have to circulate in regions where the stress is higher before any significant reduction in the dielectric strength occurs.

Bare metal parts which are not in direct thermal contact with major organic insulation, but are in contact with the oil in the transformer, may rapidly rise to high temperature. 180 °C should not be exceeded.

b) Temporary deterioration of the mechanical properties at higher temperatures could reduce the short-circuit strength.

c) Pressure build-up in the bushings may result in a failure due to oil leakage. Gassing in the bushings may also occur if the temperature of the insulation exceeds about 140 °C.

d) The expansion of the oil could cause overflow of the oil in the conservator.

e) Breaking of excessively high currents in the tap-changer could be hazardous.

1.4.1.3 *Long-term risks*

a) Cumulative thermal deterioration of the mechanical properties of the conductor insulation will accelerate at higher temperatures. If this deterioration proceeds far enough, it may reduce the effective life of the transformer, particularly if the latter is subjected to system short circuits.

b) Other insulation materials, as well as structural parts and the conductors, could also suffer ageing at higher temperature.

c) The contact-resistance of the tap-changers could increase at elevated currents and temperatures and, in severe cases, thermal runaway could take place.

d) The gasket materials in the transformer may become more brittle at elevated temperatures.

The short-term risk normally disappears after the load is reduced to normal level but, from the point of view of reliability, it may have a more significant impact than long term effects.

This guide recognizes that the loading capability could be restricted both by the short-time and the long-time effects. The tables and diagrams are calculated according to the traditional methods of determining the life expectancy of the mechanical properties of the paper insulation as affected by time and temperature, while the limitations on the maximum hot-spot temperatures are based on considerations of the risk of immediate failure.

1.4.2 *Transformer size*

The sensitivity of transformers to loading beyond nameplate rating usually depends on their size. As the size increases, the tendency is that:

a) the leakage flux density will increase;
b) the short-circuit forces increase;
c) the volumes of dielectrically-stressed insulation increase;
d) the hot-spot temperatures are more difficult to determine correctly.

Thus a large transformer could be more vulnerable to loading beyond nameplate rating than a smaller one. In addition, the consequences of a transformer failure are more severe for larger sizes than for smaller units.

Therefore, in order to apply a reasonable degree of risk for the expected duties, this guide considers three categories:

a) distribution transformers, for which only the hot-spot temperature and thermal deterioration have to be considered;

b) medium power transformers where the effects of leakage flux are known not to be critical; but the variations in the cooling modes must be considered;

c) large power transformers, where the effects of stray leakage flux are significant and the consequences of failure are severe.

1.4.3 *Current and temperature limitations*

With loading values beyond the nameplate rating, it is recommended that the limits stated in table 1 are not exceeded and that account be taken of the specific limitations given in 1.5 to 1.7.

Table 1 – Current and temperature limits applicable to loading beyond nameplate rating

Types of loading		Distribution transformers	Medium power transformers	Large power transformers
Normal cyclic loading				
Current	(p.u.)	1,5	1,5	1,3
Hot-spot temperature and metallic parts in contact with insulating material	(°C)	140	140	120
Top-oil temperature	(°C)	105	105	105
Long-time emergency cyclic loading				
Current	(p.u.)	1,8	1,5	1,3
Hot-spot temperature and metallic parts in contact with insulating material	(°C)	150	140	130
Top-oil temperature	(°C)	115	115	115
Short-time emergency loading				
Current	(p.u.)	2,0	1,8	1,5
Hot-spot temperature and metallic parts in contact with insulating material	(°C)	see 1.5.2	160	160
Top-oil temperature	(°C)	see 1.5.2	115	115

1.5 Specific limitations for distribution transformers

1.5.1 *Rating limitation*

This clause covers distribution transformers up to 2 500 kVA as defined in 1.3.1.

1.5.2 *Current and temperature limitations*

The limits on load current, hot-spot temperature and top-oil temperature stated in table 1 should not be exceeded. No limit is set for the top-oil and hot-spot temperature under short-time emergency loading because it is usually impracticable to control the duration of emergency loading on distribution transformers. It should be noted that, when the hot spot reaches temperatures above 140 °C to 160 °C, gas bubbles may develop which could jeopardize the dielectric strength of the transformer (see 1.4.1.2, Short-term risks).

1.5.3 *Accessory and other considerations*

Apart from the windings, other parts of the transformer, such as bushings, cable-end connections, tap-changing devices and leads, may restrict the operation with load currents exceeding 1,5 times the rated current. Oil expansion and oil pressure could also impose restrictions.

1.5.4 *Indoor transformers*

When transformers are used indoors, a correction has to be made to the rated top-oil temperature rise to take account of the enclosure. Preferably, this extra temperature rise should be determined by a test (see 2.7.6).

1.5.5 *Outdoor ambient conditions*

Wind, sunshine and rain may have some effects on the loading capacity of distribution transformers, but their unpredictable nature makes it impracticable to take these factors into account.

1.6 Specific limitations for medium power transformers

1.6.1 *Rating limitations*

This clause covers power transformers up to 100 MVA, three-phase, having the impedance restrictions referred to in 1.3.2.

1.6.2 *Current and temperature limitations*

The limits on load current, hot-spot temperature, top-oil temperature and temperature of metallic parts other than winding and leads but nevertheless in contact with solid insulating material, stated in table 1 should not be exceeded. Moreover, it should be noted that when the hot spot reaches temperatures above 140 °C to 160 °C, gas bubbles may develop which could jeopardize the dielectric strength of the transformer (see 1.4.1.2, Short-term risks).