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Note: Figures are available in GIF format in this directory. Files have the naming convention FIGxx.GIF, where xx is the figure number.

The following text has been extracted from:

Grebowsky, J. M., W. T. Kasprzak, R. E. Hartle, K. K. Mahajan, T. C. G. Wagner, "Superthermal ions detected in Venus' dayside ionosheath, ionopause, and magnetic barrier regions", J. Geophys. Res., vol 98, No. E5, pg 9055-9064, 1993.

Appendix: Response of OIMS to Superthermal Ions (pg 9062-9064).

The text has been included as part of the documentation accompanying the PVO-OIMS data in order to fulfill a requirement imposed during the PDS peer review process. The text is the appendix from the document list above. This appendix is titled 'Response of OIMS to Superthermal Ions'. According to Grebowsky et al (1993), the response of the OIMS instrument to superthermal ions is as follows:

> The Pioneer Venus Orbiter Ion Mass Spectrometer (OIMS) [Taylor et al., 1981] was designed to measure cold ionospheric plasma at Venus. When ambient ions exist with energies comparable to or exceeding those of cold ions in the frame of reference of the spacecraft, which travels at ~10 km/s, the spectrometer can often detect their presence. These 'superthermal' ions are detected as ion currents at instrument mass settings for cold ion species that are clearly not present in the environment. The energies of the superthermal ions collected could be due to thermal plasma motions and/or high bulk flow speeds (perhaps just a segment of the tail of the ion velocity distribution).
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> The basic mode of operation of the instrument (a Bennett RF ion mass spectrometer) is well understood, leading from its original conception by Bennett [1950]. Figure A1 is a schematic diagram of the sensor tube. The spacing of the grids and the frequency of the RF voltage signal that is applied simultaneously across each grid set establishes a 'resonant velocity' that an incoming ion must have to traverse the tube, from entrance to collector, and to acquire the maximum kinetic energy from the RF E field accelerations. An ion in traversing one RF grid set is accelerated to a velocity which sets its time of flight through the E-field free drift space region to the next grid set. Those ions with the resonant velocity in the drift space reach the entrance to the next RF grid set at precisely the right phase of the RF potential for further acceleration.

Nonresonant ions arrive at the RF grids at non optimal phases and do not receive the maximal acceleration. In front of the current collector plate a retarding potential VS is applied to allow only the resonantly accelerated ions to pass to the collector.

The RF frequency is the parameter which sets the precise speed which an incoming ion must have at the entrance to the first grid set to be in resonance with the subsequent RF field accelerations. This frequency and hence the resonant ion speed is held fixed in the OIMS. The acceleration voltage drop, Va, applied at the entrance to the spectrometer is varied to accelerate different incoming ion mass species to the resonance velocity; this provides the ion mass discrimination. Ions which are accelerated by the potential drop Va to speeds near multiples of the RF resonant velocity will receive partial acceleration in the RF sections. This 'harmonic' ion acceleration in the spectrometer can result in an anomalous collection current signal which could not be distinguished from that collected from the desired resonance mass. For typical ionospheric ions which have thermal energies less than 1 eV and enter the spectrometer at the PVO 10 km/s velocity, the OIMS nominal voltages were designed to prevent the harmonic ions from being collected. This was only effective, however, for relatively cold (<1 eV) ion species and not superthermal ions.

To minimize the telemetry data rate, the OIMS was designed to sample 16 discrete amu's rather than to sweep continuously through all masses. The accelerating Va potential drop at the spectrometer entrance was stepped through 16 discrete values for the nominal collection of thermal ionospheric species that were likely to be present at Venus. The retarding potential Vs on the grid before the collector plate was similarly stepped to maintain a set current collection efficiency for each amu. Since the instrument selects an ion species by using the Va to bring it to the resonant speed of the tube and because the transmission through the retarding potential grid depends on incoming particle energy, the instrument's amu response depends upon the net energy of the ions entering the spectrometer. That is, the analyzer section does not know whether the drift energy is from the Va acceleration or from ambient plasma flow. Spacecraft electrical potential and ambient plasma drift energy have the same impact on the OIMS resonance response as do Va and Vs changes.

To compensate for variations in the incoming ambient plasma energies, the Va and Vs potentials were servoed in tandem [Taylor et al., 1980a] starting from their expected cold plasma values for each amu channel. The servo logic was to seek and lock the instrument potentials for each amu sample at those values for a prefixed collection efficiency (i.e., the percentage of incoming ion flux that reaches the collector). The response time of the servo was designed to be rapid enough that it would fully adjust to anticipated variations in plasma ram energies along the spacecraft orbit. The rate of adjustment was engineered to vary proportionally to the magnitude of the collected ion current, so that in low plasma density regimes sudden changes in incoming ion energy would require a longer time for the instrument to adjust to its proper efficiency operating point than in high density regions. This time scale was of the order of minutes for the lowest measurable ion concentration regions.

Within the main body of Venus' ionosphere the servo compensation led to reliable ambient ion concentration measurements, but near the boundary of the ionosphere two features of the instrument's operation led to anomalous and yet useful responses to ambient plasma components that it wasn't

Fig. A1. Schematic diagram of the OIMS analyzer structure.

directly designed to study. First, in order to maximize the sensitivity of the instrument in low density plasma regimes the instrument voltages were automatically set more than 10 v away from the fixed servo point in regions when no, or just trace amounts of, detectable ions were present. This ensured the highest collection efficiency possible when ion concentrations increased to just measurable levels. As a result, at the inbound ionopause crossing the spectrometer was 'offtune.' The servo voltages converged toward the desired values as the ionospheric density increased; but as the response time was of the order of minutes, they did not settle at the designed operating point until the spacecraft entered into the ionosphere. Once it attained its designed operating point it remained 'tuned' to these voltages until the spacecraft left the ionosphere and encountered only trace ion concentrations. Second, the servo response was not designed to compensate for coexistent ion species with differing flow velocities. In a region with one species of cold ambient ions and a minor ion population of superthermal ions with the same atomic mass, the instrument voltages lock onto the desired operating point for the cold species most rapidly. As the instrument voltages step for amu scans, the voltages for each mass species are automatically preset prior to servoing at values consistent with the energy of that amu flowing into the instrument with spacecraft speed and these settings do not change in the short time between the cyclic scanning of all masses. Ions with energies exceeding the spacecraft speed may be detected with misidentified masses since their incoming energies effectively add to the electrical potential energies set in the spectrometer with the internal voltages alone used to identify the resonant mass.

The response of the OIMS to offsets in the operating voltages and/or the presence of superthermal O+ ions in the midst of a cold thermal O+ component is demonstrated in Figure A2. The top shows the computed response to superthermal O+ ions when the spectrometer is completely outside the ionosphere. Superthermal oxygen ions could appear in the 24 and 40 amu windows even in the absence of thermal ambient ions with these masses. They would also contribute to the current collected at the 16 amu setting, but for most energies the efficiency of collection would be less than that for the collection of cold incoming O+ ions to which the plotted efficiencies are normalized. The bottom part of the figure shows a similar calculation for superthermal protons which also are detectable by the appearance of anomalous mass signatures. Superthermal O+ ions with ambient energies exceeding 30 and 46 eV can, if their fluxes are large enough, produce current contributions in the 24 and 40 amu windows respectively. The protons are detectable in the same mass windows with higher energy thresholds. The upper limit of the instrument's capability to resolve any amu is 100 eV, which includes the spacecraft ram energy. The responses plotted in Figure A2 were computed assuming the internal voltages were set for a measurement outside of the ionosphere, where instrument voltages were intentionally offset from their desired ionosphere operating values by the order of 10-20 v depending on the mass setting. Once the spacecraft enters into the ionosphere, this voltage offset is eliminated, although somewhat slowly, by the servo mechanism. The instrument thereafter remains tuned to such optimal voltages until it exits the ionosphere and encounters only trace concentrations. The difference in response in the bulk of the ionosphere transit and outside the ionosphere is depicted in Figure A3, where the response of the 14 amu signal to superthermal O+ is shown. This calculation shows that even cold 16 amu ions collected at the spacecraft speed could produce a signal in the 14 amu window in the low density regime outside of the ionosphere. Inside the ionosphere the threshold for the detection of superthermals as 24 or 40 amu signals would be raised by 20 eV, a slightly higher change than is the case for the 14 amu signature.

Fig. A2 Effects of superthermal O+ (top) and H+ (bottom) ions on the OIMS response. The figures reflect the efficiency of collection in the mass positions of 16, 24, and 40 amu, as was numerically modeled by calculating O+ motions through the DC and RF grid voltage layout of the instrument. Effectively, normalized efficiencies which drop below the 0.001 level are undetectable. The efficiencies are normalized to the instrument efficiency of collection for cold O+ ions flowing at PV's ionosphere speed, which is ~1%.

Fig. A3. Response of the 14 amu signal computed as a function of O+ energy into the spectrometer. Inside the ionosphere and on the outbound transit through the ionopause 16 amu ions require speeds exceeding the spacecraft speed entrance velocity to appear as 14 amu signals. Outside the ionosphere due to the intentional offset of the instrument voltages, and in the inbound crossing of the ionopause where the instrument slowly servos to optimum operating voltages, even cold ionospheric O+ ions would cause such a spurious signal.

References cited in appendix.

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