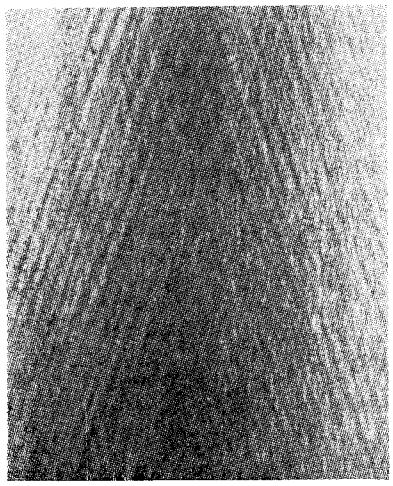

Fig. 9 Surface pattern from a re-entry body, reproduced from Ref. 3.

and the pattern in Fig. 4 occurs where the striations are predominant with a small scale criss-cross superimposed on them as in Fig. 8a. When the melted layer gets thicker, the variation in depth, if present, becomes unimportant and a pattern as shown in Fig. 9 from a re-entry body or in Fig. 5 on the model occurs. With the thin layer the viscous forces are the dominant ones; with the thick layer the viscous forces and the pressure forces are of equal importance. In both cases the presence of the vortices is a prerequisite for the phenomenon to take place. The present concept of the importance of the depth of the melted layer is supported by the observation in Ref. 3 to the effect that, in most cases, longitudinal grooves appeared upstream of the pattern. In light of the present concept this is due to the melted layer being thin upstream, whereas downstream the ablated material accumulates giving a thicker layer there.

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A Computerized Mass Spectrometer System for Spacecraft Ground Tests

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THE development of a dual-gas environmental control system for the Gemini B spacecraft required an instrument to monitor the composition of both cabin and suit atmospheres.

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During prelaunch, the Gemini B, on the pad with open hatches, has an earth atmosphere. After the hatches are closed, the cabin is purged, and a dual-gas (helium and oxygen) system supplies the cabin atmosphere on the pad. During launch and flight, a single-gas oxygen system supplies the cabin atmosphere. The atmosphere in the suits is oxygen during all mission phases.

System Description

A mass spectrometer was chosen to monitor the atmosphere in the cabin and space suits because this instrument is capable of detecting the five gases of interest (helium, water vapor, nitrogen, oxygen, and carbon dioxide) over a wide range of concentrations and, with the proper inlet system, can provide almost continuous monitoring.

The mass spectrometer system is shown schematically in Fig. 1. The gas transfer system provides gas samples from five locations in the spacecraft cabin, from three locations in each space suit, and from a common point, in the suit system. This system circulates gas, at a positive pressure, from the selected locations, past the inlet system, returning the gas to the spacecraft at a place corresponding to the sample location. This minimizes the mixing of gases in different parts of the spacecraft.

Test gases are admitted through one of two inlet systems. These inlets employ a capillary to reduce the pressure to 1 torr; a molecular leak admits the gas into the spectrometer chamber. This arrangement reduces the fractionation of the gas sample to a negligible amount. The capillaries are heated to reduce condensation of water vapor and carbon dioxide. Two inlets are used to isolate the cabin and suit environment control systems.

A diffusion pumped vacuum system was selected because of the large amount of helium in the gas mixture. The vacuum system consists of a 6-in. bakeable valve, a 4-in. liquid nitrogen-cooled trap, a 4-in. oil diffusion pump, and a 15-cfm two-stage mechanical pump. The system uses copper gaskets with sexless flanges, except for an elastomer O-ring between the diffusion pump and the trap. The 6-in. valve is used to isolate the chamber during the trap clean-up,[1] to provide a vacuum storage for the quadrupole during down time, and to provide a means of controlling the pressure in the chamber during analysis. The oil in the diffusion pump is Monsanto Sanovac 5. This oil was selected for its oxygen-compatibility[2] and to avoid the cracking problems associated with the silicone oils. The mechanical pump fluid is Monsanto MCS-585. This fluid, di-iso-decylphthalate, is also being used because it is oxygen-compatible and does not require special seals as does tricresyl phosphate.

The data acquisition system is comprised of a 100 channel analog signal conditioning unit, a test site control unit for multiplexing and digitizing, and a recording control unit which formats and records the digital data on magnetic tape. With this system, the digital formatted data at the central recording unit is made available to the computer. Also, analog signals monitored by the signal conditioning unit can be converted back to analog and displayed on the K-logger graph.

The test control system is made up of the computer, input/output (I/O) buffer, electrometer gain selection, five digital-to-analog converters (DAC) used for signal storage, and two DAC units used to supply mass selection voltages to the mass spectrometer.

The computer was programed to provide the five input voltages in sequence. Two commands were initiated for each input voltage desired. One command was sent to the "coarse" DAC. A second command was issued to the "fine" DAC. The sum of the coarse and fine DAC's appeared at the input to the gas analyzer and was monitored by the signal conditioning unit. In the event that the input voltage was not within the specified limits, the computer adjusted the fine

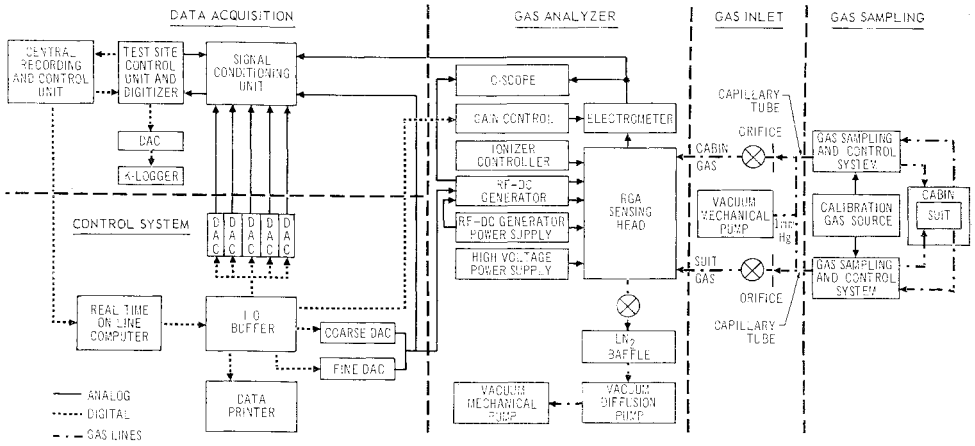

Fig. 1 Computerized mass spectrometer system connected to the spacecraft and astronauts suits. The system monitors the concentrations of helium, water vapor, nitrogen, oxygen, and carbon dioxide at various locations in the cabin and suits.

DAC to the desired input voltage before the output of the electrometer was examined.

The computer examined the electrometer output and selected the proper range. Each time a gas was detected and analyzed, it's computed value was also stored in one of the five digital-to-analog converters connected to the signal conditioning unit. The output of each of these DAC's was monitored continuously by the data acquisition system and adjusted by the computer once every second.

System Calibration

Calibration of the system includes the determination of the sensitivity factors for each of the gases, the cracking fractions for each of the gases, and the voltage for each of the mass numbers.

Mixed gases, consisting of various known concentrations of helium, nitrogen, oxygen, and carbon dioxide expected to be present in the actual test, were used for the calibration.

It was necessary that a flow be maintained across the inlet sampling tube leading to the analyzer. With a static gas condition at the inlet, there was a gradual change in the concentrations. The sensitivity factors were determined by comparing several gas mixtures. A comparison was also made which established that the calibration for both inlets to the analyzer was the same.

Oxygen had a cracking pattern that affected both the nitrogen and carbon dioxide readouts. Therefore, the magnitude of this effect was determined and appropriate factors were inserted in the computer.

The system has been checked with a variety of known gas mixtures. The results are presented in Fig. 2 where the actual concentrations are plotted vs the measured concentrations. Carbon dioxide measurements have been omitted because the concentrations were all below 10%.

Problems and Solutions

During the initial operations with the data system, the noise level was too high to obtain meaningful data even with the active filter in the electrometer. This filter was then modified by replacing the capacitors in the feedback circuit with capacitors of larger values until a suitable compromise between noise level and response time was achieved.

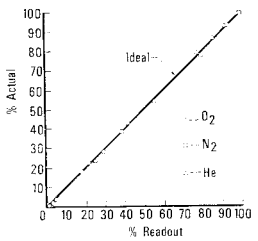

Fig. 2 Comparison of actual concentrations with concentrations measured with the computerized mass spectrometer for a variety of gas mixtures. Carbon dioxide measurements were all below 10% and have been omitted for clarity.

The effect of zero drift, primarily from the electrometer circuit, was eliminated by measuring the output signal from the gas analyzer at a point between mass 4 and 12 where mass peaks do not occur and establishing this as a zero level in the computer for each gain setting. This value was then algebraically subtracted from each of the gas signals, thus correcting for zero drift. The zero level was checked and stored each 50 sec.

To aid in eliminating some of the effect of the background gases, the complete system was heated and operated at 300°F at all times. Operating the system in this condition reduced the carbon dioxide background.

It was noted that the output data had a very low-frequency oscillation. This problem was caused by liquid nitrogen vaporizing in a long supply line during off periods and by the warming of the baffle so that some of the condensable gases were revaporized. The baffle fill system was modified to allow a continuous flow to LN_2 to the baffle so that some of the condensable gases were revaporized. The baffle fill system was modified to allow a continuous flow of LN_2 to the baffle at all times.

Erratic data were observed for gas concentrations of less than 1%. Originally the system was designed with programed electrometer range selection. For small concentrations, the signal from the electrometer became very small and data system noise became significant. This condition was improved by adding a capability to the program which would allow automatic gain change.

Peak drift is a problem that is not yet totally solved. However, many improvements have been made which have helped to stabilize peak location. It was determined that much greater stability could be realized by allowing the system to remain in standby condition as much as possible and by having, as a minimum, a 4-hr warm-up prior to determining the peak location. Line voltage stabilizing transformers were installed to prevent power fluctuation.

Another problem was a change in the sensitivity to different gases between tests. Helium and carbon dioxide were the two gases most severely affected. This is believed to be the result of a change in the ion energy which may have occurred while the ionizer control unit was in the calibration laboratory for periodic functional checks and calibration. Very small changes in the energy will produce large changes in the calculated composition.

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