

Discussion on transformer coil cooling curves, and evaluation of coil average temperature at time zero

- The extrapolation to zero time of the windings average temperature after a heat run test is of prime importance in qualifying a transformer.
- In order to have correct extrapolation we need:
 - Correct measurement of the initial coil ambient temperature and resistance;
 - Correct evaluation of the coil ambient temperature at the end of the heat run test.

IMPORTANT NOTE:

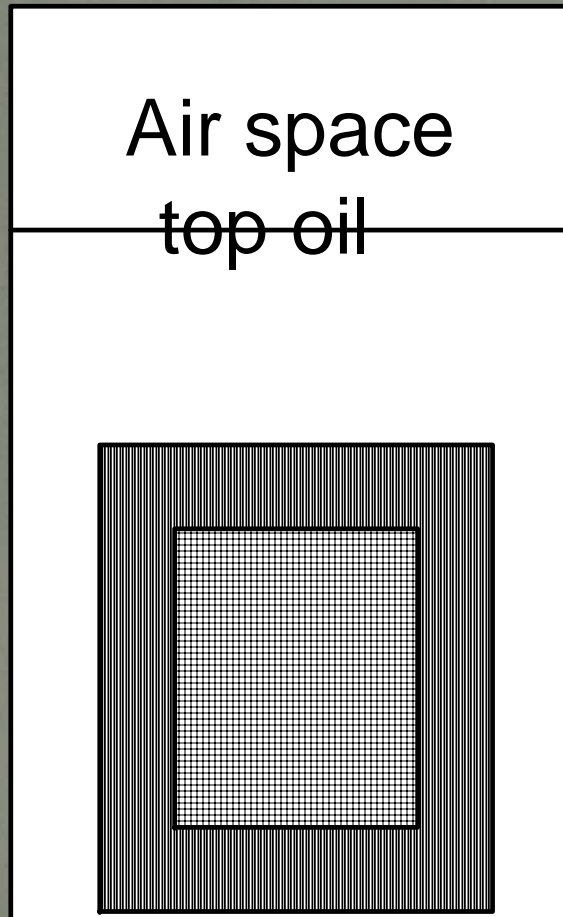
The C57.12.90 standard covers all type and size of oil filled transformers.

These ranges from 10 kVA, 2,4 kV transformers up to 1000 MVA, 800 kV class single phase or three phase transformers.

- The coils are immersed in insulating oil and surrounded for a good part by the magnetic core.
- The effect of the core varies a lot between the inner and the outer windings.
- By measuring only the average oil temperature thus not assures precise determination of the coils ambient temperatures.

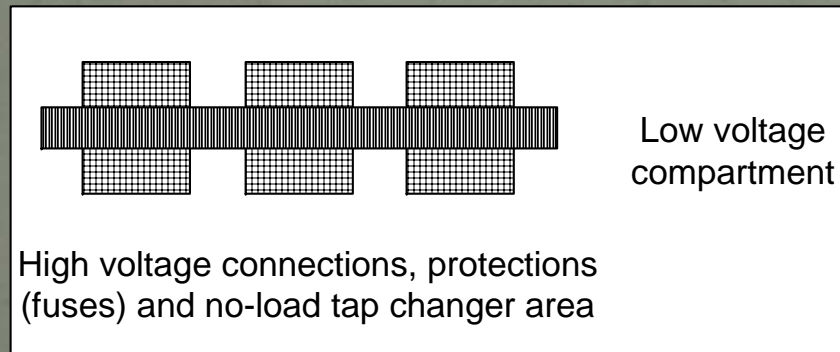
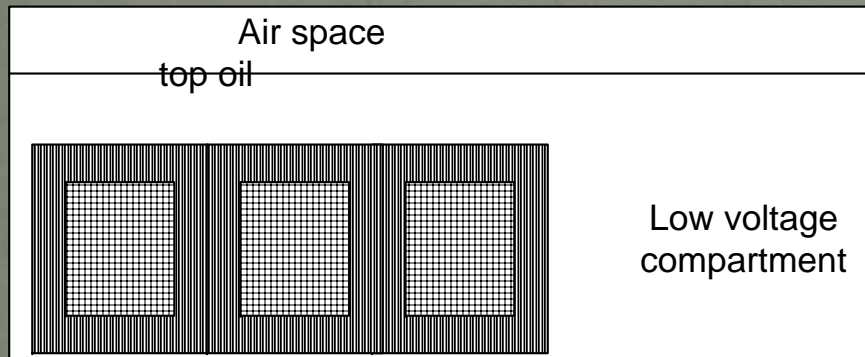
- Practical experience shows that some high voltage high power transformers have close to symmetrical positioning
- The measurement of the inlet and outlet temperatures of the cooling ducts may give sufficiently precise data to be used as the outer coils ambient.
- These cannot be applied to the inner coil.

Typical single phase pole top distribution transformers



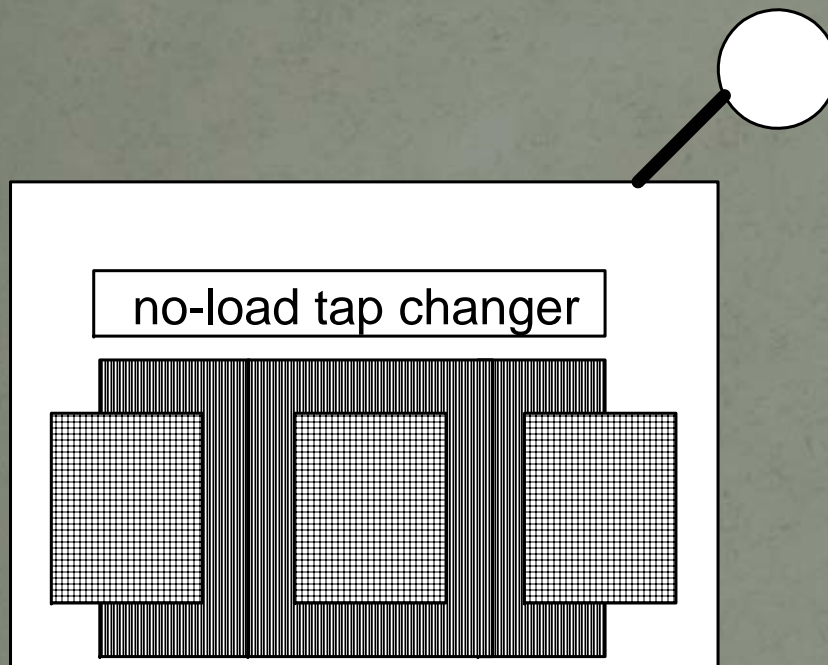
- Have no cooling ducts
- For the same tank size the core and coil dimensions may vary
- The distance between the top oil and the top of the core will also vary.
- Measuring only the top and bottom temperature does not give a correct measurement of the coil ambient oil temperature

Three phase 5 legs pad-mounted transformer.



- On one side of the transformer an important space is dedicated to the low voltages connections.
- The height of the core and coil assembly and the height of the air space also vary.
- The horizontal location of the core and coil assembly vary depending on the high voltage connections, the primary protection (fuses) and the no-load tap changer used.
- There is no clear way how the coil ambient oil temperature can be measured

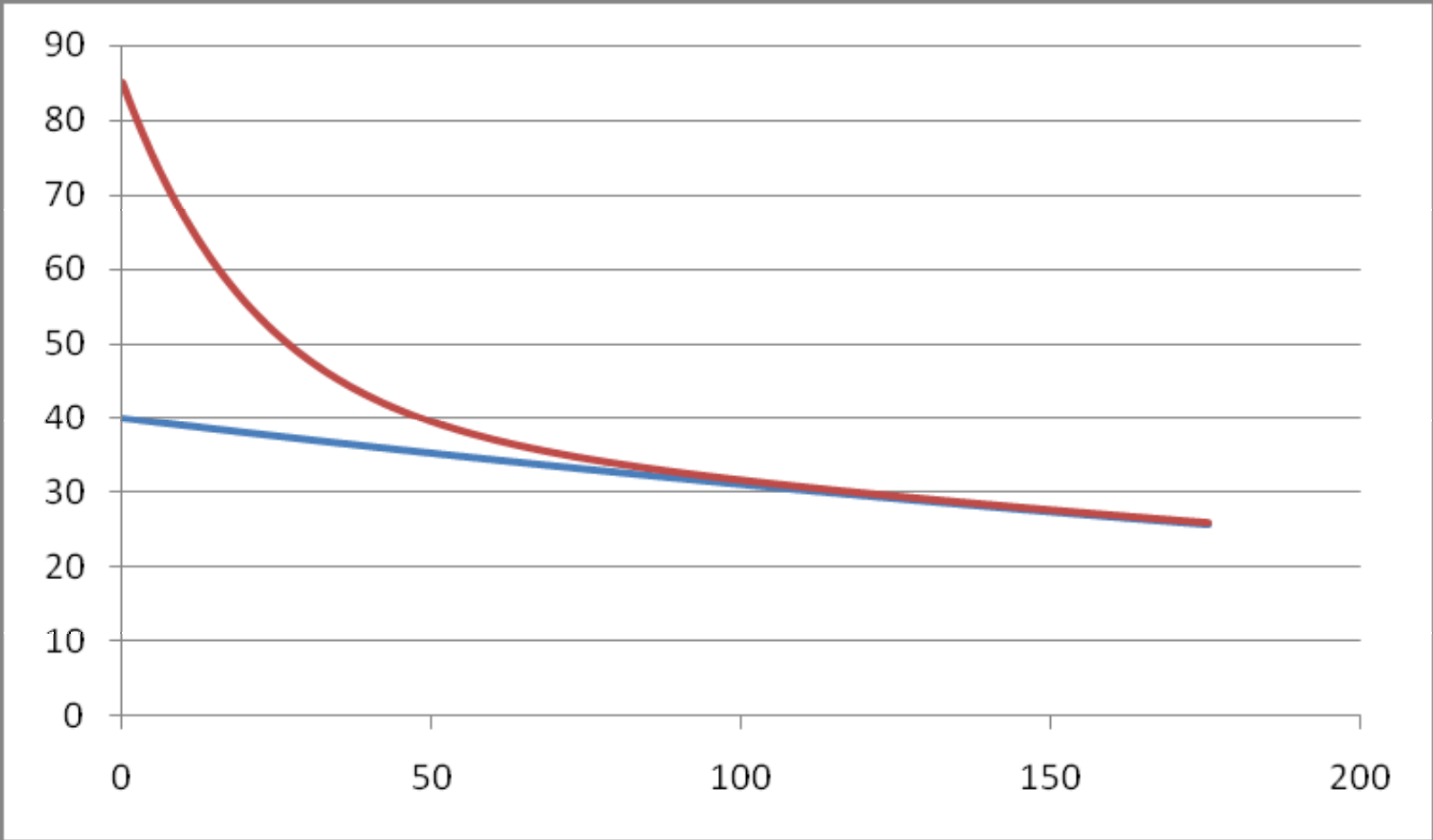
A three leg power transformer



- This transformer has 4 sets of cooling fins and the upper ducts are higher than the tap changer.
- The center phase coils ambient is different from the outer phases coils ambient.
- Cooling ducts temperature does not give a good measurement of the coils ambient

- These few examples show that quite often the measurement of the oil temperature surrounding the coils cannot be done in a sufficiently precise way to serve as an extrapolation reference for the coils cooling curves.
- The core temperature is a major contributor to the inner coil ambient

- The coil and bulk oil time constants vary a lot depending on the size and the type of construction of the windings and of the overall transformer. The ratio of the bulk oil to the coil time constant also varies a lot.
- For small transformers the bulk oil time constant could be 60 minutes or less. With increasing transformer total mass the bulk oil time constant may reach 300 to 600 minutes (5 to 10 hours).



- Correct interpolation of coils temperatures at time zero requires:
 - A rough idea of the coil and bulk oil time constants
 - Measurement of the coils resistances in a short period compared to the coil time constant. Take first measurements in less than half the coil time constant and extent measurements to not much less than the coil time constant. All the measurements should preferably be done in less than 10 to 20% of the bulk oil time constant.
 - Good engineering judgement to evaluate, by multiple interpolations, the best fit coil ambient temperature that in many cases is different from the average oil temperature.

Orientations

- Whenever possible the actual loading or the back to back method shall be the preferred way to perform the heat run tests.
- First resistances measurements, after shutdown, shall be made in not more than half the evaluate coils shortest time constant, with a maximum of 4 minutes.
- At least 10 measurements of the coils resistances shall be made in not more than 20% of the bulk oil time constant
- Multiple interpolation shall be made (good engineering judgment) to determine the best fit first order exponential coil cooling curve.
- Support and encourage the development and implementation, for type testing, of coils inner temperature devices (i.e. Fiber optics or other).