Aviation Electrical Supplies

Safety and Compliance Provisions for Aircraft Ground Support Power Supplies

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Committee Representation

The AESSC Committee was responsible for the preparation of this code and consisted of representatives from the following nominated organisations:

Aviation Industry Association of NZ Inc
Air New Zealand
Board of Airline Representatives NZ
Civil Aviation Authority of New Zealand
Ministry of Economic Development
New Zealand Airports Association
Royal New Zealand Air Force

FOREWORD TO INDUSTRY CODE

During 2006 it became apparent that there was uncertainty regarding the regulatory status and oversight of aviation electrical work and systems supplying power to aircraft. There were strongly held concerns about the levels of risk that existed and those earlier engineering decisions that affected the risk were not supported by risk assessment. The Ministry of Economic Development (MED) initiated the establishment of the Aviation Electrical Supplies Steering Committee (the AESSC) to lead the identification and development of safe practices for the management of hazards associated with electrical supplies to aircraft and aviation workshops. Additionally as part of an ongoing review of the regulations relating to electricity safety, MED (Energy Safety) proposed changes to the electricity regulations to clarify and broaden the existing exclusion of aircraft from those regulations and to explicitly extend the exclusion to cover work on aircraft and fittings of aircraft.

The broadening and clarification of this exclusion (which has now been implemented) pointed to the desirability of producing a code of practice type document, to be based on technically sound risk assessment that specifies the proper and safe management of electricity supplies to aircraft and aircraft maintenance facilities.

Representation on the AESSC included personnel from MED, Civil Aviation Authority , Aviation Industry Association, New Zealand Defence Force, Airports Association and the Board of Airline Representatives.

The AESSC advised its intention to develop an industry code or standard from an initial working document. Following a publicly advertised Request for Proposal process, Opus International was chosen by AESSC to produce the working document. The draft of a working document, the provisions of which were based on a supporting risk analysis, was produced and independently peer reviewed in June 2009 prior to circulation for public comment. Five submissions were received and the AESSC met with submitters in November 2009 and responded to the points that they made. Following some limited changes, the draft code was again circulated for industry comment in December 2010. Six submissions were received, considered and responded to. The Airports Association surveyed its members, and obtained additional advice, to establish the feasibility and cost of compliance for existing installations given that the code will apply to existing as well as to new installations.

The process used to develop the Code along with its underlying risk assessment conforms with the requirements of AS/NZS ISO 31000:2009 and the risk criterion on which the Code is based is “as low as reasonably practicable”.

Purpose of the Code:
The purpose of the Code is to provide practical guidance for the effective management of risk arising from the interface of the New Zealand MEN electrical system and the (dissimilar) power systems of aircraft in the aviation environment. The Code is applicable to both existing and future converter technologies and with current and future aircraft. The supporting risk assessment is intended to provide a basis for assessing the risk from and prioritising remedial work on existing power systems found not to comply with the Code.

The Code complies with the international standard ISO 6858:1982. It is consistent with the safety objectives of the standards prepared by the Australian and United Kingdom defence agencies who work with similar terrestrial power supply systems and is reflected in the Australian Civil Aviation Safety Authority's AC 21-99 (0) Nov 2005.

For those who are responsible for taking all practical steps to ensure a safe environment for passengers and aviation staff, this Code is a most important document.

Note: The Custodian organisation for this Code in its current form is the Aviation Industry Association (AIA). The Code is lodged on the AIA website.

If changes are made to the standards upon which this Code is based the owner organisations will consider the implications for the provisions contained in this Code and any agreed amendments will be notified on the AIA website.

November 2011

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Contents

1 GENERAL

1.1 Statutory Framework

1.1.1 Regulatory Instruments

The following legislative instruments are directly applicable to the supply of power to aircraft:

(a) Health and Safety in Employment (HSE) Act, 1992.

(b) Hazardous Substances and New Organisms Act 1996. Specifically the identification and control of hazardous areas and associated control zones.

(c) Civil Aviation Act 1990: Act and all regulations and rules made under this Act apply to every person, aircraft, aerodrome, aeronautical product, air service, and aviation related service, in New Zealand.

(d) Electricity Act 1992. Specifically Section 69, Electrical safety.

(e) The Building Act 2004, Regulations and Code

1.1.2 Scope and Limitations of Provisions

For the purposes of this Code, the term, "*Fittings of an aircraft*" is considered to include; any component that is used to supply *aircraft quality power* (power that must meet aircraft performance requirements) and to control and maintain the quality of this power (AC and or DC). This includes all components, conductors and other *electrical fittings* including those between the aircraft and the:

- Generator of engine powered Ground Power Units (*GPU*s)
- Motor generator of electro-mechanical type *GPU*s
- Output isolation transformer of static-converter type *GPU*s
- Output control circuitry of the above
- Output cables and *fittings* of the above

See Figure 1 for indicative scope boundaries.

This Code sets out the electrical requirements for the general support power supplies for aircraft and associated *fittings*, as well as the specific arrangements for supply of power for the servicing of aircraft components and other specialist aviation support equipment in *aviation support workshops*.

In addition to specific requirements in relation to ensuring the safety and quality of aircraft-quality electrical supplies, this Code also sets out a number of requirements for the associated *MEN* supply *fittings* that are additional to the requirements of the Electricity Regulations (eg additional safety features to be fitted in the *MEN* supply to *GPU*s).

1.2 Technical Overview of Key Provisions

The following summarises the essential features and principles of the technical provisions presented by this Code. Refer to the body of the Code for the full provisions. Words within the body of the Code shown in *italics* are specifically defined within Section 1.7 of this Code:

- The performance of power supplies to aircraft power systems shall conform to the requirements of MIL – STD 704F
- Aircraft supply system configurations and control interlocks shall be as required by ISO6858:1982.
- No direct electrical connection or interaction shall be allowed between the *MEN primary power* and the output power of mains supplied *Ground Power Units (GPUs)*. The transfer of energy shall be by means of magnetic coupling only.
- The design of *Ground Power Units* shall ensure a high level of isolation integrity between the *GPU* power system and the output power system and achieve low electrical noise. For static power conversion technology, this requirement shall be achieved in part by the use of an earth-shielded transformer. Alternative means of compliance are allowed (see Section 5.6).
- The neutral of the output *4-wire system* of Ground Power Units supplying AC power to aircraft shall not be *earthed*.
- The output of Ground Power Units supplying DC power to aircraft shall not be referenced to *earth*.
- Aircraft *earthing* systems and arrangements to protect against *facility* electrical power faults [*power earthing*], static charge (*static earthing*) and lightning strike are not to be interconnected and shall not be connected to the *MEN*-system earthing arrangements of the *facility*. However, these systems may be connected to a common earthing mat.
- The electrical risks associated with hazardous vapours created by the use of fuel on aircraft shall be properly managed. Hazardous area precautions shall be no less stringent than that required by AS/NZS 2430.3.2:1997 and/or the precautions required by the specialist aircraft fuelling companies.

1.3 Definitions

The reader must be cognisant of the definitions given in Section 1.7 and in particular the distinction between *earthing* and *grounding* must be recognised to enable full understanding of the provisions and explanations within this code.

1.4 Scope

1.4.1 Working Environments

All airport and maintenance base areas and environments where aircraft, covered by this Code are operated and or supported, are within scope. This includes:

(a) Ramp and layover areas: Outdoor areas where aircraft are operated and supported while on the ground;

(b) Enclosed aircraft servicing areas: Hangars and other enclosed areas where aircraft are routinely serviced;

(c) Aviation workshops: Workshops where aircraft equipment and *fittings* are routinely serviced and tested.

1.4.2 Types of Aircraft

(a) In scope

(i) Current generation civil commercial aircraft fuelled by Jet A and/or Jet A1 fuels; and/or

(ii) Military operated aircraft where the aircraft's ground power bus protection system operates in the same manner as those of civil design; and/or

(iii) Future aircraft including those using electrical energy for high power consumption systems (e.g. engine starting), voltages higher than currently employed, variable voltage, frequencies other than currently employed, and variable frequency (sometimes referred to as frequency wild) systems.

(b) Out of scope

(i) Non-commercial general aviation aircraft;

(ii) Agricultural operations;

(iii) Military remote field operations;

(iv) Experimental aircraft and support thereto;

(v) Aircraft construction prior to service testing and the associated production facilities;

(vi) Smaller commercial aircraft (nominally <5700Kg);

(vii) All aircraft burning fuels other than Jet A and/or Jet A1.

1.5 Power Systems and Equipment

The following equipment and systems are covered by this Code:

(a) Ground based power supplies and supplies to the working environment as defined in section 1.4.1. These supplies will be at the voltages and frequencies as required by MIL-STD-704F (Ref 1.6.1 (g)).

(b) Energy sources: Electrical power supplied from the following energy sources is included:

 (i) Engine driven generators;

 (ii) *MEN* (TN-C-S) supply system at voltages up to 1000V (see Figure 1 for an illustration of the scope boundary);

 (iii) Motor generators;

 (iv) Static converters.

(c) Activities: The following aircraft related activities, involving the use of ground power, are within scope:

 (i) Aircraft earthing on the ramp, layover areas and at maintenance facilities;

 (ii) Fuelling from bowsers or fixed hydrant systems;

 (iii) Fuel system operations, including flushing and draining during maintenance;

 (iv) Supply of 115V (at 400 Hz single and three phase) and other voltages to test-equipment in hangars;

 (v) Use of electrical test and maintenance equipment on aircraft (on flight line and in hangars);

 (vi) Supply of electrical power to aircraft systems.

(d) Workshops: The following *aviation workshop* supplies are within scope:

 (i) Aircraft quality supplies from the mains supply system (*MEN*);

 (ii) Multiple source systems (including combined static and motor generator supplied systems);

 (iii) Supply of 115V (at 400 Hz single and three phase);

 (iv) Supplies of 28 VDC and other DC systems;

 (v) Future supply of variable frequency and voltage.

1.6 References and Applicable Electrical Standards

1.6.1 Directly Applicable Standards and Guidance Material

The following references are directly applicable to the maintenance of safety in design, construction, maintenance and use of aircraft power supplies including the supply to aircraft in service, or undergoing maintenance and the power supplies used in aviation workshops:

(a) EN60076: Power Transformers (Parts 1, 3, 4, 5);

(b) ISO 6858:1982 (E): Aircraft Ground Support Electrical Supplies – General Requirements;

(c) ISO 1540:2006: Aerospace – Characteristics of Aircraft Electrical Systems;

(d) ISO 27027:2008: Aerospace – Solid-State Power Controller – General Performance Requirements;

(e) MIL-HDBK-217F-2: Reliability Prediction of Electronic Equipment;

(f) MIL-STD-461E: Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment;

(g) MIL-STD-704F:2004: Aircraft Electric Power Characteristics.

1.6.2 Directly Applicable Standards (Military Systems)

The following military standards are directly relevant to military aircraft power systems and are to be adhered to when designing construction, maintaining and operating military supply systems:

(h) Air Standard 25/19A: Connector for 115/200 Volt 400 Hz 3-Phase AC Servicing Power 4 May 2005 (with Australian reservation);

(i) Air Standard 25/21B: Ground Electrical Power Supplies for Aircraft. Amended 1 March 2006;

(j) Air Standard 25/25: Electrical Safety Interconnections Between Aircraft Support Equipment and Earth 4 May 2005 (Australian provisions).

1.6.3 Other Applicable Standards

The following general references may also be applicable to power systems covered by this Code. Systems and equipment shall comply to these standards except where there is a specific alternative requirement set out in this Code. The current version (latest published) revision of each standard listed shall be adhered to except where marked "*" within this list, in which case the provisions of the specifically listed version only shall be applied:

(k) AS/NZS 1020:1995: The control of undesirable static electricity

(l) AS 1055: Acoustics

(m) AS 1243:1982: Voltage transformers for measurement and protection

(n) AS 1307: Surge arresters

(o) AS/NZS 1768:2007: Lightning protection

(p) AS 1939: Degrees of protection provided by enclosures for electrical equipment

(q) AS 2374: Power transformers (series)

(r) AS/NZS 2381: Electrical equipment for explosive gas atmospheres (series)

(s) *AS/NZS 2430.3.2:1997: Classification of hazardous areas – Examples of area classification*

(t) AS 2467:2008: Maintenance of electrical switchgear

(u) AS/NZS 3000: Wiring rules

(v) AS/NZS 3013:2005: Electrical installations – Clarification of the fire and electrical performance of wiring system elements

(w) AS 4070:1992: Recommended practices for protection of low voltage electrical installations and equipment in *MEN* systems from transient over voltages

(x) AS/NZS 61000: Electromagnetic compatibility (series)

(y) Electrical apparatus for explosive gas atmospheres - Classification of hazardous areas (IEC 60079-10:2002 MOD):

(z) *CAP 074 (CAA UK) Aircraft Fuelling: Fire Prevention and Safety Measures*

(aa) *IOSA Standards Manual 2nd Edition, Revision 1, Temporary Revision 1: 2008*

1.6.4 Other Relevant Guidance Information Sources

(bb) *CASA AC: 21-99(0): November 2005, Section 2, Chapter 14 Earthing and Bonding of Aircraft and Ground Support Equipment * (Note that it is understood that at the time of writing, this AC and the similar AAP 7045-14 are due to be, or are being revised).

(cc) Australian Department of Defence, Infrastructure Management. Power Systems for Aircraft Servicing and other 400Hertz Applications

(dd) *IEEE 142-1991: The Green Book – Grounding of Industrial and Commercial Power Systems Guide*

(ee) Boeing 787 MFEPD (Prelim Release) 2006. Chapt 24 Electrical Power

(ff) Boeing 787 MFEPD (Prelim Release) 2006. Chapt 80 Starting

(gg) Paper: Use of structure's reinforcing steel as an electrical earth. PG Wright, NZ Engineering 15 Jan 1974.

(hh) Engineering Edge, Choosing the right engineer – a reference guide. Institute of Professional Engineers of New Zealand, Feb 2009, 4^{th} Edition.

1.7 Definitions and Terminology

The following terms have the following definitions within this Code or are directly relevant to the subject matter. Although similar to the normal use in general electrical texts, some additional distinction between terminologies over non-specialised usage is necessary. Notes have been added where specific source references are applicable. Of particular note is the distinction between *grounding* and *earthing*, as explained below, which is not made in some general references. Recognition and comprehension of this distinction is essential for an understanding of the material within this Code:

Aircraft power-earthing wire (lead): A lead designed to offer a low impedance earth path (<10 ohms) from an aircraft (under maintenance conditions) to the earth mass. Used during maintenance to maintain electrical safety when external electrical powered equipment is taken onboard.

Aircraft Quality Power: Electrical power supplies designed to conform to the requirements of aircraft and systems as defined by *aviation instructions* and applicable standards.

Aircraft static bonding wire (strap): A light conductor used to make a bond to drain or equalise static charge, not designed to carry fault current and that may have a high resistance (typically <10,000 ohm).

Aviation workshops: Workshops used in support of aircraft and typically supplied with specialised power supplies to the same quality and parameters as required by aircraft.

Aviation Instruction: A published instruction that forms part of the assurance of aircraft airworthiness and/or safe operation (e.g. Regulatory requirement, SOP, OEM instruction etc).

Bond(ing): An intentional low impedance electrically conducting connection made between components.

Chassis: The main metallic structure of a *GPU* that may form the electrical '*ground*' or 'earth' of the *GPU* power systems (see *Ground*). In the case of mains powered *GPU*s, this structure will usually be connected to the *primary power* earth lead and so will form an 'earthed chassis'.

Dead Front: The design of electrical installations to ensure switches, circuit breakers, switchboards, control panels and panel board fronts are covered so that no current-carrying parts are exposed in normal use.

Electrical Fitting: Meaning as per Electricity Act 1992 (also see 1.1.2).

Earth (noun): 1. The earth mass. 2. A conducting connection, whether intentional or accidental, between an electrical circuit or equipment and the earth mass. CAUTION: Compare with '*Ground*'.

Earthed: Connected to earth mass whether the connection is intentional or accidental. CAUTION: Compare with '*Grounded*'

Effectively Earthed: Effectively and intentionally connected to earth mass (as per "Earthed" within the Electricity Act).

Earthed system: A system in which at least one conductor or point is intentionally connected, either solidly or through an impedance, to Earth (see Impedance Earthed System). CAUTION: Compare with '*Grounded system'*.

Earthing system: A system that consists of all electrically interconnected *grounding* connections in a specific power system and that are in turn connected to earth, and is limited by its isolation from adjacent *earthing* systems. The isolation may be provided by transformer primary and secondary windings that are coupled only by magnetic means. Thus, the system boundary is defined by the lack of a physical connection that is either metallic or through a significantly high impedance.

Earth Shield: A foil or wire built into a transformer to act as a magnetic and electrical shield to control noise transfer and/or improve winding-to-winding fault protection.

Facility: The aircraft support infrastructure being either airport or maintenance base buildings, structures or electrical infrastructure.

Fitting of an Aircraft (also, fitting): Electrical equipment or component of an aircraft, whether fitted onboard an aircraft or not, including those parts of power supplies that must meet the performance requirements of aircraft and aircraft equipment (see also *Electrical Fitting*).

GPU: Aircraft Ground Power Unit. Any external equipment specifically designed to supply aircraft quality electrical power to an aircraft's electrical systems.

***GPU* output extension cable**: A cable not permanently fitted to a *GPU* that is fitted with a female plug and a male receptacle and designed to extend the reach of a *GPU* output cable.

Ground (noun): The designed common voltage reference point, sink, or return conductor of an electrical system used by the system as a common reference or established zero potential.
Note: US usage typically makes no specific distinction between the terms 'earth' and 'ground'. The distinction is important within the context of aircraft ground power systems.
CAUTION: Compare with '*Earth'*.

Grounded: Connected to an extended conducting body that serves as a common voltage reference or conducting path, whether the connection is intentional or accidental. CAUTION: Compare with '*Earthed*.

Grounded system: A system in which at least one conductor or point is intentionally and effectively connected to system *ground*, either solidly or through a designated impedance. CAUTION: Compare with '*Earthed system'*.

Hazardous Area: An area (three dimensional) in which an explosive atmosphere is present, or may be expected to be present, in quantities such as to require special precautions for the construction, installation and use of potential ignition sources (Ref HSNO Act, Electricity Act and Ref 1.6.3 (y)).

Hazardous Area Control Zone: An area abutting a hazardous substance location that is regulated so that: within the zone, the adverse effects of a hazardous substance are reduced or prevented, and; beyond the zone, members of the public are provided with reasonable protection from those adverse effects (Ref HSNO Act).

Impedance Earthed System: A system in which at least one conductor or point is intentionally *grounded*, through an impedance, to earth mass (also see *Earthed System*).

Low Voltage: Any voltage exceeding 50 volts a.c. or 120 volts ripple-free d.c. but not exceeding 1,000 volts a.c. or 1,500 volts d.c. (Ref Electricity Act).

MEN: Multiple Earth Neutral system of supply as generally used in New Zealand and Australia.

Power earthing: An intentional low impedance electrical connection between an electrically conductive point and the earth mass designed to withstand and facilitate flow of electrical system fault currents. This could alternatively be referred to as 'electrical safety-earthing'.

Primary Power: The input *Low Voltage* power supply to the *GPU*.

Residual Current Device (*RCD*): A device similar to a residual current circuit breaker (RCCB) that disconnects a circuit whenever it detects that the electric current is not balanced between the energized conductor and the return neutral conductor, as is the case during an earth fault. *RCD*s are designed to disconnect quickly enough to mitigate the harm to persons but are not intended to provide protection against overload or short-circuit conditions. In the United States and Canada, a residual current device is also known as a ground fault circuit interrupter (GFCI), ground fault interrupter (GFI) or an appliance leakage current interrupter (ALCI). In Australia they are sometimes known as "safety switches".

Static earthing: An intentional earthing connection designed to dissipate/bleed static charge between two points only but not carry electrical system power or fault currents. The resistance of the connection may be relatively high (~MΩ).

Separately derived supply: A wiring system of supply whose power is derived from a generator, transformer, or converter windings and has no direct electrical connection, including a solidly connected *grounded* circuit conductor, to supply conductors originating in another system. Energy transfer is achieved only by magnetic coupling.

Solidly grounded: Connected directly through an adequate *ground* connection in which no impedance has been intentionally inserted.

Three-phase, four-wire system: A system of alternating current supply comprising four conductors, three of which are connected as in a three-phase three-wire system, the fourth being connected to the neutral point (wye configured systems) of the supply or midpoint of one phase (delta-connected transformer secondary) for the purpose of conducting load current.

Three-phase, three-wire system: A system of alternating current supply comprising three conductors, each of which is used to supply the load(s). In the case of Wye configured systems, the neutral point of the supply is not connected to a supply conductor and may be left floating at the supply and/or load, or be earthed / grounded at the supply and or load.

Three-phase: A system of alternating current supply comprising three conductors, between successive pairs of which are maintained alternating differences of potential successively displaced in phase by one third of a period.

Unearthed system: A system without an intentional connection to earth except through potential indicating or measuring devices (or testing device) other than very high-impedance devices (see '*Earthed', 'Grounded' and 'Impedance Earthed System'* above).

1.8 Administration of the Document

This document is administered by the Aviation Industry Association of NZ Inc.

All correspondence regarding this code should be addressed in writing to:

The Administrator
Aviation Industry Association
PO Box 2096
Wellington

Re: Safety and Compliance Provisions for Aircraft Ground Support Power Supplies

2 Safety

2.1 Safety Principles

The use of electrical power in support of aircraft operations shall not:

(a) Compromise aircraft airworthiness or the assurance thereof.

(b) Create a credible direct or indirect safety risk to the travelling public or personnel/crew near to, boarding/disembarking or onboard an aircraft.

(c) Present an unusual or unacceptable direct or indirect safety risk to personnel operating electrical ground support equipment.

(d) Present an unusual or unacceptable direct or indirect safety risk to aviation and electrical workers within workshops where aviation power supplies are employed.

Note 1: The use of electrical power in support of aircraft operations shall:

a. Meet the requirements of the Health and Safety in Employment (HSE) Act and in particular with regard to the elimination, isolation of, and protection from, hazards.

b. Comply with the safety requirements of the Electricity Act 1992.

Note 2: Conformance with the provisions of this Code is a means of complying with Note 1 above with regard to the use of electricity in support of commercial and military aircraft operations. The aircraft power supply system is to be considered to be a 'separately derived system' of supply (see 1.7).

2.2 Basis of Compliance

2.2.1 Introduction

The electrical systems employed by aircraft differ in design, practice and operating principles to those employed for fixed terrestrial power supply systems and in particular the 230/400 V electrical distribution *Multiple Earthed Neutral* (*MEN*) system employed within Australia and New Zealand for most electrical power distribution. All practical measures shall be taken to ensure that no metallic connection is made, and so with the exception of the magnetic transfer of energy, no electrical interaction can occur between the *MEN* distribution system and the aircraft's electrical systems. This requirement extends to the design of the earthing systems under normal, fault and abnormal conditions.

2.2.2 Key Hazards

(a) Flammable levels of fuel vapour can exist around aircraft and within enclosed servicing areas. System design and operating practice and procedures shall be designed to ensure that the use of electricity in the vicinity of aircraft that may contain fuel will not generate sources of ignition.

(b) Aircraft power supplies can be lethal. Ground and workshop electrical systems and operating practice and procedures shall be designed to ensure that the use of ground mounted or mains derived electricity in support of aircraft maintenance and operations does not create a dangerous electrical shock risk to personnel operating or working in the vicinity of power supply equipment or to passengers and crew embarking/disembarking or onboard an aircraft.

(c) Aircraft airworthiness can be compromised by inadvertent damage to aircraft structure, components and/or equipment. Ground electrical system design and operating practice and procedures shall be designed to ensure that the use of ground-derived electricity in support of aircraft maintenance and operations cannot create arcing or other conditions that may damage the aircraft structure or equipment.

2.3 Specific Hazards

2.3.1 General

By effectively connecting the *MEN* power supply and the aircraft power systems, *GPU* converters act as both an interface and isolator between the two differing systems. The input side of the converter shall conform with the same electrical fault and performance criteria as the supply system, whilst the output side system forms an integral part of the aircraft electrical system and must meet aircraft requirements whilst minimising fault conditions and hazards within the aircraft/converter/power cable network.

2.3.2 Specific Electrical Hazards

(a) Personnel shock;

(b) Arcing damage to aircraft structures;

(c) Spark ignition within the potentially hazardous vapour areas near aircraft; and

(d) Stray currents (e.g. earth loops) passing via unintended paths (aircraft structure, components and or equipment positioned against the aircraft such as maintenance docks, bridges, steps, loaders, etc).

Additional hazards include the possibility of overheating of earth cables, hot aircraft power plugs, arcing due to short circuits, and interaction between the input and output systems, that could cause shocks or burns to persons touching cables and equipment nearby.

2.3.3 Hazards Specific to GPUs include:

(a) Rough handling environment: The operating environment at airports involves high intensity activity where equipment may be handled with minimum care. As a result equipment may be impacted or otherwise maltreated.

(b) Limited specialist electrical engineering knowledge: As electrical engineering and trade training is typically intended for work only on *MEN* power technology systems and equipment design, incorrect selection of equipment for, and maintenance of, ground based aircraft support electrical systems may erroneously lead to unsafe work practice and processes, inappropriate testing and inadvertent and potentially hazardous modifications. There is also the possibility that dangerous situations will be created when designing or working on aircraft electrical support equipment by the uninformed adherence to, or the strict application of, regulations and standards developed for *MEN* systems.

2.3.4 Ramp and Layover Areas

(a) The weather conditions and work environment on the ramp are demanding on equipment and personnel. Aside from the generic hazards previously mentioned, the physical hazards to equipment include:

(i) Ultraviolet radiation;

(ii) Rain/ice/snow;

(iii) Oils;

(iv) Wind blown grit;

(v) Wind blown sea salt (many airports being located near to coastlines);

(vi) Use by non-technical and physically strong personnel;

(vii) Lightning Strike

(b) Fuelling presents particular conditions that modify the generic hazard-scape. In particular, during fuelling:

(i) Large quantities of fuel vapour will be displaced and released from wing tip vents.

(ii) Pressurised hoses and hose connections create a potential source of high-pressure fuel spray (see Figure 2).

(iii) The open-air environment may at times act to dissipate fuel vapours that may be present.

(iv) The wide range of weather conditions that can exist significantly modifies the behaviour of fuel vapour, particularly following a fuel spillage.

(v) Static electricity generated across the filter bowls.

(vi) Voltages and arcing induced by lightning.

2.3.5 Hangars and Enclosed Servicing Areas

The conditions in aircraft hangars as well as the work environment differ markedly from those experienced by equipment fitted or used in ramp areas. In addition to the generic hazards previously mentioned, the following factors are also relevant:

(a) Aircraft electrical and fuel systems will be operated in other than normal configurations. Fuel systems and fuel tanks will at times be open and/or disturbed and thus spillages may occur.

(b) Fuel may be transferred between aircraft fuel tanks. By displacing vapour from the ullage of tanks, vapour will be forced from wing-tip vents.

(c) Pit areas create environments where fuel vapour can be expected to collect and remain for extended periods.

(d) Electrical equipment supplied via wandering leads from hangar supplies are routinely used onboard and around aircraft.

(e) Aircraft may be surrounded by docking and work stands, some earthed and/or fitted with reticulated power and lighting.

(f) Limited ventilation thus allowing vapour to pool or not be dispersed (particularly below wing-tip vents).

2.3.6 Aircraft Layover Situations

The layover is similar to the ramp condition but aircraft are more likely to be required to be protected against lightning strike (by *aviation instructions*). Therefore, *GPU*s potentially offer an unintended path to earth for the charge built up during a lightning strike. As this is not the intended purpose of the *GPU*s, damage may result to the unit unless a separate *bonding strap* is fitted between the aircraft and *earth.*

2.3.7 Aviation Workshops

The hazard-scape within aviation support workshops differs markedly from that experienced on ramps and in hangars.

The generic hazards are:

(a) Personnel shock from exposed components of equipment being worked on (phase to neutral (115V), phase to phase (208V), phase to structures tied to neutral (115V) or earth).

(b) Stray currents passing via unintended structural paths.

(c) Circulating currents via multiple *earthing* points.

(d) Fault currents of higher voltage systems being impressed on lower voltage systems.

(e) Phase to *earthed* structures (If system referenced to earth mass – indeterminate characteristics).

(f) Potential difference (PD) between systems.

(g) Static discharge causing damage to electronic components

(h) Flammable working fluids used in pump test rigs.

(i) In boiler test environments and other wet areas:

   (i) Personnel shock hazard will be elevated;

   (ii) Steam scalding.

The management of the electrical hazard in workshops is made complex by the various electrical conditions created during testing and the use of a wide range of electrical systems (voltage, frequency, AC/DC etc) compounded by the supply usually being derived from *MEN* power systems that are potentially lethal and can exhibit high fault currents.

Note 1: The B787 employs variable frequency and various AC supplies (including 230V) and high power DC (including 270V) systems. Workshops may therefore also need to have variable frequency AC and high power AC and DC supplies.

3 Power Supply Performance

3.1 Performance Requirement

Aircraft supply requirements are set out in the applicable aviation related international and military standards. It is imperative that these performance and protection requirements are met. The Standards are consistent. The requirements set out by these standards are nominally:

3.1.1 400 Hz Performance Requirements

(a) Continuous: 45 kVA at power factor of 0.8, per aircraft-receptacle (nominal) or

(b) Continuous: 90 kVA (per aircraft-receptacle) or

(c) Continuous 180 kVA (for converter units fitted with twin output cables supplying aircraft fitted with twin receptacles)

(d) Peak output performance: As per quoted standards. In summary:

  (i) 112.5 kVA, 0.75-1.0 power factor (per aircraft-receptacle for 5 minutes)

  (ii) Allowable voltage range: 115 VAC +/- 5V L-N RMS

  (iii) Allowable frequency range: 400 Hz +15/-15 Hz

  (iv) Max Distortion Factor:

   - Total harmonic content: 3% of fundamental
   - Individual Harmonic Content: 2% of fundamental
   - Crest Factor: 1.414 +/- 0.07
   - Max voltage modulation factor: 2.5 V peak to valley

(e) *GPU* control: See reference to 28 VDC system.

Note 1: The B777 and A380 are reported to be drawing power at power factors close to unity.

Note 2: The B787 employs electric engine starting (Ref 1.6.4 (ee) and Ref 1.6.4 (ff)). If ground power is on during engine-start or engine–turn-over, sustained full power draws at unity power factor on up to three separate supply cables/receptacles, together with the associated heating of conductors and plugs, and large system voltage drops must be expected.

Note 3: Small business jets fitted with 115 V 3 phase systems may be supplied by lower power units, typically 7.5 kVA and 15 kVA. Aside from over-power limits, all other parameters are likely to be similar to the above.

Note 4: Some aircraft manufacturers may set additional requirements (e.g. synchro-matching for no-break switching).

3.1.2 28VDC Power System Performance Requirements

(a) Continuous 28.5 V (nominal) DC

(b) +28 V over neutral (-ve tied to aircraft neutral – *unearthed* at source)

(c) DC Control conductor (linked to +ve terminal in aircraft plug)

3.1.3 28VDC Control System Performance Requirements (for 400Hz systems)

(a) As per quoted standards. In summary: EF interlock circuit connections enable aircraft supplied 28 V to latch the *GPU* output contactor.

Note: In some supply equipment technologies, the EF circuit is also used to monitor the continuity of the neutral conductor.

4 Operating and Maintenance Rules

4.1 GPUs

(a) Mobile *GPU*s shall remain outside fuelling zones during fuelling operations. Refer Figure 2 for fuelling zones.

(b) Mobile *GPU*s shall remain at least 1.5m from any part of an aircraft that contains fuel and or wing-tip vents.

(c) Mobile *GPU*s shall remain at least 3m from any open fuel tank.

(d) The following *GPU* power system-state-changes are not allowed whilst fuelling operations are being undertaken: plug-connection, energising the power supply, or plug-disconnection.

(e) No attempt shall be made to energise an aircraft cable whilst it is not connected to an aircraft or load bank or whilst the plug is not fully engaged.

(f) Tripped *GPU*s shall not be re-started without a reasonable understanding of the cause of the trip. Repeated attempts to restart, without proper investigation for the cause of tripping is prohibited.

(g) *GPU*s shall be removed from service on any evidence of damage or malfunction. They are to be tagged to prevent inadvertent use.

(h) Only appropriately trained and authorised operators and maintainers are to be allowed to operate *GPU*s.

4.2 Maintenance Rules

(a) Prior to entry into service GPUs are to be formally commissioned and tested to full design load to ensure that all the safety and performance requirements of this document and of the quoted standards have been met.

(b) GPUs shall be maintained as per the OEM's stated requirements.

(c) The following checks shall be carried out at 3-monthly intervals or following any unusual physical disturbance (beyond normal connection and disconnection to the aircraft) of the output electrical connections of a GPU or aircraft power supply cable (typically during maintenance but may include damage events such as undue strain on the cable) or damage to the GPU itself. Where faults or damage is found or work is carried out on any high-power elements (e.g. cable terminations) the GPU shall be tested to full load and proven serviceable using a suitable load bank:

  (i) Output phase conductor correct configuration and continuity;

  (ii) Output neutral continuity;

  (iii) Control conductor correct configuration and continuity;

  (iv) Correct operation of the EF trip function;

  (v) Neutral displacement trip function (AC systems);

  (vi) Input power protection function, continuity monitoring, and resistance of the primary supply earth connection and operation of the RCD (if fitted);

  (vii) Neutral to ground resistance.

  (viii) Pin retention.

Note 1: These checks are additional to the normal testing and maintenance regime required for the GPU primary power system by regulations.

(d) The electrical systems and equipment of aircraft power systems from the point of connection to the facility power supply shall only be maintained by appropriately trained maintainers holding appropriate electrical trade qualifications and with experience of industrial power equipment, who are familiar with the equipment and the provisions of the OEM's manual and applicable standards and this document.

(e) The maintenance of the mains power supply system (primary power) and associated components of mains power GPUs shall meet all regulatory requirements.

(f) GPUs shall not be maintained or have their performance setting adjusted whilst connected to an aircraft.

(g) GPUs shall be tested and confirmed to be operating correctly following any maintenance or adjustment prior to being brought into operational service and/or before being connected to an aircraft.

(h) The following safety electronic protection features that if not failsafe, or inherently safe, by design or that are not tested automatically when the unit is energised, are to be tested during servicing (recommended at least monthly):

(i) Over/under voltage protection features (AC systems)
(ii) Over/under frequency protection features (AC systems)
(iii) Neutral to earth displacement safety feature (AC systems)
(iv) Plug connected interlock safety feature (AC and DC where fitted)

(i) No modification of systems, alternative equipment used or replacement equipment selection is to be carried out without formal design review and sign-off by a chartered professional electrical engineer (see system design section below).

4.3 Use of Portable Electrical Equipment Onboard Aircraft

The use of portable mains powered electrical equipment such as hand tools; vacuum cleaners etc onboard an aircraft shall be avoided where practical alternatives are available. Preferred alternatives include equipment powered from onboard the aircraft (115V AC) and battery operated tools.

Whenever *MEN* mains power is used onboard, the supply shall be fitted with an isolating transformer, or personnel protected by *RCD* units (see 5.7.3).

Note (i): *Aviation instructions* for civil aircraft typically require a safety earth (*power earth*) to be attached to the aircraft prior to maintenance. It is of note the correct operation of tools supply *RCD*s may be dependent upon the effectiveness of this aircraft *power-earth*. It is of note that in the case that the *power earth* is inadvertently or intentionally not fitted (e.g. error during urgent repairs on the ramp or where military procedures do not require it) an RCD may not function. However, an isolation transformer would offer personnel protection in such a circumstance.

Note (ii): Additional electrical safety may also be achieved by the use of double insulated portable electrical equipment.

5 Technical Requirements and System Design

5.1 Principal Technical Requirements

All electrical power supplied to commercial and military aircraft or to associated aviation equipment shall be delivered in compliance with the technical requirements of the OEM and comply with the applicable and current standards relating to the supply of electrical power to aircraft, as detailed in Section 1.6.

5.2 Design of GPU Systems and Supplies

The system design of aircraft power supply systems, from the point of connection at the *facility* power supply, shall be designed to meet the technical requirements given by this Code. Design of these systems shall be signed off by a professional electrical engineer (eg CPEng or CertEtn, see Section 5.8.1) with appropriate experience of industrial power systems or industrial DC systems, as appropriate. Full knowledge and understanding of the contents of this Code and the requirements of the directly applicable international and aviation standards is essential (see Section 1.6).

GPU extension cables need to be specifically designed and suitable for the working environment.

5.3 Earthing of Aircraft

5.3.1 Aircraft Power Earthing System

Aircraft *power earthing* arrangements used during maintenance (as required by *aviation instructions*) shall be designed so that the aircraft structure remains - under any electrical fault condition (50 Hz or 400 Hz systems) - at the same potential as the local earth mass and any structures that may be near to it. This requires that the aircraft's safety earth (*power earthing*) points are independently connected directly to the *facility* structure and or the associated earth mat and not connected to an earthing bar of the *facility's MEN* power supply system. The *earthing system* shall be designed so as to prevent any latent system fault negating the above or causing the aircraft to become a current fault path to earth. The *MEN* earth system shall therefore be itself connected directly to the earth-mat or structural *earth*.

5.3.2 Aircraft Static Earthing System

Earthing points designed for static control purposes shall not be inter-connected to aircraft *power earthing* points or the *facility MEN earthing* systems. Aircraft power supply systems shall not interact with *static earthing* arrangements during either normal or fault conditions.

Given the large distances that may be involved, where earthing points are fitted in Ramp areas, great care must be exercised to ensure potential differences between earth points, and the potential for earth loops to be created, are avoided.

5.4 Separation of Power Supply Systems

(a) Mains supplied *GPU*s shall be designed and constructed to ensure a very high level of isolation is maintained between the LV *primary power* (*MEN* supply) and the output power (aircraft power). This may be effected by means of:

(i) Physical separation within a motor generator set.

(ii) Electrical isolation within a transformer (within the power supply chain):

(b) Where static conversion technology is employed, an isolation transformer shall be fitted between the input system (or any intermediate power system) and the 115/200 V four wire power system. This transformer shall:

(i) Be constructed to an insulation standard at least equal to “double insulation” or reinforced insulation.

(ii) Incorporate an earthed shield.

(iii) Not create a voltage off-set within the secondary side system.

5.5 Detailed Technical Requirements

5.5.1 Ground Power Units (GPUs)

*GPU*s shall meet the technical, safety, operational and performance requirements of (Ref 1.6.1 (b) and 1.6.1 (g)). The output power systems of *GPU*s shall be designed and maintained as a ‘*separately derived supply’*. The following additional requirements are required for use within New Zealand (as illustrated in Figure 1):

(a) All *GPU*s:

(i) The output neutral of the *GPU*’s output shall not be connected to the frame of the *GPU* or to any other earthed point. The only exception to this rule shall be where the power electronic switching technology employed and isolation transformer design are such that the output requires capacitive coupling to suppress high frequency noise, in which case a high-impedance connection meeting the performance specification given by the ‘Alternative Means of Compliance’ (Section 5.6) of this ‘Code only shall be employed.

(ii) Where output side internal systems share a common *ground*, they must be separately *bonded* to that *ground* (Ref 1.6.1 (b) and Ref 1.6.4 (bb)). This *ground* may be connected to the output neutral. This output systems *ground* must not be *earthed (see also 5.5.1 (b) below)*.

(iii) In addition to the output protection requirements of Ref 1.6.1 (b), *GPU*s shall be fitted with output over-current protection. Further protection is allowed.

(iv) GPUs shall be constructed and maintained so that all electrical components are clear of the ground and ideally at least 0.5 meters above ground level.

(v) The EF interlock jumper (bridge) shall be fitted within the *GPU* and cable assembly - EF bridges shall not be fitted within aircraft power *output extension cables*.

*CAUTION: GPU*s shall NOT be fitted with safety interconnection leads (*bonding leads*) between the aircraft and any part of the *GPU*.

(b) Mains Powered *GPU*s:

(i) The output neutral of the *GPU* (aircraft AC power supply) shall not be solidly *bonded* to *earth*. This requirement does not preclude a very high impedance coupling to *earth* that may be required to control noise on the aircraft power supply.

(ii) Similarly, output side conductors of aircraft DC power supplies (*GPU* power DC output) shall not be *bonded* to *earth.*

(iii) The voltage difference between earth mass (the earthed chassis) and the neutral of the *GPU* AC output power system shall be monitored. The potential difference shall be used to immediately initiate the output breaker trip (or otherwise de-energise the output) on the lowest practical potential difference setting. This setting shall not exceed 50V.

(iv) The *grounds* of the *primary-side* and output-side of *GPU*s must be maintained electrically and physically separate. The primary-side system *ground* may be *earthed*. The output-side *ground* shall not be formed by, or be connected to, the chassis of the unit (see 5.5.1 (a)(ii) above).

(v) The chassis/frame of mains power supplied *GPU*s shall be *earthed* via an input system earth conductor to the earth bus of the input *MEN* power supply.

(vi) The continuity of this earth link shall be of high-integrity and if the connection is made by means of a plug/socket, the earth continuity shall be monitored. A loss of continuity shall de-energise the *GPU primary supply*.

Note: Input system *RCD* protection is recommended to protect personnel from input system faults.

(c) Engine Driven *GPU*s:

(i) A protection feature shall be fitted to detect *ground* faults (phase to chassis and neutral to chassis). Detection of a fault shall, as a minimum, de-energise the output.

5.5.2 Lightning

The protection of aircraft from the effects of lightning whilst on the ramp or hardstand shall be accomplished separately to any aircraft power supply system that may be employed (i.e., Aircraft power supplies shall not to be employed as a means of lightning bonding to earth).

5.6 Alternative Means of Technical Compliance (400 Hz GPU Earthing and Isolation)

The following alternative means of compliance to the above requirements may be considered where modification of existing *GPU* systems is required:

5.6.1 System Bonding

Where electrical noise impressed on *GPU* output power is found to be present and outside tolerance, or that may create a hazard, the following steps shall be taken:

(a) The design of the output transformer should be investigated and action taken to eliminate the noise at source or through earth shielding of the output transformer.

(b) Where the above is not practical, a high impedance electrical filter may be fitted between output neutral and earth. This filter shall be designed to control the noise whilst also preventing unsafe voltages to exist. The selection of the filter impedance must be confirmed as suitable by testing. The fundamental concept is to filter out noise whilst presenting a high-impedance path to *earth* at the rated frequencies.

5.6.2 System Isolation

Existing systems that are found not to conform to the isolation requirements given above may achieve a similar level of safety by other means. Where such systems are to be used, a formal analysis is to be carried out to demonstrate that at least the same level of isolation is achieved. Such analysis is to be formally recorded and the system features that are required to maintain the safety of the system, specifically identified.

5.7 Hangars and Aircraft Servicing Areas

5.7.1 Fixed Electrical Systems

Electrical systems fitted in enclosed aircraft servicing areas such as hangars shall be positioned clear of any area where fuel vapours could be present or be suitable for use in hazardous areas. This requires that:

(a) Any electrical equipment fitted within pits, sumps and other depressions in the floors of aircraft servicing areas shall be rated and maintained as required for Hazardous Zone 1 areas.

(b) All electrical supply systems of fixed *GPU*s within servicing areas shall be mounted at least 0.5 meters above the hangar floor level.

(c) All general 50Hz mains supplies for hand held and portable appliances for servicing of aircraft including those feeding socket boards shall be protected by automatic disconnection of supply under fault conditions augmented by *RCD*s or by use of Class 2 isolation transformers. See AS/NZS3000 (Ref (u)) for requirements of *RCD*s and electrical separation (Isolated Supply – Figure 7.7 of the Reference).

(d) All stands and work-platforms that may be used for work on open fuel tanks, engines and or areas near to vents are to be fitted with *bonding* points (see Section Bonding of Ground Support Equipment (GSE)).

(e) Where electrical fittings need to be installed or used in designated hazardous atmosphere zones (including the fuel vapour zones created by the positioning of aircraft and as designated by *aviation instructions*), they shall comply with hazardous atmosphere requirements (Ref 1.6.3(r)).

(f) For permanently installed equipment allowance needs to be made for the variability of positioning of aircraft in the hangar (eg it may be appropriate to use, say, a 3m distance from wing tip areas to ensure compliance with the designated 1.5m distance).

5.7.2 Movable Electrical Equipment

The use of movable electrical equipment in areas associated with any fuel and other flammable liquids and vapours is to be managed within the context of the Principal's Health and Safety policy and processes.

The following precautions shall apply to hangars and servicing areas as a minimum:

(a) All electrical supply systems of mobile *GPU*s within servicing areas shall be mounted at least 0.5 meters above the hangar floor level.

(b) All other mobile and movable electrical equipment intended for use in aircraft servicing areas (including socket boards) shall be mounted or placed on structures so that the electrical fittings are at least 0.5m above floor level. Where this is not participable (eg design of OEM specified equipment) appropriate and effective explosion protection techniques or work control procedures shall be used.

(c) Where electric equipment is required to be used in wing-tip and/or under-wing and/or tank areas of fuelled aircraft, procedural precautions shall be employed to ensure that suitable and effective explosion protection techniques are used (Ref 1.6.3(r)).

(d) All general supplies for servicing of aircraft including those feeding socket boards shall employ *RCD*s (for personnel protection) or isolation transformers.

(e) Fuel tank entry procedures shall include a provision to ensure that aircraft are electrically de-energised prior to tank opening and purging.

5.7.3 Hand Tools and Power Supplies

The following hand tool supplies can be used in hangars:

(a) 115V AC (50Hz or 60Hz) direct from onboard general power sockets;

(b) 50V or 60Hz AC;

(c) Battery powered tools;

(d) 115 and 230V AC mains (where supplies employ *RCD*s for personnel protection or isolation transformers).

All tools and supply equipment shall be suitable for the hazardous vapour zones or moisture conditions where they are to be used.

5.7.4 Special Tools

AS/NZS3000 (Ref (u)) applies to all general supplies. However, some tools called up by *aviation instructions* may not meet New Zealand specific requirements or power requirements. In these cases, these tools are to be supplied by isolated supplies (isolation transformers and or frequency converters). These tools are to be used, maintained and tested to the OEM's instructions.

Test equipment that is required to be connected to aircraft (shared *ground)* but that are powered separately to the aircraft, are to be supplied from separated (isolated) *unearthed* supplies.

5.8 Workshop Design

5.8.1 Design of Workshop Supplies

(a) The design of workshop supply systems is to be approached with great care and take due account of such factors as; the complexity of the potential interactions between differing power systems, the need to service electrical equipment designed to principles that differ from those appropriate to the *MEN* supply system, the need for staff to at times work on and test equipment with exposed conductors and electrically active cases and, the need to prevent unintended interaction between systems.

(b) The design of workshop systems (and any subsequent modifications) shall only be undertaken by chartered professional electrical engineers (CPEng) with knowledge and experience of both *earthed* and *un-earthed* industrial systems and the specialised requirements of high frequency and aviation support power supplies. This demanding requirement may necessitate the involvement of more than one specialist. Each design shall be independently peer reviewed by a chartered professional engineer or appropriately experienced Engineering Technologist (ETPract). Once the design philosophy and subsequent specification has been developed, the selection of specific equipment and detailing of layout for use, may be best handled by technician engineers (eg CertETn).

(c) Construction and maintenance personnel working on these systems shall ensure strict adherence to the design intent and original specification. They shall also meet the requirements of the applicable parts of Electricity Regulations where these apply. Any apparent conflict between the design and the applicable Regulations or standards shall be brought to the attention of the lead design engineer for review and decision.

(d) Where a recognised design organisation is overseeing or undertaking the design, the selection and control of the qualifications of personnel employed in the design process may be managed by means of the policy and procedures of the organization. However, where such an organisational framework is not in place, a professional engineer with the required theoretical electrical system knowledge shall oversee the design process.

CAUTION: Much of the equipment and systems employed within *aviation workshops* is required to conform to specific technical requirements that may differ from that normally found in more general applications and local systems. The strict application of some of the technical requirements of the New Zealand Electricity Regulations and associated Standards may therefore not be suitable, may not result in a safe system, and may compromise the performance of these systems. In this regard, attention is drawn to the fact that the specialist systems required by '*aviation instructions'* and the supplies to, or equipment used in the servicing of aircraft fittings, may be considered to be 'fittings of aircraft' under the Electricity Act and so are exempted under the Electricity Regulations (see Section 1.6).

5.8.2 Workshop Technical Requirements

(a) All workshop power supplies that may be applied to aircraft fittings shall meet the provisions of the applicable standards (eg ISO6858 Ref 1.6.1 (b)) and/or specific *aviation instructions* (eg MIL-STD 704 Ref 1.6.1 (f)).

(b) All equipment and electrical fittings selected and employed in power supply systems and *aviation workshops* shall be suitable for the voltage, frequency (or DC), system and electrical power being conducted (e.g. switches, sockets, cabling).

(c) Supply systems to workbenches and test rigs shall be designed to ensure that, with the exception of the transfer of electrical energy by magnetic means, no interaction between the *MEN* system of supply, or between each different power system, can occur under normal, unintended (procedural errors) and fault conditions.

(d) The power supply source (neutral or phase) of each separate system designed to supply power to aircraft fittings shall not be connected to earth. This requirement does not preclude the use of very high impedance grounding for the purpose of controlling noise and or managing static discharge.

(e) Workshop supply system technology shall not produce high frequency noise or voltage spikes that could damage equipment or that represent a hazard to personnel.

(f) All conductive workbenches shall be earthed to the immediate local earth mass.

(g) Each individual supply system shall be separated from the *MEN* supply source (no metallic connection).

(h) Where multiple power supplies are used in a work area, independent outlets for each supply must be used, i.e. different power supplies cannot use a common outlet.

Note: However, a common connector may be used for multiple power supplies at the input / output point of a piece of aviation electrical, electro-mechanical or electronic equipment if this is required by the equipment or fitting design.

(i) Care shall be taken to ensure all technical requirements associated with static discharge devices are met including separation from power *grounds* and *power earths*. Where power supply earthing and electro-static discharge grounds share a common reference, they shall be separately *bonded* to that *ground* (See Section 5.5.1 on bonding).

(j) The design of the *earthing* and *bonding* arrangements or each separate power system shall be subject to a safety analysis assessment to confirm that unsafe situations cannot occur under system fault conditions. The safety analysis must identify and take due account of possible interactions between power systems and earthing systems.

(k) Given that workshop technicians may work on live equipment, kill switches shall be provided throughout a workshop so that if operated all electrical power in the workshop is de-energised in the event of a hazardous situation occurring.

5.8.3 Operational Considerations

(a) When the design and layout of equipment rooms and location of electrical equipment is being considered, restricted access requirements shall be considered. Dead-front construction should be utilized whenever practical. Where dead-front construction is not possible, as may be the case for certain industrial configurations or in existing installations (e.g. transformer bays), all exposed electrical equipment should be placed behind locked doors or gates or otherwise suitably guarded.

(b) Proper barricading, warning signs, and guarding should be installed and maintained on energized systems or around machinery that could be hazardous, or is located in occupied areas. Where isolation is not practicable, work procedures shall be established and implemented within the context of the user organisation's health and safety regime.

(c) Work on energized power systems or equipment shall only be permitted where properly qualified and authorised personnel are available to perform such work and only if it is essential. Although safety risk dominates, equipment damage can also occur. Unintentional grounding or phase-to-phase short-circuiting of equipment that is being worked on, or inadvertently modified without full design process, due to human error is a particular and serious potential cause of failure and harm. By careful design, such as proper spacing and barriers, and by enforcement of health and safety procedures, the designer can and should minimize this risk. *GPU* technology in particular presents particular hazards such as unanticipated back-feeds through control circuitry, potential via instrument transformers or test equipment, or charge from capacitors, presents a danger to maintenance personnel.

(d) Particular effort must be applied to ensuring workshop systems allow avionics and other staff to meet the specific requirements of equipment OEMs and other *aviation instructions*. It is essential that the specific work process needs of workshop staff should be researched and fully understood as part of the development of user specifications and prior to the detailed design and layout phase.

6 Bonding and Earthing Procedures

6.1 General Instructions

This Section contains the procedures and sequences to be used for electrical *earthing* and *bonding* of aircraft and ground support equipment. It is recommended that personnel involved in aircraft ground handling and maintenance observe these precautions.

Correct electrical *earthing* and *bonding* procedures are essential to minimise the hazards associated with static electricity and power earth loops. *Bonding leads*, which have been designed to provide this *earthing* and *bonding* for aircraft and equipment, must be connected correctly and in the proper sequence.

6.1.1 Aircraft Earthing Procedure

Where aircraft are to be earthed to control static build-up, a purpose designed and constructed *bonding lead* shall be connected/disconnected using the following sequence (unless otherwise directed by the specific *aviation instructions*):

(a) Connect the *bonding lead* clamp to a known serviceable earth point and then …

(b) Connect the connector pin or clamp to an appropriate location on the aircraft.

The disconnection procedure is the reverse of the above connection sequence i.e. the connector pin or clamp is removed from the aircraft followed by the lead clamp from the earth point.

6.1.2 Bonding Ground Support Equipment (GSE) to Aircraft

Where GSE is required to be bonded to an aircraft, personnel are responsible for ensuring that the proper sequence of earthing or bonding is observed and that the connections are correctly made. Where no specific instructions are given, the sequence given above should be used.

6.2 Refuelling Aircraft from Hydrant Systems or Fueller (Pressure Fuelling)

The fuelling company's published fuelling procedures, including bonding procedures, shall be strictly followed. The following additional precautions shall be incorporated into operational procedures:

(a) Connection, energising or disconnection of *GPU* power cables shall not be carried out during fuelling operations.

(b) If an energised *GPU* trips; re-energising the *GPU* shall not be attempted unless and until the cause of the fault is known not to have been caused by an unsafe condition or until after fuelling operations have been completed.

(c) Fuelling procedures are not to be continued if sparking is evident during the bonding procedure. The cause of any sparking shall be investigated and cleared before further attempts to bond are undertaken. Sparking may be caused by static charge (would be expected to cause a short duration spark) or electrical power systems faults (would be expected to cause a more prolonged arc) and must be investigated. Where a *GPU* was connected to the aircraft, the following initial steps are recommended:

   (i) De-energise and disconnect the *GPU*. Reattempt bonding.

   (ii) If the spark does not repeat, this suggests that the *GPU* may have been the cause of the original sparking. The *GPU* should therefore be taken out of service for inspection and testing.

6.3 Use of General Purpose GSE for Fuel Tank Maintenance

Work stands used in conjunction with fuel tank maintenance should be fitted with *bonding leads* to enable the stand to be connected to the aircraft. The stand should also be fitted with a static discharge plate made of copper, zinc or zinc-coated material. The plate should be welded or bolted to the handrail at the entrance to the stand and should be marked "Personnel Static Discharge Plate".

7 Illustrations

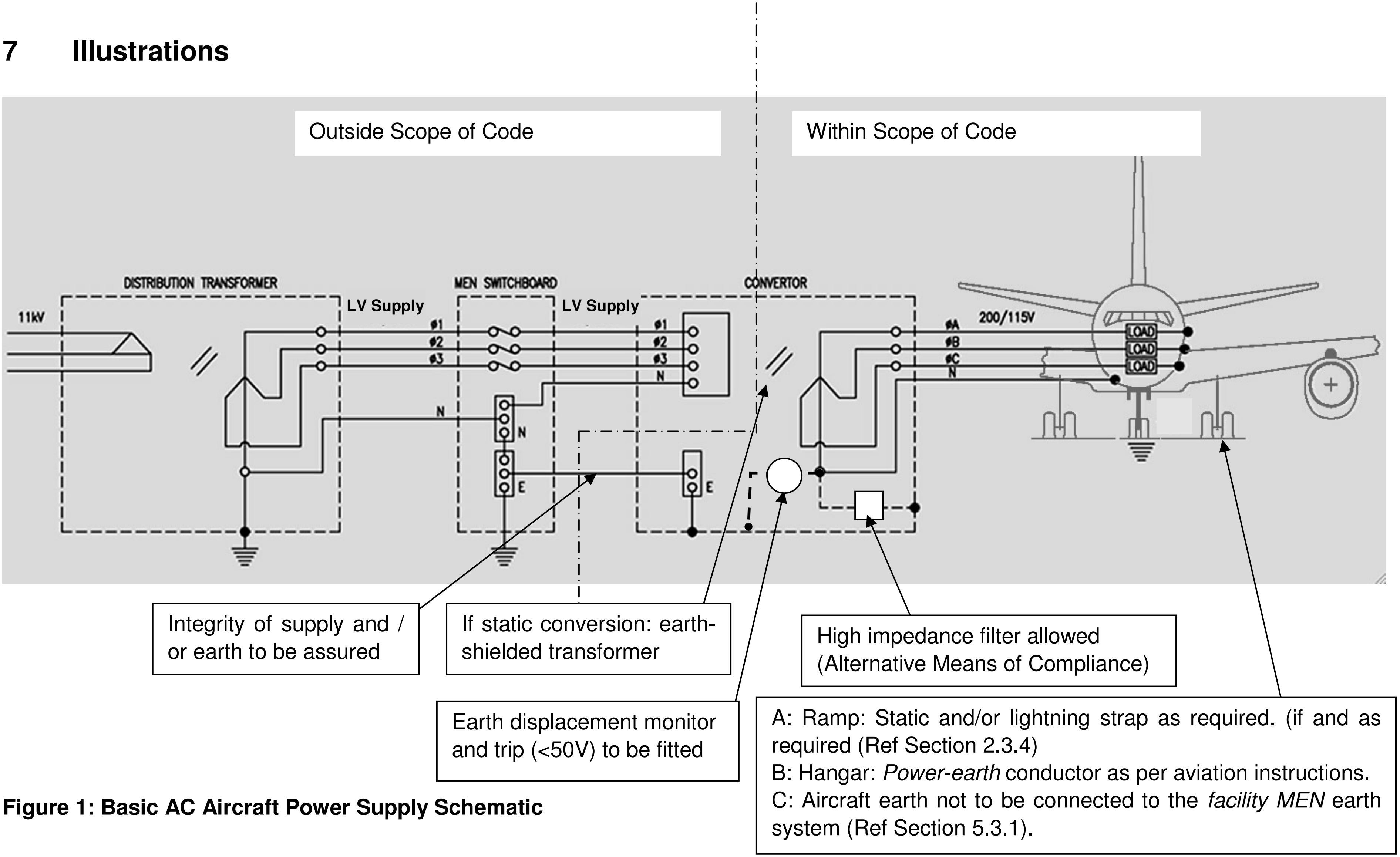

Figure 1: Basic AC Aircraft Power Supply Schematic

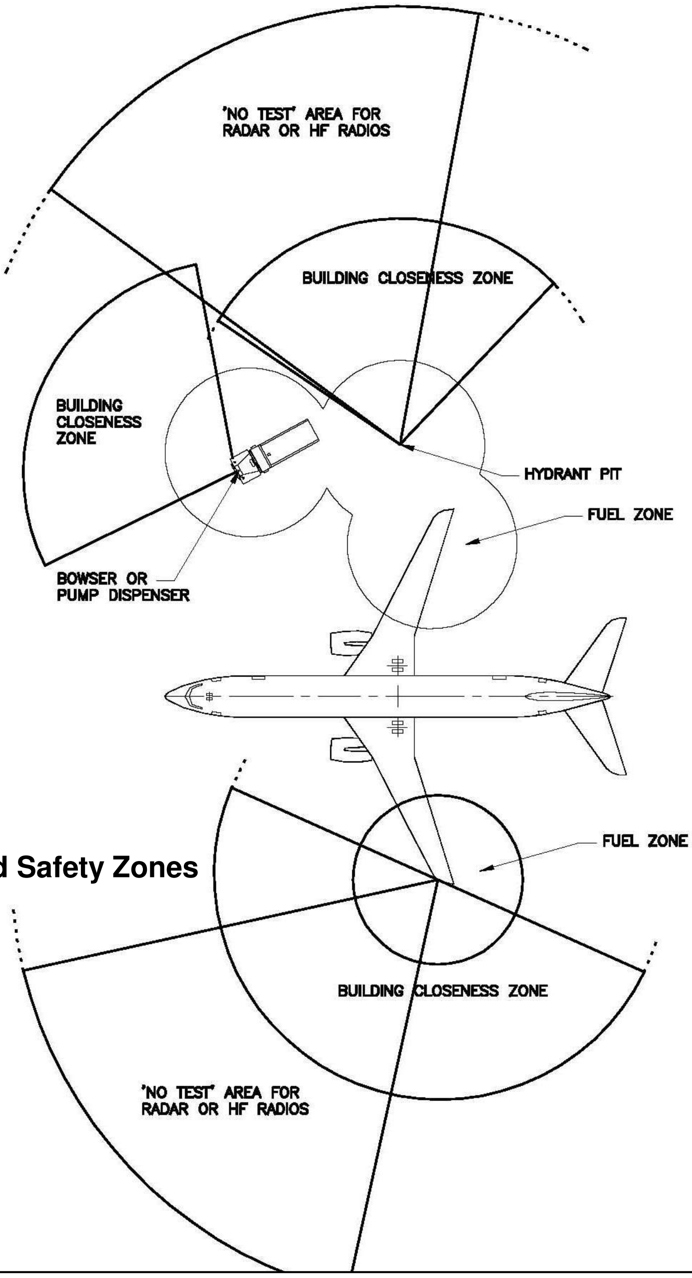

Figure 2: Aircraft Fuelling and Safety Zones

Fuelling Areas/Zones (radius):

- Fuelling Zone (centred on vents, hose couplings, fuelling connections):
  - large aircraft (typically jet): 6m
  - small aircraft (typically turbo-prop): 3m
- Limit to closeness of buildings during fuelling: 15m (air-bridges and access ways excluded)
- No testing of radar or HF equipment: 30m

GPU positioning:

A. During fuelling operations: Not within any Fuelling Zone

B. Other times: Not within 3m of wing tips

Not within 1.5m of the wings or other fuel containing part of the aircraft

Intentionally Blank