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Outline of Investigation for Power Supplies, Medium Voltage

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Summary of Topics

This second issue of the Outline of Investigation for Power Supplies, Medium Voltage, UL 2877, covers requirements for power supplies with input voltage ratings greater than 1000 V, to 15 kV.

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INTRODUCTION

1 Scope

1.1 These requirements cover power supplies having ac or dc input voltage ratings above 1000 V, up to 15 kV, and ac or dc output voltage ratings up to 15 kV.

1.2 These power supplies may have one or more circuits that are classified as safety extra low voltage (SELV).

1.3 These requirements cover equipment intended for use in ordinary locations in accordance with the National Electrical Code.

1.4 These requirements also cover open type, or partially enclosed power supplies intended to be installed in equipment where the overall assembly is investigated using this outline of investigation, or another applicable standard for medium voltage equipment.

2 Glossary

2.1 The definitions in UL 347 are applicable. Where definitions in this outline conflict with definitions in UL 347, the definitions in this outline take precedence.

2.2 SELV CIRCUIT – A secondary circuit with voltages that do not exceed a safe value under normal operating conditions and single fault conditions.

NOTE: The voltage limits for SELV circuits are specified in 18.1.

2.3 BASIC INSULATION – Insulation to provide protection against electric shock.

2.4 DOUBLE INSULATION – Insulation consisting of basic insulation, plus supplementary insulation.

2.5 MODULAR CONSTRUCTION POWER SUPPLIES – Power supplies using multiple modules, each with low voltage input and output voltage ratings. Refer to 19.1.

2.6 REINFORCED INSULATION – A single insulation that provides equivalent protection against electric shock as double insulation.

2.7 REMOVABLE MODULE – A portion of a modular construction power supply that is capable of being removed for replacement without opening the power supply enclosure or disassembly of parts other than those within the removable portion.

2.8 STANDBY CURRENT – The current that flows in the input circuit of a power supply when the power supply is connected to a source of rated voltage, but is not delivering load current.

2.9 SUPPLEMENTARY INSULATION – Insulation that is independent of, and in addition to, basic insulation, that provides the same level of insulation as the basic insulation, should the basic insulation fail.

3 Components

3.1 A component of a product covered by this Outline shall comply with the requirements for that component and shall be used in accordance with its recognized rating and other limitations of use. See Appendix A for a list of standards covering components used in the products covered by this outline. A component is not required to comply with a specific requirement that:

- a) Involves a feature or characteristic not required in the application of the component in the product covered by this outline, or
- b) Is superseded by a requirement in this outline.

3.2 Components that provide isolation between medium voltage circuits and low voltage circuits (such as transformers, optical isolators, and the like) shall be provided with sufficient insulation to withstand the rated power frequency dielectric voltage and rated impulse voltage between the circuits.

3.3 Components that provide isolation between medium voltage circuits and SELV circuits shall be provided with double or reinforced insulation, and the insulation shall be sufficient to withstand 160% of the rated power frequency dielectric voltage and 160% of the rated impulse voltage between the circuits.

4 Units of Measurement and Undated References

4.1 Values stated without parentheses are the requirement. Values in parentheses are explanatory or approximate information.

4.2 Any undated reference to a code or standard appearing in the requirements of this outline shall be interpreted as referring to the latest edition of that code or standard.

5 Normal and Special Service Conditions

5.1 Normal service conditions

5.1.1 Apparatus within the scope of this standard shall be capable of operation within its performance specifications under the following conditions:

- a) For equipment that is cooled by air, either ventilated or nonventilated, the temperature of the air outside of the enclosure and the ambient temperature is above 0°C but does not exceed 40°C, and its average value, measured over a period of 24 h, does not exceed 35°C, and
- b) The equipment is located where:
 - i) the influence of solar radiation is not significant, such as indoors or similarly protected locations;
 - ii) the altitude does not exceed 1 000 m (3 300 ft);
 - iii) the ambient air is not significantly polluted by dust, smoke, corrosive and/or flammable gases, vapors, or salt, and
 - iv) the average value of the relative humidity, measured over a period of 24 h, does not exceed 95% non-condensing.

5.2 Special service conditions

5.2.1 Altitude

5.2.1.1 Installation at altitudes above 1000 m up to 3000 m is also recognized in this standard. Variations in the design will in some cases be required. For example, considerations should be made for temperature rise, insulation level, and mechanical parameters affected by lower ambient pressures. In such cases, the manufacturer shall supply de-rating factors to be applied to the normal service condition ratings and any necessary setting adjustments.

5.2.2 Solar radiation

5.2.2.1 If the effects of solar radiation are significant, the principles stated in ANSI/IEEE C37.24, Guide for Evaluating the Effect of Solar Radiation on Outdoor Metal-Enclosed Switchgear, may be used for guidance.

CONSTRUCTION

6 General

6.1 Equipment as covered by this outline shall:

- a) Be so constructed as to provide for compliance with the rules for installation and use of such equipment as given in the National Electrical Code, ANSI/NFPA 70; and
- b) Employ materials that are acceptable for the particular use.

7 Enclosures

7.1 This section does not apply to open type power supplies. For partially enclosed power supplies, this section applies to any portion of the power supply that may form part of the overall assembly enclosure when assembled into other equipment.

7.2 In addition to the following, the enclosure requirements of UL 50 and UL 50E apply. If there is a conflict between the requirements in this outline and UL 50 or UL 50E, the requirements in this outline apply.

7.3 Enclosures shall be metallic, and built to the requirements of UL 50 and UL 50E, except that enclosure thickness shall be in accordance with 7.15. External parts of the power supply may be of insulating material, provided that all medium-voltage parts are completely enclosed by grounded metallic partitions having material thickness equivalent to that required for the enclosure. This does not preclude the use of inspection windows or ventilation openings as detailed in 7.4 and 7.5, respectively.

7.4 Inspection windows may be provided and form part of the enclosure when all of the following conditions are met:

- a) The window shall have an infrared viewport that complies with UL 50V, or shall be of clear safety-type glass, wire-reinforced glass, or another clear material found suitable with respect to flammability and UV resistance in accordance with UL 746C;
- b) The window shall be secured in such a manner that it cannot be removed without tools; and

c) The window shall meet the requirements of the impact and pressure tests for viewing panes specified in Section 28.

7.5 Ventilation openings may be provided when they comply with the following:

a) Ventilation openings, including perforations, louvers, and openings protected by means of wire screening, expanded metal, or a perforated cover, shall comply with the rod entry test specified in Section 29.

b) Barriers shall be provided behind all ventilating openings into medium-voltage compartments. The barrier shall be effectively secured in place and shall prevent drawing a straight line from any point outside the enclosure to any medium voltage live part, including insulated parts.

c) The diameter of the wires of a screen covering a ventilation opening shall be not less than 1.3 mm (0.050 in) if the screen openings are 320 mm² (0.497 in²) or less in area, and shall be not less than 2.06 mm (0.081 in) for larger screen openings.

d) Perforated sheet steel and sheet steel employed for expanded metal mesh shall be not less than 1.07 mm (0.042 in) thick for mesh openings or perforations 320 mm² (0.497 in²) or less in area, and shall be not less than 2.03 mm (0.080 in) thick for larger openings.

7.6 Enclosures with forced ventilation shall comply with 7.7 and 7.8.

7.7 When ventilation is accomplished by one or more blowers within the enclosure that provide a positive intake and exhaust, the ventilation openings shall be located such that the exhaust air is not directed toward the area occupied by the equipment operator.

7.8 When equipment incorporates a blower motor, it shall comply with the Inoperative Blower Motor Test, Section 33.

7.9 When a power supply is provided with filters for ventilation openings, the construction shall comply with the Clogged Filter Test, Section 34, and with (a) or (b) below:

a) The filters shall be located in a medium voltage compartment so that the filters cannot be replaced without opening a door or cover to the compartment. The door of the compartment shall be interlocked in accordance with Section 11, Interlocking.

b) The filters shall be located outside of a medium voltage compartment, so that the filters may be replaced without opening the medium voltage compartment. During any period of filter replacement, including with a filter access cover open and no filter installed, the construction shall comply with 7.5.

7.10 Enclosures shall comply with the rod entry test of Section 29.

7.11 Doors and covers shall be provided with means such as latches, locks, interlocks, bolts or screws for firmly securing them in place. Covers of compartments containing medium-voltage components shall be bolted closed.

7.12 If uninsulated live parts are exposed by the opening of a door or cover, means shall be provided to secure it in the closed position. This securement means shall require the use of a tool other than a key to open the door or cover. If parts operating above 1000 V are exposed by the opening of a cover or door, a warning marking shall be provided in accordance 40.1(a).

7.13 Parts mounted on the interior of a door shall be effectively guarded or enclosed to provide protection against unintentional contact when the door is opened for maintenance of the equipment.

7.14 The following requirements shall apply to power supplies intended for outdoor use:

- a) External hinged doors or covers shall be provided with stops to hold them in the open position;
- b) Enclosures shall be subjected to the driven rain test described in Section 31 in addition to any test requirements for the Type designation marked on the enclosure in accordance with UL 50E;
- c) Enclosures shall have provisions for locking to prevent access to medium-voltage compartments; and
- d) Consideration should be given to prevention of condensation and entry of snakes, rodents, etc.

7.15 The thickness of a sheet-metal enclosure at points to which a wiring system is to be connected shall be not less than 0.8 mm thick for uncoated steel, 0.9 mm thick for zinc-coated steel, and 1.2 mm thick for non-ferrous metal. Enclosure thickness at points other than where a wiring system is to be connected shall be not less than that specified in Table 7.1 or Table 7.2. With reference to Table 7.1 and Table 7.2, a supporting frame is a structure of angle or channel or folded section of sheet metal, which is attached to and has the same outside dimensions as the enclosure surface, and which has torsional rigidity to resist the bending moments that are applied by the enclosure surface when it is deflected. A structure which is as rigid as one built with a frame of angles or channels has equivalent reinforcing. Constructions without supporting frame include:

- a) A single sheet with single formed flanges – formed edges;
- b) A single sheet which is corrugated or ribbed;
- c) An enclosure surface loosely attached to a frame, for example, with spring clips; and
- d) An enclosure surface having an unsupported edge.

Table 7.1
Thickness of sheet metal for enclosures: carbon steel or stainless steel

Without supporting frame ^a		With supporting frame ^a		Minimum thickness mm
Maximum width mm ^b	Maximum length mm ^c	Maximum width mm ^c	Maximum length mm ^c	
100	Not limited	160	Not limited	0.6 ^d
120	150	170	210	
150	Not limited	240	Not limited	0.75 ^d
180	220	250	320	
200	Not limited	310	Not limited	0.9
230	290	330	410	
320	Not limited	500	Not limited	1.2
350	460	530	640	
460	Not limited	690	Not limited	1.4
510	640	740	910	
560	Not limited	840	Not limited	1.5
640	790	890	1090	
640	Not limited	990	Not limited	1.8
740	910	1040	1300	
840	Not limited	1300	Not limited	2.0
970	1200	1370	1680	
1070	Not limited	1630	Not limited	2.5
1200	1500	1730	2130	
1320	Not limited	2030	Not limited	2.8
1520	1880	2130	2620	
1600	Not limited	2460	Not limited	3.0
1850	2290	2620	3230	

^a See 7.15.

^b The width is the smaller dimension of a rectangular piece of sheet metal which is part of an enclosure. Adjacent surfaces of an enclosure are able to have supports in common and be made of a single sheet.

^c "Not limited" applies only when the edge of the surface is flanged at least 12.7 mm or fastened to adjacent surfaces not normally removed in use.

^d Sheet steel for an enclosure intended for outdoor use shall be not less than 0.86 mm thick.

Table 7.2
Thickness of sheet metal for enclosures: aluminium, copper or brass

Without supporting frame ^a		With supporting frame ^a		Minimum thickness mm
Maximum width mm ^b	Maximum length mm ^c	Maximum width mm ^b	Maximum length mm ^c	
75	Not limited	180	Not limited	0.6 ^d
90	100	220	240	
100	Not limited	250	Not limited	0.75
125	150	270	340	
150	Not limited	360	Not limited	0.9
165	200	380	460	
200	Not limited	480	Not limited	1.2
240	300	530	640	
300	Not limited	710	Not limited	1.5
350	400	760	950	
450	Not limited	1100	Not limited	2.0

Table 7.2 Continued

Without supporting frame ^a		With supporting frame ^a		Minimum thickness mm
Maximum width mm ^b	Maximum length mm ^c	Maximum width mm ^b	Maximum length mm ^c	
510	640	1150	1400	
640	Not limited	1500	Not limited	2.4
740	1000	1600	2000	
940	Not limited	2200	Not limited	3.0
1100	1350	2400	2900	
1300	Not limited	3100	Not limited	3.9
1500	1900	3300	4100	

^a See 7.15.

^b The width is the smaller dimension of a rectangular piece of sheet metal which is part of an enclosure. Adjacent surfaces of an enclosure are able to have supports in common and be made of a single sheet.

^c "Not limited" applies only when the edge of the surface is flanged at least 12.7 mm or fastened to adjacent surfaces not normally removed in use.

^d Sheet aluminium, copper or brass for an enclosure intended for outdoor use shall be not less than 0.74 mm thick.

8 Grounding and Bonding

8.1 An enclosure shall have provision for permanent and effective grounding of exposed non-current-carrying metal parts. The means for grounding shall consist of a ground bus or ground stud with provisions for the mounting of pressure terminal connectors acceptable for use with conductors of the size indicated in Table 3 of UL 347. At all points of connection between the ground bus or the equipment grounding conductor and the assembly, any nonconductive coating, such as paint, shall be removed or penetrated to provide a good electrical connection. Bolts or screws engaging at least two full threads in the penetrated metal shall be considered to have provided adequate penetration.

8.2 There shall be provision for permanently and effectively grounding a metal plate that covers uninsulated live parts. All dead metal parts that are likely to be touched by persons and are likely to become energized shall be grounded.

8.3 If the requirements of 8.1 and 8.2 cannot be visually verified, the grounding provisions shall be tested in accordance with Section 30.

8.4 A ground bus shall be provided for all power supplies consisting of multiple vertical sections.

8.5 When a ground bus is provided, it shall be of equivalent cross-sectional area to the conductors shown in column 2 or 3 of Table 3 of UL 347. Splice bars shall be provided for field splicing sections as needed.

8.6 When a ground bus is not provided, the following terminals shall be provided on the frame or enclosure:

a) One terminal for an equipment-grounding conductor of a size in accordance with Table 3 of UL 347 to ground the power supply frame; and

b) One terminal for an equipment-grounding conductor to bond all outgoing conduits to the enclosure frame. This connection shall accommodate an equipment-grounding conductor in accordance with Table 3 of UL 347 corresponding to the largest branch circuit. When the power supply is provided with only SELV output circuits and the power is supply provided only with connectors or receptacles for connection to the SELV output circuits, such that there are no outgoing conduits, this terminal is not required.

8.7 Other than as noted in 8.8, power supplies shall include one of the following provisions for the termination of the grounding conductor associated with each incoming or outgoing circuit other than an SELV circuit, or provision for field installation of wire connectors suitable for that purpose:

- a) For each circuit, a suitable stud or bolt mounted on the grounding bus or controller structure, together with a standard complement of hardware to secure a suitable wire connector (the connector need not be furnished);
- b) For each circuit, a wire connector evaluated in accordance with UL 486A-486B, located either on the grounding bus or elsewhere on the power supply structure, or
- c) For each circuit, a termination pad with drilling in accordance with ANSI/NEMA CC1, Electric Power Connection for Substations.

8.8 Power supplies intended to be terminated with field wiring larger than 10 AWG (5.26 mm²) need not have the wire connectors attached if connector and grounding kits that will properly accommodate conductors suitable for the ampere rating of the device are made available by the manufacturer and identified for use in accordance with 41.1(j). Grounding kits may be provided for all sizes of conductors. See 13.5 for requirements for connector and grounding kits.

9 Protective Devices

9.1 Power supplies shall be provided with the following protective features:

- a) Output short circuit protection to prevent fire and shock hazards when the output circuit is subjected to a short circuit, either between conductors of the output circuit, or from one conductor of the output circuit to ground;
- b) Output overload protection to prevent fire and shock hazards when the output circuit is subjected to foreseeable overload conditions; and
- c) Input circuit overcurrent protection to prevent fire and shock hazards under any single fault condition within the power supply. This input circuit overcurrent protection may be omitted from the power supply when the power supply required input overcurrent protection device is specified in accordance with 40.3.

9.2 When overcurrent protection is provided by fuses, a fuse shall be provided in each ungrounded conductor of the protected circuit. For single phase power supplies having one line conductor and one grounded circuit conductor (neutral conductor), overcurrent protection shall not be provided in the grounded circuit conductor (neutral).

9.3 Overcurrent protective devices used in branch circuit applications shall be of the type suitable for use in branch circuit applications, and shall have appropriate voltage and interrupting ratings.

10 Isolating Means

10.1 If the power supply is provided with an isolating means that isolates the power supply from the incoming medium voltage supply, the requirements in Section 5.202 of UL 347 apply.

10.2 If an isolating means is not provided, the power supply shall be marked in accordance with 40.1(l).

11 Interlocking

11.1 Isolating means interlocks

11.1.1 Other than as noted in 11.1.2, when a power supply is provided with an isolating means, it shall be rated for making and interrupting the input circuit when the power supply is loaded to the maximum rated output.

11.1.2 The isolating means need not be rated for making and interrupting the power supply input circuit when the isolating means is provided with interlocks complying with the following:

- a) Interlocking shall be provided by mechanical means, and shall not rely on electrical contacts or solenoids. Supplemental electrical interlocks may be provided in addition to the required mechanical interlocks but shall not defeat the mechanical interlocking;
- b) Interlocking shall prevent the isolating means from being opened or closed when the power supply is delivering current;
- c) The interlocks shall prevent the isolating means from being closed and initiating current flow through the power supply without another manual action, such as manual operation of a "power on" switch for the power supply or similar action; and
- d) The isolating means is tested in accordance with Section 27 for making and breaking the standby current of the power supply.

11.2 Drawout element interlocks

11.2.1 In addition to the requirements of Clause 11.1, power supplies using a drawout element as an isolation means for a medium voltage circuit shall be provided with mechanical interlocks that will:

- a) Positively lock the drawout element in the housing when the primary disconnecting devices are in their fully closed or fully connected position;
- b) Discharge or block stored-energy devices prior to complete removal of the drawout element; and
- c) Prevent contact with medium-voltage live parts as determined by the rod entry test in Section 29 with the drawout element in the disconnected and with the drawout element removed from the enclosure.

NOTE: Means to padlock a shutter assembly in a closed position may be used to meet this requirement when the drawout element is removed from the cubicle.

11.2.2 In addition to the requirements of Clause 11.2.1, a power supply using a drawout element that is used as the isolating means shall be provided with an automatic shutter assembly or the equivalent that:

- a) Is maintained in the closed position in a manner that prevents inadvertent opening. Opening of the shutter shall require a degree of difficulty involving a minimum of two separate and distinct operations. Turning a knob, or moving a lever, or removing a single bolt, or the like, shall not be considered to provide the required degree of difficulty; and
- b) Complies with the shutter integrity test described in Section 32.

11.2.3 Other than as described in 11.2.4, a drawout element that is not intended to be used as an isolating means shall be interlocked to prevent withdrawal of the element when the isolating means is closed, or shall be located behind doors that are interlocked with the isolating means, such that the non-isolating type drawout element may not be withdrawn or inserted unless the isolating means is open. It shall also be constructed such that it is not possible to close the door and isolating means until the non-isolating drawout element is fully inserted.

11.2.4 Individual modules of a modular power supply need not be interlocked with the isolating means when all of the following conditions are met:

- a) Disconnection of the module from the power supply requires a degree of difficulty involving a minimum of two separate and distinct operations. Turning a knob, or moving a lever, or removing a single bolt, or the like, shall not be considered to provide the required degree of difficulty;
- b) An automatic shutter assembly or the equivalent is provided to prevent contact with medium-voltage live parts as determined by the rod entry test in Section 29, when the removable module is in any position between the connected and fully removed positions;
- c) The shutter assembly required in (b) complies with 11.2.2(a) and (b); and
- d) Electrical disconnection of the removable module is accomplished using switches or connectors that are rated for interruption of the current and voltage involved unless the power supply is provided with a means to automatically bypass the connection point, such that the removal of the module does not cause the module to make or break current when inserted or removed.