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ROCKET MEASUREMENTS OF MESOSPHERIC AND LOWER THERMOSPHERIC COMPOSITION

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Measurements of the major and some of the minor neutral atmospheric species have been obtained from six rocket flights in the 65—120 km altitude region. The instruments were launched on 7 March 1970 (solar eclipse), 20 November 1970 ($\chi = 98°$), 5 October 1971 ($\chi = 90°$ and $\chi = 115°$), and 12 April 1972 (2000 and 2016 LST). The instrument used to obtain these measurements is a recently developed RF quadrupole mass spectrometer which employs a liquid nitrogen cooled cryosorption pump. The species measured include N_2, O, O_2, Ar, CO_2, O_3, and other minor constituents. The instrument uses two ionizing energies on alternate one-second spectral scans. The lower ionizing energy of about 20 eV allows extension of the atomic oxygen measurement down to about 85 km. Profiles of the individual constituents obtained from the 20 November flight are presented and comparison is made with the results of one of the flights on 5 October 1971. The individual atomic oxygen profiles exhibit variations in the 85—120 km region which show strong effects from dynamic and transport processes in this region.

1. Description of the Experiment

The experiment, referred to as NACS (Neutral Atmospheric Composition Spectrometer) is a quadrupole analyzer utilizing rods of 0.381 cm diameter and 7.6 cm length (Fig. 1). The ion source is mounted directly below the entrance orifice plate which also serves as the anode for the ion source. The filament and accelerator electrode are cylindrically symmetrical. The objective of this design is to provide a high density of ionizing electrons in the region where the gas sample effuses through the orifice. This configuration enhances the signal for the incoming sample and minimizes the background signal from unpumped gases in the instrument and/or from particles reflected in the ion source region. Since several species of interest are chemically reactive, reflected particles may not give a true measure of the atmospheric species. Another advantage of this type of source is that its symmetry minimizes effects associated with the vehicle motion. The electron ionizing energy was switched between two values on alternate mass spectra. This capability allows a better measurement of some of the species (particularly atomic oxygen) because the fraction of molecules which are dissociatively ionized in the ion source is considerably less for 20 eV ionizing electrons than for 100 eV ionizing electrons (less than 0.5% for 20 eV electrons compared with about 10% for 100 eV electrons).

The cryosorption pump removes the incoming gas flux and maintains a low background pressure in the region of the analyzer. The cryosorption pump was made by bonding a 5 Å molecular sieve onto aluminum plates which have been

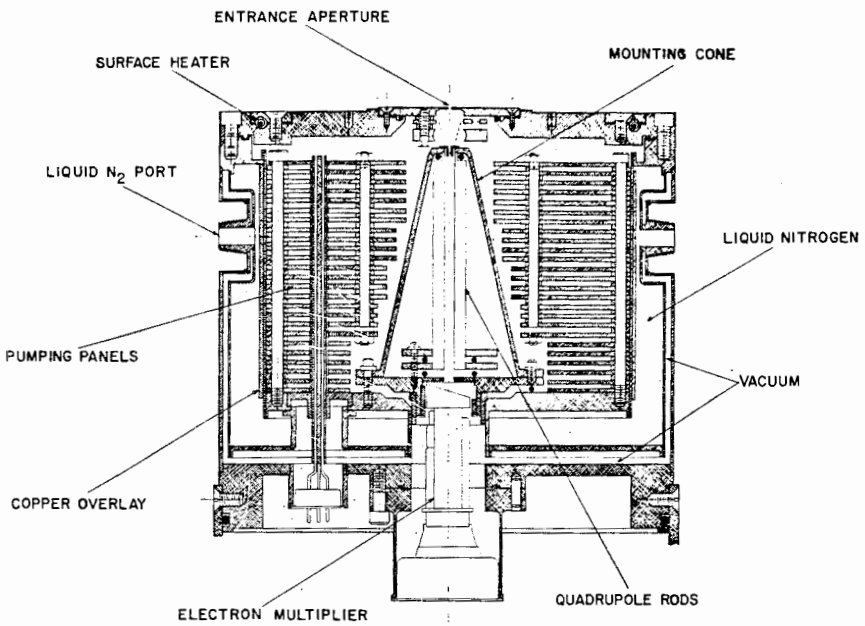

Fig. 1. Schematic drawing of the NACS instrument.

cross-mill grooved. These plates are sandwiched into a dewar which is cooled with liquid nitrogen. High pumping speeds are obtained for most atmospheric species (about 100 liter s^{-1} for nitrogen). The gas capacity of the pump is many times greater than the gas load presented in a single rocket flight. The holding time after removal of liquid nitrogen is considerably longer than the typical 6-minute rocket flight.

2. Flight Data and Results

The results presented were obtained by the following procedure. The current for each mass of interest was divided by the N_2 current in that spectrum. When the nitrogen mass peak was off scale, its value was obtained by taking the proper ratio of the 14-amu peak which comes from dissociative ionization of N_2. The current ratio was then divided by the ratio of ionization cross sections of the mass of interest and molecular nitrogen. The laboratory calibrations had shown that the only measurable mass discrimination in this instrument was due to the differences in ionization cross sections.

Fig. 2 shows the ratio of the currents measured at the 16 and 32 amu peaks as a function of altitude. The advantage of using two electron ionization energies is apparent in this figure. The background level due to dissociative ionization of molecular oxygen is considerably less for the lower ionizing energy and allows the atomic oxygen profile to be extended to significantly lower altitude. The higher ionization energy is used to determine the atomic oxygen density for the upper part of the profile and the curve for the lower ionization energy is normalized to it.

Altitude profiles for several of the constituents measured on 20 November 1970 are shown in Fig. 3. The mass density, measured by Theon and Horvath [1], was used to determine the species densities from the current ratios of each of the species to molecular nitrogen, the ionization cross section, and the mean molecular mass determined from the mass spectrometer measurement. The ionization cross sections used for N_2, O_2, Ar, and CO_2 were those of Rapp and Golden [2]

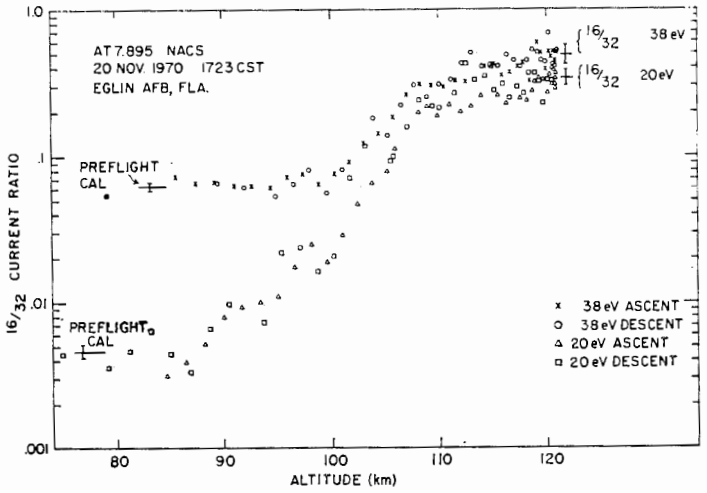

Fig. 2. Current ratio of the 16 to 32 amu peaks for two ionizing energies for 20 November 1970 flight.

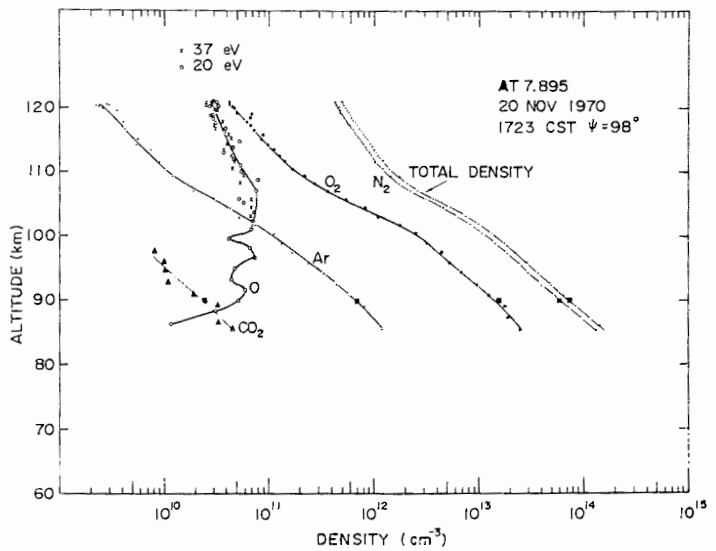

Fig. 3. Altitude profiles for major constituents measured on the 20 November 1970 flight.

and the O cross section used was from the work of Fite and Brackmann [3]. A background signal from residual gas which entered at low altitude was removed from the O_2 and Ar signals. The vehicle developed a very large coning angle which caused large modulations of the incoming gas flux. This modulation was used to remove the background signals of the residual gas. The modulation of the N_2 signal agreed well with that expected for the $F(s)$ sampling function. The departure of the O_2 and Ar signal modulation from that expected from the sampling theory was used to determine the magnitude of the background signal. At the 90 km level, the squares shown represent the ground level mixing ratios of each of the constituents. The N_2, O_2, Ar, and CO_2 measurements agree well with the ground level concentrations at lower altitudes. The O profile shows very complicated structure with a peak density slightly less than 10^{11} cm^{-3} in the vicinity of 107 km. The structure in the atomic oxygen profile was observed on both the ascent and descent portions of the flight. Turbulent layers were observed on chemical trails up to an altitude of 112 km during the same time period as this measurement. A comparison of this result with a theoretical calculation exhibits a similar profile with even an indication of the structure in the O profile presented here [4].

In Fig. 4 the measured ratio of the Ar/N_2 densities is shown as a function of altitude. Because of the scatter in the data when this ratio is determined, the curves shown follow the limits on the experimental points. The ratio indicates a mixed atmosphere to an altitude in the vicinity of 105 — 110 km. Chemical trail measurements showed turbulent and laminar layers up to 112 km.

In Fig. 5, the N_2 and O profiles from the flight on 20 November 1970 are compared with a measurement on 5 October 1971. A large difference in the atomic oxygen profile shape and density between the two flights was observed. The

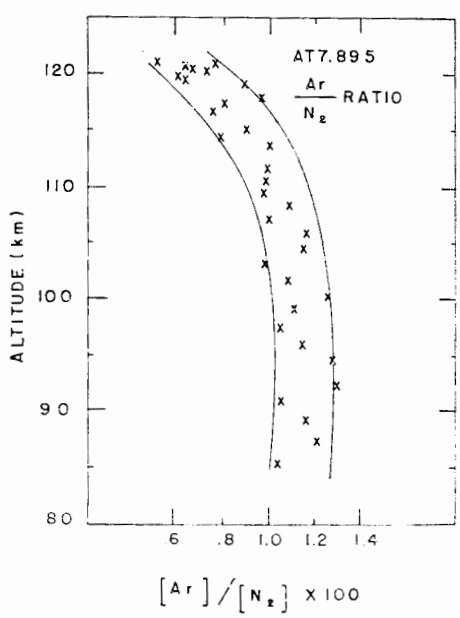

Fig. 4. Measured Ar/N_2 density ratio for the 20 November 1970 flight.

5 October 1971 flight shows an atomic oxygen profile more typical of that expected for a lower altitude turbopause. The measurements show that large variations in the atomic oxygen profile do occur and that atmospheric dynamics is quite important in establishing the atomic oxygen profile. The theoretical predictions of Keneshea and Zimmerman [5] agree well with these measurements.

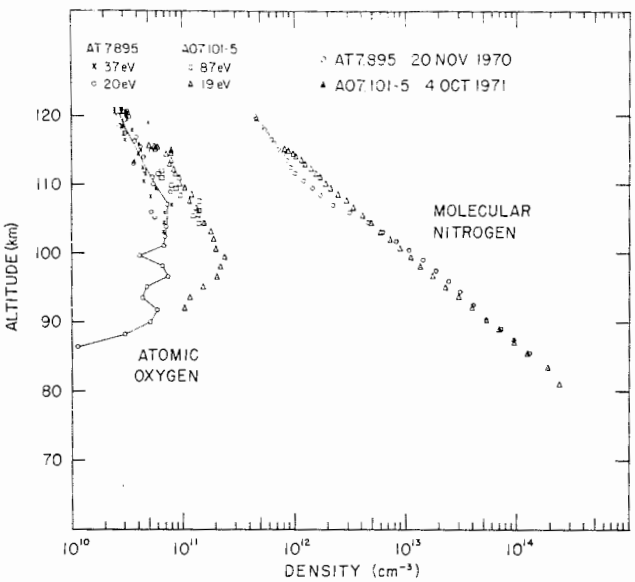

Fig. 5. Comparison of the O and N_2 profiles for flights on 20 November 1970 and 5 October 1971.

The atomic oxygen measurements should be regarded as a lower limit at the present time. Wind tunnel simulations and further measurements of atomic oxygen should clarify its actual density in this region.

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