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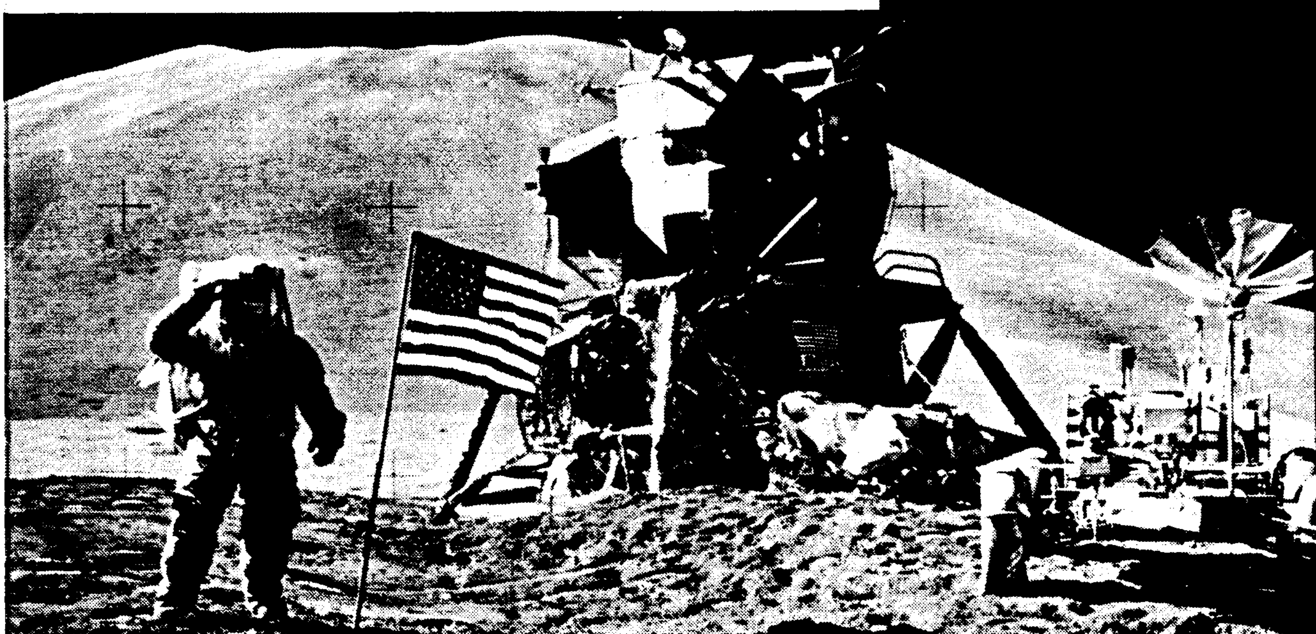
APOLLO 15

Preliminary Science Report



NATIONAL AERONAUTICS
AND SPACE ADMINISTRATION

13. Cold Cathode Gage Experiment (Lunar-Atmosphere Detector)

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OBJECTIVES OF THE EXPERIMENT

Although the lunar atmosphere is known to be tenuous, its existence cannot be doubted because the solar wind striking the lunar surface constitutes one source, and there may be other sources as well. The most significant source of lunar atmosphere, if it should prove detectable, is degassing from the interior. Such degassing would constitute useful information on how planetary atmospheres originate.

The gas concentration at the lunar surface must depend on the balance between source and loss mechanisms as well as on properties of diffusion over the lunar surface. The dominant loss mechanisms for lunar gases are thermal escape for particles lighter than neon and escape through interaction with the solar wind after photoionization has occurred for neon and heavier particles. The gas particles lighter than neon have such high thermal velocities that a significant fraction of them can escape from the gravitational field of the Moon owing to their greater-than-escape velocity. The average lifetime on the Moon for helium is approximately 10^4 sec. Heavier particles, with lower thermal velocities, have longer lifetimes; the lifetime for neon is approximately 10^{10} sec, and the lifetime for heavier particles is much longer.

Particles exposed to solar ultraviolet radiation become ionized in approximately 10^7 sec; and, once ionized, the particles are accelerated by the electric field associated with the motion of the solar wind. The initial acceleration is at right angles to the direction of both the solar wind and the embedded magnetic field; then, the direction of motion is deviated by the magnetic field so that the ionized particle acquires an average velocity equal to the solar-wind-velocity component perpendicular to the embedded magnetic field. The time required for this acceleration is approximately the ion gyro period in the embedded magnetic field. The radii of gyration for most ions are comparable to or greater than the lunar radius. As a consequence of this acceleration process, particles in the lunar atmosphere are largely swept away into space within a few hundred seconds (the ion gyro period) after becoming ionized. Thus, the time required for ionization regulates the loss process, which results in lifetimes for particles in the lunar atmosphere on the order of 10^7 sec.

The cold cathode gage experiment (CCGE) was included in the Apollo lunar surface experiments package (ALSEP) to evaluate the amount of gas present on the lunar surface. The CCGE indications can be expressed as concentration of particles per unit volume or as pressure, which depends on the ambient temperature in addition to the concentration. The amount of gas observed can be compared with the expectation associated with the solar-wind source to obtain an indication of whether other sources of gases are present. Contamination from the lunar module (LM) and from the astronaut suits constitutes an additional source, but one that should decrease with time in an identifiable way. In the long run, measurements of actual composition of the lunar atmosphere should be made with a mass spectrometer to examine constituents of particularly great interest geochemically and to identify and discriminate against contaminants from the vehicle system.

INSTRUMENT DESCRIPTION

The essential sensing element of the CCGE consists of a coaxial electrode arrangement, as shown in figure 13-1. The cathode consists of a spool that is

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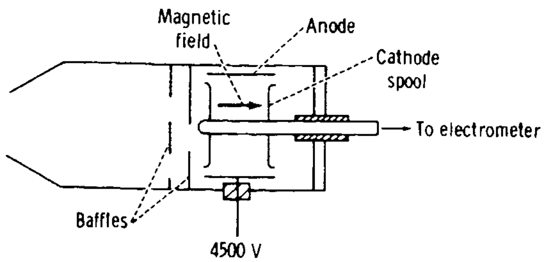

FIGURE 13-1.–Diagrammatic representation of the cold-cathode ionization gage used in the CCGE.

surrounded by a cylindrical anode. A magnetic field of approximately 0.090 T is applied along the axis, and 4500 V are applied to the anode. A self-sustained electrical discharge develops in the gage in which the electrons remain largely trapped in the magnetic field with enough energy to ionize any gas particles that they strike. The current of ions collected at the cathode is a measure of the gas density in the gage.

The response of the CCGE in terms of cathode current as a function of gas concentration is shown in figure 13-2. The CCGE response depends to a rather modest degree on the gas composition; thus, as long as the gas composition remains unknown, a fundamental uncertainty remains in the interpretation of the data. Usually, the results are expressed in terms of equivalent nitrogen response (i.e., the concentration of nitrogen that would produce the observed response). The true concentration varies from this result by a factor that is usually less than 2.

Instrument temperature was monitored by means of a sensor on the CCGE. Because no temperature control exists, the temperature range is approximately 100 to 350 K.

The CCGE was closed with a dust cover that did not constitute a vacuum seal. The cover was removed on command by using a squib motor and was then pulled aside by a spring. Because the CCGE was not evacuated, adsorbed gases produced an elevated level of response when the gage was initially turned on. Baking the CCGE on the lunar surface at 350 K for more than a week during each lunar day drove the adsorbed gases out of the gage.

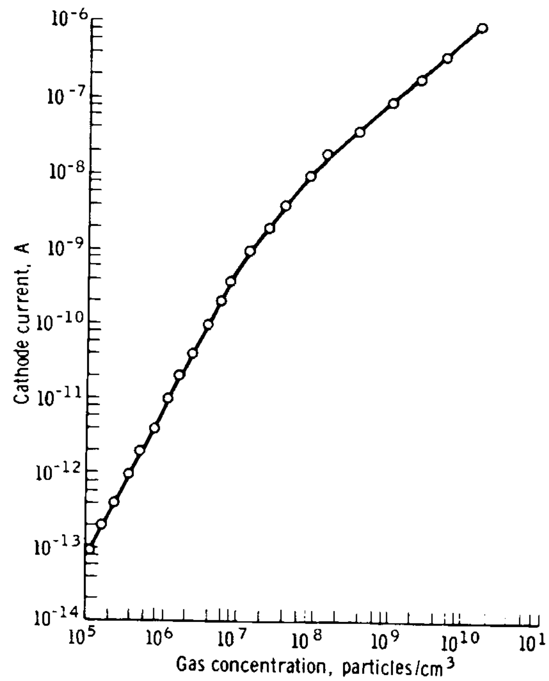

FIGURE 13-2.–Response curve for the CCGE.

Electronic Circuitry

A description of each of the major CCGE assemblies follows.

Electrometer amplifier.–An autoranging, autozeroing electrometer amplifier monitors current outputs from the sensor or from the calibration-current generators in the 10^{-13}- to 10^{-6}-A range. The output ranges from −15 mV to −15 V. The output of the electrometer is routed to an analog-to-digital converter. The electrometer consists of a high-gain, low-leakage differential amplifier with switched high-impedance feedback resistors and an autozeroing network.

The electrometer operates in three automatically selected overlapping ranges: (1) most sensitive, (2) midrange, and (3) least sensitive. Range 1 senses currents from approximately 10^{-13} to 9.3×10^{-11} A; range 2, currents from approximately 3.3×10^{-12} to 3.2×10^{-9} A; and range 3, currents from approximately 10^{-9} to 9.3×10^{-7} A.

Power supply.–The 4500-V power supply consists of a regulator, a converter, a voltage-multiplier network, and the associated feedback network of a low-voltage power supply. The regulator furnishes approximately 24 V for conversion to a 5-kHz square wave, which is applied to the converter transformer. The output of the converter transformer is applied to a voltage-multiplier network (stacked standard doublers), the output of which is filtered and applied to the CCGE anode.

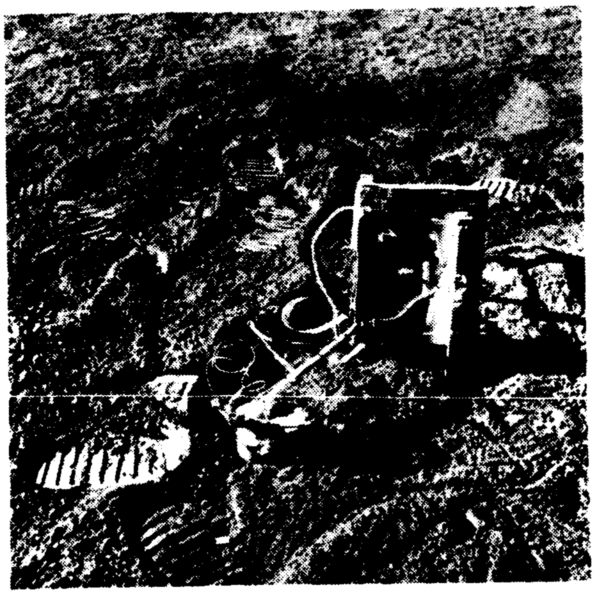

FIGURE 13-3.–The CCGE and SIDE as deployed on the lunar surface. The cold-cathode ionization gage is attached to the lower end of the extended leg of the SIDE (AS15-86-11597).

Deployment

The electronics for the CCGE are contained in the suprathermal ion detector experiment (SIDE), and the command and data-processing systems of the SIDE also serve the CCGE. The CCGE is attached to an extended leg of the SIDE on its northeast face, approximately 33 cm from the SIDE. The experiment was deployed so that the LM descent stage was outside the CCGE field of view, which looked northward. In figure 13-3, the CCGE is shown deployed on the lunar surface.

RESULTS

The CCGE was turned on at approximately 19:34 G.m.t. on July 31, 1971. On initial activation, the gage indicated full scale; but, after approximately 30 min of operation, the output began to drop. The high voltage was then commanded off to allow the instrument to outgas. The gage has not been operated for prolonged periods during the lunar day because of voltage restrictions placed on the high-voltage power supply in the SIDE package, as described in section 12, Suprathermal Ion Detector Experiment.

The experiment was operated four more times for periods of approximately 30 min each to observe the effects of the LM depressurizations for the second and third periods of extravehicular activity (EVA) and for the equipment jettison and to observe the effects of the LM lift-off from the lunar surface. In each of the three LM depressurizations, the output of the experiment was driven to full scale for approximately 30 sec, as indicated in figure 13-4 for the third EVA. The double off-scale peaks separated by approximately 30 sec were caused by the cracking and the closing of the depressurization valve on the LM; and the third peak resulted from opening the hatch. The response during the ascent-stage lift-off is shown in figure 13-5.

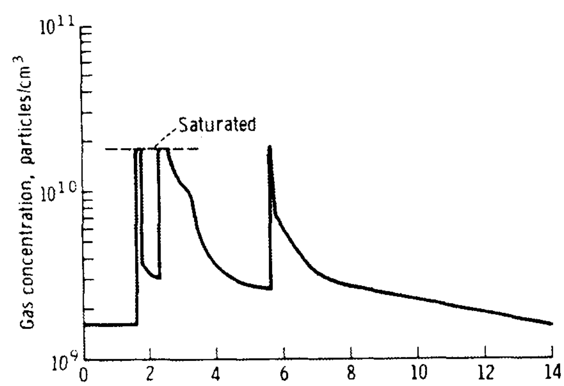

FIGURE 13-4.–Gas concentration detected during depressurization of the LM for the third EVA.

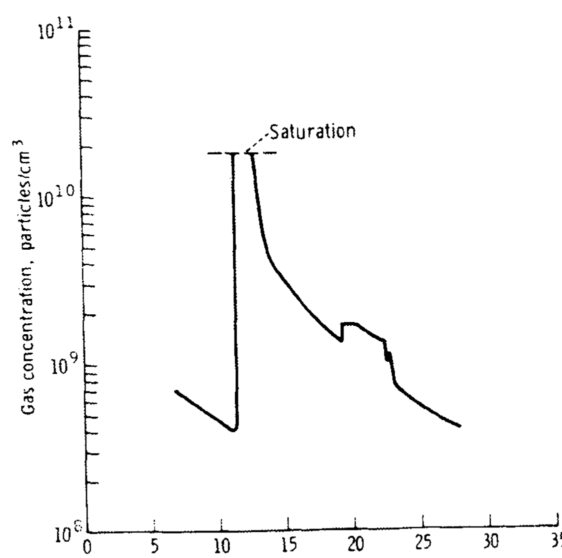

FIGURE 13-5.–Gas concentration detected during ascent-stage lift-off.

The gage was off scale for approximately 90 sec, after which the gas concentration fell rapidly. The cause of the approximate 4-min increase in response at approximately 8 min after lift-off is not known. At 20 min after lift-off, the gas concentration was back to approximately the value that prevailed before lift-off.

The temperature history of the gage during the first month on the lunar surface is shown in figure 13-6. The temperature rose to a maximum of approximately 350 K, near local noon. The sharp dip in the temperature curve near midday was caused by an eclipse of the Sun. A sharp increase in the rate of temperature fall at approximately 09:20 G.m.t. on August 13 indicates sunset at the gage approximately 5 hr before the Sun zenith angle became 90°; the calculated time for the latter occurrence is 14:14 G.m.t. Sunrise occurred at approximately 00:20 G.m.t. on August 29, approximately 17 hr after the time of 90° zenith angle, 07:22 G.m.t. on August 28.

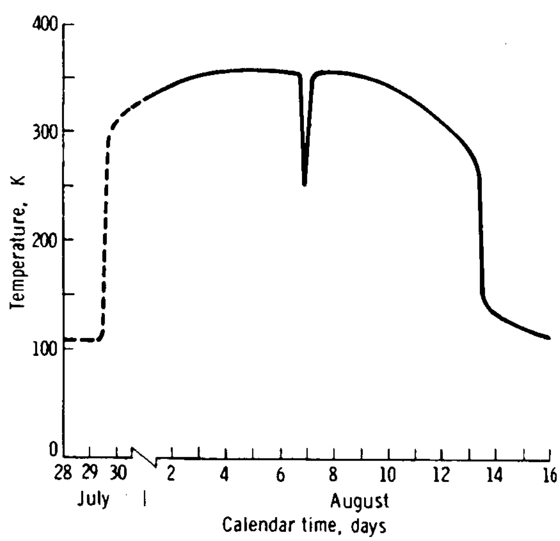

FIGURE 13-6.–The temperature history of the cold-cathode ionization gage during the first month on the lunar surface. The sharp dip in temperature near midday was caused by a lunar eclipse at the Apollo 15 ALSEP site.

The response history during the first sunset is shown in figure 13-7. A large increase in gas concentration occurred just after sunset, which (according to the temperature data) occurred at 09:20 G.m.t. on August 13. The increase lasted approximately a day, after which the response fell to a low value that is characteristic of lunar nighttime

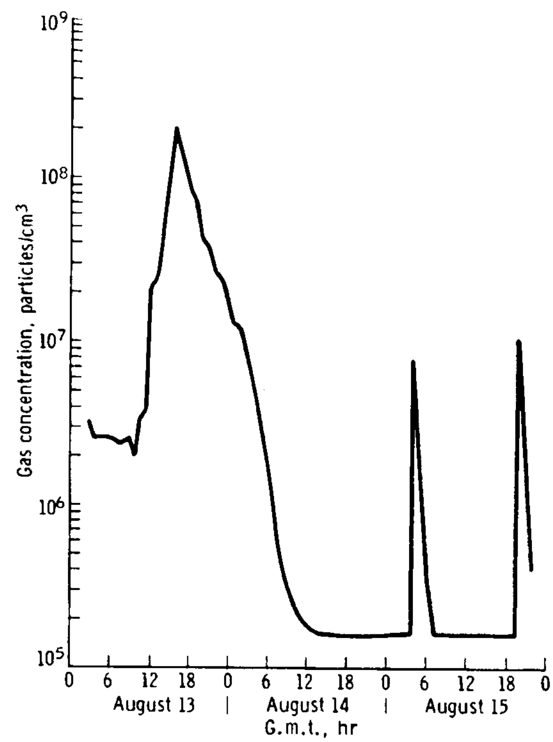

FIGURE 13-7.–Gas concentration detected during the first lunar evening after deployment of the CCGE. Sunset occurred at approximately 09:20 G.m.t. on August 13.

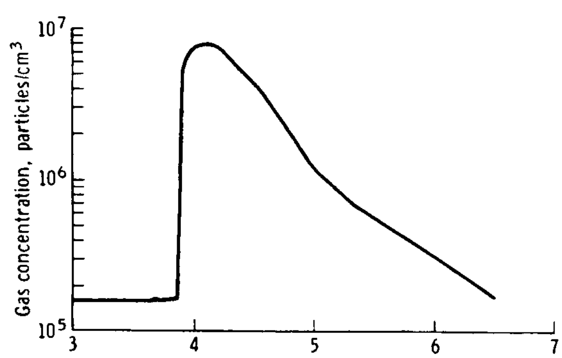

FIGURE 13-8.–Variation in gas concentration from 03:00 to 06:00 G.m.t. on August 15.

conditions. The source of the increase is not known, but it was probably the LM. An increase of lesser magnitude but of longer duration occurred after the first lunar sunset on Apollo 14.

The two shorter duration peaks on August 15, also shown in figure 13-7, are shown in greater detail in figures 13-8 and 13-9. A single peak somewhat similar

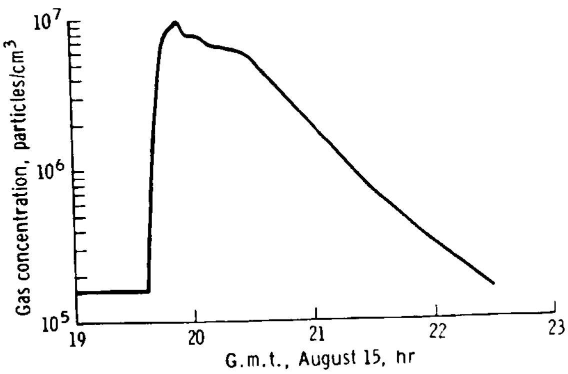

FIGURE 13-9.–Variation in gas concentration from 19:00 to 22:00 G.m.t. on August 15.

to these was seen on Apollo 14, also not long after sunset. No other peaks of this magnitude have been seen on Apollo 14 after the first month of operation, and this circumstance suggests that the peaks shown in figures 13-8 and 13-9 were caused by gas release at the LM.

The gas concentrations observed during sunlit periods appear to be caused by release of adsorbed gases associated with the landing operations. However, at the low nighttime temperatures, the contaminant gases remain adsorbed on the lunar surface; the observed concentrations are believed to be representative of natural ambient conditions. The observed concentrations are lower than might be expected from the solar wind, which should provide a nighttime atmospheric concentration of neon in excess of 10^6 atoms/cm^3 if as much neon is released from the lunar surface as impinges upon it from the solar wind. The fact that the observed concentrations are almost an order of magnitude lower than the expected concentration suggests that the lunar surface is not saturated with neon and that the rate of neon release from the lunar surface is much slower than the rate of neon implantation.

The LM impact was not detected by the Apollo 14 CCGE, and data are not complete enough at present to determine whether the LM impact was detected by the Apollo 15 CCGE. The CCGE was turned off at the times of the solar eclipse on August 6 and the solar flare on September 1. No easily recognizable correlations were found between transient gas events as seen on the CCGE and the response of other ALSEP instrumentation.

The data presented in this report are preliminary and may be changed significantly when data tapes become available.

ACKNOWLEDGMENTS

The CCGE sensor was supplied by the Norton Company, with the assistance of Frank Torney. The electronics were built by Marshall Laboratories (now Time Zero Corporation) under subcontract to Rice University. The authors are grateful to Dr. John Freeman and his associates at Rice University for their assistance in assuming contractual responsibility for development and production of the gage electronics in connection with the SIDE.