IMEKO 20th TC3, 3rd TC16 and 1st TC22 International Conference
Cultivating metrological knowledge
27th to 30th November, 2007. Merida, Mexico.

A calibration system for ptu devices

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Abstract

Devices measuring pressure, temperature and humidity simultaneously are known as PTU devices. There are hardly any commercial calibration systems for the PTU devices available for low temperatures (< 0 °C). To obtain more comprehensive data on the performance of PTU devices, a new calibration system is developed at MIKES. In this PTU Apparatus, pressure, temperature and humidity can be controlled simultaneously so that all combinations over the ranges are possible. The nominal ranges of the system are the following: absolute pressure 500 hPa … 1200 hPa, temperature -52 °C … +80 °C and relative humidity 10 % … 95 %. The estimated uncertainties (k = 2) of the pressure, temperature and humidity are 10 Pa, 0,1 °C to 0,3 °C and 1 %RH to 3 %RH, respectively. The construction and operation as well as the results of operational tests of the PTU Apparatus are reported in this paper.

Keywords: pressure, temperature, humidity, simultaneously control, PTU devices

1. Introduction

Typical applications for PTU devices are e.g. weather observation systems and wrist computers. At the moment, pressure transducers of the PTU devices are usually calibrated separately from the temperature and humidity sensors, because there are hardly any commercial calibration systems for the PTU devices available for low temperatures (< 0 °C). This kind of calibration procedure means that e.g. the possible humidity or temperature related behaviour of the pressure transducers can not be seen.

To obtain more comprehensive data on the performance of PTU devices, a new calibration system is developed at MIKES. In this PTU Apparatus pressure, temperature and humidity can be controlled simultaneously. On the one hand this makes the apparatus very interesting and useful for different kinds of research purposes. On the other hand the apparatus can serve manufacturers of PTU devices during the research and development process, testing and calibration.

In this paper, the principle of operation and constructed apparatus are described. Tests covering pressure and temperature control in the whole range of interest are reported. Also, results of a preliminary test on humidity control are presented.

2. Operating principle and construction

2.1 Operating principle

The system diagram is illustrated in the Figure 1 and the system in operation in the Figure 2. The supply pressure to a dew point generator is controlled with a Fairchild pressure regulator and it is measured with an MKS capacitive transducer. The pressure inside the measuring chamber is controlled using Bronkhorst line pressure regulators in the pipelines before and after it. The first one regulates forward pressure and the second one regulates back pressure. The pressure inside the chamber is measured with a Vaisala digital barometer type PTB220. With the three regulators it is possible to control the dew point generator pressure and the measuring chamber pressure separately and always keep the dew point generator pressure higher than the atmospheric pressure.

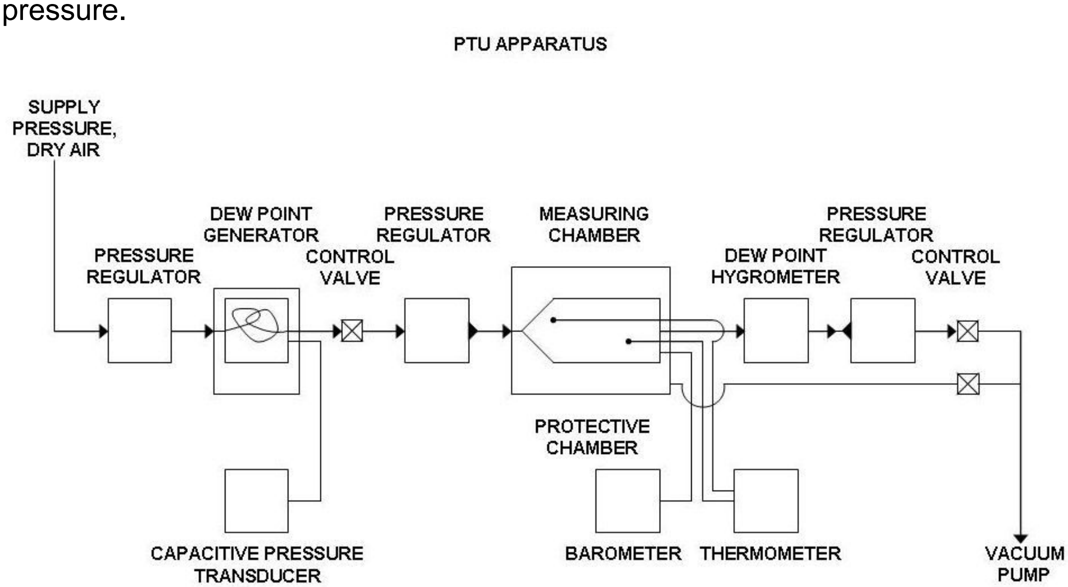

Figure 1. The system diagram of the PTU Apparatus. Supply pressure (dry air) goes to the dew point generator through the pressure regulator which keeps the dew point generator pressure higher than the atmospheric pressure. After that the air flow goes to the measuring chamber through the forward pressure regulator. After the measuring chamber the air flow goes to the dew point hygrometer and finally through the back pressure regulator to the vacuum pump. The dew point generator pressure is measured with a capacitive pressure transducer. The measuring chamber pressure and temperature are measured by the barometer and by two K-type thermocouples.

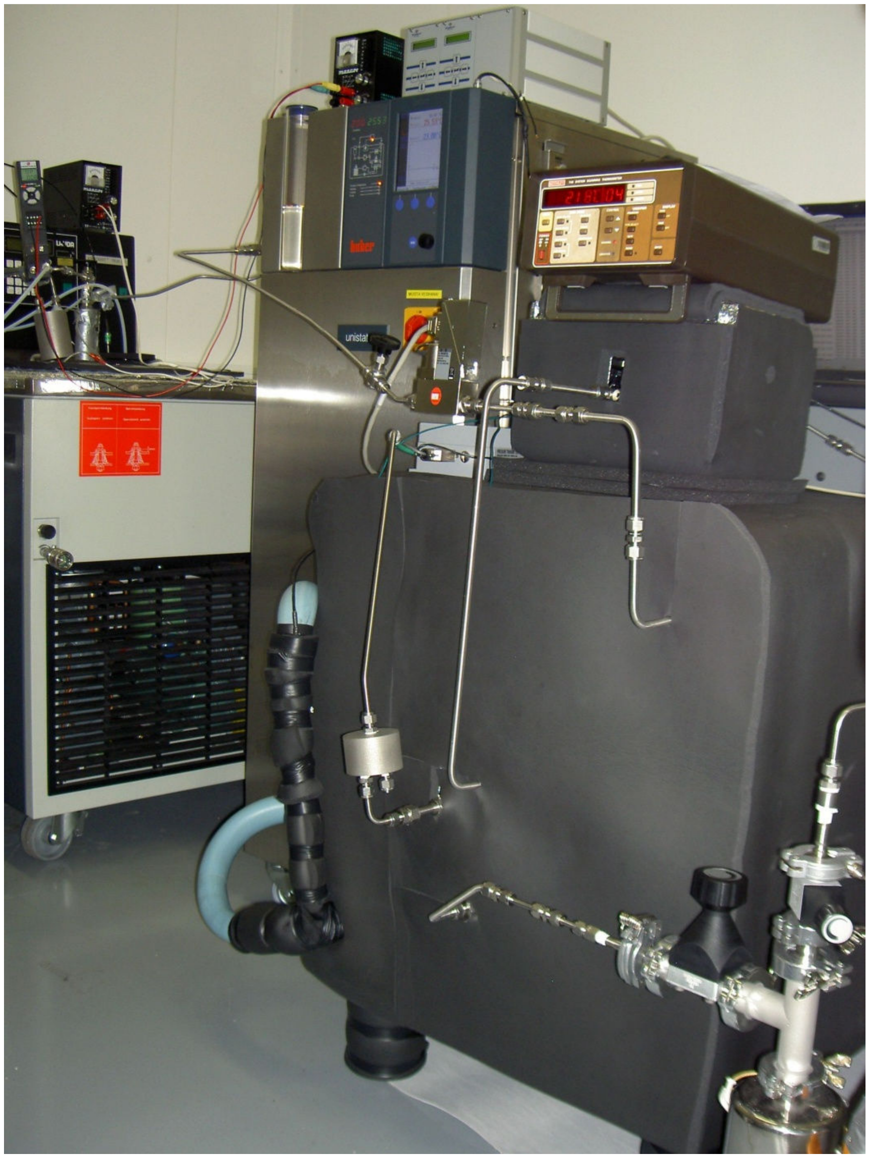

Figure 2. The PTU Apparatus in operation. In the foreground the protective chamber where the measuring chamber is located into the horizontal position. In the middle the heat transfer system thermostat. In the background the dew point generator located into the bath.

For the temperature control, heat transfer oil circulates in a system consisting of a Huber Unistat 815w thermostat and a spiral pipeline. The control is based on the temperature measured from the circulation system return line with a Pt-100 transducer. At present, the temperature inside the chamber is measured with two K-type thermocouples but will be replaced by Pt-100 probes in near future. The first one is located 100 mm and the other one 300 mm deep from the straight end of the measuring chamber to observe the differences in the temperature along the chamber.

The dew-point temperature in the chamber is controlled by a dew point generator MDFG (in the two-pressure mode) supplying air into the measuring chamber. The technical details of the MDFG are described in [1] and [2]. The relative humidity is determined from the dew-point temperature and the air temperature in the chamber using the well-known mathematical formulae [3]. The dew-point temperature is monitored with a dew point hygrometer EdgeTech type Dew Master DM-C1-S3.

The nominal ranges of the PTU Apparatus are the following: absolute pressure 500 hPa … 1200 hPa, temperature -52 °C … +80 °C and relative humidity 10 % … 95 %. All combinations over the pressure, temperature and humidity ranges are possible. The estimated measurement uncertainties (k = 2) of the pressure, temperature and humidity are 10 Pa, 0,1 °C to 0,3 °C and 1 %RH to 3 %RH, respectively.

2.2 Construction

The measuring chamber is made of stainless steel and it has a cylindrical shape with a conical head (Figure 3). Inner diameter of the measuring chamber is 150 mm and the volume is 7 litres. To prevent leaks inwards, the measuring chamber is located in a protective chamber so that the air pressure round the measuring chamber is lower than inside it. This is a very important point because otherwise the surrounding air together with water vapour will very easily get into the measuring chamber. Even a very small amount of water vapour can change humidity value significantly, especially at the low end of the temperature range.

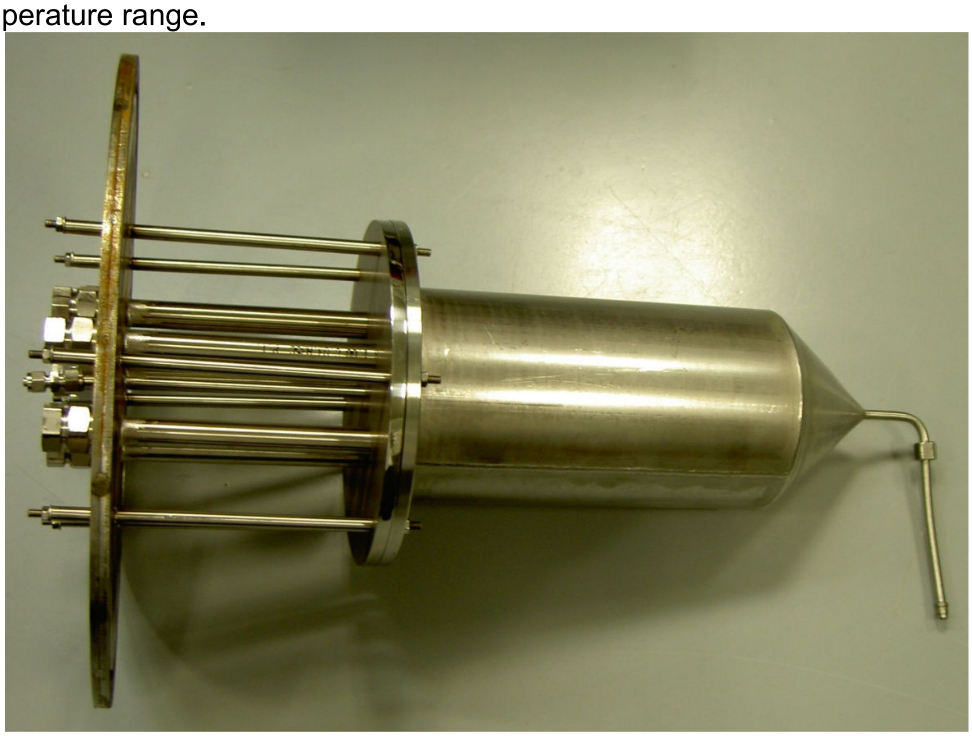

Figure 3. The measuring chamber of the PTU Apparatus. The measuring chamber has a cylindrical shape with a conical head. Inner diameter of the measuring chamber is 150 mm and the volume is 7 litres.

The protective chamber surrounding the measuring chamber is 500 mm wide and high, and 700 mm deep. A pipeline for heat transfer oil is located onto the inner surface of it. The pipeline is a spiral with a shape of square. A measuring chamber is located into the protective chamber to the horizontal position.

3. Operational tests

3.1 Pressure and temperature

The pressure controlling tests for the PTU Apparatus at absolute pressures 500 hPa and 1100 hPa were done both at -52 °C and +80 °C. It takes approximately 24 h the system is cooled down and stabilised. Heating the system takes only half of that time, approximately 12 h. After the stabilisation the temperature differences observed between the two temperature transducers at -52 °C were less than 0,1 °C and less than 0,2 °C at +80 °C. A temperature drift of 0,5 °C was observed at -52 °C during a 24 h period. The maximum temperature deviation during a 8h period was ±0,1 °C. At +80 °C, the monitoring period was 8h. During that time there were a 0,5 °C drift in temperature and ±0,2 °C deviation.

The tests on the pressure control were made at absolute pressures 500 hPa and 1100 hPa for an half an hour at a time (Figures 4 and 5). The maximum deviation of ±0,15 hPa was observed at 500 hPa abs. at -50 °C. Otherwise the observed deviations were less than ±0,10 hPa.

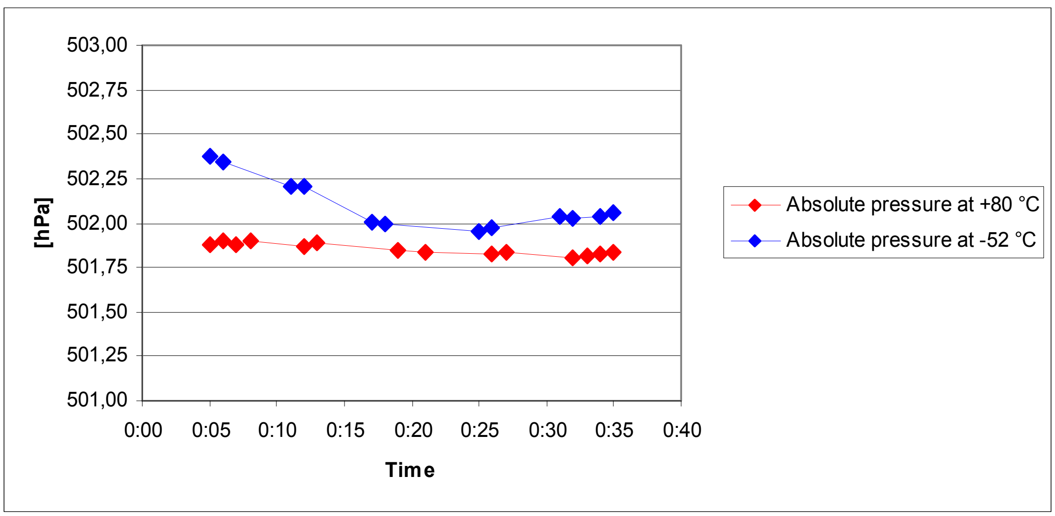

Figure 4. The test on the pressure control at absolute pressure 500 hPa. The graph shows the absolute pressure readings during an half an hour monitoring period at -52 °C and at +80 °C, the upper curve and the lower curve, respectively.

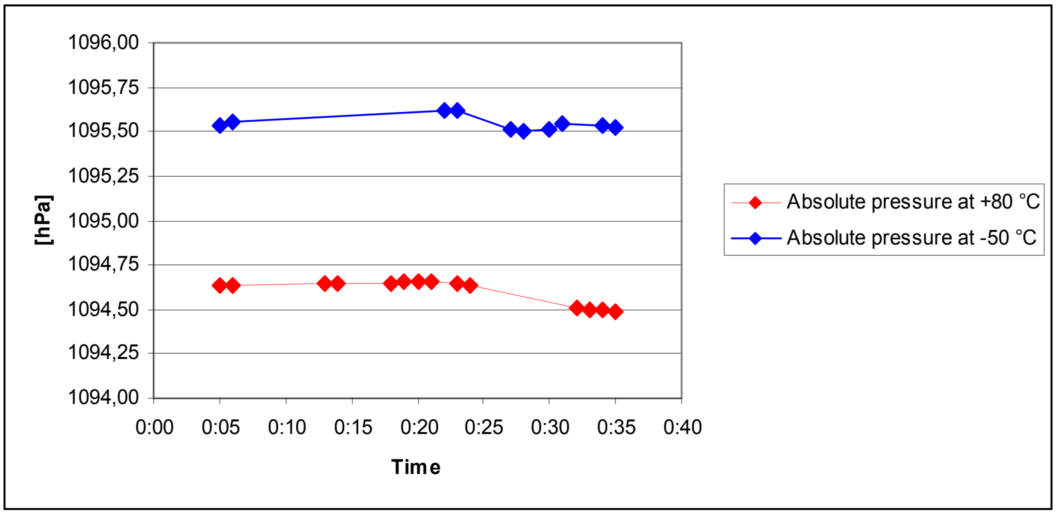

Figure 5. The test on the pressure control at absolute pressure 1100 hPa. The graph shows the absolute pressure readings during an half an hour monitoring period at -52 °C and at +80 °C, the upper curve and the lower curve, respectively.

The test on the long time pressure control was carried out at 1075 hPa abs (Figure 6). During a 36 h period the maximum deviation observed at 1075 hPa abs. was ±0,15 hPa. During that time the system was cooled down from the room temperature to approximately 13,5 °C, and the pressure control system could handle the change in the temperature.

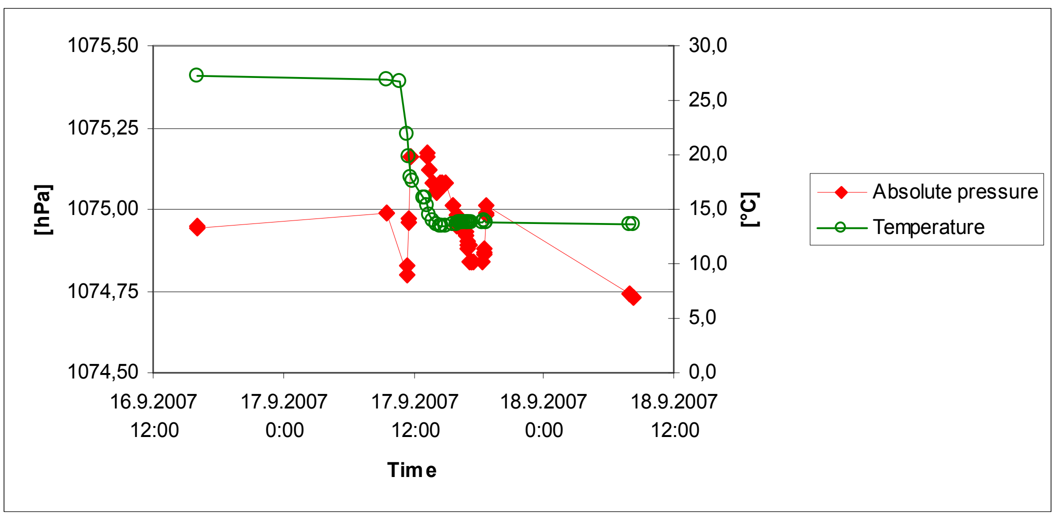

Figure 6. The test on the long time pressure control at absolute pressure 1075 hPa. The graph shows the absolute pressure readings and the temperature readings during a 36 h monitoring period. The system was cooled down to approximately 13,5 °C and the pressure was controlled at 1075 hPa.

3.2 Humidity

In the humidity test the measuring chamber was maintained at 13,8 °C and the pressure inside the chamber was controlled to 1075 hPa abs. The dew point generator temperature was 12,5 °C and pressure inside it was kept at 1560 hPa abs. Because of the effect of the pressure difference between the saturation pressure and the test pressure the dew point temperature was 7,0 °C in the measuring chamber. The corresponding relative humidity is 64 %RH.

A rise of the humidity in the measuring chamber from the frost-point temperature of -14 °C to the dew-point temperature of 7 °C (from 10 %RH to 64 %RH) takes approximately half an hour. After that, however, it takes still time to reach a stable humidity in the chamber (Figure 7). Humidity changes in the measuring chamber are monitored by the dew-point hygrometer.

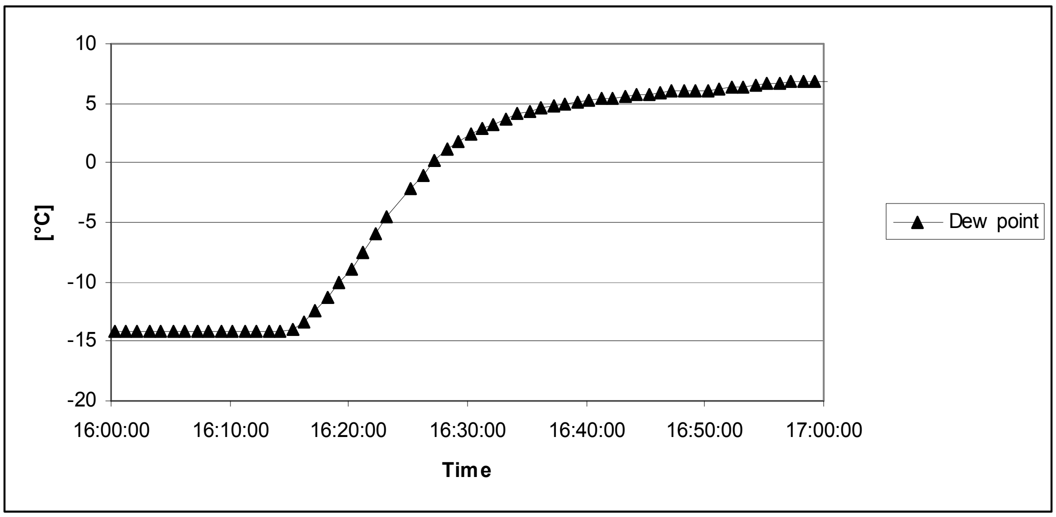

Figure 7. The humidity test. The graph shows the dew point hygrometer readings: A rise of the humidity in the measuring chamber from the frost-point temperature of -14 °C to the dew-point temperature of 7 °C.

3.3 First measurements for a PTU device

A PTU device type TR-73U was used as a test piece to demonstrate, how to test and calibrate devices by the PTU Apparatus. TR-73U is a data logger capable of measuring, displaying and recording temperature, relative humidity and barometric pressure data. The device was located into the measuring chamber and it was kept there during the humidity test described in the Chapter 3.2. The data collected by the device together with the data recorded by the PTU Apparatus reference instruments is presented in the Figure 8.

The Figure 8 shows the change in the relative humidity observed by the test device as the relative humidity of approximately 10 %RH rises to 64%RH (frost-point temperature of -14 °C rises to the dew-point temperature of 7 °C) inside the measuring chamber. The tested PTU device repeats the change in relative humidity pretty well, but with a delay of approximately 10 – 20 minutes.

As the Figure 8 shows, the temperature readings of both the test device and the PTU Apparatus thermometer stay very stable during the test. The maximum difference observed between the temperature readings is maximum 0,2 °C.

It can be seen from the Figure 8 that there is a difference between the test device and the PTU Apparatus barometer PTB220 absolute pressure readings. The maximum difference is 2,8 hPa. Equal difference was observed when the test device was compared to the barometer at the room temperature and at the relative humidity 45 %RH. On the basis of this it can be concluded that the difference in the pressure readings is neither temperature nor humidity dependent.

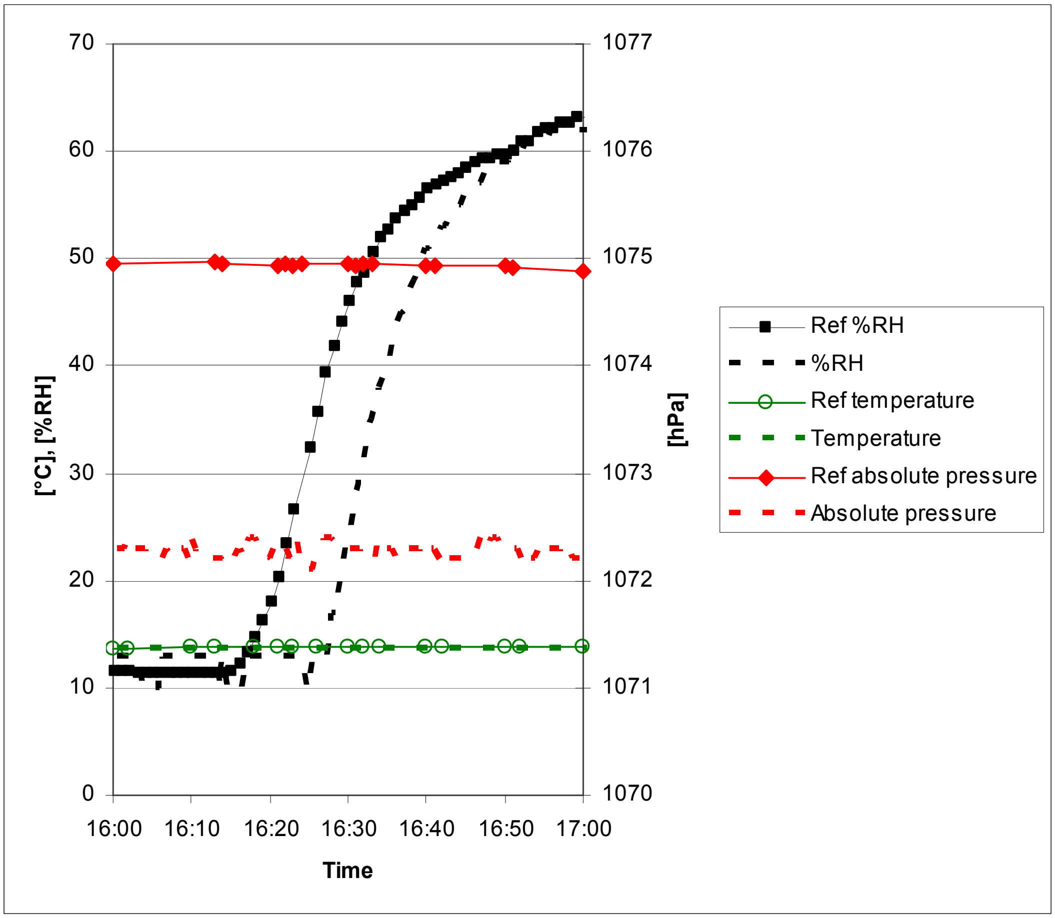

Figure 8. Measurements for a PTU device. The graph shows the data collected by the test device together with the data recorded by the PTU Apparatus reference instruments. The left hand side y-axis is for the temperature and the relative humidity readings in °C and in %RH. The right hand side y-axis is for the absolute pressure readings in hPa. The curves from up to down as they appear on the left hand side y-axis are as follows: the reference absolute pressure readings (barometer), the absolute pressure readings of the test device, the reference temperature readings (K-type thermocouple), the temperature readings of the test device, the relative humidity readings of the test device and the reference relative humidity readings calculated from the dew-point temperature readings (dew point hygrometer).

4. Discussion and conclusions

The operational test results on the PTU Apparatus are very promising. Many problems have been solved during the work done until now. The operation of the pressure and temperature controls is satisfactory but the humidity control needs further work.

By September 2007 only one test on the humidity control (described in Chapter 3.2) was carried out. Next step in the PTU Apparatus development is the construction of a heating system to the pipeline between the dew-point generator and the measuring chamber as well as between the measuring chamber and the dew-point hygrometer. After this improvement it is possible to control humidity also in the temperature range above ambient temperature. Also, an automate data collection system will be developed for the PTU Apparatus.

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