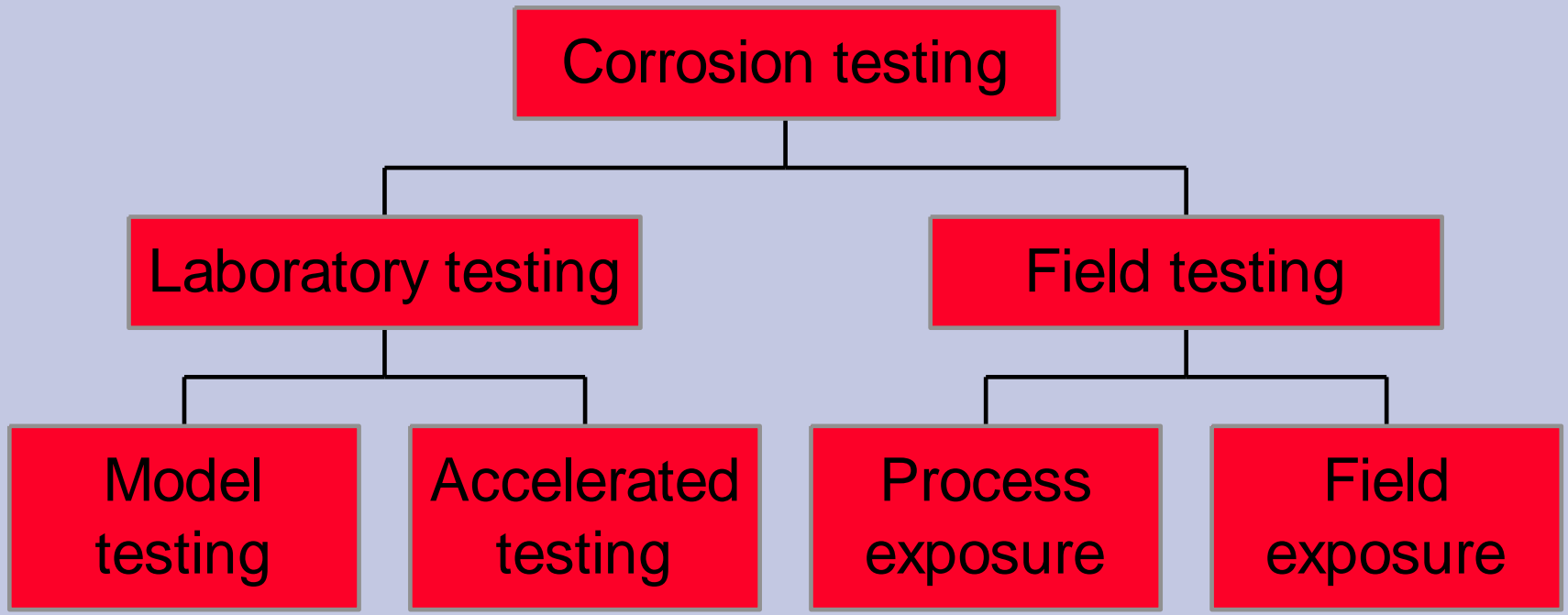




Corrosion testing

Classification of methods for corrosion testing



Accelerated testing

ISO/WD Corrosion of metals and alloys — Corrosion tests in artificial atmospheres — Guideline for selection of accelerated corrosion test for product qualification

Scope

- This Technical Specification is applicable for the selection of suitable accelerated atmospheric corrosion tests for qualification of products with metallic materials without or with permanent corrosion protection or temporary corrosion protection.
- In the Technical Specification the following aspects are taken into account:
 - Categories of accelerated atmospheric corrosion tests
 - Recommended fields of application for the different kinds of tests and their suitability
 - Corrosivity of tests and relative corrosion rates of standard metals
 - Requirement on test equipment, criteria for reproducibility and correlation with in-service performance
 - Recommended procedures for product qualification
- The main purpose of the Technical Specification is to present a framework for comparing the different accelerated corrosion test methods, which presently are available as international standards. The suitability of a test method varies with the requirements set by the intended application of the product.

Categories of accelerated atmospheric corrosion tests

Category of test		Examples of standards
A	Continuous salt spray tests	ISO 9227; IEC 60068-2-11
B	Tests with alternating immersion of test objects in a salt solution followed by drying or intermittent salt spraying and drying	ISO 11130; IEC 60068-2-52
C	Tests with cyclic variation of humidity (dry/wet) and including also steps of salt spraying	ISO 11474, ISO 14993; ISO 11997-1:Cycle B; ISO 11997-2; ISO 16151; ISO 16701, ISO 20340
D	Tests with continuous exposure to atmospheres with low concentrations of corrosion promoting gases and at moderately high humidity	ISO 10062; IEC 60068-2-60
E	Tests with continuous exposure to atmospheres with higher concentrations of corrosion promoting gases and at higher humidity including also steps of drying and short period of salt spraying	ISO 21207
F	High humidity tests	IEC 60068-2-78, IEC 60068-2-30, NT ELEC 025 (with condensation) ¹

Comparison of corrosivity of accelerated test methods using standard specimens

Test method / exposure time ¹⁾	Metallic mass loss of carbon steel (g/m ²)	Metallic mass loss of zinc (g/m ²)
Atmospheric corrosivity category C3 for 10 years	400 - 940	40-140
ISO 9227 for 19 days	480 - 860	240 - 710
ISO 14993 for 7 days	530 - 800	100 -170
ISO 16151 A for 12 days	460 - 880	140 -250
ISO 16151 B for 15 days	470 - 870	15 - 50
ISO 16701 for 19 days	630 - 710	25 -35
ISO 21207 B for 24 days	670 ²⁾	104 ²⁾
ISO 11997-1:C2 for 32 days	670 ²⁾	241 ²⁾
ISO 11474 for 4 months	670 ²⁾	63 ²⁾

¹⁾ Mean testing times have been estimated from metallic mass loss data found in the respective standards and it has further been assumed that metallic mass loss versus exposure time for the accelerated tests is linear

²⁾ Available data is limited so that it is not possible to give an allowed range of metallic mass loss in those cases

Characteristics of salt spray test ISO 9227

Item \ Test method	NSS	AASS	CASS
Temperature	35 °C ± 2 °C	35 °C ± 2 °C	50 °C ± 2 °C
Average collection rate for a horizontal collecting area of 80 cm ²	1,5 ml/h ± 0,5 ml/h		
Concentration of sodium chloride (collected solution)	50 g/l ± 5 g/l		
pH (collected solution)	6,5 – 7,2	3,1 – 3,3	3,1 – 3,3

Corrosivity of salt spray tests

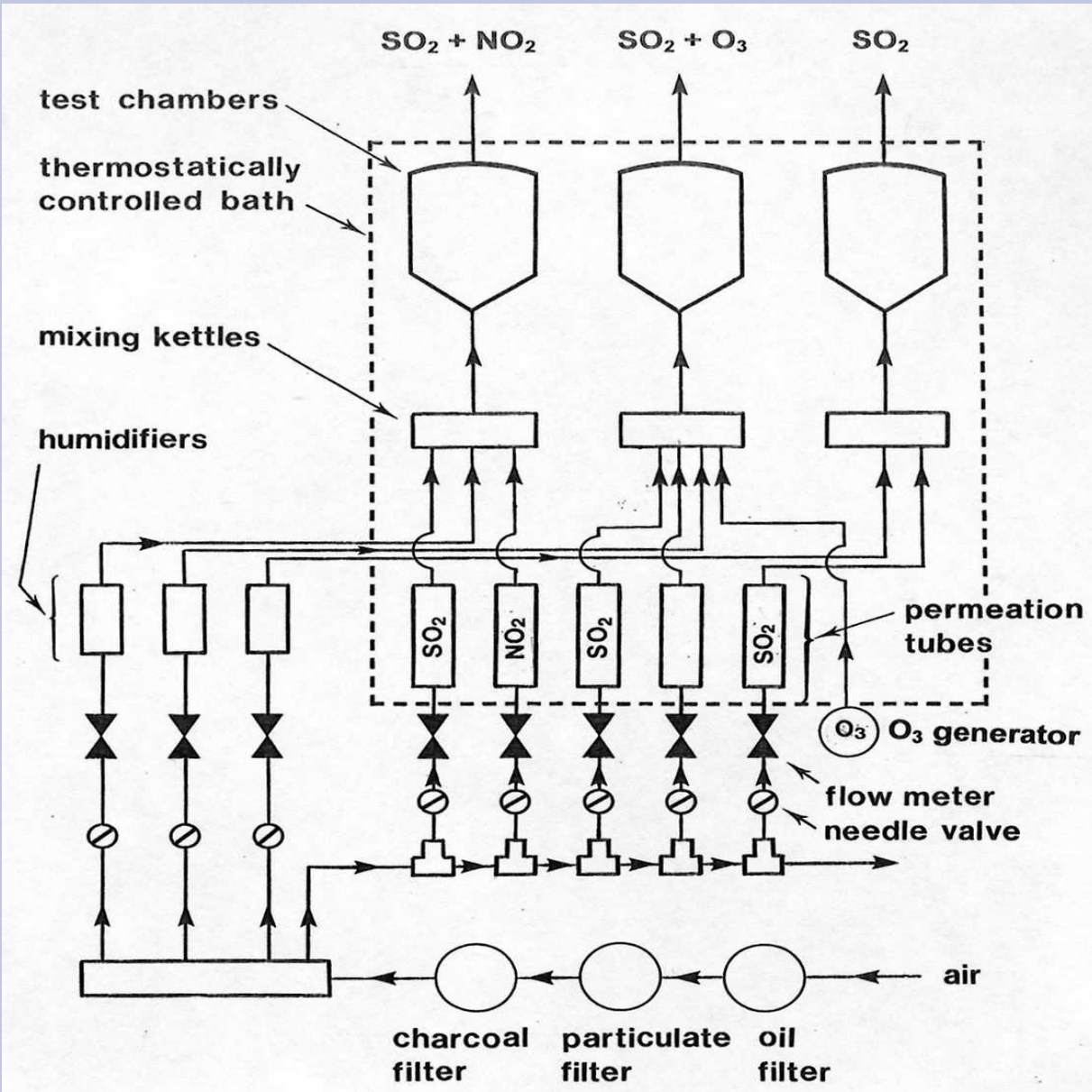
Test method	Test duration (h)	Mass loss of the steel reference specimens (g/m ²)	Mass loss of the zinc reference specimens (g/m ²)	Mass loss based relative corrosion rate steel to zinc
NSS	48	70 ± 20	50 ± 25	
AASS	24	40 ± 10	30 ± 15	
CASS	24	55 ± 15	50 ± 20	

Corrosion tests in artificial atmosphere at very low concentrations of polluting gas(es)

ISO 10062

Test method	Sulphur dioxide (volume fraction)	Hydrogen sulphide (volume fraction)	Nitrogen dioxide (volume fraction)	Chlorine (volume fraction)
A	$(0,5 \pm 0,1) \cdot 10^{-6}$	-	-	-
B	-	$(0,10 \pm 0,02) \cdot 10^{-6}$	-	-
C	-	-	-	$(0,02 \pm 0,005) \cdot 10^{-6}$
D	$(0,5 \pm 0,1) \cdot 10^{-6}$	$(0,10 \pm 0,02) \cdot 10^{-6}$	-	-
E	$(0,20 \pm 0,05) \cdot 10^{-6}$	-	$(0,5 \pm 0,1) \cdot 10^{-6}$	-
F	$(0,5 \pm 0,1) \cdot 10^{-6}$	$(0,10 \pm 0,02) \cdot 10^{-6}$	-	$(0,02 \pm 0,005) \cdot 10^{-6}$

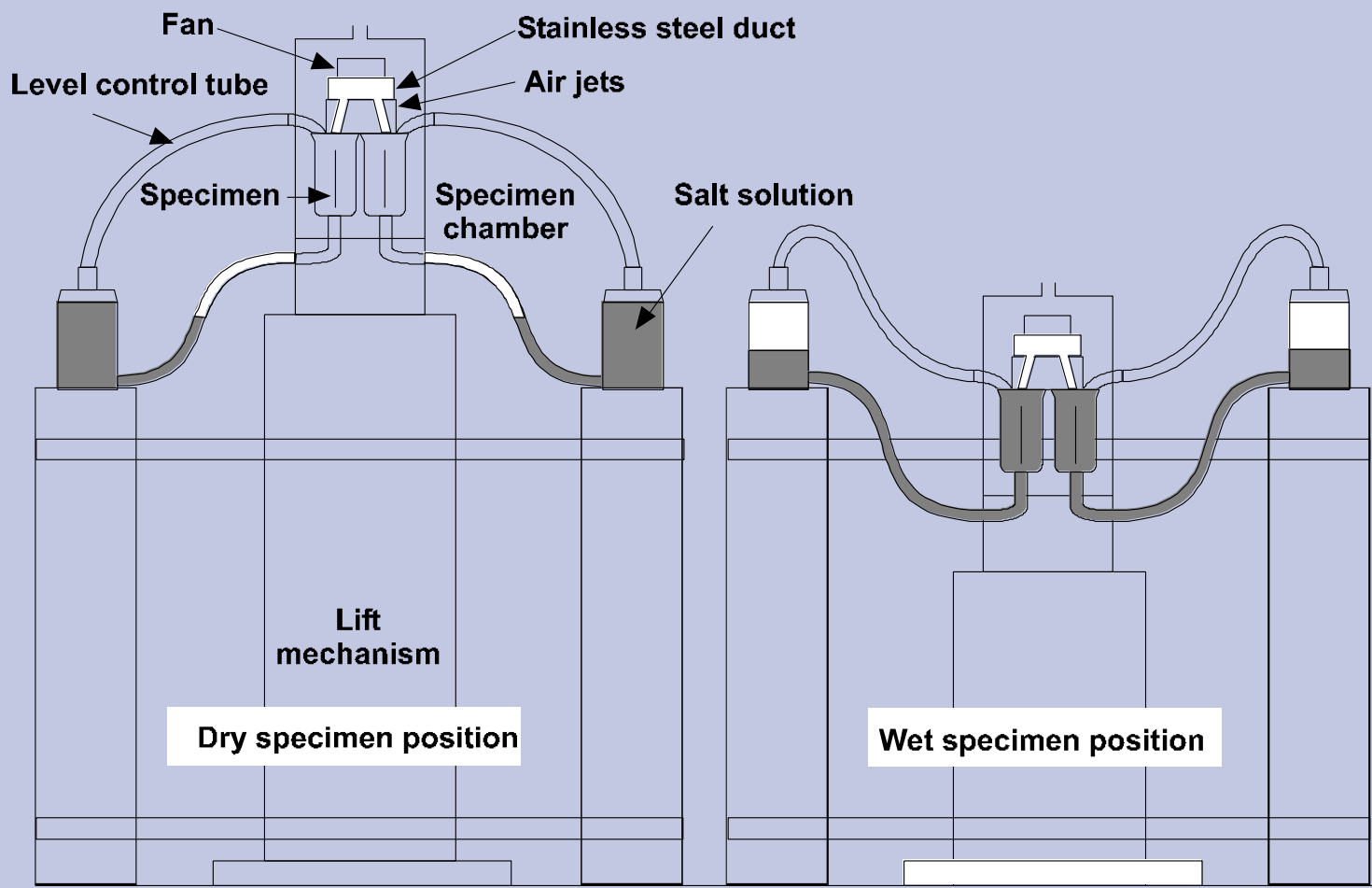
Possible design of a laboratory test equipment



Alternate immersion test in salt solution, ISO 11130

Test solution	Composition
Neutral salt solution	Sodium chloride (NaCl): 3,5 g/l
Deicing salt solution	Sodium sulphate (Na ₂ SO ₄): 0,500 g/l Sodium sulphite (Na ₂ SO ₃): 0,250 g/l Sodium thiosulphate (Na ₂ S ₂ O ₃): 0,100 g/l Sodium chloride (NaCl): 52,5 g/l Calcium chloride dihydrate (CaCl ₂ · 2H ₂ O): 52,5 g/l
Acidic salt solution	Sodium chloride (NaCl): 50 g/l pH = 3,5
Ocean water	see ISO 11130 for specification

Possible design of a test equipment for immersion tests



(a)

Accelerated outdoor test by intermittent spraying of a salt solution (Scab test), ISO 11474, test conditions

- In this method, the corrosion process during outdoor exposure is accelerated by intermittently spraying a solution of sodium chloride (mass fraction 3 %) twice a week, 3 4 days apart, onto the test surface. The test duration is normally six months.



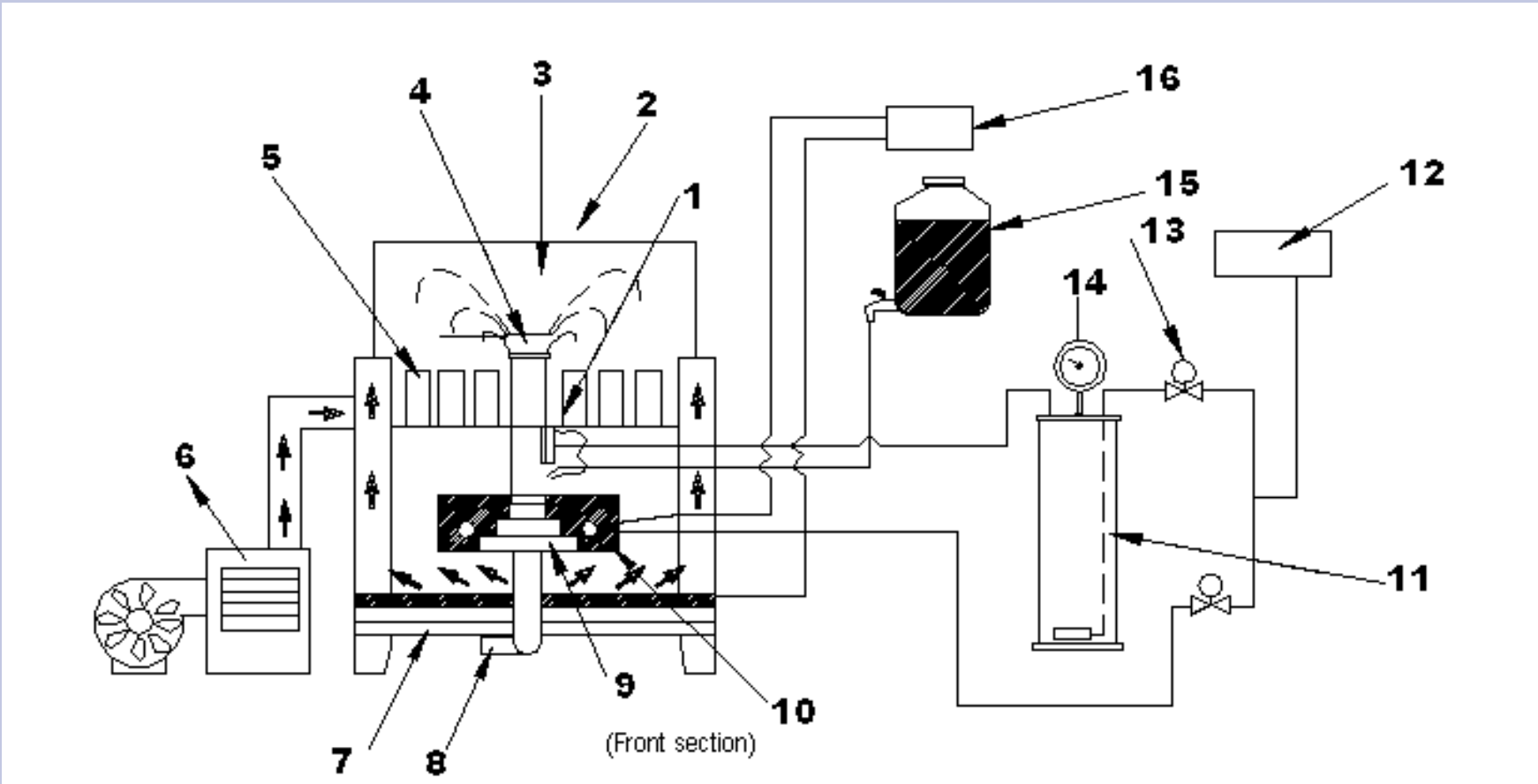
Accelerated testing involving cyclic exposure to salt mist, "dry" and "wet" conditions, ISO 14993, test conditions

1	Salt mist conditions	Temperature = 35°C Salt solution = 50 g NaCl / litre
2	"Dry" conditions (The air is purged during dry conditions)	Temperature = 60°C Relative humidity < 30 %RH
3	"Wet" conditions (Condensation on the test specimens shall not occur during wet conditions)	Temperature = 50°C Relative Humidity > 95 %RH
4	Period and content of a single exposure cycle	Total period 8 hours, as follows: Salt mist spray: 2 hours "Dry" conditions: 4 hours "Wet" conditions: 2 hours (These times include the time for reaching the specified temperature for each condition)
5	Time to reach the specified condition (i.e. period taken for temperature and humidity to reach the specified values once the test condition has begun)	Mist to "Dry": < 30 minutes "Dry" to "Wet": < 15 minutes "Wet" to Mist: < 30 minutes (Mist conditions are attained almost instantaneously once this condition begins)
6	Angle at which test specimens are supported	20° to the vertical

Corrosivity of accelerated testing involving cyclic exposure to salt mist, "dry" and "wet" conditions, ISO 14993

Test duration (h)	Mass loss of the steel reference specimens (g/m ²)	Mass loss of the zinc reference specimens (g/m ²)
48	200 ± 40	40 ± 10

Accelerated testing involving cyclic exposure to salt mist, "dry" and "wet" conditions, ISO 14993, possible design of test equipment



Accelerated cyclic tests with exposure to acidified salt spray, 'dry' and 'wet' conditions, ISO 16151, test conditions

	Issue	Method A	Method B
1	Acidified salt mist conditions	Temperature = 35°C Salt solution: 50 g NaCl/litre pH = 3,5	Temperature = 35°C Ocean salt solution: 6 g/l pH = 2,5
2	"Dry" conditions	Temperature = 60°C Relative humidity < 30 %RH	Temperature = 60°C Relative humidity < 30 %RH
3	"Wet" conditions	Temperature = 50°C Relative Humidity > 95 %RH	Temperature = 40°C Relative Humidity = 85 %RH
4	Period and content of a single exposure cycle	Total period 8 hours: Acidified salt mist: 2 h "Dry" conditions: 4 h "Wet" conditions: 2 h (These times include the time for reaching the specified temperature for each condition)	Total period 8 hours: Acidified salt mist: 1 h "Dry" conditions: 4 h "Wet" conditions: 3 h (These times include the time for reaching the specified temperature for each condition)
5	Time to reach the specified condition (i.e. period taken for temperature and humidity to reach the specified values once the test condition has begun)	Mist to "Dry": < 30 min "Dry" to "Wet": < 15 min "Wet" to Mist: < 30 min (Mist conditions shall be attained almost instantaneously once this condition begins)	"Mist" to "Dry": < 30 min "Dry" to "Wet": < 15 min "Wet" to "Mist": < 30 min (Mist conditions shall be attained almost instantaneously once this condition begins)
6	Angle at which test specimens are supported	20° to the vertical	20° to the vertical

Corrosivity of accelerated cyclic tests with exposure to acidified salt spray, 'dry' and 'wet' conditions, ISO 16151

Method	Test duration (h)	Mass loss of the steel reference specimens (g/m^2)	Mass loss of the zinc reference specimens (g/m^2)
A	48	110 ± 35	32 ± 9
B	96	180 ± 54	9 ± 5

Accelerated corrosion test involving exposure under controlled conditions of humidity cycling and intermittent spraying of a salt solution, ISO 16701

- The following scheme of cycles is adopted. In the 1st cycle, the 8th cycle, the 15th cycle, and subsequently every seventh cycle, a cycle A with salt spraying is used. In the other cycles, a cycle B involving humidity changes between a low and a high value, is used.
- **Cycle B** is composed of the following steps:
 - Exposure at 35°C and 95 % RH for 4 h
 - Exposure at 35°C to a linear reduction of relative humidity with time from 95 % RH to 50 % RH over a total period of 2 h
 - Exposure at 35 °C and at 50 % RH for 4 h
 - Exposure at 35°C to a linear increase of relative humidity with time from 50 % RH to 95 % RH over a total period of 2 h
- **Cycle A** consists of the following steps:
 - Spraying of the test objects inside the climate chamber at 35°C with a sodium chloride solution (concentration 10 g/l and pH = 4,2) at a linear downward flow rate of 15 mm h⁻¹ for 15 min
 - Exposure at 35°C for 1 h 45 min with the relative humidity set point at 95 % - 99 % RH in such a way that the test objects remain wet
 - These steps are then repeated in sequence two more times to give a total period of wetness of 6 h.

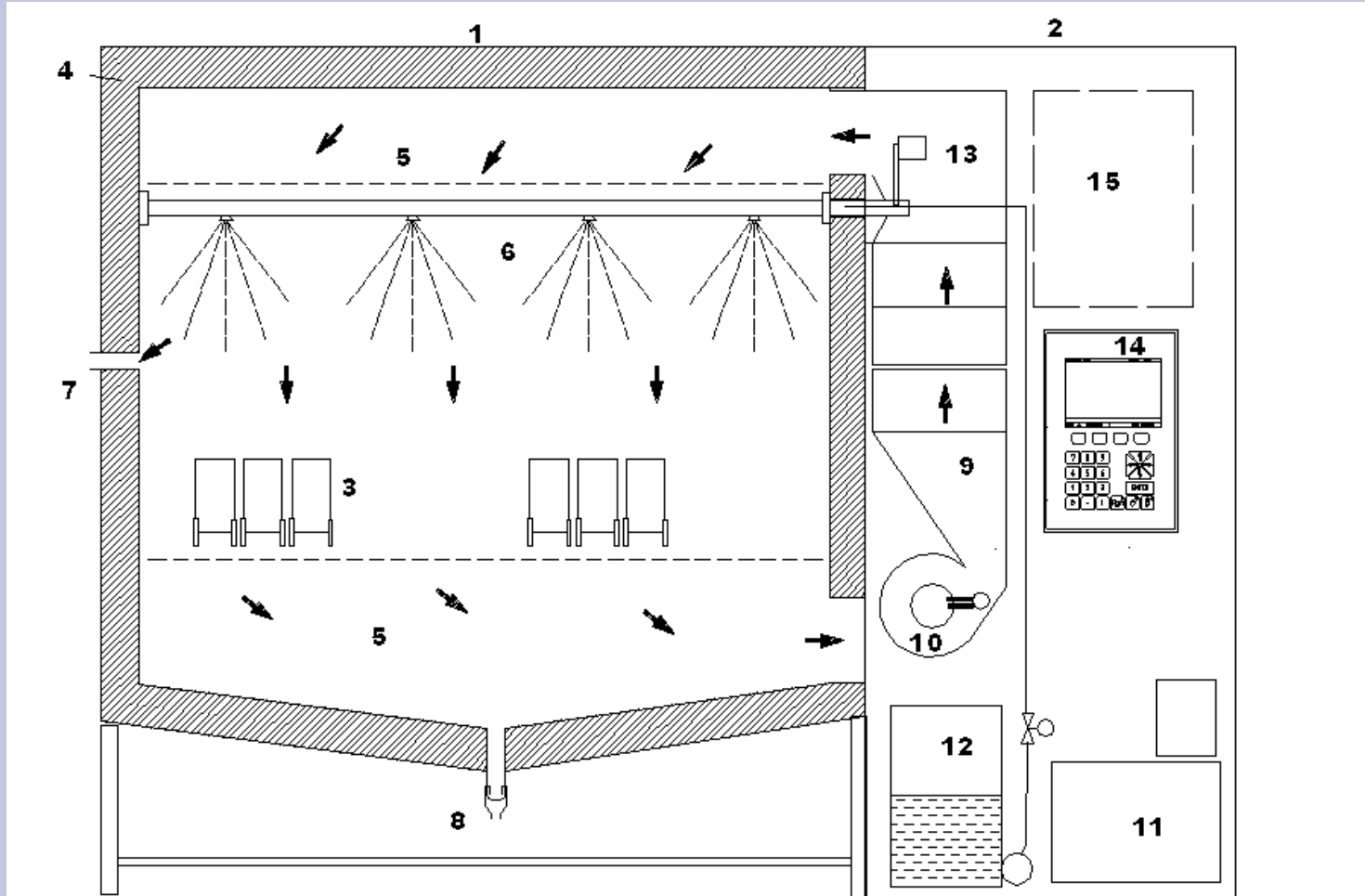
Accelerated corrosion test involving exposure under controlled conditions of humidity cycling and intermittent spraying of a salt solution, ISO 16701

- Recommended field of applications
 - The test applies to metals and their alloys, metallic coatings (anodic and cathodic), chemical conversion coatings, and organic coatings on metals. The method is especially suitable for comparative testing of surface treatment systems.
 - The test method has been developed for simulation of corrosion on open surfaces (cosmetic corrosion) and consequently the dry periods are relatively short. As the drying up time in crevices is usually much longer, prolonged drying periods are needed to simulate corrosion phenomena in specimens with crevices in a realistic way. The method is thus preferably recommended for evaluation of corrosion and corrosion protection on open surfaces.

Accelerated corrosion test involving exposure under controlled conditions of humidity cycling and intermittent spraying of a salt solution, ISO 16701, corrosivity of tests

Material tested	Metal losses in thickness obtained after test (μm)	
Cold rolled carbon steel	115 -130	(4 weeks of exposure)
	180 -220	(6 weeks of exposure)
	315 -385	(12 weeks of exposure)
Pure zinc	5 - 7	(4 weeks of exposure)
	7 -10	(6 weeks of exposure)
	15 - 20	(12 weeks of exposure)

Accelerated corrosion test involving exposure under controlled conditions of humidity cycling and intermittent spraying of a salt solution, ISO 16701, suitable design



Suitability of corrosion test methods for different fields of application

(P = Preferred kind of method, U = Useful for comparative testing of similar products,

N = Not useful unless for quality control of the same product)

Field of application		Suitability of different categories of corrosion tests					
Description	Corrosivity	A (constant salt spray)	B (alternative immersion)	C (humidity cycling with salt spraying)	D (air pollutant exposure)	E (air pollutant exposure, drying and salt spray)	F (condensation)
Marine constructions	Top site (C4-C5)	N	U	P	-	P ²⁾	-
	Splash (C5)	N	U	-	-	-	-
	Sub-sea ¹⁾	-	-	-	-	-	-
Automotive	Chassis (C4-C5)	N	U	P	-	P ²⁾	-
	Engine compartment (C2-C4)	N	U	P	-	P ²⁾	-
	Passenger compartment (C1)	-	-	-	P ²⁾	-	P
Building constructions	Open (C3-C5)	N	U	P	-	P ²⁾	-
	Sheltered (C2-C4)	N	U	P	-	P ²⁾	-
	Indoor (C1-C2)	-	-	-	P ²⁾	-	P
Electric devices	Severe(GX)	U ³⁾	U ³⁾	U ³⁾	-	P	P ⁴⁾
	Harsh (G3)	U ³⁾	U ³⁾	U ³⁾	-	P	P ⁴⁾
	Mild to Moderate (G1-G2)	-	-	-	P		P