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ELECTROSTATIC INFLECTOR IN STRAIGHT SECTION 26 OF PS

Proposal for reconstruction

The inflector is used for injecting the linac beam into the PS. The existing construction (Fig. 1) consists of two curved electrodes made of 8 mm thick titanium sheets placed inside a rectangular vacuum tank. Each electrode can be displaced individually; the HT electrode via insulators by hand, the earth electrode (septum) via horizontal supports by electromotors. The supports of both electrodes are mounted on the vertical walls of the vacuum tank. The tank is connected rigidly to the chamber 26 and flexibly by bellows, to the chamber 25. The complete assembly is sitting on a framebox made of steel profiles normaly used for instrument racks. This box is housing a resistance with insulators for the protection of the HT cable. The positioning of the inflector tank is done by three adjustable feet placed between the tank and the base-frame.

Mean parameters of the inflector

- Voltage between electrodes, max 150 kV;
- nominal distance between electrodes 45 mm;
- radius of electrode curvature 31400 mm;
- length of electrodes 1928,8 mm;
- height of electrodes min. 200 mm;
- thickness of earth electrode on the downstream end (septum) max. 0,5 mm;
- movement of downstream ends of electrodes ± 10 mm from nominal position, perpendicular to the beam;
- movement of upstream ends of electrodes + 20 mm (toward the beam) and - 15 mm in the other direction.

Mechanical tolerances for the inflector

- For the distance between electrodes $\pm$ 0,2 mm;
- for the curvature of electrodes $\pm$ 1 mm;
- the electrodes should be vertical for better than 0,2 mm in 80 mm in the middle 80 mm of the electrode height;
- the resolution and repetitivity of electrode displacement better than $\pm$ 0,1 mm.

The construction of the existing inflector shows some weak points :

- the electrodes are too flexible; the ratio between the thickness and length is too small;
- the electrodes are mounted on the walls of a rectangular vacuum tank which cannot guarantee a stable support. Changes in atmospheric pressure may distort the tank enough to displace the electrodes;
- the electrodes are moved by rods or insulators which slide through vacuum seals; this causes a faster forming of oil deposits on the electrodes;
- the inflector is mounted on a base which is not stable enough;
- the septum electrode is a rather expensive element and in addition to that, it cannot be quickly dismantled to be replaced by a new one.

The last point is a serious disadvantage considering that the septum, no matter how well it is made, will always be a vulnerable element and a highly radioactive one.

Proposed changes

To better the chances for a multiturn injection the proposed new construction shown on Fig. 2, Fig. 3 and Fig. 4 includes :

- a new rigid set of electrodes built into one functional unit with an inexpensive and easily exchangeable earth electrode;

- the electrodes mounted on their own supports mechanically separated from the vacuum tank with the movement mechanism put directly on the base of the inflector, thus eliminating all sliding vacuum seals, and
- a new stable base to support the inflector unit.

Special care has been taken to use as many elements of the existing construction as possible. The vacuum tank, except for two holes in the bottom plate, has not been changed. The existing supports of the tank are also used. The HT cable with the end insulator remains unchanged.

New set of electrodes

The new set of electrodes (Fig. 4) consists of a C-profiled bar (body) which carries both electrodes. The HT electrode is mounted on two tubular steatite insulators with one end clamped into a cup on the body and the other end screwed into the electrode. The position of the HT electrode, relative to the body and septum, can be changed by sliding the insulators inside the cups. The earth electrode (septum) a 0,4 mm thick plate is simply pressed against the curved sides of the body by two bars with "finger contacts". Both bars are mounted on three vertical C-shaped rods thus forming a framelike unit which can pivot for a small angle on three hinges to facilitate the mounting of the septum foil. The force to press the septum against the body is produced by three quick action latches; the finger contacts are distributing this force more or less equally along the septum electrode. A force of 1 to 2 kg per cm length is big enough to provide a good thermal contact between septum and body (about 10 W per cm length, per $1^{\circ}C$) and small enough to allow a free thermal expansion of the septum.

In a multiturn injection regime, for a beam current of 100 mA, the septum electrode will normally be heated with 75 W. If the electrodes are not in the right position to the beam or in case of a HT supply drop-out with the beam still on, the septum may stop the full beam, which would amount to 250 W.

The part of the septum touched by the proton beam can be of any length, but a heat distribution of 1 W per cm length under normal conditions and 10 W per cm length in extreme cases, can be safely supposed. The width of the heated area is supposed to be 20 mm. Because of the poor thermal conductivity of stainless steel and the thinness of the septum, almost all of the heat is dissipated by radiation. About 25% to 35% of it will be radiated on the HT electrode and electrode body, the rest on the tank walls. The maximum temperature of the septum is in the horizontal plane of symmetry with isothermal lines parallel to this plane.

For different heat distributions per unit length and different surface qualities of the septum electrode, the maximum calculated temperatures are given in the following table.

Case	Heat intensity in W/cm length	1	5	10
A	Maximum temperature	330°C	680°C	890°C
B	Maximum temperature	270°C	590°C	760°C
C	Maximum temperature	130°C	440°C	590°C

Case A is for a septum of a 0.4 mm thick stainless steel sheet with coefficients of emissivity 0.06 for the HT electrode and the inside surface of the septum and 0.12 for the outside surface of the septum. This would correspond to new clean inside surfaces and slightly roughened outside surface of the septum.

Case B is valid for the same septum, but with coefficients of emissivity 0.1 and 0.2 for surfaces with a thin layer of organic materials.

Case C stands for the same quality of septum surfaces, but made from a different metal with a five times higher thermal conductivity than stainless steel.

The temperature fall-off from the middle of the septum to the edge is not linear. It is very steep near the middle and almost flat near the edges. More so for case A and B and less for case C.

The HT electrode on which part of the heat from the septum is radiating can in the worst case reach a temperature of 180°C.

The electrode body remains relatively cold; if the full beam is absorbed by the septum the temperature of the body will not be higher than 100°C.

From the thermodynamical point of view some practical conclusions can be made :

- the septum electrode cannot be effectively protected by cooling either the electrode on the periphery or the body which carries the septum;

- the septum can be damaged if a small area of septum is hit by the proton beam with a heat intensity greater than 10 W/cm^2, say in the case of a bump which would, because of the irregular temperature field, continue to grow;

- it is of a double advantage to make the outer surface of the septum as rough as possible; by doing this the septum temperature will be lower and a smaller percentage of heat will be radiated on the HT electrode;

- it is not necessary to provide either the HT electrode or the electrode body with a cooling system.

The best method to protect the septum is by shielding it from the proton beam with suitable blocks of graphite or heavy metal. This can be done without difficulties for the upstream end of the septum with a block mounted on the electrode body. To protect the downstream end of the septum the protection block must be, however, mounted on a separate adjustable support to position the block against the outside edge of the PS beam. In figs. 5 and 6 is shown the proposed constructions of electrode body and the HT electrode. In order to simplify the machining, the profile of the electrodes is not an arc but a polygon with eight straight sections. The error thus made is smaller than 0,23 mm.

HT Supply

The HT supply is done through the existing insulator. Only the protection shield on top of the insulator has to be changed. The contact to the HT electrode is made by a helicoidal spring, which is producing a contact force of about 3 kg over the total travel of the electrode. The arrangement is shown on fig. 3.

Supports

The two supports for the electrodes are mechanically separated by stainless steel bellows from the vacuum tank and mounted directly on two concrete blocks. Because of the torsional rigidity of the bellows, the supports are provided with ball bearings on which the electrode body can freely rotate without a play in horizontal direction. Both supports are guided by a key in the direction perpendicular to the longitudinal axis of the tank. Each support can be moved by a screw mechanism, working against a spring, driven directly by a stepping motor. Because this system does not need gear reduction, the play, when reversing the movement, is reduced to a minimum. With a screw of 1 mm pitch and a stepping motor with 200 steps per revolution, a movement of 0,1 mm will take 20 steps of the motor. The reading of the position can be done by a pulse counter, the zero positioning by a microswitch mounted on the support slider. By moving the support between two limit switches mounted on a known distance, the functioning of the stepping motor can be easily checked.

Base of the inflector

For the new base of the inflector, two rectangular concrete blocks have been chosen. In the top surface of the block are imbedded two steel plates for mounting the support of the tank and the support of the electrode. The space between the concrete blocks can be used for housing the existing resistance for protection of the HT cable.

Cost of the reconstruction

Electrode body with HT electrode	Sw.Frs. 12,000.-
Two stainless steel septum electrodes	Sw.Frs. 500.-
Two supports complete with bellows and moving mechanism	Sw.Frs. 3,000.-
Two stepping motors	Sw.Frs. 2,500.-
Two concrete blocks	Sw.Frs. 1,000.-
Total	Sw.Frs. 19,000.-

The electrodes can be made in six weeks. The complete reconstruction can be finished in ten weeks.

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Distribution

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