# RESULTS OF ACCELERATED AGING TESTS OF EXTERNAL LIGHTNING CONNECTION COMPONENTS ACCORDING EN 50164-1

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**Abstract**
Since Benjamin Franklin invented the lightning rod, buildings and installations have been protected against direct lightning strokes. New standards define the accelerated aging of materials such as connecting components, conductors. This paper describes the application of the technology for such tests in laboratory, first results and conclusions for the best combination of materials.

**Keywords:** Connecting components, chemical treatment, salt mist , SO2, aging, sparking, contact, properties of combined materials.

## 1. INTRODUCTION

A lightning protection system LPS consists of four elements:
1. An air termination which receives the lightning

2. A down conductor which leads the lightning current to the earth termination

3. An earthing electrode which distributes the lightning current into earth.

4. All measures for the potential equalisation.

In practise the inter connection of the components 1-4 is performed using connection components such as bridging components, expansion pieces, connectors, clamps, pipe clamps, test joints. The connection components are stressed due to the environmental influences such as moisture, chemicals air contents, Chemical contents in rain, sun radiation, heat variation and may therefore age with time of operation. When aging occurred the effect of a lightning current to such components may the following:
-connection components may have increased resistance due to a corroded surface which may cause electrical sparking and a subsequent fire.
-connection components may corrode so far that a lightning current may damage the arrangement mechanically and the whole system does not function any further. In this case also sparking may occur or even interruption of a connection would lead to fire.
To avoid above mentioned cases the connection components shall be tested after accelerated aging in laboratory to demonstrate their lightning current carrying capability under aged conditions.

## 2. HISTORICAL BACKGROUND

Early standards, e.g. the German VDE1802:05.30, for LPS were focussed on the definition of dimensions of LPS. Lightning current tests were not foreseen. The manufacturers of LPS-equipment worked out a new standard for connecting components in LPS. 1986 the German standard DIN48810 was created and a test with lightning current was defined but not a certification. This standard did not include the latest knowledge of lightning currents as published in IEC1312-1.

## 3. ACTUAL STATE OF STANDARDISATION

The CENELEC TC81X/WG2 created a new standard for testing of connecting components [1]. This standard is for both the accelerated aging and the electrical test using lightning current impulses according to [2].

## 4. TEST PROCEDURE

The manufacturer has the choice to define a test level for his products according to table 1. A lightning rod and its corresponding connecting components will be tested using class H due to the full lightning current. Other components which are not stressed by the full lightning current, may be tested with class N.
The manufacturer has to implement the new standard into his product range. A novelty is the standardised arrangement of conductors and connecting elements during the test. It is easy to recognise that the components are stressed due to the electro dynamic forces. A standardised test arrangement is shown in fig.1.

**Table 1** Test sequence

a) Salt mist treatment; cyclic ( 3 days )
b) Humid sulphurous atmosphere treatment (7 days )
c) Ammonia atmosphere treatment (for copper alloys with a copper content lower than 80 %)
d) Components embedded in the ground are treated with a solution of chloride and sulphate for 28 days

| **class N** | **class H** |
|---|---|
| $I_{max}$= 50kA ± 10% | $I_{max}$= 100kA ± 10% |
| W/R = 0,63 MJ/Ω ± 20% | W/R = 2,5 MJ/Ω ± 20% |
| $t_d \leq$ 2ms | $t_d \leq$ 2ms |

**Measurement of the contact resistance**
$R_{contact} \leq 1m\Omega$
(measured with a source of at least 10 A)

**Observation**
- not any crack to normal or correct vision
- no loose parts or deformation

**Measurement of the loosening torque for screwed clamps**
$0{,}25M_A \leq M_L \leq 1{,}5\ M_A$
$M_A$: tightening torque
( acc. to manufacturers declaration)

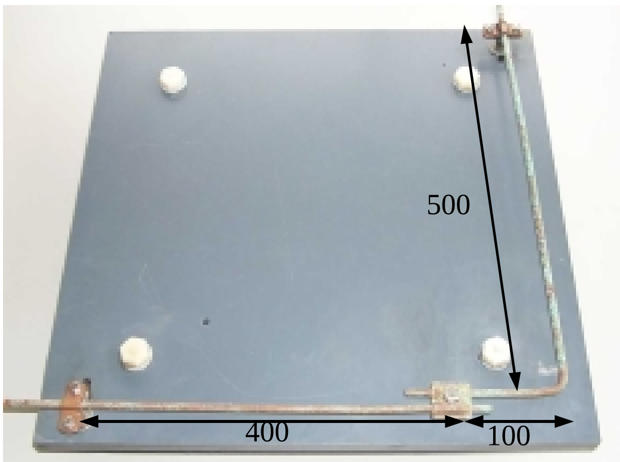


**Fig.1** Test arrangement

## 4.1 Preparation of specimen

According to Table 1 the specimen have to be prepared using different chemical treatments. Fig.2 and 3 show the installed equipment for such chemical treatments. Fig 4 shows the measurement of loosening torque's for screwed clamps.

**Fig.2** Apparatus for accelerated artificial aging.

**Fig. 3** Apparatus for accelerated artificial aging. (SO2)


**Fig. 4** Measurement of loosening torque

## 4.2 Selection of materials

Manufacturers use different materials such as aluminium, copper, hot dipped galvanized steel as well as stainless steel. Due to economical reasons connecting components are made from different metals and their alloys. As an example for long duration tests the so called “Vario quick connector” [3] was chosen. This connector is available in hot dipped galvanized steel, stainless steel, copper, aluminium as well as composite from two metals.

In lightning protection installations further combinations of different materials are used e.g. conductors from aluminium and clamps made from galvanized or stainless steel.

In the matrix in table 2 the conductor materials are shown together with the material of the connecting components. 40 combinations are possible but some of them are not applied due to corrosion requirements. Some other combinations are not useful. It was therefore necessary to concentrate on the most important practical applications. For the “Vario quick connector” 16 tests had to be performed. The results will give some guide to testing and leads to the conclusion that not all combinations of the product range must be tested.

## 4.3 Results

Table 2 shows the matrix of tested arrangements of materials and their combination. Fig. 5 shows the pictures of tested arrangements of rods and clamps in original condition before accelerated aging using chemical treatment. Fig 6 and fig.7 show the same arrangements after different chemical treatment according to table1. Fig.8 shows same arrangement after impulse current test using 10/350µs wave with 100 kA peak value.

The materials behave different because of their electrical and mechanical properties. Copper and Aluminium have a good conductivity but their mechanical strength is lower compared to steel. Different steel materials such as hot dipped galvanized steel or stainless steel show a much higher mechanical strength but their conductivity is lower especially in case of stainless steel.

Table 2 shows the results of galvanized steel as conductor material. Using galvanized steel sparking between the contact areas occurs due to the higher current density at the contact area and the galvanized layer of the conductor. The local heating reaches temperatures above the melting temperature and some of the galvanized metal will melt. Liquid melted metal in the contact area has a lower conductivity and therefore intensive sparking in the clamp occurs. Sparking inside the clamp will cause mechanical stress. Charge transfer at the footing points of arcs leads to further melting of

**Table 2**: Matrix of tested conductor materials and connecting components

| **Solid round conductor 8 mm** / **Connecting component** | **Hot dipped galvanized steel** | | **Aluminium** | | **Copper** | | **Stainless-Steel (V2A)** | |
|---|---|---|---|---|---|---|---|---|
| | PC | CC | PC | CC | PC | CC | PC | CC |
| 249/Steel, hot dipped galvanized | 0 | H | H | H | *) | *) | *) | *) |
| 249/Aluminium | *) | *) | H | H | *) | *) | *) | *) |
| 249/Copper | *) | *) | *) | *) | H | H | *) | *) |
| 249/V2A-Steel | 0 | 0 | H | H | *) | *) | H | H |
| 249/Zweimetall(Cu/Al) | *) | *) | H* | H* | H* | H* | *) | *) |

H= Class H (100kA, Impulse current 10/350µs)
H*=second conductor made from stainless steel
0= Test not passed
*) = test not meaningful
PC= Parallel connector
CC=Cross connector

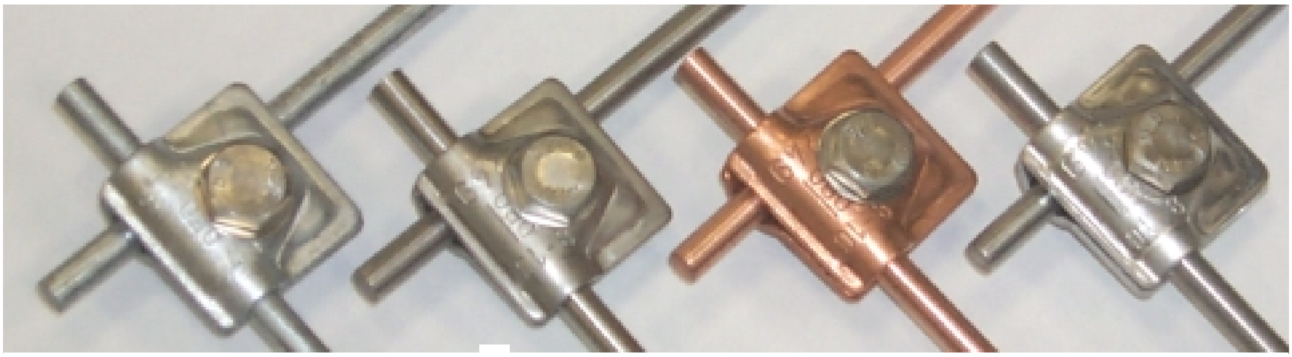

**Fig.5** Original arrangements of rods and clamps: All Bolts are made from stainless steel.
Conductor and clamp, from left to right: hot dipped galvanized steel; stainless steel; copper, Aluminium.

**Fig.6** Arrangemensts after chemical treatment (Salt mist). All Bolts are made from stainless steel.
Conductor and clamp, from left to right: hot dipped galvanized steel; stainless steel; copper, Aluminium.

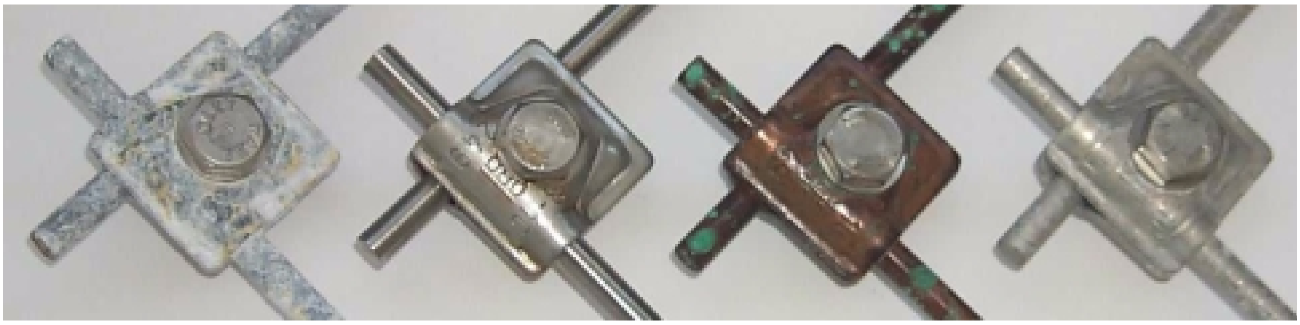

**Fig. 7** Arrangements after chemical treatment ( Salt mist and sulphorous atmosphere). All Bolts are made from stainless steel.
Conductor and clamp, from left to right: hot dipped galvanized steel; stainless steel; copper, Aluminium.

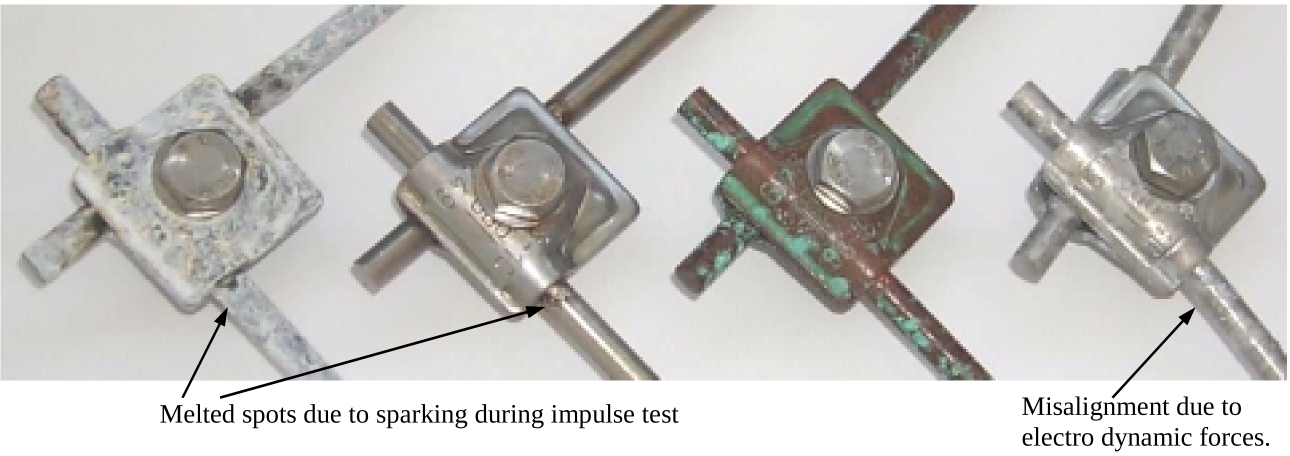


**Fig. 8** Arrangements after chemical treatment according to fig. 6 and fig. 7 and impulse current test.
All Bolts are made from stainless steel.
Conductor and clamp, from left to right: hot dipped galvanized steel; stainless steel; copper, Aluminium.

**Fig.9a.** Bottom view of a vario quick connector after test with lightning impulse current 10/350µs and 100 kA peak value.

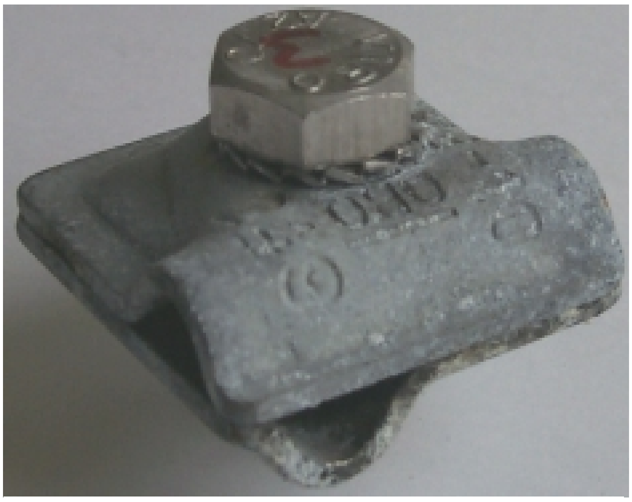

**Fig.9b.** Top view of a vario quick connector .

metal. Such melting caused loosening of the clamp and consequently the capability to handle large lightning impulse currents reliable is no further possible.
According to table 2 one specimen made from hot dipped galvanized steel did not pass the test. It is the question whether the hot dipped galvanized steel conductor or the hot dipped galvanized steel connector has caused such a result. The answer is given in the next row in table 2 where the hot dipped galvanized steel connector is combined with a aluminium conductor. In this case the contact resistance is quite lower and both have successfully passed the test with class H.
All other combinations of materials were successful and passed the class H.
Fig. 9 shows the detailed view of the vario quick connector after testing with impulse current 10/350µs with 100 kA peak value. The toothed lockwasher was damaged due to the current flow and had lost its mechanical properties. Afterwards the bolts were loose and mechanical and electrical reliable connection was no longer given. This result required a new washer as shown in fig.10. The toothed lockwasher was therefore replaced

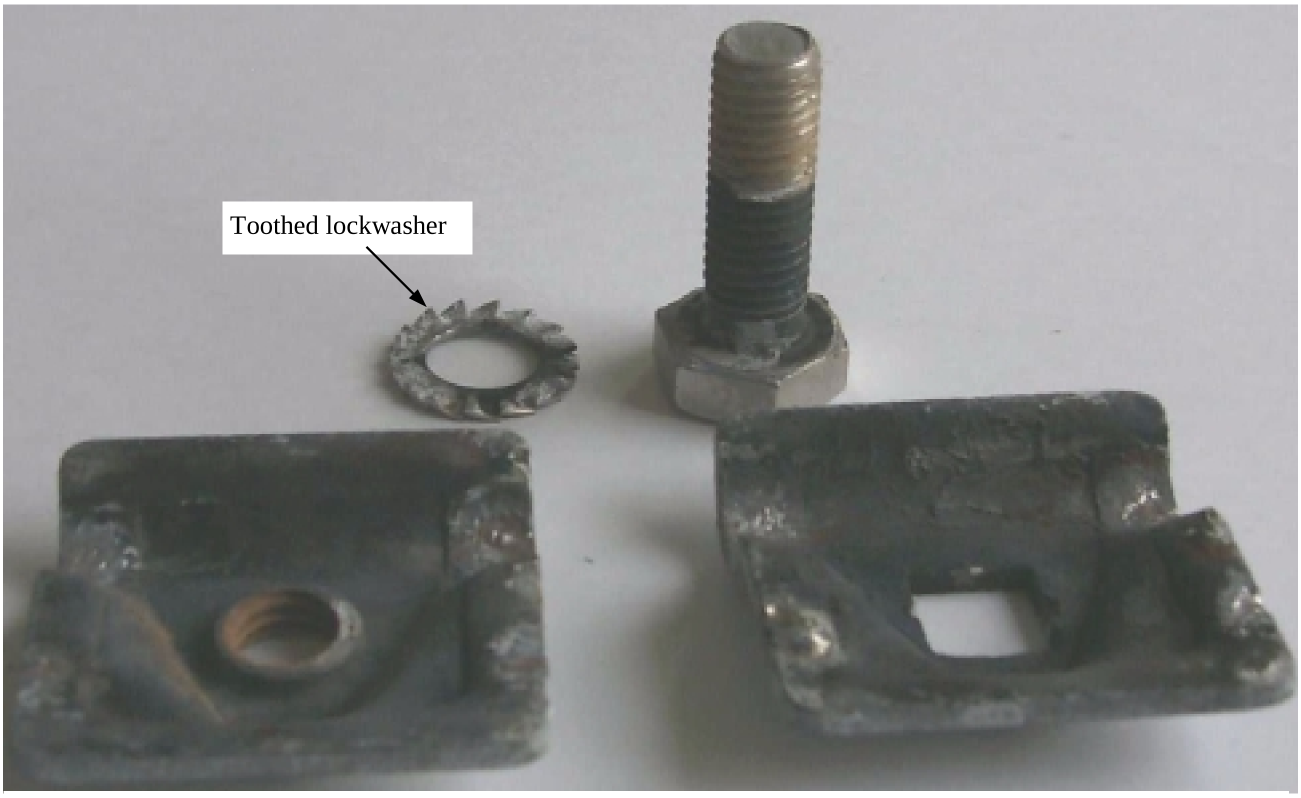


**Fig. 9c** Internal view of a vario quick connector after chemical treatment and test with lightning impulse current 10/350µs and 100 kA peak value.

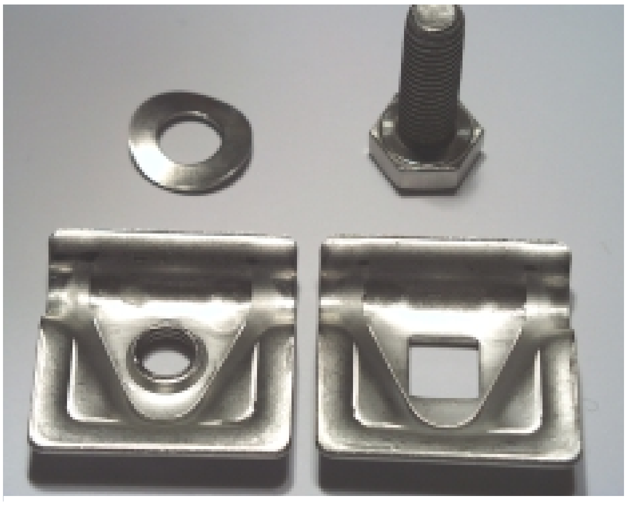

**Fig.10** Vario quick connector with a new spring lock washer for electrical and mechanical reliable connection, compare fig. 9.

by a spring lock washer which have shown a successful performance after lightning current impulse tests.

## 5 CONCLUSIONS

Chemical treatment of lightning connecting components as well as conductor material has been applied to a variety of existing products made from different materials such as hot dipped galvanized steel, stainless steel, copper and aluminium.
The results shown in this paper are representative for a series of tests with different lightning protection components. The results appear also in other tests and can be summarised as follows:

**Connector material**

1. Test with combined materials from hot dipped galvanized steel have always shown some problems e.g. sparking of contacts , loosening of washers, as mentioned above.

2. Conductors made from aluminium and clamps made from hot dipped galvanized steel are applicable and did pass all the tests.

3. Conductors made from copper and clamps made from copper are applicable and passed all tests.

4. Conductors made from stainless steel and clamps made from stainless steel are applicable and passed all tests.

**Test strategy**

In the existing installations mixed materials will be found as conductor material as well as clamp materials.
It is not a sufficient strategy to test only the material with the poorest conductivity and conclude from these results that all other combinations are applicable. Due to the physical mechanism at the contact surface many parameters influence the reliability of a clamp which might be stressed by lightning impulse current in the expected lifetime of some 10 to 30 years.

**Consequences for the development of new connecting components**

From the results one can conclude that reliable connecting components require spring lock washers since the toothed lockwashers have shown mechanical damages which results in loosed bolts. They have to be replaced using spring lock washers.

**Influence of tests on the expected life time**

The tests have given results from which one can choose the optimal combination of materials. The expected life time of an external lightning protection installation will be significantly longer since the tested connecting components are not damaged during a lighting impulse current.

**Reliability considerations**

The reliability of the external lightning protection installation will be sufficiently increase when components are installed which are recommended from the manufacturer after tests with chemical treatments and lightning current tests.

## 6 REFERENCES


[1] Draft pr EN 50164-1/B September 1997. English version Lightning Protection Components (LPC) Part 1: Requirements for connection components Version B

[2] IEC-1024-1-1

[3]OBO Product catalogue, www.obo-bettermann.de