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The importance of temperature index and the relation to thermal class of materials und system

By Gunther Baumgarten

1 Temperature index (TI)

In data sheets of electro insulation materials you will find many interesting figures. One of these is the temperature index. The temperature index is given as a figure without any unit and very often without any further explanation. The intention of this paper is to discuss the kinds of temperature index and the relation to thermal classes of materials and systems.

1.1 Theory

To understand the theory of temperature index (TI) some assumptions have to be made prior to further discussions:

- The decomposition of the electrical insulation is the limiting factor of the lifetime of the electrical equipment.
- The decomposition is following the kinetic rules of a chemical reaction.
- Nearly all decomposition reactions of electrical insulating materials are following a chemical reaction first order or pseudo first order.

All reactions first order will give a straight line in a log-time – reciprocal absolute temperature – graph.
This allows us to make forecasts to the behaviour of a material due to temperature and time.

1.2 Characteristics of influence to a TI

The general problem is to determine the reaction velocity of the decomposition reaction. In most cases it is impossible to determine concentrations of components. To solve this problem defined test method and defined endpoint criteria are used.
Several temperature-time data are obtained und put into a log-time – reciprocal absolute temperature – graph. A regression line is calculated and the line is extrapolated to a defined time.

1.2.1 Test method

The test method has to reflect the main stress of an insulating material during its lifetime. The common main stresses are voltage stress or mechanical stress.

Example: intended use: wire enamel - test method: proof voltage

1.2.2 Endpoint criteria,

The end point criteria should reflect level of decomposition acceptable to the insulation material.
The value 50 % of the initial value is very often used, but there are also a lot of fixed values in use.

1.2.3 Extrapolation time

The extrapolation time should be the intended time of use of the equipment.

Examples:
For an electrical machine industry 20.000 h is very often used, this is about two years and three month.

But there are other possibilities due to the use of the equipment:

- A coffee grinder is running about 50 h in total during a period 20 years.
- The generator of a car is used for about 3000 h during its existence. During the same period of time the starter is used for less than 50 h.
- On the other end a transformer or generator of a power plant hat to run for more than 25 years, that's about 200.000 h

1.3 Summary

A temperature index without any further explanations is useless.
There is not one temperature index for a material, there can be defined as much TIs as desired.
It is important to know:

- Which test method was used and does this method of test reflect the main stress.
- Is the endpoint criterion in line with the requirements of my equipment.
- How long is the active time of an equipment during its life, and is this reflected by the extrapolation time.

This can only be done by the manufacturers of the equipment, but most TIs are produced by manufacturers of the materials.

To solve this problem, IEC 60216-2 [1] is giving common accepted methods of test and endpoint criteria for materials and its intended use.
IEC 60216 is using an extrapolation time of 20.000 h if not otherwise stated.

2 Thermal class

The thermal class is classifying a material or system into a given temperature range. It is always linked to the intended use of a material and the main stress to a material.

2.1 Thermal class of a material

The thermal class of a material is equal to the numerical value of the recommended maximum continuous use in degree Celsius. The materials are classified into groups with defined temperature ranges.

2.2 How to get from a Temperature index to the thermal class of a material

The first item to clarify is the intended use of a material. With this knowledge it is possible to search for a common accepted method of test and end end-point criteria.

Table 1 – Thermal classes according to IEC 60085

Temperature	Index	Thermal Class
≥90	<105	90
≥105	<120	105
≥120	<130	120
≥130	<155	130
≥155	<180	155
≥180	<200	180
≥200	<220	200
≥220	<250	220
≥250	<275	250

If there is no common accepted method, the supplier and purchaser have to agree on a method by their best knowledge and experience.
The TI obtained after the thermal endurance experiment is classified in to one of the defined thermal classes in IEC 60085 [2].
If there are already established materials for the intended use, with field experiences, the procedure according to IEC 60216-5 [3] should be used to classify a new material in conjunction with an established one.

2.3 Thermal class of a system

The first item to clarify is the intended use of an insulating system. General considerations how to test a system could be tested can be taken from IEC 60505 [4].
For systems in the area of rotating machines or transformers, system tests according to IEC 61857-21 [5] can be used.
The experiment itself is constructed like a TI-experiment. Several temperature-time data are obtained und put into a log-time – reciprocal absolute temperature – graph. A regression line is calculated. A figure accordingly to a TI is calculated and the TI is classified into one of the thermal classes.

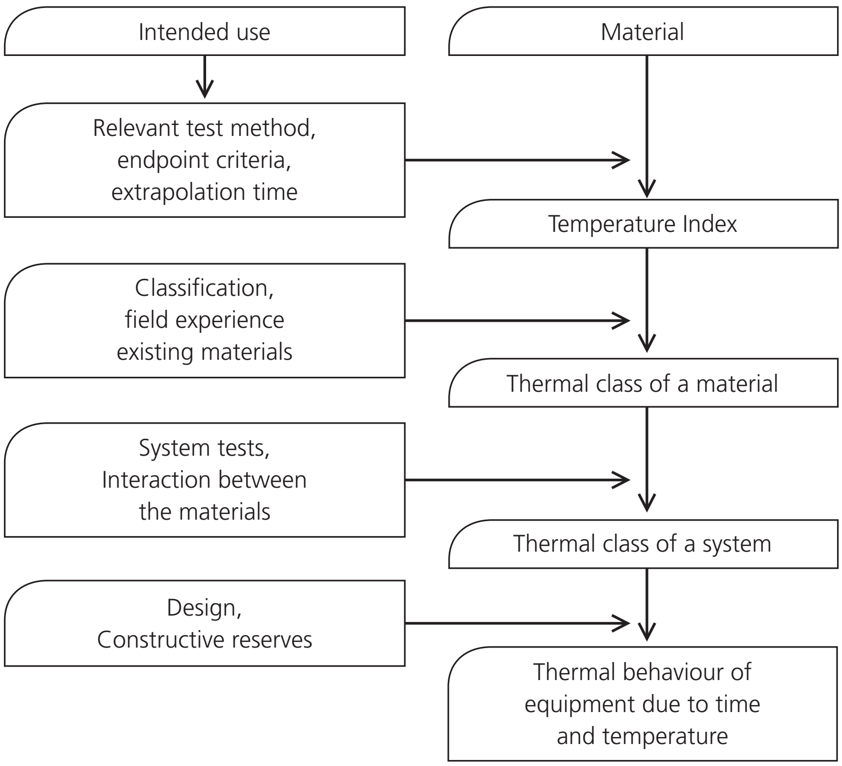
2.4 Relation between thermal class of a material and a system

There is no direct relation between the class of a material and the behaviour of the material in a system.
According to IEC 60085, the class of a material is determined by thermal endurance tests following the instruction in IEC 60216 and the class of a system is determined by systems tests following the instruction in IEC 60505.
The main reasons why the thermal class of a material cannot be used for system are chemical and physical interactions between the components of a system during production and use. In practise positive and negative synergetic effects can be observed.
A class 155 material may fit into a class 180 systems without problems. On the other end, if materials are chosen by inexperienced designers of equipment or unknown incompatibilities are occurring, even class 200 materials may fail in a class 180 system.

3 Influence of the design to the lifetime of an equipment.

The last step in this discussion is the relation between established and tested systems to the real design of a equipment or machine.
The correlation between systems and real equipment is based on well-established and conservative designs. If an unusual design is used, or equipment is pushed to the technical possible borderline this correlation may become invalid. In such a case the equipment itself has to be tested.

4 Conclusion



5 References

[1] IEC 60216-2 Electrical insulating materials - Thermal endurance properties – Part 2: Determination of thermal endurance properties of electrical insulating materials - Choice of test criteria

[2] IEC 60085 Electrical insulation - Thermal evaluation and designation

[3] IEC 60216-5 Electrical insulating materials - Thermal endurance properties – Part 5: Determination of relative thermal endurance index (RTE) of an insulating material

[4] IEC 60505 Evaluation and qualification of electrical insulation systems

[5] IEC 61857-21 Electrical insulation systems - Procedures for thermal evaluation – Part 21: Specific requirements for general-purpose models - Wire-wound applications