Transformer Safety

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Creepage and Clearance

- **Creepage** – Critical safety distance between two conductors along a solid surface
- **Clearance** – Critical safety distance between two conductors through air
Working Voltage

• The highest voltage across the insulation barrier at the maximum rated input voltage and under normal operating conditions.

• R.M.S. – creepage
• Peak – clearance
Overvoltage Category

<table>
<thead>
<tr>
<th>Overvoltage category</th>
<th>Equipment and its point of connection to the AC mains</th>
<th>Examples of equipment</th>
</tr>
</thead>
</table>
| IV                   | Equipment that will be connected to the point where the mains supply enters the building | • Electricity meters  
 • Communications ITE for remote electricity metering |
| III                  | Equipment that will be an integral part of the building wiring | • Socket outlets, fuse panels and switch panels  
 • Power monitoring equipment |
| II                   | Pluggable or permanently connected equipment that will be supplied from the building wiring | • Household appliances, portable tools, home electronics  
 • Most ITE used in the building |
| I                    | Equipment that will be connected to a special mains in which measures have been taken to reduce transients | • ITE supplied via an external filter or a motor driven generator |

• Where? – Where is the equipment connected in relation to the hazardous line voltage?
Pollution Degree

- What is the environment like where the equipment is located?

- **Pollution Degree 1** - No pollution or only dry, non-conductive pollution. The pollution has no influence. (Ex: Clean room, hermetically sealed components)

- **Pollution Degree 2** - Only non-conductive pollution occurs except occasionally a temporary conductivity caused by condensation is expected. (Ex: Office and laboratory setting)

- **Pollution Degree 3** - Conductive pollution occurs or dry non-conductive pollution occurs which becomes conductive due to condensation. (Ex: Industrial manufacturing, construction, agriculture settings)

- **Pollution Degree 4** - Continuous conductivity occurs due to conductive dust, rain, or other wet conditions. (Ex: Outdoor equipment)
Pollution Degree - continued

Example taken from IEC 62368-1:2018

<table>
<thead>
<tr>
<th>Pollution degree (see 5.4.1.5)</th>
<th>( X ) mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0,25</td>
</tr>
<tr>
<td>2</td>
<td>1,00</td>
</tr>
<tr>
<td>3</td>
<td>1,50</td>
</tr>
</tbody>
</table>
Material Group

• Comparative Tracking Index (CTI) rating of materials
  – Test procedure outlined in IEC 60112

<table>
<thead>
<tr>
<th>IEC rating (Material Group)</th>
<th>UL rating (PLC)</th>
<th>Comparative Tracking Index (volts)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>0</td>
<td>( \geq 600V )</td>
</tr>
<tr>
<td>II</td>
<td>1</td>
<td>( 400V \leq \text{CTI} &lt; 600V )</td>
</tr>
<tr>
<td>IIIa</td>
<td>2</td>
<td>( 250V \leq \text{CTI} &lt; 400V )</td>
</tr>
<tr>
<td>IIIb</td>
<td>3</td>
<td>( 175V \leq \text{CTI} &lt; 250V )</td>
</tr>
<tr>
<td>None</td>
<td>5</td>
<td>( 100V \leq \text{CTI} &lt; 175V )</td>
</tr>
<tr>
<td>None</td>
<td>5</td>
<td>( 0V \leq \text{CTI} &lt; 100V )</td>
</tr>
</tbody>
</table>

Best material
Insulation Grade

• **Functional Insulation** – Only necessary for the proper functioning of equipment.

• **Basic Insulation** – Insulation applied to live parts to provide basic protection. (1 layer)

• **Supplementary Insulation** – Independent insulation applied to reduce the risk of electric shock in the event of a failure of basic insulation. (2 layers)

• **Double Insulation** – Insulation made up of both basic insulation and supplementary insulation. (1 layer + 2 layers = 3 layers)

• **Reinforced Insulation** - Single insulation system that provides a degree of protection equivalent to double insulation. (3 layers)
How does safety affect transformers?

• **Cost - Material**
  
  • 26AWG Grade 2, enamel magnet wire
    – Billed by the weight of copper used
  
  • 26AWG, reinforced insulated wire
    – Billed by the length of wire used

*Design tip – place the insulated wire on the low turn side of the transformer to minimize the length of wire used*
How does safety affect transformers?

- **Cost – Manufacturing**
  - **Enamel wire** can often be direct terminated and direct soldered
    - Multi-arbor winding machines to auto wind and auto terminate several parts at one time
  - **Insulated wire** must first be stripped prior to soldering
    - Single arbor winding machine
    - Stripping process adds cost
    - Manual termination adds cost
How does safety affect transformers?

- **Size**
  
  - Reinforced insulated designs for PD2, OVCII, and standard offline working voltage generally need to meet in the range of 4-8mm.
  
  - Common misconception when determining creepage and clearance. This may be true on the surface of the PCB but it is not valid within the transformer at the component level.

[Diagram of transformer with dimensions and labels]
How does safety affect transformers?

- **Size** – Actual creepage and clearance

  ![Transformer Diagram](image)
How does safety affect transformers?

- **Size** – How to meet creepage and clearance?
How does safety affect transformers?

- **Size** – Actual creepage and clearance

Design tip – Use caution when placing insulated wire on corner pins
How does safety affect transformers?

- **Size – continued**

  - 12.70mm
  - 15.00mm
  - 25.90mm
  - 30.20mm
How does safety affect transformers?

- **Performance**

  - 26AWG Grade 2, enamel magnet wire
    - **MAX. OD = 0.46mm**

  - 26AWG, reinforced insulated wire
    - **MAX. OD = 0.66mm**

Standard coil construction with the high turn primary split around the secondary. When using magnet wire for all windings (functional insulation) we will only have tape and the enamel coating to separate the primary and secondary.
How does safety affect transformers?

• Performance

- Leakage – additional insulation increases separation between windings resulting in higher leakage
- DC Resistance – Larger OD may affect layering. This affects the mean length turn and can increase DCR. Not only on the winding using insulated wire but also the windings after it.

Does my coil still fit on the same bobbin when I change to insulated wire? This can result in the need for larger components which impacts size and cost.
Questions?