NASA TECHNICAL NOTE

NASA TN D-5447

c. 1

NASA TN D-5447

ATMOSPHERIC DENSITIES MEASURED BY THE EXPLORER 17 DENSITY GAUGES: ANALYSIS OF ERRORS AND THEIR EFFECTS UPON THE MEASUREMENTS

by George P. Newton and Richard Horowitz

Goddard Space Flight Center
Greenbelt, Md.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION • WASHINGTON, D. C. • NOVEMBER 1969

ATMOSPHERIC DENSITIES MEASURED BY THE EXPLORER 17 DENSITY GAUGES: ANALYSIS OF ERRORS AND THEIR EFFECTS UPON THE MEASUREMENTS

By George P. Newton and Richard Horowitz

Goddard Space Flight Center
Greenbelt, Md.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

For sale by the Clearinghouse for Federal Scientific and Technical Information
Springfield, Virginia 22151 – Price $3.00

ABSTRACT

The atmospheric total density data from the Explorer 17 Atmospheric Density Experiment are presented. The equations used for interpretation of the gauge output currents in terms of atmospheric density are derived. Possible systematic error due to gauge calibration, energetic gas beam-surface interaction, adsorption-desorption effects, chemical compound production, and gauge nonlinearity are evaluated; and it is concluded that the previously reported density values should be increased by 35 percent. The effects of variations in atmospheric composition on the density values are as follows: If an atmosphere of 100% atomic oxygen was assumed, but the atmosphere was really 100% helium, the density values should be increased by a factor of 1.6. Correspondingly, if the atmosphere was really 100% molecular nitrogen, the density values should be decreased by a factor of 0.72.

CONTENTS

ATMOSPHERIC DENSITIES MEASURED BY THE EXPLORER 17 DENSITY GAUGES: ANALYSIS OF ERRORS AND THEIR EFFECTS UPON THE MEASUREMENTS

by

George P. Newton and Richard Horowitz

Goddard Space Flight Center

INTRODUCTION

The total atmospheric density experiment was one of three aeronomy experiments carried on the Explorer 17 aeronomy satellite. The satellite was launched on 2 April 1963 into an orbit with a 58 degree inclination, a perigee altitude of 256 km and an initial apogee altitude of 920 km. Its active lifetime was 100 days. The satellite and its instrumentation are described elsewhere (Horowitz, 1963; Spencer, 1965).

The sensors used for the density measurements were a modified Bayard-Alpert and two modified Redhead magnetron cold cathode ionization gauges. Each type of sensor is shown in cross section in Figures 1 and 2. The electronic instrumentation, preflight calibration and processing, and orbital operation of these gauges are described in previous publications (Newton et al., 1963; Newton et al., 1965; Pelz and Newton, 1967).

Data were recorded in real time for 4 minute intervals by the minitrack ground stations listed in Table 1. Conclusions drawn from the total atmospheric density experiment data have been

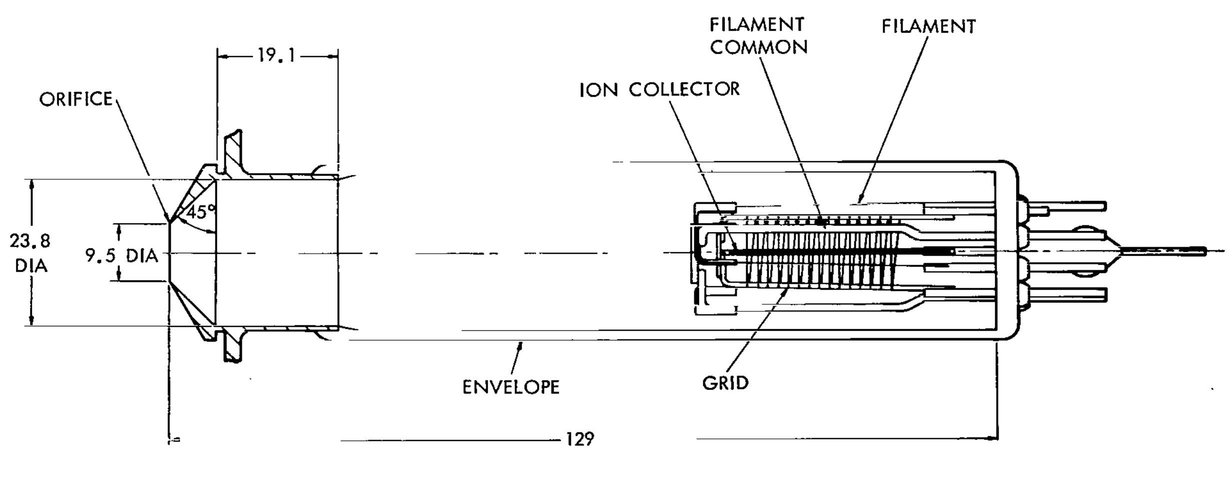

Figure 1—Cross-section of Bayard-Alpert flight gauge. All dimensions are in millimeters.

reported previously (Newton et al., 1963; Newton et al., 1964; Newton et al., 1965; Newton, 1967). The present report presents the data; gives the theory used to interpret the measured data in terms of atmospheric densities; and evaluates some possible systematic errors in the density values not previously discussed in detail.

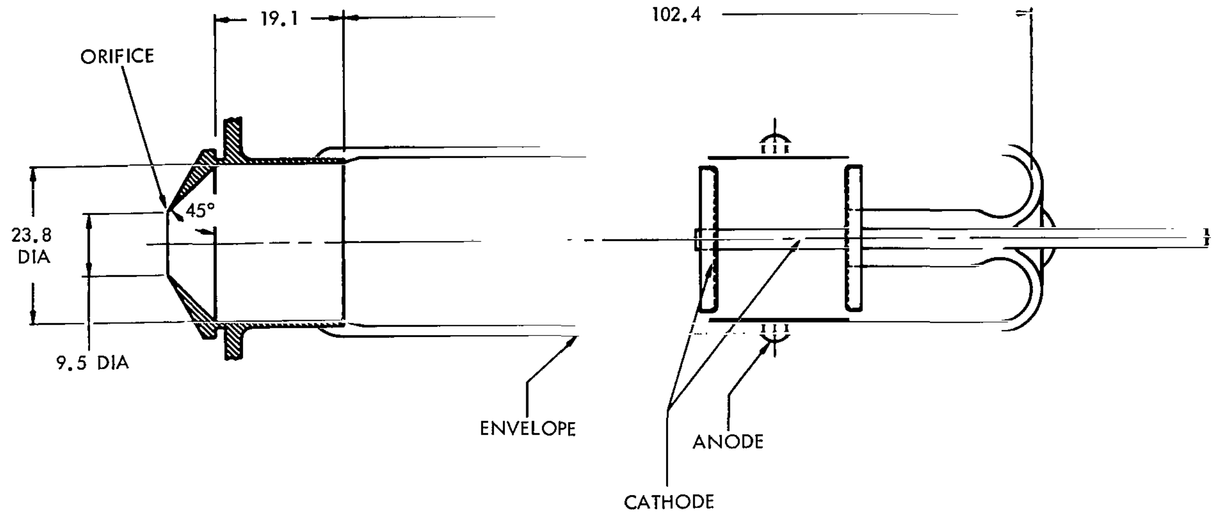

Figure 2—Cross-section of Redhead flight gauge. All dimensions are in millimeters.

Table 1

Minitrack Ground Station Locations.

Station	Geographic Latitude	Geographic Longitude
College, Alaska, USA	64°N	212°E
Winkfield, England	51°N	359°E
Grand Forks, Minnesota, USA	48°N	262°E
Saint Johns, Newfoundland	47°N	307°E
Blossom Point, Maryland, USA	38°N	283°E
Mojave, California, USA	35°N	243°E
Fort Myers, Florida, USA	27°N	278°E
Quito, Equador	1°S	281°E
Johannesburg, South Africa	26°S	28°E
Woomera, Australia	31°S	137°E
Santiago, Chile	33°S	289°E

MEASUREMENT TECHNIQUE AND INTERPRETATION

The techniques used for making density measurements with manometers in rockets (Schultz et al., 1948; Havens et al., 1952; Horowitz and Kleitman, 1953) were applied to the Explorer 17 density measurements. The theory used to interpret the gauge output currents in terms of atmospheric densities is presented in the Appendix A. This theory takes into consideration the presence of more than one gas species in the atmosphere, the nonlinearity of the cold-cathode gauges and the composition sensitivity of the gauges. Also discussed in the Appendix A are examples of the effects of variations in composition, both in the atmosphere and within the gauge enclosure, upon the measured densities.

SOURCES OF SYSTEMATIC ERROR

The precision of the data and the effects of absolute calibration errors, uncertainty in the gas composition of the atmosphere, satellite attitude and velocity uncertainties, and satellite position uncertainties on data accuracy were discussed in an earlier report (Newton et al., 1965). The effect of the recombination of atomic oxygen inside the gauges was also evaluated (Newton et al., 1965). It is possible that additional uncertainties in the density values, not previously evaluated in detail, could be generated by one or more of the following sources:

(1) The calibration error which arises from insertion of a cold trap between the McLeod gauge and the calibration system (Ishii and Nakayama, 1962; Meinke and Reich, 1963)

(2) The interaction of the atmospheric gas beam generated by satellite motion with the internal geometry of the gauges (Newton et al., 1968)

(3) The adsorption and desorption of gas by the gauge internal surfaces (Moe 1966; Moe and Moe, 1968)

(4) The production of chemical compounds within the gauges (Von Zahn, 1967)

(5) The errors which result from the assignment of equivalent constant sensitivities to the nonlinear gauges

The effect of the calibration error (1) has recently been evaluated by comparing our secondary nitrogen calibration standards with two nitrogen calibrations obtained by techniques independent of the McLeod gauge and its attendant problems.* The results of this comparison indicate a systematic 20 percent error in our calibrations. This error is consistent in magnitude with the estimated error of the "Ishii effect" (Ishii and Nakayama, 1962) for our calibration geometry and is in the same direction. Accepting this systematic error results in a systematic increase in our density values by 20 percent.

*These calibrations were kindly provided by Mr. F. Kern of LRC and Mr. W. Fulton of MSFC. Both used a measured gas flow technique. The results of their calibrations are believed to be accurate to better than 90 percent, with an expected error of ±5 percent for pressures above 10^{-8} Torr.

The effect of the interaction error (2) has also been investigated (Newton et al., 1968); according to preliminary conclusions, if there were no specular collisions and no adsorption of the gas in the gauges, the atmospheric density values would be decreased by approximately 10 to 22 percent, depending on angle of attack. The mean effect of this on the Explorer 17 results, obtained by averaging over all angles of attack, is to decrease the density by approximately 13 percent.

The adsorption-desorption effect (3) has been investigated by Moe and Moe (1968) and by Newton et al., (1968). Moe and Moe conclude that adsorption-desorption effects could cause the gauge-measured atmospheric density to be underestimated by 34 percent. Their theory assumes that a complete adsorption-desorption cycle occurs during each satellite spin cycle. However, the minimum pressures observed by the gauges during each spin cycle are different for increasing and decreasing altitude passes. This indicates that the adsorption-desorption process is not fully completed during each spin cycle, but has at least some component with a characteristic time of the order of an orbit period. The impact of this on the results of the Moe theory is not known to the authors.

Newton et al., (1968) considered the combined effects (2) and (3). Their results, for an adsorption probability of 0.003, which is close to that used by Moe and Moe (1968), lead to similar conclusions regarding the effect on the density values. However, the desorption phenomenon was ignored in the calculations of Newton et al. Recent analysis using Explorer 32 gauge data (Silverman and Newton, in preparation) of the spin cycle minimum pressure, considering variations over time intervals comparable to orbital periods, indicates that the adsorption probability should be smaller than 0.003 by approximately a factor of four. This would result in a decrease of the previously calculated error in the density values due to effects (2) and (3). The questions of the actual effects of and associated density errors due to considerations (2) and (3) must remain open at this time, since the actual condition of the gauge internal surfaces and the results of collisions of entering atmospheric particles with those surfaces are still unknown. However, regardless of these unknowns, it appears at this time that the maximum possible error due to effects (2) and (3) is approximately +35 percent and that the actual error probably is much less than 35 percent.

Production of chemical compounds within the gauges (4) is not believed to be significant. Our laboratory experience with the gauges in molecular oxygen indicate that CO and CO_2 production by the gauges is negligible. However, if the phenomenon of atomic oxygen entering the gauge and being converted on a one-to-one basis to CO were to occur, then the effect upon the atmospheric density values would be to decrease them (as can be seen from Equation A14 of the Appendix). This is because the effect of the mass increase of the gas inside the gauge would more than offset the difference in gauge sensitivity between the two gases.

Table 2

Summary of Errors Due To Effects (1) Through (5).

Effect	Maximum Uncertainty (percent)	Probable Uncertainty (percent)
(1)	+20	+20
(2)	-22	< +10 (?)
(3)	+35	
(4)	NA	0
(5)	+15	+5
Total	+48	+35

The error due to effect (5), the use of constant sensitivities, is discussed in the Appendix. The result is that the error averaged over altitude is probably less than +10 percent.

Table 2 provides a summary of the effects of (1) through (5) on the density values previously reported. Columns 12 and 14 in Table 3 are the unadjusted and composition adjusted densities, respectively, which have been corrected for the total probable uncertainty shown in Table 2, that is +35 percent.

Figure 3 shows the new estimated error as a function of altitude (similar to Figure 3 in Newton et al., 1965).

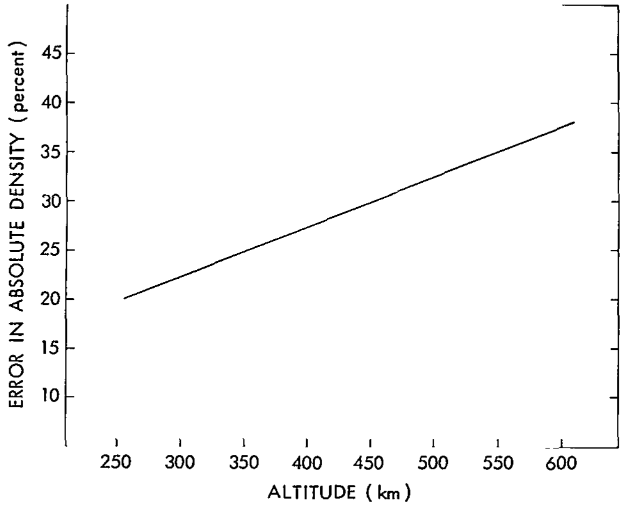

Figure 3—Percent error in absolute value of atmospheric density versus altitude. Selection of data analyzed allows this form of presentation.

THE EXPLORER 17 ATMOSPHERIC DENSITY EXPERIMENT DATA INCLUDING EFFECTS OF VARIATIONS IN COMPOSITION AND OF SYSTEMATIC ERRORS

Generally, each four-minute interrogation of the satellite by a ground station resulted in several hundred density measurements (one measurement for each satellite rotation). To simplify the data handling, a straight line representing a visual average of this data when plotted on a log ρ vs altitude plot was used to represent the data from each pass. The endpoints of this line for each usable turn-on of the Explorer 17 Atmospheric Density Experiment are presented in Table 3. The columns in this table, reading from left to right, are:

(1) The three letter station code for the stations of Table 1

(2) The orbit number corresponding to the orbit of the data-producing interrogation

(3) The date the data were obtained

(4) The start and end altitude of the line representing the data

(5) The start and end local time of the data

(6) The geographic longitude and latitude of the subsatellite point at the start and end of the data-producing orbit segment

(7) The mean Greenwich time for the start of the data

(8) The start and end densities of the line representing the data, uncorrected for composition (N_2, 16 as discussed in Appendix A)

(9) The daily geomagnetic activity index, A_p, for the day the data were obtained

(10) The daily solar intensity index, $F_{10.7}$, for the day the data were obtained

(11) The composition adjustment factor applied to the data (using the Explorer 17 diurnally averaged mass spectrometer data (Reber and Nicolet, 1965))

(12) The densities of column 8 adjusted for the probable systematic error as discussed in the previous section

(13) The start and end composition-adjusted densities originally published

(14) The densities of column 13 adjusted for the probable systematic error discussed in the previous section.

Table 3

Atmospheric Density Values From Explorer XVII Pressure Gauge Experiment
April-June 1963.

STATION	PASS	DATE	ALTITUDE (KM)	LOCAL TIME (HRS)	GEOGRAPHIC LONGITUDE (DEGREES)	GEOGRAPHIC LATITUDE (DEGREES)	MEAN GMT (HRS)	RHO N2.16 DENSITY (GM/CC)	A (P)	F (F10.7)	COMP. (K)	CORRECTED RHO N2.16 DENSITY (GM/CC)	COMPOSITION ADJUSTED DENSITY (GM/CC)	CORRECTED COMPOSITION ADJUSTED DENSITY (GM/CC)
BPO	6	403	523	5.16	-103	40	12.06	2.0E-17	4.	74.	1.030	2.7E-17	2.1E-17	2.8E-17
			592	5.82	-94	31		1.3E-17				1.8E-17	1.3E-17	1.8E-17
BPO	19	404	440	3.84	-75	50	8.86	6.7E-17	13.	70.	0.993	9.0E-17	6.7E-17	9.0E-17
			505	4.75	-62	41		1.9E-17				2.6E-17	1.9E-17	2.5E-17
BPO	35	405	513	4.61	-90	39	10.66	4.1E-17	32.	72.	1.020	5.5E-17	4.2E-17	5.6E-17
			581	5.25	-82	30		2.3E-17				3.1E-17	2.3E-17	3.2E-17
BPO	49	406	461	3.76	-80	45	9.12	7.5E-17	19.	78.	0.999	1.0E-16	7.5E-17	1.0E-16
			528	4.54	-69	36		3.4E-17				4.6E-17	3.4E-17	4.6E-17
BPO	64	407	465	3.60	-84	43	9.23	5.5E-17	15.	80.	1.000	7.4E-17	5.5E-17	7.4E-17
			530	4.32	-74	34		3.6E-17				4.9E-17	3.6E-17	4.9E-17
BPO	93	409	441	2.87	-74	44	7.82	5.5E-17	7.	82.	0.992	7.4E-17	5.5E-17	7.4E-17
			500	3.58	-64	36		1.7E-17				2.3E-17	1.7E-17	2.3E-17
BPO	118	410	281	18.43	-77	32	23.59	1.3E-14	2.	82.	0.785	1.8E-14	1.0E-14	1.4E-14
			268	19.08	-68	41		1.9E-14				2.6E-14	1.5E-14	2.0E-14
BPO	148	412	275	18.12	-85	37	23.82	1.8E-14	9.	93.	0.781	2.4E-14	1.4E-14	1.9E-14
			262	18.93	-74	46		2.2E-14				3.0E-14	1.7E-14	2.3E-14
BPO	182	415	440	1.55	-78	37	6.77	1.2E-16	15.	88.	0.980	1.6E-16	1.2E-16	1.6E-16
			476	1.92	-73	32		4.6E-17				6.2E-17	4.5E-17	6.1E-17
BPO	192	415	292	16.95	-82	34	22.44	1.4E-14	15.	88.	0.790	1.9E-14	1.1E-14	1.5E-14
			269	17.74	-71	44		2.5E-14				3.4E-14	2.0E-14	2.7E-14
BPO	197	416	425	1.13	-86	39	6.87	9.2E-17	6.	86.	0.977	1.2E-16	9.0E-17	1.2E-16
			485	1.75	-77	29		2.4E-17				3.2E-17	2.3E-17	3.2E-17

Table 3 (continued)

STATION	PASS	DATE	ALTITUDE (KM)	LOCAL TIME (HRS)	GEOGRAPHIC LONGITUDE (DEGREES)	LATITUDE (DEGREES)	MEAN GMT (HRS)	RHO N2.16 DENSITY (GM/CC)	A (P)	F (F10.7)	COMP. (K)	CORRECTED RHO N2.16 DENSITY (GM/CC)	COMPOSITION ADJUSTED DENSITY (GM/CC)	CORRECTED COMPOSITION ADJUSTED DENSITY (GM/CC)
BPO	236	418	300	16.08	-75	35	21.13	1.0E-14	15.	88.	0.789	1.3E-14	7.9E-15	1.1E-14
			275	16.78	-66	44		2.3E-14				3.1E-14	1.8E-14	2.4E-14
BPO	241	419	380	23.85	-84	42	3.45	6.0E-15	10.	84.	0.890	8.1E-16	5.3E-16	7.2E-16
BPO	285	422	350	22.72	-81	44	4.11	1.4E-15	11.	72.	0.865	1.9E-15	1.2E-15	1.6E-15
			360	22.90	-78	42		9.4E-16				1.3E-15	8.1E-16	1.1E-15
BPO	310	423	320	14.51	-81	36	19.93	3.7E-15	9.	71.	0.821	5.0E-15	3.0E-15	4.1E-15
			290	15.21	-71	44		9.0E-15				1.2E-14	7.4E-15	1.0E-14
BPO	325	424	310	14.47	-83	40	20.02	3.1E-15	2.	73.	0.809	4.2E-15	2.5E-15	3.4E-15
			280	15.38	-76	48		7.6E-15				1.0E-14	6.1E-15	8.3E-15
BPO	330	425	420	22.95	-82	28	4.44	6.2E-17	4.	72.	0.950	8.4E-17	5.9E-17	8.0E-17
			456	23.26	-78	22		2.3E-17				3.1E-17	2.2E-17	2.9E-17
BPO	384	428	323	13.33	-81	41	18.74	4.4E-15	3.	78.	0.822	5.9E-15	3.6E-15	4.9E-15
			288	14.29	-67	50		9.3E-15				1.3E-14	7.6E-15	1.0E-14
BPO	388	429	325	20.74	-71	41	1.47	2.7E-15	4.	73.	0.845	3.6E-15	2.3E-15	3.1E-15
			335	20.94	-68	39		1.8E-15				2.4E-15	1.5E-15	2.1E-15
BPO	413	430	360	12.27	-74	36	17.23	1.3E-15	23.	80.	0.865	1.8E-15	1.1E-15	1.5E-15
			347	12.45	-72	39		1.9E-15				2.6E-15	1.6E-15	2.2E-15
BPO	418	501	320	20.22	-81	40	1.59	4.6E-15	35.	82.	0.845	6.2E-15	3.9E-15	5.2E-15
			330	20.37	-78	38		3.1E-15				4.2E-15	2.6E-15	3.5E-15
BPO	443	502	359	11.80	-84	39	17.42	2.6E-15	24.	82.	0.860	3.5E-15	2.2E-15	3.0E-15
			324	12.44	-75	46		5.2E-15				7.0E-15	4.5E-15	6.0E-15

Table 3 (continued)

STATION	PASS	DATE	ALTITUDE (KM)	LOCAL TIME (HRS)	GEOGRAPHIC LONGITUDE (DEGREES)	GEOGRAPHIC LATITUDE (DEGREES)	MEAN GMT (HRS)	RHO N2,16 DENSITY (GM/CC)	A (P)	F (F10.7)	COMP. (K)	CORRECTED RHO N2,16 DENSITY (GM/CC)	COMPOSITION ADJUSTED DENSITY (GM/CC)	CORRECTED COMPOSITION ADJUSTED DENSITY (GM/CC)
BPO	458	503	376	11.33	-92	37	17.48	1.4E-15	14.	81.	0.865	1.9E-15	1.2E-15	1.6E-15
			330	12.10	-81	45		4.2E-15				5.7E-15	3.6E-15	4.9E-15
BPO	472	504	380	11.05	-73	37	15.93	1.1E-15	19.	82.	0.880	1.5E-15	9.7E-16	1.3E-15
			355	11.42	-68	42		2.0E-15				2.7E-15	1.8E-15	2.4E-15
BPO	492	506	296	18.57	-87	40	0.38	7.2E-15	9.	87.	0.820	9.7E-15	5.9E-15	8.0E-15
			320	19.05	-80	34		2.9E-15				3.9E-15	2.4E-15	3.2E-15
BPO	506	506	273	17.54	-78	47	22.78	2.0E-14	9.	87.	0.798	2.7E-14	1.6E-14	2.2E-14
			299	18.42	-66	38		6.6E-15				8.9E-15	5.3E-15	7.1E-15
BPO	516	507					14.52		6.	88.	0.895			
			383	10.32	-63	40		6.6E-16				8.9E-16	5.9E-16	8.0E-16
BPO	546	509					14.68		14.	88.	0.899			
			387	9.81	-73	42		9.4E-16				1.3E-15	8.5E-16	1.1E-15
BPO	561	510	371	9.85	-73	45	14.73	1.7E-15	14.	87.	0.875	2.3E-15	1.5E-15	2.0E-15
			356	10.14	-69	48		2.6E-15				3.5E-15	2.3E-15	3.1E-15
BPO	595	512	286	16.61	-75	36	21.62	1.7E-14	9.	87.	0.809	2.3E-14	1.4E-14	1.9E-14
			302	17.04	-69	30		1.1E-14				1.5E-14	8.9E-15	1.2E-14
BPO	679	518	508	6.28	-84	34	11.91	2.9E-17	3.	98.	0.994	3.9E-17	2.9E-17	3.9E-17
			443	7.01	-74	43		1.0E-16				1.3E-16	9.9E-17	1.3E-16
BPO	694	519	496	6.16	-87	37	11.99	2.5E-17	5.	99.	0.992	3.4E-17	2.5E-17	3.3E-17
			432	6.96	-76	46		1.2E-16				1.6E-16	1.2E-16	1.6E-16
BPO	698	519	259	13.79	-74	43	18.76	3.7E-14	5.	99.	0.779	5.0E-14	2.9E-14	3.9E-14
			269	14.54	-64	34		2.3E-14				3.1E-14	1.8E-14	2.4E-14

Table 3 (continued)

STATION	PASS	DATE	ALTITUDE (KM)	LOCAL TIME (HRS)	GEOGRAPHIC LONGITUDE (DEGREES)	GEOGRAPHIC LATITUDE (DEGREES)	MEAN GMT (HRS)	RHO N2,16 DENSITY (GM/CC)	A (P)	F (F10.7)	COMP. (K)	CORRECTED RHO N2,16 DENSITY (GM/CC)	COMPOSITION ADJUSTED DENSITY (GM/CC)	CORRECTED COMPOSITION ADJUSTED DENSITY (GM/CC)
BPO	723	521	477	4.95	-69	42	10.04	4.0E-17	5.	88.	0.999	5.4E-17	4.0E-17	5.4E-17
			512	5.60	-74	37		1.3E-17				1.8E-17	1.3E-17	1.8E-17
BPO	738	522	516	5.23	-79	37	10.53	1.0E-17	3.	89.	1.000	1.3E-17	1.0E-17	1.3E-17
			481	5.63	-74	42		3.1E-17				4.2E-17	3.1E-17	4.2E-17
BPO	768	524	500	4.95	-85	42	10.64	1.4E-17	2.	89.	0.997	1.9E-17	1.4E-17	1.9E-17
			470	5.34	-80	46		2.9E-17				3.9E-17	2.9E-17	3.9E-17
BPO	831	528	267	10.66	-78	45	15.88	2.5E-14	16.	79.	0.775	3.4E-14	1.9E-14	2.6E-14
			258	11.37	-68	37		3.2E-14				4.3E-14	2.5E-14	3.3E-14
BPO	876	531	262	10.21	-87	39	16.02	2.8E-14	9.	89.	0.772	3.8E-14	2.2E-14	2.9E-14
			257	10.77	-79	31		3.0E-14				4.0E-14	2.3E-14	3.1E-14
BPO	890	601	259	9.36	-76	45	14.44	3.9E-14	11.	84.	0.780	5.3E-14	3.0E-14	4.1E-14
			276	10.19	-64	35		3.0E-14				4.0E-14	2.3E-14	3.2E-14
BPO	935	604	264	9.11	-82	36	14.58	1.9E-14	5.	79.	0.772	2.6E-14	1.5E-14	2.0E-14
			256	9.66	-74	28		2.6E-14				3.5E-14	2.0E-14	2.7E-14
BPO	949	605	288	8.07	-73	45	12.95	6.0E-15	2.	78.	0.789	8.1E-15	4.7E-15	6.4E-15
			265	8.84	-62	36		1.7E-14				2.3E-14	1.3E-14	1.8E-14
BPO	964	606	282	8.03	-75	42	13.04	5.0E-15	16.	77.	0.787	8.1E-15	4.7E-15	6.4E-15
			267	8.51	-68	36		1.1E-14				1.5E-14	8.7E-15	1.2E-14
BPO	994	608	275	7.75	-80	37	13.12	1.2E-14	12.	90.	0.780	1.6E-14	9.4E-15	1.3E-14
			259	8.35	-72	28		2.6E-14				3.5E-14	2.0E-14	2.7E-14
MOJ	7	403	517	5.07	-129	41	13.68	2.1E-17	4.	74.	1.023	2.8E-17	2.1E-17	2.9E-17
			586	5.75	-119	31		1.0E-17				1.3E-17	1.0E-17	1.4E-17

Table 3 (continued)

STATION	PASS	DATE	ALTITUDE (KM)	LOCAL TIME (HRS)	GEOGRAPHIC LONGITUDE (DEGREES)	GEOGRAPHIC LATITUDE (DEGREES)	MEAN GMT (HRS)	RHO N2.16 DENSITY (GM/CC)	A (P)	F (F10.7)	COMP. (K)	CORRECTED RHO N2.16 DENSITY (GM/CC)	COMPOSITION ADJUSTED DENSITY (GM/CC)	CORRECTED COMPOSITION ADJUSTED DENSITY (GM/CC)
MOJ	21	404	484	4.47	-115	44	12.13	3.6E-17	19.	70.	1.000	4.9E-17	3.6E-17	4.9E-17
			530	5.00	-107	36		1.9E-17				2.6E-17	1.9E-17	2.6E-17
MOJ	36	405	490	4.33	-118	42	12.24	5.0E-17	32.	72.	1.007	6.7E-17	5.0E-17	6.8E-17
			550	4.96	-110	34		2.1E-17				2.8E-17	2.1E-17	2.9E-17
MOJ	243	419	447	0.64	-121	31	8.73	6.2E-17	10.	84.	0.991	8.4E-17	6.1E-17	8.3E-17
			483	0.96	-117	26		2.4E-17				3.2E-17	2.4E-17	3.2E-17
MOJ	420	501	338	20.49	-125	36	4.84	3.9E-15	35.	82.	0.858	5.3E-15	3.3E-15	4.5E-15
			350	20.66	-123	33		2.5E-15				3.4E-15	2.1E-15	2.9E-15
MOJ	493	506	294	18.50	-112	41	1.96	7.1E-15	3.	87.	0.825	9.6E-15	5.9E-15	7.9E-15
			320	19.03	-104	34		2.4E-15				3.2E-15	2.0E-15	2.7E-15
MOJ	508	507	301	18.44	-114	38	2.06	6.2E-15	6.	88.	0.835	8.4E-15	5.2E-15	7.0E-15
			330	18.94	-107	30		2.1E-15				2.8E-15	1.8E-15	2.4E-15
MOJ	547	509	465	8.94	-109	30	16.21	1.0E-16	14.	85.	0.992	1.3E-16	9.9E-17	1.3E-16
MOJ	759	523	259	12.89	-115	38	20.57	2.6E-14	3.	93.	0.777	3.5E-14	2.0E-14	2.7E-14
			269	13.52	-106	28		1.6E-14				2.2E-14	1.2E-14	1.7E-14
NFL	4	403	463	4.39	-66	43	8.79	4.2E-17	4.	74.	0.999	5.7E-17	4.2E-17	5.7E-17
			525	5.20	-54	40		1.6E-17				2.2E-17	1.6E-17	2.2E-17
NFL	16	404	440	3.85	-51	49	7.27	6.9E-17	19.	70.	0.975	9.3E-17	6.7E-17	9.1E-17
			472	4.35	-44	46		3.6E-17				4.9E-17	3.5E-17	4.7E-17
NFL	33	405	475	4.18	-48	44	7.40	7.7E-17	32.	72.	0.997	1.0E-16	7.7E-17	1.0E-16
			495	4.42	-45	42		5.8E-17				7.3E-17	5.8E-17	7.9E-17

Table 3 (continued)

STATION	PASS	DATE	ALTITUDE (KM)	LOCAL TIME (HRS)	GEOGRAPHIC LONGITUDE (DEGREES)	GEOGRAPHIC LATITUDE (DEGREES)	MEAN GMT (HRS)	RHO N2.16 DENSITY (GM/CC)	A (P)	F (F10.7)	COMP. (K)	CORRECTED RHO N2.16 DENSITY (GM/CC)	COMPOSITION ADJUSTED DENSITY (GM/CC)	CORRECTED COMPOSITION ADJUSTED DENSITY (GM/CC)
NFL	254	420	315	22.26	-60	52	2.29	4.6E-15	7.	78.	0.855	6.2E-15	3.9E-15	5.3E-15
			355	23.25	-46	45		8.0E-16				1.1E-15	6.8E-16	9.2E-16
NFL	785	525	280	10.68	-51	52	14.10	1.2E-14	8.	83.	0.785	1.6E-14	9.4E-15	1.3E-14
			263	11.65	-37	45		2.2E-14				3.0E-14	1.7E-14	2.3E-14
NFL	800	526	282	10.39	-56	52	14.17	1.3E-14	6.	76.	0.785	1.8E-14	1.0E-14	1.4E-14
			263	11.42	-42	44		2.6E-14				3.5E-14	2.0E-14	2.8E-14
NFL	815	527	281	10.24	-59	51	14.21	1.1E-14	7.	80.	0.785	1.5E-14	8.6E-15	1.2E-14
			262	11.25	-45	42		2.7E-14				3.6E-14	2.1E-14	2.9E-14
NFL	841	529	500	3.86	-56	47	7.63	3.8E-17	21.	80.	0.997	5.1E-17	3.4E-17	5.1E-17
			465	4.44	-48	51		5.4E-17				7.3E-17	5.4E-17	7.3E-17
NFL	856	530	497	3.73	-59	48	7.67	3.0E-17	12.	83.	0.995	4.0E-17	3.0E-17	4.0E-17
			460	4.35	-50	52		6.4E-17				8.6E-17	6.4E-17	8.6E-17
NFL	874	531	296	8.86	-58	51	12.75	8.6E-15	9.	89.	0.793	1.2E-14	6.8E-15	9.2E-15
			270	9.85	-44	43		2.4E-14				3.2E-14	1.9E-14	2.6E-14
NFL	889	601	302	8.47	-64	51	12.77	1.5E-14	11.	84.	0.798	2.0E-14	1.2E-14	1.6E-14
			272	9.53	-49	43		3.4E-14				4.6E-14	2.7E-14	3.7E-14
NFL	903	606	300	7.52	-57	47	11.34	3.4E-15	16.	77.	0.795	4.6E-15	2.7E-15	3.6E-15
			270	8.42	-44	37		1.4E-14				1.9E-14	1.1E-14	1.5E-14
NFL	977	607	340	6.26	-52	52	9.76	2.2E-15	43.	84.	0.837	3.0E-15	1.8E-15	2.5E-15
			297	7.39	-36	45		7.5E-15				1.0E-14	6.3E-15	8.5E-15
NFL	992	608	331	6.30	-52	50	9.78	1.2E-15	12.	90.	0.833	1.6E-15	1.0E-15	1.3E-15
			293	7.27	-38	43		5.9E-15				8.0E-15	4.9E-15	6.6E-15

Table 3 (continued)

STATION	PASS	DATE	ALTITUDE (KM)	LOCAL TIME (HRS)	GEOGRAPHIC LONGITUDE (DEGREES)	LATITUDE (DEGREES)	MEAN GMT (HRS)	RHO N2.16 DENSITY (GM/CC)	A (P)	F (F10.7)	COMP. (K)	CORRECTED RHO N2.16 DENSITY (GM/CC)	COMPOSITION ADJUSTED DENSITY (GM/CC)	CORRECTED COMPOSITION ADJUSTED DENSITY (GM/CC)
GFO	120	411	261	19.89	-105	49	2.91	2.1E-14	3.	88.	0.778	2.8E-14	1.6E-14	2.2E-14
			270	20.99	-89	55		1.5E-14				2.0E-14	1.2E-14	1.6E-14
GFO	193	416	265	17.98	-92	46	0.11	3.8E-14	6.	88.	0.776	5.1E-14	2.9E-14	4.0E-14
GFO	208	417	268	17.56	-99	45	0.20	2.3E-14	7.	87.	0.778	3.1E-14	1.8E-14	2.4E-14
			262	18.18	-91	50		3.2E-14				4.3E-14	2.5E-14	3.4E-14
GFO	252	419	270	16.86	-90	48	22.89	2.5E-14	10.	84.	0.778	3.4E-14	1.9E-14	2.6E-14
			262	17.78	-77	53		3.3E-14				4.5E-14	2.6E-14	3.5E-14
GFO	267	420	276	16.23	-100	45	22.94	1.9E-14	7.	78.	0.784	2.6E-14	1.5E-14	2.0E-14
			264	17.19	-87	52		2.6E-14				3.5E-14	2.0E-14	2.8E-14
GFO	271	421	335	22.60	-105	48	5.60	1.8E-15	4.	74.	0.860	2.4E-15	1.5E-15	2.1E-15
			355	23.01	-99	44		8.0E-16				1.1E-15	6.9E-16	9.3E-16
GFO	297	422	279	15.79	-110	47	23.13	1.1E-14	11.	72.	0.785	1.5E-14	8.6E-15	1.2E-14
			264	16.88	-94	54		2.7E-14				3.6E-14	2.1E-14	2.9E-14
GFO	300	423	310	21.56	-98	51	4.12	5.3E-15	9.	71.	0.845	7.2E-15	4.5E-15	6.0E-15
			349	22.49	-85	43		1.4E-15				1.9E-15	1.2E-15	1.6E-15
GFO	315	424	320	21.66	-98	48	4.21	3.7E-15	2.	73.	0.856	5.0E-15	3.2E-15	4.3E-15
			355	22.37	-88	41		9.2E-16				1.2E-15	7.9E-16	1.1E-15
GFO	355	426	301	14.26	-89	44	20.20	5.8E-15	5.	72.	0.801	7.8E-15	4.6E-15	6.3E-15
			279	15.07	-77	51		9.0E-15				1.2E-14	7.2E-15	9.7E-15
GFO	385	428	303	13.79	-98	46	20.34	7.4E-15	3.	78.	0.801	1.0E-14	5.9E-15	8.0E-15
			276	14.90	-82	53		1.3E-14				1.8E-14	1.0E-14	1.4E-14

Table 3 (continued)

STATION	PASS	DATE	ALTITUDE (KM)	LOCAL TIME (HRS)	GEOGRAPHIC LONGITUDE (DEGREES)	GEOGRAPHIC LATITUDE (DEGREES)	MEAN GMT (HRS)	RHO N2.16 DENSITY (GM/CC)	A (P)	F (F10.7)	COMP. (K)	CORRECTED RHO N2.16 DENSITY (GM/CC)	COMPOSITION ADJUSTED DENSITY (GM/CC)	CORRECTED COMPOSITION ADJUSTED DENSITY (GM/CC)
GFO	389	429	305	20.27	-101	46	3.03	4.3E-15	4.	78.	0.837	5.8E-15	3.6E-15	4.9E-15
			331	20.85	-93	40		1.9E-15				2.6E-15	1.6E-15	2.1E-15
GFO	429	501	349	12.18	-101	39	18.93	3.4E-15	35.	82.	0.855	4.6E-15	2.9E-15	3.9E-15
			320	12.74	-93	45		6.1E-15				8.2E-15	5.2E-15	7.0E-15
GFO	444	502	342	12.07	-104	42	19.03	3.6E-15	24.	82.	0.851	4.9E-15	3.1E-15	4.1E-15
			320	12.53	-98	46		5.3E-15				7.2E-15	4.5E-15	6.1E-15
GFO	474	504	327	11.96	-108	47	19.20	6.8E-15	19.	82.	0.827	9.2E-15	5.6E-15	7.6E-15
			293	13.04	-93	54		1.6E-14				2.2E-14	1.3E-14	1.8E-14
GFO	488	505	372	10.91	-100	40	17.59	1.4E-15	10.	84.	0.862	1.9E-15	1.2E-15	1.6E-15
			325	11.81	-87	48		5.2E-15				7.0E-15	4.5E-15	6.1E-15
GFO	503	506	374	10.65	-105	40	17.67	1.5E-15	9.	87.	0.865	2.0E-15	1.3E-15	1.8E-15
			330	11.49	-93	48		3.9E-15				5.3E-15	3.4E-15	4.6E-15
GFO	507	507	278	17.77	-99	45	0.39	1.5E-14	6.	88.	0.810	2.0E-14	1.2E-14	1.6E-14
			306	18.55	-88	36		4.8E-15				6.5E-15	3.9E-15	5.2E-15
GFO	548	509	323	11.14	-102	52	17.96	5.3E-15	14.	88.	0.825	7.2E-15	4.4E-15	5.9E-15
			290	12.45	-83	57		1.9E-14				2.6E-14	1.6E-14	2.1E-14
GFO	607	513	335	10.11	-97	54	16.59	9.4E-15	22.	89.	0.840	1.3E-14	7.9E-15	1.1E-14
			303	11.28	-80	57		2.0E-14				2.7E-14	1.7E-14	2.3E-14
GFO	625	514	261	15.00	-100	47	21.69	3.8E-14	12.	95.	0.778	5.1E-14	3.0E-14	4.0E-14
			270	15.72	-90	39		3.2E-14				4.3E-14	2.5E-14	3.4E-14
GFO	739	522	508	5.30	-102	39	12.14	1.7E-17	3.	89.	0.994	2.3E-17	1.7E-17	2.3E-17
			446	6.11	-91	47		8.0E-17				1.1E-16	8.0E-17	1.1E-16

Table 3 (continued)

STATION	PASS	DATE	ALTITUDE (KM)	LOCAL TIME (HRS)	GEOGRAPHIC LONGITUDE (DEGREES)	GEOGRAPHIC LATITUDE (DEGREES)	MEAN GMT (HRS)	RHO N2,16 DENSITY (GM/CC)	A (P)	F (F10.7)	COMP. (K)	CORRECTED RHO N2,16 DENSITY (GM/CC)	COMPOSITION ADJUSTED DENSITY (GM/CC)	CORRECTED COMPOSITION ADJUSTED DENSITY (GM/CC)
GFO	754	523	453	5.80	-96	47	12.22	3.9E-17	3.	93.	0.942	5.3E-17	3.7E-17	5.0E-17
			413	6.51	-86	52		1.0E-16				1.3E-16	9.4E-17	1.3E-16
COL	197	416	271	20.40	-154	57	6.07	[illegible].0E-14	6.	88.	0.793	2.7E-14	1.6E-14	2.1E-14
			295	22.00	-130	57		1.0E-14				1.3E-14	7.9E-15	1.1E-14
COL	418	501	265	15.60	-147	57	13.40	3.2E-14	35.	82.	0.776	4.3E-14	2.5E-14	3.4E-14
COL	433	502	265	15.50	-150	58	1.50	3.2E-14	24.	82.	0.776	4.3E-14	2.5E-14	3.4E-14
COL	507	507	267	14.60	-145	58	9.25	2.5E-14	6.	83.	0.776	3.4E-14	1.9E-14	2.6E-14
			261	15.90	-125	56		3.3E-14				4.3E-14	2.6E-14	3.5E-14
COL	522	508	265	14.70	-144	57	12.30	2.9E-14	10.	86.	0.776	3.9E-14	2.3E-14	3.0E-14
COL	728	521	350	8.39	-153	57	18.64	1.3E-15	5.	88.	0.845	1.8E-15	1.1E-15	1.5E-15
			310	9.89	-132	58		4.3E-15				5.8E-15	3.6E-15	4.9E-15
COL	743	522	345	8.42	-154	57	18.70	1.5E-15	3.	89.	0.843	2.0E-15	1.3E-15	1.7E-15
			305	9.98	-131	57		5.5E-15				7.4E-15	4.6E-15	6.3E-15
COL	758	523	333	8.71	-151	58	18.80	2.4E-15	3.	93.	0.832	3.2E-15	2.0E-15	2.7E-15
			295	10.30	-128	56		8.0E-15				1.1E-14	6.7E-15	9.0E-15
COL	772	524	375	7.23	-149	56	17.17	4.4E-16	2.	89.	0.867	5.9E-16	3.8E-16	5.1E-16
			328	8.77	-126	58		2.6E-15				3.5E-15	2.3E-15	3.0E-15
COL	773	524	334	8.54	-154	58	18.82	2.1E-15	2.	89.	0.835	2.8E-15	1.8E-15	2.4E-15
			296	10.10	-131	56		6.8E-15				9.2E-15	5.7E-15	7.7E-15

Table 3 (continued)

STATION	PASS	DATE	ALTITUDE (KM)	LOCAL TIME (HRS)	GEOGRAPHIC LONGITUDE (DEGREES)	GEOGRAPHIC LATITUDE (DEGREES)	MEAN GMT (HRS)	RHO N2.16 DENSITY (GM/CC)	A (P)	F (F10.7)	COMP. (K)	CORRECTED RHO N2.16 DENSITY (GM/CC)	COMPOSITION ADJUSTED DENSITY (GM/CC)	CORRECTED COMPOSITION ADJUSTED DENSITY (GM/CC)
COL	787	525	376	7.05	-152	57	17.07	6.5E-16	8.	83.	0.868	8.8E-16	5.6E-16	7.6E-16
			328	8.36	-129	58		2.7E-15				3.6E-15	2.3E-15	3.2E-15
COL	788	525	334	8.40	-157	58	18.88	3.2E-15	8.	83.	0.835	4.3E-15	2.7E-15	3.6E-15
			295	9.96	-134	55		7.9E-15				1.1E-14	6.6E-15	8.9E-15
COL	802	526	353	7.64	-144	58	17.28	1.4E-15	6.	75.	0.855	1.9E-15	1.2E-15	1.6E-15
			331	8.38	-134	58		2.4E-15				3.2E-15	2.1E-15	2.8E-15
COL	803	526	333	8.31	-159	58	18.92	3.1E-15	6.	76.	0.842	4.2E-15	2.6E-15	3.5E-15
			295	9.79	-137	54		7.1E-15				9.6E-15	5.9E-15	8.0E-15
COL	817	527	373	6.86	-156	57	17.29	6.0E-16	7.	80.	0.851	8.1E-16	5.2E-16	7.0E-16
			329	8.32	-135	57		2.6E-15				3.5E-15	2.2E-15	3.0E-15
COL	831	528	418	5.52	-152	55	15.88	2.3E-16	16.	79.	0.900	3.1E-16	2.1E-16	2.8E-16
			364	6.98	-137	58		1.8E-15				2.4E-15	1.6E-15	2.2E-15
COL	875	531	455	4.23	-149	54	14.19	6.8E-17	9.	89.	0.934	9.2E-17	6.4E-17	8.6E-17
			395	5.68	-128	58		2.9E-16				3.9E-16	2.7E-16	3.7E-16
COL	877	531	355	6.87	-159	57	17.51	1.5E-15	9.	89.	0.853	2.0E-15	1.3E-15	1.7E-15
			314	8.21	-140	54		4.7E-15				6.3E-15	4.0E-15	5.4E-15
COL	891	601	385	5.83	-151	58	15.92	9.0E-16	11.	84.	0.881	1.2E-15	7.9E-16	1.1E-15
			357	6.67	-139	57		1.4E-15				1.9E-15	1.2E-15	1.7E-15
COL	935	604	433	4.13	-153	57	14.38	4.1E-17	5.	79.	0.913	5.5E-17	3.7E-17	5.1E-17
			376	5.69	-131	57		2.9E-16				3.9E-16	2.6E-16	3.6E-16
COL	950	605	440	3.80	-159	57	14.42	1.7E-17	2.	73.	0.930	2.3E-17	1.6E-17	2.1E-17
			400	4.84	-144	56		7.6E-17				1.0E-16	7.1E-17	9.5E-17

Table 3 (continued)

STATION	PASS	DATE	ALTITUDE (KM)	LOCAL TIME (HRS)	GEOGRAPHIC LONGITUDE (DEGREES)	GEOGRAPHIC LATITUDE (DEGREES)	MEAN GMT (HRS)	RHO N2,16 DENSITY (GM/CC)	A (P)	F (F10.7)	COMP. (K)	CORRECTED RHO N2,16 DENSITY (GM/CC)	COMPOSITION ADJUSTED DENSITY (GM/CC)	CORRECTED COMPOSITION ADJUSTED DENSITY (GM/CC)
COL	965	606	425	4.05	-156	58	14.47	1.5E-17	16.	77.	0.909	2.0E-17	1.4E-17	1.8E-17
			377	5.36	-137	57		9.0E-17				1.2E-16	8.2E-17	1.1E-16
WNK	16	404	407	3.23	-12	53	4.05	1.1E-16	19.	70.	0.951	1.5E-15	1.0E-16	1.4E-16
			469	4.33	4	46		3.1E-17				4.2E-17	2.9E-17	4.0E-17
WNK	31	405	454	3.90	-4	47	4.17	4.9E-17	32.	72.	0.992	6.6E-17	4.9E-17	6.6E-17
			488	4.37	3	43		1.8E-17				2.4E-17	1.8E-17	2.4E-17
WNK	45	406	405	2.87	4	52	2.64	1.4E-16	19.	78.	0.933	1.9E-16	1.3E-16	1.8E-16
			438	3.47	12	48		7.9E-17				1.1E-16	7.4E-17	1.0E-16
WNK	60	407	408	2.75	0	51	2.76	1.5E-16	15.	80.	0.933	2.0E-16	1.4E-16	1.9E-16
			440	3.30	8	47		8.4E-17				1.1E-16	7.3E-17	1.1E-16
WNK	103	414	333	23.80	-5	54	12.14	3.4E-15	17.	87.	0.855	4.6E-15	2.9E-15	3.9E-15
			345	0.15	0	53		2.1E-15				2.8E-15	1.8E-15	2.4E-15
WNK	237	418	314	22.34	-9	53	23.00	5.4E-15	15.	88.	0.851	7.3E-15	4.6E-15	6.2E-15
			357	23.52	7	46		1.1E-15				1.5E-15	9.4E-16	1.3E-15
WNK	356	429	303	13.65	-5	47	14.02	6.4E-15	4.	78.	0.801	8.6E-15	5.1E-15	6.9E-15
			275	14.85	12	54		1.3E-14				1.8E-14	1.0E-14	1.4E-14
WNK	426	501	300	13.33	-13	50	14.20	1.6E-14	35.	82.	0.800	2.2E-14	1.3E-14	1.7E-14
			274	14.54	5	55		2.8E-14				3.8E-14	2.2E-14	3.0E-14
WNK	562	510	265	16.33	-4	47	16.61	3.6E-14	14.	87.	0.787	4.9E-14	2.8E-14	3.8E-14
			285	17.22	9	38		1.8E-14				2.4E-14	1.4E-14	1.9E-14
WNK	618	514	351	9.54	-10	52	10.22	3.5E-15	12.	95.	0.845	4.7E-15	3.0E-15	4.0E-15
			311	10.83	9	57		8.3F-15				1.2E-14	7.4E-15	1.0E-14

Table 3 (continued)

STATION	PASS	DATE	ALTITUDE (KM)	LOCAL TIME (HRS)	GEOGRAPHIC LONGITUDE (DEGREES)	GEOGRAPHIC LATITUDE (DEGREES)	MEAN GMT (HRS)	RHO N2,16 DENSITY (GM/CC)	A (P)	F (F10.7)	COMP. (K)	CORRECTED RHO N2,16 DENSITY (GM/CC)	COMPOSITION ADJUSTED DENSITY (GM/CC)	CORRECTED COMPOSITION ADJUSTED DENSITY (GM/CC)
WNK	635	515	266	13.40	-3	55	13.62	3.2E-14	6.	98.	0.775	4.3E-14	2.5E-14	3.3E-14
			260	14.64	15	48		4.0E-14				5.4E-14	3.1E-14	4.2E-14
WNK	738	522	296	10.44	-4	57	10.73	3.6E-15	3.	87.	0.793	1.2E-14	6.8E-15	9.2E-15
			270	11.83	16	51		1.3E-14				2.4E-14	1.4E-14	1.9E-14
WNK	753	523	288	10.66	-2	55	10.80	9.4E-15	3.	93.	0.709	1.3E-14	6.7E-15	9.0E-15
			270	11.60	12	51		1.5E-14				2.0E-14	1.1E-14	1.4E-14
WNK	754	523	268	11.76	-10	50	12.46	1.7E-14	3.	93.	0.786	2.3E-14	1.3E-14	1.8E-14
			259	12.62	2	42		2.6E-14				3.5E-14	2.0E-14	2.8E-14
WNK	765	524	478	5.28	-8	45	5.83	2.1E-17	2.	89.	0.962	2.8E-17	2.0E-17	2.7E-17
			416	6.31	7	52		9.4E-17				1.3E-16	9.0E-17	1.2E-16
WNK	768	524	288	10.50	-5	55	10.87	5.2E-15	2.	89.	0.790	1.1E-14	6.5E-15	8.7E-15
			266	11.70	12	48		1.6E-14				2.2E-14	1.3E-14	1.7E-14
WNK	783	525	288	10.33	-8	54	10.90	5.1E-15	8.	83.	0.790	1.1E-14	6.4E-15	8.6E-15
			266	11.47	8	47		1.8E-14				2.4E-14	1.4E-14	1.9E-14
WNK	810	527	458	4.98	-15	50	6.02	3.9E-17	7.	80.	0.937	5.3E-17	3.7E-17	4.9E-17
			397	6.27	3	56		1.5E-16				2.0E-16	1.4E-16	1.9E-16
WNK	840	529	403	5.80	-5	53	6.14	4.3E-16	21.	80.	0.905	5.8E-16	3.9E-16	5.3E-16
			387	6.22	1	57		9.4E-16				1.3E-15	9.5E-16	1.1E-15
WNK	842	529	311	8.71	-11	55	9.46	5.6E-15	21.	80.	0.809	7.6E-15	4.5E-15	6.1E-15
			279	9.94	7	49		2.1E-14				2.8E-14	1.7E-14	2.3E-14
WNK	853	530					2.82		12.	83.	1.006			
			520	3.42	9	46		2.0E-17				2.7E-17	2.0E-17	2.7E-17

Table 3 (continued)

STATION	PASS	DATE	ALTITUDE (KM)	LOCAL TIME (HRS)	GEOGRAPHIC LONGITUDE (DEGREES)	GEOGRAPHIC LATITUDE (DEGREES)	MEAN GMT (HRS)	RHO N2.16 DENSITY (GM/CC)	A (P)	F (F10.7)	COMP. (K)	CORRECTED RHO N2.16 DENSITY (GM/CC)	COMPOSITION ADJUSTED DENSITY (GM/CC)	CORRECTED COMPOSITION ADJUSTED DENSITY (GM/CC)
WNK	854	530	500	3.70	-12	48	4.50	3.4E-17	12.	83.	1.000	4.6E-17	3.4E-17	4.6E-17
WNK	899	602	475	3.56	-19	53	4.75	3.8E-17	10.	81.	0.970	5.1E-17	3.7E-17	5.0E-17
			430	4.55	-2	55		1.0E-16				1.3E-16	9.7E-17	1.3E-16
WNK	900	602	391	5.57	-11	58	6.33	2.0E-16	10.	81.	0.878	2.7E-16	1.8E-16	2.4E-16
			349	6.83	7	57		1.3E-15				1.8E-15	1.1E-15	1.5E-15
WNK	901	602	341	7.08	-13	56	7.95	2.8E-15	10.	81.	0.845	3.8E-15	2.4E-15	3.2E-15
			311	8.02	1	53		4.8E-15				6.5E-15	4.1E-15	5.5E-15
WNK	914	603	466	3.58	-16	55	4.69	4.1E-17	6.	81.	0.955	5.5E-17	3.9E-17	5.3E-17
			430	4.40	-5	57		1.2E-16				1.6E-16	1.1E-16	1.5E-16
WNK	916	603	334	7.14	-13	55	8.03	3.0E-15	6.	81.	0.832	4.0E-15	2.5E-15	3.4E-15
			295	8.33	4	49		6.3E-15				8.5E-15	5.2E-15	7.1E-15
WNK	945	605	356	6.16	-4	56	6.45	4.3E-16	2.	78.	0.853	5.8E-16	3.7E-16	5.0E-16
			310	7.48	15	50		3.5E-15				4.7E-15	3.0E-15	4.0E-15
WNK	975	607	338	6.33	-3	53	6.54	2.2E-15	43.	84.	0.839	3.0E-15	1.8E-15	2.5E-15
			305	7.21	10	47		8.0E-15				1.1E-14	6.7E-15	9.1E-15
WNK	990	608	317	6.68	1	49	6.60	1.7E-15	12.	90.	0.827	2.3E-15	1.4E-15	1.9E-15
			305	6.99	6	46		3.2E-15				4.3E-15	2.6E-15	3.6E-15
SNT	27	404	620	16.96	-85	-37	22.68	3.8E-18	19.	70.	1.050	5.1E-18	4.0E-18	5.4E-18
			550	17.53	-78	-28		1.9E-17				2.6E-17	2.0E-17	2.7E-17
SNT	154	413	833	4.97	-77	-20	10.14	1.5E-17	10.	89.	1.260	2.0E-17	1.9E-17	2.6E-17
			875	5.44	-71	-29		1.1E-17				1.5E-17	1.4E-17	1.9E-17

Table 3 (continued)

STATION	PASS	DATE	ALTITUDE (KM)	LOCAL TIME (HRS)	GEOGRAPHIC LONGITUDE (DEGREES)	GEOGRAPHIC LATITUDE (DEGREES)	MEAN GMT (HRS)	RHO N2,16 DENSITY (GM/CC)	A (P)	F (F10.7)	COMP. (K)	CORRECTED RHO N2,16 DENSITY (GM/CC)	COMPOSITION ADJUSTED DENSITY (GM/CC)	CORRECTED COMPOSITION ADJUSTED DENSITY (GM/CC)
SNT	759	523	535	16.11	-71	-27	20.88	1.7E-17	3.	93.	1.035	2.3E-17	1.8E-17	2.4E-17
			600	16.65	-64	-36		2.3E-18				3.1E-18	2.4E-18	3.2E-18
SNT	789	525	558	15.77	-78	-33	20.98	1.5E-17	8.	83.	1.040	2.0E-17	1.6E-17	2.1E-17
			590	16.06	-74	-37		5.8E-18				7.8E-18	6.0E-18	8.1E-18
SNT	833	528	516	14.66	-72	-31	19.47	3.5E-17	16.	79.	1.015	4.7E-17	3.6E-17	4.8E-17
			555	15.01	-67	-36		1.4E-17				1.9E-17	1.4E-17	1.9E-17
SNT	966	606	475	12.03	-68	-36	16.58	3.1E-17	11.	84.	1.000	4.2E-17	3.1E-17	4.2E-17
			510	12.39	-63	-40		1.0E-17				1.3E-17	1.0E-17	1.3E-17
QUI	13	404	405	18.82	-82	-7	0.32	2.0E-16	19.	70.	0.889	2.7E-16	1.8E-16	2.4E-16
			355	19.22	-77	2		9.0E-16				1.2E-15	8.0E-16	1.1E-15
QUI	264	420	542	13.38	-91	-7	19.45	4.6E-17	7.	78.	1.006	6.2E-17	4.6E-17	6.2E-17
			488	13.72	-86	1		7.5E-17				1.0E-16	7.5E-17	1.0E-16
QUI	278	421	604	12.74	-77	-15	17.89	1.6E-17	4.	74.	1.036	2.2E-17	1.7E-17	2.2E-17
			533	13.18	-71	-5		3.7E-17				5.0E-17	3.8E-17	5.2E-17
QUI	788	525	328	13.96	-78	6	19.19	3.0E-15	8.	83.	0.869	4.0E-15	2.6E-15	3.5E-15
			380	14.42	-72	-5		6.3E-16				8.5E-16	5.5E-16	7.4E-16
QUI	803	526	333	13.73	-82	3	19.21	1.6E-15	6.	76.	0.857	2.2E-15	1.4E-15	1.9E-15
			343	13.83	-81	1		1.2E-15				1.6E-15	1.0E-15	1.4E-15
QUI	877	531	329	12.33	-83	-2	17.85	1.9E-15	9.	89.	0.860	2.6E-15	1.6E-15	2.2E-15
			356	12.58	-79	-8		5.6E-16				7.6E-16	4.8E-16	6.5E-16
JOB	740	522	510	16.26	28	-22	14.42	3.4E-17	3.	89.	1.017	4.6E-17	3.5E-17	4.7E-17
			570	16.71	34	-31		9.8E-18				1.3E-17	1.0E-17	1.3E-17

Table 3 (continued)

STATION	PASS	DATE	ALTITUDE (KM)	LOCAL TIME (HRS)	GEOGRAPHIC LONGITUDE (DEGREES)	GEOGRAPHIC LATITUDE (DEGREES)	MEAN GMT (HRS)	RHO N2.16 DENSITY (GM/CC)	A (P)	F (F10.7)	COMP. (K)	CORRECTED RHO N2.16 DENSITY (GM/CC)	COMPOSITION ADJUSTED DENSITY (GM/CC)	CORRECTED COMPOSITION ADJUSTED DENSITY (GM/CC)
JOB	888	601	458	13.23	25	-27	11.59	6.1E-17	11.	84.	0.995	8.2E-17	6.1E-17	8.2E-17
			496	13.55	29	-32		2.5E-17				3.4E-17	2.5E-17	3.4E-17
OOM	721	521	553	16.91	135	-27	7.96	2.1E-17	5.	88.	1.053	2.8E-17	2.2E-17	3.0E-17
			622	17.48	142	-36		5.3E-18				7.2E-18	5.6E-18	7.5E-18
OOM	736	522	545	16.59	129	-27	8.00	1.7E-17	3.	89.	1.045	2.3E-17	1.8E-17	2.4E-17
			613	17.15	137	-36		6.7E-18				9.0E-18	7.0E-18	9.5E-18
OOM	795	526	531	15.44	133	-30	6.59	3.1E-17	6.	76.	1.034	4.2E-17	3.2E-17	4.3E-17
			603	16.08	142	-39		7.6E-18				1.0E-17	7.9E-18	1.1E-17
OOM	987	608	419	11.13	134	-29	2.20	3.2E-16	12.	90.	0.940	4.3E-16	3.0E-16	4.1E-16
			440	11.34	137	-32		1.6E-16				2.2E-16	1.5E-16	2.0E-16
FTM	20	404	513	4.83	-86	40	10.56	2.1E-17	19.	70.	1.021	2.8E-17	2.1E-17	2.9E-17
			580	5.49	-76	31		1.0E-17				1.3E-17	1.0E-17	1.4E-17
FTM	34	405	489	4.34	-70	42	9.01	4.8E-17	32.	72.	1.003	6.5E-17	4.8E-17	6.5E-17
			525	4.75	-64	38		2.6E-17				3.5E-17	2.6E-17	3.5E-17
FTM	301	423	463	23.81	-91	24	5.92	3.3E-17	9.	71.	1.000	4.5E-17	3.3E-17	4.5E-17
			530	0.30	-85	13		1.0E-17				1.3E-17	1.0E-17	1.3E-17
FTM	369	427	356	13.03	-83	33	18.58	1.6E-15	10.	75.	0.863	2.2E-15	1.4E-15	1.9E-15
			335	13.33	-79	38		2.9E-15				3.9E-15	2.5E-15	3.4E-15
FTM	442	502	490	10.52	-77	16	15.68	5.5E-17	24.	82.	0.988	7.4E-17	5.4E-17	7.3E-17
			440	10.91	-72	24		1.4E-16				1.9E-16	1.4E-16	1.9E-16
FTM	640	515	295	16.16	-85	28	21.83	2.1E-14	6.	98.	0.834	2.8E-14	1.8E-14	2.4E-14
			335	18.71	-77	17		6.5E-15				8.8E-15	5.4E-15	7.3E-15

Table 3 (continued)

STATION	PASS	DATE	ALTITUDE (KM)	LOCAL TIME (HRS)	GEOGRAPHIC LONGITUDE (DEGREES)	GEOGRAPHIC LATITUDE (DEGREES)	MEAN GMT (HRS)	RHO N2.16 DENSITY (GM/CC)	A (P)	F (F10.7)	COMP. (K)	CORRECTED RHO N2.16 DENSITY (GM/CC)	COMPOSITION ADJUSTED DENSITY (GM/CC)	CORRECTED COMPOSITION ADJUSTED DENSITY (GM/CC)
FTM	649	516	590	6.12	-84	19	11.74	6.5E-18	8.	100.	1.027	8.8E-18	6.7E-18	9.0E-18
			525	6.62	-77	29		1.9E-17				2.6E-17	2.0E-17	2.6E-17
FTM	664	517	602	5.77	-90	19	11.79	4.6E-18	6.	100.	1.035	6.2E-18	4.8E-18	6.4E-18
			535	6.28	-83	29		1.7E-17				2.3E-17	1.8E-17	2.4E-17
FTM	678	518	596	5.57	-70	21	10.24	3.2E-18	3.	98.	1.043	4.3E-18	3.3E-18	4.5E-18
			560	5.84	-66	26		8.2E-18				1.1E-17	8.6E-18	1.2E-17
FTM	758	523	275	13.71	-79	25	19.01	1.4E-14	3.	93.	0.803	1.9E-14	1.1E-14	1.5E-14
			306	14.25	-72	14		5.0E-15				6.7E-15	4.0E-15	5.4E-15
FTM	773	524	268	13.26	-86	27	19.04	1.6E-14	2.	89.	0.793	2.2E-14	1.3E-14	1.7E-14
			295	13.82	-79	16		5.4E-15				7.3E-15	4.3E-15	5.8E-15

REFERENCES

1. Horowitz, R., "S-6, an Aeronomy Satellite," *Advan. Astronautical Sci.* 12:1963.

2. Spencer, N., "The Explorer XVII Satellite," *Planet. Space Sci.* 13:593, 1965.

3. Newton, G. P., Pelz, D. T., Miller, G. E,, and Horowitz, R., "Response of Modified Redhead Magnetron and Bayard-Alpert Vacuum Gauges aboard Explorer 17," Transactions of the Tenth National Vacuum Symposium, edited by George H. Bancroft, pp. 208-212, The Macmillan Company, New York, 1963.

4. Newton, G. P., Horowitz, R., and Priester, W., "Atmospheric Densities from Explorer 17 Density Gauges and a Comparison with Satellite Drag Data," *J. Geophys. Res.* 69:4690-4692, 1964.

5. Newton, G. P., Horowitz, R., and Priester, W., "Atmospheric Density and Temperature Variations from the Explorer XVII Satellite and a Further Comparison with Satellite Drag," *Planet. Space Sci.* 13:599-616, 1965.

6. Newton, G. P., "Evidence for a Latitudinal Variation of the Neutral Atmospheric Density," Trans. Am. Geophys. Union; Abstract C-A85, p. 75, 1967.

7. Pelz, D., and Newton, G., "Pressure Conversion Constants for Magnetron Ionization Gauges," *J. Vac. Sci. and Tech.* 4:239, 1967.

8. Schultz, F. V., Spencer, N. W., and Reifman, A., Upper air research program, progress report 2, Contract W-33-038; AC-14050 Eng. Res. Inst. Univ. Mich. p. 129, July 1948.

9. Havens, R. J., Koll, R. G., and La Gaw, H. E., "The Pressure, Density, and Temperature of the Earth's Atmosphere to 160 kilometers," *J. Geophys. Res.* 57: p. 59, 1952.

10. Horowitz, R., and Kleitman, D., "Upper Atmosphere Research Report XVIII," U. S. Naval Research Lab. Report 4246, Oct. 1953.

11. Ishii, H., and Nakayama, K., "A Serious Error Caused by Mercury Vapour Stream in Measurement with a McLeod Gauge in the Cold Trap System," Trans. 8th AVS Vas. Symp. p. 519, 1962.

12. Meinke, C. and Reich, G., "Influence of Diffusion on the Measurement of Low Pressure with the McLeod Vacuum Gauge, *Vacuum* 13:579, 1963.

13. Newton, G. P., Silverman, P., and Pelz, D., "Interactions between a Hypersonic Neutral Gas Beam and an Orified Pressure Gauge Mounted on a Spinning Satellite," Trans. Sixth Rarefied Gas Dynamics Symp., Boston, Mass., 1968.

14. Moe, K. and Moe, M. M., "The Effect of Adsorption on Densities Measured by Orbiting Pressure Gauges," *Planet. Space Sci.* 15:1329, 1967.

15. Moe, M. M., and Moe, K., "The Roles of Kinetic Theory and Gas-Surface Interactions in Measurements of Upper-Atmospheric Density," Trans. Sixth Rarefied Gas Dynamics Symp., Boston, Mass., 1968.

16. Von Zahn, U., "Mass Spectrometric Measurements of Atomic Oxygen in the Upper Atmosphere: A Critical Review," *J. Geophys. Res.* 72:5933-5937, 1967.

17. Reber, C. A., and Nicolet, M., "Investigation of the Major Constituents of the April-May 1963 Heterosphere by the Explorer XVII Satellite," *Planet. Space Sci.* 13:617-646, 1965.

Appendix A

Development of Equations Used to Interpret the Ion Current in Terms of Atmospheric Density

The purpose of this appendix is to develop the equations used to interpret the ion current measured at the gauge cathodes in terms of the atmospheric density. This development will be done for nonlinear gauges, considering both the case of zero recombination and that of total recombination of reactive gas species inside the gauge volume. By appropriate approximations the nonlinear results will be reduced to the results for a linear gauge. The composition sensitivity of the measurements will also be discussed.

The Gauge Equation

Assume the gauge has a pressure response given by

$$I_j = C_j(P) P_j , \tag{A1}$$

where

I_j = the gauge cathode current measured when a gas of species j is the only gas present in the gauge

P_j = the partial pressure of gas species j inside the gauge, and

$C_j(P)$ = the pressure conversion constant of gas species j, which for a cold-cathode gauge is a function of pressure, and for a Bayard-Alpert gauge is a constant (the "sensitivity" of the gauge).

The pressure conversion constant C_j for a given species of gas is experimentally determined, using Equation A1 by calibrating the gauge with that species only present in the gauge. If a particular species cannot be isolated so that its conversion coefficient may be determined in this way, then the ratio of the conversion constant for that gas species to the known conversion constant of another gas species is assumed to be equal to the ratio of the ionization cross-sections of the two species.

If a mixture of gases is in the gauge it is assumed that the total cathode current is the sum of the currents which would be generated by each gas individually,

$$I_T = \sum_j I_j = \sum_j C_j(P) P_j , \tag{A2}$$

where

I_T = the total measured cathode current.

Relationship Between Atmospheric Density and Gauge Cathode Current (Zero Recombination)

The gauge is moving relative to the atmosphere and is exposed to the atmosphere through an orifice. It is assumed that:

(1) The mean free paths of the particles are so large that the entering and exiting particles at the orifice do not interfere with one another.

(2) The distribution functions describing the velocities of the entering and exiting particles are Maxwellian, with the former being the distribution corresponding to the atmospheric temperature and the latter being the distribution corresponding to the gauge wall temperature.

Because the vacuum time constants of the gauges are small compared to the satellite spin period, it is also assumed that:

(3) There is equilibrium between the mass flux of particles entering and leaving the gauge volume.

With these assumptions, the pressure of gas species j inside the gauge is given by (see Schultz et al., 1948; Horowitz and Kleitman, 1953):

$$P_j = n_j K\sqrt{TT'}\, F(S_j) = n_T X_j k \sqrt{TT'}\, F(S_j) , \tag{A3}$$

where

n_j = atmospheric number density of species j,

T = atmospheric temperature, °K,

T' = gauge wall temperature, °K,

k = Boltzmann's constant,

n_T = atmospheric total number density,

$X_j = \frac{n_j}{n_T}$ = fractional abundance of gas species j,

$S_j \quad \frac{V_\perp}{U_j}$

U_j = most probable speed of atmospheric particles of gas j,

$V_\perp$ = satellite velocity component normal to the gauge orifice plane,

$$F(S_j) = e^{-S_j^2} + \sqrt{\pi}\, S_j \left[1 + \operatorname{erf}(S_j)\right] ,$$

$$\operatorname{erf}(S_j) = \frac{2}{\sqrt{\pi}} \int_0^{S_j} e^{-S^2} dS .$$

Combining Equations A2 and A3 we have

$$I_T = \sum_j C_j(P)\; n_T X_j k \sqrt{TT'}\, F(S_j) . \tag{A4}$$

Also, the atmospheric density can be written

$$\rho = n_T \sum_j X_j m_j , \tag{A5}$$

where

m_j = mass of one molecule (or one atom, if dissociated) of species j.

Thus Equations A4 and A5 relate the measured cathode current to the atmospheric density.

Relationship Between Atmospheric Density and Gauge Cathode Current (Total Recombination)

Making the same three assumptions as in the previous section, and assuming that total recombination of species j occurs inside the gauge volume, we have when we equate the mass flux entering and leaving the gauge volume:

$$\frac{Hn_j U_j}{2\sqrt{\pi}} F(S_j) = \frac{2H\xi_{2j} U_{2j}}{2\sqrt{\pi}} ,$$

where

H = the orifice area,

the subscript $2j$ means that the mass in the U_{2j} term is the molecular mass after recombination of the dissociated atoms of species j,

ξ_{2j} = number density inside the gauge of the recombined molecular form of species j.

The factor of two occurs because the particles leaving the gauge are twice as heavy as the entering particles.

$$\xi_{2j} = \frac{1}{2} n_j \frac{U_j}{U_{2j}} F(s_j) ,$$

whence

$$P_{2j} = \xi_{2j} k T' = \frac{1}{2} n_j k \sqrt{TT'} \sqrt{\frac{m_{2j}}{m_j}} F(s_j)$$

$$= \frac{1}{\sqrt{2}} n_j k \sqrt{TT'} F(s_j) = \frac{1}{\sqrt{2}} n_T x_j k \sqrt{TT'} F(s_j) , \tag{A6}$$

which differs from P_j (Equation A3) by the factor $1/\sqrt{2}$.

When Equation A6 is used in Equation A2 to find the total current, the conversion constant for the molecular species, C_{2j}, must be used. Thus we have

$$I_T = \sum_j \frac{1}{\sqrt{2}} C_{2j} (P) n_T x_j k \sqrt{TT'} F(s_j)$$

$$+ \sum_i C_i (P) n_T x_i k \sqrt{TT'} F(s_i) \tag{A7}$$

where $\sum_j$ is over the reactive gas species, which totally recombine inside the gauge, and $\sum_i$ is over the nonreactive gas species.

Equation A7 may be put in the same form as Equation A4 if the following convention is adopted: if total recombination of a particular gas species is to be assumed, the $C_j (P)$ term for that gas species must be replaced in the sum by $C_{2j} (P)/\sqrt{2}$.

Relationship Between Atmospheric Density and Spin-Modulated Cathode Current (Linear Gauge)

The customary technique for measuring the atmospheric density with gauges is to take the difference between the gauge output currents when the orifice normal makes the smallest angle with the velocity vector (maximum ram velocity) and when the orifice normal makes the largest angle with the velocity vector (minimum ram velocity). Using Equation A4 under these conditions, and assuming the atmospheric structure parameters do not change over the time and distance increments required for the vehicle to rotate 1/2 of a spin cycle, we have

$$\Delta I_T = I_x - I_N$$

$$= \sum_j n_T x_j k \sqrt{TT'} \left[C_j (P_x) F(S_{jx}) - C_j (P_N) F(S_{jN}) \right] \tag{A8}$$

where the subscripts X and N indicate quantities evaluated at the maximum and minimum ram velocity conditions, respectively. (One advantage of this procedure is that if a current caused by residual pressure from wall outgassing is present in addition to the other gas currents, and if the residual pressure is constant throughout the spin cycle, this current will not effect the ΔI_T value.)

Equation A8 may be written as

$$\Delta I_T = \sum_j \frac{1}{2} \rho U_{I\bar{m}} U_{o\bar{m}} x_j \left[C_j (P_x) F(S_{jx}) - C_j (P_N) F(S_{jN}) \right] , \tag{A9}$$

where $U_{I\bar{m}}$ and $U_{o\bar{m}}$ are the most probable speed of a particle of mass $\bar{m}$ inside the gauge and outside it in the atmosphere respectively.

For a linear gauge mounted on the spin equator, Equation A9 reduces to

$$\rho = \frac{\Delta I_T}{\sqrt{\pi}\, U_{I\bar{m}} V_{\perp x} \sum_j x_j C_j \sqrt{\frac{m_j}{\bar{m}}}} , \tag{A10}$$

since C_j is independent of pressure.

The computer program which calculated the densities for the Explorer 17 data converted the measured currents to pressures using the gauge sensitivity for molecular nitrogen and a mean molecular mass of 16 for the atmosphere. Also, the calculated densities were normalized by multiplying by 1.83 to the averaged effect between no and total recombination of oxygen inside the gauge. Thus we have for the calculated densities

$$\rho_{N_2,16} = 1.83 \frac{\frac{\Delta I_T}{C_{N_2}}}{\sqrt{\pi}\, U_{I,16} V_{\perp x}} = 1.83 \frac{\Delta P_{N_2}}{\sqrt{\pi}\, U_{I,16} V_{\perp x}} . \tag{A11}$$

Thus if we calculate the ratio

$$K \equiv \frac{\rho}{\rho_{N_{2,16}}} = \frac{\sqrt{\frac{\bar{m}}{16}}}{1.83 \sum_j x_j \sqrt{\frac{m_j}{\bar{m}}} \frac{C_j}{C_{N_2}}}, \tag{A12}$$

we can use Equation A12 to adjust the calculated density to any composition (and by our convention we may also calculate the effect of total recombination).

For a nonlinear gauge mounted on the satellite spin equator an iterative procedure is required to solve Equation A9 exactly, since in this case $C_j(P_x)$ also contains the density ρ. This iterative procedure may be avoided by making several approximations, as discussed below.

Relationship Between Atmospheric Density and Spin-Modulated Cathode Current (Nonlinear Gauge)

We have developed Equation A9 as the general expression relating the atmospheric density and the ΔI_T observed during the satellite spin. If we interpret the observed maximum and minimum cathode currents as being due to nitrogen gas only, Equation A9 may be rewritten as follows:

$$\rho = \frac{I_x - I_N}{\frac{1}{2} U_{I\bar{m}} U_{o\bar{m}} \sum_j x_j \left[C_j(P_x) F(S_{jx}) - C_j(P_N) F(S_{jN})\right]}$$

$$= \frac{C_{N_2}(P_X) P_X - C_{N_2}(P_N) P_N}{\frac{1}{2} U_{I\bar{m}} U_{o\bar{m}} \sum_j x_j \left[C_j(P_x) F(S_{jx}) - C_j(P_N) F(S_{jN})\right]}$$

$$= \frac{P_X - \frac{C_{N_2}(P_N)}{C_{N_2}(P_X)} P_N}{\frac{1}{2} U_{I\bar{m}} U_{o\bar{m}} \sum_j x_j \left\{\frac{C_j(P_x)}{C_{N_2}(P_x)} F(S_{jx}) - \frac{C_j(P_N)}{C_{N_2}(P_x)} F(S_{jN})\right\}} \tag{A13}$$

where P_X and P_N are, respectively, the maximum and minimum equivalent nitrogen pressures during the spin cycle. Several approximations will now be made.

(a) As is usually the case for satellites, $S_{jx} \gg 1$ and $S_{jn} \ll -1$; therefore

$$F(S_{jx}) = 2\sqrt{\pi}\, S_{jx}$$

and $F(S_{jn})$ is negligible compared to $F(S_{jx})$.

(b) $\dfrac{C_j(P_N)}{C_{N_2}(P_X)} \leq 1$.

(c) $\dfrac{C_{N_2}(P_N)}{C_{N_2}(P_X)} \simeq 1$.

(d) $\dfrac{C_j(P_x)}{C_{N_2}(P_X)} = \dfrac{C_j}{C_{N_2}}$.

Approximation (b) is not very critical, since $C_j(P_n)/C_{N_2}(P_X)$ is the coefficient of the $F(S_{jN})$ term which by approximation (a) is usually extremely small when compared to $F(S_{jx})$. Approximation (c) is not very critical, since for large maximum-to-minimum pressure ratios where $C_{N_2}(P_N)/C_{N_2}(P_X) \simeq$ 2 the minimum pressure P_N is small compared to the maximum pressure P_X and there is little difference between subtracting P_N and subtracting 1/2 P_N from P_X in Equation A13. Furthermore, if the maximum-to-minimum pressure ratio is small, the ratio $C_{N_2}(P_N)/C_{N_2}(P_X)$ is nearly unity because $C_{N_2}(P_N)$ is a slowly varying function of the pressure. The error introduced by approximation (d) can be seen from Figure A1. In Figure 1A, the lines represent the Bayard-Alpert gauges values used in analysis of all of the data reported and the points represent the correct values for the equatorial NRC gauge. It is seen that the values used for the sensitivity ratios for the NRC gauge are too large by a percentage dependent on gas composition and pressure. This causes the previously reported density values to be too low by approximately 0 percent at perigee and approximately 12 percent at altitudes between 300 km and 550 km.

Making these approximations, Equation A13 may now be written as

$$\rho = \frac{P_X - P_N}{\sqrt{\pi}\, U_{I\bar{m}}\, U_{o\bar{m}} \sum_j x_j \dfrac{C_j}{C_{N_2}} S_{jx}}$$

$$= \frac{P_X - P_N}{\sqrt{\pi}\, U_{I\bar{m}}\, V_{1x} \sum_j x_j \dfrac{C_j}{C_{N_2}} \sqrt{\dfrac{m_j}{\bar{m}}}} \; . \qquad \text{(A14)}$$

If we calculate the ratio $\rho/\rho_{N_{2,16}}$ using Equations A14 and A11, and remember that $\Delta P_{N_2} = P_X - P_N$, we obtain Equation A12.

Equation A12 was used to calculate a "composition adjustment factor," K. These K values were applied to the calculated values of $\rho_{N_{2,16}}$, using the relative composition obtained by diurnally averaging the Explorer 17 mass spectrometer results. The variation of K with the various assumed atmospheric compositions is illustrated in Figures A2 through A7, and illustrates the generally small sensitivity of the densities to composition uncertainties for gauge pressures greater than 10^{-9} Torr.

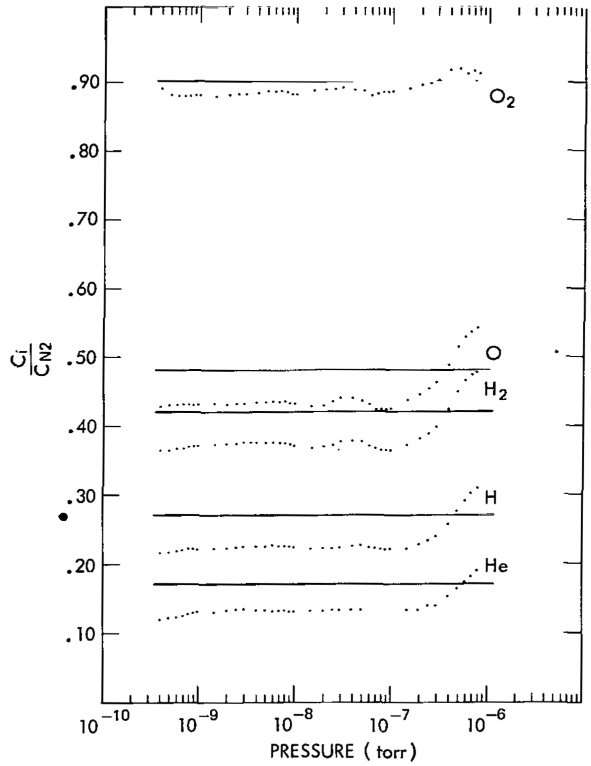

Figure A1—C_i versus pressure for various gases. The lines represent the Bayard-Alpert gauge values. The points represent the Redhead gauge values. Values for atomic oxygen, molecular hydrogen and atomic-hydrogen are calculated as explained in the text.

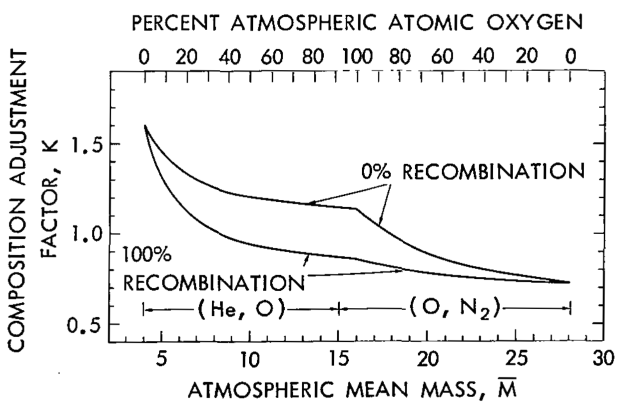

Figure A2—Composition adjustment factor versus atmospheric mean mass for the indicated binary atmospheric gas mixtures. The two cases of no and total recombination of atomic oxygen in the gauges are presented.

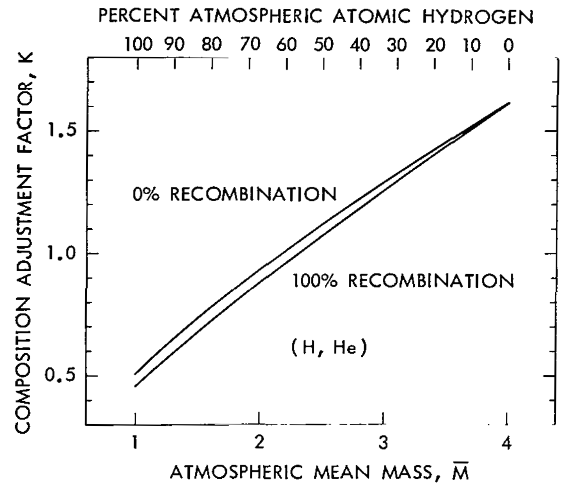

Figure A3—Composition adjustment factor versus atmospheric mean mass for a binary atmospheric mixture of helium and atomic hydrogen. The two cases of no and total recombination of atomic hydrogen in the gauges are presented.

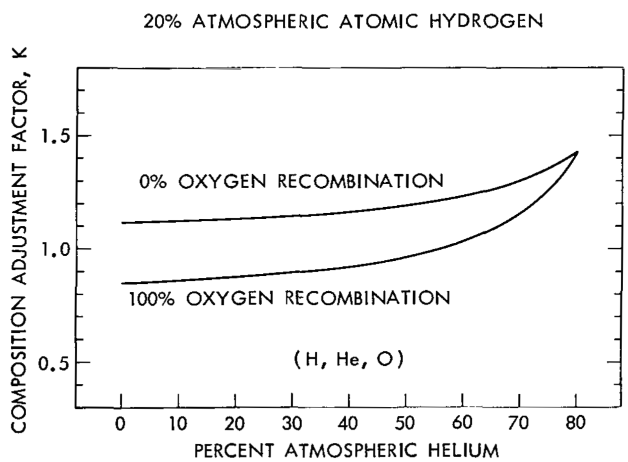

Figure A4—Composition adjustment factor versus percent atmospheric helium for a tertiary atmosphere of atomic oxygen, atomic hydrogen and helium. Because of the small effect of atomic hydrogen recombination, the two cases of no and total recombination of atomic hydrogen are not shown.

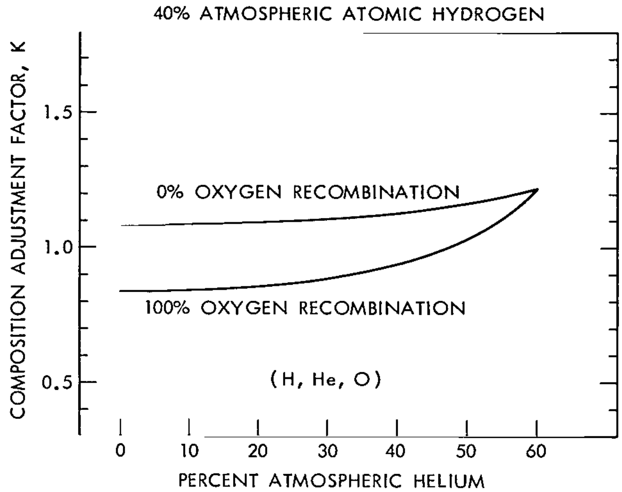

Figure A5—Composition adjustment factor versus percent atmospheric helium for a tertiary atmosphere of atomic oxygen, atomic hydrogen and helium. Because of the small effect of atomic hydrogen recombination, the two cases of no and total recombination of atomic hydrogen are not shown.

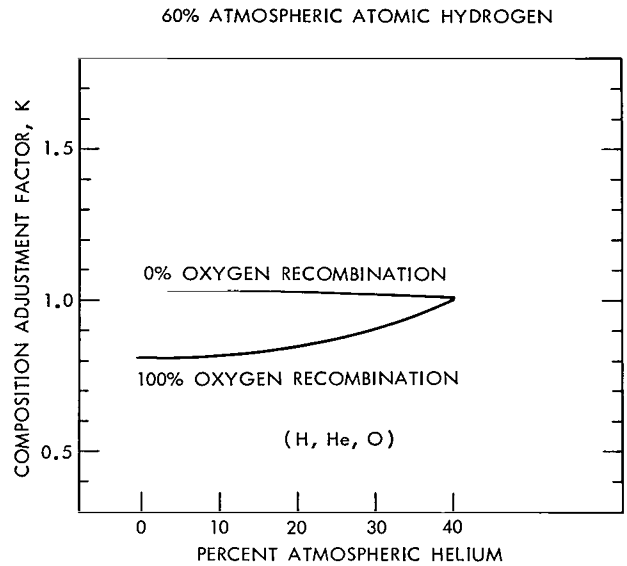

Figure A6—Composition adjustment factor versus percent atmospheric helium for a tertiary atmosphere of atomic oxygen, atomic hydrogen and helium. Because of the small effect of atomic hydrogen recombination, the two cases of no and total recombination of atomic hydrogen are not shown.

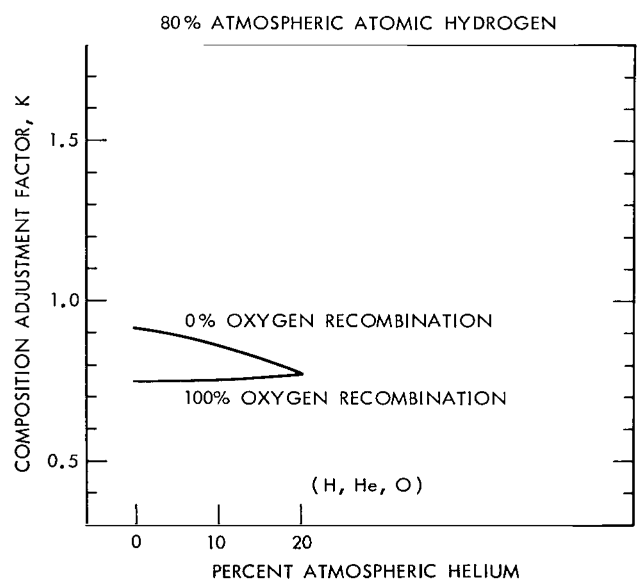

Figure A7—Composition adjustment factor versus percent atmospheric helium for a tertiary atmosphere of atomic oxygen, atomic hydrogen and helium. Because of the small effect of atomic hydrogen recombination, the two cases of no and total recombination of atomic hydrogen are not shown.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D. C. 20546

OFFICIAL BUSINESS

FIRST CLASS MAIL

POSTAGE AND FEES PAID
NATIONAL AERONAUTICS ANI
SPACE ADMINISTRATION

POSTMASTER: If Undeliverable (Section 158 Postal Manual) Do Not Return

"The aeronautical and space activities of the United States shall be conducted so as to contribute . . . to the expansion of human knowledge of phenomena in the atmosphere and space. The Administration shall provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof."

— NATIONAL AERONAUTICS AND SPACE ACT OF 1958

NASA SCIENTIFIC AND TECHNICAL PUBLICATIONS

TECHNICAL REPORTS: Scientific and technical information considered important, complete, and a lasting contribution to existing knowledge.

TECHNICAL NOTES: Information less broad in scope but nevertheless of importance as a contribution to existing knowledge.

TECHNICAL MEMORANDUMS: Information receiving limited distribution because of preliminary data, security classification, or other reasons.

CONTRACTOR REPORTS: Scientific and technical information generated under a NASA contract or grant and considered an important contribution to existing knowledge.

TECHNICAL TRANSLATIONS: Information published in a foreign language considered to merit NASA distribution in English.

SPECIAL PUBLICATIONS: Information derived from or of value to NASA activities. Publications include conference proceedings, monographs, data compilations, handbooks, sourcebooks, and special bibliographies.

TECHNOLOGY UTILIZATION PUBLICATIONS: Information on technology used by NASA that may be of particular interest in commercial and other non-aerospace applications. Publications include Tech Briefs, Technology Utilization Reports and Notes, and Technology Surveys.

Details on the availability of these publications may be obtained from:

SCIENTIFIC AND TECHNICAL INFORMATION DIVISION

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Washington, D.C. 20546