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PHENIX TEC-TRD Detector Gas System

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Система газообеспечения детектора TEC-TRD в эксперименте PHENIX

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Аннотация

Описано устройство и основные принципы работы рециркуляционной системы газообеспечения детектора TEC-TRD в эксперименте PHENIX [1]. Система обеспечивает детектор TEC газовой смесью P10 ($Ar+10\%CH_4$), детектор TRD – смесью ($He+40\%Xe+10\%CH_4$) и стабилизирует давление в детекторах и утилизирует смесь, содержащую ксенон. Автоматизированная система контроля и съёма данных защищает детектор в случае аварийных ситуаций, накапливает информацию с датчиков давления, температуры и анализаторов CH_4, O_2 и H_2O.

Abstract

The PHENIX TEC-TRD Gas System was designed to supply the Time Expansion Chambers (TECs) with the P10 ($Ar+10\%CH_4$) and the Transition Radiation Detectors(TRDs) with $He+40\%Xe+10\%CH_4$ mixtures at a controlled pressure and collect the mixture containing Xenon. This system regulates the pressure of mixture while monitoring mixture temperature, flammable gas content, Oxygen and Moisture. A computer control/data acquisition system collects and logs the gas system operating parameters while providing a means of remotely controlling system valves.

General description

The primary purpose of the TECs/TRDs Gas System, shown in Fig.1, is to provide P10 pure mixture to the TECs or He+40%Xe+10%CH4 to the TRDs at the correct pressure. Refer to Table 1 for a list of Gas System parameters. A design of this system is the same as in our publications [2,3] but has some peculiarities which are described below.

The system operates nominally as a closed circuit gas system with the majority of mixture recirculating through the TECs/TRDs and delivery system. During normal operation a small amount of fresh mixture is added and an equivalent quantity of the existing mixture is vented. The gas system can be operated in an open system configuration for purging. In the case of using the mixture containing Xenon the existing mixture is collected with the compression system and then used as the part of make-up mixture.

The mixture circulation rate through the compressor is 800 l/hr and 400-450 l/hr through the TECs/TRDs . The gas system contains two small membrane compressors SC1, SC2, one active and one spare, each capable of 800 l/hr at 90"WC gauge pressure. The 90"WC output pressure from the compressor is reduced to 2"WC by the pressure regulator PCV1. The return gas manifold is maintained at 1.0mm WC above atmospheric pressure by a differential pressure transmitter PT1 and pneumatic PID controller that operates a bypass valve. The bypass shunts flow from the compressor discharge line directly back to the compressor's inlet. A second bypass valve MV5 is manually adjusted to enable the automatic control loop to be used within its optimum range.

The purity and composition of the mixture is monitored using oxygen, methane and humidity analyzers. A fraction of the recirculating mixture or all flow can be passed through a purifier and dryer to remove moisture and contaminants as needed.

A computer driven data acquisition/control system monitors all of the process variables. The computer system flags quantities which fall outside of predefined limits and initiates corrective action. However, where the safety of equipment or personnel are affected, a relay based, hardwired interlock system connected to redundant set of sensors control the action of all key based controls fail.

It is imperative, for the safety of the decides, that the TECs/TRDs inside pressure accurately track barometric pressure. A rapid change in atmospheric pressure is typical preceding storms and hurricanes. To assure that the TECs/TRDs follow a fast rise in atmospheric pressure, a relatively large flow of inert gas will admitted into the vessels in the event that normal pressure controls fail to keep up with "falling" internal pressure. The vent lines and associated valves are sized to allow for rapid venting of the TECs/TRDs mixture to prevent a high internal pressure in the case of the fast barometric pressure fall. In addition the bubbler connected to the TECs/TRDs return manifolds will vent in the event that all other measures fail.

Table. Performance of gas system

Mixtures	(10+/-0.1%)CH_4 in Ar He+40%Xe+10%CH_4
Compressor pressure	60-100 "WC
Mixture supply pressure	2.0" WC
Mixture return pressure	1.0+/-0.2 mmWC
Recirculation flow	800 l/hr
Purge Mixture flow	600 l/hr
Mixture flow through TECs/TRDs	400-450 l/hr
Make-up mixture flow	0.5-10 l/min
Oxygen content	< 10 ppm
Water content	< 5 ppm

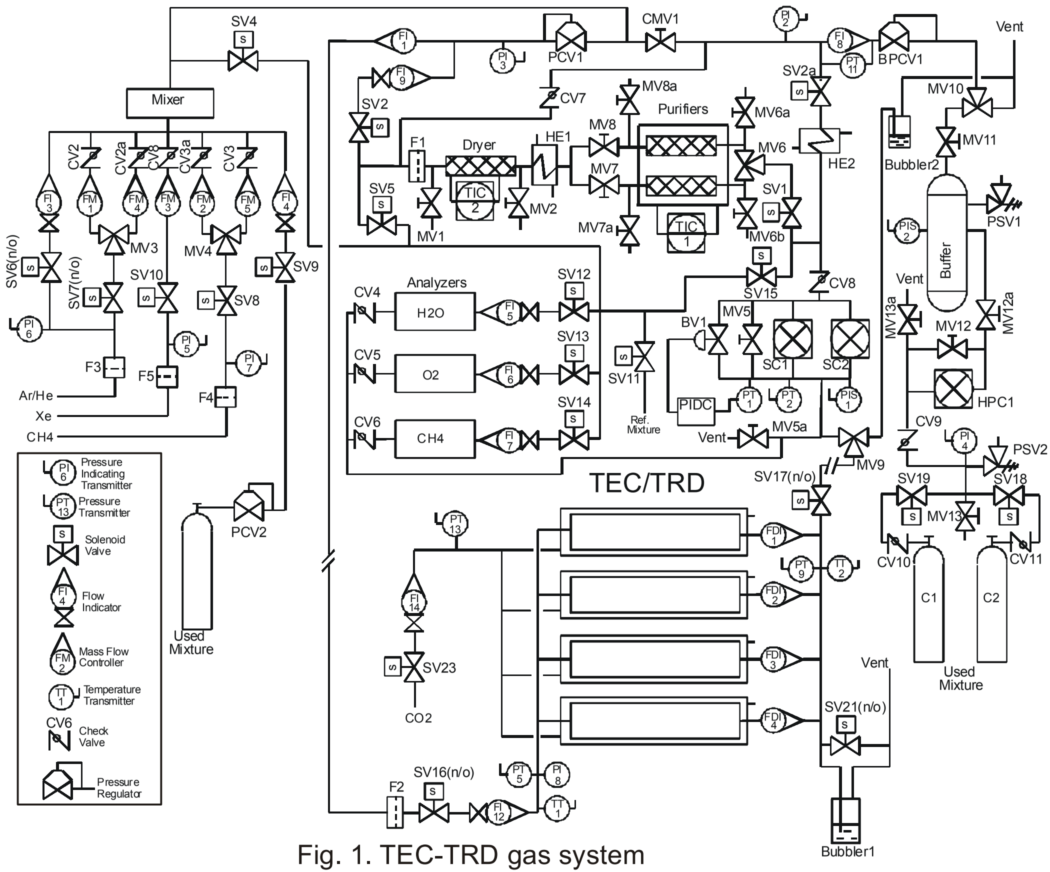

Fig. 1. TEC-TRD gas system

Pressure control

There are two sources of pressure in the system, the first is the compressors located at the exit of the TECs/TRDs. The second is the flow of fresh mixture through the mixing manifold. Nominally the pressure within the TECs/TRDs is controlled by maintaining a constant pressure upstream of the TECs/TRDs via the pressure reducing regulator PCV1 and varying the pressure downstream of the TECs/TRDs by regulating the amount of mixture shunted from the compressor output to inlet. On a longer time scale the flow of fresh mixture is constant.

The output from the compressor is 800 l/hr at 100"WC. A back pressure regulator BPCV1 in the outlet line is set to 90"WC thus maintaining a maximum delivery pressure independent of the compressor output. This pressure is reduced to 2"WC by the pressure regulator PCV1.

The TECs/TRDs exhaust pressure, measured at the return gas manifold is maintained at 1.0 mm WC by a TESCOM ER3000 electropneumatic PID controller. A 0-2.5 mmWC differential pressure transmitter PT1 on the return manifold produces a 4-20 mA output that the PID controller compares to a set-point value. If the transmitter signal is different from the setpoint the controller sends a pneumatic output signal to the bypass control valve. The bypass shunts flow from the compressor discharge line directly back to the compressor's inlet opening the bypass valve causes the TECs/TRDs exhaust pressure to rise and closing the valve makes the pressure fall. A second bypass valve MV5, manually adjusted during the initial system set-up, enables this automatic control loop to be used within its optimum range.

The fresh mixture is admitted between the pressure regulator PVC1 and back pressure regulator BPCV1. The quantity of fresh mixture may be changeable in the range of 1.0-10l/min with the mass flow controllers FM1 and FM2 in the case of P10 mixture or 0.5-6LPM with the mass flow controllers FM3,FM4 and FM5 for He+40%Xe+10% CH_4 mixture. Simultaneously, gas is removed from the system through the back pressure regulator BPCV1. To have the stable content of fresh mixture the Argon mass flow controller FM1 operates the Methane one FM2. It means that FM1 is a master and FM2 is a slave. The same takes place in the case of Xenon containing mixture. Helium FM4 flow mass controller operates the Xenon FM3 and Methane FM5 ones. These units are normally locally controlled. The quantity and composition of fresh mixture are monitored with PC data acquisition/control system.

When the return manifold pressure, as measured by PT2 is more than 2.5 mmWC above the atmospheric one, the gas control system will close the solenoid valve SV7 in the fresh mixture supply line and open the vent line valves SV21 allowing mixture to vent directly to the atmosphere. Also, a pressure indicating switch PIS1 has a set-point of 2.5 mm WC and it can operate SV7 and SV21 as the computer control system. When the TECs/TRDs and supply manifold pressure measured with the pressure transmitter PT5 will be more than 10 mm WC or exit pressure measured by PT9 will be more 6 mm WC the gas control system will close SV7 and open SV21. Should the exit pressure reach 8 mm WC, the exit TECs/TRDs mixture will vent to the atmosphere through the bubbler B1. With this arrangement the TECs/TRDs are protected from either flow controller malfunction, a rapid drop in atmospheric pressure and/or a failure of the back pressure regulator.

In the event of a rapid rise in atmospheric pressure, or effectively a fast drop in the TEC's/TRDs internal pressure (up to 6 mBar/min), a dual set point Dwyer differential pressure transmitter PT2 in the return manifold will trip as the pressure falls below 0.5mm WC causing an audible and visual alarm. When the pressure at PT2 falls below 0.2 mmWC gage a second set-point trips and the computer control system system will stop compressor, shut-off the flow of Methane and pass inert gas by opening solenoid valve SV6 to supply an additional 10 LPM of inert gas.

A pressure indicating switch PIS1 with dual set points is also installed in the return manifold. This switch is not connected to the computer control system but instead is hardwired to perform the same functions as computer in the event of a falling TECs/TRDs pressure. Thus the system is equipped with two separate means of preventing the TECs/TRDs from experiencing an external over pressure.

In the case of detectors leakage the flow direction indicators FDI1, FDI2, FDI3 and FDI4 will show which detector has the leak and the computer control system will inform about this by the audible signal and flashing light.

In the event of a power failure, the solenoid valves SV6, SV16, SV21 will open, or remain open and SV8, SV9 and SV10 will close, causing 10 l/min of inert gas to flow through the TECs/TRDs. This flow rate is adequate to assure that fluctuations in the atmospheric pressure will not result in the creation of over or negative pressure inside the TECs/TRDs.

Temperature Measurement

Two 100 Om RTD temperature transmitters TT1, TT2 are used to measure the input and output TECs/TRDs mixture temperature. The data of measured mixture temperature are logged for later use in data reduction.

Mixture Control

Along with automated valve control, the gas system's dedicated computer controlled data acquisition provides constant monitoring of the mixture composition vie measuring the mass controllers output signals. Methane analyzer will be used periodically to check Methane content in the mixture. The mixture ratio is fixed by the Teledyne mass flow controllers FM1, FM2 or the FM3,FM4 and FM5 ones. The stability of the flow controllers is sufficient to make variation in the mixture negligible.

Gas Sampling

The gas system is equipped with Teledyne 3010TA Oxygen, Kahn Moisture and California ZRH1 Methane analyzers plumbed such that each section of the gas system can be selected separately for evaluation.

All analyzers data are read and archived by the computer data acquisition system and used to control the gas system.

Gas Purification

A mixture dryer and purifier withdraws a portion (about 3 l/min) of the reciculating flow upstream of the pressure regulator (PCV1) and delivers the conditioned gas to the recirculating flow downstream of PCV1 in the case of P10 mixture. For Xenon containing mixture all amount of recirculating flow can be passed through the Purifier/Dryer to reduce the Oxygen and Water content to the optimum level in TRDs. The dryer is made from the a stainless steel tube containing 3 lbs of molecular sieve (zeolite 13X) as adsorbent. This amount permits the removal of about 1 lbs water vapor to 2-3 ppm level at room temperature. Filters are installed upstream and downstream of the adsorbent to prevent particles from entering to the mixture stream. A heating element is placed outside the dryer. As the thermal insulation a glass tissue is used. The dryer is regenerated by heating to 350-400 C with purging of Argon. The purge gas enters at the top of the dryer and exits at the bottom carrying with it the water vapor. A temperature transmitter installed inside the dryer is connected to the temperature indicating controller TIC2 that supports the dryer temperature on the set-pointed level during the regeneration. A moisture analyzer is used to measure the quantity of the water in the circuit before and after the dryer to determine when the adsorbent is saturated.

There are two purifiers. One is in the operation and the second one is a spare. They were combined to one unit because theirs operating and regenerating temperature is 220C.

Both of them were filled with the pure copper. In our case only one regeneration was done after the purifiers production. Methane presence in the mixture permits to regenerate the purifier during the mixture purification process from Oxygen. The some chemical reactions take place inside the purifier at 220C temperature. They are as following:

$CH_4 + H_2O= CO + 3H_2$

$CO + H_2O = CO_2 + H_2$

$CH_4 + O_2 = CO_2 + 2H_2$

$2Cu + O_2 = 2CuO$

$CuO + H_2 = H_2O + Cu.$

The production of Hydrogen is enough to regenerate the purifier. Xenon containing mixture analyses shown up to 1500ppm of Hydrogen in the mixture. Oxygen content downstream of purifier was less than 5ppm.

Water vapors and CO_2 were cached with the dryer. 220C temperature is supported with TIC1 temperature indicating controller.

A heat exchanger HE1 is used to reduce the mixture temperature coming into the dryer. Usage solenoid valves SV1,SV2 and SV2a permits to direct mixture to different ways or to isolate the purifier/dryer from the main circuit when they do not in use

A 10 micron filter is installed after the purifier/dryer to prevent dust from passing into the main mixture supply line.

Compression system

All Xenon containing mixture coming out from the gas system through BPCV1 at the flow about 1LPM is collected in 200 liters buffer. At 2.7PSI buffer pressure RIX dry piston high pressure compressor HPC1 starts to compress the mixture to the one of the cylinders C1 or C2. HPC1 automatically stops at 0.3PSI buffer pressure. At 1000PSI pressure C1 is automatically exchanged on C2 or versa visa with analog electronic system. Filled cylinder with Xenon containing mixture is connected to the fresh supply gas manifold and used as the part of make up mixture.

Data acquisition and control

The gas system is controlled by a PC-based DAQ subsystem. All sensors are read by National Instruments SCXI-1600 DAQ module using analog multiplexer SCXI-1100. Analog outputs of the DAQ module are used to control flowmeters. Solenoid valves and compressors are controlled by SCXI-1163 isolated digital output module using solid state relays.

The main computer software [4] has been developed with Borland Delphi for the Windows platform. It provides reliable data acquisition, alarm conditions handling and manual control of the gas system. Also, all events and process variables are logged. The software is divided by multiple processes that communicate making use of special operating system kernel objects.

The main process reads all sensors values and passes them to other processes. In order to make DAQ more reliable, it has been divided by two threads: one for the Graphical User Interface (GUI) and one for the data acquisition. The GUI thread shows all gas system parameters including valves state in the main window and handles operator actions. The DAQ thread acquires all the process variables, writes them into shared memory and checks alarm conditions. Every alarm setting contains alarm threshold, alarm message and control template, which indicates alarm set and release action for every controlled device, e.g. valve or compressor. This allows user to have a very flexible configuration of system behavior.

The second process, Data Writer, reads current process variables acquired by the main process and writes them to the MS Access database. Using a separate process for this critical operation improves overall software stability and decreases response time for gas system events.

All data from the gas system are kept in MS Access database, giving one a possibility to use native MS Access tools for converting and analyzing these data. Besides, this simplifies dramatically access to the certain data in a huge database (for example, 3.5 month database has approximately 200 thousands of records). Sometimes it is useful to get fast results and charts from the database during the gas system operation. A special tool for working with the database has been developed. This program (DB Viewer) provides visualization of the data from any system sensor at any given date for one of three periods (day, week or month). It also allows user to convert data from the database to tab-delimited text file for external analysis. There is a possibility to read all system parameters with 1 second period, which is useful for fast reaction to the gas system alarms. Nevertheless the data is written to the database once per minute (if no alarms happen) to reduce database size.

Experimental Results

In this paper we are presented some experimental results of TECs/TRDs gas system for 5 months operation in 2006. During this run as the mixture the He+40%Xe+10%CH_4 one was used.

As shown in Fig.2 the mixture pressure stability upstream of the compressors PT2 was in range of +/-0.2mm WC at 0.6mm WC differential pressure level. The mixture differential pressure downstream of TRDs PT9 was supported at 6.8+/-0.5mmWC for one month operation. It is shown in Fig.3. Also, we can see in these plots that the barometric pressure PTB was changed in the range of 992-1028mBar for this time. It means that the gas system provides very stable detector operation in the recirculation mode during the long time.

According to the experimental results shown in Fig.4, Oxygen content in the mixture downstream of TRDs was 227±7 ppm and Water admixture was in the range of 9-10 ppm for one month operation. Outgoing mixture from the dryer/purifier had 1-2 ppm Water and 9 ppm Oxygen. This content of Water and Oxygen with such stability was supported for 5 months operation.

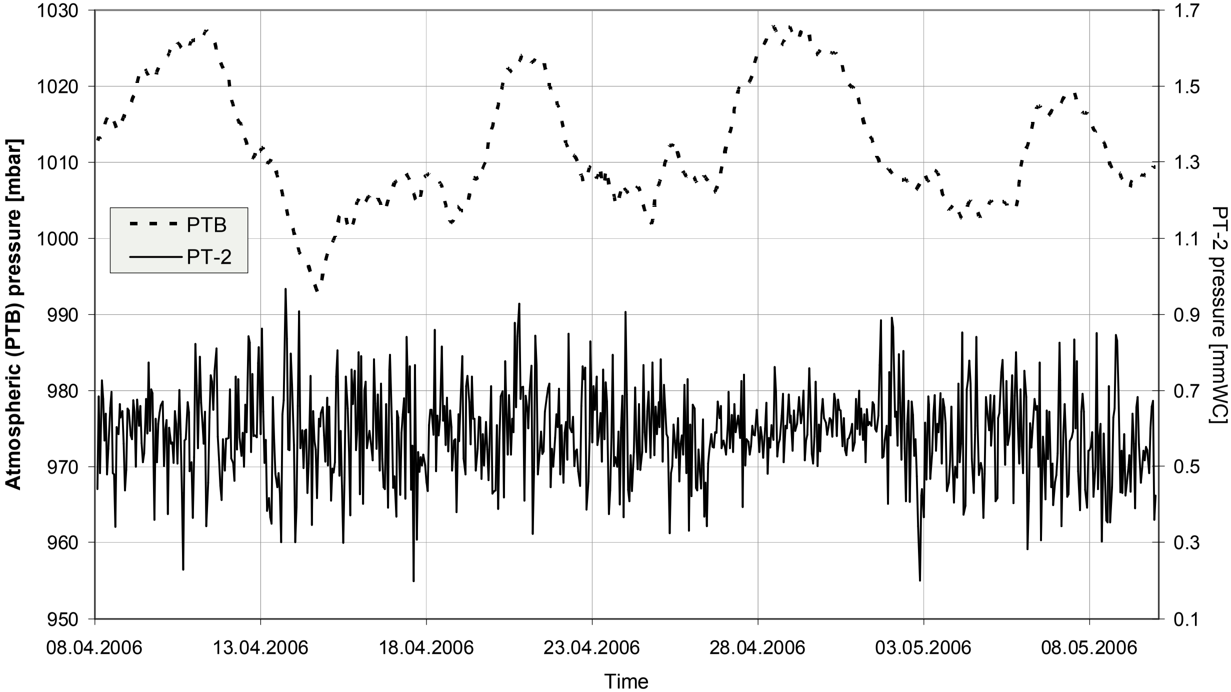

Fig. 2. Pressure stability upstream of the compressors

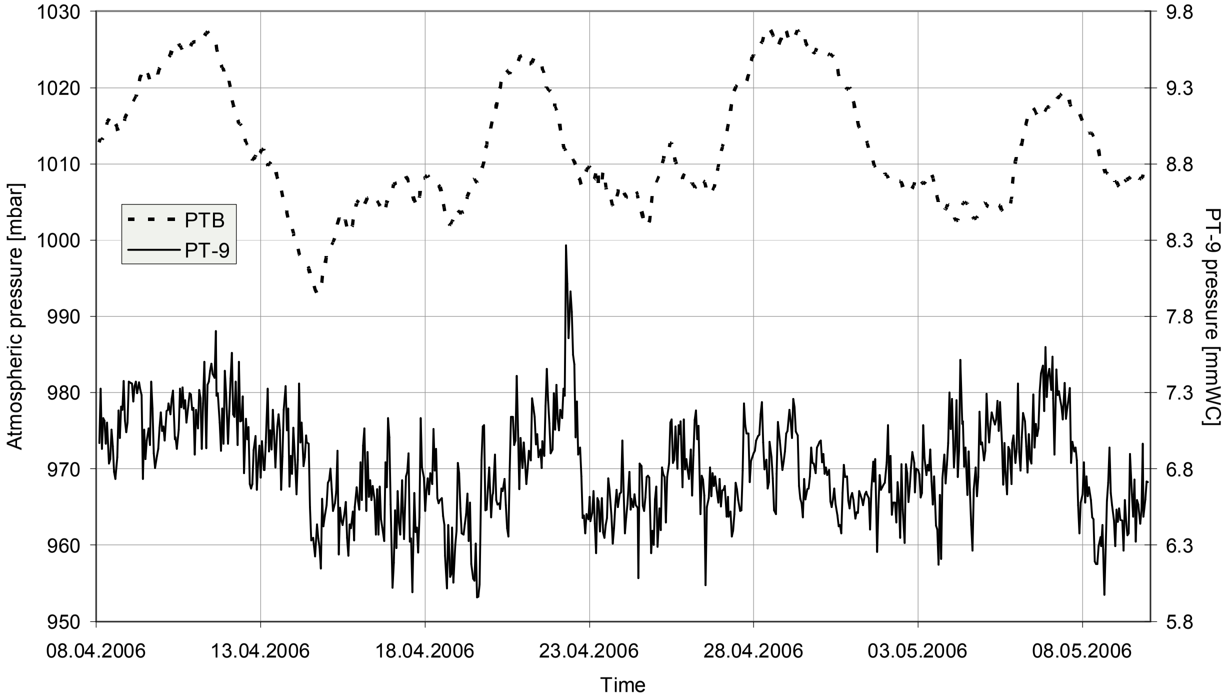

Fig. 3. Differential pressure downstream of detector.

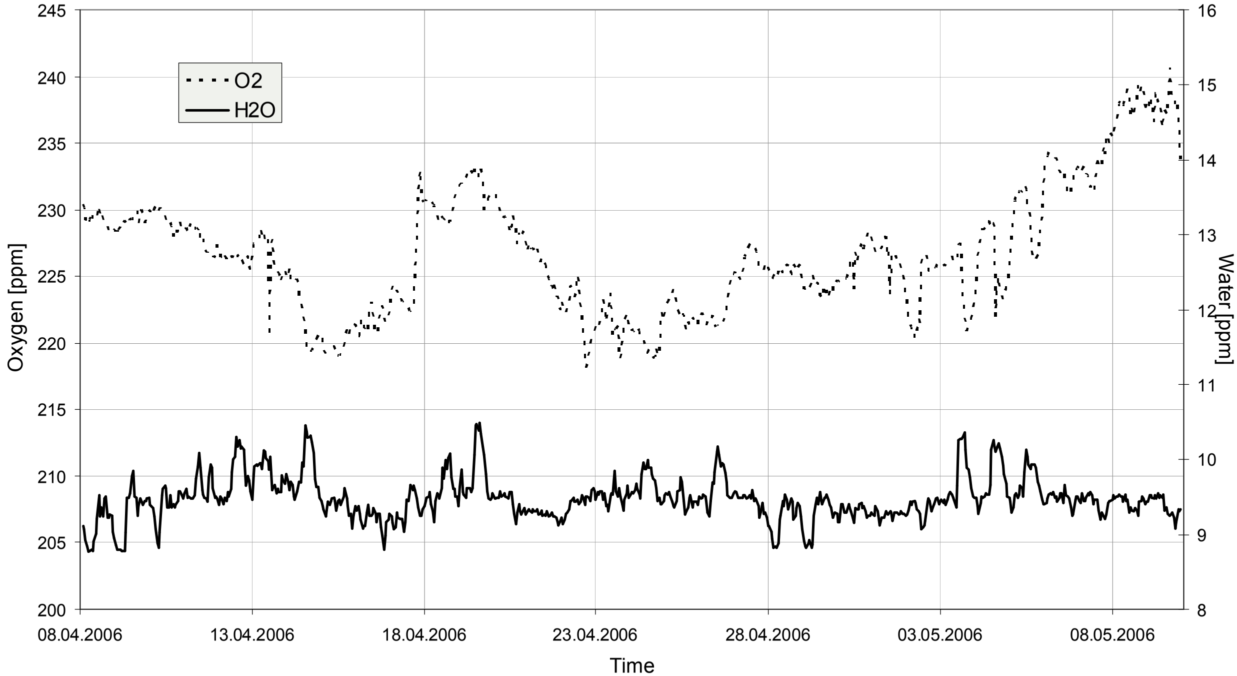

Fig. 4. Oxygen and Water content in the detector.

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