

IMPROVEMENT OF THE RUN-TIME OF 35 MBAR HELIUM GAS PUMPING UNITS FOR THE SUPERCONDUCTING LINEAR ACCELERATOR S-DALINAC*

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Abstract

The superconducting Darmstadt linear accelerator S-DALINAC (see Fig. 1) has been designed to provide electron beams of up to 130 MeV for nuclear and astrophysical experiments [1]. The accelerating cavities are operated in a liquid helium bath at 2 K. To achieve this temperature the cryostat has to be pumped down to a pressure of 35 mbar which was done by a system of pumping units connected in series, when the accelerator started its operation in 1991. In 2005 this system was replaced by four parallel switched pumping stations. In the first three years of their operation, the reliability of the accelerator was very poor due to repeated breakdowns of the pumping stations caused by overheating. In addition the high temperatures lead to an early decay of the gaskets used. The problem was solved by installing oil cooling systems and more appropriate shaft sleeves at the pumping stations. We will report on the technical efforts we made and thereby further increased the availability of the accelerator significantly.

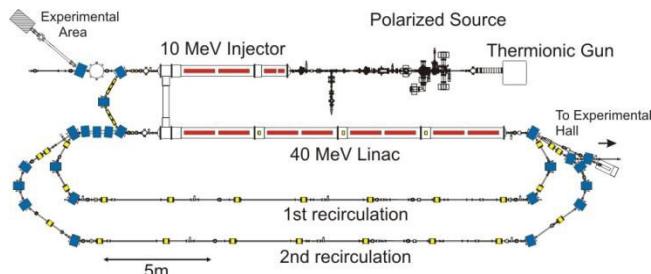


Figure 1: The Superconducting Darmstadt Linear Accelerator S-DALINAC.

INTRODUCTION

The cryostat of the S-DALINAC consists of six modules housing twelve superconducting cavities and containing a total of 600 liters of liquid helium in their helium vessels in normal operating state. The maximum gas flow caused by the thermal load of the superconducting cavities is calculated with 6 g per second gaseous helium. To reach a pressure of 35 mbar four pumping units, shown in Fig. 2, are used, each one with a throughput of up to 2 g per second. One unit serves as a stand by redundancy. They are built up of one single stage, oil sealed rotary vane backing pump (Oerlikon Leybold Sogevac SV 1200) and one roots pump (Oerlikon Leybold RUVAC RA 7001). The rotational speed of the rotary vane pump is constantly 11.7 Hz; the roots pump is equipped with a frequency converter and runs at variable

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speed from 8.4 Hz to 33 Hz. The rotation speed control is effected by a Siemens SIMATIC S7 PLC according to the pressure set value of 35 mbar. The lubrication is done by dehumidified BREOX LUBRICANT B35® synthetic oil. The reliable work of these devices is essential for a successful operation of the accelerator.



Figure 2: Four parallel switched Pumping Units.

ROOTS PUMPS

Roots pumps contain in their pump casing two symmetrical impellers rotating in opposite directions. The impellers are synchronised by a toothed gearing so that they move past each other and the casing without contact but with a small clearance. The motor of the pump is directly flanged to the coupling housing. The pump shaft and the motor shaft are linked by means of an elastic coupling. The shaft of the other impeller is driven via a synchromesh gear. The feed through of the shaft (Fig. 3) of the impeller between the evacuated bearing chamber and the ambient is sealed by two shaft seals. In order to reduce wear on the shaft, these shaft seals run on a stainless steel shaft sleeve and are lubricated with oil. They are located in a shaft seal housing having a separate oil reservoir. The housing is air-cooled. The air flow is produced by a motor fan [2].

Temperature Issues

Roots blowers are standard industrial products and usually designed to pump air. Due to the five times higher heat capacity of Helium compared to air, one has to arrange an adequate cooling for all machine parts. Critical spot in our system was the shaft seal housing with its separate oil reservoir of approximately not more than one liter volume. The air-cooling is insufficient for the heat input and that leads to an overheating of the shaft seal

housing and subsequently of the complete roots pump. PTC resistors are implemented to protect the pump from damage; the trigger temperature is 160 °C for shutdown. Several times the shutdown temperature was reached, the pumping units switched off and accelerator operation was impossible.

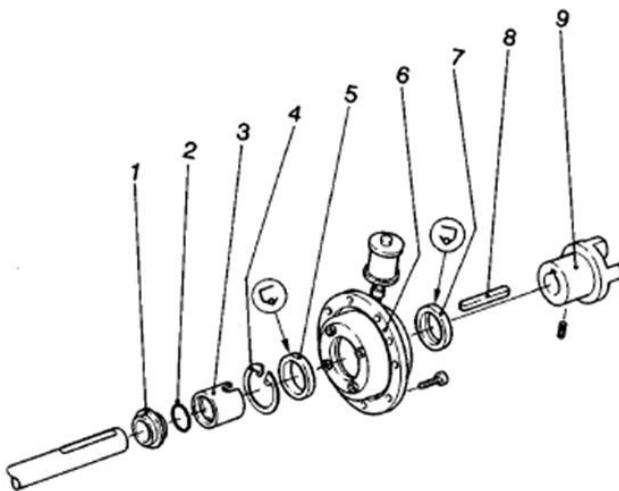


Figure 3: Scheme of shaft feed through [2]: spacing ring (1), O-Ring (2), bushing (3), securing ring (4), shaft seal (5), shaft seal housing (6), shaft seal (7), key (8) and coupling half (9).

Abrasion of Shaft Seals and Sleeves

The increase of the shaft seal housing temperature leads to a change of the physical and chemical properties of the oil used for lubrication. The viscosity decreases significantly from 33 cSt at 40 °C to 4.2 cSt at 130 °C and with a localised heating from above 150 °C the oil decomposes slowly [3]. The lubrication between the



Figure 4: Roping at the shaft sleeve. The picture shows a close-up of a notch (1.5 mm width, 0.5 mm depth) on a stainless steel shaft sleeve (50 mm diameter).

shaft seal and the sleeve gets inadequate. The temperature at the seal edge can increase by up to 50 °C, in extreme cases by up to 80 °C above the environmental temperature as a result of the increasing shear forces in the lubricant and the low thermal conductivity of the elastomer [4]. Wear and heat cracks may occur at the shaft seal and roping begins at the surface of the sleeve (see Fig. 4).

THE OIL COOLING SYSTEM

To avoid overheating it is compulsory to cool down the oil in the shaft seal housing to an appropriate temperature. The idea was to bring the oil out of the chamber, dissipate the heat and increase the total amount of liquid. In 2008 a piping and a commercial oil radiator were installed; also an oil feed pump was employed to force the oil to circulate. For a better heat exchange a centrifugal fan directly flanged to the radiator produces a cased airflow (see Fig. 5). With these modifications the oil volume was increased from 1 liter up to 4.5 liters as well.

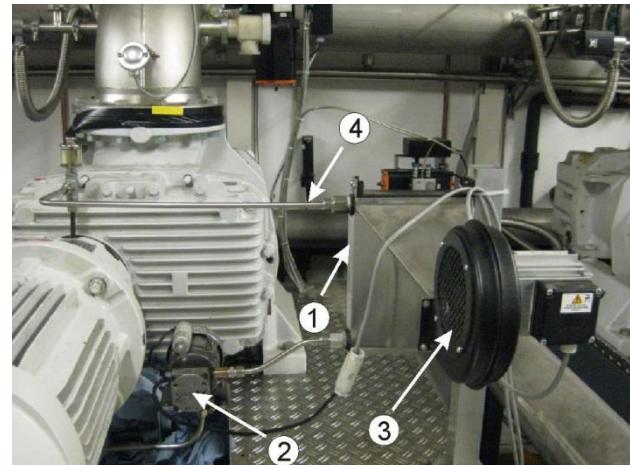


Figure 5: Oil cooling system: oil radiator (1), oil feed pump (2), centrifugal fan (3) and piping (4).

Temperature Measuring

The temperatures were measured in the outlet gas flow with a PT 100 instrument shunt and with an infrared temperature measuring device and an emission-foil placed on the outer surface of the shaft seal housing. The new oil cooling system allows us to run the pumping units at a temperature level which is in average 25 to 30 °C below the level of 2007 (see Fig. 6). Until now neither the shutdown temperature nor the critical range for oil and seals were reached. The pumping station rarely affects the reliability of the accelerator any more.

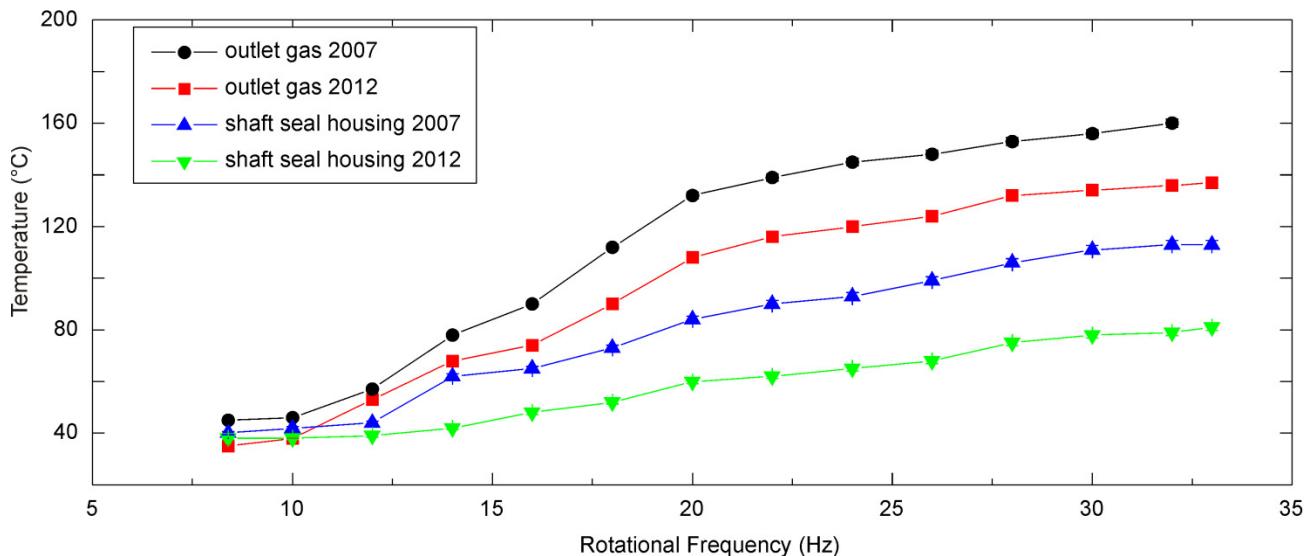


Figure 6: Temperature depending on the Rotational Frequency of the pump before (2007) and after (2012) installing the circulating oil cooling system.

CERAMIC COATED SHAFT SLEEVES

High temperatures lead to a hardening of the elastomer of the shaft seals. The result is a slowly roping at the surface of the shaft sleeve that impairs the seal integrity. If a seal fails, a leak occurs. The oil loss can be outwards or into the suction chamber, it depends on which of the two gaskets is affected. In both cases we are forced to switch off the engine and replace the broken parts. The average lifetime of bushing and gasket in 2007 was about 600 hours, which means once a month a maintenance work for one week and during this time no accelerator operation. On the one hand the temperature issue was solved by installing the oil cooling system; on the other hand we want to be sure to avoid the notch on the sleeve. Therefore we applied a ceramic coated bushing to maximise the skin hardness of the bearing surface.

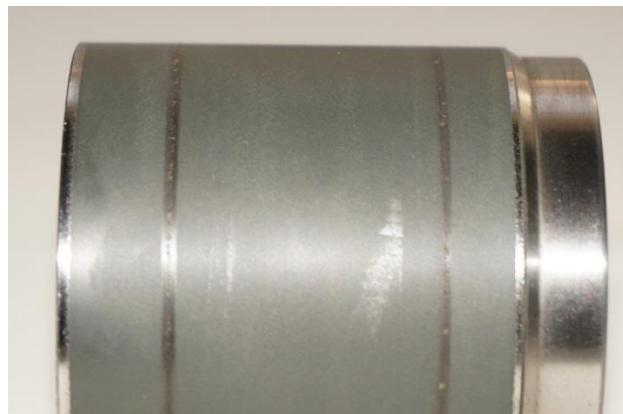


Figure 7: Ceramic Coated Sleeve (52 mm length, 50 mm diameter, 0.5 mm ceramic coating) shows oil residues but no signs of roping after 9000 operating hours.

The ceramic was coated in a flame spraying process with a thickness of 0.3 to 0.5 mm. After a run-time of about 9000 hours there was no sign of roping on the tread (see Fig. 7).

CONCLUSION

We equipped our pumping station with an efficient oil cooling system and chose appropriate materials for the shaft sleeves. These technical efforts lead to a high reliability of the engine and accordingly to a significant better availability of the accelerator. Since 2008 there was no breakdown caused by overheating.

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