Experimental data collection system for reading pressure levels in a vacuum environment

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Abstract. The University of Oradea is working on developing a research base in material sciences with capabilities of vacuum deposition. The laboratory will be equipped with two deposition system along with with other research equipment, mainly an atomic force microscope and a Nano indenter for material characterization. This paper presents the continuity of our efforts to install two vacuum deposition systems that will be part of the SMARTMAT Laboratory at the University of Oradea. As steps were made in cleaning the equipment, we now focus on obtaining high vacuum. In this process, a constant monitoring solution of the pressure inside the chamber is required, and the steps taken to realize it are presented in this paper. The main focus of the paper is the data acquisition system implemented for monitoring several parameters of which vacuum is the most important. The system will be based on two Pfeiffer Gauges for vacuum and a National Instruments PXI system.

1. The work so far

By now, we have successfully cleaned [1] two deposition systems (sputtering and evaporation). Tests were made by our team regarding the electrical/electronic parts [2]. Both pumps (primary plus turbomolecular and the other one that works by diffusion) were serviced externally.

As we are waiting for different parts to arrive, and the lack of research funding put us on a halt with the turbomolecular pump (the bearing needs replacement, and the pump needs service that can only be made by specialized personnel with the right equipment), we are not wasting time and decided to test the tightness of both vacuum chambers [3]. We primarily developed the system with the evaporation system [4], as the chamber is smaller, has fewer gaskets, and the vacuum system is 100% working. We also ran a few tests on the sputtering system (the one with the two pumps – primary and turbomolecular) but as the turbomolecular pump was making a whirring sound, we thought that the bearing is not in good condition, so we decided that the risk to ruin it entirely was not worth it to use it before we could replace the part.

2. Reading system architecture

The system was made with readily available equipment in the lab. For the hardware equipment, we used a PXI computer from National Instruments, a small router, and cables with standard Ethernet RJ45 connectors. On top of that, we already have the equipment up to the translator (two sensors connected to it). Surely any PC would have been great for this experiment, but as we would like to further automate the process and install new sensors on the vacuum systems, the PXI is an ideal solution as it has the platform needed for the job. Our system is similar to the one presented in figure 1 and needs some additional interface panels

Figure 1. A PXI system same as our own, model number 1042, but with more interfaces

Figure 2. Pfeiffer Gauges translating sensor input into visual pressure output in mBar.

For the software part, all of the architecture was made inside the lab, and tuned specifically for the Pfeiffer DualGauge presented in figure 2. Unfortunately, the SingleGauge does not have an Ethernet port, so extra programming and connections are required to use it for history recording.

2.1. Hardware setup description

As mentioned, the physical setup consisted of the PXI, a router, cable, the Pfeiffer DoubleGauge, two sensors, and the actual system that was pumping out the air to make a vacuum.

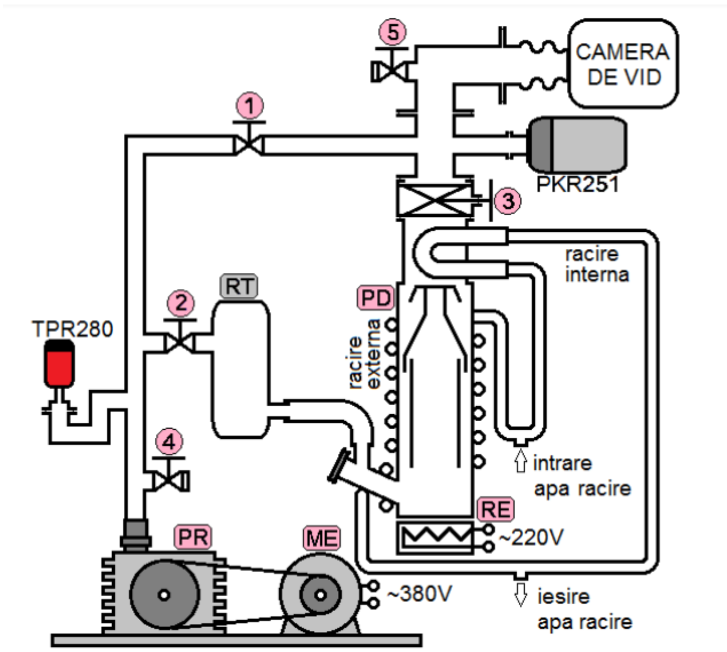

Figure 3. Vacuum system with the depiction of the position of sensors
ME – Electric Motor
PR – Rotating Pump
PD – Diffusion Pump
RT - Reservoir
RE – Electric Heater
TPR280 – pressure sensor
PKR251 – pressure sensor
Intrare apa racier – cold water input
Iesire apa racier – hot water output
Camera de vid – vacuum chamber
Racire externa – external cooling
1, 2, 3, 4, 5 - valves

The vacuum system of the evaporation deposition system, along with the two sensors mounted on it, is presented in figure 3. On channel one, we have the TPR280 sensor, and on channel two, we have the PKR251 sensor in our current configuration. The connection between the sensors and the Pfeiffer DualGauge is made with a special connector and cannot be directly connected to the PXI, as we need the translation for the signal coming out of the sensor. The gauge automatically recognizes the coupled sensor and reads its signal, outputting a value in mBar, as seen in figure 2. The -2 or E-3 represents the power of 10 with which you need to multiply the shown value indicated on display.

So, the DualGauge shows a value of 0.0326 mbar, and the SingleGauge shows a value of 0.0091 mBar. In this case, the differences observed are because one of the sensors is connected to the primary pump and the other one to the turbomolecular one. Usually there is a reading error between 0.3 to 0.5 display units on the DualGauge between the two sensors if they are connected to the same pump.

2.2. Software setup description

The software has 3 parts: the connection protocol that needed to be configured, the collection and storage of data in a database and the display module, as seen in figure 4.

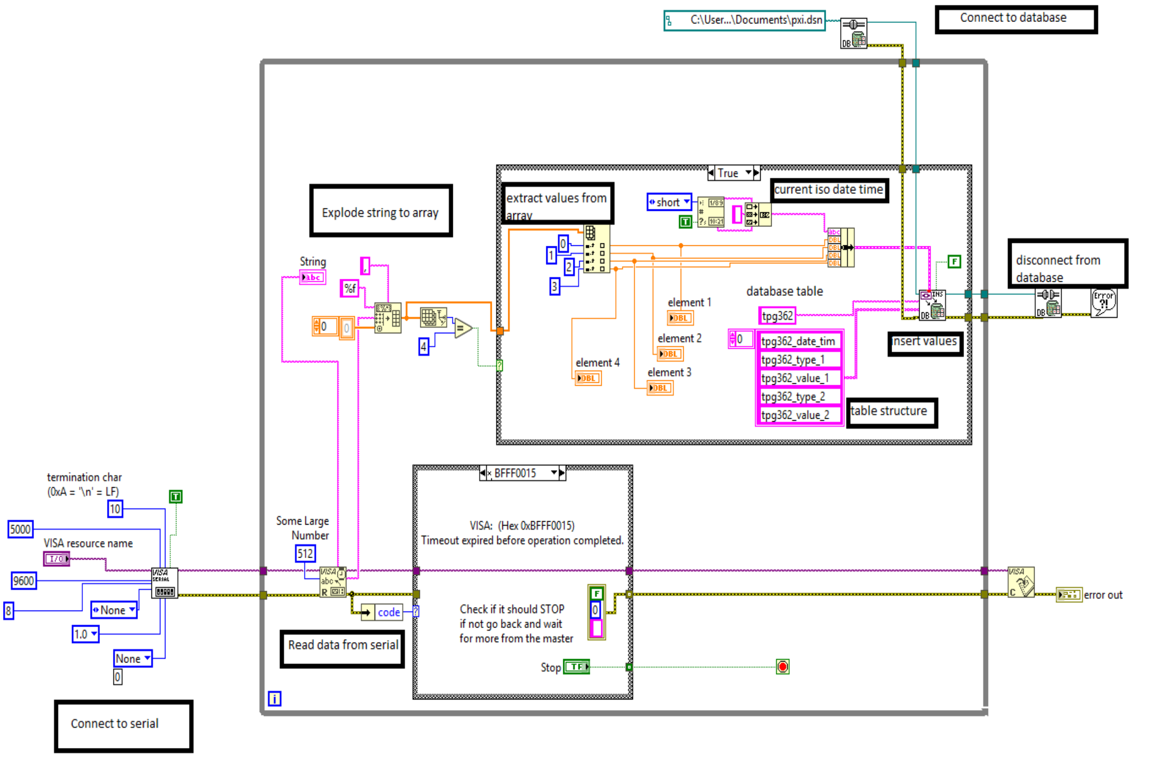

Figure 4. Block diagram from LabView

The connection protocol was configured for the system to communicate with the Pfeiffer DualGauge, with the help of proprietary software from National Instruments. Data for the configuration was taken from the technical book of the Gauge. All of the setups had a visual interface, so no coding was needed. It's still a manual connection for the time being, as each startup of the system requires manual input of the parameters to successfully connect to the Pfeiffer Gauge.

The collection and storage of data in a database was the most complicated part, as it needed a connection with a running database (made with phpMyAdmin) on the computer. This had to be connected to the program that processes the incoming data from the Pfeiffer and stores it for further use. Also, there was necessary preparation of the data to register it in a database, as the values came as a string and needed to be stored as an array. Date and time variables were introduced, which were read from the actual values of the OS. All the computing was made in LabView, which controlled all the processes – collection, reading, processing, adding time and date, insert value to DB

The last step was to read the data from the database and put it into a chart for real-time viewing. This was especially useful as we could see a history of about 1 minute on the graph and draw a fast conclusion if our efforts to seal the system are right or not. A little program was made in python, which collected data from the database and plotted it to a chart. The tricky part was to correctly adjust the viewing scale, as the data plotted was anywhere between 10^3 to 10^{-6}.

The export function of the database was beneficial, as we could export our data into an excel file, and then import it into MATLAB, comparing different setups.

3. Results and interpretation

Once the system was in place, the results were easy to extract and interpret, as seen in figure 5. The data collected gave us an idea of the approximate location of one leakage, and we managed to seal it by adding rubber seals and special vacuum Vaseline. Also, we could compare how fast it could achieve a high vacuum, as we tested in different experimental conditions (temperature and volumes).

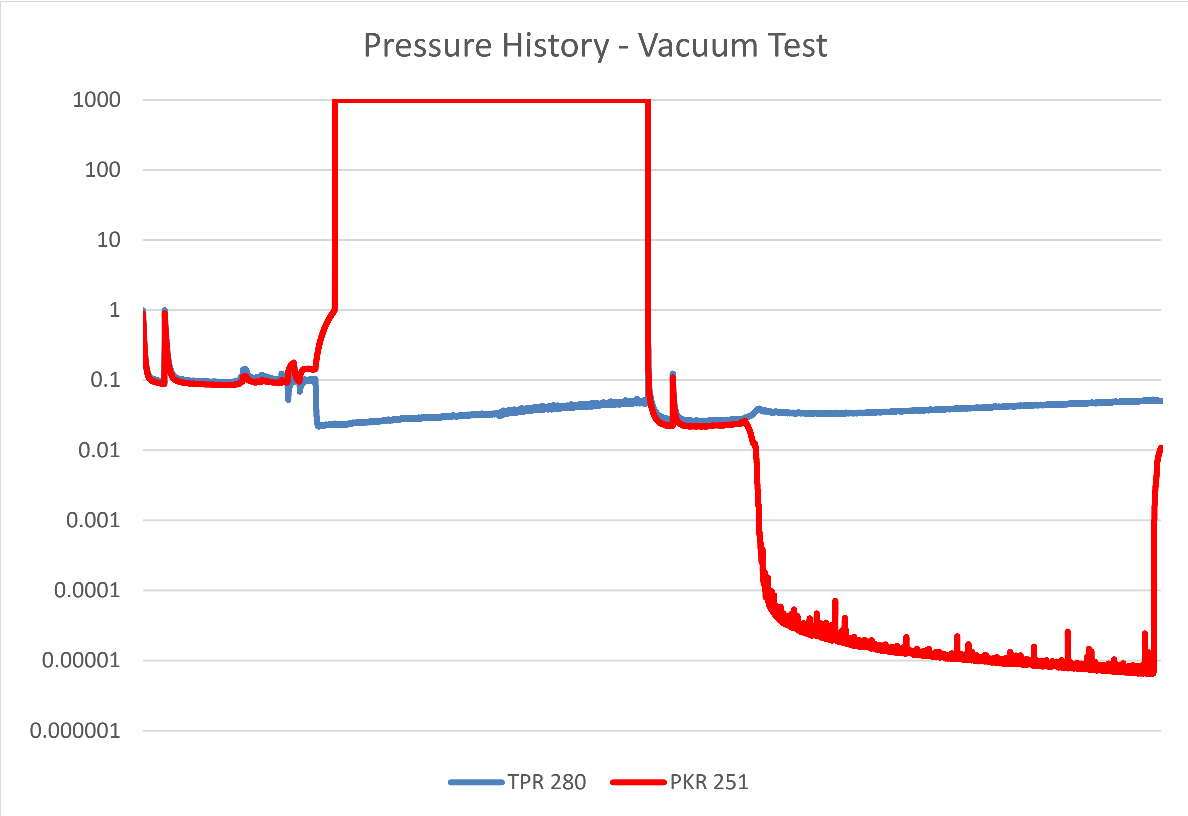

Figure 5. Exported chart

As valve 1, from figure 1 closes, and valve 3 opens, the PKR 251 sensor will measure vacuum generated by the diffusion pump. After sealing all leakages, we obtained a vacuum of E-6, which is recommended for the evaporation deposition system [5],[6].

Further tests will be made before starting the deposition process [7], as the fluctuations in pressure seen on the graphics need to be completely eliminated. By then, we estimate that a temperature sensor will be integrated into the vacuum chamber, electrical heater, and on the pump, to fully observe the temperature impact on the vacuum. The upward trend of the blue line is surely determined by the heating of the oil in the rotating pump, and the vacuum generated by the diffusion can also be improved by tweaking the temperature with the help of the external cooling. Once we can gather this data, the next step is to automate the process, to obtain the best vacuum and maintain it relatively at a stable value.

4. Conclusion

This experimental setup helped us understand where leakages appeared in the system but also found out that the pumps (rotating and diffusion pump) have their limitations, and a temperature management system is critical in obtaining and maintaining a high and stable vacuum.

Our next steps regarding the experimental setup are to make it easier for any user to start it and export the registered values, to install some temperature sensors and find the right temperatures for obtaining a stable and high vacuum, and ultimately build a sustainable system, that can maintain a pre-set vacuum value through the help of all the installed sensors and a few actuators.

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