

---

---

**Crop protection equipment —  
Droplet-size spectra from atomizers  
— Measurement and classification**

*Équipement de protection des cultures — Spectres de taille des  
gouttes des systèmes d'atomisation — Mesurage et classification*





**COPYRIGHT PROTECTED DOCUMENT**

© ISO 2018

All rights reserved. Unless otherwise specified, or required in the context of its implementation, no part of this publication may be reproduced or utilized otherwise in any form or by any means, electronic or mechanical, including photocopying, or posting on the internet or an intranet, without prior written permission. Permission can be requested from either ISO at the address below or ISO's member body in the country of the requester.

ISO copyright office  
CP 401 • Ch. de Blandonnet 8  
CH-1214 Vernier, Geneva  
Phone: +41 22 749 01 11  
Fax: +41 22 749 09 47  
Email: [copyright@iso.org](mailto:copyright@iso.org)  
Website: [www.iso.org](http://www.iso.org)

Published in Switzerland

# Contents

	Page
<b>Foreword</b> .....	<b>iv</b>
<b>Introduction</b> .....	<b>v</b>
<b>1 Scope</b> .....	<b>1</b>
<b>2 Normative references</b> .....	<b>1</b>
<b>3 Terms and definitions</b> .....	<b>1</b>
<b>4 Droplet size measurement</b> .....	<b>2</b>
<b>5 Classification</b> .....	<b>4</b>
<b>6 Test report</b> .....	<b>5</b>
<b>Annex A (informative) Droplet size class shortcuts</b> .....	<b>6</b>
<b>Bibliography</b> .....	<b>7</b>

## 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 on the voluntary nature of the 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 the following URL: [www.iso.org/iso/foreword.html](http://www.iso.org/iso/foreword.html)

This document was prepared by Technical Committee ISO/TC 23, *Tractors and machinery for agriculture and forestry*, Subcommittee SC 6, *Equipment for crop protection*.

## Introduction

The measurement and classification of droplet size spectra for applications of pesticides and other chemicals facilitate the description of sprays and therefore enhance efficacy and spray drift management.

Most atomizers produce a spectrum of droplet sizes, giving different droplet size spectra in different operating conditions.

Measurement systems and laboratories can produce different absolute values for a given droplet spectrum. Differences are usually due primarily to sampling effects, dynamic size range capabilities, data processing and reporting. Some of these differences can be minimized through the use of appropriate sampling techniques. However, discrete differences in absolute values of droplet size spectra can still remain between measurement systems, especially where spatial size distribution (size distribution of particles in a given volume of space where there is no significant variation in the distribution during the sampling interval) and flux size distribution (size distribution of particles passing through a sampling zone during a given interval of time where individual particles are counted and sized) lead to sampling differences.

An approach that has been successfully used for describing spray droplet size spectra using standardized terminology involves the use of reference sprays to define reference categories for increased uniformity in the relative measures and classification of spray droplet spectra among different measurement systems and laboratories<sup>[1][2]</sup>. This is the approach taken by this document.

Each measurement facility should determine its own “in-house” reference categories using this document (with one set for each measurement system and sampling method), and then classify sprays being measured using the same measurement and sampling procedures as those for the respective reference sprays. For example, reference curves from one source (laboratory, measuring instrument and sampling technique) cannot be used to classify sprays from a different measurement source.

Using the classification of droplet size spectra, it is also possible to provide appropriate information to the user.



# Crop protection equipment — Droplet-size spectra from atomizers — Measurement and classification

## 1 Scope

This document specifies procedures for classifying droplet size spectra from atomizers used in spraying for crop protection. It provides a reference system for defining classes of droplet size spectra.

Depending on their function principle and individual setup, measuring systems for droplet sizing can give different results. This document provides a means of comparing measured droplet size spectra to reference spectra and enables relative comparisons of droplet size spectra obtained from different measuring systems.

## 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 5681, *Equipment for crop protection — Vocabulary*

ISO 5682-1, *Equipment for crop protection — Spraying equipment — Part 1: Test methods for sprayer nozzles*

## 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 5681 and the following apply.

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

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

### 3.1

#### **droplet size class**

range between two reference droplet size spectra

### 3.2

#### **reference droplet size spectrum**

droplet size spectrum that defines the border between two *droplet size classes* (3.1) obtained by reference nozzle/spray pressure combinations using filtered water as the liquid

### 3.3

#### **droplet volume fraction**

$D_{v0,x}$

droplet diameter where the fraction 0,x of the spray volume is in smaller droplet sizes

### 3.4

#### **volume median diameter**

$D_{v0,5}$

droplet size where half the volume of the spray is in larger droplet sizes and half in smaller droplet sizes

## 4 Droplet size measurement

Measurements are carried out using at least three candidate single atomizers out of a batch of at least 10 atomizers of the same type, with a maximum deviation of flow rate of  $\pm 3\%$  from the value specified by the manufacturer at the reference rating recommended spray pressure, or parameters measuring the flow rate in accordance with ISO 5682-1. It is important to ensure that a representative sample of an atomizer's spray pattern is used that covers the entire droplet size spectra and accounts for all emitted droplets in a given sample time interval. During the measurement of all sprays, the spraying liquid shall have a temperature within  $5\text{ }^{\circ}\text{C}$  of the ambient air temperature, and temperature differences between measurements made with the reference nozzle and the candidate atomizer should be less than  $5\text{ }^{\circ}\text{C}$ . The air and liquid temperatures shall be recorded at the time of measurement.

For comparisons between laboratories, it is recommended to perform the drop size measurements with a spray liquid having a temperature of  $(20 \pm 2)\text{ }^{\circ}\text{C}$ , in a controlled environment with an air temperature of  $(20 \pm 2)\text{ }^{\circ}\text{C}$  and a relative humidity of 40 % to 80 %.

The droplet size spectrum can be measured with any non-intrusive measuring system (sampling instrument does not contact the spray or disturb the carrier air) that is appropriate for the range of droplet size and velocity within the spray and the properties of the spraying liquid. Examples for those systems are phase Doppler<sup>[4][6]</sup> light scatter, laser diffraction, or imaging principles. The instrument and measurement system shall enable repeatable measurements for the reference sprays with maximum  $D_{v0,5}$  deviations between replicate (minimum three) measurements of  $\pm 10\%$ , for the same setting and measuring situation.

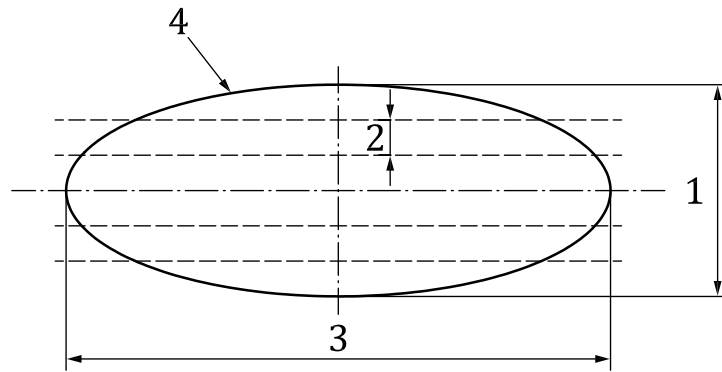
For laser diffraction measurement systems, a minimum of three separate measurements per nozzle shall be averaged to establish the cumulative volume-versus-droplet size spectra relationship, including values of  $D_{v0,1}$ ,  $D_{v0,5}$  and  $D_{v0,9}$ , and with  $D_{v0,1}$  and  $D_{v0,5}$  replicates less than  $\pm 5\%$ . With single particle counter systems, the forward speed or measuring time shall be adjusted to obtain maximum  $D_{v0,1}$  and  $D_{v0,5}$  deviations between replicate measurements of less than 10 %.

A representative cross-section average sample shall be obtained across the entire spray plume, with droplet size measurement being conducted at a distance of 30 cm to 50 cm from the reference nozzle outlet or at an appropriate distance for measuring a fully atomized spray, noting the manufacturer's recommendations. The sample distance shall enable representative sampling without intrusion into the spray spectrum formation process. The sampling time shall be uniform for all positions in the spray jet.

For measuring systems with a point wise measuring principle, as in phase Doppler devices, continuous or stepwise movement of the point of measurement relative to the spray fan is required in order to obtain a representative sample of droplets. These relative movements shall follow straight lines along one of the central axes immediately below the atomizer. At least two additional movement lines shall be used at each side of one of the main axis, as shown in [Figure 1](#).

In case of continuous movement, the forward speed shall be constant for all movement lines. For stepwise movement, the measuring time shall be the same at each measuring position. Forward speed, measuring time and/or number of discrete movement lines shall be adjusted to obtain a maximum  $D_{v0,5}$  deviation between replicate measurements of  $\pm 10\%$ , and where possible and appropriate, to sample at least 10 000 droplets per individual nozzle.



**Key**

- 1 depth of spray fan
- 2 minimum 5 equally spaced lines
- 3 width of spray fan
- 4 spray fan footprint

NOTE More lines of measurement may reduce variability of results.

**Figure 1 — Line measurement positions**

Determine the depth and width (see [Figure 1](#)) of the spray fan using water-sensitive paper, horizontal patternator, or a similar means, and document in the test report.

For double-orifice nozzles, each single spray fan should preferably be measured and reported separately. Turn the nozzle in such a way that the single spray to be measured is directed vertically downwards and proceed as described above. Sample at least 5 000 droplets for each spray fan and merge the data with a volume weighted technique after measuring both spray fans and report the results. If spray geometry or design dictates, measure both spray patterns simultaneously in one scan to account for any interactions.

Liquid flow rate shall be measured using an appropriate technique such as a Coriolis-type<sup>[5]</sup> mass flow sensor, a calibrated flow turbine, a positive gear displacement meter or a mass loss system with an accuracy of at least  $\pm 1\%$  of the measuring value.

Atomizer output shall remain constant during the measurement process with a maximum deviation of  $\pm 2,5\%$  of the rated value as given in ISO 5682-1. Consistency of output rate can be monitored by flow rate or pressure or other appropriate parameters. For hydraulic nozzles, the recommended point for pressure measurements is at the nozzle body, near the nozzle tip, using a capillary tube connected to a calibrated pressure gauge. A similar location is recommended for other atomizers.

Verification or calibration to known standards of any measurement method is essential. Instrument particulars, such as size range configuration, obscuration, multiple scattering, verification, droplet path angle, calibration and repeatability shall be addressed such that accurate and repeatable (not more than 5 % deviation for  $D_{v0,5}$ ) day-to-day measurements are obtained.

Many other factors shall be considered when sampling the spray, including sampling distance (recommended to be 30 cm to 50 cm from hydraulic nozzles, or as appropriate for sampling a fully-atomized spray). The same procedures shall be followed as those used for the reference spray as appropriate, including sample size, at least ensuring a steady-state operating procedure of atomizers for data collection, instrument configuration and use, and data processing software settings. However, most of these are instrument-specific, so rather than providing detailed guidelines for measurement considerations in this document, the user is referred to appropriate standards and user manuals for their measuring instrument.

## 5 Classification

Classification is based on the comparison of the spray droplet size spectrum produced by an atomizer under certain operating conditions (e.g. spray pressure, liquid flow rate) with reference spectra.

The boundaries/borders between these size classes are defined by spraying water (clean and free of particulates) through the reference nozzle at pressure combinations given in [Table 1](#).

**Table 1 — Reference nozzle/flow rate (pressure) combinations**

Droplet size spectra class boundary	Nozzle	Reference flow rate ( $\pm 2\%$ ) l/min	Reference pressure <sup>a</sup> kPa
XF/VF	Mee Fog IP®-16 <sup>b</sup> impaction pin	0,486	550
VF/F	TeeJet® TP11001-SS <sup>c</sup>	0,490	450
F/M	TeeJet® TP11003-SS	1,175	300
M/C	TeeJet® TP 11006-SS	1,94	200
C/VC	TeeJet® TP 8008-SS	2,706	220
VC/XC	TeeJet® TP 6510-SS	2,529	120
XC/UC	TeeJet® TP 6515-SS	3,407	100

NOTE An explanation of the droplet size classes used can be found in [Annex A](#).

<sup>a</sup> Pressure can be used to monitor flowrate during testing.

<sup>b</sup> Mee Fog IP®-16 is the trademark of a product supplied by Mee Industries Inc. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of the product named. Equivalent products may be used if they can be shown to lead to the same results.

<sup>c</sup> TeeJet® is the trademark of a product supplied by Spraying Systems Company. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of the product named. Equivalent products may be used if they can be shown to lead to the same results.

A nozzle body strainer, or screen, is not used for any reference nozzle in this document. The water should be filtered prior to the pressure measurement location to avoid the need for strainers or screens at the nozzle.

The individual reference nozzles<sup>1)</sup> shall fulfil specific requirements concerning flow rate and droplet size spectra. The  $D_{v0,5}$  of the individual reference nozzles shall not deviate by more than 2 % from the  $D_{v0,5}$  of a master nozzle. This shall be certified for each set of reference nozzles by the nozzle manufacturer. Reference nozzle sets should be periodically checked by the test facility as appropriate, through measurements of liquid flow rate, for possible wear. Reference nozzles shall not be subjected to wear-inducing conditions (such as the use of abrasives or harsh chemicals) that could alter orifice size, shape, smoothness, flow rate or spray angle. Expected life of these reference nozzles with water only is greater than 5 000 h.

Reference class spectra and test droplet size spectra to be classified shall all be measured with the same device and set-up as used for similar droplet sizes.

The results shall be presented by the characteristic diameters corresponding to the 10 % ( $D_{v0,1}$ ), 50 % ( $D_{v0,5}$ ) and 90 % ( $D_{v0,9}$ ) cumulative volumes of the spray.

Classify the droplet size spectrum so that its  $D_{v0,1}$ ,  $D_{v0,5}$  and  $D_{v0,9}$  parameters are between the parameters of the relevant boundary spectra. If those parameters fit into two different classes, classify the droplet size spectrum as for the majority of the parameters or, if they fit into three different classes,

1) Reference nozzles, pre-screened for laboratory testing by flow rate and  $D_{v0,5}$ , can be obtained upon request from the Spraying Systems Company, at TeeJet Technologies North Ave. P.O. Box 7900 Wheaton, IL 60187, (or ISO. Ref.Set@TeeJet.com). This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of the product named. Equivalent products may be used if they can be shown to lead to the same results.

classify according to the fit of  $D_{v0,5}$ . Use of the  $D_{v0,9}$  crossing into a finer class shall not be used to reduce the class droplet size rating compared to the  $D_{v0,5}$  rating.

Droplet size spectra for any liquids can be classified using this document as long as the reference categories are measured for water. Certain types of nozzles and atomizers can require liquids other than water for their evaluations, according to manufacturer guidelines. Retain the data and test nozzles preferably for 10 years.

## 6 Test report

The results of the droplet size measurements in terms of the characteristic diameters  $D_{v0,1}$ ,  $D_{v0,5}$  and  $D_{v0,9}$  and the spray class, as well as those values for the reference sprays, shall be stated in a test report. The report shall also contain the atomizer type and model and include spray liquid and ambient air temperatures.

These characteristic diameter statistics summarize spray spectra for category selection. In case measurements are used in spray deposition models or are subject to additional requirements (e.g. regulatory provisions), data for the whole droplet spectrum shall be included.

The exact instrument model and key operating parameters, lens(es) and/or optical range, software version(s), drop size range, and number of droplets if measurable, shall at minimum be reported.

## Annex A (informative)

### Droplet size class shortcuts

If letter symbols and/or colour coding are used to display the classifications, the scheme shown in [Table A.1](#) is recommended<sup>[1]</sup>.

**Table A.1 — Droplet size class colour symbol chart**

Classification category	Symbol	Colour code
Extremely Fine	XF	Purple
Very Fine	VF	Red
Fine	F	Orange
Medium	M	Yellow
Coarse	C	Green
Very Coarse	VC	Blue
Extremely Coarse	XC	White
Ultra Coarse	UC	Black

## Bibliography

- [1] ASABE S572. *Spray Nozzle Classification by Droplet Spectra*. American Society for Agricultural and Biological Engineers
- [2] DOBLE S.J., MATTHEWS G.A., RUTHERFORD I., SOUTHCOMBE E.S.E. A system for classifying hydraulic and other atomizers into categories of spray quality. *Proceedings British Crop Protection Conference - Weeds*, 1985, 1125–1133
- [3] SOUTHCOMBE E.S.E. MILLER P C H, Ganzelmeier H. van de Zande J. C, Miralles A, and Hewitt A J., The international (BCPC) spray classification system including a drift potential factor, *Proceedings Brighton Crop Protection Conference, Weeds*, November 1997, Brighton. UK, p 371-380
- [4] [Sankar SV, Bachalo WD](#), Response characteristics of the phase Doppler particle analyzer for sizing spherical particles larger than the light wavelength, *Appl. Opt.* 1991 Apr 20;30(12):1487-96. doi: .10.1364/AO.30.001487
- [5] WANG T. Coriolis Review 2014 <https://www.repository.cam.ac.uk/bitstream/handle/1810/246007/Coriolis-draft-paper-V8.1-FMI-Larger-Fonts.pdf?sequence=1>
- [6] Phased Doppler light scattering; <http://www.dantecdynamics.com/measurement-principles-of-pda>

