

THERMAL ANALYZER FOR PLANETARY SOILS (TAPS) EXPERIMENT: FUNCTIONS AND DESIGN OPTIONS. James L. Gooding, SN21/Planetary Science Branch, NASA/Johnson Space Center, Houston, TX 77058 USA.

Introduction. Detailed exploration of the solar system will require compact instruments for in-situ analysis of water and related substances in planetary surface materials [1]. Motivations for such analyses include scientific investigation of the nature and histories of volatile compounds (compounds of H, C, N, O, P, and S) on planets as well as evaluation of the resource potential of planetary materials. In-situ analyses are needed as ground truth for remote-sensing data and as companions or precursors to samples returned to Earth.

A well-established method for evaluating volatile components in soils involves controlled heating (or cooling) of a sample with chemical analysis of gases that are released (or absorbed). Detectable phenomena include freezing, melting or evaporation of ices as well as solid-state transitions and decrepitation of minerals (Fig. 1). By combining a solid-state thermodynamic analyzer with an evolved-gas analyzer (Fig. 2), the forms and abundances of the volatile-bearing materials can be determined. The Thermal Analyzer for Planetary Soils (TAPS) defined here represents a product line of distinct but interrelated instruments with individual performance characteristics selected to match the exploration objectives and payload limitations of different flight projects (Fig. 3). The expected applications of TAPS to planetary exploration are as follows:

- Moon: Reconnaissance for ices at the lunar poles and surveys for ore minerals elsewhere
- Mars: Identification of ices, water-bearing minerals, carbonates, and nitrates
- Asteroids or comets: Identification of ices and water-bearing minerals; "fingerprint" comparison with meteorites
- Venus: Identification of sulfide, oxide, and carbonate minerals.

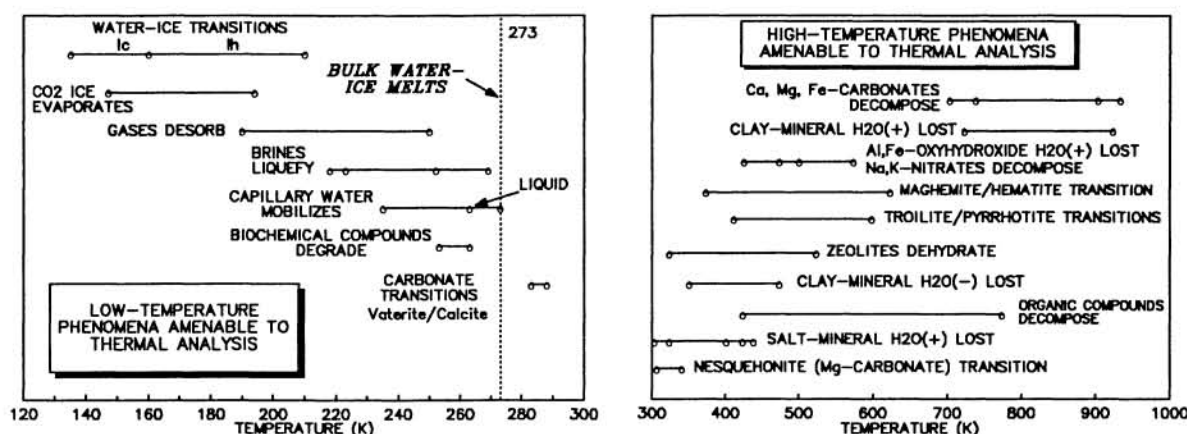


Figure 2. Physical-chemical phase transitions and reactions in geologic and chemical materials that can be detected and measured with thermal-analytical instruments. DTA and DSC can detect virtually all of these phenomena whereas TG only applies to weight-change phenomena. Both icy and rocky planets offer measurement opportunities of fundamental importance.

Possible Sensor Combinations. Three of the most widely used laboratory methods of solid-state thermal analysis are thermogravimetry (TG), differential thermal analysis (DTA), and differential scanning calorimetry (DSC). TG, which measures weight loss or gain, would not be applicable in the microgravity environment of an asteroid or comet and, therefore, is not a good general choice for TAPS. DTA measures temperature differences produced by absorption or release of heat from a sample, relative to a reference material (usually held separately in the same oven) that has a smooth, continuous heat-capacity function (i.e., no phase changes); a variation on this method, in which enthalpy function is computed from temperature difference, is sometimes denoted as heat-flux DSC. Power-compensated DSC directly measures the differential power required to null temperature differences between the sample and an equivalent but separate reference oven. DTA hardware is usually simpler than DSC hardware but DSC holds the advantage of being quantitative. In general, DSC is the most versatile choice for the TAPS thermodynamic analyzer. DSC provides diagnostic heat-flow fingerprints for many planetary materials [2,3] and can detect hydrated minerals at < 1 wt. % concentration [4].

THERMAL ANALYZER FOR PLANETARY SOILS (TAPS): Gooding J. L.

Gas chromatography (GC) and mass spectrometry (MS) are powerful choices for the evolved-gas analyzer and have been flown previously in numerous planetary missions, but both are relatively complex and have different assets and liabilities [1]. Infrared (IR) spectrophotometry could be as complex as a Fourier-transform interferometer or as simple as one or more single-channel detectors centered on diagnostic absorption bands of IR-active gas species. For the most compact versions of TAPS, evolved-gas analysis could be as plain as a single-function, solid-state water sensor or a small array of single-function sensors (e.g., H_2O , CO_2 , SO_x , NO_x). An example of data expected from a DSC with two single-function gas sensors is shown in Fig. 4.

Sample Presentation. Thermal analysis can be performed on solid samples of any particle size or shape although, for geologic materials, best results are usually obtained for silt- or sand-sized samples of 10-50 mg. Requirements for sample preparation are minimal for TAPS; fine-grained planetary regolith materials should be acceptable as found. Even though sample delivery to a passive, immovable TAPS would not be any more demanding (and perhaps less demanding) than for the Viking Lander biology and GCMS experiments, significant advantages lie in a deployable TAPS with integrated sampling ability. For the most compact versions of TAPS, in which a single analysis would meet measurement objectives, the sample oven of the thermodynamic analyzer could serve a dual function as a sample acquisition device. In such a design, the open oven could be directly inserted into the soil or sediment deposit of interest and then sealed before analysis. In a more sophisticated TAPS, a rotary paddle device, integrated into a package designed to be rested on the planetary surface, could be used to individually fill DSC-style sample containers by insertion into the underlying material.

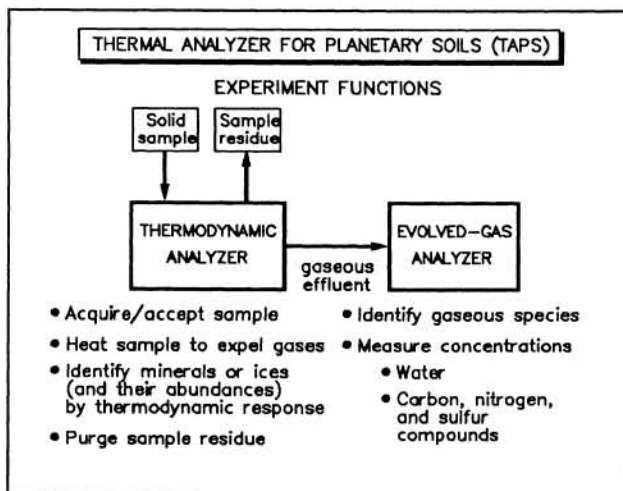


Figure 2. Functions of thermodynamic, evolved-gas, and sampling sub-systems in TAPS.

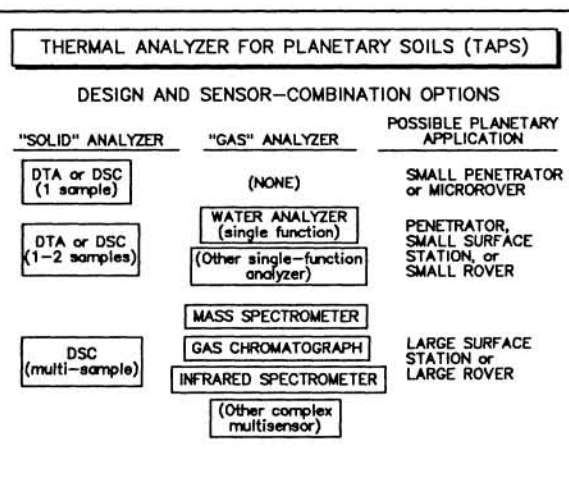


Figure 3. Possible thermodynamic ("solid") and evolved-gas ("gas") sensors for TAPS planetary applications.

References: [1] Gooding J. L. (1989) In I. R. Harrison (Ed.), *Proc. 18th NATAS Conf., Vol. 1*, 222-228. [2] Gooding J. L., Kettle A. J., and Lauer H. V. Jr. (1990) In I. R. Harrison (Ed.), *Proc. 19th NATAS Conf., Vol. 1*, 9-15. [3] Gooding J. L. and Allton J. H. (this volume). [4] Gooding J. L., Kettle A. J., and Lauer H. V. Jr. (this volume).

Figure 4. Simulated TAPS data from a DSC with single-function H_2O and CO_2 sensors. The TA array represents equally weighted digital mixing of power-compensated DSC data for gypsum, goethite, nontronite, and aragonite. The EGA arrays represent response functions estimated for solid-state gas sensors.

