IEC 60076-22-2

Edition 1.0 2019-01

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Power transformers –
Part 22-2: Power transformer and reactor fittings – Removable radiators

Transformateurs de puissance –
Partie 22-2: Accessoires pour transformateurs de puissance et bobines d'inductance – Radiateurs détachables

IEC 60076-22-2:2019-01(en-fr)

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POWER TRANSFORMERS –

Part 22-2: Power transformer and reactor fittings – Removable radiators

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The text of this International Standard is based on the following documents:

CDV	Report on voting
14/895/CDV	14/917A/RVC

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 60076 series, published under the general title *Power transformers*, can be found on the IEC website.

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INTRODUCTION

Under the part title “Power transformer and reactor fittings" this part of IEC 60076-22 covers the removable radiators used in the cooling circuits of power transformers and reactors.

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POWER TRANSFORMERS –

Part 22-2: Power transformer and reactor fittings – Removable radiators

1 Scope

This part of IEC 60076 applies to radiators mounted on liquid immersed power transformers according to IEC 60076-1 and reactors according to IEC 60076-6 with and without conservator for indoor or outdoor installation. It outlines the service conditions and the mechanical and electrical requirements that are common to this equipment.

It also outlines the operation requirements specific to this equipment as well as the preferred dimensions relevant for interchangeability and the type and routine tests to be performed.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60076-1, *Power transformers – Part 1: General*

IEC 60076-7, *Power transformers – Part 7: Loading guide for oil-immersed power transformers*

IEC 60296, *Fluids for electrotechnical applications – Unused mineral insulating oils for transformers and switchgear*

ISO 4406, *Hydraulic fluid power – Fluids – Method for coding the level of contamination by solid particles*

ISO 12944 (all parts), *Paints and varnishes – Corrosion protection of steel structures by protective paint systems*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1
removable radiator
component through which the transformer insulating liquid circulates and is cooled

Note 1 to entry: The component is removable from the transformer for shipment and maintenance purposes.

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Note 2 to entry: This component has natural cooling capacity.

Note 3 to entry: Radiator cooling systems can be equipped with fans and/or circulating pumps.

4 General requirements

4.1 General

The normal service conditions set out in IEC 60076-1 represent the normal scope of operation of the equipment specified in this document.

For any unusual service conditions which require special consideration in the design of the equipment, see IEC 60076-1; operation under such unusual service conditions shall be subject to agreement between the purchaser and supplier, as they require special consideration in the design of the equipment.

4.2 External corrosion protection

The materials used for the construction of the equipment and the surface treatment shall be resistant to accidental contact with the insulating liquid and suitable to withstand the environmental conditions given in 4.1. The corrosion protection shall be agreed between purchaser and manufacturer according to ISO 12944 (all parts). The responsibility to specify the correct level of corrosion protection lies with the purchaser and is dependent on the environment where the transformer will be located and on the durability required. Unless otherwise specified, minimum withstand level shall be C4 medium durability according to ISO 12944-6.

Due to the specific painting process of radiators a common final colour would be a great contribution to reducing the environmental pollution. Unless differently specified by the purchaser, RAL 7031, 7032 or 7033 are the recommended final colours.

4.3 Internal corrosion protection

In consideration of the storage conditions and expected time between shipment and commissioning, the corrosion protection on the inner side of the radiator shall be agreed between purchaser and manufacturer. As a minimum requirement, precautions shall be taken to prevent the ingress of moisture and the development of internal corrosion. The internal flushing with insulation liquid fully miscible and compatible with the liquid to be used in service conditions and the use of blanking plates with gaskets are considered as a minimum. Internal painting, nitrogen filling, dehydrating material, etc., can be used as other or additional solutions.

4.4 Insulating liquid characteristics

If not otherwise specified, the insulating liquid shall be mineral oil according to IEC 60296 and the operating temperature shall be in accordance with IEC 60076-7.

When the insulating liquid is not mineral oil then the viscosity variation, the operating temperature and all the other operating characteristics shall be indicated by the purchaser.

5 General characteristics and requirements

5.1 Main components

The main radiator components are:

- header; collectors on the top and bottom of the radiator;
- connection flanges; flanges which connect the radiators to the transformer tank;

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- cooling elements; elements of the radiator which dissipate the heat;
- lifting lugs; devices used to lift the radiator;
- securing plates; facilities to connect the radiators to one another for stiffening purposes;
- fan attachments; optional facilities for fan installation on the side and on the bottom.

The headers shall be made in such a way as to guarantee a complete filling and a complete draining. Oblique elements or reduced elements are acceptable.

The layout is given in Figure 6 and Figure 7, and in Figure A.1 to Figure A.5.

The radiators shall be provided with an air vent device on the top header and a draining device on the bottom header.

5.2 Radiator types defined in this document

The designations to identify the types of radiator are:

Common radiator types

FG radiators with square flanges and elements of equal length (see Figure 6)

FR radiators with square flanges with lowered upper header (see Figure 7)

Alternative design types

FA radiators with square flanges and elements of unequal length (see Figure A.1)

FG-L radiators with square flanges and elements of equal length with a number of bevelled elements on the left side (see Figure A.2)

FG-R radiators with square flanges and elements of equal length with a number of bevelled elements on the right side (see Figure A.3)

FAR radiators with square flanges with sloped down external elements, without or with lowered upper header (see Figure A.4)

FG1A radiators with or without square flanges without header, without or with out of centre connection (see Figure A.5)

5.3 Materials

The radiator elements shall be made of stamped steel sheets or steel pipes (round, oval or finned pipes) with a minimum thickness of 1,0 mm. For enhanced mechanical performance a thickness of 1,2 mm can be specified by the purchaser for the stamped steel sheets. Other materials and thicknesses may be used upon agreement between manufacturer and purchaser.

5.4 Dimensions and tolerances

To ensure interchangeability between radiators of different manufacturers, the tolerances given in Figure 6 to Figure A.5 are mandatory.

There shall be at least two lifting lugs, one at the top and one at the bottom of the radiator, which shall have a 30 mm minimum hole diameter.

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The radiators shall not deflect from horizontal by more than 2 mm/m without oil. For this reason, the stiffening number and distances illustrated on Figure 6 to Figure A.5 are the minimum required. Additional stiffening may be agreed between purchaser and manufacturer depending on:

- transformer specific requirements (for instance reactors, noise requirements);
- seismic and environmental specific severe conditions.

The manufacturer shall provide a table indicating exactly the surface in m^2, the weight in kg and the capacity of oil per element in function of the height of the element itself. The table does not include the data associated with the radiator nozzles. Table 1 is an example of such a table.

Table 1 – Radiator characteristics form

ELEMENT HEIGHT (mm)	ELEMENT SURFACE (m^2)	ELEMENT WEIGHT (kg)	ELEMENT CAPACITY (dm^3)
800	XXXX	XXXX	XXXX
.....	.....	.....	.....
3 500	XXXX	XXXX	XXXX

5.5 Preparation for transport and storage

It is the responsibility of the manufacturer to prepare the radiator flanges for shipment in order to prevent particles or contaminants from entering the radiator during transport or storage, and precautions shall be taken to ensure that there is no deterioration caused by moisture.

Unless otherwise specified the storage configuration shall be designed to ensure a minimum storage period of six months in the environmental conditions defined in IEC 60076-1.

All measures shall be taken to avoid mechanical damage to the elements such as:

- rubber, or wooden material between the radiators to avoid scratches of the external treatment on the cooling elements;
- plastic belts to keep the radiators tight to the pallet and to each other;
- robust pallets to ensure protection under the radiators from the forklift handling.

For international shipment, a wooden cage is recommended, unless otherwise agreed with the buyer.

5.6 Identification of radiators

The radiators shall bear the name or the logo of the manufacturer, a lot identification number and the production site, in order to identify the radiators in the field.

6 Tests

6.1 Routine tests

6.1.1 Tightness tests

The radiator shall be submitted to one of the following tightness tests; the choice of the test shall be at the discretion of the radiator manufacturer:

- hydraulic test with transformer oil filled at 60 °C ± 5 °C and pressure of 200 kPa for 3 h;

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- pneumatic test with compressed air under water at 200 kPa for a period of not less than 30 min;
- pneumatic test with compressed air under water at 500 kPa for a period of not less than 5 min.

For the above listed tests the acceptance criterion is that in the mentioned period no leakage shall be detected by visual inspection.

Different testing procedures may be agreed between purchaser and manufacturer.

6.1.2 Surfaces

6.1.2.1 Visual inspection

The radiators shall be visually inspected and there shall be no visible deformations, damages or bumps.

6.1.2.2 Inspection of the external paint

The total and partial thickness of the different coats shall be measured in accordance with the procedure described in ISO 12944-7.

Upon request from the customer, a control sheet shall be available to demonstrate the quality of the external paint application. Therefore, a control sheet should be prepared, where the manufacturer records all the relevant parameters of each lot of production. In particular, ambient temperature and humidity during application, type of pre-treatment of the surface (sandblasting, degreasing), lot and type of painting used, temperature and time of drying and final thicknesses measured after each coat shall be recorded; if required, result of the adhesion test should also be recorded.

6.1.2.3 Internal surfaces

All internal surfaces shall be cleaned so thoroughly that no subsequent cleaning by the purchaser will be required.

For the measurement of the cleanliness of the internal surfaces, the purchaser shall specify the acceptance criteria by means of particles count according to ISO 4406.

For radiators with unpainted internal surfaces, if no criteria are specified, then flushing using a maximum 20 µm filter to detect the presence of any particles or contaminations shall be carried out as a minimum requirement.

For radiators with painted internal surfaces, if no criteria are specified, visual inspection is the minimum requirement to ensure that no detached particles are present within the radiator and that the internal surface is dry and the paint has a good adhesion. The coating used shall be agreed between purchaser and manufacturer; it shall be compatible with transformer insulating and cooling fluid and shall not break down over time and compromise the integrity of the electrical equipment.

6.2 Type tests

6.2.1 Cooling performance

6.2.1.1 Overview

This procedure describes the method that shall be used to determine the cooling performances of the radiators in ONAN conditions; the purpose of the type test is to obtain the following results:

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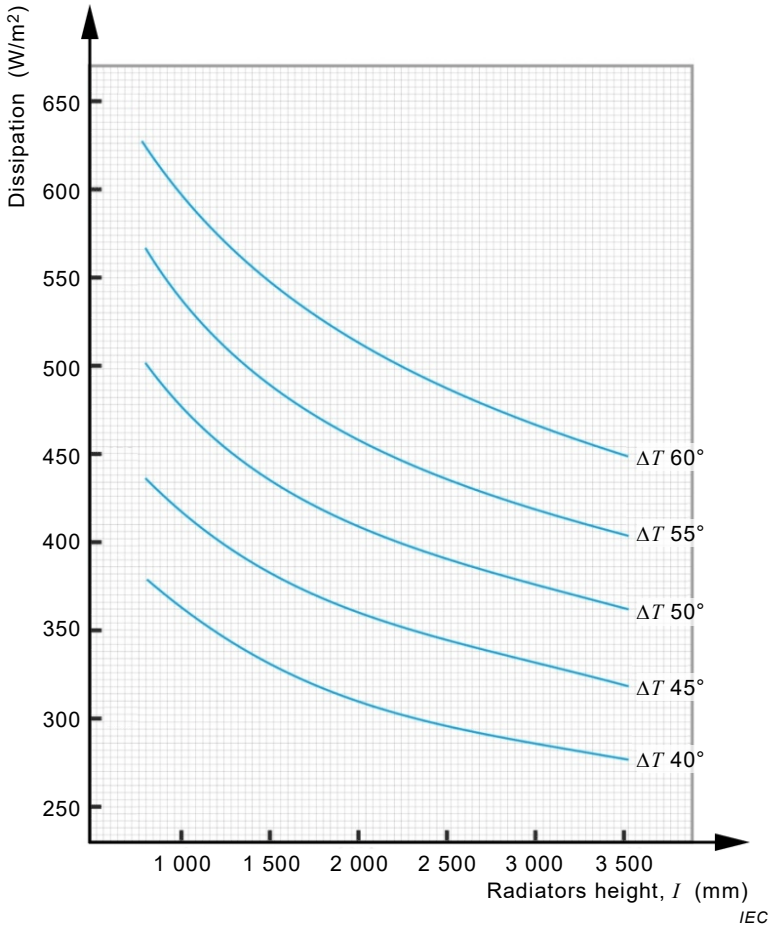
a) The diagram showing the specific heat dissipation of the radiator (W/m^2) as a function of the radiator height (mm) and of the temperature rise of the average oil over the ambient air (K). Figure 1 shows a typical diagram.



NOTE ΔT is intended as average oil temperature rise $[\Delta T_{avg,oil}] = (0{,}5x([T_{i,oil}]+[T_{o,oil}])) - [T_{amb}]$.

Figure 1 – Radiators' dissipation diagram

b) The value of the corrective coefficient KN as a function of the number of elements of the radiator; this coefficient is used to correct the specific heat dissipation of a radiator depending on the number of elements of the radiators itself. Figure 2 shows a typical diagram.

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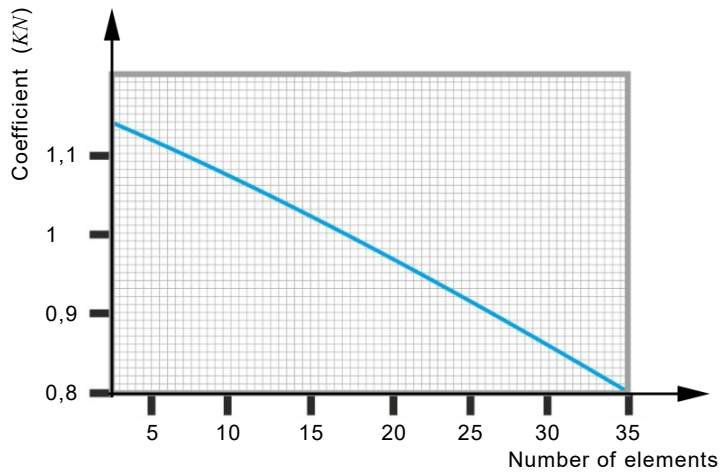

KN coefficient where *N* is the number of elements for each radiator

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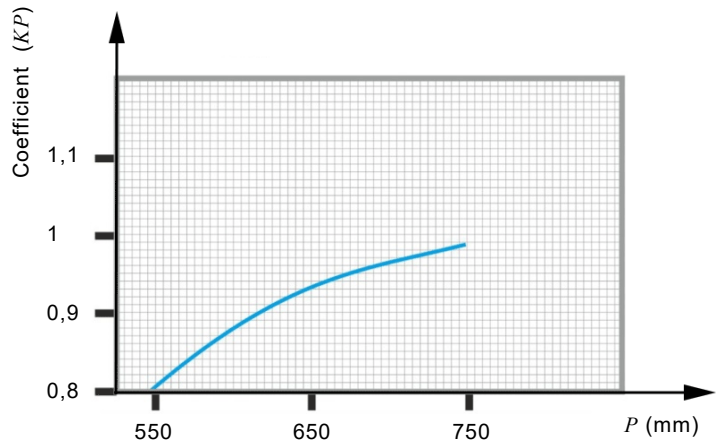
Figure 2 – Coefficient *KN*

c) The value of the corrective coefficient *KP* as a function of the distance between the radiators (pitch). This coefficient is used to correct the specific heat dissipation of a radiator depending on the difference between centres of adjoining radiators. Figure 3 shows a typical diagram.



KP coefficient where *P* is the difference between centre of adjoining radiators (pitch)

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Figure 3 – Coefficient *KP*

d) The value of the corrective coefficient *KDH* as a function of the difference *DH* in height between the horizontal centreline of the active part of the transformer and the horizontal centreline of the radiators. This coefficient is used to correct the specific heat dissipation of a radiator depending on the difference between the two horizontal centre lines. Figure 4 shows a typical diagram.

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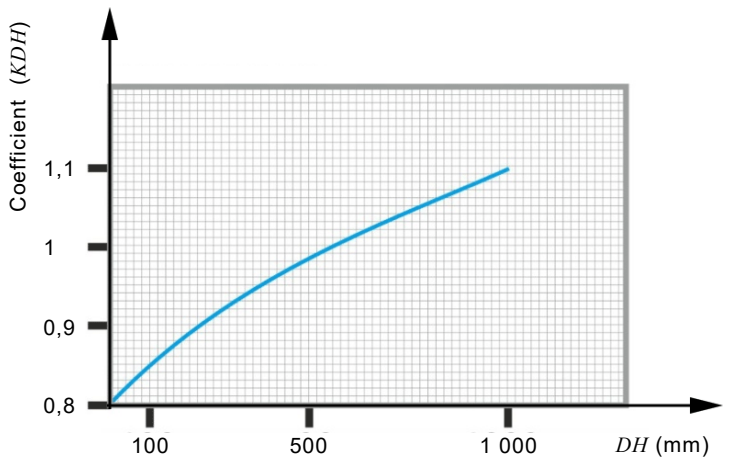

KDH coefficient where *DH* is the difference in height between the nucleus centre line and radiator

IEC

Figure 4 – Coefficient *KDH*

The cooling capacity of a radiator depends on the average oil temperature rise and the height of the elements. This value shall be corrected by the coefficients *KN*, *KP* and *KDH*.

These diagrams are applicable for ONAN applications only. For ONAF, OFAN or OFAF applications, they have to be adjusted by multiplicative factors, peculiar to every configuration.

6.2.1.2 Type test conditions

The heat dissipation tests shall be performed in a closed and stable environment, within a suitable area, which maintains the ambient temperature stable without variation due to the thermic test itself or to the external climate conditions. This ambient temperature shall be maintained at around 25°C ± 5°C.

The ratio between the volume of the hot oil used in the cooling test and the volume of the room where the tests are performed shall be higher than 1:100.

The specific dissipation curves shall be obtained by testing several times the cooling performances of a specific radiator filled with transformer mineral oil and attached in its normal vertical position to a tank with a well-known oil capacity, dimensions and heat dissipation. The tank shall be designed in such a way that its heat dissipation capacity does not influence the dissipation characteristics of the radiator (see 6.2.1.5).

The radiator painting thickness shall be 120 µm ± 10 %.

The radiators tested shall be of the FG type. The dissipation characteristics of the FR type radiators shall be calculated by interpolation.

No other tests conditions are admissible.

6.2.1.3 Values and parameters to be measured

During the test, the following parameters shall be measured:

- ambient temperature [T_{amb}]: defined as the average of three air temperatures measured by thermocouples immersed in oil and placed in the position described in Figure 5 at 2 m from the ground, with at least 2 m of free space around them;

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- radiator oil temperature at inlet [$T_{i,oil}$]: oil inlet temperature measured on the radiator at a distance of 50 mm from the inlet flange, using a thermocouple placed on the external surface and well isolated from the ambient environment, or in a thermometer pocket;
- radiator oil temperature at outlet [$T_{o,oil}$]: oil outlet temperature measured on the radiator at a distance of 50 mm from the outlet flange, using a thermocouple placed on the external surface and well isolated from the ambient environment, or in a thermometer pocket;
- maximum tank oil temperature [$T_{top,oil}$]: temperature measured on the hottest point of the tank on the top of the tank itself;
- maximum oil temperature rise [$\Delta T_{max,oil}$] = [$T_{top,oil}$] - [T_{amb}];
- average oil temperature rise [$\Delta T_{avg,oil}$] = (0,5 x ([$T_{i,oil}$] + [$T_{o,oil}$])) - [T_{amb}];
- total cooling capacity [q_{TOT}]: equivalent to the total power generated by the electrical resistors immersed in oil inside the tank;
- cooling capacity of the tank [q_t]: the heat dissipated by the tank only, without any radiator attached;
- radiator cooling capacity [q_{rad}] = [q_{TOT}] - [q_t] expressed in kW.

All the values listed above shall be measured in the test conditions described in 6.2.1.2.

6.2.1.4 Instrument characteristics and requirements

The data collection system shall be based on the following elements:

- automatic temperature data collection system;
- thermocouple with functioning range -10 °C to +300 °C;
- monitoring system of the electric power of the oil immersed resistance.

The temperature data collection system shall have a minimum resolution of 0,1 °C, and accuracy of ±1,5 %.

The only admitted heat source are batches of electric resistance immersed in oil with a regulation system of the input power which allows a continuous regulation.

All instruments shall be calibrated and certified.

6.2.1.5 Characteristics of the tank used for dissipation tests

The tank shall be equipped with a conservator to compensate the oil expansion. The shape of the tank shall be such as to guarantee a uniform temperature distribution in any area. A cylindrical shape is the preferred solution.

The tank shall be large enough to ensure a minimum ratio of 1:10 between the oil volume of the tank and the biggest radiator and high enough to allow the mounting of the biggest radiator on test.

To ensure a good temperature distribution inside the tank, a study of the temperature shall be performed during the heat test of the tank alone.

The resistor inside the tank shall have an adjustable position making it possible to change the DH parameter.

The tank shall be insulated to provide an emission of maximum 1 $Wm^{-2}K^{-1}$. The conservator does not require to be insulated. Figure 5 shows a typical test layout.

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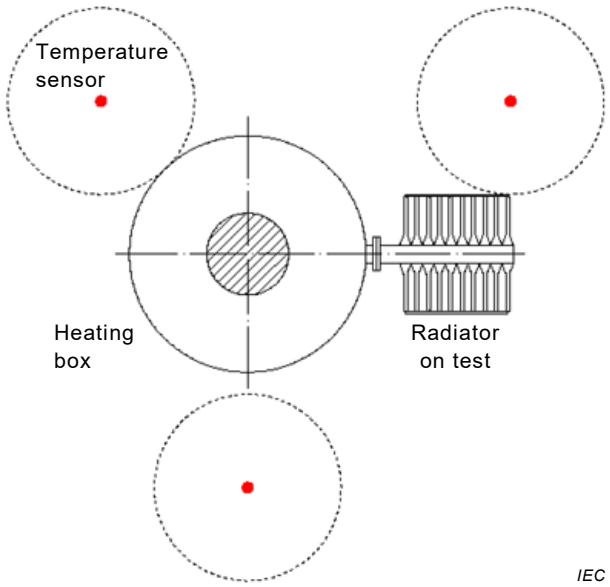

Figure 5 – Test layout

6.2.1.6 Dissipation test method

6.2.1.6.1 Tank dissipation test

The tank should start the heating process by increasing the input power to the resistors in order to reach at least three different temperature rises (60 K, 50 K and 40 K).

The values of the top oil temperature rise and average oil temperature rise shall be recorded at least every 30 min. When the top oil temperature rise rate of change has fallen below 0,5 K/h and has remained there for a period of 4 h, then the tank is considered to have reached stability. The three values of power (kW) corresponding to the three different temperatures shall be recorded.

The manufacturer shall provide in his report the following parameters:

- tank dimension, oil capacity and surface;
- tank insulation characteristics;
- oil type and its characteristics;
- top and average oil temperature rise for each specific electric power dissipated.

Other values of tank heat dissipation (KW) corresponding to a different oil temperature rise can be calculated by interpolation.

6.2.1.6.2 Radiators dissipation tests

Each dissipation test shall be carried out by changing only one parameter at a time from the following:

- number of elements: N;
- difference between the radiator centre line and the active part centre line: DH;
- distance from one radiator to the other, which is the pitch between radiators: P.

The distance between the first element and the test tank shall be 300 mm.

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For each dissipation test, a report shall be done with the following parameters:

– radiator characteristics (oil capacity, surface, weight, height, number of elements);
– oil type and its characteristics;
– top and average oil temperature rise for each specific electric power dissipated;
– DH (centre lines difference).

The test shall be performed as follows:

Start the dissipation test by energizing the resistor inside the test tank. The input power in kW shall be comparable to the expected radiator and tank losses at the required temperature rise.

Wait for the thermal stability, then adjust the input power in order to reach the required temperature rise.

When the top oil temperature rise rate of change has fallen below 0,5 K/h and has remained there for a period of 4 h, then the tank is considered to have reached stability; at this point the test is considered completed.

The radiator specific dissipation at a certain temperature rise will be calculated by deducting the tank dissipation at the same temperature rise from the total losses measured during the test.

The manufacturer shall conduct these tests for at least four radiator heights (for instance 800 mm, 1 600 mm, 2 400 mm, 3 200 mm), with a DH = 0 condition, no other radiators nearby and with a certain number of elements decided by the manufacturer (for example 20 elements).

The tests as described above on the four radiators shall be conducted at three average oil temperature rises (60 K, 50 K and 40 K).

6.2.1.6.3 *KDH* diagram generation

The same radiators used for the tests above (four radiators) shall be used by adjusting the height of the resistor inside the test tank in order to change the value of DH: at least three different positions of the resistor shall be tested at the three different temperature rises (60 K, 50 K and 40 K) for each radiator. For example: 350 mm, 700 mm, 1 000 mm. The different positions shall change by at least 300 mm.

6.2.1.6.4 *KN* diagram generation

Three tests with different number of elements shall be carried out for each radiator height, and for the three temperature rises above (60 K, 50 K and 40 K). The number of elements shall change in steps of 10 (for example 5, 15, 25 elements).

6.2.1.6.5 *KP* diagram generation

Three dissipation tests for each radiator height (four radiators) and for the three temperature rises (60 K, 50 K and 40 K) shall be performed using thermal insulating panels at the two sides of the radiator, to simulate the proximity of other radiators. The panels shall be as high as the tested radiator and with thermal conductivity of less than 1 $Wm^{-2}K^{-1}$. Each test should be carried out by changing the distance of the panels by at least 100 mm, for example at 50 mm, 150 mm, 250 mm from the tested radiator.

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