A Versatile UHV Sample Transfer System*

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ABSTRACT

A vacuum transfer system has been developed that allows samples to be inserted from air into an Auger analyzer. Following an initial analysis they may then be moved to and from a separate vacuum chamber for other studies. The system is constructed of standard UHV components and is unlimited with respect to the transfer distance. All-metal sealed valves isolate the various chambers so that the vacuum integrity of each is maintained. The sample size is limited only by the smallest constriction within the components which, in the system described, is 2 cm. The transfer is rapid and is capable of being controlled remotely for use in a hostile environment.

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DISCLAIMER

INTRODUCTION

Surface analysis techniques such as Auger Electron Spectroscopy, AES, are very powerful techniques but are often frustrated in application because it is diffucult or impossible to transfer a sample with a potentially interesting surface condition to the analysis chamber without contaminating it to the point where no useful information can be obtained. In order to preserve the surfaces for analysis it is usually necessary to handle them quickly under ultra-high vacuum conditions. We have developed a system for this purpose which is versatile and relatively inexpensive.

This paper describes an ultra-high vacuum transfer system developed for use in tokamaks which are devices used in fusion energy research. It is necessary to transport samples used to study plasma-wall interactions from the plasma experiment to a special chamber where AES and other surface analytical techniques are available. Samples surfaces are studied to determine what changes are caused by exposure to the high temperature plasmas in the fusion device. Although the equipment was developed for this specific use, the technique may find other applications where it is desirable to transfer samples from one environment to another under ultra-high vacuum conditions through valves and/or over long distances. The apparatus can also be used as a simple vacuum lock to introduce samples from air or controlled atmospheric environment into an ultra-high vacuum system. Typical applications might include the transfer of samples from corrosive or harsh environments to a surface analytical facility where AES, SIMS, ESCA or other surface analysis techniques are available. Samples might also be transferred from a manufacturing facility or surface treatment facility to an anlaysis chamber without exposure to air.

DESIGN CRITERIA

The equipment to be described below was designed to meet the following criteria:

1. Samples must be transferred over distances of 1–5 m from the fusion experiment to the surface analysis station without altering their surface compositions significantly. This dictated the use of ultra-high vacuum techniques. Base pressures in the 10^{-10} torr range are desirable.
2. The transfer device should also permit transfer through valves and permit closing the valves with the sample on either side of them so as to allow isolation of the sample in any one of several areas of the system.
3. The transfer system must be compatible with operation in a tokamak environment which means it must be able to resist vibration and baking to 250–400°C; it should not include magnetic materials.
4. It is desirable to be able to transfer the sample into separate chambers for sample preparation, analysis or storage and to position the sample accurately inside the tokamak for exposure to the plasma environment.
5. The system should provide for the transfer of the sample to a remote location under ultra-high vacuum in a detachable module.
6. It must be possible to insert or remove samples from the system without exposing the analysis chamber, sample preparation region or tokamak to air.
7. Commercial components were to be used in so far as possible for economy and convenience.

DESIGN CONCEPT

The most difficult of the above criteria are 1 and 2, i.e., transfer over long distances and through valves with the option of closing any valve with the sample on either side. These criteria were met through the design of a carriage (sample carrier) which rides on a simple track from one region of the system to another. The carrier or carriage is able to span gaps in the track to permit the insertion of suitable gate valves. The carriage receives its mobility through the use of drive stations mounted on either side of the valves. The carriage may be moved by various driving mechanisms including belts, wheels or gears. With the last arrangement, the sample may be moved any required distance if enough drive stations are provided. Figure 1 shows a schematic arrangement for such a transfer system. Any required number of work areas may be included.

If suitable means are provided, the sample (or samples) may be removed from the carriage in any location for individualized preparation or examination. In our system, this is accomplished through the use of a rod manipulator. The rod passes through a ball pivot and may be pivotted in any direction, moved back and forth through the ball, or rotated about its axis. The end of the rod is fitted with a screw thread which may be screwed into a suitable threaded hole in the sample holder and the sample and holder removed from the sample carriage. The sample may remain on the rod manipulator for examination or other operations or it may be placed in a work station on a carrousel or a suitable precision manipulator, the screw thread disengaged and the sample examined by any suitable surface analysis technique.

APPLICATION

Figures 1, 2 and 3 illustrate this concept applied to our specific problem. In these illustrations the sample is shown on a sample holder, which may be placed on end of a carriage, shown in region 1 of the system. The carriage may be moved by the drive station D_1 through an open valve VT into region 2 and, if valve VG-1 and VG-2 are open, into region 3 where driver D_4 may be used to maneuver the carriage back and forth and to position the sample carefully at the edge of the plasma. Valve VG-1 may be closed during exposure of the sample to the plasma. After the sample is exposed to the plasma, valve VG-1 may be opened, the sample moved back through region 2 into region 3 and picked up by the rod manipulator and placed on the precision XYZ manipulator in the sample analysis area. The rod manipulator reaches into the tee-valve to engage the sample holder. The tee-valve VT may be closed as soon as the carriage is moved slightly from the transfer position. While the sample is isolated in the analysis chamber, new samples may be introduced into region 2 by opening that region to air, removing the carriage and placing a new sample on the carriage.

Samples may also be removed to a remote location for examination without exposure to air if the assembly enclosed in dotted lines is available. In this event, the carriage with the sample in position, is moved into region C and the gate valve BGC closed. The carrier then, with its own separate vacuum pump, may be removed at flange, FP. The detached system, C, may be then carried to any desired location, reattached to a suitable port on another vacuum system and the sample moved into the new system for further operations.

Figure 2 shows a cross section of the transfer tube. The carriage rides on ball bearings which are guided by the channel-track assembly. The carriage is driven by a spur gear mounted on the shaft of a rotary feedthrough.

Figure 3 shows an enlarged view of the carriage, the sample holder, and the carriage drive station. The sample is mounted on a removable holder which fits into a pocket on the front of the carriage. The sample and holder are easily removable from the pocket in front of the carriage and transferred to a pocket on the precision XYZ manipulator shown in Fig. 1 by means of the rod manipulator.

Most of the components shown in Fig. 1 and Fig. 2 are easily recognizable as standard commercial ultra-high vacuum equipment designed for use with one and one-half inch OD tubing. The gears, racks, and bearings are also standard commercial items. Sizes may be chosen to suit the particular needs of the apparatus.

COMMENTS ON PERFORMANCE

The system shown schematically in Fig. 1 has been developed during the past several years. It is possible to obtain vacuums in the 10^{-10} torr range with suitable pumping and bakeout practice. We have discovered, however, that for many purposed sample transfer at 10^{-8} torr is satisfactory if accomplished in a reasonably short time (the major residual gas in our system is usually hydrogen). Some degree of mechanical aptitude is required to learn to use the rod manipulator since in our system a mirror must be used to see the sample holder when it is in the tee valve.

The sample holder is usually held on the carriage with the help of a spring clip and detent. For our purposes, it is sometimes necessary to design complex samples and sample holders involving mechanical motion, electrical connections, and special materials. Such variations are possible and in our case have been both practical and very useful.

The rod manipulator provides an endless opportunity to manipulate the samples. They can be rotated, bent, fractured, rubbed, pushed, scratched, moved close to a window for a closer look at color or some strange artifact, attached to electrical plugs placed on a stage or in a storage area or even dropped into a valve, ion sputter gun or some equally unfortunate spot.

We have been very pleased with the reliability, flexibility and overall performance of this system which has operated successfully on several tokamaks, ISX-A in Oak Ridge, T-12 at the Kurchatov Institute in Moscow and Doublet III at General Atomic in San Diego.

FIGURE CAPTIONS

1. Schematic drawing of the Sample Transfer System designed for research related to plasma-wall interactions in fusion energy.
2. Cross-section of the Sample Transfer System showing the pinion gear drive.
3. Diagram of the sample carriage, sample holder, pinion gear drive and rod manipulator showing the functional relationships.

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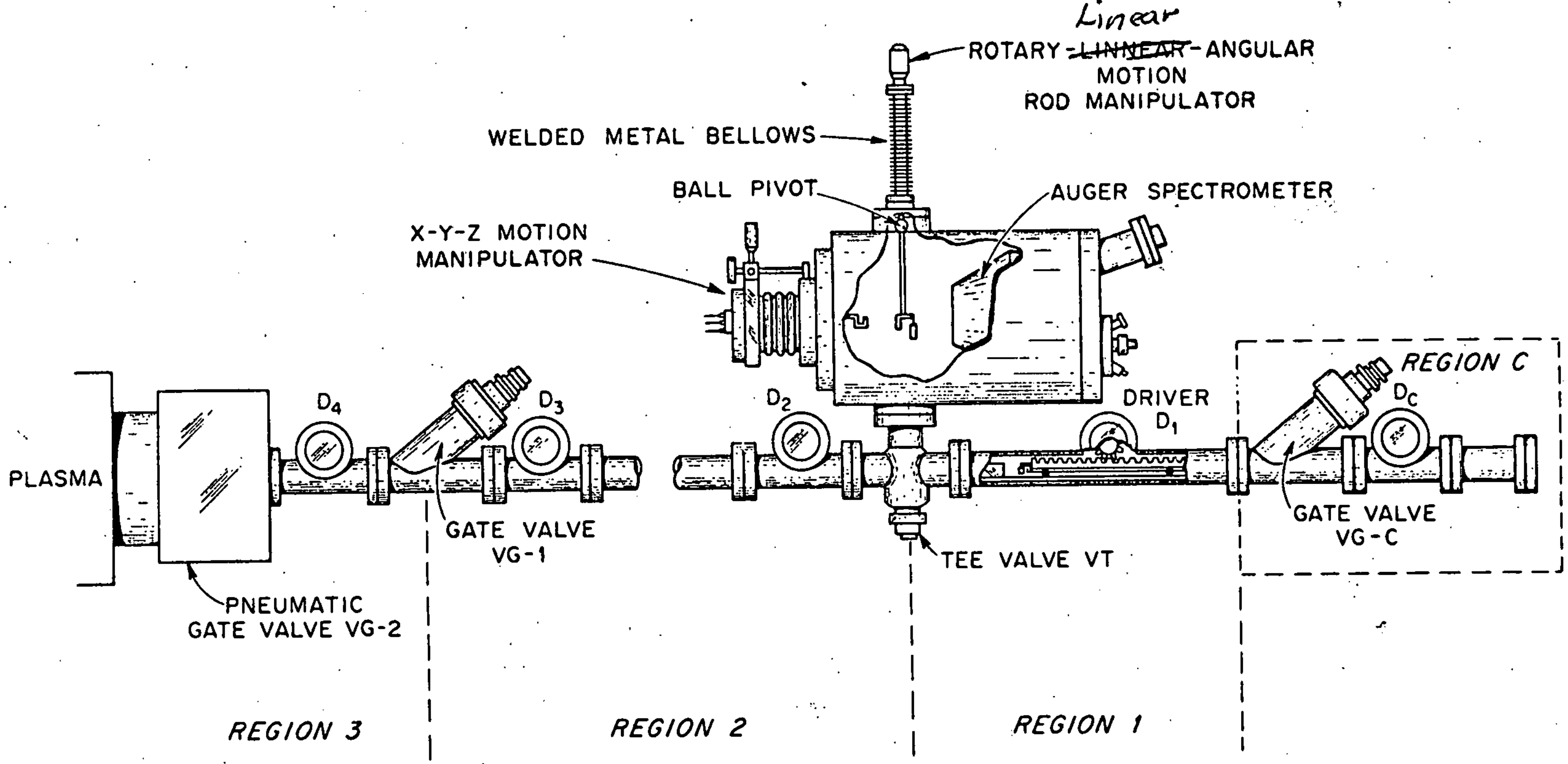

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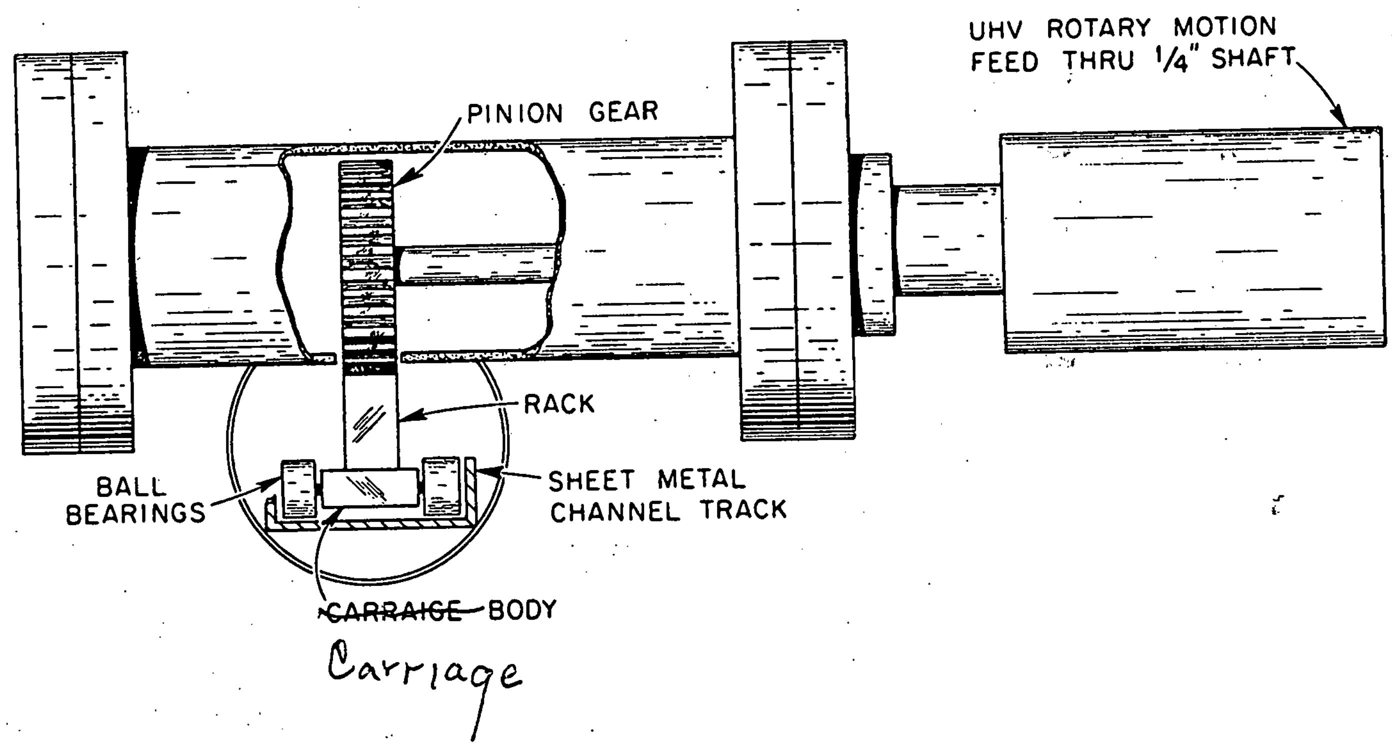

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