RUNTIME EXPERIENCE AND IMPURITY INVESTIGATIONS AT THE ELBE CRYOGENIC PLANT

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Abstract

The superconducting linear accelerator ELBE at the Forschungszentrum Dresden/Rossendorf has two superconducting accelerator modules and a superconducting photo injector (SRF-Gun). They are operated by a cryogenic Helium plant with a cooling power of 200 W at 1.8 K. Since the commissioning of the plant in 1999 minor and major impurity problems have influenced the operation stability of the plant. The presentation will give an overview of the ELBE cryogenic system and will focus on the different sources of plant contamination and their effects on the plant operation, which have been found during the nearly 10 years of plant lifetime. Especially the contamination with oil brake up components as well as air and water from different sources have limited the run periods of the plant and effected special service and maintenance procedures.

INTRODUCTION

The ELBE radiation source [1] is a superconducting electron LINAC operating in cw mode. The maximum operation parameters of the source are up to 40 MeV electron energy and a beam current of 1mA. The electrons are converted in different experimental stations in gamma rays, X-rays, FEL-light, neutrons and positrons to serve as secondary electromagnetic sources for a variety of experiments.

An essential part of the medium energy electron source are the two accelerator cryostats, each equipped with two 9 cell superconducting TESLA type cavities working at 1.3 GHz. Both cryostats are connected via a 1.8 K valve box and a long transfer line to the Helium plant. In 2006 the transfer line system was upgraded to fit the Rossendorf SRF-Gun cryostat [2] to the Helium system.

The Helium cryogenic plant is a refrigerator type plant from Linde adapted to accelerator operation needs with a low pressure return line from the cryostats, a cold compressor system and originally with 3 Kaeser CSV 150 screw compressors for vacuum pumping in the warm cycle. The high pressure compressors are a Kaeser FS440 and a smaller CS91 to have the flexibility to operate the plant in different modes (full, cryostat standby, coldbox standby at lN_2 temperature).

EXPERIENCE OF PLANT OPERATION

Over the nearly 10 years of plant operation the major difficulties and insistent problems had been due to contamination issues. Only in the phase of commissioning the plant with the cryostat system a complicated problem with the pressure instability of the cold compressor system had caused longer operation failures and additional investigations.

Besides minor problems with failures of compressors, turbines, etc., which could be solved normally in adequate service times, the limitation of plant runtime and failures are due to impurity loads to the coldbox.

Mostly smaller sources of water and air contamination had been found before it was discovered that the cracking of the Breox® oil in the vacuum screw compressors leads to a high load of the coldbox with water, formaldehyde and other organic components.

Contamination with water

From at least the year 2000 on water was found in the cold box in the maintenance periods. In the first years we have determined the quantity of water by flushing the coldbox with dry nitrogen gas and measuring the humidity with a dew point meter. In the first heat exchangers of the coldbox we found approx. 50 ml of water at the maintenance. In 2005 we have changed the method because of the inaccuracy of the nitrogen flushing method described above and tried to measure the water content more precisely by collecting the water in a cold trap. The method of vacuum pumping different sections of the coldbox over a cold trap is much more precise and efficient and extracts the water in approx. one day from the cold box. In the 3rd maintenance in 2005 we have collected a quantity of 260 ml water from the coldbox. This leads to the idea to investigate the water content in the compressor oil. The analysis shows around 60 ppm in the used oil and around 3500 ppm in the new oil. The difference has been extracted into the coldbox and the big charcoal adsorber. The charcoal adsorber once loaded with water, acts therefore as a secondary water source uploading the buffered water content into the coldbox over time.

Air contamination

Pumping the high-pressure cycle of the helium plant without the coldbox connected a steady increase of the nitrogen contents measured with the multi component detector could be found, see Fig. 1. The leakage analysis of the compressor stations in static conditions has brought no findings. Therefore the rotary seal, separating the pure helium in the compressor from the outside air, could be a potential leakage system during compressor operation. We built therefore an additional buffer in front of the rotary seal; which could be flushed with helium gas. The results are shown in Fig. 1. Over the operation time of around 12 hours no contamination of the compressor cycle with air (N_2) could be measured.

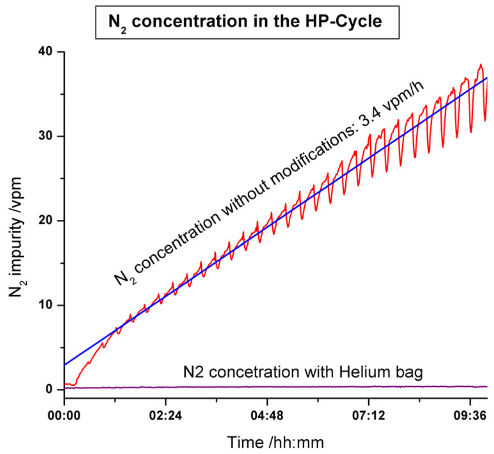


Figure 1. Nitrogen concentration in the warm helium cycle without modifications and with a helium gas bag in front of the rotary seal of the compressors.

Hydrocarbon contamination

Despite the described attempts to single out simple sources of contamination in the helium cycle the run time of the cryogenic plant could not be extended over more then 3 month. Moreover water was still found in the plant after warm up. In addition from 2006 on we discovered that the internal coldbox charcoal adsorber at N_2 temperature starts to disintegrate. The charcoal dust is deposited mainly in the very fine turbine inlet filter as well as in the second adsorber pretending similar pressure drops and temperature level shifts like real contaminations.

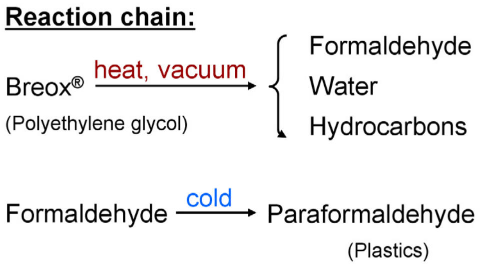
Figure 2: Paraformaldehyde generation in the coldbox. Here a picture from the cone of a hand valve of the internal N_2-adsorber is shown.

From 2007 on there have been some distinct hints that in our plant a more complicated impurity source exists: 1) in the maintenances we noticed a dominant smell of organics at plant warm up, 2) in the intensified pumping of the coldbox over a cold trap we found a white deposit in the liquid, 3) in the mass spectrum analysis we found a large background of unexpected and unexplained masses. A more detailed chemical analysis of residua of the coldbox liquid showed predominately the organic components formaldehyde, paraformaldehyde and acetic acid. We investigated therefore also the formaldehyde concentration in the warm helium cycle during the run of the plant, see table 1. The formaldehyde concentration was measured in the main high pressure (HP) helium cycle and in the vacuum pump cycle, measured for all of the 3 vacuum screw compressors (CSV 6310 – 6330) used with "old" and new Breox® oil.

Table 1: Formaldehyde concentration

	"old"-Breox® oil	new Breox® oil
	µg/m³	µg/m³
HP-Cycle	101	
CSV6310		740
CSV6310	1810	965
CSV6310		636

For both using new or old Breox® compressor oil we found high concentration of formaldehyde in the vacuum cycle. Taking into account the dilution of the vacuum mass flow in the high pressure helium stream because the flow is higher by one order of magnitude, the formaldehyde is predominantly produced in the vacuum cycle. Together with the massive findings of paraformaldehyde (see Fig. 2) in the coldbox through chemical and endoscopic investigations we deduce the following:



The paraformaldehyde polymerizes especially in the heat exchangers, where the temperature zone is between the boiling point and the melting point of formaldehyde. This process leads to a very rapid pressure drop in the coldbox. In addition we observed through this paraformaldehyde contamination an ongoing disintegration of the internal adsorbers (probably by physical processes).

MEASURES FOR PLANT RECOVERING

In a first step we tried to extract the paraformaldehyde from the internal coldbox by chemical processing. Hot water and acid or alkaline dilution are a good solvent for paraformaldehyde, known from literature and own investigations with the coldbox residua. Together with

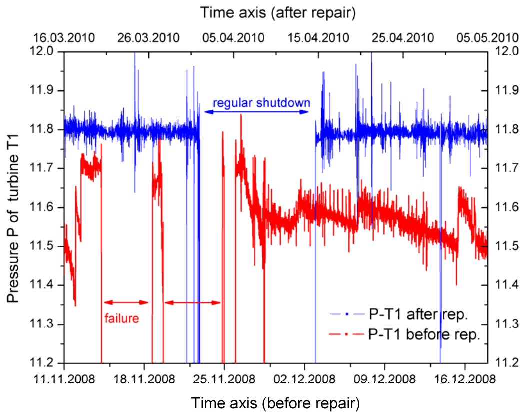


Figure 3: Behaviour of the pressure in front of turbine T1 before the repair of the plant (red curve) and after the repair (blue curve). No pressure drop of the blue curve is seen after a regular run time of the plant.

the Linde service several attempts had been made to remove the paraformaldehyde deposit from the internal coldbox by this processing. Unfortunately the heat exchangers could not be recovered completely by this method for unknown reasons.

Therefore the decision was made to replace not only the source of the formaldehyde generation (the vacuum screws) by dry running vacuum pumps but also to replace the first three heat exchangers in the coldbox. For the first runs of the coldbox after repair the blue curve in Fig. 3 demonstrates that the plant has recovered completely.

REFERENCES

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