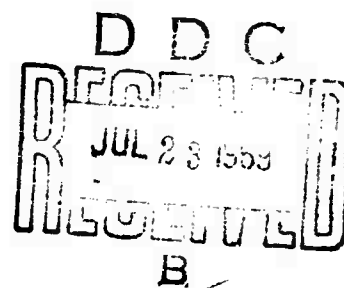


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CREATION OF AN ATMOSPHERE FOR THE MOON*

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The problems which must be solved for successful establishment of a Moon base would be greatly simplified if the moon were provided with an atmosphere like that of the earth containing oxygen, nitrogen, carbon dioxide and water. This would be true even if the atmosphere had only a few millimeters pressure and endured for only a few hundred years.

For example the problem of cooling nuclear power reactors would be diverted from considerations of molten or powdered rock as coolant to the standard method using circulating water if pools of water existed on the surface of the moon. Problems of growth of fresh animal and plant food supply would be made earthlike by the existence of an oxygen-and carbon-dioxide-containing atmosphere. Lethal radiations from solar flares would be shielded from living material on the lunar surface by atmospheric material extending a scale height upward. All the chores of service men living at the moon base would become more earth like and they would be much more able to work efficiently and stay well at their work.

We describe a method of creating a lunar atmosphere. The nature of the presently existing lunar atmosphere has been much investigated theoretically and to some extent experimentally. Recent measurements have set a very rough value $\sim 10^6$ particles/cm³.

The surface temperature and gravitational field are such that particles moving ballistically without inter-particle collisions would be bound for

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relatively long periods of time, e.g. atomic N and O for ~ 20 -40 years, and molecular N_2 and O_2 for $\sim 10^6$ years.⁽¹⁾ If the moon's magnetic field is $\leq 5 \cdot 10^{-5}$ gauss so that the solar wind continuously sweeps the lunar surface, then estimates⁽²⁾ suggest that elastic scattering by the solar wind on a collisionless low density atmosphere would reduce the residence lifetime of a species of mass ~ 50 to about 1 year (assuming a solar wind flux of $\sim 10^9/\text{cm}^2 \text{ sec}$ at $\sim 2 \cdot 10^8 \text{ cm/sec}$). However the exact value of the lunar magnetic field is not known. The moon may have a weak intrinsic magnetic field or a weak magnetic field derived from induced electric currents⁽³⁾ of strength $\geq 10^{-4}$ gauss, in which case the solar wind would be unable to enter and deplete the lunar atmosphere.

At the same time the solar wind is a source of atmospheric particles. Estimates of its rate of supply⁽²⁾ to the lunar atmosphere suggest that build up may equal sweep rate. In agreement with this estimate it is relevant to note recent studies of Earth's paleomagnetism⁽⁴⁾ showing that every half to one million years Earth's magnetic field reverses itself, and in so doing may pass through zero field. If the rate of change near zero is roughly linear, there may have been several intervals of a few hundred years or more each during which, because the magnetic field was less than 10^{-4} gauss, the solar wind blew against our atmosphere. Yet there is no evidence that the earth has been without an atmosphere in the last several thousand million years. It would seem that either the solar wind helped build it or at least did not greatly deplete it.

It is generally assumed⁽²⁾ that the moon like the planets, is composed of primitive matter. However the moon seems to have some internal heating as shown by photographs from lunar orbiting satellites showing lava flows. In the case of the planets, being larger than the moon, there must always have been larger gravitational heating, and internal stress and deformation in proportion to their size, giving rise to out-gassing and formation of the planetary atmospheres. But it seems probable that the moon, of mass too small to have

been thoroughly melted by gravitational energy or by radioactive heating, has never been out-gassed. Despite some regions where out flow of lava appears to have occurred, the greater part of its surface would appear to be sealed by a crust sintered by impact of solar particle radiation.

A recent discussion of the composition of primitive carbonaceous chondrites⁽⁵⁾ indicates them to be the parent meteorites rich in volatile matter, containing up to 20% water, and 10% complex carbonaceous compounds, as well as "substantial quantities" of nitrogen and inert gases. We assume here that the moon is made of the same material. Except for the uppermost few meters of the crust, the moon, unlike the larger bodies, that is the planets, has never been out gassed, and contains stored internally the water and gaseous material evidenced by primitive chondrites. In the case of the planets, internal heating and internal stresses have caused out gassing to proceed steadily so that the atmosphere has evolved. The present day planetary atmospheres are what remains of the gases which have come out and escaped.

That the moon is to some extent also out-gassing steadily is clear from the long list of visual observations of gaseous disturbances in lunar craters (compiled in reference 2). Recently NASA color photographs were obtained of red glows before dawn in the lunar crater Aristarchus.⁽⁶⁾

If the lunar crust were deliberately and methodically broken, simulating earthquake and volcanic activity on the planets, some of the stored gases and vapors could be released and would form a lunar atmosphere.

We assume then the moon to be made of primitive carbonaceous chondrite material and that a lunar atmosphere of average molecular weight ~ 30 (earth-like) will endure on the moon for a useful length of time ($\sim 10^6$ years).

We estimate here very roughly the number of nuclear bombs needed to produce the atmosphere if they were used to plow the moon's surface.

We assume that a 1 kilo-ton bomb which moves $7 \times 10^9 \text{ cm}^3$ of material⁽⁷⁾ of density $\sim 2 \text{ gm/cm}^3$ on earth, moves 6 times more on the moon. The broken

rock consisting of 20% water plus substantial amounts of gases, produces 1.6×10^{10} gm of water. This if spread on the area of the moon, $.10^{17} \text{ cm}^2$, produces a layer of $1.8 \times 10^{-7} \text{ gram/cm}^2$ or 2.1×10^{-10} atmospheres from a 1 kilo-ton bomb. Therefore 10^5 megatons will provide 2.1×10^{-2} atmospheres, or 21 grams/cm^2 ; pools of water for cooling reactors and growing fish and seaweed could then exist on the moon, most stably at the poles.

After establishment of a low density atmosphere, it might then be possible to populate the moon with organisms which could produce atmospheric gases faster than they can escape. Plants produce oxygen and acids which disintegrate rock, and bacteria release NH_3 and other nitrogenous gases.

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