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Essais d'environnement –

Partie 2:
Essais –
Essai L: Poussière et sable

Environmental testing –

Part 2:
Tests –
Test L: Dust and sand

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Contents

Introduction

The tests described in this part of IEC 68-2 give information on effects for which the relevant specification may specify assessment criteria. Some of such effects are:

a) ingress of dust into enclosures;

b) change of electrical characteristics (for example, faulty contact, change of contact resistance, change of track resistance);

c) seizure, or disturbance in motion of bearings, axles, shafts and other moving parts;

d) surface abrasion (erosion);

e) contamination of optical surfaces; contamination of lubricants;

f) clogging of ventilating openings, bushings, pipes, filters, apertures necessary for operation etc.

Different tests have been specified to consider diversified aspects which may be used to verify constructional integrity of electrotechnical products or to simulate the conditions of operation in service.

The tests differ by the character of the air flow carrying the particulate matter, and by the type of such matter, resulting in a special methodology for each test.

1 General

This survey indicates the general structure of the dust/sand tests included in this publication. The structuring and a summary of the characteristics of the different tests are given in Figure 1 and Table 1. It should be noted that the dust test of IEC 529 has its equivalent in the proposed method La2. See also Annex A.

1.1 Scope

This part of IEC 68-2 specifies test methods to determine the effects of dust and sand suspended in air, on electrotechnical products.

The test methods of this standard are not intended for the testing of air filters. Only method Lc2 is suitable for the simulation of the erosion effects of high velocity (more than 100 m/s) particles.

1.2 Description of Test L

The dust and sand test is structured into three groups:

La: *non-abrasive fine dust.* A test which is primarily oriented towards investigation of the seals of the test specimen. The test specimen is exposed to a very fine dust in the form of talc or an equivalent. The effects of temperature cycling resulting in a pressure difference between the inside and outside of the specimen may be reproduced.

Lb: *free settling dust.* A test which is oriented towards investigation of the effects when simulating conditions at sheltered locations. The test specimen is exposed to a low-density dust atmosphere created by the intermittent injection of a small quantity of dust which is allowed to fall by gravity onto the specimen.

Lc: *blown dust and sand.* A test which is oriented towards investigation of the seals and the effect of erosion when simulating outdoor and vehicle conditions. The test specimen is exposed to either a turbulent or a laminar air flow to which is added a quantity of dust, sand or a dust/sand mixture.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of IEC 68-2. At the time of publication, the editions indicated were valid. All normative documents are subject to revision, and parties to agreements based on this part of IEC 68-2 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 529:1989, *Degrees of protection provided by enclosures (IP code).*

IEC 721-2-5:1991, *Classification of environmental conditions — Part 2: Environmental conditions appearing in nature — Section 5: Dust, sand, salt mist.*

3 Definitions

For the purpose of this part of IEC 68-2 the following definitions apply.

3.1
dust

particulate matter of unspecified origin or composition whose size ranges from 1 µm to 150 µm (see note to **3.7**)

Table 1 — Summary of test characteristics

Procedure	Dust/sand type	Particle size	Dust/sand concentration	Notes
Test La				
Method La1	Talc or FE powder	< 75 µm	600 g/m2/h (grams per square metre per hour) deposit on reference surface	Test includes a cycling of the air pressure in the chamber
Method La2	Talc or FE powder	< 75 µm	2 kg/m3^{3}(chamber volume)	Air pressure in the specimen may be reduced
Test Lb	Olivine or quartz or feldspar	< 75 µm	6 g/m^{2}/d (grams per square metre per day) deposit on reference surface	Free settling dust
Test Lc				
Method Lc1	Olivine or quartz or feldspar	< 75 µm or < 150 µm or < 850 µm	1 g/m^{3} or 3 g/m^{3} or 10 g/m^{3}	Blown dust and sand Recirculating chamber
Method Lc2	Olivine or quartz or feldspar	< 75 µm or < 150 µm or < 850 µm	1 g/m^{3} or 3 g/m^{3} or 10 g/m^{3}	Free blowing dust

3.2
dust concentration

total mass of dust particles per unit volume of air

3.3
humidity

relative humidity is defined as the ratio of the actual vapour pressure in the air at any temperature to the maximum of saturation vapour pressure at the same temperature

3.4
hygroscopic

having a tendency to absorb moisture

3.5
particle size

general dimension of the dust and sand particles based on the premise that the particles are spheres; commonly measured by sieving, by calculating settling velocities, or by determining areas of microscopic images

3.6
sand

grains vary from spherical to angular whose size lies between 100 µm and 2 000 µm, but for environmental testing, the range is usually restricted from 150 µm to 850 µm (see note to **3.7**)

3.7
sieve (square-meshed)

intended for the particle size analysis of the material to be sieved, which conforms to a test sieve standard specification

NOTE In test Lc of this standard the word "dust" has been used to include "sand".

4 Test La: non-abrasive fine dust

4.1 Method La 1: cyclic air pressure

4.1.1 *Object*

The object of this test is to determine the degree of protection against ingress of fine dust into electrotechnical products.

4.1.2 *General description*

Method La1 is a dust test in which the specimen is exposed to a dust-laden air flow containing non-abrasive powder of particle size < 75 µm (see **4.3**). The test does not simulate natural or induced environments.

A vertical air flow downwards is specified for the test.

For enclosures of a specific category the pressure in the dust chamber is varied cyclically in order to encourage the ingress of powder.

4.1.3 *Description of test apparatus*

The test chamber shall expose the test specimen to a mainly vertical, non-laminar air flow containing a specified quantity of test dust. For this purpose, the test dust shall be agitated and blown into a sealed chamber. It shall be possible to cycle the chamber pressure as required by **4.1.4.6**.

Dust settled in the base of the test chamber shall be brought back into circulation.

The volume of the specimen shall be no more than 25 % of the test chamber volume and its base shall be no more than 50 % of the horizontal working space surface of the test chamber.

If the size of the specimen does not comply with this standard, the relevant specification shall prescribe which of the following procedures shall be applied:

a) testing of individually enclosed sections of the product;

b) testing of representative parts of the product comprising components such as doors, ventilating openings, seats, shaft seals etc, with the delicate parts of the product such as terminals, collector rings etc, in position at the time of testing;

c) testing of smaller products having the same design details as full scale products.

An example of a suitable test apparatus is given in Figure 3.

4.1.4 *Test conditions*

4.1.4.1 *Test dust*

The test dust consists of dry fine-granular non-abrasive powder which shall be able to pass through a square-meshed sieve with a nominal wire diameter of 50 µm and a nominal width between wires of 75 µm.

Talc can be used for this test as analysis shows that it meets these requirements (see **4.3.4.2**).

The test dust shall not be used for more than 20 tests. Care should be taken to keep the powder dry to maintain its fine granularity. It shall be dried by heating for 2 h at + 80 °C before use.

4.1.4.2 *Dust concentration*

The quantity of test dust used for the test shall be sufficient to obtain a uniform deposition on the reference surface in the chamber of (600 ± 200) $g/m^2/h$.

4.1.4.3 *Air flow*

The air flow in the test chamber shall be mainly vertical from top to bottom and it should not be laminar.

4.1.4.4 *Air velocity*

The air velocity shall give the possibility to generate a homogeneous distribution of the dust in the test chamber.

4.1.4.5 *Humidity*

The relative humidity in the test chamber shall be less than 25 %. This may be achieved by raising the test chamber air temperature. (see clause **A.3**).

4.1.4.6 *Air pressure in the specimen*

Depending on the operating conditions there are two different categories of specimen enclosures.

Category 1: enclosures where an air pressure different from the environmental atmospheric air pressure may occur, for example caused by thermal cycling effects during operation.

Category 2: Enclosures where the air pressure is that of the ambient air pressure.

The relevant specification shall state the category of the enclosure and the pressure reduction.

4.1.4.6.1 A specimen with a category 1 enclosure shall be introduced into the test chamber and mounted in its normal operating position. It shall be submitted to periods of reduced pressure specified in Figure 2. The pressure reduction below ambient shall be 2 kPa (20 mbar) or 5 kPa (50 mbar), as prescribed in the relevant specification.

The dust shall be injected during each single cycle as shown in Figure 2.

4.1.4.6.2 A specimen with a category 2 enclosure shall be introduced into the test chamber and mounted in its normal operating position. The vacuum pump shall not be operating in such a case.

4.1.4.7 *Severities*

The test severity defined by air pressure in the chamber and duration of test, depending on the category of enclosure (see **4.1.4.6**) shall be prescribed by the relevant specification.

Category 1: pressure reduction of 2 kPa (20 mbar) or 5 kPa (50 mbar), as required by the relevant specification, for a duration of 2 h.

Category 2: atmospheric pressure for a duration of 4 h.

4.1.5 ***Preconditioning***

The relevant specification may call for a preconditioning.

4.1.6 ***Initial measurements***

The specimen shall be submitted to visual, dimensional and functional checks prescribed by the relevant specification.

4.1.7 ***Testing***

The test chamber air shall be at a temperature high enough to ensure a relative humidity of 25 % or less. The specimen, while being at the ambient temperature of the laboratory, shall be introduced into the test chamber in the unpacked, switched-off, "ready for use" state, in its normal operating position or as otherwise specified in the relevant specification. In the case of multiple specimens, care shall be taken that the specimens neither touch each other nor shield each other against the influence of dust.

The relevant specification may call for the specimen to be switched on and/or operated during the test.

Dust shall be introduced into the chamber so that the specified concentration is maintained during the time specified for injection (category 1) or throughout the test duration (category 2).

At the end of the conditioning, the specimen shall remain in the closed test chamber until the dust has settled.

4.1.8 ***Intermediate measurements***

The relevant specification may call for measurements during or at the end of conditioning while the specimen is still in the test chamber. If such measurements are required, the relevant specification shall define the measurements and the period or periods after which they shall be carried out.

4.1.9 ***Recovery***

Unless otherwise required by the relevant specification, the specimen shall remain under standard atmospheric conditions for recovery for 2 h.

4.1.10 ***Cleaning***

The relevant specification may prescribe removal of external surface dust to be carried out prior to final measurements.

4.1.11 ***Final measurements***

After recovery the specimen shall be submitted to visual, dimensional and functional checks prescribed by the relevant specification.

4.1.12 *Information to be given in the relevant specification*

When this test is included in the 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 subclauses listed below, paying particular attention to the items marked with an asterisk (*) as this information is always required.

	Subclause
a) Procedure to apply if the size of the specimen does not comply with this standard	**4.1.3**
b) Category of enclosure and pressure reduction*	**4.1.4.6**
c) Severities*	**4.1.4.7**
— air pressure in the chamber*	
— duration of test*	
d) Preconditioning	**4.1.5**
e) Initial measurements*	**4.1.6**
f) State of specimen, electric loading or operating during testing*	**4.1.7**
g) Position of the specimen if different from the normal operating position	**4.1.7**
h) Intermediate measurements	**4.1.8**
i) Recovery	**4.1.9**
j) Cleaning of the specimen	**4.1.10**
k) Final measurement*	**4.1.11**

4.2 Method La2: constant air pressure

4.2.1 *Object*

The object of this test is to determine the degree of protection against ingress of fine dust into electrotechnical products.

4.2.2 *General description*

Method La2 is a dust tightness test in which the specimen is exposed to a heavily dust-laden air flow containing non-abrasive powder of particle size < 75 µm. The test does not simulate natural or induced environments.

A vertical downwards air flow is specified for the test.

Enclosures of a specified category are tested with the internal air pressure lower than the surrounding atmospheric air pressure in order to encourage the ingress of powder.

The specified quantity of powder ensures that the dust concentration is extremely high and uniform. No means for monitoring the dust density is specified.

4.2.3 *Description of test apparatus*

The test chamber shall expose the test specimen to a mainly vertical, downwards non-laminar air flow containing a specified quantity of test dust. For this purpose the powder will be agitated and blown into a sealed test chamber. Air will, if prescribed by the relevant specification, be extracted from the specimen by a vacuum pump to enable the dust-laden test chamber air to penetrate through gaps, bushings or the like into the specimen. The pressure reduction shall be adjustable and shall be monitored. The extraction rate shall be measured.

Dust settled in the test chamber shall be brought back into circulation.

The volume of the specimen shall be no more than 25 % of the test chamber volume, and its base shall be no more than 50 % of the horizontal working space surface of the test chamber.

If the size of the specimen does not comply with this standard, one of the following procedures shall be applied as prescribed by the relevant specification:

a) testing of individually enclosed sections of the product;

b) testing of representative parts of the products comprising components such as doors, ventilating openings, seats, shaft seals etc, with the delicate parts of the product such as terminals, collector rings etc. in position at the time of testing;

c) testing of smaller products having the same design details as full-scale products.

An example of a suitable test apparatus is given in Figure 4.

4.2.4 ***Test conditions***

4.2.4.1 *Test dust*

The test dust is identical to that prescribed in **4.1.4.1** for method La1.

4.2.4.2 *Dust concentration*

The quantity of test dust used for the test shall be at least 2 kg per cubic metre test chamber volume.

4.2.4.3 *Air flow*

The air flow in the test chamber shall be mainly vertical from top to bottom and it should not be laminar.

4.2.4.4 *Air velocity*

The air velocity shall give the possibility to generate a homogeneous distribution of the dust in the test chamber.

4.2.4.5 *Humidity*

The relative humidity in the test chamber shall be less than 25 %. This may be achieved by raising the test chamber air temperature (see clause **A.3**).

4.2.4.6 *Air pressure in the specimen*

Depending on the operating conditions there are two different categories of specimen enclosures.

Category 1: enclosures where an air pressure different from the environmental atmospheric air pressure may occur, for example caused by thermal cycling effects during operation.

Category 2: enclosures where the air pressure is that of the ambient air pressure.

The relevant specification shall state the category of the enclosure and the pressure reduction.

4.2.4.6.1 A specimen with a category 1 enclosure shall be introduced into the test chamber and mounted in its normal operating position. It shall then be connected to a vacuum pump which maintains the air pressure inside the specimen below atmospheric air pressure. For this purpose, a suitable hole in the enclosure should be provided. If there is already a drain hole for condensed water in the walls of the enclosure, the vacuum pipe shall be connected to this hole. No special hole for the test shall be drilled in this case. If there is more than one drain hole in the walls of the enclosure, the vacuum pipe shall be connected to one of them and the others shall be sealed during the test.

4.2.4.6.2 A specimen with a category 2 enclosure shall be introduced into the test chamber and mounted in its normal operating position. All ordinary openings in the enclosure shall be left open.

4.2.4.7 *Severities*

The severity defined by the air pressure and by duration of test, depending on the category of enclosure (see **4.2.4.6**) shall be prescribed by the relevant specification.

Category 1

Air pressure:

— 2 kPa (20 mbar), 5 kPa (50 mbar) or 10 kPa (100 mbar).

Duration of the test

— if, with the maximum reduced pressure stated in the relevant specification, the rate of air flow is less than 40 volumes per hour, the test shall be continued until 80 volumes have been drawn through, or a period of 8 h has elapsed.

— if a rate of air flow of 40 to 60 volumes per hour is attained, the duration is 2 h.

The object of the test is to extract from the specimen a volume of air corresponding to at least 80 times the free volume of air inside the enclosure of the specimen. However, the rate of extraction shall at no time exceed 60 volumes per hour.

Category 2

Air pressure:

— normal air pressure

Duration of the test:

— 8 h

4.2.5 ***Preconditioning***

The relevant specification may call for preconditioning.

4.2.6 ***Initial measurements***

The specimen shall be submitted to visual, dimensional and functional checks prescribed by the relevant specification.

4.2.7 ***Testing***

The test chamber air shall be at a temperature high enough to ensure a relative humidity of 25 % or less. The specimen, while being at the ambient temperature of the laboratory, shall be introduced into the test chamber in the unpacked, switched-off, "ready for use" state, in its normal operating position or as otherwise specified by the relevant specification. In the case of multiple specimens care shall be taken that the specimens neither touch each other nor shield each other against the influence of dust.

The relevant specification may call for the specimen to be switched on and/or operated during the test.

When the specimen has been introduced into the test chamber, the vacuum pump shall be connected and switched on if this applies (category 1).

The testing begins by injecting the test dust.

At the end of the conditioning the vacuum pump shall be switched off (category 1) and the specimen shall remain in the closed test chamber until the dust has settled.

4.2.8 ***Intermediate measurements***

The relevant specification may call for measurements during or at the end of the conditioning while the specimen is still in the test chamber. If such measurements are required, the relevant specification shall define the measurements and the period or periods after which they shall be carried out.

4.2.9 ***Recovery***

Unless otherwise required by the relevant specification, the specimen shall remain under standard atmospheric conditions for recovery for 2 h.

4.2.10 ***Cleaning***

The relevant specification may prescribe removal of external surface dust to be carried out prior to final measurements.

4.2.11 ***Final measurements***

After recovery, the specimen shall be submitted to visual, dimensional and functional checks prescribed by the relevant specification.

4.2.12 ***Information to be given in the relevant specification***

When this test is included in the relevant specification, the following details shall be given, insofar as they are applicable. The relevant specification shall supply information (see IEC 68-5-1 clause **11**) as required in the subclauses listed below, paying particular attention to the items marked with an asterisk(*) as this information is always required.

		Subclause
a)	Creation of a vacuum inside the specimen	**4.2.3**
b)	Procedure to be applied if the size of the specimen does not comply with this standard	**4.2.3**
c)	Category of enclosure and pressure reduction*	**4.2.4.6**
d)	Severities*	**4.2.4.7**
	— air pressure*	

— duration of the test*

e)	Preconditioning	**4.2.5**
f)	Initial measurements*	**4.2.6**
g)	State of specimen, electric loading or operation during testing	**4.2.7**
h)	Position of the specimen, if other than the normal operating position	**4.2.7**
i)	Intermediate measurements	**4.2.8**
j)	Recovery	**4.2.9**
k)	Cleaning	**4.2.10**
l)	Final measurements*	**4.2.11**

4.3 Guidance for test La

4.3.1 *Methods of verification of the degree of protection against ingress of dust into electrotechnical products*

The two main parameters of the test methods are:

a) a heavily non-abrasive dust laden air surrounding the specimen;

b) simulated pressure changes, relative to ambient surroundings or within the specimen.

It shall be emphasised that the described methods are designed as tightness tests, and are neither intended, nor suitable for simulation of any natural dust environment.

Basic philosophy and methods of generating the test conditions are described and alternatives for test dust are discussed.

Furthermore, severity and factors affecting reproducibility are described, and some comments to interpretation of results and safety precautions are given.

The test apparatus for method La2, described in **4.3.3.3** is identical to the test apparatus for the dust tightness test specified in IEC 529.

4.3.2 *Basic philosophy behind test La, non-abrasive fine dust test*

4.3.2.1 *General*

The purpose of tests carried out in accordance with test La is to determine the degree of protection offered by enclosures against ingress of fine dust into electrotechnical products.

Tests carried out in accordance with test La are primarily carried out in order to verify the dust tightness of the specimen, and secondarily to verify harmful effects of any dust penetrating into the specimen. Also safety and hazard effects of dust penetrating into the specimen can be verified by this dust test method.

Safety and hazard effects arising from dust in electrotechnical products may be electric shocks generated by conductive dust, or fire and explosions caused by combustible dust.

To analyze the requirements and limitations to the test method some reflections on dust sources, actions and effects are made in the following sub-clauses.

4.3.2.2 *Sources of dust*

The dust appearing in the surroundings of electrotechnical products is generated by several sources. The dust may be quartz, coal, deicing salts, fertilizers for example penetrating into the products, for instance through ventilating holes or leaking enclosures.

The dust may also be small fibres from cotton or wool, real or artificial, generated from cloth or carpets by normal use in living rooms and offices.

Other sources are dust from seeds in barns, or flour being ground in mills.

The particle size varies from fractions of a 1 µm to the order of 100 µm.

4.3.2.3 *Actions and effects of dust*

4.3.2.3.1 *Penetration*

Penetration of dust into a specimen can occur as follows. It can be:

— carried in by forced air circulation, for example for cooling purposes;

— carried in by thermal motion of the air;

— pumped in by variations in the atmospheric pressure caused by temperature changes;

— blown in by wind.

4.3.2.3.2 *Primary effects*

The dust itself can have one or more of the following harmful effects:

a) seizure of moving parts;

b) abrasion of moving parts;

c) adding mass to moving parts thereby causing unbalance;

d) deterioration of electric insulation;

e) deterioration of dielectric properties;

f) clogging of air filters;

g) reduction of thermal conductivity;

h) interference with optical characteristics.

4.3.2.3.3 *Secondary and combined effects*

The presence of dust, in combination with other environmental parameters, can have harmful effects on the specimen, for example corrosion and mould growth. Especially, a damp heat environment in connection with chemically aggressive dust causes corrosion. Furthermore, clogged filters and other reductions of ventilation or cooling may cause over-heating and fire hazard.

Investigation of the effects of non-conducting and corrosive dusts, for example de-icing salts can be carried out by a dust test using test dust mixed with the actual aggressive material, followed by a damp heat test.

However, in order to maintain reproducibility, dividing the investigation into a dust test using a neutral dust, followed by a standardized corrosion test should be considered.

In order to investigate effects caused by hygroscopic dust material, cotton linters may be mixed into the test dust, and follow the dust test by a corrosion test.

4.3.2.4 *Test for verification of tightness against dust*

4.3.2.4.1 *Movement of air into the specimen*

Looking at the mechanisms which support penetration of dust into the specimen (see **4.3.2.1**), it can be seen that an air movement into, or in and out of the specimen is needed for the test method.

The air movement can be accomplished by operating the specimen continuously or intermittently depending on its construction, (see **4.3.2.5**), or by creating a stream of air with a fan. The air movement can also be created by a continuous or cyclic air pressure change in the specimen, relative to ambient, using an air pressure system.

The latter way has been selected for the present method, as the object is to verify dust tightness primarily, and to maintain a high degree of reproducibility. It is also a relatively simple way to create the air movement. It can, in some cases, complicate interpretation of the tests results (see **4.3.8**).

4.3.2.4.2 *The chamber dust concentration*

The purpose of the test method is to verify the dust tightness of the specimen and not to simulate the dust conditions in which the specimen is intended to operate.

Consequently, the requirement of the chamber dust environment is only to establish a heavily dust laden volume of air surrounding the specimen. The dust concentration shall be very high compared with concentrations found under actual operational conditions either natural or man made, in order to get an ample amount of dust to facilitate investigation of dust ingress.

For information, the dust deposit rate of the present test method, (which shall not be monitored) is approximately 10^4 times the dust deposit rate of the free settling dust test method Lb.

4.3.2.4.3 *Constant versus cyclic pressure*

The present non-abrasive dust test La calls for a simulated pressure difference between the exterior and the interior of the specimen.

In the method La1 the pressure difference is cyclic and established by variation of the chamber pressure.

In the Method La2 the pressure difference is constant and established by connecting a vacuum pump to the specimen.

The advantages of method La1 are:

— the pressure difference is cyclic as normally found under operational conditions;

— the cyclic pressure does not tend to clog leakages with the test dust as observed when using constant pressure;

— as the cyclic pressure is established by variation of the chamber pressure, the integrity of the specimen is not affected, and further, no doubt arises in selecting an existing hole for the pump connection.

The advantage of method La2 is:

— the method La2 is recognized by many test laboratories and well-established in other IEC publications.

4.3.2.4.4 *Selection of dust particle size*

For evaluation of the dust tightness of a specimen, the test may be carried out with dust material of any kind. The major requirement is the particle size distribution which shall contain the smallest particle sizes found in actual operation locations. Only a soft material is needed to detect the tightness of a specimen. The reason to choose a soft material is to protect the specimen against abrasive effects.

4.3.2.5 *Operational state of the specimen during conditioning*

The operational state of the test specimen can affect dust penetration, depending on the type and characteristics of the specimen.

The pumping effect of a heat generating specimen of closed construction is simulated by the chamber air pressure system and therefore, the specimen can be in the switched off condition during conditioning.

Sealing of moving parts, for example motor shafts and push-buttons may be affected by the movement, and the specimen shall consequently be tested in the operational state.

The present dust test method is not suitable for testing specimens of open construction, for example specimens with open forced air cooling and specimens with ventilation openings for convection cooling, as the chamber dust concentration is too high to give reasonable interpretation of the results.

4.3.3 ***Methods of generating the test conditions***

4.3.3.1 *General requirements*

General requirements of the following parameters shall be fulfilled in order to generate reproducible test conditions:

a) dust concentration;

b) uniformity of dust distribution;

c) temperature;

d) relative humidity;

e) electrostatic charge build-up;

f) the simulated air pressure to the specimen;

g) dust characteristics

The parameters a) to f) are controlled by the design of the test apparatus. Guidance on design of the test apparatus is found in **4.3.3.2** and **4.3.3.3**. Guidance on selection of the test dust is found in **4.3.4**.

4.3.3.2 *Test apparatus for Method La1 (cyclic air pressure)*

4.3.3.2.1 *The test chamber*

An example of a suitable test chamber is shown in Figure 3. It is advised that the inner surface of the chamber is electrically conductive and grounded to avoid electrostatic charge build up. If electrostatic effects on the dust penetration into the specimen is the object of a test, the specimen has to be charged relative to the chamber.

The humidity is most conveniently controlled by raising the test chamber temperature. One way to establish isothermal conditions inside the chamber is a design consisting of an inner chamber made of aluminium, surrounded by an outer chamber made of thermal insulating material. Controlled heated air is circulated in the space between the inner and outer chamber. Air guide plates are situated in this space in order to distribute the steam of air evenly. The principle is equal to that of a free field temperature chamber.

The cyclic air pressure action on the specimen is established by variation of the test chamber pressure. That requires an air tight construction of adequate strength to withstand the specified pressure. (see **4.3.3.2.3**).

4.3.3.2.2 *The dust injection system*

The dust injection system shall be able to maintain a uniform suspension of dust with adequate density in the test chamber. This function can be realized using a screw conveyor to transport the dust from the bottom of the chamber to the top. The dust density can be controlled by the speed of the screw conveyor. Depending on the shape of the chamber bottom and the floating properties of the dust, a mixing device may be needed to guide the dust to the inlet of the screw conveyor. The uniformity of the suspended dust can be controlled by a fan placed horizontally at the outlet of the screw conveyor.

4.3.3.2.3 *The cyclic air pressure system*

Cyclic air pressure shall be introduced to the specimen in order to simulate natural pressure variations and consequently increase the possibility of penetration of dust into the specimen.

The cyclic air pressure is established by cyclic variation of the test chamber pressure.

A test pressure cycle consists of a low pressure phase followed by an ambient pressure phase inside the chamber.

The test cycle introduces an exchange of air from the outside to the inside of the specimen during the pressurization phase (i.e. return to ambient pressure).

The advantage of performing the pressure variation by changing the chamber pressure instead of changing the internal pressure of the specimen is keeping the integrity of the specimen (see **4.3.2.4.3**).

4.3.3.3 *Test apparatus for method La2 (constant air pressure)*

The constant air pressure test apparatus for method La2 is identical to the test apparatus described in IEC 529.

The test consists in placing the specimen in a suitable closed chamber in which talc is kept in suspension by a high velocity air stream. The air pressure inside the specimen is kept at a constant pressure below the ambient pressure. The test duration depends partly on the size of the specimen, partly on total leakage of the specimen, which determine the volume of air being exchanged.

The requirements and main features of the test apparatus are described in the following subclauses.

4.3.3.3.1 *The test chamber*

An example of a suitable test chamber is shown in Figure 4. Advice on the construction of the test chamber in order to maintain reproducibility of temperature, relative humidity and electrical charge build up, is given in **4.3.3.2.1**.

4.3.3.3.2 *The dust injection system*

The dust injection system shall be able to maintain a uniform suspension of dust with adequate concentration in the test chamber. This function is realized using an air loop system including a fan to circulate the dust. Means to establish a uniform dust deposit is needed and may be a secondary fan at the top of the chamber. The function can also be realized, using a screw conveyor system and a fan as described in **4.3.3.2.2**.

4.3.3.3.3 *The constant air pressure system*

The constant air pressure action to the specimen is established by connecting a vacuum pump to the specimen itself. This may in some cases interfere with the integrity of the specimen when drilling a hole in the enclosure is necessary (see **4.3.2.4.3**).

4.3.4 ***Test dust***

For evaluation of the dust tightness of a specimen, talc is specified as the standard dust but the test may be performed with dust material of any kind.

The major requirement is the particle size distribution which shall contain the smallest particle sizes found in actual operation locations. An average of 35 % by weight less than 1 μm is observed in various locations. Only a soft material is needed to detect the tightness of a specimen. The reason to choose a soft material is to protect the specimen against abrasive effects.

4.3.4.1 *Composition of the dust*

Five characteristics are of importance when selecting the grade of dust for the test:

a) availability;

b) hardness;

c) hygroscopicity;

d) chemical inactivity;

e) health hazard.

One readily available dust material for test La is talc. Talc is a magnesium silicate with a hardness of 1 on the Mohs scale, one of the softest minerals. Talc is highly hygroscopic which requires drying of the material before use for test in order to avoid agglomeration of the dust particles. For the same reason, the dust test shall be performed at elevated temperature to keep the relative humidity in the test chamber at least below 25 %. Talc is chemically inactive.

Another dust material for test La is fire extinguishing (FE) powder. FE powder consists of granulated sodium hydrogencarbonate ($NaHCO_3$) or potassium hydrogencarbonate ($KHCO_3$) coated with a metallic stearate. It has the advantage of being low hygroscopic caused by a sealing of the powder particles, which also makes the FE powder very easy flowing. The disadvantage of FE powder is that some FE powder materials are chemically aggressive, which may be harmful to the specimen if exposed to high humidity after the dust test. It is consequently advised to consult the manufacturer of FE powder concerning that matter. The FE powder has a hardness of approximately 3 on the Mohs scale.

Health hazard aspects are dealt with in clause **A.5**.

4.3.4.2 *Particle size distribution*

The test specification calls for a test dust which shall be able to pass through a square meshed sieve whose nominal wire diameter is 50 µm and the nominal width between wires is 75 µm. Optical analysis of a typical talc has given the following particle size distribution:

— smaller than 63 µm	100	% by weight;
— smaller than 40 µm	45	% by weight;
— smaller than 20 µm	9	% by weight;
— smaller than 10 µm	0,9	% by weight;
— smaller than 5 µm	less than 0,2	% by weight.

The following particle size distribution was found for a FE powder:

— smaller than 85 µm	100	% by weight;
— smaller than 40 µm	26	% by weight;
— smaller than 20 µm	5	% by weight;
— smaller than 10 µm	0,7	% by weight;
— smaller than 5 µm	less than 0,2	% by weight.

It can be seen that both powders have a very low content of small particles, (less than 0,2 % smaller than 5 μm) which calls for further investigations as natural dust contains high amounts below that particle size.

Talc will, however, during recirculating be ground down and will therefore contain a larger content of small particles when the test dust has been recirculated a couple of times.

For measuring of the particle size distribution several methods are available. Some are based on optical analysis of a sample of dust.

4.3.5 ***Severities of the test***

4.3.5.1 *Method La1*

The severity of method La1 is proportional to the duration of the conditioning (number of pressure cycles) and the pressure difference between the exterior and the interior of the specimen.

The severity can be changed by selecting proper values of the two parameters, but the maximum practical pressure difference is limited by the strength of the specimen and the chamber.

4.3.5.2 *Method La2*

The severity of method La2 is proportional to the duration of the conditioning and the pressure difference between the exterior and the interior of the specimen.

The severity can be changed by selecting proper values of the two parameters, but the maximum practical pressure difference is limited by the strength of the specimen.

4.3.5.3 *Specified severities*

The duration of conditioning and the pressure difference are determined by the characteristics of the specimen, whether this is of closed or open construction.

4.3.6 ***Reproducibility of the test***

The reproducibility of the non-abrasive fine dust test is dependent on the test parameters which are:

— relative humidity;

— dust concentration;

— dust uniformity;

— dust characteristics;

— simulated air pressure;

— duration of conditioning.

4.3.6.1 *Methods La1 and La2*

The relative humidity is normally kept below 25 % by raising the test temperature, in order to avoid agglomeration of the dust particles. In locations of high relative humidity, this requirement may necessitate the use of a dehumidifier system.

The dust concentration is extremely high and has consequently only a negligible influence on the reproducibility.

The dust uniformity has a high influence on the reproducibility and much care shall be taken to obtain a good dust uniformity.

The dust characteristics have a high influence on the reproducibility. In particular, the particle size distribution shall be checked in order to evaluate the content of small particle sizes (see **4.3.4.2**).

The duration or number of pressure cycles has a high degree of reproducibility.

4.3.6.2 *Method La1*

The pressure difference is cyclic as normally found under operational conditions.

The cyclic pressure does not tend to clog leakage paths by the dust as observed when using constant pressure.

Unlike method La2, the cyclic pressure is established by variation of the chamber pressure. The integrity of the specimen is not interfered with when drilling a hole for connection of the pump if needed, and no doubt arises in selecting an existing hole for the pump connection.

The said factors contribute to a high reproducibility of test method La1.

4.3.6.3 *Method La2*

Method La2 is recognized by many test laboratories and well established in other IEC publications.

This does not in itself balance the drawbacks of this method compared with method La1 (see **4.3.6.2**).

On the other hand, skilled test personnel, aware of the said drawbacks, are able to perform reproducible tests in accordance with the specified method La2.

4.3.7 ***Applicability limits of the test***

It is emphasized that the described method is designed as a tightness test, and is neither intended for, nor fit for simulation of any natural dust environment.

Only a soft material is needed to detect the tightness of a specimen. The reason to choose a soft material is to protect the specimen against abrasive effects.

Consequently no abrasive effects to the specimen can directly be evaluated using the test method.

4.3.8 ***Interpretation of results***

The interpretation of test results of the non-abrasive fine dust test may be somewhat difficult, especially to interpret the harmful effect to a specimen into which dust has penetrated. In the following subclauses, guidance is given for interpretation of results in some special cases.

4.3.8.1 *No penetration of dust is observed*

Interpretation of the result of this case is easy.

4.3.8.2 *Penetration of dust has been observed*

In this case, the interpretation of result is more difficult. The test engineer has to evaluate the harmful effect to the specimen and also hazardous effects arising from the penetrated dust.

4.3.8.3 *Harmful effects to the specimen*

Dust can have one or more of the harmful effects as detailed in **4.3.2.3.2** and **4.3.2.3.3** and these should be assessed where appropriate or applicable.

5 Test Lb: free settling dust

5.1 Object

The object of this test is to determine the effect of free settlement of fine dust on electrotechnical products. The test is applicable for simulation of environments in sheltered and enclosed spaces without special dust emitting processes and with negligible air movements (for example living rooms, offices, laboratories, room for light industry, store rooms, etc.) where dust may accumulate over a long period.

5.2 Method Lb

5.2.1 ***General description***

The test provides for a low concentration of a specified dust which is injected into the chamber at intervals and allowed to settle upon the specimen. The dust settlement rate is kept within specified limits, and the air velocity is kept near zero, so as not to interfere with the settlement of finer dust particles. The chamber temperature is raised above the ambient temperature in order to maintain a low relative humidity.

5.2.2 ***Description of test apparatus***

The test apparatus consists of a test chamber with the following characteristics:

— the horizontal area of the chamber shall be big enough to maintain the uniformity of the dust settlement on the specimen within the specified limits;

— the chamber shall be high enough to maintain an air velocity around the specimen near zero during conditioning;

— the inner surface of the chamber shall be electrically conductive and grounded in order to avoid static charge build-up;

— the relative humidity in the test chamber shall be less than 25 %. This may be achieved by raising the test chamber air temperature (see clause **A.3**).

The test dust shall be injected into the upper part of the chamber by means of a horizontal air flow which shall be high enough to diffuse the dust and produce a dust deposit of the specified uniformity on the specimen. The air flow when injecting dust shall not raise the air velocity at the specimen to more than 0,2 m/s.

The specific dust deposition and the uniformity shall be measured by placing suitable sample plates horizontally at positions near the specimen. The plates shall be weighed before and after conditioning. The specific dust deposition on the test area shall be (6 ± 1) g/m^2 measured over a period of 24 h.

An example of a suitable test apparatus is shown in Figure 5.

5.2.3 ***Test dust***

The test dust is specified in **6.1.4.1**, variant 1, fine dust.

Other test dusts such as composite test dusts (for example containing linters, soil or cement) may be considered for specific applications. These shall however, be carefully tailored and guidance for that is given in Annex A.

Re-use of the test dust is not permitted.

5.2.4 ***Severities***

The severity as indicated by the duration of conditioning shall be given in the relevant specification.

Duration: 1 day
3 days
10 days
30 days

5.2.5 ***Preconditioning***

The relevant specification may call for preconditioning.

5.2.6 ***Initial measurements***

The specimen shall be submitted to the visual, dimensional and functional checks prescribed by the relevant specification. All features of the specimen likely to affect the test results such as covers, sealings or filters shall be inspected to ensure that the instructions of the relevant specification have been followed.

5.2.7 ***Testing***

The test chamber shall be at the ambient temperature of the laboratory. The specimen shall be introduced into the chamber either in the unpacked switched off, "ready for use" state, or as otherwise specified in the relevant specification. Where a specified mounting position is required, it shall be prescribed in the relevant specification. The temperature of the chamber shall be raised to (40 ± 2) °C. The rate of change of temperature shall not exceed 0,1 °C per minute, or the chamber shall be allowed to stabilize thermally for at least 2 h. Then the specified dust shall be injected into the chamber for 1 min, followed by a period of 59 min for settling the dust. The period of injection shall be adjusted to produce the specified deposition rate.

Following conditioning the temperature of the chamber shall be lowered until it is within the limits for standard atmospheric conditions for testing. The rate of change of temperature shall not exceed 1 °C per minute averaged over a period of not more than five minutes. The chamber shall remain closed for a period sufficient to allow the dust to settle, to minimize the risk of dust inhalation. This may take up to 12 h.

5.2.8 ***Intermediate measurements***

The relevant specification may call for intermediate measurements of the specimen during conditioning. Intermediate measurements which would require removal of the specimen from the chamber are not permissible.

5.2.9 ***Recovery***

Unless otherwise required by the relevant specification, the specimen shall remain under standard atmospheric conditions for recovery for 2 h.

5.2.10 ***Final measurements***

The specimen shall be submitted to the visual, dimensional and functional checks prescribed by the relevant specification. Special attention shall be given to dust deposits on or inside the test specimen which may consequently lead to damage or malfunctioning of the specimen.

5.2.11 ***Information to be given in the relevant specification***

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

	Subclause
a) Type of dust, if other than standard	**5.2.3**
b) Severity*	**5.2.4**
— duration of the test	
c) Preconditioning	**5.2.5**
d) Initial measurements*	**5.2.6**
e) State ot the specimen as introduced into chamber	**5.2.7**
f) Mounting position if different from that of the normal operating position	**5.2.7**
g) Intermediate measurements	**5.2.8**
h) Recovery	**5.2.9**
i) Final measurements*	**5.2.10**

5.3 Guidance for test Lb

5.3.1 ***Methods of simulation***

This subclause describes methods of simulation designed to examine the effect of free settling dust on equipment and components.

The main characteristic of the environment to be simulated is fine dust as it appears in sheltered and enclosed locations, where the dust is settling without influence of air movements.

5.3.2 ***Properties and effects of dust in sheltered and enclosed locations***

5.3.2.1 *Sources of dust*

The dust appearing in closed or sheltered locations is generated by several sources. The dust may be for example quartz, de-icing salts or fertilizer, penetrating into the sheltered and enclosed locations, for instance through ventilating ducts or leaking windows.

The dust may also be small fibres from cotton or wool, real or artificial, generated from cloth or carpets by normal use in living rooms and offices.

Other sources are dust from seeds in barns, or flour being ground in mills.

Materials and particle size distributions differ depending on the type of dust. Common to them is the maximum particle size (see **5.3.3.2** and **5.3.4.3**).

5.3.2.2 *Actions and effects of dust*

In sheltered and enclosed locations with negligible air movement, the following actions and effects of dust are recognized.

5.3.2.2.1 *Settlement*

Settlement of dust on the specimen can occur due to four different mechanisms:

a) settlement in stagnant air;

b) settlement on sheltered surfaces;

c) attraction by electrostatic forces;

d) trapping in narrow openings.

Air movements tend to retard or inhibit the settlement of dust, and shall therefore be avoided in the work space of a test chamber.

Trapping in narrow spaces occurs in filters on specimens fitted with forced air-cooling devices.

5.3.2.2.2 *Penetration*

Penetration of dust into a specimen can occur as follows. It can be:

— carried in by forced air circulation, for example for cooling purposes;

— carried in by thermal motion of the air;

— pumped in by thermal expansion or variations in the atmospheric pressure caused by temperature changes.

5.3.2.2.3 *Primary effects*

The dust itself can have one or more of the following harmful effects:

a) seizure of moving parts;

b) abrasion of moving parts;

c) adding mass to moving parts thereby causing unbalance;

d) deterioration of electrical insulation;

e) deterioration of dielectric properties;

f) clogging of air filters;

g) reduction of thermal conductivity;

h) interference with optical characteristics.

5.3.2.2.4 *Secondary and combined effects*

The presence of dust in combination with other environmental parameters, can have harmful effects on the specimen, for example corrosion and mould growth. Especially a damp heat environment causes corrosion in connection with chemically aggressive dust. Furthermore, clogged filters and other reductions of ventilation or cooling may cause overheating and fire hazard.

5.3.3 ***Basic philosophy behind test Lb, free settling dust***

To cover the whole field of effects that dust may have on samples, numerous parameters shall be taken into consideration.

5.3.3.1 *Locations*

Outdoor dust environments, for example dust storms arising in desert locations, the local environment around a driving vehicle on dusty roads, create effects on specimens due to air movement, which differ considerably from the effects created by dust in sheltered or enclosed locations.

5.3.3.2 *Dust and sand characteristics*

A pronounced difference in the dust characteristics is present in the various locations.

In sheltered and enclosed locations dust materials of all kinds may be found, for example quartz, flour, cement, organic fibres, etc.

The particle size and particle size distribution also varies considerably depending on whether outdoor, driving vehicle or sheltered location is considered. In outdoor locations, the maximum grain size tends to be higher than in sheltered or enclosed locations due to the filtering effect of the shelter. The maximum grain size in sheltered or enclosed locations is in the order of 100 µm.

5.3.3.3 *Use of this method for other locations*

The above considerations have resulted in this test method which is primarily designed to verify the effect of dust on samples placed in sheltered or enclosed locations.

However, the test method can also in some cases be used to verify dust effects on samples placed in other locations.

As an example, the test method can be used to verify the quality of an air filter placed in the inlet of an air pollution sampler for outdoor use.

5.3.3.4 *Operational state of the specimen during conditioning*

The operational state of the test specimen can affect dust trapping and dust penetration, depending on the type and characteristics of the specimen.

Trapping of dust in narrow spaces occurs in filters on specimens fitted with forced air cooling. Such equipment should therefore be conditioned with the air-cooling system swiched on.

Penetration of dust occurs with heat-generating specimens with ventilating openings for convection cooling. Such specimens should preferably be tested in the switched on condition.

Heat generating specimens of closed construction should preferably be operated intermittently in order to obtain a pumping effect by thermal cycling.

5.3.4 ***Method of generating the test conditions***

5.3.4.1 *General requirements*

General requirements of the following parameters shall be fulfilled in order to generate reproducible test conditions:

a) dust settling concentration;

b) dust settling uniformity;

c) air velocity at the specimen;

d) temperature;

e) relative humidity;

f) electrostatic charge build-up;

g) dust characteristics.

Parameters a) to f) are controlled by design of the test apparatus. Guidance on design of the test apparatus is found in **5.3.4.2**. Guidance on selection of the test dust is found in **5.3.4.3**.

5.3.4.2 *The test apparatus*

In the following, sentences in italics are quoted from the Lb test method specification described in **5.2**.

The test apparatus consists of two main parts:

— the test chamber;

— the dust injection system.

5.3.4.2.1 *The test chamber*

The horizontal area of the chamber shall be big enough to maintain the uniformity of the dust settlement on the specimen within the specified limits.

The uniformity of the dust settlement is controlled by the dust injection system. It is very difficult to design a dust injection system which is able to keep the uniformity inside the specified limits over the entire horizontal area of the test chamber.

Experience has shown that a horizontal area of the test chamber, which is at least twice the horizontal area of the specimen, is suitable.

The chamber shall be high enough to maintain an air velocity around the specimen near zero during conditioning.

Near zero is arbitrarily chosen as 0,2 m/s. In order to avoid air movements around the specimen caused by the dust injection system, it has been found necessary to choose a chamber height which is four or five times the longer of the horizontal dimensions if they are not equal.

The inner surface of the chamber shall be electrically conductive and grounded in order to avoid electrostatic charge build up.

In order to control influence on the test conditions from electrostatic charge build up, the chamber itself shall be electrically conductive and grounded. If electrostatic effects on the dust sedimentation on the specimen is the object of a test, the specimen shall be charged relative to the chamber.

The relative humidity in the test chamber shall be less than 25 %.

The influence of humidity is most conveniently controlled by raising the test chamber temperature. One way to establish isothermal conditions inside the tower-shaped chamber is a design consisting of an inner chamber made of aluminium, surrounded by an outer chamber made of thermal insulating material. Temperature controlled air is circulated in the space between the inner and outer chamber. Air guide plates are situated in the space in order to distribute the stream of air evenly. The principle is equal to that of a free field temperature chamber.

See clause **A.3** regarding the relative humidity in the chamber.

5.3.4.2.2 *The dust injection system*

The test dust shall be injected into the upper part of the chamber by means of a horizontal air flow which shall be high enough to diffuse the dust and produce a dust deposit of the specified uniformity on the specimen.

In the following some design guides on the dust injection system are given:

In order to obtain the specified uniformity (6 ± 1) g/m^2/day, as measured by the dust collector plates, a volume of air of approximately 0.01 m^3 per cubic metre of the chamber shall be circulated during the injection period of 1 min.

A suitable air velocity through the injector system is approximately 2 m/s.

For a test chamber with a size of 10 m^3, the above figures result in a dust injection tube diameter of 33 mm.

It is recommended to choose a fan with variable speed in order to have the possibility to make a final adjustment of the dust deposit uniformity. Furthermore, guiding fins may have to be situated at the injector system outlet.

In order to minimize wear of the fan, the dust input to the injection system shall be at the fan outlet.

Dosage of the dust is a difficult matter. The following system has proved to operate quite well.

The cylinder glass contains the dust. The lid is equipped with a manifold through which compressed air is guided through fine holes into the glass. The air stream stirs up the dust and the dust is guided through a tube to the dust injection system.

The following parameters control the amount of dust being injected:

a) compressed air volume per unit of time (given by the air pressure and the total inlet area of the holes);

b) distance between inlet holes and top of dust (this distance shall be long compared with the height of the dust);

c) compressed air supply time.

The specific dust deposition and the uniformity shall be measured by placing suitable sample plates horizontally at positions near the specimen.

The amount of dust injected into the chamber can be checked by the weight loss of the dust container. This check is only a rough guide, as part of the injected dust tends to stick to the chamber walls. This effect acts as an apparently larger “horizontal” area of the chamber, and is dependent on the actual chamber design.

5.3.4.3 *The test dust*

The dust selected for the free settling dust test may be either actual dust from the environment for which the specimen is intended, or a standard test dust. For reproducibility reasons a standard test dust has been selected for the test method, and is preferred. This test dust is specified in **6.1.4.1**, variant 1, fine dust.

Olivine [$(Mg, Fe)_2SiO_4$] a commonly available industrial mineral used in foundries and for sand blasting.

Feldspars are chemical compositions of silica, alumina and alkali oxides. If undecomposed by the action of volcanic gases or water, these minerals are almost as hard as quartz.

The method for measuring of particle size distribution in **4.3.4.2** is recommended.

5.3.5 ***Severities of the test***

The severity as indicated by the duration of conditioning shall be given in the relevant specification.

The severity of the test is solely given by the duration of testing. Dust deposit per day is 6 g/m^2.

The relationship between the severity and real conditions is difficult to determine.

Real conditions vary considerably, and the purpose of the test is to demonstrate survival of the specimen in a reproducible way and not necessarily to imitate real conditions. The selected severity level may even be controlled by the importance of the function of the specimen.

Consequently, only guidelines can be given in order to have an idea of the relationship between the severity levels of the test and some values from real conditions.

5.3.5.1 *Reference values*

The following Table 2 is reproduced from IEC 721-2-5. The values have been converted from $mg/m^2/h$ to $g/m^2/d$.

Table 2 — Typical dust and sand sedimentation rates

Region	Dust and sand sedimentation $g/m^2/d$
Rural and suburban	0,01 – 0,36
Urban	0,36 – 1,00
Industrial	1,00 – 2,00

Based on those values and as *rough* guideline the acceleration factors in Table 3 are obtained.

Table 3 — Acceleration factor

Region	Acceleration factor
Rural and suburban	600 – 17
Urban	17 – 6
Industrial	6 – 3

5.3.6 ***Reproducibility of the test***

The reproducibility of the free settling dust test is dependent on the test parameters which are:

- — temperature;
- — relative humidity;
- — dust concentration;
- — dust composition;
- — duration of conditioning.

Temperature is easily controlled within the specified limits.

The relative humidity is normally kept below 25 % by conducting the test at (40 ± 2) °C. In warm and damp areas this requirement may necessitate the use of a dehumidifier system.

Dust concentration and uniformity require some experience and skill to keep within the specified limits. Measuring of the parameters (increase of weight of the sample plates) requires a high accuracy.

As the dust composition has a relevant effect on the specimen, it shall always be specified when other test dusts, or compositions of dust and other materials, than those specified are used.

The duration has a high degree of reproducibility.

5.3.7 ***Applicability limits of the test***

The applicability limits of the test is first and foremost the fact that this test method operates with free settling dust.

Consequently, no blast erosive effect on the specimen, for example impact erosion, impact crackling and shot peening, can be evaluated using this method.

5.3.8 ***Interpretation of results***

The interpretation of test results of the free settling dust test shall take into account the harmful effects arising from both settlement and penetration of dust. In the following, guidance is given on interpretation of results in some special cases.

5.3.8.1 *Harmful effects to the specimen*

Dust can have one or more of the harmful effects as detailed in **5.3.2.2.3** and **5.3.2.2.4** and these should be assessed where appropriate or applicable.

5.3.8.2 *Settlement and penetration of dust have been observed*

The harmful effects (see **5.3.2.2.3**), a), b) and c), are evaluated by inspection after conditioning, where the specimen has been operated in accordance with the relevant specification.

The effects d) and e) shall be evaluated assuming the dust to be conducting, ion-conducting when wet, or chemically aggressive. The dust test may be followed by a humidity or corrosive test in order to improve the confidence of the interpretation.

The harmful effects f), g) and h) are verified by functional tests of the specimen after testing, perhaps including measurements of temperature rise.

5.3.8.3 *Settlement, but no penetration of dust is observed*

Verification of the effect arising from settlement of dust on outer surfaces is performed by functional tests of the specimen, including operation of knobs and keys.

Settlement on outer cooling surfaces may necessitate measurements of temperature rise of the specimen.

6 Test Lc: blown dust and sand

In this test use of the word “dust” covers dust or sand as appropriate.

6.1 Method Lc1: recirculating chamber

6.1.1 *Object*

The object of this test is to determine possible harmful effects on electrotechnical products from particulate matter carried by a stream of air. The test is applicable for the simulation of open air dust environments induced by natural conditions or man-made disturbances such as vehicle movements.

It may also be used in place of test La for investigation of the degree of protection against ingress of fine dust into electrotechnical products.

6.1.2 *General description of the test*

Method Lc1 is a dust test in which the specimen is exposed to an airflow containing dust of specified particle size. A horizontal airflow is specified for the test because both the wind movement and the main moving direction of objects are prevalently horizontal for the majority of practical cases.

Continuous monitoring and control of the dust density is specified.

6.1.3 *Description of test apparatus*

The test apparatus consists of a chamber with the following characteristics:

— the test chamber shall provide a constant horizontal laminar air flow containing a specified quantity of test dust;

— the test chamber should have a nearly cubic shape. The lengths of the edges within the flow cross-section shall be at least three times the maximum vertical and horizontal edge length of the specimen in a cross-section plan being perpendicular to the flow direction. Means should be available for heating or cooling of the test chamber;

— control of the dust concentration shall be achieved by a sensor (for example measuring of reflected light) and a continuously working control device controlling a dosage valve. The test dust shall be injected intermittently through the dosing valve into the air channel;

— a mounting plate shall be provided for the mounting of the specimen. The mounting plate should allow the test specimen to be rotated in order to expose all sides of the specimen to the flow of the dust;

— appropriate devices may be provided to operate the specimen during testing;

— the materials used for the test apparatus shall be resistant to temperature and the test dust. The materials used shall not affect the characteristics of the test dust.

If the size of the specimen does not comply with this standard, one of the following procedures shall be applied as prescribed by the relevant specification:

a) testing of individually enclosed sections of the product;

b) testing of representative parts of the product comprising components such as doors, ventilating openings, seats, shaft seals, etc. with the delicate parts of the product such as terminals, collector rings, etc. in position at the time of testing;

c) testing of smaller products having the same design details as full-scale products.

An example of a suitable test apparatus is shown in Figure 6.

6.1.4 ***Test conditions***

6.1.4.1 *Test dust*

The dust shall be clean, free from carbonaceous material or other impurities and shall be used in a dry condition. The material shall consist of olivine, quartz or undecomposed feldspar.

The particle size distribution shall lie within the limits of:

Variant 1: fine dust

- smaller than 75 µm 100 % to 96 % by weight;
- smaller than 40 µm 87 % to 81 % by weight;
- smaller than 20 µm 70 % to 64 % by weight;
- smaller than 10 µm 52 % to 46 % by weight;
- smaller than 5 µm 38 % to 32 % by weight;
- smaller than 2 µm 20 % to 15 % by weight.

Variant 2: coarse dust

- smaller than 150 µm 100 % to 99 % by weight;
- smaller than 105 µm 86 % to 76 % by weight;
- smaller than 75 µm 70 % to 60 % by weight;
- smaller than 40 µm 46 % to 35 % by weight;
- smaller than 20 µm 30 % to 20 % by weight;
- smaller than 10 µm 19 % to 11 % by weight;
- smaller than 5 µm 11 % to 5 % by weight;
- smaller than 2 µm 5 % to 1,5 % by weight.

Variant 3: sand

- smaller than 850 µm 100 % to 94,5 % by weight;
- smaller than 590 µm 98,3 % to 93,3 % by weight;
- smaller than 420 µm 83,5 % to 74,5 % by weight;
- smaller than 297 µm 46,5 % to 43,5 % by weight;
- smaller than 210 µm 17,9 % to 15,9 % by weight;
- smaller than 149 µm 5,2 % to 4,2 % by weight.

Other test dusts such as "composite test dusts" (for example containing linters, soil or cement) may be considered for specific applications. These shall, however, be carefully tailored and guidance for that is given in Annex A.

6.1.4.2 *Dust concentration*

The dust concentration shall be selected from the following concentrations:

1 g/m^3 ± 0,3 g/m^3

2 g/m^3 ± 0,5 g/m^3

5 g/m^3 ± 1,5 g/m^3

10 g/m^3 ± 3 g/m^3

as required by the relevant specification.

6.1.4.3 *Air flow*

The air flow in the test chamber shall be primarily laminar, i.e. with only small turbulence, and horizontal.

6.1.4.4 *Air velocity*

The air velocity shall be selected from the following velocities:

V	V^2
1,5 m/s ± 0,2 m/s	2,25
3,0 m/s ± 0,3 m/s	9
5,0 m/s ± 0,5 m/s	25
10 m/s ± 1 m/s	100
15 m/s ± 1,5 m/s	225
20 m/s ± 2 m/s	400
30 m/s ± 3 m/s	900

As required by the relevant specification.

For coarse dust, velocities below 5 m/s are not recommended. For sand, only 20 m/s and 30 m/s applies.

Care shall be taken, in particular when using the higher air velocities, that the maximum operating temperature of the specimen is not exceeded.

6.1.4.5 *Air pressure in the specimen*

Depending on the relevant operating conditions there are two different categories of specimen enclosures.

Category 1: the air pressure within the specimen differs from the atmospheric air pressure (reduced).

Category 2: the air pressure in the specimen is that of the ambient air pressure.

See **6.3.4.2.3**

The relevant specification shall state the category of the enclosure and the pressure reduction (category 1).

6.1.4.6 *Humidity*

The relative humidity in the test chamber shall be less than 25 %. This may be achieved by raising the test chamber temperature (see clause **A.3**).

6.1.4.7 *Duration*

The duration of exposure shall be measured from the switching on of the test apparatus. The duration shall be selected from the following:

2 h,
4 h,
8 h,
24 h,

or as stated in the relevant specification.

6.1.4.8 *Mounting*

The specimen shall be mounted on the mounting plate of the test chamber in its normal operating position or as otherwise stated in the relevant specification.

6.1.4.9 *Severities*

The severity is defined by:

- dust concentration (see **6.1.4.2**);
- air velocity (see **6.1.4.4**);
- duration of exposure (see **6.1.4.7**);
- air pressure:

category 1: pressure reduction of 2 kPa (20 mbar), 5 kPa (50 mbar) or as stated in the relevant specification,

category 2: ambient air pressure,

as required by the relevant specification.

6.1.5 ***Preconditioning***

The relevant specification may call for preconditioning.

6.1.6 ***Initial measurements***

The specimen shall be submitted to the visual, dimensional and functional checks prescribed by the relevant specification.

6.1.7 ***Testing***

The test chamber air shall be at a temperature high enough to ensure a relative humidity of 25 % or less. The specimen, while being at the ambient temperature of the laboratory, shall be introduced into the test chamber in the unpacked, switched-off, "ready for use" state, in its normal operating position or as otherwise specified. In the case of multiple specimens, care shall be taken that the specimens neither touch each other nor shield each other against the influence of dust in an inappropriate manner.

If required by the relevant specification, the specimen shall be switched on and/or operated during the test. The conditioning begins when injecting the test dust.

At the end of the conditioning, the specimen shall be left in the closed test chamber until the dust has settled.

6.1.8 ***Intermediate measurements***

The relevant specification may call for measurements during or at the end of conditioning while the specimen is still in the test chamber. If such measurements are required, the relevant specification shall define the measurements and the period or periods after which they shall be carried out.

6.1.9 ***Recovery***

Unless otherwise specified by the relevant specification, the specimen shall remain under standard atmospheric conditions for recovery for 2 h.

6.1.10 ***Cleaning***

The relevant specification may prescribe removal of external surface dust to be carried out prior to final measurements.

6.1.11 ***Final measurements***

After recovery the specimen shall be submitted to the visual, dimensional and functional checks prescribed by the relevant specification.

6.1.12 ***Information to be given in the relevant specification***

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

		Subclause
a)	Type of dust*	**6.1.4.1**
b)	Category of enclosure*	**6.1.4.5**
c)	Severities	
	— dust concentration*	**6.1.4.2**
	— air velocity*	**6.1.4.4**
	— duration*	**6.1.4.7**
	— air pressure*	**6.1.4.9**
d)	Preconditioning	**6.1.5**
e)	Initial measurements*	**6.1.6**
f)	State of specimen, operation during testing	**6.1.7**
g)	Mounting position if different from that of the normal	**6.1.4.8** and **6.1.7**

h)	Intermediate measurements	**6.1.8**
i)	Recovery	**6.1.9**
j)	Cleaning of the specimen	**6.1.10**
k)	Final measurements*	**6.1.11**

6.2 Method Lc2: free blowing dust

6.2.1 *Object*

The object of this test is to determine possible harmful effects on electrotechnical products from particulate matter carried by a stream of air. The test is applicable for simulation of environments in dusty open-air areas and also for test specimens that are of a size where it is impossible to carry out test method Lc1. Methode Lc2 can also, due to its capability of inducing high air velocities, simulate the abrasive effects of dust and sand.

6.2.2 *General description of the test*

Method Lc2 is a test in which the specimen is exposed to a dust laden airflow containing dust of specified particle size. A horizontal, primarily laminar airflow is specified for the test as both the wind movement and the main moving direction of technical objects are horizontal for the majority of practical cases.

Permanent monitoring of the dust concentration is specified.

6.2.3 *Description of test apparatus*

The essential equipment for this test is:

One (or several), air mover(s) arranged in a way that a reasonably homogeneous laminar and horizontal air flow can be produced. Arrangements to prevent interference from environmental factors such as wind and precipitation shall be made as appropriate.

The air mover should have a device that injects the test dust in accordance with Figure 7. The test dust shall be injected evenly and the control of the concentration shall be achieved by a sensor, (for example measuring reflected light).

For low air velocities, less than some 10 m/s, the air mover can be a fan but for higher velocities an ejector-type device driven by compressed air is more suitable.

6.2.4 *Test conditions*

6.2.4.1 *Test dust*

The composition and particle size distribution of the test dust, as required by the relevant specification, is specified in **6.1.4.1**.

6.2.4.2 *Dust concentration*

The dust concentration shall be selected from those specified in **6.1.4.2**.

6.2.4.3 *Air flow*

The air flow in the test chamber shall be primarily laminar, i.e. with only small turbulence, and horizontal.

6.2.4.4 *Air velocity*

The air velocity shall be selected from those specified in **6.1.4.4**.

Two additional velocities are specified for test method Lc2:

V	V^2
50 m/s ± 5 m/s	2 500
100 m/s ± 10 m/s	10 000

6.2.4.5 *Humidity*

This test is not sensitive to the relative humidity as such but it is important that the test dust and the arrangements to feed it into the airstream ensure dry conditions, in order to ensure that clogging and agglomeration of the actual test dust is avoided.

6.2.4.6 *Duration*

The duration of exposure shall be measured from the switching on of the test apparatus. The duration shall be selected from the following:

2 h,

4 h,

8 h,

24 h,

or as stated in the relevant specification.

6.2.4.7 *Mounting*

The specimen shall be mounted on a pedestal or mounted in its normal configuration or as otherwise stated in the relevant specification.

6.2.4.8 *Severities*

The severity is defined by:

— dust concentration (see **6.2.4.2**);

— air velocity (see **6.2.4.4**);

— duration of exposure (see **6.2.4.6**);

as required by the relevant specification.

6.2.5 ***Preconditioning***

The relevant specification may call for preconditioning.

6.2.6 ***Initial measurements***

The specimen shall be submitted to the visual, dimensional and functional checks prescribed by the relevant specification.

6.2.7 ***Testing***

The test specimen shall be at the ambient temperature of the laboratory or similar test area. The specimen shall be mounted in the unpacked, switched-off "ready for use" state, in its normal operating position or as otherwise specified. In the case of multiple specimens, care shall be taken that the specimens neither touch each other nor shield each other against the influence of the dust.

If required by the relevant specification the specimen shall be switched on and/or operated during the test. The conditioning begins when injecting the dust.

At the end of the conditioning the specimen shall be left in the test area until the dust has settled.

6.2.8 ***Intermediate measurements***

The relevant specification may call for measurements during or at the end of conditioning while the specimen is still in the test environment. If such measurements are required, the relevant specification shall define the measurements and the period or periods after which they shall be carried out.

6.2.9 ***Recovery***

Unless otherwise specified by the relevant specification the specimen shall remain under standard atmospheric conditions for recovery for 2 h.

6.2.10 ***Cleaning***

The relevant specification may prescribe removal of external surface dust to be carried out prior to final measurements.

6.2.11 ***Final measurements***

After recovery the specimen shall be submitted to the visual, dimensional and functional checks prescribed by the relevant specification.

6.2.12 *Information to be given in the relevant specification*

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

		Subclause
a)	Test dust*	**6.2.4.1**
b)	Severities*	
	— dust concentration*	**6.2.4.2**
	— air velocity*	**6.2.4.4**
	— duration*	**6.2.4.6**
c)	Preconditioning	**6.2.5**
d)	Initial measurements*	**6.2.6**
e)	State of specimen, operation during testing	**6.2.7**
f)	Mounting position if different than the normal operating position	**6.2.4.7** and **6.2.7**
g)	Intermediate measurements	**6.2.8**
h)	Recovery	**6.2.9**
i)	Cleaning of the specimen	**6.2.10**
j)	Final measurements*	**6.2.11**

6.3 Guidance for test Lc

6.3.1 *Methods of simulation*

This subclause describes methods of simulating the effects of blown dust and sand on equipment and components.

The characteristic of the environment to be simulated is blown particles as it appears in dusty regions or induced by vehicles.

6.3.2 *Properties and effects of blown dust and sand*

6.3.2.1 *Sources*

The blown dust and sand are generated by several sources, but the most common are quartz and soil from the ground in almost all regions.

Materials and particle size distribution differ with the various dusts. Common to them is the maximum particle size (see **6.3.3.2** and **6.3.4.4**).

6.3.2.2 *Action and effects of dust and sand*

For equipment that is exposed to blown dust and sand, natural or induced, the following actions and effects of dust and sand are recognized:

6.3.2.2.1 *Penetration*

Penetration of dust and sand into a specimen can occur as follows. It can be:

— blown in by wind;

— carried in by forced air-circulation, for example for cooling purposes.

6.3.2.2.2 *Primary effects*

The dust and/or sand itself can have one or more of the following harmful effects:

a) seizure of moving parts;

b) abrasion of moving parts;

c) adding mass to moving parts thereby causing unbalance;

d) deterioration of electric insulation;

e) deterioration of dielectric properties;

f) clogging of air filters;

g) reduction of thermal conductivity, causing overheating and fire hazard;

h) interference with optical characteristics.

6.3.2.2.3 *Secondary and combined effects*

The presence of dust in combination with other environmental parameters, can have harmful effects on the specimen, for example corrosion and mould growth. Especially damp heat environment causes corrosion in connection with chemically aggressive dust. Furthermore, clogged filters and other reductions of ventilation or cooling may cause overheating and fire hazard.

6.3.3 ***Basic philosophy behind test Lc, blown dust and sand***

To cover the whole field of effects that dust and sand may have on samples, several parameters have to be taken into consideration.

6.3.3.1 *Locations*

Outdoor dust and sand environments, for example dust storms arising in desert locations, the local environment around a driving vehicle or an aircraft in dusty areas, create effects on samples due to air movement.

6.3.3.2 *Dust and sand characteristics*

The dust and sand characteristics are different in different locations.

The dust is mainly quartz or feldspar but other dust materials of all kinds may be mixed with it, for example cement, limestone, clay etc.

6.3.3.3 *Operational state of the specimen during testing*

The operational state of the test specimen can affect dust trapping and dust penetration, depending on the type and characteristics of the specimen.

Trapping of dust in narrow spaces occurs in filters of specimens with forced air cooling. Such equipment should therefore be conditioned with the air-cooling system switched on.

Penetration of dust occurs with heat generating specimens with ventilating openings for convection cooling. Such specimens should preferably be tested in the switched on condition.

Heat-generating specimens of closed construction should preferably be operated intermittently in order to obtain a pumping effect by thermal cycling.

6.3.4 ***Method of generating the test conditions***

6.3.4.1 *General requirements*

General requirements to the following parameters shall be fulfilled in order to generate reproducible test conditions:

a) dust or sand concentration;

b) dust concentration uniformity;

c) air velocity at the specimen;

d) temperature;

e) relative humidity;

f) electrostatic charge build-up;

g) dust characteristics.

Parameters a) to f) are controlled by the design of the test apparatus. Guidance on design of the test apparatus is found in **6.3.4.2** and **6.3.4.3**. Guidance on selection of the test dust is found in **6.3.4.4**

6.3.4.2 *Test apparatus for method Lc1*

The test apparatus consists of three main parts:

— the test chamber;

— the injection system;

— the specimen pressure control system.

6.3.4.2.1 *Test chamber*

The test chamber should have a nearly cubic shape. The lengths of the edges within the flow cross-section shall be at least three times the maximum vertical and horizontal edge length of the specimen in a cross-section plane being perpendicular to the flow direction. Means should be available for heating or cooling of the test chamber.

It shall expose the test specimen to a constant, horizontal and primarily laminar air flow containing a specified quantity of test dust.

The chamber shall have a pre-chamber just upstream of the actual test chamber, both chambers having the same flow cross-section. With air guide vanes arranged immediately behind the inlet aperture of the air channel leading to the pre-chamber a laminar horizontal air flow can be produced by the complete arrangement. A blower generating the air flow in the test apparatus is arranged immediately after the test chamber. It will extract the air from the test chamber and will feed it back into the pre-chamber by means of an air channel.

Below the test chamber a collecting tank is arranged for the test dust. In this way a decrease of the circulating dust quantity will be obtained and the dust density control made more effective.

A mounting plate shall be provided for the mounting of the specimen. The mounting plate shall allow the test specimen to be rotated in order to expose all sides of the specimen to the flow of dust.

The materials used for the test apparatus shall be resistant to temperature, humidity and the test dust. The materials used shall not affect the characteristics of the test dust.

6.3.4.2.2 *Injection system*

The test dust shall be intermittently injected into the air channel by a dosage valve.

The reservoir that contains the test dust shall be designed in such a way that clogging and agglomeration is avoided. This can be made by blowing warm dry compressed air through the test dust reservoir.

Control of the dust density shall be achieved by a sensor and a continuously working control device controlling the dosing valve.

One possible sensor is a device that has an optical fibre cable that leads light to the test chamber. Another optical fibre cable leads the light that is reflected by dust particles to a photocell in the sensor.

6.3.4.2.3 *Air pressure in the specimen*

Depending on the relevant operating conditions there are two different categories of test specimen enclosures.

Category 1: inside this category of specimen enclosure an air pressure drop below the environmental atmospheric air pressure may occur, for example caused by thermal cycling effects during operation.

A category 1 specimen enclosure, when installed in the test chamber will be connected to a vacuum pump which maintains the air pressure inside the specimen below atmospheric air pressure. For this purpose a suitable hole in the enclosure should be provided. If there is already a drain hole for condensed water in the walls of the specimen, the vacuum pipe shall be connected to this hole. No special hole for the test shall be drilled in this case. If there is more than one drain hole in the walls of the specimen, the vacuum pipe shall be connected to one of them and the others shall be sealed during the test.

The value of pressure difference shall be specified in the relevant specification.

Category 2: inside this category of specimen enclosure, drop below the environmental atmospheric air pressure will not occur.

A category 2 specimen enclosure will not be connected to a vacuum pump.

For any electrotechnical product to be tested, the category of the specimen shall be stated in the relevant specification.

The relevant specification may specify that the test specimen shall be installed on a rotating mounting plate during conditioning. By this method the influence of dust on the side walls of the specimen is more homogeneous.

6.3.4.3 *Test apparatus for method Lc2*

The test apparatus consists of two main parts:

— the device which generates the airflow (air mover);

— the injection system.

6.3.4.3.1 *Air mover*

To induce the specified air velocity two air movers are suitable.

For air velocities less than or equal to 10 m/s, a fan with variable speed can be used.

If higher air velocities are required an air mover powered by compressed air is suitable. This air mover is based upon the "Coanda effect".

To prevent the natural wind velocities interfering, if the test is done outdoors, the air mover and the test specimen shall be sheltered in an appropriate way. This arrangement shall also prevent precipitation interfering with the test.

6.3.4.3.2 *Injection system*

The test dust is injected into the airstream.

One possible injection system is shown in Figure 7.

The test dust is in a controlled dry atmosphere which prevents clogging and agglomeration. The dust or sand is transported by a small bucket elevator to an inclined table which by vibrations induced by a shaker passes it to the ejector.

It is important that the placing of the injection systems does not interfere with the airstream.

Control of the dust density shall be achieved by a sensor (for example measuring of reflected light).

6.3.4.4 *Test dust/sand*

Two standard dusts and one standard sand are specified and preferred. However, the relevant specification may prescribe another dust or sand. Details of the test dusts or test sand are given in **6.1.4.1**.

For measuring the particle size distribution several methods are available. Some are based on optical analysis of a sample of the dust or sand.

6.3.5 ***Severity of the test***

The duration of exposure shall be measured from the switching on of the test apparatus. The duration shall be selected from the following:

2 h,

4 h,

8 h,

24 h,

or as specified in the relevant specification.

6.3.5.1 *Method Lc1*

The severity of method Lc1 is proportional to the duration of the conditioning and the air velocity in the test chamber.

6.3.5.2 *Method Lc2*

The severity of method Lc2 is proportional to the duration of the conditioning and the air velocity around the specimen.

6.3.6 ***Reproducibility of the test***

The reproducibility of the blowing dust test is dependent on the test parameters which are:

a) temperature;

b) relative humidity;

c) dust concentration;

d) dust uniformity;

e) dust characteristics;

f) duration of conditioning.

Temperature is easily controlled inside the specified limits for method Lc1, but is more difficult, and could be impossible, if method Lc2 is performed outdoors.

The relative humidity shall be kept below 25 % (Lc1). In warm and damp areas this requirement may necessitate the use of a dehumidifier system (see clause **A.3**).

The dust or sand uniformity has a higher influence on the reproducibility and much care shall be taken to obtain a good dust or sand uniformity.

The dust characteristics have a high influence on the reproducibility. The particle size distribution shall be checked in order to evaluate the content of small particle sizes.

The duration has a high degree of reproducibility.

6.3.7 ***Applicability limits of the test***

The applicability limits of the test are first and foremost the fact that this test method operates with blowing dust.

6.3.8 ***Interpretation of results***

The interpretation of test results of the blowing dust test shall take into account the harmful effects from penetrated dust. In the following, guidance is given on interpretation of results in some special cases.

6.3.8.1 *Harmful effects to the specimen*

Dust can have one or more of the following harmful effects:

a) seizure of moving parts;

b) abrasion of moving parts;

c) deterioration of electric insulation;

d) deterioration of dielectric properties;

e) clogging of air filters;

f) reduction of thermal conductivity, causing overheating and fire hazard;

g) optical interference;

h) erosion/abrasion of surfaces.

The harmful effects a) and b) are evaluated by inspection after conditioning, where the specimen has been operated in accordance with the detailed specification.

The effects c) and d) have to be evaluated assuming the dust to be conducting, ion-conducting when wet, or chemically aggressive. The dust test may be followed by a humidity or corrosive test in order to improve the confidence of the interpretation.

The harmful effects e), f) and g) are verified by a functional test of the specimen after conditioning, perhaps including measurements of temperature rise.

The effects of h) can be visually assessed.

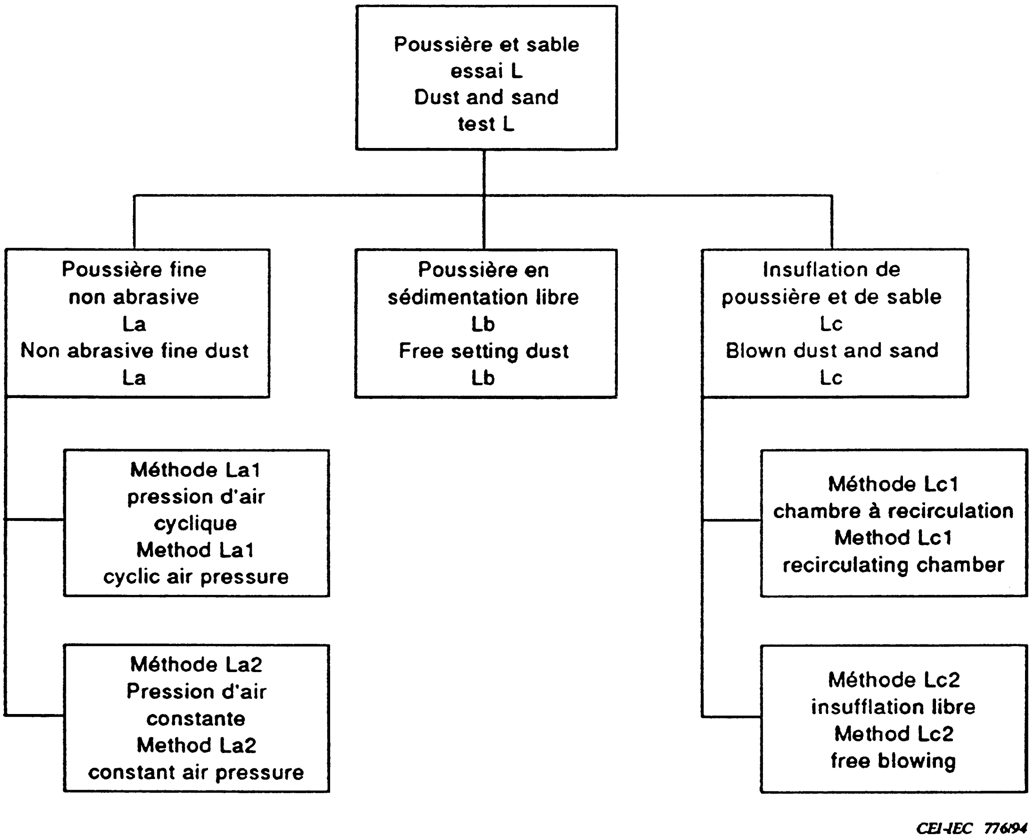

Figure 1 — Structuring of test methods

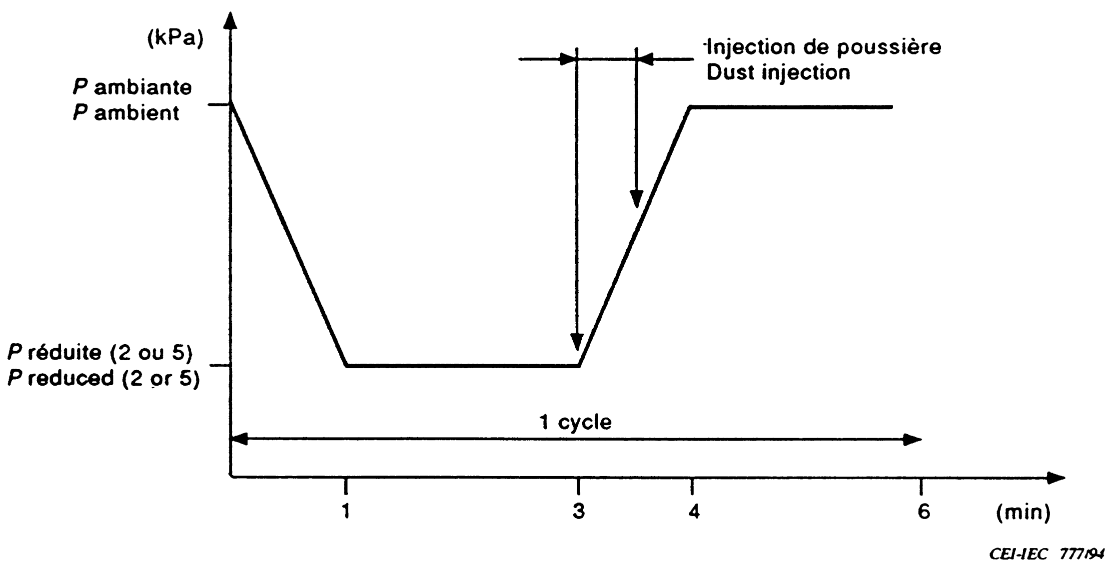

Figure 2 — Pressure cycle in the test chamber — Category 1

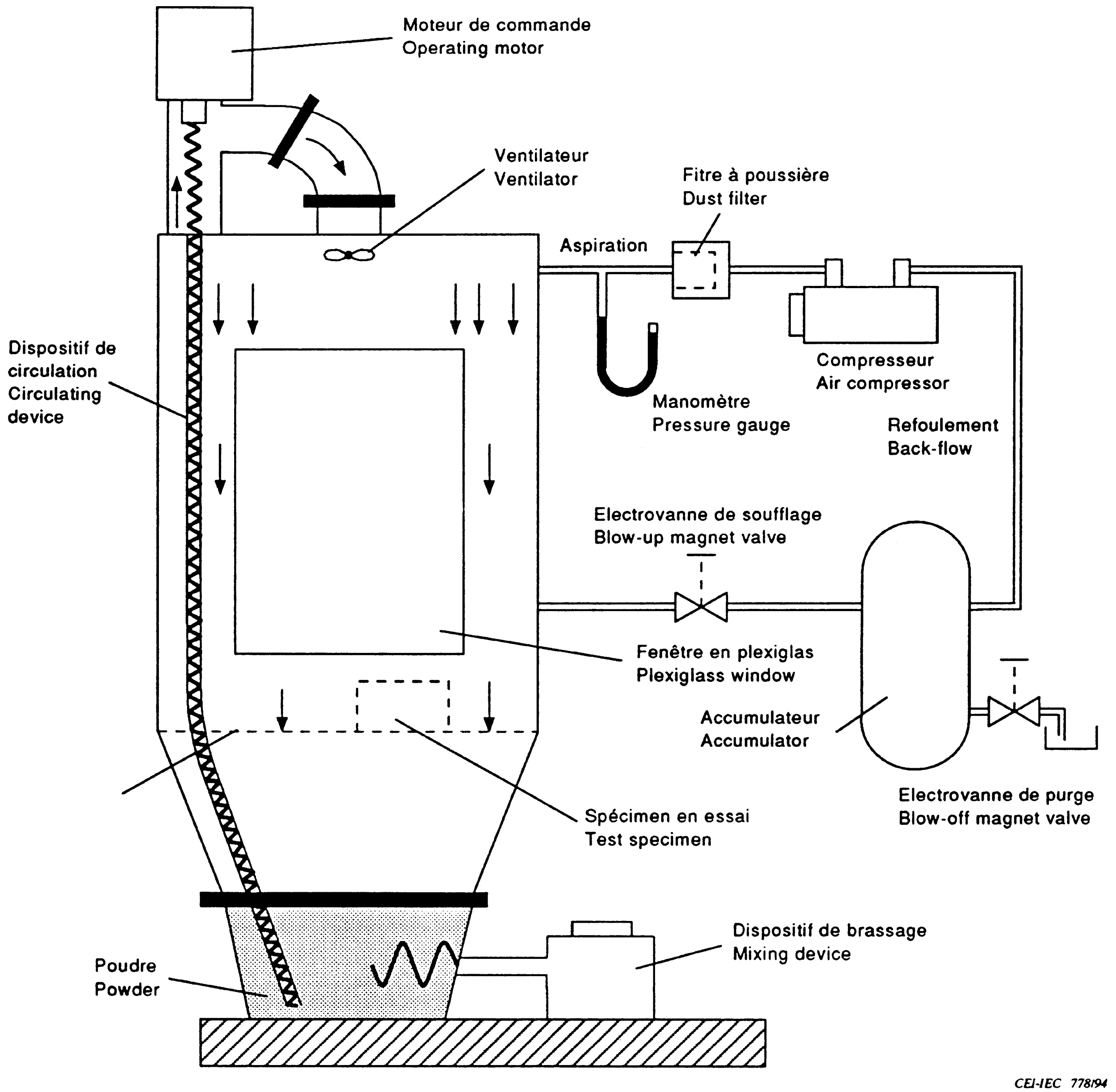

Figure 3 — Example of a suitable test chamber for method La1

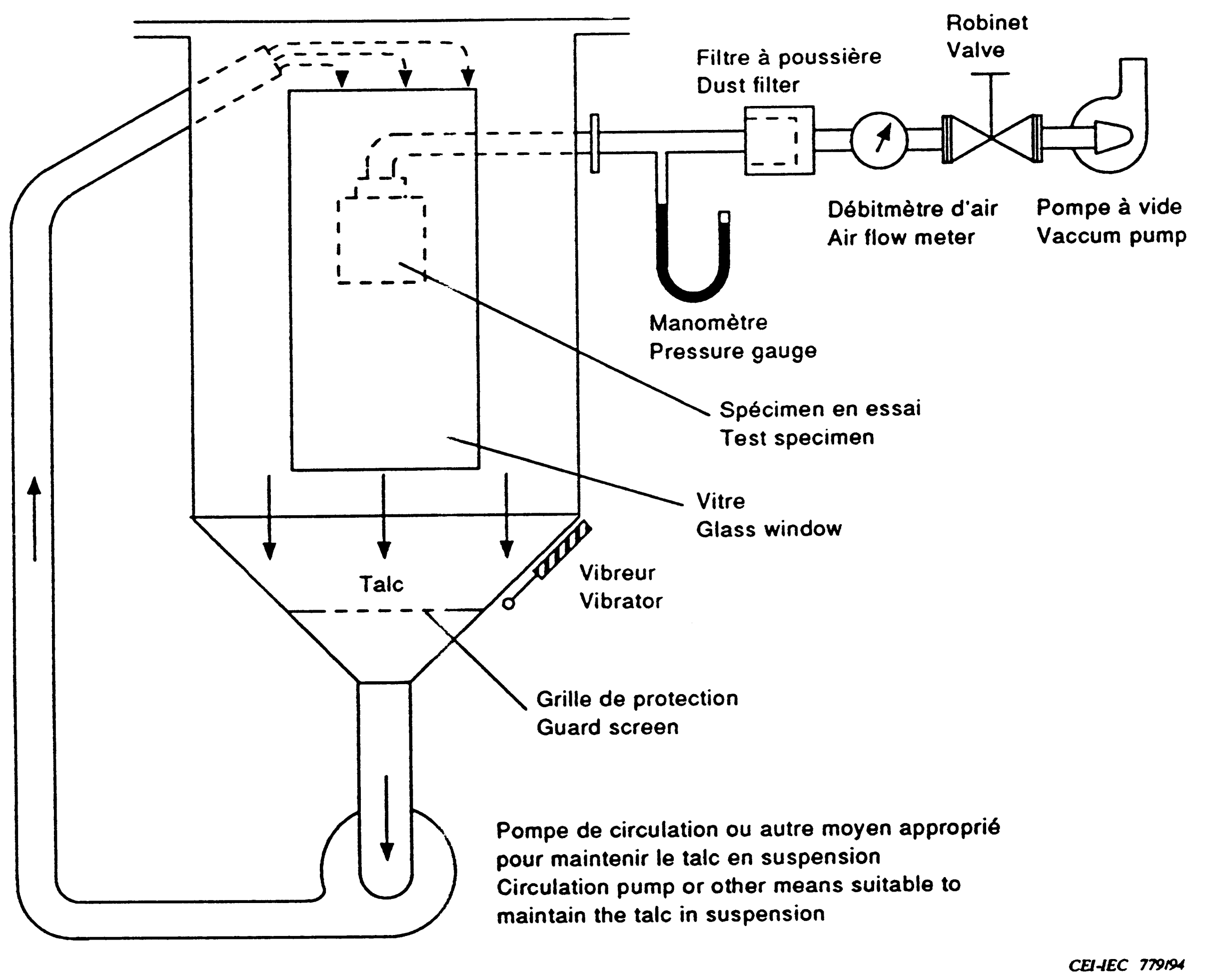

Figure 4 — Example of a suitable test chamber for method La2

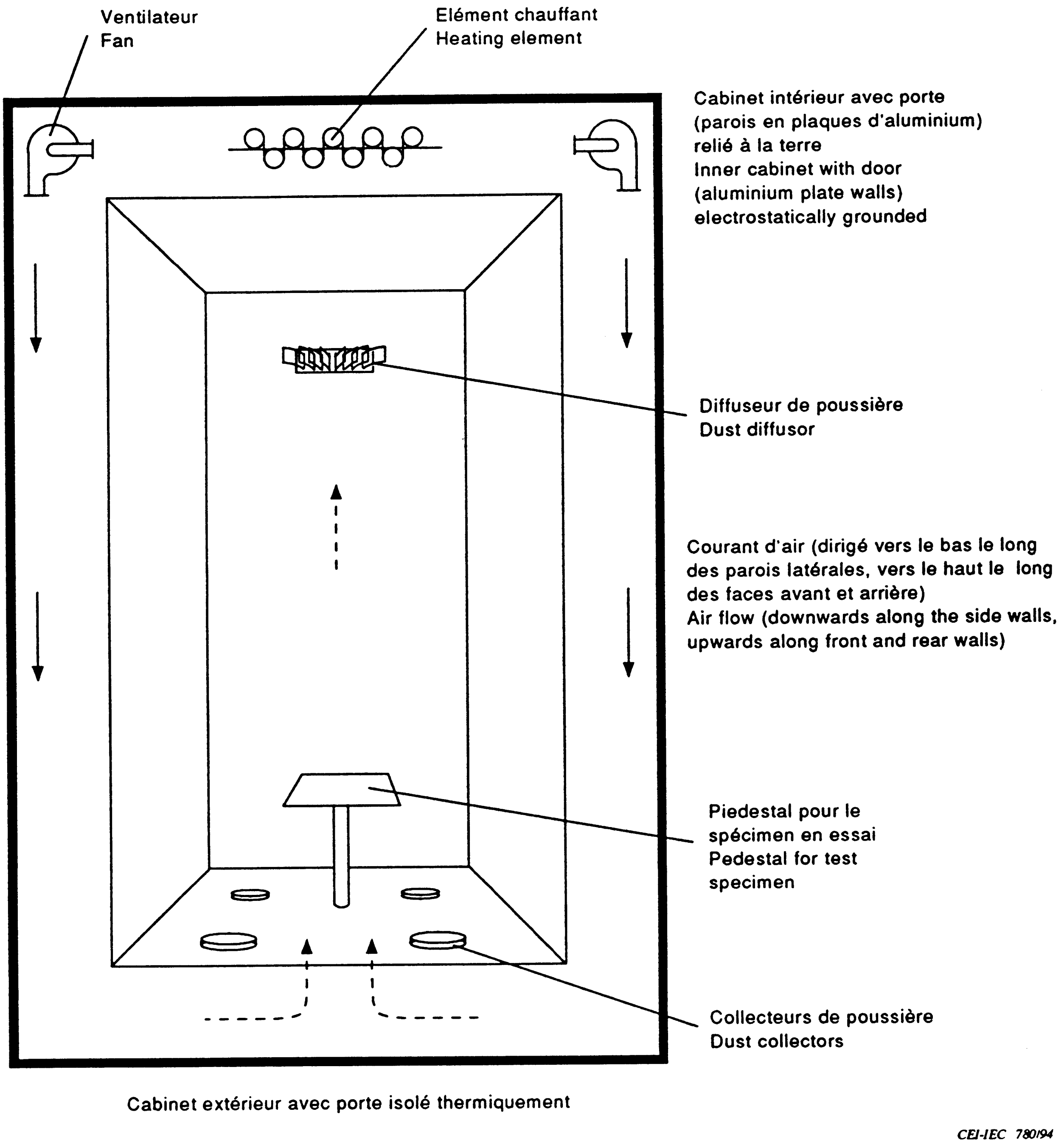

Figure 5 — Example of test apparatus for test Lb

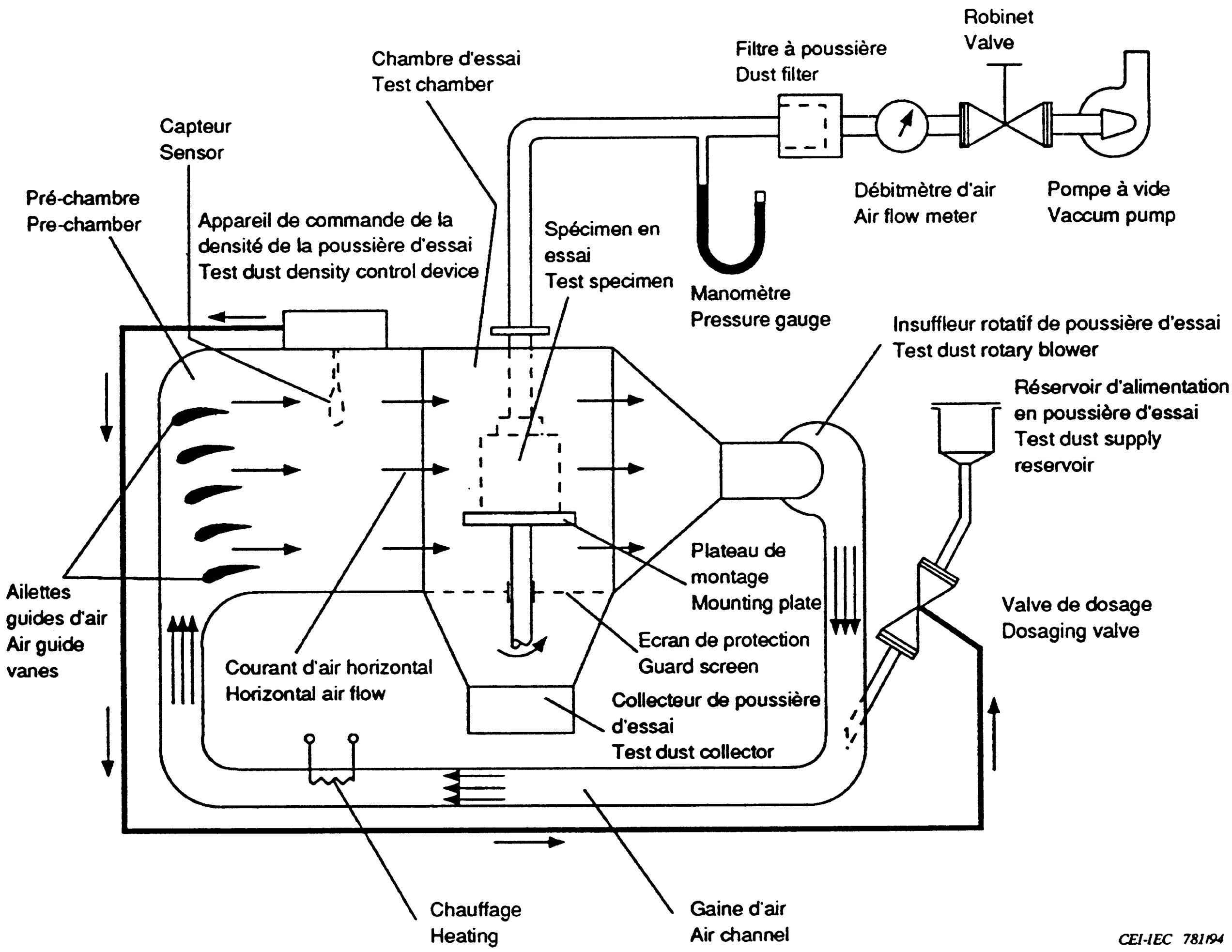

Figure 6 — Principal layout of test apparatus for method Lc1

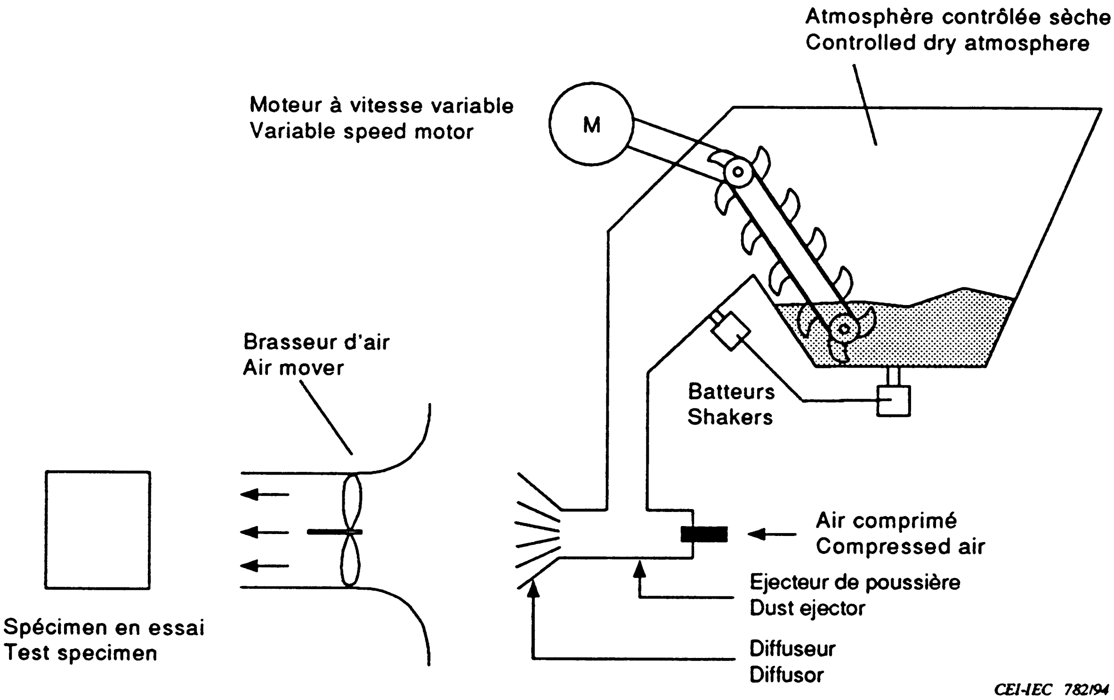

Figure 7 — Example of dust injection system for method Lc2

Annex A (informative)
General guidance

A.1 Characteristics of test dust

NOTE In this part of IEC 68-2 use of the word "dust" is intended to cover sand where appropriate.

A.1.1 *Types of test dust*

The type of basic dusts included in test L are:

a) Crystalline minerals, for example quartz, olivine or feldspar;

b) Talc;

c) FE powder.

It is important in order to avoid unwanted side effects that the test dusts are free from contaminants, in particular salts and biological material.

Crystalline materials are often specified for test because it is the main constituent of many dusts occurring in nature. It therefore reproduces many of the damaging effects experienced by products in desert and similar dusty regions. The salient feature of these materials is their hardness, a property which can result in rapid wear, binding or damage to products, particularly moving parts.

Other important characteristics of these dusts are that they are non-absorbent and chemically inert. Therefore, the corrosion of metals which can occur when other types of dust are present in combination with moisture or gases in the atmosphere is not reproduced.

Quartz (SiO_2) is the common reference mineral. Other test dusts with similar properties which may be specified as alternatives to quartz are undecomposed feldspar and olivine.

Olivine [$(Mg, Fe)_2SiO_4$] a commonly available industrial mineral used in foundries and for sand blasting.

Feldspars are chemical compositions of silica, alumina and alkali oxides. If undecomposed by the action of volcanic gases or water, these minerals are almost as hard as quartz.

Talc (hydrated magnesium silicate) is specified for test La and it is the dust which has been used for some years in the IEC 529 test method for electrical equipment. The predominant features of the dust are that it is non-abrasive and hygroscopic. This dust is intended to provide a suitably severe test of the sealing properties of enclosures for electrical equipment, however, because of its hygroscopicity it is essential to maintain the dust in a dry condition to avoid clogging of any gaps in the enclosure casing.

The non-abrasive property of this dust precludes its use as a general purpose test dust since the primary requirement for this is a hard material such as quartz.

FE powder is a fire extinguisher powder composed primarily of sodium or potassium hydrogencarbonate with a small amount of magnesium stearate bonded to the surface of the particles in order to assist free running and prevent clogging. It is available in the equivalent size range to talc but is not hygroscopic and is somewhat harder having a Mohs scale hardness around 2,0 compared to 1,0 for talc. It should be observed that there is a hardness variation between different FE powders and that the hardest may be abrasive on soft surfaces.

A.1.2. *Particle size*

The ranges of particle size included in this test are:

a) quartz, feldspar, olivine:	fine dust	< 75 µm;
	coarse dust	< 150 µm;
	sand	< 850 µm;
b) talc		< 75 µm;
c) FE powder		< 75 µm.

The particle size distribution for group a) is given in Figure A.1.

When considering the effect of dust particle size, the first consideration is whether or not the product has a protective enclosure. When an enclosure is provided, the choice is between a specially derived dust which has become established as an effective check of the sealing ability of electrical enclosures, i.e. talc or FE powder, or a quartz dust with a suitable particle size range in order to investigate possible detrimental effects of ingressed particulate matter. In the latter case, both the fine and coarse quartz dust contain small particles while sand contains mainly large particles. Therefore, when a test is required simply to determine the adequacy of a protective case or enclosure a dust containing particles small enough to represent the expected in-service environment should be chosen.

The second situation is where the product considered is not protected by an enclosure, but is directly exposed to the dust environment. In general, the choice of particle size range will be that most representative of the real environment. The dust and sand specified in this test have been chosen to represent the majority of real environment conditions when considered singly or in combination.

A.1.3 *Particle hardness*

Hardness of the individual particles can determine the ability to scratch objects upon contact. Sand, which consists mainly of tiny broken chips of crystalline quartz or other mineral, is generally harder than most fused silica glass compositions. Therefore, sand can scratch the surface of most glass optical devices. Pressure applied over trapped grains of sand can cause fractures to occur. Table A.1 lists a few common substances and hardness levels according to Mohs Scale. Those substances with a higher number can scratch any with a lower number.

Table A.1 — Hardness scale

Mohs scale	Référence material	Others
1	Talc	Graphite, alabaster, diatomaceous
2	Gypsum	Kaolinite, galena, mica
3	Calcite	Barite, marble, serpentine, aragonite, dolomite
4	Fluorite	
5	Apatite	Asbestos, opal, fibre glass
6	Orthoclase	Magnetite, feldspar, agate, purite
7	Quartz	Flint, fuse silica, olivine, andalusite, tourmaline
8	Topaz	Emery
9	Corundum	Sapphire, silicon carbide, tungsten carbide
10	Diamond	

A.2 Other dusts

Other test dusts such as “composite test dusts” (for example containing linters, soil or cement) may be considered for specific applications. These shall, however, be carefully tailored using the guidance given in the following.

A.2.1 *Ion-conducting materials*

Investigation of the effects of ion-conducting and corrosive dusts, for example de-icing salts may be performed by a dust test using test dust mixed with the actual aggressive material, followed by a damp heat test.

However, in order to maintain reproducibility, it is better to divide the investigation into a dust test using a neutral dust, followed by a standardized corrosion test.

A.2.2 *Hygroscopic materials*

In order to investigate effects caused by hygroscopic dust materials, cotton linters may be mixed into the test dust, and follow the dust test by a corrosion test.

A.2.3 *Fibrous materials*

Cotton linters may be used in order to investigate the clogging effect of textile fibre placed in ventilating openings.

A.3 Effect of humidity on test dust

A.3.1 It has been found necessary to keep the relative humidity within a test chamber lower than 25 % to prevent clogging of the test dust.

Test apparatus is not required to monitor or control the relative humidity. It is sufficient to heat the air within the chamber to a temperature which is dependent upon the laboratory temperature and relative humidity. In hot, humid climates this may not be possible as raising the test temperature above 40 °C is not advised. In such cases, the laboratory may be air conditioned or dehumidification of the test chamber air may be necessary. Reference to Figure A.2 indicates the maximum relative humidity at given temperatures which can be reduced to 25 % by raising the temperature to + 40 °C.

A.4 Effects on electrotechnical products

A.4.1 *Introduction*

Dust and sand may act as physical agents, chemical components, or both, in promoting the deterioration of materials or function of equipment. It may also act as unwanted abrasive on moving components of machinery, and even stationary surfaces can be damaged by the abrasive action of windblown particles. Alternatively, the effect may depend on the physical and chemical nature of the particles and the nature of the material with which they are in contact. Thus a film present on the surface of a metal may accelerate corrosive action, while a similar deposit on an insulator surface can impair its electrical properties.

A.4.2 *Abrasive effects*

Dust and sand, under the dynamic influence of winds of high velocity, can act as damaging abrasives of stationary surfaces, and instantaneously airborne particles thrown up in the wake of moving vehicles accelerate the corrosion of metallic surfaces by removing protective coatings or by disturbing semi-protective films of corrosion products.

The degree of surface abrasion will depend on the velocity of the impinging particles relative to the surface. A marked deterioration in the optical quality of aircraft windscreens has been reported after test flights at heights of 60 m and speeds of between 290 m/s to 320 m/s over the North African deserts.

Wind-driven dust and sand can roughen the surface of insulants and insulators thus impairing their electrical surface properties. The surface conductivity of phenolics having roughened surfaces has been measured as ten times greater than identical materials with smooth surfaces, at a relative humidity of 50 %.

A.4.3 *Corrosion of metals*

A.4.3.1 *General*

Dust and sand, in conjunction with other environmental factors such as moisture, can be responsible for the commencement and acceleration of the corrosion on metals. Films of particulate matter deposited on metal surfaces may be a mixture of inert, chemically active, absorbent or non-absorbent particles and therefore the resulting corrosive processes are complex.

A.4.3.2 *Chemically inert particles*

Inert particles that are hygroscopic will commence to absorb moisture and any corrosive vapours present in the atmosphere, at low relative humidities. The particles, in this instance, act as vehicles for the aqueous electrolyte by which the electrochemical reaction of atmospheric corrosion proceeds and enhance the corrosive effect.

Inert non-absorbent particles have little effect on the corrosive process except by helping to retain the moisture and by screening the metal at the point of contact, causing differences in the concentration of oxygen over the surface. These differences may cause intensive localized corrosion to occur.

A.4.3.3 *Chemically active particles*

Particles originating from natural or industrial sources may be chemically active and provide corrosive electrolytes when dissolved. Many clays, a principle source of natural outdoor dusts, are hydrated silicates of aluminium and give alkaline reactions, while several of the soluble salts contained in soil particles are sulphates giving acid reactions.

The rusting of iron can be accelerated by the presence of ammonium sulphate particles. These occur as a dust in urban areas.

Calcium carbonate in the form of seashell fragments occurs as the dominant constituent of dust on coral islands and can prove corrosive. Volcanic ash can accelerate the rusting of iron.

A.4.4 *The contamination of electrical insulator surfaces*

Sand and the majority of dusts usually deposited on insulant surfaces are poor conductors in the absence of moisture. The presence of moisture, however, will result in the dissolving of the soluble particles and the formation of conducting electrolytes. The insoluble particles present will tend to retain the electrolyte on the surface and increase the effective thickness of the moisture film. The formation of such films is promoted by an environment where dry, dusty periods and wet, humid periods alternate.

As a result of the conductivity of such surface film, the leakage currents flowing over contaminated power line insulators can be of the order of one million times greater than those which flow through clean, dry insulators.

If the insulant is in a strong electric field, such as power line insulators, the build up of the film will also be encouraged by the attraction of airborne particles to the areas having steep voltage gradients.

A.4.5 *Miscellaneous effects*

A.4.5.1 *Promotion of mould growth*

Dust adhering to the surface of materials may contain organic substances that provide a source of food for micro-organisms. Surfaces of materials such as ceramics and optical glasses, that are not normally susceptible to microbial attack when dust free, may therefore become overgrown with moulds or algae.

A.4.5.2 *Electrical contacts and connectors*

As stated previously, sand and the majority of dusts are poor electrical conductors when dry, therefore particles deposited on switch, relay or any electrical contacts can impair operation by increasing the contact resistance.

Dust and sand accumulating in electrical connectors can make mating or disconnection difficult.

A.4.5.3 *Cooling systems*

A reduction in heat transfer rates can be caused by the formation of insulating layers and can lower the efficiency of cooling systems.

A.4.5.4 *Electrostatic effects*

The electrostatic charges produced by friction of the particles in sand storms can interfere with the operation of equipment and sometimes be dangerous to personnel. The breakdown of insulators, transformers and lightning arresters, and the failure of car ignition systems has been known to occur as a result of such charges. The electrostatic voltages produced can be large. Voltages as high as 150 kV have made telephone and telegraph communications inoperable during sand storms.

A.5 Safety precaution

A.5.1 *Hazardous effects*

All harmful effects to the specimen may cause hazardous situations for personnel.

If the dust test is part of a safety evaluation, inspection of settlement or penetration of dust has to be performed with the utmost care, and the guidance given in clause **A.4** should be used in connection with experience in the field of safety tests, and using a worst case interpretation.

A.5.2 *Health hazard*

Precautions are necessary to avoid any health hazard due to inhaling of dust. These shall include:

— adequate sealing of the test chamber;

— permitting the dust to settle before opening the chamber door;

— the use of suitable protective masks and clothing;

— the proper cleaning, servicing and maintenance of the equipment including efficient filters in, for example vacuum cleaners.

A.5.2.1 *Talc*

Excessive talc inhalation can cause talc pneumoconiosis. Other respiratory conditions with cough, sputum formation, and breathlessness can also be encountered after prolonged exposure. Because of the range of other materials with which talc is associated the medical literature has not clearly identified conditions exclusively related to talc in its pure form.

Exposures limits

Talc should be controlled so that exposure concentrations do not exceed 10 mg/m^3 for total talc in air, and 1 mg/m^3 for respirable dust in air (8 h time weighted average concentrations).

A.5.2.2 *Other dusts and sand*

Quartz flour can cause silicosis, a severe lung disease, that may be complicated by lung cancer.

NOTE Olivine contains ≤ 1 % free SiO_2 and is considered to be a low-risk mineral.

Cotton linters are allergens that can cause respiratory problems for an allergic person.

Because of these circumstances it is important to observe the quoted health hazard rules.

Two factors which might be of importance are given below:

a) amorphous materials, for example glass, are less dangerous than crystalline materials.

b) dust particle sizes between 0,5 μm and 5 μm are the most dangerous.

Olivine and feldspar are crystalline materials.

The conclusion today is, that it is impossible to find a dust material which is harmless to use in this test method. Personnel protection devices such as dust masks and goggles should therefore be used.

A.5.3 *Explosive danger*

There is no danger of explosion if talc is used as the test dust, but if other dust are specified, consideration should be given to the following fact: Combustible materials in the form of fine dust become explosive when the concentration in air exceeds 20 g/m^3.

A.6 Test L and IEC 529 comparison

IEC 529 includes a "characteristic numeral" for a number of degrees of protection. The designation to indicate the degrees of protection consists of the characteristic letters IP followed by two numerals. The first numeral indicates the degree of protection against solid objects and dust provided by the enclosures. The second numeral indicates the degree of protection provided by the enclosure with respect to harmful ingress of water. The classification for the first numeral is shown in Table A.2 together with a reference to the appropriate test methods.

Regarding the testing, the test method La2 from IEC 68 point of view can be considered as a "relevant specification".

Table A.2 — Comparison of test methods

Test L method	IEC 529 first characteristic numeral	Description	IEC 529 test method subclause
No test	0	Not protected	No test
No test	1	Protected against solid objects > 50 mm	**7.1**
No test	2	Protected against solid objects > 12 mm	**7.2**
No test	3	Protected against solid objects > 2,5 mm	**7.3**
No test	4	Protected against solid objects > 1 mm	**7.4**
La1 or La2	5	Dust-protected	**7.5**
La1 or La2	6	Dust-tight	**7.6**

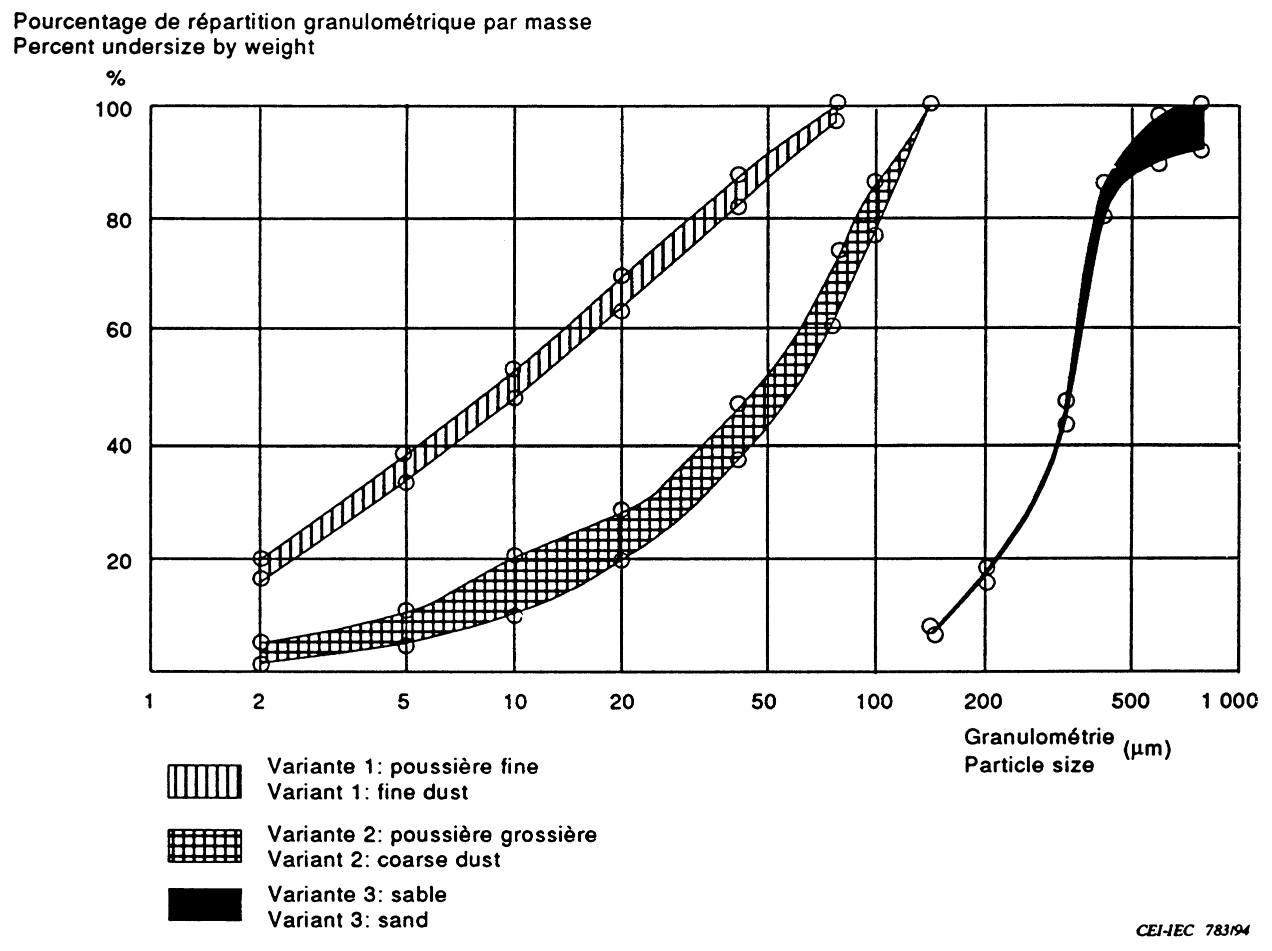

Figure A.1 — Particule size distribution

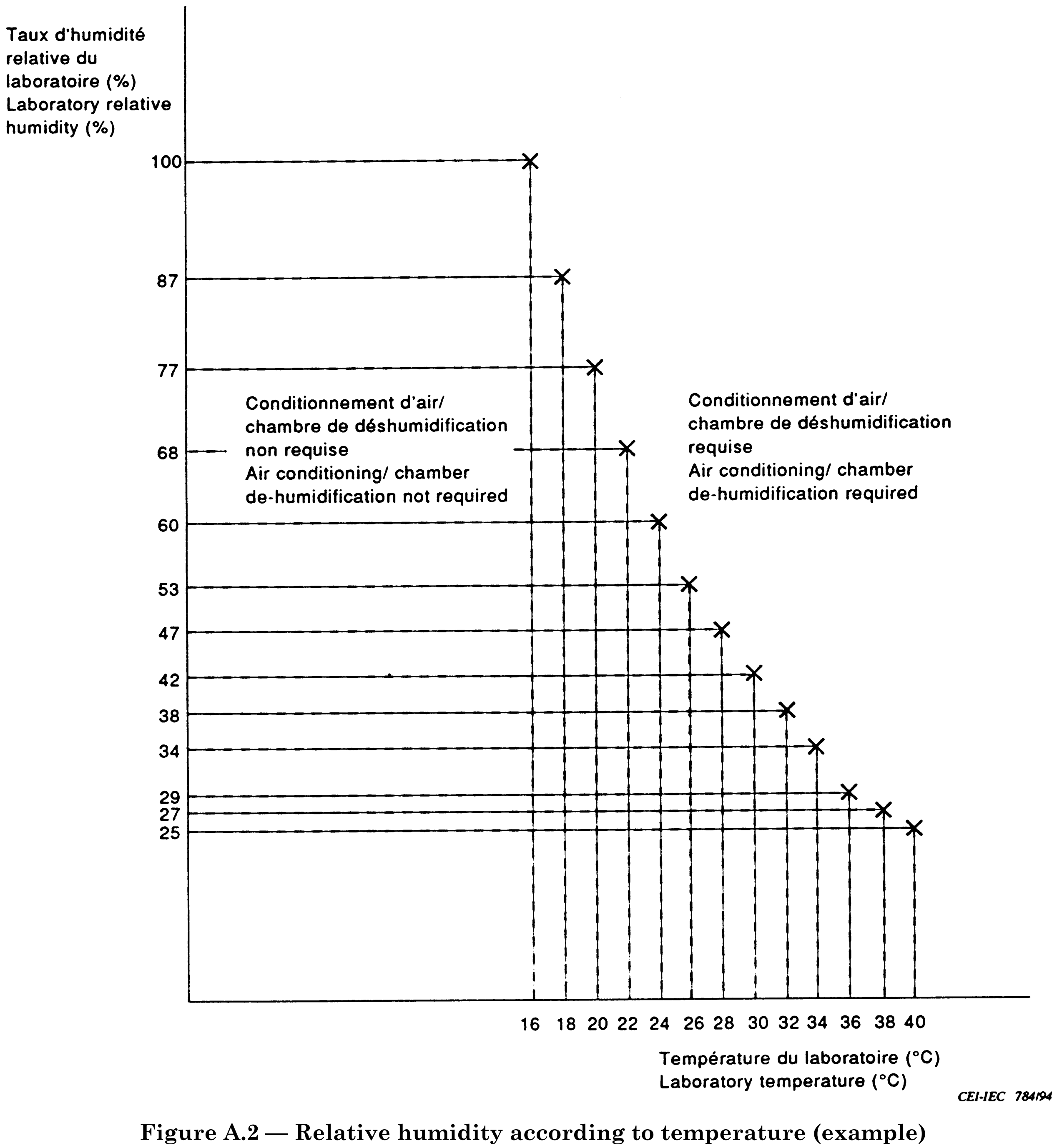

Figure A.2 — Relative humidity according to temperature (example)

Annex B (informative)
Bibliography

Dust test similar to method La2, are given in the following documents:

IEC 34-5:1991, *Rotating electrical machines — Part 5: Classification of degrees of protection provided by enclosures of rotating electrical machines (IP code).*

IEC 947-1:1988, *Low-voltage switchgear and controlgear — Part 1: General rules.*

NOTE 1 The test methods of IEC 529, (listed in the normative references) include those of IEC 34-5 and IEC 947-1.

NOTE 2 Harmonized as EN 60947-1:1991 (modified).

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