0.7721 g sec^{-1} cm^{-2}. The opening of the exhaust gas sampler probe is 1.29 cm^2 in area, giving a mass flow rate of 1.09 g/sec. Assuming all exhaust products impinging upon the open area are pulled into the sampling system, a total of 81.8 g should be collected in all four traps (A, B, C, and D) for the 150-second firing (test 005) less the background (test 006). The actual amount extracted with a mixture of benzene and methanol was 0.178 g. Several factors could lead to this large difference between theoretical and actual yields, including (i) trapping efficiencies, (ii) solubility of trapped species in the benzene and methanol mixture, and (iii) reduced flow due to more complex flow dynamics than assumed. The experiment was not originally designed to obtain quantitative data on the organic products, but an estimate of organic material produced can be made assuming the trapping efficiency is 100 percent for the organic components of the exhaust gases. If the ion intensities of various species in all the spectra taken (some of which are listed in Table 2) are summed, the gases NH_3, H_2O, CO, NO, O_2, and NO_2 account for 87.7 percent (*6*) of the total exhaust product extract; the compounds containing only C, H, and O amount to 6.0 percent (*6*); and the components consisting of C, H, and N (with traces of O) amount to 5.8 percent (*6*). The latter two compound groups can be considered the organic exhaust products, and they amount to 11.8 percent of the extract.

In conclusion, virtually all LM engine exhaust products are of low molecular weight, the most being free and combined gases. The organic products are somewhat minor in concentration and quite varied in composition (see Table 2). Of particular interest are the following compounds: acetylene, hydrogen cyanide, ethylene, formaldehyde, propadiene, ketene, cyanous acid, hydrazoic acid, various methylamines, acetaldehyde, methyl nitrite, formic acid, nitrous acid, butadiyne, various hydrazines, nitromethane, and some nitrosohydrazines with traces of other oxidation derivatives of UDMH and hydrazine.

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6. These estimated percentages were calculated on the assumption that the sensitivities were inversely proportional to the molecular weight within each homologous series and also directly proportional to the number of π-electrons in each structure.
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Superpressure Balloon Flights in the Tropical Stratosphere

Abstract. *Seven balloons were launched successfully from Ascension Island in January 1969. The balloons, flown at altitudes of 20 and 24 kilometers, will make possible a detailed analysis of the stratospheric circulation near the equator and will hopefully lead to an understanding of the quasi-biennial stratospheric oscillation in the tropics.*

In March 1966 flights of superpressure balloons (nonextensible balloons that are not vented and float at a predetermined altitude characterized by constant density) were begun from Christchurch, New Zealand (*1*). Since that time 200 flights have been made in a joint New Zealand–U.S. program. The longest flight thus far is 441 days at an altitude of 16 km (100 mb). The average duration for stratospheric flights in the last year has exceeded 6 months. The balloons fly stably at their design altitude, never deviating by more than 30 m from a surface of altitude characterized by constant density. Thus far the balloons have been located by telemetry of the elevation angle of the sun (*2*). In 1970 a much more precise location system, which uses the Nimbus D satellite, is planned. The Nimbus D program is intended to demonstrate the feasibility of the location of balloon vehicles by satellite. Included in plans for the future is the intention to fly several thousand balloons at a number of altitudes in both hemispheres with a satellite being used to locate the balloons and to transmit to the ground.

In this first test program to demonstrate the capability of balloon tracking with the Nimbus D satellite, a meaningful research objective was desired. The decision was made to use this program to study the quasi-biennial wind oscillation, with the use of balloons flown from a launch site near the equator. The oscillation, which has yet to be adequately explained, is a major feature of the circulation of the tropical stratosphere (*3*). During the course of a cycle the wind direction near the equator reverses from east to west, and the speed at some levels changes by as much as 50 m/sec. Ascension Island, situated 8° south of the equator in the mid-Atlantic, was chosen as the launch site since the island provides excellent logistic support with its radar stations and satellite communications links.

Three groups of launches were planned to test launch techniques and the performance of balloon vehicles. The location system to be used on these flights consists of a sun-angle sensor which varies the period of repetition of a letter of the Morse code that identifies the balloon. Cooperative tracking stations include Ascension Island, Boulder, Buenos Aires, Christchurch, Honolulu, Huancayo, Manila, Point Reyes, California, Mauritius Island, Pretoria, Santiago, and Jerusalem. Although this crude system positions a balloon only once daily with an accuracy of no better than 100 km, it is nevertheless adequate for delineating the large-scale features of the stratospheric circulation.

The first series of flights was conducted in May–June 1968. The problem of launching the large (11 m in diameter) delicate balloons from an island where the winds are always in excess of 5 m/sec and usually in excess of 7 m/sec was solved by the use of a launch wagon which carried the balloon down the runway until its speed equalled the wind speed whereupon the balloon was launched at a relative wind speed of zero without damage. The first series of flights was handicapped by an excessive ascent rate near float altitude which caused balloon damage. The longest flight achieved on this first series was 10 days.

In the second series, conducted in January 1969, the excessive ascent rate was reduced by the inclusion of a ballast of Freon-11 in a black plastic container. A period of 6 hours was required to evaporate all the Freon and permit

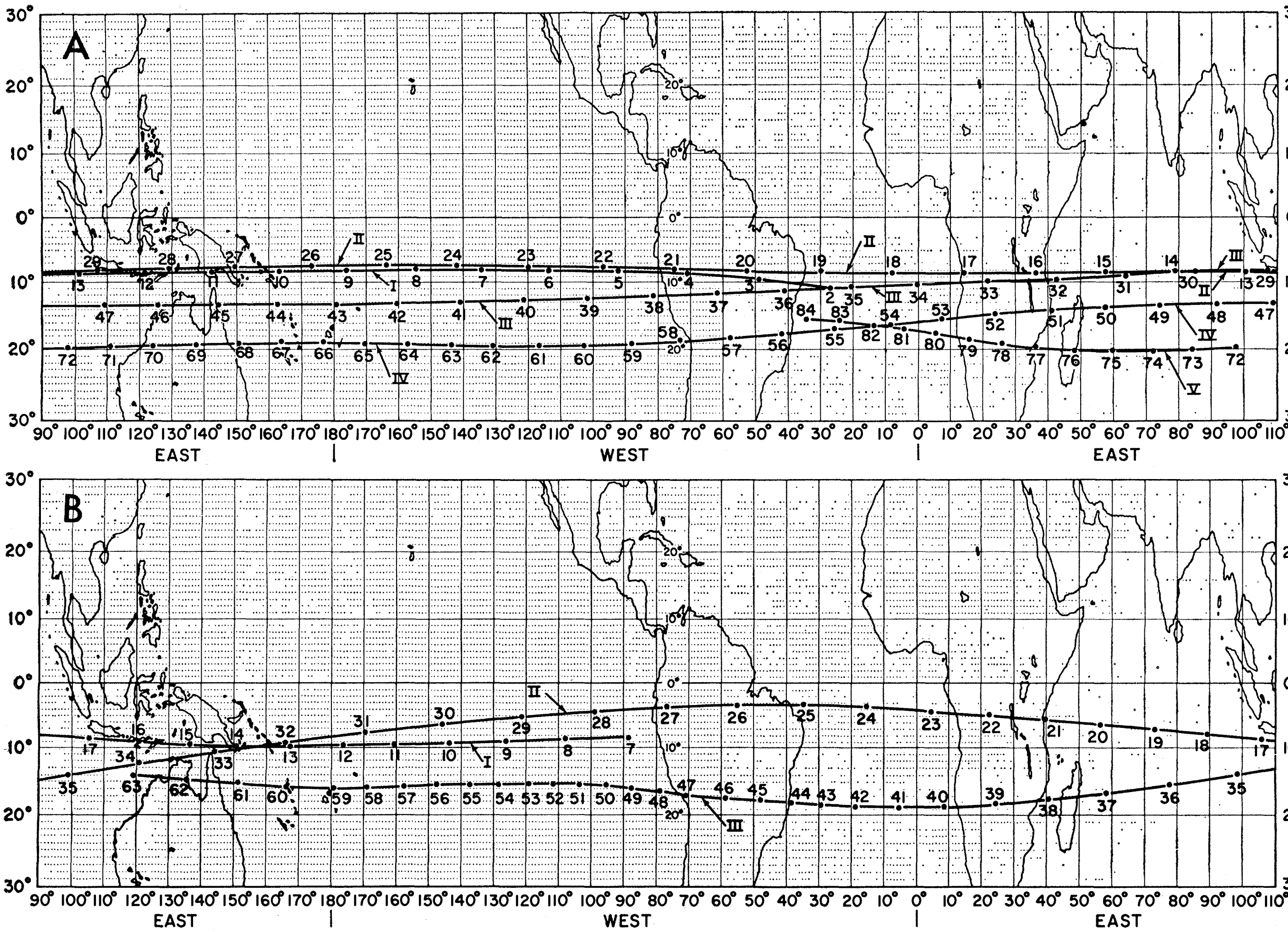

Fig. 1. (A) Trajectory for balloon 12 EW (24 January to 17 April 1969) at 50 mb. (B) Trajectory for balloon 09 EA (21 January to 31 March 1969) at 30 mb. Numbers next to points on the curves indicate the number of days of balloon life.

the balloon to reach its design superpressure. With this technique, nine balloons were launched, seven of which flew successfully. Of these launched balloons, four were flown at an altitude of 20 km (50 mb) and three were flown at an altitude of 24 km (30 mb).

A new series of flights was conducted in August 1969 to further refine the balloon vehicle and launch technique for the 30 forthcoming balloon flights to be made in conjunction with the Nimbus D satellite.

The results of the flights of the seven balloons flown successfully in January 1969 have revealed a number of distinctive circulation features. At both flight levels the drift has been from east to west along slightly undulatory paths. Average easterly wind speeds for the first orbit or two were 26 m/sec at 50 mb and 22 m/sec at 30 mb with average speeds over a 2-day period along segments of the orbits varying by as much as 50 percent above and below the longer-term mean values. The latitudinal oscillations were confined to the belt between 2°N and 25°S. The flow characteristics described above are illustrated by the trajectories in Fig. 1, which depict the balloon motions during the 2- to 3-month period after release.

The preliminary indication of substantial velocity fluctuations, presumably associated with long waves imbedded in the general east-to-west flow, are of special interest, since it has been hypothesized that such fluctuations must exist to account for the periodic appearance of westerly momentum above the equator during the course of the quasi-biennial oscillation (*4*). Several investigators have described equatorial wave motions (*5*) and considered their possible role in the quasi-biennial oscillation (*6*). Time-series analyses of wind and temperature soundings from widely spaced equatorial locations give observational support for the two main wave modes predicted by theory (*7*). The superpressure balloon flights offer a unique description of the stratospheric waves and their relation to the quasi-biennial oscillation. As the results of more flights for different phases of the cycle become available, the horizontal balloon technique will hopefully contribute to a better understanding of this strange phenomenon.

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