BS EN 50216-10:2009

BSI British Standards

Power transformer and reactor fittings —

Part 10: Oil-to-air heat exchangers

National foreword

This British Standard is the UK implementation of EN 50216-10:2009.

The UK participation in its preparation was entrusted to Technical Committee PEL/14, Power transformers.

A list of organizations represented on this committee can be obtained on request to its secretary.

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Foreword

This European Standard was prepared by the Technical Committee CENELEC TC 14, Power transformers.

The text of the draft was submitted to the formal vote and was approved by CENELEC as EN 50216-10 on 2008-10-21.

This European Standard is to be read in conjunction with EN 50216-1:2002, *Power transformer and reactor fittings - Part 1: General*.

The following dates were fixed:

– latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2009-11-01
– latest date by which the national standards conflicting with the EN have to be withdrawn	(dow)	2011-11-01

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1 Scope

EN 50216-10 describes oil-to-air heat exchangers that means a heat exchanger for the cooling of the transformer oil using a forced oil circuit and a forced air circuit.

The oil-to-air heat exchangers are not included in the scope of the Pressure Equipment Directive 97/23/EC according to Article 1, § 3.12.

This standard establishes essential dimensions and the requirements to ensure interchangeability and adequate mounting of the oil-to-air heat exchangers.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendment) applies.

EN 50216-1:2002	Power transformers and reactor fittings - Part 1: General
EN 60296	Fluids for electrotechnical applications - Unused mineral insulating oils for transformers and switchgear (IEC 60296)
EN 60721-3-4	Classification of environmental conditions - Part 3: Classification of groups of environmental parameters and their severities - Section 4: Stationary use at non-weatherprotected locations (IEC 60721-3-4)
EN 754-2	Aluminium and aluminium alloys - Cold drawn rod/bar and tube - Part 2: Mechanical properties
EN 1092-1	Flanges and their joints - Circular flanges for pipes, valves, fittings and accessories , PN designated - Part 1: Steel flanges
EN 1386	Aluminium and aluminium alloys - Tread plate - Specifications
EN 10025:1990 [1)]	Hot rolled products of non-alloy structural steels - Technical delivery conditions
EN 10130	Cold rolled low carbon steel flat products for cold forming - Technical delivery conditions
EN 10217-1	Welded steel tubes for pressure purposes - Technical delivery conditions - Part 1: Non-alloy steel tubes with specified room temperature properties
EN 12451	Copper and copper alloys - Seamless, round tubes for heat exchangers
EN ISO 3506-1	Mechanical properties of corrosion-resistant stainless steel fasteners - Part 1: Bolts, screws and studs (ISO 3506-1)
ISO 4406	Hydraulic fluid power - Fluids - Methods for coding the level of contamination by solid particles

3 Definitions

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

3.1
oil header
oil collecting and guiding compartment with flange connections to connect the heat exchanger with the oil circuit of the transformer

3.2
tube sheets
tubes are connected at both ends with tube sheets. The connection must be oil tight

3.3
heat exchanger
device for exchanging heat from one medium to the other

[1)] Replaced by EN 10025 series, Hot rolled products of structural steels.

3.4
cooling unit
unit, consisting of heat exchanger, fan with air chamber and oil pump

3.5
turbulators
inserts to generate turbulent oil flow

3.6
passes
number of passes via heat exchanger. Number “1” means that the oil is streaming in one way without any redirection from one oil header to the other (oil inlet and outlet in the opposite oil headers)

4 Requirements

4.1 Rated values

Values for inquiry (minimum):

-	rated cooling capacity	Q_r	kW
-	maximum air temperature at inlet	t_1'	°C
-	average oil temperature	t_{2m}	°C
-	oil temperature difference (min. value/max. value)	Δt_2	K
-	maximum sound power level	L_w	dB(A)
-	direction of air flow through heat exchanger	forced / induced draught	
-	minimum ambient temperature		°C

For the case of order the following rated values should be fixed:

-	rated cooling capacity	Q_r	kW
-	rated air flow quantity	V_1	m³/s
-	rated oil flow quantity	V_2	m³/h
-	direction of air flow through heat exchanger	forced / induced draught	
-	air temperature at inlet	t_1'	°C
-	air temperature at outlet	t_1''	°C
-	oil temperature at inlet	t_2'	°C
-	oil temperature at outlet	t_2''	°C
-	air side pressure drop	Δp_1	Pa
-	oil side pressure drop	Δp_2	kPa
-	maximum sound power level (without tolerance)	L_w	dB(A)
-	minimum ambient temperature		°C

4.2 Rated cooling capacity

The rated cooling capacity of the heat exchanger is the minimum capacity, which the manufacturer has to guarantee. It is based on following conditions of heat exchanger at its time of manufacturing.

No margin above defined rated cooling capacity; additional cooling capacity has to be agreed between purchaser and manufacturer.

Unless otherwise agreed between purchaser and manufacturer the calculation of rated cooling capacity must consider dry ambient air at a pressure of p_{abs} = 101,3 kPa and all types of transformer oil according to EN 60296.

Rated air-and oil-flow under consideration of permissible pressure drop.

The direction of air through the heat exchanger is forced or induced draught (shall be presented in the printout).

The point of operation on the fan characteristic curve for nominal air duty shall be at least 15 % below the area of instability. Thereby all resistances for the air flow are considered (heat exchanger, direction changes, protection screen, measures for noise reduction). The difference of at least 15 % is the maximum pressure loss caused by possible air side fouling.

Conversion of rated cooling capacity into other operating conditions can be calculated according to Annex B. Changes of flow quantities should generally be co-ordinated with the manufacturer.

4.3 Mechanical design

The mechanical design is based on environmental conditions described in EN 50216-1, Clause 3. The maximum oil temperature is 100 °C. Other environmental conditions, temperatures as well as other cooling liquids shall be agreed between manufacturer and purchaser.

On their air side the cooling pipes are equipped with cooling fins. The environmental conditions have to be considered for the choice of the materials and/or the combination of the tubes and cooling fins.

Connection between cooling pipes and tube sheets has to be oil tight. Excessive thermal expansion has to be avoided by appropriate design features.

The heat exchanger has to be designed for outside mounting without further protection and without any place to cumulate rain or condense water.

For transformers with frequency 50 Hz the resonance frequency of the operable heat exchanger must not be in the range of (80 – 320) Hz, for transformers with frequency 16 2/3 Hz not in the range of (25 – 180) Hz. Tolerances are not considered.

Vibration of pipes with fins or coil body has to be avoided by an appropriate number of supports.

Headers carry flanges for connection to the oil circuit. Types of flanges and fixing have to be agreed. The number of oil side passes is odd for the flange arrangements A1, B1, C1 and even for A2, B2, C2 according to Figure A.2.

It must be possible to clean the heat exchanger on the air side by means of water under high pressure.

The heat exchanger has to be vacuum proof.

For material selection criteria refer to A.4.

The maximum permissible oil pressure in service for the heat exchanger is limited to 350 kPa.

4.4 Protection of surfaces

4.4.1 Inner surfaces

Oil-proof and heat-resistant (min. 100 °C [2)]) protection.

4.4.2 Outer surfaces

Pipes and fins protected against corrosion.

The joints between tubes and tube sheets must be closed long term flexible and heat resistant up to 100 °C [2)].

The corrosion protection system has to be agreed between manufacturer and purchaser considering the environmental conditions.

The environmental conditions must be according to EN 60721-3-4.

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2) Deviations in the temperature must be agreed between manufacturer and purchaser.

5 Designation

5.1 Designation of the heat exchangers

The following heat exchangers are differentiated:

- OAA oil-to-air heat exchanger with vertical cooling pipes and horizontal air direction
- OAB oil-to-air heat exchanger with horizontal cooling pipes and horizontal air direction
- OAC oil-to-air heat exchanger with horizontal cooling pipes and vertical air direction
- OAxF fan arrangement is forced-draft type
- OAxI fan arrangement is induced-draft type

EXAMPLE:

Designation of an oil-to-air heat exchanger with vertical cooling pipes, horizontal air direction of forced draft type, rated cooling capacity 315 kW (315), oil temperature rise 45 K (45), arrangement of flanges C1 according to A.1.2:

Oil-to air heat exchanger EN 50216-10–OAAF-315/45-C1.

5.2 Rating plate information

The rating plate shall carry following data. It has to be observable when the heat exchanger is assembled to the transformer:

- manufacturer;
- designation according to 5.1;
- serial number;
- year of manufacturing;
- maximum oil pressure at service [kPa];
- maximum oil temperature [°C];
- minimum ambient temperature [°C].

Rating data:

- rated cooling capacity [kW];
- rated air flow / oil flow quantity [m³/h];
- temperature for air and oil at inlet and outlet [°C];
- pressure drop of oil and air [kPa/Pa];
- type of tubes [3)]:
    - oO oval tube without turbolators,
    - oR circular tube without turbolators,
    - mO oval tube with turbolators,
    - mR circular tube with turbolators;
- mass of heat exchanger without oil [kg];
- oil volume [dm³].

Design of rating plate:

- material: consistent against rust and acids.

Other designs are possible by special agreement.

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3) Select correct type.

6 Tests

6.1 Routine tests

6.1.1 Tightness tests

The oil-to-air heat exchanger has to be filled with transformer oil with a temperature of (60 ± 5) °C and a pressure of 500 kPa. The pressure shall be applied for 6 h, starting after removal of all leaks. At the visual inspection no further leakiness must be recovered.

The oil side of the oil-to-air heat exchanger may be submitted to the following alternative tightness tests by agreement between manufacturer and purchaser:

- hydraulic test with transformers oil filled at ambient temperature and a pressure of 500 kPa for 3 h;
- pneumatic test with compressed air under water at 500 kPa for 2 h;
- for the above period any leakage (by visual inspection) has to be detected.

6.1.2 Visual inspection of the surfaces

6.1.2.1 Outer surfaces

Visual the surfaces shall be free of damages, deformations and dirt. Every sort of filling compounds shall not be used.

6.1.2.2 Inner surfaces

Visual the surfaces shall be free of damages, deformations and dirt. The heat exchanger shall be flushed on the oil-side with transformer oil via micron filter as long as size and amount of particles is less than the agreed limited value. The flushing oil shall be in accordance to EN 60296. During flushing the oil flow velocity shall be sufficient. Thereupon the heat exchanger is ready to operate. Number and size of particles, as well as particle test procedure and flushing velocity or other cleaning criteria (e.g. according to ISO 4406) have to be agreed.

6.2 Type tests

6.2.1 Test of the rated values

Usually rated values are tested together with the transformer. Separate type tests must be agreed between manufacturer and purchaser.

6.2.2 Test of the outside painting

The thickness of painting must be according to the ordering data. With respect to the protection of surfaces, described in 4.4, an inspection on manufacturers site or other tests can be agreed between manufacturer and purchaser.

7 Preparation for transport and storage

Immediately after the flushing procedure the transformer oil has to be removed entirely by using filters. All flanges are closed with covers. As an option, on purchaser demand, the heat exchanger shall be filled under an overpressure of approximate 30 kPa with nitrogen or synthetic air (humidity less than 10 %) using a valve installed in one of the blind flanges. For long-term storage, that has to be indicated by the purchaser, the overpressure must remain minimum 5 kPa and therefore has to be checked regularly.

All threats and thermometer pockets are to be closed to keep them clean.

8 Mounting and service, service conditions

All characteristics described in this standard, mainly rated cooling capacity, are based on the pre-condition that there are no reductions of free air flow caused by any arrangements on sites.

Annex A
(normative)

Design details of heat exchangers

A.1 Dimensions and designs

Dimensions indicated for the drawings below, the exact position of flanges and their diameter, as well as fixing of heat exchangers have to be agreed generally. Arrangement of lifting lugs, air- and drain plugs have to be chosen according to the design of the heat exchanger.

A.1.1 Schematic design of cooling unit (without oil pump)

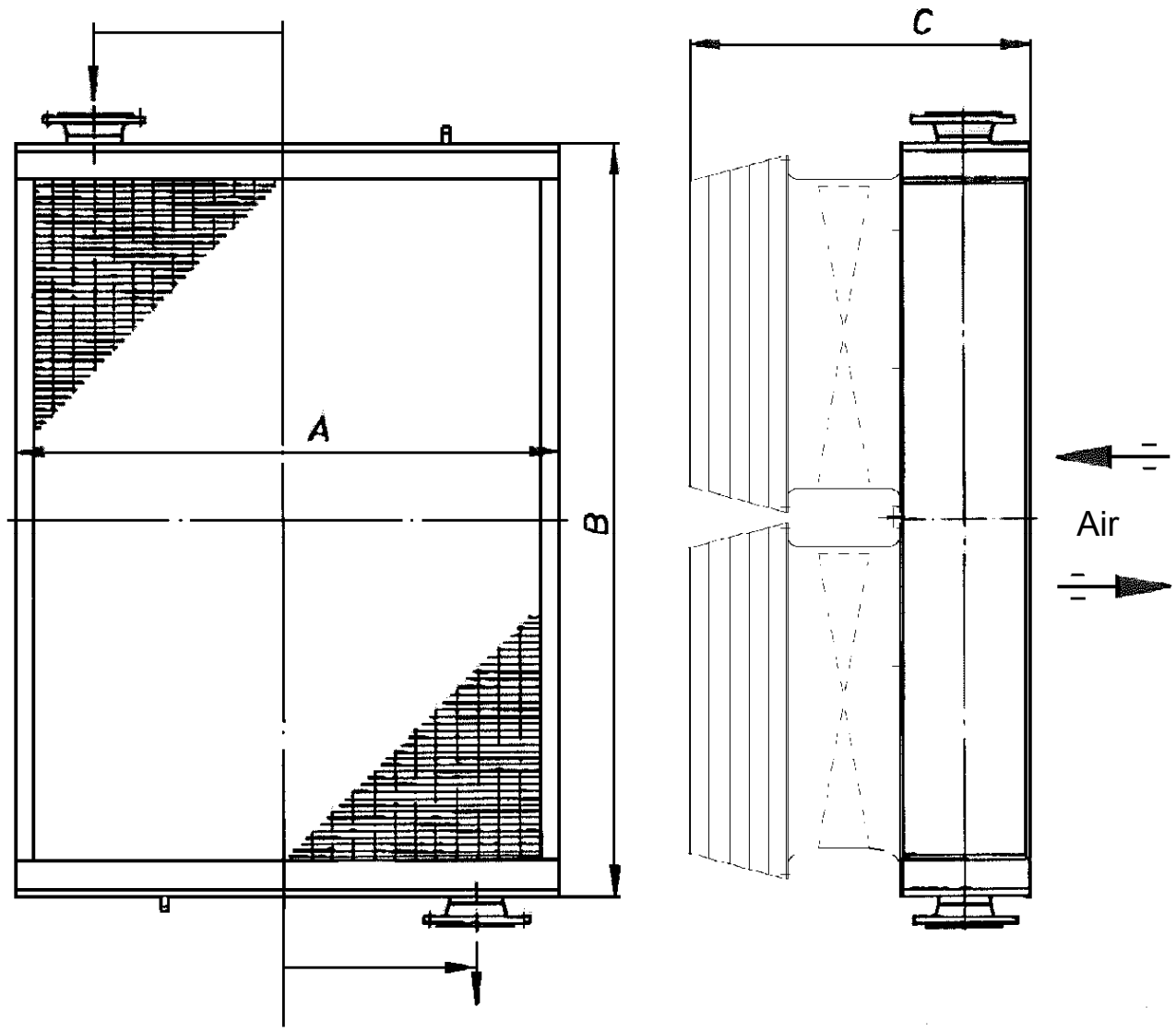
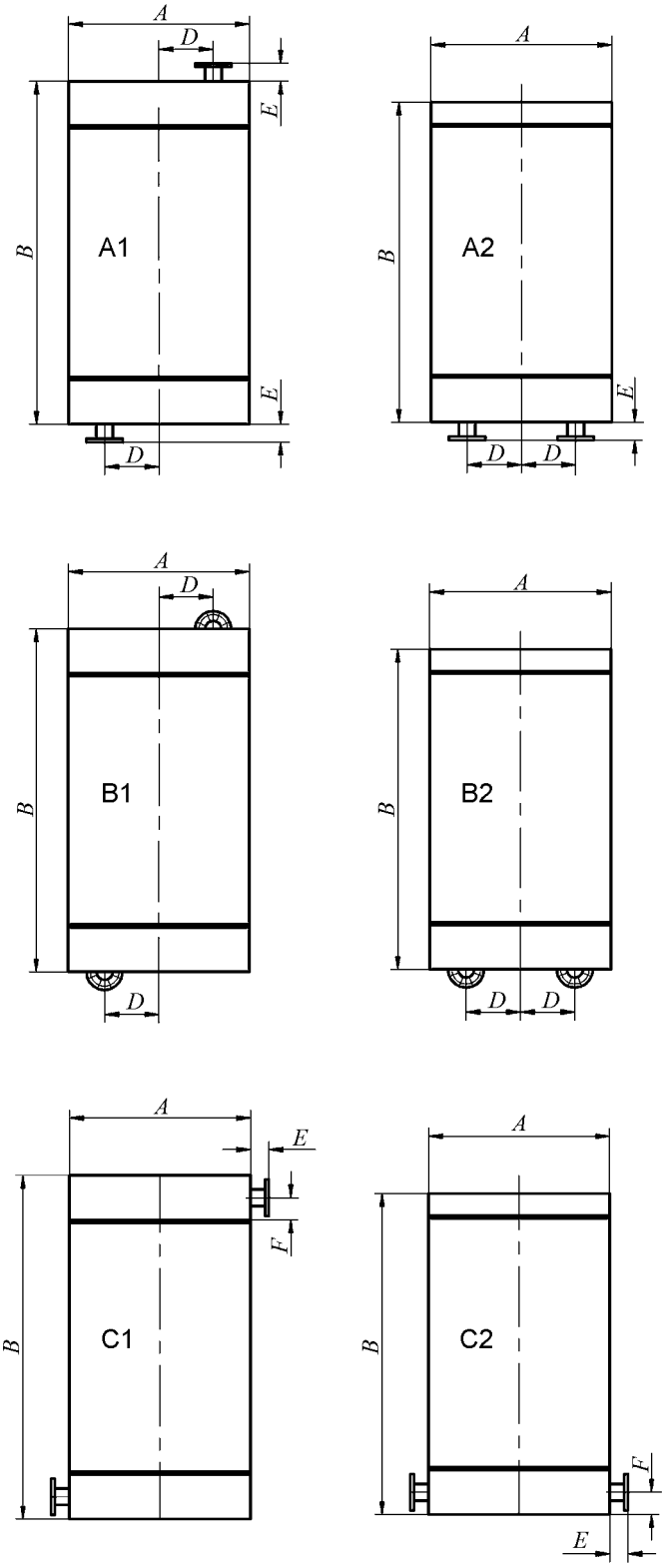


Figure A.1 – Schematic design of cooling unit (without oil pump) – Arrangement of flanges A1

A.1.2 Versions of flange arrangement



Versions A1, B1, C1 can be used laterally reversed and are to be marked in that case with "*" (for example A1*).

Detail nozzle position must be agreed between manufacturer and purchaser.

Figure A.2 – Versions of flange arrangement

A.3 Parts list

Table A.1 – Parts list

Number	Description	Remark
2	Connection flanges EN 1092-1/01/…/PN 10	For connection to oil circuit, diameter to be agreed
1 [a]	Plug for air release	Venting of oil circuit
1 [a]	Plug for draining	Residual oil
2	Lifting lugs	For transport, assembly and disassembly
1	Blind flange including gasket and fastenings	For closing oil circuit during transport or storage
1	Blind flange with vent including gasket and fastenings	For closing oil circuit during transport or storage and filling with synthetic air
2	Earthing cam	
1	Rating plate	See 5.2
1	U-bolt cable hanger	Fixing of cable
NOTE Further equipment to be agreed additionally.		
[a] Number and location defined by number of passes and mounting position.		

A.4 Constructional materials – Common selection of materials

Example aluminium, aluminium alloy:

- tube sheets: aluminium alloy EN-AW 6061 according to EN 1386
- tubes: aluminium alloy EN-AW 3003 according to EN 754-2
- side walls: mild steel S235JRG2 according to EN 10025
- header: mild steel S235JRG2 according to EN 10025
- flanges: mild steel S235JRG2 according to EN 10025
- supporting sheets: rimmed steel DC01 according to EN 10130, surface type (B), surface treatment extra smooth (b)
- screws and nuts: non-magnetic material according to EN ISO 3506-1

Example steel, mild steel:

- tube sheets: mild steel S235JRG2 according to EN 10025
- tubes: according to EN 10217-1, minimum mild steel S235JR
- side walls: mild steel S235JRG2 according to EN 10025
- header: mild steel S235JRG2 according to EN 10025
- flanges: mild steel S235JRG2 according to EN 10025
- supporting sheets: rimmed steel DC01 according to EN 10130, surface type (B), surface treatment extra smooth (b)
- screws and nuts: non-magnetic material according to EN ISO 3506-1

Commonly used materials:

Tube sheets:

S235JRG2 / 1.0038; P265GH / 1.0425; EN-AW 6061; EN AW-AlMg1SiCu; X5CrNiN19-9 / 1.4315; X3CrNiCu19-9-2 / 1.4560; X6CrNiTi18-10 / 1.4541; X6CrNiMoTi17-12-2 / 1.4571

Tubes:

S235JRG2 / 1.0038; P235GH-TC1 / 1.0305; Cu-DHP / CW024A according to EN 12451; EN-AW 3003; EN AW-AlMn1Cu; X5CrNiN19-9 / 1.4315; X3CrNiCu19-9-2 / 1.4560; X6CrNiTi18-10 / 1.4541; X6CrNiMoTi17-12-2 / 1.4571

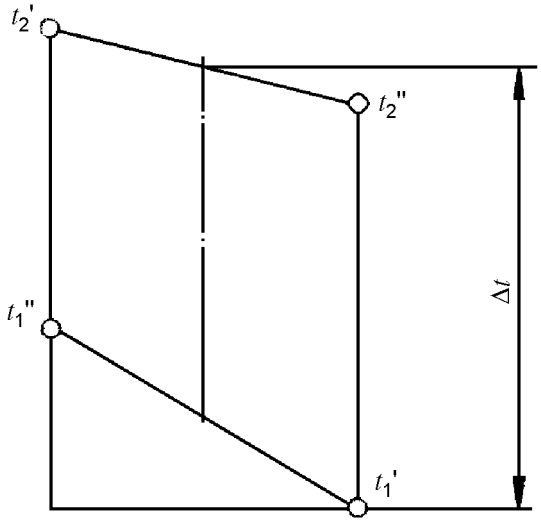
Side walls, header, flanges, supporting sheets:

S235JRG2; X5CrNiN19-9 / 1.4315; X3CrNiCu19-9-2 / 1.4560; X6CrNiTi18-10 / 1.4541; X6CrNiMoTi17-12-2 / 1.4571

Annex B
(normative)

Performance of heat exchangers

B.1 Performance of heat exchangers



The rated cooling capacity follows the relation:

$Q_r = V_1 \cdot c_1 \cdot \rho_1 \cdot (t_1'' - t_1')$

$Q_r = V_2 \cdot c_2 \cdot \rho_2 \cdot (t_2'' - t_2')$

Figure B.1 – General diagram for cooling temperatures

In the range of ambient temperature from +10 °C to +40 °C, cooling capacity is with reduced, but for many cases sufficient, accuracy proportional to oil temperature difference Δt when oil temperature at inlet changes but rated flow quantities remain constant (see 4.1).

In case of deviation of air temperature at inlet, all other temperatures (t_1'', t_2', t_2'') change in the same way if cooling capacity and flow quantities remain constant.

CAUTION: Change of air flow quantity always causes change of sound power level!

Basic values for calculation

Dry air at a pressure of p_{abs} = 101,3 kPa [4]:

-	density	$\rho_1 = 1{,}292 \times 273{,}2 / (273{,}2 + t_1')$	kg/m³
-	specific heat capacity	$c_1 = 1{,}006 + 0{,}000\,05 \times t_1'$	kW s/(kg K)

Transformer oil according to EN 60296:

-	density	$\rho_2 = 880 - 0{,}65 \times (t_2' + t_2'') / 2$	kg/m³
-	specific heat capacity	$c_2 = (493 + 1{,}177 \times (t_2' + t_2'') / 2) \times 10^{-6}$	kW h/(kg K)

[4] Temperature when entering heat exchanger.

B.2 Variation of cooling capacity as function of average oil temperature rise

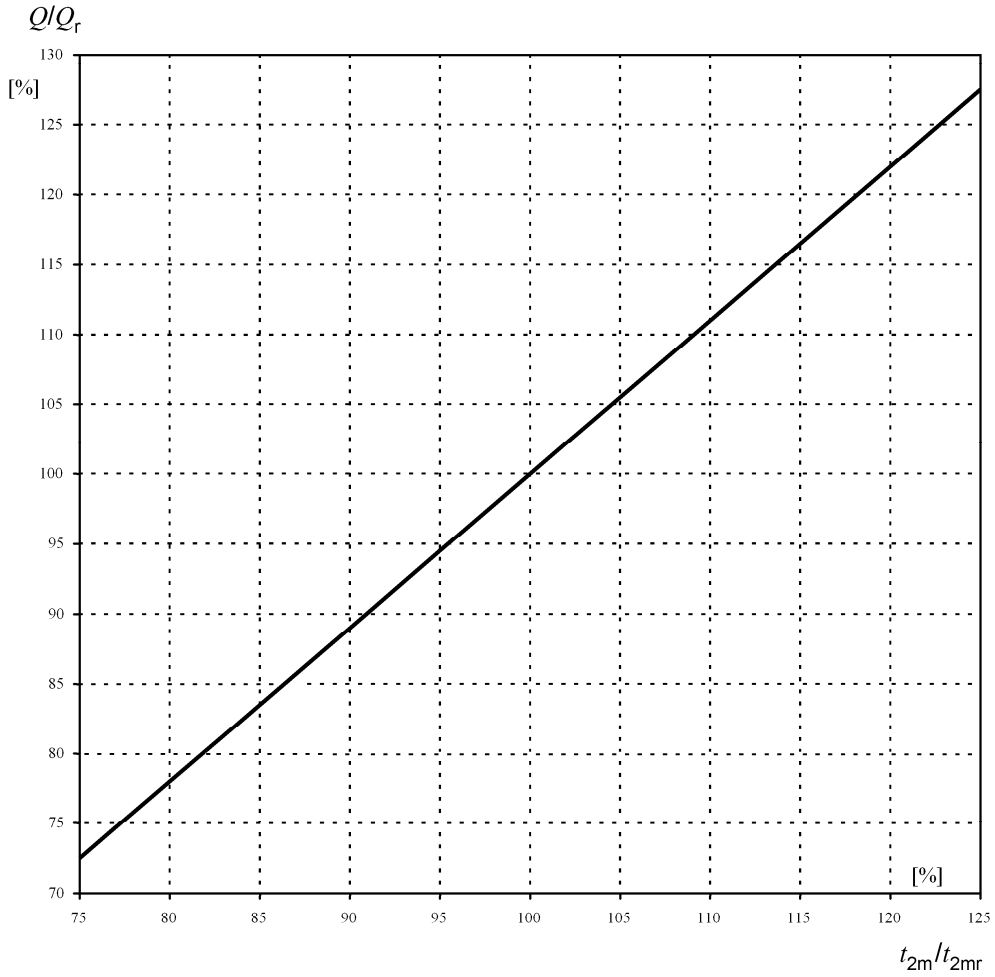


Figure B.2 – Variation of cooling capacity as function of average oil temperature rise

The conversion covers the range of ± 25 % (corresponding to roughly ± 10 K).

B.3 Variation of cooling capacity for modified flow quantities

B.3.1 Variation of cooling capacity as function of air flow quantity

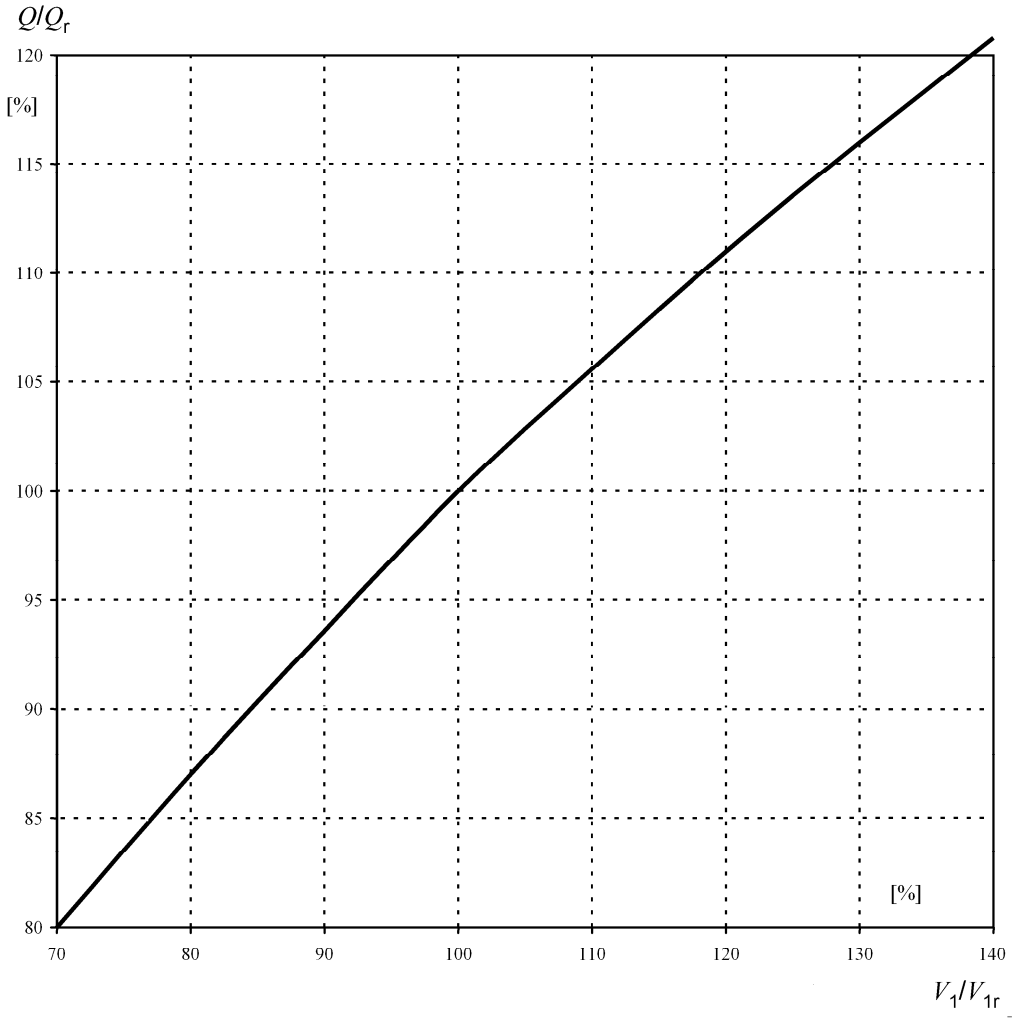


Figure B.3 – Variation of cooling capacity as function of air flow quantity

Oil flow quantity and temperatures for oil inlet and outlet remain constant, air side pressure drop and temperature of air at outlet change.

B.3.2 Variation of cooling capacity as function of oil flow quantity

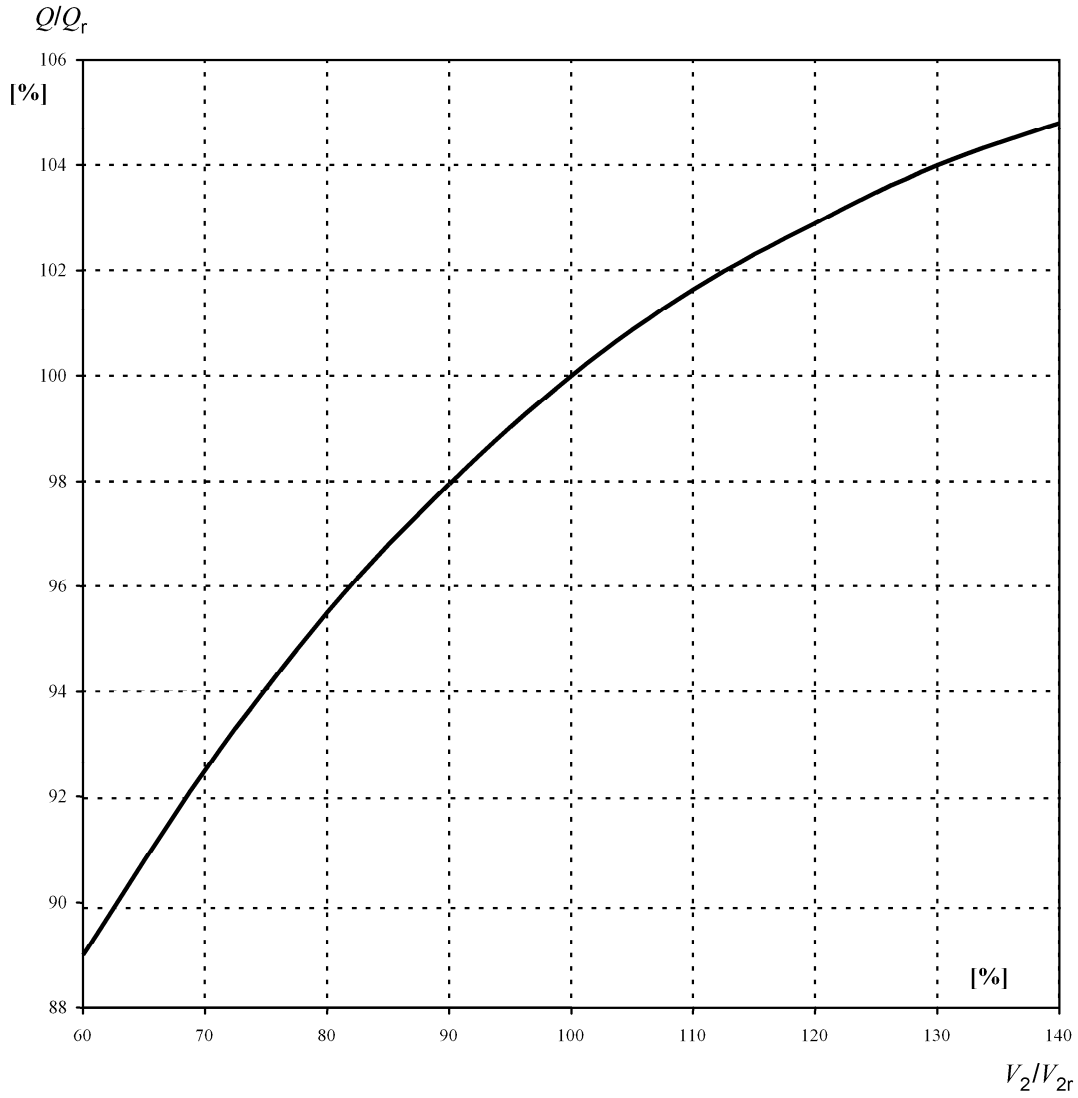


Figure B.4 – Variation of cooling capacity as function of oil flow quantity

Air flow quantity remains constant as well as air temperature at inlet and outlet and average oil temperature difference. Oil side pressure drop and oil temperature at inlet and outlet are changed.

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