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INTERNATIONAL STANDARD

colour inside

Environmental testing –
Part 2-60: Tests – Test Ke: Flowing mixed gas corrosion test

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Part 2-60: Tests – Test Ke: Flowing mixed gas corrosion test

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International Standard IEC 60068-2-60 has been prepared by IEC technical committee 104: Environmental conditions, classification and methods of test.

This third edition cancels and replaces the second edition, published in 1995, and constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- updated IEC format;
- updated normative references list;
- addition of information of the working volume;
- revision of the test procedure;
- revision of the figures in Annex B.

The text of this standard is based on the following documents:

FDIS	Report on voting
104/655/FDIS	104/656/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 60068 series, published under the general title *Environmental testing*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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ENVIRONMENTAL TESTING –

Part 2-60: Tests – Test Ke: Flowing mixed gas corrosion test

1 ~~General~~ Scope

This part of IEC 60068-2 determines the corrosive influence of operating and storage indoor environments on electrotechnical products components, equipment and materials, particularly contacts and connections, considered separately, integrated into a subassembly or assembled as a complete equipment.

It provides test methods giving information, on a comparative basis, to aid the selection of materials, choice of production processes and component design, with regard to corrosion resistance. A guide to the selection of methods and test duration is provided in Annex C.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

~~60512-2: 1985, *Electromechanical components for electronic equipment; basic testing procedures and measuring methods – Part 2: General examination, Electrical continuity and contact resistance tests, Insulation tests and voltage stress tests*~~

IEC 60512-2-1, *Connectors for electronic equipment – Tests and measurements – Part 2-1: Electrical continuity and contact resistance tests – Test 2a: Contact resistance – Millivolt level resistance method*

IEC 60512-3-1, *Connectors for electronic equipment – Tests and measurements – Part 3-1: Insulation tests – Test 3a: Insulation resistance*

ISO 431~~:1981~~, *Copper refinery shapes*

3 Test apparatus

The test apparatus consists of a climatic system, test enclosure, gas delivery system and means for measuring gas concentration.

Details of design and construction are optional but shall be such that the conditions specified for each method are fulfilled throughout the working volume and shall comply with the following requirements:

- water droplets or aerosols shall not be injected into the test enclosure;
- air and water used shall be sufficiently clean in order not to affect performance of the test;
- the test atmosphere shall flow through the enclosure in such a manner as to ensure uniform test conditions within the working volume;
- the sampling point for gas analysis shall be in the working volume of the test enclosure;
- the exhaust gases shall be treated in accordance with the relevant regulatory stipulations;

– the wet bulb pod shall be placed in the test chamber in such a manner not to exceed 0,1 % of the cross-section of the test chamber.

Because of the strong synergistic effect and the so called “memory effect” (i.e., it is difficult to fully remove the chlorine compounds from the chamber, tubes, etc.), it is recommended that enclosures and tubing used for tests that incorporate chlorine only be used for chlorine tests.

The working volume is the volume within which the individual corrosion (~~weight~~ mass increase of copper coupons expressed in mg/($dm^2 \times$ day) according to Annex A) at each location differs by a maximum of 15 % from the average corrosion of all coupons within the working volume.

4 Severities

The test severity shall be given in the relevant specification. It is defined by

– the test method, chosen from Table 1,

– the test duration.

Preferred durations, in days, are 4, 7, 10, 14 and 21.

Four methods are defined. The different parameters for each method are summarized in the following Table 1. A guidance for the use of each method is given in Clause C.3.

Table 1 – Test conditions

Parameters	Method 1	Method 2	Method 3	Method 4
H_2S (10^{-9} vol/vol) ~~1)~~	100 ± 20	10 ± 5	100 ± 20	10 ± 5
NO_2 (10^{-9} vol/vol) ~~2)~~		200 ± 50	200 ± 50	200 ± 20
Cl_2 (10^{-9} vol/vol) ~~3)~~		10 ± 5	20 ± 5	10 ± 5
SO_2 (10^{-9} vol/vol) ~~4)~~	500 ± 100			200 ± 20
Temperature (°C) [a]	25 ± 1	30 ± 1	30 ± 1	25 ± 1
RH (%) [a]	75 ± 3	70 ± 3	75 ± 3	75 ± 3
~~Volume changes per hour~~	~~3 – 10~~	~~3 – 10~~	~~3 – 10~~	~~3 – 10~~
~~Weight increase of copper coupons mg/($dm^2 \times$ day) according to annex A~~	~~1,0 – 2,0~~	~~0,3 – 1,0~~	~~1,2 – 2,2~~	~~1,2 – 2,4~~
Rate of ventilations per hour	3 to 10	3 to 10	3 to 10	3 to 10
Mass increase of copper coupons mg/($dm^2 \times$ day) according to Annex A	1,0 to 2,0	0,3 to 1,3	1,2 to 2,2	1,2 to 2,4

~~1) H_2S: 1 $\mu g/m^3$ = 0,71 mm^3/m^3~~

~~2) NO_2: 1 $\mu g/m^3$ = 0,53 mm^3/m^3 (10^{-9} vol/vol) = UNIT ($\mu g/m^3$)~~

~~3) Cl_2: 1 $\mu g/m^3$ = 0,34 mm^3/m^3~~

~~4) SO_2: 1 $\mu g/m^3$ = 0,38 mm^3/m^3~~

NOTE Since the nature of the corrosive attack is different for test Methods 1 to 4, neither their numbering nor the corresponding ~~weight~~ mass increase of copper coupons reflect their severity.

[a] Different temperature and humidity values (e.g. 40 °C and 80 %RH) may be used based upon mutual agreement between the interested parties. The mass increase may be different from the given values.

5 Preconditioning

The relevant specification may require preconditioning of specimens, for example cleaning or mechanical operation.

6 Initial measurements

Initial measurements shall be carried out as required by the relevant specification.

Generally, these measurements are:

- contact resistance measurements for electromechanical product components (see ~~IEC 60512-2, test 2a~~ IEC 60512-2-1);
- insulation resistance measurements (see ~~IEC 60512-2, test 3a~~ IEC 60512-3-1).

7 Testing

7.1 General

Samples exposed in the tests shall be

- the specimens being evaluated,
- corrosion monitor materials.

7.2 Test specimens

The relevant product specification shall define the conditions of the specimens during the test, for example mated or unmated for connectors; contacts open or closed for switches, operated or electrically loaded.

The duration of the operation or loading of heat-dissipating specimens, shall be such that the temperature and the relative humidity in the working volume remain within the specified tolerances.

The conditions of the specimens and the test chamber shall be such that condensation on the specimens shall not occur when they are introduced into the test chamber.

The total volume of the test specimens should not exceed 10 % of the volume of the working area of the test chamber. If the total volume of the test specimens exceed 10 %, the amount exceeding 10 % shall be included in the test report.

The total surface area of the test specimens should not exceed 10 % of the surface area of the working area of the test chamber. If the total surface of the test specimens exceed 10 %, the amount exceeding 10 % shall be included in the test report.

A minimum space between specimens might be 10 mm so as not to disturb the uniform air flow.

7.3 Corrosivity monitoring materials

Copper coupons shall be exposed with the test specimens in order to verify the conformance of the test ~~specimen~~ condition.

A minimum of five test coupons of copper, prepared in accordance with Annex A, shall be exposed with the test specimens for the same duration. Their mass increase ~~in weight~~ during the test, measured by a balance with ~~appropriate sensitivity~~ a resolution of 0,01 mg, shall be taken as a measure of the corrosion and as a monitor of the reproducibility and repeatability of the test.

Other vehicles, for example, gold-plated coupons or other specimens (see B.6.3) can be used in addition to the copper coupons.

7.4 Testing procedure

One of the following test procedures shall be used:

Test procedure 1

When the test atmosphere does not contain chlorine (Method 1) or when the method for measuring chlorine concentration does not suffer interference from the other gases present in the test atmosphere, the following procedure shall be ~~adopted~~ used:

- after the specified temperature is stabilized, start the flow of humid air, allow to stabilize and adjust temperature and humidity not to accumulate the condensation on the inner wall of the test chamber and the test specimen;
- start the flow of the gases into the humid air stream and allow to stabilize;
- measure and adjust gas concentrations. Allow to stabilize. When it is necessary to measure chlorine concentration, total chlorine (not only chlorine gas, Cl_2) present in the test atmosphere is taken as a measure of chlorine gas concentration. The chlorine added to the test atmosphere shall still only be in the form of chlorine gas, Cl_2;
- introduce the test specimens and the corrosion monitoring materials as prescribed in 7.3. The copper coupons shall be exposed with the test specimens for the ~~full test period~~ first 4 days during a test duration. The copper coupons might be exposed another 4 days during a test duration, if necessary. It shall be included in the test report. The test specimens and the corrosion monitoring materials shall be distributed uniformly in the working volume. They shall not come in contact with one another nor shield one another from the test atmosphere. The test specimens shall be in the condition (for example, mated/unmated, electrically loaded or operated) as stated in the relevant specification. The test duration shall be measured from this point;
- allow the test conditions to stabilize, which may require considerable time. Measure and adjust, if necessary, temperature, humidity and gas concentrations. During these adjustments, any overshooting of gas concentration shall be avoided. Maximum allowed duration of this period of stabilization and adjustments, to prescribed values, is 24 h;
- during the course of testing, temperature, humidity and gas concentrations shall be kept within the prescribed limits. The chamber is allowed to be opened during the test.

  The number of openings shall be limited.

  No opening is allowed for a test duration shorter than 4 days.

  One opening is allowed for a test duration of between 4 and 10 days.

  One opening per week is allowed for a test duration exceeding 10 days.

  The duration of these openings shall be limited to the time necessary to remove and introduce specimens and/or copper coupons;
- at the end of the test period, remove the specimens and the corrosion monitoring materials.

Test procedure 2

When chlorine is present in the test atmosphere (Methods 2 to 4) and when the method for measuring chlorine suffers interference from other gases in the test atmosphere, the following procedure shall be used:

- after the specified temperature is stabilized, start the flow of humid air, allow to stabilize and adjust temperature and humidity so as not to accumulate the condensation on the inner wall of the test chamber and the test specimen;
- start the flow of chlorine into the humid air stream and allow to stabilize;
- measure and adjust the chlorine concentration. Allow to stabilize;
- introduce the test specimens and the corrosion monitor materials as prescribed in 7.2. The copper coupons shall be exposed with the test specimens for the ~~full test period~~ first 4 days during a test duration. The copper coupons might be exposed another 4 days during a test duration, if necessary. It shall be included in the test report. The test specimens and the corrosion monitoring materials shall be distributed uniformly in the working volume. They shall not come in contact with one another nor shield one another from the test atmosphere. The test specimens shall be in the condition (for example, mated/unmated, electrically loaded or operated) as stated in the relevant specification;
- allow temperature, humidity and chlorine concentration to stabilize, which may require considerable time due to initially high reaction or adsorption rates of chlorine with surfaces. If necessary, measure and adjust the chlorine concentration. During this adjustment, any overshooting of gas concentration shall be avoided. The chlorine concentration shall remain stable for 2 h minimum. The maximum allowed duration of this period of chlorine stabilization and adjustments, to prescribed values, is 24 h;
- start the flow of the remaining gases and allow to stabilize. Measure and adjust, if necessary, temperature, humidity and gas concentrations, excluding chlorine. During these adjustments, any overshooting of gas concentration shall be avoided. The maximum allowed duration of this period of stabilization and adjustments, to prescribed values, is 24 h. The test duration is measured from the moment when all gases are present in the test atmosphere;
- during the course of testing, temperature, humidity and gas concentrations shall be kept within the prescribed limits. Chlorine concentration, however, cannot be controlled during the test. The way to ensure that values remain within the set limits is to carry out the chlorine measurement ~~prescribed~~ after finishing the test (see below). The chamber is allowed to be opened during the test.

  The number of openings shall be limited.

  No opening is allowed for a test duration shorter than 4 days.

  One opening is allowed for a test duration of between 4 and 10 days.

  One opening per week is allowed for a test duration exceeding 10 days.

  The duration of these openings shall be limited to the time necessary to remove and introduce specimens and/or copper coupons;
- at the end of the test period, stop the flow of gases except chlorine which shall remain running. Allow sufficient time to empty the chamber of the other gases, to an extent sufficient to avoid interference with chlorine analyses;
- measure the chlorine concentration which ~~will have to~~ shall be within the limits prescribed in order for the test to be valid;
- remove the test specimens and the corrosion monitoring materials.

8 Recovery

After removal of the specimens from the test chamber, they shall be stored in accordance with the relevant specification prior to final measurements.

9 Final measurements

The final measurements shall be carried out as required by the relevant specification which may also require a visual examination of the specimens after the test.

The relevant specification shall provide the criteria upon which the acceptance or rejection of the specimen is to be based.

If the necessary measurements cannot be made within the specified time, the period of storage under recovery conditions may be extended to a maximum of one week. Such an extension shall be mentioned in the test report.

10 Information to be given in the relevant specification

When this test is included in a relevant specification, the following details shall be given, in so far as they are applicable. The relevant specification shall supply information as required in the clauses listed below, paying particular attention to the items marked with an asterisk (*) as this information is always required.

	Clause
a) Method*	~~3~~4
b) Test duration*	~~3~~4
c) Preconditioning of the specimens	~~4~~5
d) Initial measurements*	~~5~~6
e) Conditions of the specimens during the test*	~~6~~7
f) Operation and loading during testing	~~6~~7
g) Recovery and duration*	~~7~~8
h) Final measurements* and possible visual examination	~~8~~9
i) Criteria of acceptance or rejection*	~~8~~9

11 Information to be given in the test report

Information to be given in the test report is as follows:

- test method;
- test duration;
- preconditioning;
- method and results of initial measurement;
- conditions and duration of test;
- operation and loading during test;
- recovery and duration;
- method and results of final measurement;
- individual ~~weight~~ mass increase of copper coupon in mg/(dm^2 × day);
- any deviation from the standard.

Annex A
(normative)

Corrosion monitoring copper coupons

A.1 General

Copper coupons are exposed with the test specimen in order to verify the conformance of the test to the limits set out in this standard. The ~~weight gain~~ mass increase of the coupons shall be taken as a measure of this conformity.

A.2 Nature and dimension

The coupons shall be made from half hard OFHC copper (Cu-OF according to ISO 431) sheet, maximum thickness of 0,5 mm, and have a total surface area of 0,1 dm^2 to 0,2 dm^2 each. The surface of the coupon is an essentially faultless surface (free from pores, marks, scratches and any light colouration) and a matt finish (arithmetically mean deviation of the profile $Ra = 0{,}15\ \mu m \pm 0{,}1\ \mu m$).

A.3 Cleaning procedure

Before the start of the test, the copper coupons shall be cleaned, as described below, weighed by a balance with ~~appropriate sensitivity~~ a resolution of 0,01 mg and stored for a maximum of 120 h in a desiccator with non-corrosive dehydrating agent.

The cleaning procedure of the copper coupons shall be as follows:

- cathodic degrease in 1 N NaOH, for 15 s to 30 s, at 5 V to 10 V, using a stainless steel anode or platinium anode;
- rinse with tap water;
- rinse with demineralized water;
- activate by dipping in 10 % H_2SO_4, for 20 s to 30 s;
- rinse with tap water;
- rinse with demineralized water;
- rinse with alcohol: denatured ethyl alcohol or isopropyl alcohol;
- dry with warm air (about 50 °C).

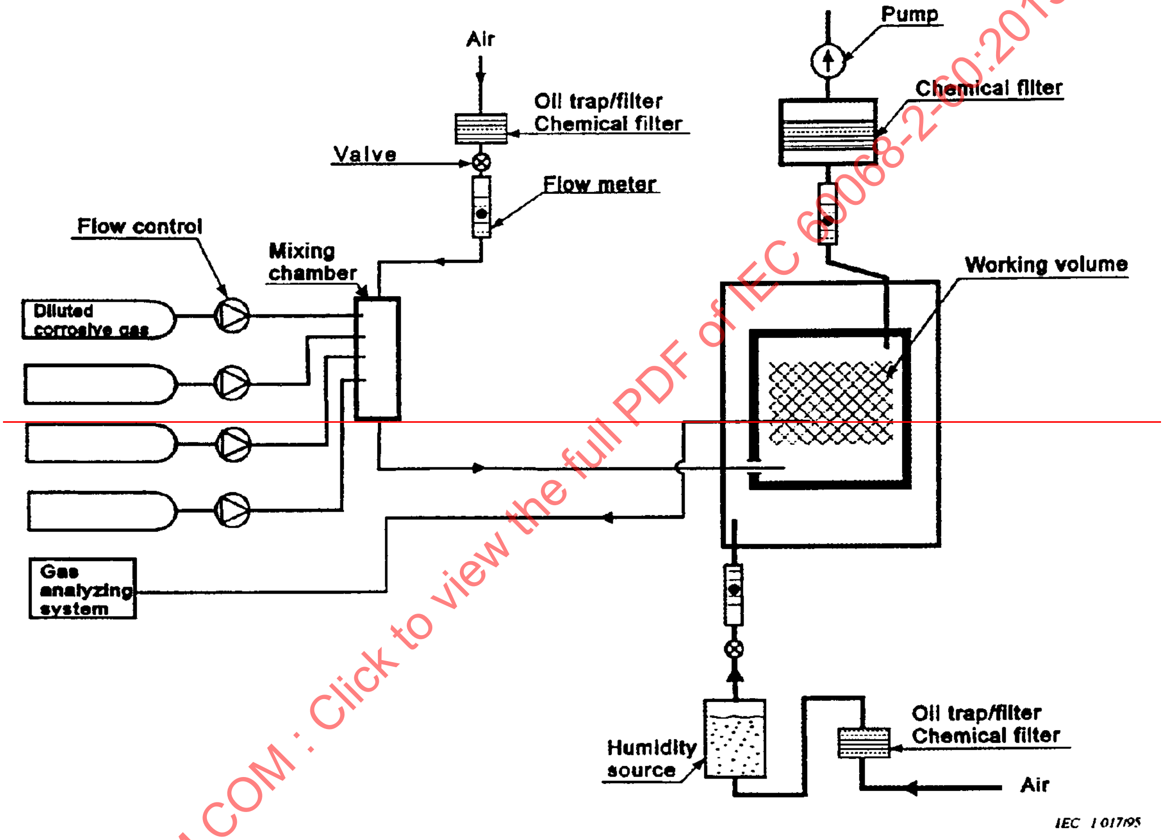
All solutions shall be prepared with demineralized water, of at least the same quality as used in the climatic system.

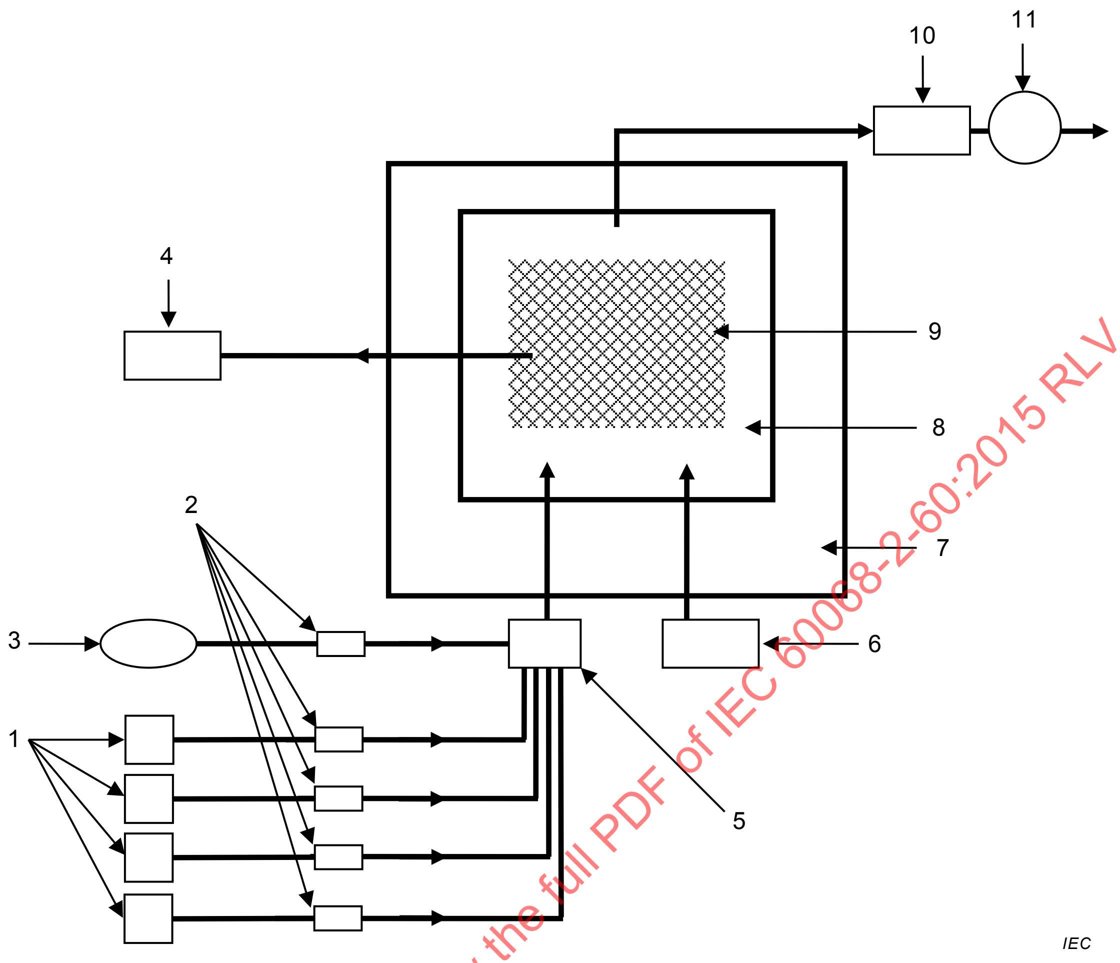
Annex B
(informative)

Description of test apparatus

B.1 General

The test apparatus consists of a climatic system, a test enclosure, a gas delivery system and gas analysing systems. An example of test apparatus is shown in Figure B.1~~, B.2 and B.3~~.



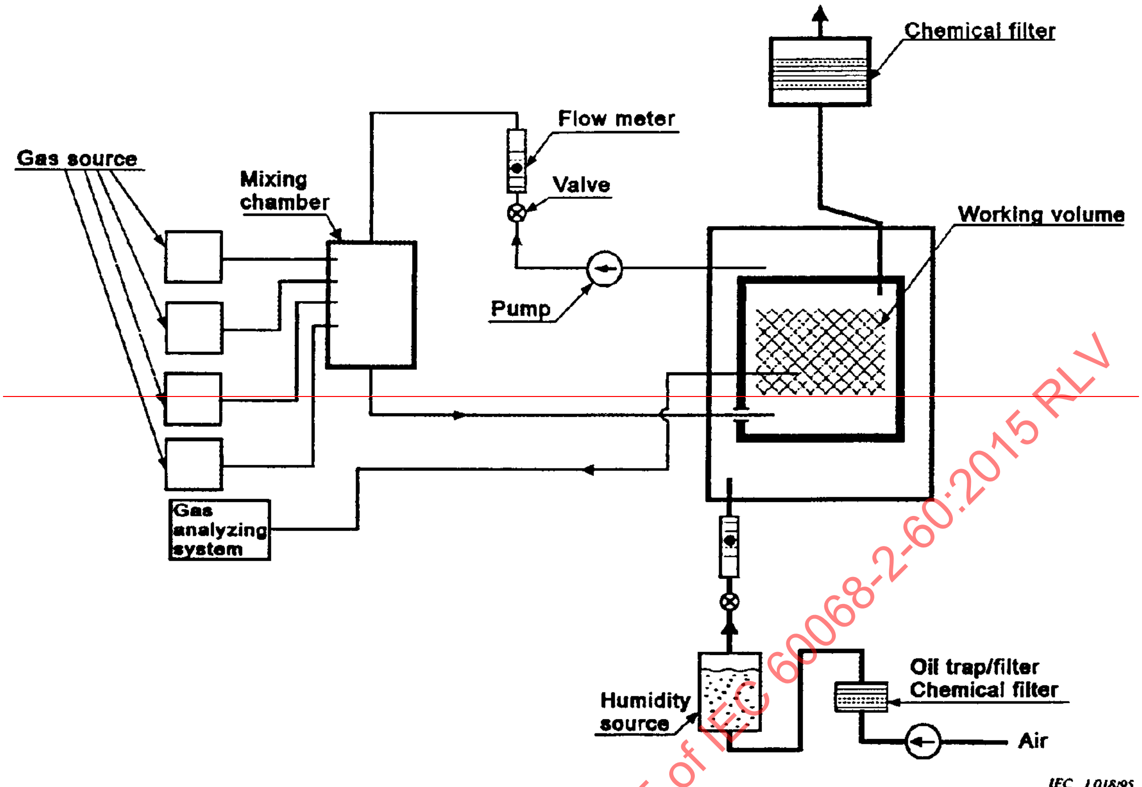


Key

1	Gas source	7	Conditioning chamber
2	Flow controller	8	Test chamber
3	Air supply	9	Working volume
4	Gas analysing system	10	Chemical filter
5	Gas mixing chamber	11	Pump
6	Humidity source		

Figure B.1 – Example of test apparatus

~~Gas delivery using gas bottles with diluted gas,~~
~~outer chamber with humid air,~~
~~premixing corrosive gases with dry air,~~
~~negative pressure within test enclosure.~~

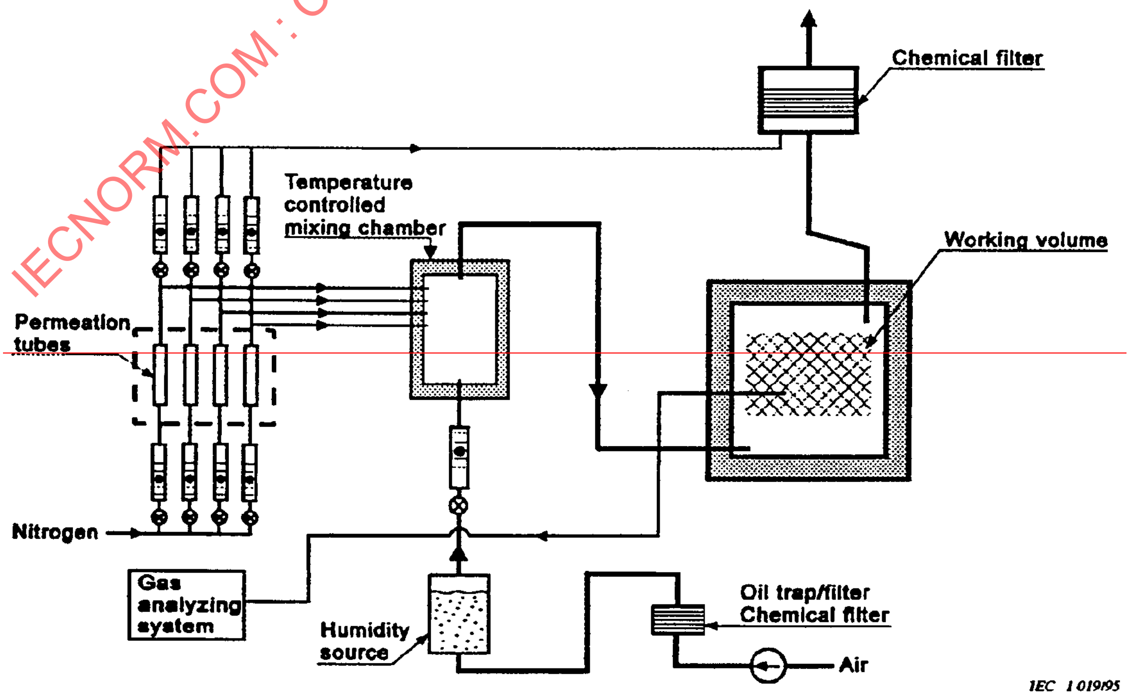


IEC 1018/95

~~NOTE Test apparatus with positive pressure shall be handled very carefully. In case of leakage, the laboratory air will be polluted by air escaping from test apparatus.~~

~~**Figure B.2 – Example of test apparatus**~~

~~Outer chamber with humid air,~~
~~mixing corrosive gases with humidified air,~~
~~positive pressure within test enclosure.~~



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~~NOTE Test apparatus with positive pressure shall be handled very carefully. In case of leakage, the laboratory air will be polluted by air escaping from test apparatus.~~

~~**Figure B.3 – Example of test apparatus**~~

~~No outer chamber (heated walls),~~
~~gas delivery using permeation tubes,~~
~~premixing corrosive gases with humidified air,~~
~~positive pressure within test enclosure.~~

B.2 Climatic system

The climatic system supplies humidified air to the test enclosure. A common way is to bubble pressurized air through a water bath held at a temperature above the dew point of the humidified air needed. When calculating the temperature any additional adding of dry air to the test atmosphere should be taken into account. The relative humidity of the air in the test enclosure should be periodically checked and the temperature of the water bath adjusted accordingly.

Pressurized air should be cleaned from oil and pollutants. One or several oil traps, oil filters and chemical filters, such as a combination of dry active carbon and a molecular sieve, should be used and regenerated at regular intervals. Alternatively, synthetic air can be used. Water should be distilled or deionized.

The humidified air can be introduced into the test enclosure by the method shown in Figure B.1. In this case, the air from the test enclosure is exhausted by suction thereby producing a lower pressure in the test enclosure than in the outer chamber. This humidified air from the outer chamber is sucked into the test enclosure through a hole, the size of which affects the pressure difference. The flow rate of the air out of the enclosure is adjusted to obtain the specified number of volume changes per hour. The lower pressure within the test enclosure, as compared with the ambient, may however cause difficulties when using ~~some~~ certain instruments for gas analysis.

~~In figure B.2, humidified air is pumped into the outer chamber and passed through the inner chamber via a hole in the wall. This way a higher pressure within the inner chamber, as compared to the ambient, can be obtained thus making gas sampling easier and reducing the risk of influence from the outer atmosphere. The inner chamber is however still at a lower pressure than the outer chamber. In figure B.2, mixing the gases with humidified air is shown. This way larger amounts of air can be used thus allowing lower gas concentrations when mixing.~~

~~In order to fulfil the requirements on humidity stability, a temperature stability better than ±0,5 °C is needed. In order to achieve the required temperature stability, a water or air jacket around the test enclosure may be necessary. An air jacket is used in figures B.1 and B.2 while air jacket, water jacket or electrically heated walls can be used in an equipment corresponding to figure B.3.~~

B.3 Test enclosure

The constituents of the test atmosphere are chemically active and hence liable to adsorb, absorb or react with the materials of construction of the test enclosure and of tubes. Materials recommended for test enclosures are glass, polymethylmetacrylate (PMMA), polytetrafluoroethylene (PTFE), polyvinylidenfluorid (PVDF) and an austenitic stainless steel of the 18 % Cr, 10 % Ni type with added Mo, Ti, Nb or other resistant materials, in order to increase the resistance to chlorine compounds, essential for this application. Higher amounts of the gases than specified are often ~~to be~~ added, especially regarding chlorine, in order to obtain specified concentrations in the working volume. When using some types of stainless steel, corrosion of the enclosure will occur. A “~~running~~ burn-in” period, during which gas adsorption rates will be unusually high, might be necessary for new chambers.

The minimum volume of the test enclosure is recommended to be 0,1 m^3.

The test enclosure may be of any shape. A cylindrical shape generally produces a more uniform air flow and a larger working volume relative to the volume of the enclosure as compared to a cubical shape.

It is recommended that the test enclosure enables the samples to be exposed only incidentally to sunlight or other light sources.

The design of the chamber should allow easy and thorough cleaning of walls and other parts within the enclosure. Walls may be heated, to specified temperature or slightly higher, in order to avoid condensation; normally an air jacket (may be an outer chamber) or a water jacket is used.

The enclosure should be fitted with suitable gas-tight seals to enable electrical measurements and all electrical and mechanical operations to be performed during the test.

The test atmosphere is preferably injected through opening(s) in the bottom of the chamber and exhausted through opening(s) in the opposite wall (top of the chamber). Baffles in front of the opening(s) can be used in order to improve uniformity of the air flow.

Tubes for the exhaust can be heated in order to avoid condensation and corrosion.

Forced movement of the air is allowed, in order to improve uniformity, provided the requirements in Table 1 are met. Forced movement of the air can be achieved by the use of fans or by moving the test objects slowly through the atmosphere by using a carousel. In general, fans produce turbulent air movement which tends to increase the rate of corrosion. To avoid that, the air velocity to the test specimen shall be as low as possible. Uniform air velocity when using carousels is only produced at a constant diameter. When using fans or carousels, power dissipation from this equipment should be taken into account. Fans can normally be placed far from the test objects so that heat dissipation does not affect test performance. For carousels, the motor is normally positioned outside the chamber to avoid heat dissipation within the test enclosure. The effect of fans or a carousel can be investigated prior to use (see Clause B.7).

B.4 Gas delivery system

The gas supply system, tubing, valves etc., should not adsorb or absorb gases to an extent affecting the performance of the test. PTFE is a generally used material in tubings. Valves, etc., are generally manufactured from acid proof steel, preferably coated with PTFE on the surfaces in contact with the gas. ~~Especially~~ Chlorine, in particular, attacks acid proof steel in the presence of humidity.

Gases used can be supplied by permeation tubes with purified air, synthetic air or nitrogen as carrier gas. An alternative method is to use gas cylinders, preferably with diluted gas (usually in nitrogen).

Gases used should be clean enough not to affect performance of the test. The recommended purity level for active gases other than the specified gas is a maximum concentration of 0,1 % of the active gas concentration; gas such as nitrogen monoxide in nitrogen dioxide is allowed at higher concentrations to a maximum of 10 % of the specified gas.

For regulating gas flow dosing pumps, orifices or mass flow meters can be used. Mass flow meters are recommended for regulating the diluted corrosive gases.

Before introducing the corrosive gases in the test enclosure, it is recommended to use a mixing chamber. The concentration of the individual corrosive gases, when mixing with other corrosive gases, should avoid unwanted reactions between the gases.

B.5 Analysing system

B.5.1 Temperature and humidity

For measuring temperature and humidity, methods unaffected by corrosive gases ~~included~~ present can be used. Humidity and temperature may be controlled before mixing with diluted corrosive gas. In test apparatus, according to Figure B.1 ~~and B.2~~, this would be in the outer chamber. In this case, the settings are adjusted according to the mixing with the diluted corrosive gases. The correlation between the true humidity and temperature in the test enclosure and the temperature and humidity normally measured outside should be checked periodically (normally twice per year). This exposure of instruments to the corrosive environment in the test enclosure is recommended to be limited.

B.5.2 Gases

In order to avoid condensation in sampling tubes, these tubes can be heated. Relative humidity in the tubes should be 80 % maximum, preferably lower.

Possible effects of the pressure difference between the test enclosure and outside of the chamber on the function of the gas analysing instruments should be checked thoroughly. Most instruments require gas samples of ambient pressure. When having a negative pressure in the test enclosure, some instruments may have difficulties ~~sucking~~ evacuating the air out of the enclosure, thus giving too low readings. A positive pressure is more easily managed, in this case measures in order to reduce pressure to ambient can easily be taken.

Examples of instrument types which can be used for sulphur dioxide are UV-fluorescence, conductometry and colorimetry.

For hydrogen sulphide, UV-fluorescence, gas chromatography with flame photometric detection, adsorption on gold film sensor (interference by NO_2), conductometry or colorimetry may be used.

For nitrogen dioxide, chemiluminiscence or colorimetry may be used.

Chlorine gas (Cl_2) can be measured using electrochemical methods or colorimetry. Both methods are affected by the other corrosive gases used in the test atmosphere. The chlorine analysis can accordingly only be conducted when the other gases are absent.

After mixing all gases, total chlorine may be analysed using ionic chromatography. Chlorine content using this method is taken as a measure of Cl_2 concentration.

Instruments used should be calibrated according to the manufacturer's instructions. Additionally, all instruments should be periodically calibrated using gas calibration sources. When using UV-fluorescence type instruments, air should be used as carrier gas in the gas calibration source since different readings are obtained when using nitrogen as compared to when using air.

It is also important to note that many instruments (for example, UV-fluorescence for SO_2 analysis) are affected by relative humidity. The same relative humidity in the carrier gas, from the calibration unit, as in the sampling tube may be difficult to achieve. In this case, readings using pure air from the chamber, using the same temperature, humidity, flow and the same heating of tubes as when taking gas samples, are taken and compared with readings for pure carrier gas from the calibration unit. When analysing the corrosive gas from the chamber, the reading is adjusted accordingly.

B.6 Other corrosion monitoring methods

B.6.1 ~~Weight~~ Mass increase

For the ~~weight~~ mass increase of copper, a balance with a ~~sensivity~~ resolution of 0,01 mg should be used.

~~When using longer exposure times (10 days or more) a balance with a sensitivity of 0,1 mg can be used.~~

Immediately before weighing the corrosion monitoring coupons, the balance should be calibrated.

For monitoring of corrosion by determining mass gain of copper or silver, a quartz microbalance can be used. Since the copper-coated quartz crystals cannot be cleaned using the method described in Annex A, the method should be calibrated by comparing with mass gain measurements for copper coupons cleaned according to the standard and weighed on a normal analytical balance.

B.6.2 Surface analysis of monitoring coupons

Investigation of the corrosion layers produced on the surface of the coupons exposed in any of the four methods described by this standard, gives additional information regarding the nature, chemical composition, layer structure and thickness of the corrosion products.

Appropriate methods such as coulometric reduction, cyclic voltametry, X-ray microanalysis (SEM EDS, WDS or microprobe), Auger electron spectroscopy (AES), secondary ion mass spectrometry (SIMS), electron spectroscopy for chemical analysis (ESCA), are available instrumental techniques for these studies.

B.6.3 Visual examination

The use of gold-plated coupons or other specimens as additional corrosion monitoring materials is recommended in order to determine the dominating corrosion mechanism.

Dominant mechanism found in Methods 1, 2 and 4 is pore corrosion and creep corrosion in the case of Method 3.

B.7 Calibration of the chamber

The working volume of a new chamber, as well as after changes in geometry or air flow, should be determined using copper coupons. Copper coupons (cleaned according to Annex A) are positioned at different locations within the chamber, with a minimum of three coupons at each location.

Maximum loading of the chamber may also be estimated using copper coupons. At maximum loading, the corrosion should be within the tolerances given in Table 1. It should be noted that organic materials may absorb just as much or even more corrosive gas as metallic materials.

Annex C
(informative)

Guide to the selection of methods and test duration

C.1 ~~Introduction~~ Introductory remarks

Corrosion of electrotechnical products during storage or operation in indoor locations is affected by climatic factors such as temperature, relative humidity, air velocity and rate of change of temperature and humidity. Additionally, gaseous pollutants seriously affect the rate of corrosion as well as the ~~relative~~ occurrence of different corrosion mechanisms. Contaminants on the surface such as dust, oil and compounds liberated from plastic materials may affect the rate and mechanism of corrosion.

All gases used in the test atmospheres have natural sources; however, different gaseous pollutants dominate in different field environments:

- sulphur dioxide and nitrogen oxides from combustion of fossil fuels and in traffic environments;
- hydrogen sulphide in the vicinity of petrochemical and steel industry, decaying organic matter, stagnant water and animal shelters;
- hydrogen sulphide and chlorine compounds in the vicinity of pulp and paper industry.

The test methods in this standard are not designed to correspond to a specific type of environment. The test methods have been chosen to produce corrosion products observed in the field for materials normally used in electrotechnical products.

C.2 Function of corrosive gases used in the tests

Hydrogen sulphide has a strong corrosive influence on many metals, especially silver and copper.

In Method 1, there is a synergistic effect of sulphur dioxide and hydrogen sulphide. This implies that an enclosure and tubing used with hydrogen sulphide cannot be used for a pure sulphur dioxide corrosion test. In Method 4, sulphur dioxide is added because sulphur dioxide has a corrosive effect on nickel, as well as on steel and zinc.

Nitrogen oxide is used, mainly as an oxidant in test Methods 2 to 4.

Chlorine is seldom observed as a major pollutant in the field. In test Methods 2 to 4, it is partly used as an oxidant and partly as a chlorine compound. The chloride formed when reduced has the ability to penetrate protective oxide layers on metallic surfaces. Having this dual effect, chlorine shows a strong synergistic effect when combined with ~~especially~~, in particular, hydrogen sulphide. Because of the strong synergistic effect and the so called “memory effect” (i.e., it is difficult to fully remove the chlorine compounds from the chamber, tubes, etc.), it is recommended that enclosures and tubing ~~once~~ used for tests that incorporate chlorine ~~cannot~~ only be used for ~~a test not specifying the presence of~~ chlorine tests.

C.3 Use of the different test methods

Although copper is considered to be a good monitoring material, its ~~weight gain~~ mass increase in the test method is not, in general, related to the corrosion of other metallic samples.

Test Method 1 can be used as a pore corrosion test on gold coatings. A test duration of 10 days is appropriate for openly exposed gold coated surfaces.

Test Method 1 can also be used for testing of contacts with gold-plated surfaces, contacts to be used in mild environments (for example telecommunication centres in “clean” surroundings). In this case, a duration of 10 to 21 days is appropriate.

Test Methods 2 and 4 are appropriate for electrotechnical products to be used in moderately corrosive environments. Such environments may be found in telecommunication centres, most office environments and some industrial instrument rooms. In these environments, the predominant corrosion mechanism on gold coatings is pore corrosion.

Test Method 3 is appropriate for more corrosive environments. Such environments may be found in instrument rooms in industry and some industrial locations. In these environments, gold coatings are prone to pore corrosion and creep of corrosion of products.

For test Methods 2 to 4, test durations of four to seven days are useful for visual assessment of coating systems. The appearance is influenced by the materials used. Four to 10 days test duration is appropriate for short-life products and 7 to 21 days for products with higher requirements for reliability and life.

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INTERNATIONAL STANDARD

NORME INTERNATIONALE

Environmental testing –
Part 2-60: Tests – Test Ke: Flowing mixed gas corrosion test

Essais d'environnement –
Partie 2-60: Essais – Essai Ke: Essai de corrosion dans un flux de mélange de gaz

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

ENVIRONMENTAL TESTING –

Part 2-60: Tests – Test Ke: Flowing mixed gas corrosion test

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.

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International Standard IEC 60068-2-60 has been prepared by IEC technical committee 104: Environmental conditions, classification and methods of test.

This third edition cancels and replaces the second edition, published in 1995, and constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- updated IEC format;
- updated normative references list;
- addition of information of the working volume;
- revision of the test procedure;
- revision of the figures in Annex B.

The text of this standard is based on the following documents:

FDIS	Report on voting
104/655/FDIS	104/656/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 60068 series, published under the general title *Environmental testing*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

ENVIRONMENTAL TESTING –

Part 2-60: Tests – Test Ke: Flowing mixed gas corrosion test

1 Scope

This part of IEC 60068-2 determines the corrosive influence of operating and storage indoor environments on electrotechnical products components, equipment and materials, particularly contacts and connections, considered separately, integrated into a subassembly or assembled as a complete equipment.

It provides test methods giving information, on a comparative basis, to aid the selection of materials, choice of production processes and component design, with regard to corrosion resistance. A guide to the selection of methods and test duration is provided in Annex C.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60512-2-1, *Connectors for electronic equipment – Tests and measurements – Part 2-1: Electrical continuity and contact resistance tests – Test 2a: Contact resistance – Millivolt level resistance method*

IEC 60512-3-1, *Connectors for electronic equipment – Tests and measurements – Part 3-1: Insulation tests – Test 3a: Insulation resistance*

ISO 431, *Copper refinery shapes*

3 Test apparatus

The test apparatus consists of a climatic system, test enclosure, gas delivery system and means for measuring gas concentration.

Details of design and construction are optional but shall be such that the conditions specified for each method are fulfilled throughout the working volume and shall comply with the following requirements:

- water droplets or aerosols shall not be injected into the test enclosure;
- air and water used shall be sufficiently clean in order not to affect performance of the test;
- the test atmosphere shall flow through the enclosure in such a manner as to ensure uniform test conditions within the working volume;
- the sampling point for gas analysis shall be in the working volume of the test enclosure;
- the exhaust gases shall be treated in accordance with the relevant regulatory stipulations;
- the wet bulb pod shall be placed in the test chamber in such a manner not to exceed 0,1 % of the cross-section of the test chamber.

Because of the strong synergistic effect and the so called “memory effect” (i.e., it is difficult to fully remove the chlorine compounds from the chamber, tubes, etc.), it is recommended that enclosures and tubing used for tests that incorporate chlorine only be used for chlorine tests.

The working volume is the volume within which the individual corrosion (mass increase of copper coupons expressed in mg/($dm^2 \times$ day) according to Annex A) at each location differs by a maximum of 15 % from the average corrosion of all coupons within the working volume.

4 Severities

The test severity shall be given in the relevant specification. It is defined by

- the test method, chosen from Table 1,
- the test duration.

Preferred durations, in days, are 4, 7, 10, 14 and 21.

Four methods are defined. The different parameters for each method are summarized in the following Table 1. A guidance for the use of each method is given in Clause C.3.

Table 1 – Test conditions

Parameters	Method 1	Method 2	Method 3	Method 4
H_2S (10^{-9} vol/vol)	100 ± 20	10 ± 5	100 ± 20	10 ± 5
NO_2 (10^{-9} vol/vol)		200 ± 50	200 ± 50	200 ± 20
Cl_2 (10^{-9} vol/vol)		10 ± 5	20 ± 5	10 ± 5
SO_2 (10^{-9} vol/vol)	500 ± 100			200 ± 20
Temperature (°C) [a]	25 ± 1	30 ± 1	30 ± 1	25 ± 1
RH (%)[a]	75 ± 3	70 ± 3	75 ± 3	75 ± 3
Rate of ventilations per hour	3 to 10	3 to 10	3 to 10	3 to 10
Mass increase of copper coupons mg/($dm^2 \times$ day) according to Annex A	1,0 to 2,0	0,3 to 1,3	1,2 to 2,2	1,2 to 2,4

NOTE Since the nature of the corrosive attack is different for test Methods 1 to 4, neither their numbering nor the corresponding mass increase of copper coupons reflect their severity.

[a] Different temperature and humidity values (e.g. 40 °C and 80 %RH) may be used based upon mutual agreement between the interested parties. The mass increase may be different from the given values.

5 Preconditioning

The relevant specification may require preconditioning of specimens, for example cleaning or mechanical operation.

6 Initial measurements

Initial measurements shall be carried out as required by the relevant specification.

Generally, these measurements are:

- contact resistance measurements for electromechanical product components (see IEC 60512-2-1);
- insulation resistance measurements (see IEC 60512-3-1).

7 Testing

7.1 General

Samples exposed in the tests shall be

- the specimens being evaluated,
- corrosion monitor materials.

7.2 Test specimens

The relevant product specification shall define the conditions of the specimens during the test, for example mated or unmated for connectors; contacts open or closed for switches, operated or electrically loaded.

The duration of the operation or loading of heat-dissipating specimens, shall be such that the temperature and the relative humidity in the working volume remain within the specified tolerances.

The conditions of the specimens and the test chamber shall be such that condensation on the specimens shall not occur when they are introduced into the test chamber.

The total volume of the test specimens should not exceed 10 % of the volume of the working area of the test chamber. If the total volume of the test specimens exceed 10 %, the amount exceeding 10 % shall be included in the test report.

The total surface area of the test specimens should not exceed 10 % of the surface area of the working area of the test chamber. If the total surface of the test specimens exceed 10 %, the amount exceeding 10 % shall be included in the test report.

A minimum space between specimens might be 10 mm so as not to disturb the uniform air flow.

7.3 Corrosivity monitoring materials

Copper coupons shall be exposed with the test specimens in order to verify the conformance of the test condition.

A minimum of five test coupons of copper, prepared in accordance with Annex A, shall be exposed with the test specimens for the same duration. Their mass increase during the test, measured by a balance with a resolution of 0,01 mg, shall be taken as a measure of the corrosion and as a monitor of the reproducibility and repeatability of the test.

Other vehicles, for example, gold-plated coupons or other specimens (see B.6.3) can be used in addition to the copper coupons.

7.4 Testing procedure

One of the following test procedures shall be used:

Test procedure 1

When the test atmosphere does not contain chlorine (Method 1) or when the method for measuring chlorine concentration does not suffer interference from the other gases present in the test atmosphere, the following procedure shall be used:

- after the specified temperature is stabilized, start the flow of humid air, allow to stabilize and adjust temperature and humidity not to accumulate the condensation on the inner wall of the test chamber and the test specimen;
- start the flow of the gases into the humid air stream and allow to stabilize;
- measure and adjust gas concentrations. Allow to stabilize. When it is necessary to measure chlorine concentration, total chlorine (not only chlorine gas, Cl_2) present in the test atmosphere is taken as a measure of chlorine gas concentration. The chlorine added to the test atmosphere shall still only be in the form of chlorine gas, Cl_2;
- introduce the test specimens and the corrosion monitoring materials as prescribed in 7.3. The copper coupons shall be exposed with the test specimens for the first 4 days during a test duration. The copper coupons might be exposed another 4 days during a test duration, if necessary. It shall be included in the test report. The test specimens and the corrosion monitoring materials shall be distributed uniformly in the working volume. They shall not come in contact with one another nor shield one another from the test atmosphere. The test specimens shall be in the condition (for example, mated/unmated, electrically loaded or operated) as stated in the relevant specification. The test duration shall be measured from this point;
- allow the test conditions to stabilize, which may require considerable time. Measure and adjust, if necessary, temperature, humidity and gas concentrations. During these adjustments, any overshooting of gas concentration shall be avoided. Maximum allowed duration of this period of stabilization and adjustments, to prescribed values, is 24 h;
- during the course of testing, temperature, humidity and gas concentrations shall be kept within the prescribed limits. The chamber is allowed to be opened during the test.

  The number of openings shall be limited.

  No opening is allowed for a test duration shorter than 4 days.

  One opening is allowed for a test duration of between 4 and 10 days.

  One opening per week is allowed for a test duration exceeding 10 days.

  The duration of these openings shall be limited to the time necessary to remove and introduce specimens and/or copper coupons;
- at the end of the test period, remove the specimens and the corrosion monitoring materials.

Test procedure 2

When chlorine is present in the test atmosphere (Methods 2 to 4) and when the method for measuring chlorine suffers interference from other gases in the test atmosphere, the following procedure shall be used:

- after the specified temperature is stabilized, start the flow of humid air, allow to stabilize and adjust temperature and humidity so as not to accumulate the condensation on the inner wall of the test chamber and the test specimen;
- start the flow of chlorine into the humid air stream and allow to stabilize;
- measure and adjust the chlorine concentration. Allow to stabilize;
- introduce the test specimens and the corrosion monitor materials as prescribed in 7.2. The copper coupons shall be exposed with the test specimens for the first 4 days during a test duration. The copper coupons might be exposed another 4 days during a test duration, if necessary. It shall be included in the test report. The test specimens and the corrosion monitoring materials shall be distributed uniformly in the working volume. They shall not come in contact with one another nor shield one another from the test atmosphere. The

test specimens shall be in the condition (for example, mated/unmated, electrically loaded or operated) as stated in the relevant specification;

- allow temperature, humidity and chlorine concentration to stabilize, which may require considerable time due to initially high reaction or adsorption rates of chlorine with surfaces. If necessary, measure and adjust the chlorine concentration. During this adjustment, any overshooting of gas concentration shall be avoided. The chlorine concentration shall remain stable for 2 h minimum. The maximum allowed duration of this period of chlorine stabilization and adjustments, to prescribed values, is 24 h;
- start the flow of the remaining gases and allow to stabilize. Measure and adjust, if necessary, temperature, humidity and gas concentrations, excluding chlorine. During these adjustments, any overshooting of gas concentration shall be avoided. The maximum allowed duration of this period of stabilization and adjustments, to prescribed values, is 24 h. The test duration is measured from the moment when all gases are present in the test atmosphere;
- during the course of testing, temperature, humidity and gas concentrations shall be kept within the prescribed limits. Chlorine concentration, however, cannot be controlled during the test. The way to ensure that values remain within the set limits is to carry out the chlorine measurement after finishing the test (see below). The chamber is allowed to be opened during the test.

  The number of openings shall be limited.

  No opening is allowed for a test duration shorter than 4 days.

  One opening is allowed for a test duration of between 4 and 10 days.

  One opening per week is allowed for a test duration exceeding 10 days.

  The duration of these openings shall be limited to the time necessary to remove and introduce specimens and/or copper coupons;
- at the end of the test period, stop the flow of gases except chlorine which shall remain running. Allow sufficient time to empty the chamber of the other gases, to an extent sufficient to avoid interference with chlorine analyses;
- measure the chlorine concentration which shall be within the limits prescribed in order for the test to be valid;
- remove the test specimens and the corrosion monitoring materials.

8 Recovery

After removal of the specimens from the test chamber, they shall be stored in accordance with the relevant specification prior to final measurements.

9 Final measurements

The final measurements shall be carried out as required by the relevant specification which may also require a visual examination of the specimens after the test.

The relevant specification shall provide the criteria upon which the acceptance or rejection of the specimen is to be based.

If the necessary measurements cannot be made within the specified time, the period of storage under recovery conditions may be extended to a maximum of one week. Such an extension shall be mentioned in the test report.

10 Information to be given in the relevant specification

When this test is included in a relevant specification, the following details shall be given, in so far as they are applicable. The relevant specification shall supply information as required in the clauses listed below, paying particular attention to the items marked with an asterisk (*) as this information is always required.

		Clause
a)	Method*	4
b)	Test duration*	4
c)	Preconditioning of the specimens	5
d)	Initial measurements*	6
e)	Conditions of the specimens during the test*	7
f)	Operation and loading during testing	7
g)	Recovery and duration*	8
h)	Final measurements* and possible visual examination	9
i)	Criteria of acceptance or rejection*	9

11 Information to be given in the test report

Information to be given in the test report is as follows:

- test method;
- test duration;
- preconditioning;
- method and results of initial measurement;
- conditions and duration of test;
- operation and loading during test;
- recovery and duration;
- method and results of final measurement;
- individual mass increase of copper coupon in mg/($dm^2 \times$ day);
- any deviation from the standard.

Annex A
(normative)

Corrosion monitoring copper coupons

A.1 General

Copper coupons are exposed with the test specimen in order to verify the conformance of the test to the limits set out in this standard. The mass increase of the coupons shall be taken as a measure of this conformity.

A.2 Nature and dimension

The coupons shall be made from half hard OFHC copper (Cu-OF according to ISO 431) sheet, maximum thickness of 0,5 mm, and have a total surface area of 0,1 dm^2 to 0,2 dm^2 each. The surface of the coupon is an essentially faultless surface (free from pores, marks, scratches and any light colouration) and a matt finish (arithmetically mean deviation of the profile Ra = 0,15 µm ± 0,1 µm).

A.3 Cleaning procedure

Before the start of the test, the copper coupons shall be cleaned, as described below, weighed by a balance with a resolution of 0,01 mg and stored for a maximum of 120 h in a desiccator with non-corrosive dehydrating agent.

The cleaning procedure of the copper coupons shall be as follows:

- cathodic degrease in 1 N NaOH, for 15 s to 30 s, at 5 V to 10 V, using a stainless steel anode or platinium anode;
- rinse with tap water;
- rinse with demineralized water;
- activate by dipping in 10 % H_2SO_4, for 20 s to 30 s;
- rinse with tap water;
- rinse with demineralized water;
- rinse with alcohol: denatured ethyl alcohol or isopropyl alcohol;
- dry with warm air (about 50 °C).

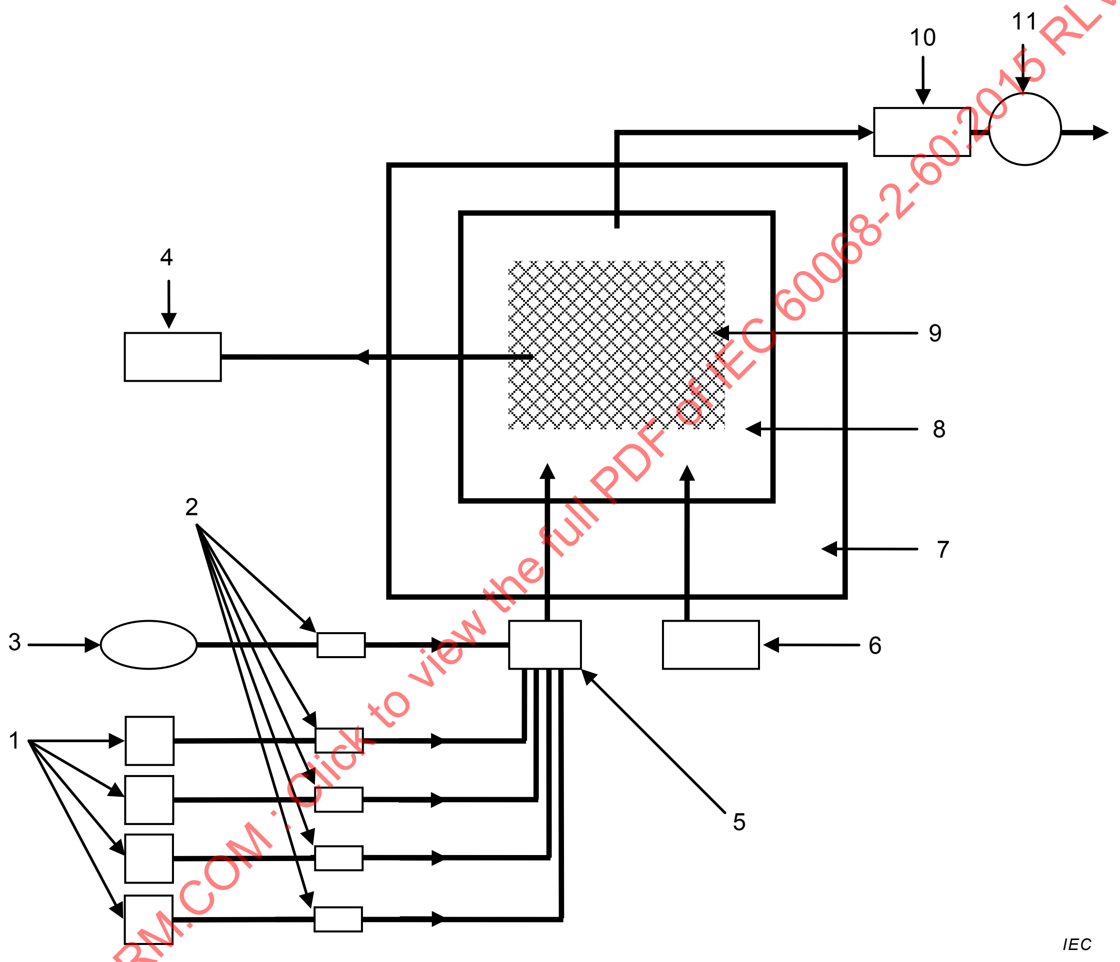
All solutions shall be prepared with demineralized water, of at least the same quality as used in the climatic system.

Annex B
(informative)

Description of test apparatus

B.1 General

The test apparatus consists of a climatic system, a test enclosure, a gas delivery system and gas analysing systems. An example of test apparatus is shown in Figure B.1.



Key

1	Gas source	7	Conditioning chamber
2	Flow controller	8	Test chamber
3	Air supply	9	Working volume
4	Gas analysing system	10	Chemical filter
5	Gas mixing chamber	11	Pump
6	Humidity source		

Figure B.1 – Example of test apparatus

B.2 Climatic system

The climatic system supplies humidified air to the test enclosure. A common way is to bubble pressurized air through a water bath held at a temperature above the dew point of the humidified air needed. When calculating the temperature any additional adding of dry air to the test atmosphere should be taken into account. The relative humidity of the air in the test enclosure should be periodically checked and the temperature of the water bath adjusted accordingly.

Pressurized air should be cleaned from oil and pollutants. One or several oil traps, oil filters and chemical filters, such as a combination of dry active carbon and a molecular sieve, should be used and regenerated at regular intervals. Alternatively, synthetic air can be used. Water should be distilled or deionized.

The humidified air can be introduced into the test enclosure by the method shown in Figure B.1. In this case, the air from the test enclosure is exhausted by suction thereby producing a lower pressure in the test enclosure than in the outer chamber. This humidified air from the outer chamber is sucked into the test enclosure through a hole, the size of which affects the pressure difference. The flow rate of the air out of the enclosure is adjusted to obtain the specified number of volume changes per hour. The lower pressure within the test enclosure, as compared with the ambient, may however cause difficulties when using certain instruments for gas analysis.

B.3 Test enclosure

The constituents of the test atmosphere are chemically active and hence liable to adsorb, absorb or react with the materials of construction of the test enclosure and of tubes. Materials recommended for test enclosures are glass, polymethylmetacrylate (PMMA), polytetrafluoroethylene (PTFE), polyvinylidenfluorid (PVDF) and an austenitic stainless steel of the 18 % Cr, 10 % Ni type with added Mo, Ti, Nb or other resistant materials, in order to increase the resistance to chlorine compounds, essential for this application. Higher amounts of the gases than specified are often added, especially regarding chlorine, in order to obtain specified concentrations in the working volume. When using some types of stainless steel, corrosion of the enclosure will occur. A “burn-in” period, during which gas adsorption rates will be unusually high, might be necessary for new chambers.

The minimum volume of the test enclosure is recommended to be 0,1 m^3.

The test enclosure may be of any shape. A cylindrical shape generally produces a more uniform air flow and a larger working volume relative to the volume of the enclosure as compared to a cubical shape.

It is recommended that the test enclosure enables the samples to be exposed only incidentally to sunlight or other light sources.

The design of the chamber should allow easy and thorough cleaning of walls and other parts within the enclosure. Walls may be heated, to specified temperature or slightly higher, in order to avoid condensation; normally an air jacket (may be an outer chamber) or a water jacket is used.

The enclosure should be fitted with suitable gas-tight seals to enable electrical measurements and all electrical and mechanical operations to be performed during the test.

The test atmosphere is preferably injected through opening(s) in the bottom of the chamber and exhausted through opening(s) in the opposite wall (top of the chamber). Baffles in front of the opening(s) can be used in order to improve uniformity of the air flow.

Tubes for the exhaust can be heated in order to avoid condensation and corrosion.

Forced movement of the air is allowed, in order to improve uniformity, provided the requirements in Table 1 are met. Forced movement of the air can be achieved by the use of fans or by moving the test objects slowly through the atmosphere by using a carousel. In general, fans produce turbulent air movement which tends to increase the rate of corrosion. To avoid that, the air velocity to the test specimen shall be as low as possible. Uniform air velocity when using carousels is only produced at a constant diameter. When using fans or carousels, power dissipation from this equipment should be taken into account. Fans can normally be placed far from the test objects so that heat dissipation does not affect test performance. For carousels, the motor is normally positioned outside the chamber to avoid heat dissipation within the test enclosure. The effect of fans or a carousel can be investigated prior to use (see Clause B.7).

B.4 Gas delivery system

The gas supply system, tubing, valves etc., should not adsorb or absorb gases to an extent affecting the performance of the test. PTFE is a generally used material in tubings. Valves, etc., are generally manufactured from acid proof steel, preferably coated with PTFE on the surfaces in contact with the gas. Chlorine, in particular, attacks acid proof steel in the presence of humidity.

Gases used can be supplied by permeation tubes with purified air, synthetic air or nitrogen as carrier gas. An alternative method is to use gas cylinders, preferably with diluted gas (usually in nitrogen).

Gases used should be clean enough not to affect performance of the test. The recommended purity level for active gases other than the specified gas is a maximum concentration of 0,1 % of the active gas concentration; gas such as nitrogen monoxide in nitrogen dioxide is allowed at higher concentrations to a maximum of 10 % of the specified gas.

For regulating gas flow dosing pumps, orifices or mass flow meters can be used. Mass flow meters are recommended for regulating the diluted corrosive gases.

Before introducing the corrosive gases in the test enclosure, it is recommended to use a mixing chamber. The concentration of the individual corrosive gases, when mixing with other corrosive gases, should avoid unwanted reactions between the gases.

B.5 Analysing system

B.5.1 Temperature and humidity

For measuring temperature and humidity, methods unaffected by corrosive gases present can be used. Humidity and temperature may be controlled before mixing with diluted corrosive gas. In test apparatus, according to Figure B.1, this would be in the outer chamber. In this case, the settings are adjusted according to the mixing with the diluted corrosive gases. The correlation between the true humidity and temperature in the test enclosure and the temperature and humidity normally measured outside should be checked periodically (normally twice per year). This exposure of instruments to the corrosive environment in the test enclosure is recommended to be limited.

B.5.2 Gases

In order to avoid condensation in sampling tubes, these tubes can be heated. Relative humidity in the tubes should be 80 % maximum, preferably lower.

Possible effects of the pressure difference between the test enclosure and outside of the chamber on the function of the gas analysing instruments should be checked thoroughly. Most instruments require gas samples of ambient pressure. When having a negative pressure in the test enclosure, some instruments may have difficulties evacuating the air out of the enclosure, thus giving too low readings. A positive pressure is more easily managed, in this case measures in order to reduce pressure to ambient can easily be taken.

Examples of instrument types which can be used for sulphur dioxide are UV-fluorescence, conductometry and colorimetry.

For hydrogen sulphide, UV-fluorescence, gas chromatography with flame photometric detection, adsorption on gold film sensor (interference by NO_2), conductometry or colorimetry may be used.

For nitrogen dioxide, chemiluminiscence or colorimetry may be used.

Chlorine gas (Cl_2) can be measured using electrochemical methods or colorimetry. Both methods are affected by the other corrosive gases used in the test atmosphere. The chlorine analysis can accordingly only be conducted when the other gases are absent.

After mixing all gases, total chlorine may be analysed using ionic chromatography. Chlorine content using this method is taken as a measure of Cl_2 concentration.

Instruments used should be calibrated according to the manufacturer's instructions. Additionally, all instruments should be periodically calibrated using gas calibration sources. When using UV-fluorescence type instruments, air should be used as carrier gas in the gas calibration source since different readings are obtained when using nitrogen as compared to when using air.

It is also important to note that many instruments (for example, UV-fluorescence for SO_2 analysis) are affected by relative humidity. The same relative humidity in the carrier gas, from the calibration unit, as in the sampling tube may be difficult to achieve. In this case, readings using pure air from the chamber, using the same temperature, humidity, flow and the same heating of tubes as when taking gas samples, are taken and compared with readings for pure carrier gas from the calibration unit. When analysing the corrosive gas from the chamber, the reading is adjusted accordingly.

B.6 Other corrosion monitoring methods

B.6.1 Mass increase

For the mass increase of copper, a balance with a resolution of 0,01 mg should be used.

Immediately before weighing the corrosion monitoring coupons, the balance should be calibrated.

For monitoring of corrosion by determining mass gain of copper or silver, a quartz microbalance can be used. Since the copper-coated quartz crystals cannot be cleaned using the method described in Annex A, the method should be calibrated by comparing with mass gain measurements for copper coupons cleaned according to the standard and weighed on a normal analytical balance.

B.6.2 Surface analysis of monitoring coupons

Investigation of the corrosion layers produced on the surface of the coupons exposed in any of the four methods described by this standard, gives additional information regarding the nature, chemical composition, layer structure and thickness of the corrosion products.

Appropriate methods such as coulometric reduction, cyclic voltametry, X-ray microanalysis (SEM EDS, WDS or microprobe), Auger electron spectroscopy (AES), secondary ion mass spectrometry (SIMS), electron spectroscopy for chemical analysis (ESCA), are available instrumental techniques for these studies.

B.6.3 Visual examination

The use of gold-plated coupons or other specimens as additional corrosion monitoring materials is recommended in order to determine the dominating corrosion mechanism.

Dominant mechanism found in Methods 1, 2 and 4 is pore corrosion and creep corrosion in the case of Method 3.

B.7 Calibration of the chamber

The working volume of a new chamber, as well as after changes in geometry or air flow, should be determined using copper coupons. Copper coupons (cleaned according to Annex A) are positioned at different locations within the chamber, with a minimum of three coupons at each location.

Maximum loading of the chamber may also be estimated using copper coupons. At maximum loading, the corrosion should be within the tolerances given in Table 1. It should be noted that organic materials may absorb just as much or even more corrosive gas as metallic materials.

Annex C
(informative)

Guide to the selection of methods and test duration

C.1 Introductory remarks

Corrosion of electrotechnical products during storage or operation in indoor locations is affected by climatic factors such as temperature, relative humidity, air velocity and rate of change of temperature and humidity. Additionally, gaseous pollutants seriously affect the rate of corrosion as well as the occurrence of different corrosion mechanisms. Contaminants on the surface such as dust, oil and compounds liberated from plastic materials may affect the rate and mechanism of corrosion.

All gases used in the test atmospheres have natural sources; however, different gaseous pollutants dominate in different field environments:

- sulphur dioxide and nitrogen oxides from combustion of fossil fuels and in traffic environments;
- hydrogen sulphide in the vicinity of petrochemical and steel industry, decaying organic matter, stagnant water and animal shelters;
- hydrogen sulphide and chlorine compounds in the vicinity of pulp and paper industry.

The test methods in this standard are not designed to correspond to a specific type of environment. The test methods have been chosen to produce corrosion products observed in the field for materials normally used in electrotechnical products.

C.2 Function of corrosive gases used in the tests

Hydrogen sulphide has a strong corrosive influence on many metals, especially silver and copper.

In Method 1, there is a synergistic effect of sulphur dioxide and hydrogen sulphide. This implies that an enclosure and tubing used with hydrogen sulphide cannot be used for a pure sulphur dioxide corrosion test. In Method 4, sulphur dioxide is added because sulphur dioxide has a corrosive effect on nickel, as well as on steel and zinc.

Nitrogen oxide is used, mainly as an oxidant in test Methods 2 to 4.

Chlorine is seldom observed as a major pollutant in the field. In test Methods 2 to 4, it is partly used as an oxidant and partly as a chlorine compound. The chloride formed when reduced has the ability to penetrate protective oxide layers on metallic surfaces. Having this dual effect, chlorine shows a strong synergistic effect when combined with, in particular, hydrogen sulphide. Because of the strong synergistic effect and the so called “memory effect” (i.e., it is difficult to fully remove the chlorine compounds from the chamber, tubes, etc.), it is recommended that enclosures and tubing used for tests that incorporate chlorine only be used for chlorine tests.

C.3 Use of the different test methods

Although copper is considered to be a good monitoring material, its mass increase in the test method is not, in general, related to the corrosion of other metallic samples.

Test Method 1 can be used as a pore corrosion test on gold coatings. A test duration of 10 days is appropriate for openly exposed gold coated surfaces.

Test Method 1 can also be used for testing of contacts with gold-plated surfaces, contacts to be used in mild environments (for example telecommunication centres in “clean” surroundings). In this case, a duration of 10 to 21 days is appropriate.

Test Methods 2 and 4 are appropriate for electrotechnical products to be used in moderately corrosive environments. Such environments may be found in telecommunication centres, most office environments and some industrial instrument rooms. In these environments, the predominant corrosion mechanism on gold coatings is pore corrosion.

Test Method 3 is appropriate for more corrosive environments. Such environments may be found in instrument rooms in industry and some industrial locations. In these environments, gold coatings are prone to pore corrosion and creep of corrosion of products.

For test Methods 2 to 4, test durations of four to seven days are useful for visual assessment of coating systems. The appearance is influenced by the materials used. Four to 10 days test duration is appropriate for short-life products and 7 to 21 days for products with higher requirements for reliability and life.

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SOMMAIRE

COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

ESSAIS D'ENVIRONNEMENT –

Partie 2: Essais – Essai Ke: Essai de corrosion dans un flux de mélange de gaz

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La Norme internationale IEC 60068-2-60 a été établie par le comité d'études 104 de l'IEC: Conditions, classification et essais d'environnement.

Cette troisième édition annule et remplace la deuxième édition publiée en 1995. Cette édition constitue une révision technique.

Cette édition inclut les modifications techniques majeures suivantes par rapport à l'édition précédente:

- mise à jour du format de l'IEC;
- mise à jour de la liste de références normatives;
- ajout d'informations concernant le volume de travail;

– révision de la procédure d’essai;

– révision des figures dans l’Annexe B.

Le texte de cette norme est issu des documents suivants:

FDIS	Rapport de vote
104/655/FDIS	104/656/RVD

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à l'approbation de cette norme.

Cette publication a été rédigée selon les Directives ISO/IEC, Partie 2.

Une liste de toutes les parties de la série IEC 60068, publiées sous le titre général *Essais d'environnement*, peut être consultée sur le site web de l'IEC.

Le comité a décidé que le contenu de cette publication ne sera pas modifié avant la date de stabilité indiquée sur le site web de l’IEC sous "http://webstore.iec.ch" dans les données relatives à la publication recherchée. A cette date, la publication sera

- reconduite,
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- remplacée par une édition révisée, ou
- amendée.

ESSAIS D'ENVIRONNEMENT –

Partie 2: Essais – Essai Ke: Essai de corrosion dans un flux de mélange de gaz

1 Domaine d'application

La présente partie de l'IEC 60068-2 établit l'influence corrosive de l'environnement sur des composants de produits électrotechniques, des équipements et des matériels, en fonctionnement ou stockés à l'intérieur de bâtiments, en particulier sur des contacts et des connexions, pris individuellement, intégrés dans un sous-ensemble ou faisant partie d'un équipement complet.

Cette norme présente des méthodes d'essais comparatifs permettant de sélectionner des matériaux, de choisir des procédés de fabrication et de concevoir des composants en fonction de la résistance à la corrosion. Un guide pour la sélection des méthodes et des durées d'essai figure en Annexe C.

2 Références normatives

Les documents suivants sont cités en référence de manière normative, en intégralité ou en partie, dans le présent document et sont indispensables pour son application. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

IEC 60512-2-1, *Connecteurs pour équipements électroniques – Essais et mesures – Partie 2-1: Essais de continuité électrique et de résistance de contact – Essai 2a: Résistance de contact – Méthode du niveau des millivolts*

IEC 60512-3-1, *Connecteurs pour équipements électroniques – Essais et mesures – Partie 3-1: Essais d'isolement – Essai 3a: Résistance d'isolement*

ISO 431, *Formes brutes d'affinage du cuivre*

3 Appareil d'essai

L'appareil d'essai est constitué par un système climatique, une chambre d'essai, un système de production de gaz et des moyens pour mesurer la concentration gazeuse.

Les détails de conception et de construction sont libres, mais doivent être tels que les conditions spécifiées pour chaque méthode soient remplies dans la totalité du volume de travail et doivent respecter les exigences suivantes:

- aucune gouttelette d'eau ou d'aérosol ne doit être injectée dans la chambre d'essai;
- on doit utiliser de l'air et de l'eau suffisamment propres pour ne pas affecter la qualité des résultats d'essai;
- la circulation de l'atmosphère d'essai à travers la chambre doit permettre d'obtenir des conditions d'essai uniformes dans le volume de travail;
- le point de prélèvement pour les analyses de gaz doit être situé dans le volume de travail de la chambre d'essai;
- le traitement des gaz rejetés doit être conforme aux règles en vigueur;

- l'ensemble à bulbe humide doit être placé dans la chambre d'essai de façon à ne pas dépasser 0,1 % de la section transversale de la chambre d'essai.

En raison de l'importance de l'effet de synergie et de ce que l'on appelle l'"effet de mémoire" (à savoir qu'il est très difficile d'éliminer complètement les composés chlorés de la chambre, des tubes, etc.), il est recommandé que des enceintes et des tubes utilisés pour des essais comprenant du chlore soient uniquement utilisés pour les essais au chlore.

Le volume de travail est le volume dans lequel la corrosivité individuelle (augmentation de la masse des coupons de cuivre en mg/(dm^2 × jour) conformément à l'Annexe A), diffère en chaque point au maximum de 15 % de la corrosivité moyenne obtenue avec tous les coupons placés à l'intérieur du volume de travail.

4 Sévérités

La sévérité de l'essai doit être précisée dans la spécification particulière concernée. Elle est définie par:

- la méthode d'essai, choisie dans le Tableau 1,
- la durée de l'essai.

Les durées préférentielles, en jours, sont égales à 4, 7, 10, 14 et 21.

Quatre méthodes sont définies. Les divers paramètres de chaque méthode sont résumés dans le Tableau 1 ci-dessous. On trouvera à l'Article C.3 un guide pour chaque méthode.

Tableau 1 – Conditions d'essais

Paramètres	Méthode 1	Méthode 2	Méthode 3	Méthode 4
H_2S (10^{-9} vol/vol)	100 ± 20	10 ± 5	100 ± 20	10 ± 5
NO_2 (10^{-9} vol/vol)		200 ± 50	200 ± 50	200 ± 20
Cl_2 (10^{-9} vol/vol)		10 ± 5	20 ± 5	10 ± 5
SO_2 (10^{-9} vol/vol)	500 ± 100			200 ± 20
Temperature (°C) [a]	25 ± 1	30 ± 1	30 ± 1	25 ± 1
HR (%)[a]	75 ± 3	70 ± 3	75 ± 3	75 ± 3
Taux de ventilation	3 à 10	3 à 10	3 à 10	3 à 10
Augmentation de masse des échantillons de cuivre mg/(dm^2 × jour) selon l'Annexe A	1,0 à 2,0	0,3 à 1,3	1,2 à 2,2	1,2 à 2,4

NOTE Comme la nature de la corrosion est différente selon les Méthodes d'essai 1 à 4, ni leur numéro ni l'augmentation de masse des échantillons de cuivre ne reflètent leur degré de sévérité.

[a] D'autres valeurs de température et d'humidité, telles que 40 °C et 80 %HR, peuvent être utilisées sur la base d'un accord mutuel entre les parties concernées. L'augmentation de masse peut être différente des valeurs indiquées.

5 Préconditionnement

La spécification particulière peut exiger un préconditionnement des spécimens, par exemple un nettoyage ou une manœuvre mécanique.

6 Mesures initiales

Les mesures initiales doivent être effectuées conformément à la spécification particulière.

Ces mesures concernent en général:

- la mesure de la résistance de contact pour les composants électromécaniques (voir l'IEC 60512-2-1);
- la mesure de la résistance d'isolement (voir l'IEC 60512-3-1).

7 Essais

7.1 Généralités

Les échantillons soumis aux essais doivent être:

- les spécimens en cours d'évaluation;
- les matériaux de contrôle de la corrosivité.

7.2 Spécimens d'essai

La spécification particulière du produit doit définir l'état des spécimens pendant l'essai, par exemple connecteurs accouplés ou désaccouplés; contacts ouverts ou fermés pour les commutateurs, en fonctionnement ou sous tension.

La durée de fonctionnement ou d'alimentation électrique des spécimens qui dissipent de la chaleur doit être telle que la température et l'humidité relative du volume de travail demeurent dans les limites de tolérance spécifiées.

L'état des spécimens et les conditions dans la chambre d'essai ne doivent pas provoquer de condensation sur les spécimens lors de leur introduction dans la chambre d'essai.

Il convient que le volume total des spécimens d'essai ne dépasse pas 10 % du volume de la surface de travail de la chambre d'essai. Si le volume total des spécimens d'essai dépasse 10 %, la quantité excédant 10 % doit figurer dans le rapport d'essai.

Il convient que la surface totale des spécimens d'essai ne dépasse pas 10 % de la surface de la zone de travail de la chambre d'essai. Si la surface totale des spécimens d'essai dépasse 10 %, la quantité excédant 10 % doit figurer dans le rapport d'essai.

L'espace minimal entre les spécimens peut être de 10 mm de manière à ne pas perturber le flux d'air uniforme.

7.3 Matériaux de contrôle de la corrosivité

Des coupons de cuivre doivent être exposés en même temps que les spécimens d'essai afin de vérifier la conformité de la condition d'essai.

Cinq coupons d'essai de cuivre au minimum, préparés conformément aux indications de l'Annexe A, doivent être exposés en même temps que les spécimens d'essais, et ce pour la même durée. Leur augmentation de masse durant l'essai, mesurée à l'aide d'une balance avec une résolution de 0,01 mg, doit être prise comme mesure de la corrosivité et comme moyen de contrôle de la reproductibilité et de la répétabilité de l'essai.

En plus de ces coupons de cuivre, on peut également utiliser d'autres supports, par exemple des coupons recouverts d'or ou d'autres échantillons (voir B.6.3).

7.4 Procédures d’essai

On doit utiliser l'une des procédures d'essai décrites ci-dessous:

Procédure d’essai 1

Lorsque l'atmosphère d'essai ne comporte pas de chlore (Méthode 1) ou lorsque la méthode de mesure du taux de chlore n'interfère pas avec les autres gaz présents dans l’atmosphère d’essai, on doit procéder de la façon suivante:

- après stabilisation de la température spécifiée, commencer l’admission du flux d’air humide, laisser stabiliser puis régler la température et l’humidité afin d’éviter l’accumulation de condensation sur la paroi intérieure de la chambre d’essai et sur le spécimen d’essai;
- commencer l'admission du flux gazeux dans le courant d'air humide et laisser stabiliser;
- mesurer et régler les concentrations de gaz. Laisser stabiliser. Lorsqu’il est nécessaire de mesurer la concentration en chlore, le chlore total (pas seulement le chlore gazeux, Cl_2) présent dans l’atmosphère d’essai est pris comme mesure de la concentration en chlore gazeux. Le chlore ajouté à l'atmosphère d'essai doit toujours être uniquement du chlore gazeux, Cl_2;
- introduire les spécimens d'essai et les matériaux de contrôle de la corrosivité comme stipulé au 7.3. Les coupons de cuivre doivent être exposés en même temps que les spécimens d'essai, pendant les 4 premiers jours d’une durée d’essai. Les coupons en cuivre peuvent être exposés 4 jours supplémentaires pendant la durée d’essai, si nécessaire. Cela doit figurer dans le rapport d’essai. Les spécimens d'essai et les matériaux de contrôle de la corrosivité doivent être répartis uniformément à l'intérieur du volume de travail. Ils ne doivent pas venir en contact les uns avec les autres et aucun ne doit faire écran aux autres dans l'atmosphère d'essai. Les spécimens d'essai doivent se trouver dans l'état indiqué par la spécification particulière (par exemple enfiché/désenfiché, sous tension ou en fonctionnement). La durée de l'essai doit être mesurée à partir de ce moment;
- laisser les conditions d'essai se stabiliser, ce qui peut prendre beaucoup de temps. Si nécessaire, mesurer et régler la température, l'humidité et les concentrations gazeuses. Eviter tout dépassement excessif de la concentration en gaz au cours de ces réglages. La durée maximale de cette période de stabilisation du chlore et de réglages, aux valeurs prescrites, est de 24 h;
- au cours des essais, la température, l'humidité et les concentrations gazeuses doivent rester dans les limites fixées. L’ouverture de la chambre est autorisée au cours de l’essai.

  Le nombre d'ouvertures doit être limité.

  Aucune ouverture n’est autorisée pour une durée d'essai inférieure à 4 jours.

  Une ouverture est autorisée pour une durée d'essai entre 4 jours et 10 jours.

  Une ouverture par semaine est autorisée pour une durée d'essai supérieure à 10 jours.

  La durée d'ouverture doit être limitée au temps nécessaire pour enlever ou introduire des spécimens et/ou des coupons de cuivre;
- à la fin de la période d'essai, retirer les spécimens et les matériaux de contrôle de la corrosivité.

Procédure d’essai 2

Lorsque l'atmosphère d'essai comporte du chlore (Méthodes 2 à 4) et lorsque la méthode de mesure du chlore interfère avec les autres gaz dans l’atmosphère d’essai, on doit procéder de la façon suivante:

- après stabilisation de la température spécifiée, commencer l’admission du flux d’air humide, laisser stabiliser puis régler la température et l’humidité afin d’éviter l’accumulation de condensation sur la paroi intérieure de la chambre d’essai et sur le spécimen d’essai;

- commencer à admettre le flux de chlore dans le courant d'air humide et laisser stabiliser;
- mesurer et régler la concentration en chlore. Laisser stabiliser;
- introduire les spécimens d'essai et les matériaux de contrôle de la corrosivité, comme stipulé au 7.2. Les coupons de cuivre doivent être exposés en même temps que les spécimens d'essai, pendant les 4 premiers jours d'une durée d'essai. Les coupons en cuivre peuvent être exposés 4 jours supplémentaires pendant la durée d'essai, si nécessaire. Cela doit figurer dans le rapport d'essai. Les spécimens d'essai et les matériaux de contrôle de la corrosivité doivent être répartis uniformément à l'intérieur du volume de travail. Ils ne doivent pas venir en contact les uns avec les autres et aucun ne doit faire écran aux autres dans l'atmosphère d'essai. Les spécimens d'essai doivent se trouver dans l'état indiqué par la spécification particulière (par exemple enfiché/désenfiché, sous tension ou en fonctionnement);
- laisser s'équilibrer la température, l'humidité et la concentration en chlore. Cela peut prendre beaucoup de temps du fait de la réaction ou des taux d'adsorption du chlore avec les surfaces, qui peuvent être élevés au départ. Si nécessaire, mesurer et régler la concentration en chlore. Au cours de ces réglages, tout dépassement excessif de la concentration en gaz doit être évité. La concentration en chlore doit rester stable pendant au moins 2 h. La durée maximale de cette période de stabilisation du chlore et de réglages, aux valeurs prescrites, est de 24 h;
- commencer à admettre le flux des gaz restants et laisser stabiliser. Si nécessaire, mesurer et régler la température, l'humidité et les concentrations en gaz, à l'exclusion du chlore. Au cours de ces réglages, tout dépassement excessif de la concentration en gaz doit être évité. La durée maximale de cette période de stabilisation du chlore et de réglages, aux valeurs prescrites, est de 24 h. La durée des essais est mesurée à partir du moment où tous les gaz sont présents dans l'atmosphère d'essai;
- au cours des essais, la température, l'humidité et les concentrations gazeuses doivent rester dans les limites fixées. Cependant, la concentration en chlore ne peut pas être contrôlée au cours de l'essai. Le moyen de s'assurer que les valeurs ne dépassent pas les limites fixées est de mesurer le taux de chlore à la fin de l'essai (voir ci-dessous). L'ouverture de la chambre est autorisée au cours de l'essai.

  Le nombre d'ouvertures doit être limité.

  Aucune ouverture n'est autorisée pour une durée d'essai inférieure à 4 jours.

  Une ouverture est autorisée pour une durée d'essai entre 4 jours et 10 jours.

  Une ouverture par semaine est autorisée pour une durée d'essai supérieure à 10 jours.

  La durée de ces ouvertures doit être limitée au temps nécessaire pour enlever ou introduire des spécimens et/ou des coupons de cuivre;
- à la fin de la période d'essai, arrêter l'admission des gaz, excepté le chlore qui doit continuer à être introduit. Attendre suffisamment pour évacuer de la chambre les autres gaz, jusqu'à atteindre des teneurs suffisamment faibles pour ne pas interférer avec les analyses du chlore;
- mesurer le taux de chlore, qui doit être dans les limites fixées pour que les essais puissent être validés;
- retirer les spécimens d'essai et les matériaux de contrôle de la corrosivité.

8 Reprise

Après avoir retiré les spécimens de la chambre d'essai, on doit les entreposer dans les conditions définies par la spécification particulière, avant de procéder aux mesures finales.

9 Mesures finales

Les mesures finales doivent être effectuées conformément à la spécification particulière qui peut aussi exiger une inspection visuelle des spécimens après l'essai.