ETSI TS 103 586 V1.1.1 (2019-04)

TECHNICAL SPECIFICATION

Environmental Engineering (EE); Liquid cooling solutions for Information and Communication Technology (ICT) infrastructure equipment

Reference
DTS/EE-0166

Keywords
cooling capacity, energy efficiency

ETSI

650 Route des Lucioles
F-06921 Sophia Antipolis Cedex - FRANCE

Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Siret N° 348 623 562 00017 - NAF 742 C
Association à but non lucratif enregistrée à la
Sous-Préfecture de Grasse (06) N° 7803/88

Important notice

The present document can be downloaded from:
http://www.etsi.org/standards-search

The present document may be made available in electronic versions and/or in print. The content of any electronic and/or print versions of the present document shall not be modified without the prior written authorization of ETSI. In case of any existing or perceived difference in contents between such versions and/or in print, the prevailing version of an ETSI deliverable is the one made publicly available in PDF format at www.etsi.org/deliver.

Users of the present document should be aware that the document may be subject to revision or change of status. Information on the current status of this and other ETSI documents is available at https://portal.etsi.org/TB/ETSIDeliverableStatus.aspx

If you find errors in the present document, please send your comment to one of the following services:
https://portal.etsi.org/People/CommiteeSupportStaff.aspx

Contents

Intellectual Property Rights 4

Foreword 4

Modal verbs terminology 4

Introduction 4

1 Scope 5

2 References 5
2.1 Normative references 5
2.2 Informative references 6

3 Definition of terms, symbols and abbreviations 6
3.1 Terms 6
3.2 Symbols 7
3.3 Abbreviations 7

4 ICT equipment liquid cooling requirements and energy efficiency 7
4.1 Introduction 7
4.2 Cooling requirements for equipment 7
4.3 Liquid cooled equipment energy efficiency 8

5 Specifications for liquid cooling solutions 8
5.1 General requirements 8
5.2 Liquid flow rate range vs. dissipated power 9
5.3 Temperature of touchable parts 9
5.4 Max pressure drop per liquid flow rate 9
5.5 Max pressure drop per air flow rate 9
5.6 Pipe threads 9
5.7 Coolants and cooling distribution units 9
5.8 Max pressure and tightness 9
5.9 Liquid connectors positions 9
5.10 Accessibility in case of cooling with heat exchanger 10

6 Benchmark methods to evaluate cooling system efficiency and energy efficiency 10

Annex A (informative): Cooling principles and impact on reliability and energy consumption 12

A.1 Air cooling principles and limitations 12

A.2 Reliability issues 13

A.3 Energy consumption 13

A.4 Heat reuse possibilities 14

Annex B (informative): Cooling implementation options 15

B.1 Example of liquid cooling at the cabinet level 15

B.2 Example of liquid cooling at the component level 18

B.3 Example of liquid cooling by immersion 20

B.4 Example of topology of the cooling distribution at the room and building level 21

History 23

Intellectual Property Rights

Essential patents

IPRs essential or potentially essential to normative deliverables may have been declared to ETSI. The information pertaining to these essential IPRs, if any, is publicly available for **ETSI members and non-members**, and can be found in ETSI SR 000 314: *"Intellectual Property Rights (IPRs); Essential, or potentially Essential, IPRs notified to ETSI in respect of ETSI standards"*, which is available from the ETSI Secretariat. Latest updates are available on the ETSI Web server (https://ipr.etsi.org/).

Pursuant to the ETSI IPR Policy, no investigation, including IPR searches, has been carried out by ETSI. No guarantee can be given as to the existence of other IPRs not referenced in ETSI SR 000 314 (or the updates on the ETSI Web server) which are, or may be, or may become, essential to the present document.

Trademarks

The present document may include trademarks and/or tradenames which are asserted and/or registered by their owners. ETSI claims no ownership of these except for any which are indicated as being the property of ETSI, and conveys no right to use or reproduce any trademark and/or tradename. Mention of those trademarks in the present document does not constitute an endorsement by ETSI of products, services or organizations associated with those trademarks.

Foreword

This Technical Specification (TS) has been produced by ETSI Technical Committee Environmental Engineering (EE).

Modal verbs terminology

In the present document "**shall**", "**shall not**", "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the ETSI Drafting Rules (Verbal forms for the expression of provisions).

"**must**" and "**must not**" are **NOT** allowed in ETSI deliverables except when used in direct citation.

Introduction

Electrical energy supplied to ICT equipment, and more generally to electronic equipment, is nearly totally converted into heat by resistive losses, leading to temperature increase of the equipment itself and its surrounding environment. Except for very low power (ICT end-user equipment), ICT equipment should be cooled to ensure reliable operation and an acceptable lifetime. Air-cooling is up to now dominating in the telecommunication industry. ETSI EN 300 019 series [i.2] specify environmental conditions for different types of locations, to ensure proper operation of air cooled telecommunication equipment.

With the emergence of high density racks and cabinets, thermal loads above 7 kW become widely used while density increase remains on-going. These high loads cabinets lead also to thermal management issues at the room level. More than ever, separation of hot and cold aisles is necessary and moreover, prevention of hot spots when high and medium or low loads are mixed in the same room is hard to achieve.

Liquid cooling solutions provide opportunities to solve efficiently these problems and to reduce significantly cooling energy consumption and, thus, overall ICT energy consumption. Moreover, such technologies can lead to improved temperature control at the component level and consequently, better reliability. Thanks to higher cooling capacity, ICT equipment can be more compact leading thus, to space savings. At last, heat reuse can be also considered with very high efficiency optimizing this way, ICT energy efficiency.

1 Scope

The present document covers following applications:

- Liquid cooling at the cabinet/rack level.
- Liquid cooling at the product level.
- Liquid cooling via immersion in dielectric liquid.

The present document specifies the following items:

- Liquid circulation layout (connection of multiple units).
- Liquid flow rate range vs. dissipated power.
- Max pressure drop per liquid flow rate.
- Max pressure drop per air flow rate.
- External pipe diameter range and pipe threads.
- Valves requirements.
- Coolants and cooling distribution unites.
- Max pressure and tightness.

Furthermore, the present document provides:

- Benchmark methods to evaluated different cooling system efficiency.

2 References

2.1 Normative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

Referenced documents which are not found to be publicly available in the expected location might be found at https://docbox.etsi.org/Reference/.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

The following referenced documents are necessary for the application of the present document.

[1] ETSI EN 300 019-1-3 (V2.4.1): "Environmental Engineering (EE); Environmental conditions and environmental tests for telecommunications equipment; Part 1-3: Classification of environmental conditions; Stationary use at weatherprotected locations".

[2] ETSI EN 300 019-1-4 (V2.2.1): "Environmental Engineering (EE); Environmental conditions and environmental tests for telecommunications equipment; Part 1-4: Classification of environmental conditions; Stationary use at non-weatherprotected locations".

[3] ISO 228-1: "Pipe threads where pressure-tight joints are not made on the threads -- Part 1: Dimensions, tolerances and designation".

[4] BS EN 805:2000: "Water supply. Requirements for systems and components outside buildings".

NOTE: Available at https://shop.bsigroup.com/ProductDetail/?pid=000000000019983094.

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] CENELEC EN 60950-1: "Information technology equipment - Safety; Part 1: General requirements".

[i.2] ETSI EN 300 019 (all parts): "Environmental Engineering (EE); Environmental conditions and environmental tests for telecommunications equipment".

[i.3] IEC 62368-1: "Audio/video, information and communication technology equipment - Part 1: Safety requirements".

[i.4] ETSI ES 203 474 (V1.1.1): "Environmental Engineering (EE); Interfacing of renewable energy or distributed power sources to 400 VDC distribution systems powering Information and Communication Technology (ICT) equipment".

NOTE: Available at http://portal.etsi.org/webapp/ewp/copy_file.asp?wki_id=43366.

3 Definition of terms, symbols and abbreviations

3.1 Terms

For the purposes of the present document, the following terms apply:

cabinet: free-standing and self-supporting enclosure for housing electrical and/or electronic equipment

component: part or sub-part of an equipment that dissipates heat and needs to be cooled

Cooling Distribution Unit (CDU): unit used to separate or isolate the ICT equipment cooling loop from the facilities cooling loop, consisting of a liquid to liquid heat exchanger with at least one pump, temperature and pressure controls

cooling efficiency: ability of a given cooling system to lower equipment temperature towards the cooling fluid temperature

ICT equipment: information and communication equipment (e.g. switch, transmitter, router, server and peripheral devices) used in telecommunication centres, data-centres and customer premises (see ETSI ES 203 474 [i.4])

NOTE 1: It is integrated in a rack or cabinet

NOTE 2: If the liquid cooling system is provided by the supplier, it will be considered herein that this system is part of the ICT equipment. Thus, for an equipment with liquid cooling system at the component level (cold plate), the boundary of the ICT equipment will be the rack/cabinet. For an ICT equipment cooled by a rear door heat exchanger, the boundary of the ICT equipment will be the cabinet including the heat exchanger. For a system cooled by immersion, the boundary will be the tank and its control system.

heat exchanger: device used to transfer heat from one fluid to another liquid cooling system

NOTE: System that controls or influence the temperature if a liquid in order to use it to cool component or equipment or hot air issuing equipment.

pPUE: ratio between the energy consumption of the equipment plus the cooling system, divided by the energy consumption of the cooling system alone

rack: free-standing or fixed structure for housing electrical and/or electronic equipment

3.2 Symbols

For the purposes of the present document, the following symbols apply:

Cp	Specific heat (J/kg/°C)
dP	Pressure drop (Pa)
P	Electrical power consumed by the equipment (W)
Qm	Mass flow rate (kg/s)
Qv	Liquid volume flow rate (l/min)
ρ	Liquid density (kg/m^3)
T	Temperature (°C)
T_{amb}	Ambient Temperature surrounding the equipment (°C)
T_{ext}	External Temperature outside the building or outdoor cabinet (°C)
T_{in}	Temperature at the inlet of the liquid cooling system, at the main liquid connector of the equipment
T_{out}	Temperature at the outlet of the liquid cooling system, at the main liquid connector of the equipment
ΔT	Temperature difference (°C)

3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

CDU	Cooling Distribution Unit
CTE	Coefficient of thermal expansion
HEX	Heat exchanger
ICT	Information and Communication Technology
IT	Information technology
PCB	Printed circuit board
PUE	Power usage effectiveness

4 ICT equipment liquid cooling requirements and energy efficiency

4.1 Introduction

In the present clause, the liquid cooling requirements and energy efficiencies of equipment are defined.

4.2 Cooling requirements for equipment

Liquid cooled equipment for non-weather protected locations shall be compliant with ETSI EN 300 019-1-4 [2] and shall be compliant with any of the liquid inlet temperature class defined in table 1.

Liquid cooled equipment for weather protected locations shall be compliant with ETSI EN 300 019-1-3 [1] and shall be compliant with any of the liquid inlet temperature class defined in table 1.

Table 1: Classes defining liquid inlet temperature range and relevant minimum percentage of heat to water

Type of liquid cooling system	Liquid inlet temperature range	Minimum Percentage of heat to water
Rear door heat exchanger (A1)	+10 °C to +25 °C	80 %
Cold plate at the component level (A2)	+10 °C to +40°C	70 %
Immersion system (A3)	+10 °C to +50 °C	80 %

Liquid inlet temperature measurement $T_{liq\text{-}in}$ shall be considered at the position where operators shall provide liquid connection to the equipment.

Ratio of heat removed by liquid shall be computed with the following formula:

$$\text{Heat ratio} = Qm_{liq} \text{ x } Cp_{liq} \text{ x } (T_{liq\_out} - T_{liq\text{-}in}) \text{ / Total power dissipated by the equipment}$$

Liquid output temperature measurement $T_{liq\text{-}out}$ shall be considered at the position where operators provide connection for liquid return from the equipment.

If a CDU is provided, it shall be considered as a part of the equipment, and heat losses of this piece of equipment will be taken into account.

Liquid cooling at the cabinet level is a technology that can lead to class A1 cooling performances (example is described in clause B.1).

Liquid cooling at the component level is a technology that can lead to class A2 cooling performances (example is described in clause B.2).

Liquid cooling by immersion is a technology that can lead to class A3 cooling performances (example is described in clause B.3).

4.3 Liquid cooled equipment energy efficiency

Energy efficiency targets shall be measured in the following normal conditions:

- External (Outdoor) temperature T_{ext}=45 °C.
- Ambient (Room) temperature T_{amb} = 25 °C.

The equipment power consumption shall be considered at its maximal value.

The key indicator shall represent the impact of the cooling energy on the whole equipment energy consumption.

Partial PUE (Power Usage Effectiveness) can be used:

$$pPUE = \frac{\text{Equipment power consumption} + \text{Cooling energy consumption}}{\text{Equipment power consumption}}$$

Cooling energy consumption shall take into account internal elements required to cool the equipment in the above mentioned normal conditions (pumps, fans, control system).

Table 2: Energy efficiency classes

Cooling pPUE classes	pPUE
Class B1	≤ 1,01
Class B2	1,01 < pPUE ≤ 1,05
Class B3	1,05 < pPUE ≤ 1,10
Class B4	> 1,10

5 Specifications for liquid cooling solutions

5.1 General requirements

Liquid cooled equipment shall be compliant with ETSI EN 300 019-1-3 [1] or ETSI EN 300 019-1-4 [2] depending on their locations.

5.2 Liquid flow rate range vs. dissipated power

Liquid flow rate (in l/min) and dissipated power are linked by the following steady state power balance:

$$Q_V = (60\ 000 \times P) / (\rho \times Cp \times (T_{liq\_out} - T_{liq\text{-}in}))$$

5.3 Temperature of touchable parts

For safety purpose, the temperature of touchable part will be compliant with the applicable safety standards (e.g. CENELEC EN 60950-1 [i.1] or IEC 62368-1 [i.3]).

5.4 Max pressure drop per liquid flow rate

Pressure drop per liquid flow rate shall not be higher than:

$$dP_{liquid} = 25 \times Qv_{liquid}^2$$

Qv is the liquid volume flow rate expressed in l/min.

5.5 Max pressure drop per air flow rate

If the cooling system consists in transferring heat from air flow to liquid flow (examples in clause B.1), pressure drop per air flow rate shall not be higher than:

$$dP_{air} = 1{,}3 \times 10^{-6} \times Qv_{air}^2$$

Qv is the air volume flow rate expressed in l/min.

5.6 Pipe threads

If pipe threads are used, they shall be compliant with ISO 228-1 [3].

5.7 Coolants and cooling distribution units

If the equipment is cooled internally by another closed loop fluid than the liquid used at the room and building level (e.g. oil, low pressure two phase fluid, very pure water), the supplier shall provide CDU(s) with at least N+1 system-level pump redundancy to adapt to room where water cooling is available (where N is the number of pumps needed to provide the nominal total flow rate).

The liquid cooling system shall not create hazard in terms of product safety. For this scope the relevant ICT safety standards apply (e.g. IEC 62368-1 [i.3]). Liquid lifetime shall be at least 10 years, unless restrictions from National Regulation apply.

5.8 Max pressure and tightness

The equipment shall be tested at a pressure level of three times of the nominal pressure with the method described in BS EN 805 [4].

To ensure proper operation of the whole cooling system, commissioning shall be made at full load.

5.9 Liquid connectors positions

For equipment installed on raised floors, fluid connections shall be provided at the bottom of the rack/cabinet. For equipment installed on slab floors, fluid connections shall be provided at either the top or the bottom of the rack/cabinet.

5.10 Accessibility in case of cooling with heat exchanger

If the HEX is not a part of the cabinet, it shall be easily moved to gain access to equipment for servicing. If the HEX is a part of the cabinet (for example figure B.1c), it shall be easily removed or be mounted on a door to gain access to equipment for servicing.

6 Benchmark methods to evaluate cooling system efficiency and energy efficiency

To evaluate the cooling system, the equipment shall be installed in a climatic chamber with the ability to control the ambient temperature with ±1 °C accuracy.

The following instrumentation is required.

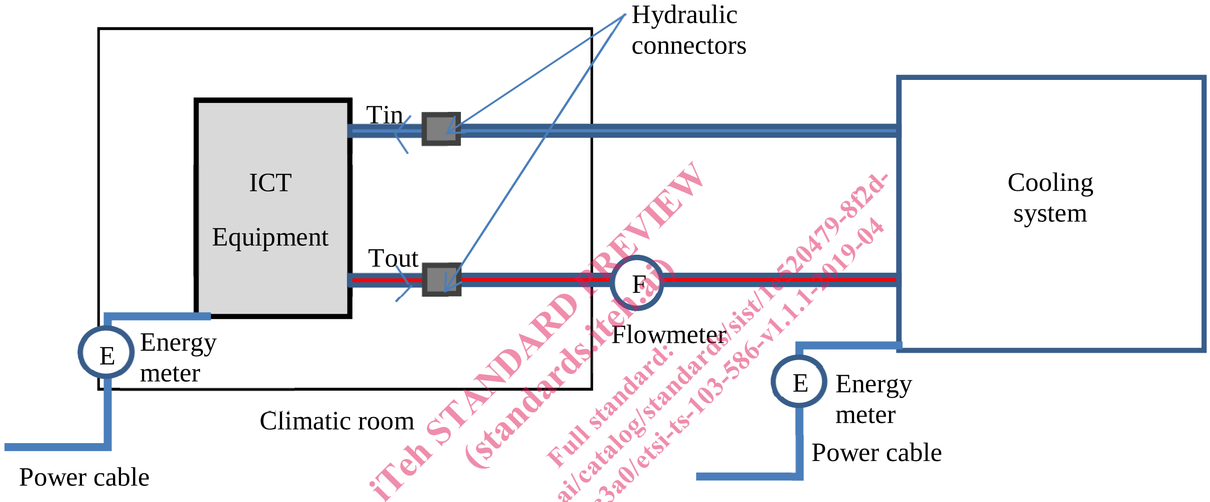

Figure 1: Experimental setup to evaluate energy efficiency

Power dissipation shall be computed in the following way.

Main power measurement shall be performed with an energy meter for AC, and voltmeter and ammeter for DC, measurements. Power values shall be based on supplier data if direct measurement is not possible. If the measured value is not steady, a mean value over 5 minutes shall be computed.

Temperature of the liquid shall be measured at the input and output with a calibrated thermocouple whose junction will be placed at the centre of the duct:

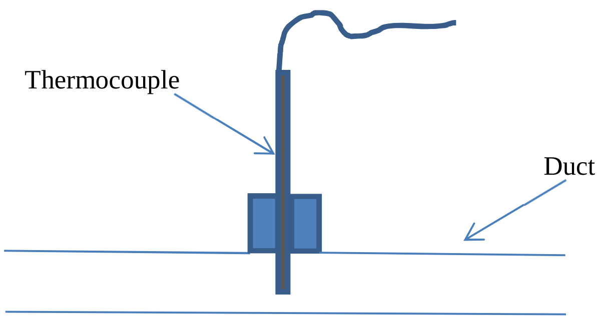

Figure 2: Liquid temperature measurement

A flow meter with 5 % accuracy shall be used.

Ducts shall be thermally insulated.