CALCULATION OF THE VACUUM SYSTEM OF THE MCC 30/15 CYCLOTRON

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Abstract

The concentration of molecules of residual gases has the big meaning in the process of acceleration the hydrogen's ions and deuterium's ions in cyclotron, as the intensive recharge of accelerated ions proceeds on these molecules. That is why the big attention was paid to the calculation of vacuum systems on the period of projecting the MCC-30/15 cyclotron. The MCC-30/15 cyclotron enabled to choose the optimal facilities of pumping speed and pumping location. The universal algorithm of calculation the vacuum systems has been developing in NIIEFA during the last few years. This algorithm is based on the method of electro- pneumatic analogies. It was adapted for identification the distribution of pressure the residual gases in vacuum chamber of multisector cyclotron. The algorithm was also realized in program application. The results of works with the developed program application are: the picture of sector's distribution of pressure the residual gases in median plane. On the ground of these results is easy to calculate the losses of accelerated beam on the whole of trajectory. The permissible level of the losses on the molecules of residual gases was accepted 7-10% from the beam's input current for the MCC-30/15 cyclotron. After the results was clarified that the pumping with the help of two vacuum pumps provides such level of losses. These pumps should have the speed of 4500 l/s (hydrogen). The pumps are located oppositely to each other and attached to the peripheral circular cannel of vacuum chamber.

A universal algorithm, based on the method of electropneumatic analogies, to be used for the calculation of vacuum systems of different types is being developed in the D.V. Efremov Institute (NIIEFA). When carrying out the computations of the vacuum system of the of the MCC-30/15 cyclotron, this algorithm was adapted to determine the distribution of the residual gas pressure in the vacuum chamber of a multi-sector cyclotron and was realized as an application program The result of using this developed application program is a pattern of the sector distribution of residual gas pressures in the median plane. Based on the pattern obtained, it is possible to calculate with a sufficient degree of accuracy the losses of an accelerated beam over its whole trajectory. For the MCC-30/15 cyclotron, a permissible level of losses by the residual gas molecules was taken to be 7-10 % from the beam input current. As a result of the computations carried out, it was found out that this level of losses allows the cyclotron to be pumped by two high-vacuum pumps with a pumping speed of 4500 l/s (hydrogen) attached to the peripheral ring channel of the vacuum chamber diametrically opposite to each other.

The concentration of molecules of residual gases is of major importance in the process of acceleration of hydrogen and deuterium ions in a cyclotron as these molecules are involved in intensive charge-exchange of the ions accelerated. Therefore when designing the MCC-30/15 cyclotron, much attention was given to the calculation of the vacuum system, which allowed optimal pumping means, their location and pumping capacities to be chosen.

For the last few years, a universal algorithm, based on the method of electropneumatic analogies, to be used for the calculation of vacuum systems of different types have been developed in the D.V. Efremov Institute. The use of this method allows a model of the vacuum system to be constructed, which characterizes flowing of residual gases in the molecular mode. When developing the electropneumatic model, all the main parameters important when calculating vacuum systems are taken into account:

- molecular weight of the gases inside the vacuum system and their temperature;
- configuration of the inner surfaces of the vacuum volumes of the vacuum system (the chamber to be evacuated, connecting pipelines, etc.);
- materials of the inner surfaces of the vacuum volumes and of the surfaces of the elements located inside the vacuum volumes;
- characteristics of high-vacuum pumping means (the pumping capacity and ultimate vacuum) and their location.

The model obtained as a result, a branched electric circuit, is further calculated by the node-voltage method.

The algorithm based on the electropneumatic model intended for the calculation of vacuum systems was successfully used in NIIEFA to calculate the distribution of partial pressures in the vacuum chambers of linear accelerators. Nowadays, this algorithm is also adapted to determine the distribution of residual gas pressures in the vacuum chamber of a multi-sector cyclotron. Several fundamental problems have been solved, which allows the modeling of 3-D vacuum chambers of complicated configurations to be started.

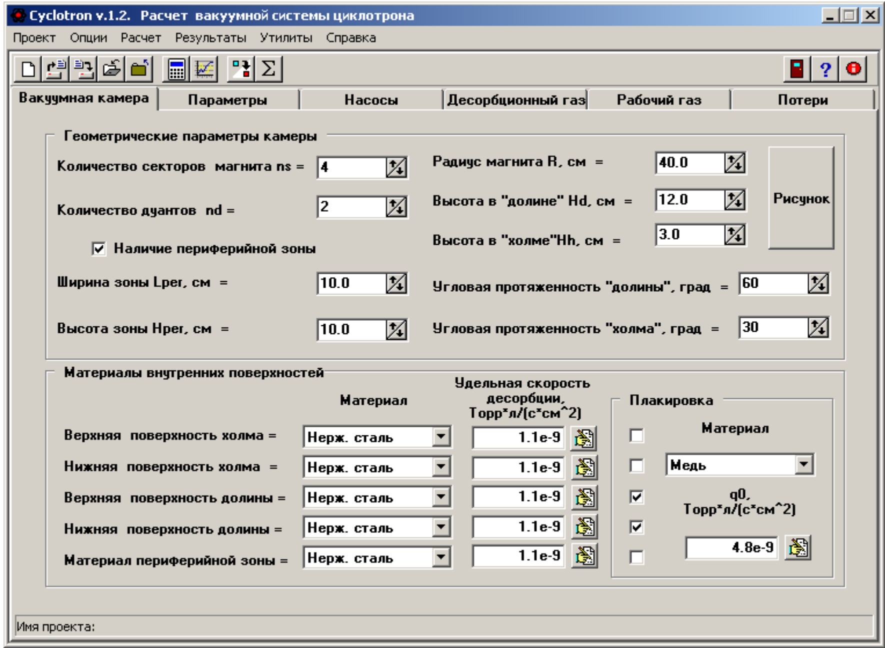

Figure 1: The interface of the program for the calculation of the vacuum system of a multi-sector cyclotron (a tab used to specify the main parameters characterizing the vacuum chamber).

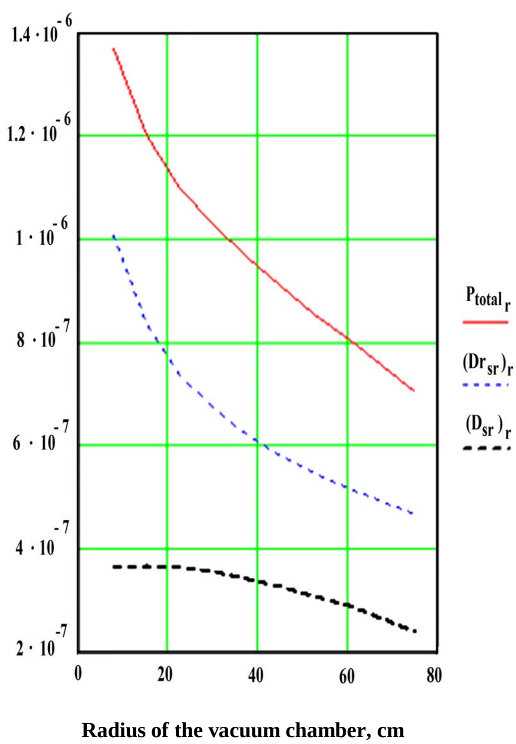

Figure 2: Averaged distributions of pressures in the vacuum chamber of the MCC-30/15 cyclotron (P_{total} is the gas mixture pressure; Dr_{sr} is the partial pressure of hydrogen and D_{sr} is the partial pressure of nitrogen).

The algorithm obtained has been realized in two versions: as a software module of the Mathcad software package and as a ready application program in the C^{++} language; figure 1 shows the main window of this application program.

A result of the application program developed is a pattern of the sector distribution of pressures of the main residual gases, air and hydrogen, in the median plane. Figure 2 shows averaged sector distributions of partial pressures of both aforementioned gases and the pressure of the mixture of these gases when two Coolstar 3500 cryogenic pumps with a pumping speed of 3500 l/s for nitrogen and 4500 l/s for hydrogen are used to evacuate the chamber after its long-term training. The pumps are located diametrically opposite to each other and attached to the peripheral ring channel of the vacuum chamber opposite the valleys not occupied with dees.

On the basis of the obtained pattern of the pressure distribution, one can calculate the beam losses of accelerated ions by residual gas molecules with a high degree of accuracy. Under given conditions, it is defined that losses by hydrogen molecules are about 1% of the beam input current and losses by nitrogen molecules are approximately 4.5 %. Nowadays, works are underway on the integration of the module for the calculation of beam losses into the application program developed.