USEFULNESS OF ESE AND IONIFLASH MACH ON LIGHTNING PROTECTION INSTALLATIONS

M. Troubat

France Paratonnerres, 9 rue Columbia 87068 Limoges, m.troubat@france-paratonnerres.com

Abstract. *This paper deals with the reliability and the efficiency of the Early Streamer Emission (ESE) technology. It aims to be a complete answer to opponent of this modern and avant-gardist technology.*

I. INTRODUCTION

The ESE technology is a modern technology. Indeed, the first product appears in the early 80's and has been tested and optimized in the famous and referenced laboratory of the Renardières in France.

As a reminder, a lot of important discoveries in the field of the lightning and long space discharges have been performed in this laboratory [1].

Then, in July 1995 the first ESE standard (NFC 17-102) [2] has been published. Since this date, the lightning protection world and the market have been purely modified.

The partisans of the Franklin rod and mesh wires also known as the conventional technology, were disturbed by this new competitor, and have begun a campaign of depreciation on the technology.

This document will answer to the opponent of the ESE technology by establishing the usefulness and the reliability of the Early Streamer Emission Air-Terminal.

Some general information will first be proposed.

Then, a review of the international positions and standards will be given.

Then the last 30 years of field experiments, field experiences and surveys realized will be described.

Finally, the paper will focus on the particularities of the IONIFLASH MACH® that positioned it as the most performing, and reliable ESE among the worldwide lightning protection devices proposed.

II. GENERAL INFORMATIONS AVAILABLE

II.1. GIMELEC website [3]

The GIMELEC is the unit syndicate of 200 companies (Electricity, automation solutions for the energy, construction, industry, data center, infrastructure and lightning).

The members of the D84 division (lightning division) of the GIMELEC have recently created a website dedicated to the Early Streamer Emission Technology.

This site aims to serve as a useful tool for learning about lightning risk in order to deal with it as efficiently as possible.

II.2. ILPA web site [4]

The International Lightning Protection Association (ILPA) is an association that federates a lot of actors in the ESE technology. It aims to be a technical place to talk and speak about the efficiency of the ESE Technology.

It organizes every two years a symposium dealing with the lightning protection with ESE air-terminals.

On the ILPA website many information and technical papers are available.

For example, the map below gives interesting information of the use of the ESE technology all over the world. It appears that this modern technology is widely used.

Indeed, the countries:

- In red are the one where it isn't usually stated in specifications.
- In green is where it is widely stated in specifications
- In grey, it is the one where it is regularly stated in specifications

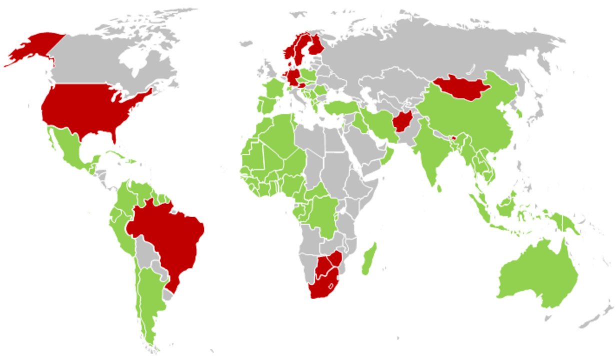


Fig. 1. Use of ESE air-terminal in the world

III. ESE ALL OVER THE WORLD

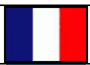
III.1. ESE standards in force

The first ESE standard was published in 1995 in France. This NFC 17-102 standard has been recently updated in 2011 [5].

The French standard is not the only one ESE standard in the world. Several countries have implemented their own ESE standard mainly inspired from the French one.

The table 1 recapitulates all known ESE standard.

Table 1. ESE standards all over the world

ESE Standards			
France		NFC 17-102	[5]
Argentina		IRAM 2426	[6]
Bulgaria		4/22.12.2010 r 3A LIGHTNING	[7]
Portugal		NP 4426	[8]
Republic of Macedonia		MKS N.B4 810	[9]
Romania		I-7	[10]
Serbia		JUS N.B4.810	[11]
Slovakia		STN 34 1398	[12]
Spain		UNE 2186	[13]

It is important to note that some other ESE standards may exist without been citing above in the table 1.

Moreover, some standards are in progress in other countries. They will be available soon…

III.2. European commission

A few years ago, the National Standardization Committee of Slovenia has decided to forbid the selling and the installation of ESE air-terminals.

ILPA organization has opposed itself to the prohibition. Finally, the European Commission has considered this interdiction as illegal. [14]

It has been asked to Slovenia to re-authorize the use of ESE air-terminals.

III.3. CENELEC and IEC positions

In the standardization committees, a long and rough war took place from 2003 to 2009.

Since 2003, works to harmonize all lightning standards all over the world have been done in working groups. Finally in 2006, a new international standard was born: the EN 62305-3

Unfortunately, the ESE air-terminals were excluded and not considered in this standard.

Indeed, during the development of the standard and at the final stage of the vote, the countries with a national ESE standard were in minority part. And even if they defended the ESE as the best they could, the standard was published with a voluntary omission.

With this new international standard, it was endorsed that all standards in conflict should disappear in the next three years.

All the opponents of the ESE technology have claimed during three years all over the world that the ESE standards were going to be withdrawn. This international smear campaign has been harmful to the ESE technology:

- Final users have decided not to use the ESE air-terminal
- Some national committees have forbidden ESE technology (like in Slovenia)
- Some national committees have restricted the use of ESE air-terminal as simple rod.

During the BT 134 Meeting [15] on April 22nd and 23rd, 2009 in Vilnius, the CENELEC noted the position of the French standardization Committee, which confirms the non conflicting status of the NFC 17-102 ESE standard.

Therefore, the French standard can definitely coexist with the previously mentioned recent European standards (EN 62305 series)

In April 2010, the epilogue of this fight arrived.

Partisans of the conventional technology asked the Technical Board of the CENELEC to withdrawn the NFC 17-102 and all other ESE standards.

The decision of the BT is the 136 (statement 11 to 14) [16]:

- *D136 / 011:* BT noted the information provided by CLC/TC 81X concerning the relation between the EN 62305 series (Protection against lightning) and NF C 17-102 (Protection of structures and open areas against lightning using early streamer emission air terminals)
- *D136 / 012:* BT decided by majority not to establish a BTTF to deal with the ESE system at European level
- *D136 / 013:* BT asked those national committees that have a national standard endorsing the ESE system, to ensure that this national standard will no longer contain any reference to the installation provisions of the EN 62305 series and sequently to offer the corresponding national standard to IEC for possible endorsement at international level.
- *D136 / 014:* BT asked CLC/TC 81X to examine the possibility to establish a pure performance standard, independent from any technology and enabling the development of existing and future technologies on lightning protection systems and report back to BT

In conclusion it means that there is no conflict between the 62305-3 and NFC 17-102 standards.

Moreover, it opens the way to the development of an international ESE standard at the IEC level.

IV. MORE THAN 35 YEARS OF FEEDBACK

Since the installation of the first ESE air-terminal, the technology has been criticized a lot by misinformed opponents.

They used to say that

- ESE air-terminals don't work properly.
- ESE air-terminals only work in laboratories (for small distance)
- ESE air-terminals don't protect such a wide volume

The last 35 years of field experience have shown that ESE air-terminals are efficient and that the ESE solution is a reliable solution for lightning protection.

These sections aim to show last progress and field experiences.

IV.1. Tests in situ

Some ESE manufacturers have designed a lot of tests in situ.

Two kinds of test are available:

- The UTE protocol which aims to validate the volume of protection
- The comparative protocol which ails to compare ESE to simple rod

Those tests enable to validate the in situ proper functioning of the ESE air-terminal.

a - UTE protocol

The UTE protocol aims to compare the attraction efficiency of the ESE with respect to the edge and corner effect (simple point effect).

An ESE is installed in the middle of a flat roof with a sufficient area. The ESE is linked to two interconnected earthing systems via two down conductors.

A collecting conductor of 50mm² is installed all around the roof along the edge. Two 1kV spark gaps are installed where the collecting conductor cross the down conductors.

Moreover, 3 lightning strike counters are installed:

- The 1st one is located just below the ESE
- The last two are located on the down-conductors

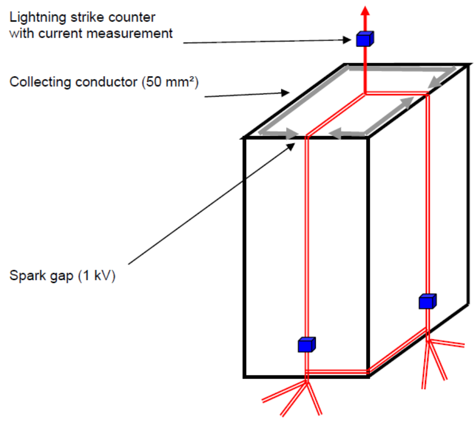


Fig. 2. Typical sketch of the UTE protocol

The comparison of the 3 lightning strikes will confirm the efficiency of the ESE:

The three lightning counters are able to measure the current (to check if the current is within model limits or not) and to give date and time of events.

With such a limited instrumentation we are then able to check if a lightning strikes the ESE or not and in the last case, it this is a failure of the ESE or if the current is too low to be collected (according to model),

A local and independent supervising body is established by the manufacturer in charge of each experiment, and validates the installation as well as the monitoring of the lightning counters.

Since 2005, 4 sites of experiments have been installed in the world:

- Philippines
- Indonesia
- Pic du Midi in France
- South Africa

The first results confirm the proper functioning of the ESE technology.

b - Comparative protocol

Another kind of test is the comparative protocol.

It aims to compare the in situ working of two technologies of air-terminals. The most efficient one will then capture most lightning than the other.

In 2011, France Paratonnerres has set up a comparative test in a church in Romania.

This church is composed of a double bell tower and is perfectly symmetrical.

Fig. 3. Satu Mare church in Romania

The IONIFLASH MACH® air-terminal is installed with respect to the NFC 17-102 rules on the right bell tower. The simple rod is installed on the left tower in the same conditions.

Both systems are connected to two down-conductors and two earthing systems.

As the four earthing systems are connecting together in the soil, the visible equivalent resistance seen by the lightning is the same for both air-terminals.

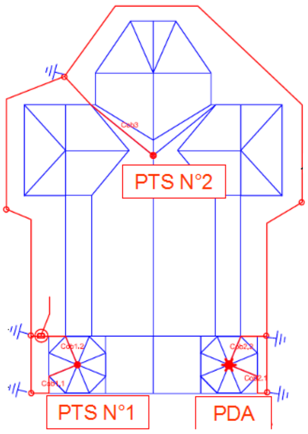


Fig. 4. Comparison test protocol

For both air-terminals, the most direct down-conductor to the earthing system is equipped with a lightning strike counter.

A local and independent supervising body has been established by France Paratonnerres, and validates the installation as well as the monitoring of the lightning counters.

IV.2. Pure Performance Standard

Regarding the decision BT136/D14 of the Technical Board of the CENELEC, it is asked to study the possibility to establish a standard to validate in situ the well working of a lightning protection technology.

As a response, a project of European standard (Pr EN 50622) to validate in situ, all lightning protection systems is in progress.

This project standard called Pure Performance Standard aims to analyze the efficiency of a technology by comparing the number of interceptions regarding the keraunic activity of the site and the possible bypasses in the declared protection volume.

IV.3. Empirical surveys

A recent empirical survey [17] realized in 2011 explains that during the last 30 years, the cumulated number of ESE installed all over the world is estimated at 550000 units.

It is equivalent to 4,5 millions of accumulated years of experience.

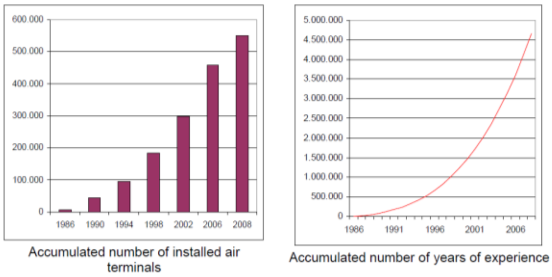


Fig. 5. Accumulated experience [18]

The world keraunic map shown below enables to determinate an average lightning strikes Ng around 2.5 strikes per km² per year.

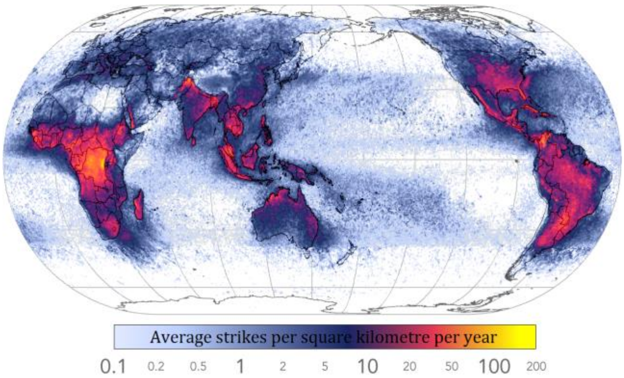


Fig. 6. World keraunic map

The number of lightning strikes expected regarding the technology used is given below:

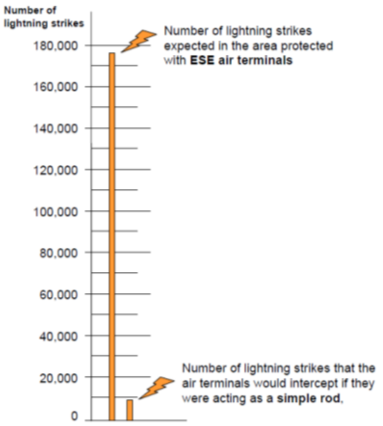


Fig. 7. Expected number of strike on the air-terminal

According to standards theory, an acceptable number of bypasses is possible.

Table 2. Typical maximum and minimum peak current

	Level I	*Level II*	*Level III*	*Level IV*
Minimum peak current (kA)	3	5	10	15
Probability of greater lightning parameters	99%	95%	91%	84%

The result of this comparison indicates that in the second case more than 165000 lightning discharges would not have been intercepted and therefore would have caused damage to protected structures, and therefore thousands of claims. Obviously this is not the case. The available data gives a very low number of incidents.

IV.4. Marketing surveys

Moreover, the last OPM survey [18] realized between 2012 and 2014, concludes that the users of the ESE air-terminals are globally satisfied (93%) with their lightning protection, and 82% are convinced by the liability of the technology

IV.5. Millau Viaduct ESE protection

One of the common critics is about the Leader emitted by the ESE air-terminal which is the principle of the ESE technology. The opponents of ESE technology have said that there is no ESE effect.

Nowadays, they agree that the effect is possible in laboratory. However, they claim that it can't work in nature because of a difference of scale between the nature and the laboratory.

Recent results and pictures have shown that ESE air-terminals are able to generate upward streamers.

For example, 7 ESE air-terminals installed on the 7 piles of the viaduct of Millau have generated simultaneously 7 leaders.

Two of them have evaluated and have reached the downward streamer and lightning return strokes occur about 10kA. The lightning strokes haven been registered according to Météorage analysis [19].

The strike is composed of 3 negative arcs around 10kA and of a positive arc of 100kA.

This one is located at 11km of the picture point and is situated at the background of the picture. It is the most brilliant channel that illuminates the bottom of the cloud.

The 3 negative arcs are located at the direct proximity of the piles of the viaduct.

According to the picture published, we can estimate that upward leaders are greater than 100 meters.

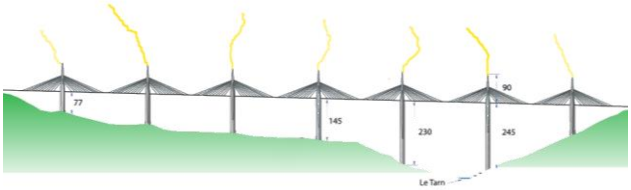


Fig. 8. Leaders emitted by the ESE

We can easily consider the 3 lightning strokes (N°2, N°6 and N°7) on the Figure 2 and for the 4 others they are considered as upward leader that haven't reached the downward streamer of the cloud.

Fig. 9. Picture of the above lightning strokes

We can conclude that the ESE principle is active and if the leader has been created earlier than a simple rod, it has stayed alive and finally has caught the lightning.

IV.6. Speed of the leader of the ESE air-terminals

Concerning the speed of the upward leader, we are not actually able to surely define it.

With the latest generation of high speed cameras, some observation and measurements have been realized and data available are now more and more precise.

Upward leader has been recently measured with a high speed camera at a speed about 6.10^5m/s. However, this speed is only a 2 dimensions measurement.

We can think that the real speed is faster because the third dimension has not been considered.

For sure, the speed of the upward leader is not as slowly as claimed by some people.

V. THE IONIFLASH MACH®

The Early Streamer Emission air terminal IONIFLASH MACH ® is a non-electronic system. The absence of electronic makes it extremely reliable and easy to install on a very large variety of sites.

In addition, the materials used to make IONIFLASH MACH ® have been selected for their resistance to both corrosion and very high temperatures

V.1. Functioning

When the downward leader gets close to the ground (about 100 metres above the point), it generates an electric field above it which rises up to 100 kilovolts per metre.

This is when the corona discharge effect takes place, changing suddenly from a position at the tip to an upward leader.

These positive upward leaders suddenly move in the direction of the downward leader. One of the leaders, the closest or the one which has started earlier or the one which has travelled the faster comes into contact with the downward leader. Then, the ionised air channel is in connection with both the ground and the cloud, and the return stroke can take place, engendering a high lightning current of many kA.

The air terminal IONIFLASH MACH ® is a device for lightning protection with a spherical metal part fixed to the top. This sphere is insulated from the rod by a ring made from a material with very high electrical insulation properties.

When a storm comes, the external electrode (sphere) charges under the influence of the electric field until the potential reaches a critical value from which a spark appears between the exterior electrode and the tip of the central electrode. The tip enables the plasma to be created around it.

The plasma, in association with the intense electric field created close by the tip, constitutes the first stage of development of an upward leader.

The spark produced at the top of the IONIFLASH MACH ® air terminal will initiate the advance of the discharge, engendering an upward leader moving in the direction of the downward leader.

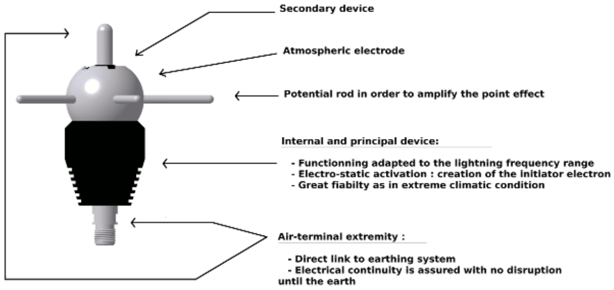


Fig. 10. IONIFLASH MACH®

V.2. The IONIFLASH MACH® Technology

The IONIFLASH MACH® is the first Early Streamer Emission Air Terminal in the history of the lightning protection which transposes the last research results and tests in real conditions of lightning.

Long research studies have highlighted the superiority of the performance of a rounded tip compared to a sharp rod, both positioned in the same conditions, in laboratory and in real conditions of lightning.

The rounded tip shows a much higher efficiency.

Thanks to the design of the IONIFLASH MACH®, the concentration and the electric field lines control at the top of the air terminal amplify and regulate considerably the ionization, starting factor of the propagation of the upward leader.

The connection process of the upward leader with the downward leader becomes intensified, synchronically supplied by the principal spark gap and the auxiliary spark gap.

The IONIFLASH MACH® tip in ellipsoid of revolution and the conception of the spark gaps working in extreme climatic conditions demonstrate the precursory and regular character of the propagation of the IONIFLASH MACH® upward leader, connecting and ensuring the capture of the downward leader to the earth.

Indeed, for a level of electric field given, the sharp rods produce too many charges compared to the round tips.

V.3. The range

The IONIFLASH MACH® is a complete range from 15 to 60µs of advance time.

Fig. 11. The range

Table 3. Characteristics

	MACH NG15	*MACH NG25*	*MACH NG30*	*MACH NG45*	*MACH NG60*
Δt (µs)	15	25	30	45	60
safety rate	73 %	68 %	66 %	61 %	56 %
K ratio	0,61	0,76	0,74	0.44	0,29

- Very low dispersion performance
- Works according to lighting spectrum frequency (0 to 10MHz)
- Is not sensitive to bad weather thanks to its internal spark gap
- Two spark gaps devices with dimensions enabling them to be used whatever the weather conditions are (rain, snow, hail…)
- No electronic parts => No energy consumption
- Electrostatic activation of the streamer emission when the Electromagnetic earth field gets larger.
- No fragile components => Stainless steel metal parts
- Always works at optimum level after 2 series of tests with 7 lightning strikes in normalized wave 10/350 µs @100kA (in positive and negative polarity)
- The Eco-conception of IONIFLASH MACH® respects the environment.
- Excellent carbon footprint.
- Patented technology
- 7-years Guarantee
- Life duration > 35 years

V.4. The test of the IONIFLASH MACH® in laboratories

The IONIFLASH MACH ESE air-terminals have passed the complete sequence of tests of the NFC 17-102 standard (2011). Some tests have been realized in a more severe way than required in order to warranty the most important liability to our products.

a - General test

The engraving laser of the IONIFLASH MACH® meets the requirements of marking of the test. It is indelible with time.

b - Mechanical tests

The continuous axis of the ESE IONIFLASH MACH® trough which the lightning current passes, presents a minimal section of 200mm ² according to the requirements of this test.

c - Environmental tests

The IONIFLASH MACH® has passed the environmental tests:

Salt mist treatment with a severity of level 2 according to the EN 60068-2-52 [20].

Humid sulphurous treatment with a 7 cycles sequence according to the EN ISO 6988 [21].

d - Electrical tests

The IONIFLASH MACH® range has been tested in lightning attachment impact with a 10/350µs waveform at 100kA and passes the test requirements.

Indeed, the IONIFLASH MACH® has been impacted by 2 series of 7 impacts at 100kA (while the standard requires only 3 impacts), one in negative polarity and one in positive polarity.

The air-terminals show no deterioration or perforation, except the parts through which the current is flowing, where tracks of initiating and fusion appear.

e - Efficiency tests

The ESE IONIFLASH MACH® is designed to reduce the average statistical time associated with the initiating of the upward streamer.

The MACH® presents an advanced time in comparison with a simple reference rod (PTS) tested in the same conditions. This gain is evaluated in high voltage laboratory

f - Insulation test in rain condition

Moreover, the good insulation of the IONIFLASH MACH® has been tested in rain conditions with respect to the IEC 60060-1 standard [22].

In High voltage laboratories, the breakdown voltage in dry and rain conditions is compared.

The IONIFLASH MACH® ESE are very well insulated and their working isn't disturbed by the rain pollution.

Insulation tests are realized both in continuous and impulse voltage.

Moreover, the IONIFLASH MACH® air-terminals have passed insulation tests in rain conditions.

Tests have been performed according to IEC 60060-1 standard protocol.

The insulation of the early streamer emission device is greater than 97 %.

VI. CONCLUSION

For 35 years, the ESE technology has proved its efficiency and its reliability.

Field experiences, theoretical studies and recent survey show that the ESE technology is useful.

In situ tests all over the world confirm the good behaviour of the ESE technology. The establishing of performance standard (requested by the CENELEC) is recognition of the ESE technology.

Last NFC 17-102 standard evolution, position it as severe and restrictive standard.

Indeed, some requirements are more severe than some in the IEC 62305-3 standard. Moreover, the complete test sequence is defined and established in order to only select performing ESE.

REFERENCES

[1] Renardières Laboratory results

[2] NFC 17-102 Standard, France, Ed.1 – 1995

[3] GIMELEC website, http://www.earlystreameremission.com

[4] ILPA website, http://www.intlpa.org

[5] NFC 17-102 Standard, France, Ed.2 – 2011

[6] IRAM 2426 Standard, Argentina

[7] 4/22.12.2010 r 3A Standard, Bulgaria

[8] NP 4426 Standard, Portugal

[9] MKS NB4 810 Standard, Republic of Macedonia

[10] I-7 Standard, Romania, 2013

[11] JUS NB4 810 standard, Serbia

[12] STN 34 1398, Slovakia Standard

[13] UNE 21186 Standard, Spain, Ed.2 - 2012

[14] European commision decision, *"IEC 62305-4"*, Ed.2 - 2010.

[15] CENELEC BT desicion 134, April 2009.

[16] CENELEC BT desicion 136, April 2010.

[17] V. Pomar, S. Polo, S. Fauveaux, "Effectiveness of worldwide existing ESE lightning Protection Systems manufactured in Europe", 2011, ILPA website

[18] "Enquête sur les paratonnerres à dispostifs d'amorçage (PDA)", OP Marketing survey - 2014.

[19] "Foudroiement du viaduc de Millau", http://www.meteorage.fr/actualites/note-technique, August 2013

[20] Environmental tests – Salt mist treatment, IEC 60068-2-52, December 1996

[21] Metallic covers – Test in the sulfur dioxide with general condensation of the humidity, EN ISO 6988, April 1995

[22] High-voltage test techniques – Part 1: General definitions and test requirement, Ed.3 September 2010