# DESIGN OF ACCELERATION SYSTEM FOR $H^-$ ISOCHRONOUS CYCLOTRON AT GATCHINA[1]

**S. P. Dmitriev, G. F. Mikheev, G. A. Riabov, V. P. Fominenko**

## 1. Introduction

A design of an accelerating system (AS) of Gatchina Isochronous Cyclotron has some peculiarities connected with the fact that it accelerates only $H^-$ ions up to 80 MeV. First of all, AS has to operate at the fixed frequency. Secondly, AS has to provide the energy gain $\Delta W = 200$ KeV/turn to cut down the $H^-$ losses due to electric dissociation and the losses on the residual gas up to $\leq 5\%$, as well as to reduce the number of ion revolutions up to $\leq 400$ to avoid the losses of isochronism. The chosen magnetic field parameters, the magnet pole geometry and the design of vacuum chamber (VC) [1, 2] were used as input data for AS design.

## 2. Accelerating System Parameters

**2.1.** The two-dee system,operating on the second harmonik of ion revolution with frequency $f_0 = 41.2$ MHz was chosen.This system is compact and provides the energy gain under relatively small values of the RF losses and the dee voltage amplitude. The AS geometry is represented in Fig.1a. AS is formed of two 1/4-wave resonators exited in phase. The resonator dees are bridged in the center as shown in Fig.2.

The resonator geometry is chosen on the basis of the approximate analysis in which the RF losses are minimized. As a result of the analysis the dee angle is chosen $\alpha = 60°$ and the resonator parameters $l_s$ and $h/2$ are nearly equal.

The design of AS demands an accurate determination of the resonance frequency. An exact calculation for irregular shape of the resonator requires much more complicated and lengthy computations and usually in practice it is not done. Therefore approximate calculation [3] was used to determine the value $l_s$ (position of shorting plate) under designed value $f_0$. In the calculation the resonator is represented as a sequence of transmission lines having different characteristic impedances $Z_0$.The dee length $l_D$ is divided into $n$ short sections with

[1]The work is supported by Russian Foundation of Fundamental Researches, 93-02-167118

different $Z_{0i}$ and the section $l_s$ is represented by one transmission line with $Z_{0s}$. The voltage and current along resonator length and RF power losses were determined by application of the transmission line equations for each short section. A length of a section $l_s$ is determined from: $l_s = \lambda_0/2\pi \arctan X_n/Z_{0s}$, where $X_n$ — input impedance of nonuniform line $l_D$ at the end of short section $n$. The calculation errors are connected with complications of resonator cross-section and with discontinuous variation of the transverse dimensions.The calculated resonance frequency agrees within 6% with experimental data for the AS model.

AS parameters:

dee: aperture $a = 30$ mm, dee-ground liner gap $C = 33$ mm, dee radius $R = 1$ m, dee angle $\alpha = 60°$, accelerating gape $d = 20$ mm;

resonator box: height $h = 466$ mm, width $b = 1060$ mm, stem width $b' = 430$ mm, stem length $l_s = 210$ mm;

electric parameters: energy gain per turn $\Delta W = 200$ keV/turn, dee voltage amplitude $U = 61$ kV, dee voltage drop 12%, quality factor $Q = 3400$, dee RF losses $P_D = 2 \cdot 5.6$ kW, box RF losses $P_b = 2 \cdot 15.2$ kW, total resonator RF losses $P = 41.6$ kW.

**2.2.** AS is entirely located inside VC, and the access to AS can be obtained only after the upper part of a magnet together with the VC lid are lifted up. The upper and lower AS ground liners are formed by VC lids surfaces. The VC lids are welded of the bimetal plates (the stainless steel of 16 mm thickness, copper of 2 mm thickness). The use of bimetal makes enable to reduce the outgassing surface and RF losses. The side walls of the resonator are made of copper plates of 2 mm thickness. The upper and lower ground liners are separated by a gap ~5 mm and connected only on the shorting plate by clamping contact. The ground liners are water-cooled therefore the VC lids have cooling cannels. The side walls and shorting plate are cooled with the use of the water-pipes soldered to them. The dees are also welded of bimetal plates (the stainless steel of 1.5 mm thickness, copper of 1.5 mm thickness). The dee stem is fastened to the shorting plate. The dee fastening has a positioning device. After the dee positioning they are bridged with a removable rigid shorting jumper having different configuration dependig on the internal or external ion source being used. A frequency tuning device such as a tuning capacitor with $\Delta f/f_0 = 2\%$, a fine trimmer $\Delta f/f_0 = 0.3\%$ are attached to the shorting plate as well as RF probes and an RF power input.

## 3. Models of Accelerating System

Measurements of the AS models need the exact determination of the stem length $l_s$ so that the difference between the AS frequency and the designed value $f_0$ would not be more then 0.5%. The voltage drop along dee and the tuning bands for $f_0$ was measured on the model, too. The models were made of two-side copper-clad plastic, usually used for printed-circuit boards. One side of the covering was used as current conductive surface of AS, and the other one was used for soldering the stiffening plates. This made possible to manufacture large surfaces of plastic plates of 2 mm thickness. The models were made knock-down. The knock-down design of the model enables to do easily the modifications of the AS geometry and to investigate alternative versions of AS.

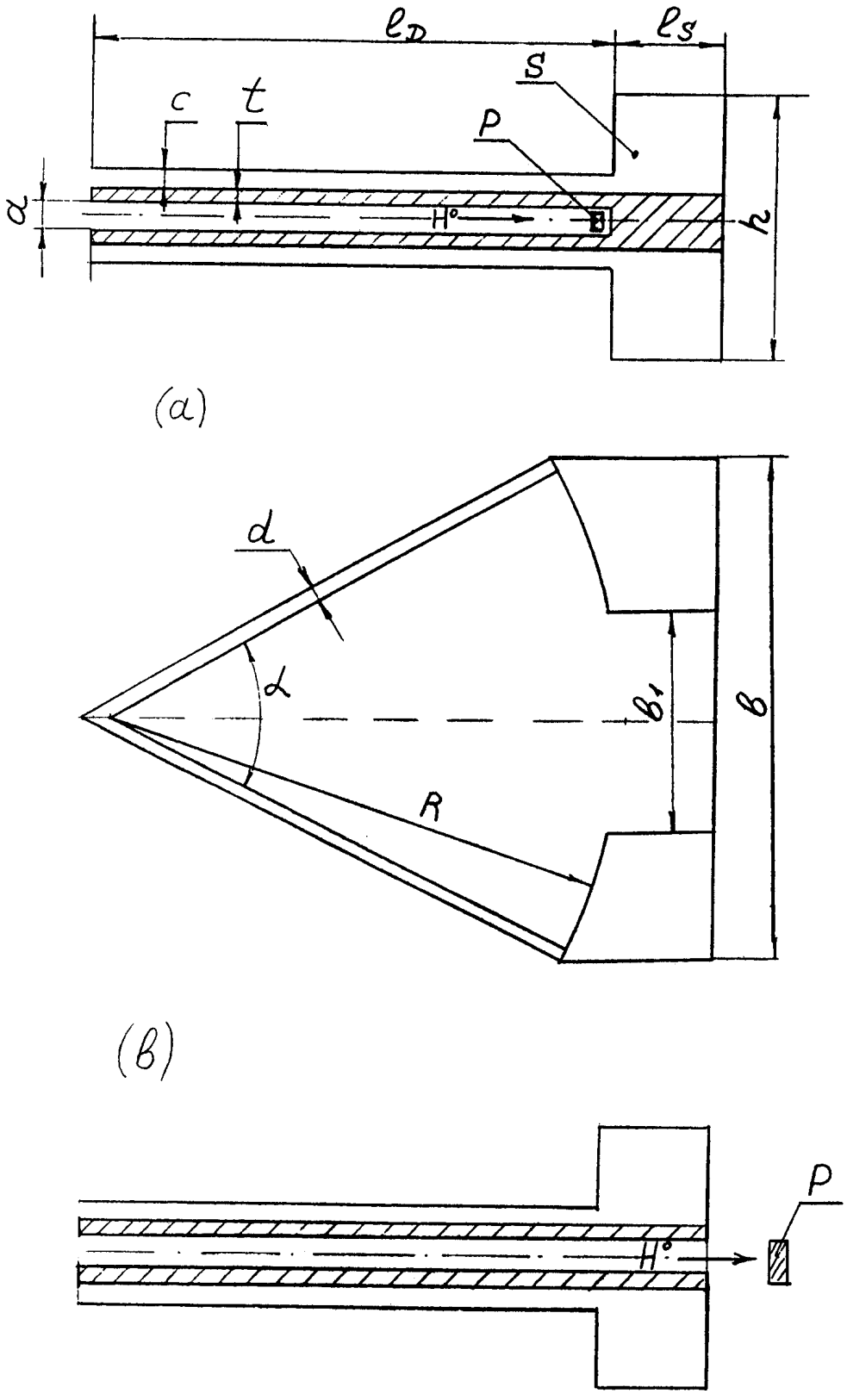


**Fig.1.** Accelerating system geometry

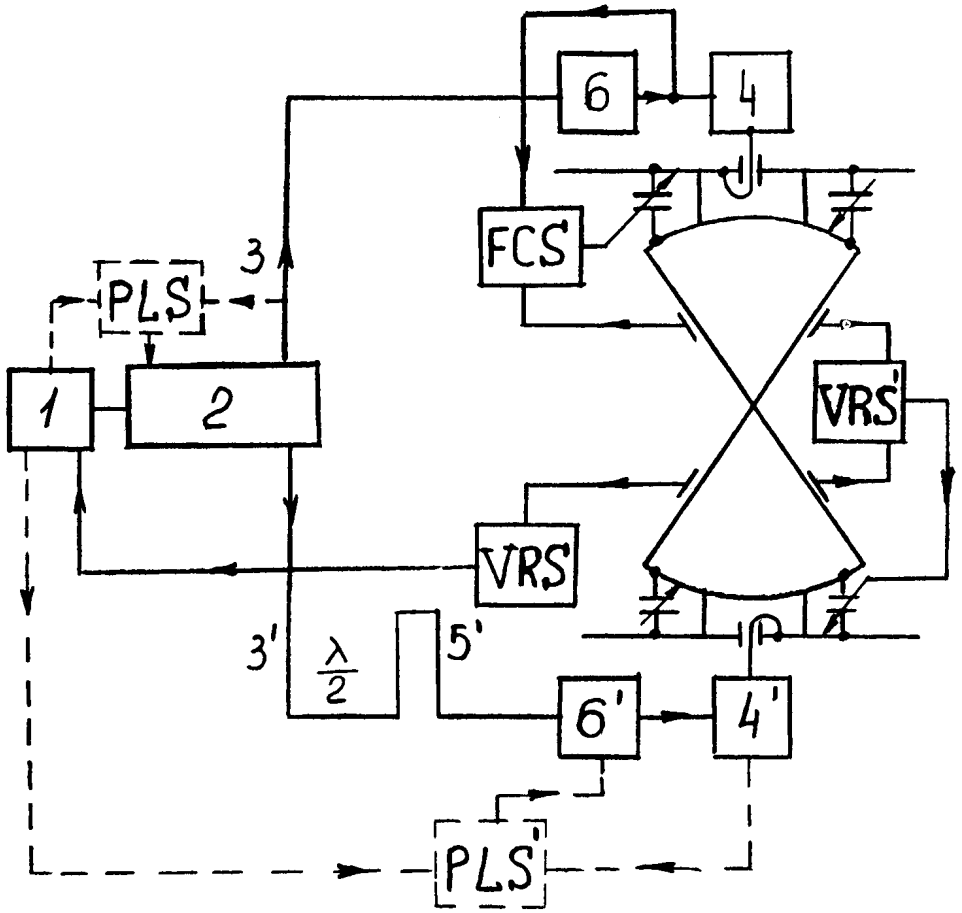


**Fig.2.** RF system block-diagram

## 4. Block-diagram of RF System

Block-diagram of RF power system and the automatic regulation system are shown in Fig.2. An oscillator (1) tuned on the frequency $f_0 = 41.2$ MHz ($\Delta f/f = 10^{-6}$) exits a 10 kW driver amplifier (2). The push-pull output of the driver amplifier is connected with two final amplifiers each of 40 kW (4,4') by means of two transmission lines (3,3'). 180 deg.out of phase is compensated by using an additional half-wave section (5) for one of the transmission lines. Blocks (6,6')-are coupling matching transformers. Each final amplifier is inductively coupled to the dee resonator by means of the coupling loop and the resonant 1/4-wave coaxial line. The final amplifiers are powered by series-regulated 10 kV, 160 kW anode power supply. This supply provides a dee voltage regulation as well as fast crowbar protection. The automatic regulation system consists of dee voltage (VRS,VRS'), frequency (FCS) and phase (PLS,PLS') regulations [4].

## 5. Radiation Problems and Shielding

Disadvantage of the negative ion cyclotron is stripping the $H^-$ ion in the acceleration process and a neutral beam formation. Resulting neutral hydrogen atoms follow straight trajectories, stopping at the first surface they encounter. Graphit or aluminium neutral beam buffles are placed in the vacuum chamber to shield the device components installed on the median plane. If it is necessary to work in the chamber this buffles may be quickly removed. The

arc-shaped aluminium buffle $P$, length 1 m is plased inside the dee as shown in Fig.1a. To avoid the radiation problem the alternative AS design can be proposed [5]. In this design the upper and lower parts of the resonator are separated with the ample clearance on the median plane to allow for the passage of neutral beam as shown in Fig.1b. The additional advantage of this type of AS design is possibility to avoid the clamping contact between upper and bottom resonator parts. However in our case the realization of such AS system is difficult because it requires considerable changes of AS and VC designs.

## 6. Present Status

The design and the drawings have been acomplished. The manufacturing the bimetal plates for dee and the vacuum chamber lids is started. The driver amplifier on 10 kW has been accomplished and manufacturing the final amplifiers is started. The progress in the project realization is restrained by deficient finansing.

REFERENCES


1. *Abrosimov N.K. et al.* XIII International Conference on Cyclotrons and their applications. Vancouer, Canada, 6–10 July 1992. P.58.
2. *Abrosimov N.K. et al.* XIII Conference on the Charged Particles Acceleratos. Dubna, 13–15 October, 1992. P.155.
3. *Van Genderen W. et al.* // NIM, 1987. P.161.
4. *Vorogushin M.F. et al.* Radio engineering systems cyclotrons. Energoisdat, 1989.
5. *Dmitriev S.P. et al.* Resonance system of cyclotron, author's sertificate №1793568.