	10.1	11.9
AT-AL-H-4	600×120×50	700	40	6	8	7.7	8.9
AT-AL-H-5	400×120×50	460	35	5	8	5	5.7
AT-AL-H-6	500×100×40	580	40	5	6	4.2	5.2
AT-AL-H-7	400×100×40	460	30	4	6	3.5	3.9
AT-AL-H-8	300×100×40	360	30	4	6	2.5	2.8

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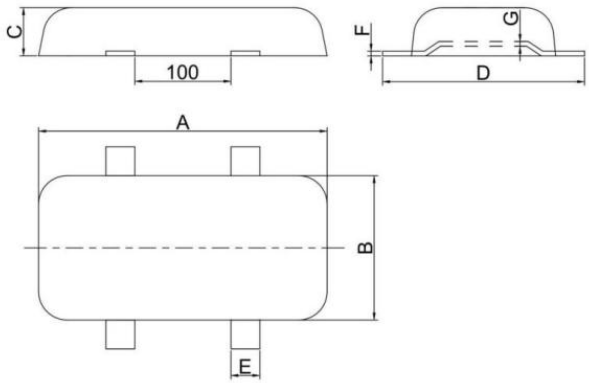
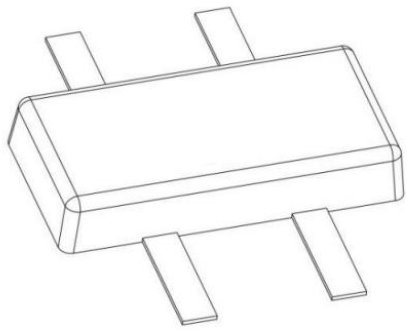
AT-AL-H-9	250×100×40	300	30	4	6	2.1	2.3
AT-AL-H-10	180×70×40	230	25	4	6	0.8	1

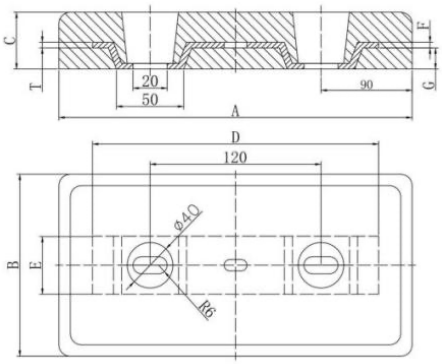
Hull Anode (Double Core)

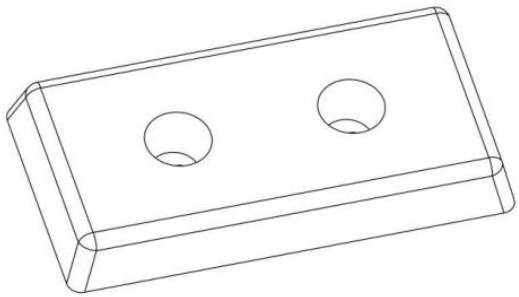




Model	Size / mm	Core Size /mm				Net Weight /kg	Gross Weight /kg
	A×B×C	D	E	F	G		
AT-AL-H-11	300×150×50	360	30	4	6	5.6	6.2
AT-AL-H-12	300×150×40	360	30	4	6	4.4	5

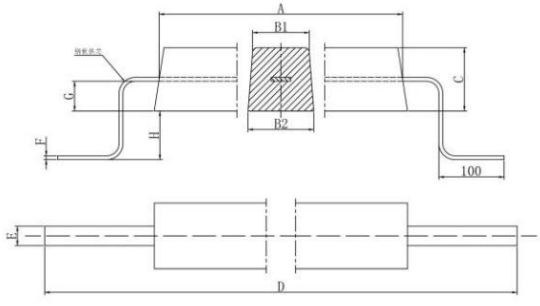
Hull Anode (Bolted Type)

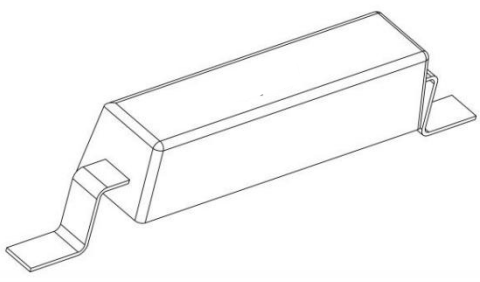




Model	Size / mm	Core Size /mm				Net Weight /kg	Gross Weight /kg
	A×B×C	D	E	F	G		
AT-AL-H-13	300×150×50	250	50	3	10	5.6	5.8
AT-AL-H-14	300×150×40	250	50	3	10	4.4	4.6

Ballast Tank Anode





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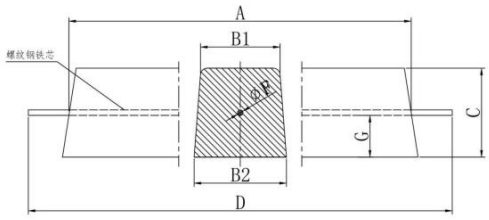
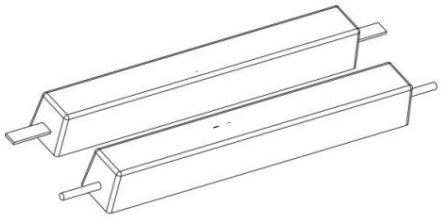
Model	Size / mm	Core Size /mm					Net Weight /kg	Gross Weight /kg
	A×（B1+B2）×C	D	E	F	G	H		
AT-AL-T-1	500×（115+135）×130	800	50	6	40	60	21.4	23.6
AT-AL-T-2	1500×（65+75）×70	1800	-	ϕ12	35	40	19	21.5
AT-AL-T-3	500×（110+130）×120	800	50	6	40	60	18.9	21.1
AT-AL-T-4	1000×（58.5+78.5）×68	1300	-	ϕ12	20	40	12.1	13.3
AT-AL-T-5	800×（56+74）×65	1100	-	ϕ12	20	40	8.8	9.8
AT-AL-T-6	1150×（48+54）×51	1450	-	ϕ12	15	35	7.5	8.8
AT-AL-T-7	250×（80+100）×85	310	30	4	8	0	5	5.3
AT-AL-T-8	200×（70+90）×70	260	30	3	8	0	2.9	3.1

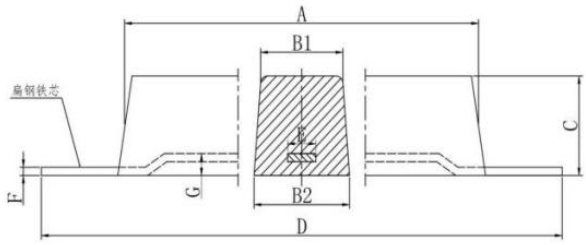
Jetty Pile Anode

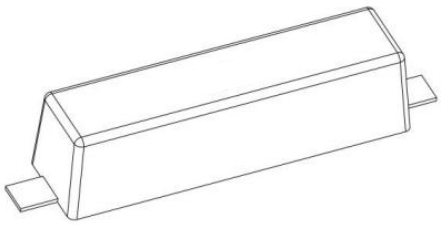




Model	Standard Size /mm	Threaded Core Size /mm			Flat Core Size/mm				Net Weight /kg	Gross Weight /kg
	A×（B1+B2）×C	D	F	G	D	E	F	G		
AT-AL-I-5	1500×（148+178）×170	1800	25	65	1800	50	8	65	110	116.8
AT-AL-I-6	850×（180+220）×180	1100	25	70	1100	60	8	70	81.3	85.4
AT-AL-I-7	800×（200+280）×150	1050	25	55	1050	60	8	55	76.6	80.5
AT-AL-I-8	700×（160+220）×180	950	22	70	950	60	8	70	63.8	66.5
AT-AL-I-9	1250×（115+135）×130	1500	18	45	1500	40	8	45	53.8	56.7
AT-AL-I-10	1000×（115+135）×130	1250	18	45	1250	40	8	45	43	45.4
AT-AL-I-11	750×（115+135）×130	1000	16	45	1000	40	6	45	32.3	33.8
AT-AL-I-12	500×（115+135）×130	750	16	45	750	40	4	45	21.6	22.7

Cooling System Anode (Slender Type)





Model	Size / mm	Core Size /mm				Net Weight /kg	Gross Weight /kg
	A×（B1+B2）×C	D	E	F	G		
AT-AL-E-1	1200×（200+280）×150	1400	70	10	10	114.2	121.7
AT-AL-E-2	800×（200+280）×150	1000	60	8	10	76.6	80.2
AT-AL-E-3	1000×（115+135）×130	1200	50	6	10	42.9	45.6

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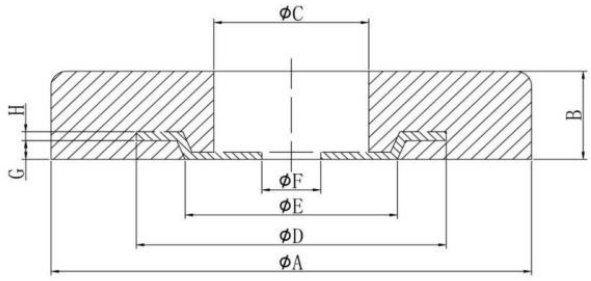
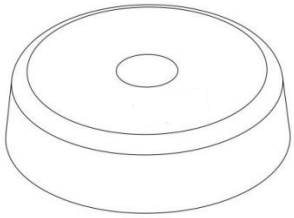
AT-AL-E-4	500×（115+135）×130	620	50	6	10	21.4	22.8
AT-AL-E-5	1000×（80+100）×80	1200	30	4	8	19	20
AT-AL-E-6	500×（105+135）×100	620	40	4	10	15.9	16.6
AT-AL-E-7	500×（80+100）×80	620	30	4	8	9.5	10
AT-AL-E-8	400×（110+120）×50	500	35	3	6	6	6.3
AT-AL-E-9	300×（140+160）×40	360	60	3	6	4.6	5
AT-AL-E-10	200×（90+110）×40	250	30	3	6	2	2.15

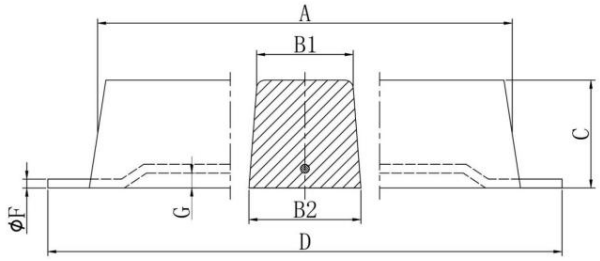
Cooling System Anode (Disk Type)

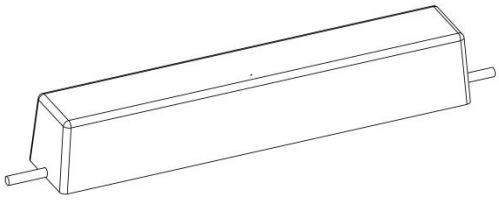




Model	Size / mm		Core Size /mm					Net Weight /kg	Gross Weight /kg
	A×B	C	D	E	F	H	G		
AT-AL-E-11	300×60	40	80	50	12	4	8	10.7	10.8
AT-AL-E-12	360×40	50	100	70	14	4	6	10.3	10.5
AT-AL-E-13	300×40	40	80	50	12	4	6	7.1	7.2
AT-AL-E-14	200×50	35	75	45	10	4	6	3.8	3.9
AT-AL-E-15	180×50	35	75	45	10	4	6	3.0	3.1
AT-AL-E-16	120×100	30	75	45	10	4	10	2.5	2.6

Tank Internal Anode





Model	Size / mm	Core Size /mm			Net Weight /kg	Gross Weight /kg
	A×（B1+B2）×C	D	F	G		
AT-AL-C-1	750×（115+135）×130	900	16	10	32.3	33.7
AT-AL-C-2	500×（115+135）×130	650	16	10	21.5	22.5
AT-AL-C-3	500×（105+135）×100	650	16	10	15.8	16.8
AT-AL-C-4	300×（105+135）×100	400	10	10	9.6	9.8

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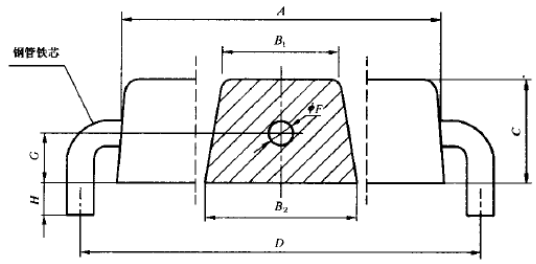
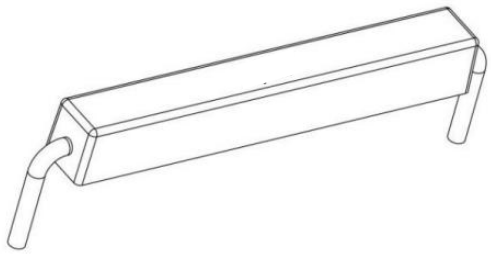
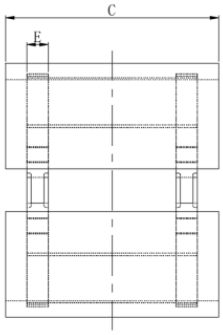
Marine Structure Anode

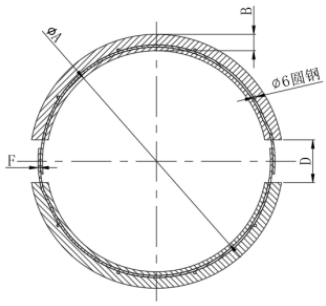


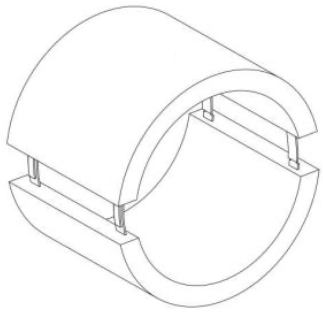


Model	Size / mm	Core Size /mm				Net Weight /kg	Gross Weight /kg
	A×（B1+B2）×C	D	F	H	G		
AT-AL-I-1	2300×（220+240）×230	2500	60*6	300	110	309.7	334.8
AT-AL-I-2	1600×（200+210）×220	1800	60*6	300	90	181.6	201
AT-AL-I-3	1500×（170+200）×180	1700	48*4	300	80	126.7	136.6
AT-AL-I-4	900×（150+170）×160	1100	42*4	300	70	58.3	64.6

Bracelet Anode







Model	Size / mm				Core Size /mm		Net Weight /kg	Gross Weight /kg
	A	B	C	D	E	F		
AT-AL-Z-1	365.6	38.1	500	100	50	5	53.9	59.9
AT-AL-Z-2	365.6	58.5	520	100	50	5	88.8	94.8
AT-AL-Z-3	365.6	58.1	500	100	50	5	88	94.1
AT-AL-Z-4	365.6	38.5	500	100	50	5	54.6	60.6
AT-AL-Z-5	467	38.5	500	100	50	5	71.3	78.6
AT-AL-Z-6	467	58.5	500	100	50	5	114.2	121.5
AT-AL-Z-7	518	38.5	500	100	50	5	79.7	87.6
AT-AL-Z-8	518	68.5	500	100	50	5	151.9	159.8
AT-AL-Z-9	722.4	78.5	650	150	50	6	305.3	317.3
AT-AL-Z-10	722.4	58.5	650	150	50	6	221.1	233.1
AT-AL-Z-11	830	110	300	150	40	6	232	242.6
AT-AL-Z-12	830	120	300	150	40	6	258	268.6
AT-AL-Z-13	1035	80	350	150	40	8	236	253.3

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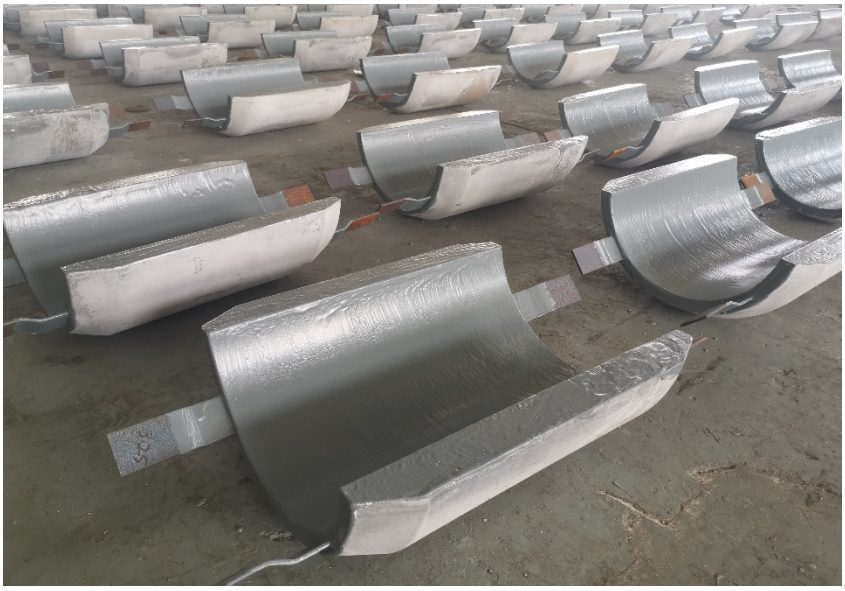

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