Mobile dry pumping stations for PETRA III beamlines

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Abstract. The PETRA storage ring at DESY will be upgraded to a third generation synchrotron radiation source with 14 beamlines in the PETRA III project. Mobile pumping stations will be needed for the initial pump down of the beamlines and beamline components. They will also be provided for users to pump down their experimental chambers and include the possibility of leak detection and bake out control. Since the layout of the old pumping station design used at DORIS beamlines does not fulfil today's requirements, a new pumping station was developed. In contrast to the former design it has a dry pumping system and uses a by-pass of the turbo molecular pump for fast pump down of the attached vacuum chamber. The new control system is implemented as a binary sequential control, which runs on two CPLD-Chips (Complex Programmable Logical Device). It controls the pump down process, the bake out of the attached vacuum component, toggling of the roughing pump, and the blocking of reverse gas flow to prevent contamination of the vacuum system with particles. The pumping station is controlled via a local front panel and accessible via Ethernet for remote operation.

1. Introduction

The PETRA storage ring at DESY will be upgraded to the third generation synchrotron radiation source PETRA III, with 14 beamlines [1] operated under UHV conditions. The vacuum specification [2] demands a hydrocarbon and particle free vacuum system. The pumping system has to be free of vibrations. For these reasons ion pumps are used to pump the beamline continuously. Since ion pumps need a pressure below 10^{-6} mbar to start operation, mobile pumping stations are used for the initially pump down of the beamlines. After reaching the pressure of 10^{-6} mbar, the pumping station will be switched off. The pumping stations can be also be used wherever a dry and particle free vacuum has to be generated. They will be provided for users to pump down their experimental chambers, give them the leak detection option and the control of their bake out systems.

2. Requirements

The following tasks summarize the requirements of the pumping station shown in figure 1:

- dry pumping for hydrocarbon free vacuum
- by-pass line to bridge the turbo molecular pump for fast initial pump down
- buffer recipient (BR) to allow roughing pump toggling
- possibility of leak detection and residual gas analysis
- exclusion of reverse gas flow to avoid particle back streaming

- remote control via Ethernet
- mobile, compact, and robust design

Figure 1. Prototype of the pumping station. For mobility reasons it has a very narrow and rigid frame with pivoting wheels and four crane eyes. For easy access the angle valve is the only part which sticks out of the pumping station frame. The electrical power supplies of the pumping station are completely covered for safety reasons. 20 of these stations will be built for PETRA III beamlines.

3. Vacuum system

The vacuum setup (see figure 2 and 3) is based on the typical setup of turbo pumping stations. Special on the presented design are the switch able by-pass line (4), bridging the turbo molecular pump (7), and the buffer recipient (6) between the fore pump (1) and the turbo molecular pump (7). A scroll pump is chosen as fore pump.

This dry roughing pump delivers sufficiently low ultimate pressure combined with good pumping speed for a combination with modern turbo molecular pumps [3]. A security valve (2) prevents the wear debris created in the scroll pump from entering the vacuum system in case of fore pump venting. The security valve (2) only opens in the case that the fore pump is active.

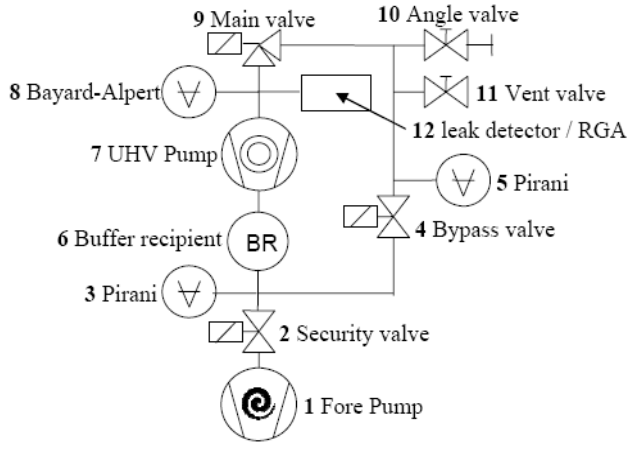

Figure 2. Scheme of the vacuum setup

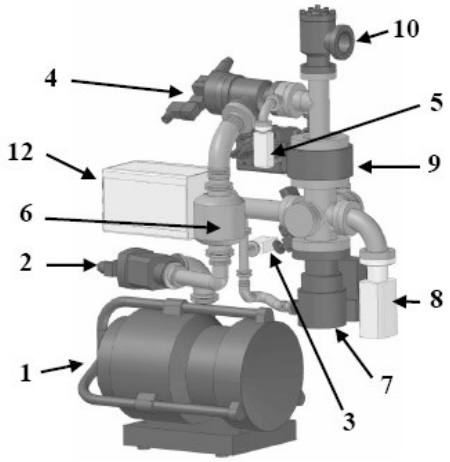

Figure 3. Model of the vacuum system, for numbering see figure 2

The by-pass line connects the backing pump (1) directly with the recipient connected to the pumping port with the angle valve (10).The line increases the conductance for pumping down by roughly one order of magnitude as compared to the turbo molecular pump with Holweck stage. The pump down of a vented system starts with an open by-pass and a closed main valve, followed by a phase with running turbo molecular pump and open main valve. At the final pumping state the by-pass valve (4) is closed. Now the gas flow is strongly reduced and the backing pump (1) can be switched off and on, controlled by the pressure of the Pirani (3). This toggling of the fore pump related to BR pressure increases the time between maintenance operartions of the fore pump.

The Bayard-Alpert gauge (8) controls the bake out of the recipient by measuring the high vacuum pressure. The leak detector / RGA (12) permits leak detection as well as the measurement of the residual gas composition during pump-down and bake-out. The by-pass line provides the possibility of counter flow leak detection.

4. Control system

The pumping station control unit V2 [4] is the successor of a pump unit control that was developed in 1979 on the basis of a 1-bit-processor [5]. The new control unit keeps applying the concept of a binary sequential control with the implementation of the more advanced CPLD-chips (Complex Programmable Logical Device).

Figure 4 shows the front panel of the control unit for local operation and the Ethernet interface for remote control of the pump process. A block diagram of the control hardware is shown in figure 5. It comprises three euro card circuit boards in a rack frame:

- the main board with the CPLDs
- an Ethernet board
- a relay board with 24 V relays.

The relay board directly drives the electro-pneumatic valves as well as the mains operated devices (bake out, fore pump etc.) via contactors. This pumping station control will not only be used for the PETRA III mobile pumping stations but also for stationary or user-made pumping units. Special software versions can be created for any needs special applications.

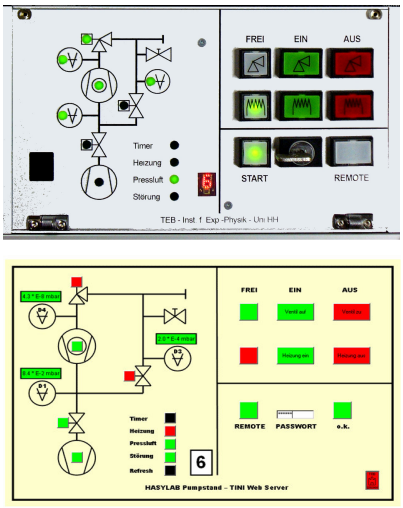

Figure 4. Top: Control front panel, bottom: Web interface

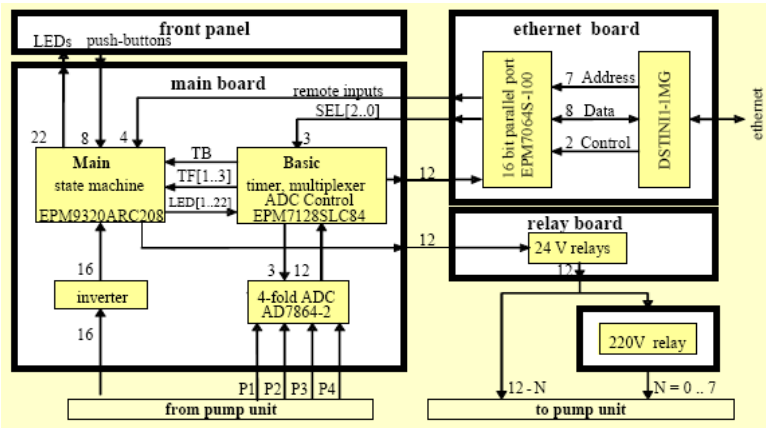

Figure 5. Block diagram of the pumping station's control hardware

5. Program flow

The binary sequential control was implemented as a state machine. It runs through three main program sections and the additional program feature fore pump toggling:

- Self test

The pumping station starts pumping with the main valve and the bypass valve is closed. Predefined pressure thresholds must be exceeded within certain time spans. By these means the station is checked for larger leaks and fore pump defects. In those cases the pumping station is switched off and an error code is displayed on the front panel.

- Pump down

The control unit opens the bypass valve and / or the main valve, depending on the states of predefined pressure thresholds. Reverse gas flow is avoided to prevent particle flow into the recipient by appropriate switching of the valves. The valves are only opened with a pressure gradient at the respective valve points towards the pump. The main valve opens if both sides of the valve are on high vacuum. The bypass valve is opened to maximize the gas flow until turbo molecular pump operation is reached.

- Bake out

The control unit switches the bake out system of the attached recipient on and off. The bake out causes a pressure rise due to increased thermal desorption. When the high vacuum threshold is exceeded, the bake out is interrupted until the pressure drops below the threshold again. This procedure guarantees a fail safe operation of the bake out process.

- Fore pump toggling

The fore pump is switched off as soon as high vacuum (8 in figure 2) is reached and the fore vacuum pressure (3 in figure 2) falls below the predefined threshold. The pump restarts when the threshold is exceeded again. The gas from the turbo molecular pump is accumulated in the buffer recipient. By this means the fore pump runs less than 5% of the overall pumping time (see figure 6), which corresponds to a substantial prolongation of the maintenance intervals.

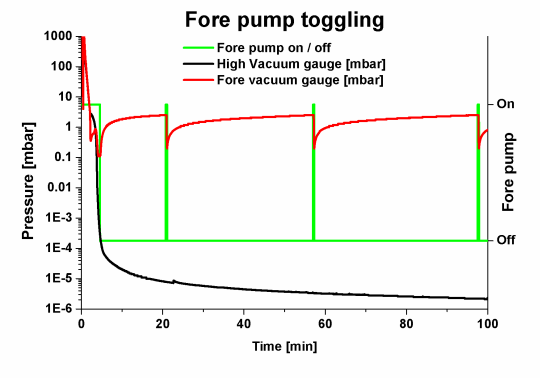

Figure 6. The diagram shows the fore vacuum pressure (3 in figure 2) and the high vacuum pressure (8 in figure 2) while pumping down a mirror chamber of approximately 50 litres. The high vacuum pressure is not affected by the increase in the fore vacuum pressure. With improving high vacuum the delay between the pumping phases of the fore pump gets larger.

6. Conclusions

A new pumping station was designed to exactly fit the needs of the new PETRA III beamlines and experiments. It creates a hydrocarbon-free and particle-free vacuum. For quick roughing it has a bypass line parallel to the turbo molecular pump. A buffer recipient was introduced to allow toggling of the fore pump, which increases the life time of this pump more than twenty-fold.

7. References

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