DATA REQUIREMENTS FOR VERIFICATION OF RAM GLOW CHEMISTRY

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Abstract. A set of eleven questions has been posed regarding the surface chemistry producing the ram glow on the space shuttle. The questions surround verification of the chemical cycle involved in the physical processes leading to the glow. The questions, and a matrix of measurements required for most answers, are presented. The measurements include knowledge of the flux composition to and from a ram surface as well as spectroscopic signatures from the UV-visible-IR. A pallet set of experiments proposed to accomplish the measurements will be discussed. An interim experiment involving an available infrared instrument to be operated from the shuttle Orbiter cabin will also be discussed.

Introduction

Several papers in this report address the surface chemistry involved in production of the "red" ram glow associated with the space shuttle.

Questions to Address-Surface Ram Glow

The following is a set of questions that we have assembled which are aimed at further understanding and quantifying the glow processes. This set of questions is a general set that needs answers to further clarify and quantify the physical processes involved. First we address a set of questions for glow from a given material:

1. How does NO_2 material exit flux relate to the NO_2 continuum glow on the material?
2. How does NO material exit flux relate to NO beta, delta, and/or gamma band emission?
3. How does the NO_2 continuum glow extend into the infrared? Does it continue to drop as we observe between 7000 and 8000 Å?
4. Is the NO_2 "fine structure" superimposed on the continuum as it is in the laboratory spectrum?
5. Is there a component of N2 1PG, and if so, how does it extend into the IR?
6. How does 1-5 vary with material temperature (between ~250° and 400° K)?
7. How does 1-5 vary with NI and OI flux from the atmosphere? (i.e., How can we expect the glow to vary with altitude?)
8. How does 1-5 vary with ram angle to the sample surface?
9. Does O_2 become a production factor at low altitude as implied by the AE-C data?
10. How do different material surfaces influence 1-9 above?
11. How does the chemistry become enhanced/quenched with controlled injection of NO and other gases?

This set of questions addresses process verification and quantification for temperature and materials. The experimental approach is outlined below as to how many of these questions can be addressed.

Technical Approach-Experimental Method

The all-up matrix approach with the pallet instruments yields the ultimate in answers to the questions regarding the physical processes, but there are some intermediate experiments that can be assembled quickly which can answer some very important questions.

A portable CVF (Circular Variable Filter) instrument has been fabricated and is available as a candidate instrument to observe the IR component of glow from the Orbiter cabin. The aft flight deck window has reasonable transmission between 1.2 and 2.4 microns (~40%-variable). Figure 1 shows a mechanical configuration of the instrument, and Table 1 is a summary of the optical characteristics.

We herein describe a set of experiments which would answer many of the questions addressed above. This constitutes operating a set of instruments in the space shuttle bay which would monitor the flux of molecules impinging on and emanating from a surface in ram. At the same time, observations of the glow on the surface would be monitored in the UV, visible, and IR wavelengths. A glow mission would require a few orbits of dedicated attitude to perform the glow studies, at low-Earth orbit (~250 km). The instruments would be preprogramed to perform the experiment sequences during the glow attitudes. We have structured a set of instruments which can provide significant information on the processes. Some of the questions posed would require a quality, high-resolution visible spectrometer, as well as a high-resolution cryogenic IR instrument. In the spirit of "a step at a time" and low cost, we have structured an essential set of pallet instruments which can provide many important answers to key processes. A high-resolution visible spectrometer (~1 Å resolution) and a cryogenic IR instrument are desirable for follow-up studies as we now understand the chemistry. A basic set of experiments without these refinements is described herein.

The instruments we envision include a sample surface plate (~1 meter x 1 meter) which would be positioned in the pallet in such a way that the ram atmosphere could be directed towards it. An optical sensing stand would view the plate from nearly edge-on to take advantage of the near surface brightness emanating from the plate surface. The plate would be tipped up, and a mass spectrometer would view the plate from near 45° to plate normal. This set of instruments would constitute the main glow package (see Figure 2).

The plate would be coated with one material and on subsequent mission opportunities, other materials would be studied. The plate would ideally have provision for heating electrically so the plate temperature could be elevated to near 400° K. It is possible to make a plate which could rotate to subject two-three different surfaces to ram during a mission, but our initial consideration is to have a single surface. The plate would contain a baffle on the down viewing side of the optical package, such that a black background would be provided to the glow viewing instruments.

The optical package will include three instruments which will document glow from the UV to the IR. The instruments are summarized in Table 2. Instrument 1 will be an automated version of the hand-held instrument which has flown as a locker experiment in the Orbiter. This instrument will operate in an imaging mode, as well as a spectrometer mode, to clarify the glow in the 4000-8000 Å wavelength region. This instrument will document the spatial distributions of the glow and provide the bridge of measurement to the early data set. Instrument 2 will be the UV instrument to clarify NO band emission (as well as any presently unknown UV emissions). Filters for the known NO band emissions between 2000 and 4000 Å will be included. The instrument will consist of a UV imager bore-sighted with an f5, 1/8th meter spectrometer. The spectrometer would scan from 2000-4000 Å while the imager documents the spatial distributions of the UV glow. Instrument 3 will consist of a thermal, electrically cooled PbS detector to cover the IR wavelengths between 1 and 3+ microns. The IR shape of the NO_2 continuum and possibly other glowing candidates would be measured with this instrument.

A mass spectrometer of the type which is designed to examine the entrance and exit flux of NI, OI, NO, and NO_2 from the surface plate will be located separately from the optical instruments. This instrument is essential to document the constituent phenomena associated with the chemical processes. The instrument herein is one very different from the AE instrument in that the requirement is to make the measurement of ambient NO and NO_2 emanating from the plate. In order to accomplish this, the instrument must be of a type where the molecules are ionized external to an instrument orifice before any wall collisions have occurred. Next, this produced beam would be focused and mass-analyzed as in a conventional mass spectrometer. The instrument would be an orifice-pumped instrument with a mechanical flag in the orifice. The pumping is necessary to minimize orifice collisions in the high-density shuttle environment. The mechanical flag allows a degree of direction control of the sampling beam. The flag would alternately direct molecules from a surface sample plate and from the atmosphere to be sampled by the instrument.

The above surface plate, optical cannister, and mass spectrometer are all essential to a basic pallet payload. A matrix of problems versus instruments has been produced (see Table 3). For most of the questions at hand, several instruments are desired. Model atmospheres can be used with some reliability for the atmospheric flux to the spacecraft, but the measurement with the mass spectrometer is best. Only the mass spectrometer can resolve what is coming off the plate in the way of mass species.

We are also giving consideration to gas release cannisters which, when released, would be located such that the drift cloud would pass over the plate. It has been noted that the thruster effluent acts to enhance the stand-off ram glow significantly for several seconds when impinging on a ram Orbiter surface. The thruster gas consists of significant amounts of NO, which we believe adds to the surface monolayer of NO. This additional source of NO seems to deplete in less than 1 minute in ram. Gas cannisters with NO and other gases which in fact would act to quench the process would be considered. The gas cannisters could be relatively small in size and of the single release type.

We suggest that the "shuttle hitchhiker" concept be a candidate facility within which experiments could be structured. The "hitchhiker" offers a simple interface and minimal delivery time before mission execution. At the same time, it appears to offer command and data handling capabilities which are adequate for the required measurements.

Summary

There are a number of questions which need to be answered to further understand the physical and chemical processes involved in ram glow. The basic questions are scientifically important to understanding the interaction of the atmosphere with the fast moving spacecraft. The questions are well suited to be explored with well known, state-of-the-art instrumentation which can be implemented into a shuttle pallet payload for experiment implementation. the exciting results will be scientifically interesting in themselves since low-energy neutral beams of 5-10 eV are difficult to implement in the laboratory with significant flux levels. The experiments will also yield useful information regarding potential background contamination for planned and future experiments. Through understanding the physical processes, we can understand how to engineer our instrumentation and plan our operations of space optical instrumentation with minimal signal degradation.

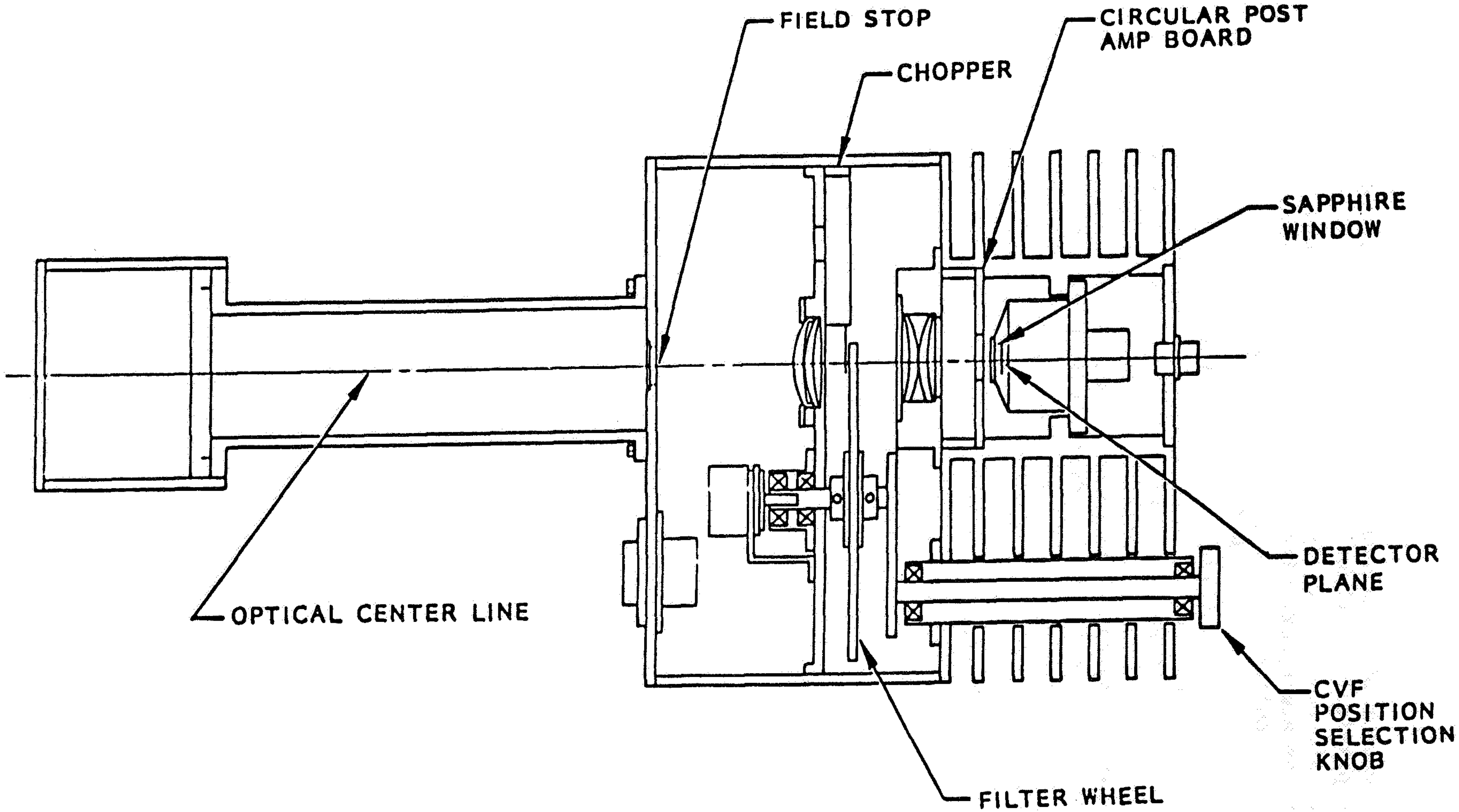

Fig. 1. A cross section of the Circular Variable Filter (CVF) instrument for infrared detection of the spacecraft glow. The instrument contains a five-element lens set defining a 2 degree FOV. The circular variable filter scans from 1.3 to 3.2 microns. The detector is a PbS material, 4 mm sq., thermal electrically cooled to 193° K. Detector and window temperatures are recorded as well as detector signal and wavelength position during instrument's operation.

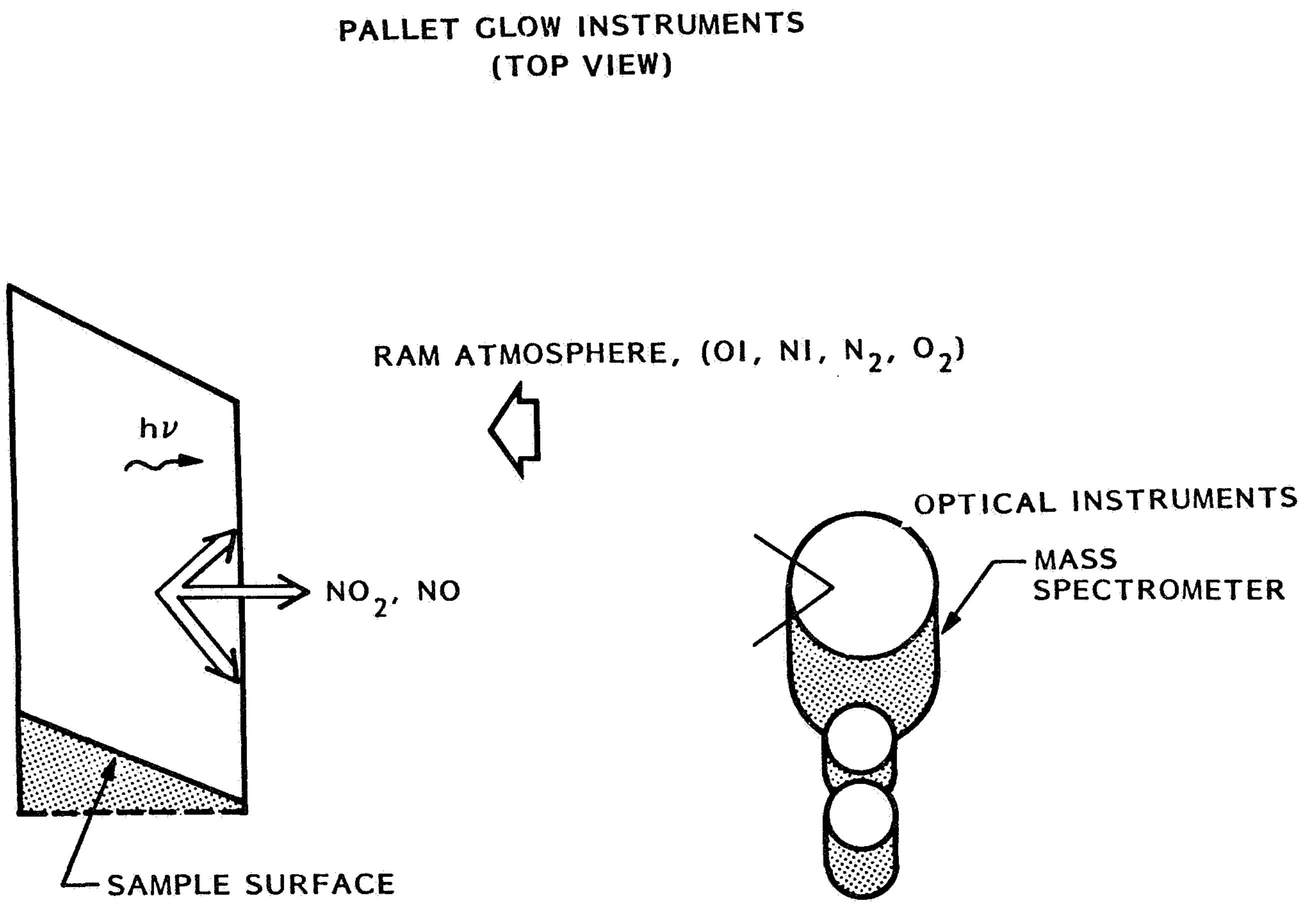

Fig. 2. A schematic representing the pallet-based instruments viewing molecules and glow emanating from a sample surface.

TABLE 1. OPTICAL CHARACTERISTICS OF THE CVF SPECTROPHOTOMETER

PORTABLE INFRARED SPECTROPHOTOMETER [CVF]

* FIELD-OF-VIEW - 2 degress (full)

* WAVELENGTH RESOLUTION - Bandwidth <3% tuned wavelength

* SPECTRAL RANGE - 1.3 to 3.2 microns per scan + shutter
  [reasonable aft window transmission 1.2-2.4 microns]

  - Broadband mode - use SC window as filter

* SENSITIVITY - 80 Rayleighs/Angstrom for 1-second integration
  [detector = 4 x 4 mm, PbS, TE cooled to <200 kelvin]

* POWER - ~17 watts (measured)

* VOLUME - Optical system: L = 35 cm, Width = 12.5 cm
  Electronics: L = 20 cm, Width = 20 cm, Ht. = 20 cm

* DATA AND CONTROL - TRS 80 + recorder

TABLE 2. A SUMMARY OF A CANDIDATE SET OF PALLET INSTRUMENTS SUITABLE FOR STUDY OF SPACECRAFT RAM GLOW

PALLET GLOW INSTRUMENTATION

#1 RED BROADBAND IMAGING SPECTROPHOTOMETER
* 20 degree FOV
* 4000-8000 Angstroms
* Resolution 30 Angstroms
* Imaging or spectrometer mode

#2 UV BROADBAND IMAGING SPECTROPHOTOMETER
* 20 degree FOV
* 2000-4000 Angstroms
* Resolution 30 Angstroms
* Imaging and spectrometer mode

#3 IR CVF SPECTROPHOTOMETER
* 2 degrees FOV
* Spectral range 0.8-3.0 microns
* Resolution 3%

#4 MASS SPECTROMETER (OPEN SOURCE)
* 2 degrees FOV
* Flag directed beam (10 degree deflection)
  (monitor source flux and background)
* Pumped orifice

TABLE 3. A MATRIX OF QUESTIONS VERSUS INSTRUMENTS REQUIRED TO PROVIDE ANSWERS TO THE QUESTIONS IN A GLOW EXPERIMENT SCENARIO

MATIX OF CURRENT PROBLEMS VS. PROPOSED INSTRUMENT

Instrument # / Problem #	1 Im & Sp	2 Im & Sp	3 IR-CVF	4 Mass Spect.	5 (Future Release
1. NO_2 flux versus NO_2 glow?	X		*	X	
2. NO flux versus NO glow?		X		X	
3. NO_2 extend to IR?	*		X		
4. NO_2 fine structure?	*				
5. N_2 1PG superimposed?	*		X		
6. 1-5 vary with temperature?	X	X	X	X	
7. 1-5 vary with NI and OI flux?	X	X	X	X	
8. 1-5 vary with ram angle?	X	X	X	X	
9. 02 at low altitude?	X	X	*	*	
10. Other materials response?	X	X	X	X	
11. Constituent enhance/quenching?	X	*	*	*	X

X - Major instrument
* - Contributing instrument