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by

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ABSTRACT

The CERN LEP radiofrequency (RF) accelerating system consists of 128 Cu cavity units (accelerating and storage). Before installation each cavity unit along with all pumps and components is baked for 24 hours. After this bakeout each cavity unit is conditioned up to a maximum RF power of 140 kW and run at various intermediate power levels for up to two weeks. The pressure after bakeout is typically in the low 10^{-10} Torr range containing mainly H_2 with traces of CH_4 , CO, H_2O and CO_2 . With the introduction of RF power the gases desorbed are H_2 , CH_4 , H_2O , CO and CO_2 with, in some cavity units, heavier masses around 55 and 75. After this RF conditioning the average CO equivalent pressure at 125 kW RF power is in the low 10^{-9} Torr range.

INTRODUCTION

The CERN LEP radiofrequency (RF) accelerating system consists of 128 OFHC Cu accelerating and OFHC Cu + 0.1% Ag storage cavities each of which provides an accelerating voltage of 3.2 MV for the e^+ and e^- beams at a nominal RF input power of 125 kW. The average accelerating electric field at this power level is 3.1 MVm^{-1} in the accelerating gaps.

At these relatively high electric field gradients any stray electrons (from cosmic rays or field emission) are accelerated into the Cu wall where they may create x-rays which, in turn, create photoelectrons which may also be accelerated in the electric field. These energetic electrons may desorb tightly bound gas from the inner walls of the cavities and the resulting increase in pressure, although not detrimental to the operation of the cavities themselves, lowers beam lifetime and creates a background at the interaction point due to off momentum e^+ and e^- produced by beam-residual gas Bremsstrahlung¹.

Each cavity unit (1 accelerating cavity and 1 storage cavity) along with all pumps and components is baked for 24 hours at 150°C with superheated water circulating in the cooling channels. Stainless steel components such as vacuum gauges, gas analysers, ion pumps and sublimation pumps are baked to 300°C with electric heating jackets.

Each cavity is pumped with a 400 ls^{-1} sputter ion pump and a Ti sublimation pump. During evacuation from atmospheric pressure and during the 24 hour bakeout the cavity unit is pumped with a 500 ls^{-1} turbomolecular pump (Fig. 1).

After this 24 hour bakeout each cavity unit is conditioned up to a maximum RF power of 140 kW and run at various intermediate power levels for up to two weeks.

Fig. 1 : An RF cavity unit on its conditioning stand

In this publication we:

- a) present in detail the vacuum behaviour of a typical cavity unit during RF conditioning based on observations of the complete conditioning cycle of 10 cavity units;
- b) predict the effective CO pressure in the LEP RF system which is used to estimate the background in the interaction region with the cavities at full power from measurements of the total and partial pressures in 122 out of the 128 cavity units completed to date.

CHEMICAL CLEANING

After all machining and just before final welding all the Cu accelerating and storage cavity elements were cleaned by the following procedure:

1. Degrease in perchloroethylene (C_2Cl_4) vapour at $121^\circ C$.
2. Ultrasonic clean in alkaline detergent ($pH = 9.7$) solution at $60^\circ C$ for 5 to 10 minutes.
3. Rinse in cold demineralized water.
4. Deoxidize in a 50% by volume hydrochloric acid (HCl) bath at room temperature for between 5 and 15 minutes the time depending on the thickness of the oxide on the item to be treated.
5. Rinse in cold demineralized water.

6. Passivate in a solution containing 80 gl^{-1} of chromium trioxide (CrO_3), i.e. chromic anhydride or 'chromic acid' and $3 \text{ cm}^3 \text{ l}^{-1}$ of sulphuric acid (H_2SO_4).
7. Rinse in cold demineralized water.
8. Air dry after rinsing in hot demineralized water or alcohol at room temperature.

RESULTS

a) Vacuum limit

After baking the cavity unit for 24 hours at 150°C (300°C for some components) the pressure 17 hours after the end of the bakeout, with the cavity unit still warm ($\sim 35^\circ\text{C}$), is typically in the low 10^{-10} Torr range. There is quite a spread in limit pressures and in Fig. 2 are shown the spectra from two extremes - RF unit 034 with 4×10^{-11} Torr and RF unit 084 with 4.2×10^{-10} Torr.

The residual gas contains mostly H_2 with traces of CH_4 , H_2O , CO and CO_2 .

Fig. 2 : Spectra from two cavity units just after bakeout

b) Conditioning

For the RF conditioning of the RF cavity units a fully automatic conditioning system has been built² which enables RF input power of up to 140 kW to be introduced into the cavity unit without discharges and for sufficient time to reduce the RF induced pressure rise to the low 10^{-9} or high 10^{-10} Torr range.

By adjusting the input RF power the automatic control system limits the pressure rise and, as the interior surfaces clean up under the energetic electron bombardment, the power is slowly increased to the maximum of 140 kW. Once at full power the input power may be kept constant or cycled up and down and with time the pressure slowly decreases.

With the calibrated total pressure gauge and calibrated residual gas analyzer the pressures and spectra were recorded at intervals during the conditioning cycle. The main gases desorbed were H_2 , CH_4 , CO , CO_2 and H_2O and the behaviour of these five gases with time and RF power is shown in Fig. 3.

The automatic system keeps the pressure $\leq 2 \times 10^{-7}$ Torr as the input power is slowly increased. After typically 10 to 20 hours full power can be applied and the pressure decreases as the surfaces clean up. All the gases tended to decrease with time, but H_2O showed sometimes a different behaviour not totally understood but perhaps more linked to the temperature of the cavity or local heating of, say, a tuner.

Apart from the five main gas species desorbed, some higher mass species are also seen. This is illustrated in Fig. 4 where the residual gas spectrum before introduction of RF power is shown and no heavy mass species are detected. The relatively high mass 16 is an artefact in the analyzer (O^+ from the ion source).

Fig. 3 : The total and partial pressures as a function of time during RF conditioning.

The centre spectrum of Fig. 4 was taken with 35 kW of RF power during the conditioning up to full power with the total pressure limited automatically to 2×10^{-7} Torr. There the heavy masses around 55 and 70 are evident - but only at a level about a factor of 100 below the main gases. Also visible are the groups around 28 and below 44.

Fig. 5 : The CO equivalent pressure for each cavity unit at 125 kW

These equivalent CO partial pressures were then summed to give the total equivalent CO pressure which is then used to calculate the background.

This procedure was carried out systematically for each cavity unit during conditioning and the results are shown in Fig. 5 for 80 cavity units.

Despite the relatively large scatter in the total CO equivalent pressures, it can be seen that, as the production of cavities proceeds, there is a gradual improvement, i.e. lowering of the CO equivalent pressure - a reflection of the manufacturers learning curve!

In the 122 cavity units conditioned and stored ready for installation the average CO equivalent pressure was 1.1×10^{-9} Torr.

CONCLUSIONS

In the 122 RF cavity units so far baked and conditioned the vacuum limit after bakeout is typically in the low 10^{-10} Torr range containing mainly H_2 with traces of CH_4 , CO, H_2O and CO_2 .

With the introduction of RF power the gases desorbed are H_2 , CH_4 , H_2O , CO and CO_2 with, in some cavity units, heavier masses around 55 and 75.

Limiting the pressure to 2×10^{-7} Torr during conditioning means that full power was reached after about 20 hours.

After RF conditioning at up to 140 kW RF power for between 1 and 2 weeks the average CO equivalent pressure at 125 kW input power is 1.1×10^{-9} Torr.

This figure will, of course, decrease with time as the cavity units are run for longer times in the LEP machine.

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