ISO TC 20/SC 14

DRAFT n°8, Date: 2010-03-10

ISO/CD 10788(E)

ISO TC **20**/SC **14**/WG 4

Secretariat: ANSI (AIAA)

Space systems – Lunar Simulants

Systêms spatiaux -

Document type: International Standard
Document subtype: CD
Document stage: (30) Committee
Document language: E

Contents

Page

1 Scope ... 1

2 References ... 1
2.1 Normative References ... 1
2.2 Informative References ... 1
2.3 Terms and definitions ... 1
2.4 Abbreviated terms ... 2

3 Characteristics of Lunar Regolith Previously Defined in the Lunar Sourcebook© ... 2
3.1 Minerologies ... 2
3.2 Physical and Chemical Properties ... 3
3.2.1 Physical Properties ... 3
3.2.1.1 Geotechnical Properties ... 3
3.2.1.2 Electrical and Electromagnetic Properties ... 3
3.2.2 Chemical Properties ... 3

4 Quantitative Measurement Properties of Lunar Simulants ... 4
4.1 Comparative Baseline ... 4
4.2 Impurities and Contamination ... 4
4.3 Validation of Figures of Merit ... 4
4.4 Composition Figure of Merit ... 4
4.4.1 Composition Figure of Merit (FoM) Equation ... 4
4.4.2 Particles ... 5
4.4.3 Grain types ... 5
4.4.3.1 Crystalline Solids ... 5
4.4.3.2 Glasses ... 5
4.5 Size Distribution Figure of Merit ... 6
4.5.1 Size Distribution FOM Equation ... 6
4.5.2 Particles from 4 cm to 75 microns ... 6
4.5.3 Particles from 100 microns to 1 micron ... 6
4.5.4 Particles finer than 2 microns ... 7
4.6 Shape Figure of Merit ... 7
4.6.1 Shape FoM Equation ... 7
4.6.2 Sphericity ... 7
4.6.3 Angularity ... 7
4.7 Density Figure of Merit ... 7
4.7.1 Density FoM Equation ... 7
4.7.2 Measurement ... 7

5 Quantitative Properties of Lunar Simulants ... Error! Bookmark not defined.
5.1 Physical Properties ... Error! Bookmark not defined.
5.1.1 Geotechnical Properties ... Error! Bookmark not defined.
5.1.2 Electrical and Electromagnetic Properties ... Error! Bookmark not defined.
5.2 Chemical Properties ... Error! Bookmark not defined.

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 CD 10788 was prepared by Technical Committee ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 14, *Space systems and operation,* Working Group 4*, Space Environments*.

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 References

2.1 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

2.2 Informative References

NASA/TM-2008-215261, NASA Technical Memorandum: The Need for High Fidelity Lunar Regolith Simulants

Carrier, W. David, III, 1973, Lunar Grain Size Distribution: The Moon, v. 6, p. 250-263.

Jolliff, B. L., M. A. Wieczorek, et al. (2006). New views of the Moon. Chantilly, Va., Mineralogical Society of America.

Papike, J. J. (1998). Planetary Materials. Washington, D. C., Mineralogical Society of America. Terms, definitions and abbreviated terms

2.3 Terms and definitions

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

Agglutinate –
A 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.

Angularity -
From the Glossary of Geology, an expression of roundness (i.e., a poorly rounded grain is described as angular.

Sphericity -
The degree to which the shape of a particle approaches a sphere.

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.

Dust -
A component of regolith which is affected by dominant forces in addition to or other than gravity. These other forces may include electrostatic forces

Note – There is no established particle size definition for dust. The current dust size definition used at NASA is 20 micrometers or less. The reasoning for this selection was based on analogy with pulmonary considerations behind US Environmental Protection Agency and US Occupational Safety and Health Administration rules related to lower gravity.

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.

Lunar terrains –
Mare and Highlands.

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.

2.4 Abbreviated terms

RFD – Relative Frequency Distribution

TBD for this document. Complete in DIS/FDIS stage.

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

3.1 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

3.2 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. These properties are qualitative and quantitative.

3.2.1 Physical Properties

3.2.1.1 Geotechnical Properties

Particle Size Distribution

Particle Shapes

Specific Gravity

Bulk Density

Porosity

Relative Density

Compressibility

Shear Strength

Permeability and Diffusivity

Bearing Capability

Slope Stability

Trafficability

3.2.1.2 Electrical and Electromagnetic Properties

Electrical conductivity

Photoconductivity

Electrostatic Charging

Dielectric Permittivity

3.2.2 Chemical Properties

Major Elements

Incompatible Trace Elements

Miscellaneous Minor Elements

Siderophile Elements

Vapor-Mobilized Elements

Solar Wind Implanted Elements

4 Quantitative Measurement Properties of Lunar Simulants

Lunar simulants may be measured as lunar samples were measured and published (reference section 3). However, the quality of lunar simulants measured in this way cannot be readily compared to lunar source material nor communicated across development and operational communities. Comparison of these measures for simulants for other than scientific purposes is not recommended.

The more useful qualification of lunar simulants is tied to lunar minerologies and is expressed most concisely in four figures of merit: Composition, Size, Shape and Density. The figures of merit for lunar simulants range from zero to one. A figure of merit value of zero indicates no useful correlation to a comparative sample. A figure of merit value of one indicates exact correlation as defined by the standard measurements to a comparative sample. A specific quantitative measure for lunar regolith simulants is made only in comparison to other simulants or with relation to sampled lunar materials from Apollo and Lunakhod missions. Data from existing lunar samples are necessary to use these figures of merit.

4.1 Comparative Baseline

Comparative (quantitative) measures shall be stated for lunar simulants. Figures of merit for a simulant shall be stated against a single baseline. If multiple baselines are referenced for a simulant a complete set of figures of merit shall be calculated for each reference.

4.2 Impurities and Contamination

Simulants may not be completely defined by these Figures of Merit for reasons of mineralogical impurity and contamination of the simulant by organic/inorganic materials.

Impurity of the sample/simulant measured shall be stated in percent of the sample mass.

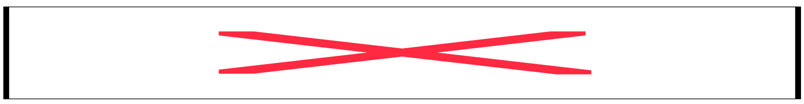
Contamination of the sample/simulant shall be stated in percentage of the sample volume. Characterization of the sample contamination and the nature of that contamination shall be stated if an analysis is performed.

4.3 Validation of Figures of Merit

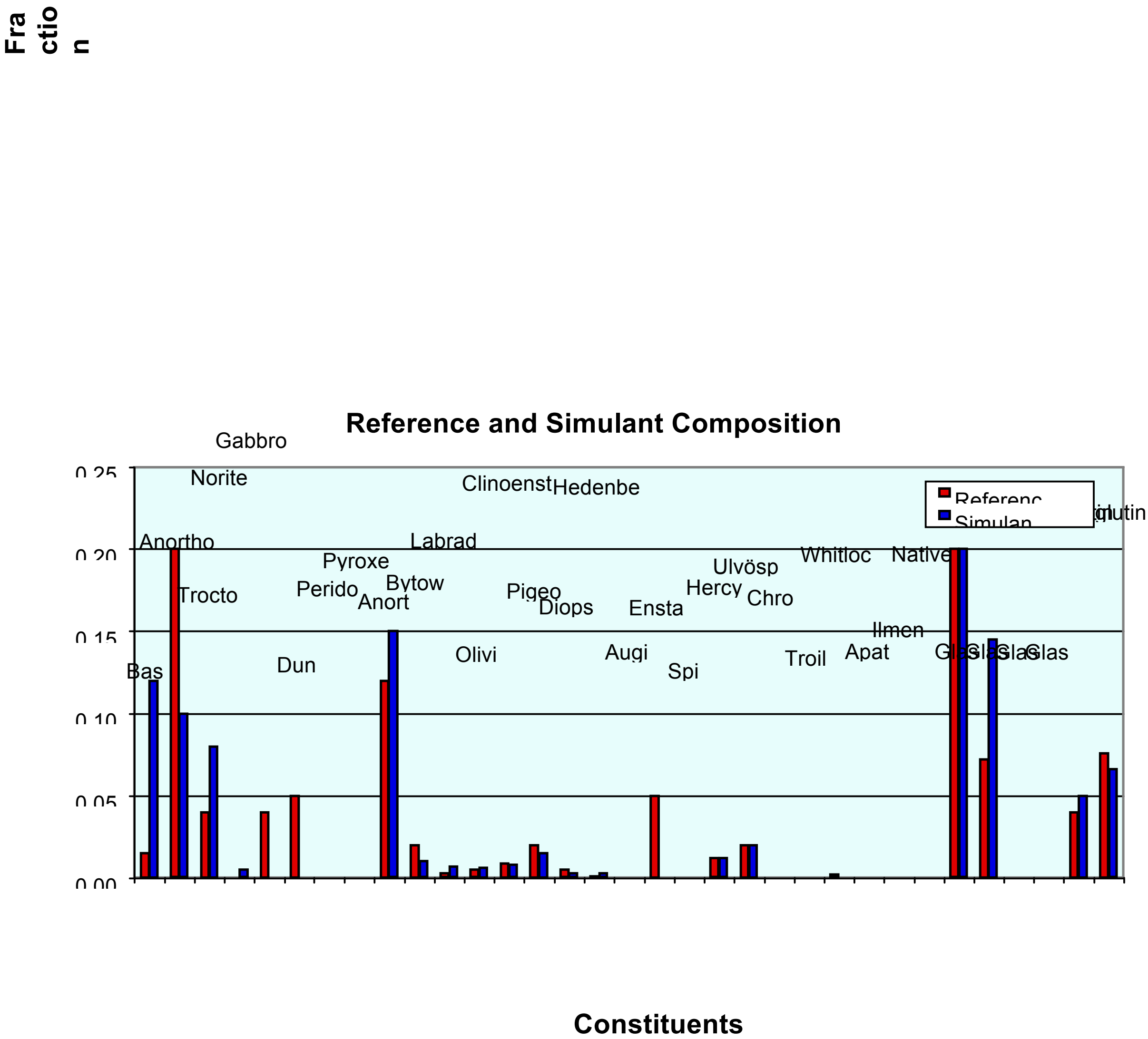
Calculation of figures of merit for a simulant shall be performed and recorded for each use. In the event a volume of simulant is re-used, the figures of merit shall be recalculated in accordance with this standard.

4.4 Composition Figure of Merit

4.4.1 Composition Figure of Merit (FoM) Equation



where $\max_i(w)$ is the i^{th} largest element of *w.*



Example

4.4.2 Particles

Compositions are defined for particles. A particle may be made up of one or more grains. A particle may be composed of a combination of crystalline solids, glass, or a mixture of these and may contain voids. The smallest particle is a single grain of material.

4.4.3 Grain types

Grain types shall be described as crystalline solids (agglutinates, lithic fragments) or glass.

4.4.3.1 Crystalline Solids

Crystalline solids shall have structure at the level of an X-ray.

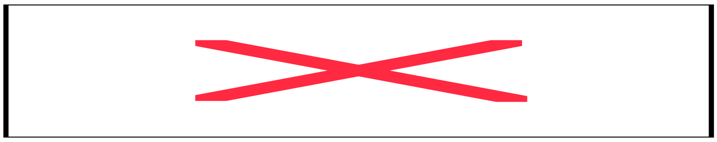
4.4.3.2 Glasses

Glasses shall be made from the rest of the material in the simulant

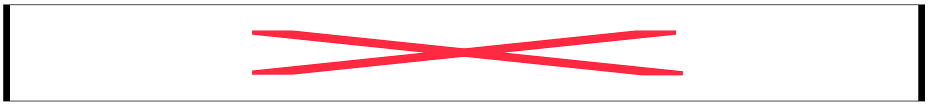
Glasses shall have a normative mineralogy within the range of the moon.

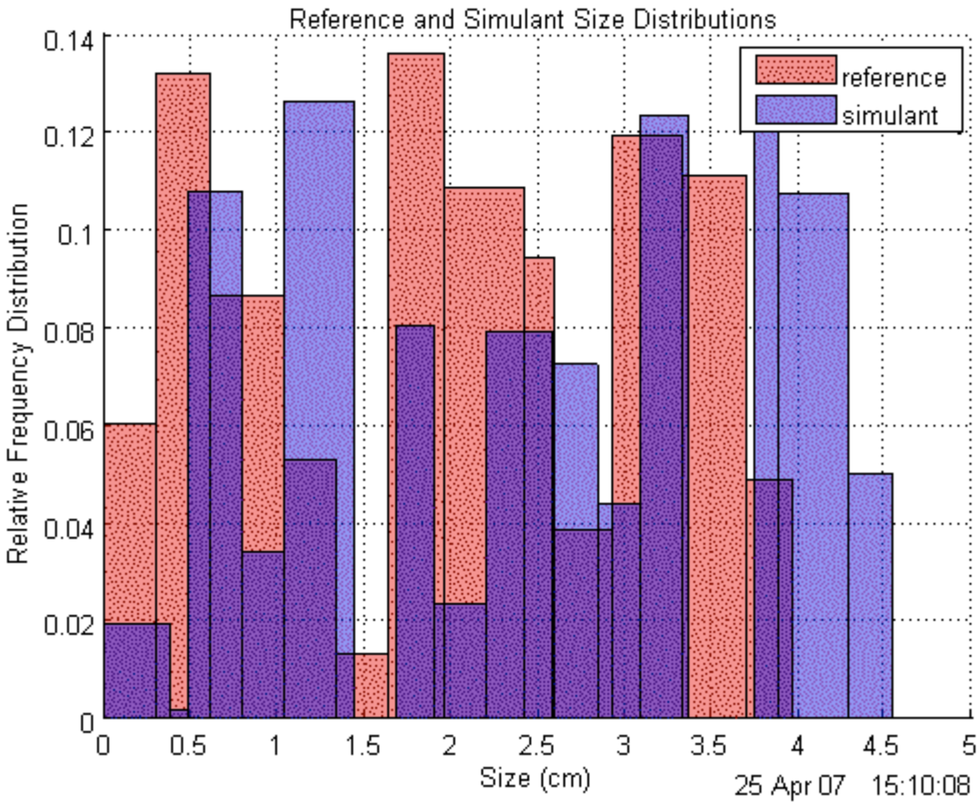
4.5 Size Distribution Figure of Merit

4.5.1 Size Distribution FOM Equation



with the further constraint





Example

4.5.2 Particles from 4 cm to 75 microns

Particles from 4 cm to 75 microns shall be measured by the method of sieving.

4.5.3 Particles from 100 microns to 1 micron

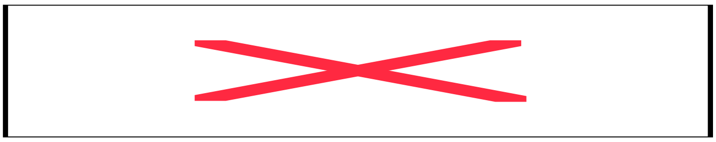
Particles of Apollo and simulant materials between 100 microns and 1 micron shall be analyzed by the method of optical imaging.

4.5.4 Particles finer than 2 microns

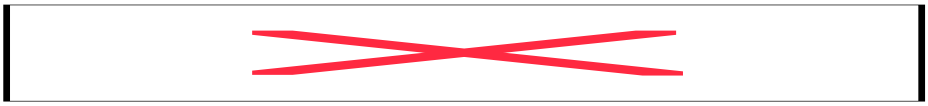
Particles finer than 2 microns shall be measured by the method of aerosol dispersion.

4.6 Shape Figure of Merit

4.6.1 Shape FoM Equation



with the further constraint



4.6.2 Shape

Shape shall be determined by the combined sphericity and angularity of the particles.

4.6.3 Sphericity

Sphericity shall be determined to define particle shape.

4.6.4 Angularity

Angularity shall be determined to define particle shape.

4.7 Density Figure of Merit

4.7.1 Density FoM Equation

$$FoM = \begin{cases} \dfrac{1}{density\_quotient\_limit}\left(\dfrac{simulant\_density}{reference\_density}\right) + \dfrac{density\_limit - 1}{density\_quotient\_limit} & for\ 1 - density\_quotient\_limit \le \dfrac{simulant\_density}{reference\_density} < 1 \\ \dfrac{-1}{density\_quotient\_limit}\left(\dfrac{simulant\_density}{reference\_density}\right) + \dfrac{density\_limit + 1}{density\_quotient\_limit} & for\ 1 \le \dfrac{simulant\_density}{reference\_density} < 1 + density\_quotient\_limit \\ 0\_otherwise & \end{cases}$$

4.7.2 Measurement

Density shall be measured by taking a sufficiently large enough sample so that the sample follows the particle size distribution of the material as defined in the slides on Size Distribution.