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**Measurement and characterization of  
particles by acoustic methods —**

**Part 2:  
Linear theory**

*Caractérisation des particules par des méthodes acoustiques —  
Partie 2: Théorie linéaire*



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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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see [www.iso.org/directives](http://www.iso.org/directives)).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see [www.iso.org/patents](http://www.iso.org/patents)).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see [www.iso.org/iso/foreword.html](http://www.iso.org/iso/foreword.html).

This document was prepared by Technical Committee ISO/TC 24, *Particle characterization including sieving*, Subcommittee SC 4, *Particle characterization*.

This second edition cancels and replaces the first edition (ISO 20998-2:2013), which has been technically revised.

The main changes are as follows:

- References to relaxation mechanisms that affect attenuation
- Additional explanatory notes for [Table 1](#)
- Clarification of notation used in [Formula \(9\)](#)
- Minor editorial changes

A list of all parts in the ISO 20998 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at [www.iso.org/members.html](http://www.iso.org/members.html).

## Introduction

It is well known that ultrasonic spectroscopy can be used to measure particle size distribution (PSD) in colloids, dispersions, and emulsions<sup>[1],[2],[3],[4]</sup>. The basic concept is to measure the frequency-dependent attenuation or velocity of the ultrasound as it passes through the sample. The attenuation spectrum is affected by scattering or absorption of ultrasound by particles in the sample, and it is a function of the size distribution and concentration of particles<sup>[5],[6],[7]</sup>. Once this relationship is established by empirical observation or by theoretical calculations, one can estimate the PSD from the ultrasonic data. Ultrasonic techniques are useful for dynamic online measurements in concentrated slurries and emulsions.

Traditionally, such measurements have been made off-line in a quality control lab, and constraints imposed by the instrumentation have required the use of diluted samples. By making in-process ultrasonic measurements at full concentration, one does not risk altering the dispersion state of the sample. In addition, dynamic processes (such as flocculation, dispersion, and comminution) can be observed directly in real time<sup>[8]</sup>. This data can be used in process control schemes to improve both the manufacturing process and the product performance.

While it is possible to determine the particle size distribution from either the attenuation spectrum or phase velocity spectrum, the use of attenuation data alone is recommended. The relative variation in phase velocity due to changing particle size is small compared to the mean velocity, so it is often difficult to determine the phase velocity with a high degree of accuracy, particularly at ambient temperature. Likewise, the combined use of attenuation and velocity spectra to determine the particle size is not recommended. The presence of measurement errors (i.e. “noise”) in the magnitude and phase spectra can increase the ill-posed nature of the problem and reduce the stability of the inversion.



# Measurement and characterization of particles by acoustic methods —

## Part 2: Linear theory

### 1 Scope

This document specifies requirements for ultrasonic attenuation spectroscopy methods for determining the size distributions of a particulate phase dispersed in a liquid at dilute concentrations, where the ultrasonic attenuation spectrum is a linear function of the particle volume fraction. In this regime particle-particle interactions are negligible. Colloids, dilute dispersions, and emulsions are within the scope of this document. The typical particle size for such analysis ranges from 10 nm to 3 mm, although particles outside this range have also been successfully measured. For solid particles in suspension, size measurements can be made at concentrations typically ranging from 0,1 % by volume up to 5 % by volume, depending on the density contrast between the solid and liquid phases, the particle size, and the frequency range<sup>[9],[10]</sup>. For emulsions, measurements can be made at much higher concentrations. These ultrasonic methods can be used to monitor dynamic changes in the size distribution.

### 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 14488, *Particulate materials — Sampling and sample splitting for the determination of particulate properties*

ISO 20998-1:2006, *Measurement and characterization of particles by acoustic methods — Part 1: Concepts and procedures in ultrasonic attenuation spectroscopy*

### 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 20998-1 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

#### 3.1

##### **coefficient of variation**

ratio of the standard deviation to the mean value

#### 3.2

##### **dimensionless size parameter**

representation of particle size as the product of *wavenumber* (3.4) and *particle radius* (3.3)

#### 3.3

##### **particle radius**

half of the particle diameter