OIL-FREE PUMP STATIONS FOR PUMPING OF THE SUPERCONDUCTING CAVITIES OF THE TESLA TEST FACILITY

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Abstract

After the final chemical treatment and high pressure rinsing procedures the cleanliness of superconducting cavity surfaces must be preserved in order to allow the operation at high gradients and high Q. Therefore oil-free pump stations are used at the TESLA Test Facility (TTF) at DESY/Hamburg for vacuum drying and leak check of assembled cavities before RF testing as well as for pump down of completely assembled cavity strings and beam line sections of the superconducting linac. The pump stations run in a self safe mode and are operated manually or via computer. They are integrated into the general control system of TTF to ensure automatic data logging and storage of long term data as needed for the quality control of the superconducting cavity treatment and linac operation. Special care is taken to pump down and venting procedures. Presently 15 stations of two types equipped with scroll pumps and turbomolecular pumps (magnetic or ceramic bearings) are in use at TTF. Most of the electronics is made in house to allow compatibility with the TTF control system. The operational experience as well as the reliability of components during the past years will be presented.

1 INTRODUCTION

The linear accelerator of the TESLA Test Facility (TTF) at DESY/Hamburg uses superconducting cavities of high gradient and high quality factor to accelerate electrons up to 1 GeV in its final stage [1]. In order to achieve high gradients of 25 MV/m at $Q_0 > 5 \cdot 10^9$ as required for the proposed TESLA linear accelerator [2] the superconducting cavities must have ultra clean surfaces especially on the inside. Dust particles can act as field emitters and thus limit the performance of the cavities [3]. In addition it is well know that contaminations by hydrocarbons on the cavity surfaces may result in a substantial degradation in cavity performance [4].

Therefore the cavities have to undergo special treatment and assembly procedures comparable to those used for the production of highly integrated semiconductors. The risk to contaminate the superconducting cavities with particles and/or hydrocarbons during the following assembly and operation needs to be absolutely avoided.

Cleaning and assembly of the cavities is performed in a dust free environment starting with chemical etching of the cavity surface. Next the cavities as well as all auxiliary components are cleaned to class 10 level using an ultrasonic bath, high pressure rinsing, etc. followed by the complete assembly of the cavities with all auxiliary components in a clean room of class 10.

During the following pump down and leak check procedures a faulty pump stations running with turbomolecular pump and a conventional roughing pump with lubricants might introduce hydrocarbons into a clean cavity. As long as the pump station is operating under standard conditions back streaming of hydrocarbons is suppressed. If however the turbomolecular pump is stopped, contaminations by hydrocarbons from the rotary pump are visible in the UHV-part as soon as the rotation speed of the TMP has fallen below 50% of its nominal value [5]. Therefore pump stations are usually isolated automatically by a valve once an error occurs or the pumps are stopped. Nevertheless there is no absolute guarantee to close off the pump station in case of a leaky valve or serious failure which could result in severe damage of e.g. an assembled cavity string.

At the TESLA Test Facility 9 pump stations are continuously operated at the clean rooms and test facilities for leak check and pumping of superconducting cavities. In addition several movable pump stations are used at varying locations for e.g. pump down of the linac beam vacuum system, test of new vacuum components etc. In order to achieve as much safety as possible oil-free pump stations are consequently used at TTF during the complete procedure of the cavity preparation and testing as well as for pump down and venting of the beam vacuum at the TTF linac. In addition special care is taken to pump down and venting procedures using the oil-free pump stations to avoid contamination by particles.

Figure 1: Oil-free pump station as used at the TESLA Test Facility.

2 DESCRIPTION OF THE OIL-FREE PUMP STATIONS

Fig. 1 shows a photograph of an oil-free pump station as used at TTF. A schematic layout is shown in Fig. 2. When starting this project complete pump stations fulfilling the requirements as described below were not available from vacuum industry. Therefore the stations are assembled on a movable frame in house using standard components as much as available.

For the first pump stations build several years ago the only oil-free primary pump available was a diaphragm pump. Due to the high ultimate pressure of these pumps a backing turbomolecular pump is necessary to further reduce the pressure for optimal performance of the main turbomolecular pump. Another drawback of the diaphragm pump is the extremely low capacity to pump water vapor.

Since a few years scroll pumps are an alternative [6] offering much higher pumping speed (factor 6), about a factor 100 lower ultimate pressure as well as a reasonable water vapor capacity compared to diaphragm pumps. Some technical data of both pumps are shown in Tab. 1. Compared to the first generation of scroll pumps some improvements with respect to the location of the gas outlet as well as adding an air ballast valve even improved the capability to pump water vapor as needed for example when pumping a cavity after high pressure rinsing. Meanwhile all pump stations at TTF are equipped with scroll pumps.

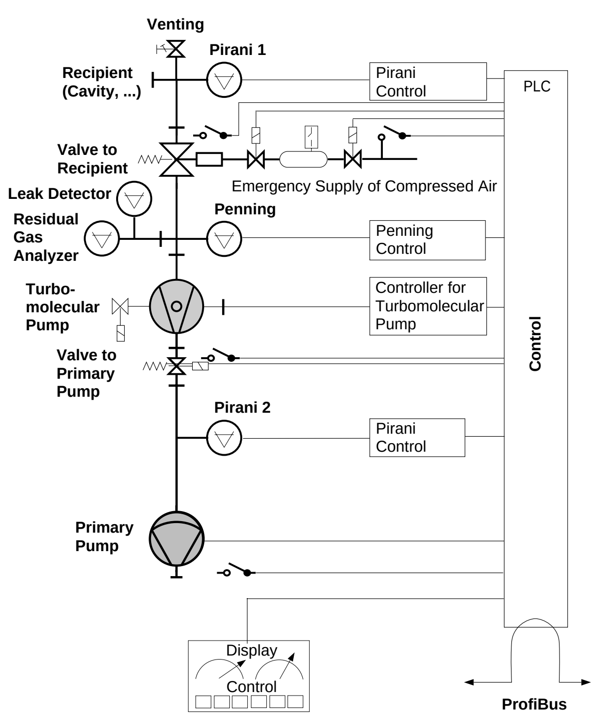

Figure 2: Schematic layout of the oil-free pump station.

Table 1: Technical data of the primary pumps.

	Scroll Pump	Diaphragm Pump
Pumping speed	25 m^3/h	3.6 m^3/h
Ultimate pressure	10^{-2} mbar	2 mbar

Two types of oil-free turbomolecular pumps with magnetic or ceramic bearings are presently in use. Some technical data of these pumps are given in Tab. 2. Due to the better robustness the pumps with ceramic bearings are mainly used in areas where vibrations of the ground frequently occur.

Table 2: Technical data of the turbomolecular pumps.

	Turbomolecular Pump	
Bearings	magnetic	ceramic
Pumping speed	170 l/s	250 l/s
Startup pressure	12 mbar	< 5 mbar
Base pressure	$\approx 10^{-10}$ mbar	$\approx 10^{-10}$ mbar
Compression ratio	He: $4 \cdot 10^7$	He: 10^5
Rotational speed	50.000 RPM	56.000 RPM
startup time	4 min.	3 min.
Cooling	air	air

Each stations is equipped with two Pirani gauges and a Penning gauge allowing continuous pressure readings. The main purpose of the Pirani gauge however is to switch the Penning gauge and the turbomolecular pump on or off.

To isolate the pump station from the component to be pumped a pneumatic all metal valve is used. Compressed air for valve operation is available from permanent distribution lines within the TTF hall. If the valve has to be closed during an air-supply failure, a small reservoir of compressed air is mounted underneath the pump station. The cylinder contains enough air for about 10 actions of the valve. Its pressure is controlled by a simple pressure monitor. If the pressure drops below a certain value the control system gives a warning to the operator. In addition a second valve is located between the primary and turbomolecular pump.

The pump stations are usually equipped with a leak detection head. If needed a residual gas analyzer can be added.

Programmable logic controllers (PLC) are used to guarantee a self safe operation of the pump station. Computer controlled read out is realized by Profibus. Status information as well as control of the pump stations are available remotely as well as locally. The data are logged and stored in an archives system with long term history as needed for the quality control of the superconducting cavity treatment and linac operation.

In order to fulfill the above requirements as well as allow compatibility with the general TTF control system [7] most of the readout and control electronics like for the Pirani and Penning gauge, leak detector, residual gas analyzer and pump station had to be developed in house as they were not available on the market.

The connection of a movable pump station to the data acquisition and control system is done via frequently located sockets within the TTF experimental hall. In addition a manual control box can be plugged into the pump station electronic crate.

One speciality in the operation of the pump stations is the fact, that they are not vented routinely in order to slow down the turbomolecular pump. Venting is done only in case of an emergency once the valve to the recipient has closed. This reflects the fact that the possible damage to a superconducting cavity might easily surpass the damage to the pump station.

3 APPLICATIONS AT THE TESLA TEST FACILITY

Oil-free pump stations are in use for a large variety of applications at TTF.

At the clean room used to prepare the superconducting cavities two stations are permanently installed outside the clean room and connected via fixed pump lines to the class 10 areas. Here the cavities are usually pumped after high pressure rinsing and 24 hours drying at air in the class 10. Although the cavities are no longer really wet, the water vapor load to the pumps is still high. Later in the process the assembled cavities are pumped down and leak checked before test in a vertical or horizontal cryostat. The same applies to the assembled cavity strings. In addition, the vacuum components for the TTF linac are pumped dry and leak checked after particle cleaning [8]. For venting an ultra pure gas supply of argon is available in the clean room.

During the module assembly outside the clean room mobile pump stations are used for further leak checks of the cavity string at various assembly steps.

At the various cavity test facilities of TTF permanent pump stations are installed to pump the cavity vacuum at the horizontal test cryostat.

Within the TTF linear accelerator no ultra pure gas supply for venting is available. Therefore mobile pump stations are used to pump down and vent the cavity strings as well as all sections of the beam line vacuum.

4 PUMP DOWN AND VENTING PROCEDURES

In order to minimize the risk to contaminate the superconducting cavities with particles during operation within the TTF linac, all vacuum components of the line beam line are carefully cleaned to make them particle free and installed using local clean rooms [8].

Crucial operations with respect to particle contamination in the linac are pump down and venting of the beam vacuum. Both processes are done slowly trying to avoid turbulences.

While inside the TTF clean room argon gas from an ultra pure gas distribution line is used for venting, such system is not available at locations outside the clean room. Therefore venting is done using dry gas from a liquid nitrogen dewar using a set-up as shown in Fig. 3. Integrated into the vent line are a dryer, a needle valve and two particle filters stopping all particles larger than 0.2 μm. Before venting the vent line is cleaned by applying pump and purge several times using the oil-free pump station. Venting is done slowly by reducing the gas flow in a controlled way by using the primary pump of the pump station in the beginning.

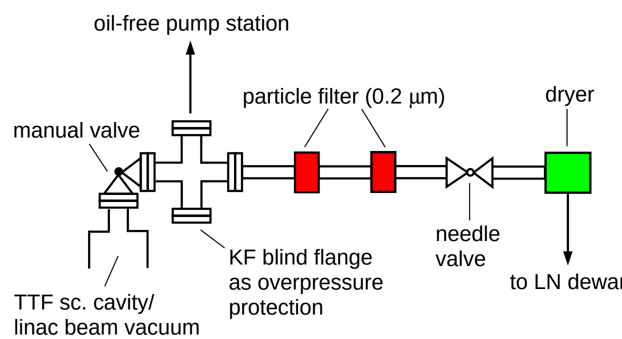

Figure 3: Schematic layout of the set-up used for venting of particle cleaned vacuum systems at TTF.

5 OPERATING EXPERIENCE

The first oil-free pump station at TTF started operation in 1996. Presently 15 oil-free pump stations are continuously in use operated by many users. The reliability of these stations is quite high. Nevertheless nearly all failures possible did occur during the past years, however no significant damage to a cavity has occurred so far.

The component with the highest failure rate is the scroll pump. Fig. 4 shows the total operating hours so far resp. the operating hours up to the first failure of the scroll pumps. Presently three different types of pumps are in use. In most cases the first break down of the pumps occurs well below 10.000 hours of operation. However three pumps of the first generation (type A) run more than 20.000 hours before failing. Although the layout of the pump has been improved to allow better pumping of water vapor, there seems to be no improvement with respect to the failure rate.

The turbomolecular pumps are running quite reliable. Fig. 5 shows the total operating hours resp. the operating hours up to the first failure of the turbomolecular pumps with magnetic bearings (type A) and ceramic bearings (type B). Four pumps are even running more than 40.000 hours without problems. However several pumps failed already well below 10.000 hours running time. One

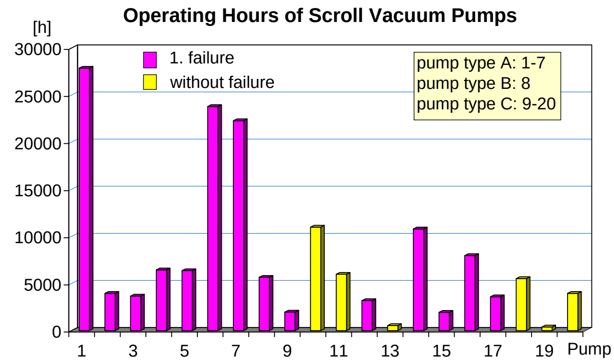

Figure 4: Total operating hours and operating hours up to the first failure of all scroll pumps in use.

problem might be than some pump stations are operated in areas where the ground is not really solid. Here vibrations might effect the pumps, however further investigations are needed to confirm this observation.

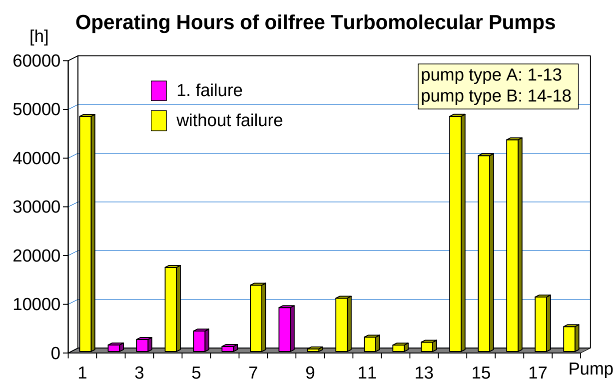

Figure 5: Total operating hours and operating hours up to the first failure of the turbomolecular pumps with magnetic bearings (type A) and ceramic bearings (type B).

6 CONCLUSIONS

In order to achieve as much safety as possible oil-free pump stations are consequently used at TTF during the complete procedure of the cavity preparation and testing as well as for pump down and venting of the beam vacuum at the TTF linac. Presently 15 stations are continuously in use operated by many users. The reliability of these stations is quite high. Despite nearly all failures possible did occur during the past years, no significant damage to a cavity or cavity string has occurred so far.

Our experience show that for large facilities it is worthwhile to take the additional effort of using oil-free pump stations to minimize the risk of damaging a well performing superconducting cavity.

7 ACKNOWLEDGEMENT

We would like to thank our colleagues of the MVP vacuum group at DESY, especially K.H. Wroblewski and J. Wojtkiewicz for their excellent work and technical support.

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