# Information paper on EN 15316-2-3 Heating systems in buildings Space heating distribution systems

**Laurent Socal**
Edilclima, Italy
**Johann Zirngibl**
CSTB, France

More information can be found at the CENSE project website: *www.iee-cense.eu*

Similar Information Papers on CENSE and/or other European projects can be found at the Buildings Platform website: *www.buildingsplatform.eu*

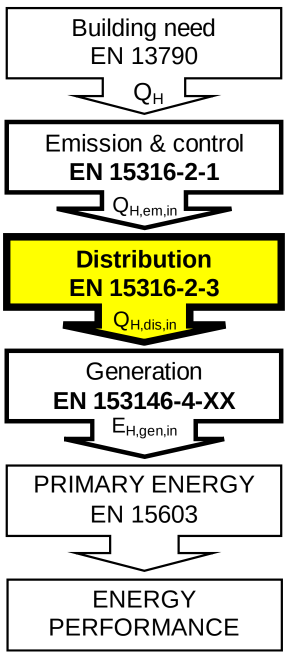


Figure 1:*The calculation of the distribution losses is the second step in the heating system Energy calculation*

Distribution subsystems look simple but underestimation of losses can give unexpected results. Distribution losses are affected not only by piping insulation but also by operating temperatures. High unexpected losses (up to 20%) usually occur in constant high temperature distribution schemes (most new centralized heating systems in Italy). In these cases very high insulation levels are necessary to prevent poor system performance. Also, when too little insulation is installed initially, any retrofit solution is tremendously expensive.

Also, the water distribution circuit type may affect generator performance. Experience has shown that a number of 'condensing generators do not condense at all (thus losing up to 10% efficiency) because of poor consideration of distribution circuits effect on water temperature.

Electric energy can also be a concern. A circulator of 100 W kept running 24/24 for 180 days in a 100 m² flat would use 10 kWh/m² (with a primary energy factor of 2,5)!

This paper gives a short introduction to the CEN standard EN 15316-2-3 for calculating heat losses and auxiliary energy needs from heating system distribution systems. It contains explanations of the calculation methods with details on the input and output data and links with other CEN standards.

The basis of the detailed method is simple physics but this standard defines a method to build sound correlations to simplify calculations in most common cases. Consideration is also given to operating temperatures, which are relevant to the performance of modern generation systems (heat pumps and condensing boilers).

The standard was approved at formal vote in May 2007.

EUROPEAN COMMISSION
Directorate-General for Energy and Transport

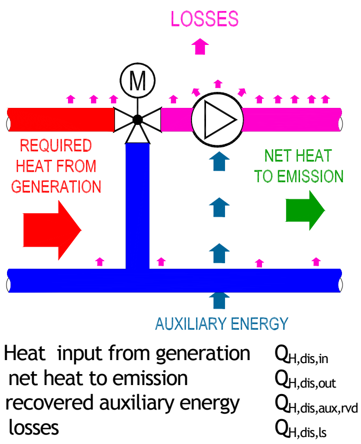


Figure 2: *Basic energy balance of the distribution subsystem*

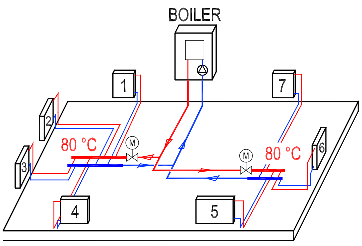


Figure 3: *Star (or parallel) distribution network with zones*

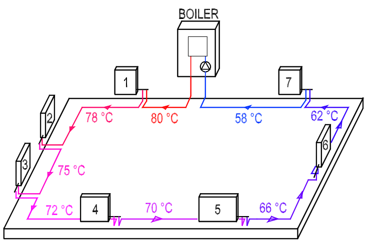


Figure 4: *Ring (or single-pipe or series) distribution network*

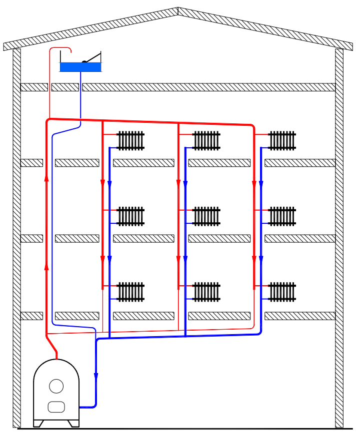

Figure 5: *Vertical shafts distribution network (typical of older buildings)*

## 1 > Scope of the standard

This standard gives both detailed and simplified methods for the calculation of heat losses and auxiliary energy needs of the distribution sub-system for heating. It is part of the EN 15316 series for the calculation of heating system energy requirements and system efficiencies.

The required heat output, $Q_{H,dis,out}$, is calculated according to the part of the standard dealing with heat emission and control (EN 15316-2-1) and forms an input to this standard.

Pipe sizing is not covered by this standard; its purpose is meant to calculate the in-use energy performance of a given heating system distribution network, either existing or as designed and sized.

This standard also includes a method (clause 8) to calculate water temperature (flow and return) within the distribution network at actual operating conditions. This is required for detailed calculation of losses as well as for performance calculation of boilers and heat pumps.

The domestic hot water distribution sub-system is treated in EN 15316-3-2, even though there are many common concepts.

This standard covers water based distribution networks. Heat losses from air ducts are covered in the ventilation standards: EN 15241 clause 6.3.2 and EN 15243 clause E.1.2.

## 2 > Principle of the methods

The detailed calculation of heat losses takes into account the following factors for each homogeneous pipe element:

- length of pipe element;
- conductivity and thickness of insulating layer;
- location (indoor, outdoor, underground, embedded within walls, etc.);
- internal (water) and external (surroundings) temperature;
- operation time.

This standard allows three levels of calculation of heat losses:

- detailed approach;
- detailed approach with simplified input;
- tabulated values.

The common input data is the heat required by the attached emission and control sub-system(s) $Q_{H,em,in}$.

Some losses can be towards the heated space and are therefore recoverable. This standard allows both explicit and implicit calculation of recovered heat losses:

- explicit calculation means that recoverable losses are given as an output of this calculation. These data are used, together with recoverable losses from other parts, to calculate actual recovered losses that reduce heating needs (see EN 15603).
- Implicit calculation means that recovered losses are taken into account as a reduction of losses within the distribution part. There is no data output for recoverable losses.

The auxiliary energy calculation starts from the mechanical energy need for water circulation, given by flow rate and total head loss. This information comes from the heating system design. The effect of the pump efficiency is taken into account by a series of correction factors accounting for the various influences on pump performance.

Three levels of auxiliary energy calculation are allowed: detailed, simplified and tabulated. The recovery of auxiliary energy, as heat, is taken into account, too.

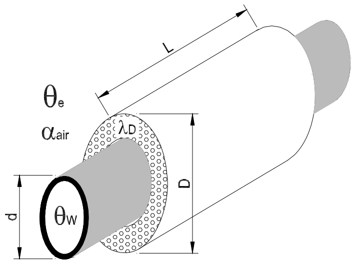


*Figure 6: Detailed approach for heat losses.*
*Parameters required to calculate heat losses of a pipe element:*
*L: length of element*
*d: pipe outer diameter*
*D: insulation outer diameter*
*$\lambda_D$: insulation conductivity*
*$\alpha_{air}$: external heat transfer coefficient*
*$\theta_W$: water temperature*
*θe: surrounding temperature*

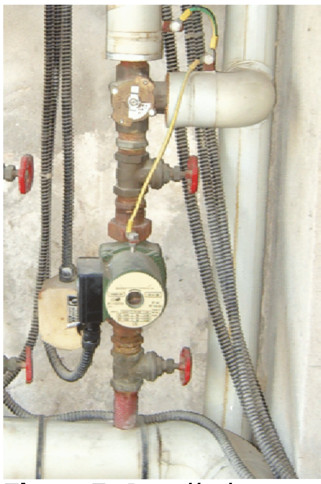

**Figure 7:** *Detailed approach. A non-insulated pipe is accounted for explicitly.*

The water temperature calculation is performed according to the following data:

- energy to be supplied to the heated space during the calculation interval;
- type of emitters (i.e. radiators, panels, etc.);
- type of emitter control (i.e. on/off, varying flow, varying temperature, etc.);
- type of hydraulic connection of emitters (i.e. direct connection, with mixing valve, with by-pass valve, etc.).

The common output data is

- heat required from the generation sub-system(s) $Q_{H,dis,in}$;
- auxiliary energy need for distribution $E_{H,dis,aux}$;
- recoverable losses, if not already accounted for as reduction of losses;
- flow and return temperature.

Annex A of the standard specifies how to generate simplified methodologies for calculation of distribution heat loss. An example of a complete calculation, using the simplified method, is given in clause A.5.

Specific input for detailed and simplified methods is detailed in the following paragraphs.

## 3 > Distribution heat losses

Distribution heat losses calculation is defined in clause 7 of EN 15316-2-3.

Detailed calculation method

The detailed calculation defined in clause 7.2 is the reference method.

The principle is to sum up all losses from pipe elements using basic physics formulae (see figure 6).

For each element the following data is needed:

- pipe length in m;
- linear thermal transmittance (loss factor) in W/(m·K)
- temperature of water inside the pipe in °C;
- surroundings temperature in °C.

The linear thermal transmittance of the pipe element has to be calculated according to clause 7.3 which requires knowledge of the following values: (see figure 6):

- pipe outer diameter in m;
- thickness of insulating layer in m;
- thermal conductivity of insulating layer in W/(m·K);
- external heat transfer coefficient in W/(m²·K).

For embedded or underground pipes, the following additional data are also required

- depth from ground surface in m;
- thermal conductivity of walls or ground in W/(m·K);
- distance between pipes running parallel to each other.

Any non-insulated piping element is also taken into account explicitly (see figure 7) as losses from non insulated pipes equals losses of 10 to 20 times longer insulated pipes.

Simplified method for heat loss calculation

The simplified method is defined in clause A.3 (see figures 8 and 9)

The basic idea is to use the detailed method with simplified input data:

- the distribution network is divided into three parts: horizontal distribution, vertical distribution and terminal connection pipes;

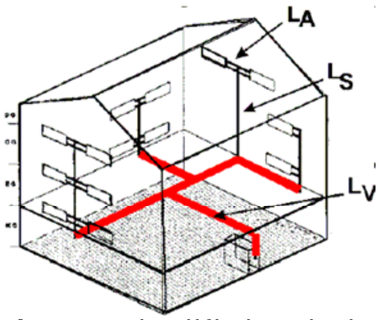


**Figure 8**: *Simplified method: Length of pipes in parts $L_A$, $L_S$ and $L_V$ are given through correlations with building dimensions.*

Table A.4 — Approximation of pipe lengths (two-pipe heating systems)

| Values | Result | Unit | Part V (from the generator to the shafts) | Part S (vertical shafts) | Part A (connection pipes) |
|---|---|---|---|---|---|
| Mean surrounding temperature | | °C | 13 respectively 20 | 20 | 20 |
| Pipe length in case of shafts in outside walls | L | m | $2 \cdot L_L + 0{,}01625 \cdot L_L \cdot L_W^2$ | $0{,}025 \cdot L_L \cdot L_W \cdot h_{ev} \cdot N_{ev}$ | $0{,}55 \cdot L_L \cdot L_W \cdot N_{ev}$ |
| Pipe length in case of shafts inside the building | L | m | $2 \cdot L_L + 0{,}0325 \cdot L_L \cdot L_W + 6$ | $0{,}025 \cdot L_L \cdot L_W \cdot h_{ev} \cdot N_{ev}$ | $0{,}55 \cdot L_L \cdot L_W \cdot N_{ev}$ |

**Figure 9:** *Simplified method: correlations between pipe length and building dimension.*

| $A_{h,z}$ [m²] | Generators with standard water volume | | |
|---|---|---|---|
| | Two-pipe-system with radiators Type of pump control: | | |
| | pump not controlled | dpconst | dpvariabel |
| 100 | 99 | 64 | 53 |
| 150 | 126 | 82 | 68 |
| 200 | 151 | 98 | 82 |
| 300 | 196 | 127 | 106 |
| 400 | 238 | 154 | 129 |
| 500 | 278 | 180 | 150 |
| 600 | 316 | 205 | 171 |
| 700 | 354 | 229 | 192 |
| 800 | 391 | 253 | 211 |
| 900 | 427 | 276 | 231 |
| 1 000 | 463 | 299 | 250 |

**Figure 10:** *Tabulated method for auxiliary energy need Auxiliary energy need in kWh/year is given:*

- *as a function of zone floor area (row)*
- *for 5000 heating hours per year*
- *according to pump control type (3 columns)*
- *according to distribution network typology (separate tables)*

- a total length for each part is estimated according to the floor area and the external dimensions of the building; the total estimated length is used instead of the individual element lengths;
- linear thermal transmittances are given in tables according to building age and type.

The correlations between building size and pipe length and the tables for linear thermal transmittances may be modified on a national basis to reflect local building practices and dates of changes to regulations.

Non-insulated elements may be taken into account with an equivalent length of (insulated) pipe.

Tabulated heat loss calculation

Distribution heat losses (kWh/year) are given in tables for each type of distribution system.

Values in the tables may be calculated at national level with the simplified or detailed method.

Great care must be given in specifying boundary conditions for such tables. Boundary conditions include:

- insulation levels;
- network topology;
- temperature levels;
- type of water circuit.

## 4 > Auxiliary energy demand

The distribution auxiliary energy calculation is defined in clause 6 of EN 15316-2-3.

**Detailed method**

The reference method is the detailed calculation procedure, which is defined in clause 6.3.

The calculation starts from the knowledge of flow rate and heat loss from which the mechanical energy required to circulate the water in the distribution circuit is calculated.

The effects of pump type, pump control mode, varying flow rate and the distribution network typology, according to varying heat requirements, are described by a series of multiplying factors:

- ß takes into account part-load operation of the heating system
- $f_S$, the correction factor for supply flow temperature control, takes into account the presence or absence of outdoor temperature compensation;
- $f_{NET}$ is the correction factor for hydraulic networks and differentiates between ring line, star type or vertical column network (see figures 3, 4 and 5);
- $f_{SD}$ takes into account any oversizing of the heat emitters;
- $f_{HB}$ takes into account any hydraulic unbalance;
- $f_{GPM}$ takes into account integrated management of the circulation pump within the heat generator;
- $f_n$ takes into account pump mechanical efficiency;
- $f_{PL}$ takes into account pump performance at part load;
- $f_{PSP}$ takes into account correct selection of the pump compared to the design requirement;
- $f_C$ takes into account the type of pump control.

Tabulated values, graphs, formulas and instructions to calculate all the required factors are given in clauses 6.3.4, 6.3.5 and A.1.3.

The calculation of auxiliary energy requirement is performed on a yearly

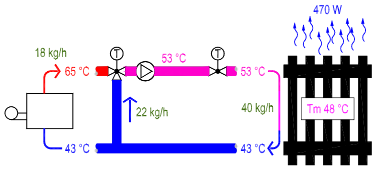


Figure 11: *Emitter connection through a mixing valve.*
*Typical for central control or for lower temperature emitters.*
*Distribution network temperature is the same as emitters temperature*
*Flow rate before the mixing valve is less than in the emitters.*

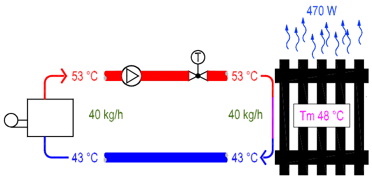


Figure 12: *Direct connection of heat emitters to the boiler room collectors.*
*Typical for thermostatic valves.*
*Distribution network temperature is the same as emitters temperature*
*Flow rate in the distribution network is the same as in the emitters.*

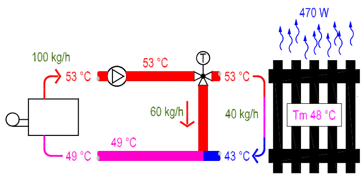


Figure 13: *Emitter connection with a by-pass.*
*Typical for the connection of HVAC hot heat exchanger or single pipe circuits.*
*Distribution network losses increase when the emitter power is reduced.*
*Flow rate in the network is greater than required by the emitters causing higher auxiliary energy needs.*

basis. Clause 6.5 specifies how to split the yearly value into monthly values.

Auxiliary energy recovery as heat is covered in clause 6.6. A simple proportionality is considered appropriate.

**Simplified method**

The simplified method is described in clause A.1.

The simplification consists of grouping and reducing the number of correction factors.

**Tabulated method**

The tabulated method is described in clause A.2 (see figure 10).

Distribution auxiliary energy need is given in kWh/year according to the floor area of the heated zone, the distribution type and the pump control type.

Tables are filled with values calculated with the detailed method.

Values in the tables are to be calculated at national level with appropriate assumptions reflecting local practices.

## 5 > Water temperature calculation

Calculation of flow and return water temperature is required because actual operating conditions have a strong influence on modern heat generator performance.

- Condensing boilers are sensitive to water return temperature to the boiler. The effect can be as high as ±10% on boiler efficiency;
- Heat pumps are sensitive to water flow temperature to distribution system. The effect can be as high as ±20% on the COP.

In both cases, the lower the water temperature, the better the generator performance. Unfortunately the highest water temperatures are required when the most energy and the highest power level is required. Therefore a correct calculation of water temperature according to operating conditions is necessary to calculate generator performance.

Clause 8 of EN 15316-2-3 gives a procedure to calculate flow and return temperature at the beginning of each single distribution circuit. The effect of connecting multiple distribution circuits to the boiler room collectors and the influence of the generator hydraulic connections are described in annex H of EN 15316-4-1.

Flow and return temperatures at emitter level is calculated first. They depend on:

- the type of emitters (radiators, embedded panels, air heaters);
- the size (nominal power) of installed emitters;
- the monthly load (actual operating average power);
- the type of control of the emitters;
- the operation time.

Three basic types of emitter control are specified (see figures 11 to 13):

- constant flow rate, varying temperature (parallel connection of emitters without local control) (figure 11);
- constant flow temperature, continuously varying flow rate (thermostatic valves) (figure 12 and 13);
- both flow rate and flow temperature constant, on/off operation (room thermostat control).

Also the effect of the hydraulic connection is taken into account. Three basic types of connections have been considered

- mixing valve (figure 11);

- direct connection (figure 12);
- by-pass control (figure 13).

This highlights the effect of hydraulic connections. Ignoring this fact may prevent condensation even with low temperature emitters whilst proper design allows attainment of the highest efficiencies with condensing boilers even in the coldest months and using radiators.

## 6 > FAQ

Why 3 levels (detailed, simplified and tabulated method) for heat loss calculation?

No single method is the right solution for all cases.

The detailed method will always work but requires a lot of input data.

The simplified method is a good compromise in many cases. The simplification of input may come from correlations or from the knowledge of the network typology. Pipe lengths are then dependent on building size.

The tabulated method is obviously the fastest and the simplest but there are very often hidden boundary conditions, like temperature patterns according to water circulation in distribution network:

- losses are usually proportional to energy requirements when there is a continuous control of either flow rate (thermostatic valves) or temperature (central control);
- losses are constant or may even increase with lower heating energy requirements when there is permanent circulation at high temperature in the main shafts (by-pass control of emitters, zones with 3-way valves).

Are national annexes always required?

Yes.

The detailed method requires few national data.

The simplified and tabulated methods are based on correlations and tables that are prepared nationally.

## 7 > References


1. EN 15316-3-2 Domestic Hot Water systems - distribution



**CENSE partners:**
TNO (NL; coordinator), CSTB (FR), ISSO (NL), DTU (DK), Fraunhofer (DE), ESD (GB), FAMBSI (FI), EDC (IT)
**Associated partners:**
HTA Luzern (CH), BRE (GB), Viessmann (DE), Roulet (CH), JRC IES (EC)
*Link: www.iee-cense.eu*

Original text language: English

**Disclaimer:** CENSE has received funding from the Community's Intelligent Energy Europe programme under the contract EIE/07/069/SI2.466698.