DEVELOPMENT OF A VACUUM TRANSFER SYSTEM
FOR TOKAMAK PLASMA IMPURITY STUDIES

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By

KLAUS KURT WALTER WITTANN, B.S.M.E.

A Report

Submitted to the School of Graduate Studies

in Partial Fulfilment of the Requirements

for the Degree

Master of Engineering

McMaster University

April 1978

MASTER OF ENGINEERING (1978)
(Engineering Physics)

McMASTER UNIVERSITY
Hamilton, Ontario

TITLE: Development of a Vacuum Transfer System for Tokamak Plasma Impurity Studies

AUTHOR: Klaus Kurt Walter Wittann, B.S.M.E. (Michigan Technological University)

SUPERVISOR: Dr. J.E. Robinson

NUMBER OF PAGES: iv, 15

ABSTRACT

A surface station consisting of a sample manipulator and transfer system was developed to allow the study of plasma - first wall interactions in ALCATOR at M.I.T. A disc shaped probe is located at the plasma edge and rotated past an aperture in a shield to obtain time resolved data. Samples can be analysed in situ or transported under vacuum to McMaster University. The transfer process from the surface station to the 'vacuum suitcase' is accomplished by means of pressure locks.

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1. INTRODUCTION

The interaction of the energetic plasma with wall surfaces in today's nuclear fusion devices (Tokamaks) leads to an influx of heavy ion impurities into the plasma. However, only a low level of impurities can be tolerated if significant cooling of the hot plasma is to be avoided. In order to study this pheonomena, one would like to know what impurities are present in the plasma at any time during the discharge cycle. One way to investigate the problem is by exposing a clean sample surface to the edge of the plasma and then performing a quantitative surface analysis by one or several standard surface analysis techniques.

Since no such surface analysis station existed at the ALCATOR Tokamak at M.I.T. (Boston), it was proposed to construct a device similar to those used in Garching[1] and Princton[2]. The exposed surfaces would be subsequently analysed with two instruments at McMaster University (Hamilton).

Sample quickload and vacuum transfer devices were needed to keep the samples at pressures below 3 x 10^{-8} Torr at all times after exposure and during transport between surface analysis stations.

The purpose of this report is to present the final design of the sample manipulators, the quickload, and the transfer system to be employed as a link between three surface analysis stations.

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1 P.H. Staib, G. Staudenmaier, J. Nuclear Mater. 63 (1976) 37-46.

2 S.A. Cohen, H.F. Dylla, Plasma Physics Lab., Princton University.

2. OBJECTIVES

2.1 The Need for a Vacuum Transfer System

Changes in the composition of the first wall in a Tokamak as well as the influx of heavy ion impurities into the plasma can be studied by introducing a chemically clean surface into the plasma limiter shadow. During the high current plasma discharge this surface is rotated past an aperture but is otherwise covered by a shield. This results in a time resolved exposure. Several such exposures are necessary to obtain significant amounts of ion deposits on the sample surface. If the ion impurities present in each discharge are not varying for various discharges, then the surface composition of the sample gives the relationship between impurities and time during any discharge cycle. It thus becomes necessary to construct a device that is able to expose a sample with a high degree of accuracy and repeatability.

The surface can then be analysed by Auger Electron Spectroscopy (AES), Secondary Ion Mass Spectrometry, Rutherford Backscattering and Ion Induced X-Rays. The AES analysis will be carried out in situ. For the others it is planned to move the samples under vacuum to McMaster University, Hamilton. This necessitates the construction of a vacuum transfer chamber and quick loading mechanisms at each of the three surface analysis stations.

2.2 Specifications

2.2.1 Surface Analysis Station for ALCATOR

The station has to be capable of performing the following functions listed below.

a) It mustmove a sample with a chemically clean surface to a predetermined position in the plasma limiter shadow within 1 mm tolerance and repeatability. Approximately 1.8 m travel is required past the last possible point of support.

b) It must rotate the sample past a 2 mm wide aperture at a pulse signal from ALCATOR. One rotation of the sample corresponds to 0.700 seconds. Acceleration time must be less than 0.005 seconds.

c) It must stop after one rotation at the zero rotational reference position.

d) It must be capable of repeating steps (b) and (c) for a predetermined number of times.

e) It must be able to withdraw the sample from ALCATOR and position it in the analysing chamber.

f) It must rotate the sample selectively to any one of a number of azimuthal positions.

g) It has to perform the AES analysis.

In addition to the functional requirements the station has to satisfy the following criteria.

a) It must be of sufficient structural rigidity to assure alignment during transport and installation in Boston.

b) It must be able to maintain a pressure below 3×10^{-8} Torr in the analysing chamber, while isolated from ALCATOR.

c) It must be made of high vacuum compatible materials, i.e. the materials must have a low rate of outgassing and resist galling when in contact with each other.

2.2.2 Quick Load Device

This device must be able to introduce samples into a vacuum chamber without disturbing the main vacuum. It has to accept either samples at atmospheric pressure or samples from the transfer chamber. In addition it must accept sample holders that carry small material samples to be analysed instead of the samples exposed at ALCATOR. A minimum of vacuum feed throughs should be utilized in the design.

2.2.3 Vacuum Transfer Chamber

The transfer chamber must store a maximum number of samples, while keeping the size and weight to a minimum. It interconnects with the quick load devices for loading and unloading, but must have an independent battery operated vacuum pump.

3. DESIGN

3.1 Design of Surface Analysis Station

The surface analysis station is installed on the outside perimeter of the Tokamak (Fig. 1). Samples are introduced to the analysis chamber and attached to the end of the manipulator by a spring loaded pin.

3.1.1 The Sample Manipulator

The manipulator transports the sample between the analysis chamber and the sampling position (Fig. 2). It consists of two 8'-6" long concentric tubes travelling together as a unit. The tubes are supported by four hour-glass shaped pinch roller assemblies. The roller assembly near the analysing chamber transmits the translational drive force from a stepping motor to the travelling tubes via a pinion and rack arrangement. The sample is mounted in a holder at the end of the innermost of the two tubes. This inner tube is free to rotate with respect to the outer tube. The outer tube is prevented from rotating by two flat metal strips spot welded to the top and bottom of the entire length of the tube respectively. A long round bar driven by a second stepping motor is keyed to the inside tube to impart the rotating motion to the sample. This bar telescopes in and out of the inner tube, when the tube assembly is in translational motion. Two optical sensors signal the reference position for the translational

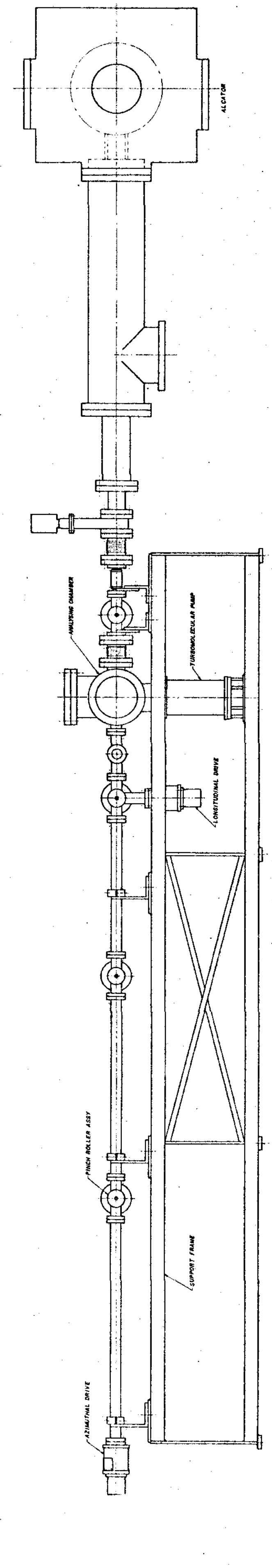
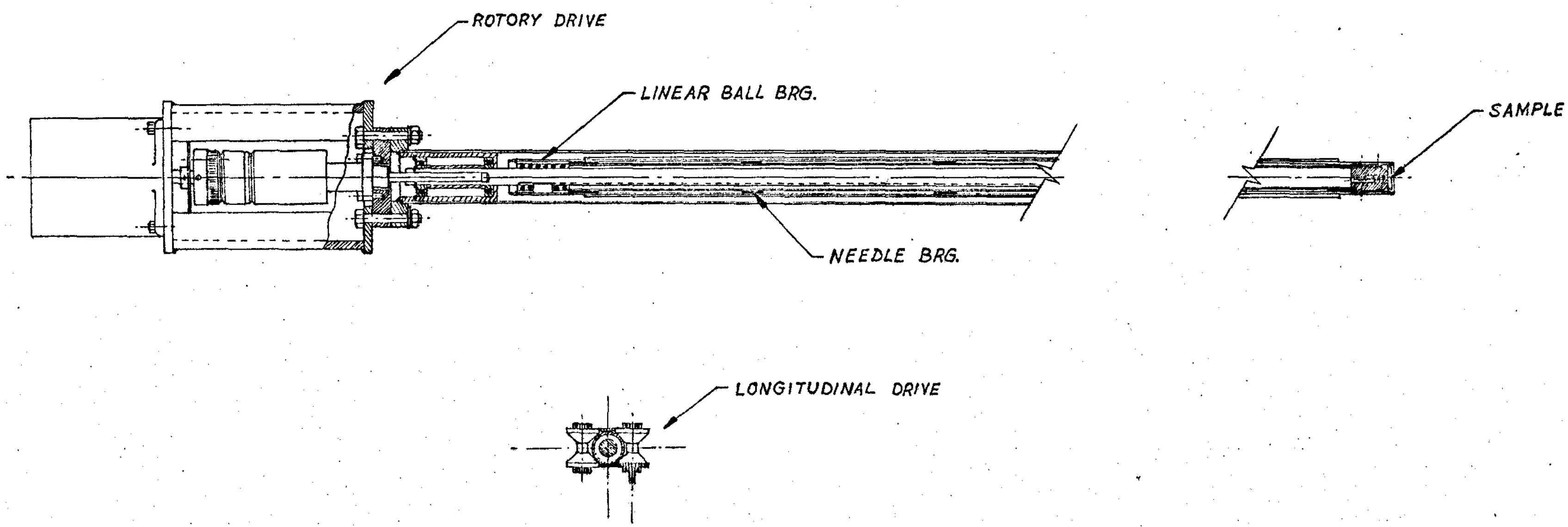

ALCATOR
ANALYSING CHAMBER
TURBOMOLECULAR PUMP
LONGITUDINAL DRIVE
PINCH ROLLER ASSY
SUPPORT FRAME
AZIMUTHAL DRIVE

Fig. 1



SAMPLE MANIPULATOR

FIG. 2

and rotational motion. Guide roller bearings and the bearings between the two tubes are dry lubricated by Molybdenum-Disulfide. Stainless steel is used throughout, except for friction pairs where a nickel alloy is used in contact with stainless steel.

3.1.2 The Analysis Chamber

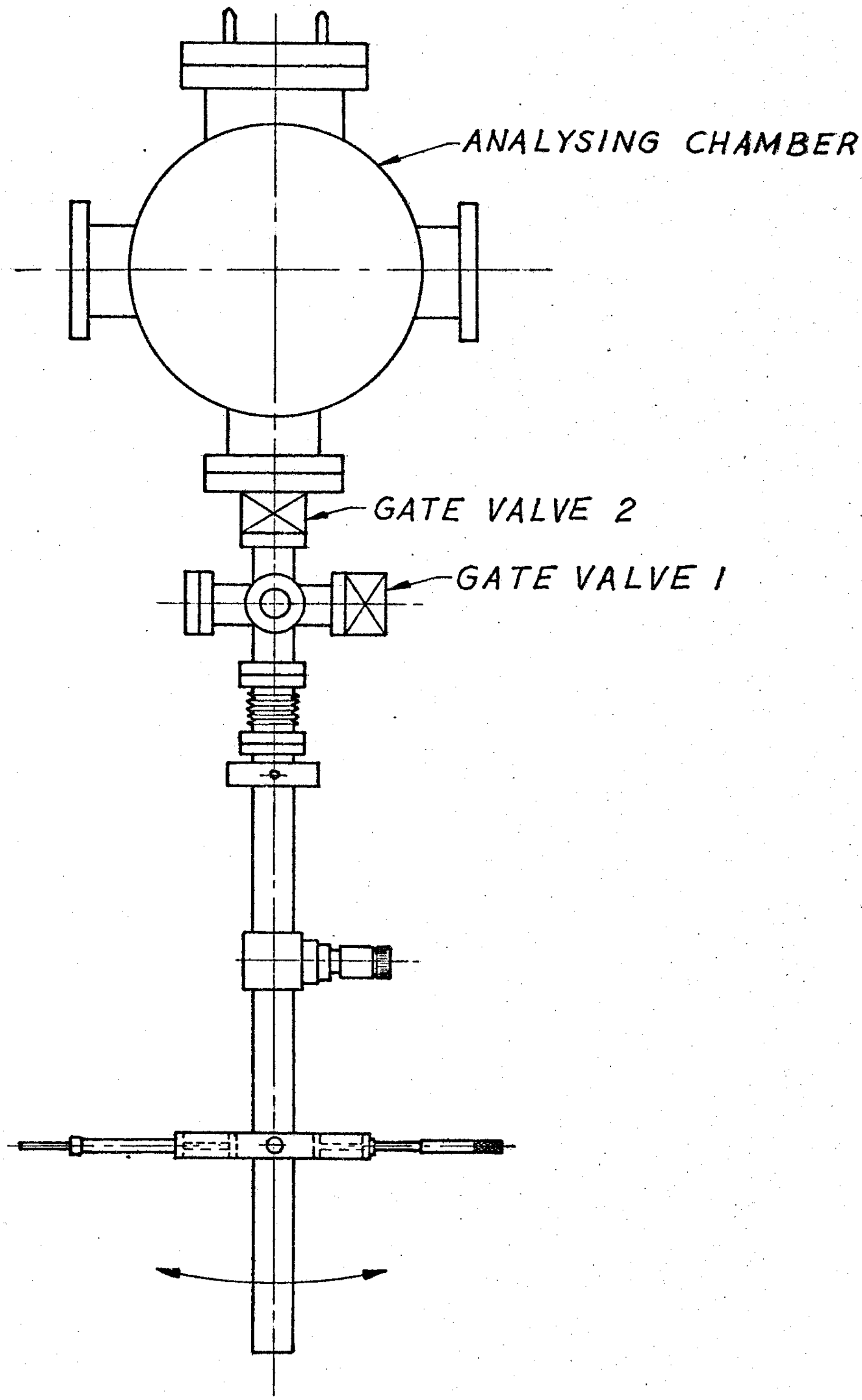
The analysis chamber houses the AES analyser and an ion sputtering gun. It is evacuated by a 450 ℓ/s turbo molecular pump. All flanges used are standard CON-FLAT flanges. Welds are on the inside of the chamber to eliminate virtual leaks due to small crevices.

3.1.3 The Support Structure

The support structure is made of 2 inch square aluminum box section and 3/8 inch aluminum plate. This construction keeps the maximum deflection below 0.001 inches when the apparatus is picked up at both ends in transport.

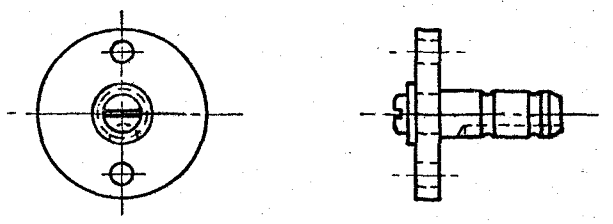
3.2 Design of the Quick Load Device

A quick load device is permanently installed at each of the three surface analysis stations. A typical installation is shown in Fig. 3. The samples to be loaded are permanently mounted on a short shaft. This combination will be referred to as the sample (Fig. 4). Alternatively an assembly consisting of a hexagonal material sample carrier and a shaft (Fig. 5) may be loaded to the quick loader through gate valve 1 and accepted by a carrying fork (Fig. 6). This fork has

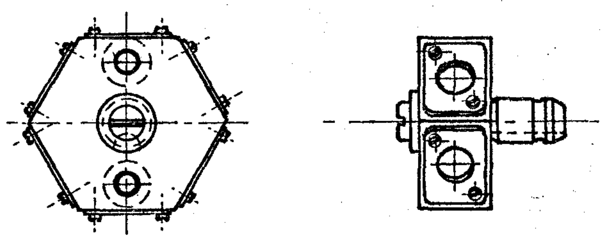


QUICK LOAD DEVICE

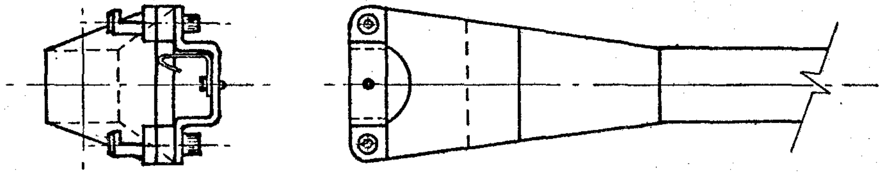
FIG. 3



SAMPLE
FIG.4



MATERIAL SAMPLE CARRIER
FIG.5



CARRYING FORK
FIG.6

two protruding hooks which are inserted into two corresponding holes in the sample. Once in place on the fork, the sample is held on the hooks by means of a flat spring. Now gate valve 1 is closed and the quick loader is evacuated if the sample was introduced at atmospheric pressure. Then gate valve 2 is opened and the sample is moved into the analysing chamber by a pinion and rack arrangement. The rack is gimbal mounted. This allows the operator to align the sample with the sample holder inside the chamber and to push it into the detent position. Now the operator presses the fork down against the force of the flat spring, thus clearing the sample of the two hooks. He then completely withdraws the fork from the sample, moves the fork out of the chamber and closes gate valve 2.

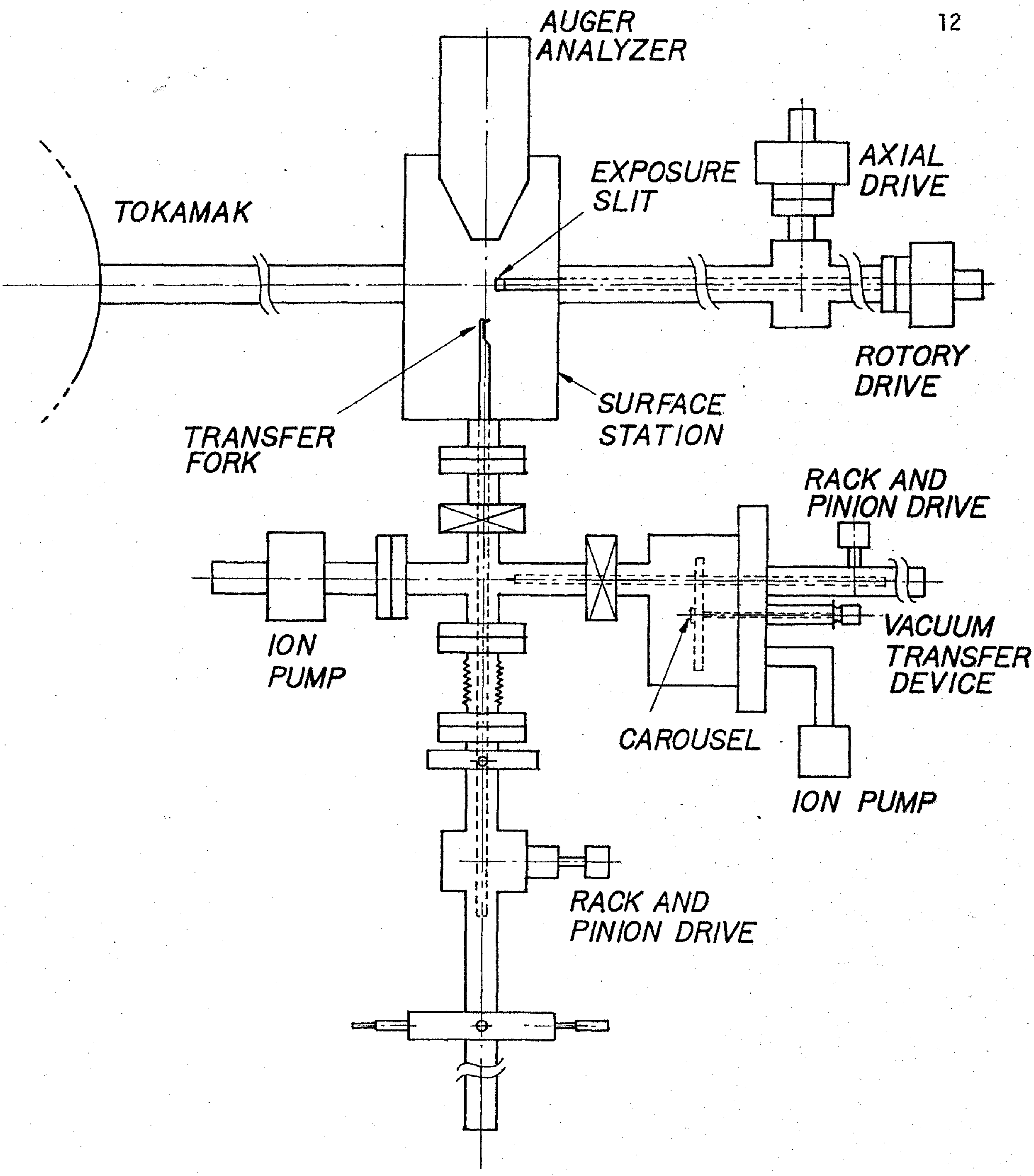
To withdraw the sample from the chamber, the reverse procedure is followed.

3.3 Design of the Transfer Chamber

The chamber allows the storage of 15 samples. This was thought to be a good compromise between capacity and weight constraints.

Samples are held by a circular rotary table (Fig. 7). To load the table, a rack is advanced through one of the holes in the table, past the open gate valve, and into the 6-way cross of the quick loader. There, the rack is charged with a sample. The rack then moves the sample to the storage table, where it draws the sample shaft into the receiving hole. Now the rack can be withdrawn from the sample which is held in place by a cantilevered spring.

To unload a sample, the rack is pushed against the sample shaft

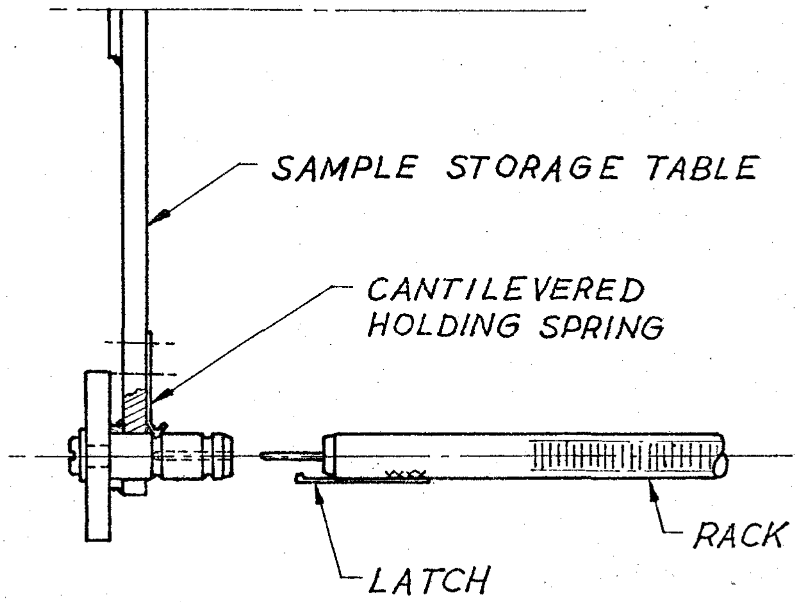


TRANSFER CHAMBER ATTACHED TO SURFACE STATION

FIG. 7

and automatically latches on to it. The force necessary to hold the sample in place during the latching operation is provided by the canti-levered spring previously mentioned. This spring is designed to exert a low resistive force on the sample upon loading, but a high resistive force, when the sample is unloaded (Fig. 8).

After latching between sample and rack has taken place, the force on the rack is increased until it exceeds the holding force of the canti-levered spring. Then the rack carries the sample to the quickload device, where it is taken over by the loading fork.



HOLDING AND LATCHING MECHANISM

FIG. 8

4. DISCUSSION OF RESULTS

Surface analysis stations are used in many laboratories throughout the world. Many man-hours of labor are wasted when vacuum chambers are let up to air pressure each time a sample is introduced to the system. This practise also leads to a high contamination of the vacuum vessel and the pump. These problems may be eliminated by the use of quick load devices. In some instances the samples must be kept under vacuum continuously in order to prevent oxidation and adsorption at the surface. In this case a quick load device is the only answer if the samples are to be transported.

It is believed that the developed system represents a viable and economic answer to the problem.