UL 101

STANDARD FOR SAFETY

Leakage Current for Utilization Equipment

UL Standard for Safety for Leakage Current for Utilization Equipment, UL 101

Sixth Edition, Dated July 31, 2017

SUMMARY OF TOPICS

This revision of ANSI/UL 101 dated December 30, 2019 includes a title change to Standard for Safety for Leakage Current for Utilization Equipment and Scope To Reflect That The Impact And Application Of The Standard Requirements Include Other Products As Well As Appliances: 1.1, Sections 2, 3, Table 4.1, 4.1.2, 5.1.1, Subsections 5.3, 5.4, Appendix A, A1.4, A3.1, A6.1

The new and revised requirements are substantially in accordance with Proposal(s) on this subject dated June 21, 2019 and October 4, 2019.

Text that has been changed in any manner or impacted by UL's electronic publishing system is marked with a vertical line in the margin.

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Leakage Current for Utilization Equipment

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The most recent designation of ANSI/UL 101 as an American National Standard (ANSI) occurred on December 13, 2019. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, and Title Page.

Comments or proposals for revisions on any part of the Standard may be submitted to UL at any time. Proposals should be submitted via a Proposal Request in UL's On-Line Collaborative Standards Development System (CSDS) at https://csds.ul.com.

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INTRODUCTION

1 Purpose

1.1 To minimize the risks of physical reaction to electrical shock or inability to let go a live part of the user, or burns to the user, from exposure to leakage currents from utilization equipment under foreseeable use conditions, this standard provides:

a) Leakage current limits;

b) Methods, specifications for measuring equipment, and test conditions for measurement of leakage currents.

2 Scope

2.1 This standard applies to cord- and plug-connected household and similar utilization equipment (see Definitions, Section 3) typically rated 20 A or less, nominal 50 or 60 Hz, having 3-wire (including equipment grounding conductor) or 2-wire cords, and intended for use on supply circuits not exceeding 300 V to ground.

NOTE: The scope statement in 2.1 does not exclude utilization equipment currently rated higher than 20 A or voltage rated higher than 300 V from referencing this standard.

2.2 This standard does not apply to utilization equipment having a grounded connection made at the factory to the neutral terminal. The values in this standard do not provide protection against the minute currents which could cause ventricular fibrillation if applied directly to the heart, as via a heart catheter.

3 Definitions

3.1 APPLIANCE – (As referred to in this standard) – Utilization equipment that uses electric energy for some function, usually complete in itself, generally other than industrial, normally built in standardized sizes or types which is installed or connected as a unit to perform one or more functions. For example, a toaster, flatiron, washing machine, hand drill, food mixer, air conditioner, gas appliance with electrical controls, kerosene heater with electric blower.

NOTE: Appliances not intended for normal household use but which nevertheless may be a source of danger to the public, such as appliances intended to be used by laymen in shops, appliances used in commercial kitchens, in light industry, and the like, are within the scope of this standard.

3.2 *Revised and relocated to 3.7.1*

3.3 *Revised and relocated to 3.7.2*

3.4 *Revised and relocated to 3.7.3*

3.5 FORESEEABLE USE – Specified use conditions and other use conditions which a prudent person might assume would cause no immediate hazard. An open ground is considered to be a condition of foreseeable use.

3.6 LEAKAGE CURRENT – Electric current which flows through a person upon contact, between accessible parts of an appliance and:

a) Ground, and

b) Other accessible parts of the appliance.

3.6.1 LET-GO CURRENT – A threshold current value, above which a substantial portion of the population may cause involuntary muscle reaction and not able to let-go of an electrically-energized part(s).

3.7 MIU-MEASUREMENT INDICATION UNIT – Is the output voltage (V3) in millivolts rms from the measurement instrument in Figure 5.3 divided by 500 (the value in ohms of the resistance in parallel with V2 in the measurement instrument circuit). (The indication is essentially the rms value of a 60 Hz sinusoidal leakage current in mA. It may not be a direct indication of the rms or other common amplitude quantifier of leakage current when the leakage current is of complex waveform or frequency other than 50 or 60 Hz.)

3.7.1 PRODUCT, FIXED – Utilization equipment that is fastened or otherwise secured at a specific location and permanently connected electrically.

3.7.2 PRODUCT, PORTABLE – Utilization equipment that is actually moved or can easily be moved from one place to another in normal use.

3.7.3 PRODUCT, STATIONARY – Utilization equipment that is not easily moved from one place to another in normal use.

3.8 REACTION CURRENT – A threshold current value, above which a substantial portion of the population may be caused to react involuntarily to the sensation of current.

3.9 SHEATHED HEATING EQUIPMENT LEAKAGE CURRENT – Current through insulating material (normally MgO) between the current-carrying conductor and the metallic sheath.

3.10 UTILIZATION EQUIPMENT – A product that utilizes electric energy for electronic, electromechanical, chemical, heating, lighting, or similar purposes.

NOTE 1: Throughout this standard the terms "product," and "unit" refer to utilization equipment.

NOTE 2: Utilization equipment covered in this in this standard include appliances, luminaires, information technology and similar equipment.

PERFORMANCE

4 Leakage Current Limits

4.1 General

4.1.1 When measured in accordance with the test method covered in this standard, the measurement indication shall not exceed the values shown in Table 4.1.

Table 4.1
Maximum allowable measurement instrument indication based on reaction

Type of products	Indication in MIU (for a 60 Hz sine wave leakage current, the values are approximately milliamperes, rms)
Two-wire cord- and plug-connected products	0.50 MIU
Three-wire (including grounding conductor) cord- and plug-connected portable products	0.50 MIU
Three-wire (including grounding conductor) cord- and plug-connected stationary or fixed products	0.75 MIU
Three-wire (including grounding conductor) fixed lighting products. Less or equal to 150 V to ground	0.5 MIU
Three-wire (including grounding conductor) fixed lighting products. Higher than 150 V to ground	0.75 MIU

4.1.2 In addition to the limits in Table 4.1, to avoid undue risks of severe body tissue burns, the leakage current shall be not greater than 70 mA rms, measured as V2 (volts rms) divided by 0.5 (kilohms), using the measuring instrument of Figure 5.3 with the frequency-sensitive network disconnected. (See Appendix B for the performance specifications of the modified measuring instrument). Because in the low frequency range, the maximum allowable current based on reaction is less than the maximum allowable current based on body tissue burn, the burn current limit generally applies only when high frequencies are involved.

Exception No. 1: For products having metal-sheathed heating elements for which the operating conditions and present technology does not permit compliance with the limits in Table 4.1 during heat-up and cool-down, the maximum allowable indication of the measurement instrument for periods not exceeding 5 minutes during heat-up and not exceeding 5 minutes during cool-down is 2.5 MIU. For other periods of operation, the leakage current shall be within the limits specified in Table 4.1. (See 5.4.12 and 5.4.13.)

Exception No. 2: Those conductive parts of an product that comply with all of the specifications in Items (a) through (e) below may be permitted by the product standard to have a leakage current from simultaneously accessible parts to the grounded supply conductor higher than specified in Table 4.1, but in no case shall the leakage current be greater than 3.5 MIU. The leakage current between simultaneously accessible parts shall not exceed the values shown in Table 4.1. (See 5.4.2.)

a) The product requires EMI suppression filtering for compliance with FCC regulations. (See A3.1.)

b) The product is equipped with a grounding-type supply cord and plug.

c) There is a low probability that a path for available current through the body will exist in the expected environment. If the available current flows to ground, this will involve consideration of the probability that the user will be grounded during the use of the product.

d) There is a low probability that high leakage conductive parts will be contacted during normal use, as defined in the product standard.

e) The probability of injury resulting from an involuntary reaction is small. (See Rationale.)

Exception No. 3: For an product that upon loss-of-grounding, dependably disconnects all sources that can produce leakage current, the leakage current, when measured in accordance with the test method covered in this standard, shall not exceed 5 MIU with the grounding conductor open and with the loss-of-grounding circuit disabled. (See A5.)

The leakage current, when measured in accordance with the test method covered in this standard, except that the equipment grounding conductor is connected to the grounded supply conductor at the receptacle feeding the product, shall not be more than the values shown in Table 4.1. This measurement will typically not involve current between accessible parts and the grounded supply conductor, but will involve currents that may flow from one part of the product to another.

4.2 Departure from leakage current limits

4.2.1 Leakage currents for certain additional tests (see A1.4) that do not represent normal use (but may reflect some degree of abuse or certain failure modes) and exceeding the limits stated above, but not exceeding 5 MIU at 50 – 60 Hz (see A5.2) may appear in individual product standards. If so they should appear with a statement justifying them.

5 Test Method and Instrumentation for Measurement of Leakage Current

5.1 General

5.1.1 This test provides a measurement of leakage current from utilization equipment.

5.2 Characteristics of measurement circuit and measurement instrument

5.2.1 Measurement circuit – The measurement circuits for leakage current shall be as shown in Figure 5.1 and Figure 5.2.

5.2.2 Measurement instrument – The measurement instrument is defined in items 5.2.3 – 5.2.6. The instrument that is actually used for measurement need only indicate the same numerical value (see also B1.3) for the particular measurement as would the defined instrument. The instrument used need not have all the attributes of the defined instrument. The measurement instrument is only to be used where the current limit is not greater that 5 MIU for nominal 50 or 60 Hz sinusoidal currents, or not greater that 2 MIU for any higher frequencies. Above these values, an instrument designed to respond to the physiological effect of let-go is applicable.

5.2.3 Over the frequency range 20 Hz to 1 MHz with sinusoidal currents, the performance of the instrument shall be as specified in 5.2.4 – 5.2.5.

5.2.4 The measured ratio V1/I1 with sinusoidal voltages is to be as close as feasible to the ratio V1/I1 calculated with the resistance and capacitance values of the measurement instrument shown in Figure 5.3. (See Appendix B.)

5.2.5 The measured ratio V3/I1 with sinusoidal voltages is to be as close as feasible to the ratio V3/I1 calculated with the resistance and capacitance values of the measurement instrument shown in Figure 5.3. (See Appendix B.) V3 is to be measured by the meter M in the measuring instrument. If meter M has been calibrated to indicate directly in MIU, the indication of the meter is to be divided by 2 to obtain rms volts.

5.2.6 The meter M in the measurement instrument shall indicate, in MIU, 2.0 times the effective value (rms) of the voltage applied to it. (See A6.) The following shall be considered in the determination of the MIU:

a) The frequency response of the frequency sensitive network of the measurement instrument as defined here approximates the inverse of the experimentally determined 50 percentile threshold of perception curve for hand holding a small wire normalized to 0.5 milliampere at 60 Hz.

b) Under some circumstances where higher frequency components are present, shielding of the measurement instrument and its leads may be necessary to maintain its accuracy.

5.3 Test conditions

5.3.1 The product is to be tested for leakage current without any energization after the manufacturing, packaging and shipping process. It is to have all its switches and thermostats closed, but its grounding conductor, if any, is to be open at the receptacle feeding the product.

5.3.2 Additional testing should be carried out at conditions such as preconditioning, temperature, humidity, as prescribed in relevant product standards, or lacking a product standard, at conditions which are intended to stimulate anticipated use.

5.3.3 The supply voltage is to be sinusoidal of 50Hz or 60Hz, without a DC component, adjusted to the first available of the following:

a) The voltage specified for the leakage current test in the product standard;

b) The voltage specified for the normal temperature test in the product standard; or

c) Maximum rated voltage.

5.3.4 Motor-operated products shall be operated under the condition and duration of load simulating normal operation, which is generally specified for the normal temperature test in the product standard. In addition, products with speed controls are to be tested at the speed setting producing the maximum leakage currents.

5.3.5 Heating and cooking products are to be operated under that set of conditions considered to represent normal operation (ordinarily the normal temperature test as specified in the product standard, with the maximum heat setting of the controls), except that cycling of the thermostat is to be induced by a reduced setting, if necessary, before completing the test program. Some heating products such as broilers, are constructed with thermostats that do no open when at their highest settings. To detect the maximum leakage current, the cycling condition may be required to be induced.

5.4 Test procedure

5.4.1 Connect the product for test as shown in Figure 5.1 or Figure 5.2, whichever is appropriate as determined by the rating of the product.

5.4.2 The measurement instrument shall be connected:

a) Between the accessible parts and the grounded supply conductor; and

b) Between simultaneously accessible parts of the product.

Simultaneously accessible parts shall be tested individually and collectively for current in a path to the grounded supply conductor and from one part to another. The grounding terminal at the attachment plug is considered to be an accessible part.

5.4.3 Parts shall be considered to be accessible unless guarded by an enclosure considered suitable for protection against shock hazard.

5.4.4 Parts shall be considered to be simultaneously accessible when they can be readily contacted by one or both hands of a person at the same time.

5.4.5 These measurements do not apply to intentionally energized conductive parts operating at voltages that are considered to be nonhazardous and are so stated in the product standard.

5.4.6 If a conductive surface other than metal is used for the enclosure or part of the enclosure, the leakage current is to be measured using a metal foil with an area of 10 x 20 centimeters in contact with the surface. Where the surface is less than 10 x 20 centimeters, the metal foil is to be the same size as the surface. The metal foil is not to remain in place long enough to affect the temperature of the product. This test method in the product standard may need to be modified for application to a specific type of product design.

5.4.7 With test switch S1 open and the product in the “as received” condition, the product shall be connected to the measurement circuit. All its switches and thermostats are to be closed, but its grounding conductor shall be open at the receptacle feeding the product.

5.4.8 With test switch S2 in the A position note the measurement instrument indication.

5.4.9 Repeat 5.4.8 with test switch S2 in the B position.

5.4.10 Test switch S1 shall then be closed energizing the product.

5.4.11 Within a period of 5 seconds, after the closing of S1, the leakage current shall be measured using both positions of test switch S2. In the case of a product with more than one speed, the various speed conditions are to be checked as quickly as possible to determine the maximum leakage current condition.

5.4.12 Measure the leakage current, using both positions of S2 until final operating test conditions are reached.

5.4.13 Open S1 – measure the leakage current as the product cools, using both positions of S2. Continue to measure until the leakage current has stabilized or is decreasing.

Figure 5.1

Leakage current measurement circuit used for products intended for connection to 120 V circuits

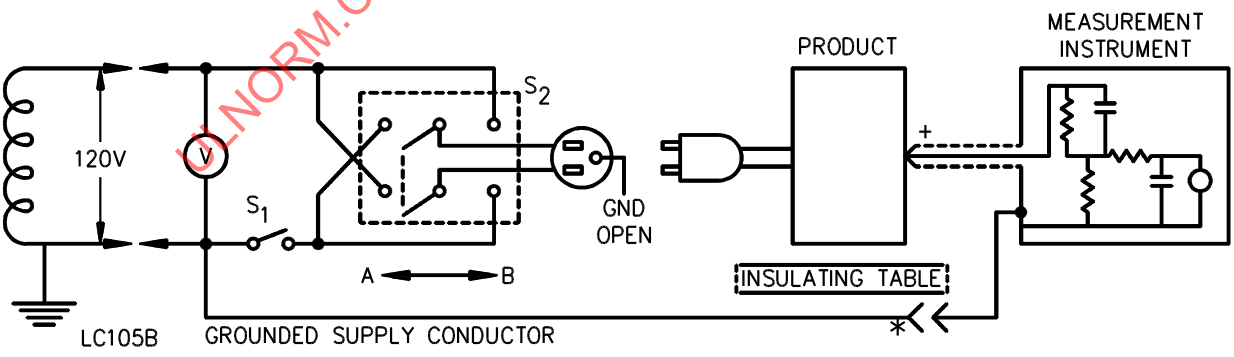
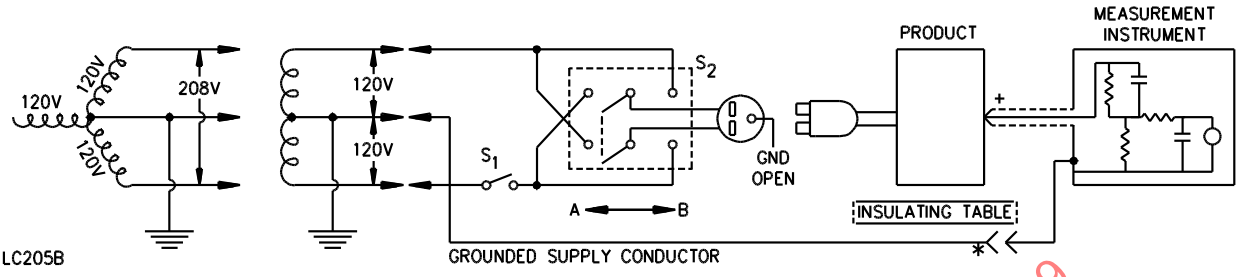


Figure 5.2

Leakage-current measurement circuit used for grounded or ungrounded 208 V or 240 V products intended for connection to three-wire neutral grounded circuits



* Separated and used as clip when measuring currents from one part of product to another.

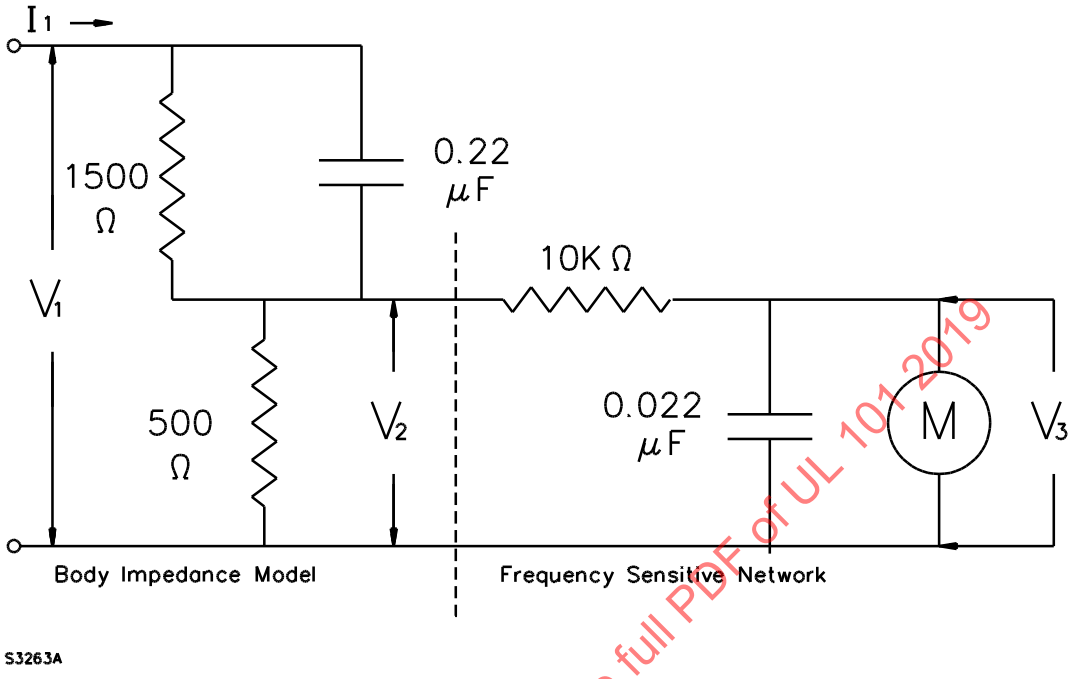
+ Probe with shielded lead.

Note 1. All voltages shown in Figure 5.1 and Figure 5.2 are nominal. (See 5.3.3.)

Note 2. If it is not feasible to isolate the product from ground, the supply circuit shall be isolated from ground. It may then also be necessary to reverse the leads of the measurement instrument.

Figure 5.3

Measurement instrument for reaction



Guidance for the calibration of this instrument is given in Appendix B.

APPENDIX A

This appendix is not a part of the American National Standard for Leakage Current for Utilization Equipment. They are intended to provide background and assistance in utilizing the standard.

RATIONALE

A1 Rationale for Limits

A1.1 The experiments on which this standard are based were done at 60 Hz. The results have been extrapolated to 100 kHz, based on the work by Dalziel. The limits set are not low enough to prevent being felt, but are below the reaction current for most people. In addition, the limits set are sufficiently low that they should protect against direct injury (asphyxiation or ventricular fibrillation), or indirect injury (inability to let go) provided that the current path is through the person's skin.

A1.2 This standard is not intended to provide protection against the minute currents which could cause ventricular fibrillation if applied directly to the heart, as via a cardiac catheter.

A1.3 The 70 mA limit (generally applicable only at high frequencies) incorporated in this standard may not prevent a burn if the area of contact is small, and exposure is of extended duration. This 70 mA limit will be encountered under the following conditions:

Limit in MIU	Frequency in kHz
0.5	100
0.75	67.6
2.5	20.0
3.5	14.5
5.0	10.2

A1.4 Other leakage current limits between 0.5 MIU and not exceeding 5.0 MIU may be specified in some product standards, such as:

a) 5.0 MIU after the product has been subject to abnormal conditions, such as a shorted thermostat or a burnout test, (see 4.2).

b) 3.5 MIU in situations where it has been determined that reaction is not likely to result in an injury (see Table 4.1, exception 2).

c) 5.0 MIU for products having a loss-of-grounding detector which dependably opens all live conductors upon loss of ground (see Table 4.1, exception 3). The 5 MIU limit is based on work by Dalziel on the physiological hazard of let-go.

A1.5 The term MIU (Measurement Indication Units) has been used in this standard to identify the numerical indication of the output meter. This indication is often erroneously labeled “milliamperes”, although in the case of 60 Hz sine wave leakage current it is approximately correct. (0.5 MIU @ 60 Hz is approximately 0.5 mA). The difficulty is that at 100 kHz, 70 mA of sine wave current will flow, and still produce an indication of only 0.5 MIU. This is just the situation desired, since it requires 140 (70 mA / 0.5 mA) times as much current for a person to perceive a 100 kHz sine wave as it does to perceive a 60 Hz sine wave.

A1.6 The intent is to have the meter produce the same numerical indication (MIU) for a shock perception of the same intensity, regardless of the frequency and current actually flowing. In some IEC standards, the term “weighted current” is used in place of MIU.

A1.7 Some difficulty is encountered experimentally in comparing the perception levels over frequencies from 60 Hz to 100 kHz as the sensation changes at about 50 kHz from one of internal muscle stimulation

to a feeling of warmth (where a steady contact is maintained). Intermittent contact will generally produce a pinprick sensation and introduce other break points.

A2 Rationale for Flexible Metal Foil

(See 5.4.6.)

A2.1 A 10 x 20 cm foil is used to simulate a hand touching a highly resistive, but conductive surface. Where this contact is intended to sum the leakage currents available over the surface, it will be necessary to take special care (in some cases conductive gel may be necessary) to see that the foil is in intimate contact over its entire surface.

A2.2 Foil may also be used at high frequencies to sum the capacitively coupled leakage currents from an insulating surface. In this case, intimate contact is not as important.

A3 Rationale for Products Requiring EMI Filtering to Meet FCC Requirements

(See 4.1.2, Exception 2)

A3.1 EMI filtering generally involves the use of capacitors between the supply conductors and the grounding conductor. This increases the leakage current, which may be as high as 3.5 MIU. The higher leakage current value may be accepted if the product complies with all of the specifications in Exception 2 of 4.1.2. An example of a product that has a low probability of producing an injury resulting from an involuntary reaction is one whose use does not involve:

a) Dangerous heights, such as, use on a ladder or a roof top;

b) Dangerous moving parts, such as, tools or electric knives; and

c) Injurious spills, such as, a cooking product with hot liquid;

d) Frequent exposure to grounded objects;

e) Frequent contact with conductive parts on the product that involve leakage currents greater than 0.5 MIU (with an open ground).

A4 Rationale for Humidity Conditioning

(See 5.3.2.)

A4.1 Humidity conditioning generally has an effect on the leakage current from products, particularly those utilizing fibrous insulation or insulation having hygroscopic properties. It is suggested that unless otherwise specified for the product, that the following humidity conditioning and leakage current testing be conducted.

A4.2 After being operated for a sufficient period of time to eliminate most previously absorbed moisture, the product is to be heated to a temperature above 34° C to reduce the likelihood of initial moisture condensation during conditioning. The heated sample is to be placed in a humidity chamber and is to remain for 48 hours with the chamber controlled to a relative humidity of 88 ±2% within a temperature range of 32 ±2°C.

A4.3 Following the conditioning, the sample is to be tested unenergized as described in 5.4.1 – 5.4.9. The sample is then to be energized, and tested as described in 5.4.10 – 5.4.13. The test of 5.4.12 is to be discontinued when the leakage current stabilizes or decreases.

A4.4 If possible, these leakage current tests should be conducted in the humidity chamber. If this is not feasible, the tests should be conducted as quickly as possible after the sample has been removed from the chamber so as to reduce the drying effect of the cooler room air.

A5 Rationale for Higher Leakage Current Levels

(See 4.1.2 Exception 3, 4.2 and Figure A5.1.)

A5.1 Under special situations, the product standard may elect to be concerned about other physiological effects such as let-go. Such consideration is generally outside the scope of this standard. Suggested methods of measurement for these higher values may be found in Technical Report IEC 60990, Methods of Measurement of Touch-Current and Protective Conductor Current.

A5.2 Let-go thresholds exceed 4.5 mA at 50 – 60 Hz and follow a different frequency response curve than is provided by the networks described in this standard. Where higher frequency (generally above 10 kHz) limit values exceed 2.0 MIU, the frequency response network based on the physiological effect of let-go should be used. (IEC 60990, Methods of Measurement of Touch-Current and Protective Conductor Current)

Figure A5.1