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A 35-MV TANDEM VAN DE GRAAFF - THE VIVITRON

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Summary

The Strasbourg project is a 35 MV Van de Graaff tandem whose design incorporates some new features and ideas. All the electrical characteristics are very conservative, specially for the accelerating tube which is a standard one, but the philosophy and some rules to build such an accelerator are new.

General description (fig. 1)

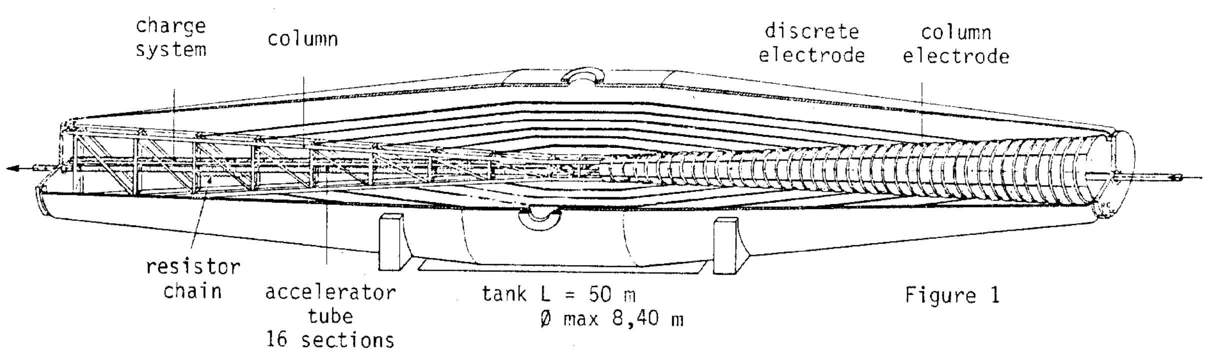

Figure 1

The tank is close to 50 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 8 tube sections 100" long, capable of 4.5 MV each. The column is assembled in an internal structure derived from two cantilevers of 8 sections, each attached to the basis. Each column section is made of beams in composite material, epoxy and glass fiber and not subdivided. An alternative possibility of structure is a suspended bridge thrown from one side to the other of the tank. Both solutions have been studied and are mechanically possible. Around this structure there are 36 column electrodes on each side. They act as a large spark gap. They are connected through a small spring with the tube resistor chain. The charging system is a small belt running, close to the tube, at a speed of roughly 8 m/s and with a high charge density.

Outside the column, in the space between it and the tank, there are discrete electrodes assembled in 7 porticos (named Vivitron porticos) and connected at the right place to the column at the dead sections.

Compared with the classical tandem, the technique of discrete electrodes allows two things :

- first to reduce the radial dimensions. In figure 2 we show a comparison between a classical design and the new one for the same 35 MV voltage and the same field of 12 MV/m at the terminal
- second to reduce the stored energy which is homogeneously distributed.

So the lower dimensions allow us to choose an horizontal machine.

The other important choice is the use of not subdivided insulators of composite material in place of the usual glass - metal insulators.

Principle of construction [1)]

a) Energy dissipation

The stored energy in such a machine is essentially located outside the column and in the event of a spark, the dissipation of this energy must follow some rules :

- it must take place first in SF_6 gas outside the column
- second, the inside of the column must be considered very sensitive to this energy and well protected for any electrical phenomena. So, the whole column is considered as one insulator to be protected and the column electrodes react as spark-gaps for the remaining energy not dissipated outside the column.

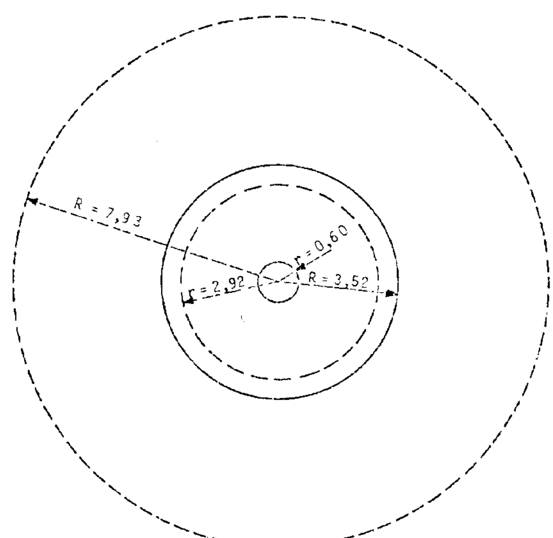

Figure 2

The dotted line corresponds to a classical design of a 35 MV electrostatic machine. The full line corresponds for the same voltage to the radial dimensions of the Vivitron. The field in the space between electrodes is nearly uniform (max field 12 MV/m).

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b) Conductors problems

These considerations bring us to the rules related to the conductors and insulators.

Usually the kind of electrical phenomena between conductors are defined by the Paschen law which gives a relation taking in account gas pressure and distances. Our design philosophy includes now a geometrical factor derived from the Laplace equation.

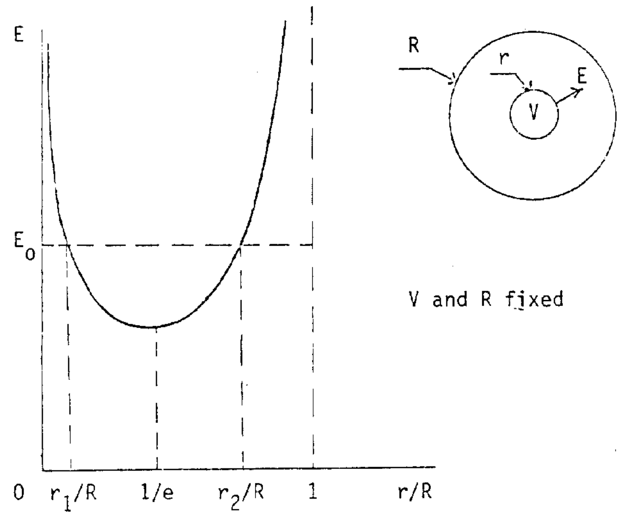

Figure 3

Figure 3 shows as an example the case of two electrodes in the coaxial geometry, which is the situation of the terminal electrode in the tandem accelerator. The curve gives the field on the internal elrctrode versus its geometrical radius r where the radius of the external electrode R and the voltage are fixed. The flat minimum determined two regions with different electrical behaviour :

- the region at the right side of the curve (large radii) corresponds to nearly homogeneous field and the discharge should have very low time constant
- the region at the left side corresponds to diverging field and determines electrical phenomena close to the corona discharge
- the minimum of the curve corresponds to the situation with the lowest field for a given voltage.

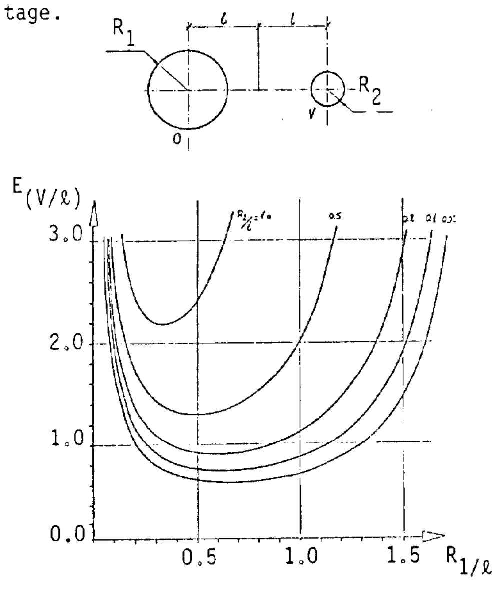

Figure 4

The same law of behaviour of conductors can be shown for other geometries like the case of parallel conductors (figure 4) and appears to be a general law. So one can use this properties for the design of conductors and to use them to protect insulators like in the column of the accelerator.

c) Discrete electrodes

We made the field calculation using 8 series of 7 discrete electrodes. Figure 5 shows how homogeneous is the field almost every where.

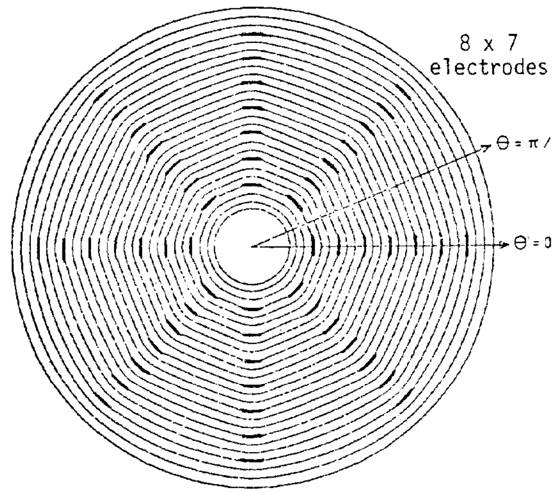

Figure 5

Figure 6 shows the potential and the field versus the radius. On the lower drawing one see the case $\theta=0$, where one look on a radius going through the electrodes and $\theta=\pi/8$ on a line equidistant of the two sets of electrodes. The field excursion is always low and the maximum stress magnification factor on the electrodes is of order of 1.4.

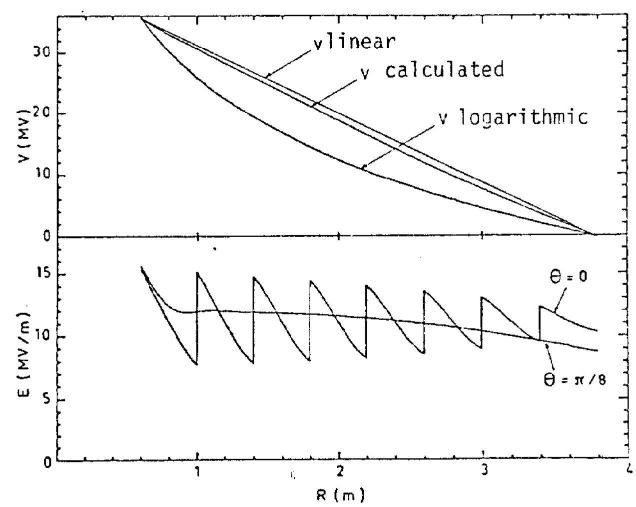

Figure 6

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 a same voltage smaller radial dimensions.

The principle of discrete electrodes has been applied on the MP tandem of our laboratory. One set of 8 electrodes at half potential allows to bring the voltage from 15 to 18 MV which is now the usual working voltage.

d) Column insulator

We use undivided fiber glass epoxy insulators. This material has very suitable mechanical properties and replaces with large advantage the usual glass insulators. We made high voltage tests on samples and it appears that the breakdown field is largely higher than necessary in the machine.

In view to test the properties of large insulators and to experiment on scale 1/1 the design philosophy of the protection, we worked out an experiment using our 5.5 MV CN Van de Graaff.

It consists in a test of a column section of the Vivitron. The CN terminal electrode is in the original location and will be brought up to 4.5 MeV by the classical belt charging system. A single mechanical construction is built with composite insulator rods. Figure 7 shows this design and also the column electrodes.

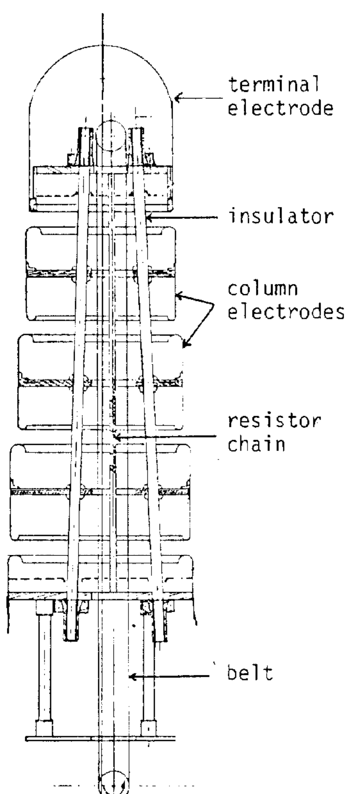

Figure 7

The field inside the column is low as well as the stored energy. The insulating supports are in the location where the field is nearly homogeneous and not very different of the value on the central axis. The column electrodes are supported by insulators and connected through one wire to a resistor chain located near the axis. Except this 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 figure 3. At the contrary the gap between electrodes corresponds to the right side of this curve.

Figure 8 shows the pattern of the equipotential lines.

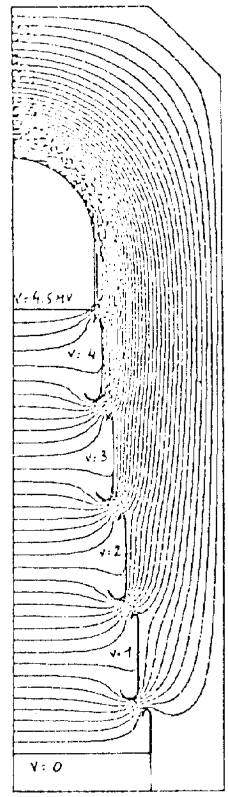

Figure 8

The aim of the experiment is 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 specially close to the terminal and column electrodes. We do not use discrete electrodes for this mounting. The materiality of the energy are the electrical charges on the external surfaces. When there is a spark,

- the stored energy must be dissipated in the gas
- the remaining charges will go along the column through the column electrodes acting as spark gaps
- inside the column and specially the resistor chain simulating the tube is protected against discharges.

This experiment is now in going on.

Performances of the Vivitron

Figure 9 shows the energy versus the ion mass obtained for different type of strippers, gas, foil or a combination of two of them. The intensity depends on the performance of the negative ion sources, the stripping yield and the foil life time. With light ions (masses of O to Ca) where the gas stripper is usual, the intensity can reach 10^{12} pps for 1 μA at the source. For heavier ions (Ca to I) with the use of carbon strippers one can reach 6 - 10 MeV/A and 10^{11} pps. The heaviest ions correspond to 5 - 8 MeV/A but only a few 10^{9} pps. The beam properties are those usual with tandem. DC beam with a good emittance, energy definition of about 10^{-4} etc. The change in energy can be performed in a few minutes as well as the change to an other ion species.

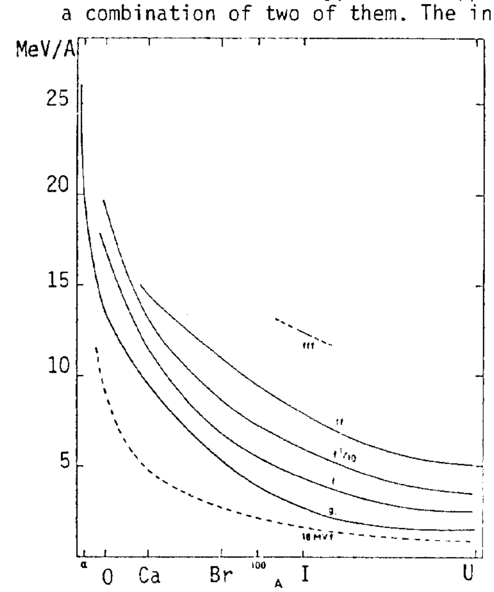

Figure 9

1)-Proc. 3rd Int. Conf. Electrostatic Accelerator Technology, Oak Ridge, April 1981
-CRN-VIV-4, July 1982