PROJECTS OF AN ELECTRON COOLING SYSTEMS AT AN ENERGY OF ELECTRONS OF 35 AND 300 KEV FOR IMP (LANZHOU, CHINA)

B.N.Sukhina, E.I.Antokhin, V.N.Bocharov, A.V.Bubley, S.N.Chumakov, A.D. Goncharov, B.I. Grishanov, A.N. Kerginsky, V.V. Kolmogorov, E.S. Konstantinov, S.G. Konstantinov, G.S. Krainov, A.M. Kudryavtsev, N.K. Kuksanov, G.F. Kuznetcov, S.A. Labutsky, P.V. Logatchov, A.S. Medvedko, D.G. Myakishev, P.I. Nemytov, V.M. Panasyuk, V.V. Parkhomchuk, D.V. Pestrikov, S.P. Petrov, V.B. Reva, R.A. Salimov, B.A. Skarbo, A.N. Smirnov, B.M. Smirnov, V.S.Tupikov, M.E.Veis, BINP, Novosibirsk, Russia

Abstract

The projects of an electron cooling systems at an energy of electrons of 35 and 300 keV are presented. Based on BINP technologies these self-contained electron cooling systems includes both a gun and a collector with a magnetic system and a relevant power supply with high voltage terminals.

1 INTRODUCTION

Installations under consideration in the present paper designed for the CSR Project (Institute of Modern Physics, IMP, China) are the outgrowth of ideas already realised in the project of the cooler for SIS (Darmstadt, Germany) [1] which was designed and manufactured at BINP, Novosibirsk. The central part of the magnetic system (the long solenoid of the cooling section) is planned to be made of separate sections, as well as for SIS cooler. But in this project, the possibility to correct the position of each section for attaining required parameters not only for the specified magnetic field is envisaged. The special system of mechanical alignment of sections was designed, that enables one to align each section with respect to all three spatial coordinates.

The second distinctive feature of these installations is the use of electrostatic bends in the toroidal sections. The stable operation of an electron cooler requires the reliable cleaning of an electron beam from the secondary ions and electrons. To this end, electrostatic electrodes with a transverse field are installed on the electron beam trajectory for the clearing of ions and slow electrons of ionisation from the beam. In toroidal sections, installing of electrostatic plates with a field which provides simultaneously the bending and cleaning will improve the operation of the facility at large electron currents of up to 3 A. Near the ion beam, bending is provided by only transverse magnetic field but in the region of electrostatic plates, bending is provided by the combination of the electric and magnetic fields. Such a solution enables the compensation for the kick of an electric field to an electron beam by introducing the magnetic field. This decision allows to control the electron beam reflected from the collector and it gives the hope for the substantial reduction of the recuperation voltage required for the electron collector.

2 GENERAL DESCRIPTION

2.1 Main parameters of installations

The main parameters of installations EX-35 and EX-300 at an electron energy of 35 and 300 kV, respectively, are presented in Table 1.

Table 1: Main parameters

Paremeters	EX-35	EX-300
Operation energy of:		
Ions, [MeV/u]	10-50	25-500
Electrons, [keV]	4-35	10-300
Electron gun perveance, [$\mu A/V^{3/2}$]	2.5	2.5
Ion beam momentum spread	$\pm 1.5\cdot 10^{-3}$	$\pm 5\cdot 10^{-3}$
Ion beam emittance, ε_x, ε_y [$\pi\cdot$mm$\cdot$mrad]	150, 20	30, 30
Electron beam current, [A]	3	3
Electron beam radius at cooling section, [cm]	2.5	2.5
Cathode radius, [cm]	1.25	1.25
Magnetic field at cooling section, [kG]	0.6-1.5	0.6-1.5
Length of cooling solenoid, [m]	4.0	4.0
Parallelity of the cooling solenoid field	$\leq 10^{-4}$	$\leq 10^{-4}$
Electron loss rate	$\leq 3\cdot 10^{-4}$	$\leq 3\cdot 10^{-4}$
Basic vacuum pressure, [torr]	$2\cdot 10^{-11}$	$2\cdot 10^{-11}$

2.2 Layout of EX-35 and EX-300

General view of electron cooling devices is shown in Fig. 1 and Fig. 2. The general arrangement of the electron coolers EX-35 and EX-300 is similar with the difference determined by the high voltage unit because of different requirements to electron beam energies: 35 keV and 300 keV, respectively.

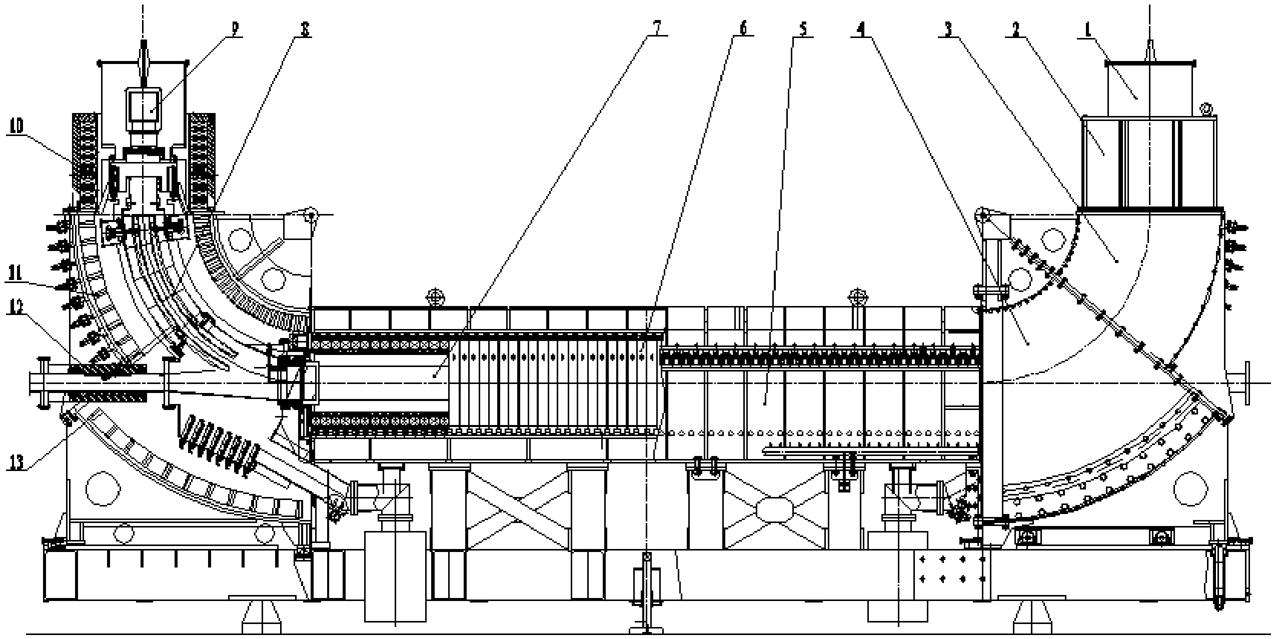

Figure 1: General arrangement of the EX-35 electron cooling device at an electron energy of 35 keV. 1-electron gun, 2-gun solenoids, 3-toroid 40^o, 4-toroid 50^o, 5-main solenoid, 6-main solenoid coil, 7-vacuum chamber, 8-electrostatic deflector, 9- collector, 10-collector solenoids, 11-toroid 40^o coil, 12- correcting magnet, 13-toroid 50^o coil.

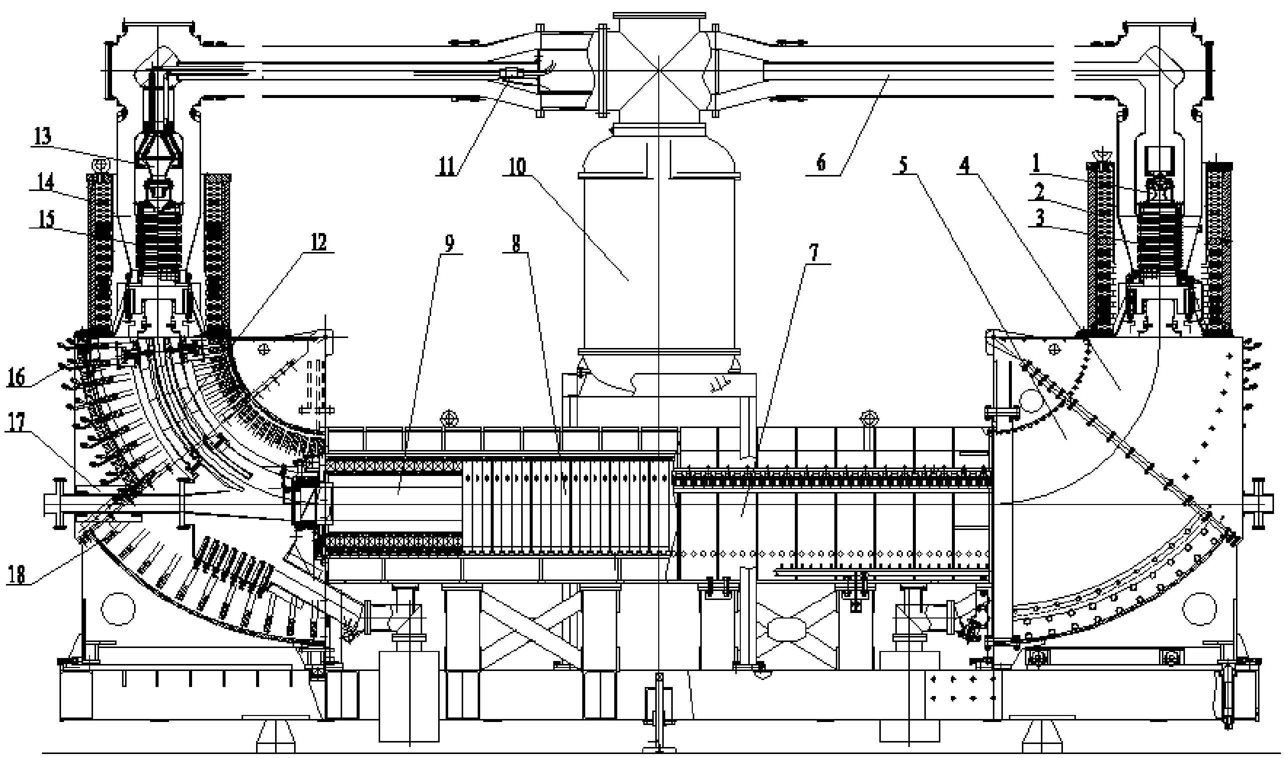

Figure 2: General arrangement of the EX-300 electron cooling device at an electron energy of 300 keV. 1-electron gun, 2-gun solenoids, 3- accelerating tube, 4-toroid 40^o, 5- toroid 50^o, 6- SF_6 high voltage feeder, 7-main solenoid, 8-main solenoid coil, 9-vacuum chamber, 10-300 kV rectifier, 11-collector cooling system, 12-electrostatic deflector, 13-collector, 14-collector solenoids, 15- decelerating tube, 16- toroid 40^o coil, 17- correcting magnet, 18- toroid 50^o coil.

Electron coolers consist of the following main components:

1. Magnetic system that forms and transports an electron beam from the electron gun to the collector of electrons.
2. Electron gun and collector of electrons.
3. Vacuum chamber with a pumping system.
4. Power supply system.
5. Cooling system.

Since the requirements to the basic technical parameters and geometric sizes of the cooling sections of facilities EX-35 and EX-300 are the same, these parts of the devices including the main solenoid of the cooling section, vacuum chamber with a pump system, toroidal bends with an electrostatic deflection system, as well as the supports are made of the identical units thereby reducing substantially the time of development and the production cost of the devices.

2.3 The electron gun and collector

The gun voltage range is 4-35 kV for EX-35. The gun is mounted on the insulator with standing voltages up to 35 kV. The first power supply changes the difference of potentials between the cathode and anode ranging from 4 to 11.3 kV. In this case, the electron emission current from the cathode will be varied from 0.632 A up to 3 A. With the help of the second power supply the energy of the electron beam can be increased up to 35 kV.

For the EX-300 electron gun it is necessary to make the postaccelerating section of up to 300 kV. For the EX-300 electron gun at the minimum voltage of 10 kV the current value will be 2.5 A and for the voltage of 11.3 kV, the maximum current of 3 A will be achieved. Then with this current, the electron beam is accelerated up to 300 keV.

With the help of a 2 kV power supply connected between the cathode and gun control electrode one can produce the negative electric field at the cathode edge thereby suppressing the emission of electrons at this place.

The following Fig. 3 shows the behaviour of the magnetic field, axial distribution of electrical field and the beam profile in the cathode region obtained with the SUPERSAM program. The voltage on the control electrode corresponds to –2.5 kV, magnetic field on the cathode 5 kG. The emission radius reduces by a factor of ~1.5.

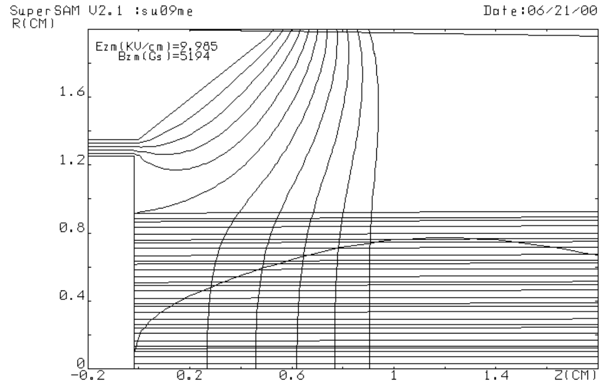

Figure 3: Decreasing of the emitting diameter at -2.5 kV voltage at the control electrode.

The collector should be able to dissipate an average power of up to 15 kW at 5 kV, and should have a relative current losses less than $3\cdot10^{-4}$ at 3 A. Collector manufactured as an axially symmetric solid copper element, 18 cm in diameter and 17 cm long, and has cooling channels in its body. To reduce admissible level of additional leaks of current through the collector cooling system it was decided to use transformer oil as cooling liquid. Transformer oil is circulated in a self-contained system for a forced cooling through the channels, pipe ducts and a radiator. The flowing water from a common cooling system cools the radiator surface at a ground potential. The maximum temperature of the collector vacuum surface is 135 ^{o}C.

REFERENCES

[1] M. Steck et. al., Comissioning of the electron cooling device in the ion synchrotron SIS, EPAC'98, Stockholm, June 1998.

[2] B.N. Sukhina et. al., Conceptual project of an electron cooling system at energy of electrons of 350 keV, NIM A 441 (2000) pp. 87-91.