THE STRASBOURG PROJECT. A 35 MV VIVITRON TANDEM

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Abstract

The 35 MV Vivitron Van de Graaff Tandem Accelerator presented is based on some new ideas. As well as tests which have been performed, the principles of construction, conductor problems and insulator problems are described. The machine is now under construction and the beam is expected in 1990.

Since the last international conference an important decision has been taken, it is to build this new accelerator, the Vivitron, in the near vicinity of the existing Tandem MP machine. This decision had as consequence a large amount of design work and also fondamental tests made in view to verify the ideas on which the Vivitron is based.

1. General description[1-4]

The Strasbourg machine is a 35 MV Van de Graaff Tandem accelerator whose design incorporates some new features and ideas. All the electrical characteristics are very conservative, especially for the accelerator tube, which is a standard inclined field tube, but the philosophy and some rules to build such an accelerator are new (fig. 1).

The tank is 51 m long and has 8.4 m diameter in the center. On each side of the terminal electrode of 1.4 m diameter, there are 9 tube sections on each side (7 of 100" and 2 of half length). The column is assembled in an internal structure using epoxy-glass fibre insulating material. On each side of this structure there are 48 column electrodes. They act as large spark gaps. This column is attached on and supported by the tank through insulated epoxy posts. These insulators together with the discrete electrodes constitude the mechanical structure of the machine. These electrodes assembled in 7 porticos are connected at the right place to dead sections. The charging system is a small belt running close to the tube at a speed of 8 m/s.

2. Principles of construction

One of the new principles developed by M.Letournel comes from the will to lower at any place the mean electrical field, to allow a higher field but in an appropriate geometric configuration, where sparks can occur, and to have a lower field always with appropriate design, on places where weak parts should be protected. Another idea has to do with the location of stored electrostatic energy which should be dissipated mainly outside the column and far away from the column or other difficult items. The consequences are the introduction of discrete electrodes, the use of undivided insulators and great care in the design of the geometry of the construction.

3. Conductor problems

The illustration of these ideas is given in the case of the coaxial cylinder (fig. 2). This shows the situation of the terminal electrode in an electrostatic accelerator. The curve gives the field on the internal electrode versus its geometrical radius r, where the radius of the external electrode, the tank wall and the voltage are fixed. One observes a minimum for the curve at $r/R = 1/e = 1/2.72$. In a classical tandem one chooses this ratio as a good design. On both sides of the minimum one determines two regions with different electrical behaviour :

- the region of the right side (large radii) corresponds to a nearly homogeneous field and discharges with very low time constant
- the region of the left side corresponds to a diverging field and determines more stable situation and electrical phenomena close to the corona discharge.

The same law of behaviour of conductors can be shown for other geometries like the case of parallel conductors and appears to be a general law.

So one can use these properties for the design of conductors, in such a way that they would act either as spark gaps (right side) or to protect insulated parts (left side).

4. Discrete electrodes

The design consists of 7 sets of 7 electrodes at voltages linearly distributed. One can see how homogeneous is the field between the terminal electrode and the tank. Fig. 3 shows the potential and field versus the radius. On the lower drawing one can see the case $\theta = 0$, where one looks on a radius going through the electrodes and $\theta = \pi/8$ on a line equidistant from the two sets of electrodes. The field excursion is always low and the maximum stress magnification factor on the electrodes is of the order of 1.4.

Knowing that the electrostatic energy which is stored in the space between electrodes is proportional to the square of the field intensity, we see that the use of discrete electrodes brings a much more uniform distribution of the energy than in the previous situation. This is also the construction principle which gives for the same voltage smaller radial dimensions.

The principle of discrete electrodes has been applied on the MP Tandem of our laboratory. One set of electrodes at half potential brings the voltage from 15 to 18 MV which is now the usual working voltage.

5. Stored energy

One can calculate that the stored electrical energy in the 35 MV Vivitron is about 400 kJ (at a comparison a 13 MV classical Tandem stores 60 kJ). In the case of the Vivitron where the longitudinal field inside the column is 17 kV/cm as a mean, the stored energy in the column is only 1 part of 100 of whole energy. This is a very favorable situation. On the other hand, in case of a spark, very often induced by the column, the design of the discrete electrodes hinders its propagation. The machine is like a set of machines one in the other.

6. Column insulator

The mechanical strength problems led us to use epoxy glass fibre material for the column. We used these materials in large pieces in such a way to avoid using any metallic part, like dividing electrodes. These metal parts would focus electrical field lines. Avoiding this, one can have better electrical behaviour. In order to find out the suitable material but also to test the ideas developed here, we worked out several experiments using our 5.5 MV CN Van de Graaff machine. So we tested two different 1/1 scale model of a section of the Vivitron (working voltage 4.5 MeV), fig. 4. The CN terminal electrode is in the original location and will be brought up to 5.5 MV by classical belt charging system. The field inside the column is low as well as the stored energy. The insulating structure is in the location where the field is nearly homogeneous and not very different from the value on the central axis. The column electrodes are supported by insulators and connected to a resistor chain located near the axis. A part from these resistors there are no metallic parts inside the column. They are protected by cylindrical metallic sleeves. This design corresponds to the left side of the curve of fig. 2. On the contrary the gap between electrodes correponds to the right side of the curve.

The aim of the experiment was to show how the stored energy dissipates following the rules that we determined as a construction principle. This stored energy is mainly located outside the column and especially close to the terminal and column electrodes. We do not use discrete electrodes for this mounting. The materialities of the energy are the electrical charges on the external surfaces.

This experiment allowed us to make the final design. We built a second model corresponding exactly to the Vivitron. All these tests confirmed the good choice made.

7. Insulating plots

The gap between the column, discrete electrodes and tank wall has a mean field of 100 kV/cm. To hold the column and discrete electrodes, specially designed insulators were necessary. We used those designed by C. Cooke. In fig. 5 we see how these plots behave in a coaxial geometry. The field is lowered near the end and larger between. If one compares the field versus the radius we observe higher field values far from the insulator than in the vicinity. So this type of design is very suitable for a coaxial geometry, or a non uniform field geometry. The fig. 6 shows the equipotential lines in the Vivitron. The type of plots made of epoxy charged alumina has been extensively tested in our CN machine. We found that well mounted plots behave very well. We observed that with our geometry sparks do not give significant damage.

So it appears through all the calculations we made, through tests of the 1/1 model in very diverse situations that one can make a final design for the construction of the 35 MV Vivitron. Extensive model calculation also confirmed our choice.

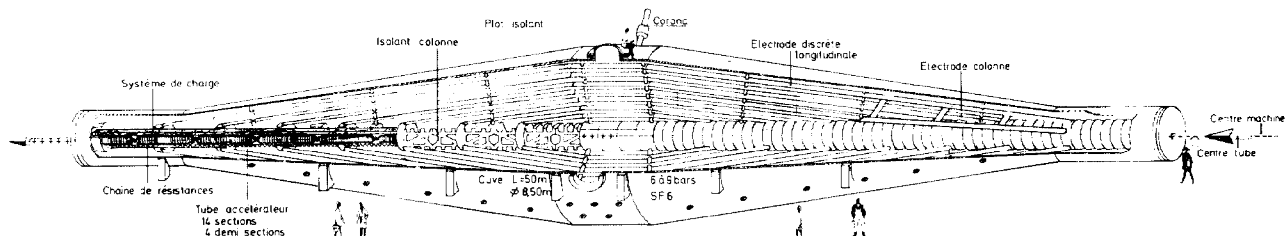


Figure 1

8. Performances of the Vivitron

Depending on the choice of stripper (gas, foil or a combinaison of two of them) the energy goes from 15 to 20 MeV/A for the lightest ions and to 5 MeV/ for the heaviest. The expected intensity reaches 10^{12} pps for light ions but only a few 10^{9} pps for the heavy ions. The beam properties are those usual with Tandem.

9. Present status (fig. 7)

The new accelerator is located near the MP building. The 51 m long tank is on place. Most of the parts necessary for the high voltage generator (column insulators, radial insulators, column electrodes, discrete electrodes, ...) are delivered. The construction will start now and we hope to be able to make the first electrical tests end of 1988. The accelerator tube comes later, as the injector, beam transport line, etc ... We hope to be ready for the beam in 1990.

10. References

1) Proc. 3rd Int. Conf. Electrostatic Accelerator Technology, Oak Ridge, 1981
2) 1983, Particle Accelerator Conf. Santa Fe
3) Rapport CRN-VIV-12, septembre 1983
4) Proc. 4th Int. Conf. Electrostatic Accelerator Technology, Buenos Aires, 1985

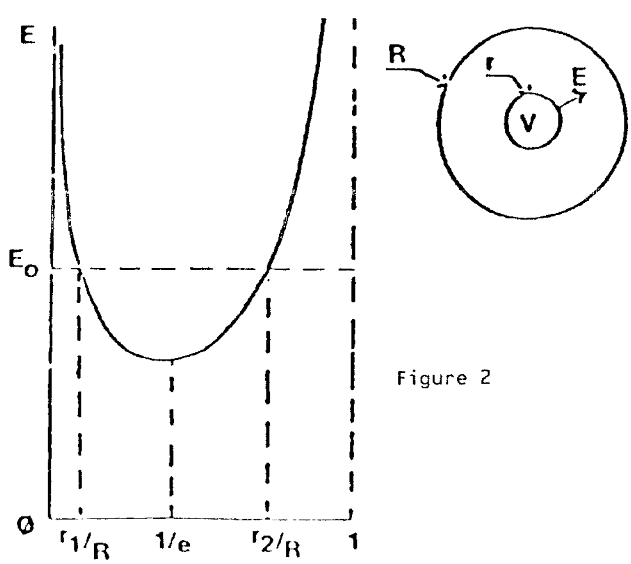


Figure 2

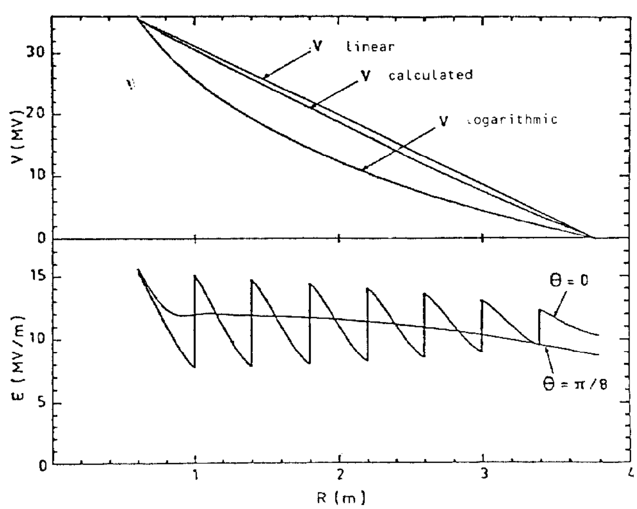


Figure 3

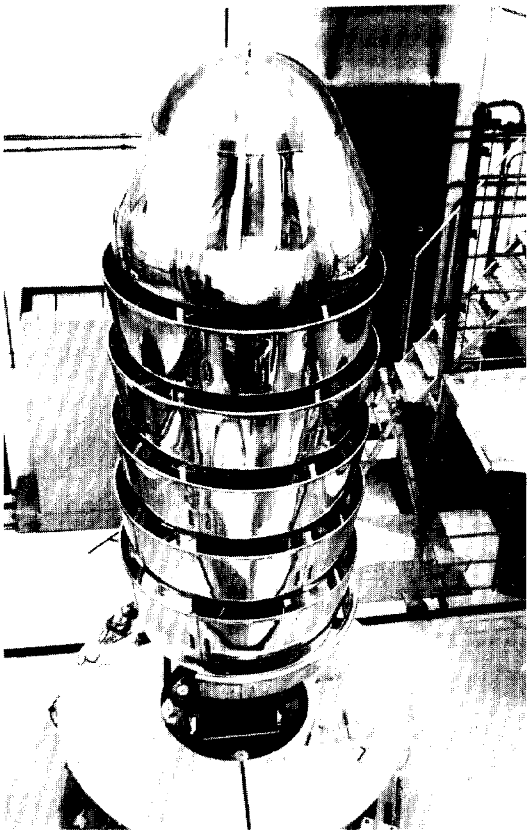
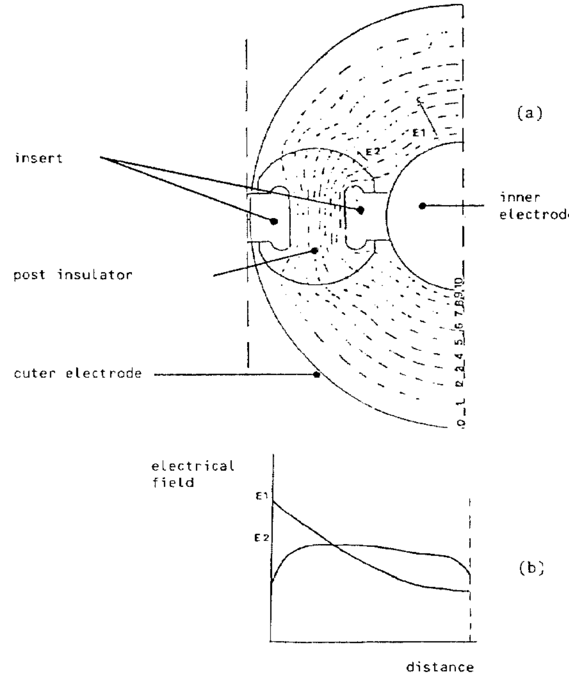


Figure 4



a) Equipotential lines around an insulating post
b) Field variation between inner and outer electrode
- far away from the insulator(E1)
- near the surface of the insulator(E2)

Figure 5

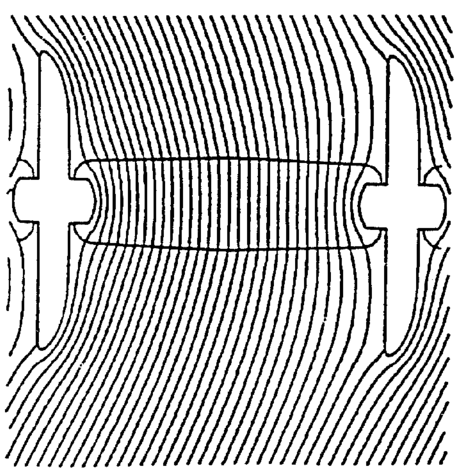


Figure 6

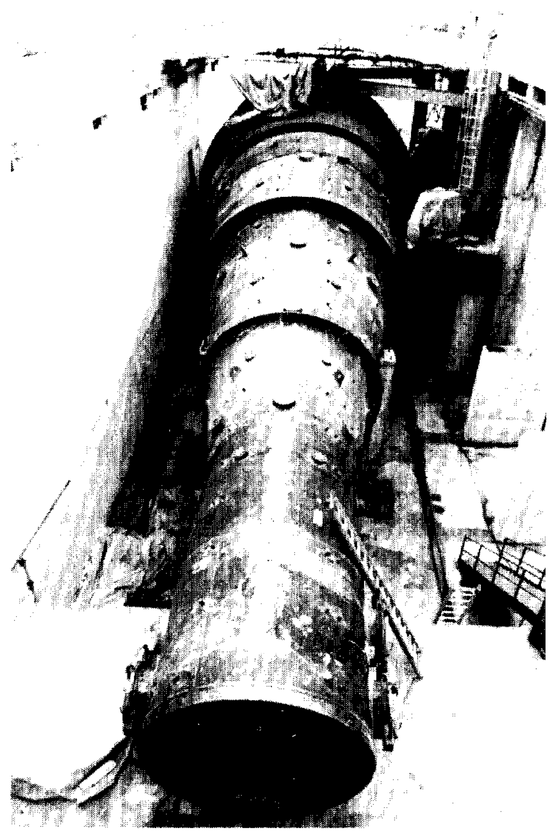


Figure 7