

Corrosion Accelerated Test with Controlled Humidity (CATCH)

Testing for aluminum materials in automotive applications

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Content

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Background

SAE China (CSAE) began a project in 2016 to develop a new corrosion test method for domestic manufacturers. Goals were:

- Reduce redundant testing within domestic market
- Observe best practices from global OEM testing
- Develop test that could be used for validation and QC
- Start method development focusing on **steel substrates**



中国汽车工程学会

China Society of Automotive Engineers

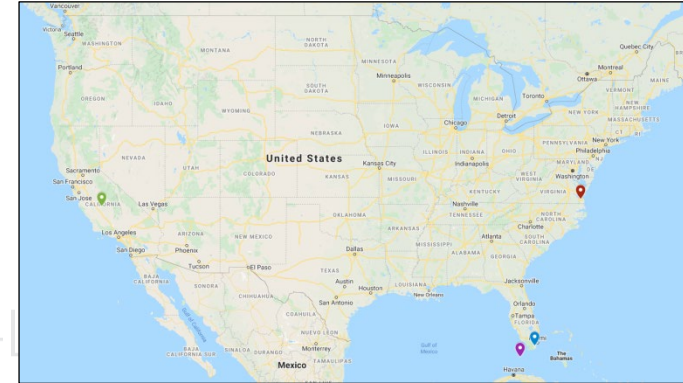
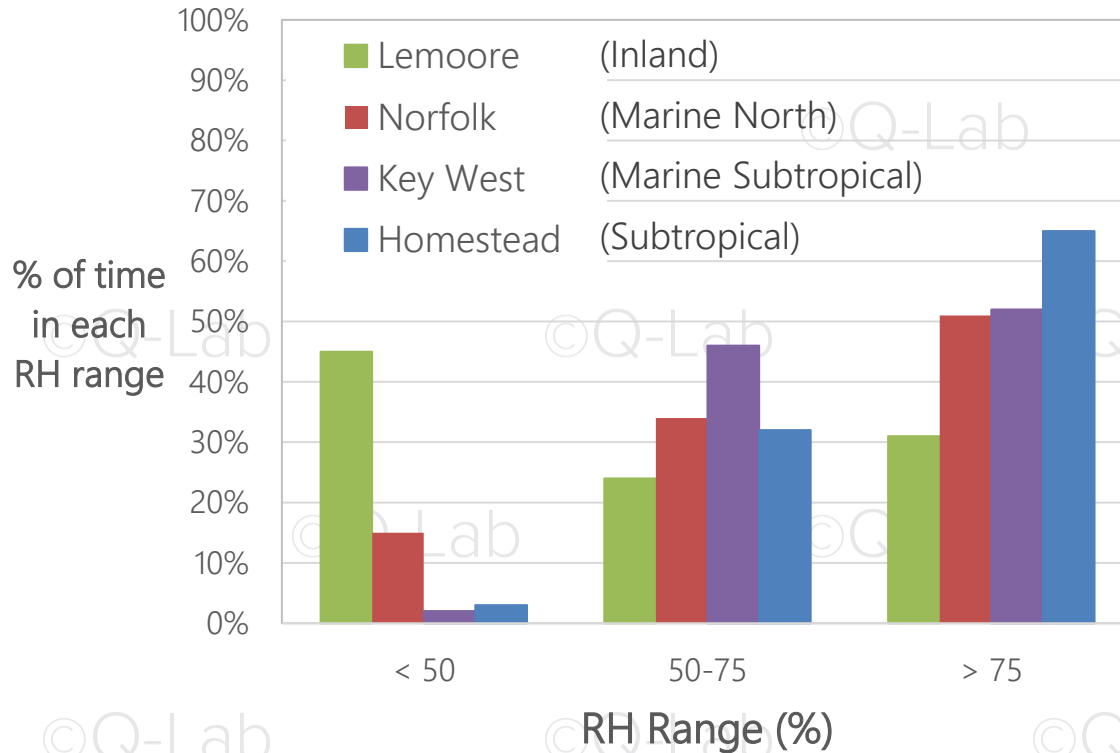
Technical Background

- Relative humidity control is critical to laboratory repeatability
 - It's also a key determinant of corrosion behavior
 - Different RH levels can produce different corrosion mechanisms
- During last 10-15 years, automotive methods with precise RH control have become popular

Relative Humidity and Galvanic Corrosion

Condition	RH Range	Result
Dry	$\leq 50\%$	Very little corrosion from NaCl
Electrolytic cells near salt crystals; film formation as RH increases	50-76%	<ul style="list-style-type: none">• Corrosion of steel and aluminum• Al-Steel galvanic couple broken
Uniform Electrolytic Film formation	$\geq 76\%$	<ul style="list-style-type: none">• Maximum cathode area for steel• Deeper non-uniform corrosion• Al corrosion in galvanic couple with steel

RH Conditions in the Natural Environment



Summary of Environmental Conditions

First-Generation Cyclic Automotive Standards

Cycle	Solution	Spray Type	RH < 50%	50% ≤ RH < 76%	RH ≥ 76%
ISO 11997-1 Cycle A	NaCl 5.0% pH = 7	Fog	48%	3%	49%
VW PV1210	NaCl 5.0% pH = 7	Fog	9%*	7%	85%

Summary of Environmental Conditions

Modern Automotive Corrosion Standards

Cycle	Solution	Spray Type	RH < 55%	55% ≤ RH < 76%	RH ≥ 76%
Ford L-467 Volvo ACT2	NaCl 0.5% pH uncontrolled	Shower	0%	66%	34%
GMW 14872	NaCl 0.9% CaCl ₂ 0.1% NaHCO ₃ 0.075% pH uncontrolled	Shower	47% (22% of cycle < 30%)	15% (40% of cycle is 30-76%)	38%
Renault D17 2028 (ECC1)	NaCl 1.0% pH 4.0 (H ₂ SO ₄)	Fog	8%	62%	30%
VDA 233-102	NaCl 5.0% pH neutral	Fog	23%	17%	60%
Volvo ACT 1	NaCl 1.0% pH 4.2 (H ₂ SO ₄)	Shower	33%	15%	52%
CATCH	NaCl 1.0% pH 4.0-4.2 (H ₂ SO ₄)	Shower	19%	33%	48%

Initial Study: Steel Substrates

Initial Study Participants

Q-Lab China (Lead Company)

Chery Auto - Shanghai

FAW

FAW - Tianjin

Changan Auto

Guanzhi Auto

BYD Auto

Institute of Metal Research, CAS

Dongfeng Auto

Hainan Institute

Jianghuai Auto

725 Institute

FAW-VW

59 Institute

Shenlong Auto

SGS - Shanghai

Shanghai Auto

CTI - Shanghai

Nanjing Auto

Intertek - Shanghai

Guangzhou Auto

Emtek - Suzhou

Changan Ford

Shanghai Hanhai

PATAC

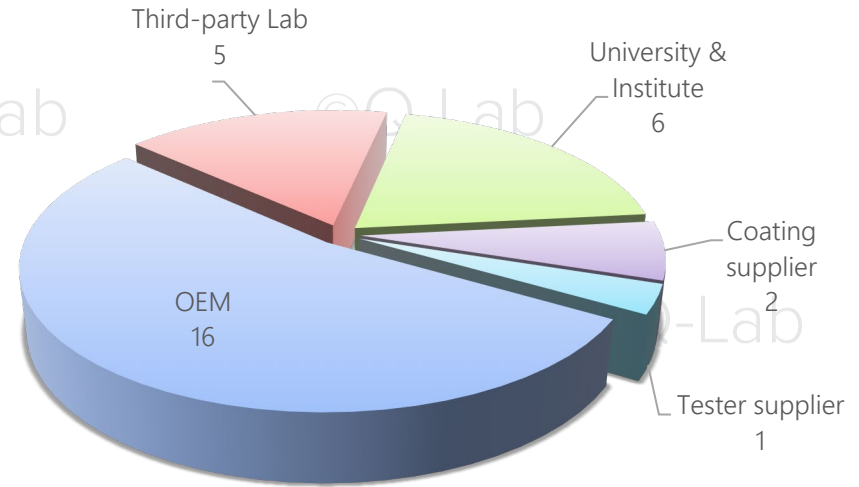
AkzoNobel - Shanghai

Wuhu Kaiyi Auto

Km-Tech - Shanghai

Wuhan University of Science & Technology

University of Science & Technology Beijing



Test Methods & Materials

Steel Substrate Study

Methods

- ASTM B117
- ISO 11997-1 Cycle A
- GMW 14872
- Ford L-467
- VW PV1210
- Outdoor multiple sites (natural)
- Outdoor 2 sites (salt -enhanced)
- CATCH

Materials

- 5000 specimens total
 - Substrates
 - Cold-Rolled Steel (various OEM specifications)
 - Galvanized sheets
 - Pretreatments
 - 6 Types
 - Primers
 - 3 types, or omitted
 - Basecoat/clearcoat (several varieties)
- OR
- 1k water based, solvent based, powder

Test Methods Evaluated

Test Method	ASTM B117	ISO 11997-1 Cycle A	GMW 14872	Ford L-467	PV 1210	CATCH
Total duration (cycles)	<i>n/a</i>	252	72	10	27	72
Total duration (time)	2016 h 84 days 7 weeks	2016 h 84 days 7 weeks	1728 h 72 days 6 weeks	1728 h 72 days 6 weeks	2016 h 84 days 7 weeks	1728 h 72 days 6 weeks

Outdoor Tests

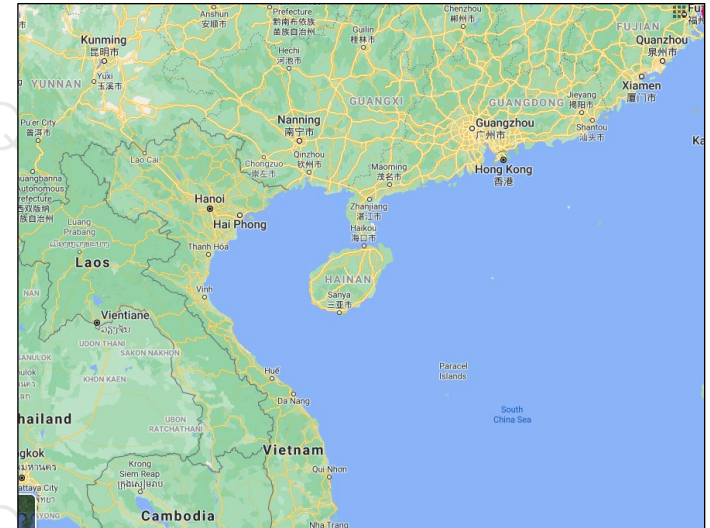


Xiamen, China

- Oceanfront Racks
- 12 months natural exposure

Hainan Island, China

- 12 months, natural
- 21 months, natural
- 12 months, salt spray enhanced

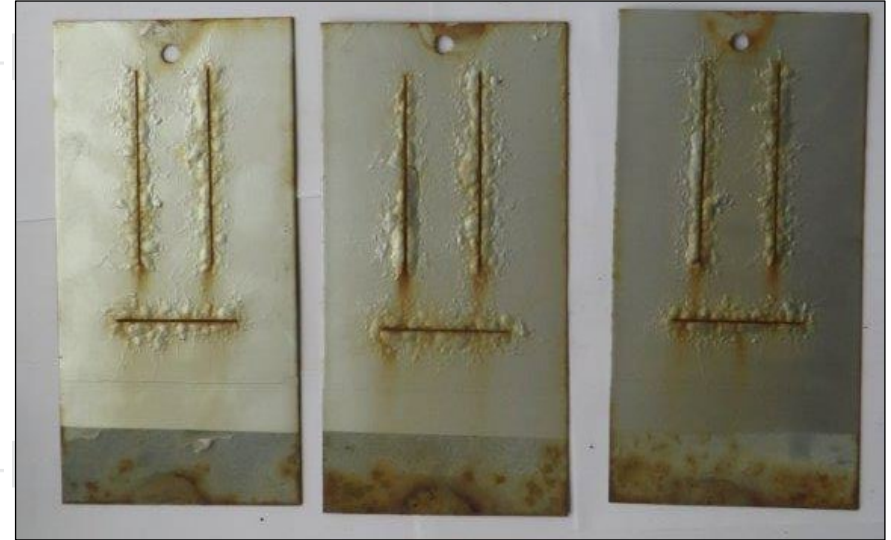


Filiform Corrosion on Steel Panels

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Subtropical Site (not near ocean)
Filiform corrosion



Oceanfront Site
Blistering, filiform corrosion

Wide Range of Durability

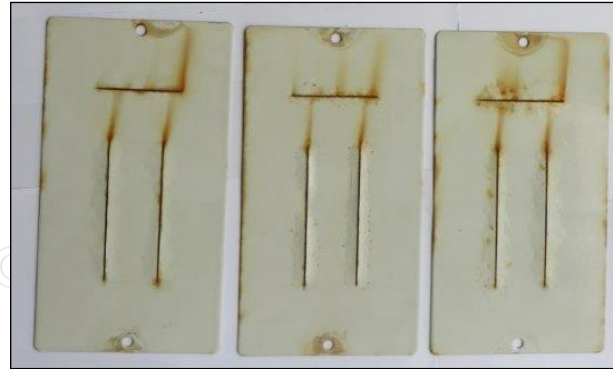
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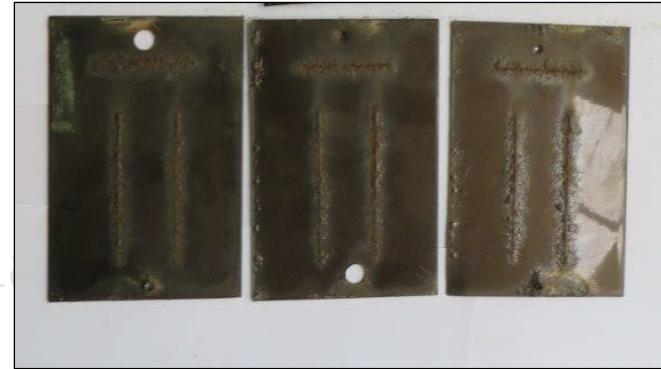
Good

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Intermediate

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Poor

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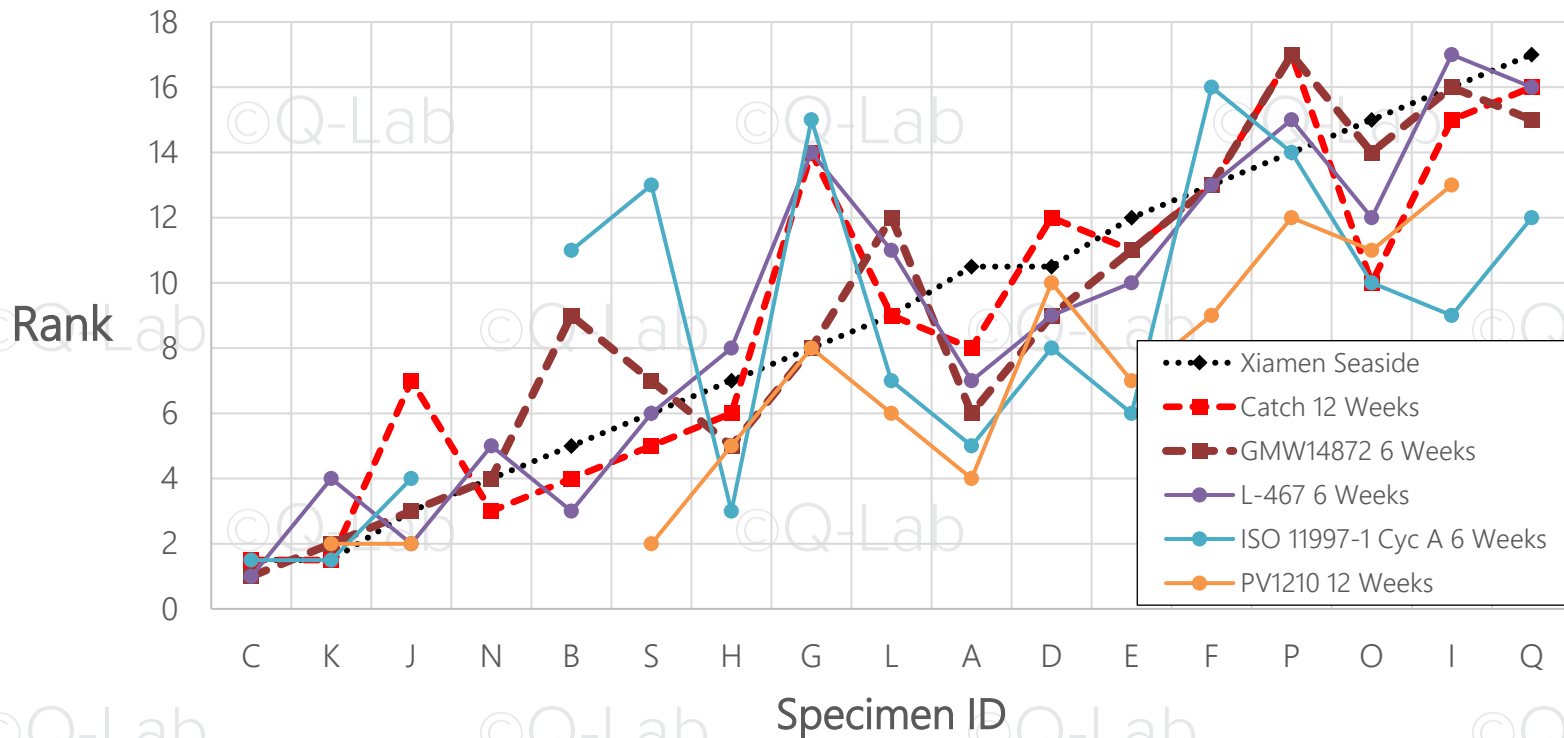
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Spearman Rank

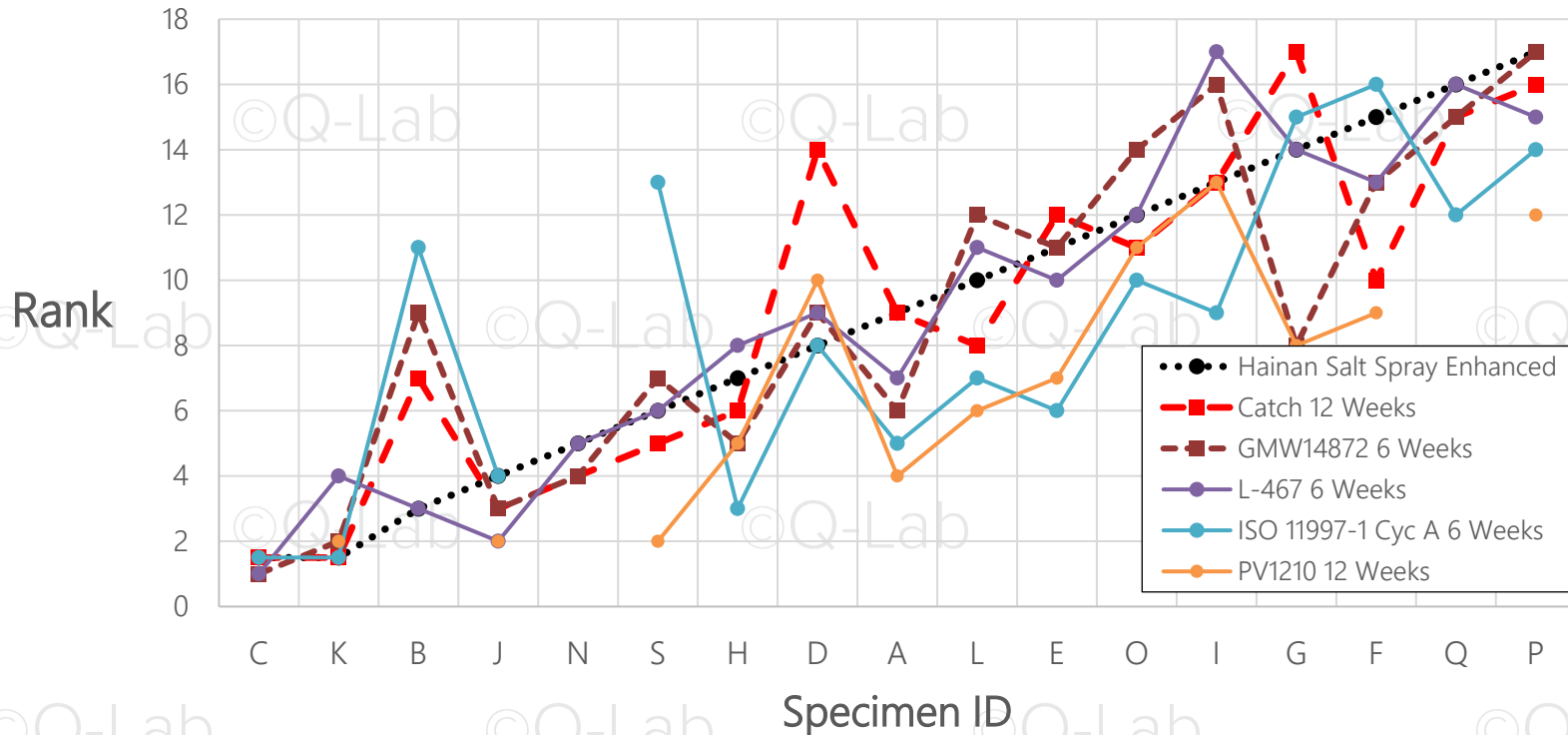
Laboratory versus Outdoor Tests

Laboratory Test (weeks) → Outdoor Test ↓	CATCH		GMW14872		Ford L-467		ISO 11997-1 Cyc A		PV1210
	6	12	6	12	6	12	6	12	12
Hainan 12 months	0.82	0.83	0.82	0.72	0.90	0.85	0.45	0.61	0.58
Hainan 21 months	0.83	0.83	0.77	0.72	0.87	0.84	0.39	0.55	0.53
Hainan salt spray enhanced 12 months	0.81	0.84	0.84	0.76	0.90	0.83	0.53	0.71	0.65
Xiamen (seaside) 12 months	0.79	0.89	0.82	0.67	0.95	0.94	0.71	0.78	0.66

Rank Order: Xiamen Seaside Exposure



Rank Order: Hainan Salt Spray Outdoor



Aluminum Substrates

First-round test

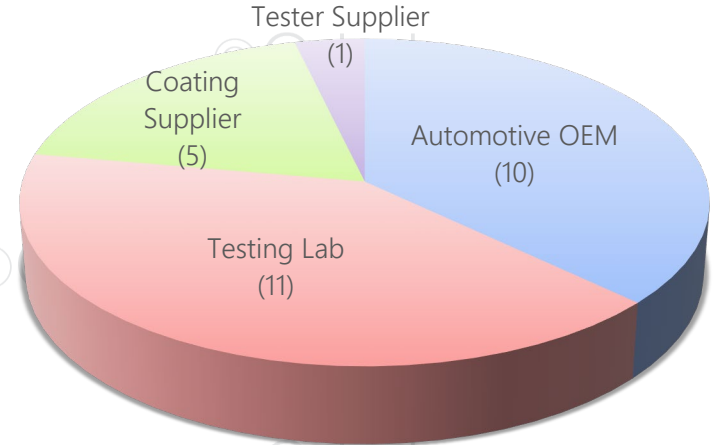
Aluminum Substrate Study

- Automotive lightweighting efforts are aimed at better efficiency
- There was no clear standard for aluminum body panels
- Goal: conduct comparison tests between laboratory and outdoor methods in order to achieve:
 - Verification of corrosion resistance of aluminum alloy coatings
 - Performance verification of coatings developed and applied to aluminum alloy substrates
 - Quality control of anti-corrosion performance for aluminum alloy coating

Participants in This Study

- Lead company: JAC Auto
- Participant companies (27):
 - Q-Lab China
 - Zhongtai Auto
 - Beijing Benz
 - AkzoNobel
 - Weikai Lab
 - Meixin Lab
 - Hainan automotive research institute

- Liaoning Zhongwang
- BYD Auto
- Xince Lab
- CTI Lab
- Nannan aluminum processing
- Empirechem



Comparison test

Two rounds of tests:

- **First-round goal:** Achieve acceptable correlation to outdoor tests and pass/fail QC results with good agreement
- **Second-round goal:** Determine if the test can be run faster

Test specimens

- 53 different specimens, 1033 panels
- Variables:
 - **Aluminum Substrate:** 5000 series, 6000 series, different profiles
 - **Pre-processing:** silane, phosphating, zirconium
 - **Electrophoretic coating:** 3 types
 - **Finish:** 2 types

Corrosion test methods

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Test method	CASS	AASS	Filiform	CATCH*	Outdoor - Spray salt water	Road enhanced corrosion
Reference	ISO 9227	ISO 9227	SAE J2635	T/CSAE 71	ASTM D6675	QC/T 732
Salt solution pH value Deposition rate	NaCl: 50 g/L CuCl ₂ dehydrate: 0.26 g/L pH = 3.1~3.3 1 ~ 2mL/h	NaCl: 50 g/L pH = 3.1~3.3 1 ~ 2mL/h @80 cm ²	Same as CASS	NaCl: 10 g/L pH = 4.0 39-79 mL/h	NaCl: 50 g/L 2× per week	NaCl: 50g/L
Temperature and RH	50 °C	35 °C	6 hours CASS + 60 °C, 85 %RH	-	-	-
Total test duration	240 h	1980 h	6 h CASS + 672 h	2980 h	12 month	120 days

*CATCH: Corrosion Acceleration Test with Controlled Humidity

CATCH test cycle

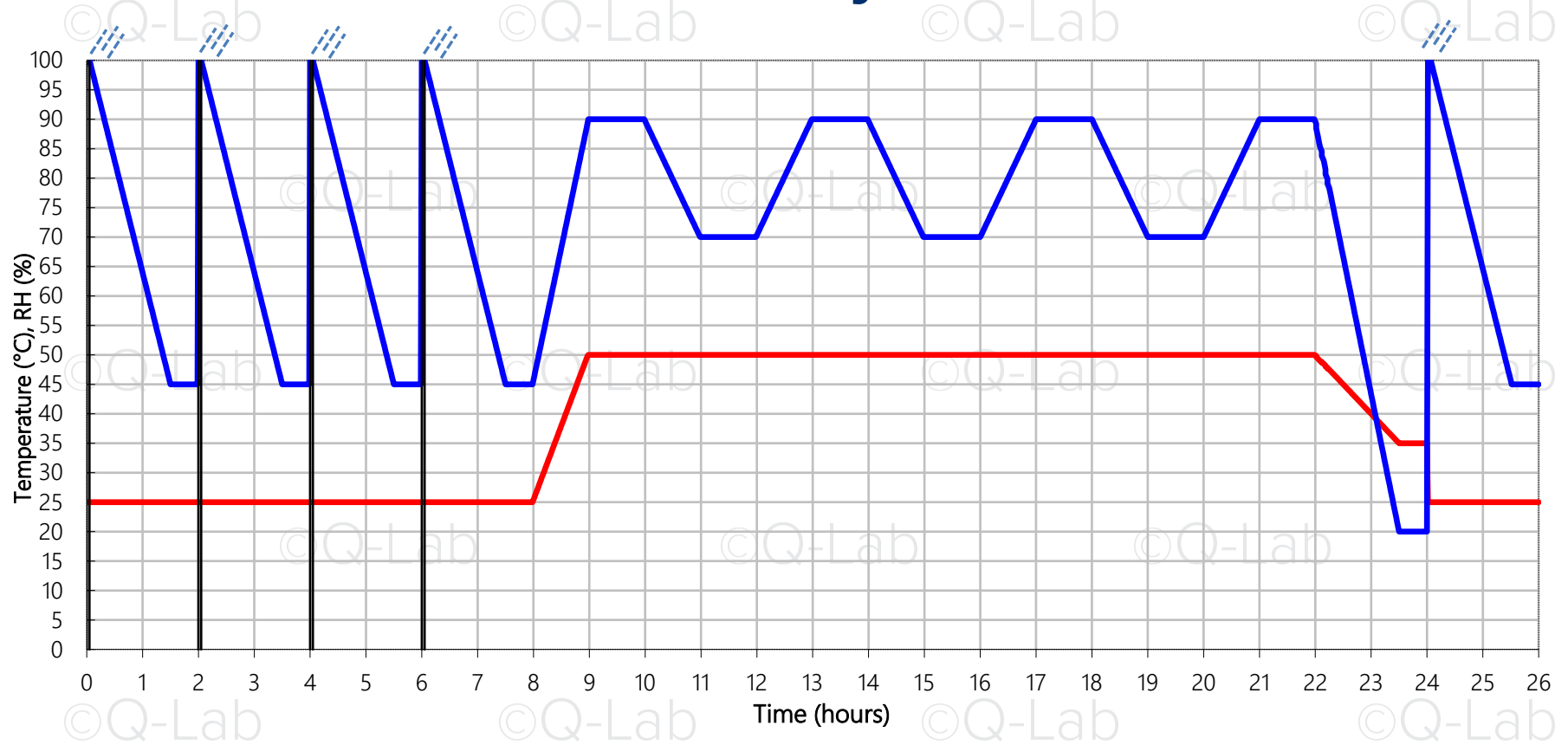
Step	Function	Chamber air temp (°C)	RH (%)	Step time (hh:mm)	Ramp	Ramp time (hh:mm)
1	Subcycle: repeat steps 2-3 4×					
2	Shower	25		0:04		
3	RH	25	45	1:56	Linear	1:26
4	Subcycle: repeat steps 5-6 3×					
5	RH	50	90	2:00	Linear	1:00
6	RH	50	70	2:00	Linear	1:00
7	RH	50	90	2:00	Linear	1:00
8	RH	35	20	2:00	Linear	1:30
9	Final step – go to step 1					

Solution: Sodium Chloride (NaCl): 1% pH = 4.0,
Shower deposition: 39-79 mL @ 80 cm²

CATCH Cycle

Chamber Temperature
Chamber Relative Humidity

Test Solution:
1% NaCl, pH = 4.0 or 3.0 by addition of
sulfuric acid (H_2SO_4), 0.5M



Q-FOG CRH cyclic corrosion chamber



Outdoor accelerated corrosion



Outdoor accelerated corrosion

Road-Enhanced Test



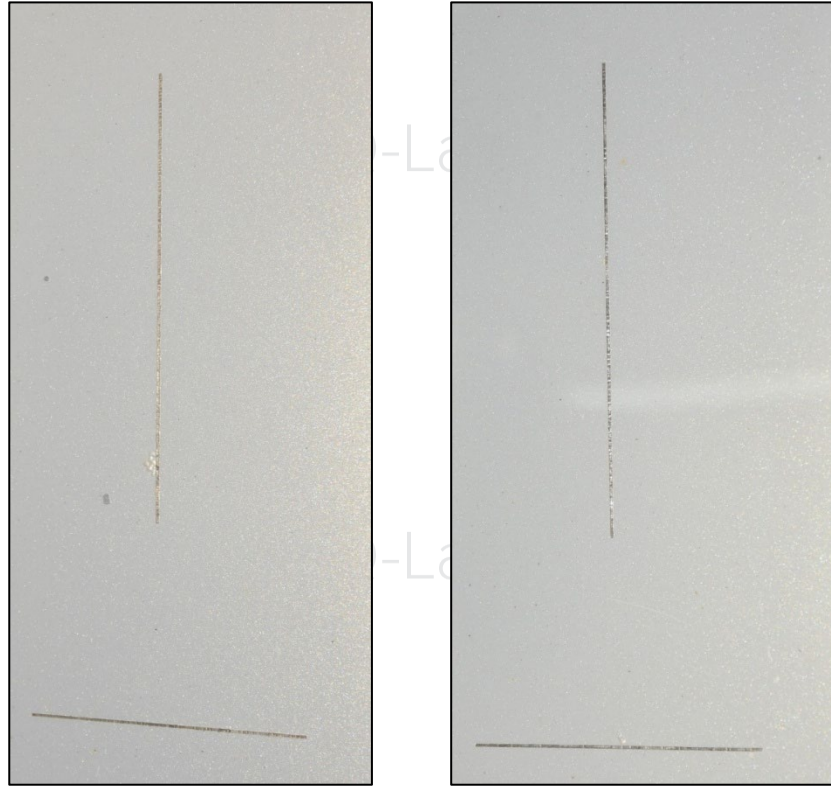
Typical corrosion morphologies of aluminum alloy composite coating

ab

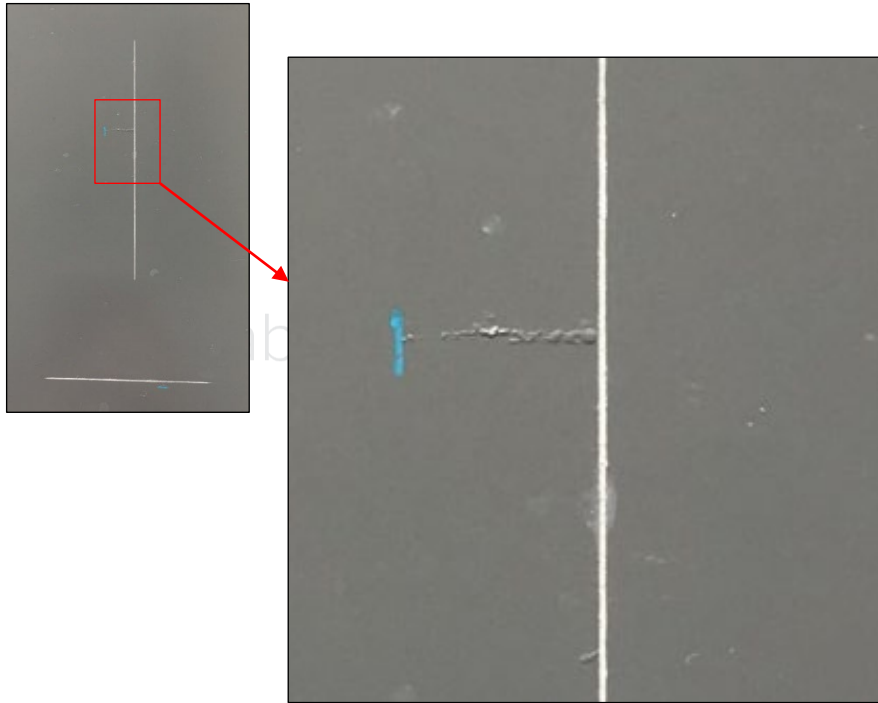
Type	Description
A	Filiform corrosion—individual filaments
B	Filiform corrosion -- Multiple filaments which form a network and spread out from the scribed line
C	Single or multiple corrosion blisters from the scribed line
D	Other forms of corrosion, usually a combination of the above three types



High-Performing Coatings



Corrosion Morphologies A&B

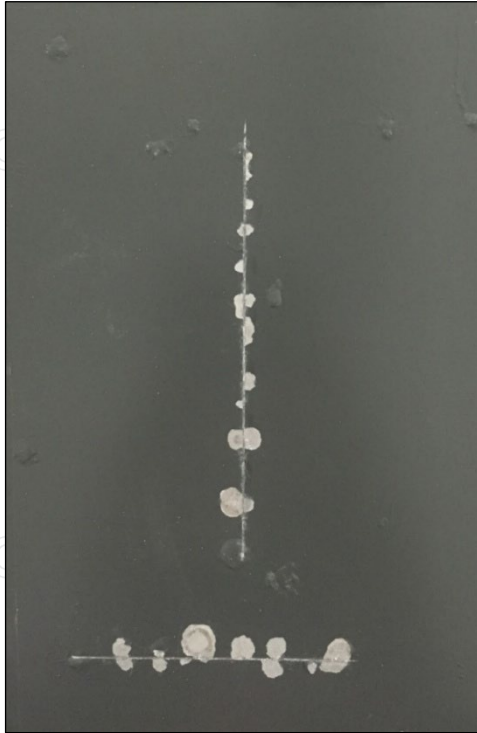


Corrosion morphology – Type A



Corrosion morphology – Type B

Corrosion Morphologies C&D



Corrosion morphology – Type C



Corrosion morphology – Type D

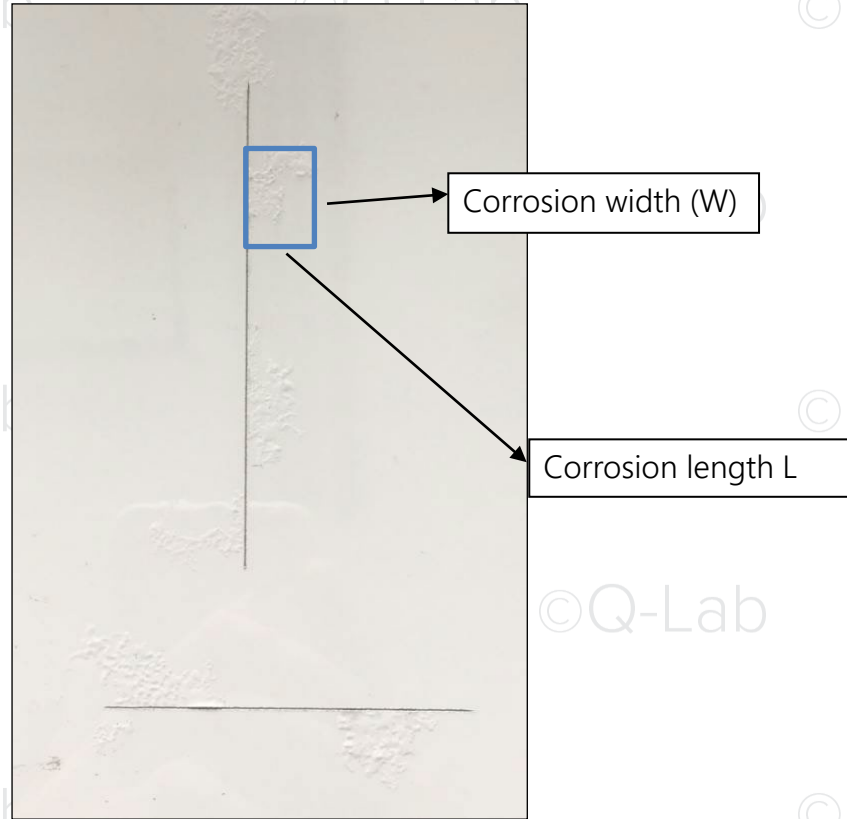
Test results

- One set of specimens tested by road-enhanced corrosion
 - 120 cycles (120 days)
- A different set exposed to salt spray enhanced natural test
 - 12 months
- Both tests compared with lab accelerated corrosion test methods

Test results

Calculate the corrosion area:
Corrosion area = $L \times W$

Measure manually or using
photography and CAD software



Lab tests compared to Road-enhanced test

Specimen no.	Road-enhanced corrosion	CASS	AASS	Filiform	CATCH
12	0	9.8	1.9	2.0	0.5
24	0	4.9	2.2	0.5	0.0
5	0.4	42.3	14.3	3.5	1.0
2	0.5	18.9	7.8	0.0	1.0
14	1.0	157.7	7.0	5.0	1.5
18	1.4	79.6	3.8	4.5	11.0
16	1.5	59.8	18.3	7.5	13.5
20	3.5	44.5	5.3	3.0	10.5
23	14.3	62.4	15.5	325.0	29.0
21	28.9	59.5	9.5	7.0	17.0

Lab tests compared to Salt Water Spray

Specimen no.	Spray salt water	CASS	AASS	Filiform	CATCH
35	0.0	3.3	0.0	2.5	0.0
45	10.7	31.6	12.0	9.4	2.3
44	20.0	28.0	10.6	5.1	4.6
50	31.0	33.2	8.3	17.7	9.3
47	73.7	65.9	171.1	10.3	108.6
46	53.7	356	392	35.9	102.0
42	133.0	363	2104	193.9	194.3
41	718.3	1508	3554	30.1	516.3
37	1750.7	615	2698	5.2	316.3

Correlation

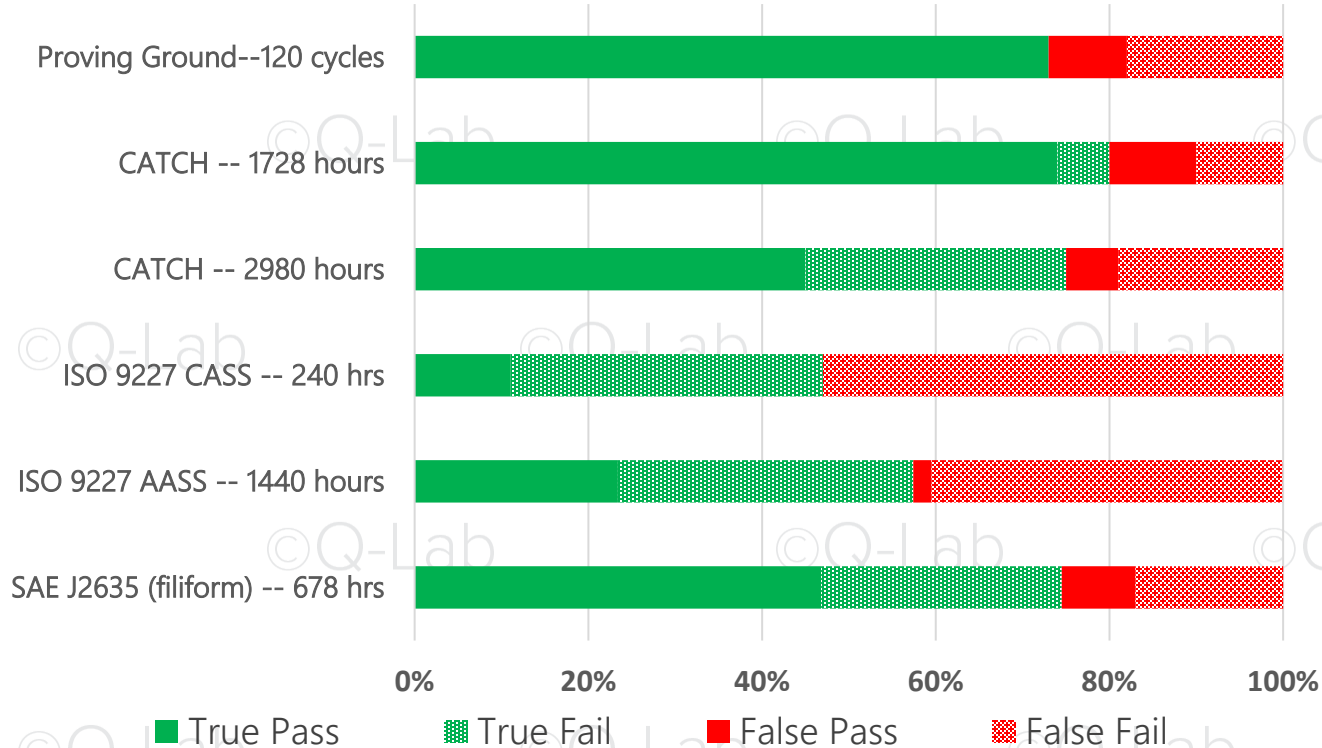
- Comparison of chamber versus outdoor test results
 - True pass/fail
 - False pass/fail
- Spearman Rank Correlation Coefficient
 - Pearson correlation inappropriate due to non-linearity of dataset (2-3 orders of magnitude between best and worst performers)
 - Complete data and subsets examined

Spearman Rank

Test Method	Correlation vs Outdoor Salt Spray	Correlation vs Proving Ground
Outdoor Salt Spray	<i>1.00</i>	0.58
Proving Ground	0.58	<i>1.00</i>
CATCH 1728 hours	0.71	0.56
CATCH 2980 hours	0.79	0.52
CASS (ISO 9227) 240 hours	0.69	0.30
AASS (ISO 9227) 1440 hours	0.66	0.07
SAE J26353 (filiform) 678 hours	0.48	0.05

CATCH is best, but why not use simpler and faster CASS and AASS tests?

Pass/Fail Correlation: Salt-Accelerated Outdoor



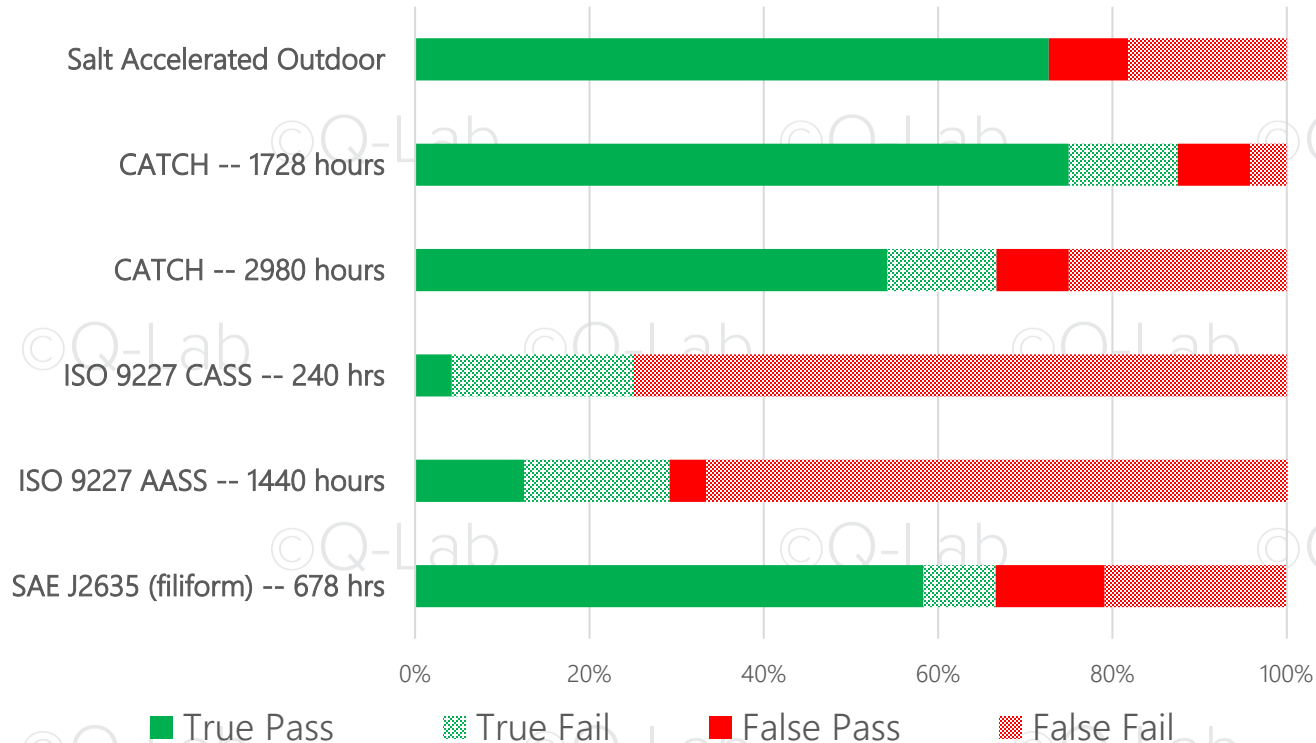
Green means agreement between outdoor test and chamber test

Red means that outdoor test and chamber test do not give same pass/fail results

Solid colors refer to specimens that passed the chamber test

Textured colors refer to specimens that failed the chamber test

Pass/Fail Correlation: Proving Ground



Green means agreement between outdoor test and chamber test

Red means that outdoor test and chamber test do not give same pass/fail results

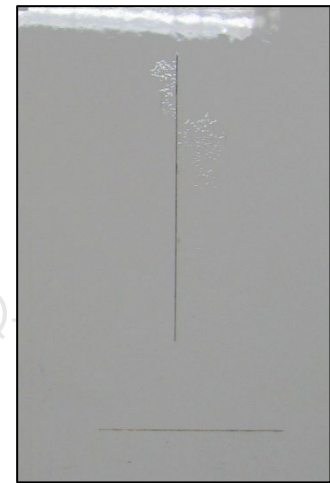
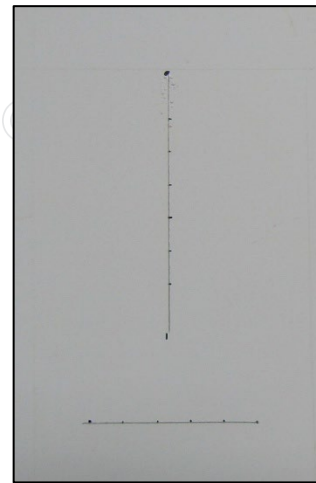
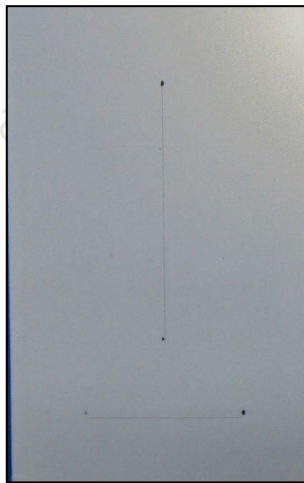
Solid colors refer to specimens that passed the chamber test

Textured colors refer to specimens that failed the chamber test

CATCH results

Aluminum panels:
CATCH - 2980 h

(from left to right:
good, middle, bad)



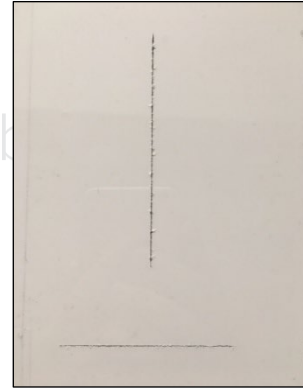
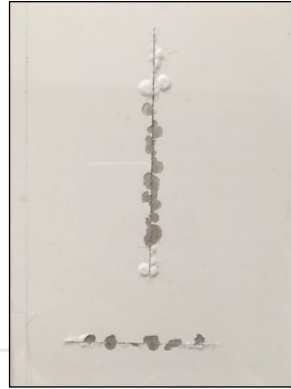
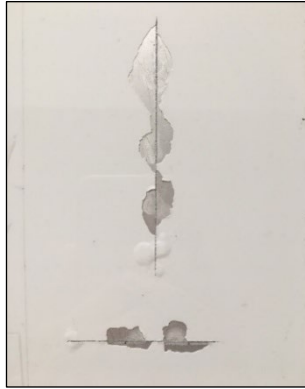
Steel panels:
CATCH - 1728 h

(from left to right:
good, middle, bad)

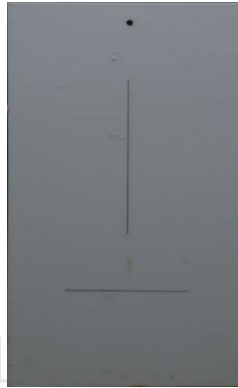


Corrosion morphology comparison

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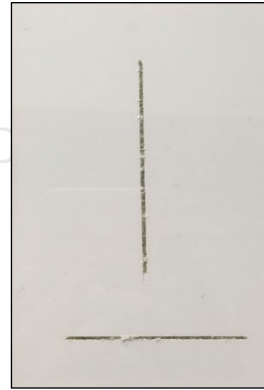
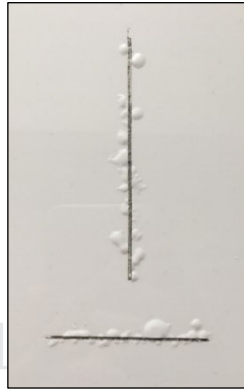
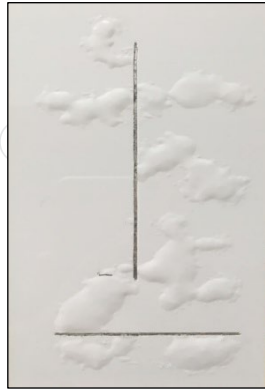


CASS
240 hours



Spray salt water
12 months

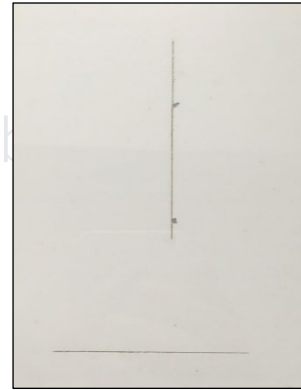
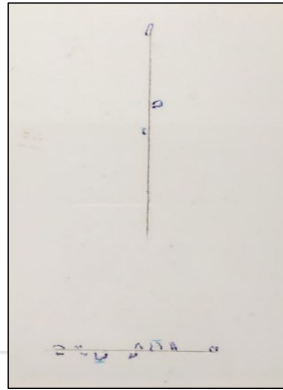
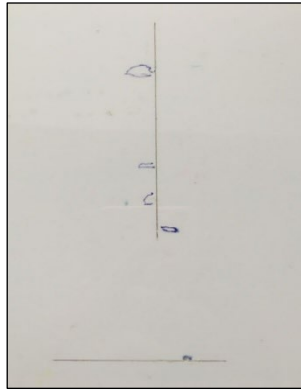
Corrosion morphology comparison



AASS
1980 hours

Spray salt water
12 months

Corrosion morphology comparison



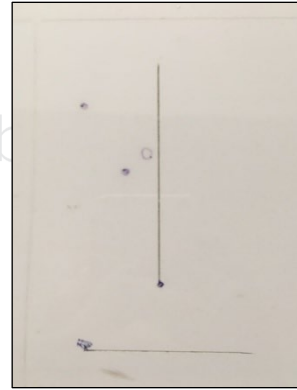
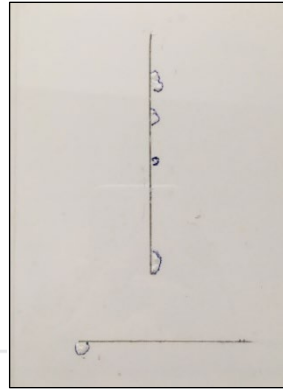
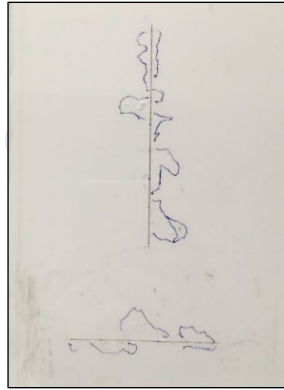
Filiform
678 hours



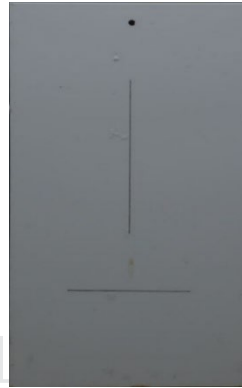
Spray salt water
12 months

Corrosion morphology comparison

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CATCH
2498 hours



Spray salt water
12 months

Summary of Aluminum test

- CATCH results show that anti-corrosion performance of Al panels is better than that of steel panels.
- CATCH produces similar corrosion morphology to outdoor spray salt water, with good correlation
- Anti-corrosion performance of coated Al panels:
 - Closely related to electrophoresis, surface treatment, and substrate
 - Not correlated to finish type
- Corrosion morphology of Al panels is quite different from that of steel panels

Analysis of Aluminum test results

- There are differences of corrosion morphology between different test methods
- CATCH test method is consistent with the test design
- CATCH test method delivers similar corrosion morphology with outdoor spray salt water, with good correlation
- CATCH test method also has good correlation with road enhanced corrosion

Aluminum Substrates

Second-round test

Second round test

- The correlation between CATCH and both outdoor spray salt water and road-enhanced corrosion is good, but the CATCH test method is slow
 - CATCH 1728 h (2.4 months) or 2980 h (4.1 months)
 - Outdoor spray salt water 12 months
- CASS, AASS, and SAE J2635 tests suggest acidifying solution to accelerate corrosion (pH 3.0 instead of 4.0)

Correlation between different-pH CATCH Tests

pH	CATCH 3.0					CATCH 4.0		
Time (hours)	336	600	864	1296	1728	864	1296	1728
A	0.00	0.45	0.72	1.67	2.65	0.13	0.65	0.99
B	0.00	0.05	0.16	0.29	0.49	0.00	0.00	0.00
C	0.00	0.50	1.11	1.60	2.49	0.00	0.00	0.06
D	0.00	0.09	0.18	0.20	0.80	0.00	0.00	0.00
E	0.17	0.23	0.59	0.98	1.56	0.17	0.35	0.56
F	0.43	0.72	0.98	1.05	2.22	0.21	0.50	0.88
G	1.18	1.63	1.92	2.40	4.11	0.50	0.98	1.76
H	2.67	7.48	9.51	14.55	20.77	2.53	4.84	6.76
I	0.00	0.59	0.92	1.43	3.24	0.00	0.26	0.29
J	0.72	1.66	2.88	5.30	7.80	0.48	0.79	1.02
Total	5.2	13.4	19.0	29.5	46.1	4.0	8.4	12.3

CATCH pH3.0 vs. CATCH pH4.0

- The corrosion area of CATCH pH3.0 after 600 h matches CATCH pH4.0 after 1728 h
- The correlation coefficient between CATCH pH 3.0 600 h and CATCH pH4.0 1728 h is **0.87**

CATCH 3.0 Correlation

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Test Method	CATCH 3.0 Test Time			
	600 h	864 h	1296 h	1728h
Proving Ground	0.73	0.72	0.82	0.80
CATCH 4.0 1728 hrs	0.87	0.77	0.84	0.84

Good correlation in all cases

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CATCH Conclusions

- CATCH demonstrated good correlation in corrosion extent and morphology compared to outdoor tests
- SAE China published CATCH 3.0 as a new standard: **T/CSAE 130-2020**
- 672 hours exposure recommended
- 1 hour “pressure cooker” test can be used for pre-screening to eliminate very bad performers

Thank you for your time.

Questions?
info@q-lab.com

We make testing simple. |

