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AEP-29

PROTECTION OF AIRCRAFT CREW AND SUB-SYSTEMS IN FLIGHT AGAINST ELECTROSTATIC CHARGES

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1. AEP-29 - PROTECTION OF AIRCRAFT CREW AND SUB-SYSTEMS IN FLIGHT AGAINST ELECTROSTATIC CHARGES - is a NATO UNCLASSIFIED publication. The agreement of nations to use this publication is recorded in STANAG 3856.

2. AEP-29 is effective upon receipt.

A. GRØNHEIM
Major General, NOAF
Chairman MAS

RECORD OF NATIONAL RESERVATIONS

PAGES	NATIONAL RESERVATIONS
1 to 5	BE, TU
ANNEX A	BE, TU
ANNEX B	BE, TU
ANNEX C	BE, TU, NO

NATION	RESERVATIONS
BE	Implementation will depend on the compliance of foreign aircraft manufacturers with the requirements laid down in the STANAG.
TU	STANAG 3856 will be utilized at the aircraft which will be produced in the future.
NO	NO ratified STANAG 3856 with reservation to Annex C of AEP-29.

RECORD OF CHANGE

Date of Change	Date Entered	Effective Date	By Whom Entered

ALLIED ENGINEERING PUBLICATION
(AEP 29)

PROTECTION OF AIRCRAFT CREW AND SUB-SYSTEMS IN FLIGHT AGAINST ELECTROSTATIC CHARGES

PROTECTION OF AIRCRAFT CREW AND SUB-SYSTEMS IN FLIGHT AGAINST ELECTROSTATIC CHARGES

PURPOSE

1. The purpose of this document is to provide design guidance and concepts to protect aircraft crew and sub-systems in flight against the effects of electrostatic charge accumulation by:

   (a) considering electrostatic charge phenomena as a potential risk for aircraft crew and sub-systems in flight

   (b) designing the aircraft such that the aircraft crew and sub-systems are protected against the effects of electrostatic charge accumulation

   (c) making necessary arrangements for verifying and maintaining the efficacy of the protection.

   The agreement of nations to use AEP-29 is recorded in STANAG 3856.

RELATED DOCUMENTS

2. STANAG 3659 AE - Electrical bonding requirements for metallic aircraft systems.

NOTE

3. The present publication is not concerned with the risk of electrostatic effects to aircraft on the ground. The publication contains the following specific Annexes:

ANNEX A: DESCRIPTION OF ELECTROSTATIC CHARGING PHENOMENA

ANNEX B: ANTISTATIC PROTECTION OF AIRCRAFT CREW AND SUB-SYSTEMS IN FLIGHT

ANNEX C: VALIDATION OF ANTISTATIC PROTECTION OF AIRCRAFT CREW AND SUB-SYSTEMS IN FLIGHT

ACCUMULATION OF ELECTROSTATIC CHARGES

4. Annex A provides, for information, a description of electrostatic charge phenomena.

5. The total charge current to be considered in order to design the protection is given by the following formula :

$$I_t = I_c * S_a * V / 600$$

where I_t = the total charge current (μA)

I_c = charge current density (300 $\mu A/m^2$)

S_a = the frontal surface area of the aircraft (m^2)

V = the aircraft speed (in knots)

ANTISTATIC PROTECTION

6. Antistatic protection of an aicraft in flight relies on :

(i) electrical continuity between the constituant parts of the airframe

(ii) the treatment of insulating surfaces (application of surface metallisation such as conductive coatings or conductive paint)

(iii) use of static dischargers

7. Annex B provides, for information, more detail on these three points.

8. Stanag 3659 details the arrangements relative to electric continuity between the constituant parts of the airframe.

9. The maximum value of surface resistivity to be taken into account for the treatment of insulating surfaces in 100 M ohms per square.

10. If the use of static discharges is necessary, the minimum number is defined by the following formula :

$N = I_t / I_d$

where I_t = the total charge current

I_d = nominal current of a discharger

(a maximum value of 50 μA for I_d may be used)

11. In order to guarantee satisfactory operation of radio frequency equipment, it is preferable to use static dischargers which allow electromagnetic decoupling of the discharge.

VALIDATION

12. The aircraft qualification process should contain verification procedures permitting validation of the antistatic protection.

13. Annex C describes, for information, some verification procedures which can be applied under the heading of validation.

14. As a minimum, the following points are to be verified :

a) electrical continuity of the airframe

b) the resistivity of the surface metallization on insulating surfaces

c) electrical bonding of metallized surfaces to the airframe structure

d) the installation and location of the static dischargers

e) static discharger DC resistance

f) electrical bonding of the static discharger base to the airframe structure

g) RF noise generated by the static discharger

MAINTENANCE

15. There is a risk that constituent parts of the antistatic protection will degrade with time

16. The maintenance documents must contain instructions necessary to guarantee performance of the antistatic protection throughout the life cycle of the aircraft

ANNEX A

DESCRIPTION OF ELECTROSTATIC CHARGING PHENOMENA

1 ACCUMULATION OF ELECTROSTATIC CHARGES

Every aircraft in flight is subject to the phenomenon of static electrification. Three charging processes can be identified :

- charging by triboelectric and charge collection effects,

- charging due to propulsion system exhaust gases,

- induced charges caused by external electric fields.

1.1. Triboelectricity and charge collection

The triboelectric effect is the electric charging of the aircraft in flight, by the impingement of particles such as water droplets, rain, snow, ice crystals and sand or dust particles. A charge collection process occurs when the aircraft passes through a zone of such particles. The contact of these particles with the skin of the aircraft leaves an electric charge on the surface.

Depending upon the nature, size, density and relative velocity of the particles impacting the skin, a greater or lesser charge current is created. The current densities which have been determined for various types of precipitation are as follows :

cirrus	=	50 to 100 $\mu A/m^2$
strato-cumulus	=	100 to 200 $\mu A/m^2$
snow	=	300 $\mu A/m^2$

On rare occasions levels of 400 $\mu A/m^2$ have been observed.

1.2. Propulsion system exhaust gases

Certain powerplants release to the atmosphere ionised combustion products which have the effect of charging the aircraft. Depending on the type and the operating characteristics of the engine, absolute currents from 0 to 400 μA can be obtained. In this case the charging process is independant of meteorological conditions.

This phenomenon negligible in the case of propeller driven aircraft is very important in aircraft having engines with after-burn. It can, in some cases, help to discharge the aircraft (ejection of negative charges).

1.3. Ambient electric field

When an aircraft passes through storm areas it is subject to an intense electric field which may favour local discharge and modify the individual charge of the aircraft. For an aircraft to be used in all weather conditions this phenomenon can be relatively frequent and difficult to control.

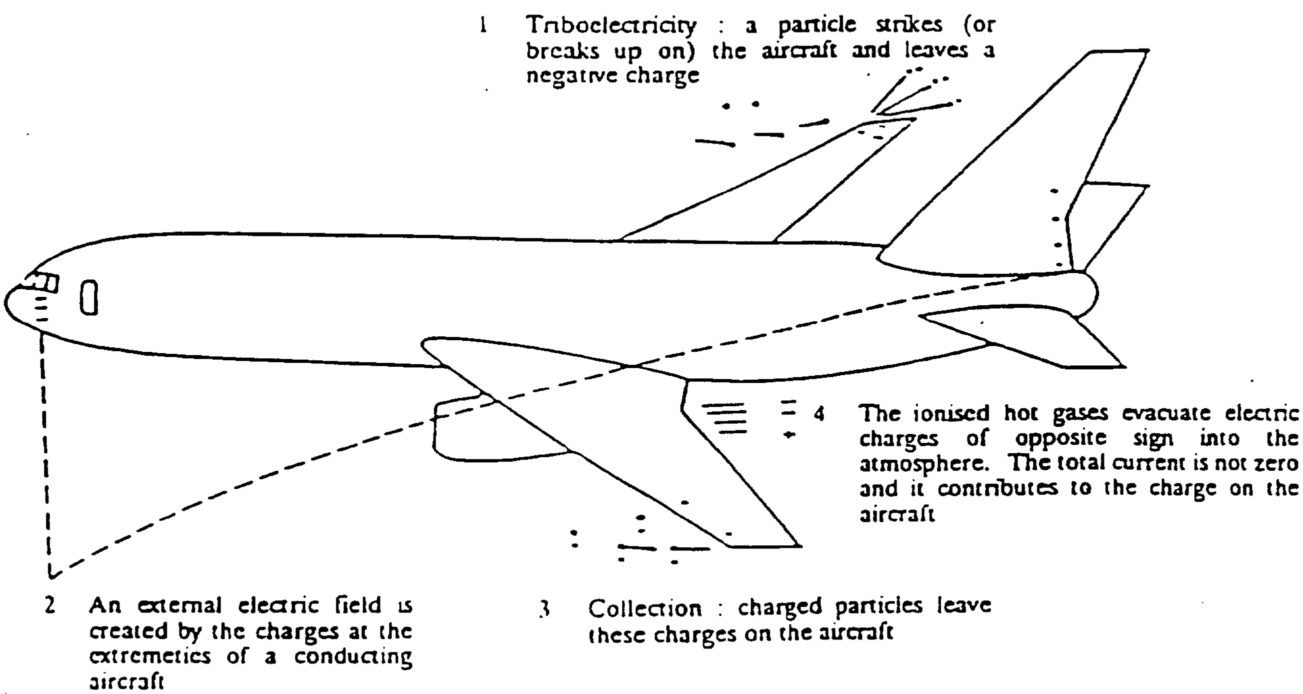

Figure A1 : Charge phenomena of an aircraft

2 THE DISCHARGE PROCESS

The accumulation of electric charges gives rise to an increase in the potential of the aircraft. Above a certain threshold discharge phenomena appear which tend to establish an electrical equilibrium. These are :

- discharges to the atmosphere (CORONA),

- discharges on the aircraft :
  - between insulated conducting surfaces
  - on insulating surfaces
  - discharges to the earth

2.1. Discharges to the atmosphere

For a spherical conducting body the electric field takes up a uniform distribution on the surface. On an aircraft with more complex geometry the amplitude of the field at any point depends on the convexity at the point (point effect) and is thus particularly high at the extremities (wings and tail unit). When a point reaches the critical value for discharge in air, a CORONA discharge occurs and this tends to balance the effect of the charge. If the potential continues to rise other discharge points appear. The process reverses as soon as the charge decreases.

The phenomenon is complicated by the fact that in storm clouds or those tending to the storm conditions, the electric field is not homogeneous.

2.2. Discharges between insulated conducting surfaces

Two adjacent conducting surfaces, insulated the one from the other, can reach very different potentials. When the potential difference exceeds the breakdown threshold discharge between the two surfaces takes place, manifesting itself in the form of sparks.

2.3. Discharges on insulating surfaces

On an insulating surface the charges generated cannot move. The growth of the charges gives rise to a local increase in the electric field. When the discharge threshold is reached streamers develop flowing towards nearby conducting surfaces. On the windscreen it is visible as long brush discharges (St Elmo's Fire).

2.4. Discharge to the earth

In some cases a discharge can occur between the ground and an aircraft at a very high potential due to the accumulation of electrostatic charge. This can apply particularly in helicopter lifting operations, in which discharge can take place between the store being carried and the ground.

2.5. Discharges to the earth, after landing

During landing, contact of the tyres with the ground in generally sufficient to allow discharge of the residual electric charge on the aircraft.

Insufficiently protected non-conductive surfaces can remain charged and thus comprise a potential risk for the generation of an electric spark which is hazardous to personnel or materiel on the ground.

3 ADVERSE EFFECTS ON AIRCRAFT IN FLIGHT

3.1. Discharges into the atmosphere

Electrostatic discharges are accompanied by electromagnetic phenomena which disturb the operation of some electronic communications, navigation and detection equipment. The emitted spectrum covers a wide range of frequencies and is of concern mainly for equipment operating in the ranges 10 kHz to 200 MHz and even at 400 MHz. Such equipment includes but is not limited to:

- HF, VHF and sometimes UHF communication equipment
- VLF, OMEGA, LORAN, HF and V/UHF RADIO COMPASS, VOR and ILS navigational receivers

The parasitic signal is directly captured by the antenna (CORONA discharges on the antenna itself), or is indirectly received by coupling of the noise source at the antenna.

This gives rise to :

- a reduction or degradation of the sensitivity of detection equipment
- interference in communications to the point of rendering them inaudible
- a significant reduction of range or the presentation of erroneous navigational information

These perturbations, which often occur under poor conditions of visibility, create serious problems in the execution of flights. It should be noted that the smaller the aircraft the greater is the risk that coupling of the discharge source to the antenna will be serious.

The electrostatic phenomena may also have other adverse effects such as :

- disturbance of electronic equipments by direct discharge through their own circuits
- transient disturbance of the supply network resulting from the discharge of a window fitted with a heating circuit
- risk of explosions in storage tanks
- electric shocks to the crew

3.2. Discharges to the ground

This risk applies to helicopters. The discharge of the energy accumulated by the helicopter may be dangerous for the ground personnel who deal with the store in transit before it has reached earth potential, or dangerous for the store itself.

The following table lists the risks for man as a function of the discharge energy.

Author	Energy mJ	Probable reaction
Schneider (1974)	1	Threshold of perception
Douglas et al (1974)	28	Feeble shock
Schneider	40	Light shock without consequence
Douglas	50	Skock in the fingers
Schneider	100	Severe shock without consequence
Douglas	112	Painful shock
Douglas	152	Shock felt in the wrist
Douglas	200	Shock felt in the wrists and ankles
Douglas	250	Heavy shock with no danger
Schneider	500	Heavy shock causing muscular pains
Rogers (1967)	500	Threshold of movement control
Schneider	800	Very heavy shock with loss of consciousness but without lasting lesions
Schneider	1000	Maximum shock, fainting, may cause death

Fig A2 : Probable reactions of individuals

ANNEX B

ANTISTATIC PROTECTION OF AIRCRAFT CREW AND SUBSYSTEMS IN FLIGHT

1 GENERAL

The antistatic treatement of an aircraft is aimed at reducing the undesirable effects of discharges. For this, three conditions must be fulfilled :

(1) The encouragement of the free circulation of charges by connecting all conducting elements together to form an equipotential airframe structure.

(2) The prevention of the localised accumulation of electric charges by applying an appropriate conducting treatment to the whole external insulating surface. This treatment to be electrically connected to the adjacent metallic structure.

(3) The ensuring of charge flow in a controlled manner using potential dischargers.

The antistatic protection design must take into account all the elements making up the external geometry of the aircraft : structure and equipment must be included with moveable elements in all possible configurations. The treatment is developed for a given version of the aircraft. Any subsequent modification of the structure (antenna, etc) may affect the efficiency of the treatment and must be considered with this in mind.

2 ELECTRICAL CONTINUITY

The effectiveness of the treatment depends primarily on establishing the "equipotential" of the airframe structure, that is, maintaining at the same potential all the conducting elements of the external envelope of the aircraft. This includes metallic skin, conductive coatings, conductive paint, and conductive treatments of insulating surfaces and equipment.

The effectiveness of the electrical continuity will be dependent upon the allowable levels of metallization or conductive surface treatment.

In the case of conducting treatments applied to insulating elements the value of the metallisation to be obtained, which is a function of the resistivity of the treatment and of the position of the measurement points, must be decided for each individual case.

Attention is drawn to the need to effect a viable metallisation, which applies a sufficient number of earth contact points and a suitable corrosion protection.

3 SURFACE TREATMENT

This has as its aim to render conducting, in the electrostatic sense of the term, the whole of the surface comprising the external envelope of the aircraft. It thus deals with :

- the main skin

- the external insulating surfaces

- external equipment

3.1. The main skin

This is usually made of conducting materials (aluminium alloys or carbon composites) constructed to obtain good electrical continuity and should therefore represent a satisfactory solution. Nevertheless the external face of the skin may be rendered more or less insulating by the presence of non-conducting products eg anodic oxidation products and paint for the metal or resin and paint in the case of the composite.

The insulation depends on the dielectric characteristics and the thickness of the products used. As a certain degree of insulation may be accepted it is desirable to qualify each of the solutions proposed by appropriate electrostatic tests.

The decorative elements, identification marks or protections (insignia, letters, bands etc) which have been applied to the surface of the aircraft may be responsible for localised discharges :

- if they are conductors, but insulated from the structure by the finish paint, they form a capacitor which will discharge by breakdown of the insulating layer,

- it they are insulators, they reinforce the dielectric insulation of the paint and may be the seat of streamer discharges.

Inasmuch as they cannot be eliminated and if they constitute a risk of compromising the antistatic protection, an appropriate solution must be researched (point metallisation, surface treatment etc.)

3.2. External insulating surfaces

The protection of insulating materials is based on a conductive treatment of the surface. Among the possible processes are :

- deposition of metal oxides or salts (for glass),
- use of aluminium spraying,
- use of conducting paints (low resistivity),
- use of antistatic paints (high resistivity).

All conductive treatments of insulating surfaces must be electrically connected to the adjacent metallic structure. The electrical connection shall maintain the equipotential levels at the connection.

The choice of a solution must take into consideration the operational needs of the element concerned and is thus the result of a compromise.

In the case where a conducting treatment cannot be applied to a given surface, either because there is no adequate solution or because of particular constraints, the protection of susceptible equipments must be achieved indirectly, e.g. by increasing the decoupling between the sensitive element and the potential source of the noise.

3.2.1. Optically transparent surfaces

Depending on their position on the aircraft, optically transparent surfaces may be subject to triboelectric phenomena to a greater or lesser extent. The windscreen or cockpit surfaces are particularly exposed, while the passenger windows are relatively well shielded.

Windscreens are sometimes subject to luminous discharges which can be annoying for the crew. When they are equipped with a heating lattice, electric discharges from the windscreen may give rise to high transient overvoltages on the supply networks and this can have serious consequences for equipments connected to the supply. These discharges can give rise to mechanical stresses and crack the windscreen. A conductive treatment will resolve these problems.

Such a treatment usually consists of depositing a fine film of gold or of a metal oxide or salt on the surface of the transparent material. It must satisfy the requirement for optical transparency and have an adequate mechanical strengh to resist erosion and abrasion (due to screen wipers).

It is recommended that a conducting treatment should be applied to all transparent surfaces subject to air impact, even when they are small eg anti-collision lights.

In cases where a conducting coating is not used it is recommended that the level of overvoltage that may be imposed on the circuits (de-icing...) be considered and protections applied.

3.2.2. Electromagnetically transparent surfaces

Usually a surface treatment based on antistatic paints will satisfy electromagnetic radiation requirements when the surface resistivity is between 10M Ohms and 100M Ohms per square, this is the case for radomes covering the antenna of the following equipments :

- communication (VHF, UHF, IFF),

- navigation (VLF, radio compass, VOR, ILS, TACAN).

It is nevertheless recommended that, for each specific configuration, it should be checked that the applied treatment allows satisfactory operation.

For centimetre wavelengths and more especially for high performance radars the above treatment should be prohibited with regard to system performance. There is a place, if necessary, for ensuring the protection of other equipments sensitive to discharges which may be produced on the radome, using another method (space decoupling for example).

3.2.3. Other surfaces

These are all those surfaces which do not have special optical or electromagnetic properties. In general they consist of components in glass fibre composites such as access ports, wing tips, wing fillets, etc. The surface resistivity of the applied treatment is only limited by a maximum value ($R \leq$ 100M Ohms per square) in order to ensure proper flow of the charges.

3.3. External equipment

It is recommended that the rules of antistatic protection be applied to all equipement mounted on the exterior of the aircraft.

3.3.1. Antennas

The RF antennas are to be examined as they may be the source of electrostatic discharges. The existence of good coupling with respect to the equipment attached to them increases the risk of static discharges.

3.3.2. Antenna with insulating cover

An antistatic treatment of the surface is recommended as heavy discharges can occur at the surface.

3.3.3. Whip aerials

These antennas have a "point effect" that can favour CORONA discharges. The use of this type of antenna is strongly opposed.

3.3.4. Anticollision and navigation lights

These have cowlings or casings in glass or plastic and it is recommended that these be metallised. In the case of glass, a solution similar to that for the windscreen may be applied.

3.3.5. Other equipment

It is recommended that all other installed equipment be examined to determine any possible influence on the general treatment of the aircraft (CORONA discharges etc) and to define, where necessary, an appropriate treatment.

- It is recommended that all external stores (non permanent loads) be examined as far as the following are concerned :

- effects on the basic treatment of the aircraft,

- the possibility of CORONA or surface discharges.

The antistatic protection of these stores may be effected using the same techniques as those applied to the aircraft.

4. STATIC DISCHARGERS

Once the aircraft is made into an equipotential structure it is possible to control electrostatic discharges to the atmosphere, for example by using a network of static dischargers properly disposed. To design such a network it is necessary to :

a) evaluate the total current of the charge,

b) determine the total number of static dischargers to be installed,

c) determine the distribution of the dischargers on the aircraft.

These different tasks may be undertaken empirically, or by relying on the results of laboratory tests, or through experience. The present state of the art only allows the application of an empirical method as described at the end of this paragraph.

4.1. Evaluation of the total current

The total current may be determined using the empirical formula :

$$i_T = i_C * s_A * \frac{V}{600}$$

where i_T = total current (μA)

i_C = current density of the charge (μA/m^2)

s_A = frontal area of the aircraft (m^2)

V = speed of the aircraft (in knots)

i_C is the most probable maximum value and can be taken as 300 μA/m^2 taking into account the values given in Annex A.

This formula applies quite well for light and medium weight aircraft. For heavy aircraft is slightly over estimates the value of the current.

In this latter case the effect of aerodynamic downwash on the flux of incident particles is relatively large, thus reducing the number of particles striking the frontal surface of the aircraft.

4.2. Determination of the total number of dischargers

The total number of dischargers to be implemented is given by :

$$N_D = \frac{i_T}{i_D}$$

where N = total number of dischargers

i_T = total discharge current

i_D = nominal current of the discharger

The value of 50 µA can be used for i_D.

4.3. Choice of type of discharger and characteristics

There are two main types of discharger :

- trailing edge dischargers,
- extremity dischargers.

These dischargers are designed as demountable elements which are generally attached to special supports.

The effectiveness of a given type of discharger depends on the following characteristics :

- an adequate current/voltage discharge curve,
- RF discharge noise,
- continuous discharge current rating,
- electromagnetic decoupling of the discharge,
- DC resistance :
    - trailing edge mounted, 6M to 200M Ohms,
    - extremity mounted, 6M to 120M Ohms.

The effectiveness can be measured using the methods and criteria defined in ANNEX C. The dischargers must also be capable of performing in the defined operational environment.

4.4. Distribution of dischargers

It is recommended that the following technical principles be applied :

The dischargers must be located at extremities and at the trailing edge of the surfaces showing the maximal point effect, such as wings, vertical and horizontal tail units.

The distribution must take account of the distance of the element under consideration with respect to the centre of the aircraft. For example, in the case of a classical aircraft shape one must use a distribution which is almost indentical for the five extremities to be equipped, increasing the quantity reserved for the half wings which are at a relatively larger distance.

There may well be other elements whose prominent position requires the insertion of dischargers to avoid the appearance of uncontrolled discharges eg fairings for flap controls under the wing, pitot tubes etc.

A careful examination of the geometry will allow the critical points to be identified and protected.

A CORONA discharge can also appear prematurely in zones of high aerodynamic depression. Such is the case for the extremities of wings and tail units protected by so-called extremity dischargers.

4.5. Rules for installation

It is recommended that the following technical principles be applied :

Dischargers at the trailing edge :

- should be fixed as close as possible to the trailing edge,
- the most outboard discharger must be situated at the extremity of the surface of interest,
- the spacing between two consecutive dischargers must not be less than 300 mm,
- the long axis of each discharger must be aligned in the direction of the aerodynamic flow,
- on a mobile surface eg an aileron, the dischargers may be fixed alternately on one side and on the other to balance the effects,
- the electrical connection of the base of the static discharger to the structure must ensure a proper bonding resistance (1 Ohms or less) and effective corrosion protection.

Extremity dischargers :

These must be situated at the points of highest aerodynamic depression whilst respecting the rules given above in the last two indented sections.

Special cases :

On insulating structures (wing tips) the dischargers must be connected to the conducting layer or to the nearest earth for example by means of a metallic joining strip.

4.6. Helicopters

The principles of protection described in the preceding paragraphs remain valid in the case of helicopters. However attention must be drawn to the special aerodynamics of rotating wings and the possibility that the effectiveness of the static dischargers will be reduced during hover conditions.

This may become dangerous during lifting operations as the residual potential of the vehicle may be sufficient to cause a discharge. Protection may then be obtained by a device which ensures that the aircraft is earthed :

- a helicopter to ground cable,

- a safety rod on the ground...

ANNEX C

VALIDATION OF ANTISTATIC PROTECTION OF AIRCRAFT CREW AND SUBSYSTEMS IN FLIGHT

1 PLAN FOR THE VALIDATION OF AN AIRCRAFT FOR ELECTROSTATIC CHARGES

If the establishment of a validation plan for electrostatic charge protection is foreseen at the conception of the aircraft it is recommended that the designer should base his work on the following plan which describes the main steps to be followed during the following development phases :

a) design phase of the aircraft,

b) production phase of the prototype.

1.1. Design phase

Stage 1 : Verify adherence to the metallisation standards, including those for the equipments and the external loads.

Stage 2 : Treat the entire outer surface to ensure adequate surface conductivity or resistivity with emphasis on :

- RF transparent materials - radomes, antennas, etc.,
- optical transparencies : windscreens, portholes,
- other material.

Stage 3 : Ensure electrical connection between the conducting surface treatment and the adjacent metallic airframe structure.

Stage 4 : Check that the finish paints, distinctive markings etc. do not degrade the above performances.

Stage 5 : Define the required number of static dischargers and their installation locations using the appropriate design guidelines and specifications available.

1.2. Production phase of the prototype

Stage 6 : Test the electrical conductivity or resistivity of the entire outer surface.

Stage 7 : Raise the aircraft to a high potential to check the discharge points.

Stage 8 : Verify the operation of RF equipment during bombardment with an ion gun, or another system which allows a charge current to be generated on the surfaces.

Stage 9 : Ensure that the zones of maximum coupling are protected against possible discharges.

Stage 10 : Modify the defined rules as a result of the data obtained.

Stage 11 : Test the electrical bonding of static dischargers and surface treatments to the airframe structure.

2 VALIDATION TESTS

2.1. General rules

Performance of qualification tests to verify protection against static electricity depends, in most cases, on the availability of continuous high voltage and very high voltage generators. The attention of users should be drawn to the potential risks when using such generators and the necessary safety measures which must be adopted to protect test personnel (delineation of safety zones, grounding procedures, automatic circuit breakers, training and instruction of personnel, etc.). The various probes and pick-up devices, transmission networks, data measurement and acquisition systems needed for the different tests must also be adequately protected to withstand the severe electromagnetic environment associated with the tests.

2.2. Note

The tests described below have as their aim the qualification of the protection of an aircraft against static electricity. For this they are carried out on a complete aircraft. They may, however, for special needs, be applied to parts of the aircraft.

2.3. Test for injection of electrostatic charge

2.3.1. Objective

The object of this test is to determine the level of the perturbations caused by the appearance of charges, locally on an aircraft and/or to check the efficiency of protection.

2.3.2. Field of application

This test is applicable to the whole surface of the aircraft liable to be charged in flight. It is usable especially for dielectric surfaces whether metallised or not.

2.3.3. Test specimen

The test specimen consists of a production aircrafts or a model that is electrically representative of the outer surface/envelope and includes the electrical and electronic equipment and circuits of the aircraft (the number and type of circuits and equipment can be limited to those that are the most susceptible/vulnerable).

2.3.4. Test equipment

The test equipment comprises :

- a charge generator or a continuous very high voltage supply which allows the charges to be generated,
- measuring instruments to monitor operation of the generator (high voltage, current injected...),
- measuring and recording instruments to monitor the perturbations produced in the equipments,
- means to detect and characterise a discharge.

This is not a complete list and may be added to according to the special needs of the test.

2.3.5. Setting up the test

Where a charge generator is used, it is positioned relative to the surface which is to be the object of the injected charge.

Where a high voltage generator is used, on of the poles of the generator is connected to the specimen, the other pole being connected to an electrode of carbon fibres positioned with respect to the surface or the point of injection.

The level of injection current to be achieved is a function of the zone of the aircraft :

- for a frontal surface : 400 $\mu A/m^2$
- for a lateral surface : 100 $\mu A/m^2$

In all cases the aircraft is decoupled from the ground and positioned as far as possible from surrounding metallic objects.

2.3.6. Test procedure

a) Position the generator, the injection circuit and the diagnostic equipment

b) Check the equipment and the surroundings for test safety

c) Check that the start up of the measuring system is not subject to any interference

d) Measure the charge current by interposing a metal plate connected to the circuit by a micro-ammeter between the generator and the injected charge surface

e) Apply the impact current to the surface under test, carry out the measurements and record the data. The test must be maintained for a period sufficient to allow the streamers to appear

f) Check that the operation of the system is not subjected to any interference

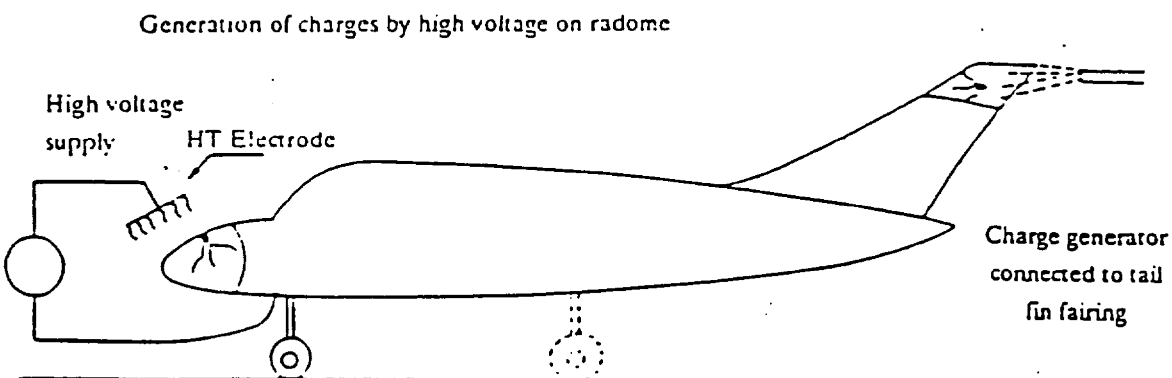

Figure C1 : Example of charge injection test

2.4. Tests for increase in potential

2.4.1. Objective

The object of this test is to determine the level of the perturbations caused by a rise in the potential of an aircraft.

2.4.2. Field of application

This test is applicable to any aircraft.

2.4.3. Test specimen

The test specimen is identical to that in paragraph 2.3.3. "test specimen".

2.4.4. Test equipment

The test equipment consists of :

- a continuous high voltage generator,

- measuring instruments necessary to characterise the operation of the generator,

- measuring and recording equipment to characterise the perturbations caused,

- means to allow observation of glow discharges.

This list is not definitive and may be extended as a function of the special needs of the test.

2.4.5. Setting up the test

The specimen is insulated from the ground at a height sufficient to reduce ground effects.

The high voltage is applied between earth and the aircraft. The point of connection to the specimen must be chosen to reduce its effect and the generator must be distant (several metres) from the test specimen.

The voltage to be applied is determined by the current supplied by the generator which should be :

$$I_g = J * S * \frac{V}{600} + I_t + 10\%$$

where I_g = generator current (mA)

J = charge current density (mA/m^2)

I_t = test assembly loss current

S = frontal surface of the aircraft (m^2)

V = speed of the aircraft (in knots)

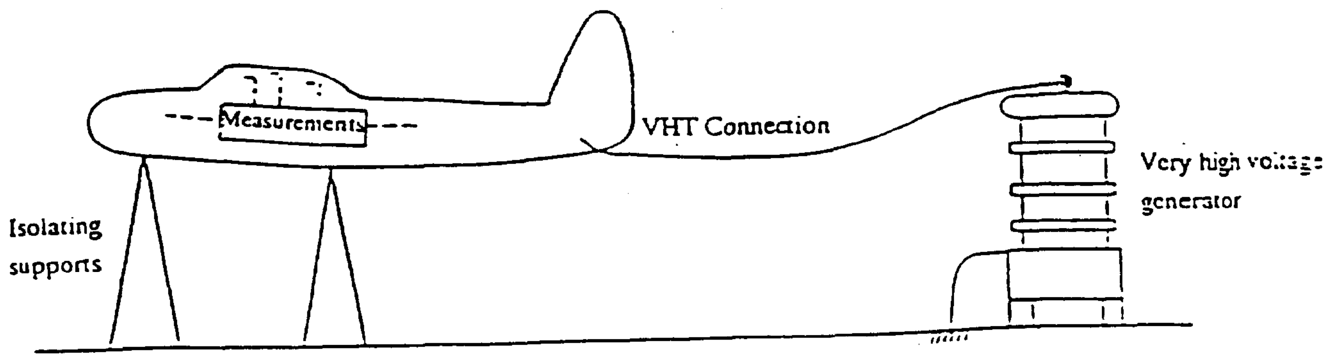

Figure C2 : Example of test for rise in potential

2.4.6. Test procedure

a) Position the insulating assembly and the high voltage generator connected to the assembly

b) Check the equipment and the test area for safety

c) Measure the loss current of the assembly by drawing the loss current curve as a function of test voltage

d) Put the specimen on the insulating assembly and connect it to the generator

e) Check the equipment and the test area for safety

f) Check that the operation of the system is not subject to any interference

g) Progressively apply high voltage and make and record measurements

LIST OF EFFECTIVE PAGES (LEP)

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ORIGINAL	I Title (reverse blank)
ORIGINAL	III (reverse blank)
ORIGINAL	V, VI
ORIGINAL	VIa (reverse blank)
ORIGINAL	VII (reverse blank)
ORIGINAL	1 Title (reverse blank)
ORIGINAL	2 to 5
ORIGINAL	A-1 to A-6
ORIGINAL	B-1 to B-9 (reverse blank)
ORIGINAL	C-1 to C-6
ORIGINAL	LEP-1 (reverse blank)

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