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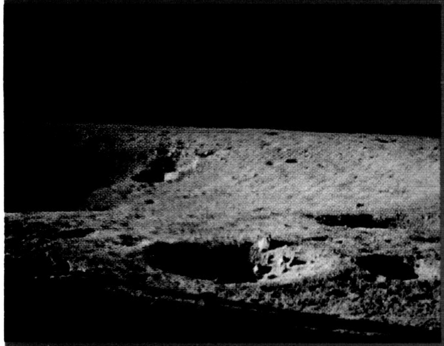
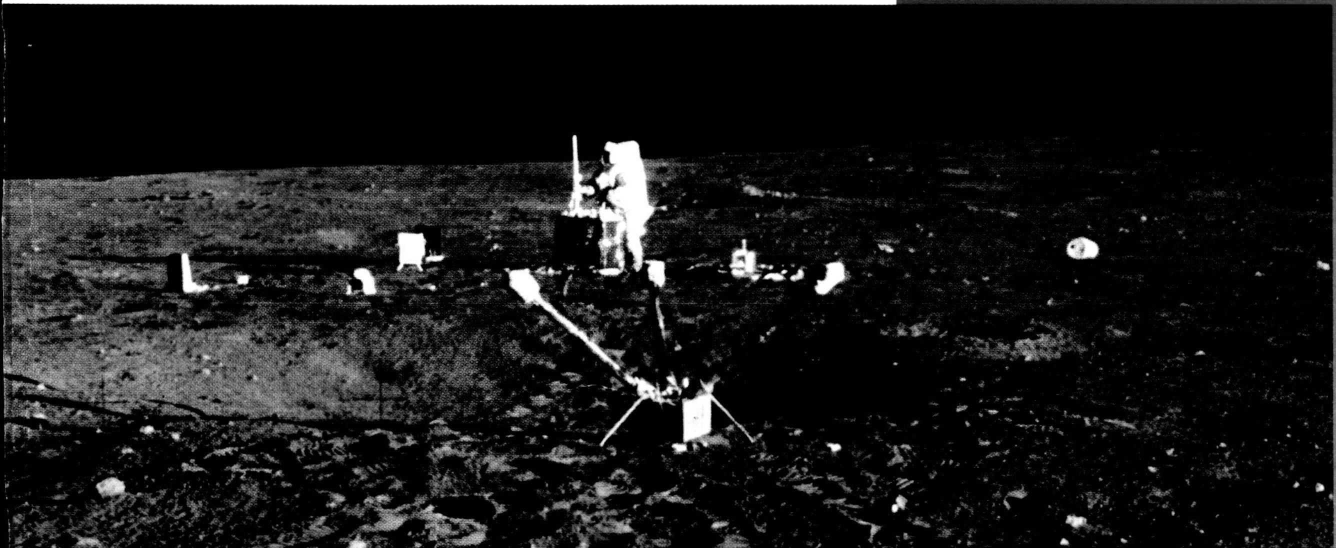
Preliminary Science Report





NATIONAL AERONAUTICS
AND SPACE ADMINISTRATION

7. Cold Cathode Gage (Lunar Atmosphere Detector)

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Purpose of the Experiment

Although the lunar atmosphere is known to be extremely tenuous, its existence cannot be doubted. At the very least, the solar wind striking the lunar surface constitutes a source mechanism. The expected atmospheric concentration depends upon the equilibrium between source and loss mechanisms. The observations of the lunar atmosphere will be of greatest significance if the dominant source mechanism for the atmosphere is internal (i.e., geochemical) rather than external (i.e., the solar wind).

The dominant loss mechanisms for lunar gases are expected to be thermal escape, for particles lighter than neon, and removal through ionization, for particles heavier than neon. At the temperatures encountered on the lunar surface, thermal velocities for the lighter gas particles are such that a significant fraction of the particles has greater than escape velocity. The average lifetime before escape for particles on the warmest portion of the Moon is approximately 10^4 sec for helium and 10^7 sec for neon. Heavier particles require much longer to escape by thermal motion. However, all particles exposed to solar ultraviolet radiation become ionized in approximately 10^7 sec. Once the particles are ionized, they 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 imbedded magnetic field. The direction of motion is then deviated by the magnetic field such that the particle acquires a velocity equal to the component of the solar-wind velocity that is perpendicular to the imbedded magnetic field. The time required for this second acceleration is approximately equal to the ion gyro period in the imbedded magnetic field, and the radii of gyration for most ions are comparable to the lunar radius or greater. Consequently, most particles in the lunar atmosphere are 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 and results in lifetimes of the order of 10^7 sec.

The cold cathode gage gives indications of the amount of gas present but not of the composition of the gas. The measured amount of gas can be compared with the amount expected from the solar-wind source to indicate whether or not other sources are present. Contamination from the vehicle system, of course, constitutes an additional source mechanism, but such a source should decrease with time in an identifiable way. Eventually, however, measurements of actual composition should be made with a mass spectrometer to examine constituents of particularly great interest and to discriminate against known contaminants from the vehicle system.

The Instrument

The basic sensing element of the cold cathode gage consists of a coaxial electrode arrangement as depicted in figure 7–1. The cathode consists of a spool surrounded by a cylindrical anode. A magnetic field of approximately 900 G is applied in the direction of the axis, and a voltage of +4500 V is applied to the anode. A self-sustained Townsend discharge develops in the gage. In this discharge, trapped electrons in the magnetic field have enough energy to ionize any gas particles they strike. The current of ions

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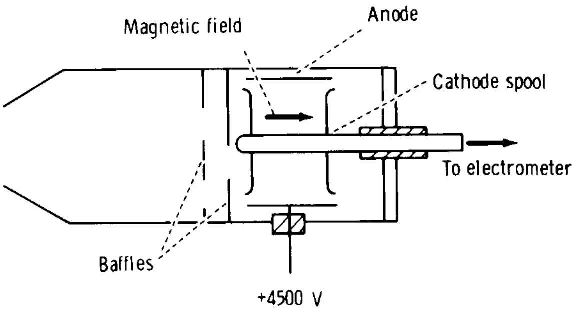

FIGURE 7-1. — Diagram of cold cathode gage sensor.

collected at the cathode is a measure of the gas density in the gage.

Figure 7–2 shows the response of the cold cathode gage in terms of cathode current as a function of pressure. It is usual to express the response in terms of pressure, although the gage is actually sensitive to gas density. If the gage temperature differs significantly from approximately 21.1° C, the reading should be corrected for the temperature difference. The gage response is also slightly dependent on gas composition. As long as the gas composition remains unknown, a fundamental uncertainty remains in the interpretation of the data. It is usual to express the results in terms of the nitrogen pressure that would produce the observed response. The true pressure will vary from this nitrogen pressure by a factor usually smaller than 2.

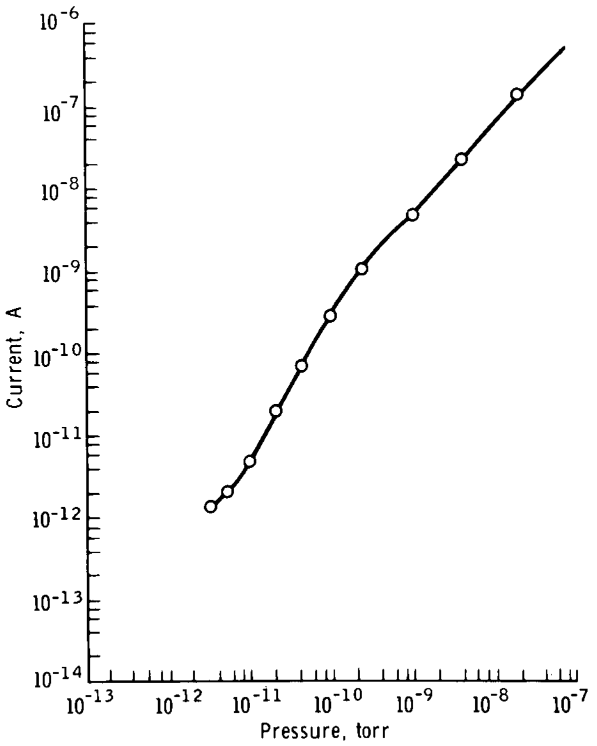

FIGURE 7-2. — Cold cathode gage response.

A temperature sensor was mounted on the gage to determine the gage temperature. There was no temperature control; therefore, the expected range was approximately 100° to 400° K.

The gage was closed (sealed) with a dust cover. This cover did not provide a vacuum seal. The cover was removed on command by utilizing a squib motor to release the cover, which was then pulled aside by a spring. Because the gage was not evacuated and sealed, adsorbed gases could produce an elevated level of response when the gage was first turned on. The baking of the gage on the lunar surface at 400° K for more than a week during the lunar day was expected to drive the adsorbed gases out of the gage.

The Electrometer

An auto-ranging, auto-zero electrometer monitors current outputs from the sensor or from the calibration current generators in the 10^{-13} to 10^{-16} A range. The output of the electrometer ranges from -15 mV to -15 V. The output of the electrometer is fed to the analog-to-digital (A/D) converters. The electrometer consists of a high-gain, low-leakage differential amplifier with switched high-impedance feedback resistors and an auto-zero network.

The electrometer operates in three automatically selected, overlapping ranges: range number 1, most sensitive; range number 2, midrange; and range number 3, least sensitive. Range number 1 senses current from approximately 10^{-13} to 9.3×10^{-11} A. Range number 2 senses currents from approximately 3.3×10^{-12} to 3.2×10^{-9} A. Range number 3 senses currents from approximately 10^{-9} to 9.3×10^{-7} A. The electrometer transfer function is shown in figure 7–3 in A/D readout counts as a function of input current (theoretical and measured curves) for a typical system.

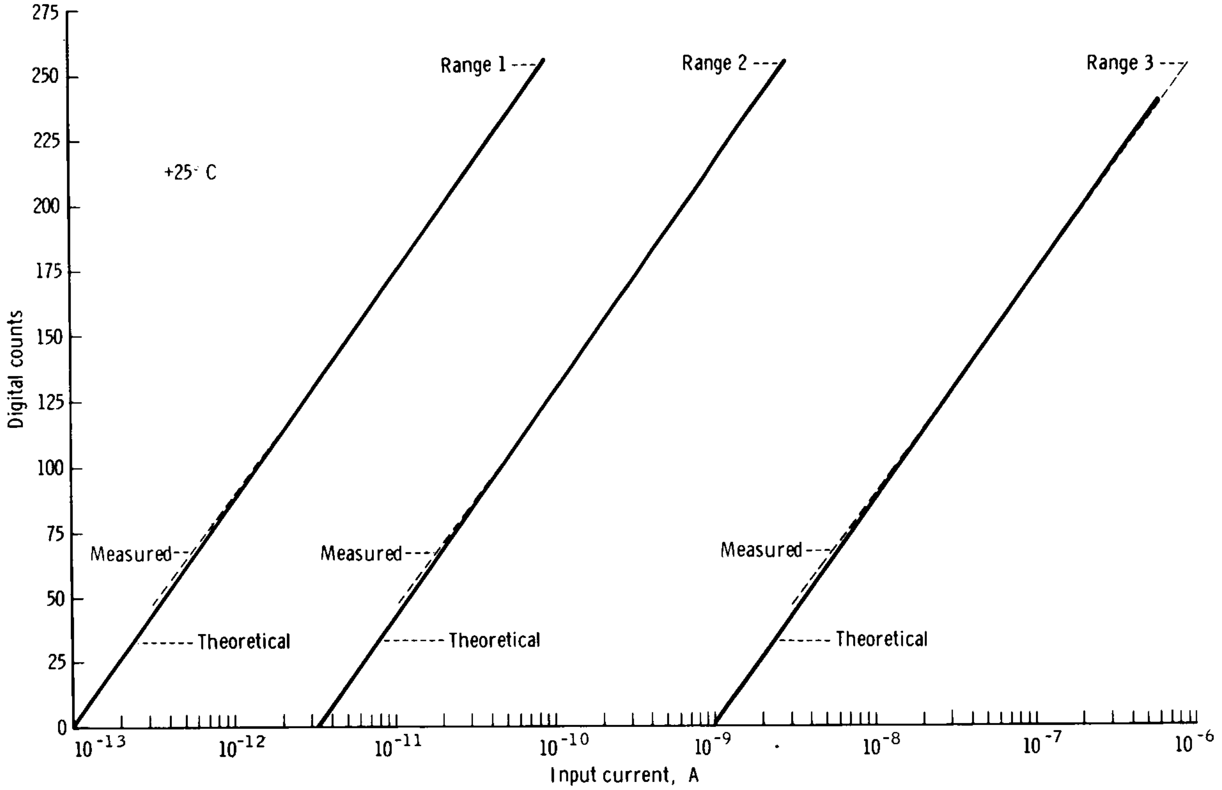

FIGURE 7-3. — Electrometer transfer function.

The 4500-V Power Supply

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

Deployment

The electronics for the cold cathode gage were contained in the suprathermal ion detector experiment (SIDE). The command and data-handling systems of the SIDE also served the cold cathode gage. The gage was physically separable from the SIDE package and was connected to it by a cable approximately 1 m long.

When the SIDE was deployed, the cold cathode gage was removed from its storage position in the SIDE. It was intended that the gage opening would be oriented horizontally and would face the pole, generally away from the descent stage of the lunar module (LM). The cable proved to be cold and stiff, and in the lunar gravity, even the relatively heavy gage was not adequate to hold the extended cable straight. Consequently, the gage tipped to face in a generally upward direction.

Results

The cold cathode gage was turned on at approximately 19:18 G.m.t. on November 19, 1969. At first, a full-scale response was obtained because of gases trapped within the gage. The time history is shown in figure 7–4. After approximately 1 hr, the response changed perceptibly from the full-scale reading. After 7 hr, the indication was approximately 1.2×10^{-8} torr. When the LM was depressurized, prior to the second extravehicular activity (EVA) period, the re-

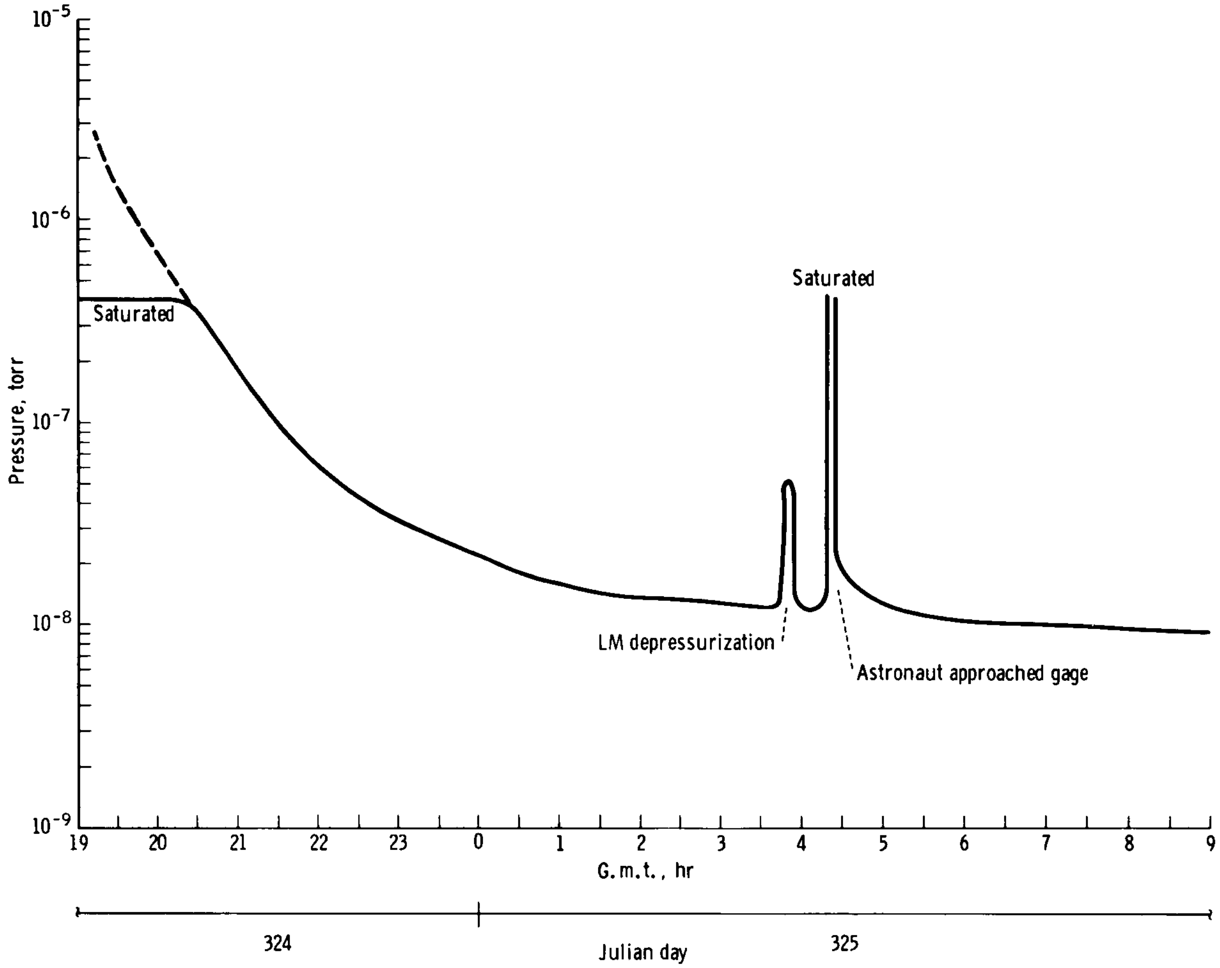

FIGURE 7-4. — Cold cathode gage response history.

sponse rose to at least 5×10^{-8} torr. The exact value is in doubt, because a calibration cycle obscured the data at the time of maximum pressure. The increase in pressure at the gage as a result of the release of gas from the LM is in reasonable agreement with expectations, based upon the amount of gas released. The release of 3 kg of gas in 10^2 sec should have produced a directed or dynamic pressure of 2×10^{-7} torr at a distance of 200 m. However, the obscuration of data near the peak of the pressure pulse probably eliminates any prospect of making meaningful diffusion studies based on the data.

During the second EVA period the gage response went off scale when an astronaut approached because of gases released from his portable life-support system. This response is also in agreement with expectations, but no close comparison with the predicted response can be made because of the lack of quantitative information on the separation between the astronaut and the gage.

An apparent catastrophic failure occurred after approximately 14 hr of operation when the 4500-V power supply shut off. Two possibilities exist. Either there was a failure, such as a short circuit, in the high-voltage supply, or the toggle command failed. (Its failure mode was such as to turn off the high voltage.) There appears to be no way to distinguish between these two possibilities, but the latter appears to be the more likely. In test and development, no failures were encountered with the high-voltage power supply. However, logic failures did occur that were brought about as a result of arcing when the package was tested under inadequate vacuum. The failure may have been brought about by arcing, which was associated with gassing in the electronics package as it heated up on the lunar surface.

In summary, the results show that the ambient lunar atmospheric pressure is less than 8×10^{-9} torr. Contamination of the experiment site by the landing operations does not produce a local atmosphere in excess of 8×10^{-9} torr after approximately 20 hr. The gas cloud around an astronaut on the lunar surface exceeds the upper range of the gage (approximately 10^{-6} torr) for a distance of several meters from the astronaut; however, no perceptible residual contamination at the 10^{-8} torr level remains around the gage for longer than a few minutes after his departure.