Modern Corrosion Testing

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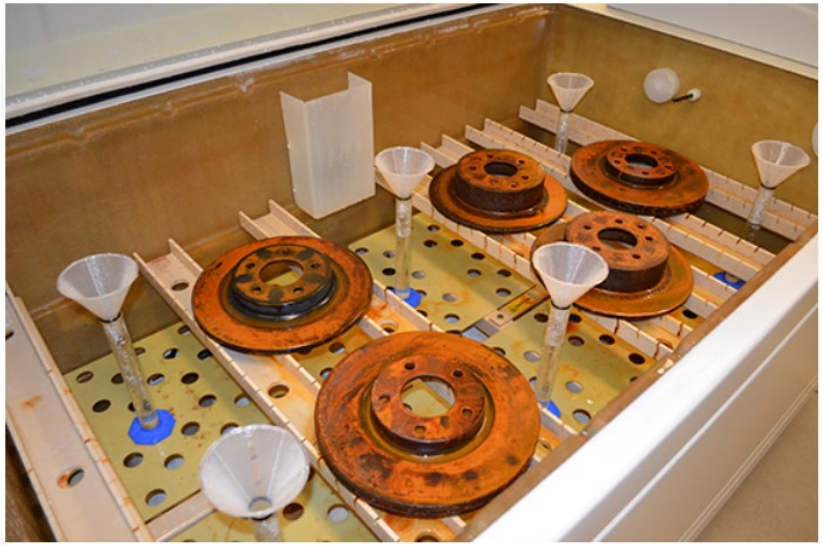
녹음하기

Administrative Notes

You'll receive a follow-up email from info@email.q-lab.com with links to take a survey and download the presentation content

Use the **Q&A feature in Zoom** to ask us questions today!

We make testing simple.



Thank you for attending our webinar!

We hope you found our ***Modern Corrosion*** webinar to be helpful and insightful. The link below will give you access to the slides and recorded webinar.

Q-Lab Corporation

- 1956년 창업
- 내후/내광성/부식 시험 전문 기업

Our Mission

Make Testing Simple for Our Customers

Our Goal

The most reliable, easiest-to-use testers on the planet

Q-Lab Facilities

Westlake, Ohio | *Worldwide Headquarters*

Bolton, England | *Q-Lab Europe*

Saarbrücken, Germany | *Q-Lab Deutschland*

Shanghai, China | *Q-Lab China*

Q-Lab Outdoor Weathering Sites

Miami, Florida

Phoenix, Arizona

Westlake, Ohio

Q-Lab Arizona

Topics

- Types of Accelerated tests
- Continuous Salt Spray (Neutral & Acidified)
- Wet/Dry Cyclic Tests
- First-Generation Cyclic Automotive Tests
- Modern Corrosion Test Methods
- Verifying Corrosion Test Performance

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Types of Accelerated Tests

Accelerated Test Type	Result	Test Time	Results compared to	Research? Development? Certification?
Quality Control	Pass / fail	• Defined • Short	Material specification	Certification & Research
Qualification / validation	Pass / fail	• Defined • Medium-long	Reference material or specification	Certification & Development
Correlative	Rank-ordered data	• Open-ended • Medium	Natural exposure (Benchmark site)	Development
Predictive	Service life Acceleration factor	• Open-ended • Long	Natural exposure (Service environment)	Development & Warranty Contracts

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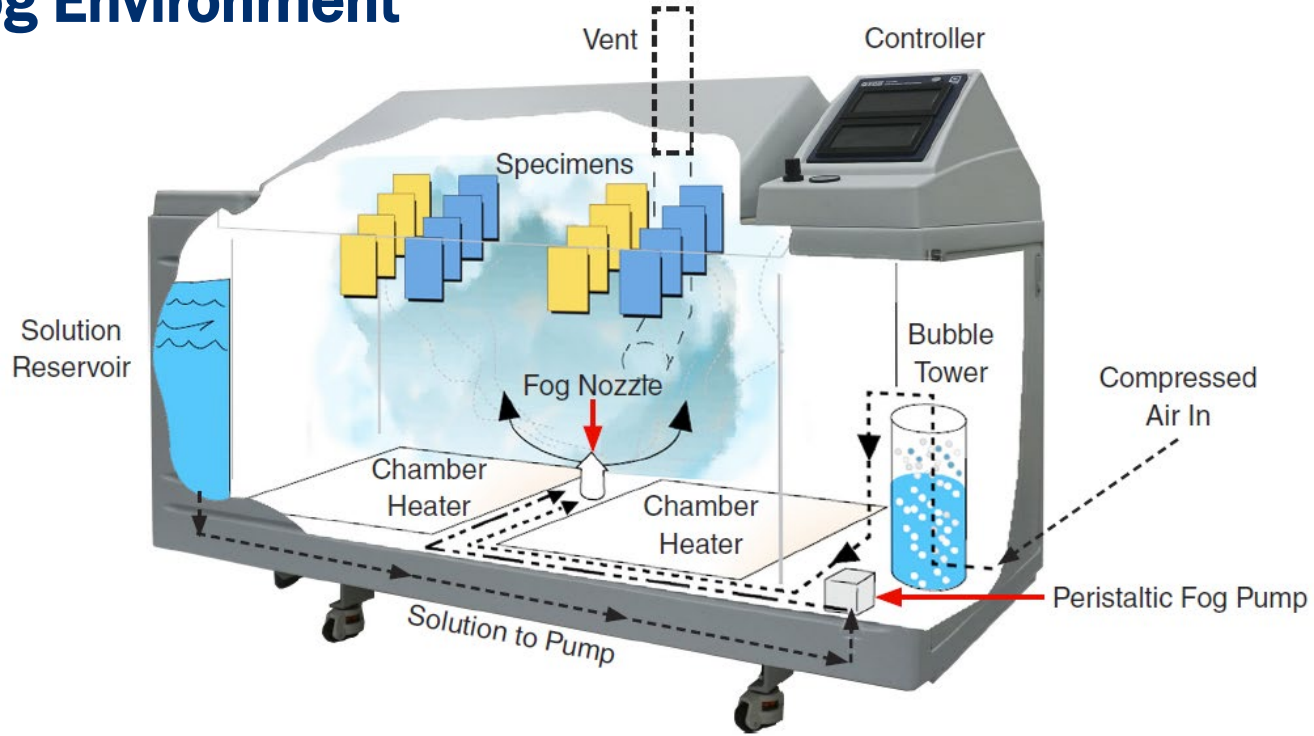
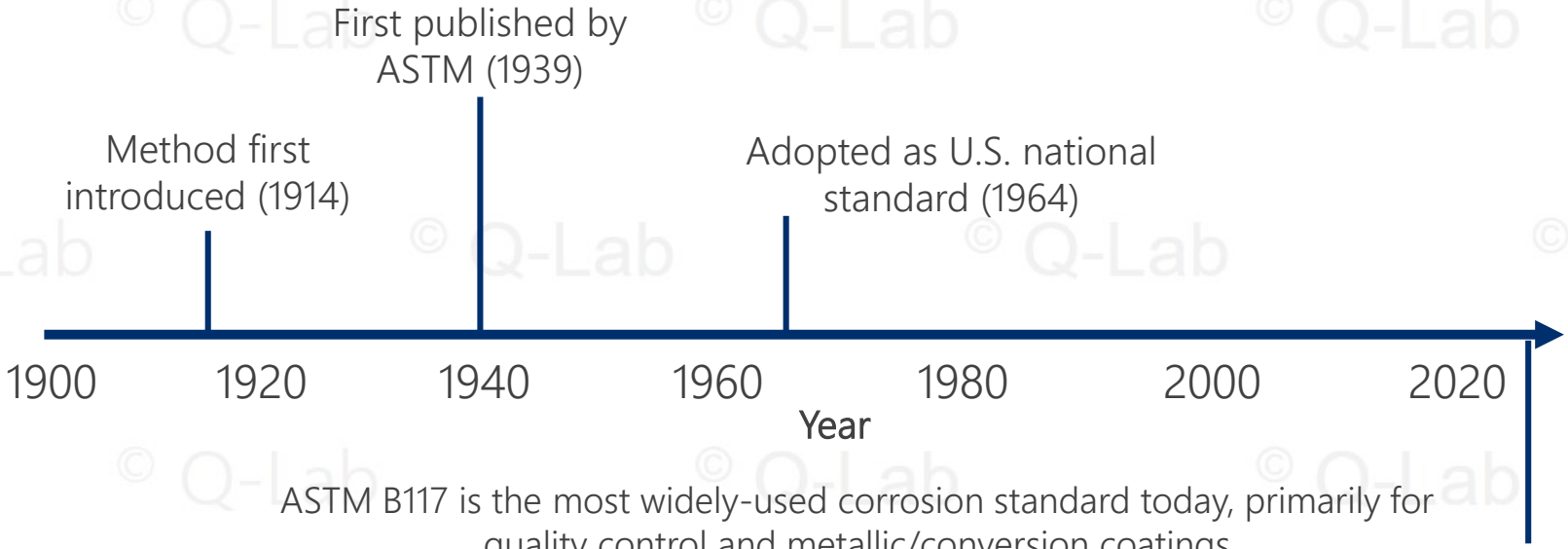
Continuous Salt Spray

Salt Fog Environment



Continuous Salt Spray(연속 염수 분무)

ASTM B117



ASTM B117 is the most widely-used corrosion standard today, primarily for quality control and metallic/conversion coatings
(ASTM B117 오늘날 가장 널리 사용 되는 표준으로, 특히 품질 관리 및 금속 도금, 코팅 평가를 위해 사용 된다.)

Continuous Salt Spray (연속 염수 분무)

ASTM B117

- 5% NaCl salt fog at 35°C
- Neutral pH
- Fine mist (atomized with compressed air) sprayed indirectly onto specimens (컴프레서를 사용한 미세분말을 시편에 간접 산포)
- ISO 9227 contains the same test
- When correctly followed, test has reasonable repeatability and reproducibility(정확한 경로를 따라 수행하면 때로는 반복 및 재현이 가능)

Limitations of Salt Spray (염수 분무 시험의 제약)

- Not a good simulation of most service environments (대부분의 실사용 환경과 차이가 있음)
- Typically produces different corrosion products than natural exposure (자연 노출 환경에서 발생되는 부식과 다름)
- Poor rank order correlation with outdoor corrosion(자연환경에서 발생되는 부식상태와의 상호연관성을 찾기 어려운 경우 많음)

- Q: What type of accelerated tests are these?

Topics

- Types of Accelerated tests
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- **Wet/Dry Cyclic Tests**
- First-Generation Cyclic Automotive Tests
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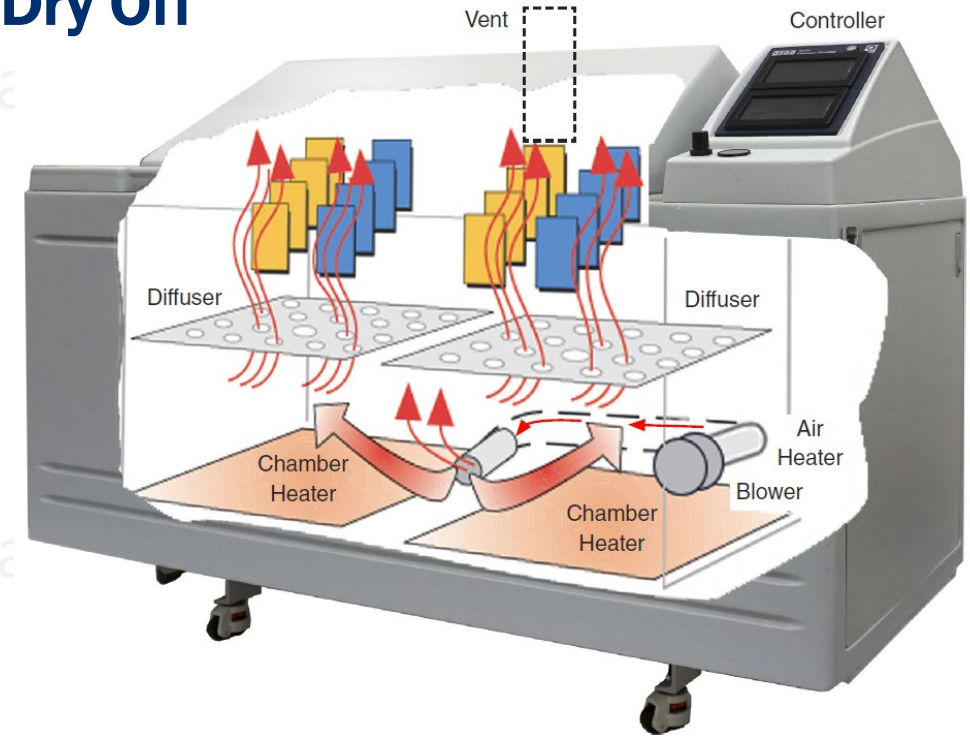
Wet/Dry Cyclic Tests

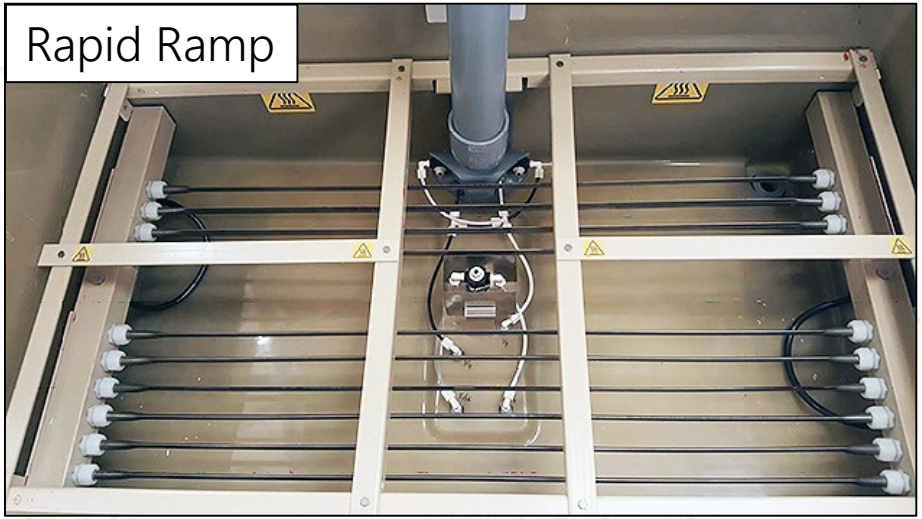
Salt Fog -> Dry Off



Heater Configurations

Flat Plate

Rapid Ramp



** Rapid Ramp Heaters required to meet some fast temperature transition times*

Wet/Dry Cyclic Tests (분무/건조 복합 시험)

Prohesion (Protection is Adhesion)

- Alternating spray and dry-off (분무 및 건조의 반복)
- Development began in England, 1960's (1960년대에 영국에서 시작)
- Dilute NaCl, $(NH_4)_2SO_4$
- American Architectural Manufacturers Association recently replaced ASTM B117 with this test in AAMA 2605, "Superior" coatings on aluminum (AAMA(미국 건축자재 생산자 협회)는 최근 ASTM B117을 AAMA 2605, "Superior" coatings on aluminum, 로 대체함)

Combined Corrosion/Weathering

- As a coating degrades from UV exposure, its ability to protect against corrosion is reduced(UV 노출로 코팅의 품질이 저하되면, 부식에 대한 저항 능력도 저하된다.)
- Sherwin Williams developed a UV + Corrosion combined cycle in the 1980's to test this (Sherwin Williams 에서 1980년대 이를 시험하기 위해 UV + Corrosion 시험법을 개발함)

Wet/Dry Cyclic Test Case Study (분무/건조 복합시험 사례 분석)

SSPC (Society for Protective Coatings)

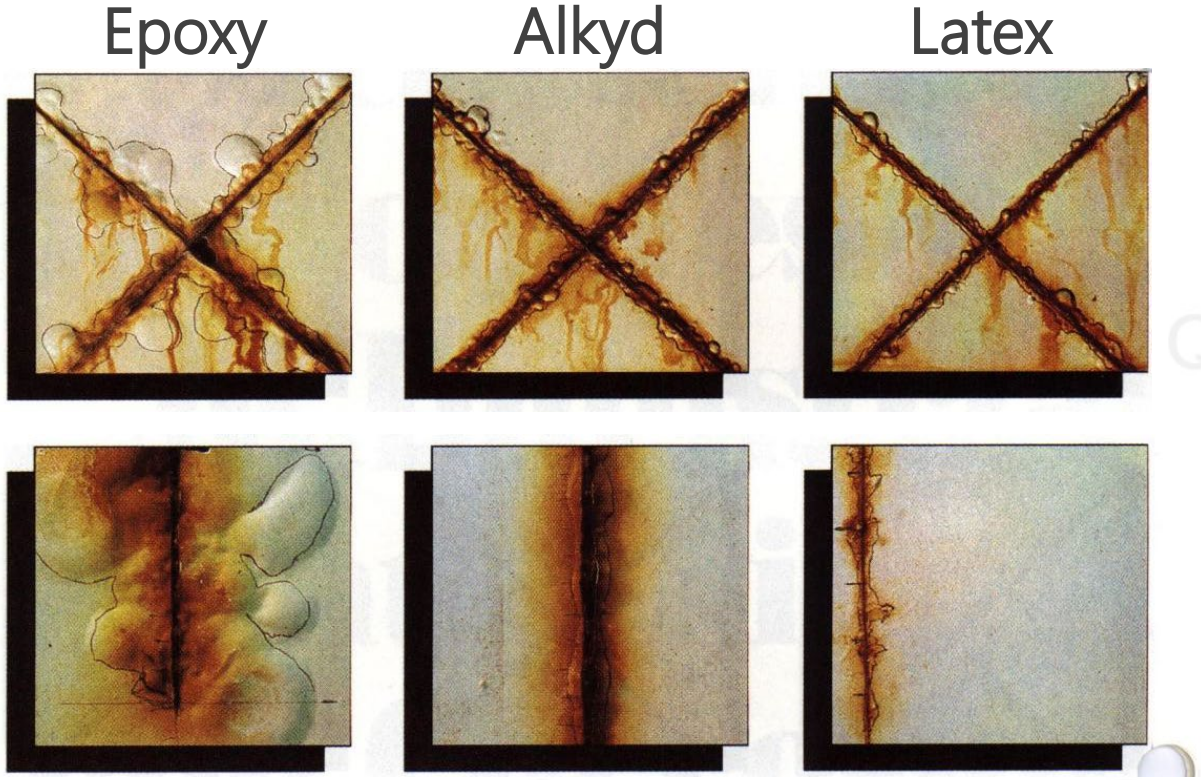
- 15 different systems included (15 개의 서로 다른 systems)
- Outdoor testing (31 months)
- Accelerated tests (2000 hours)
  - Salt spray 5%
  - Prohesion
  - 2 types of cyclic immersion
  - Combined corrosion/ weathering

SSPC Test Results

Laboratory Test Method	Correlation w/Severe Marine Environment
Conventional Salt Spray	-0.11
Prohesion	0.07
Cyclic Immersion Procedures	0.48
Cyclic Immersion with UV Procedure	0.61
Combined Corrosion/ Weathering	0.71

Good correlation from combined test! (복합 연계 시험을 통한 연관관계 확인)

Combined Corrosion/Weathering vs Outdoors



Combined Corrosion and Weathering

ISO 12944-6 (and -9)

Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
UV/condensation — ISO 16474-3			Neutral salt spray — ISO 9227			Low-temp. exposure at (−20 ± 2) °C

- 4 hours UVA-340, 0.83 W/m^2/nm at 340 nm, 60 °C
- 4 hours dark condensation, 50 °C
- 72 hour cycle

- Continuous salt fog at 35°C
- Rinse panels and put in a freezer for 24 hours
- 72 hour cycle

Wet/Dry Cyclic Test Limitations (분무/건조 복합시험의 한계)

- Poor repeatability and reproducibility (반복 및 재현 시험 불량)
- Poor correlation in some cases (자연 부식 결과와의 상관관계 결여)
  - Automotive
  - Industrial maintenance coatings on steel
- Attempts to improve correlation & repeatability include…(상관관계 향상과 반복성을 증가하기 위한 시도)
  - Wet bottom (water retained at chamber bottom) 젖은 바닥 (높은 습도를 위해 챔버 바닥에 물을 남겨둠)
  - Changing temperature of bubble tower RH를 높이기 위해 버블타워 온도를 높임
  - Both are crude "workarounds" for poor RH control technology *취약한 상대습도 조정을 위한 임시방편의 선택임*

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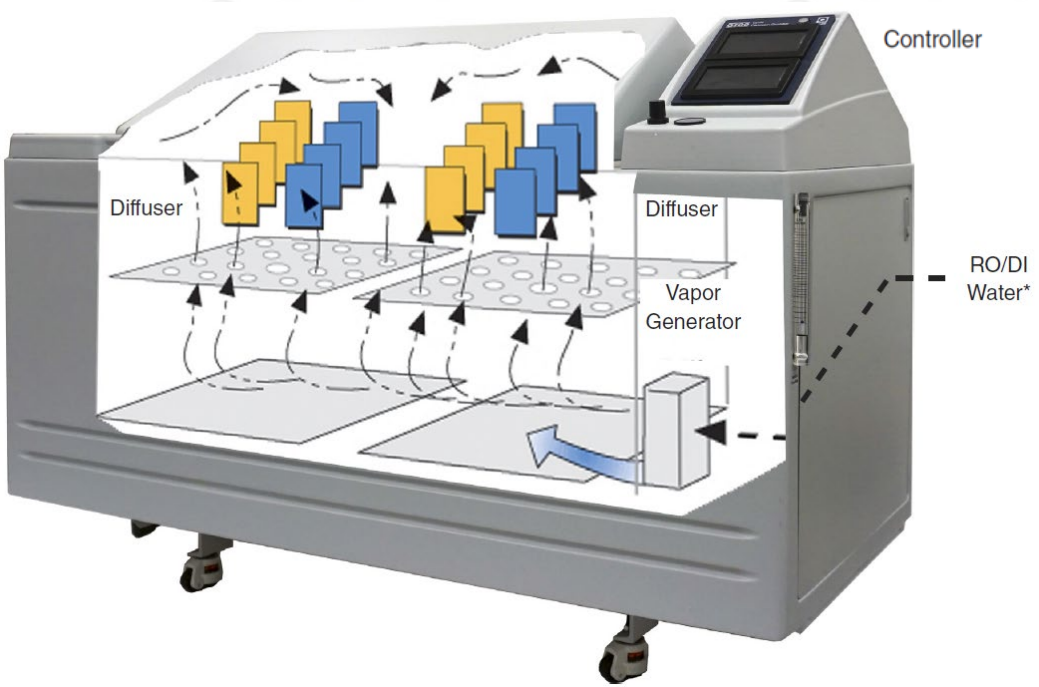
First-Generation Cyclic Automotive Tests

Salt Fog → Dry-Off → Wetting (Humid)

Wetting specimens after dry-off reinitializes corrosion



First-Gen Cyclic Automotive Tests (자동차용 1세대 복합부식시험)

Salt Fog → Dry-Off → Wetting (Humid)

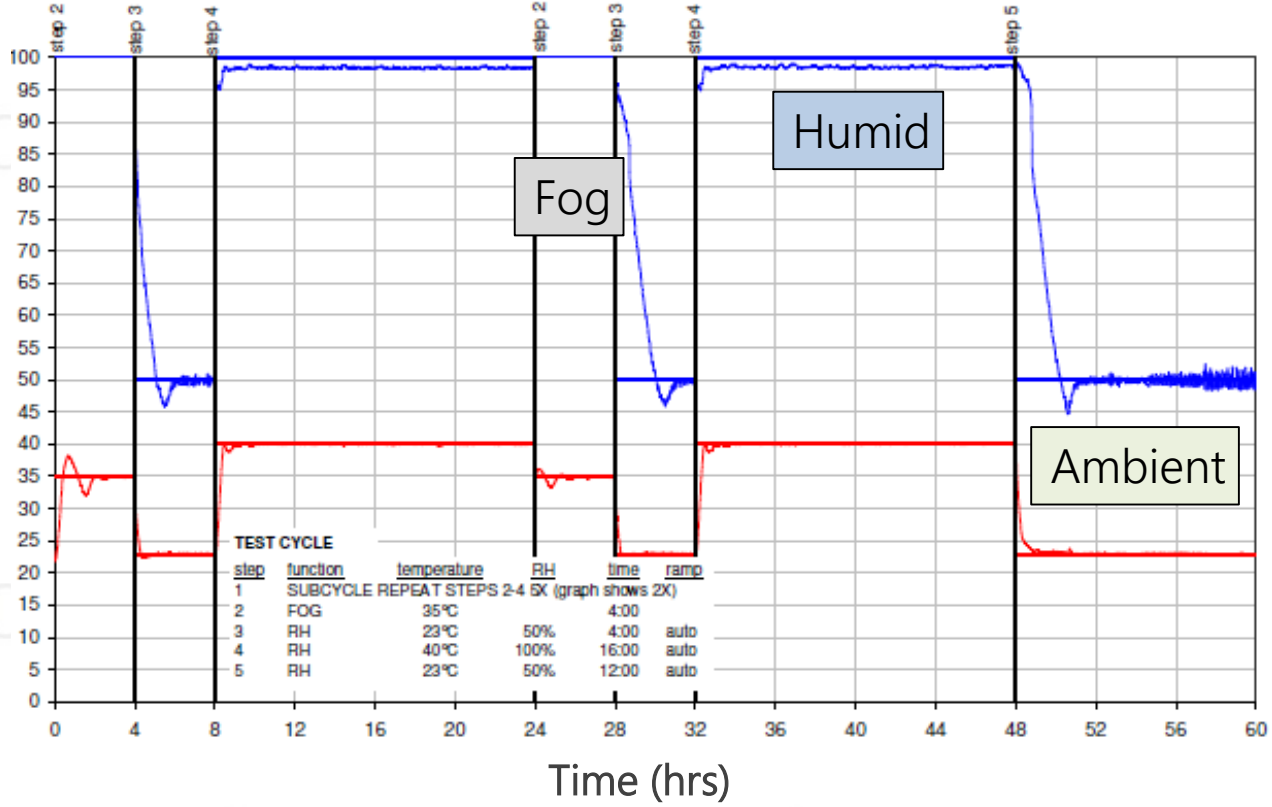
Example: GM 9540P

- NaCl and $CaCl_2$ to simulate road salts
- Solution applied by direct Spray, not Fog
- Salt spray applied intermittently in "ambient" conditions (실내 상온 환경)
- Use of **corrosion coupons** to minimize test variability (시험간 편차 극소화 목적으로 부식 쿠폰 사용)
- SAE & American Iron & Steel Institute rated this method best predictor of outdoor performance in 1991 (SAE & 미국 철강협회는 실제적 내부식성 수명 예측에 가장 최선의 시험방법으로 인정(1991년)

First-Gen Cyclic Corrosion test

RH (%)

Temp (°C)



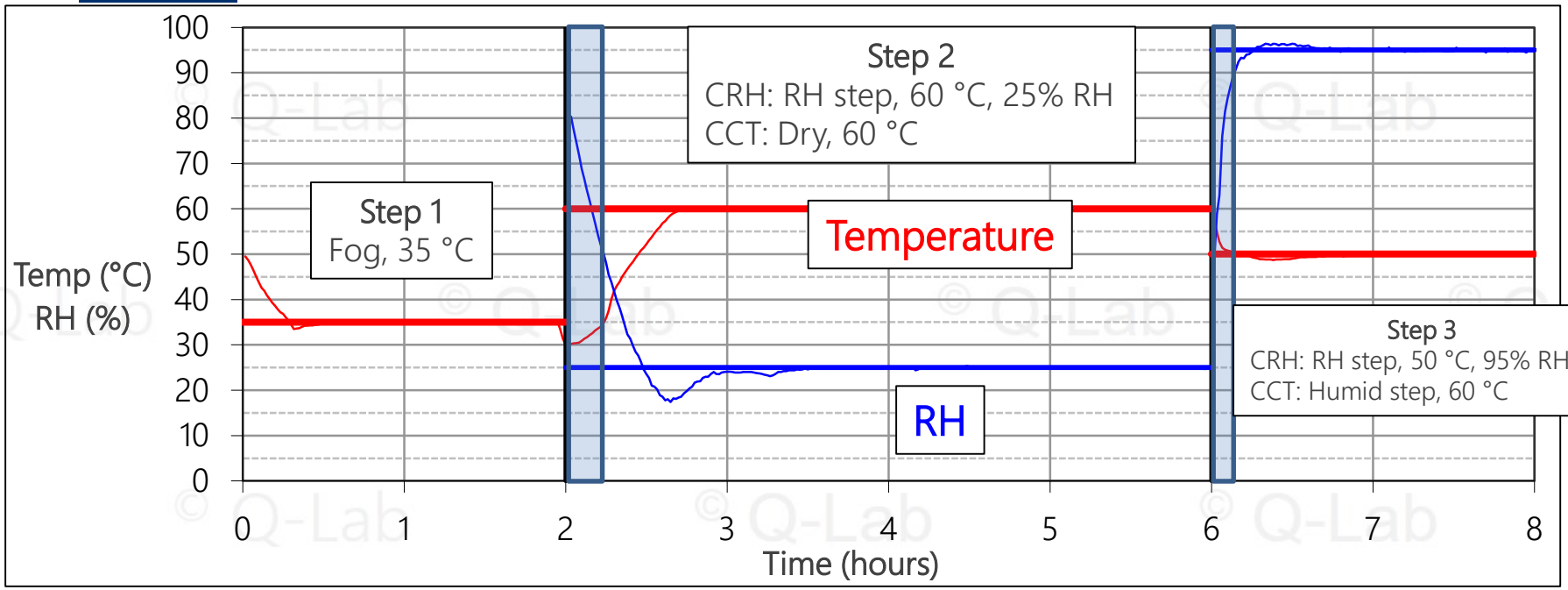
Relative Humidity and Corrosion(상대습도와 부식)

Controlling Step Transition Times 스텝 전환시간 제어

- "Linear" transition
  - Specify Time in test cycle to change test conditions 변경시간 지정
  - Tester adjusts temperature & RH for linear transition from beginning to end of ramp time 램프시간 시작부터 끝까지 균일하게 선형으로 온도 및 습도를 제어

- "Less Than" transition
  - Specify Time in test cycle to change test conditions 변경시간 지정
  - Tester attempts to achieve conditions within specified time – effectively as fast as possible 컨트롤러가 지정된 시간 까지 작업을 완료하려고 시도함
  - Fast "less than" transition times (e.g. JASO M609) designed to minimize test variability…

Fast Transition Times: JASO M609



Fast Transition Times Designed to Improve Reproducibility

Very limited time in critical RH zone of 50-90%!

Limitations of First Generation CCT 1세대 CCT의 한계

Poor Repeatability and Reproducibility! 반복 및 재현 문제점

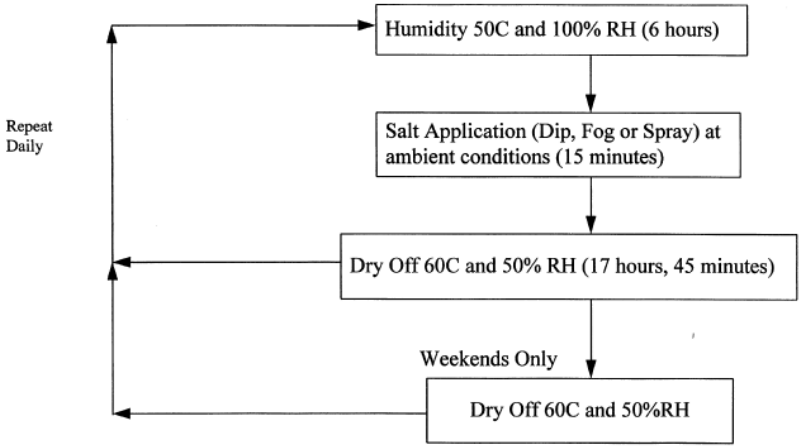
- Different corrosion chambers give different results 서로 다른 테스터의 상이한 시험결과
- Huge variations in corrosion rates between different metals from test to test 각각의 시험에 따라 금속 별 부식율이 서로 다르게 나타남

Case Study: SAE J2334

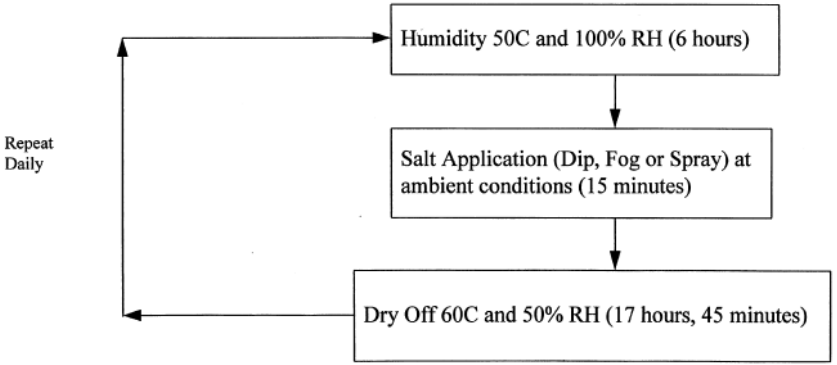
- Transition times are not specified in this standard 사이클 별 전환시간 지정 안됨.
- Coupon use is encouraged but no mass loss limits are included 쿠폰 사용이 권장되지만, 손실량에 대한 제한이 포함되지 않음.
- Some companies have implemented SAE J2334 with their own mass loss limits 일부 OEM 에서는 손실량에 대한 자체 기준을 포함함

SAE J2334 Test Cycle

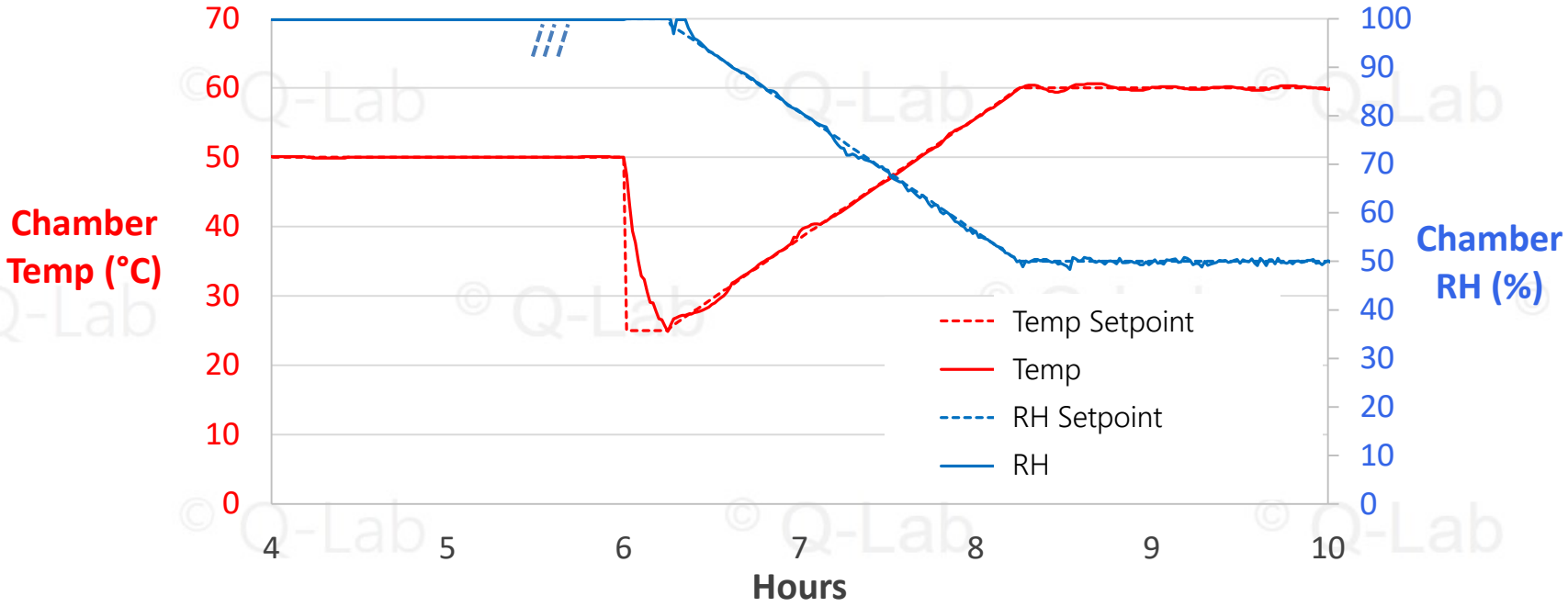
Cosmetic Corrosion LabTest Cycles
SAE J2334 - 5 Day/Week - Manual Operation



Cosmetic Corrosion LabTest Cycles
SAE J2334 - 7 Day/Week - Automatic Operation

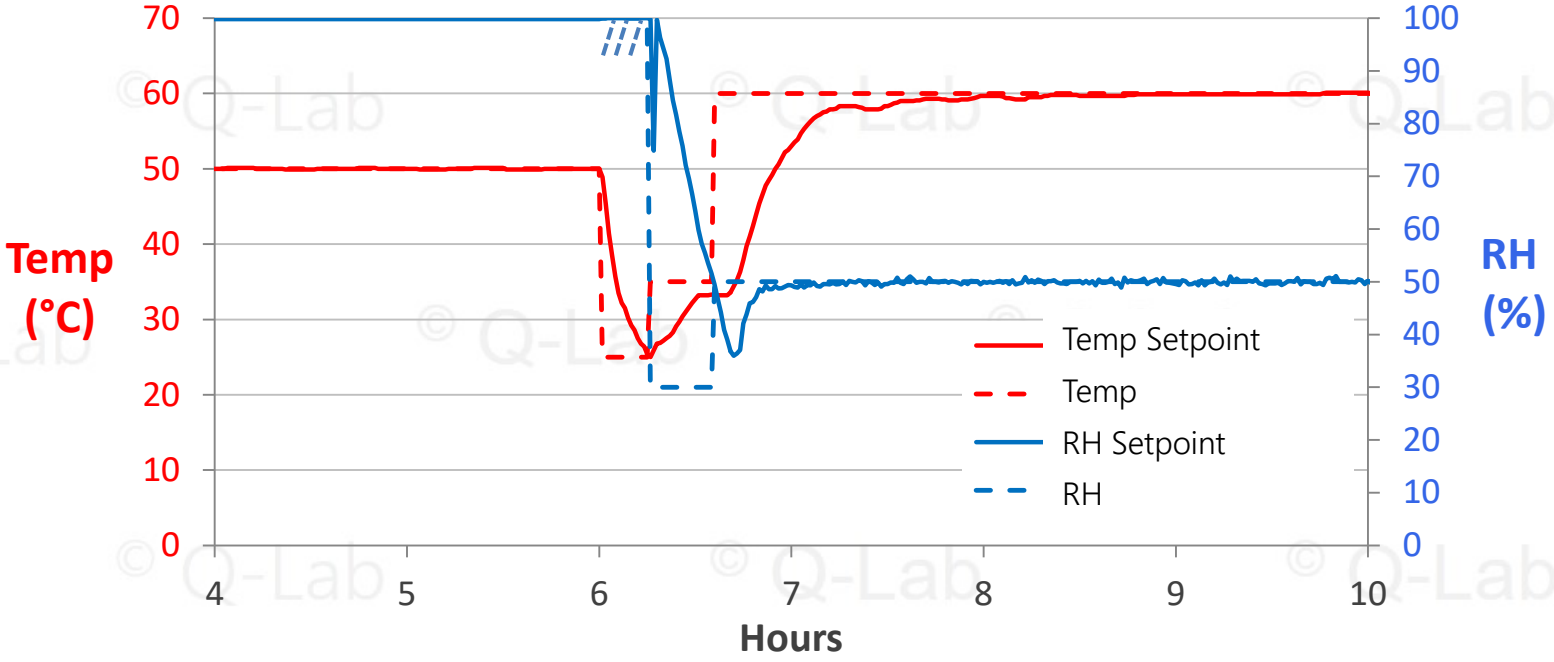


SAE J2334: Slow Dry-Off



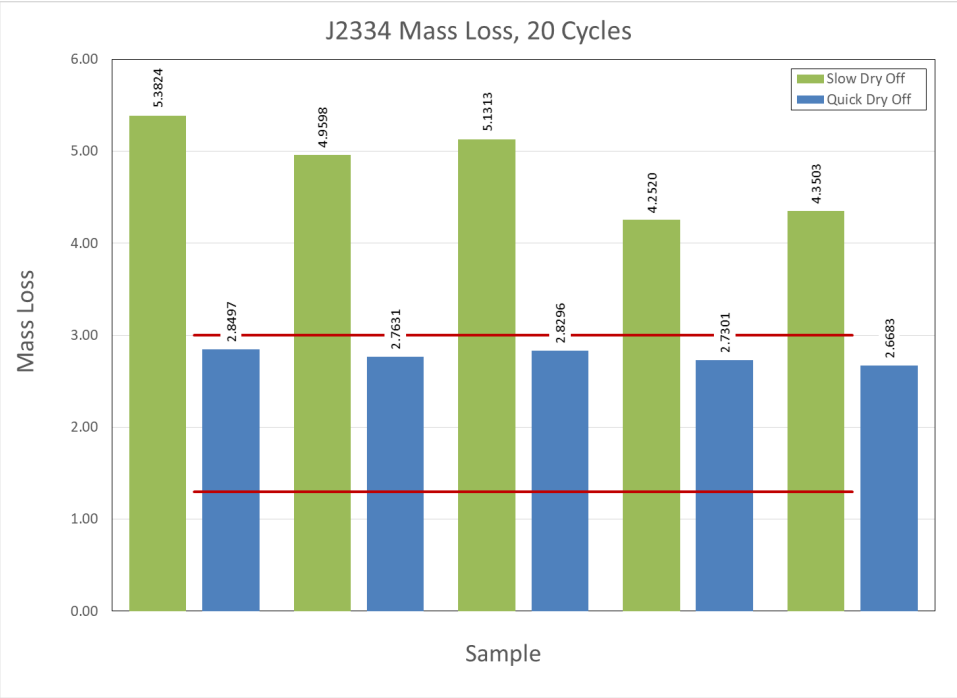
*Time above the Deliquescence RH of NaCl is about **1 hour***

SAE J2334: Fast Dry-Off



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

SAE J2334 Results



- Green bars represent test under slow dry-off conditions: panels fail
- Blue bars represent test under quick dry-off conditions: panels pass
- Red lines represent tolerance of OEM standard

First generation cyclic automotive methods

What was missing?

- Lack of comprehensive RH control 합리적인 상대습도 설정이 안됨
  - Conditions limited to full wetting, dry, uncontrolled room/ambient 세 단계의, wet, dry, ambient, 제한된 사이클
  - No control of RH transition times – used “workarounds” like fast transition times 사이클간 변환시간 조정 불능
  - Variable specimen dry-off rates 물질 별 물기가 마르는 시간 상이
  - No RH values in critical transition zones (DRH) 중요한 전이구간에서 상대습도 조정 곤란(DRH)
- Slow application of salt solution (fog) **염수 분무 실행효과 미흡 (fog)**
  - Little time for dry-off and re-wetting of specimens 건조시간 및 염수에 적시는 시간 모두 부족

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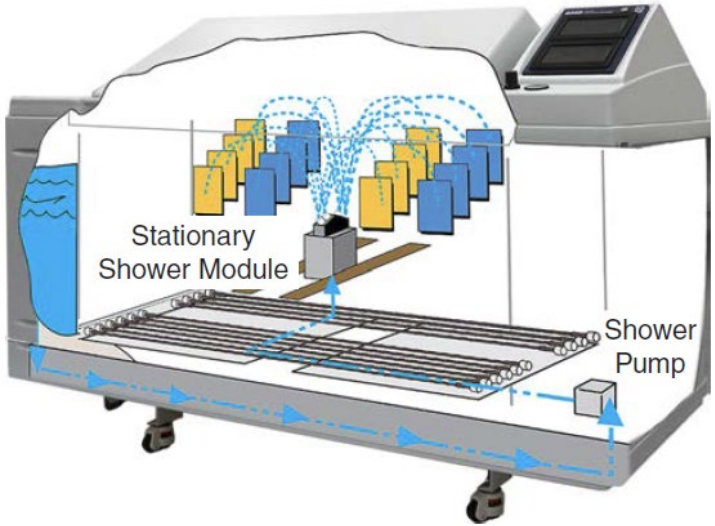
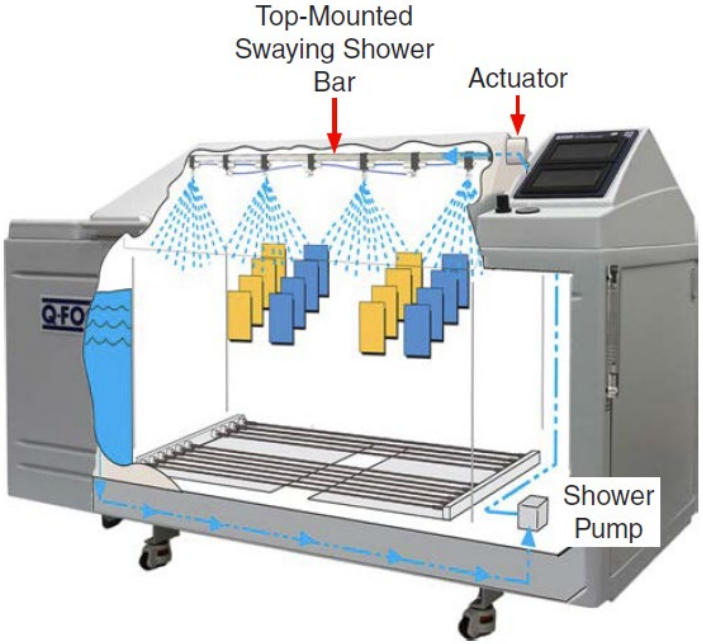
Modern Corrosion Tests

Shower Function



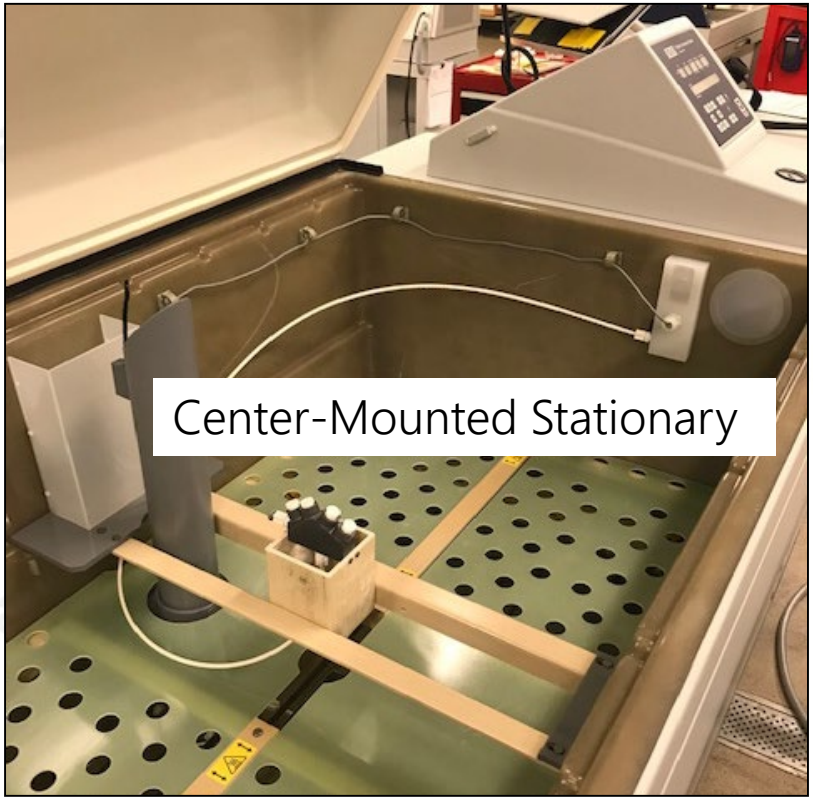
Stationary Shower Module (SSM)



Top-Mounted Swaying Shower Bar (TSSB)

Faster application of salt solution than Fog

Shower Configurations



Modern Automotive Corrosion Tests

Fog

- Toyota TSH1555G
- VDA 233-102
- Renault D17 2028 (ECC1)

Shower

- GMW 14872
- Volvo ACT 1
- ISO 16701
- Volvo ACT 2/ Ford L-467

No one "right way" to run a test but shower/spray has gained popularity

Relative Humidity & Corrosion

- Corrosion accelerates once it starts 부식은 일단 시작하면 가속화 됨.
  - Formation of complex oxides 복합산화물 생성
  - Wet time increases as new oxides form 물질이 젖게 되면 새로운 산화물 생성 시작
- Salts deliquesce at different RH values 소금은 각각 다른 RH 조해성을 갖는다.
- Formation of liquid solutions affects corrosion by creating a galvanic couple 상대습도가 변화함에 따라 염수 유형에 따른 알루미륨/철 의 전해 부식 정도가 변화 한다

Automotive Tests & Road Salt

- Salts *deliquesce* - they absorb moisture from the atmosphere until they dissolve and form a solution. 조해 - 물질이 대기 중의 수분을 받아들여 일정 수준을 넘으면 스스로 녹아서 용액이 되는 현상.
- All soluble salts will liquefy for RH values <100% 모든 용해염은 상대습도 100% 미만 조건에서는 액화한다.
- This leads to increased time of wetness and increased corrosion 이런 이유로 물질이 젖어 있는, 즉 수분을 함유하는 시간이 늘어나면, 그 결과 부식이 증가한다.

Deliquescence Relative Humidity (DRH)

Salt	DRH
Potassium Chloride (KCl)	85%
Sodium Chloride (NaCl)	*76%*
Calcium Chloride ($CaCl_2$)	*31%*

If the environment is above this RH, a liquid salt solution will form

Galvanic Corrosion

Active (Anode)

Noble (Cathode)

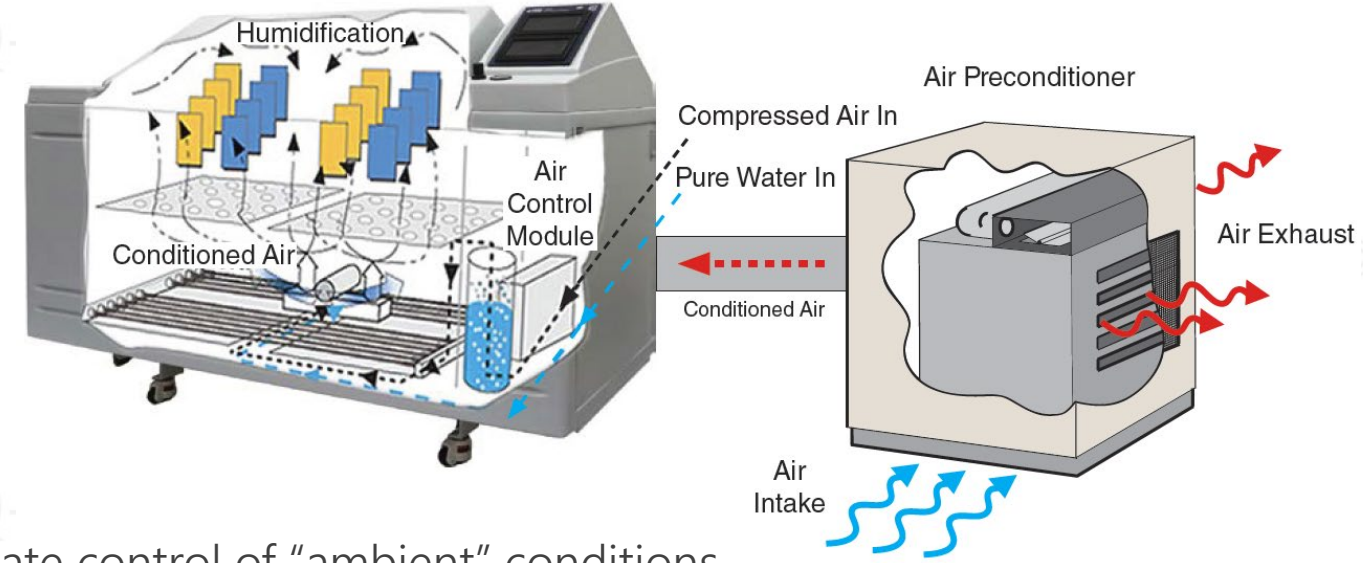
Magnesium
Zinc
Aluminum
Cast Iron/low carbon steel
Steel (low alloy)
Brass
Copper
Nickel
Stainless Steel (passive)
Silver
Gold
Platinum

- Affects products made from metals
  - Steel
  - Aluminum
  - Magnesium alloys
- Organic & Inorganic Protective Coatings

Galvanic Corrosion

Modern Corrosion Tests

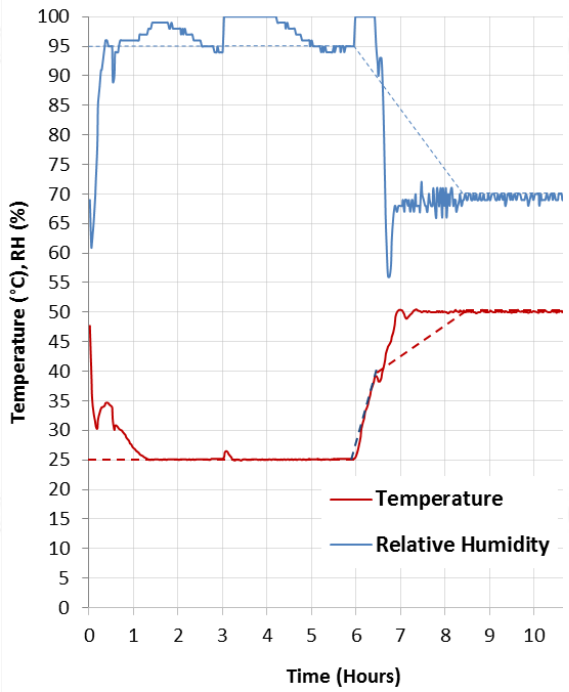
Air Preconditioner



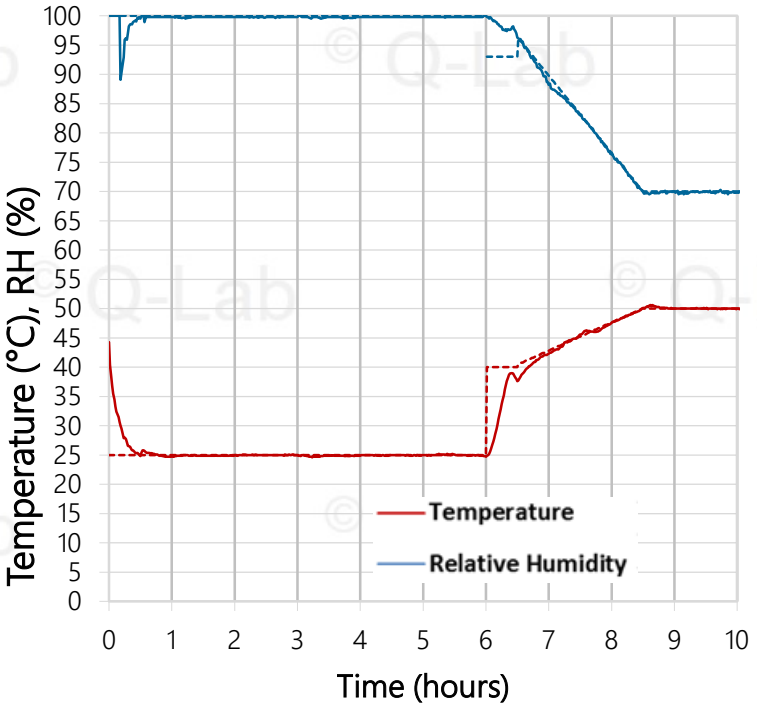
- Accurate control of “ambient” conditions
- Accurate Ramping of Temperature & Humidity

Performance Improvement with Preconditioner

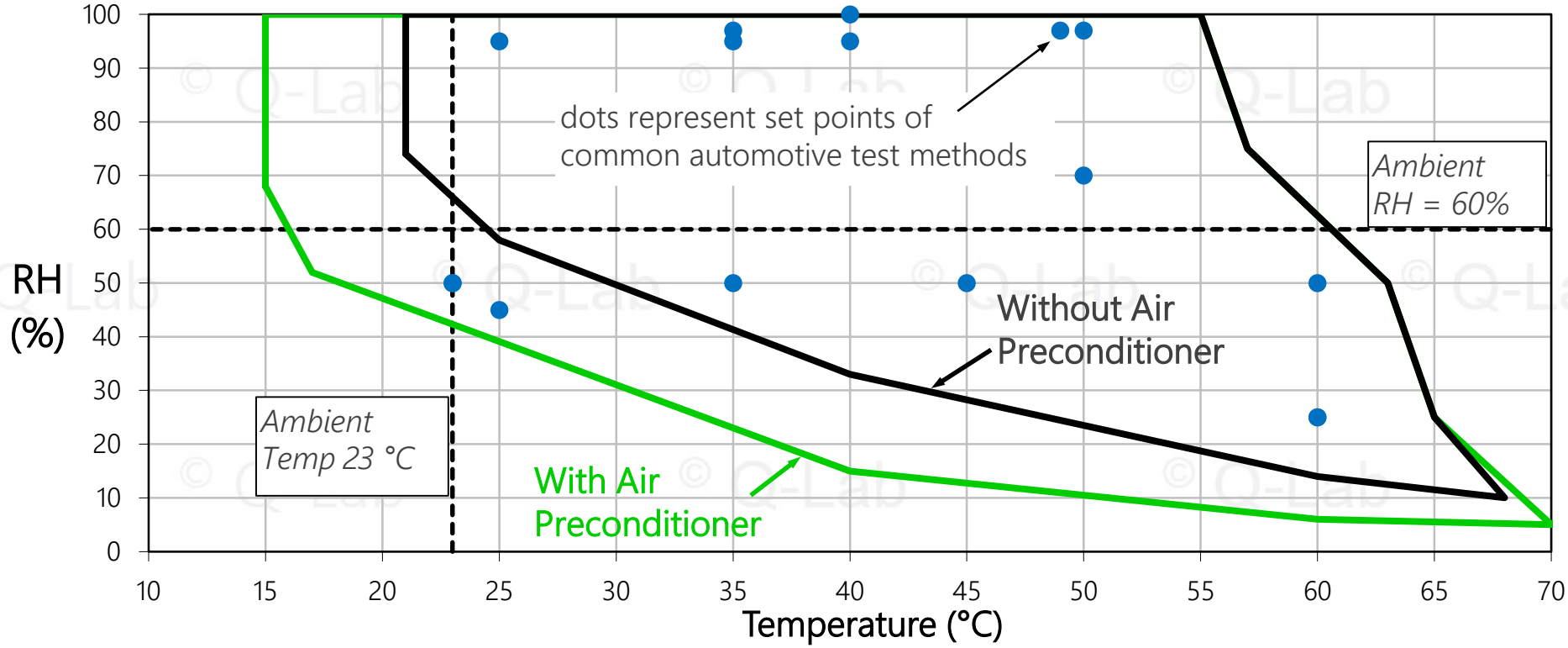
No Air Preconditioner



With Air Preconditioner

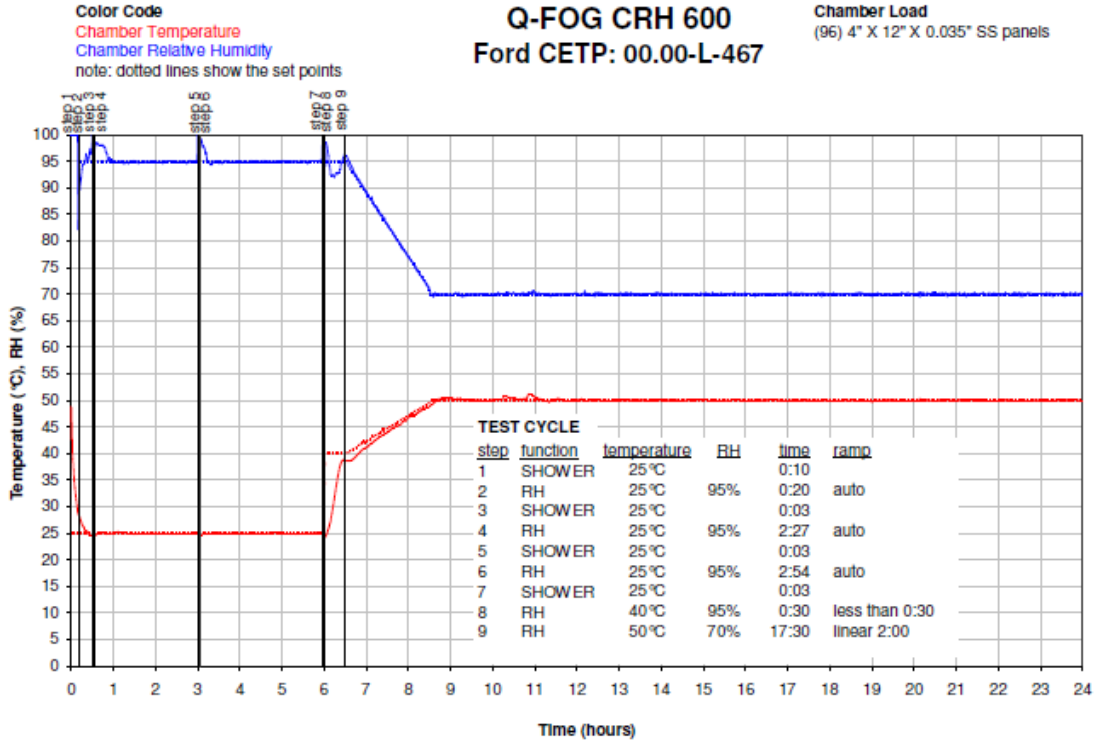


Q-FOG Operational Range: Well-Controlled Lab

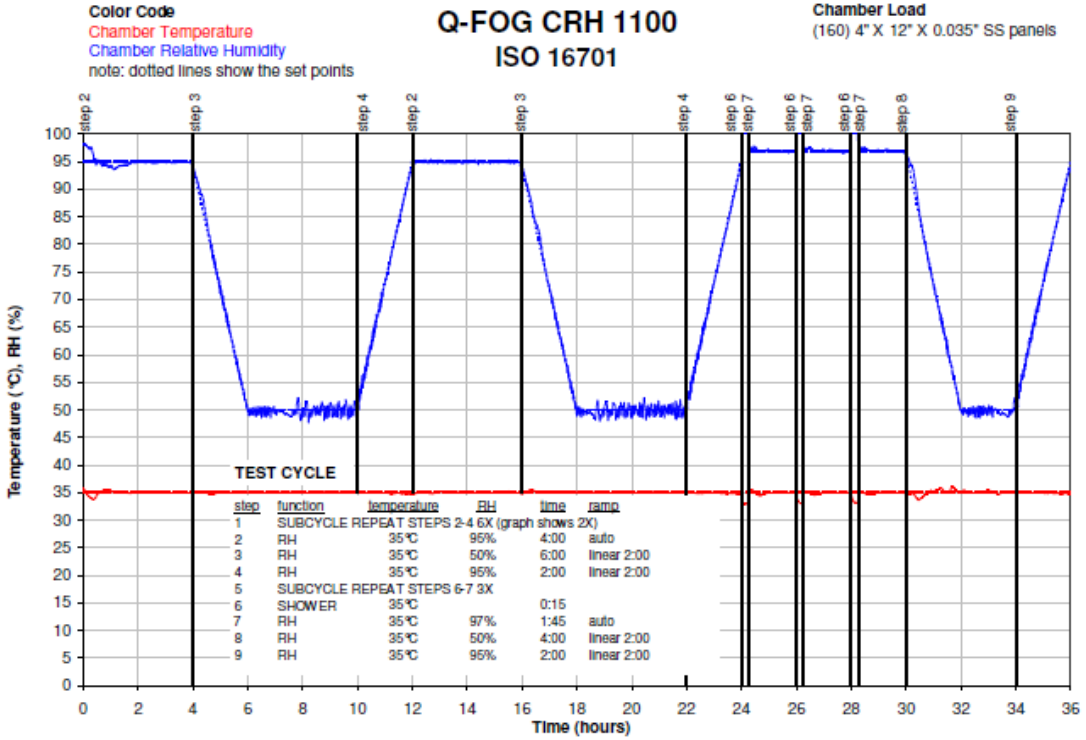


Modern Corrosion Test Examples

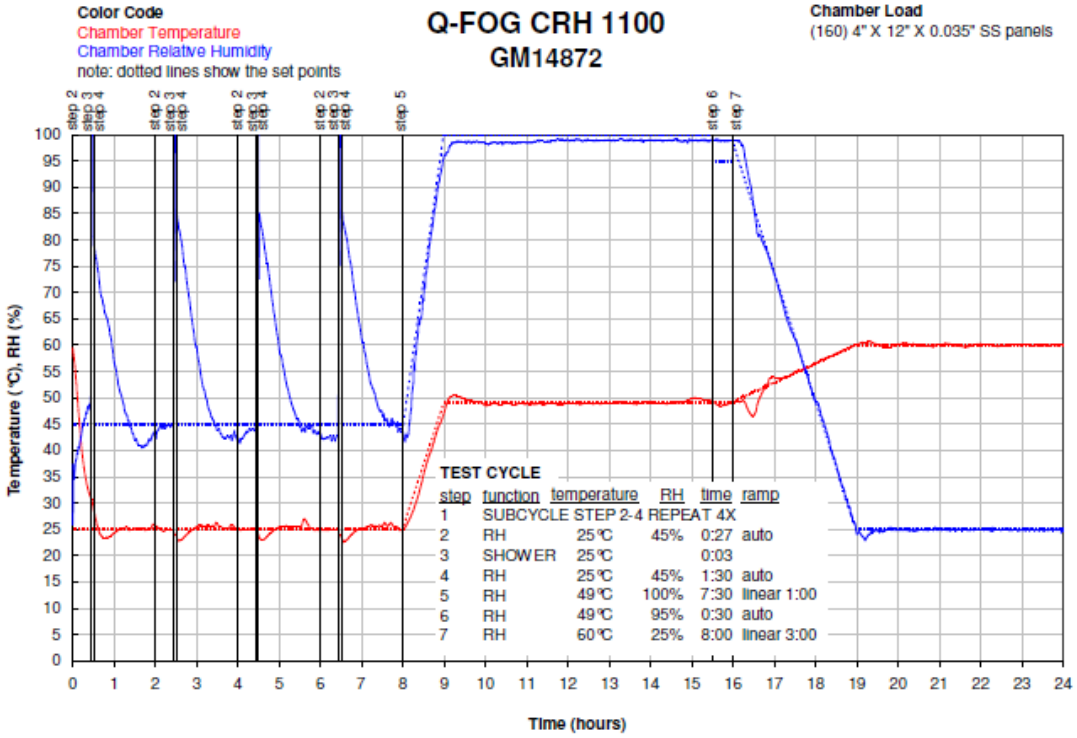
Ford CETP:00.00-L-467



ISO 16701



GMW 14872

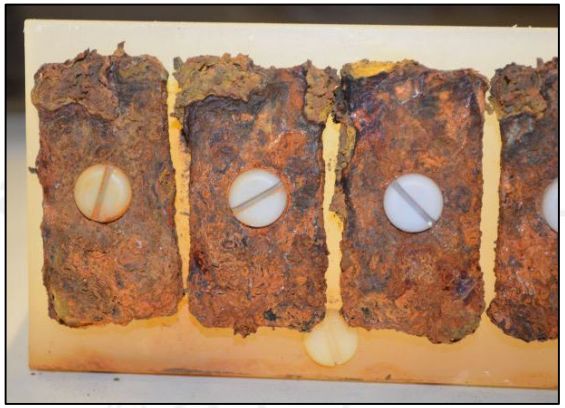


Topics

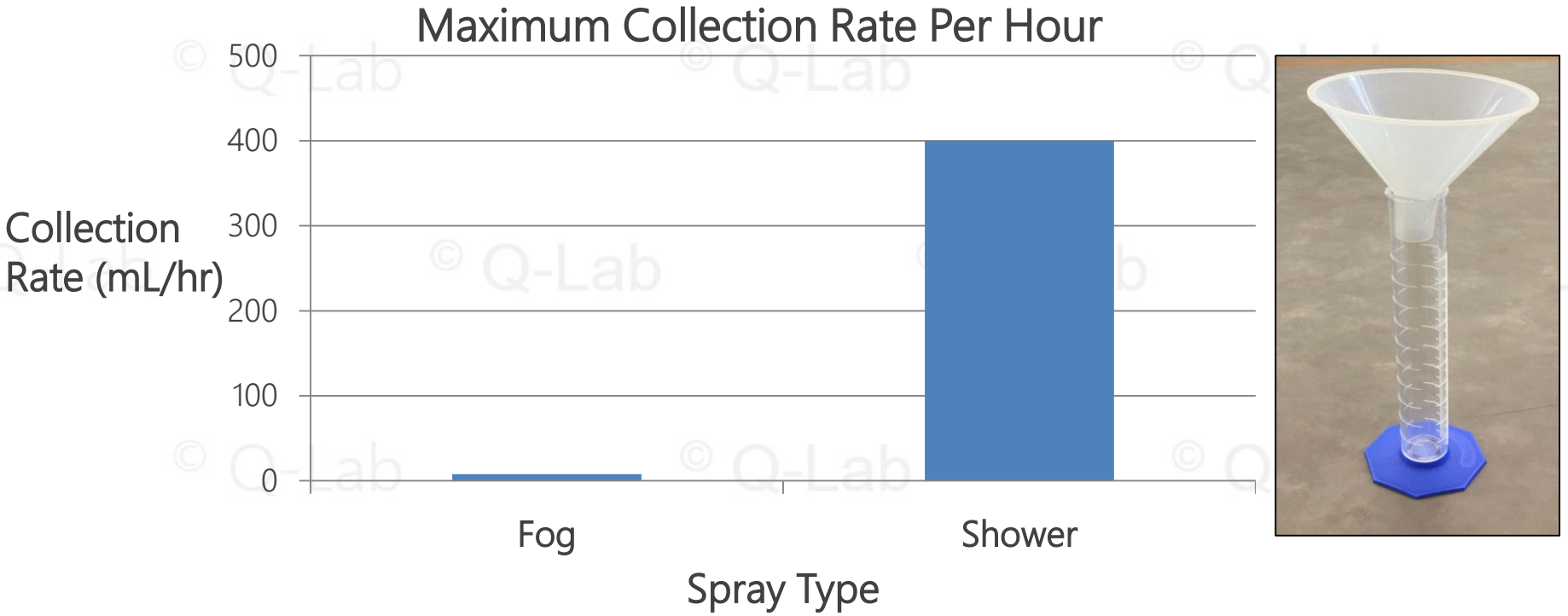
- Types of Accelerated tests
- Continuous Salt Spray (Neutral & Acidified)
- Wet/Dry Cyclic Tests
- First-Generation Cyclic Automotive Tests
- Modern Corrosion Test Methods
- Verifying Corrosion Test Performance

Corrosion (Mass-Loss) Coupons

- Standardized metal specimens
- Mass loss due to corrosion is measured during a test
- Used by GM, VDA, ISO 16701 standards, and many others
- GMW 14872 requires a specific rate of mass loss throughout a test
- Ensures corrosion chamber is maintaining proper conditions and operator is running the test correctly



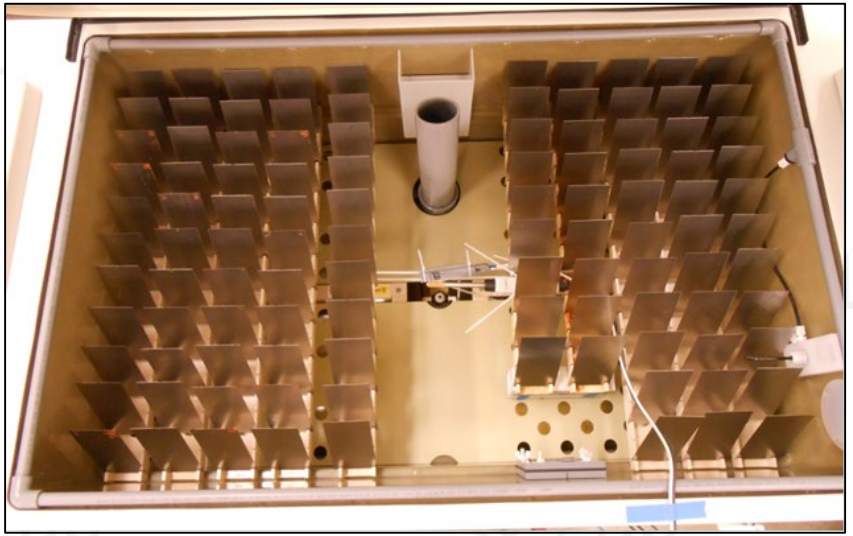
Pluviometry



Independent Verification

- Accurate and Precise Temperature/RH Sensor placed in center of chamber to independently verify Q-FOG CRH controller reading

- Chamber is full of steel panels



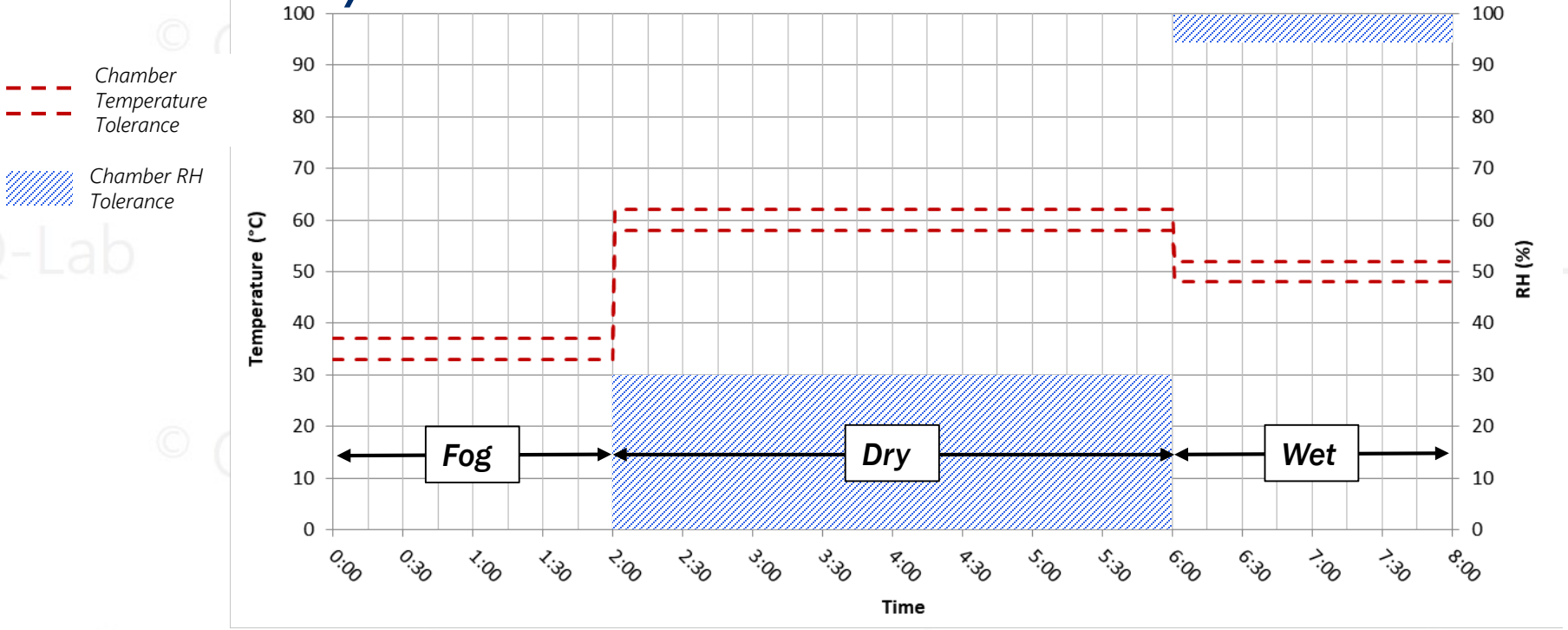
Verify Test in a Full Chamber

- To confirm a chamber is able to satisfy test requirements, validation should be conducted in a full chamber
- Additional thermal mass of a fully-loaded chamber with metal panels will delay reaching temp setpoints

Verify that the test conditions can be reached with a chamber filled with specimens

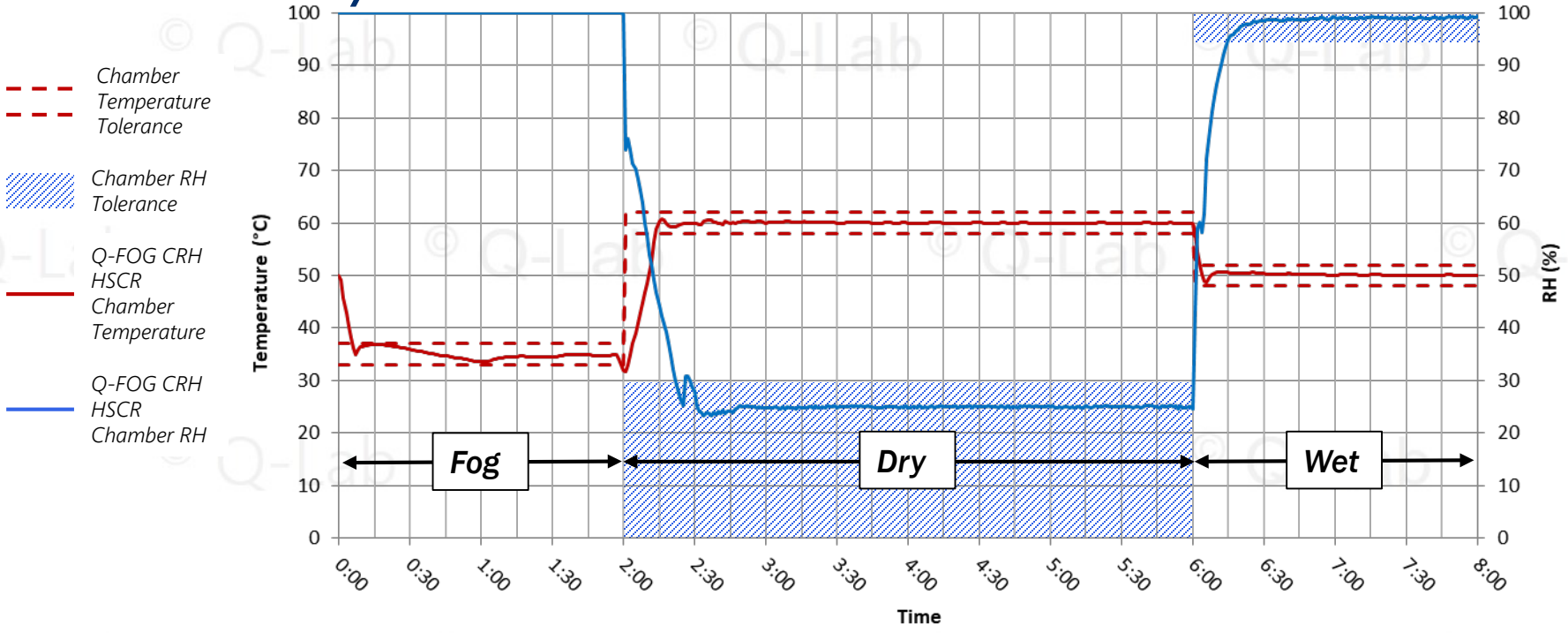
Q-FOG CRH HSCR Chamber Data

JASO M609 / ISO 14993



Q-FOG CRH HSCR Chamber Data

JASO M609 / ISO 14993



Q-FOG CRH HSCR Chamber Data

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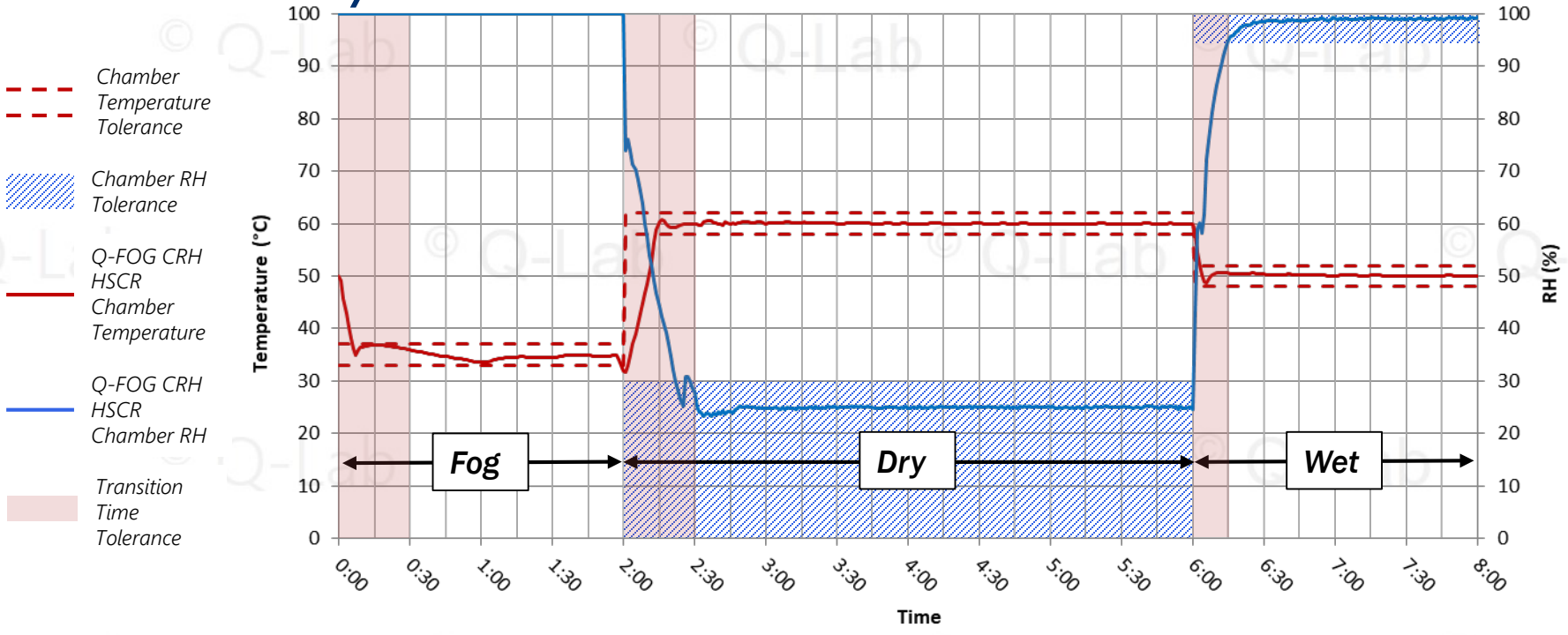

Conclusions

- Salt spray tests are good pass/fail screening tests 연속 염수분무 시험은 1차적 pass/fail 시험으로 유용
- Wet/Dry tests are good comparative tests for some systems but not repeatable
  시험 어떤 경우 비교 시험으로 유용, 하지만 반복 시험을 통한 검증은 어려움
- Combined weathering / corrosion cycles can provide good outdoor correlation for some materials 내후성/부식 연계 시험은 어떤 경우 자연노출 시험과의 상호 연관성 비교에 유용
- First-generation cyclic automotive tests are comparative tests but not repeatable
  1세대 복합부식시험은 비교 시험으로 유용, 하지만 반복시험을 통한 검증이 문제점
- Modern automotive corrosion tests are more realistic and offer better repeatability and reproducibility 최신의 자동차 부식시험은 어느 경우보다 자연노출 시험결과와 상호연관성 좋고, 반복 및 재현 가능

Thank you for your attention!
Questions?

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