Investigating the function of the expansion valve of the heat pump

Objects of the experiment

- To study the operational components of the expansion valve by means of a technical drawing (cross section) of the valve.
- To understand the control and protection function of the expansion valve.
- To record the temperature courses at the inlet and outlet of the evaporator and to investigate the control effect of the valve by comparing these courses.

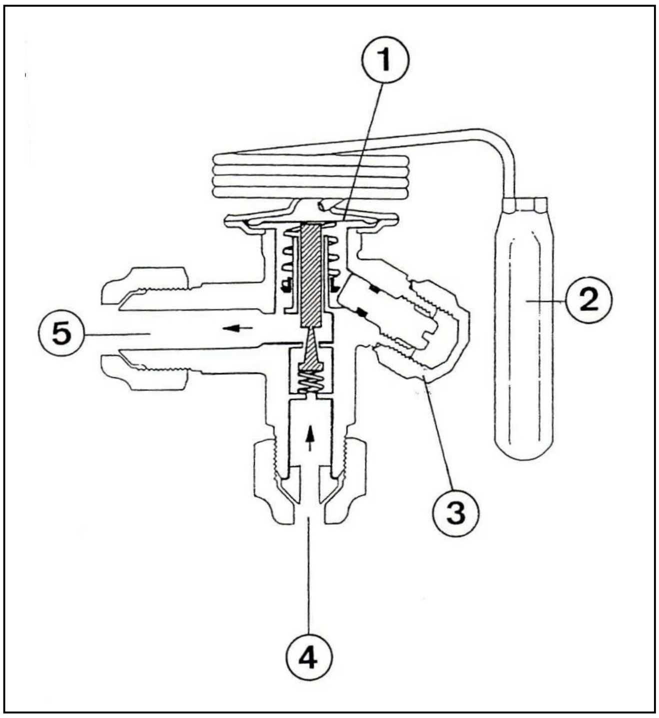


Fig. 1: Cross sectional drawing of the expansion valve schematically. Shaded: control cone of the injection valve. Flow direction of the coolant marked by arrows.
(1) membrane
(2) temperature probe: gas-filled metal capsule which is clamped on the outlet of the evaporator.
(3) adjustment screw
(4) inlet port
(5) outlet port

Principles

The expansion valve of the heat pump is with respect to its function the counterpart to the compressor. It controls the amount of liquefied coolant streaming under high pressure towards the evaporator. The amount is limited in such a manner that only the amount of coolant can reach the evaporator which can be evaporate completely. The expansion valve reduces the support of coolant if not enough heat energy is reaching the coolant in the evaporator.

In this way it is avoided reliably, that liquid coolant from the evaporator can enter the compressor and destroy the device (i.e. so called "beat by a liquid"). As control variable the superheating of the coolant in the evaporator is used, i.e. the difference between the temperature T_V of the gaseous coolant at the output of the evaporator and the evaporation temperature T_S of the gas-liquid mixture in the evaporator:

$$\Delta T = T_V - T_S \qquad \text{(I)}$$

T_S: evaporation temperature

T_V: coolant temperature

The vapour pressure curve of the coolant relates unambiguously the evaporation temperature T_S and the pressure p_V on the evaporator side and can therefore be read off on the most outer scale of the low-pressure manometer.

The supply of coolant should be activated not before ΔT is exceeding a certain value. This problem is solved technically by a membrane which is governing the aperture of the injection jet of the coolant (Fig. 1). The lower side of the membrane is linked with the output of the valve. On the lower surface of the membrane is therefore acting the pressure p_V. On the same membrane side a spring is pressing towards the membrane simultaneously. On the upper surface of the membrane is acting the opposite pressure p_1 of a temperature probe which is fixed at the output of the evaporator. (At the heat pump used here it is covered by a black heat insulating jacket.)

Fö / Bi 0107

Apparatus

1 Heat pump 389 521
1 Digital Thermometer 666 209
2 Temperature Sensor, NiCr-Ni 666 193
1 Digital stopwatch.. 313 12

Additionally recommended:

RS 232 cable, 9-pole 729 769

additionally required:

1 PC with Windows 98 or higher

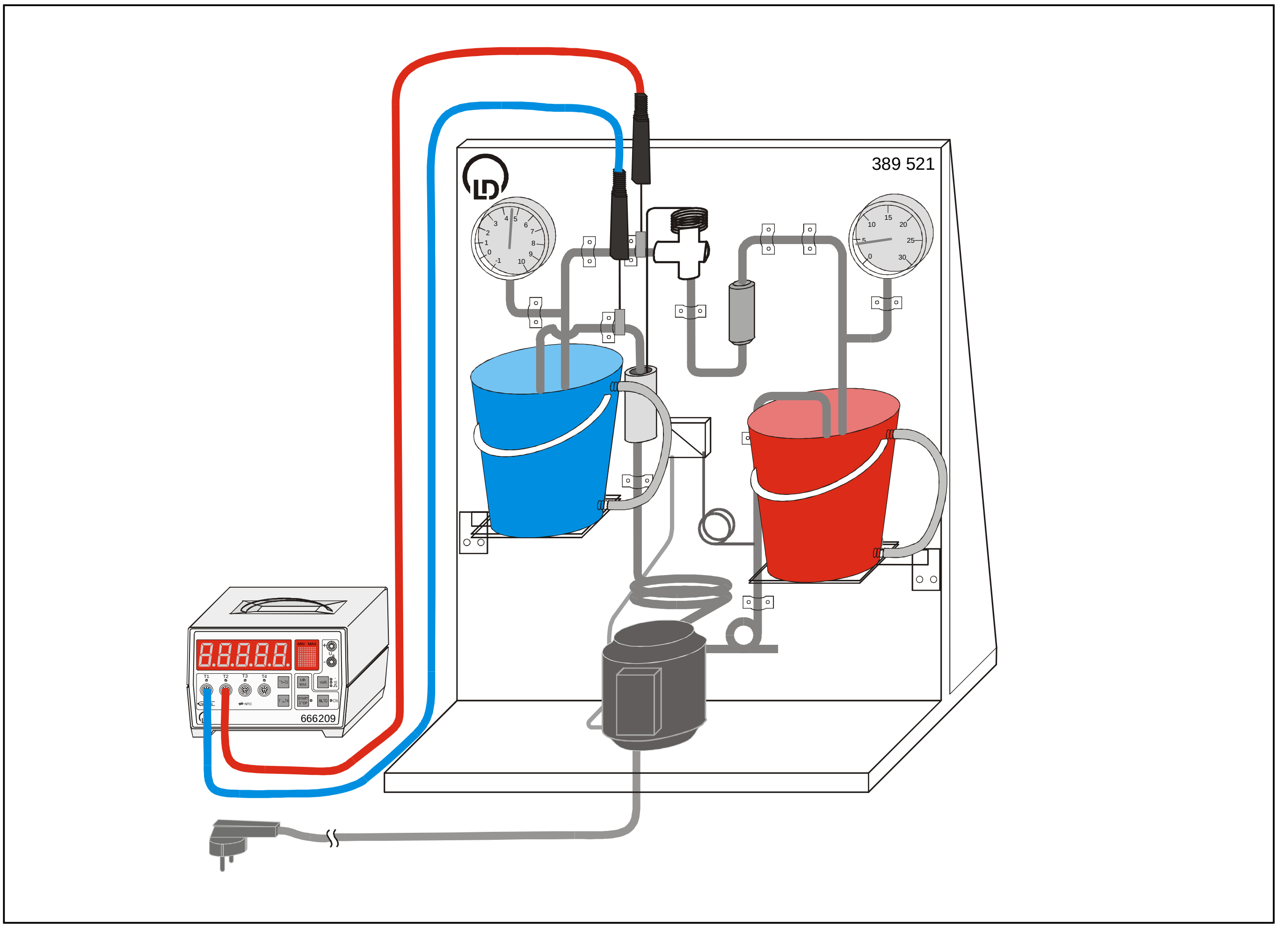
In case of missing superheating ($\Delta T = 0$) the values of p_V and p_1 are equal and the valve will be kept closed by the force of the spring. If ΔT is rising the pressure difference $p_1 - p_V$ will increase to a value when the valve will open against the spring force. By adjusting the spring force via an external screw the superheating ΔT can be preset. The default value is set to $\Delta T = 6$ K and must not be varied in any case as it is critical for safe operating conditions of the compressor.

Setup

Arrange and connect the equipment components according to Fig. 2.

- Connect the top and bottom hose nipples of each vessel using the section tube. (Alternatively, establish an appropriate hose connections between the water vessels and the external water circuit.)
- Clamp the copper holders for external temperature measurements (included in the scope of delivery) to the copper tube, one directly after the expansion valve (i.e. for T_S), the other near the outlet of the evaporator vale (i.e. for T_V).
- Add a drop of oil or heat-conducting paste (available in electronics shops) in the borehole of each copper hole and insert temperature sensors to establish a good thermal contact.
- Afterwards fill each vessel with water up to the 4 liter mark. Fold up the supports (i.e. trays) for the vessels and place the water vessels in their experiment positions around the copper tube windings, then fold the supports again and rest the water vessels on them.

Fig. 2: Experimental setup schematically.



Safety notes

Mind the safety notes of the instruction sheet 389 521 for the heat pump.

- The coolant circuit is pressureized. Do not attempt to open this circuit under any circumstances.
- Do not thermally insulate the compressor; this can cause the device overheat.

Carrying out the experiment

a) Manual recording

- Switch on the heat pump.
- Read off the display of the temperature meter every 10 seconds for T_V and T_S alternatively using the automatic switching function of the digital thermometer with four inputs.
- Continuously and slowly stir the water in the cold and warm vessel during the experiment.

b) Automatic recording

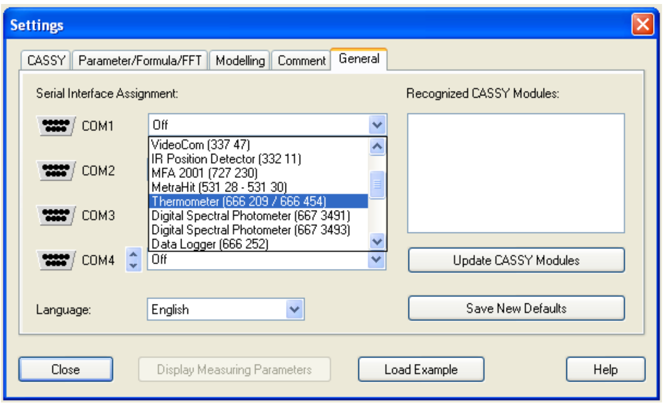
When using the RS 232 connection cable the recorded data by the Digital Thermometer can be transferred to the computer.

- If not yet installed install the software and open the software (preconfigured CASSY Lab user interface).

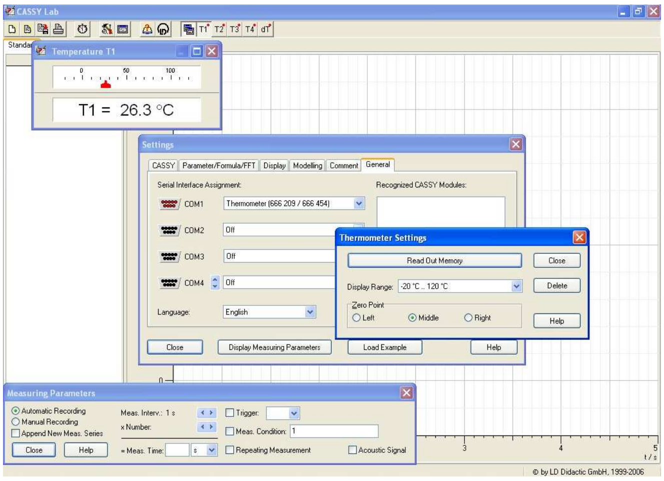
Note: The software CASSY Lab for data recording with the Digital Thermometer can also be downloaded from http://www.ld-didactic.com/

- Open the window “Settings” using the tool box button or function key F5 from the top button bar:

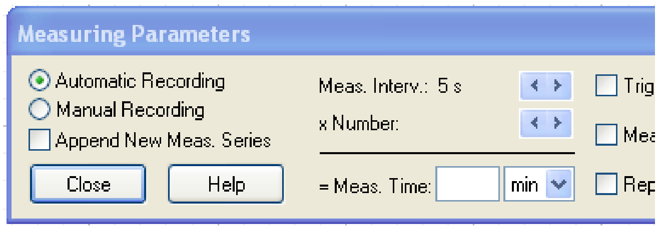
- Select the tab “General” in the window “Settings” and set the appropriate COM port by selecting the “Thermometer” detector:



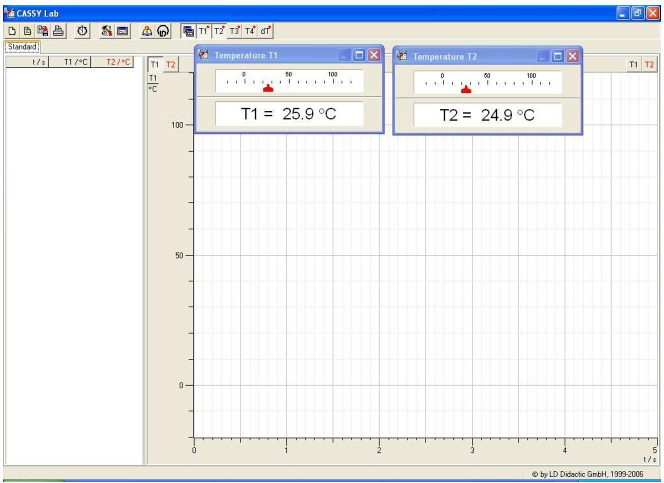
- After selecting the “Thermometer” for the appropriate Com port the software opens a table, a display and various windows: indicator for the temperature T1, the window “Thermometer Settings”, the window “Settings” and the window “Measuring Parameters”:



- In the Measuring Parameter window select 5 s as Measurement interval and select “min” as units.



- Accept the preset values in the windows Setting and Thermometer Settings by closing all windows inside the main window.
- To display the temperature T2 click on the button



Note: A measurement can be cleared with the button or the function key F4.

- Press the button or function key F9 to start recording the temperature as function of time.

Note: The button works as a toggle switch. The data acquisition can be stopped by pressing or F9.

- Continuously and slowly stir the water in the cold and war vessel during the experiment.

Note: Good result for ΔT_2 can be obtained only when properly stirred during performing the experiment.

Measuring example

a) Manual recording

Table 1: Temperature T_1 and T_2 as function of time t.

t / s	T_1 / s	T_2 / s
0	20.1	20.0
10	20.0	19.9
20	19.8	19.9
30	19.5	19.1
40	19.3	15.0
50	18.9	12.3
60	18.7	10.3
70	18.3	8.9
80	18.0	8.0
90	17.6	7.5
100	17.3	7.1
110	17.0	7.0
120	16.6	6.9
130	16.3	6.9
140	15.8	6.9
150	15.3	6.8
160	14.0	6.8
170	12.3	6.9
180	11.1	6.9
190	10.4	6.8
200	10.0	6.6
210	9.9	6.4
220	9.9	6.2
230	10.0	6.1
240	10.1	6.1
250	9.8	6.0
260	9.0	6.0
270	8.3	5.9
280	8.0	5.8
290	7.9	5.5
300	7.9	5.2
310	8.2	4.9
320	8.3	4.7
330	7.6	4.7
340	7.0	4.6
350	6.5	4.5
360	6.2	4.3
370	6.3	3.8
380	6.5	3.5
390	6.7	3.4
400	6.8	3.3

b) Automatic recording

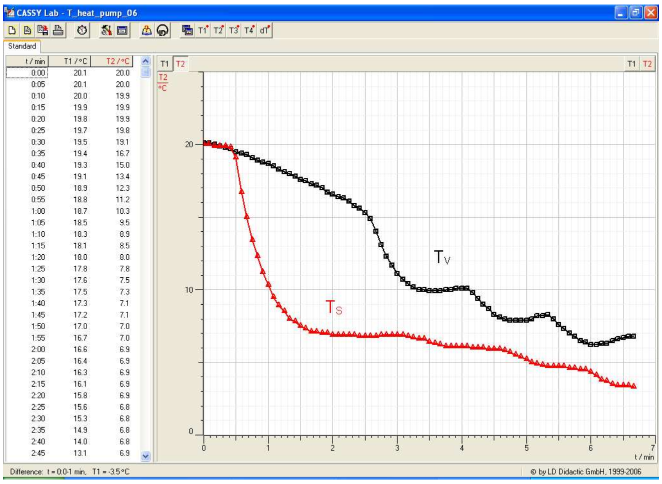


Fig. 3: Temperatures T_S at the inlet and T_V at the outlet of the evaporator as function of the time.

Note: You may label the plot using short cut key Alt-T.

Note: You may save your measurements by pressing the button or using the function key F2.

Evaluation and results

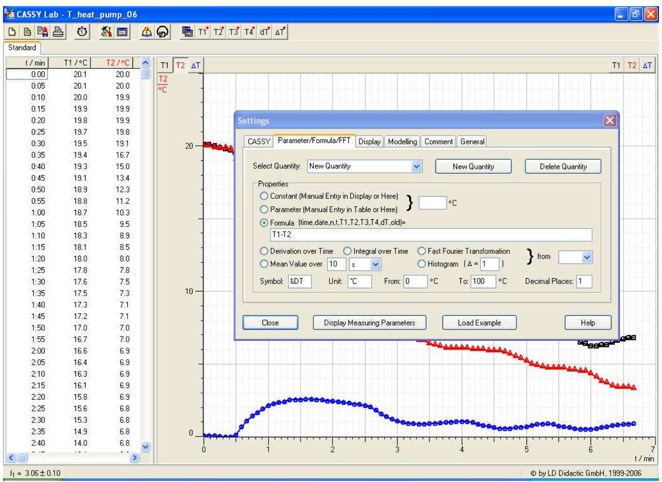
After an initial transient time of a few minutes the measured values of T_V and T_S follow a parallel course with a constant temperature difference of approximately 3K.

For Automatic recording

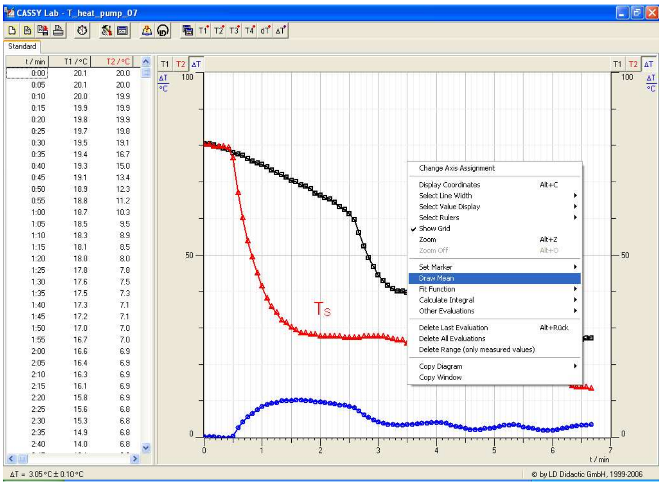
- Open the window "Settings" using the tool box button or function key F5 from the top button bar.
- Select the tab "ParameterFormulaFFT" to define the temperature difference T_V - T_S as Formula:

  T1-T2

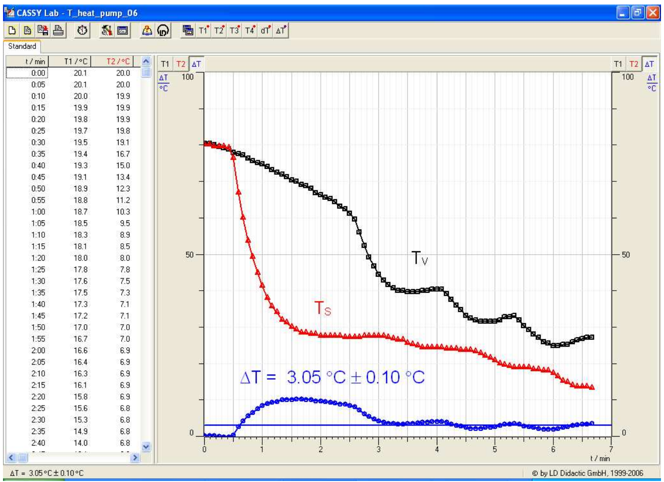
- Enter the symbol "&DT" (i.e. ΔT) unit "°C" and preset the range e.g. from 0° to 100° and close the window "Pa rameterFormulaFFT".



- Click on the button “ΔT” at the top of the y-axis to select the scale for the “blue data”.
- To calculate the mean average click into the display with the right mouse button and select the data by dragging the mouse pointer over the data after the transit time.



- After releasing the mouse pointer the the mean value is displayed and the result is shown at the left corner of the status line at the.
- The result may be displayed by “Set Marker” or Alt-T.



Supplementary information

The thermostatic expansion valve is an important assembly part of a heat pump to reach a high degree of efficiency. It is controlling the heat extraction from the cold-water reservoir in an optimal way. On the other hand, a capillary tube control, as it is used in standard refrigerators, is working optimally only for certain temperature differences between evaporator and liquefier. To avoid “beats by a liquid“ of the compressor, the amount of coolant in a standard refrigerator has to be proportioned very carefully. For the same reason it is not allowed to vary the geometrical array of the copper tubes. Therefore refrigerators whose geometrical setup is modified to demonstrate the principle of a heat pump have the risk to be destroyed by such “beats“.