IEC 60287-2-1

Edition 2.0 2015-04

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Electric cables – Calculation of the current rating –
Part 2-1: Thermal resistance – Calculation of thermal resistance

Câbles électriques – Calcul du courant admissible –
Partie 2-1: Résistance thermique – Calcul de la résistance thermique

IEC 60287-2-1:2015-04(en-fr)

IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00
info@iec.ch
www.iec.ch

About the IEC
The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications
The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigenda or an amendment might have been published.

IEC Catalogue - webstore.iec.ch/catalogue
The stand-alone application for consulting the entire bibliographical information on IEC International Standards, Technical Specifications, Technical Reports and other documents. Available for PC, Mac OS, Android Tablets and iPad.

IEC publications search - www.iec.ch/searchpub
The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee,…). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished
Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and also once a month by email.

Electropedia - www.electropedia.org
The world's leading online dictionary of electronic and electrical terms containing more than 30 000 terms and definitions in English and French, with equivalent terms in 15 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC Glossary - std.iec.ch/glossary
More than 60 000 electrotechnical terminology entries in English and French extracted from the Terms and Definitions clause of IEC publications issued since 2002. Some entries have been collected from earlier publications of IEC TC 37, 77, 86 and CISPR.

IEC Customer Service Centre - webstore.iec.ch/csc
If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: csc@iec.ch.

A propos de l'IEC
La Commission Electrotechnique Internationale (IEC) est la première organisation mondiale qui élabore et publie des Normes internationales pour tout ce qui a trait à l'électricité, à l'électronique et aux technologies apparentées.

A propos des publications IEC
Le contenu technique des publications IEC est constamment revu. Veuillez vous assurer que vous possédez l'édition la plus récente, un corrigendum ou amendement peut avoir été publié.

Catalogue IEC - webstore.iec.ch/catalogue
Application autonome pour consulter tous les renseignements bibliographiques sur les Normes internationales, Spécifications techniques, Rapports techniques et autres documents de l'IEC. Disponible pour PC, Mac OS, tablettes Android et iPad.

Recherche de publications IEC - www.iec.ch/searchpub
La recherche avancée permet de trouver des publications IEC en utilisant différents critères (numéro de référence, texte, comité d'études,…). Elle donne aussi des informations sur les projets et les publications remplacées ou retirées.

IEC Just Published - webstore.iec.ch/justpublished
Restez informé sur les nouvelles publications IEC. Just Published détaille les nouvelles publications parues. Disponible en ligne et aussi une fois par mois par email.

Electropedia - www.electropedia.org
Le premier dictionnaire en ligne de termes électroniques et électriques. Il contient plus de 30 000 termes et définitions en anglais et en français, ainsi que les termes équivalents dans 15 langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International (IEV) en ligne.

Glossaire IEC - std.iec.ch/glossary
Plus de 60 000 entrées terminologiques électrotechniques, en anglais et en français, extraites des articles Termes et Définitions des publications IEC parues depuis 2002. Plus certaines entrées antérieures extraites des publications des CE 37, 77, 86 et CISPR de l'IEC.

Service Clients - webstore.iec.ch/csc
Si vous désirez nous donner des commentaires sur cette publication ou si vous avez des questions contactez-nous: csc@iec.ch.

IEC 60287-2-1

Edition 2.0 2015-04

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Electric cables – Calculation of the current rating –
Part 2-1: Thermal resistance – Calculation of thermal resistance

Câbles électriques – Calcul du courant admissible –
Partie 2-1: Résistance thermique – Calcul de la résistance thermique

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

ICS 29.060.20 ISBN 978-2-8322-2583-7

Warning! Make sure that you obtained this publication from an authorized distributor.
Attention! Veuillez vous assurer que vous avez obtenu cette publication via un distributeur agréé.

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

____

ELECTRIC CABLES – CALCULATION OF THE CURRENT RATING –

Part 2-1: Thermal resistance – Calculation of thermal resistance

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
6) All users should ensure that they have the latest edition of this publication.
7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

International Standard IEC 60287-2-1 has been prepared by IEC technical committee 20: Electric cables.

This second edition of IEC 60287-2-1 cancels and replaces the first edition, published in 1994, Amendment 1:2001, Amendment 2:2006 and Corrigendum 1:2008. The document 20/1448/CDV, circulated to the National Committees as Amendment 3, led to the publication of this new edition. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) inclusion of a reference to the use of finite element methods where analytical methods are not available for the calculation of external thermal resistance;
b) explanation about SL and SA type cables;

c) calculation method for T3 for unarmoured three-core cables with extruded insulation and individual copper tape screens on each core;

d) change of condition for X in 5.4;

e) inclusion of constants or installation conditions for water filled ducts in Table 4.

The text of this standard is based on the following documents:

FDIS	Report on voting
20/1561/FDIS	20/1588/RVD

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

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

A list of all parts in the IEC 60287 series, published under the general title *Electric cables – Calculation of the current rating*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

INTRODUCTION

IEC 60287 has been divided into three parts so that revisions of, and additions to the document can be carried out more conveniently.

Each part is subdivided into subparts which are published as separate standards.

Part 1: Formulae of ratings and power losses

Part 2: Formulae for thermal resistance

Part 3: Operating conditions

This part of IEC 60287-2 contains methods for calculating the internal thermal resistance of cables and the external thermal resistance for cables laid in free air, ducts and buried.

The formulae in this standard contain quantities which vary with cable design and materials used. The values given in the tables are either internationally agreed, for example, electrical resistivities and resistance temperature coefficients, or are those which are generally accepted in practice, for example, thermal resistivities and permittivities of materials. In this latter category, some of the values given are not characteristic of the quality of new cables but are considered to apply to cables after a long period of use. In order that uniform and comparable results may be obtained, the current ratings should be calculated with the values given in this standard. However, where it is known with certainty that other values are more appropriate to the materials and design, then these may be used, and the corresponding current rating declared in addition, provided that the different values are quoted.

Quantities related to the operating conditions of cables are liable to vary considerably from one country to another. For instance, with respect to the ambient temperature and soil thermal resistivity, the values are governed in various countries by different considerations. Superficial comparisons between the values used in the various countries may lead to erroneous conclusions if they are not based on common criteria: for example, there may be different expectations for the life of the cables, and in some countries design is based on maximum values of soil thermal resistivity, whereas in others average values are used. Particularly, in the case of soil thermal resistivity, it is well known that this quantity is very sensitive to soil moisture content and may vary significantly with time, depending on the soil type, the topographical and meteorological conditions, and the cable loading.

The following procedure for choosing the values for the various parameters should, therefore, be adopted:

Numerical values should preferably be based on results of suitable measurements. Often such results are already included in national specifications as recommended values, so that the calculation may be based on these values generally used in the country in question; a survey of such values is given in IEC 60287-3-1.

A suggested list of the information required to select the appropriate type of cable is given in IEC 60287-3-1.

ELECTRIC CABLES – CALCULATION OF THE CURRENT RATING –

Part 2-1: Thermal resistance – Calculation of thermal resistance

1 Scope

This part of IEC 60287 is solely applicable to the conditions of steady-state operation of cables at all alternating voltages, and direct voltages up to 5 kV, buried directly in the ground, in ducts, in troughs or in steel pipes, both with and without partial drying-out of the soil, as well as cables in air. The term "steady state" is intended to mean a continuous constant current (100 % load factor) just sufficient to produce asymptotically the maximum conductor temperature, the surrounding ambient conditions being assumed constant.

This part of IEC 60287 provides formulae for thermal resistance.

The formulae given are essentially literal and designedly leave open the selection of certain important parameters. These may be divided into three groups:

– parameters related to construction of a cable (for example, thermal resistivity of insulating material) for which representative values have been selected based on published work;
– parameters related to the surrounding conditions which may vary widely, the selection of which depends on the country in which the cables are used or are to be used;
– parameters which result from an agreement between manufacturer and user and which involve a margin for security of service (for example, maximum conductor temperature).

Equations given in this part of IEC 60287 for calculating the external thermal resistance of a cable buried directly in the ground or in a buried duct are for a limited number of installation conditions. Where analytical methods are not available for calculation of external thermal resistance finite element methods may be used. Guidance on the use of finite element methods for calculating cable current ratings is given in IEC TR 62095.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60287-1-1:2006, *Electric cables – Calculation of the current rating – Part 1-1: Current rating equations (100 % load factor) and calculation of losses – General*
IEC 60287-1-1:2006/AMD1:2014

IEC 60853-2, *Calculation of the cyclic and emergency current rating of cables – Part 2: Cyclic rating of cables greater than 18/30 (36) kV and emergency ratings for cables of all voltages*

3 Symbols

The symbols used in this part of IEC 60287 and the quantities which they represent are given in the following list:

D'_a	external diameter of armour	mm
D_d	internal diameter of duct	mm
D_e	external diameter of cable, or equivalent diameter of a group of cores in pipe-type cable	mm
D_e^*	external diameter of cable (used in 4.2.1)	m
D_o	external diameter of duct	mm
D_s	external diameter of metal sheath	mm
D_{oc}	the diameter of the imaginary coaxial cylinder which just touches the crests of a corrugated sheath	mm
D_{ot}	the diameter of the imaginary coaxial cylinder which would just touch the outside surface of the troughs of a corrugated sheath = $D_{it} + 2t_s$	mm
D_{ic}	the diameter of the imaginary cylinder which would just touch the inside surface of the crests of a corrugated sheath = $D_{oc} - 2t_s$	mm
D_{it}	the diameter of the imaginary cylinder which just touches the inside surface of the troughs of a corrugated sheath	mm
E	constant used in 4.2.1.1	
F_1	coefficient for belted cables defined in 4.1.2.2.3	
F_2	coefficient for belted cables defined in 4.1.2.2.6	
G	geometric factor for belted cables	
$\overline{G}$	geometric factor for SL and SA type cables	
H	intensity of solar radiation (see 4.2.1.2)	W/m^2
K	screening factor for the thermal resistance of screened cables	
K_A	coefficient used in 4.2.1	
L	depth of laying, to cable axis or centre of trefoil	mm
L_G	distance from the soil surface to the centre of a duct bank	mm
N	number of loaded cables in a duct bank (see 4.2.7.4)	
T_1	thermal resistance per core between conductor and sheath	K·m/W
T_2	thermal resistance between sheath and armour	K·m/W
T_3	thermal resistance of external serving	K·m/W
T_4	thermal resistance of surrounding medium (ratio of cable surface temperature rise above ambient to the losses per unit length)	K·m/W
T_4^*	external thermal resistance in free air, adjusted for solar radiation	K·m/W
T'_4	thermal resistance between cable and duct (or pipe)	K·m/W
T''_4	thermal resistance of the duct (or pipe)	K·m/W
T'''_4	thermal resistance of the medium surrounding the duct (or pipe)	K·m/W
U	constant used in 4.2.7.2	
V	constant used in 4.2.7.2	
W_d	dielectric losses per unit length per phase	W/m
W_k	losses dissipated by cable k	W/m
W_{TOT}	total power dissipated in the trough per unit length	W/m
Y	coefficient used in 4.2.7.2	
Z	coefficient used in 4.2.1.1	

d_a	external diameter of belt insulation	mm
d_c	external diameter of conductor	mm
d_{cm}	minor diameter of an oval conductor	mm
d_{cM}	major diameter of an oval conductor	mm
d_M	major diameter of screen or sheath of an oval conductor	mm
d_m	minor diameter of screen or sheath of an oval conductor	mm
d_x	diameter of an equivalent circular conductor having the same cross-sectional area and degree of compactness as the shaped one	mm
g	coefficient used in 4.2.1.1	
h	heat dissipation coefficient	$W/m^2K^{5/4}$
ln	natural logarithm (logarithm to base e)	
n	number of conductors in a cable	
p	the part of the perimeter of the cable trough which is effective for heat dissipation (see 4.2.6.2)	m
r_1	circumscribing radius of two or three-sector shaped conductors	mm
s_1	axial separation of two adjacent cables in a horizontal group of three, not touching	mm
t	insulation thickness between conductors	mm
t_1	insulation thickness between conductors and sheath	mm
t_2	thickness of the bedding	mm
t_3	thickness of the serving	mm
t_i	thickness of core insulation, including screening tapes plus half the thickness of any non-metallic tapes over the laid up cores	mm
t_s	thickness of the sheath	mm
u	$\frac{2L}{D_e}$ in 4.2.	
u	$\frac{L_G}{r_b}$ in 4.2.7.4	
x, y	sides of duct bank ($y>x$) (see 4.2.7.4)	mm
θ_m	mean temperature of medium between a cable and duct or pipe	°C
$\Delta\theta$	permissible temperature rise of conductor above ambient temperature	K
$\Delta\theta_d$	factor to account for dielectric loss for calculating T_4 for cables in free air	K
$\Delta\theta_{ds}$	factor to account for both dielectric loss and direct solar radiation for calculating T_4^* for cables in free air using Figure 10	K
$\Delta\theta_{duct}$	difference between the mean temperature of air in a duct and ambient temperature	K
$\Delta\theta_s$	difference between the surface temperature of a cable in air and ambient temperature	K
$\Delta\theta_{tr}$	temperature rise of the air in a cable trough	K
λ_1, λ_2	ratio of the total losses in metallic sheaths and armour respectively to the total conductor losses (or losses in one sheath or armour to the losses in one conductor)	

λ'_{1m}	loss factor for the middle cable	Three cables in flat formation without transposition, with sheaths bonded at both ends
λ'_{11}	loss factor for the outer cable with the greater losses	
λ'_{12}	loss factor for the outer cable with the least losses	

ρ_i	thermal resistivity of the insulation	K·m/W
ρ_f	thermal resistivity of the filler material	K·m/W
ρ_e	thermal resistivity of earth surrounding a duct bank	K·m/W
ρ_c	thermal resistivity of concrete used for a duct bank	K·m/W
ρ_m	thermal resistivity of metallic screens on multicore cables	K·m/W
ρ_T	thermal resistivity of material	K·m/W
σ	absorption coefficient of solar radiation for the cable surface	

4 Calculation of thermal resistances

4.1 Thermal resistance of the constituent parts of a cable, T_1, T_2 and T_3

4.1.1 General

Clause 4 gives the formulae for calculating the thermal resistances per unit length of the different parts of the cable T_1, T_2 and T_3 (see 1.4 of IEC 60287-1-1:2006 and IEC 60287-1-1:2006/AMD1:2014). The thermal resistivities of materials used for insulation and for protective coverings are given in Table 1.

Where screening layers are present, for thermal calculations metallic tapes are considered to be part of the conductor or sheath while semi-conducting layers (including metallized carbon paper tapes) are considered as part of the insulation. The appropriate component dimensions shall be modified accordingly.

4.1.2 Thermal resistance between one conductor and sheath T_1

4.1.2.1 Single-core cables

The thermal resistance between one conductor and the sheath T_1 is given by:

$$T_1 = \frac{\rho_T}{2\pi} \ln\left[1 + \frac{2\,t_1}{d_c}\right]$$

where

ρ_T is the thermal resistivity of insulation (K·m/W);

d_c is the diameter of conductor (mm);

t_1 is the thickness of insulation between conductor and sheath mm).

NOTE For corrugated sheaths, t_1 is based on the mean internal diameter of the sheath which is given by:

$$\left(\frac{D_{it} + D_{oc}}{2}\right) - t_s$$

4.1.2.2 Belted cables

4.1.2.2.1 General

The thermal resistance T_1 between one conductor and sheath is given by:

$$T_1 = \frac{\rho_T}{2\pi} G$$

where

G is the geometric factor

NOTE For corrugated sheaths, t_1 is based on the mean internal diameter of the sheath which is given by:

$$\left(\frac{D_{it} + D_{oc}}{2}\right) - t_s$$

4.1.2.2.2 Two-core belted cables with circular conductors

The geometric factor G is given in Figure 2.

4.1.2.2.3 Two-core belted cables with sector-shaped conductors

The geometric factor G is given by:

$$G = 2\,F_1 \ln\left[\frac{d_a}{2\,r_1}\right]$$

where

$$F_1 = 1 + \frac{2{,}2\,t}{2\pi\,(d_x + t) - t}$$

d_a is the external diameter of the belt insulation (mm);

r_1 is the radius of the circle circumscribing the conductors (mm);

d_x is the diameter of a circular conductor having the same cross-sectional area and degree of compaction as the shaped one (mm);

t is the insulation thickness between conductors (mm).

4.1.2.2.4 Three-core belted cables with circular conductors

For three-core belted cables with circular conductors

$$T_1 = \frac{\rho_i}{2\pi} G + 0{,}031(\rho_f - \rho_i)e^{0{,}67\frac{t_1}{d_c}}$$

where

ρ_i is the thermal resistivity of the insulation (K·m/W);

ρ_f is the thermal resistivity of the filler material (K·m/W).

The geometric factor G is given in Figure 3.

NOTE For paper-insulated cables $\rho_f = \rho_i$ and, hence, the second term on the right hand side of the above equation can be ignored.

For cables with extruded insulation, the thermal resistivity of the filler material is likely to be between 6 K·m/W and 13 K·m/W, depending on the filler material and its compaction. A value of 10 K·m/W is suggested for fibrous polypropylene fillers.

The above equation is applicable to cables with extruded insulation where each core has an individual screen of spaced wires and to cables with a common metallic screen over all three cores. For unarmoured cables of this design t_1 is taken to be the thickness of the material between the conductors and outer covering (serving).

4.1.2.2.5 Three-core belted cables with oval conductors

The cable shall be treated as an equivalent circular conductor cable with an equivalent diameter $d_c = \sqrt{d_{cM} \times d_{cm}}$ (mm)

where

d_{cM} is the major diameter of the oval conductor (mm);

d_{cm} is the minor diameter of the oval conductor (mm).

4.1.2.2.6 Three-core belted cables with sector-shaped conductors

The geometric factor G for these cables depends on the shape of the sectors, which varies from one manufacturer to another. A suitable formula is:

$$G = 3 F_2 \ln\left[\frac{d_a}{2 r_1}\right]$$

where

$$F_2 = 1 + \frac{3t}{2\pi (d_x + t) - t}$$

d_a is the external diameter of the belt insulation (mm);

r_1 is the radius of the circle circumscribing the conductors (mm);

d_x is the diameter of a circular conductor having the same cross-sectional area and degree of compaction as the shaped one (mm);

t is the insulation thickness between conductors (mm).

4.1.2.3 Three-core cables, metal tape screened type

4.1.2.3.1 Screened cables with circular conductors

Paper insulated of this type may be first considered as belted cables for which $\frac{t_1}{t}$ is 0,5. Then, in order to take account of the thermal conductivity of the metallic screens, the result shall be multiplied by a factor K, called the screening factor, which is given in Figure 4 for different values of $\frac{t_1}{d_c}$ and different cable specifications.

Thus:

$$T_1 = K \frac{\rho_T}{2\pi} G$$

Three-core cables with extruded insulation and individual copper tape screens on each core should be treated as SL type cables (see 4.1.2.5 and 4.1.3.2).

See 4.1.2.2.4 for three-core cables with extruded insulation and an individual screen of spaced copper wires on each core or a common metallic screen over all three cores.

4.1.2.3.2 Screened cables with oval-shaped conductors

The cable shall be treated as an equivalent circular conductor cable with an equivalent diameter $d_c = \sqrt{d_{cM} \cdot d_{cm}}$.

4.1.2.3.3 Screened cables with sector-shaped conductors

T_1 is calculated for these cables in the same way as for belted cables with sector-shaped conductors, but d_a is taken as the diameter of a circle which circumscribes the core assembly. The result is multiplied by a screening factor given in Figure 5.

4.1.2.4 Oil-filled cables

4.1.2.4.1 Three-core cables with circular conductors and metallized paper core screens and circular oil ducts between the cores

The thermal resistance between one conductor and the sheath T_1 is given by:

$$T_1 = 0{,}385 \rho_T \left(\frac{2\, t_i}{d_c + 2\, t_i} \right)$$

where

d_c is the conductor diameter (mm);

t_i is the thickness of core insulation including carbon black and metallized paper tapes plus half of any non-metallic tapes over the three laid up cores (mm);

ρ_T is the thermal resistivity of insulation (K·m/W).

This formula assumes that the space occupied by the metal ducts and the oil inside them has a thermal conductance very high compared with the insulation, it therefore applies irrespective of the metal used to form the duct or its thickness.

4.1.2.4.2 Three-core cables with circular conductors and metal tape core screens and circular oil ducts between the cores

The thermal resistance T_1 between one conductor and the sheath is given by:

$$T_1 = 0{,}35 \rho_T \left(0{,}923 - \frac{d_c}{d_c + 2\, t_i} \right)$$

where

t_i is the thickness of core insulation including the metal screening tapes and half on any non-metallic tapes over the three laid up cores (mm).

NOTE This formula is independent of the metals used for the screens and for the oil ducts.

4.1.2.4.3 Three-core cables with circular conductors, metal tape core screens, without fillers and oil ducts, having a copper woven fabric tape binding the cores together and a corrugated aluminium sheath

The thermal resistance T_1 between one conductor and the sheath is given by:

$$T_1 = \frac{475}{D_c^{1{,}74}} \left[\frac{t_g}{D_c} \right]^{0{,}62} + \frac{\rho_T}{2\pi} \ln \left(\frac{d_c - 2\,\delta_1}{d_c} \right)$$

where

$$t_g = 0{,}5 \left(\left[\frac{D_{it} + D_{ic}}{2} \right] - 2{,}16\, D_c \right)$$

D_c is the diameter of a core over its metallic screen tapes (mm);