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EXPERIENCE WITH THE NEG STRIPS AT THE BROOKHAVEN HEAVY ION TRANSPORT LINE*

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INTRODUCTION

The AGS and the Tandem Van de Graaff, two valuable physics assets, are now jointed together by a transport line of 700 m in length. This line allows heavy ions from the Tandem, up to a fully stripped silicon (M=28) to be injected into the AGS and accelerated to energies of approximately 15 GeV/amu. New areas of physics research at very high nuclear densities can now be studied using some of the extensive experimental facilities already existing at the AGS. With the addition of a booster synchrotron between the Tandem and the AGS, all heavier ions up to gold can also be accelerated.

To minimize the beam loss due to charge exchange between the partially stripped heaviest ions (i.e. Au + 33 at 1 MeV/amu) and the residual gas molecules, a vacuum of 10^{-8} Torr is required for this transport line. To achieve this vacuum, we have opted to use the combination of small ion pumps (20 l/s diode type) and distributed nonevaporable getter (NEG) strips as pumps. A very simple geometry was implemented which offers low cost (<$200/m), easy installation and maintenance. Pressures of 10^{-10} and low 10^{-9} Torr have been maintained over the last two years following the initial activation. This paper describes the NEG strip system, and the experience obtained during the installation and the operation of this 700 m heavy ion transport line (HITL).

NEG STRIPS AT HITL

The layout of HITL, the Tandem, the AGS and the Booster is shown in Figure 1. By placing quadrupole doublets and steering magnets about every 70 m, the optics of the heavy ion beams is small enough that the NEG strips and their supports can sit comfortably at the bottom of the 8.8 i.d. beam pipes. Of course, the beam is offset slightly above the pipe center to allow maximum spatial extent for the beam envelope.

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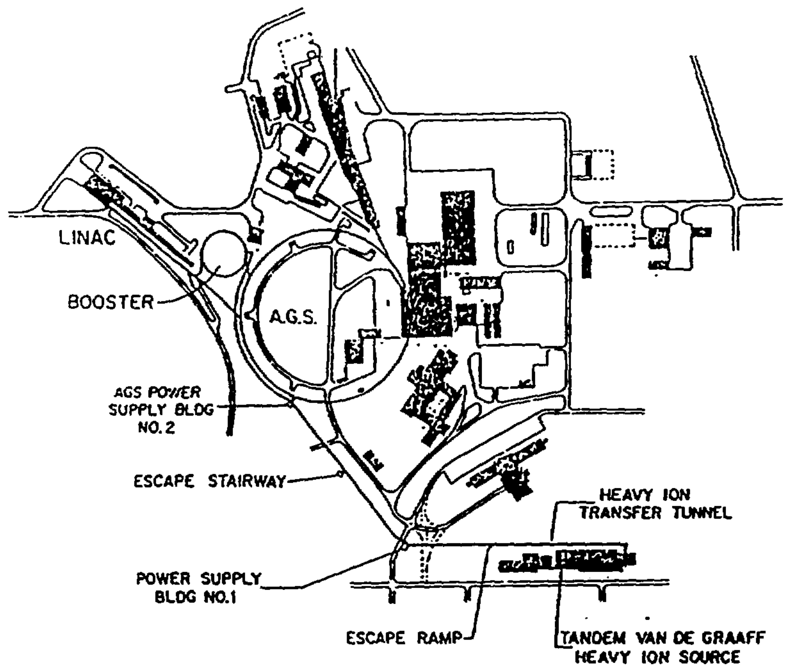


Fig. 1. The layout of the Tandem, the HITL and the AGS

Except at the Tandem end and the AGS end, the NEG strips line the whole length of the beam pipe. The vacuum sections are about 70 m in length and isolatable by gate valves located at the beam diagnostic boxes. Small ion pumps and ion gauges are located at the beam diagnostic boxes to monitor the vacuum. Details of the vacuum system design are given in references 1 and 2.

We have selected the Zr-V-Fe NEG (St707) from SEAS Getters, Inc. for its high pumping speed and capacity at room temperatures.[3] They use no power during HITL operations, and contribute no magnetic or electric fields to perturb the beam. The NEG granules are deposited on a constantan strip 3 cm wide and 0.2 mm thick. To take advantage of the longest available strips, each beam pipe was 10 meters in length. The strips were assembled to the supports and the insulators, slid into the vacuum pipe and connected to the feedthroughs located at the ends of the pipe. Figure 2(a) shows the cross-sectional view and Fig. 2(b) the uncaptured version of the NEG strip with supports and insulators inside the pipe. The maximum radial height of the NEG system is about 1.5 cm. The thermal expansion of the NEG strips during bakeout and activation is absorbed by two copper braids at either end of the pipe as shown in Fig. 2(c).

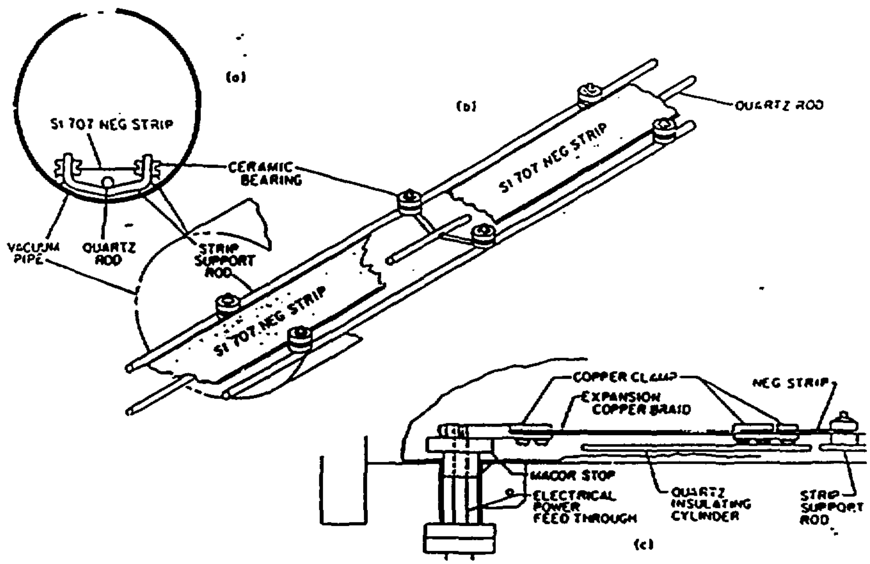


Fig. 2. The HITL vacuum pipe with NEG strip installed. (a) cross-sectional view; (b) the uncaptured version; and (c) the side view around the feedthrough.

Bakeout of the vacuum pipes and activation of the NEG strips were done by resistive heating of the constantan support strips. A current of 40 A brought the pipe to over 100°C and a current of 70 A for 30 minutes was used to activate the NEG.[1] The temperatures of the NEG strips at various heating currents as measured in a prototype setup are shown in Fig. 3.

COMMISSIONING OF THE HITL VACUUM SYSTEM

As mentioned above, the NEG strips were used as heaters during institu bakeout. One or two turbopumps were used at each section (about 70 m in average length) during bakeout and activation. Each

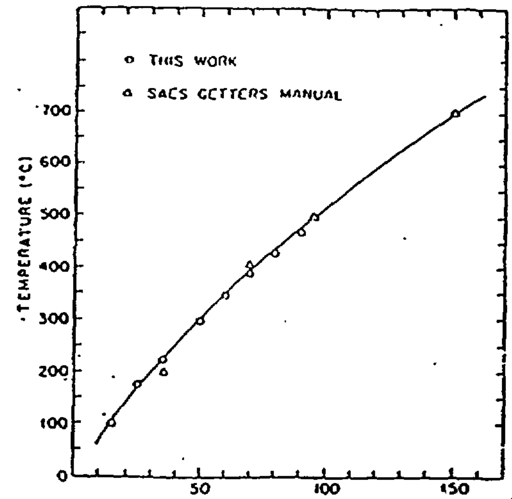
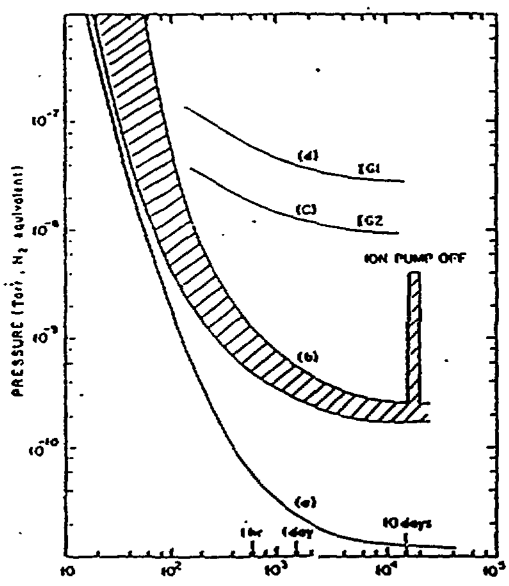


Fig. 3. Temperature of the NEG strip versus Activation



vacuum section was roughed down manually with turbopumps to 10^{-5} Torr. Then the pipes and the boxes were baked to over 100°C with 40 A current on the NEG strips, and supplemental heat was supplied with heating tapes. The activation (at 70 A x 30 minutes) was started after overnight bakeout and roughing. Due to the conductance limitation, the vacuum farthest away from the turbopump initially rose to a few microns during activation. The major component of this pressure surge is hydrogen which has little effect on the pumping behavior of the NEG.[3] After NEG activation, the ion pumps were turned on and the turbopumps valved off.

The pumpdown curves of typical vacuum sections are shown in Fig. 4. Curve (a) is that of the prototype vacuum section which did not have the beam diagnostic boxes and other higher outgassing components. The pressure distribution of some NEG-pumped HITL sections as measured at the diagnostic boxes is shown by curve 4(b). The pressures would be in the 10^{-10} Torr range one day after the roughing started and stayed in the 10^{-9} Torr range even with ion pumps off.

Fig. 4. Pumpdown curves of the HITL vacuum sections.

The higher pressures at both ends of HITL have little effect on the NEG operation as demonstrated by curves 4(c) and 4(d). Note, IG2 located at the end of the NEG pumped section, which is 10 m away from higher pressure zones (measured by IG1). No changes in pressure were observed at the NEG-pumped sections [Curve 4(b)] after several months of operation.

SYSTEM PERFORMANCE AND DIAGNOSTICS

In general, pressures at the NEG-pumped sections are in the low 10^{-9}, 10^{-10} Torr ranges, which are more than one decade lower than those at both ends pumped by large ion pumps and cryopumps. The pressure distribution along HITL with and without heavy ion beam is shown in Fig. 5. At the presence of the beam, little increase in pressure was observed at the NEG-pumped sections. The real pressure at the NEG-pumped sections should be lower than the measured ones, since the ion gauges are located at the beam diagnostic boxes which have higher outgassing and lower pumping than the NEG-lined beam pipes. With the exception of areas with component failures which required bleedup, no activation was necessary since the commissioning of the system in February, 1986.

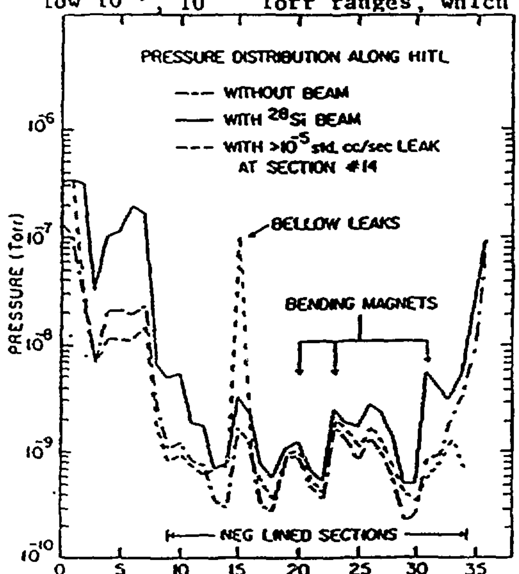


Fig. 5. Pressure distribution along HITL

The effect of large leaks on the NEG-pumped sections was observed during the summer of 1987 when pressure oscillations occurred in one section. The ion gauges and ion pumps went into cycles until the overcurrent interlock turned them off. The problem was was traced to leaks of $>10^{-5}$ std cc/sec on several bellows. The high speed of the NEG and the large spacing between the ion gauges made early detection difficult. Not until the NEG strips were saturated and the ion pumps went into argon instability, were the leaks then noticed.

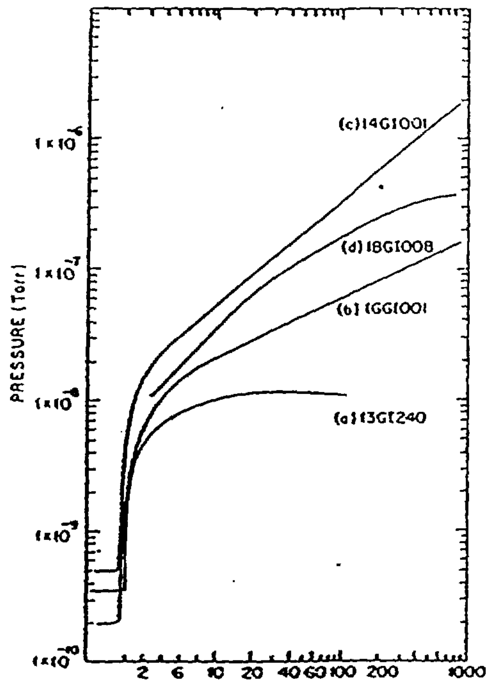


Fig. 6. "Rate of pressure rise" measurement in some vacuum sections with ion pumps off

Detection of smaller leaks were carried out when the HITL was not in use. This was accomplished by turning off the ion pumps at each section and closing the sector valve. By following the pressure rise carefully, we were able to identify sections with leaks of various magnitudes. Four examples are shown in Fig. 6. The majority of the sections follow that of curve (a) with pressures stabilized at the mid 10^{-9} Torr range. Some sections show linear increase in pressure [curves (b) and (c)] suggesting the presence of leaks. Examinations of these sections by a VG SX200 residual gas analyser (shown in Fig. 7) confirmed our expectation that the gas composition is mainly of argon (more than 90%) with the balance being methane and hydrogen. The leak rates were then calculated from the slopes of the pressure rises.
The pressures in a few sections rose slowly then peaked off at low 10^{-7}Torr [curve (d)] and are thought to be caused by some high outgassing components. The slopes of the pressure rises were not linear in these sections and could be distinguished from those due to leaks.

CONCLUSION

Pressures of 10^{-10} Torr have been achievable with a simple NEG strip based pumping system at HITL. This system offers simplicity in operation (easy installation, no powering), low cost (<$200/m or $1 per l/s) and fast pumpdown to UHV; and believes to be the first large scale application in particular accelerator vacuum systems.

This NEG strip based system will find a good application for beam transport lines where no restrictions are imposed by magnet gaps as are the cases in synchrotrons or storage rings. The

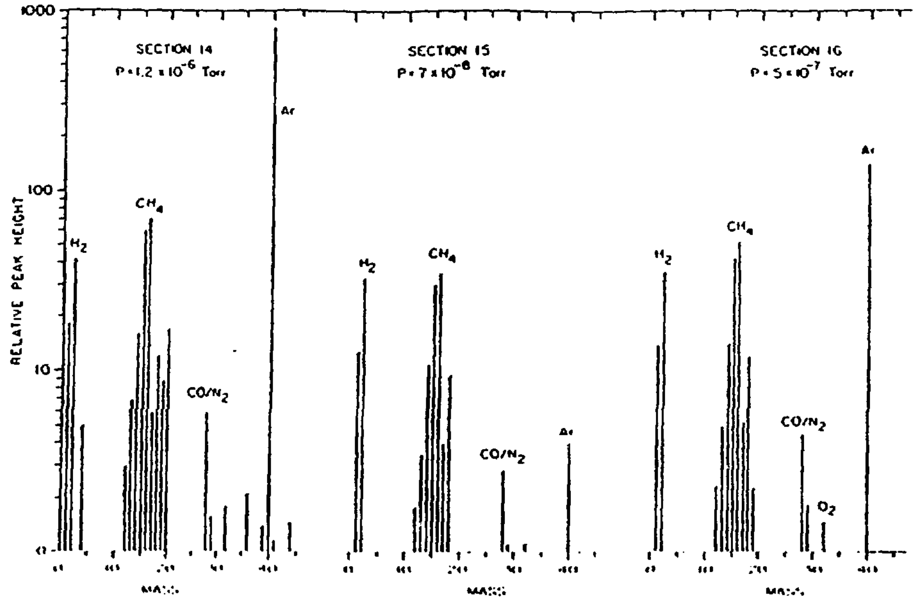


Fig. 7. RGA spectra of some NEG-pumped sections with ion pumps off.

absence of gas load due to synchrotron radiation induced desorption certainly helps prolong the period between the activation, which simplifies the operation. Replacement of a NEG strip is also easier. This system will be implemented for most beam lines at the AGS complex, in particular, the extension of HITL to the Booster, the AGS-RHIC lines and the proposed line between the Tandem and the Atomic Physics Facility at the NSLS.

The monitoring and diagnostics of the NEG pumped sections are different from those of the ion pumped system. More ion gauges will be desirable since the ion pump current is too small to be usable. On the other hand, the real leaks and the high outgassing could be distinguished by simply turning off the ion pumps and following the pressure rise.

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