# Vessel Calculation for Central Heating Systems

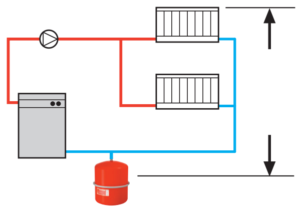
## Calculation for a Flexcon expansion vessel for central heating systems with fixed or removable diaphragm

**Basic parameters for the calculation of a Flexcon expansion vessel.**

- **Vessel volume**
  This is the total capacity of the Flexcon expansion vessel.

- **Vessel efficiency**
  This is the maximum amount of expansion water that can be contained in the vessel.

- **Static height**
  This is the height of the system from the Flexcon expansion vessel connection to the highest point of the system measured in water column metres, (1 wcm 0.1 bar).



- **Initial pressure of the Flexcon expansion vessel**
  This is the pressure measured at the nitrogen filler valve at ambient temperature and atmospheric pressure. The pressure is equivalent to the static height, rounded up to a factor of 0.5 bar.

- **Maximum working pressure**
  This is the maximum permissible system pressure at the Flexcon expansion vessel. The maximum working pressure may not exceed the maximum value indicated on the expansion vessel.

- **Output**
  This is the ratio between the gross and net vessel capacity.

$$\text{Output} = \frac{\text{Net contents}}{\text{Gross capacity}}$$

The output is determined by the ratio between initial and end pressure. In formulaic form, this is as shown below (derived from Boyle's Law):

$$\text{Output} = \frac{\text{end pressure} - \text{initial pressure}}{\text{end pressure}}$$

Note:

- pressure in bar absolute
- Max. output of Flexcon expansion vessels with fixed diaphragm 0.63.
- Max. output of Flexcon 800 litre expansion vessel = 0.5,
  Flexcon 1,000 litre expansion vessel = 0.4.
- Max. output of Flexcon M = 0.72.

If the maximum output of an expansion vessel is exceeded, the diaphragm may be subjected to tensile stress. This could lead to damage to the diaphragm or even cause it to rupture.

- **System water capacity**
  This is the total volume of water in the entire system including heat source, radiators, pipe work etc.

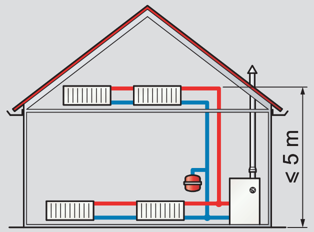
- **Expansion volume**
  The expansion volume is calculated as follows: expansion volume = water capacity x increase in volume at average heating temperature.

Example: heating temperature 90/70 °C (average 80 °C) = 2.89%.

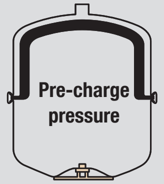
- **Safety factor**
  We recommend including a margin of 25% when calculating the expansion volume.

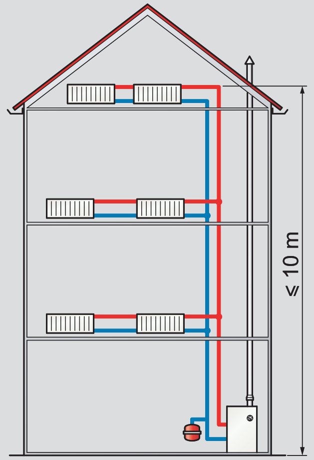
- **Gross capacity of Flexcon expansion vessels**
  The gross capacity of Flexcon expansion vessels is calculated as follows:

$$\text{Gross capacity of vessel} = \frac{\text{expansion volume x 1.25}}{\text{output}}$$



Pre-charge pressure 0.5 bar



Pre-charge pressure 1.0 bar

# Vessel Calculation For Cooling Systems

## Flexcon expansion vessels in cooling and air-conditioning systems

In a cooling system, Flexcon expansion vessels may have the following functions:

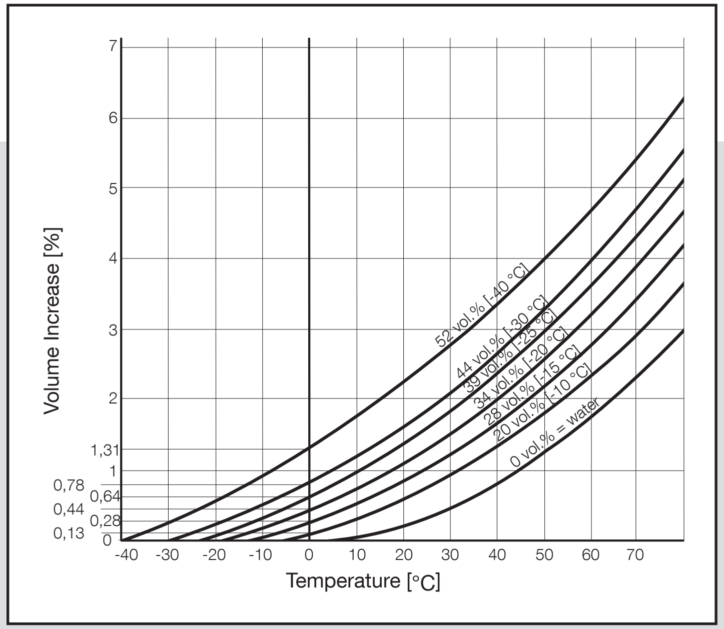
- As the system cools, the volume of the cooling water shrinks. The Flexcon expansion vessel thus gives water back to the system, maintaining system pressure.
- If the system is turned off, the water can return to the ambient temperature, allowing it to expand. The vessel absorbs this expansion volume.

## Anti-freeze has an expansion coefficient that is much greater than that of water

All Flexcon expansion vessels can be used in systems in which glycol-based anti-freeze is added to the system water.
The table below shows the increase in volume of various water/ethylene glycol mixing ratios. These are average values.

**Expansion coefficient of water with and without added anti-freeze**

| Temperature [°C] | Percentage of glycol | | | | | |
|---|---|---|---|---|---|---|
| | 0% | 10% | 20% | 30% | 40% | 50% |
| 10 | 0.04 | 0.35 | 0.67 | 0.89 | 1.31 | 1.63 |
| 20 | 0.18 | 0.50 | 0.82 | 1.04 | 1.46 | 1.78 |
| 30 | 0.43 | 0.75 | 1.07 | 1.29 | 1.71 | 2.03 |
| 40 | 0.79 | 1.11 | 1.43 | 1.65 | 2.07 | 2.39 |
| 50 | 1.21 | 1.53 | 1.85 | 2.07 | 2.49 | 2.81 |
| 60 | 1.71 | 2.03 | 2.35 | 2.57 | 2.99 | 3.31 |
| 70 | 2.25 | 2.60 | 2.92 | 3.14 | 3.56 | 3.88 |
| 80 | 2.89 | 3.22 | 3.54 | 3.76 | 4.18 | 4.52 |
| 90 | 3.58 | 3.91 | 4.23 | 4.45 | 4.87 | 5.19 |
| 100 | 4.35 | 4.63 | 4.95 | 5.17 | 5.59 | 5.90 |





## Calculation for a Flexcon vessel in a cooling system

The following data is required to calculate the required volume of Flexcon expansion vessel:

- Volume of system water.
- Percentage of added anti freeze.
- Lowest system temperature.
- Maximum system temperature (= highest ambient temperature).
- Water - anti-freeze mix expansion (percentage).
- Static height of the system above the vessel.
- Maximum working pressure.

The initial pressure of the expansion vessel is selected to match the static height of the system (above the expansion vessel). The following formula can be used to calculate the fill level of the expansion vessel at the lowest operating pressure.

$$\text{I} \quad \frac{\text{lowest operating pressure - initial pressure}}{\text{lowest operating pressure}} = \text{fill level}$$

This means that the residual factor of the expansion vessel can be determined.

Residual factor = 1 - fill level.

The end pressure must be 0.5 bar lower than the set pressure of the safety valve.

The output is calculated using the formula below:

$$\text{II} \quad \frac{\text{end pressure - lowest operating pressure}}{\text{end pressure}} \times \text{residual factor} = \text{output}$$

Note:

- Pressure in bar absolute.
- Max. output of Flexcon expansion vessels with fixed diaphragm 0.63.
- Max. output of Flexcon 800 liter expansion vessel = 0/5, Flexcon 1.000 liter expansion vessel = 0/4.
- Max. output of Flexcon M = 0.72.

**The temperature in the Flexcon expansion vessel must remain above -10 °C.**

A buffer vessel or Flexcon intermediate expansion vessel may have to be fitted between the system and the Flexcon expansion vessel.

For calculations of Flexcon expansion vessels for Solar installations, refer to the spreadsheet on www.flamco-export.com - tab; Flamco calculator.

## Example calculations for Flexcon expansion vessels

### Example 1

**Data**

- water capacity = 340 liters
- average heating temperature (90/70 °C) = 80 °C
- system height = 8 m
- end pressure = 3.0 bar
- Flexcon expansion vessel and boiler placed above.

**Calculation**

Increase in volume in % = 2.89% ≈ 2.9%

$$\text{Expansion volume} = \frac{340 \times 2.9}{100} = 9.86 \text{ liters}$$

Reserve 25% = 9.9 x 1.25 = 12.4 liters

$$\text{Output} = \frac{(3.0 + 1) - (0.5 + 1)}{(3.0 + 1)} = 0.63$$

Required gross capacity of the

$$\text{Flexcon expansion vessel} = \frac{12.4}{0.63} = 19.7 \text{ liters}$$

**The ideal model is a Flexcon 25/0.5.**

### Example 2

**Data**

- capacity unknown
- boiler output = 280 kW
- average heating temperature (80/60 °C) = 70 °C
- system height = 12 m
- end pressure = 3.0 bar
- Flexcon expansion vessel and boiler placed below.
- system components: 100% panel radiators

**Calculation**

Calculated system capacity = 280 x 8.8 = 2,464 liters

Increase in volume in % = 2.25%

$$\text{Expansion volume} = \frac{2{,}464 \times 2.25}{100} = 55.4 \text{ liters}$$

Reserve 25% = 55.4 x 1.25 = 69.3 liters

$$\text{Output} = \frac{(3.0 + 1) - (1.5 + 1)}{(3.0 + 1)} = 0.375$$

Required gross capacity of the

$$\text{Flexcon expansion vessel} = \frac{69.3}{0.375} = 184.8 \text{ liters}$$

**The ideal model is a Flexcon 200/1.5.**

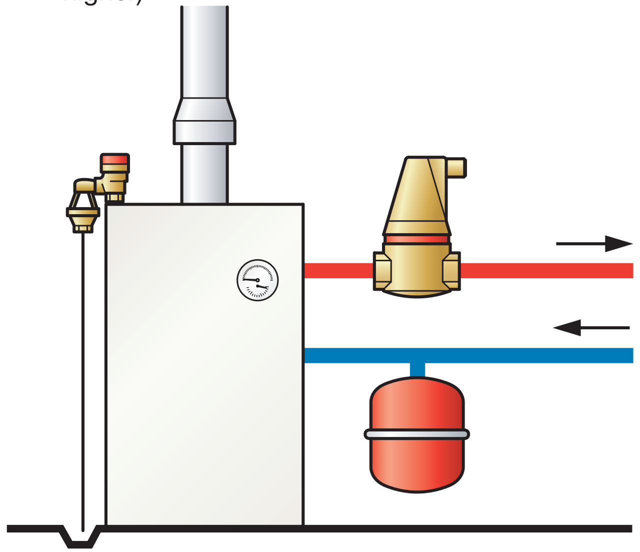
## Theory

**Minimum working pressure**

Specific circulation pumps demand a certain pressure (for instance 1 bar) in their suction pipe in order to function properly. Many modern central heating boilers are protected to a minimum working pressure of 0.8 or 1 bar. If such a pump or boiler is built in to a central heating system with a low static height, it may be more sensible to set the initial pressure of the expansion vessel to 1 bar rather than 0.5 bar.
Note that the increased initial pressure does not ensure that the minimum working pressure is replicated throughout the system! The chance of negative pressure being created high up in the system when it is cooling down, which would cause air circulation problems, is greater if the initial pressure is, say, 1 bar than if the initial pressure were set at 0.5 bar. If the pressure in the system drops below 1 bar, expansion vessels with initial pressure of 1 bar cannot give back water to the system as the expansion vessel would run dry!

**Boost pressure**

In order to prevent negative pressure and air circulation problems, it is of the greatest importance that the expansion vessel does not run dry. This is why Flamco recommends that you fill the system when it is cold and at a pressure equal to the initial pressure plus 0.2 to 0,.3 bar (if you are topping up a warmer system, the pressure must, accordingly, be higher).



An incorrect, excessive boost pressure may lead to problems. If the system in which a expansion vessel is fitted and an initial pressure of 0.5 bar is filled to 2 bar rather than 0.8 bar, 30% more of the gross capacity will already have been used up before the central heating water expands due to the increase in temperature!

$$\eta\ A = \frac{(3 + 1) - (0.8 + 1)}{(3.0 + 1)} = 0.55 = 55\%$$

$$\eta\ B = \frac{(3 + 1) - (2 + 1)}{(3 + 1)} = 0.25 = 25\%$$

Difference in output ($\eta$): 30%

## Conclusion

- A higher initial pressure in a expansion vessel does not guarantee higher system pressure.
- An incorrect, excessive boost pressure has an undue impact. Flamco recommends filling the system to the right pressure, preferably 0.2 to 0.3 bar above the initial pressure of the Flexcon expansion vessel (when cold).

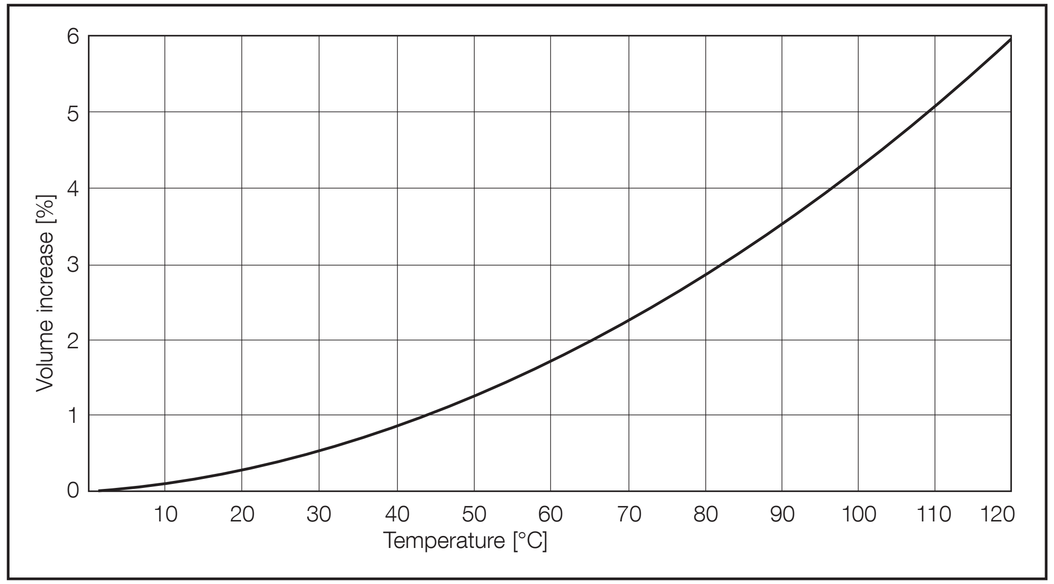
## Assistance

- To make the correct calculation in respect of which Flexcon expansion vessel to use, Flamco can offer all sorts of assistance; we can provide technical documentation, disc calculators and computer programs.

N.B.: The right place for the expansion vessel is in the system's return line, on the suction side of the circulation pump.

- **Increase in volume of water in %**
  The table below shows the percentage volume increase of water as temperature increases from 10°C to 110°C.

| Temperature increase [°C] | Volume increase [%] |
|---|---|
| 10 - 25 | 0.35 |
| 10 - 35 | 0.63 |
| 10 - 40 | 0.75 |
| 10 - 45 | 0.96 |
| 10 - 50 | 1.18 |
| 10 - 55 | 1.42 |
| 10 - 60 | 1.68 |
| 10 - 70 | 2.25 |
| 10 - 80 | 2.89 |
| 10 - 90 | 3.58 |
| 10 - 100 | 4.34 |
| 10 - 110 | 5.16 |




- **Temperature in the Flexcon expansion vessel**
  The maximum continuous temperature in the Flexcon expansion vessel is 70 °C.
  The minimum permissible temperature in the Flexcon expansion vessel is -10 °C.

**Output**
In this table you can read off the output for various levels of initial and end pressure.
We recommend a margin of at least 1.5 bar between the initial and end pressure.

| Static height [m] | Initial pressure [bar] | End pressure [bar] | | | |
|---|---|---|---|---|---|
| | | 3 | 6 | 8 | 10 |
| 5 | 0.5 | 0.63 | - | - | - |
| 10 | 1 | 0.50 | 0.71 | - | - |
| 15 | 1.5 | 0.38 | 0.64 | 0.72 | - |
| 20 | 2 | 0.25 | 0.57 | 0.67 | - |
| 25 | 2.5 | 0.13 | 0.50 | 0.61 | 0.68 |
| 30 | 3 | - | 0.43 | 0.56 | 0.64 |
| 35 | 3.5 | - | 0.36 | 0.50 | 0.59 |
| 40 | 4 | - | 0.29 | 0.44 | 0.55 |
| 45 | 4.5 | - | 0.21 | 0.39 | 0.50 |
| 50 | 5 | - | - | 0.33 | 0.45 |
| 55 | 5.5 | - | - | 0.28 | 0.41 |
| 60 | 6 | - | - | 0.22 | 0.36 |
| 65 | 6.5 | - | - | 0.17 | 0.32 |
| 70 | 7 | - | - | - | 0.27 |
| 75 | 7.5 | - | - | - | 0.23 |
| 80 | 8 | - | - | - | 0.18 |

## Approximation of the water capacity of the system

In order to be able to determine the required capacity of the Flexcon vessel, the water capacity of the system as a whole must be calculated. If it is not possible to determine the capacity of the system, it can be approximated using the historic data shown here, based on a supply/return temperature of 90/70 °C.

The water capacity of the system can be approximated by multiplying the output of the system by the values specified in the table. The table refers to new systems. For older systems, we recommend using higher values. This method is an indication only and does not guarantee a precise calculation of the capacity required for your Flexcon expansion vessel.

| Central heating system with | Capacity [l/kW] [860 kcal/h] |
|---|---|
| convectors and/or air heaters | 5.2 |
| induction units | 5.5 |
| air treatment systems | 6.9 |
| panel radiators | 8.8 |
| central heating utilities mix | 10.0 |
| column radiators | 12.0 |
| cooled water utilities mix | 20.0 |
| heated ceiling and/or under-floor heating | 18.5 |
| extensive pipework (district heating) | 25.8 |

## Derivation of units:

1 bar = 100 kPa = 100,000 Pa = 10 N/cm$^2$ = 0.9869 atm. = 10.2 wcm

1 kW = 0.29 kcal/s = 859.86 kcal/h

1 kcal/s = 4.1868 kJ/s = 4.1868 kW