FINAL RESULTS ON THE CERN PS ELECTROSTATIC SEPTA CONSOLIDATION PROGRAM

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Abstract

The CERN PS electrostatic septum consolidation program is coming to completion after almost 4 years of development. The program was started to fulfil the increased requirements on vacuum performance and the need to reduce the time necessary for maintenance interventions. The new design of septum 31, used for the so-called ’continuous transfer’ 5-turn extraction, and the related construction issues will be presented together with the operational experience gained during the PS 2002 run. In addition, the experience of two years of operation with the new generation septum 23, used for a resonant slow extraction, will be briefly discussed. The continued development undertaken since its installation in the PS ring in 2001 will also be described.

INTRODUCTION

A consolidation program was started for the electrostatic septa in the CERN PS accelerator 4 years ago. In 2001 redesigned and newly constructed for septum 23 was put into operation [1], and is used for a resonant slow extraction towards the East Hall experimental area [2]. Septum 31, constructed almost 20 years ago, is used for the so-called ‘continuous transfer’ (CT) 5-turn extraction towards the SPS. This septum used technology for its vacuum and displacement systems that is now outdated. It was decided to consolidate this high performance electrostatic deflector 31, analogue to the new design of septum 23, keeping in mind the high operational and maintenance constraints. Parallel to this effort, a development based on the existing anode design has checked the possibility to construct the septum 23 bakeable up to 100 °C.

OPERATIONAL EXPERIENCE

The new version of septum 23, installed in the PS ring in 2001, remained in the accelerator for a period of two years without any failures. Previously, the septum would have been removed from the machine after one year, stored for one year to allow radiation levels to decay and then been subjected to an overhaul procedure to restore its full operational capacity. With the new generation septa, the increased operational lifetime has now significantly reduced the maintenance required and hence the radiation exposure of personnel. The maintenance requirements have now been reduced to a 3-monthly oil change on the high-voltage feedthrough followed by a short period of reconditioning. The short HV cable between the cathode and the resistance is changed annually.

Due to the improved vacuum, as the pressure in the main vessel has now reached levels of approximately 2×10^{-9} mbar, with even 1.7×10^{-10} mbar recorded after operating the titanium sublimators, virtually no dark current (< 2 µA) has been recorded during the accelerator runs.

The new septum 31, used for continuous transfer, to the SPS [3], has been installed for the 2002 physics run. Throughout this run, a pressure of 8×10^{-9} mbar was normal and even pressures of 5.4×10^{-10} mbar were measured following sublimation, better than one order of magnitude compared with the previous generation of septa.

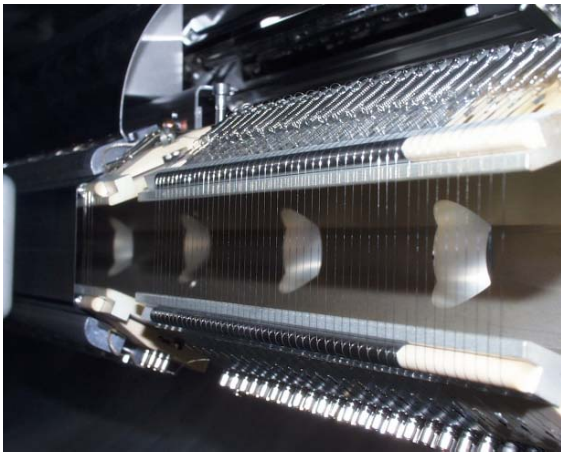

Figure 1: Septum 31 diffuser array at beam entry point of aluminium septum support

Due to the beam slicing nature of the extraction method, the septum foil is susceptible to overheating and warping from the direct impact of the beam. To reduce this effect, a diffuser is fitted to the upstream side of the septum. This diffuser consists of an array of tungsten-rhenium wires, of diameter 100 µm, spaced by 5 mm (see fig. 1), which creates a localised beam blow up and has a diluting effect in the region of the foil.

In the future, septum 31 might benefit from a new extraction method which will reduce even further the direct beam losses on the foil [4]. In the meantime the septum will continue to be replaced at yearly intervals.

Following installation in the accelerator the septa undergo a conditioning period when the voltage is increased progressively to a maximum of 250 kV for the large gap (30 mm) and 235 kV for the small gap (20 mm). The upper voltage limit is imposed by the condition of the main HV cables in the accelerator. The cable insulation properties have been deteriorated due to the effects of ageing and ionising radiation in the accelerator.

Prior to installation in the accelerator, the septa are conditioned in the test laboratory, at 280 kV for the large gap, and 250 kV for the small gap.

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NEW GENERATION SEPTUM 31

The septum 31 uses the same proven high voltage technology as septum 23, with the main parameters shown in table 1.

Table 1: Main parameters of septum 31

Cathode length	1850	mm
Operational gap width	26	mm
Theoretical beam deflection	1	mrad
Beam momentum	14	GeV/c
Operational voltage	178	kV
Septum foil thickness	0.1	mm

The aluminium ‘C’ shaped septum support holds a 100 µm thick molybdenum foil which is pre-tensioned to provide a flat surface. The molybdenum sheets are hand polished using an average grain size ceramic powder of between 2-3 µm, which results in a mirror finish. Mounted above the aluminium support is a hand polished deflector which provides protection against titanium sublimation on the active parts of the high voltage assembly (see fig. 2).

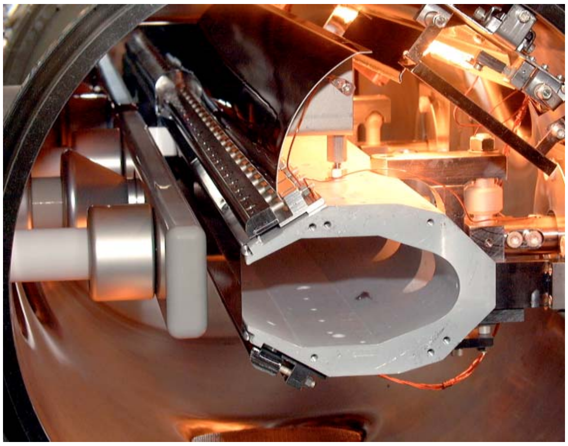

Figure 2: Septum prior to installation in PS

The high voltage feedthrough, rated at 300 kV, uses Shell Diala B oil for insulation purposes and is fitted with Peralumam PRE 30 (Peral) deflectors which are anodised in a sulphuric acid solution. A ceramic tube, connected to a wire-wound ceramic resistance, forms the main supporting structure for the feedthrough. The resistance decouples the cathode from the supply cable, to limit the energy discharged when sparking occurs between the cathode and septum.

The polished Peral cathode is anodised in a chromic acid solution which increases its voltage breakdown limit. The cathode is supported on ceramic rods fitted with Peral and stainless steel deflectors. The ceramic rods are cleaned by powder blasting, using ceramic powder of 100 µm average grain size. The deflectors are dry hand polished, mirror finished for the stainless steel type, whilst the Peral deflectors are polished and then anodised in a sulphuric solution.

The positioning systems for septum 31, being of a similar modular nature to septum 23, allow for precise movements in the radial and angular directions for the septum, and radial displacement for the cathode. The radial positioning system provides a resolution of 0.1 mm, with a 0.01 mrad resolution in the angular system. The supporting mechanical bearings for septum 23 are installed in the vacuum tank, but for septum 31 they have been externally mounted, to further improve the vacuum. The vacuum tank is UHV compatible, and equipped with “Wheeler” type flanges at each end. All vacuum joints are made of silver plated copper and are bakeable.

In the event of a failure, the high voltage feedthrough can be removed from the tank in situ, without the need to remove the complete tank from the accelerator, as was the case with the previous generation septa. This was facilitated by the addition of an intermediate flange on the vacuum tank.

To ensure RF impedance continuity, multi-contacts have been installed between the entry and exit points of the vacuum tank and the septum support. The contacts have been fitted to stainless steel plates to allow for rapid dismantling, thus reducing radiation exposure of personnel, see figure 3. The addition of the improved contact array has successfully eliminated parasitic resonances which were found on the previous generations of septa. The septum support is equipped with a slot, allowing insertion of a beam pick-up. This slot was found to be generating two major resonances. The slot has now been fitted with a cover with RF spring contacts, successfully eliminating the dangerous resonances.

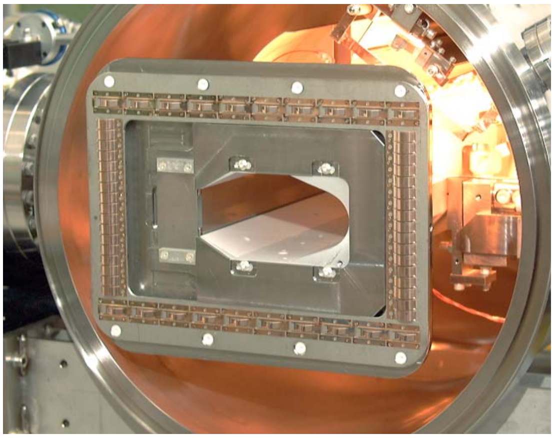

Figure 3: RF multi-contacts for impedance continuity

SEPTUM 23 BAKEABLE SUPPORT

Investigations were carried out to assess the suitability of the aluminium septum support as a bakeable system, to achieve even better vacuum levels. The main problem is thermal expansion of the complete tensioned assembly during bakeout, resulting in warping of the molybdenum foil. Due to the difference in thermal expansion coefficients between aluminium, stainless steel and molybdenum, the resulting stress levels in the sheet exceed the elastic limit of the material. During cooling the tension is reduced and the sheet adopts a corrugated profile. To reduce these thermal effects, the tensioner was rebuilt using titanium and stainless steel and the original stainless steel rods were replaced by molybdenum rods. Slits have been chemically etched into the molybdenum foil to reduce the effect of differential expansion. Figure 4 shows a cross-section of the bakeable septum support.

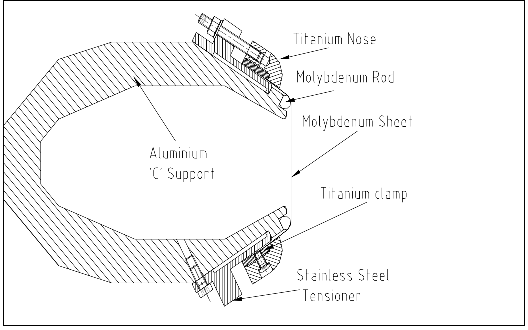

Figure 4: Cross-section of bakeable septum

A finite element analysis of the electric field was carried out and the results show that although the good field region is more uniform it is reduced in the vertical direction to 40 mm compared to 42 mm in the operational septum, see figure 5.

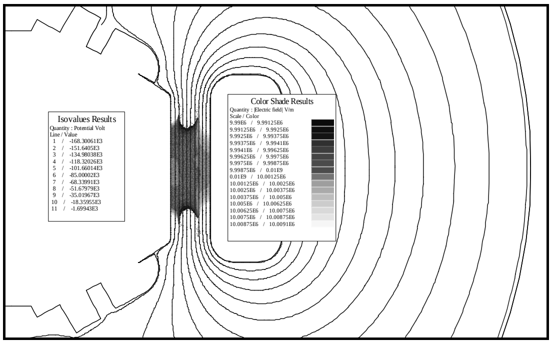

Figure 5: Electric field of bakeable septum

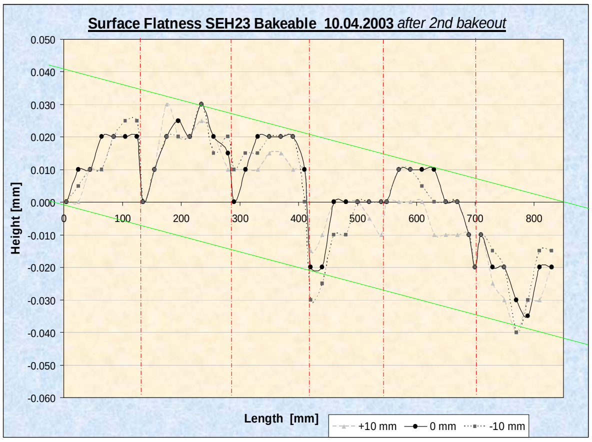

Figure 6: Surface flatness after 2nd bakeout at 100 °C

The prototype septum was assembled and underwent two bakeout cycles at 100 °C, each followed by venting with nitrogen and verification of the condition of the foil. It was found that after the second bakeout cycle, the foil retained its tension and the flatness of the sheet over the entire length of the septum remained well within the nominal limit of 100 µm (see fig. 6). High voltage testing is currently underway to verify the geometry of the titanium nose parts (see fig. 4), which have been installed closer to the foil in order to mask the slits from the cathode.

FUTURE DEVELOPMENTS

Further development of a bakeable septum 23 will be postponed due to manpower shortage. The next step should be the continuation of the development of a stainless steel septum support. The use of Invar may be considered due to its extremely low coefficient of thermal expansion. A 2.3 m bakeable support for septum 31 will also be studied at a later stage.

The adoption of 3M Fluorinert as a replacement insulation medium for the high voltage feedthrough is also planned. This would comprise a permanent system of regeneration of the liquid and thus reduce the possibilities of breakdowns, eliminate the need for the current 3-monthly oil change and reduce the risk of contamination of the PS vacuum system in case of a feedthrough failure.

A suitable high voltage cable to replace the existing type in use in the PS is presently being sought.

CONCLUSIONS

Through the application of advancing technology the vacuum levels in the septa tanks were improved by more than one order of magnitude. The performance and reliability of septum 23 has permitted its operational lifetime to be increased from one to two years. This results in lower radiation exposure for the personnel and extended cooling time for the reserve septum. There have been no high voltage breakdowns registered, the dark current is negligible and the de-conditioning effect has become noticeably lower.

The adoption of standard modular displacement systems reduces the necessary amount of reserves to be kept in stock. All electromagnetic septa in the PS are equipped with similar displacement systems, thus providing for easy interchange between septa.

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