SAE J2334

Automotive laboratory cyclic corrosion testing
汽车实验室循环腐蚀测试

Kobe Qu（瞿华盛）
Senior Technical and Marketing Manager
kqu@q-lab.com
Q-Lab Corporation

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Our subject for today

SURFACE VEHICLE STANDARD	J2334™	APR2016
	Issued 1998-06 Revised 2003-12 Stabilized 2016-04 Superseding J2334 DEC2003	
Laboratory Cyclic Corrosion Test		

Standard Summary

Foreword—This laboratory cyclic corrosion test procedure is based on a field-correlated Design of Experiment process conducted by the SAE Automotive Corrosion and Prevention Committee (SAE/ACAP) and the Auto/Steel Partnership (A/SP) Corrosion Task Force. Results from this test will provide excellent correlation to severe corrosive field environments with respect to cosmetic corrosion performance ...

前言——该实验室循环腐蚀试验程序是基于SAE汽车腐蚀与预防委员会(SAE/ACAP)和汽车/钢铁合作伙伴关系(A/SP)腐蚀工作组进行的现场相关实验设计过程。在外观腐蚀性能方面，该测试的结果将提供与严苛腐蚀环境良好的相关性...

A typical automotive paint system was used to develop this test ... If a different type of coating system is used, field correlation must be determined.

当时使用的常规的汽车涂料体系来开发该测试...如果使用不同类型的涂层系统，则必须确定和户外的相关性。

1. *Scope*—The SAE J2334 lab test procedure should be used when determining corrosion performance for a particular coating system, substrate, process, or design. Since it is a field-correlated test, it can be used as a validation tool as well as a development tool. If corrosion mechanisms other than cosmetic or general corrosion are to be examined using this test, field correlation must be established.

1.范围——在确定特定涂层系统、基材、工艺或设计的腐蚀性能时，应使用SAE J2334测试程序。由于它是一个与户外相关的测试，因此它既可以用作验证也可以用作开发。如果要使用该试验检查除外观或一般腐蚀以外的腐蚀机制，则必须建立户外相关性。

Environmental conditions 环境条件

Humid 潮湿

50 ± 2 °C
100% Relative Humidity (RH)

Three methods are permitted for producing saturating humidity:

允许使用三种方法来产生饱和湿度：

1. Wet-bottom 湿底
2. Water fog 水雾
3. Steam (vapor) generator 热蒸汽

Dry 干燥

60 ± 2 °C
50% RH ±5%

- "Additional equipment will be required to maintain the 50% relative humidity condition."

"需要额外的设备来维持50%的相对湿度条件"

- Air circulation is required to avoid stagnation and to encourage drying

需要空气循环以避免停滞并促进干燥

Environmental conditions - commentary

- "100% RH" is a casual way of stating that the chamber must produce condensing humidity

"100%RH"是一种随意的说法，表示箱内必须产生冷凝湿度

  - Note that it has no tolerance, and thus isn't an actual measurement

  请注意，它没有公差，因此不是实际的测量值

  - The standard clearly states the *intent*: "Whichever method is employed, test samples and controls are required to be visibly moist/wet."

  该标准明确规定了意图： "无论采用哪种方法，样品表面出现可见的水。"

  - RH values above 90-95% meet this goal; 100% is nearly impossible to measure precisely and is not a realistic target

  相对湿度值高于90-95%符合这一目标；100%湿度几乎不可能精确测量，也不是一个现实的目标

- Q-FOG CRH testers use the "water fog" method, though the standard says the method was developed using steam generation. We offer a wet bottom kit, but it is not needed

Q-FOG CRH使用"水雾"方法，尽管该标准使是基于蒸汽发生开发的。我们提供湿底套件，但其实并不需要

- Dry conditions require the use of "additional equipment" – a controlled RH tester like the **Q-FOG CRH**

干燥条件需要使用"附加设备"——像Q-FOG CRH一样相对湿度可控

Electrolyte (Salt) Solution 盐溶液

Composition 成分

0.5% NaCl

0.1% $CaCl_2$

0.075% $NaHCO_3$

Similar to solution used in GMW14872, which uses 0.9% NaCl

与GMW14872中使用的溶液类似，该溶液使用0.9%的氯化钠

Application 应用

Three methods are allowed: 三选一

1. Immersion 浸泡
2. Spray 喷淋
3. Fog 盐雾

All are for 15 min, even though Spray wets specimens much faster than Fog

盐水施加持续了15分钟，尽管**喷淋**湿润样品的速度比**喷雾**快得多

Fog collection of 2-4 mL/hr (2× of ASTM B117) is required

沉降量 2-4 mL/hr ， 两倍于ASTM B117

Salt Solution – details 盐配方

Chemical Component	% by Mass	Notes
Sodium Chloride[1] (NaCl)	0.9%	Reagent grade or 999 food grade
Calcium Chloride[2] ($CaCl_2$)	0.1%	Reagent grade
Sodium bicarbonate ($NaHCO_3$)	0.075%	Reagent grade (but commercial-grade also accepted)
Water	98.925%	ASTM D1193 Type IV

Electrolyte (Salt) Solution - commentary

- Guidance is provided for how to properly mix the solution

提供了如何正确混合溶液的指导

- Spray nozzles may get clogged by precipitate

喷嘴可能会被沉淀物堵塞

- pH of the salt solution must be measured and recorded prior to the start of test and on a weekly basis thereafter. No pH buffering allowed.

必须在试验开始前和试验后每周测量并记录盐溶液的pH值。不能使用pH缓冲剂。

- Test development was performed using the Immersion method; Spray is more modern and common and recommended for the Q-FOG CRH

虽然使用浸没法进行的开发；但是喷淋更现代、更常见，建议用于Q-FOG CRH

- Conductivity should be 10-12 mS at 25 °C ± 2 °C. It must be measured and recorded after mixing, and periodically as needed

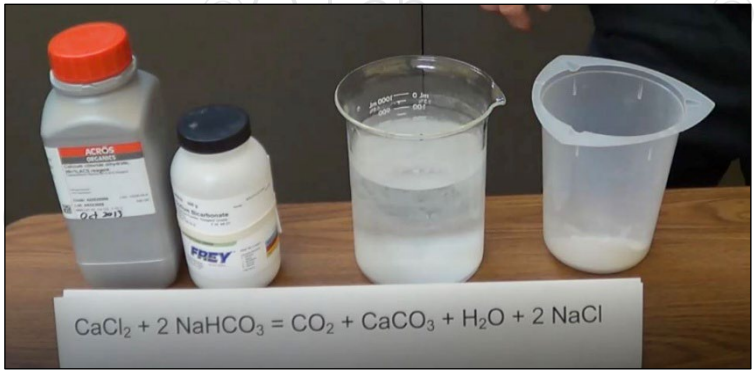
在25°C±2°C时，电导率应为10-12mS。混合后必须测量和记录，并根据需要定期测量和记录

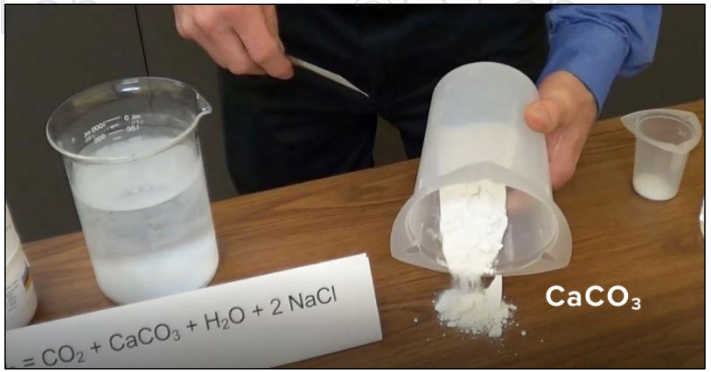
- Spray shall not be so intense as to remove corrosion products

喷淋压力不得过大，以免去除腐蚀产物

Mixing the Solution 溶液混合

Precipitation warning! 沉淀警报！





- Precipitate of Calcium Carbonate ($CaCO_3$) will form if solution isn't made properly

如果溶液制备不当，将形成碳酸钙(CaCO3)沉淀

- Calcium Carbonate ($CaCO_3$) is insoluble in water and can cause problems

碳酸钙(CaCO3)不溶于水，会引起问题

How NOT to Mix 不正确配置

Prepare two solutions individually
分别准备两种溶液

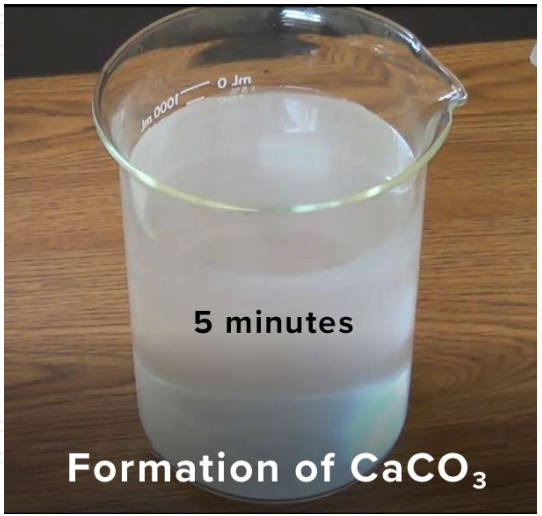
Calcium Chloride $CaCl_2 \cdot 2H_2O$

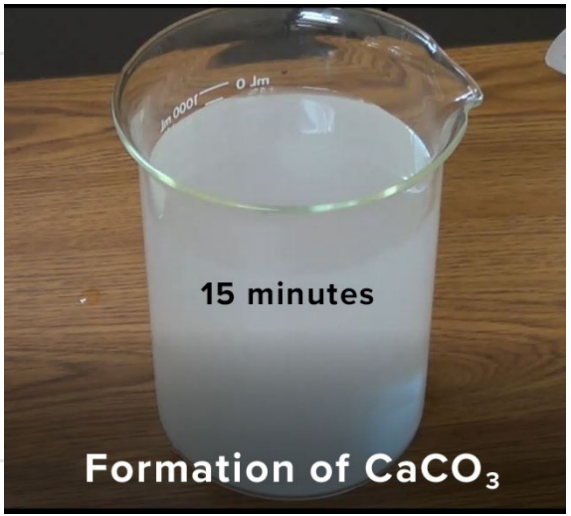
Sodium Bicarbonate $NaHCO_3$

Mix the two solutions together
混合两种溶液

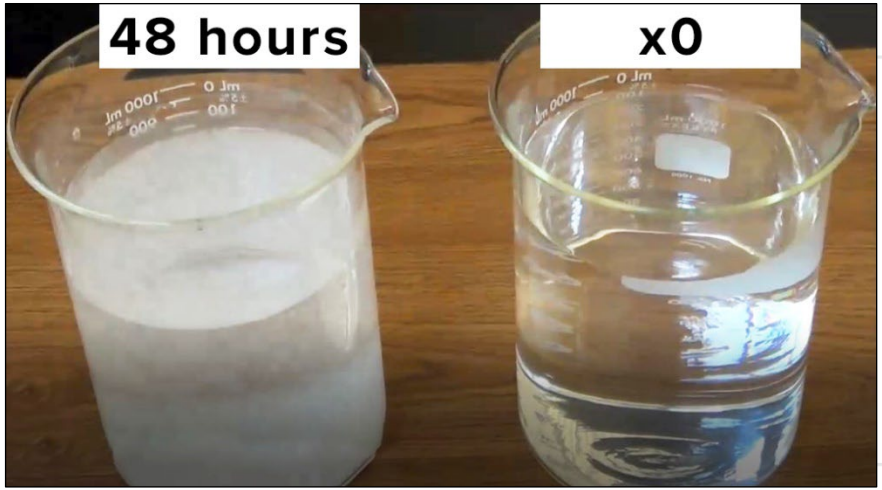
Stir both solutions until all chemicals are dissolved
搅拌两种溶液，直至所有化学物质溶解

Just watch...





“Chalk it up” to Chemistry 类似粉尘



How to Mix Solution 如何正确配置

Initial step is to determine quantity of each chemical and water needed

首先是确定每种化学物质和水的质量

1. Fill your reservoir with the full amount of water and siphon some into two containers, approximately 10% in each one

1. 将储液箱装满水，并分别虹吸到两个容器中，每个容器中大约有10%的水

How to Mix Solution 如何正确配置

2. Dissolve NaCl in the remaining reservoir water

将NaCl溶解在剩余的水中

3. Dissolve sodium bicarbonate in container 1 and calcium chloride in container 2

将碳酸氢钠溶解在容器1中，氯化钙溶解在容器2中

Container 1

Container 2

How to Mix Solution 如何正确配置

4. Pour the $NaHCO_3$ solution into the main NaCl reservoir and mix

将$NaHCO_3$溶液倒入NaCl储液箱中并混合

5. Pour the $CaCl_2$ solution into the main reservoir and mix

将氯化钙溶液倒入NaCl储液箱中并混合

Spray Nozzles 喷淋嘴

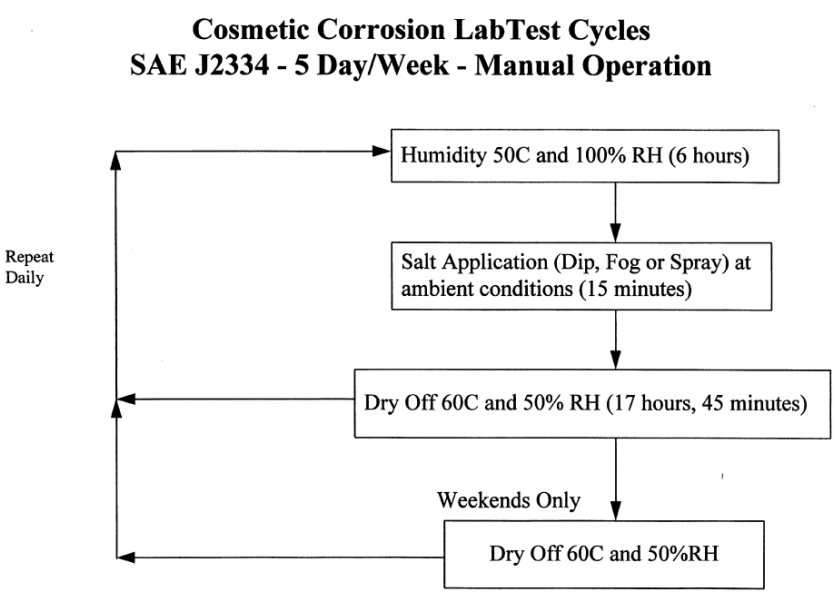
- After spray, low-pressure water flow clears out any remaining solution to prevent/minimize precipitation

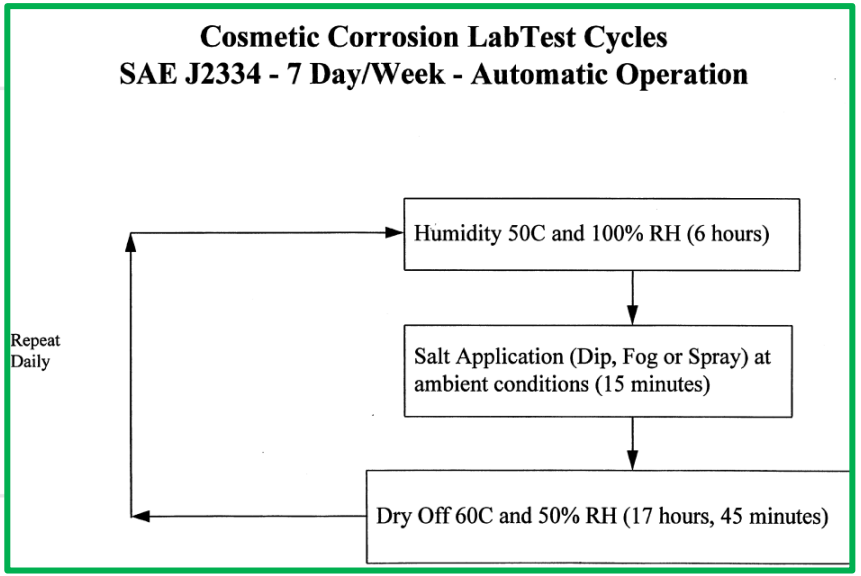
喷淋后，低压水流会清洗任何剩余的溶液，以防止/尽量减少沉淀

- Shower flow rate normalization detects low flow from clogged filters

喷淋流量标定，可检测到过滤器堵塞导致的低流量

Test Cycles





Test Programming and Setup 程序设置

SAE J2334, SAE J2721						
STEP	FUNCTION	Chamber Air Temp (°C)	RH (%)	Step Time (hh:mm)	Ramp	Ramp Time (hh:mm)
1	RH	50	100	6:00	Auto	
2	Shower	25		0:15		
3	RH	60	50	17:45	Linear	2:00
4	Final Step – Go To Step 1					

Shower Pulse Rate:	Spray ON / OFF is set in Machine Configuration. CRH600: 25 seconds ON, 35 seconds OFF. CRH1100: 20 seconds ON, 40 seconds OFF.
Shower Pump Pressure:	CRH600: 40 psi CRH1100: 80 psi

Test Cycles - commentary

- Each cycle is a 24-hour repeat

每个测试循环为24小时

- Dry-off is 3/4 of the total test time – that's quite a lot!

干燥时间占总测试时间的3/4——这相当长！

- Transition times are not defined 过渡时间未定义
  - This can lead to variability in testing

    这可能会导致测试的不一致性
- Ramp times count as part of step

过渡时间计入下一个步骤

- Minimum of 60 cycles recommended, but this is specimen-dependent

建议至少进行60个循环，但这取决于样品

Corrosion Science and SAE J2334

Relative Humidity Control

相对湿度控制

Deliquescence

盐的潮解

Deliquescence Relative Humidity (DRH) 潮解湿度

Salt	DRH
Potassium Chloride (KCl)	85%
Ammonium Sulfate $(NH_4)_2SO_4$	81%
Sodium Chloride (NaCl)	*76%*
Sodium Nitrate ($NaNO_3$)	74%
Magnesium Chloride ($MgCl_2$)	33%
Calcium Chloride ($CaCl_2$)	*31%*

If the environment is above this RH, a liquid salt solution will form
如果环境湿度高于此相对湿度，则会形成液态盐溶液

Salt and Time of Wetness 盐和潮湿时间

- Salts **deliquesce** - they absorb moisture from the atmosphere until they dissolve and form a solution

盐会潮解——它们会从大气中吸收水分，直到溶解并形成溶液

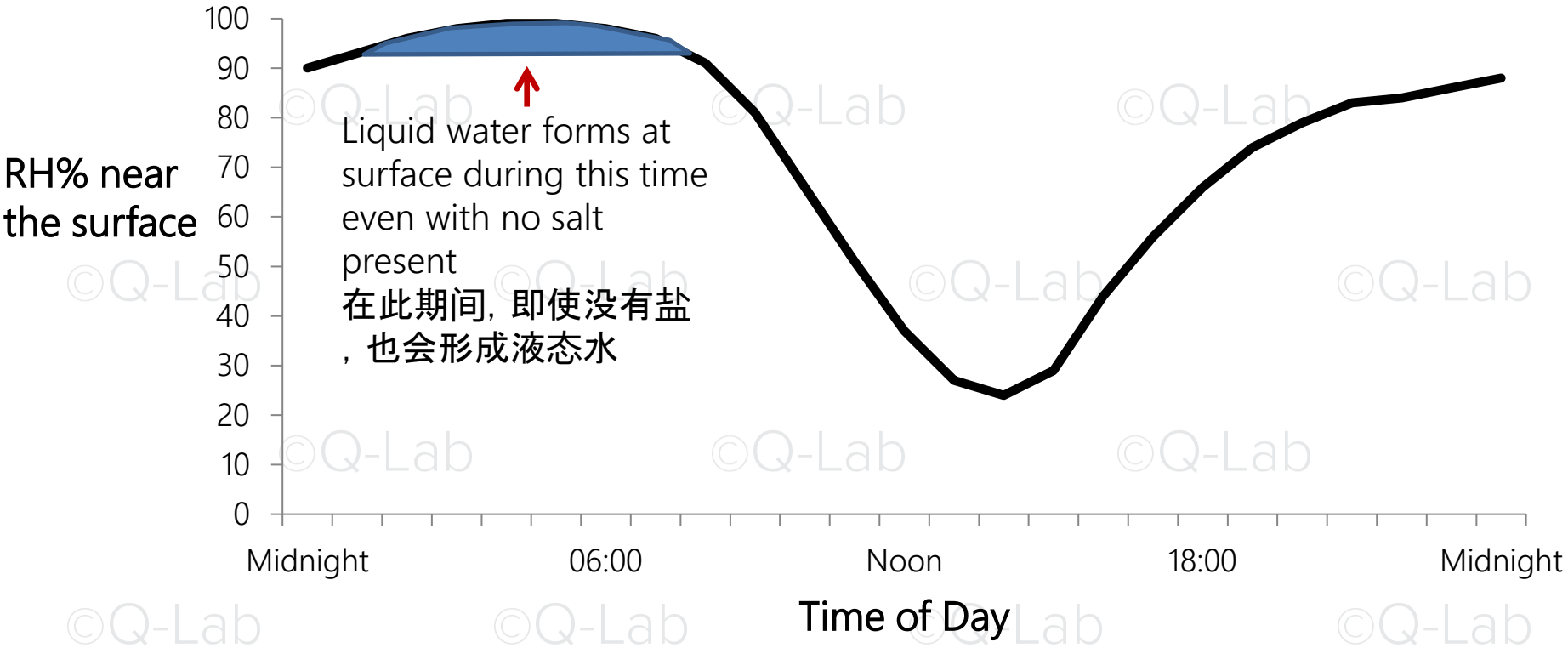
- All soluble salts will liquefy for RH values <100%

当相对湿度值<100%时，所有可溶性盐都会潮解

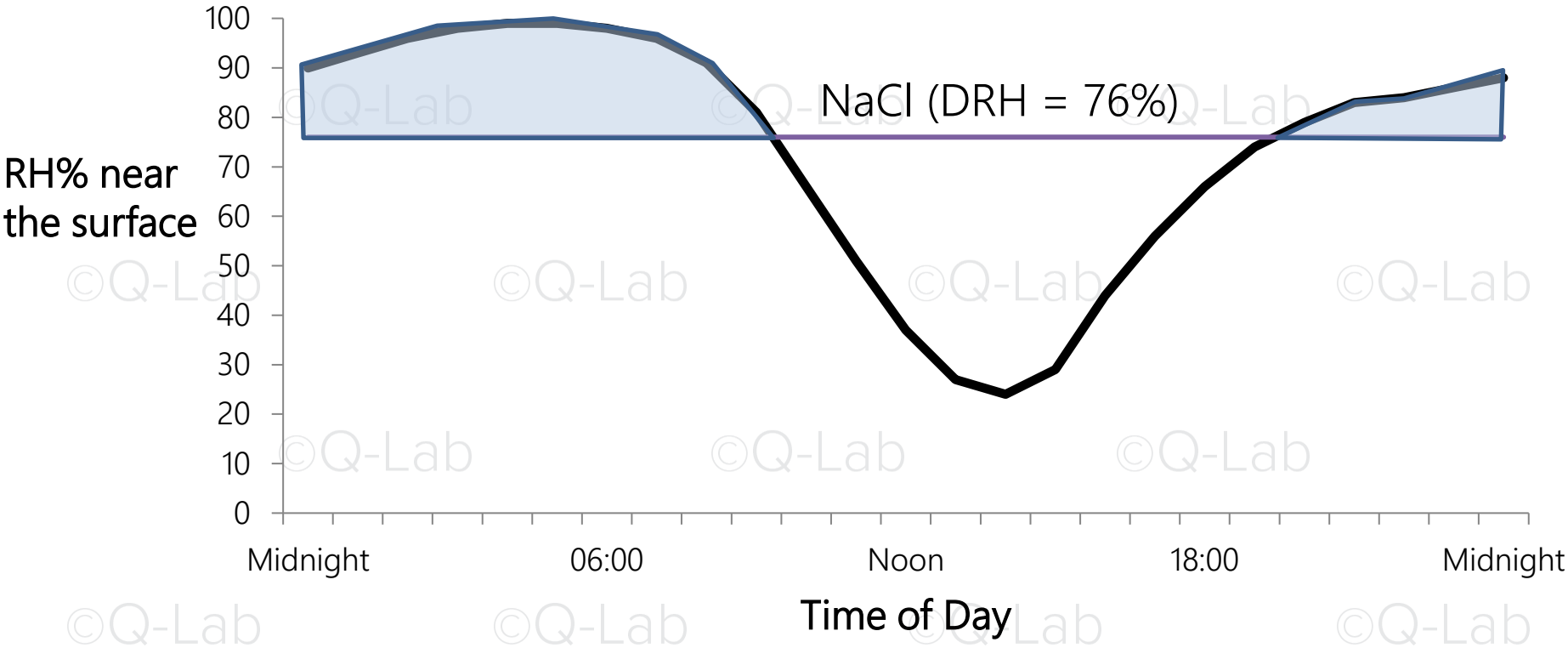
- This leads to increased **time of wetness** and increased **corrosion**

这会导致**潮湿时间**延长和**腐蚀**加剧

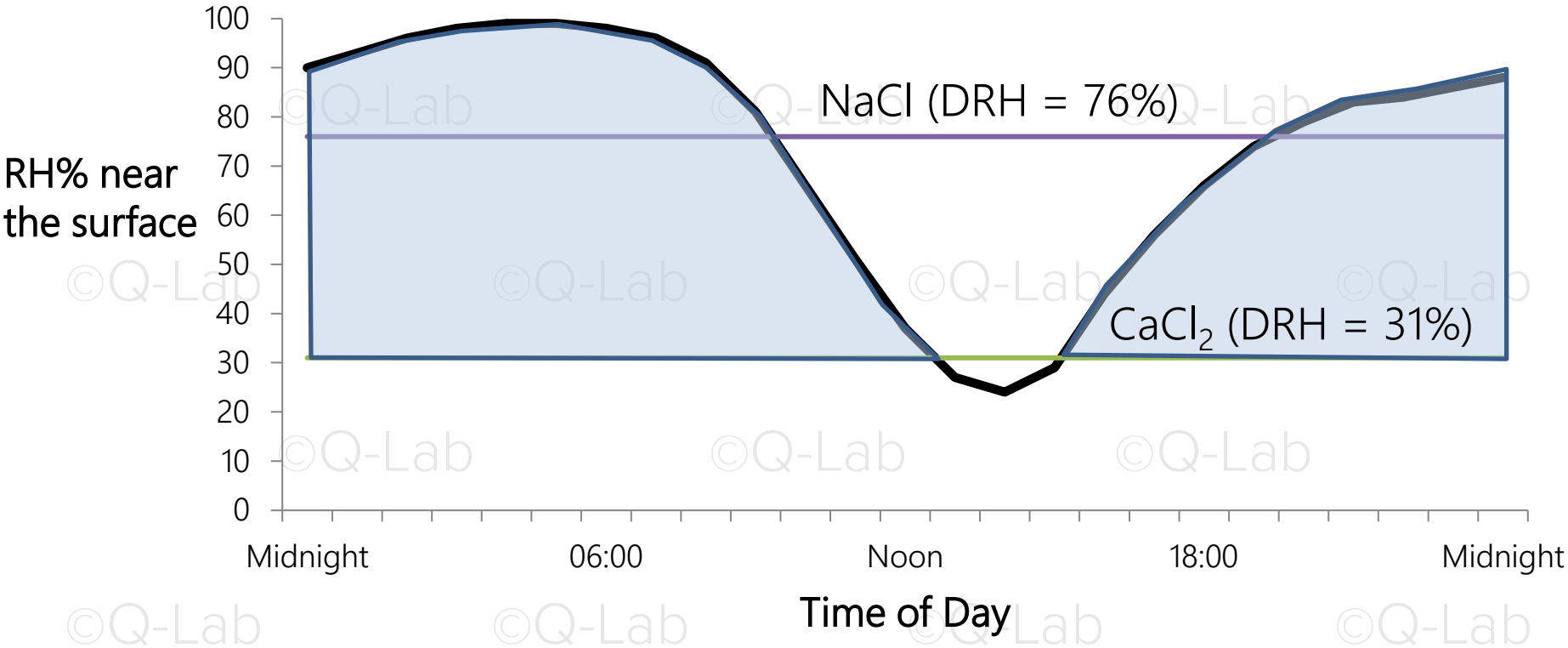
RH and Time of Wetness 相对湿度和潮湿时间



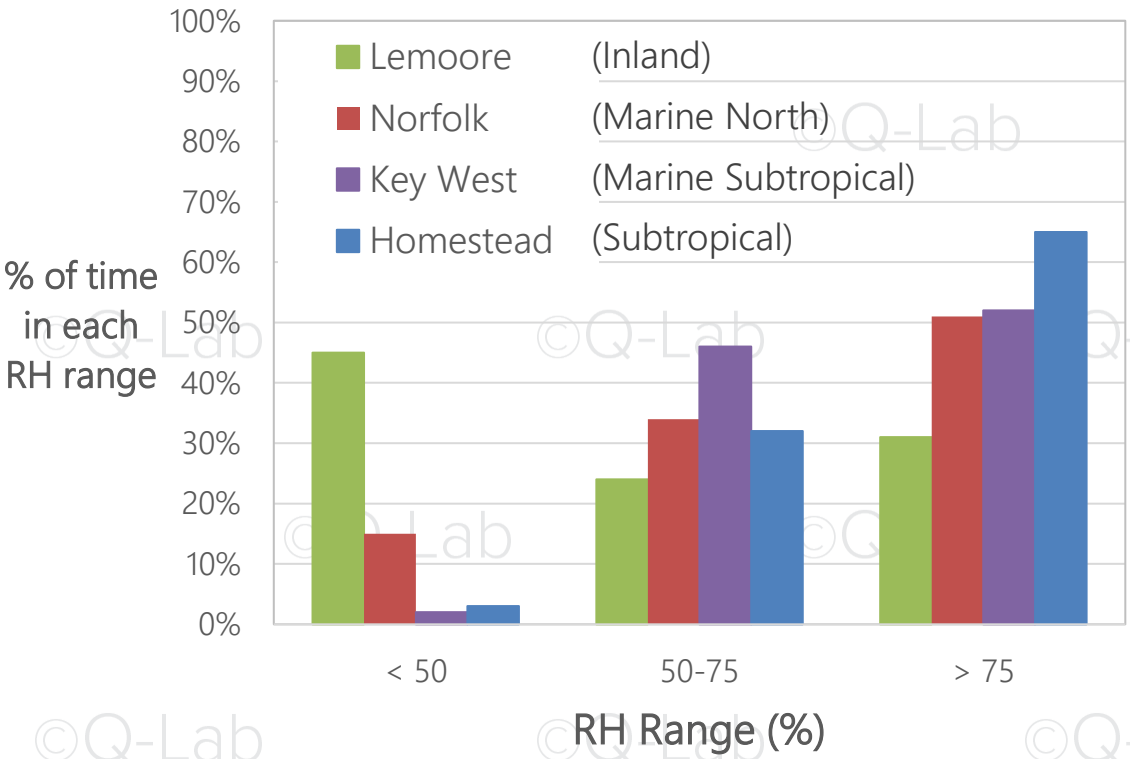
RH and Time of Wetness 相对湿度和潮湿时间

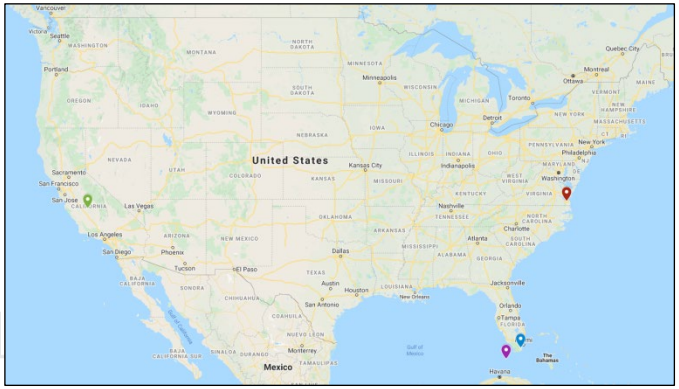


RH and Time of Wetness 相对湿度和潮湿时间



Intermediate RH Conditions are Important
中等相对湿度条件很重要





Relative Humidity and Corrosion
相对湿度和腐蚀的关系

Condition	RH Range	Result
Dry 干燥	≤ 50%	Very little corrosion from NaCl 几乎不产生腐蚀
Electrolytic cells around salt crystals; film formation as RH increases 随着相对湿度的增加，水膜形成	50-76%	• Corrosion of **steel** (maximum corroded area ~70% RH) and **aluminum** • AL-Steel galvanic couple broken 未形成电偶腐蚀，铁和铝都腐蚀
Uniform Electrolytic Film formation 均匀的电解液形成	≥76%	• Maximum cathode area for steel; deeper non-uniform corrosion • **Al corrosion** in galvanic couple with steel 电偶腐蚀机制形成，主要是铝腐蚀

Relative Humidity and Corrosion Testing
相对湿度和腐蚀的关系

- RH control between 50% and 90% is critical for test realism

50%至90%之间的相对湿度控制，对于测试的真实性至关重要

  - Affects corrosion **rate** and **morphology**

    影响腐蚀**速率**和**形态**

  - Modern Corrosion standards account for this

    现代腐蚀标准对此做出了解释

- Wet / Dry Cyclic tests like SAE J2334 do not "control the middle"

SAE J2334等干湿循环测试并不“控制中间过程”

  - RH transition times not controlled

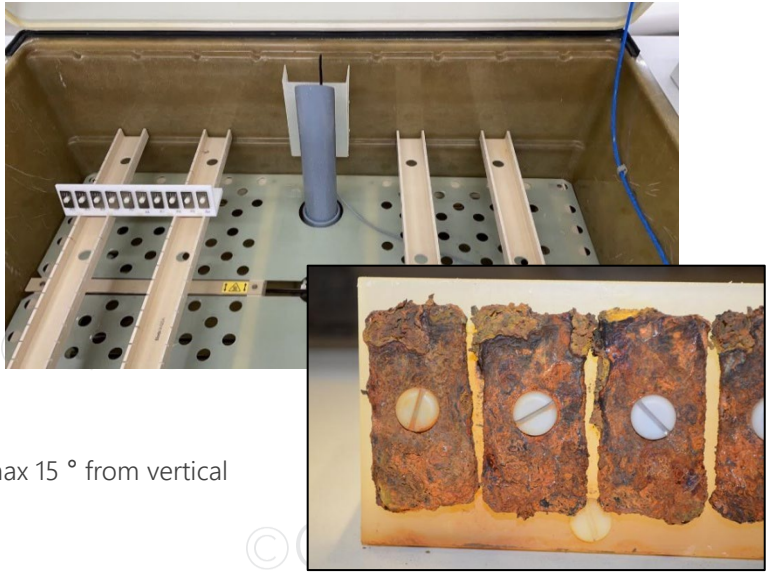
    湿度转换时间不受控制

  - Variable specimen dry-off rates

    试样干燥速率不同

SAE J2334 Case Study

Corrosion Coupons in SAE J2334 参比样板测试



- Corrosion coupons are required but there is no mass loss target

需要使用腐蚀参比样板，但没有质量损失目标

  - Generally 25.4 × 50.8 mm (1.0 × 2.0 in) pieces of bare sheet metal

  通常为25.4×50.8毫米（1.0×2.0英寸）的裸金属板

  - Always cold-rolled steel; may include zinc

  始终采用冷轧钢；可能包括锌板

  - Must be stamped with an ID

  必须加盖印章

- Clean with degreaser and weigh before use

使用前用脱脂剂清洁并称重

- Affix to nonmetallic coupon rack and electrically isolate with plastic fasteners

将其固定在非金属试样架上，并用塑料紧固件进行隔离

- Allow min. 5 mm spacing between the coupons and the rack surface; mount max 15 ° from vertical

样板和支架表面之间至少留出5毫米的间距；安装时与垂直方向的最大角度为15°

- Place near test specimens so exposure is representative

参比样板放置在试验区域，使暴露具有代表性

- Remove and analyzed periodically to monitor corrosion. Before weighing, clean the coupons using a mild “sand blast” (preferably glass beads) to remove all corrosion by-products from the coupon surface. Chemical cleaning is permitted

定期拿出进行分析，以监测腐蚀情况。称重前，使用温和的“喷砂”（最好是玻璃珠）清洁试样，以去除试样表面的所有腐蚀产物。允许进行化学清洗

OEM Corrosion Coupon Spec 案例分享

- Added mass loss requirement

增加了质量损失要求

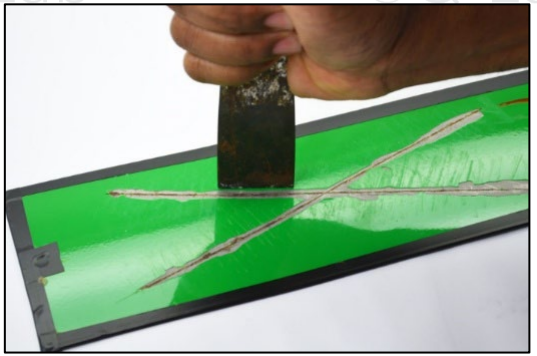
  - 20 cycles 做20个循环
  - **1.3 – 3.0 g** mass loss 质量损失 1.3-3.0g

- Includes topcoat rust specification

包括面漆腐蚀要求

  - "Creepback Value Before Scraping"
  - **Average: 4.0, maximum 6.5**

  腐蚀蔓延平均4.0，最大不超过6.5



The Problem 问题出现了

- U.S. lab “passed” a formulation (average CVBS < 3)

使用同一种涂层板，美国实验室“通过”了（平均CVBS<3）

- European lab “failed” same formulation (average CVBS > 6)

而欧洲实验室“失败”了（平均CVBS>6）

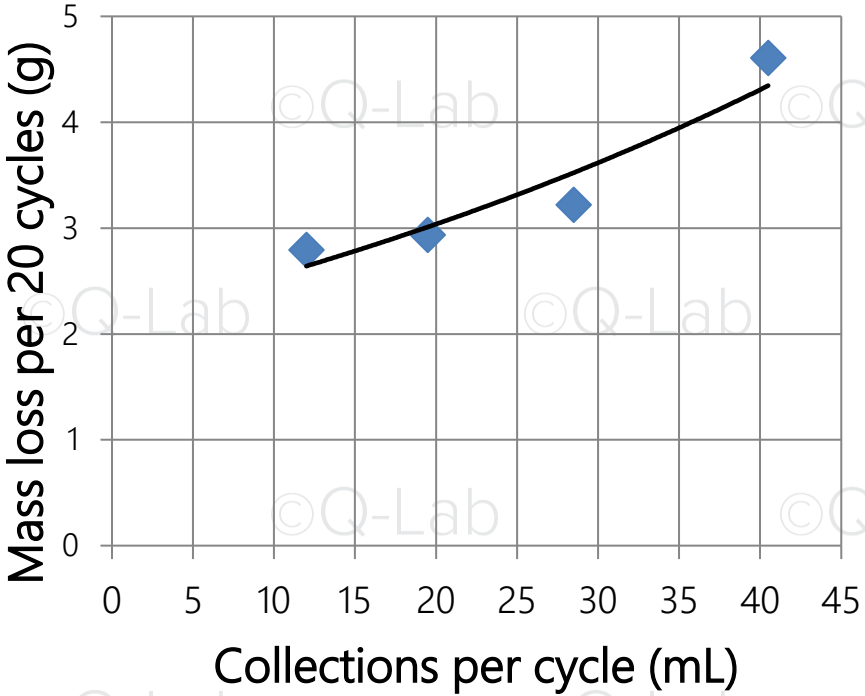
- Formulation was a proven durable system (used as a test control; should pass)

涂料配方是一种经过验证的耐用体系（用作测试对照；理应通过）

- European lab coupon mass loss too high (~5 g after 20 cycles; 3 g is max allowed)

欧洲实验室腐蚀参比样板质量损失过高（20个循环后约为5克；最大允许为3克）

Experiment 1: Salt Shower Quantification
试验1：喷淋流量调整



- Amount of collections correlated with mass loss (previously known from GMW 14872 testing)

沉降量与质量损失有关（之前从GMW 14872测试中已知）

- Adjusted spray on/off time to reduce spray (10 mL/cycle)

调整喷淋开/关时间以减少盐水施加（10 mL/cycle）

- Mass loss remained high!

质量损失仍然很高！

Experiment 2: Dry-Off Times
试验2：改变干燥时间

- Wet to dry transitions were programmed differently in U.S. lab (other chamber) and European lab (Q-FOG CRH)

美国实验室（非Q-Lab设备）和欧洲实验室（Q-FOG CRH）的干湿转换程序不同

  - 20 minute transition step added to U.S. chamber to speed up RH reduction (a common practice)

    美国的那台设备增加了20分钟的过渡步骤，以加快相对湿度的降低（一种常见做法）

- Approach: Test original default SAE J2334 cycle in Q-FOG, compare to another cycle designed to achieve faster dry-off

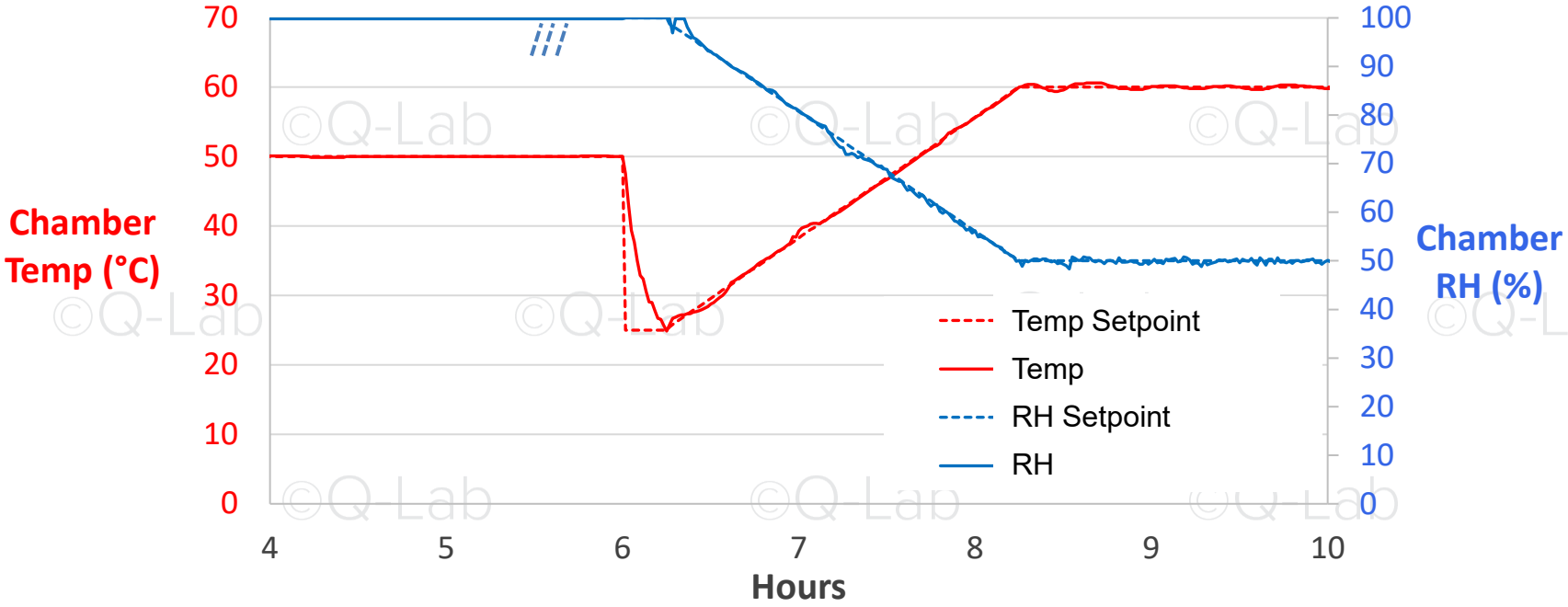
方法：Q-FOG原始默认的SAE J2334缓慢干燥循环，与另一个旨在实现更快干燥的循环进行比较

Slow Dry-off 缓慢干燥

Programming Cycle

Step	Function	Chamber Air Temp (°C)	RH (%)	Step Time (hh:mm)	Ramp
1	RH	50	100	6:00	Auto
2	Shower	25		0:15	
3	RH	60	50	17:45	Linear (2:00)

SAE J2334: Slow Dry-Off 缓慢干燥



*Time above the Deliquescence RH of NaCl is about **1 hour***

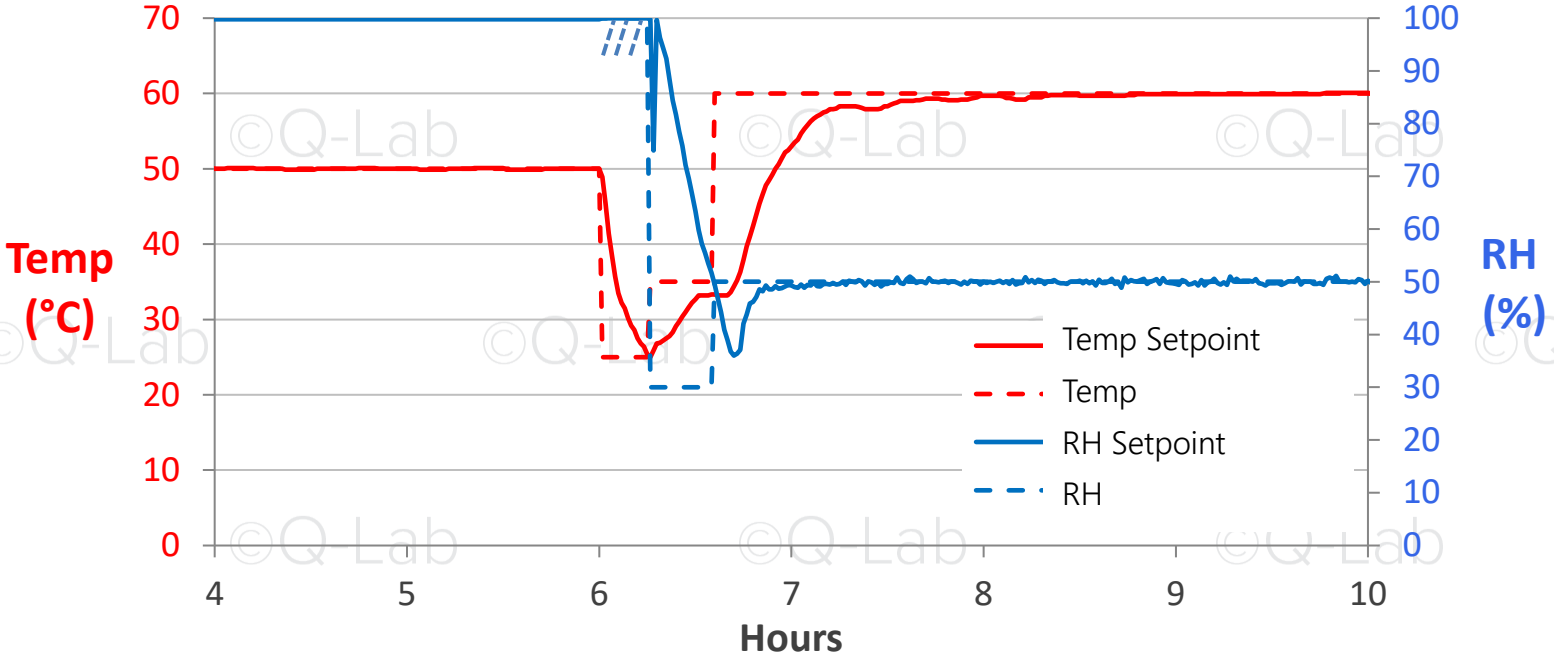
氯化钠潮解的时间大约1小时

Rapid Dry-off 快速干燥

Programming Cycle

Step	Function	Chamber Air Temp (°C)	RH (%)	Step Time (hh:mm)	Ramp
1	RH	50	100	6:00	Auto
2	Shower	25		0:15	
3	RH	35	30	0:20	
3	RH	60	50	17:25	Auto

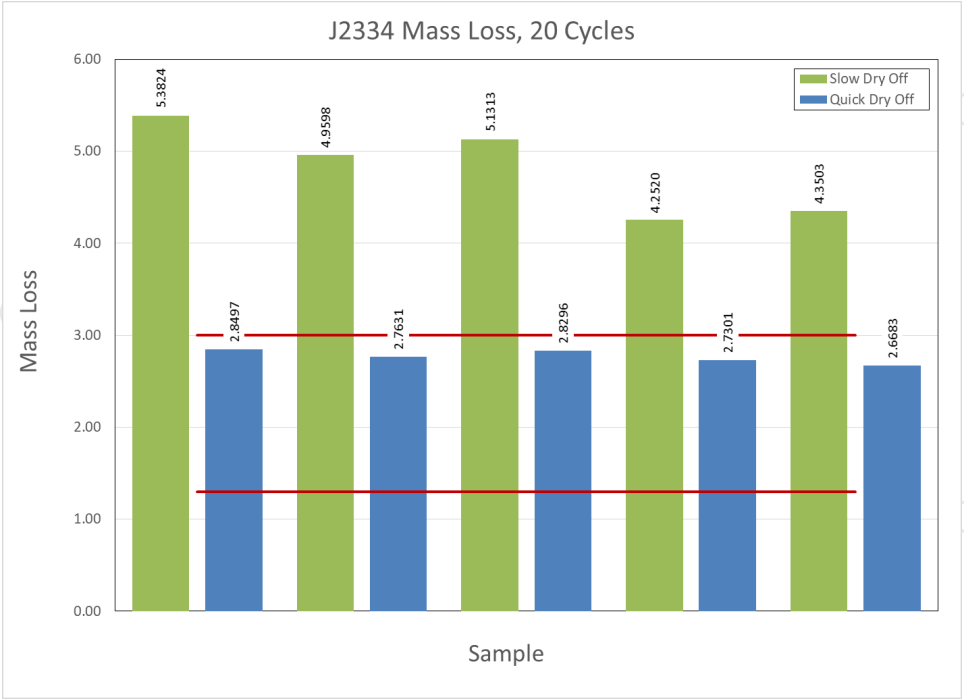
SAE J2334: Fast Dry-Off 快速干燥



*Time above the Deliquescence RH of NaCl is about **10 minutes***

氯化钠潮解的时间大约10分钟

SAE J2334 Results



- Green bars represent test under slow dry-off conditions: **panels fail**

绿色代表缓慢干燥:失效

- Blue bars represent test under quick dry-off conditions: **panels pass**

蓝色代表快速干燥:通过

- Red lines represent tolerance of OEM standard

两条红色的线是厂家的要求

SAE J2334 Summary

- SAE J2334 is a first-generation cyclic automotive test, including **humid**, **salt**, **and** dry steps

SAE J2334是第一代汽车循环腐蚀测试，包括潮湿、盐水施加和干燥步骤

- Test allows salt application by shower, fog, or immersion

测试允许通过喷淋、喷雾或浸泡来施加盐

- Salt solution is a less-concentrated version of GMW14872 – requires special attention when mixing

盐溶液使用类似 GMW 14872的低浓度盐，混合时需要特别注意

- Repeatability can be a challenge

实验可重复性可能是一个挑战

  - Transition times are not controlled

    过渡时间不受控制

  - Corrosion coupons are required, but no target is set

    需使用腐蚀参比样板，但没有设定目标

Thank you for your attention!

Questions?

Send your inquiry to:
kqu@q-lab.com

Q-Lab中国微信公众账号:
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