

NOMEX® THERMAL TECHNOLOGY SOLUTIONS FOR LIQUID-FILLED POWER TRANSFORMER CONDENSER BUSHINGS UNDER THERMAL STRESS

Real-life operating conditions of condenser bushings of high-current step-up transformers often differ from standard service conditions set out in IEEE Standards. This makes the correct choice of insulating and gasketing materials particularly important.

The current flowing in a bushing generates heat. Additional heat is generated at the bushing's terminal ends, due to the terminal environment, connection details and ambient conditions. The steady-state temperature rise at the bushing's hot spot is then determined by these heat sources, the bushing's heat-transfer characteristics and ambient conditions at the bushing's ends.

Heat in the condenser can leave the bushing only at the terminals, via transfer into the oil or the air. The temperature of the connecting bus and the surrounding media determines how much heat can be dissipated.

Special Environment

A self-cooled (i.e. non-ventilated) bus duct is a special environment, where heat dissipation may be less than ideal for a number of reasons, including poor bush-to-bushing connections. Knowledge

about the actual temperatures at bushing terminals may also be inadequate.

The standard service conditions for condenser bushings, according to IEEE Standard C57.19.00-1991 General Requirements and Test Procedure for Outdoor Power Apparatus Bushings, are:

- Ambient air temperature: minimum -30°C , maximum 40°C ;
- 24 hour average transformer oil temperature = 95°C , based on 55°C rise and 40°C ambient;
- External terminal/bus connection temperature of 70°C , based on temperature rise of 30°C , at rated current, over 40°C maximum ambient.

The thermal basis of the rating is then the bushing hot-spot temperature rise at rated current, that is 65°C maximum over ambient air temperature, and the maximum bushing temperature will be $40^{\circ}\text{C} + 65^{\circ}\text{C} = 105^{\circ}\text{C}$.

Real-Life Conditions

Standard condenser bushings, using kraft paper for the condenser core's insulation system, are designed to operate in the usual conditions described in IEEE Standard C57.19.00-1991. However, real-life service conditions can be very different

from those described in the IEEE Standard. Ambient air temperature inside the bus may well be much higher than 40°C , possibly as much as 60°C . The air-side temperature rise can be as much as 65°C , according to IEEE Standard C37.23-2003 for Metal-Enclosed Bus.

Assuming the same 24-hour average transformer oil temperature of 95°C , the amount of heat generated within the bushing remains the same. The result is that the bushing hot-spot temperature will be more than 105°C and possibly 125°C or higher, while terminal temperatures will be more than 70°C and possibly 125°C or more. Exposure to such temperatures results in severe thermal stress on the bushing insulation and sealing systems.

Bushing Insulation and Gasket Seals

Kraft paper, the most widely used insulating product in transformer bushings, is a 98°C product. Above this temperature, thermal stress will cause it to degrade rapidly in the condenser core. Unless kraft-paper insulated standard bushings are constantly operated at loads well below name-plate rating, and/or unless the bus has additional forced cooling to

keep bus duct temperatures well below the 105°C limit, such bushings will age much faster than normal. This puts transformers at risk of more maintenance down-time or even of failure, possibly resulting in loss of operating revenue.

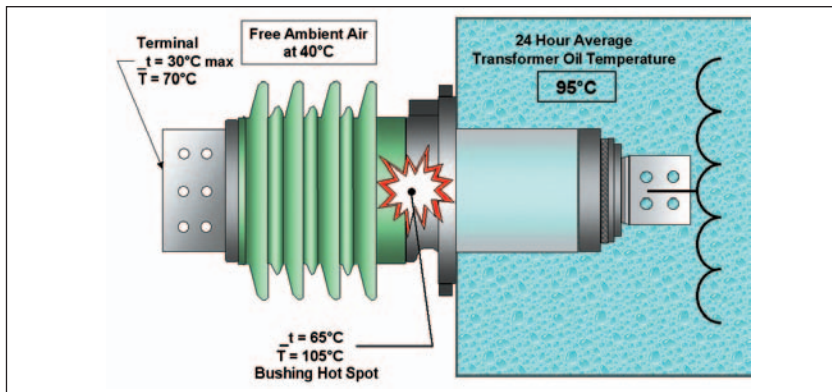
Thermal stresses also affect gasket seals of bushings. Under so-called standard conditions, seals are in contact with ambient air on one side, at no more than 40°C, and with transformer oil on the other, at up to 95°C. The oil inside the bushing is at a temperature dictated by the 65°C hottest spot rise in the bushing.

As shown above, the real-life temperatures at all these locations can be higher than standard. Like insulating materials, elastomeric seals may suffer thermal degradation at higher temperatures. The oil-resistant elastomer generally used in this application is nitrile rubber, which withstands a continuous service temperature of 100°C. However, at higher temperatures the material becomes brittle, losing its ability to seal. In addition, insufficient thermal expansion space for the oil in the bushing places mechanical stress on seals. Oil leaks are the result.

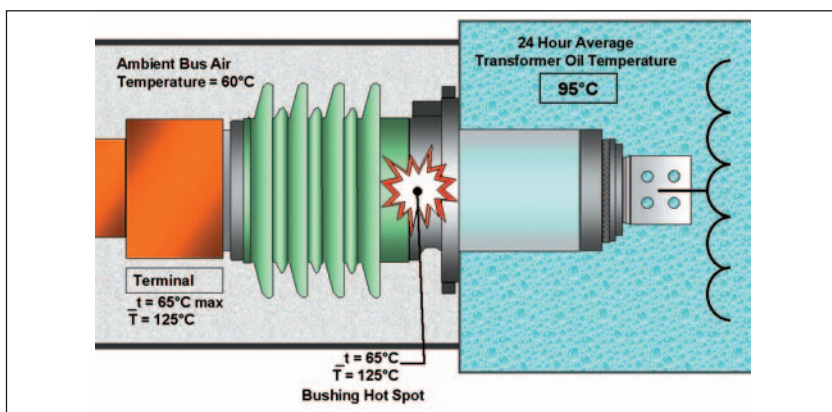
High-Temperature Solutions

For this combination of reasons, ABB chose DuPont™ NOMEX® thermal technology for insulation on its line of high-temperature condenser bushings and

DuPont de Nemours International S.A.
P.O. Box 50
CH-1218 Le Grand-Saconnex/Geneva
Switzerland
Tel: +41 22 717 5111
Fax: +41 22 717 6218
E-mail: info.nomex@che.dupont.com
www.nomex.com



Standard conditions



Possible bus duct conditions

DuPont™ Viton® fluoroelastomer for all high-temperature condenser bushing seals.

NOMEX® is an aramid (aromatic polyamide) polymer which withstands temperatures up to 220°C and has a balance of electrical, physical and chemical properties making it ideally suited for

demanding electrical insulation applications. It is widely used in transformers, motors, generators and other electrical equipment. Viton® retains its elastomeric characteristics at up to 200°C and offers excellent resistance to transformer oils and a wide range of other aggressive fuels and chemicals.

Product safety information is available upon request.

This information corresponds to our current knowledge on the subject. It is offered solely to provide possible suggestions for your own experiments. It is not intended, however, to substitute for any testing you may need to conduct to determine for yourself the suitability of our products for your particular purposes. This information may be subject to revision as new knowledge and experience becomes available. Since we cannot anticipate all variations in actual end-use conditions, DuPont makes no warranties and assumes no liability in connection with any use of this information. Nothing in this publication is to be considered as a license to operate under or a recommendation to infringe any patent right.



The miracles of science™