Barometric Pressure Information

Understanding how Barometric Pressure affects a refrigeration thermostat

Introduction

Barometric Pressure also known as atmospheric pressure is the force per unit area exerted against a surface by the weight of air above that surface in the Earth's atmosphere. In most circumstances atmospheric pressure is closely approximated by the hydrostatic pressure caused by the weight of air above the measurement point.

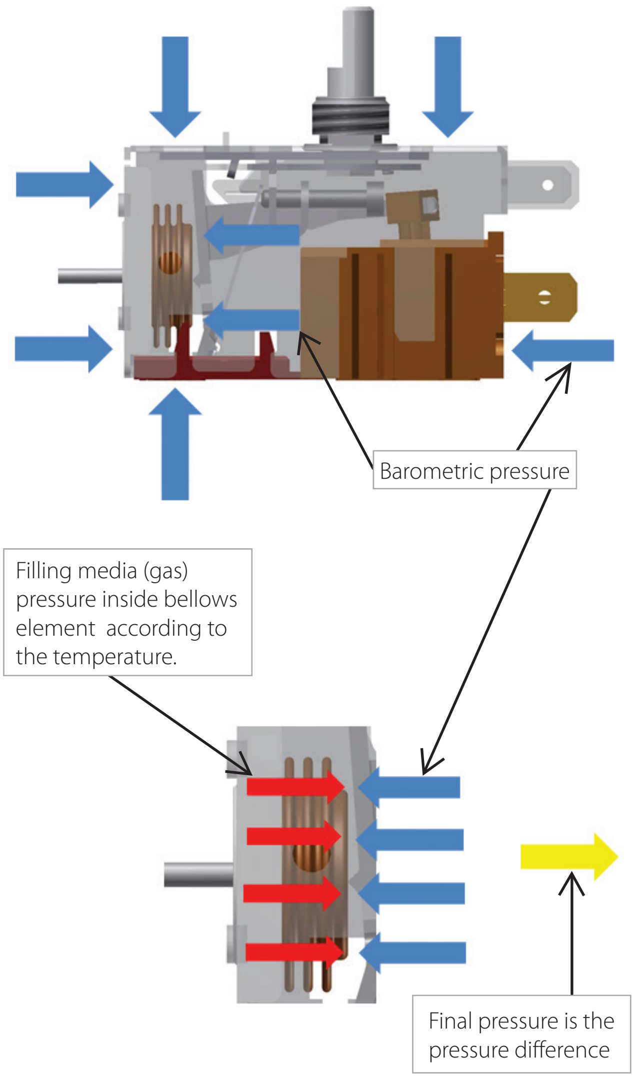
The barometric pressure depends on other factors like earth location (earth is not round), weather conditions (air humidity, air temperature, air speed) and even the sea level.

The barometric pressure is measured by a barometer (meteorological instrument that normally uses mercury for measurement, due to which we have the pressure unit "mmHg").

As barometric (atmospheric) pressure is everywhere it will also surround the thermostat (outside and also inside).

All refrigeration thermostats filled with superheated vapour have the same basic concept which is to transform temperature into pressure and then convert this pressure into force in order to open and close contacts.

This means that the filling media pressure (gas) has to overcome the barometric pressure, meaning that the final pressure is the difference between the filling media pressure and barometric pressure. The final temperature changes if the barometric pressure also changes.



All working temperatures are always specified at one barometric pressure (customer request). If the barometric pressure changes or it is different from that specified, the temperature also changes. This occurs for all vapour filled thermostats in the world.

How to calculate the temperature changes according to barometric pressure changes.

The temperature change is linked to the type of filling media inside the thermostat (gas), the working temperature and the barometric pressure changes.

This means that different thermostat designs working at the same temperature and filled with the same media (gas) will have the same temperature change according to the same barometric pressure change.

To calculate the new working temperature we need to know the following 3 data:

1. **Type of filling media (gas) inside the thermostat**
   We need to know whether the thermostat is charged with propane R290 or R134a because each type of filling media has its own pressure vs temperature relationship.

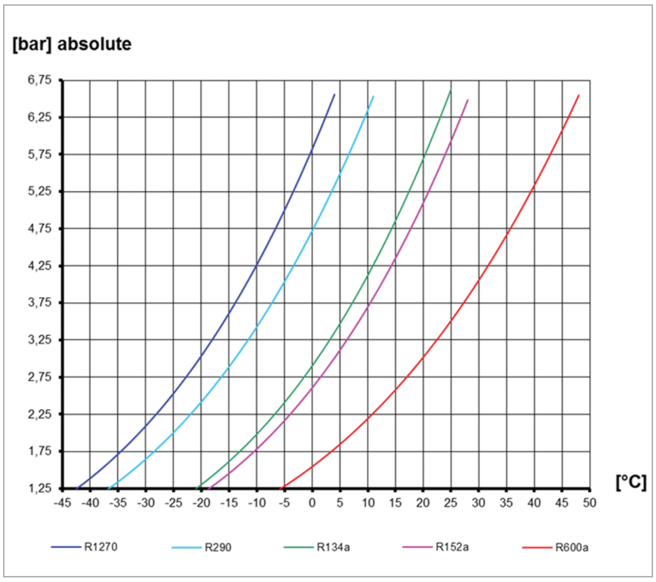
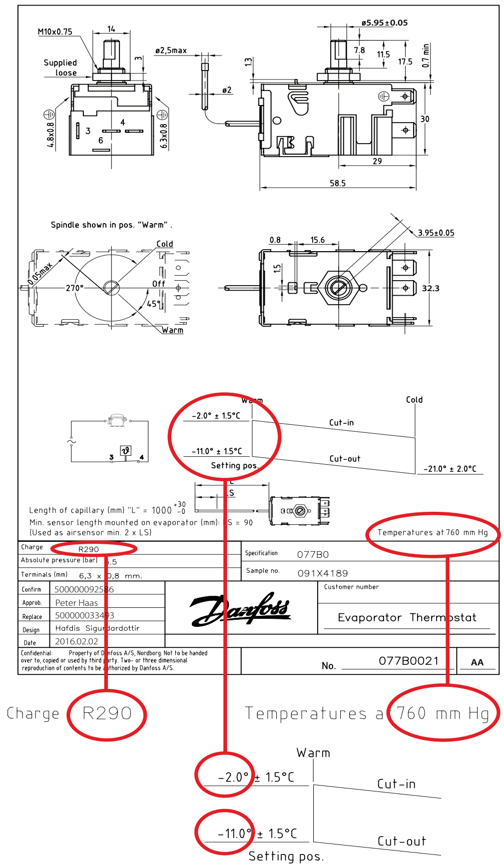


Table of vapour pressure for most common refrigerants used for charging thermostats.

2. **Thermostat working temperatures**
   We need to know the cut-out and cut-in temperatures, and the specified barometric pressure for these temperatures because the filling media relation of temperature vs pressure is not linear but exponential.

   You can find this information in the Danfoss dimension sketch or by asking Danfoss.



Example of Danfoss dimension sketch and where to find the information.

3. **Barometric pressure where the thermostat is used or is planned to be used**
   This is specified by the customer. Alternatively, there are many online sources. Or you can calculate based on the local altitude by using the barometric formula below (estimating by air mass).

$$P = P_b \times \left[\frac{T_b}{T_b + L_b \times (h - h_b)} \right]^{\frac{g_0 \times M}{R \times L_b}}$$

Formula Symbols	
P_b	Static pressure at sea level (760 mmHg)
T_b	Standard temperature (293 K)
L_b	Standard temperature lapse rate (-0.0065 K/m in ISA)
h	Height above sea level (meters)
h_b	Height at sea level (0 meters)
R	Universal gas constant for air (8.31432 N•m /(mol•K))
g_0	Gravitational acceleration (9.80665 m/s^2)
M	Molar mass of Earth's air (0.0289644 kg/mol)

Table results by formula

Altitude from sea level (m)	Barometric pressure (mmHg)
0	760
500	717
1000	675
1500	636
2000	599
2500	563
3000	529

The temperature change follows the barometric change. This means that the exact value changed by the barometric pressure will be followed by the filling media (gas inside the thermostat).

Example

1 Thermostat filled with R290
2 Thermostat working temperature cut-out -22.0 °C and cut-in -10.0 °C at 760 mmHg (sea level)
3 Now working at 500 meters from sea level equals to 717 mmHg

When moving to a higher altitude (lower barometric pressure) we still need to have the same final pressure so: The barometric pressure changed from 760 mmHg to 717 mmHg (reduced external pressure) meaning the thermostat gas needs a lower pressure to get the same final pressure as before. This difference of -43 mmHg (specified pressure – working pressure) is equal to -0.057 bar.

Original cut-out specification is -22.0 °C with R290 at 760 mmHg. Using the vapour saturated gas properties table you find that pressure related to this temperature is equal to 1.262 bar.

To achieve the same final pressure the gas will need now 1.205 bar (1.262–0.057), using again the vapour saturated gas properties table again you find the temperature that is equal to -22.7 °C.

The same calculation is valid for the cut-in temperature. See the calculation in the table for R290 gas.

Barometric pressure change : 760 to 717 = -43 mmHg => -0.057 bar difference in pressure

Cut-out -22.0 °C => 1.262 bar; -0.057 bar = 1.204 bar => -22.7 °C (0.7 degree colder)
Cut-in -10.0 °C => 2.446 bar; -0.057 bar = 2.389 bar => -10.5 °C (0.5 degree colder)

Temperature R290	Over pressure
[°C]	[bar]
-23.3	1.156
-23.2	1.164
-23.1	1.172
-23.0	1.180
-22.9	1.188
-22.8	1.196
-22.7	1.204
-22.6	1.212
-22.5	1.221
-22.4	1.229
-22.3	1.237
-22.2	1.246
-22.1	1.254
-22.0	1.262
-21.9	1.271
-21.8	1.279

Temperature R290	Over pressure
[°C]	[bar]
-11.0	2.333
-10.9	2.344
-10.8	2.355
-10.7	2.367
-10.6	2.378
-10.5	2.389
-10.4	2.401
-10.3	2.412
-10.2	2.423
-10.1	2.435
-10.0	2.446
-9.9	2.458
-9.8	2.469
-9.7	2.481
-9.6	2.492
-9.5	2.504

The optional formula below can be used instead of the vapour table.

$$T = \frac{B}{\left(A - Log\left(10^{\left(A - \frac{B}{T_0 + C}\right)} - P_0 + P\right)\right)} - C$$

Formula Symbols	
T	Final temperature at final barometric pressure (°C)
T_o	Temperature at initial barometric pressure (°C)
P	Final barometric pressure (mmHg)
P_o	Initial barometric pressure (mmHg)
A	Filling media constant A
B	Filling media constant B
C	Filling media constant C

Constant table for filling media

Gas	A	B	C
R 1270	6.89297398	816.3970935	251.1933122
R 134a	7.133349824	915.0119095	241.3949807
R 152a	7.130027652	941.3515628	245.5657134
R 290	6.878127193	833.1521839	250.5091034
R 600a	6.782784136	887.1594508	239.1543191

For more information please contact Danfoss Appliance Controls.

The 077B….EBD, 077B….L EBD can be applied on systems with R290 and R600a as the working fluid.
For countries where safety standards are not an indispensable part of the safety system Danfoss recommend the installer to get a third party approval of the system containing flammable refrigerant.