COMPARISON OF THE QUALITY OF TWO ECRIS VACUUM STANDS*

J.Pivarč†, K.D.Tumanov, V.B.Kutner, A.I.Ivanenko, J.Pivarč, jun.‡
Joint Institute for Nuclear Research, Flerov Laboratory of Nuclear Reactions
141980 Dubna, Moscow region, Russia

Abstract

The DECRIS (Dubna Electron Cyclotron Resonance Ion Source) and ECR-4M (GANIL ECRIS) high vacuum systems are described and compared. The test results of the vacuum systems are presented with respect to desorption and leakage characteristics. Also illustrated are the construction of two stands.

1 INTRODUCTION

The vacuum system (VS) of the ECR ion source is one of the main components of every source. Whereas the operating pressure ranges for the vacuum systems of accelerators are 10^{-4} - 10^{-9} Pa [1] the required operating pressure range for the vacuum system of the ECR ion source is 10^{-2} - 10^{-5} Pa, respectively. Basically, it consists of stainless steel or cooper beam tubes pumped with turbomolecular, cryopumps combined with rotary pumps and adsorption traps. A combination of turbomolecular and rotary pumps was used in the first DECRIS - 14 ion source. Another combination is being used for the ECR-4M ion source. It is mainly based on a combination of turbomolecular, cryopumps and rotary pumps.

In this paper there are presented two ECR ion source vacuum stands. Given are the constructions of the stands as well as measured residual gas analyser spectra and desorption rates and leakages.

2 DESCRIPTION OF THE STANDS

About 40 ECR ion sources stands have been built in different countries. Their performances are steadily improved over the last decade.

2.1 DECRIS-14 ion source vacuum stand

One main and two auxiliary pumping units are used providing clean, safe pumping with the pressure monitoring of the DECRIS-14 ion source vacuum stand. It is designed in order to produce an average dynamic pressure of 10^{-4} Pa. Basically, it consists of 7 cm dia stainless steel, 4 cm dia copper, 10 cm dia steel and 4 cm dia duralumin beam tubes pumped by a combination of 500 l s^{-1} turbomolecular pumps (VMN - 500) [2] and a rotary pump (BL-90) [3]. The pumping units are spaced at about 1.5 m intervals and contain besides the pumps, high vacuum gauges, electrodes and various beam diagnostic elements. The total length of the high vacuum beam tubes is about 3 m. The high vacuum volume of the stand is about 38 l.

After 20 h of pumping the leak rate of the DECRIS-14 vacuum system is bellow 5 x 10^{-3} Pa l s^{-1}. The results of the desorption rate and leakage measurements are shown in Figure 1. The best vacuum conditions are obtained after a 200 h pumping.

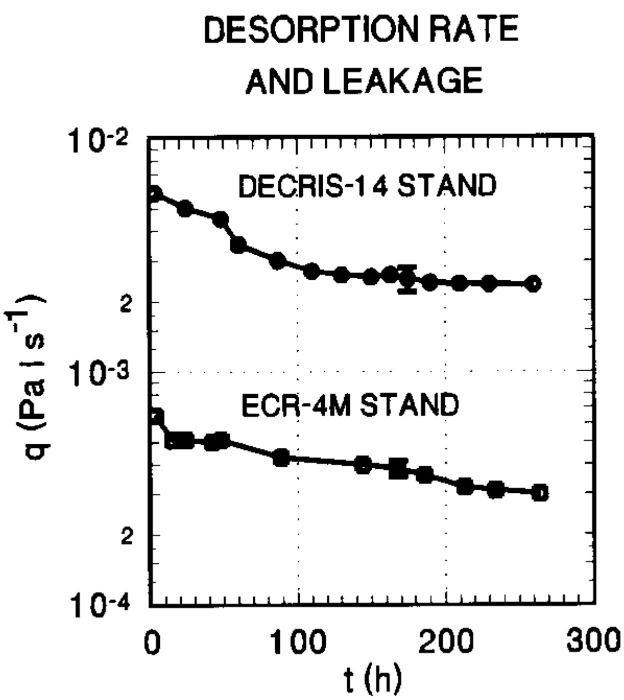

Figure 1: Measured desorption rates and leakages q of the DECRIS-14 and the ECR-4M vacuum stands as a function of pumping time 't'.

Figure 2 shows the mass spectrum of the residual gases which are evolved from the DECRIS-14 VS. A mass spectrometer MX 7304 gauge [4] was placed in the region of cube C_2. The spectrum is taken at a pressure of 1.75 x 10^{-5} Pa. By spectrum analysis one can see the subsequent contamination by hydrocarbons and other organics. The peak sets of 27,29; 39,41,43; 55,57; 69; 79; 89; 109; 119; 149 from the Rubber 7889 are shown. However, some of these hydrocarbons are also observed in the spectrum of the rotary pump oil and other elastomer seals such as 'O' ring seal VITON Roumania (peak sets: 27,29; 39,41,43; 55; 149). The spectrum illustrates the expressive water vapour contamination. All these effects could be, however, reduced by using two or more adsorption traps in sequential operation above the rotary pumps.

* Work supported by the VEGA L3 Ltd. firm, Nezábudková 20, SK-821 01 Bratislava, Slovak Republic.

† Permanent address: Institute of Physics, Slovak Academy of Sciences, Dúbravská cesta 9, SK-842 28 Bratislava, Slovak Republic.

‡ Working-place address: Martin-Luther-University, Dept. of Physics, NMR Group, Friedemann-Bach-Platz 6, D-06108 Halle/Saale, Germany.

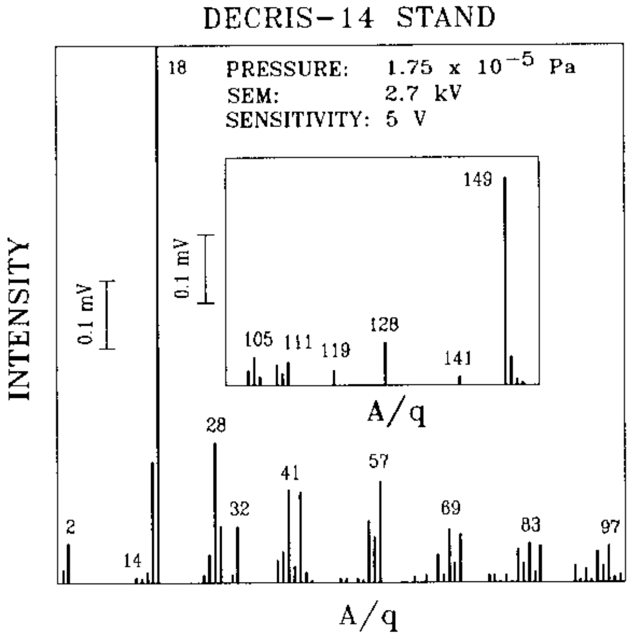

Figure 2: Measured mass spectrum of the residual gases from the DECRIS-14 vacuum stand.

2.2 ECR-4M ion source vacuum stand

The ECR-4M stand is designed to pump not only the vacuum chamber of the ECR-4M ion source but also to pump the U-400 cyclotron axial injection system with a beam analyzing magnet, diagnostic elements and vacuum gauges. It is based on double stage rotary and turbomolecular pumps but also cryopumps and an ion getter pump are used. The total pumping speed of the VS is about 7000 l s^{-1}, which allows one to produce a working pressure of about 10^{-4} Pa and 10^{-5} Pa in the region of the first stage of the ECR-4M ion source and in the region of the beam transport lines, respectively.

The VS consists of three sections:

1. The injection line section of the gases and vapours of the solid state samples (≈ 5 l).
2. The ECR-4M ion source and extraction beam line section (≈ 30 l).
3. The transport lines, beam analyzing and bending section (≈ 45 l).

All three sections are designed similarly from the point of view of vacuum technology. The first one is evacuated by Balzers TMH-064 (30 l s^{-1}) turbomolecular and double stage DUO-1.5 (0.5 l s^{-1}) forvacuum pumps.

The second one is pumped by Balzers TPH-520M (500 l s^{-1}), TMH-064 turbomolecular pumps, double stage DUO-008 (2.5 l s^{-1}) and DUO-1.5 rotary pumps, a CTI-Cryogenics CRYO-Torr 8 cryopump (1500 l s^{-1}), an Omsk NVK-3.2 (2400 l s^{-1}) cryopump and a Vacuum Prague IPT-200 (200 l s^{-1}) ion getter pump, respectively. The TPH-064 turbomolecular pump is connected to the ECR-4M high frequency input. The TPH-520M turbomolecular and CRYO-Torr 8 pumps are pumping the extraction region of the ECR-4M ion source. The NVK-3.2 cryopump and IPT-200 ion getter pump are connected to the first beam diagnostic block.

The third section is pumped by Balzers TMH-520 (500 l s^{-1}) turbomolecular and DUO-008 rotary pumps, Omsk NVK-1.5 (1200 l s^{-1}) and NVK-3.2 cryopumps, respectively. The beam transport line consists of two beam tubes of 6 cm inner diameter, three diagnostic blocks, a 102^{o} analyzing magnet and a 90^{o} bending magnet deflecting the beam from the horizontal to vertical direction, i.e. to the center part of the U-400 cyclotron.

In order to evacuate the beam lines and the cryopumps to forvacuum as well as to pump the cryopumps during regeneration a Balzers DUO-016 (5 l s^{-1}) rotary pump is used. Three stages are used in order to produce suitable operation vacuum in the beam lines and the other parts of the VS. At the beginning the system is pumped to a pressure of 1 Pa and then the turbomolecular pumps are switched on. During pumping (3 h) by the turbomolecular pumps, the cryopumps are parallelly regenerated and then the cryopumps are also switched on. At the end the VS is pumped only by the cryopumps and the TMH-064 turbopumps. In this case it is possible to attain pressures of about 10^{-5} Pa and 10^{-6} Pa after a 5 h pumping and after a 30 h pumping, respectively. At the same time a pressure of about 10^{-5} Pa was produced in the first section.

This VS mainly consists of nonmagnetic stainless steel vacuum chambers, ion beam tubes and vacuum volume channel connections. VITON 'O'-rings are used as a sealing material for the main parts of the VS but OFHC cooper gasket rings are also used in the first section. The total volume of the VS is approximately 80 l. The mass spectra of the residual gases which were evolved from the surfaces of the VS are shown in Figures 3 - 4. A mass spectrometer MX 7304 was again used [4]. The spectra were taken at pressures of (2.8 - 4.5) x 10^{-5} Pa. By spectrum analysis one can see no contamination by hydrocarbons and other organics from the rotary pump oil. However, the spectrum illustrates the expressive water vapour contamination.

The results of the desorption rate and leakage measurements for the ECR-4M stand are shown in Figure 1. The best vacuum conditions are obtained after a 200 h pumping.

The vacuum monitoring is provided from 0.1 MPa to 10^{-6} Pa by using a combination of Pirani and Penning gauges. A Balzers Total Pressure Controller TPG-300 (3 pc) and TPR 010 Pirani (8 pc), IKR 020 coaxial Penning cold cathode gauge heads (4 pc) are used.

Because of the permanent working of the VS imergency interlockings have been installed. It causes to close immediately all the electropneumaticall gate valves at a pressure of 5 x 10^{-2} Pa. At the same pressure the gate valve which separates section three from section two will also be closed. The VS is safequard yet from the side of the U-400 high VS by means of another interlock. The gate valve separating the U-400 beam line tube is interlocked by the U-400 high VS.

The service regime of the VS is secured by the IPT 200 ion getter pump. In this case pressures are about 10^{-4} Pa

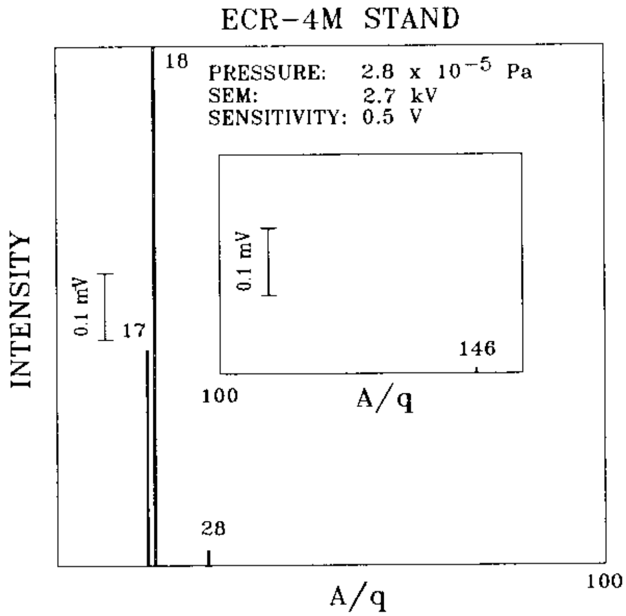

Figure 3: Measured mass spectrum of the residual gases from the ECR-4M vacuum stand.

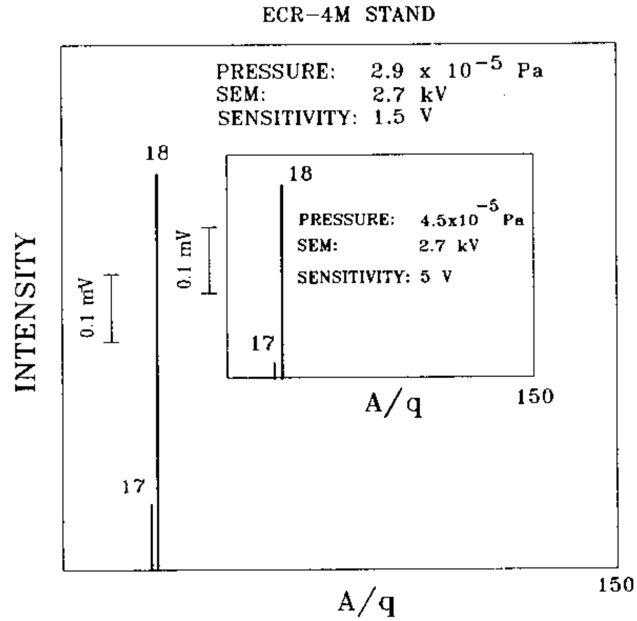

Figure 4: Other measured mass spectrum of the residual gases from the ECR-4M vacuum stand.

and 10^{-3} Pa in the extraction region of the ECR-4M ion source and in the first section, respectively.

The VS is also controled remotely from the control desk of the U-400 cyclotron. The system permits total and partial pressure readings and full operation of all the electropneumaticall valves. The valves and pumps are operated and controled from the own autonomous control desk placed at about 15 m from the 90^{o} bending magnet.

3 COMPARISON OF THE STANDS

The minimum desorption rates and least pressures producable in testing experiments of the DECRIS-14 and ECR-4M vacuum stands are shown in Table 1. It is seen that the ECR-4M vacuum stand is better than the DECRIS-14 one by a factor of 10. It follows not only from the quality of the materials used in the construction of the VS but also from the cleanliness of the pumping units. It is known that a VITON 'O' ring is better than a RUBBER 7889 ring by a factor of 15 and RAMSAY fet is worse than APIEZON 'L' grease by a factor of 100. The worst materials are PERBUNAN - N, TEXTIT, TEFLON and RUBBER 7889 (TU MCHP 7889) and the worst grease is RAMSAY fet.

In addition to the spectra expressive water vapor contamination is observed in both VS.

4 CONCLUSIONS

The present work provides new data on the desorption rates and the mass spectra of the residual gases for the ECR-4M ion source stand which is now used as the axial injection vacuum system of the U-400 cyclotron. Taken together, all these data show that it may be impossible to obtain the suitable operation vacuum (10^{-5} Pa) and the necessary cleanliness of the VS if the vacuum exposed surfaces have higher desorption rates than 10^{-3} Pa l s^{-1}.

Table 1: Minimum desorption rates and least pressures producable in testing experiments of the DECRIS-14 and the ECR-4M vacuum stands.

DECRIS-14		ECR-4M	
Desorption rate (Pa l s^{-1})	Pressure (Pa)	Desorption rate (Pa l s^{-1})	Pressure (Pa)
2.35 x 10^{-3}	1.5 x 10^{-5}	3 x 10^{-4}	3.4 x 10^{-6}

5 REFERENCES

[1] J. Pivarč, J. Vac. Sci. Technol. A12(5), 2716, 1994.

[2] Turbomolecular pump VMN-500, 126024 Kostroma, Plant "LUCH", Russia.

[3] Rotary pump BL 90, Zakład Techniki Prozniowej, Koszalin, ul. Przemysłowa 1/3, Poland.

[4] Mass Spectrometer MX 7304 (monopol), Industrial Association SPO "ELECTRON", 244030 Sumy, ul. Komsomolskaja 68a, Ukraine.