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Space systems — Lunar simulants

Systèmes spatiaux — Simulation de la poussiére lunaire

ICS 49.140

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

ISO 10788 was prepared by Technical Committee ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 14, *Space systems and operations*.

Introduction

This International Standard provides lunar systems developers and operators with a specific quantitative measure for lunar regolith simulants in comparison to other simulants and with relation to sampled lunar materials from Apollo and Lunakhod missions. Developers of lunar systems will use simulants as test materials. This International Standard is a reference for quantitative measures of lunar simulants finer than 10cm. The quantitative measures of lunar dust simulants are based on the quantitative measures of lunar regolith samples collected at multiple lunar landing sites of the Apollo missions.

This standard provides communication of the geological quality of the simulant between developing organizations and systems operations organizations.

Space systems — Lunar simulants

1 Scope

This International Standard is a reference for quantitative measures of lunar simulants. The quantitative measures of lunar simulants are based on the quantitative measures of lunar samples collected at multiple lunar landing sites of the Apollo and Lunakhod missions.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO 10788. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO 10788 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

Heiken, G., D. Vaniman, et al. (1991). Lunar Sourcebook: A User's Guide to the Moon©. Cambridge [England] ; New York, Cambridge University Press. ISSN No. 1540-7845. The Lunar Sourcebook© is a recognized international compendium of lunar information collected through the Apollo era.

Klaus K.E. Neuendorf, James P. Mehl, Jr., and Julia A. Jackson, editors. Glossary of Geology, 5th edition, American Geological Institute, ISBN 0-922152-76-4

3 Terms and definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1.1
agglutinate
vesiculated glass bonded particle containing other particles (lithic fragments), of which the bonding glass contains spherical particles of iron. The lunar spherules are typically 3 – 100 nanometers in diameter and formed contemporaneous with the glass. Six features characterize lunar agglutinates: size, surface area with relation to volume, composition, nanophase iron content, flow banding and multiple generations.

3.1.2
angularity
an expression of roundness (i.e., a poorly rounded grain is described as angular),from the Glossary of Geology

3.1.3
aspect ratio
ratio of the maximum Feret diameter divided into the orthogonal Feret diameter. Values range from >0 to 1 and equal 1 for a circle.

3.1.4
feret diameter
distance between two parallel lines which are tangent to the perimeter of a particle. The maximum Feret diameter is defined as the greatest distance between two parallel lines which are still tangent to the perimeter of the particle.

3.1.5
figure of merit
degree to which a sample matches a reference. Scaling (normalization) forces the norm of the difference of two composition vectors to lie between 0 and 1, and subtraction from unity results in a figure of merit of 1 for a perfect match and 0 for not match at all.

3.1.6
Heywood circularity factor
expression of the complexity of a particle's perimeter. Formally, the Heywood Circularity Factor is equal to 1 divided by particle perimeter divided by the circumference of a circle with the same area as the particle. This is numerically equal to the "circularity" defined by Wadell (1933). It is expressed in this manner to make it apparent that the Heywood factor is the inverse of a common definition of "circularity", another common measure. Values range from >0 to 1 and equal 1 for a circle.

3.1.7
lithic fragments
physically discrete solids of any rock type whose normative composition is within the range of the target terrain. Lithic fragments have texture and mineralogy. Texture is a more important feature than mineralogy for lithic fragments. Texture describes the grain to grain connectivity boundary. Lunar textures cannot be replicated on Earth.

3.1.8
lunar terrains
Mare and Highlands

3.1.9
regolith
all particulate surface material including rocks, soils and dust. As stated in the Introduction, this standard is limited in scope to regolith 10cm and smaller. Rocks, soils and dust are not differentiated on the basis of size.

3.1.10
re-use
after a simulant volume is used (any sequence of events in which a simulant volume is removed from a storage container) then placed back into storage, any future use constitutes re-use.

3.1.11
sphericity
degree to which the shape of a particle approaches a sphere

3.2 Abbreviated terms

c_x	the concentration, or portion, of a sample for the x^{th} item in the sample.
FoM	Figure of Merit
RFD	Relative Frequency Distribution
w_i	a weighting factor. w is a value between one and zero. i is an index which refers to the characteristic being weighted, such as glass (a grain type)

4 Characteristics of Lunar Regolith Previously Defined in the Lunar Sourcebook©

4.1 Minerologies

The lunar surface mineralogy is variable across major terrain. These properties are qualitative; they cannot be described in a quantitative manner related to any known spatial distribution across the lunar surface. A listing of the primary minerologies in the Lunar Sourcebook© is:

Silicate minerals such as Pyroxene, Plagioclase Feldspar, Olivine (Fo_{80}), and Silica minerals.

Oxide minerals such as Ilmenite, Spinels, and Armalcolite

Sulfide Minerals such as Troilite

Native Fe

Phosphate Minerals

4.2 Physical and chemical Properties

The Lunar Sourcebook© provided a compilation of properties from Apollo and Lunakhod lunar samples of use to the scientific community. These properties are listed since a large amount of data exists for lunar regolith characterization using these properties. As demanded by scientific definitions, these properties are qualitative and quantitative. This means some properties can be measured directly while others are descriptive and are not readily measurable. While these properties are of value to planetary or lunar scientists they do not address the needs of lunar systems developers and operators with a specific quantitative measure for lunar regolith simulants in comparison to other simulants and with relation to sampled lunar materials.

4.2.1 Physical properties

4.2.1.1 Geotechnical properties

a) Particle Size Distribution

b) Particle Shapes

c) Specific Gravity

d) Bulk Density

e) Porosity

f) Relative Density

g) Compressibility

h) Shear Strength

i) Permeability and Diffusivity

j) Bearing Capability

k) Slope Stability

l) Trafficability

4.2.1.2 Electrical and electromagnetic properties

a) Electrical conductivity

b) Photoconductivity

c) Electrostatic Charging

d) Dielectric Permittivity

4.2.2 Chemical properties

a) Major Elements