SIZING OF HYDRAULIC AND DOMESTIC WATER SYSTEMS

Expansion and storage vessels

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Hydronic Solutions

DOMESTIC HOT WATER PRODUCTION

Two systems are normally used to produce domestic hot water: instantaneous and storage.

The ***instantaneous*** system is designed and sized to meet the hot water requirements with a direct production, i.e. instantaneous. It is typically used for small installations where the generator (usually wall boilers or water heaters) copes limited needs for hot water.

The ***storage*** system is instead designed to cope with the demands of hot water with both direct production, and with the help of a reserve of preheated water.
It is suitable for medium-large sized systems that must serve different users.
The storage vessel (normally called storage) must be sized depending on the hot water peak consumption (related to the number of bathrooms or appliances operating during the period of increased use), on the preheating time of the storage volume and on the hot and cold water temperatures.
Compared to the instantaneous system, the storage system allows using much less powerful generators, but requires more time for heating the storage. It allows delivering hot water in the system in a more continuous and regular way, and therefore provides greater thermal efficiency.
The storage system also allows to exploit and integrate the production of hot water using renewable energy devices such as solar panels, heat pumps or solid fuel generators.

DOMESTIC HOT WATER STORAGE

SIZING

The storage sizing is performed considering the following variables:

- Peak time
  This is the time in which the hot water consumption is higher.
- Consumption of hot water during peak times
  It corresponds to the total volume of hot water consumed in relation with the peak time. (see table 1 on next page)
- Preheating period
  It is the time that can be used to bring the cold water introduced into the storage up to the required storage temperature.
- Cold water temperature
  Its value depends on many factors, such as: the soil temperature, the outside temperature, the water source area. However, in practice it can be assumed:
  10 – 12°C in northern Italy,
  12 – 15°C in central Italy,
  15 – 18°C in southern Italy.
- Temperature of use of hot water
  For the most common users, for the purposes of sizing the storage, *its value can be considered equal to 40°C*. For other types of users, however, it must be established in relation to the specific conditions under which the water is used.
- Hot water storage temperature
  Its value must be determined in relation to different needs contrasting with each other and in particular it must be chosen so as to:
  - avoid (or at least limit) corrosion phenomena and limestone deposit: phenomena that can greatly increase when the water exceeds 60°C (or 65°C);
  - limit the storage dimensions, considering that low storage temperatures greatly increase these dimensions;
  - prevent the development of bacteria, which typically can withstand for a long time at temperatures up to 50°C, but die rapidly beyond 55°C.

  In consideration of these aspects, for normal users it is generally a *good compromise to store water at 60°C*.

Heat time estimate

The required heat time, i.e. the required thermal power, can be estimated by calculating the total heat to be generated in the time interval which includes the preheating time and the peak time:

$$Q_h = \frac{C\,(T_u - T_f)}{t_{pr} + t_{pu}}$$

Calculation of the storage volume

It is possible to determine the theoretical volume of the storage starting from the reference variables; following this formulation it is possible to calculate the volume of the storage considering the amount of heat to be stored in the preheating period:

$$V_B = \frac{Q_h \cdot t_{pr}}{T_a - T_f}$$

C	=	consumption of hot water during peak times	[l]
Q_h	=	Heat time that must be transferred to the water	[kcal/h]
t_{pu}	=	Duration of peak time	[h]
t_{pu}	=	Duration of preheating time	[h]
T_f	=	Cold water temperature	[°C]
T_u	=	Temperature of use of hot water	[°C]
T_a	=	Hot water storage temperature	[°C]
V_B	=	Volume of the storage	[l]

TABLE 1: DATA FOR STORAGE CALCULATION					
USER TYPE		**Consumption during peak times**	**temperature of use**	**peak period**	**preheating period**
Residential buildings	260 l 340 l	for each flat with 1 bathroom (1) for each flat with 2 bathrooms (1)	40°C	1,5 h	2,0 h
Offices and Similar	40 l	for bathroom (WC+washbasin)	40°C	1,5 h	2,0 h
Hotels, Boarding houses and Similar (4)	180 l 130 l	for rooms with bathrooms with bathtub for rooms with bathrooms with shower	40°C	(2)	2,0 h
Hospitals (4)	120 l	for each bed	40°C	2,0 h	2,0 h
Clinics (4)	150 l	for each bed	40°C	4,0 h	2,0 h
Barracks, Colleges and Similar (4)	80 l	for each bed	40°C	2,0 h	2,0 h
Gyms and Sport Centres	150 l 60 l	for each shower for each tap	40°C	0,3 h	1,5 h
Factory changing rooms	150 l 60 l	for each shower for each tap	40°C	0,3 h	(3)

(1) The expected consumption must be multiplied by the simultaneity factor (F) which depends on the number of flats (n)

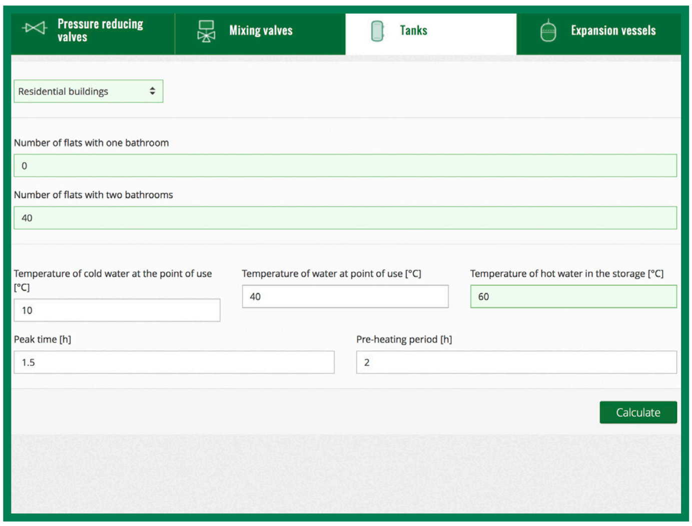
n	1–5	6–12	13–20	21–30	31–45	46–60	61–80	81–110	111–150	151–200	>200
F	1,00	0,95	0,90	0,85	0,80	0,75	0,70	0,65	0,60	0,55	0,50

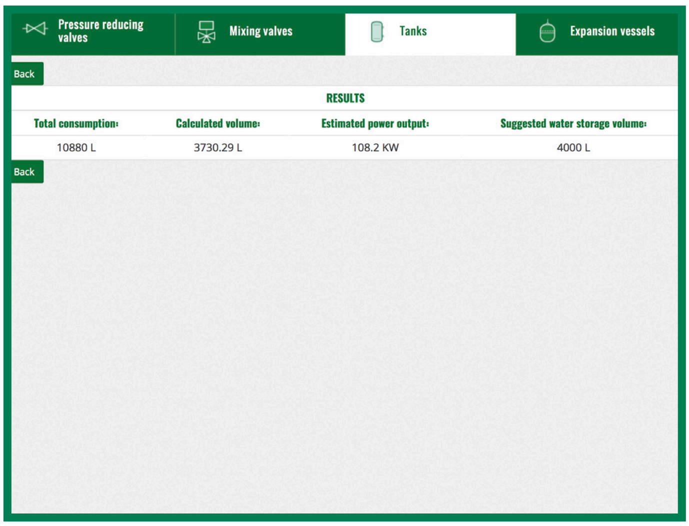
(2) **1,5 h** peak time to be considered for hotels and boarding houses with concentrated consumption (for example, those places in winter sports areas or frequented by tourist groups);
2,5 h peak time considered in hotels and boarding houses with normal water consumption (e.g. business hotels in cities).
(3) The preheating period can normally vary from 1 to 7 hours in relation to the time between the work shifts.
(4) Excluding hot water for dishwashers and washing machines, to be determined in relation to the specific characteristics (temperatures and times of operation) of the machines to be used.

SIZING WITH SOFTWARE

Determination of the storage volume for a system that produces hot water in a residential building which has 40 flats with two bathrooms.

T_{COLD} = 10°C Cold water temperature
T_{USE} = 40°C Use temperature
$T_{STORAGE}$ = 60°C Storage temperature
t_{pu} = 1,5 h Peak time (from table 1 implemented in the software)
t_{pr} = 2,0 h Preheating time (from table 1 implemented in the software)





EXPANSION VESSEL FOR DOMESTIC HOT WATER

Expansion vessels are devices designed to compensate for the increase in the volume of water due to the raising of its temperature.
It is known that liquids in general, if free to expand, vary their volume in relation to their temperature and to their specific expansion coefficient.
Considering water as a liquid the expansion volume can be expressed through the following relation:

$$E = V_0 (e - e_0)$$

where:

- E = Expansion volume, [l]
- V_0 = Volume at the initial temperature, [l]
- e = Water expansion coefficient at the final temperature
- e_0 = Water expansion coefficient at the initial temperature

Hydraulic and domestic water systems are defined as open systems. In reality, the water contained in them is in intermittently closed circuits, specifically only when there is no dispensing in progress. There is therefore an indeterminacy in assessing which is the volume of water of which to consider the expansion. In fact, a single supply of water is sufficient to significantly reduce the pressure increase induced by the increase of temperature.

Water expansion coefficients with respect to T = 4°C

T	e	T	e
0°C	0,0001	5°C	0,0000
10°C	0,0003	15°C	0,0009
20°C	0,0018	25°C	0,0030
30°C	0,0043	35°C	0,0058
40°C	0,0078	45°C	0,0098
50°C	0,0121	55°C	0,0145
60°C	0,0170	65°C	0,0198
70°C	0,0227	75°C	0,0258
80°C	0,0290	85°C	0,0324
90°C	0,0359	95°C	0,0396
100°C	0,0434		

SIZING

With this method the expansion vessels are calculated considering only the expansion of water that occurs in the storage. The expansion that occurs in the distribution and recirculation mains is neglected. With this simplification the pressure reductions induced by the opening of the taps are empirically taken into account avoiding excessive over-sizing compared to the actual needs.
The volume of the expansion vessel is calculated according to the following formulation:

$$V_V = \frac{V_B (e_B - e_0)}{1 - \frac{P_a}{P_e}}$$

where:

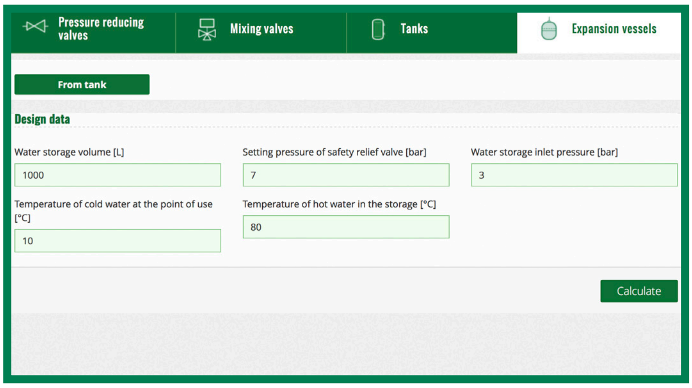
- V_v = Volume of the expansion vessel, [l]
- V_B = Volume of the storage, [l]
- e_B = Water expansion coefficient at storage temperature
- e_0 = Water expansion coefficient at the cold supply water temperature
- P_a = Absolute pressure of storage supply, equal to the setting pressure of the pressure reducing valve or at the maximum supply pressure of the mains, adding the atmospheric pressure value (equal to 1 bar) [bar]
- P_e = Absolute pressure of the system maximum operation, calculated by adding the exhaust pressure of the safety relief valve (P_{VS}) decreased by a value equal to 10% (which prevents its opening) and the atmospheric pressure (equal to 1 bar), [bar]:

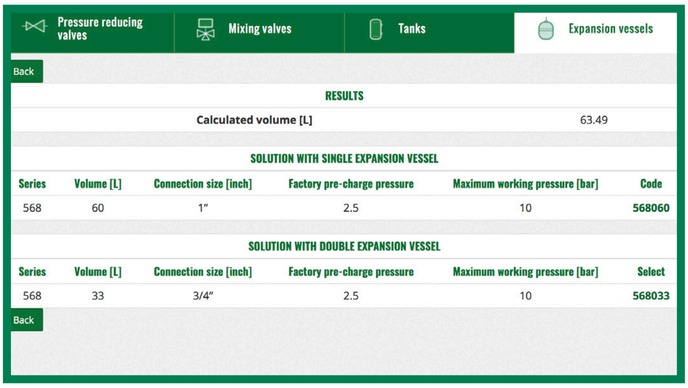
$$P_e = 0{,}9\, P_{VS} + 1 \qquad \textit{se } P_{VS} > 5 \textit{ bar}$$

SIZING WITH SOFTWARE

Sizing of an expansion vessel for a hydraulic and domestic water system with 1000 l capacity storage.

T_{COLD}	=	10°C	Cold water temperature
$T_{STORAGE}$	=	80°C	Storage temperature
P_{mains}	=	3 bar	Storage supply pressure
P_{vs}	=	7 bar	Safety relief valve intervention pressure





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