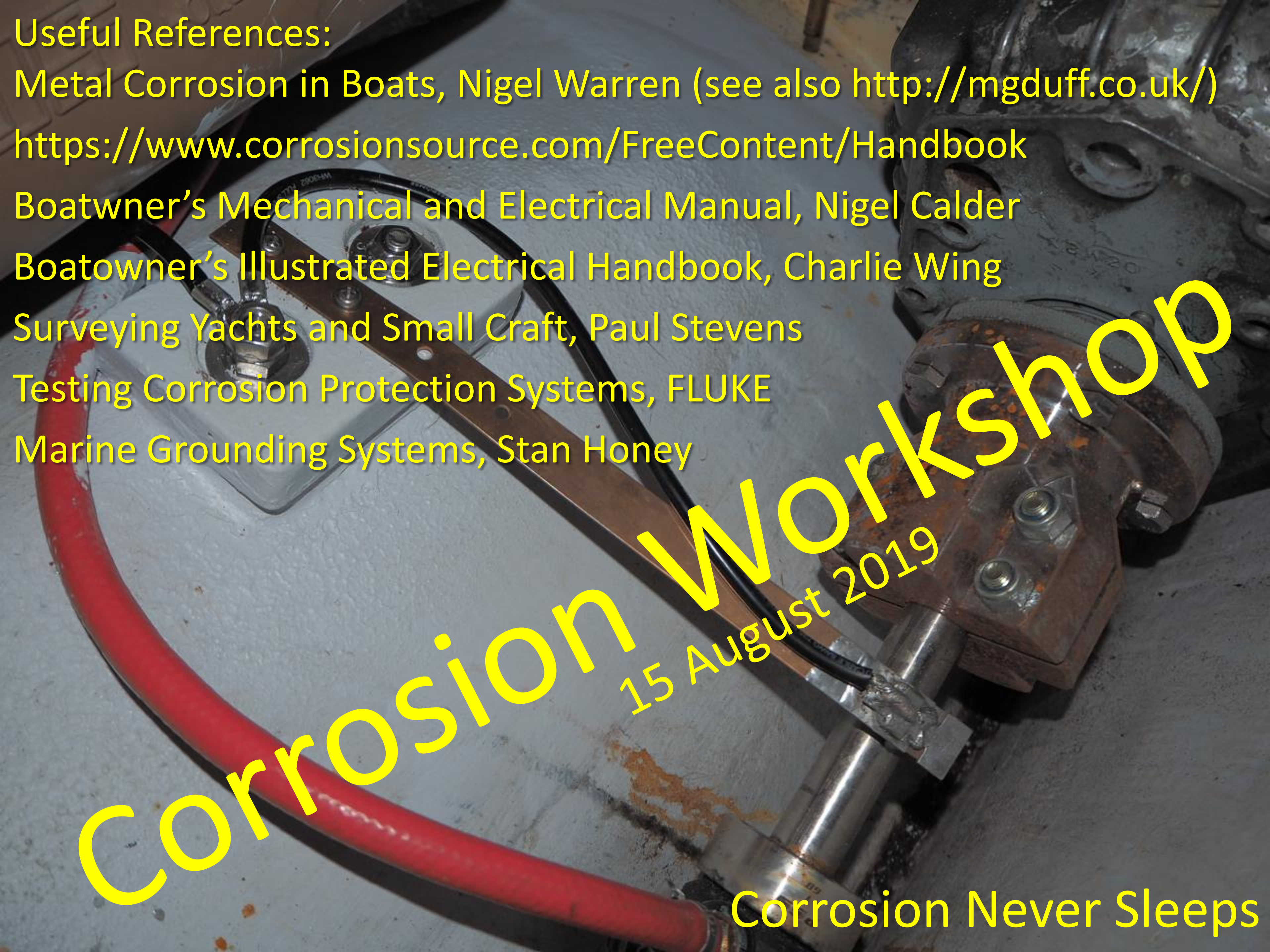


Corrosion Workshop

15 August 2019

Useful References:

Metal Corrosion in Boats, Nigel Warren (see also http://mgduff.co.uk/)

https://www.corrosionsource.com/FreeContent/Handbook

Boatwner’s Mechanical and Electrical Manual, Nigel Calder

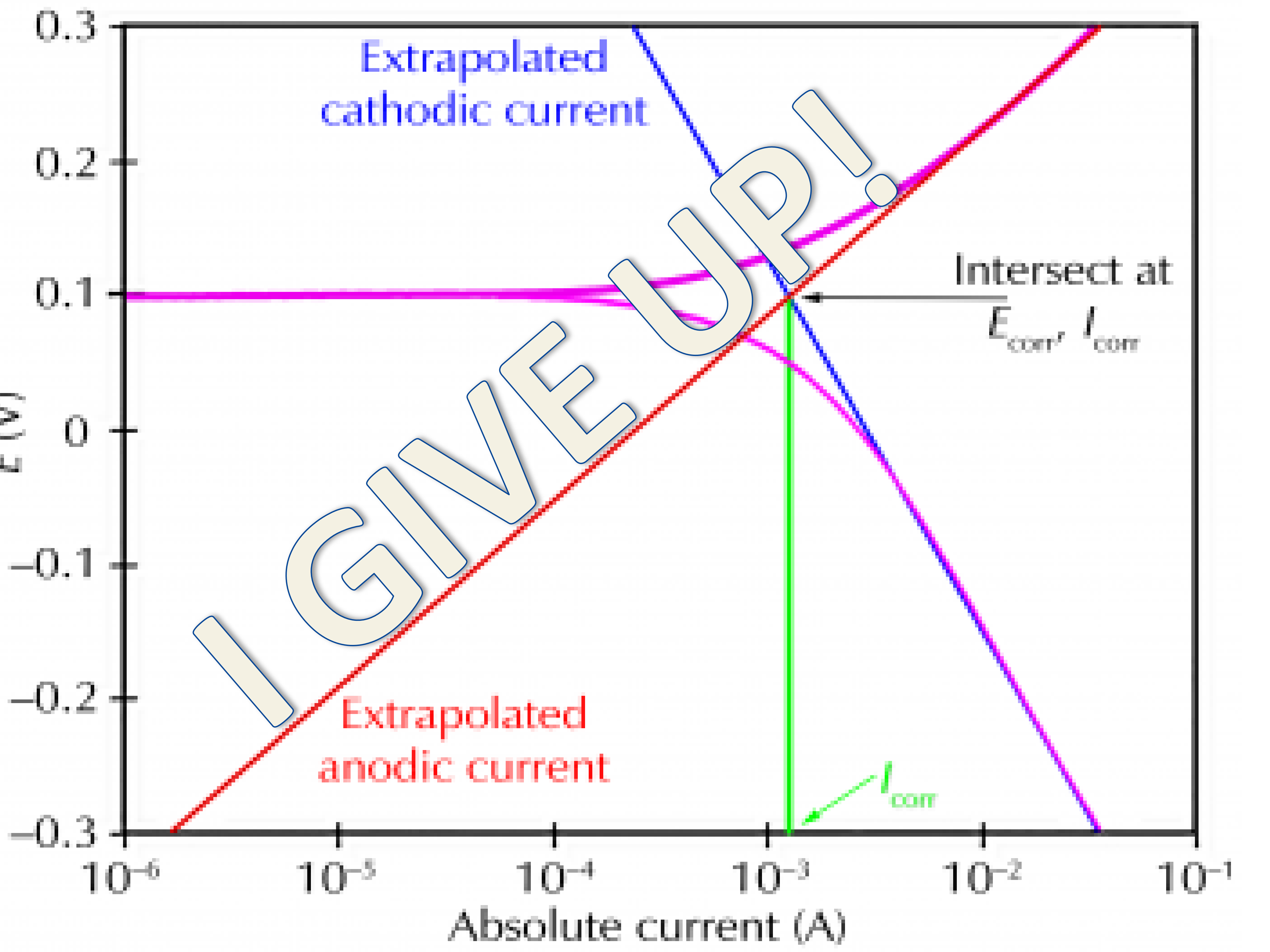
Boatowner’s Illustrated Electrical Handbook, Charlie Wing

Surveying Yachts and Small Craft, Paul Stevens

Testing Corrosion Protection Systems, FLUKE

Marine Grounding Systems, Stan Honey

Corrosion Never Sleeps



Extrapolated cathodic current
Intersect at E_{corr}, I_{corr}
Extrapolated anodic current
I_{corr}
I GIVE UP!
0.3
0.2
0.1
0
−0.1
−0.2
−0.3
E (V)
10^{-6}
10^{-5}
10^{-4}
10^{-3}
10^{-2}
10^{-1}
Absolute current (A)

Workshop Outline

- Start Experiments!
- Audience Survey & Ohm's Law
- Corrosion Quiz
- 44 Year Corrosion Journey
  - 1975 P. Class Chain Plates - Shore Power in 2019
- Upcoming Projects
  - Radios
  - Built in, on board corrosion measurement
  - Ultrasonic antifouling

Ohm’s Law

Ohms per cubic centimetre	
Pure water	20,000,000
Distilled	500,000
Rain	20,000
Tap	5,000
River	200
Coastal	30
Deep seawater	20–25

Quiz Practice: Japan

(a) Japan has 35 **islands**, of which 12 are **inhabited**.

(b) Japan has 156 **islands**, of which 46 are **inhabited**.

(c) Japan has 2,154 **islands**, of which 243 are **inhabited**.

(d) Japan has 6,852 **islands**, of which 430 are **inhabited**.

Corrosion Quiz: Q1

- Most Corrosion on boats is:
  - (a) Stress Corrosion
  - (b) Corrosion Fatigue
  - (c) Intergranular Corrosion
  - (d) Pitting
  - (e) Electrolysis
  - (f) Galvanic Corrosion
  - (g) Oxidation in Air
  - (h) Electrolytic Corrosion (Stray Current)
  - (i) De-Alloying (e.g. dezincification)

Corrosion Quiz: Q2

- Anodes can be:
  - (a) Magnesium in Fresh Water
  - (b) Zinc or Aluminium in Salt Water
  - (c) Iron (Fe)
  - (d) All of the above, depending on the situation

Corrosion Quiz: Q3

- Anode’s size and shape matters:
  (a) Bigger is always better
  (b) More surface area Is better.
  (c) Too much anode destroys copper and bronze
  (d) Too much anode can rot wood and corrode aluminium.

Corrosion Quiz: Q4

- Because galvanic voltages are very small, anodes should:
  (a) be forward of the metal it protects.
  (b) be aft of the metal it protects.
  (c) last for years and years
  (d) Always definitely have good electrical connection.

Corrosion Quiz: Q5

- Because protective galvanic currents (electron flow)through the water are very small and water generally flows from bow to stern, the anodes should be positioned:
  (a) forward of the metal it protects.
  (b) aft of the metal it protects.
  (c) in line awarthships of the metal it protects.
  (d) Since electrons don't "flow", the field energy being instantly transferred from atom to atom, only distance is important; closer is better.

Corrosion Quiz: Q6

- Two Boats on Adjacent Swing Moorings:
  - (a) Cannot cause corrosion between them.
  - (b) Can cause corrosion between them.
  - (c) Cannot usually cause corrosion between them.
  - (d) Can only cause corrosion between them if both moored by chain.

Corrosion Quiz: Q7

- Stray Current (electrolytic)Corrosion:
  - (a) Can happen in any marina even if not plugged in.
  - (b) Is stopped by a RCD.
  - (c) Is stopped by Galvanic Isolators.
  - (d) Is stopped by Isolation Transformers.

Corrosion Quiz: Q8

- If underwater fittings are electrically bonded,:
  - (a) They are protected by an anode.
  - (b) They provide a good radio ground.
  - (c) They are at risk from in-water voltage gradients.
  - (d) They should be isolated from the boat’s DC Ground.

Corrosion Quiz: Q9

- The RCD in the marina:
  - (a) Is only there to protect life, not the boat.
  - (b) Will trip is there is a 12v DC leak to earth.
  - (c) Stops battery chargers from causing corrosion.
  - (d) Is better than an Isolation Transformer.

Corrosion Quiz: Q10

- Under Water:
  - (a) Brass is OK.
  - (b) Phosphor Bronze is OK.
  - (c) Silicone Bronze is OK.
  - (d) Aluminium Bronze is OK.

Corrosion Quiz: Q11

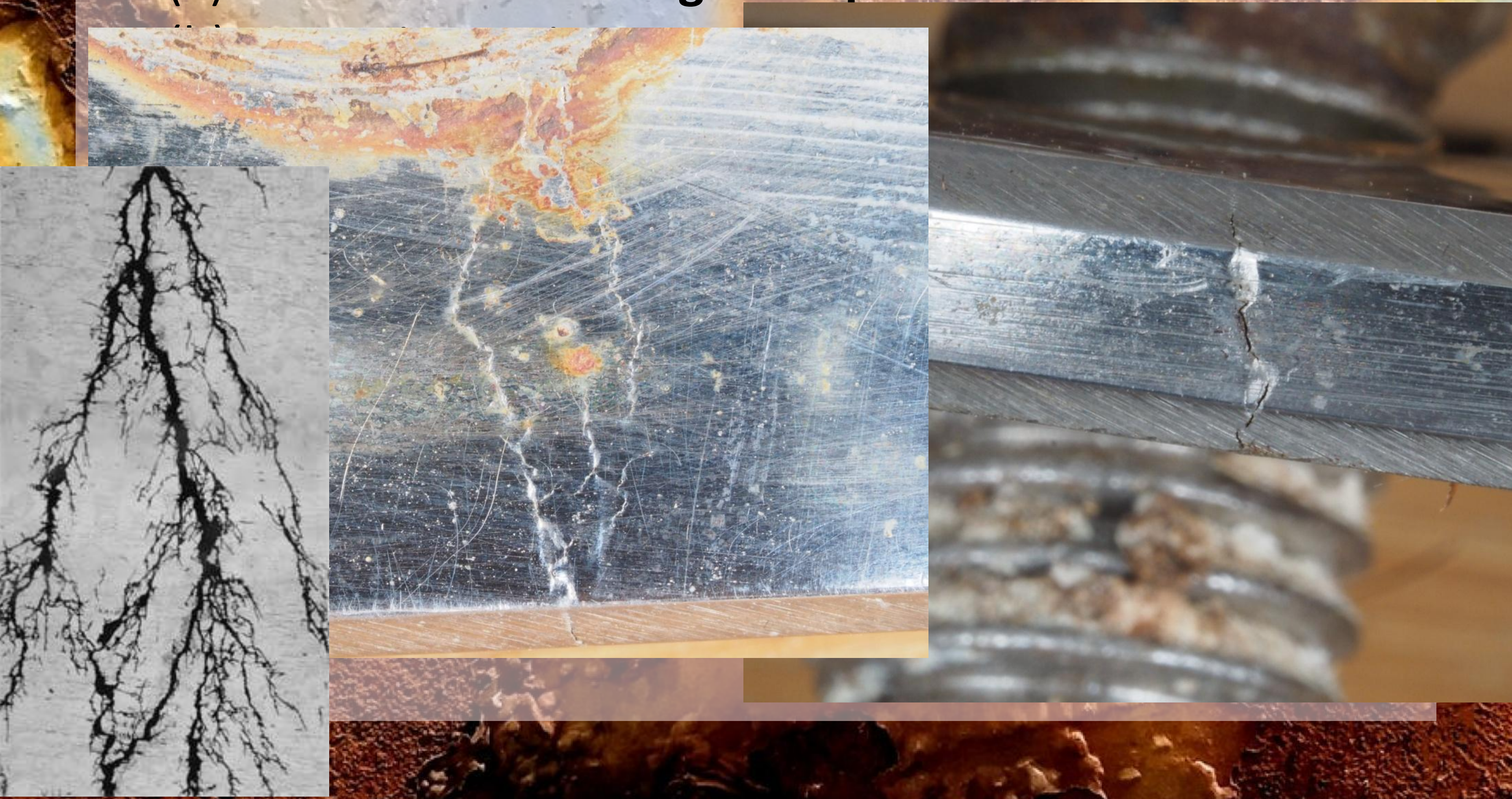
- Under Water:
  - (a) 316 Stainless Steel is OK.
  - (b) 316 Stainless Steel is OK with an anode.
  - (c) 316 Stainless Steel can pit with or without an anode.
  - (d) 316 Stainless Steel can crevice corrode even with an anode.

Corrosion Quiz: Q12

- I should be glad if my anodes:
  (a) last for ages.
  (b) erode evenly over time
  (c) disappear quickly
  (d) are now aluminium alloy

Corrosion Quiz: Q1

- Most Corrosion on boats is:
  - (a) Stress Corrosion **e.g Chainplates**



Corrosion Quiz: Q1

- Most Corrosion on boats is:
  - (a) Stress Corrosion **e.g Chainplates**
  - (b) Corrosion Fatigue: **Anything Shaking**
    24*60*60/3=28,800*30=864000
  - (a) Intergranular Corrosion **Crystal Structure Level**

Corrosion Quiz: Q1

- Most Corrosion on boats is:
  - (a) Stress Corrosion **e.g Chainplates**
  - (b) Corrosion Fatigue: **Anything Shaking**

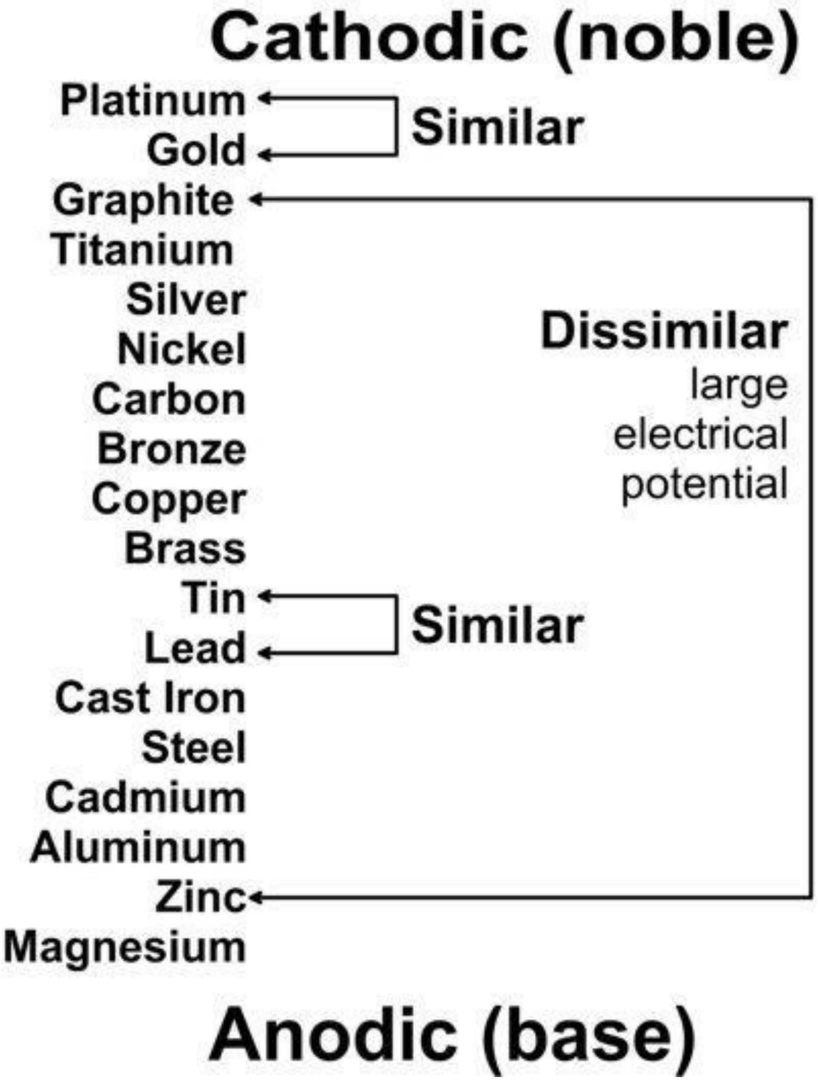
    24*60*60/3=28,800*30=864000
  - (a) Intergranular Corrosion **Crystal Structure Level**
  - (b) Pitting
  - (c) Electrolysis **Not a form of Corrosion**
  - **(d)Galvanic Corrosion**
  - (e) Oxidation in Air
  - **(f) Electrolytic Corrosion (Stray Current)**
  - (g) De-Alloying (e.g. dezincification)

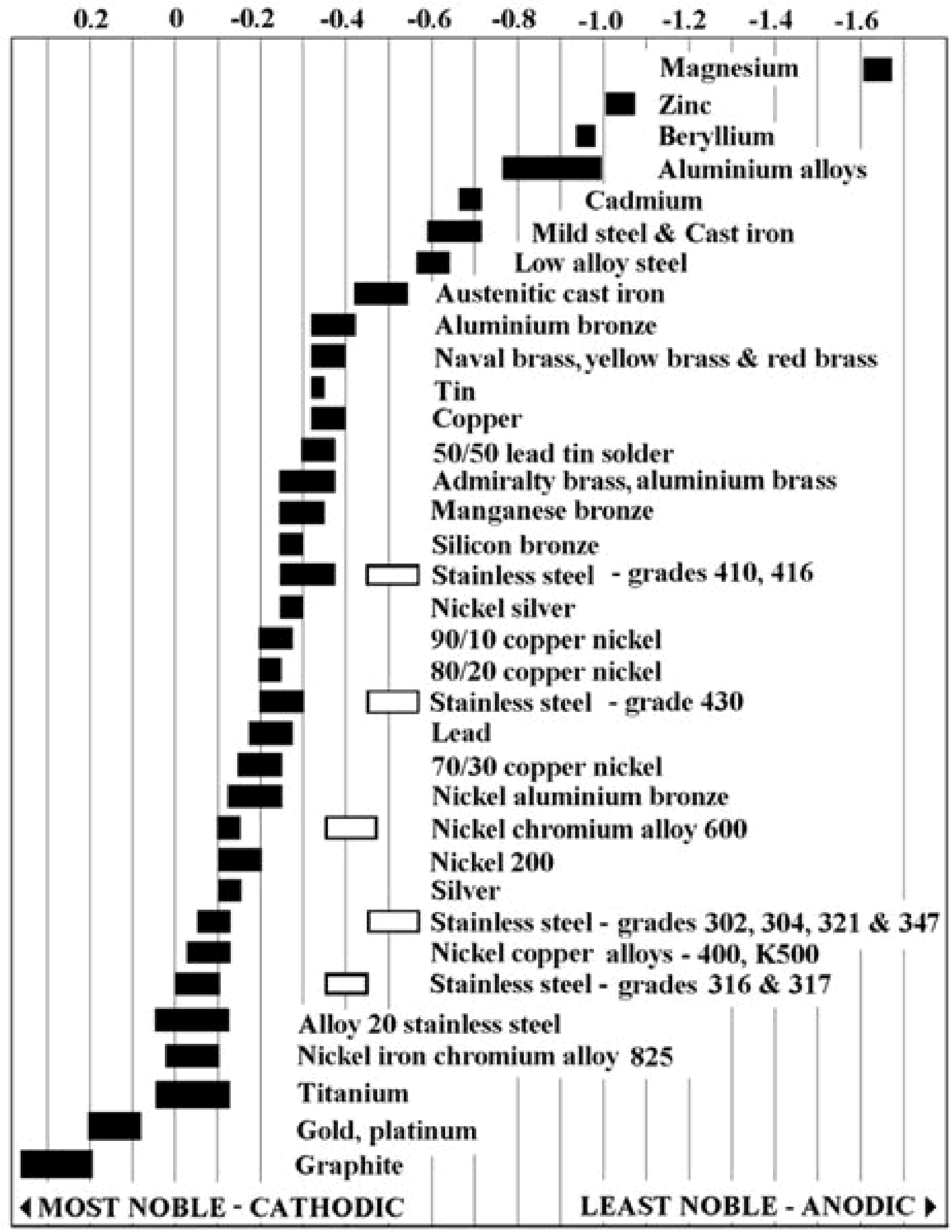
Metal Corrosion in Boats 2006

Nigel Warren's words:

Conclusion

Appreciation of the meaning of the Galvanic Series is the vital key to understanding most of the corrosion problems on board boats.
The rest is easy!

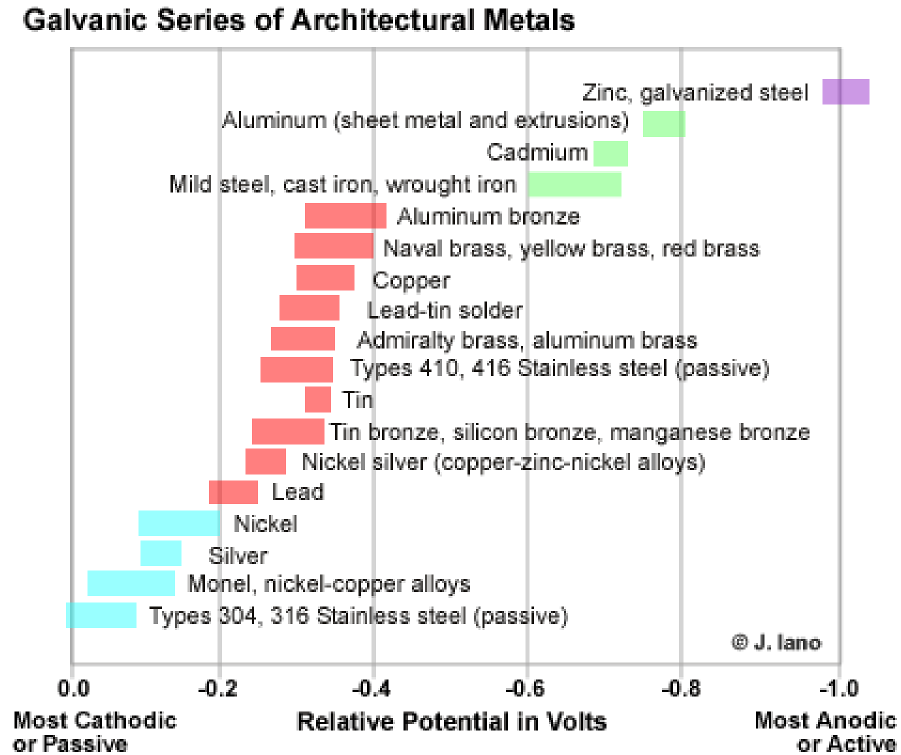

Cathodic (noble)
Platinum
Gold
Similar
Graphite
Titanium
Silver
Nickel
Dissimilar
large
electrical
potential
Carbon
Bronze
Copper
Brass
Tin
Lead
Similar
Cast Iron
Steel
Cadmium
Aluminum
Zinc
Magnesium
Anodic (base)

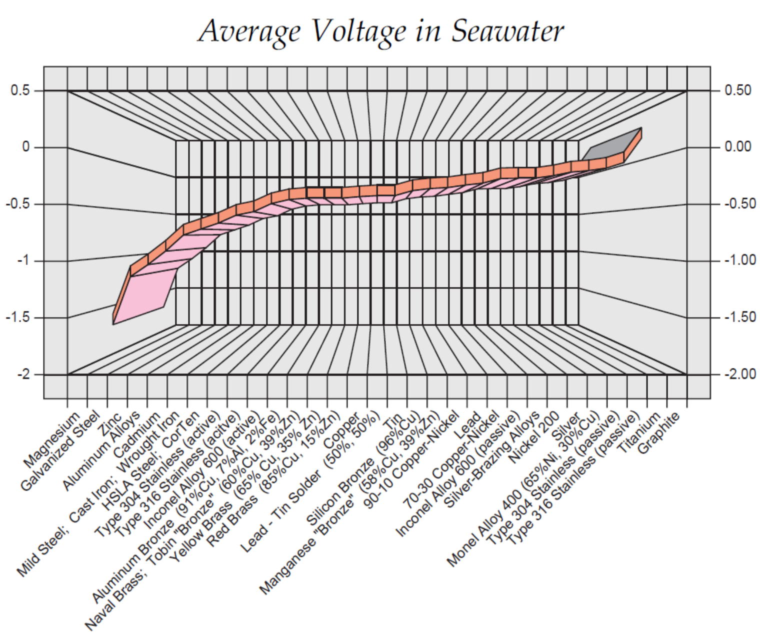

0.2
0
-0.2
-0.4
-0.6
-0.8
-1.0
-1.2
-1.4
-1.6
Magnesium
Zinc
Beryllium
Aluminium alloys
Cadmium
Mild steel & Cast iron
Low alloy steel
Austenitic cast iron
Aluminium bronze
Naval brass, yellow brass & red brass
Tin
Copper
50/50 lead tin solder
Admiralty brass, aluminium brass
Manganese bronze
Silicon bronze
Stainless steel - grades 410, 416
Nickel silver
90/10 copper nickel
80/20 copper nickel
Stainless steel - grade 430
Lead
70/30 copper nickel
Nickel aluminium bronze
Nickel chromium alloy 600
Nickel 200
Silver
Stainless steel - grades 302, 304, 321 & 347
Nickel copper alloys - 400, K500
Stainless steel - grades 316 & 317
Alloy 20 stainless steel
Nickel iron chromium alloy 825
Titanium
Gold, platinum
Graphite
MOST NOBLE - CATHODIC
LEAST NOBLE - ANODIC

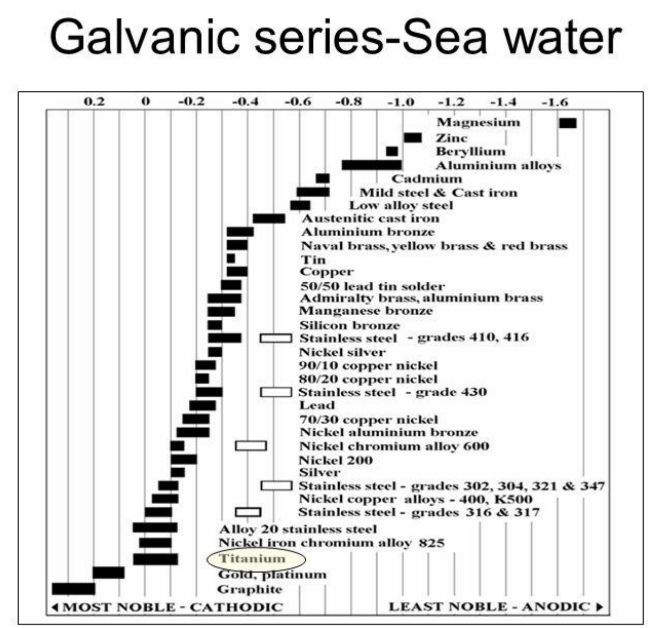
↑ LEAST NOBAL (ANODIC)

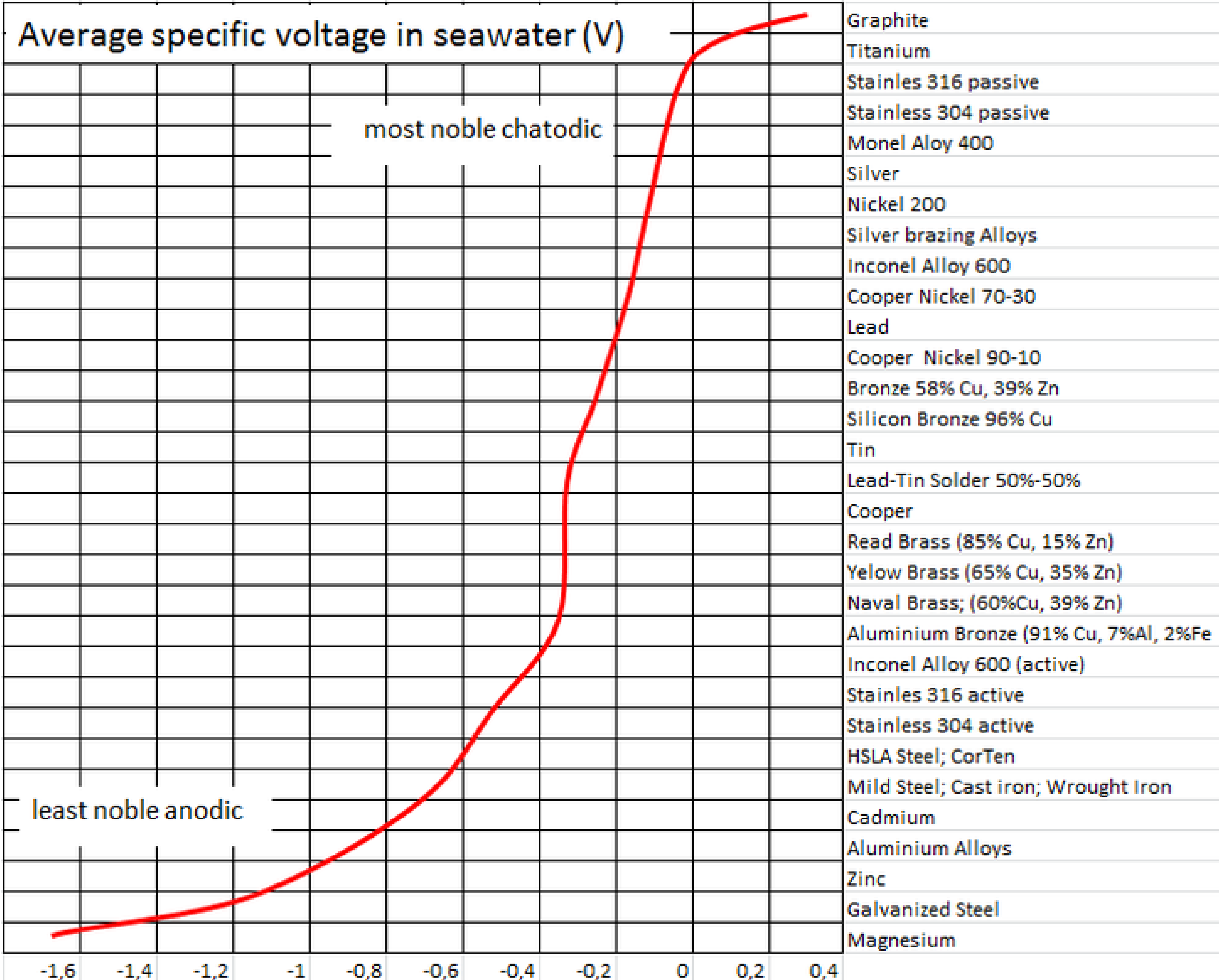
No.	MATERIAL	VOLTAGE RANGE	RELATIVE POSITION
1	Magnesium	-1.60 to -1.67	
2	Zinc	-1.00 to -1.07	
3	Beryllium	-0.93 to -0.98	
4	Aluminum Alloys	-0.76 to -0.99	
5	Cadmium	-0.66 to -0.71	
6	Mild Steel	-0.58 to -0.71	
7	Cast Iron	-0.58 to -0.71	
8	Low Alloy Steel	-0.56 to -0.64	
9	Austenitic Cast Iron	-0.41 to -0.54	
10	Aluminum Bronze	-0.31 to -0.42	
11	Brass (Naval, Yellow, Red)	-0.31 to -0.40	
12	Tin	-0.31 to -0.34	
13	Copper	-0.31 to -0.40	
14	50/50 Lead/Tin Solder	-0.29 to -0.37	
15	Admiralty Brass	-0.24 to -0.37	
16	Aluminum Brass	-0.24 to -0.37	
17	Manganese Bronze	-0.24 to -0.34	
18	Silicon Bronze	-0.24 to -0.30	
19	Stainless Steel (410, 416)	-0.24 to -0.37 (-0.45 to -0.57)	
20	Nickel Silver	-0.24 to -0.30	
21	90/10 Copper/Nickel	-0.19 to -0.27	
22	80/20 Copper/Nickel	-0.19 to -0.24	
23	Stainless Steel (430)	-0.20 to -0.30 (-0.45 to -0.57)	
24	Lead	-0.17 to -0.27	
25	70/30 Copper Nickel	-0.14 to -0.25	
26	Nickel Aluminum Bronze	-0.12 to -0.25	
27	Nickel Chromium Alloy 600	-0.09 to -0.15 (-0.35 to -0.48)	
28	Nickel 200	-0.09 to -0.20	
29	Silver	-0.09 to -0.15	
30	Stainless Steel (302, 304, 321, 347)	-0.05 to -0.13 (-0.45 to -0.57)	
31	Nickel Copper Alloys (400, K500)	-0.02 to -0.13	
32	Stainless Steel (316, 317)	0.00 to -0.10 (-0.35 to -0.45)	
33	Alloy 20 Stainless Steel	0.04 to -0.12	
34	Nickel Iron Chromium Alloy 825	0.02 to -0.10	

MOST NOBAL (CATHO








Average specific voltage in seawater (V)
most noble chatodic
least noble anodic
Graphite
Titanium
Stainles 316 passive
Stainless 304 passive
Monel Aloy 400
Silver
Nickel 200
Silver brazing Alloys
Inconel Alloy 600
Cooper Nickel 70-30
Lead
Cooper Nickel 90-10
Bronze 58% Cu, 39% Zn
Silicon Bronze 96% Cu
Tin
Lead-Tin Solder 50%-50%
Cooper
Read Brass (85% Cu, 15% Zn)
Yelow Brass (65% Cu, 35% Zn)
Naval Brass; (60%Cu, 39% Zn)
Aluminium Bronze (91% Cu, 7%Al, 2%Fe
Inconel Alloy 600 (active)
Stainles 316 active
Stainless 304 active
HSLA Steel; CorTen
Mild Steel; Cast iron; Wrought Iron
Cadmium
Aluminium Alloys
Zinc
Galvanized Steel
Magnesium
-1,6
-1,4
-1,2
-1
-0,8
-0,6
-0,4
-0,2
0
0,2
0,4

Corrosion Quiz: Q2

- Anodes can be:
  - (a) Magnesium in Fresh Water
  - (b) Zinc or Aluminium in Salt Water
  - (c) Iron (Fe)
  - **(d) All of the above, depending on the situation**

Corrosion Quiz: Q3

- Anode size and shape matters:
  - (a) Bigger is always better
  - (b) More surface area Is better.
  - (c) Too much anode destroys stainless and bronze
  - **(d) Too much anode can rot wood and corrode aluminium.**

Corrosion Quiz: Q4

- Because galvanic voltages are very small, anodes should:
  - (a) be forward of the metal it protects.
  - (b) be aft of the metal it protects.
  - (c) last for years and years
  - **(d) always definitely have good electrical connection.**

Corrosion Quiz: Q5

- Because protective galvanic currents (electron flows)through the water are very small and water generally flows from bow to stern, the anodes should be positioned:
  (a) forward of the metal it protects.
  (b) aft of the metal it protects.
  (c) to port or starboard of the metal it protects.
  (d) Since electrons don't "flow", the field energy being instantly transferred from atom to atom, only distance is important; closer to the metal it protects is better.

Corrosion Quiz: Q6

- Two Boats on Adjacent Swing Moorings:
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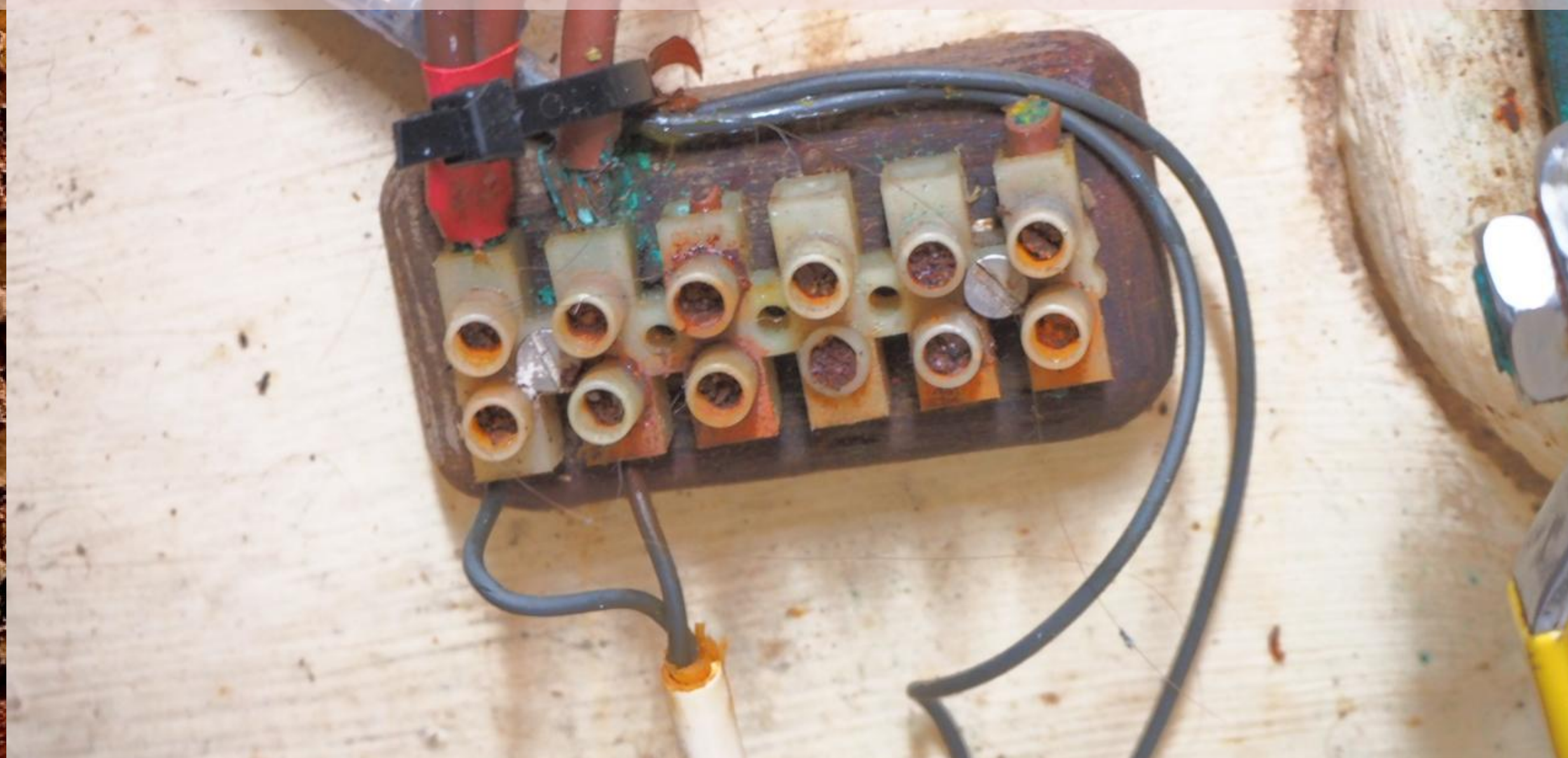

Corrosion Quiz: Q8

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Corrosion Quiz: Q9

- The RCD in the marina:
  - **(a) Is only there to protect life, not the boat.**
  - (b) Will trip is there is a 12v DC leak to earth.
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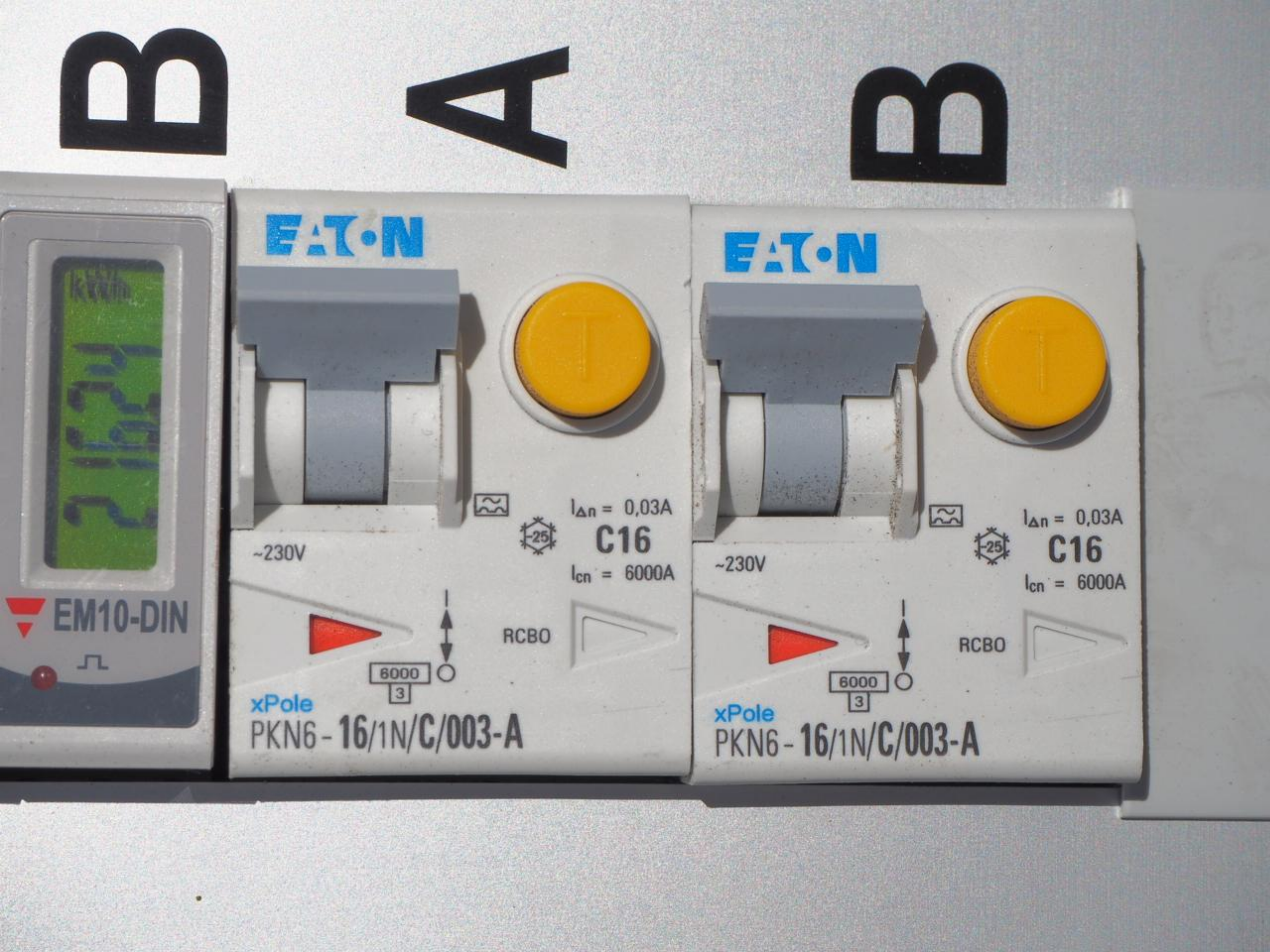
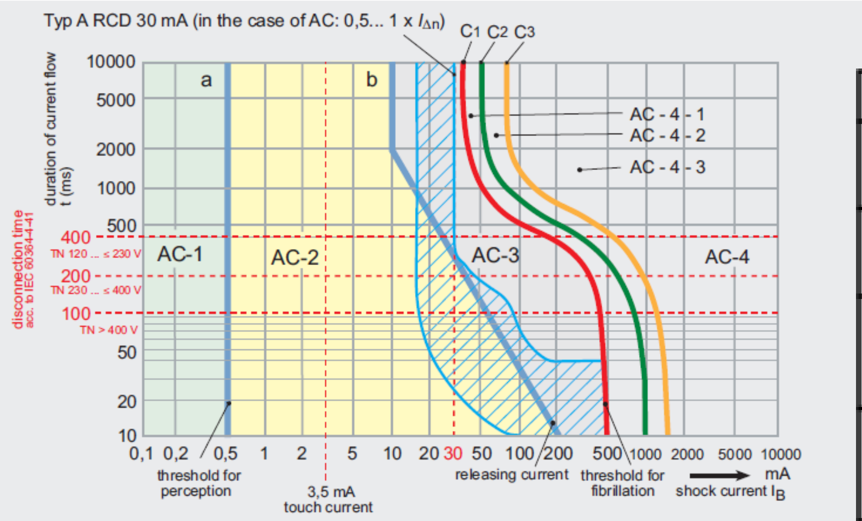
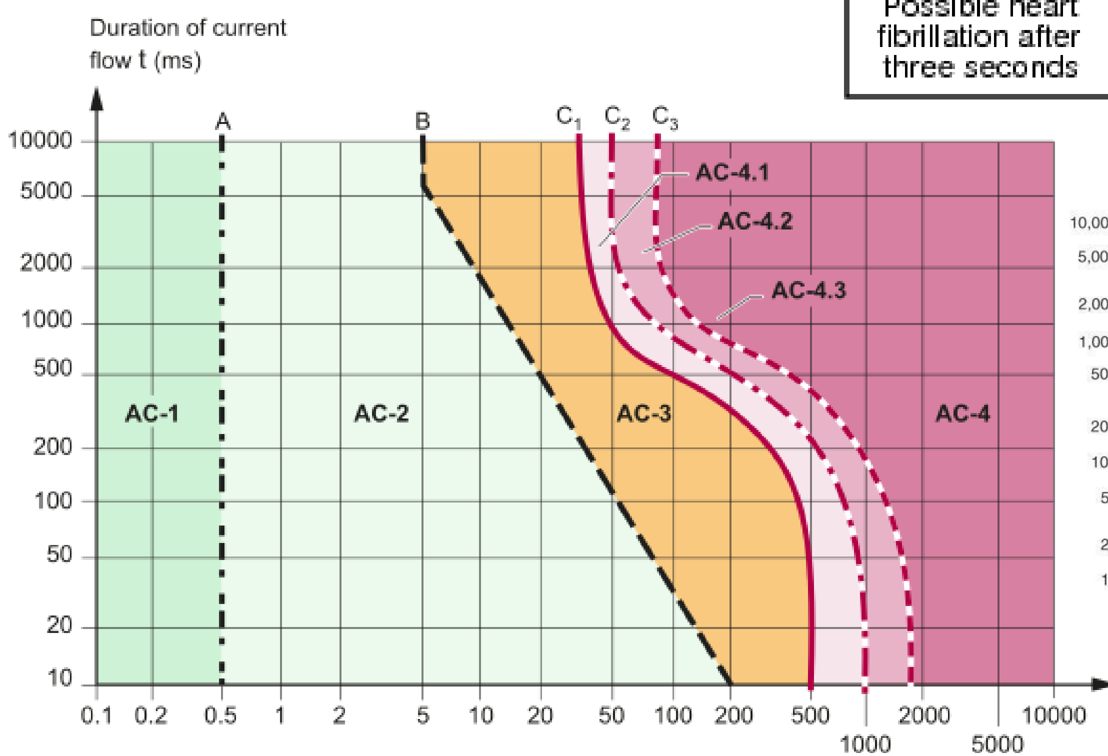
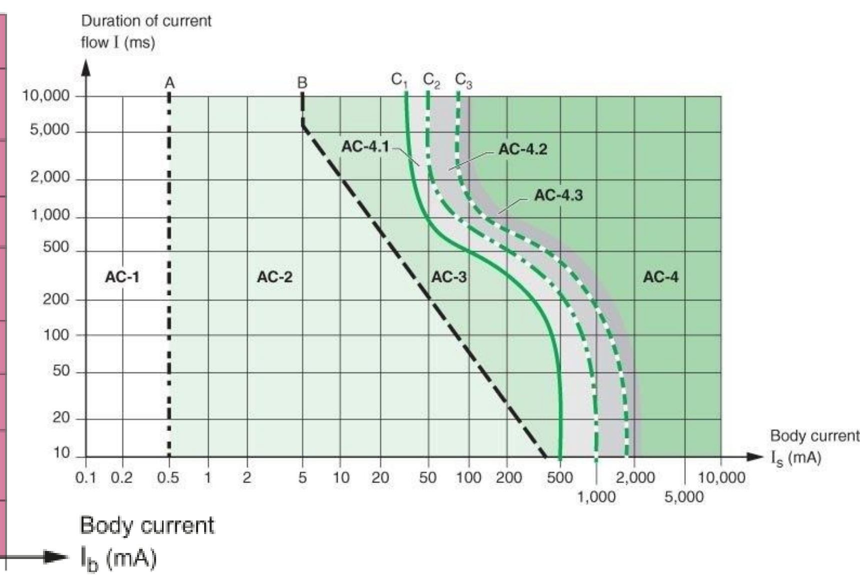
  - (d) Is better than an Isolation Transformer.


B
A
B
kWh
EM10-DIN
EATON
~230V
IΔn = 0,03A
C16
Icn = 6000A
RCBO
6000
3
xPole
PKN6 - 16/1N/C/003-A
EATON
~230V
IΔn = 0,03A
C16
Icn = 6000A
RCBO
6000
3
xPole
PKN6 - 16/1N/C/003-A



Bodily effect	*Gender*	*DC*	*60 Hz AC*	*10 kHz AC*
Slight sensation at point(s) of contact	Men	1 mA	0.4 mA	7 mA
	Women	0.6 mA	0.3 mA	5 mA
Threshold of bodily perception	Men	5.2 mA	1.1 mA	12 mA
	Women	3.5 mA	0.7 mA	8 mA
Pain, with voluntary muscle control maintained	Men	62 mA	9 mA	55 mA
	Women	41 mA	6 mA	37 mA
Pain, with loss of voluntary muscle control	Men	76 mA	16 mA	75 mA
	Women	51 mA	10.5 mA	50 mA
Severe pain, difficulty breathing	Men	90 mA	23 mA	94 mA
	Women	60 mA	15 mA	63 mA
Possible heart fibrillation after three seconds	Men	500 mA	100 mA	
	Women	500 mA	100 mA	





Zone	Boundaries	Physiological effects
AC-1	Up to curve a	Usually no reaction
AC-2	Curve a up to curve b	Usually no physiological effects
AC-3	Curve b up to curve c_1	Usually no organic damage to be expected. Likelihood of muscular contractions and difficulty in breathing, reversible disturbances of formation and conduction of impulses in the heart, including atrial fibrillation and transient cardiac arrest without ventricular fibrillation increasing with magnitude and time.
AC-4	Above curve c_1	Increasing with magnitude and time, dangerous pathophysiological effects such as cardiac arrest, breathing arrest and severe burns may occur in addition to the effects of Zone AC-3:
	$c_1 - c_2$	Probability of ventricular fibrillation increasing up to about 5%.
	$c_2 - c_3$	Probability of ventricular fibrillation increasing up to about 50%
	Beyond curve c_3	Probability of ventricular fibrillation above 50%.

RCD Regulations

In summary:

'High sensitivity' RCDs, rated 30 mA or even 10 mA, are designed to disconnect the supply within 40 milliseconds when passing 5 times its rated residual current and within 300ms at rated tripping current to protect the user.

Electricity (Safety) Regulations 2010

24Electrically unsafe RCDs

(6) Where an RCD is required by AS/NZS 3000 to be installed to protect children from the risk of electric shock from direct contact, the RCD is deemed to be electrically unsafe if—

(a)it has a rated residual current exceeding 10 milliamperes; or

(b)it has a rated residual current of 10 milliamperes or less but—

(i) it does not interrupt the current in all live conductors within—

(A) 300 milliseconds when passing its rated residual current; or

(B)40 milliseconds when passing 5 times its rated residual current; or

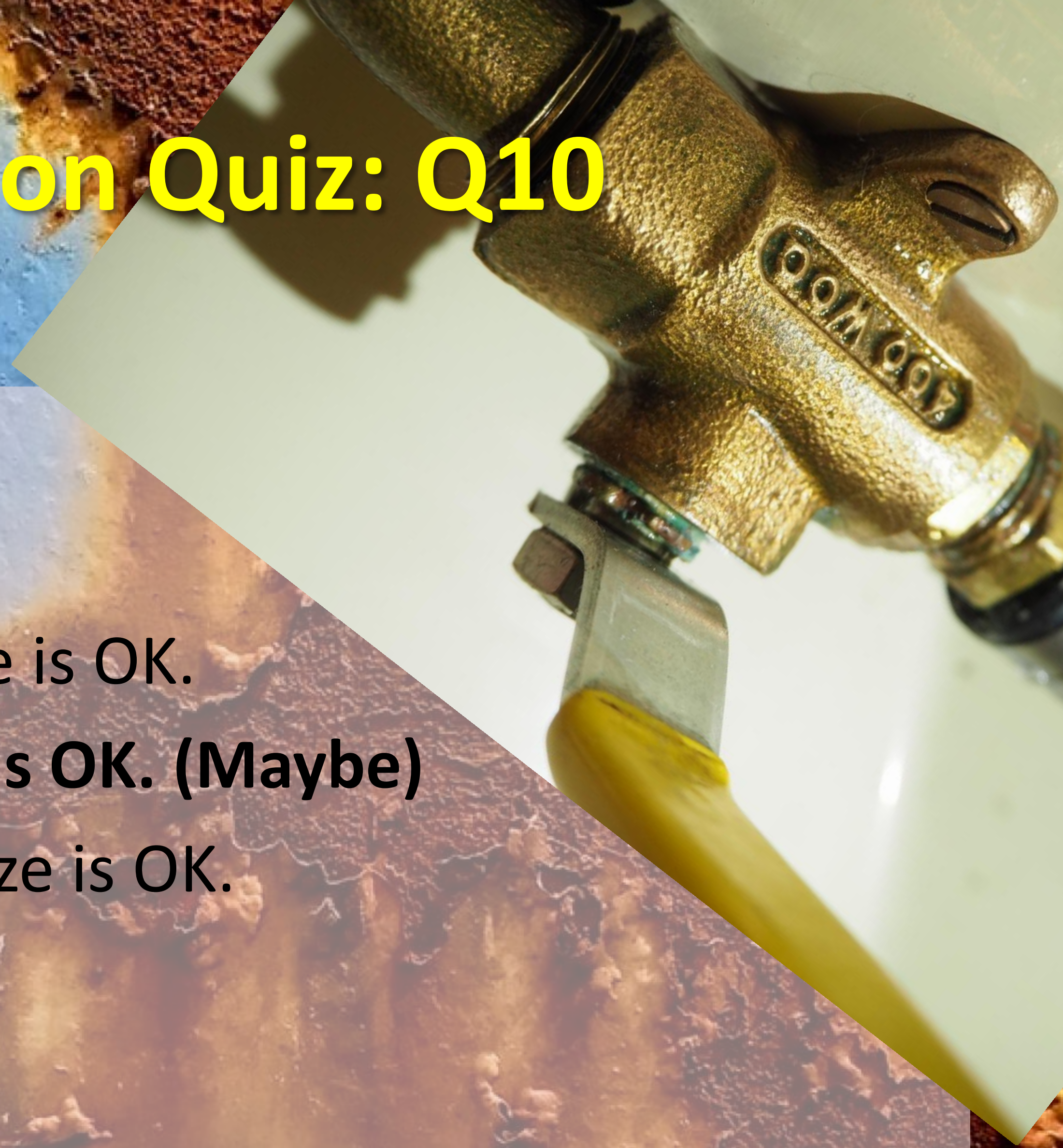

MENNEKES


MENNEKES
Push to open

MENNEKES ®
16 A - 6 h /
200-250 V ~
2P+⏚
50-60 Hz
IP 67
Typ: 1168
MQA
24
D-57399 Kirchhundem


Corrosion Quiz: Q10

- Under Water:
  - (a) Brass is OK.
  - (b) Phosphor Bronze is OK.
  - **(c) Silicone Bronze is OK. (Maybe)**
  - (d) Aluminium Bronze is OK.



What every sailor needs to know about seacocks

Thousands of yachts, including new ones, are in danger of sinking, due to through-hull fittings made from brass rather than bronze. Yacht surveyor Paul Stevens, explains how confusion in some chandleries could put your boat at risk

All boatbuilders used to fit high-quality bronze seacocks and skin fittings because cheaper brass fittings are known to fail, with potentially catastrophic results. Yet in recent years, some of the world's leading boatbuilders have been using ordinary brass fittings below the waterline. These typically consist of 40% zinc and are patently not suitable for use below the waterline. Equally worrying, many yachtsmen, due to lack of advice or good labelling, are buying replacement seacocks made of brass assuming they are buying bronze or DZR (dezincification-resistant brass). As a yacht surveyor, I have seen hundreds of brass seacocks and associatd fittings that are unfit for use in salt water, on a wide range of boats.

1998 boat built to RCD with non-marine brass valves

2009 boat: through-hull already showing the pinkish spots of classic dezincification

What's wrong with ordinary brass?

In salt water, brass – an alloy of copper and zinc – is prone to a form of corrosion called dezincification. Zinc is leached from the metal and the remaining copper shell becomes porous and fragile. The result is often referred to as the metal becoming 'carroty', due to its colour.

In the past, boatbuilders who used brass fittings were usually caught out and had to improve their specifications. But everything changed in 1998, when the European Community's Recreational Craft Directive (RCD) came into force. Where seacocks are concerned, it has made matters worse.

All boats must now conform to a wide range of compulsory ISO standards. The standard for metallic seacocks and through-hull fittings (ISO 9093-1) states: 'Materials used shall be corrosion-resistant...' But amazingly, the directive defines corrosion-resistant as: 'a material which, within a service time of five years, does not display any defect that will impair tightness, strength or function.'

➔

PHOTOS: PAUL STEVENS

Time to panic! So much electrolytic action that the plywood backing pad is disintegrating due to electrochemical decay

This yacht sank on her mooring on the River Tamar. Thousands of boats with inadequate seacocks are at risk of sharing her fate

'As a surveyor, I have seen hundreds of brass seacocks and associated fittings that are unfit for use in salt water, on a wide range of boats'

The four main types of seacock: pros and cons

Traditional

In common use for many years, this type has proved extremely reliable. It consists of a tapered, revolving hollow plug with an aperture in the side, located in a body with a matching taper. When the apertures are in line, the seacock is open. Manufactured by Blakes for decades, originally of bronze but of DZR in more recent years.

A decades-old bronze Blakes seacock: good for another 30 years or more

Pros:
- Instant visual indication of whether open or closed
- Only one moving part
- Supplied as an assembly, with fixing bolts made of material completely compatible with the seacock
- Very easy to dismantle for inspection and service

Cons:
- More expensive than other types

Gate valve assembly

This is a through-hull fitting with a gate valve and a hose tail fitting. They used to be quite widely used, but are no longer found on new boats. A gate valve is exactly what it says: a circular gate is screwed down into the body of the valve to close off the bore. Many older boats still have them. Provided good materials have been used, they will generally last well.

Many used boats have gate valves. This one is terminally corroded

Pros:
- None

Cons:
- Triple the risk of dodgy materials, because there are three separate components that are not usually supplied as an assembly
- Does not conform to the ISO standard, which requires a visual indicator as to whether the valve is open or closed
- More difficult to dismantle for inspection and servicing
- Prone to leaking, due to debris and scale building up in the bore and preventing full closure
- Gate valves have been made in their millions in ordinary brass and there is no mandatory marking scheme, so you may not be able to tell good ones from bad ones

Ball valve assembly

Through-hull fitting with ball valve and hose tail fitting. This is in almost universal use in new boats. Ball valves have a rotating ball within the bore, with a hole right through it. When this is in line with the bore, the valve is open. Only a 45° turn is required to close it, which gives the required visual indication.

Pros:
- Easy and quick to operate, with immediate visual indication
- Reliable and has a long life, provided that all the components in the assembly are made of corrosion-resistant materials such as bronze or DZR
- Less expensive than traditional seacocks, although the difference is not that significant when all three components are made of the appropriate materials

Cons:
- Requires quite a lot of space in the larger sizes as used for cockpit drains or heads discharge
- Millions made in ordinary brass. No mandatory marking scheme, so you may not be able to tell good ones from bad ones

Most modern boats have gate valves. This one needs replacing

PREFER PLASTIC?

Plastic seacocks are the choice of many long-distance cruisers. The Marelon range, made by Forespar, are glass reinforced DuPont Zytel.

Pros:
- Each assembly is sold as a unit. Fittings made of the same material to cover every installation
- No galvanic or electrolytic corrosion – a big advantage
- Minimal maintenance
- High-quality, dedicated marine products

Cons:
- Not as fire-resistant as metal, thus not ideal for use in engine spaces and other areas with a fire risk.
- More expensive than mass-produced, non-marine brass seacocks.

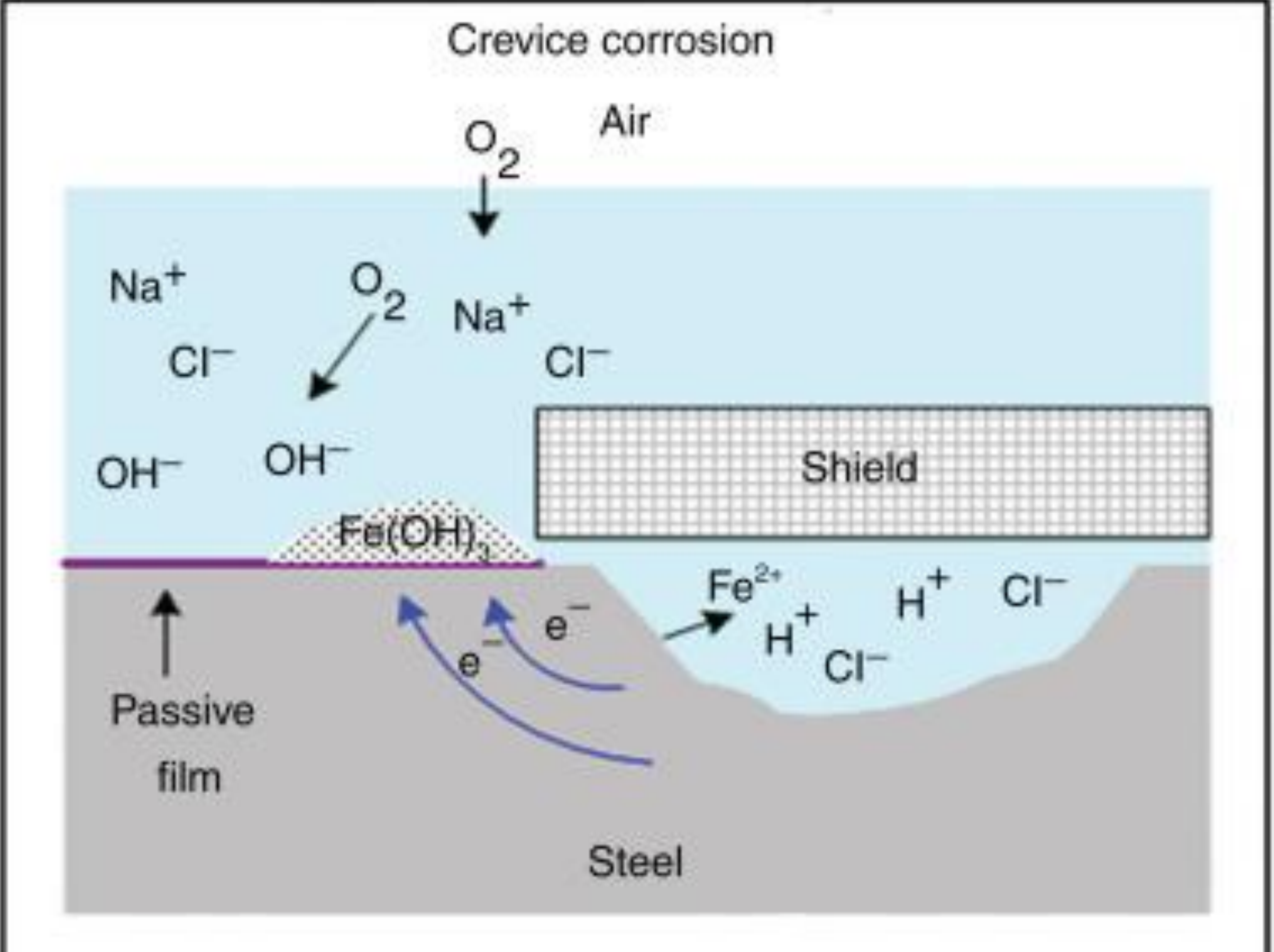
MAIN PHOTO ABOVE: RACHEL FLATT

Corrosion Quiz: Q11

- Under Water:
  (a) 316 Stainless Steel is OK.
  (b) 316 Stainless Steel is OK with an anode.
  (c) 316 Stainless Steel can pit with or without an anode.
  (d) 316 Stainless Steel can crevice corrode even with an anode.





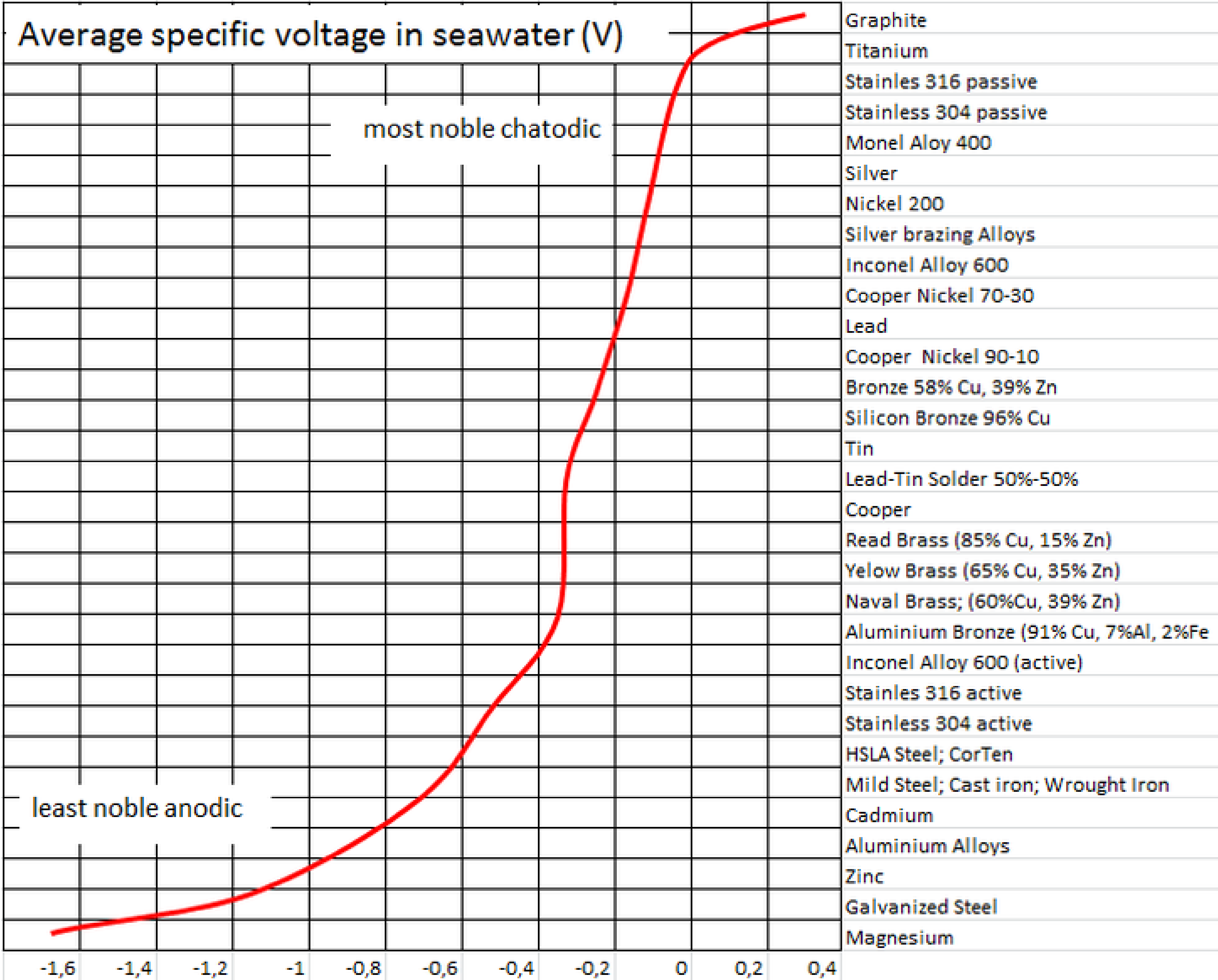


Crevice corrosion
Air
O2
Na+
O2
Na+
Cl−
Cl−
OH−
OH−
Shield
Fe(OH)3
Fe2+
H+
Cl−
e−
H+
e−
Cl−
Passive
film
Steel

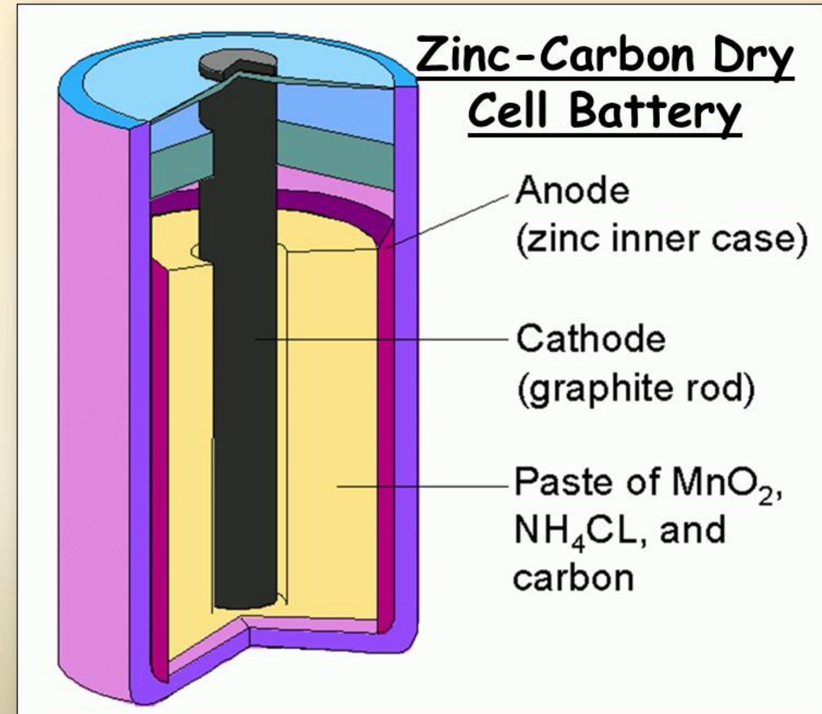
Corrosion Quiz: Q12

- I should be glad if my anodes:
  - (a) last for ages.
  - **(b) erode evenly over time**
  - (c) disappear quickly
  - (d) are now aluminium alloy

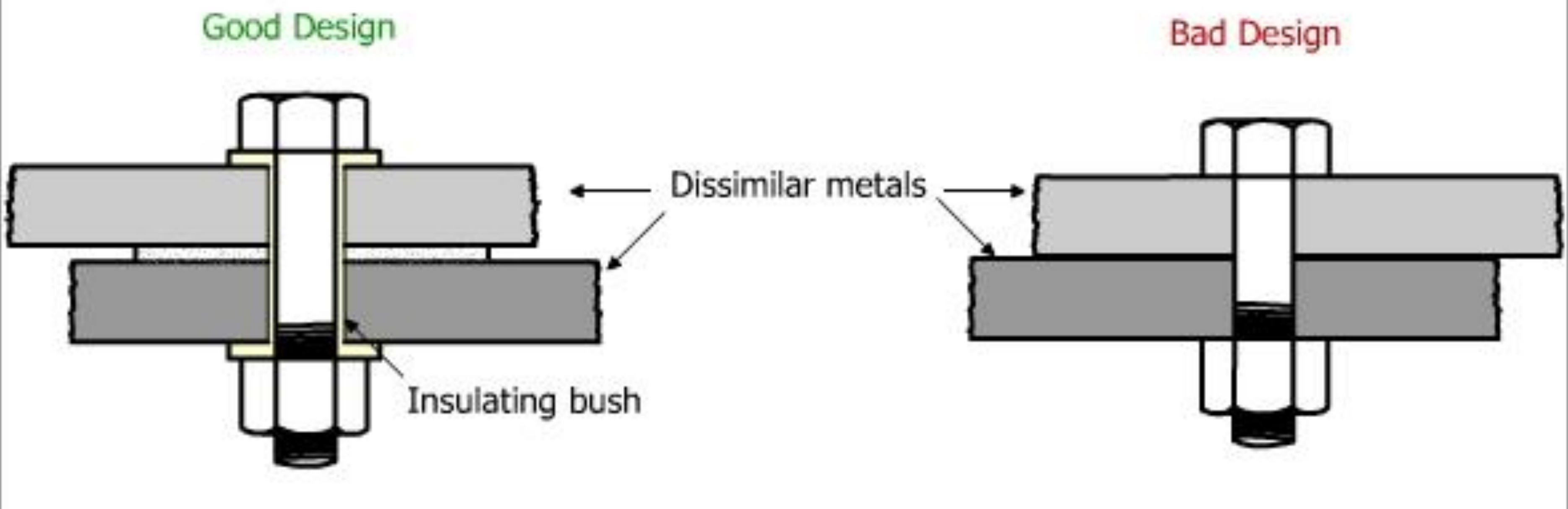
Corrosion Quiz End



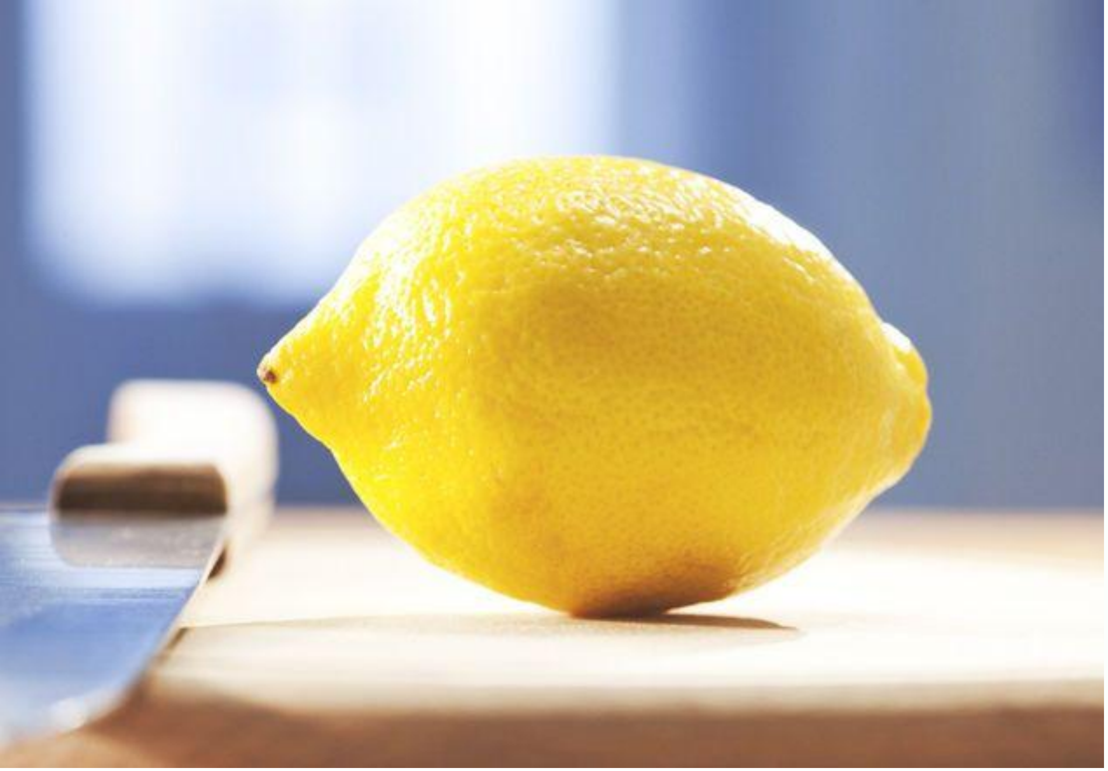
Average specific voltage in seawater (V)
most noble chatodic
least noble anodic
Graphite
Titanium
Stainles 316 passive
Stainless 304 passive
Monel Aloy 400
Silver
Nickel 200
Silver brazing Alloys
Inconel Alloy 600
Cooper Nickel 70-30
Lead
Cooper Nickel 90-10
Bronze 58% Cu, 39% Zn
Silicon Bronze 96% Cu
Tin
Lead-Tin Solder 50%-50%
Cooper
Read Brass (85% Cu, 15% Zn)
Yelow Brass (65% Cu, 35% Zn)
Naval Brass; (60%Cu, 39% Zn)
Aluminium Bronze (91% Cu, 7%Al, 2%Fe
Inconel Alloy 600 (active)
Stainles 316 active
Stainless 304 active
HSLA Steel; CorTen
Mild Steel; Cast iron; Wrought Iron
Cadmium
Aluminium Alloys
Zinc
Galvanized Steel
Magnesium
-1,6
-1,4
-1,2
-1
-0,8
-0,6
-0,4
-0,2
0
0,2
0,4


Zinc-Carbon Dry Cell Battery
Anode
(zinc inner case)
Cathode
(graphite rod)
Paste of MnO_2, NH_4CL, and carbon

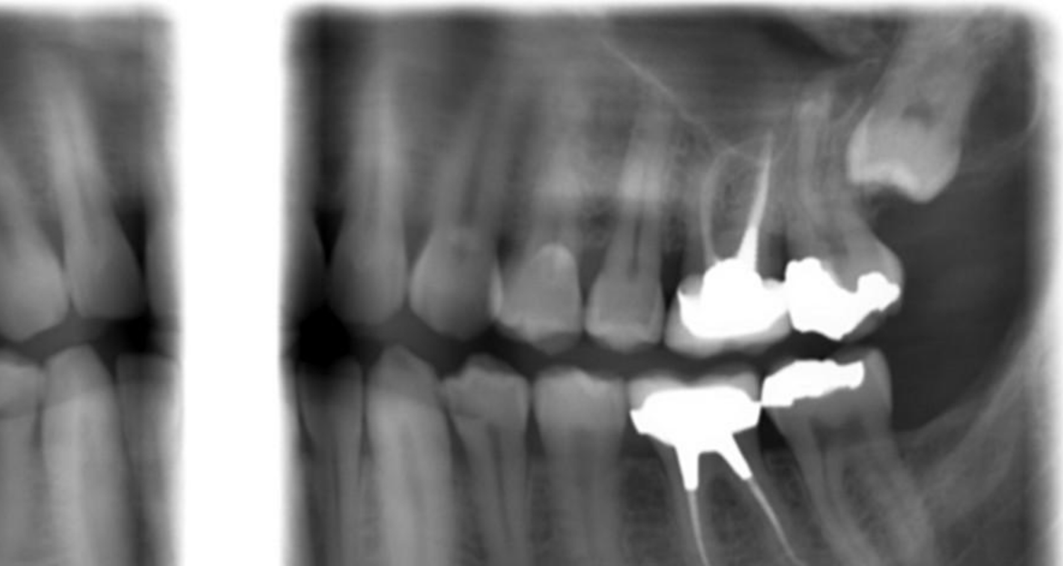

Panasonic
Carbon Zinc
Carbone-Zinc
D

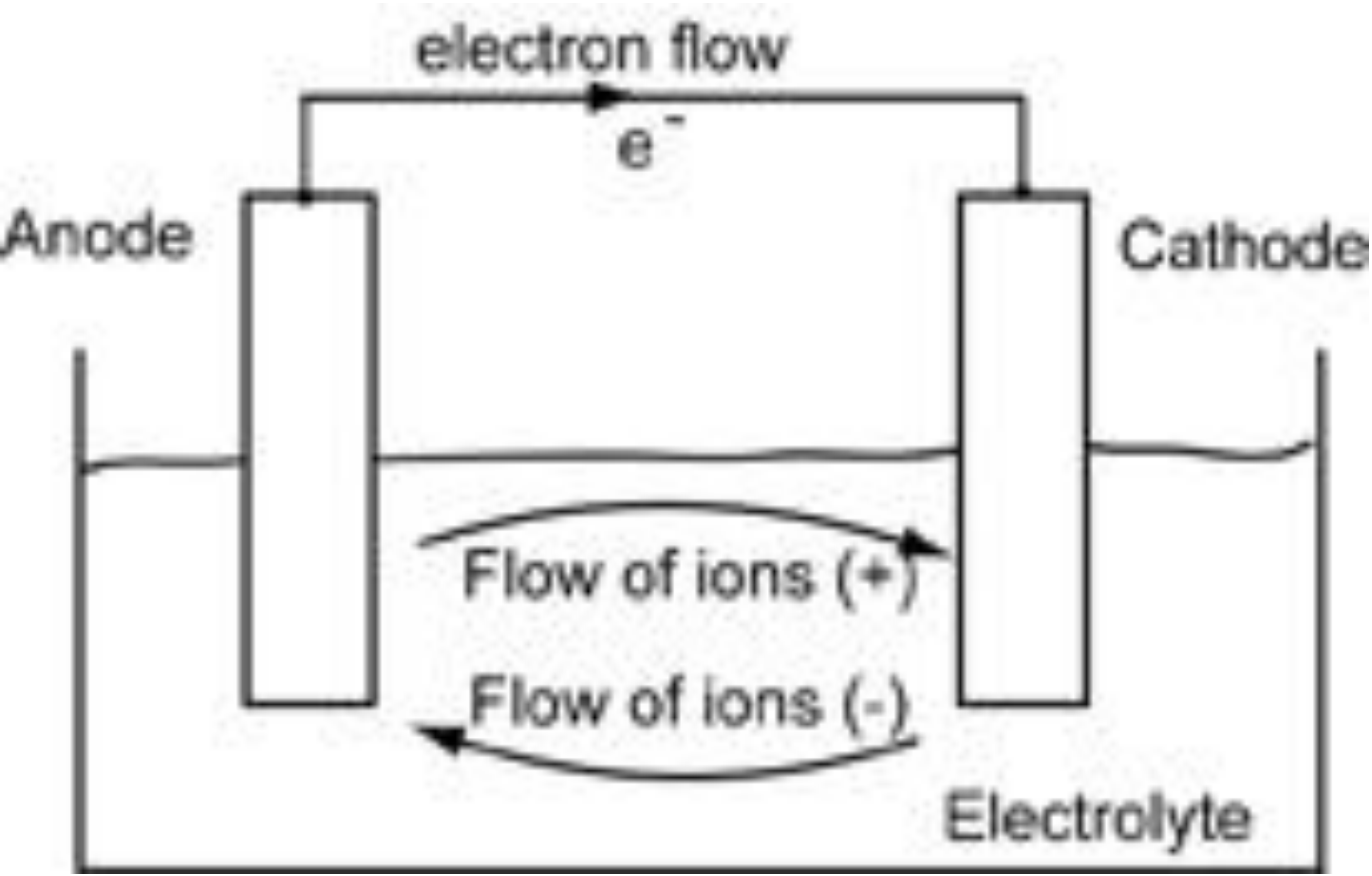


Design of bolted joints to avoid galvanic corrosion.

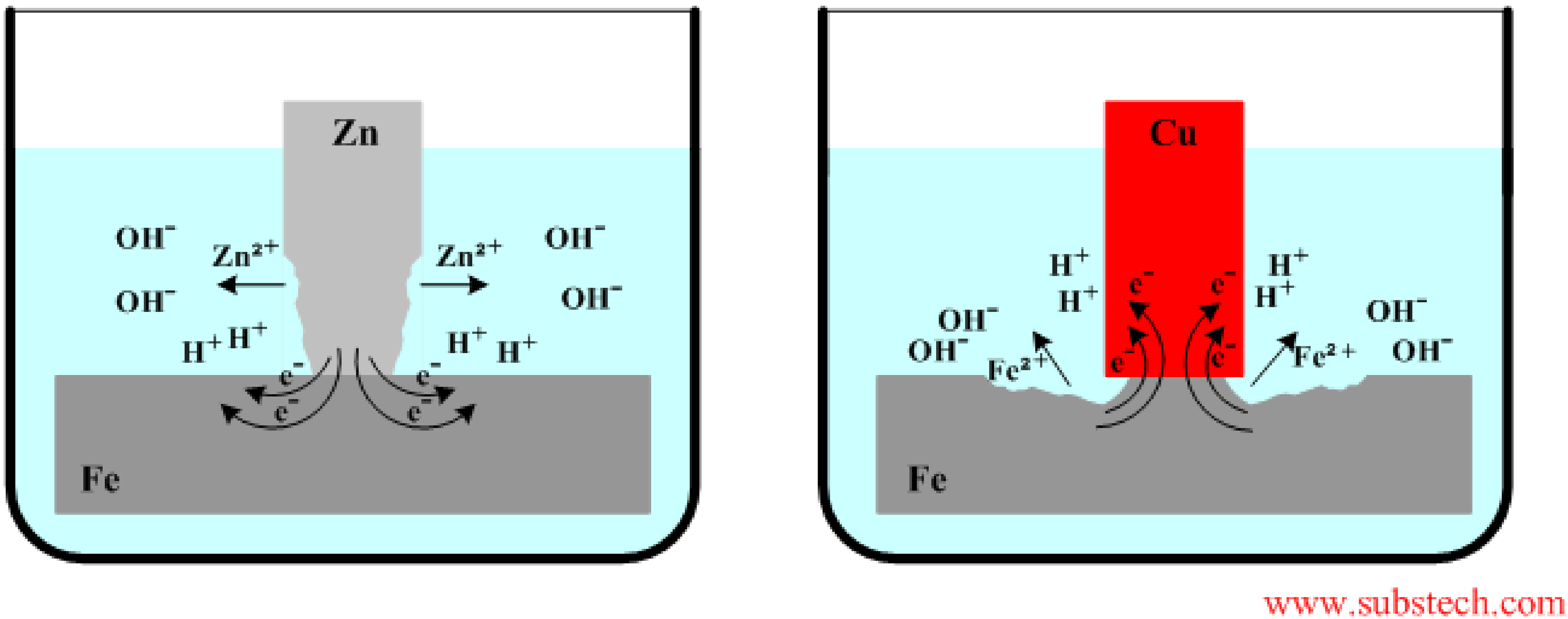


Experiment Time:

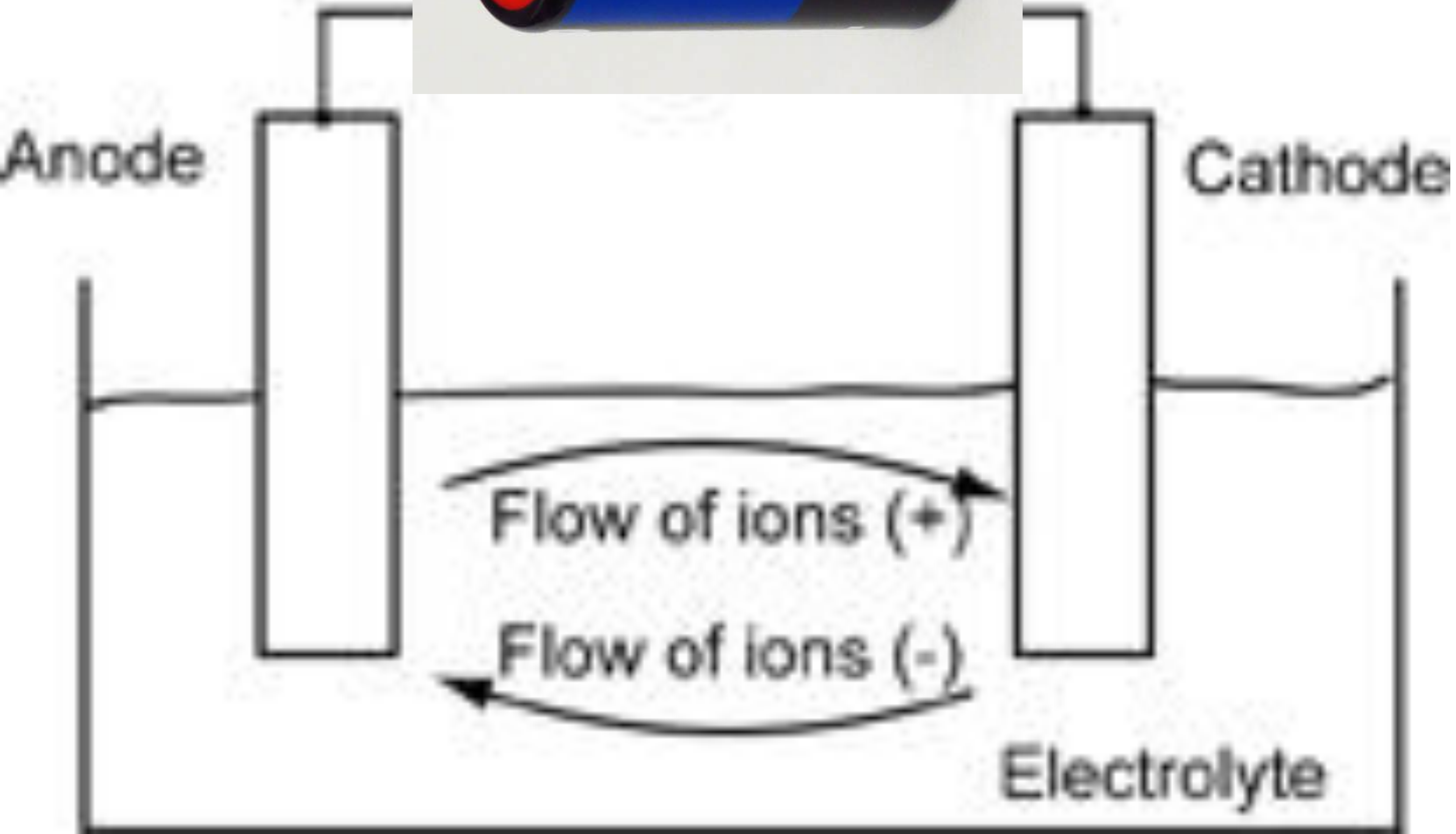


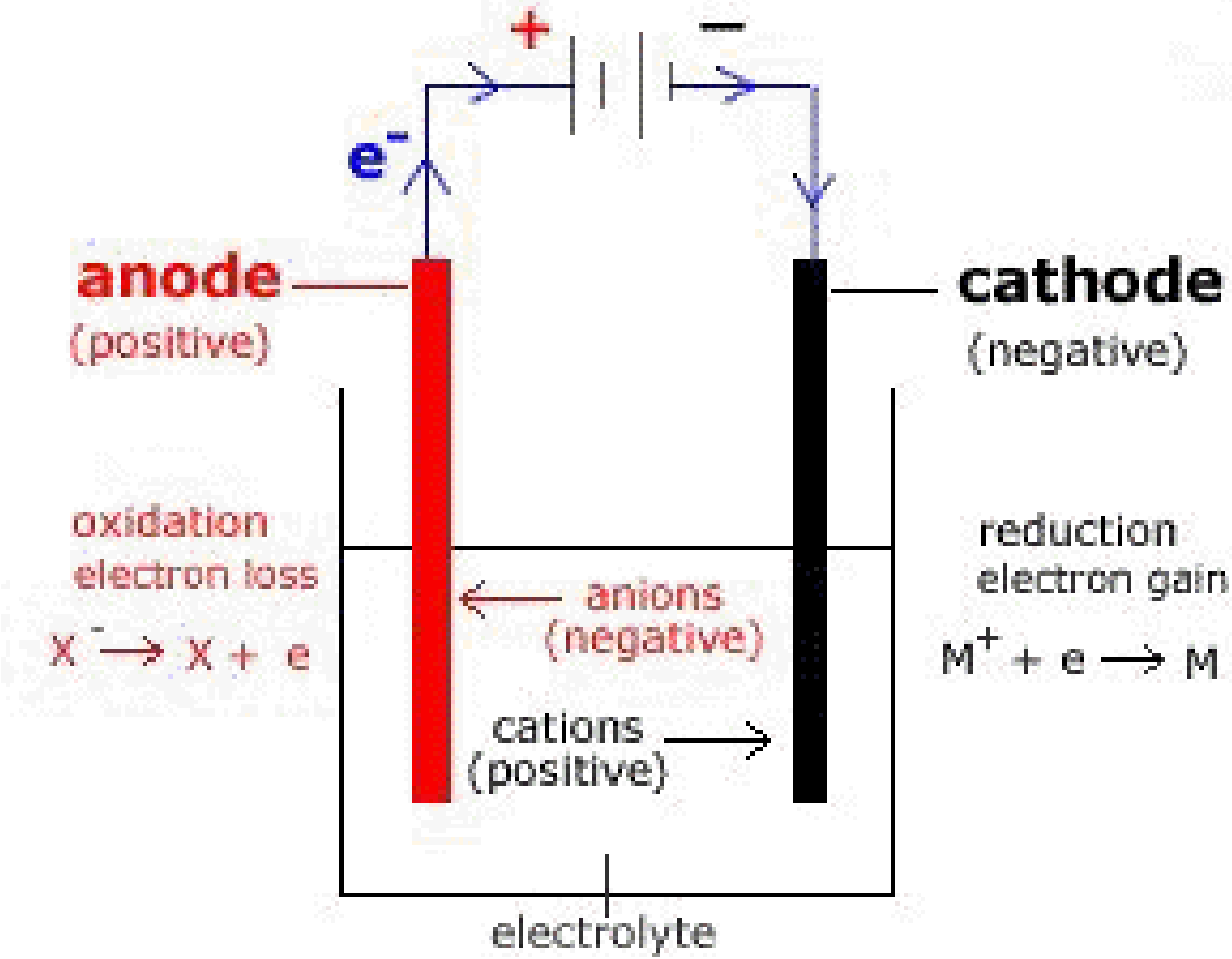

electron flow
e⁻
Anode
Cathode
Flow of ions (+)
Flow of ions (-)
Electrolyte

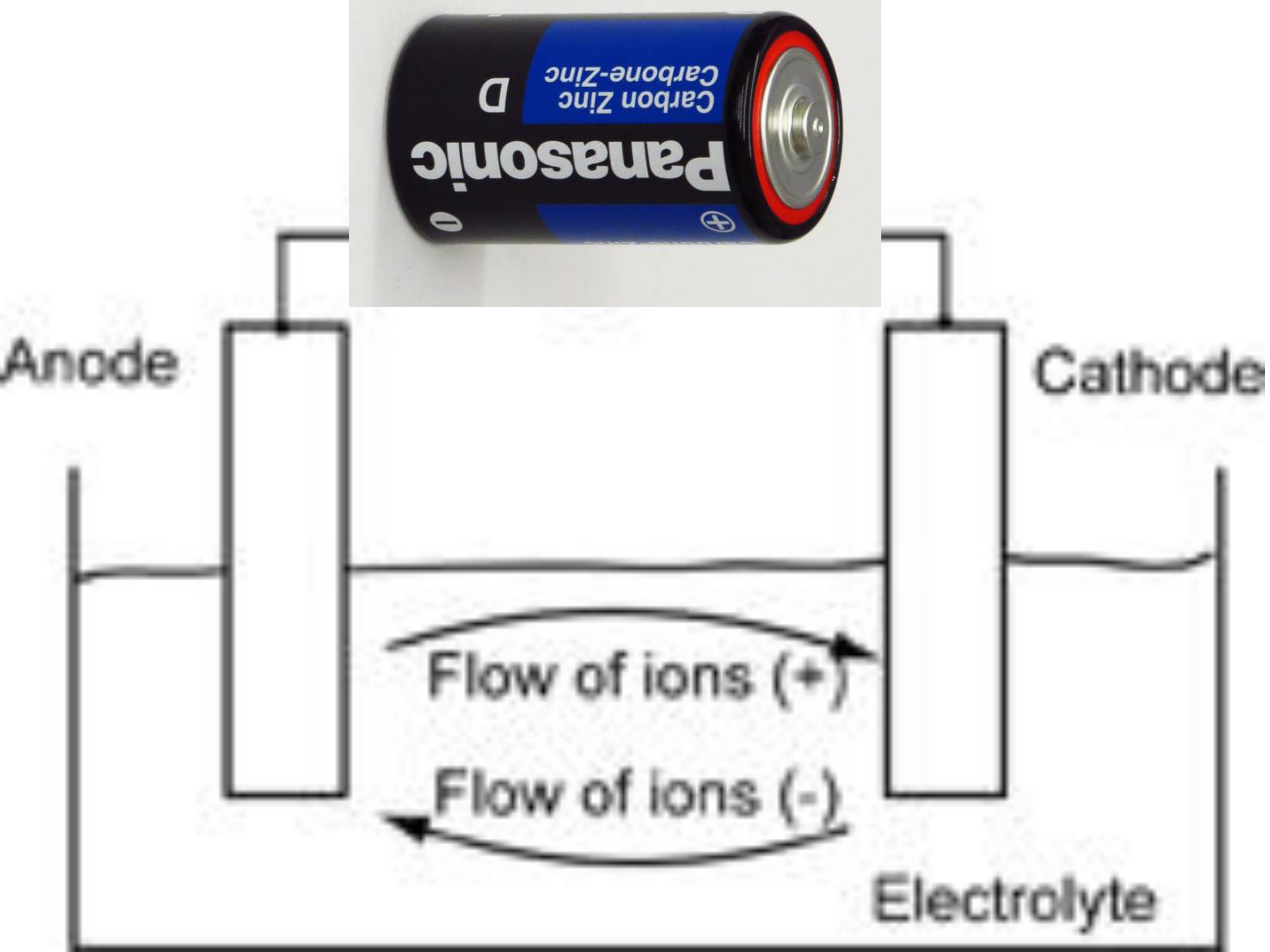
Galvanic corrosion




Panasonic
Carbon Zinc
Carbone-Zinc
D

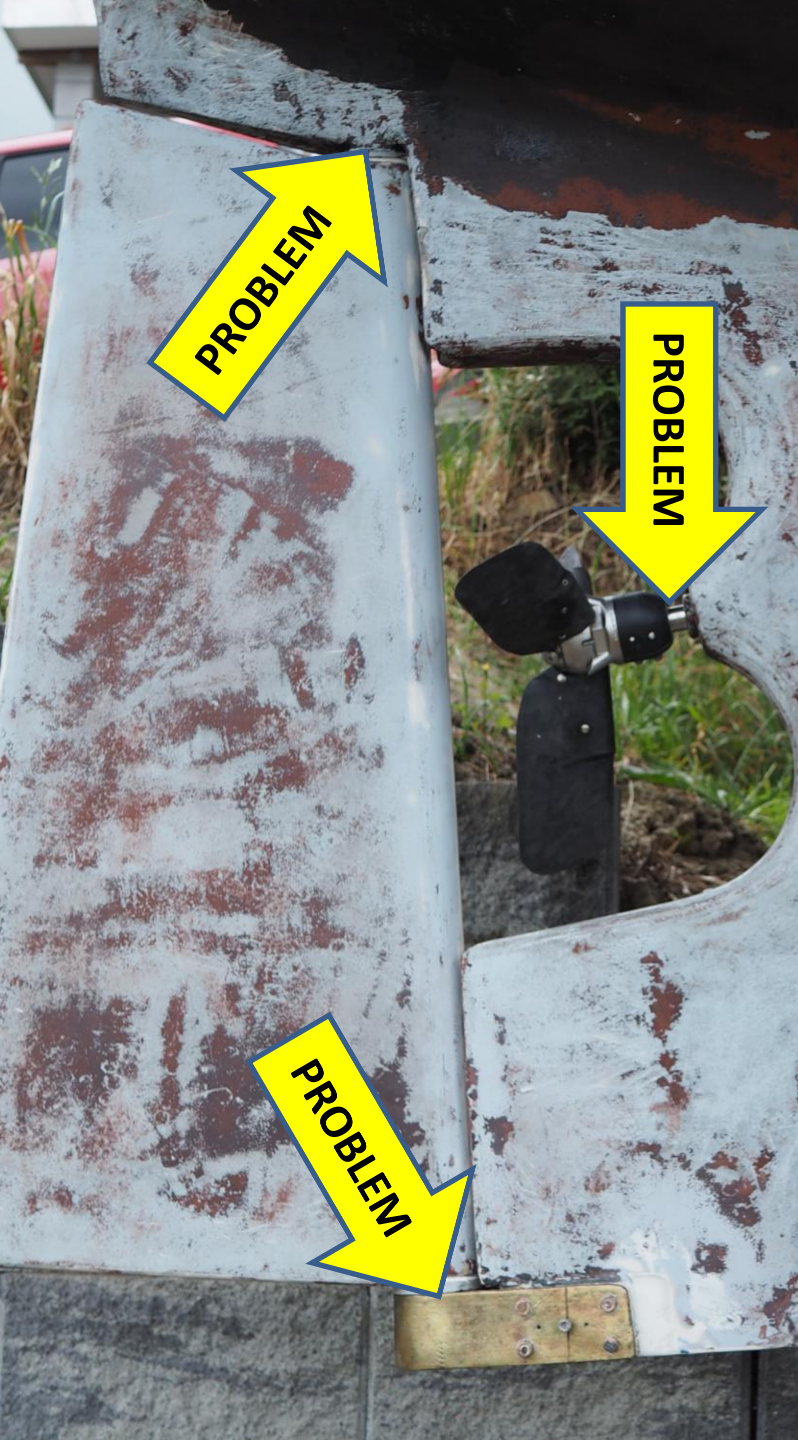

Anode
Cathode
Flow of ions (+)
Flow of ions (-)
Electrolyte

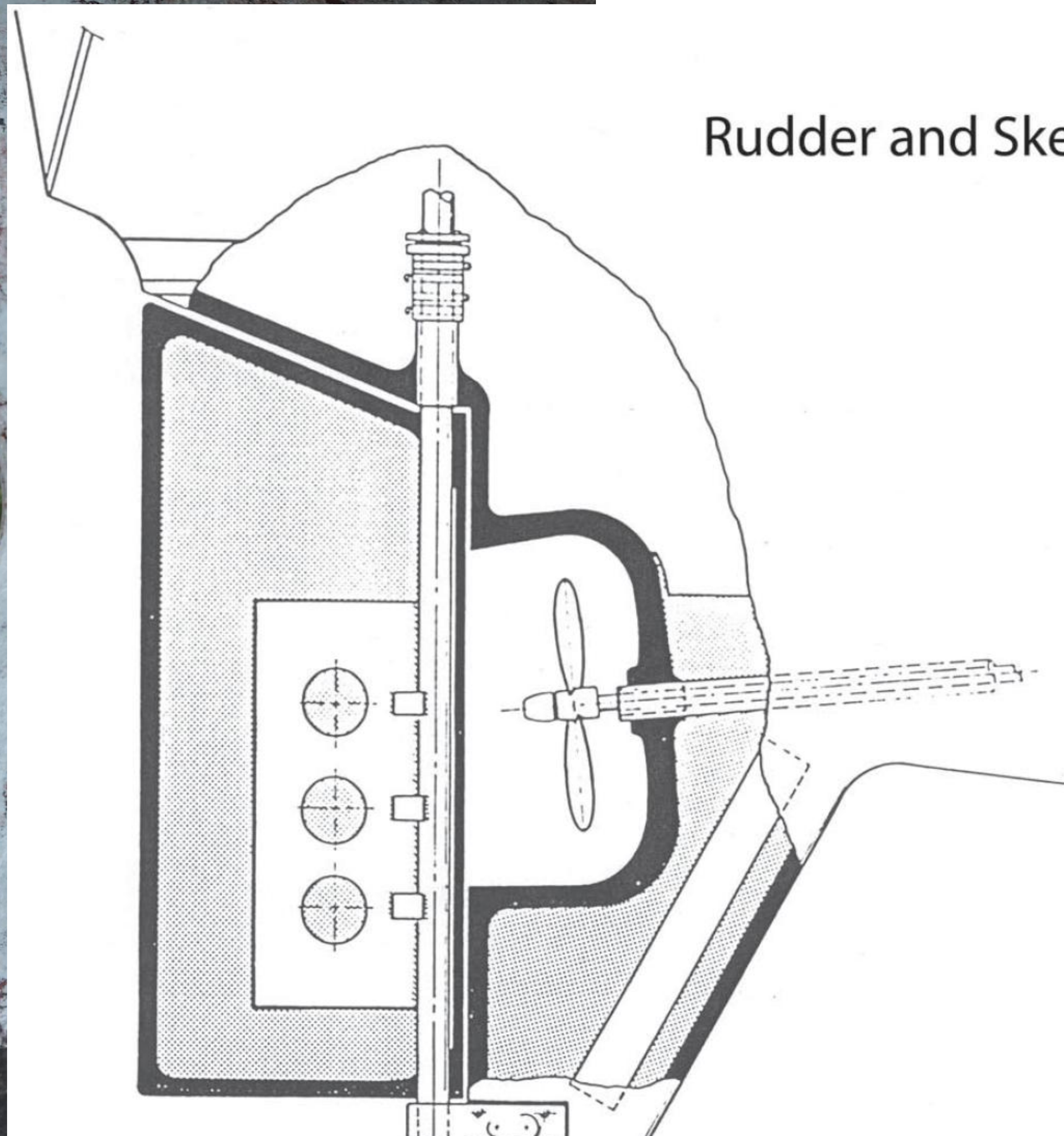

+
—
e⁻
anode
(positive)
cathode
(negative)
oxidation
electron loss
X⁻ → X + e
reduction
electron gain
M⁺ + e → M
anions
(negative)
cations
(positive)
electrolyte

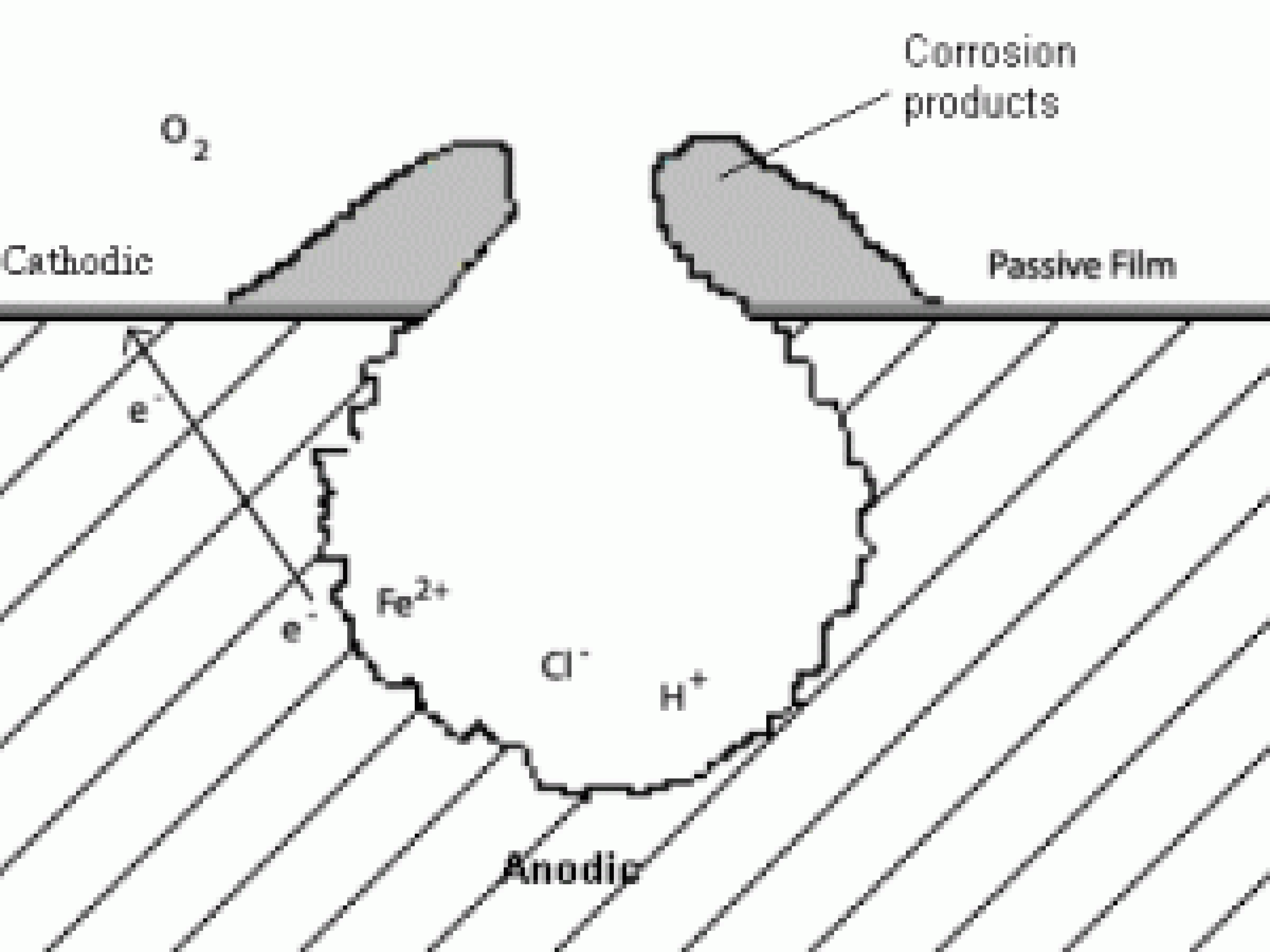

Panasonic
Carbon Zinc
Carbone-Zinc
D
Anode
Cathode
Flow of ions (+)
Flow of ions (-)
Electrolyte

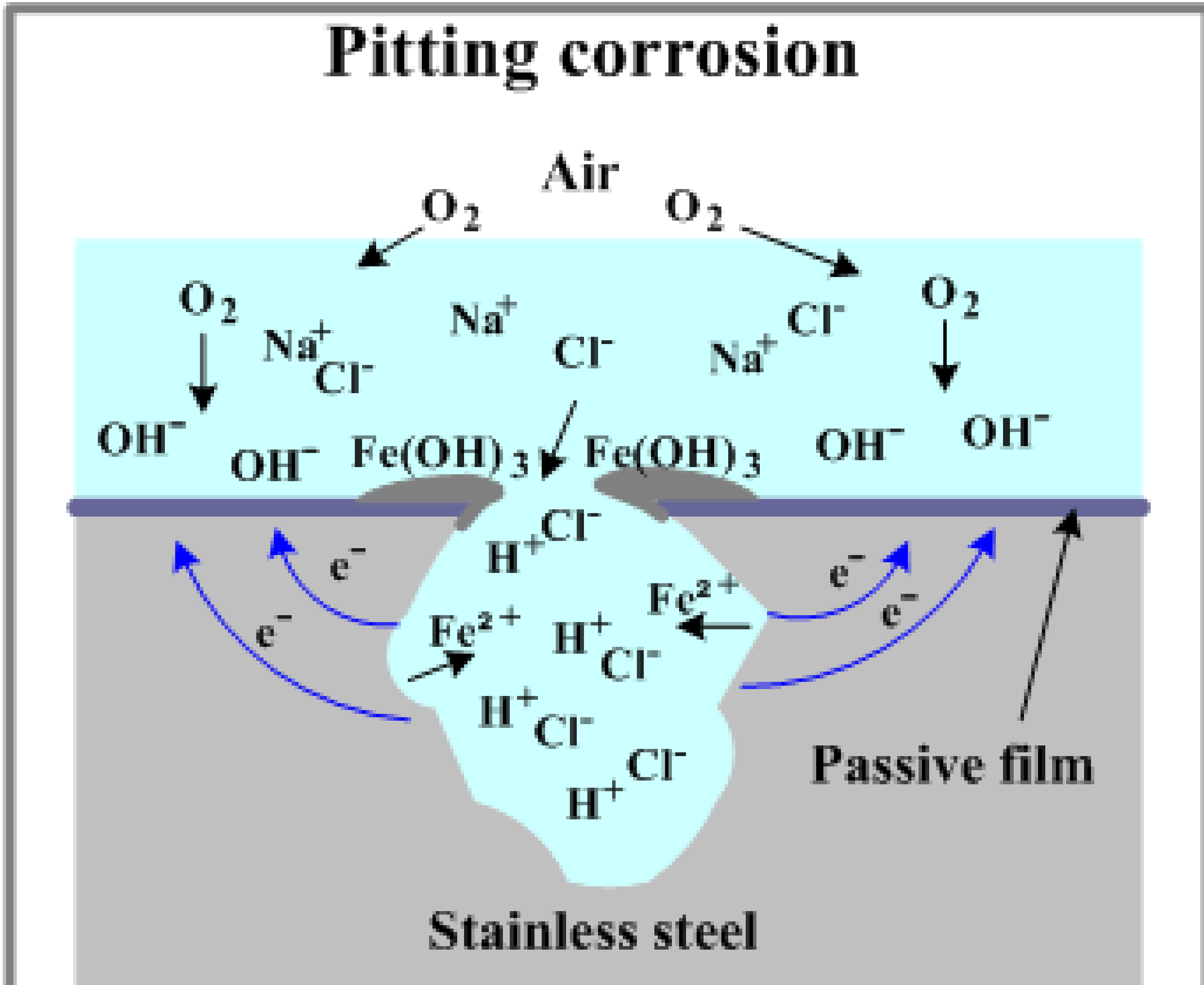

Electrolysis Elimination System
Caution
Normal
Caution
Serious
AC only
Serious
alarm
Critical
Critical
Bat pos
10 to 32 volts DC only
Bat neg
SeaBis
Email: seabisbg@gmail.com
Mobile / cell 61 (0)417 878 773
www.seabis.com
Skype address: seabis1


Electronics EZ Find 1
CORROSION TEST METER
0 100 200 300 400 500 600 700 800 900 1000 1100 1200
FREELY ERODING
PROTECTED
OVER PROTECTED
BRONZE
FREELY ERODING
PROTECTED
OVER
STEEL
FREELY ERODING
ALUMINUM
OV
YACHT CORROSION CONSULTANTS, INC.
Professional Mariner
Electronics EZ Find 1
Well Gain Electronics, Inc.


PROBLEM
PROBLEM
PROBLEM


Rudder and Ske


Corrosion products
O_2
Cathodic
Passive Film
e^-
Fe^{2+}
e^-
Cl^-
H^+
Anodic



Pitting corrosion
Air
O_2
O_2
O_2
Na^+
Cl^-
Na^+
Cl^-
Na^+
Cl^-
O_2
OH^-
OH^-
$Fe(OH)_3$
$Fe(OH)_3$
OH^-
OH^-
H^+Cl^-
e^-
e^-
Fe^{2+}
H^+Cl^-
Fe^{2+}
e^-
e^-
H^+Cl^-
H^+Cl^-
Passive film
Stainless steel


MINI DIVERS DREAM
DO NOT PAINT
Martyr
MINI DIVERS DREAM
DO NOT PAINT
CODE
190996
172615199
03 9811588
SUB TOTAL
INCLUDES GST OF:
TOTAL AMOUNT
DISPATCH METHOD
Post Haste


Martyr

Shaft Brush

Part # 20035-1

WHERE TO BUY

Overview | Physical Specs | Tech Data | Marketing Resources


EDSON NEW BEDFORD, MA. U.S.A.


CHEMZ
ANTI-SEIZE
FOR STAINLESS STEEL
Ni
NICKEL ANTI-SEIZE
Code 7443 30g


Vibra-TITE 90714
Anti-Seize
Copper & Graphite
GENERAL PURPOSE LUBRICANT
Reduces excessive wear on threads, gears, cables, chains, and sprockets.
NET WT. 4 OZ (113 g)
COMPETES WITH LOCTITE® C5-A® COPPER ANTI-SEIZE


ANTI-SEIZE TECHNOLOGY
MARINE FORMULA
44006
MARINE GRADE
NON-METALLIC ANTI-SEIZE
NET WT 6 OZ (170 g) BRUSH TOP CAN
For Professional and Industrial Use Only
KEEP CLOSED & OUT OF REACH OF CHILDREN


Vaseline
PURE
Petroleum Jelly
WHITE PETROLATUM USP
PROTECTANT
Travel Size Dispenser Cap
NET WT. 2.5 OZ.


Tef-Gel™


Pro Seal
ANTI-SEIZE LUBRICANT


JET-LUBE
MARINE GRADE
ANTI-SEIZE
NONMETALLIC PASTE
WITH MOLY
Net Contents: 1/2 Lb. (227 g.)


90616
ND INDUSTRIES
Vibra-TITE
MARINE GRADE
ANTI-SEIZE
NON-METALLIC PASTE WITH MOLY
• Protects assemblies exposed to fresh and salt water

FLUKE®

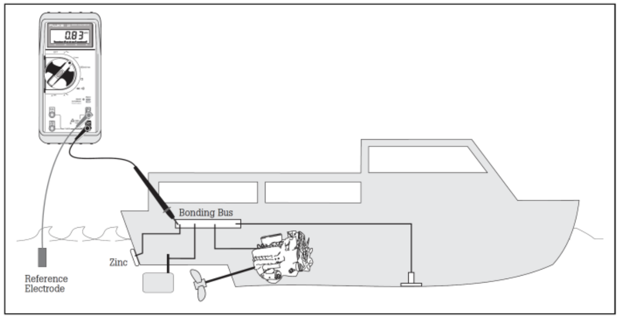
Testing Corrosion Protection Systems

Application Note

Introduction

The corrosion protection system on your boat should be checked at regular intervals. Failure to do so can lead to costly and time consuming repairs. The tools you'll need for the job include a high quality digital multimeter and a reference electrode. Fluke multimeters are ideal for corrosion system testing for several reasons. They are accurate, rugged, reliable, and most important, they have 10 Megohm input impedance in the DC volts function. The high input impedance will allow you to test your boat in either fresh water or salt water with repeatable results.

This application note will help you understand some basic corrosion mechanisms and the methods used by professionals to test corrosion protection systems. At the end of the application note, you'll find a list of references for further reading on the subject.



Basic corrosion mechanisms

In general, the term "corrosion" refers to the unwanted loss of metal from the hull and/or under-water metal fittings of the vessel. There are two main types of corrosion – mechanical and electrical. Under the electrical category, there are three common subcategories: galvanic corrosion, stray current corrosion, and crevice corrosion.

Galvanic corrosion occurs when two dissimilar metals are connected together electrically in the presence of a conductive electrolyte. Atoms in the less noble metal give up their electrons to the more noble metal and are released to flow (corrode) into the electrolyte in the form of positively charged ions.

Stray current corrosion occurs when a foreign voltage source pulls electrons out of the metal allowing the ions to flow as previously described.

Crevice corrosion is actually a form of galvanic corrosion but involves only one metal. A portion of the metal (in the crevice) becomes active (less noble) due to loss of oxygen while the remainder stays passive. If electrolyte is present, a galvanic couple is formed and the active metal is converted to ions and enters the electrolyte solution.

Principles of galvanic corrosion

Materials used in the construction of marine vessels are chosen using various criteria including cost, mechanical strength, workability and corrosion resistance. When we want to compare metals according to their corrosion resistance, we refer to a ranking list called the "Galvanic Series of Metals" often referred to as the "noble scale". This scale indicates the relative affinity that each metal has for its electrons, i.e., it ranks the metals according to their electron bonding strength.

Metals at the active (less noble) end of the scale will give up their electrons and corrode more easily than metals on the passive (more noble) end of the scale.

Galvanic Series of Metals
(alloys may vary according to composition)

Active (least noble)

Magnesium	Iron	Lead
Zinc	Brass	Titanium
Aluminum	Tin	Silver
Cadmium	Copper	Platinum
Steel	Bronze	

Passive (most noble)
Gold

Underwater metals can be protected if they are supplied with extra electrons. Active metals like zinc are commonly used to protect more noble metals. If the two metals are immersed in the same electrolyte and deliberately connected by an electrical "bonding" system, the zinc will give up its electrons to protect the more noble metal. In this configuration the zinc is called an anode and the protected metal is called the cathode.

FLUKE®

Testing with a reference electrode

When a metal is in contact with an electrolyte such as sea water, the metal will establish a natural potential or voltage with respect to the electrolyte. This natural potential (or "freely existing" potential) is the value that exists when no extra electrons are being supplied or removed by an outside voltage source. We can measure this potential with a digital multimeter and a reference electrode. The reference electrode allows us to make an electrical connection to the sea water with a known, repeatable value, i.e., a reference value.

Reference electrodes are often called "half cells" because they contain a metal and a metal compound. Popular types are Copper-Copper Sulfate and Silver-Silver Chloride. Marine system tests are often conducted with a Silver-Silver Chloride electrode (see description in reference 1).

The principle of the test is straightforward: We want to establish that the corrosion protection system is supplying enough electrons to raise the potential of the protected metal 250 mV ($^1/_4$ Volt) above the freely existing value. The test procedure is as follows: (Refer to drawing on page 1).

1. Set the multimeter function to DC volts.
2. Connect the reference electrode to the volts input jack and place the electrode in the water. Best results are obtained when the electrode is located away from the anode.
3. Connect the multimeter common jack to a probe that will be used to contact each piece of underwater metal.
4. Touch the common probe to each underwater metal fitting and record the millivolt value as displayed on the meter. If all underwater metal fittings are connected together with a "bonding" system as shown on page 1, then all readings should be identical. Some typical values for several metals are listed in Table 1.

Metal	Free Unprotected*	Protected*	Over Protected*
Steel	0.50V	0.75V	1.00V
Bronze	0.30V	0.55V	0.80V
Aluminum	0.65V	0.90V	1.05V

* Voltages given in this table are typical values obtained using a silver/silver-chloride reference electrode. Values may vary according to alloy and type of coating.

Overprotection can cause paint to peel from a metal hull, or chemical damage to a wooden hull. Refer to references 1 & 2 for more information on the dangers of over protection and details about bonding systems.

Fluke Multimeters for Marine Applications

The following Fluke Digital Multimeters are recommended for use in marine applications.

Fluke 12B
Put basic tests on automatic
- VCheck™ automatically switches from measuring ohms/continuity to ac or dc volts
- Capacitance, to 10k microfarads
- Continuity capture locates intermittent opens and shorts
- Min/Max recording with relative time stamp

Fluke 73 Series III
- Touch Hold® captures stable readings
- Auto and manual ranging
- Holster with Flex-Stand™ included
- Volts ac and dc
- Resistance
- Diode test/continuity beeper
- AC/DC current with ranges from 32 mA to 10A

Fluke 26 Series III
Same features as Fluke 73 Series III, plus:
- Rugged, overmolded case
- Tough, electrical test lead set with silicone insulation and alligator clip
- True-rms ac voltage
- AC/DC current with ranges from 4.0 mA to 10A
- Lo Ohms

Fluke 27
- Fully sealed, waterproof case
- Touch Hold® captures stable readings
- Volts, ohms, amps, continuity, diode test
- Current with ranges from 320 µA to 10A

Fluke 36 ClampMeter
- True-rms responding
- AC current to 600A
- DC current to 1000A
- AC and DC voltage to 600 Volts
- Max Hold
- Continuity beeper

Other marine application notes available from Fluke:
- Troubleshooting Marine Engine Electrical Systems
- Troubleshooting Outboard Motor Magneto Ignitions

References for additional information

1. Boat and Yacht Corrosion Control; by Yacht Corrosion Consultants 2970 Seaborg Avenue Ventura, CA 93003
2. Boatowner's Illustrated Handbook of Wiring; by Charlie Wing International Marine Camden Marine
3. Your Boat's Electrical System; by C. Miller and E.S. Maloney Hearst Marine Books

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Fluke Europe B.V.
PO Box 1186, 5602 BD
Eindhoven, The Netherlands

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Fax (31 40) 2 678 222
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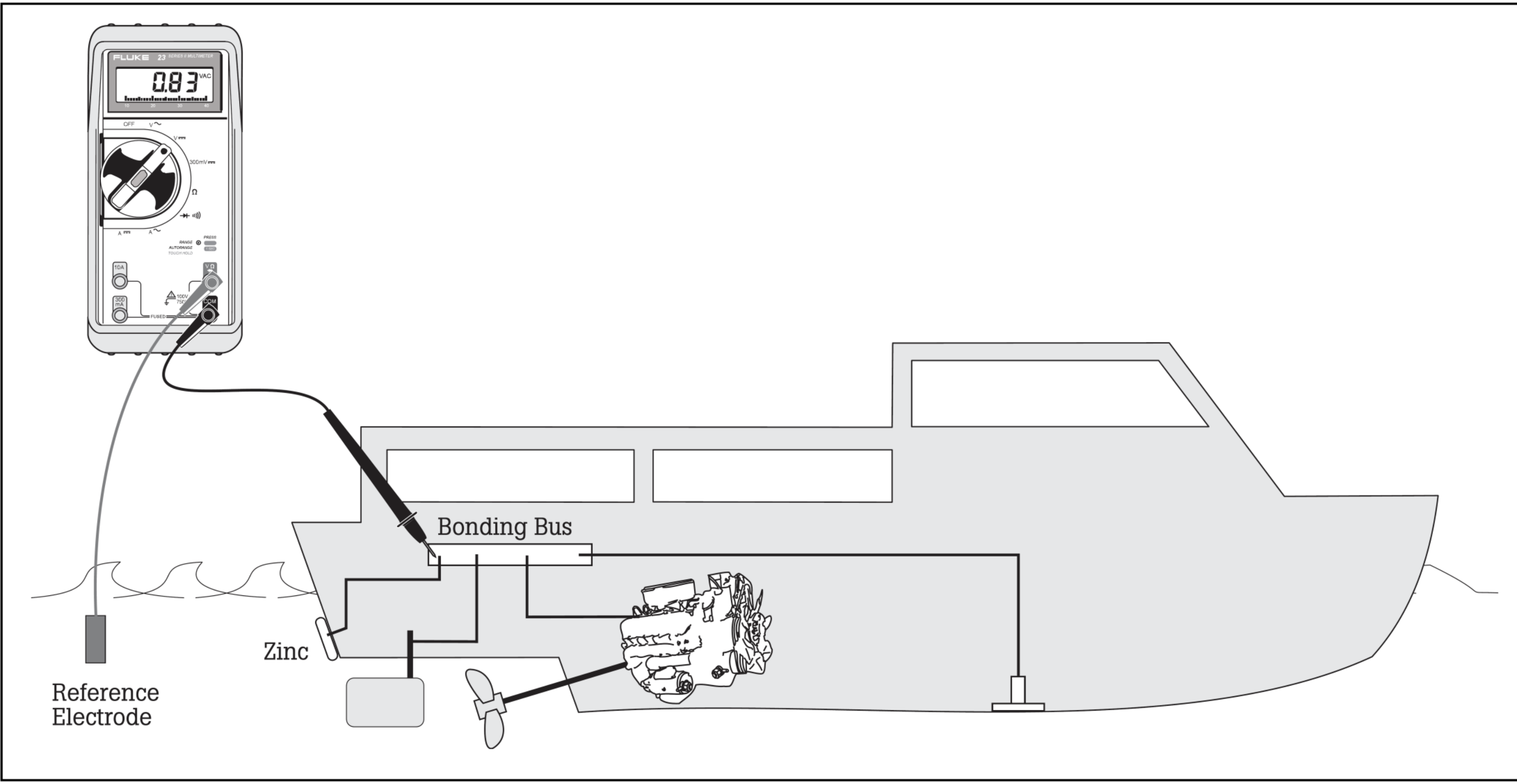


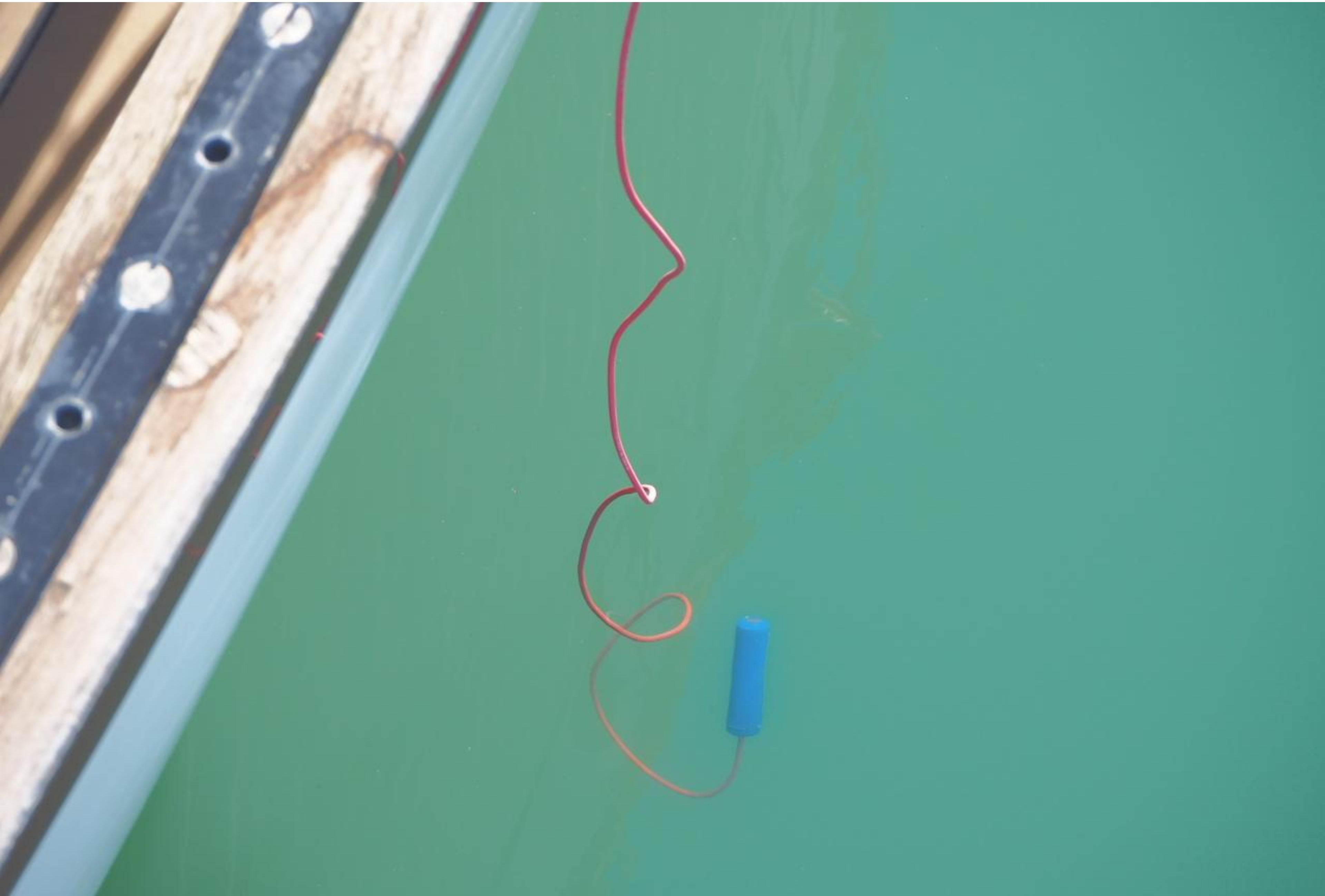
FLUKE
0.83
VAC
Bonding Bus
Zinc
Reference
Electrode

Metal	**Free Unpro-tected***	**Protected***	**Over Pro tected***
Steel	0.50V	0.75V	1.00V
Bronze	0.30V	0.55V	0.80V
Aluminum	0.65V	0.90V	1.05V

marine corrosion products

salty doggs

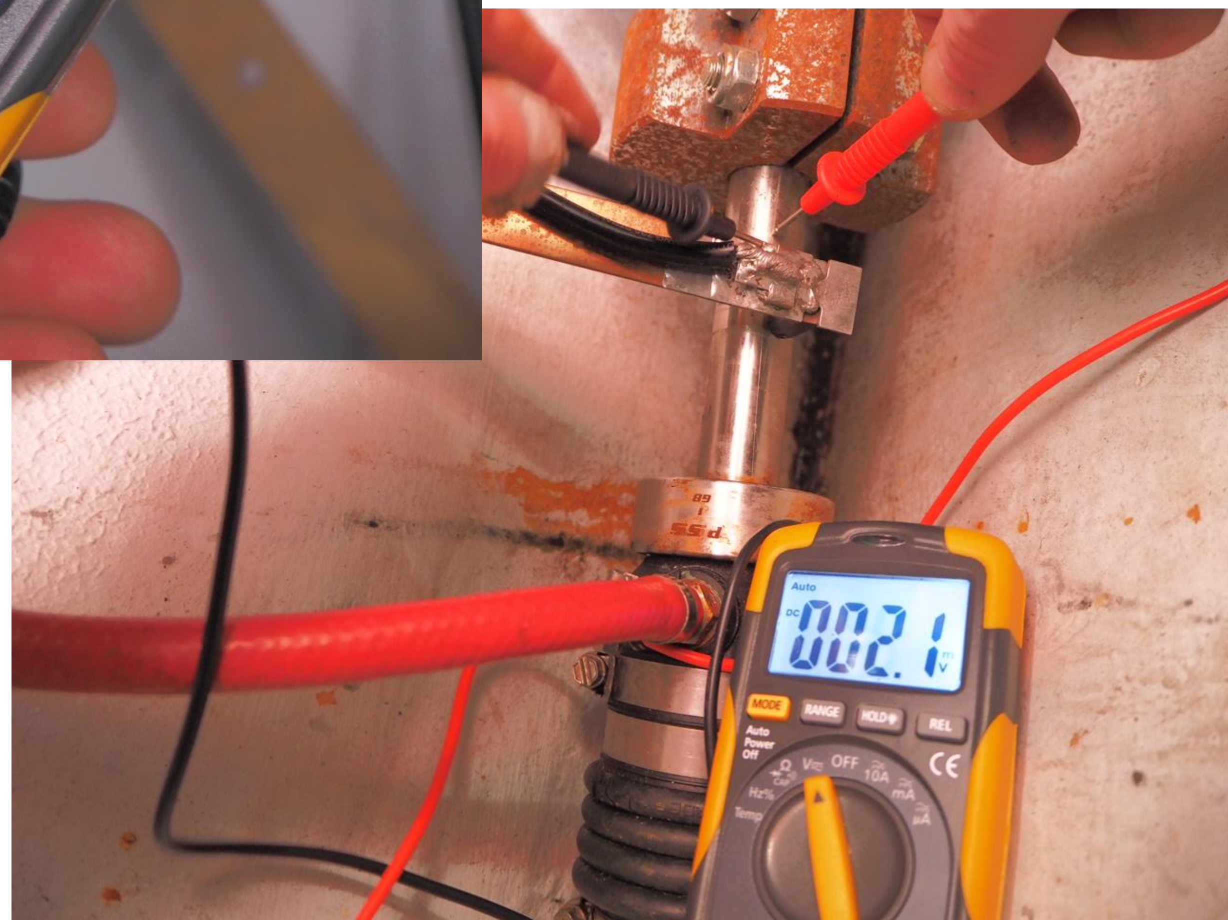
800.644.6555 saltydoggs.com



Auto
DC
-0.967
V
MODE
RANGE
HOLD
REL
Auto Power Off
OFF
10A
mA
µA
Temp
Hz%
DIGITECH
QM1323
CAT III-600V
10A
COM

etal	Free Unpro-tected*	Protected*	Over Pro tected*
teel	0.50V	0.75V	1.00V
ronze	0.30V	0.55V	0.80V
luminum	0.65V	0.90V	1.05V


Auto
DC
-0.944
V
MODE
RANGE
HOLD
REL
Auto Power Off
Temp
Hz%
OFF
10A
mA
µA
DIGITECH

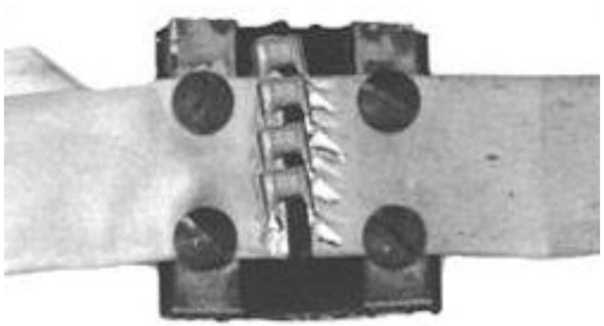

Auto
DC
002.1
mV
MODE
RANGE
HOLD
REL
Auto Power Off
OFF
10A
mA
µA

Upcoming Projects

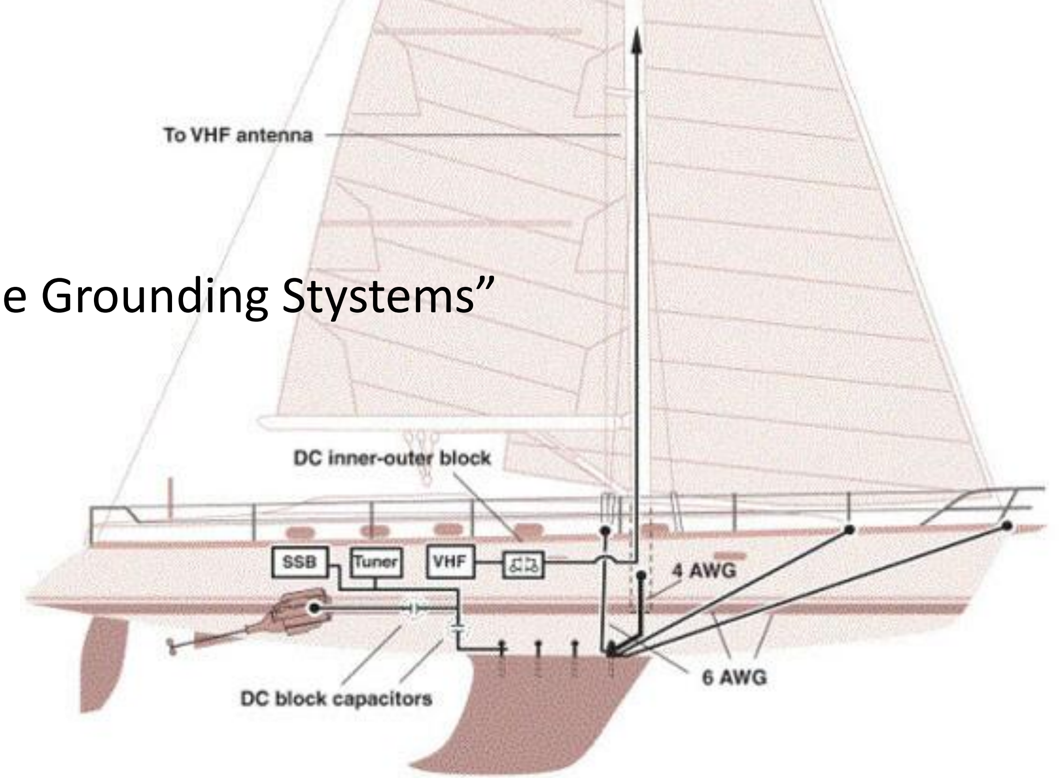
– Radios

Images from West Marine “Marine Grounding Stystems”

by Stan Honey 1996



0.15 uF ceramic capacitors



– Built in, on board corrosion measurement

– Ultrasonic antifouling

Thanks for taking part.
Andrew