SPACE SHUTTLE MECHANISTIC STUDIES TO CHARACTERIZE ATOMIC OXYGEN INTERACTIONS WITH SURFACES

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Abstract. A materials interaction experiment has been approved to study atomic oxygen interaction mechanisms and develop coatings for Space Station elements requiring long-lived operation in the LEO environment. A brief summary of this experiment is presented and the required exposure conditions are reviewed.

Introduction

An understanding of the surface chemistry which gives rise to atom/surface interactions within the orbital environment is crucial to establishing a reliable materials interaction data base for Space Station and verifying the operational capability of ground-based neutral beam facilities which simulate the space environment. One of the more important effects of these interactions is oxidation of material surfaces by atomic oxygen, a major constituent of the low-Earth orbital environment. Material interaction studies conducted during flights STS-5 and STS-8 have provided most of the current information regarding the reactivity of spacecraft materials to atomic oxygen, and the results of these studies indicate many materials such as organic films, polymers, and many composites react readily with atomic oxygen and have reactivities in the range 2.5×10^{-24} to 3.0×10^{-24} cubic centimeters per atom.

The data base provided by these, as well as those to be obtained on LDEF, will be limited in its application, however, because no information will be available which adequately explains the basic mechanisms responsible for atom/surface interactions. Another more serious limitation to this data base is that the total integrated atomic oxygen flux (fluence), derived for these flights and used to determine material interaction rates, must be estimated using thermospheric models to predict atomic oxygen number densities within the orbital environment. Typically, errors of ±25% or greater can be expected for these density estimations, and since they are used to compute fluence, these errors also appear in the surface recession rates for Space Station materials.

Experiment Description

To reslove many of these uncertainties in the data base, a flight experiment has been proposed for the space shuttle that utilizes an ion-neutral mass spectrometer to obtain in situ ambient density measurements and identify reaction products from modeled polymers exposed to the atomic oxygen environment. Using the ambient density measurements from the mass spectrometer along with material recession measurements obtained during the same exposure, accurate reaction rate data will be provided for future spacecraft performance assessment and design.

The mass spectrometer which will be provided by the Air Force Geophysical Laboratory (AFGL) and a mounting arrangement used to expose surfaces to ambient impingement will be mounted in the payload bay on an appropriate structure as shown in Figure 1. For the required exposure the Orbiter will be oriented with the -Z axis pointed into the velocity vector (payload bay in ram). This orientation will provide normal impingement on the exposed surfaces and, with the mass spectrometer entrance port aligned with the Z-axis, will provide for optimal ambient density measurements. A total exposure of 40 hours will be requested to provide significant recession and insure assessment of bulk material reactivity. Several ambient density measurements will be made during the 40-hour exposure.

In addition to the ambient density measurements, the mass spectrometer will also be used to measure products of reaction from atmospheric interaction with surfaces. For these measurements the mass spectrometer will rotate 90° relative to the Z-axis to sample gases evolved from several surfaces being exposed on a carrousel arrangement as shown in Figure 2. The carrousel will hold five surfaces which will be used to study the interaction mechanism and will be selected on the basis of information provided in that regard. One of the five surfaces may be a material which is known to produce glow such as Z-306 black paint.

To aid in providing the best ambient density and reaction product evolution measurements, the AFGL mass spectrometer will be calibrated using an atomic beam currently being developed at the Los Alamos National Laboratories. This beam generation concept is based on a laser heated plasma concept described in another paper of this meeting (see J. Cross, these proceedings) and should provide kinetic energies of up to 5 eV. Since the beam facility vacuum chamber is large, the flight mass spectrometer can be calibrated in situ and should allow a good understanding of transient processes inside the ion source. Furthermore, the beam facility will be used to characterize reaction products generated on the specific surfaces selected for inclusion on the flight experiment. This product distribution will be comparable with reaction products produced during flight to verify simulation fidelity and study reaction mechanisms.

This latter data should be of interest in glow mechanism studies, in that major constituents produced by ambient impingement will be identified and thereby provide a base of chemical species to consider for light production mechanisms.

Hardware development for the flight experiment is underway, and a late 1986 or early 1987 flight date will be requested from the STS. Funding for experiment development is being provided by Space Station and the Office of Aeronautics and Space Technology/NASA Headquarters.

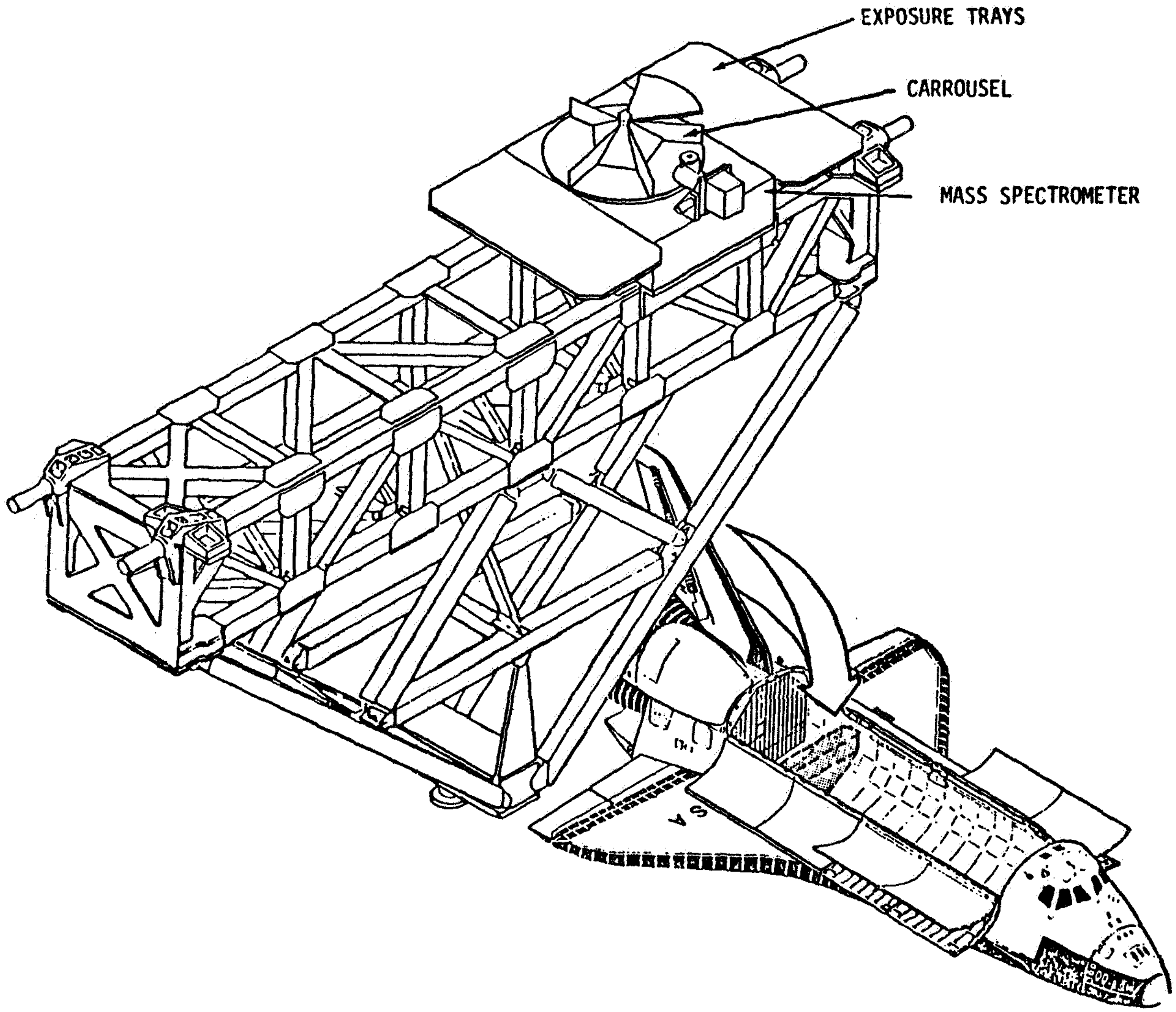

Fig. 1. Atomic oxygen experiment mounted on MPESS structure.

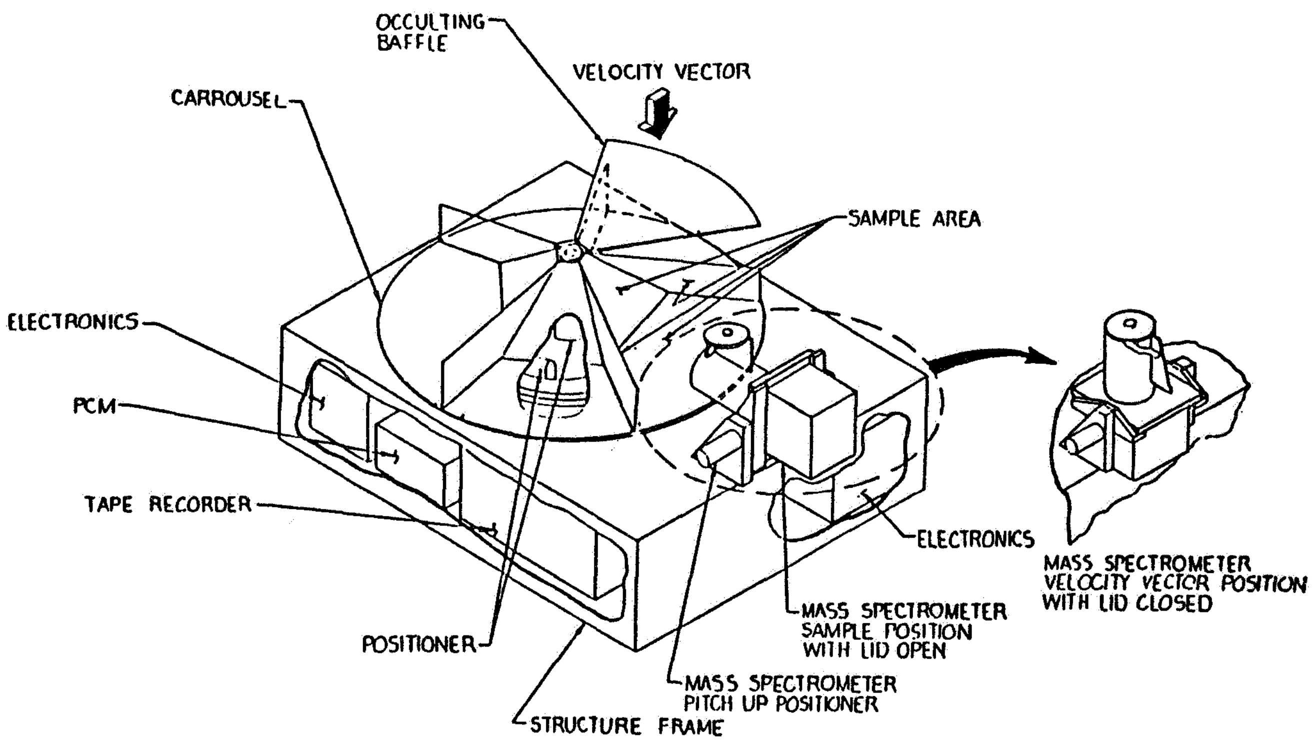

Fig. 2. Details of mass spectrometer carrousel arrangement.