

AEROSPACE RECOMMENDED PRACTICE

SAE ARP4043

REV.
B

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Superseding ARP4043A

Flight Line Grounding and Bonding of Aircraft

RATIONALE

The SAE AE-2 committee member comments point out that the static electrical bonding for aircraft practices recommended in ARP4043A provide no personnel lightning protection. Therefore, the statements in ARP4043A about the benefits of the electrical bonding practice for lightning protection are technically inaccurate. ARP4043A also conflicts with the requirements in National Fire Protection Association (NFPA) 407. Static electrical bonds between the aircraft and earth ground points are not permitted during aircraft fueling according to NFPA 407. No one in the AE-4 committee volunteered to revise the document. Also, it is mostly redundant with NFPA 407.

CANCELLATION NOTICE

This document has been declared "CANCELLED" as of October 2007. By this action, this document will remain listed in the Numerical Section of the Aerospace Standards Index.

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FOREWORD

Changes in this revision are format/editorial only.

TABLE OF CONTENTS

1. SCOPE	2
2. REFERENCES	2
3. BASIC REQUIREMENTS	3
4. BASIS FOR AIRCRAFT GROUNDING	4
4.1 Electrostatic Theory.....	4
4.2 Energy Sources.....	5
4.2.1 Triboelectric Effects	5
4.2.2 Induced Charge.....	6
4.2.3 Friction	7
4.2.4 RF Electromagnetic Energy	9
4.2.5 Lightning.....	11
4.2.6 Summary	14
4.3 Other Physical Considerations.....	15
4.4 Airframe/Personnel Electrical Parameters	15
4.5 Damage Threshold Levels	17
4.6 Analysis	18
4.6.1 Source Magnitude	18
4.6.2 Time Duration Consideration.....	20
4.6.3 Hazards	21
4.6.4 Effects of Grounding.....	21

1. SCOPE:

This ARP provides the rationale and theory of charges being present on aircraft while on the ground. The necessary implementation of safety practices are explained and defined.

2. REFERENCES:

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10. C. C. Kleronomos and E. C. Cantwell, "A Practical Approach to Establish Effective Grounding for Personnel Protection." Industrial and Commercial Power System Technical Conference, Seattle, Washington, May 1979.
11. J. E. Nanevicz, "Static Electricity Phenomena: Theory and Problems." Conference on Certification of Aircraft for Lightning and Atmospheric Electricity Hazards, ONERA, September 1978.
12. Manual on Earth-Resistance Testing No. 25Ta, Biddle Instruments, Blue Bell, Pennsylvania 19422, Copyright 1982.

2. (Continued):

13. MIL-HDBK-274, EMCS Electrical Grounding for Aircraft Safety, November 1983.

14. AFSC Design Handbook, DH1-4, Design Note 7B4, Static Electricity Considerations for Aircraft Fuel Systems, March 1984.

3. BASIC REQUIREMENTS:

Grounding is the process of connecting one or more metallic objects and ground conductors to ground electrodes. Bonding is the process of connecting two or more metallic objects together by means of a conductor. Bonding is done to equalize electrostatic potential between two or more conductive objects.

The generation of static electricity cannot be prevented entirely. Its generation is not in itself a hazard provided it can be dissipated safely. The hazard is encountered when charges accumulate to the extent that a spark discharge occurs to some other object in the presence of hazardous atmospheres, dusts, etc. Elimination of such potential hazards, therefore, requires proper grounding or neutralization of the charges to avoid dangerous accumulations.

A well-known example of static electricity is the discharge (sparking) of an accumulated charge built up on a person who has walked on a carpet in a dry room, and touches a metal door handle or radiator.

Further hazards may be encountered due to induced charges resulting from nearby lightning storms.

Aircraft shall be grounded at all times when they are parked. If a suitable ground is not available, aircraft will be bonded to servicing equipment during actual servicing. Perform grounding as follows:

- a. A grounding wire will be connected between earth, i.e., ramp ground, or safety ground, and aircraft immediately after the aircraft is parked and should not be removed until just before the aircraft is moved.

NOTE: A hazardous voltage may be on the aircraft before the ground wire is connected. To prevent a dangerous shock, the ground wire must be connected to the ground rod before making the connection to the aircraft.

- b. Grounding wires for ground support equipment (GSE) may be connected to any approved ramp ground, and do not have to be connected to the same ground as the aircraft. See paragraphs 4.2.1 and 4.2.5.2 for recommended ground resistance.

3. (Continued):

- c. The connection sequence for the preferred triangular method of grounding/bonding is as follows:
 - 1. Connect grounding wire/cable to a ramp ground.
 - 2. Connect other end of grounding wire/cable to aircraft grounding receptacle or grounding lug.
 - 3. Connect ramp cart/refueler to a ramp ground.
 - 4. Connect ramp cart/refueler to aircraft ground receptacle or grounding lug.

CAUTION: If an approved safety ground is not available for grounding the aircraft, use considerable caution if a thunderstorm is within 20 miles. Servicing and maintenance personnel can be exposed to potentially lethal electrical shocks under these conditions.

There is no way at the present time of predicting electrical discharge activity in clouds without extensive instrumentation and no way for maintenance supervisors to know when to bring personnel off aircraft because of incipient thunderstorm electrical activity. Therefore, it is recommended rather strongly that the only safe way to prevent serious shock hazard and possible fuel vapor ignition is to keep the aircraft continuously grounded.

4. BASIS FOR AIRCRAFT GROUNDING:

This section provides theory, background, and information necessary to understand the rationale behind the requirements for aircraft grounding and bonding. Theory and equations associated with both electrostatic charge generation in aircraft and grounding effects are discussed. The different aircraft servicing situations are introduced with emphasis on the hazards that can be encountered.

4.1 Electrostatic Theory:

Static electricity, by definition "electricity at rest," consists of opposite electrical charges that are usually kept apart by insulators. Potential differences involved may amount to thousands of volts. However, the flow of electricity during generation and accumulation is small, in the range of millionths of an ampere. A primary manifestation of static electricity is the discharge or sparking of the accumulated charges. Static electricity is generated by the separation of like or unlike bodies. Electrostatic charges, positive and negative, always occur in pairs. They become evident when these pairs, having been in contact with each other, are separated. For significant potential to be developed, the bodies holding the charges must become, and remain, insulated from each other. Insulation may occur through complete physical separation of the bodies or because at least one of the bodies is an insulator.

4.2 Energy Sources:

Evaluation of a situation's potential hazards is based on the source mechanism and the source magnitude of the electrical energy. With operations involving aircraft such as maintenance, fueling, and aircraft parking, the following energy sources must be considered:

- a. Triboelectric
- b. Induced
- c. Friction
- d. RF Electromagnetic Energy
- e. Lightning

The sources listed above are defined and evaluated in the following paragraphs.

- 4.2.1 Triboelectric Effects: One type of charging mechanism that can create dangerous voltages on ungrounded aircraft is triboelectric effects. These effects are generally associated with the buildup of static charges on an aircraft in flight. High static voltages, however, can result from the interaction of various materials striking a parked aircraft. Wind-blown snow or dust particles are the usual objects responsible for this charge accumulation, commonly called precipitation static or p-static.

A conservative estimate of electrical current for a moderate wind-blown dust situation is 30 microamperes (μA). In an ungrounded aircraft, this current flows from earth to the snow, dust, etc., via the tires and airframe. Thus, the potential between airframe and earth is determined almost entirely by the tire resistance. The worst-case value of 40 megohms ($\text{M}\Omega$) for tire resistance is used to compute an airframe potential of:

$$V = IR = (30 \mu\text{A}) (40 \text{ M}\Omega) = 1200 \text{ V} \quad (\text{Eq. 1})$$

These charges will accumulate until a sufficient time to discharge has passed or a person touches the aircraft. Twelve hundred volts (1200 V) exceeds parameters for nonlethal shock to personnel, and could cause a reflex action resulting in injury to personnel.

Connecting the aircraft frame to an approved ground point provides a conductive path back to ground for the static charges as they are generated. A ground point is defined as having less than 300 ohms resistance to earth.

A helicopter exemplifies triboelectric effects. Static voltages of up to 10,000 V are normally generated by a hovering helicopter. In exceptional weather conditions, charges up to 200,000 V and greater have been recorded.

Personnel must use extreme care when approaching a hovering aircraft. Strict observance of the prescribed aircraft manual procedure will prevent the serious injury that is certain to occur if the aircraft is touched prior to grounding.

4.2.2 Induced Charge: Electrical storms involve the relatively slow movement of heavily charged clouds which set up an electrostatic field over a large area of the earth's surface below the cloud. The presence of an electrical field between an active storm cloud system and the earth results in large induced charges on parked aircraft. The negative charge in the cloud attracts a positive charge from the earth onto the aircraft via the tires. This charging usually occurs at a relatively slow rate which results in relatively small current flows that cause no damage to the aircraft. If a person is in contact with the plane throughout the charging period, i.e., as the charged cloud moves slowly overhead, he will probably feel no effect.

4.2.2.1 The situation becomes a potential hazard if a sudden change in the electric field takes place (e.g., a distant lightning strike discharging the overhead cloud). The earth's surface neutralizes more quickly than the ungrounded aircraft (due to the capacitance of the aircraft and the high resistance of the tires), resulting in potentials up to 60 kilovolts (kV) from airframe to ground. A person in contact with the aircraft during this change in the electrical field acts as a resistor connected to ground, facilitating another path to ground for the accumulated charges. This person will probably feel a sharp shock, the severity of which will depend on the extent to which the aircraft was originally charged. The current shock can result in injury to personnel in two different ways:

- a. Involuntary reflex movements which can cause fatal or serious injury due to secondary effects, such as falling.
- b. Electrical effects which result directly in injury.

4.2.2.2 A person in contact with an aircraft charged by induction to 60 kV could discharge 9 joules (J) of energy from the aircraft.

$$\begin{aligned}
 U &= 1/2 CV^2 \\
 &= 1/2 (0.005 \mu F) (60 \text{ kV})^2 \\
 &= 9 \text{ J}
 \end{aligned}
 \tag{Eq. 2}$$

This level well exceeds the threshold value for lethal shock and could be fatal. To further analyze potential hazards:

$$t = RC \ln \left(\frac{E_i}{E_s} \right) \tag{Eq. 3}$$