WATER DETECTION AT THE MOON, MARS AND COMETS WITH A COMBINED NEUTRON-GAMMA RAY INSTRUMENT

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Measuring the fluxes of thermal and epithermal neutrons at a planetary object in conjunction with gamma-ray spectroscopic observations will provide information about the chemical composition of the surface which is less model-dependent than the gamma-ray measurements by themselves. We have devised a passive neutron detector for this purpose. The detector employs only two dissimilar layers of material added to a gamma-ray spectrometer. An outer layer containing samarium or cadmium absorbs most of the incident thermal neutrons, while an inner layer containing boron absorbs many of the epithermal neutrons. The neutron absorbers emit characteristic gamma rays which are measured by the gamma-ray spectrometer. Neutrons which are partially moderated in planetary materials and leak back into space may be detected and characterized by such a passive neutron detector, augmenting the compositional information gathered by the gamma-ray spectrometer and offering new information other instruments cannot provide. The neutron detector is particularly sensitive to small changes in the neutron flux produced by the presence of hydrogen as in water. It is thus also well suited to detecting and mapping small amounts of water which may be trapped near the lunar poles, searching for permafrost on Mars, and supplementing a gamma-ray spectrometer's measurement of elemental composition from orbit or in a comet nucleus via a penetrator.

An experimental model of this passive neutron detector was designed and built. Neutrons for the experiments were generated by a small Cf-252 source having a strength of about 30 microcuries. The Cf-252 source was centered in a five liter spherical flask filled with water to moderate the fast ($\approx$ 2 MeV) fission neutrons. The 83 cm^3 high-purity Ge detector and its mounting assembly were mounted vertically on a liquid nitrogen cryostat. Pulse-height data were recorded from each experiment for subsequent analysis of the Sm, B, H, and calibration lines. Three variables provided the basis for the set of experiments: 1) thickness of the Sm and B layers, 2) presence or absence of the ACS, and 3) position of the source relative to the PND's cylindrical axis.

Six experiments were performed to test the effects of Sm thickness, source position, and presence of the ACS. Three simulation models, based on different assumptions about the incident neutron fluxes, were applied to each set of experimental count rates. A simulation code was created to account for the perturbations to the incident neutron flux caused by the PND through absorption, scattering, and escape processes (1). The code tallies the effects of each event at each energy level and follows those neutrons which lose energy through scattering with H.

We observed that the Sm and B layers absorbed more neutrons than expected from calculations of normally incident neutrons on non-scattering media, and accounted qualitatively for these enhancements in terms of the distribution of incident angles and the scattering properties of the PND

and ACS. An analysis of the simulation model showed it to be inadequate in accounting for these factors. The model was empirically corrected with the experimental data and shown to work moderately well.

The empirically corrected model was used to derive a transfer function for the PND. The transfer function was applied to assumed thermal and epithermal neutron leakage fluxes from the Moon and from Mars, and to the subsurface flux of a comet nucleus, in order to calculate the expected gamma-ray count rates from a PND employed in missions to those three bodies. From the statistics of those count rates we derived water sensitivities from the measurement of neutron fluxes and gamma rays. The uncertainties in element concentrations, especially those of Fe, Ti, and the rare-earth elements, impact the sensitivity of the neutron measurements. The simultaneous application of the PND and GRS permits the improvement of both the neutron flux and element concentration determinations. The PND's sensitivity for determining H is 40 times better than that derived from a H gamma-ray signal in orbit at the Moon and 15 times better at Mars. For a comet probe, the PND provides no sensitivity advantage for water relative to the GRS, but is still valuable in finding the thermal and epithermal neutron fluxes for determining element concentrations.

REFERENCE: Metzger, A. E. and E. L. Haines, Reports of Planetary Geology and Geophysics Program-1987, NASA TM 4041, p. 213-5 (1988).