INSTYTUT FIZYKI PLAZMY I LASEROWEJ MIKROSYNTEZY
IM. SYLWESTRA KALISKIEGO

Lightning Tests Laboratory (LSWA)

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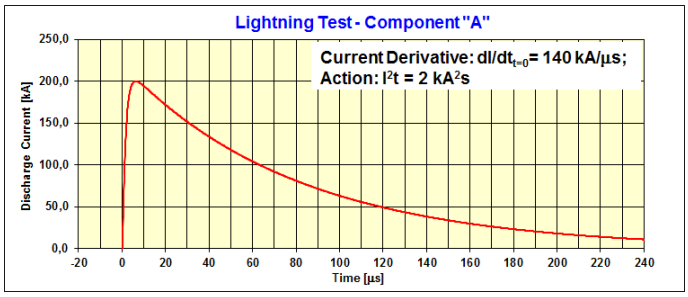
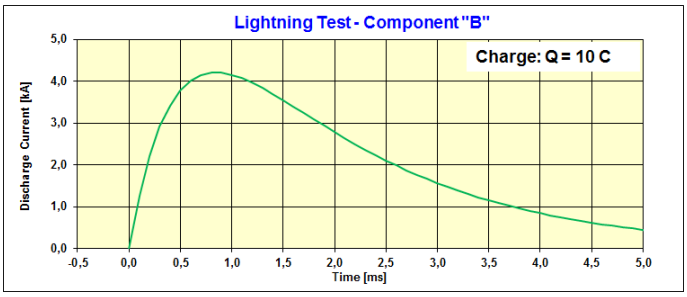
In the modern world, the dependence of almost all aspects of human activity on the proper operation of electronic systems and devices is growing. A large part of these systems must be installed as external infrastructure - exposed to direct impact of harmful environmental factors, including the effects of lightning strikes. This applies in particular to aircraft for which the probability of being struck by lightning in flight or during taxi is much higher than in the case of ground-based installations. The latter, moreover, are usually equipped with various types of security systems, the installation of which on board an aircraft is limited or completely impossible. Therefore, tests of the immunity of the aircraft itself and its avionic systems to lightning discharges are becoming an important element of quality control of the manufactured aviation equipment and have a direct impact on the safety of aviation operations. A similar situation applies to other electronic infrastructure, although in this case the effects of lightning discharges are usually less dramatic (most often temporary, reversible system failure), but they can be burdensome for large groups of people.
The growing awareness of the risks associated with lightning strikes made it necessary to analyze this phenomenon in detail and simulate its course in laboratory conditions. As a result, it led to the establishing and development of specialized research and technology centers, equipped with installations enabling precise examination of the impact of a simulated lightning discharge on the tested object.
The Lightning Tests Laboratory (LSWA) called to act in 1992, was the first research and technical centre of this type established in Poland. LSWA operates within the organizational structures of IPP&LM, and its staff consists of scientific, research and technical employees with many years of professional experience, including the generation of high-current, transient electrical discharges and broadband recording of electrical impulses.
The first commercial order carried out by LSWA was a comprehensive study of the immunity of the W-3A Sokół helicopter to the effects of a simulated lightning discharge.

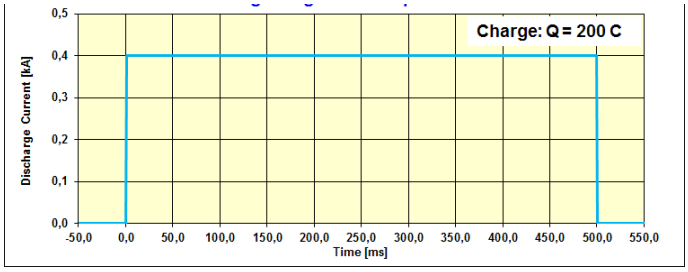
Over the course of nearly a quarter of a century, seven other types of aircraft have been subjected to a similar, comprehensive and fragmentary studies. Over time, the LSWA offer has been expanded to include testing of devices and systems outside the broadly understood aviation industry. In this regard, the more and more common immunity tests of photovoltaic installations deserve special attention, during which the correct operation of the surge arresters used in them are checked.

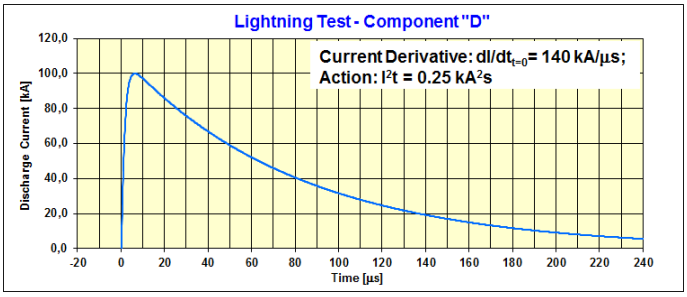
Component pulses of a simulated lightning

Many years of observations and studies of lightning have shown that in this phenomenon there are four basic types of component pulses in various combinations and scales, each of which has a slightly different way of interacting with the object. The course of the basic pulses and their most important parameters are presented in the table below.



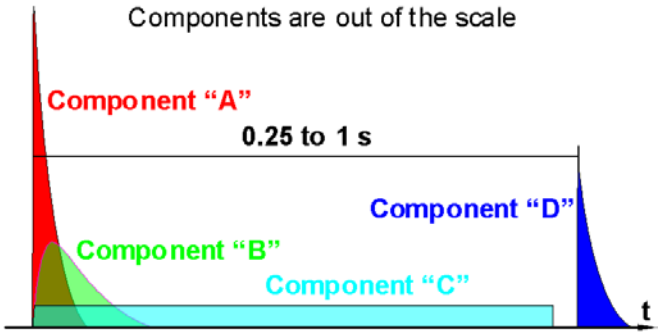


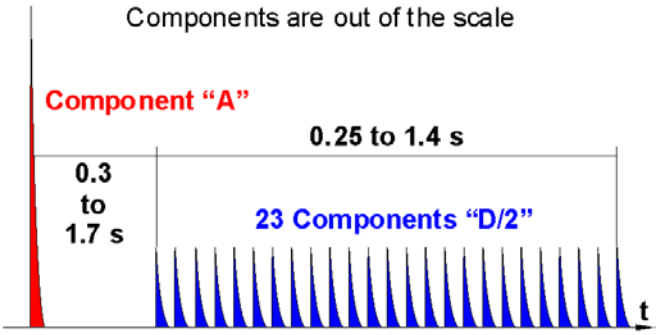




Standard models of simulated lightning

Typically two standard sequences containing different component pulses are used to simulate a lightning discharge in a laboratory. According to research conducted around the world, both standard sequences correspond to approx. 90% of the lightning observed in nature.





Classification of the effects of lightning discharges on flying objects

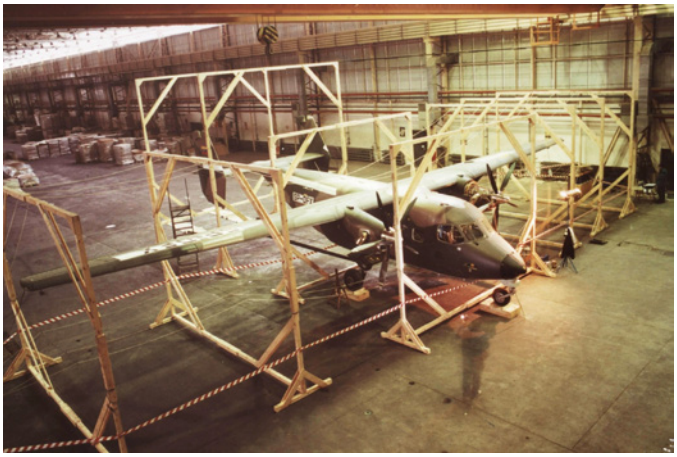
All threats to the safety of aircraft flight resulting from a lightning strike can be divided into two main groups differing in the way they interact with the object as an integral structural whole or with its avionic systems.

Direct effects:

- Burning, melting, sparking, arcing and evaporation of the coating material at the point of contact with the discharge channel, the formation of strong stresses from both the thermal shock wave associated with the discharge channel and electrodynamic forces related to the flowing current - causing loss of tightness or permanent deformation of the structural elements of the flying object;
- The rise in temperature around the discharge path (Joule heat) as well as the accompanying sparks and electrical breakdown can ignite the flying object or trigger an explosion of vapours in the fuel tanks;

Indirect effects:

- Interference or damage to control and measurement systems (so-called avionics) related to the safety of the object's flight, caused by strong electric and magnetic fields accompanying lightning discharges.



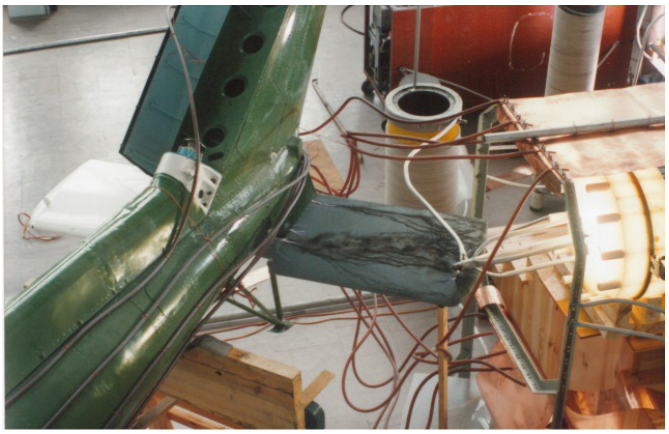
Comprehensive laboratory procedure for testing the immunity of flying objects to lightning

The comprehensive procedure consists of four different research stages:
Test for hit selectivity - determination of the most probable current flow paths through the tested object during a discharge.

This test is carried out in specially prepared, separated research laboratories. To visualize the discharge paths, a test voltage ranging from one to several MV is used, with a discharge current in the order of a few kA;

The W-3A Sokół helicopter during the hit selectivity tests carried out for the front part of the cockpit
(the tests were carried out in the High Voltage Department of Institute of Power Engineering, Warsaw-Mory)

Direct test - testing of direct effects - mechanical and electrical damage caused by a discharge affecting the most important components of the tested object indicated by its manufacturer (in the case of a helicopter, these will usually include both rotor blades, fin and tail planes, cockpit, fuel tanks, etc.). When testing direct effects, the most common is the standard sequence “A+B+C+D” carried out at full scale of a discharge (50kV/200kA, MAX);



W-3A Sokół helicopter tail plane during direct effects research;
Photograph taken during the discharge (left part); Noticeable discharge direct effects (right part)

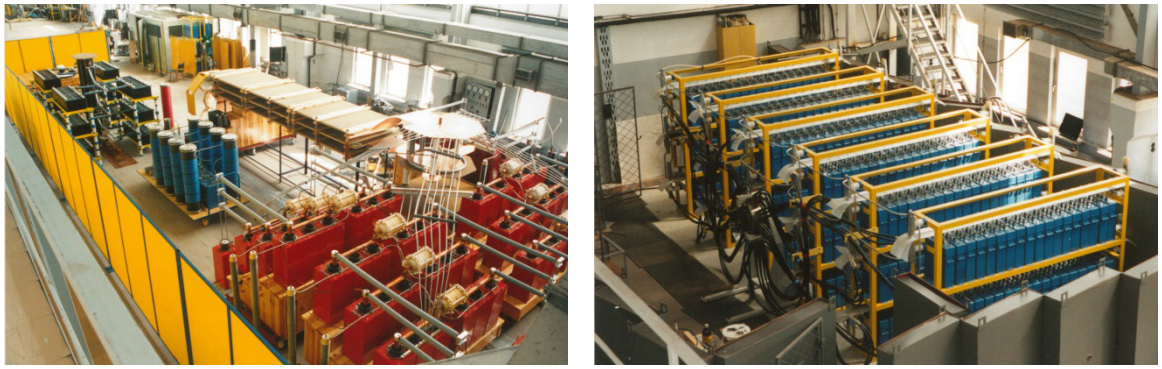
Indirect test - study of indirect effects - determination of the shape and level of electrical disturbances that may occur during the discharge in the most important avionic systems (engine supervision systems, autopilot, gyroscope, radar, etc.). When examining indirect effects, the most common is the standard sequence “A+23D/2” realized in the scale 1:10 (this applies to the current flowing around the object), and the obtained results (interference on transmission lines) are multiplied by 10;

Immunity tests - testing the stability of the operation of selected avionic systems during the introduction of disturbing signals into their installations, the parameters of which were determined on the basis of the results taken during indirect effects tests.

LSWA research and measurement infrastructure

LSWA has an internal research and measurement space with an area of over 1000 square meters, located in the main laboratory hall of IPP&LM. Thanks to the crane with a lifting capacity of 5 T installed in this space, it is possible to directly lift and move large, separated elements of aircrafts delivered for testing.
The internal research and measurement space is usually used to study the effects of the direct impact of a simulated lightning discharge on flying objects. In the case of small cubature flying objects (air taxis, drones), it can also be a site for indirect effect studies and immunity tests.
Indirect effect studies and immunity tests for larger aircraft are usually carried out in the IPP&LM inner courtyard, in which a temporary, external test and measurement space can be arranged.
Immunity tests of electronic devices or systems - not part of the aircraft, are always carried out in the internal test and measurement space.
The LSWA research and measurement base includes, among others:

- Generators of four components of a simulated lightning discharge. The peak voltage and current of the A-type component generator reach 50 kV/200 kA, respectively;
- Specialized generators 8/20 and 10/350 type for testing surge protection devices (used in power networks and photovoltaic installations) during loads caused by a simulated lightning discharge;
- Transient current surge generators working in an arrangement resulting from specific customer requirements;
- Mobile, broadband disturbance generators that enable carrying out immunity tests (also at the customer's premises);
- Stationary and mobile Faraday cages;
- Broadband digital oscilloscopes;
- High voltage and current probes, matched high voltage dividers and high current shunts.



Generators of simulated lightning discharge installed in the
internal research and measurement space of the LSWA;
View of generators of components „A", „C" i „D" (left part); View of generator of component „C" (right part)

LSWA offer

- Conducting a test procedure to determine the immunity of various types of objects (including aircraft) to the loads caused by simulated lightning. As part of this procedure, direct and indirect tests as well as immunity tests are carried out. Basically, the subsequent stages of the tests are carried out at the premises of LSWA, but if necessary (and if possible) indirect tests and immunity tests may be carried out at the customer's premises;
- Tests of surge arresters used in photovoltaic installations - in accordance with the requirements of PN-EN 61643-31: 2019;
- Examining the response of electronic devices to loads caused by high-current, transient electrical discharges, the time course and peak currents of which are determined on the basis of specific customer requirements;
- Control of the correct operation of the equipment provided by the customer in the field of high electromagnetic interference.
- The LSWA research team always makes every effort to ensure that the services offered are precisely tailored to the needs of customers, and our motto is the transparency of research procedures as well as flexibility and reliability.