

INFORMATION ON DRAW-LEAD AND DRAW-ROD BUSHING APPLICATIONS FOR THE REVISION OF C57.100 - 1995

Definitions

The following definitions can be used for the revision of this standard.

draw-lead bushing. A bushing that will allow the use of a current carrying draw-lead conductor drawn through the hollow tube and enabling its connection to the top terminal.

draw-rod bushing. A bushing that allows the use of a non-current carrying rod drawn through the hollow tube and enabling a connection between the bushing's inboard end terminal and the transformer or reactor winding lead.

draw-lead conductor. A cable or a solid conductor that has one end connected to the transformer or a reactor winding lead and the other end drawn through the bushing hollow tube and connected to the top terminal of the bushing. A solid conductor can be either one piece or multiple pieces connected together.

draw-rod. A non-current carrying rod, that has one end connected to the transformer/reactor lead end-terminal and the other end drawn through the bushing hollow tube and connected to the top end of the bushing. A draw-rod can be either one piece or multiple pieces connected together.

Guidelines on Bushing Application

Draw-Lead Application

The following guidelines can be used when bushings are used in a draw-lead application mode.

Bushing current rating

The maximum continuous current rating of the bushing in the draw-lead mode is limited to the rating specified on the bushing nameplate. The maximum continuous current rating of the draw-lead cable is determined by the size and type of the cable supplied by the transformer manufacturer. Since the draw-lead cable is an integral part of the transformer, the current rating specified on the transformer nameplate determines the rating of the draw-lead cable. When the bushing manufacturer supplies the draw-lead conductor as part of the bushing, the current is limited to the rating specified on the bushing nameplate.

Factors influencing the draw-lead cable rating

The current rating of the draw-lead cable is dependent upon several factors. These are:

- Cable cross section, number of strands, and material
- Insulation thickness, type, and the temperature limit
- Overall length of the bushing
- Top oil temperature
- Oil level in the transformer
- Oil level in the bushing central tube
- Ambient air temperature

The current carrying capacity of a cable is dependent upon the cross section of the cable as well as conductivity of the material. It is also dependent upon the type of cable (solid versus stranded). The temperature rise of the cable is dependent upon the thickness of the cable insulation. As the insulation

thickness increases, it impedes the flow of heat through the paper and results in an increase in temperature of the cable. The temperature rise limit of the cable is dependent upon the type of insulation used on the cable. For example, thermally uprated insulation would have a higher temperature limit than a non-thermally uprated insulation. Aramid and treated Kraft paper insulation would fall into the thermally uprated category.

The overall length of the bushing has an effect on the rating of the cable. For the same sized cable and the same temperature rise, the current rating of the cable would be lower for longer high voltage bushings. The longer the bushing, the more difficult it is for the heat to dissipate and therefore the cable rating must be de-rated.

The temperature of the oil in the transformer as well as the bushing immersion level influences the temperature rise of the cable. The higher the top oil temperature, the higher would be the cable temperature. Similarly, higher the lower end oil immersion level, higher would be the cable temperature. Also, the oil level in the bushing central tube influences the temperature rise of the cable. If the tube is completely filled with oil, the hottest spot temperature of the cable would be lower when compared to oil level at the mounting flange or lower. On the other hand, the temperature of the bushing central tube would be higher when the tube is completely filled with oil.

Factors influencing the draw-lead conductor rating

The current rating of the draw-lead conductor is dependent upon several factors. These are:

- Conductor cross section and material
- Conductor construction. Single piece or multiple pieces.
- Type of joint between pieces. Threaded or bolted
- Type of connection to the top terminal. Threaded or multi-spring contacts
- Overall length of the bushing
- Top oil temperature
- Oil level in the transformer
- Oil level in the bushing central tube
- Ambient air temperature

The effect of various factors on current rating and the temperature is explained in the paragraph for draw-lead cable. In addition, the resistance of the current carrying contacts affects the temperature of the conductor. Higher the contact resistance, higher would be contact temperature.

Draw-lead cable/bushing loading

The current carrying capacity of the draw lead cable is determined by the size and type of the cable used by the transformer manufacturer. The current is limited to the rating specified on the transformer nameplate.

When applying bushings in the draw-lead mode, the bushing manufacturer should be consulted for guidelines on draw-lead sizes, ratings, and loading. To minimize cable insulation loss of life during overloads, it would be preferable to choose a cable with current rating of at least 20 % above the rated current of the transformer. If higher overloads are anticipated, then cables with even greater margin should be considered.

Although specific guidelines should be obtained from bushing or transformer manufacturers, following general guidelines can be used for rating draw-lead cables with thermally uprated 65 °C insulation.

- Maximum ambient 40 °C
- Maximum cable hottest spot temperature rise above ambient air at rated current 80 K

- Maximum cable hottest spot temperature rise above ambient air under overload condition 100 K

The 80 K rise limit agrees with the maximum winding hottest spot temperature rise for 65 K rise transformers as per C57.12.00 – 2000.

The 100 K hottest spot temperature rise limit is based on maximum oil temperature of 140 °C with maximum ambient air temperature of 40 °C. Operation at hottest spot temperature above 140 °C may result in gassing of oil/paper insulation.

Draw-lead conductor/bushing loading

Like the draw-lead cable, the current carrying capacity of the draw-lead conductor is determined by the size and type of the conductor used by the bushing manufacturer. The current is limited to the rating specified on the bushing nameplate.

Although specific guidelines should be obtained from bushing manufacturers, following general guidelines can be used for rating the draw-lead conductor.

- Maximum ambient 40 °C
- Maximum conductor hottest spot temperature rise above ambient air at rated current 80 K
- Maximum conductor hottest spot temperature rise above ambient air under overload condition 100 K

The 80 K rise limit agrees with the maximum winding hottest spot temperature rise for 65 K rise transformer as per C57.12.00 – 2000.

The 100 K hottest spot temperature rise limit is based on maximum oil temperature of 140 °C with maximum ambient air temperature of 40 °C. Operation at hottest spot temperature above 140 °C may result in gassing of transformer oil.

Temperature Rise Test on Draw – Lead Bushings

A temperature rise test on a draw-lead bushing can be carried out similar to the procedure described in C57.19.00 under the section “Design Tests”. In addition, the following guidelines may be useful when carrying out such a test.

- Attach the thermocouples to the draw-lead cable/conductor 20 – 30 cm (8 – 10 inch) apart
- When possible, attach thermocouples on the condenser bushing winding tube. This will be useful in getting temperature rise information on the central tube that is in contact with condenser insulation. In such a case, a special test bushing would be required.
- The test should be done with transformer oil level within 50 mm (Aprox. 2 inch) of the bushing-mounting flange with the tube partially or completely filled with oil as per the application.
- The top oil temperature rise should be 65 K above ambient air or as per the rating of the transformer
- The test can be done at the following currents for determining the thermal constants 0.0, 0.7, 1.0, and 1.25 PU load current
- Calculate the thermal constants, using the method described in section xx.xx, “Derivation of Model Constants” These constants will be useful in estimating the cable/conductor temperature rise at different loads.

Draw-Rod Application

In a draw-rod bushing, the load current is carried mainly by the bushing central tube. The thermal characteristics of such a bushing are essentially the same as a conventional bushing. Refer to section 4,

“Thermal loading above nameplate rating for bushings applied to power transformers” for additional information.

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