Understanding Creepage & Clearance Measurements

The "Understanding the Product Safety Tests" Series

Creepage and Clearance are international compliance terms commonly referred to as "Over-Surface" and "Through-Air" Electrical Spacings in the US and Canada. Creepage & Clearance distances form part of the product's electrical insulation system that protects the user from a Risk of Shock. Creepage and Clearance measurements are required between live parts and across electrical insulating materials. Consequently, creepage & clearance distances must be measured in most electrical products as part of the compliance and certification process.

Key Definitions:

a) Creepage Distance: "Creepage Distance" is the shortest distance over surface between two conductive parts. For example, it is often necessary to measure the creepage distance between two traces across the surface of a printed circuit board.
b) Clearance Distance: "Clearance Distance" is the shortest distance through air between two conductive parts. For example, the air gap between the electrical terminals on a switch.

Purpose of the Test:

To verify that there is adequate insulation between electrical parts, to withstand the rigors of normal use, over the life of the product. This can include an accumulation of conductive contaminants that can become conductive with moisture (i.e. dust). This also includes periodic overvoltage events on the mains voltage. These events can be caused by a number of normal situations including weather and switching induced overvoltages.

Pre-Requisites Required: Considerable preparation and design review is necessary to determine where exactly in the electrical circuit that creepage & clearance distances are required and, what the required distances are for each measurement point. When using the creepage & clearance tables in the safety standard, you will have already needed to identify:

a) Installation Category which is determined by the Maximum Overvoltage possible on the mains.
b) Pollution Degree: Pollution Degree I, Pollution Degree II, or Pollution Degree III.
c) Insulation Type: Creepage & Clearance distances generally apply to Basic, Supplementary, and Reinforced insulation. (Note that Double insulation = Basic + Supplementary insulation and each of these is evaluated separately.)
d) Tracking Rating: An electrical breakdown across a creepage distance occurs when an overvoltage condition causes the voltage to arc-over the insulation = "tracking" across the surface of the material. The higher the tracking resistance rating for the insulating material, the smaller the permitted creepage distance on that material. Some certified insulating materials and bare printed circuit boards have a higher tracking rating for this reason.
e) Nominal Mains Supply Voltage: The highest rated nominal mains voltage rating for the product. Note that the nominal mains voltage is directly related to the maximum overvoltage anticipated on the mains.
f) Working Voltage: The operating voltage between two parts in question is referred to as the "working voltage". Note that many standards specify that all components conductively connected to the mains circuits are considered to be at mains voltage for the purpose of creepage & clearance measurement (rather than using their working voltage).

Measurement Objectives: The objective is likely to depend on the purpose of the measurements. This will dictate what method should be used for verifying compliance of your required creepage & clearance distances. Are you required to measure and record the data or simply verify compliance?

1. Verifying Compliance: In some circumstances, you may not need the actual measurement data. Rather, you simply need to verify that the creepage & clearance distances comply with the requirements in the standard = you just need to know that you have at least the minimum required creepage & clearance distances.
    - It can be a much quicker and easier to simply verify compliance. However, without the data, the results may be suspect since there is no proof on file that compliance was verified rather than assumed.
2. Measuring & Recording Data: In other circumstances, the actual creepage and clearance measurement data is recorded and then compared to the required distances. Some product certifications require completion of a report template that requires the data.

Test Method:

1) Not Powered: The product is not connected to power during this test.
2) Sample Preparation: Prior to reviewing creepage & clearance distances, many standards indicate that internal components should be pushed with a test finger using a small force (i.e. 10N). This represents the realities of production where components may not always be mounted in the perfect position. Similarly, enclosures are often required to be pushed with a moderate force before making measurements (i.e. 30N).
3) Verifying Compliance:
    a) If you do not need to record the data, you may prefer to simply verify that the product has the minimum required creepage & clearance distances at the required locations in the product/circuit.
    b) Creepage & Clearance spacing keys are the perfect tool for quickly verifying compliance without taking measurements. By using the spacing key that correlates with the required distance, the user can quickly determine if the key fits between the required components, traces, and circuits. When in doubt, the more precise tools used to measure creepage & clearance distances should be used.
4) Measuring Creepage & Clearance:
    a) To measure and record the creepage and clearance distances, you must use tools that display the measured result.
    b) Depending on how large or small the electrical spacings, different tools may provide better results.
    c) A calibrated small metal ruler can provide reliable results for larger measurements.
        - Note that Creepage & Clearance spacing keys can help insure a higher level of quality in making your measurements. They can help quickly verify compliance and make sure that all points along the width of the creepage or clearance distance are checked followed by measurements at key points – result is less risk in missing a non-compliant creepage or clearance distance that is hard to reach and measure.
    d) Digital calipers are also needed for creepage & clearance measurements and better than a ruler for smaller measurements.
    e) For creepage distance measurements on a printed wiring board, a small optical comparator with calibrated scale is critical (i.e. small monocle type comparator).
    f) Some product developers are using 3D imaging software to design their product which often can provide the distances – be sure to check the final product to insure compliance of the manufactured product (check with spacing keys).

Gaps, Groves, & Ridges: Due to the potential for a buildup of dust within an electrical product over time, many standards indicate that small gaps, grooves, and ridges that are less than 1 mm in width should be ignored in the measurement. If your standard has this requirement, be sure to check for an Annex in the standard that contains examples and diagrams to help you fully understand this requirement. This is especially true for "V" shaped slots where creepage distance is not measured to the bottom of the V but instead stops and cuts across the V at the 1 mm width point.

Insulation Coordination: Essential knowledge for proper creepage & clearance evaluations:

- The objective of "Insulation Coordination" is for the electrical insulation system to operate reliably through the life of the product so that electrical "breakdowns" do not occur (short-circuit condition).
- Insulation Coordination involves recognizing the importance of the pollution degree in establishing suitable creepage & clearance distances. This includes the possibility that "micro-environments" can exist within a product – areas that have a Pollution Degree higher or lower than the overall product. This can be the result of an encapsulated component or area within a product subject to a higher level of conductive contaminants (i.e. printer with conductive ink). As such, each measurement point should be reviewed for pollution degree before determining the required creepage & clearance distances in the standard.
- Insulation Coordination involves the awareness that electrical breakdowns are primarily caused by overvoltage events (voltage spikes and surges). For that reason, the required creepage distances are heavily based on the maximum overvoltage rating of the product.
- Insulation Coordination also involves the awareness that a breakdown of a creepage distance leaves permanent damage to the insulation, making further breakdowns increasingly likely. However, breakdown of a clearance distance is simply creating an arc through the air. Once the overvoltage subsides, the arc will self-extinguish leaving no permanent damage to insulation as "new insulation" (air) will immediately fill the void.
- This leads to the overall objective of Insulation Coordination and that is, if there is an electrical breakdown, we want it to be a breakdown of a clearance distance rather than a creepage distance. Because clearance distance breakdowns are self-healing while creepage distance breakdowns leave permanent damage that is susceptible to breakdown after the overvoltage event is over.
- This objective forms the basis for understanding a critical element within the Insulation Coordination principles = that the required creepage distance for each critical spacing must be greater than or equal to the required clearance distance. If the required creepage distance is less than the required clearance distance, the required creepage distance is raised to equal the required clearance distance.

As you can see, we don't simply perform the tests because they are in the standard. Each test in the standard has a set of objectives that relate to the 6 Hazards of Product Safety. Insuring that the minimum specified creepage & clearance distances are provided is a critical part of the Risk of Shock compliance review. Maintaining critical electrical spacings is very important to insuring the product insulation system continues to provide protection from a Risk of Shock, a potentially serious hazard that could lead to death by electrocution. It is therefore a very important test – another test that directly saves lives.