Chapter 5

LAYOUT OF THE STORAGE RING

5.1 Introduction

In this chapter, an over view of the SESAME storage ring will be presented with the latest improvements in the design. After the brief description of the machine, the vacuum vessels design, the materials and the manufacturing processes are discussed and followed by some descriptions about the Gate valves, bellows and the power absorbers around the ring.

5.2 The latest update:

The design of the SESAME machine has been changed in a way to guarantee the most flexible machine for future upgrading and modifications, the longest possible beam lines and the longest possible insertion devices.

Accordingly, the SESAME building has been modified to optimise the machine, the main changes in the building are: 1- the two kitchens in the ground floor have been eliminated so that the experimental hall is larger now, and symmetrical from the four sides. 2- four columns have been removed to have the longest possible beam lines. By doing these modifications the experimental hall is larger to accommodate a larger machine.

To get a larger circumference the ring was shifted in the new design by 6m from the centre of the building, which was the largest possible distance, as farther shifting will cause conflict between the shielding wall and the columns from the loading area of the building.

By having an eccentric machine, this will shorten few beam lines, but will increase some others, however the three straight sections that serve the shortest beam lines will be used for the RF cavities and for the injection.

By this design, the machine circumference increased to 128.4m, and in order to get the longest possible beam lines, the machine has been rotated around its centre, so that the beam lines avoided the conflict with the columns, and can be extended as much as possible.

5.3 Description of the SESAME machine:

The machine consists of three main parts: the storage ring, the booster and the beam lines. The booster is an 800 MeV synchrotron, which is filled by a 20 MeV Microtron. The injection in the storage ring is done at 800 MeV and then the energy of the particles is ramped up to 2.5 GeV. Three Kickers are foreseen for the injection process. The RF system of the machine consists of two pairs of cavities with 250 kW klystron system. [1]

The Storage ring consists of 8 cells, each cell hold two dipoles and a straight section between them, so in total 16 dipoles constructing the whole ring with a bending angle of 22.5°.

The storage ring will have 16 straight sections, 13 are available for the installation of the insertion devices, while two will be occupied with RF cavities and one for the injection straight. These three straights have been selected carefully as these are the straight sections which serves the shortest beam lines. The straight sections can be divided into two types according to their lengths: long straight sections (LSS) and short straight section (SSS), more details of these two types will be described in the following sections.

As for the naming system of the different dipoles and straight sections, the numbering follows the location of the dipoles and the straights from the injection line. Figure (5.1) shows an overview of the naming of the different parts of the machine; SS stands to “Straight Section”.

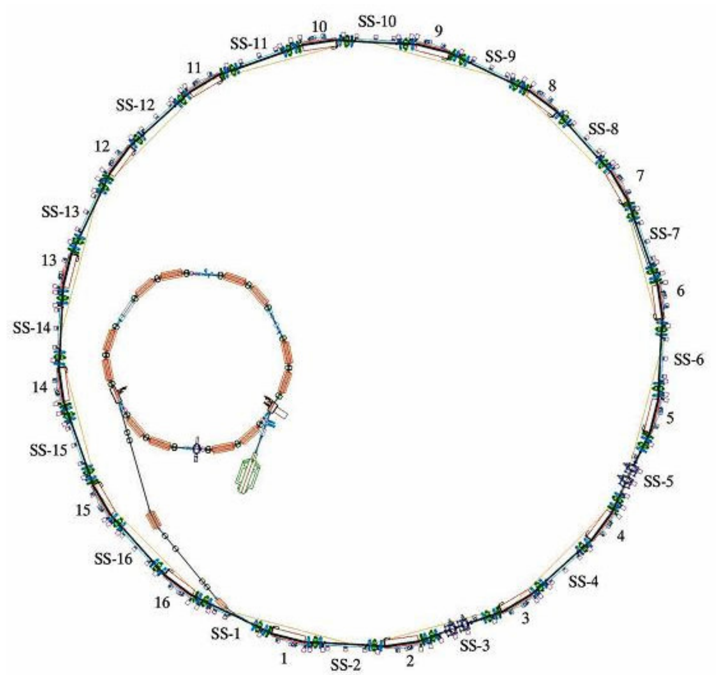

Figure 5.1: the naming system for the SESAME storage ring.

There will be two types of beam lines: zero degree beam lines and ten degrees beam lines, the zero degree beam lines are specified for the photons which produced by the insertion devices, and the ten degrees beam lines are dedicated to deliver synchrotron radiation from the bending magnets. In principle a total of 13 zero degree beam lines can be accommodated at SESAME, and 16 ten degree beam lines will be accommodated. Table (1) presents the lengths of the beam lines foreseen for SESAME; the last row of the table shows the total length of the beam lines.

Table 5.1: the lengths of the beam lines possible for the SESAME machine.

Dipole #	0°	10°
1	Injection	28.246
2	23.178	19.635
3	RF	21.968
4	21.569	21.657
5	RF	18.335
6	29.206	25.7
7	22.706	20.325
8	29.821	31.679
9	28.022	31.042
10	35.194	31.725
11	36.967	33.47
12	37.706	31.875
13	36.95	34.493
14	29.206	27.198
15	30.768	29.057
16	29.821	22.161
Total lengths of the beam lines (m)	**391.104**	**428.566**

The numbers in the table show clearly the benefits of having eccentric machine, with comparison with the “Yellow Book” which has a machine placed in the centre of the building, the maximum length which can be achieved for zero degree beam lines was 33.1m only, in the current design, beam lines with lengths of 37.7 and 36.97m are achieved. The improvement of the design is not only with the maximum length achieved for the individual beam lines but also with the total lengths of the beam lines, for the “Yellow Book” design the total length of the zero degree beam lines was 378.2m while with this design the total length of the beam lines is 391.04m.

Figure (5.2) shows the SESAME storage ring installed inside the building including the shielding walls, zero degree beam lines, and some of the ten degree beam lines, the power supplies, experimental hatches and the access bridge to the inside of the ring’s tunnel. The outer shielding wall has the thickness of 80 cm and for walls where the beam lines pass to the experimental station the thickness will be 1.0m with lead of 20cm thickness, the shielding wall shape is optimised according to the outlets of the different beam lines. The inner shielding wall has a thickness of 20 cm and continues all around the ring. An additional shielding will surround the booster synchrotron, which allows the safe access to the booster while the machine is working; the details of the shielding walls are described in chapter 14. The access to the inner side of the ring is possible using a bridge connecting the first floor of the building to the inner area near to the control room. The experimental hatches are foreseen for the experimentalists as an office for data recording and data evaluation.

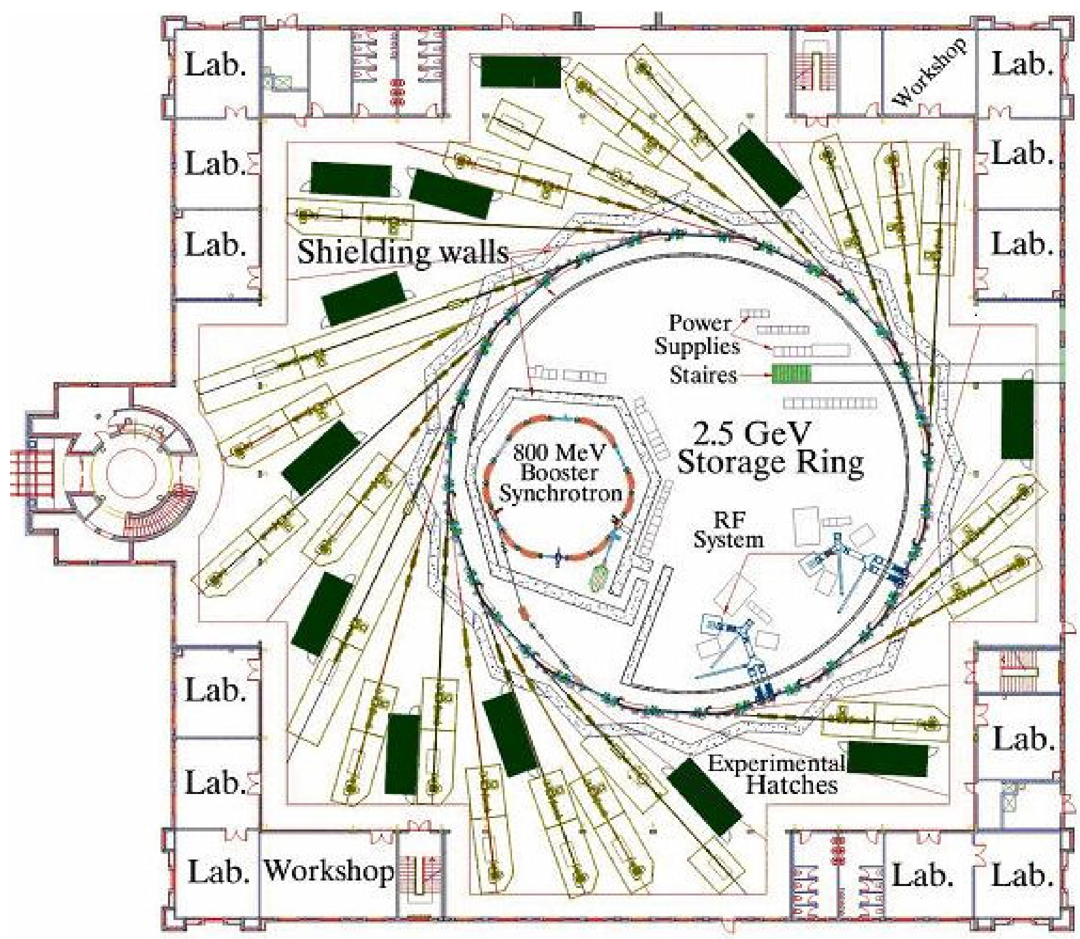

Figure 5.2: An overview of the SESAME machine and experimental hall.

The unit cell of the SESAME machine is shown in figure (5.3), the length of the unit cell is 16.05m, RF bellows are going to be used to make it possible having a clearance for the installation and the removal of the different parts of the machine and to reduce the thermal expansion in the storage ring. Two bellows will be installed on each side of the straight section, so in total there will be 32 bellows around the machine.

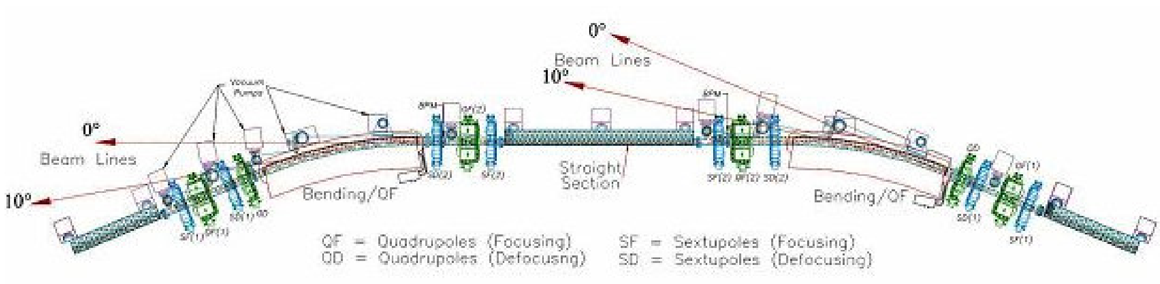

Figure 5.3: The unit cell of the storage ring.

5.4 The Vacuum Vessels Design.

The Vacuum vessel design is chamber/antechamber design, where the radiation will pass from the electron beam vacuum chamber through a gap to hit lumped absorbers distributed after each dipole, or will pass to the users. [2,3,4]

There are three main types of the vacuum chamber: the dipole vacuum chamber, the straight section vacuum chamber and the pre-dipole vacuum chamber, each of these three types is manufactured from one continues welded vacuum chamber, and connected to each other by flanges.

5.4.1 The Dipole vacuum chamber

According to the SESAME lattice design there are two types of dipole vacuum chamber, figure (5.4) shows the design of the first dipole vacuum chamber in the unit cell, and figure (5.5) shows the design of the second dipole vacuum chamber in the unit cell.

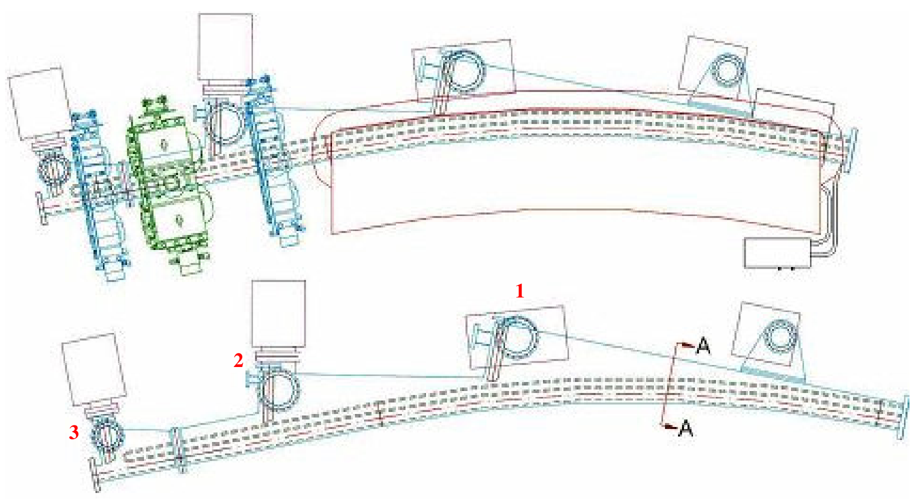

Figure 5.4: The design of the first dipole vacuum chamber in the unit cell (Type 1)

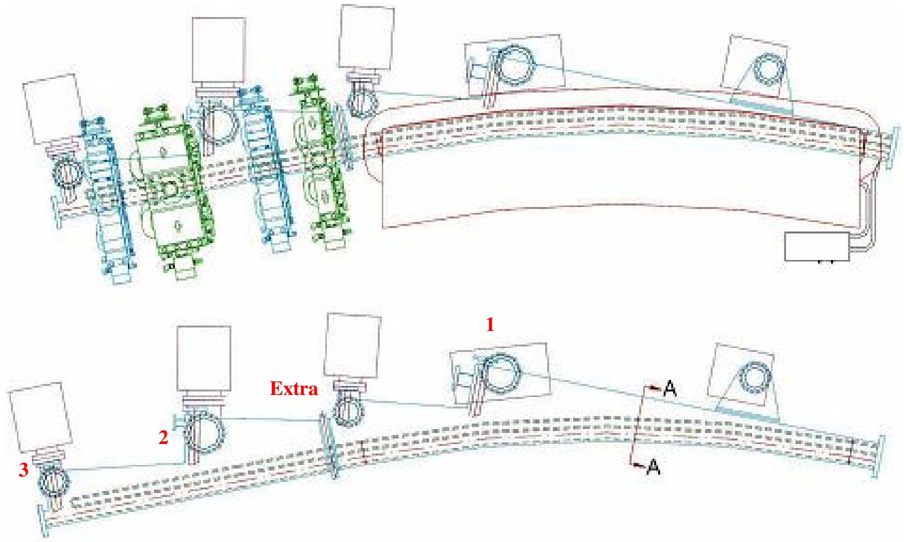

Figure 5.5: The design of the second dipole vacuum chamber in the unit cell (Type 2).

The dipole vacuum chamber has three absorbers along the chamber length with large ion pumps (some combined with TSP) connected to the vessel via pumping ports to guarantee a good pumping speed at this location, which has a large outgassing. For the second dipole vacuum chamber (type 2) another small absorber has been added following the first absorber, the reason for this is that the distance between the first and the second absorber in type 2 is larger than that of type 1, so there will be a need for an absorber in between. In the beginning of each dipole vacuum vessel a side pumping port connected to an ion pump will be used to pump down that area.

Due to the forces applied on the vacuum chamber from the atmospheric pressure side, it is necessary to support and reinforced the vacuum vessel by using strong external ribs to keep the deformation below 0.5mm. The strengtheners should be connected to the chamber using point welding method to prevent banana effect on the chamber.

Figure (5.6) shows section A-A (see figure 5.4 and 5.5) of the dipole vacuum chamber. It consists of two stainless steel plates, which are preformed by deep drawing procedure and a 7 mm thick outer wall. The two plates are electron beam welded together first, then this sub-assembly is welded to the outer wall from the external side. Because of the large surface area of the this chamber, the thickness of the stainless steel sheet used in this part is 3 mm to prevent the large deformations due to the forces acting via the atmospheric pressure.

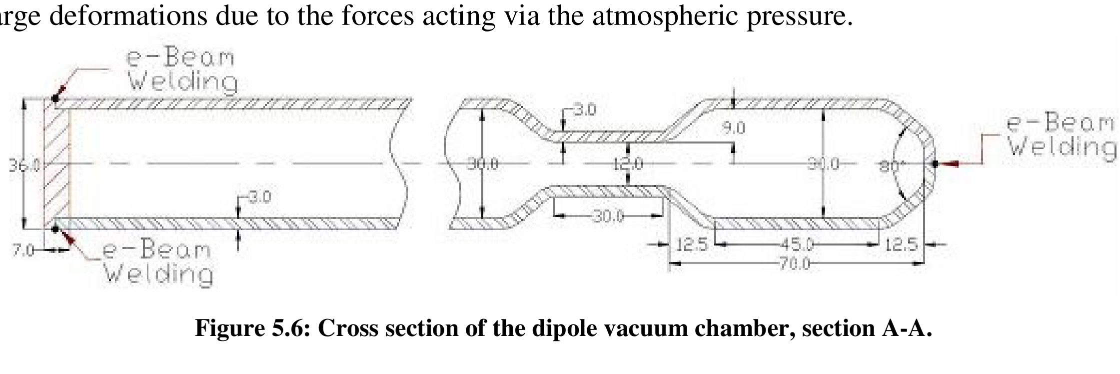

Figure 5.6: Cross section of the dipole vacuum chamber, section A-A.

5.4.2 Straight Sections

One of the main advantages of having a larger circumference that longer insertion devices can be installed, in comparison with the "Yellow Book" design, the long and short straight section lengths have been increased by 9%. Figure (5.7) and (5.8) shows the long and short straight section vacuum vessels respectively.

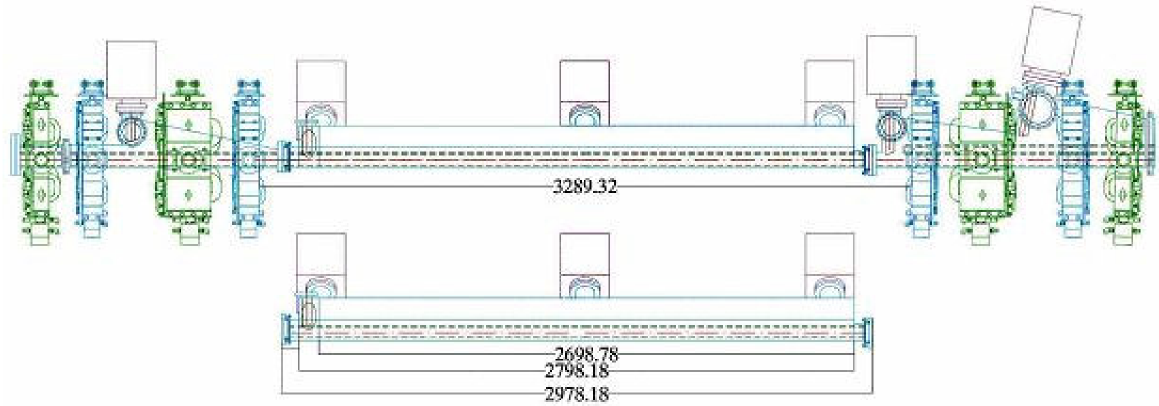

Figure 5.7: The long straight section vacuum vessel.

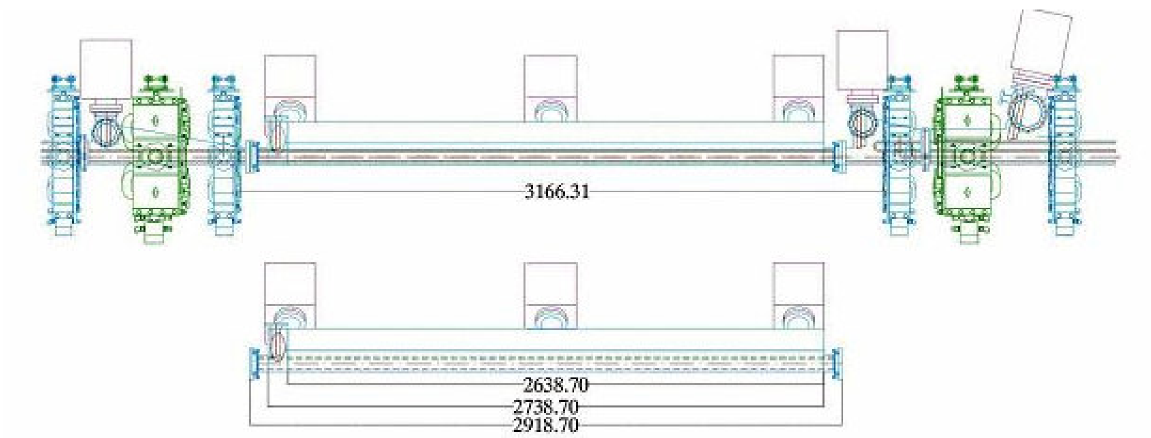

Figure 5.8 The short straight section vacuum vessel.

The total length of the long and short straight section is 2.978m and 2.918m respectively, but not all of this length is available for the insertion devices as some space is required for the flanges and bellows in each side of the straight section, then the useful length for the installation of the insertion devices for the long and short straight sections is 2.798m and 2.738m respectively. In the sections where the gate valves are installed, this length will be reduced to 2.648 and 2.588 m. Two flanges are foreseen at both ends of the straight sections to provide the possibility to change this vacuum chamber without opening the focusing magnets. This will facilitate the procedure of installation of the future insertion devices, in addition bellows will be installed by the end of the straight section, to allow clearance for the installation and removal of the vacuum vessels and to minimise the thermal expansion and contraction stresses in the storage ring. Three pumping ports are foreseen on the antechamber, which are placed with an angle of 45° in respect to the beam plane to avoid any interaction between the pumps and the possible insertion device and also the front ends, it is necessary to have a crotch absorber at the end of such a straight section to absorb the radiation coming from upstream dipole.

Figure (5.9) shows the cross section of this chamber, in the straight section vessels the antechamber is simply a tube welded to the beam chamber, the diameter of this tube is 102mm. The vacuum chamber consists of two parts which are welded together using e-beam welding method. The beam chamber is produced with folding procedure.

The advantage of this design can be summarized as the following:

- It is cheap as the manufacturing point of view because a standard tube is used as the antechamber.
- The conductance of the vacuum chamber is increased which helps to keep the pressure uniform and as low as possible in the straight section.
- All the radiated power is absorbed in a crotch absorber at the end of the chamber, so there will be no distributed outgassing from the outer walls due to direct photon adsorption effect.

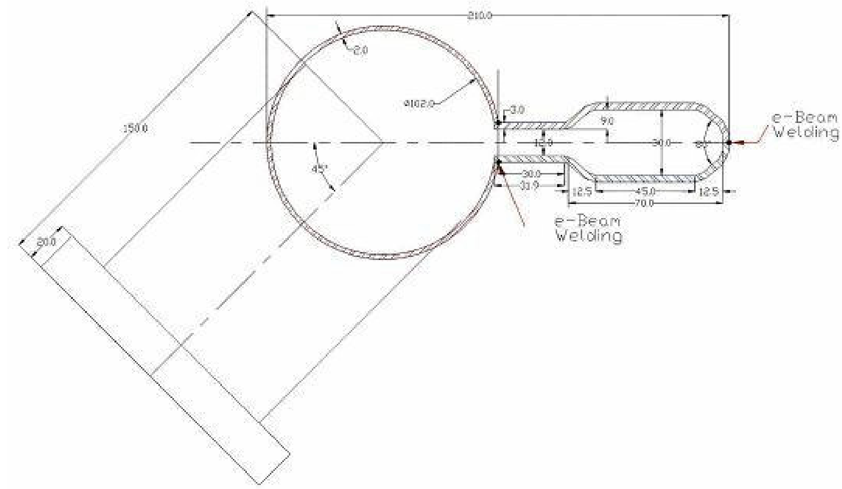

Figure 5.9: Cross section A-A in the straight section vacuum vessel.

5.4.3 Pre-Dipole Vacuum Chamber

Due to the lattice arrangement of the SESAME storage ring, and like the other vacuum vessels, the pre-dipole vacuum chamber has two types which are shown in figure (5.10). The pre-dipole consists of two symmetric parts, which are electron beam welded together. The chamber body has been made of 3 mm thick stainless steel sheets which are formed by folding procedure, while all the pumping ports are made of 2mm thick stainless steel. Figures (5.11) show the A-A cross-section of the pre-dipole vacuum chamber.

An antechamber end with a pump and absorber will be used to guarantee that no radiation from the upstream dipole may reach to this part.

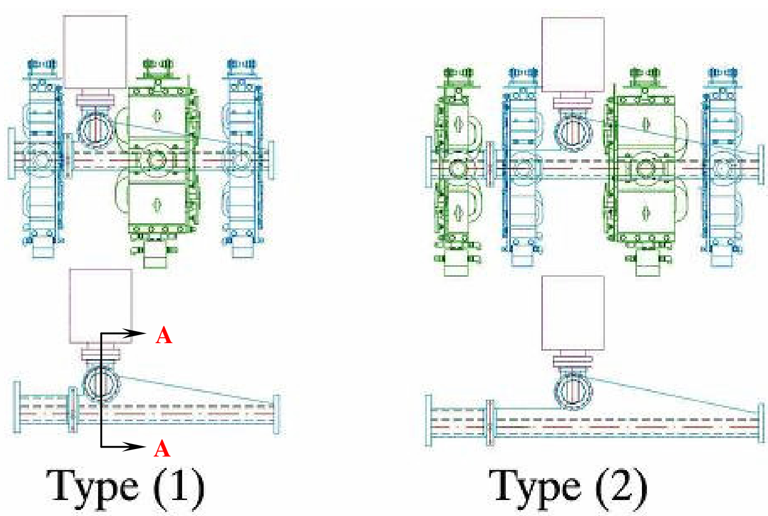

Figure (5.10) the pres-dipole vacuum chamber.

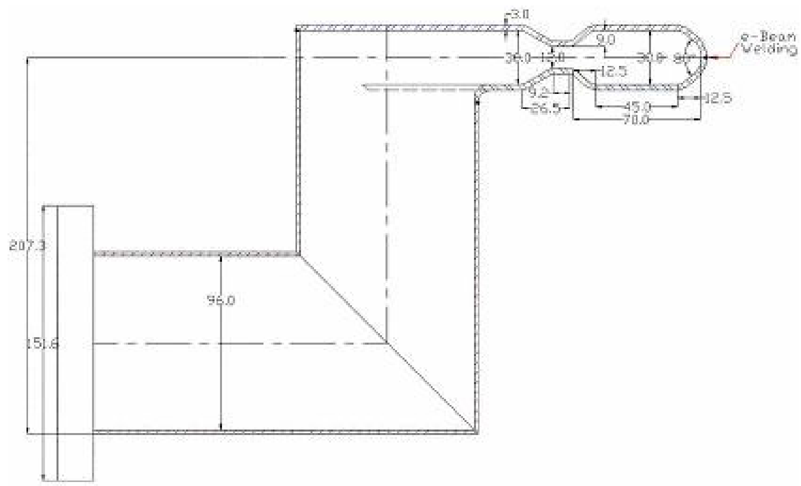

Figure 5.11: Cross section A-A in the pre-dipole vacuum vessel.

5.5 Choice of Material

In ultra high vacuum systems the materials are normally chosen due to their outgassing rates, because in UHV region the main gas load comes from the surfaces. On the other hand the material should be strong enough to withstand the forces acting from the atmospheric pressure to the under vacuum parts. The bending of the vessel walls should not exceed 0.5 mm in the worst conditions [3].

The most common material which is used in the world's accelerators is Stainless Steel. It has good mechanical properties, weld (TIG and electron beam) ability and low outgassing rate. For the SESAME storage ring, Stainless Steel 316 LN (Z2 CND) is proposed for the main chambers including Pre-dipole, Dipole and straight sections. The relative permeability of the material should not exceed 1.005 ($\mu_r \leq 1.005$)) for the raw material [2,3,5,6].

The absorbers of the synchrotron radiation on the ring should be made of a material with a high thermal conductivity. In this case, OFHC[1] copper (ASTM C 10100) is proposed for crotch absorbers. For the parts with a higher radiated power, GLIDCOP is proposed. This material has better mechanical properties compared to OFHC copper in high temperatures and is suitable for high power crotch absorbers. For more information about the materials which are used in the vacuum system and their properties please refer to the chapter 7.

5.6 Bellows and Gate Valves

The main reasons to have the bellows in the vacuum system are to make mounting procedure easier and to absorb the mechanical stresses due to the thermal expansions of the chamber. They are also useful in modifying manufacturing errors of different parts. The bellows must be RF shielded bellows to prevent sudden changes of the cross section in the beam chamber. Two RF shielded bellows per straight section (32 in the whole machine) are foreseen in SESAME storage ring. Figure (5.12) shows the position of the bellows in the straight section, and figure (5.13) presents a sketch of such a bellows [3]

[1] - Oxygen Free High Conductivity

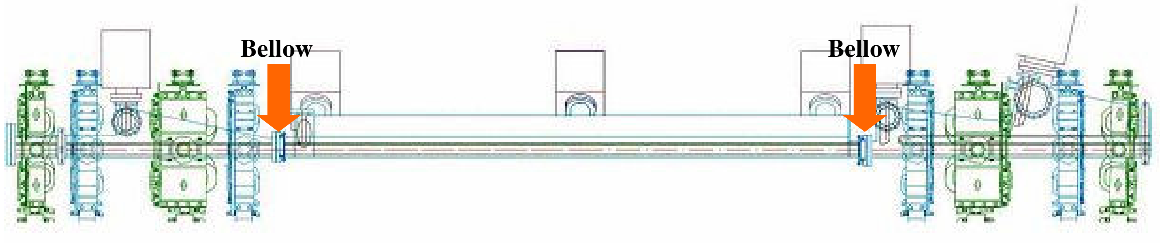

Figure 5.12 The position of the bellows in the straight section.

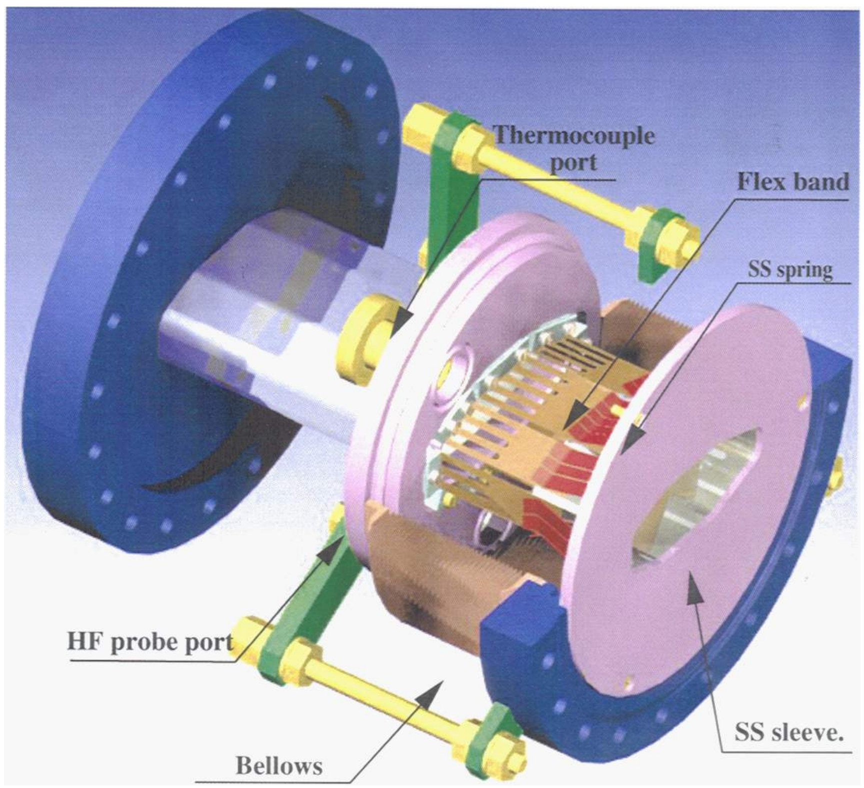

Figure 5.13: Schematic of an RF shielded bellows, SLS/SOLEIL cooperation [3].

Gate valves are mainly used to divide the machine into smaller sectors. It is so important to prevent the air to affect the entire ring in case of a leak or during maintenance and make the installation of the machine easier. SESAME storage ring will be divided into five sectors by the gate valves, each part is defined by as a separate vacuum section, which will allow a separate pumping down, and will make it possible to be isolated from the rest of the machine in case of venting for upgrading purposes or due to vacuum failures. The valves must be fast closing with the same aperture of the vacuum chamber and RF shielded by using a screen with RF fingers so the beam will see a smooth surface. The best design for the gate valves with an RF shield is commercially available from the market.

Seven Gate valves are foreseen for SESAME storage ring, one in the injection section, two pairs at both ends of the RF cavities (SS-3 and SS-5), and other two gate valves (located at SS-9 and SS-13) in order to divide the whole ring into five vacuum sectors. Due to the location of the RF cavities and the injection system in the machine, then the sectors are not similar in their size. In addition, one gate valve will be located after the Microtron, and one between the booster synchrotron and the booster-storage ring transfer line, and three to divide the microtron into three parts (originally from BESSY 1). Figure (5.14) shows the location of the gate valves around the SESAME machine.

The gate valves will be interlocked by a signal from two ion pumps located inside the vacuum section, so if two pumps indicate an increase in the pressure (above the set point) from the reading of their potential, then the beam is dumped and the valves will be closed.

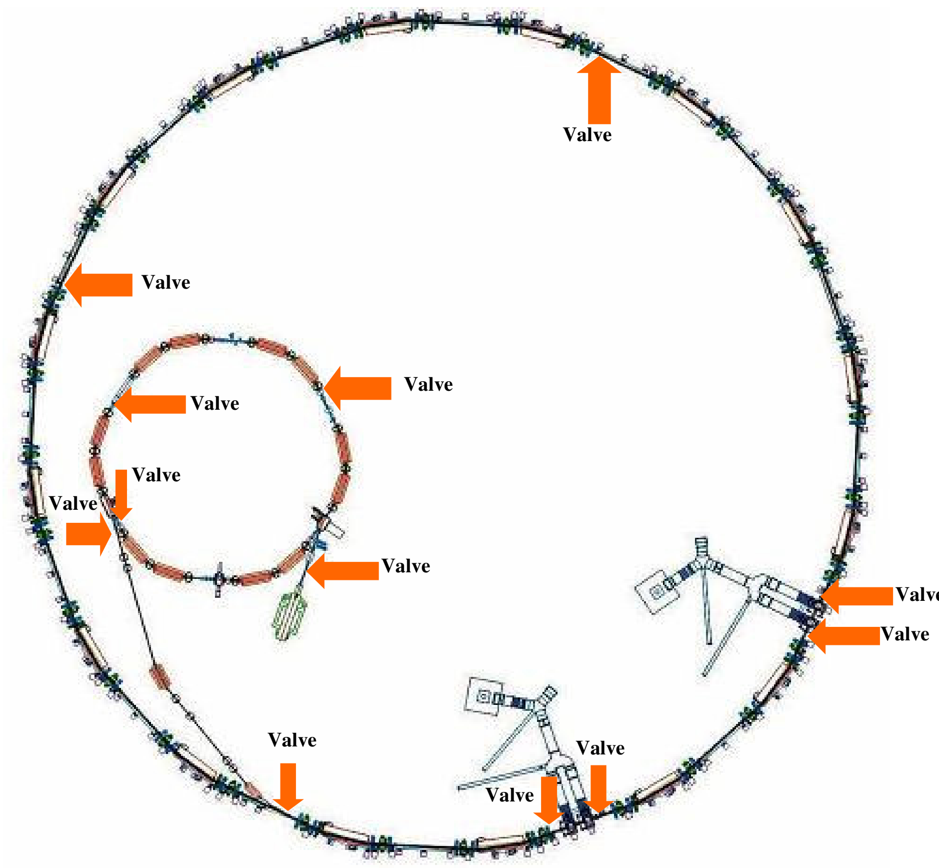

Figure 5.14: the location of the gate valves around the machine.

5.7 Synchrotron Radiation and Absorbers

Each electron/positron storage ring has a power loss due to the synchrotron radiation. This power hits the walls of the vacuum chamber and causes temperature rise. Lumped and distributed absorbers are necessary to remove the produced heat from the system. Total radiated power over the machine circumference can be calculated using equation (5.1).

$$P_T = 88.5 \frac{E^4 I}{\rho} \quad (5.1)$$

P_T : Total radiated power over machine circumference [Watts].
E : Energy of the particles [Gev].
I : The beam current [mA].
ρ : Bending Radius [m].

So, for SESAME storage ring with E=2.5 GeV and I=400 mA and ρ= 5.8519 m, total radiated power in all circumference is 236.3 kW, which means 37.6 W/mrad or 656 W/deg. The lumped absorbers in dipoles, straight sections and in the pre-dipole vacuum chamber absorb this power.

Suppose (d) corresponds the distance between the source point and a target normal to the photon beam and L the length of the target (e.g.: Crotch absorber), the linear power density W/mm is calculated by formula (5.2), figure (5.15) shows the different parameters which have been used in this formula.

$$P_l = \frac{P_T}{2.\pi.d} = \frac{P_T \times \theta}{360 \times L} \quad , \quad \theta : \text{in degrees} \qquad (5.2)$$

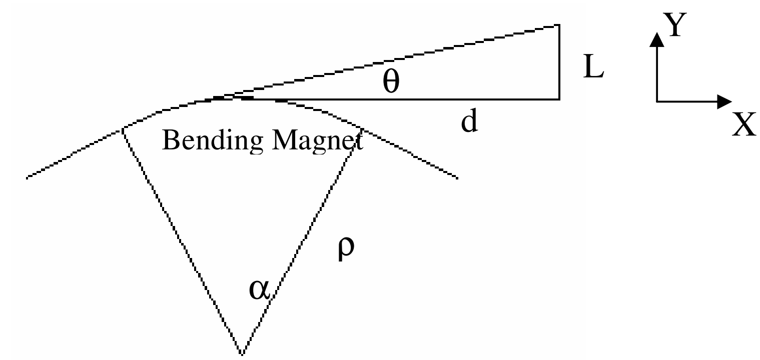

Figure 5.15: Different parameters of the Equation (5.15)

As the distribution of the absorbers in the super period cell is not symmetrical, then the power absorbed by each is different from one to another in the same cell; figure (5.16) shows the naming of the absorbers in the super period cell. There are 11 crotch absorbers for each super period cell, so in total 88 crotch absorbers are there for the whole ring. The power densities on the crotch absorbers are shown in figures (5.17) to (5.27). In these figures, "length" of the crotch means the length of the absorber, which is hit by the synchrotron radiation and measured from top to bottom, and it is not the actual length of the absorbers as the previous absorber shades part of absorber, and prevent photons of reaching it.

According to these figures, the maximum linear power density on the crotches is around 37 W/mm. In this case SLS type crotch could be a perfect selection and be used without any problem because they can withstand up to 50 W/mm.

The power densities on crotch absorber 5,6,10 and 11 are low in comparison with the other crotch absorber, then their design need to be a simple. Figure (5.28) and (5.29) show sketches of SLS type crotch absorbers [4].

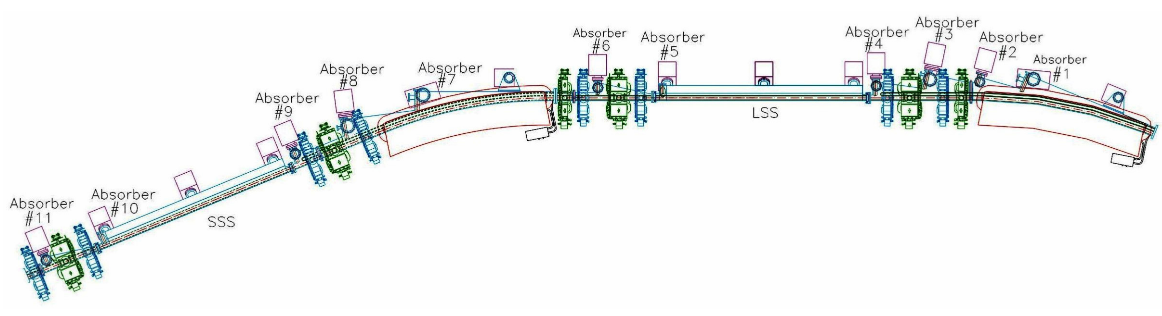

Figure 5.16: The location and the naming of the absorbers in the super period cell of SESAME.

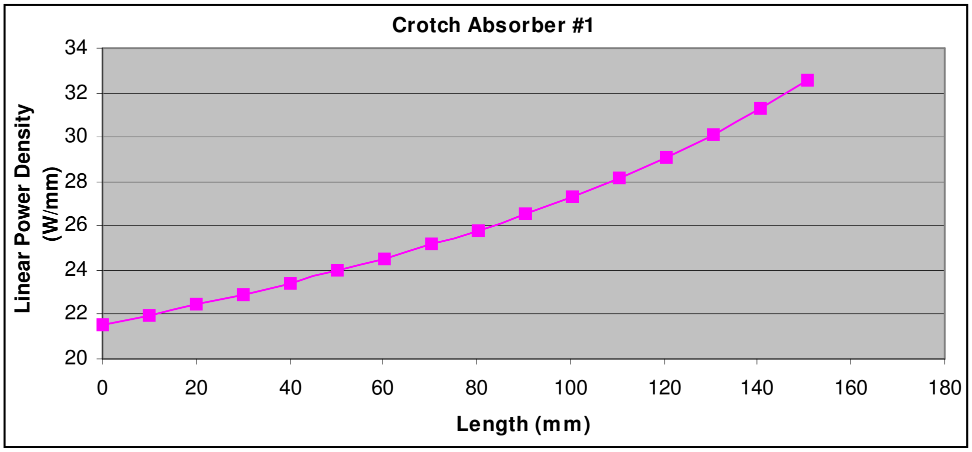

Figure 5.17: Power absorbed by the crotch absorber #1, the overall power is 4.127 kW.

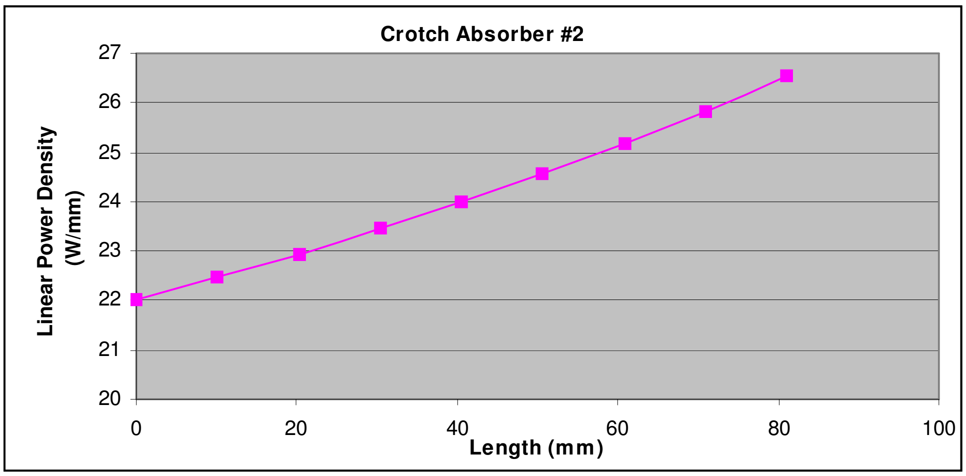

Figure 5.18: Power absorbed by the crotch absorber #2, the overall power is 2.169 kW.

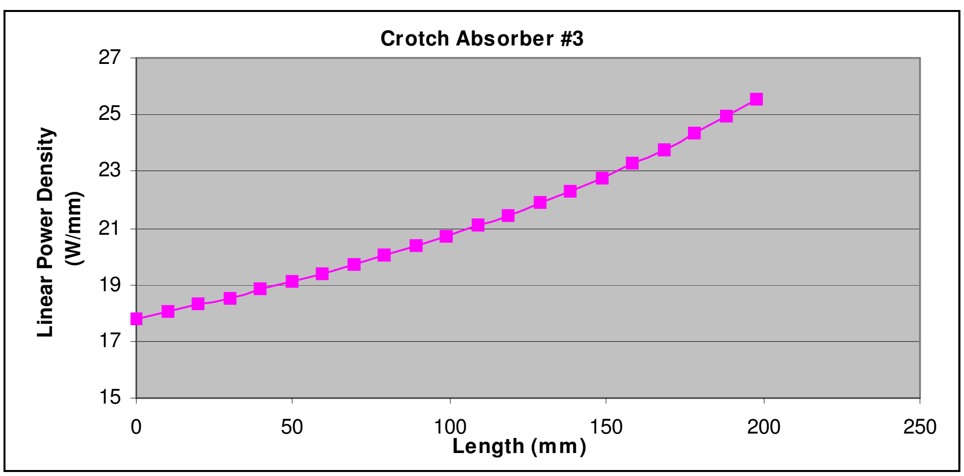

Figure 5.19: Power absorbed by the crotch absorber #3, the overall power is 4.418 kW.

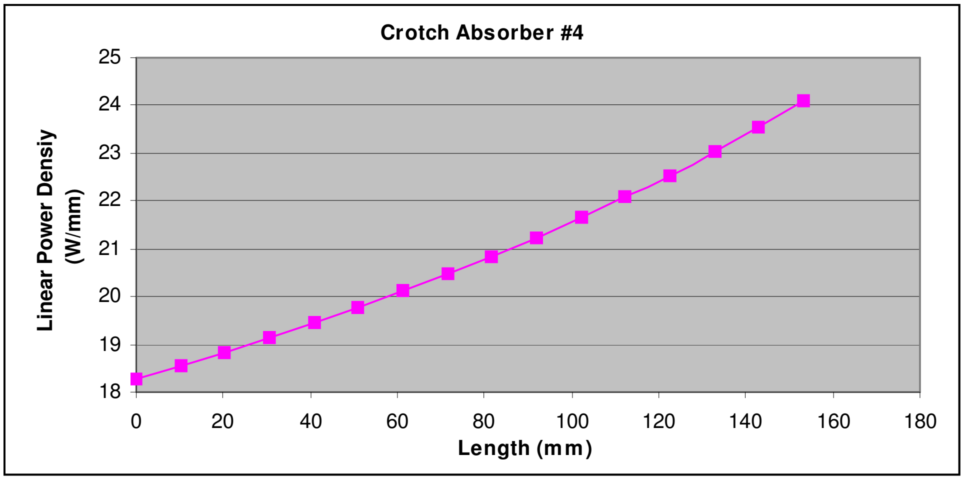

Figure 5.20: Power absorbed by the crotch absorber #4, the overall power is 3.33 kW.

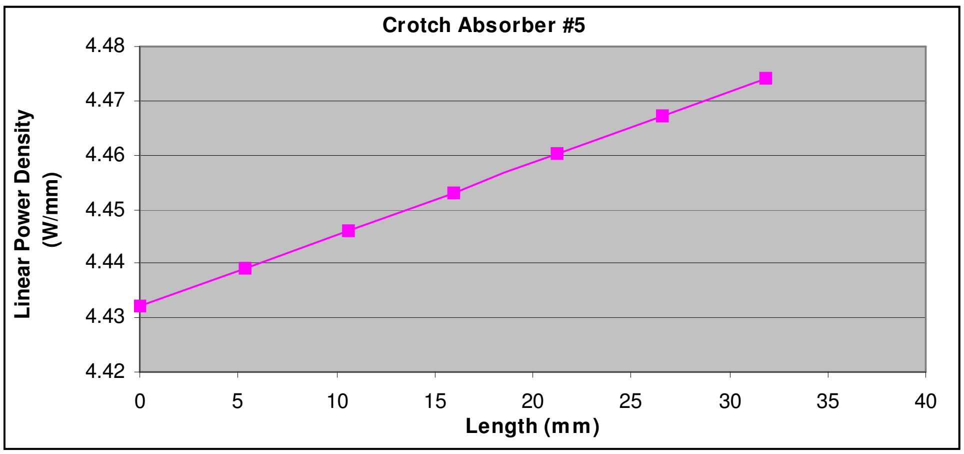

Figure 5.21 Power absorbed by the crotch absorber #5, the overall power is 0.312 kW.

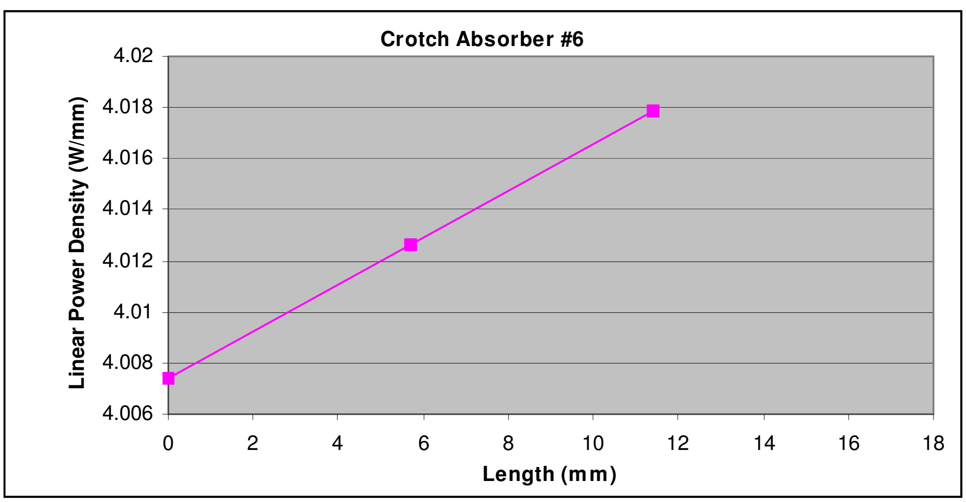

Figure 5.22: Power absorbed by the crotch absorber #6, the overall power is 0.121 kW.

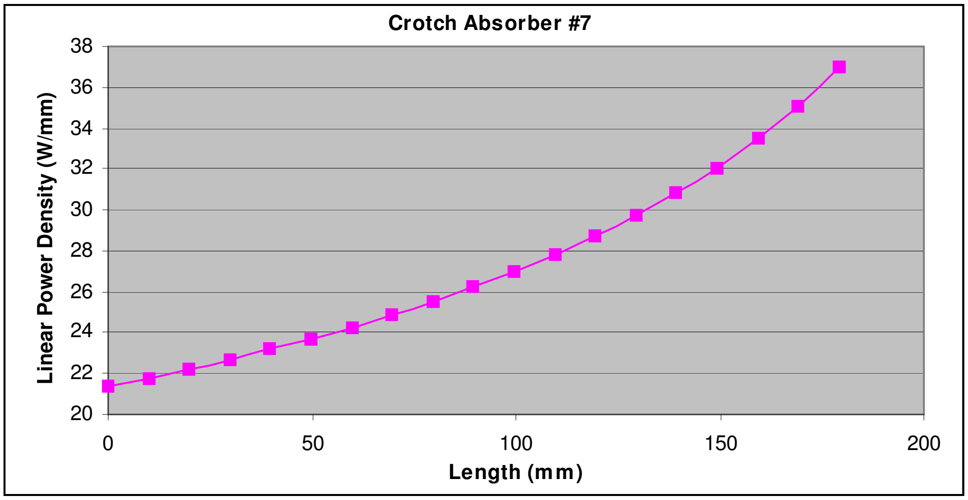

Figure 5.23: Power absorbed by the crotch absorber #7, the overall power is 5.171 kW.

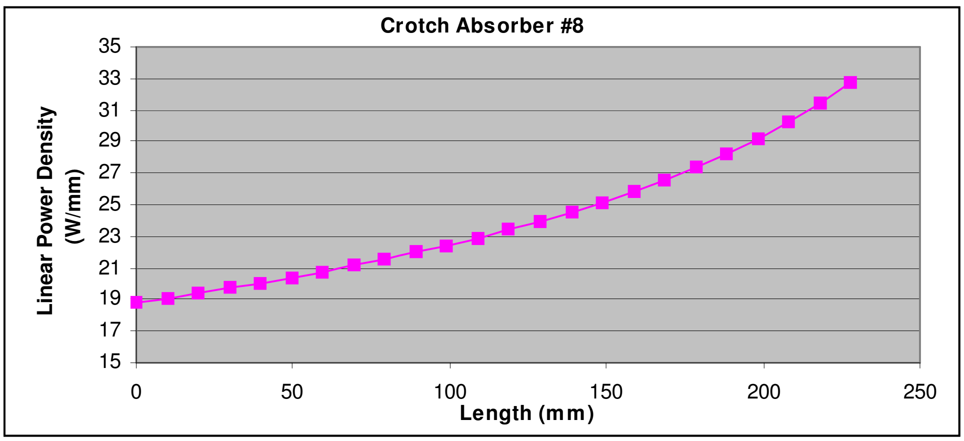

Figure 5.24: Power absorbed by the crotch absorber #8, the overall power is 5.76 kW.

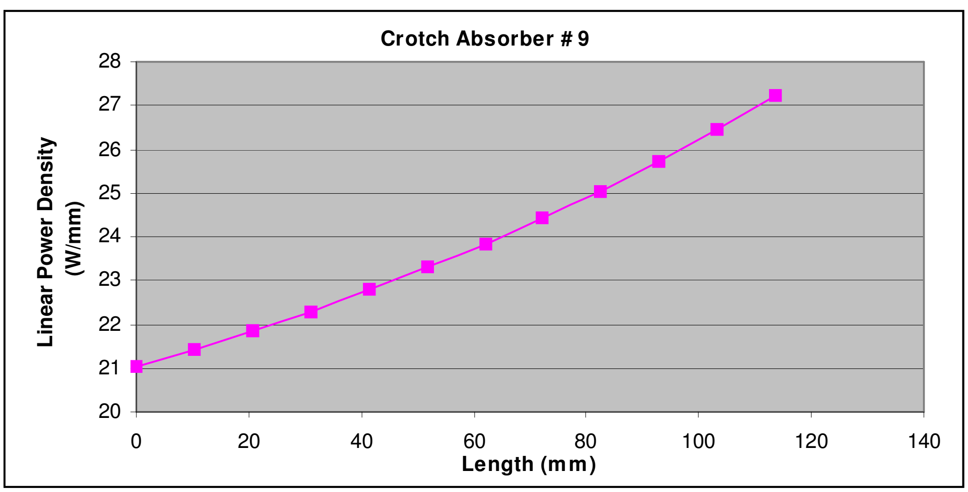

Figure 5.25: Power absorbed by the crotch absorber #9, the overall power is 2.85 kW.

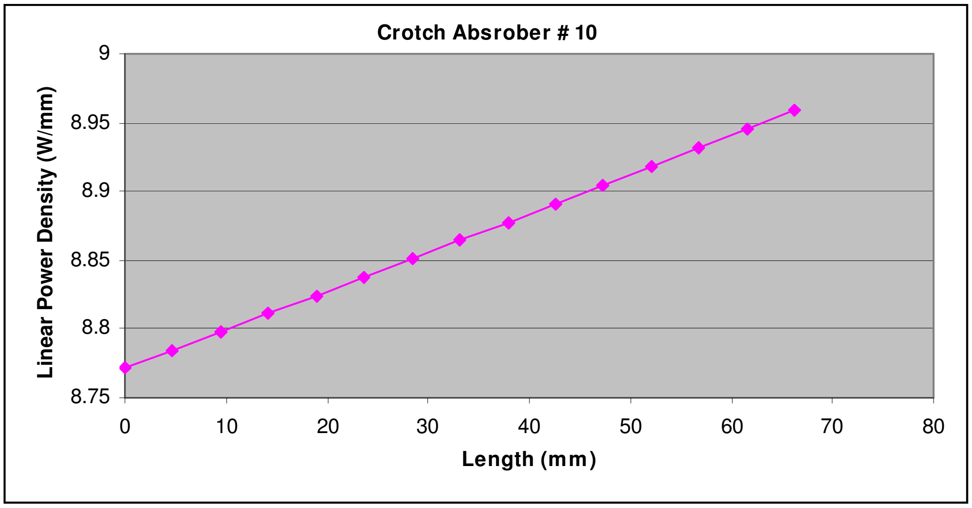

Figure 5.26: Power absorbed by the crotch absorber #10, the overall power is 0.630 kW.

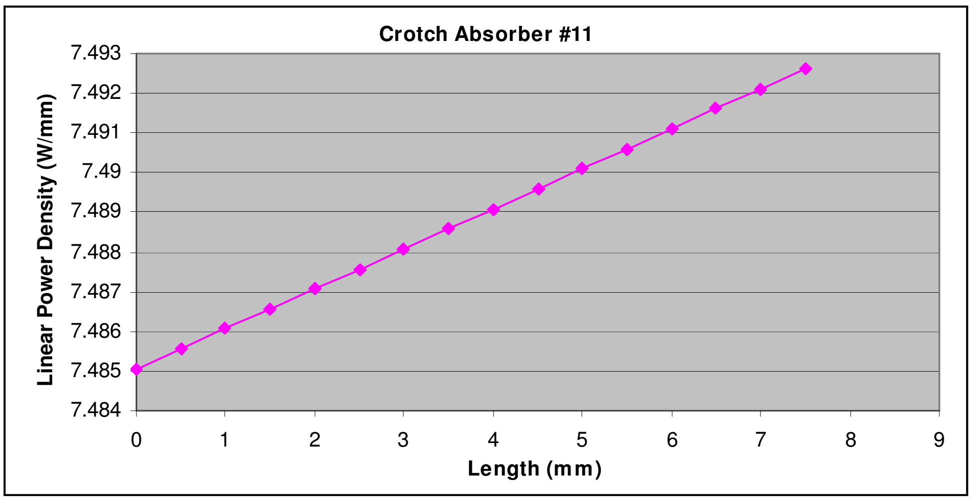

Figure 5.27: Power absorbed by the crotch absorber #11, the overall power is 0.06 kW.

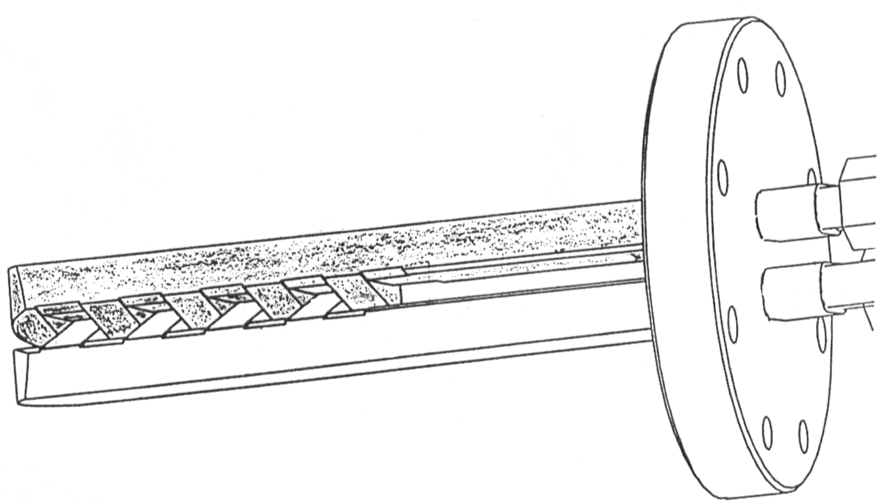

Figure 5.28: An overall view of the SLS type crotch absorber.

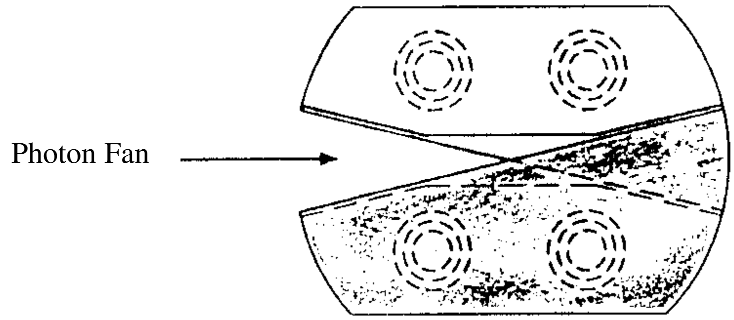

Figure 5.29: Cross section of the crotch absorber.

References

[1] D. Einfeld, SESAME, First Draft of Conceptual Design, version 8, March 2002.
[2] E.Huttel, D. Einfeld, "*The vacuum system for the synchrotron radiation Source ANKA*".
[3] SOLEIL,*"Rapport d'Avant Projet Détaillé",* June 1999.
[4] Vacuum system of SLS.
[5] Vacuum system of CLS.
[6] Vacuum system of spear III.