Status of the Installation of the AMS System at the Nuclear Regulatory Authority, in Argentina, Design of a new Stripper System

ABSTRACT

A new Accelerator Mass Spectrometer (AMS) system is under installation at the Nuclear Regulatory Authority, in Argentina. Its injection spectrometer is already operative, the electrostatic FN tandem accelerator is under high voltage test and the post accelerator spectrometer is been installed at present. A brief account on the status of the facility is presented. Results from preliminary test, for the design of a new terminal gas stripper system are presented.

1. INTRODUCTION

The main goal of the new Accelerator Mass Spectrometer (AMS) system [1], under installation at the Nuclear Regulatory Authority, is to perform AMS assays for actinides in the area of international safeguards, in particular safeguards related with ABACC + and IAEA. A survey on the present status of the AMS technique, applied to actinide isotopes, can be found in ref. [2]. In the following section we describe the status of the facility. Finally the results of some preliminary test, oriented to the design of a new terminal gas stripper system are presented.

2. THE AMS SYSTEM

2.1 Injection Line

The layout of the entire system is shown in Fig.1. A high-current sputtering ion source provides negative ions of about 34 keV of energy. The emittance matching section consists in two Einzel lens operating in telescope mode. Between them, a dog-leg steerer allow for minor alignment corrections.

A variable aperture is placed at the object focus of the 90°, 500 mm radius spilt-pole injection magnet (mass-energy product of 17.4 amu MeV). At its image focus are located the momentum defining slits, coincident with the object focus of the 90° spherical electrostatic analyzer, which has also a radius of 500 mm. Finally a third Einzel lens and another dog-leg steerer, match the beam into the accelerator.

Several tests have been done with sulfur and chlorine beams. The sample material was placed in copper holders having two different openings of 2 and 4 mm. The beam spot on the sample was usually between 0.5 and 0.7 mm in diameter. Currents between 10 and 12 uA for $^{32}$S and $^{35}$Cl were measured at the image focus of the injection magnet. The transmission through the spherical electrostatic analyzer was 97% for both beams.

+ ABACC: Brazilian-Argentine Agency for Accounting and Control of Nuclear Materials
2.2 The accelerator

The accelerator is a FN electrostatic tandem equipped with spiral inclined field acceleration tubes and a dual Pelletron charging system. Diamond-like stripping foils of 0.6µg/cm² (with supporting mesh) will be used at the terminal stripper in order to minimize energy and angular straggling when measuring actinides ions. With the same purpose, as will be discussed later, a new terminal gas stripper system is under study.

At the high-energy base of the accelerator tank, 22 cm downstream the exit of the last accelerator tube, an electric quadrupole triplet has been installed in order to keep the mass-independent tuning, along the complete system.

The isolating gas inside the pressure vessel is a standard mixture of N2 plus 20% CO2. The high voltage tests, without acceleration tubes, are under course at present.

Figure 1. Plan view of the AMS system

2.3 The high-energy line

The electric quadrupole triplet at the high-energy base of the accelerator, followed by the 22° spherical electrical analyzer, focus the beam at the object of the analyzing magnet. At this position the beam charge state already selected by the electrical analyzer enter the external gas stripper. The main purpose of this second stripping is to increase the charge state of the beam
in order to bent the actinide ions with the small 72 MeV x amu double focussing analyzing magnet. The momentum-analyzed ions are then focused at the detection chamber by mean of the magnetic quadrupole doublet, whose mass-dependent tuning is not yet relevant at this stage. Two pair of electrical deflecting plates at the entrance and exit of the analyzing magnet [3] will allow to switch between close mass isotopes, keeping fixed the magnetic field.

3. ON THE DESIGN OF A NEW STRIPPER SYSTEM

3.1 Stripping process and angular straggling

The ion charge exchange, at the terminal stripper of a tandem accelerators, is a fundamental process in AMS because allows the elimination of the molecular background from the analyzed beam. Carbon foils with thickness ranging between 2 and 20 ug/cm² are commonly used as stripping media. When lower thickness is needed, a gas flowing in a narrow canal open in both sides, is used. The theory of the charge exchanging processes has been discussed by Betz [4]. Extensive studies on charge-state distributions have been published [5,6].

Under normal conditions, the beam transmission through the accelerator depends basically on the stripping efficiency. For heavy ions like actinides the transmission is particularly affected by angular straggling at the stripping medium. To overcome this problem the thickness of the stripping media must be reduce to values only attainable using gas stripping. Calculations of ion multiple scattering, assuming screened Thomas-Fermi and Lenz-Jensen potentials [7] have been performed to estimate the angular straggling [8-9]. A particular calculation for uranium ions of 3 MeV, stripped by argon gas at the equilibrium charge exchanging density (1.E16 atoms/cm²), in a stripper canal 1 m long, indicate that a minimum diameter of 1.6 cm is needed in order to transmit 85 % of the beam [10].

Our gas stripper canal is 80 cm long, and 0.8 cm in diameter. Although the referred calculations suggest that reducing the gas thickness to pre-equilibrium densities, smaller diameters would be acceptable, we have consider relevant to study the possibility of increasing the diameter of our stripping canal.

3.2 Differential pumping

The preservation of the high vacuum at the acceleration tubes is very important for AMS in order to minimize beam loses as well as continuum energy background due to charge exchange interaction with the residual gas.

In order to increase the diameter of the stripping canal, while preserving the vacuum in the acceleration tubes, the introduction of differential pumping in the terminal, is very important. Since 1984, when for the first time a turbomolecular pump was used to recirculate the stripping gas at a tandem terminal [11] an increasing number of similar upgrading has been performed up to now [12-16].

Stripping of light ions like Be, C, Al, typically require carbon foils, in the range of 3 to 5 ug/cm². When using a gas, equivalent thickness in standard canal strippers is obtained with pressures in the range of 50-80 hPa. But the gas pressure for stripping uranium ions, should not be greater than a few hPa. In a recent AMS measurements for uranium with 3.5 MV at terminal, 5 hPa at the stripper canal was reported [17].
In order to investigate the most relevant facts involved in the design of a gas recirculator, that should operate with low pressures at the stripper canal, we built the simple differential pumping system shown in Fig. 2. The turbomolecular pump, used to recirculate de gas, has a pumping speed of 500 l/s. Interposing smaller apertures at its inlet port, the effective recirculation speed can be reduced. The stripper housing H has a volume of 1.1 liter. The turbo pump discharge is feedback to the stripping gas inlet with a tubing of 4.5 l/s conductance. The gas inlet valve V can inject nitrogen with controlled sensitivities as small as $1.0 \times 10^{-10} \text{ hPa-l/s}$. The stripper canal S has a diameter of 1.6 cm and a length of 36 cm (1.25 l/s conductance). A 2.6 l/s conductance tube communicate the stripper housing with the simulated accelerator tube T. The 300 l/s diffusion pump at P, produce an effective pumping of 30 l/s at T.

The time evolution of the pressure at S and the vacuum at H and T, have been measured for different recirculation speed. As shown in Fig. 3(a) before switching on the turbo pump, at the equilibrium vacuum established by the diffusion pump P, the pressure at S and H are higher than at T. When the recirculation begins, the pressure at the stripper S increases due to the pumping effect on the stripper housing as well as on plenum T, through conductance C. The pressure at the stripper housing reach a minimum when the molecules dragged by the turbo pump are balanced by the incoming molecular flow from both, the stripper canal exit and conductance C. Subsequently the molecular flow driven through conductance C progressively increase the pressure at H until a new equilibrium is reached on term of pumping speed at the opposite sides of conductance C. Depending on the particular design of a recirculating system, the equilibrium pressure at the stripper canal (before injecting gas) may become too high, if very low pressure are needed.

At this stage, valve V was open in order to set a 5 hPa recirculation pressure of nitrogen. As shown in fig. 3. (b) the pressure at S increased monotonically. The increasing rate diminished for higher pressure regimes. This result showing the physical interplay between the conductivity of the recirculation circuit, pressure and throughput, indicate that there is a minimum constant pressure, at the stripper canal, for a given conductivity and recirculation speed.
Reducing the effective speed of the turbo pump was possible to set low stripping pressure with excellent stability and repeatability as shown in Figure 3(c).

Figure 3. (d) shows the vacuum performance of the system for a wide range of stripping pressure at three different recirculation speeds.

The present test has been performed at the lowest vacuum expected at the terminal of our accelerator. A less restrictive compromise between the pressure level at the stripper and a too high recirculation speed can be anticipated for higher vacuums at the accelerator tubes. Additional tests for different canal stripper diameters and also lower vacuums are planed.

4. SUMMARY

The injection line is already operative, the electrostatic FN tandem accelerator is under high voltage test and the high-energy line is been installed at present. After the accelerator tubes been installed, the measured vacuum at the terminal will be a critical information to perform more realistic gas stripper simulations.
REFERENCES


