TECHNICAL REPORT

ISO/TR 22681

First edition
2019-09

Hydraulic fluid power — Impact and use of ISO 11171:2016 µm(b) and µm(c) particle size designations on particle count and filter test data

Reference number
ISO/TR 22681:2019(E)

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Published in Switzerland

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Foreword

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This document was prepared by Technical Committee ISO/TC 131, *Fluid power systems*, Subcommittee SC 6, *Contamination control*.

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.

Introduction

A minor revision to ISO 11171:2010 was approved during 2016. The revision was necessitated by a particle size shift resulting from the replacement of the particle counter calibration material, National Institute of Standards and Technology (NIST) SRM 2806a, with SRM 2806b. Prior to this revision, particle count data based upon ISO 11171 was reported in units of µm(c). Following the introduction of SRM 2806b, users of particle count data in the absence of this revision could not discern whether particle sizes being reported were based upon SRM 2806a or SRM 2806b. Hypothetically, a particle size reported as 20 µm(c) could actually be as large as 20 µm or as small as 18 µm depending upon whether SRM 2806a or SRM 2806b were used. This approximately 10 % shift in particle size can become significant in terms of the actual numbers of particles counted.

To minimize confusion and provide for clear communication, ISO 11171:2010, 6.8 and 7.1 were revised to provide a means for reporting particle size that clearly identifies the basis for reported particle size and provides the industry with tools to relate past SRM 2806a and new SRM 2806b data without extensive revisions to existing standards, specifications, and other literature. It provides a historically consistent, traceable definition of µm(c), while allowing an option to report sizes in terms of a defined µm(b) as needed. This document summarizes the underlying reasons for the minor revision and its practical impact on the industry.

Hydraulic fluid power — Impact and use of ISO 11171:2016 µm(b) and µm(c) particle size designations on particle count and filter test data

1 Scope

This document explains the use of the two acceptable methods of reporting particle size, µm(c) and µm(b), that are defined in ISO 11171:2016. It also explains the reasons for the existence of two alternative size reporting methods and its implications with respect to particle count and filter Beta Ratio data.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

No terms and definitions are listed in this document.

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

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

4 Origins of the particle size shift

ISO 11171 provides direct traceability to the standard international (SI) definition of a metre through NIST SRM 2806. ISO 11171 has been widely used to calibrate automatic particle counters (APCs) for hydraulic, lube oil, diesel fuel, and other non-aqueous liquid applications since 1999. NIST SRM 2806 is the primary calibration material used in this document.

During 2010, the original supply of SRM 2806, also sold as SRM 2806a, was exhausted. For ease of communication, the term “SRM 2806a” is used henceforth in this document to refer to both designations, SRM 2806 and SRM 2806a, of the original calibration material.

During 2014, its replacement, SRM 2806b, was released. The SRM 2806b production and certification process was overseen by an international group of experts from ISO/TC 131/SC 6. The specifications for SRM 2806b were better defined than those for SRM 2806a and it was produced by a different supplier. Advances in sample preparation and metrology were used to produce and certify SRM 2806b. A critical difference between SRM 2806a and SRM 2806b is that particle sizing was done manually from SEM micrographs with SRM 2806a, while automated image analysis was used with SRM 2806b.

This allowed an order of magnitude of more particles to be analysed and in a manner not subject to human bias. The end result was a certified calibration material, SRM 2806b, with better precision in the size distribution and a reduction in uncertainty compared to its predecessor, SRM 2806a.

An international round robin of ISO 11171 found that particle size, as defined using SRM 2806b compared to SRM 2806a, had shifted. The relationship between SRM 2806a and SRM 2806b sizes was determined from data submitted by 15 participating labs and is given by the following formula:

$$d_c = 0{,}898\ d_b$$

where

d_c is the particle size in µm(c) obtained using an APC calibrated with SRM 2806 and SRM 2806a;

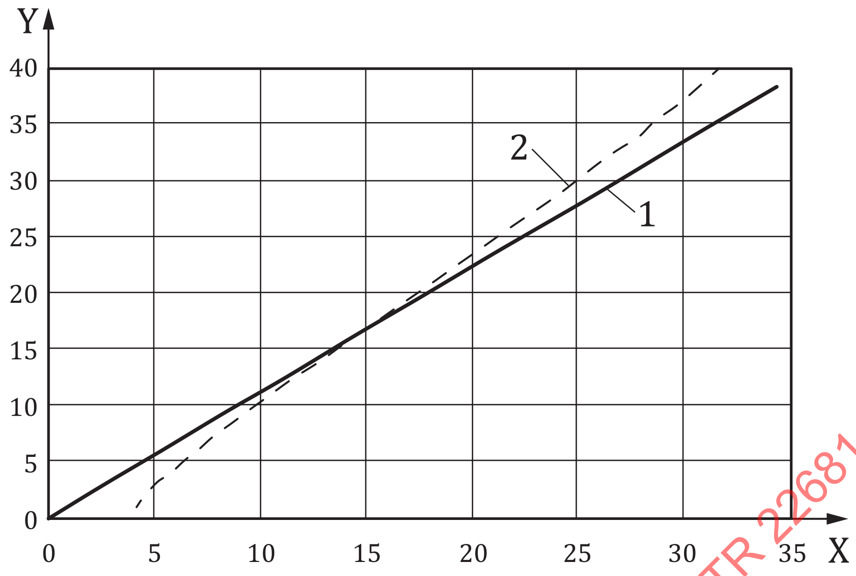
d_b is the particle size in µm(b) obtained using an APC calibrated with SRM 2806b.

As a result of the minor revision to ISO 11171, particle size reported in µm(c) is traceable to SRM 2806a using the conversion equation, or by direct measurement using an APC calibrated with SRM 2806a or SRM 2806a-traceable secondary samples in the case of data generated prior to 2016. Particle sizes traceable to SRM 2806b are reported in units of µm(b). Users of particle count data have the option to report particle size in units of either µm(c) or µm(b), or both, as appropriate. This particle size shift is within the published uncertainty of SRM 2806a, but it is great enough to affect particle count and filter test data. The magnitude of the particle size shift is illustrated graphically in Figure 1.

In Figure 1, particle size in µm(c) as determined using ISO 11171 and SRM 2806a is plotted on the X-axis. The corresponding particle size as determined using other means, i.e. using SRM 2806b or AC Fine Test Dust, is plotted on the Y-axis. The **bold** line shows the relationship between µm(c) and µm(b). The relationship passes through the origin with a slope of 1,114.

For reference, the thin line shows the relationship between µm(c) and µm sizes determined using the obsolete ISO 4402[1)] calibration method and AC Fine Test Dust. This relationship does not pass through the origin and the slope is steeper. Figure 1 demonstrates that the particle size shift with SRM 2806b is significant, yet less than what was observed when the industry transitioned from ISO 4402 to ISO 11171.

1) Withdrawn standard.



Key

Y particle size µm

X particle size, µm (c)

1 µm(b) ISO 11171

2 AC fine test dust, ISO 4402

Figure 1 — Relationship between particle sizes defined using SRM 2806a and those obtained using SRM 2806b, and using AC Fine Test Dust

5 Implications of the particle size shift

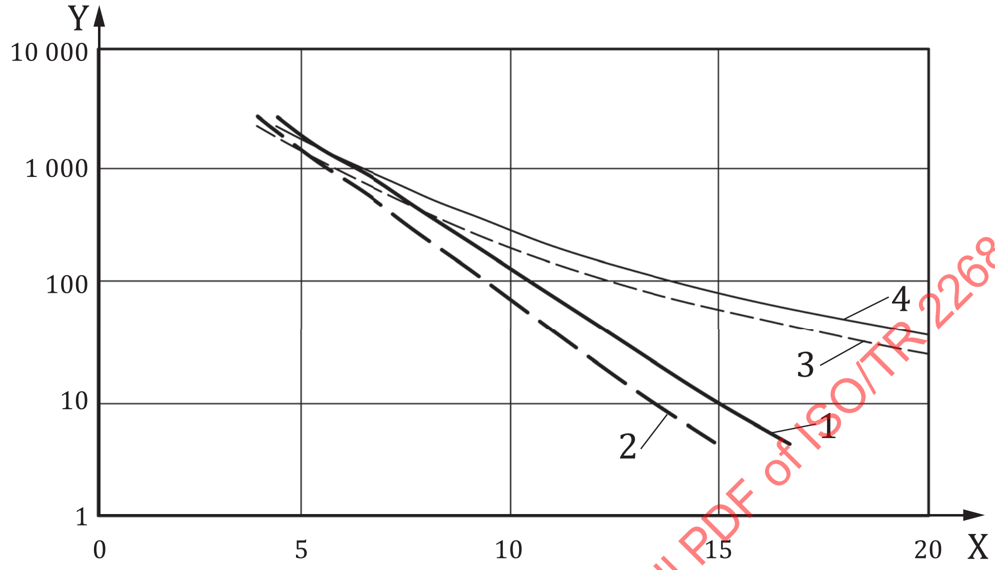
Prior to the revision in ISO 11171, there was no convenient method for users of particle count data to determine whether or not their data was affected by the particle size shift. Users could not tell whether particle count results were based upon SRM 2806a or SRM 2806b calibrations. As a result of the revision, in most cases particle count and size data reported in units of µm(c) can be used in the same manner that was done prior to the release of SRM 2806b. In those cases where µm(b) is used or compared to µm(c) data, the direction and magnitude of the correction are clearly defined and identified. The implications of the particle size shift can be discussed in terms of its impact upon particle size, particle count, ISO Code, and filter Beta Ratio results.

The impact upon particle size is illustrated in Figure 1, as previously discussed. For the particle size range from 0 to 38 µm(b), the corresponding µm(c) sizes are 10,2 % smaller. The µm(c) sizes are obtained by multiplying µm(b) sizes by 0,898. At sizes larger than 38 µm(b), latex is used for calibration and the particle size does not require correction.

The magnitude of the impact of the size shift on observed particle count data depends upon the particle size distribution of the sample in question as shown in Figure 2.

Figure 2 shows particle count data for two different dusts, ISO MTD (thin lines) and ISO UFTD (**bold lines**). ISO MTD is used in ISO 16889 filter testing. ISO UFTD is a finer dust with a steeper particle size distribution such as might be found downstream of a high performance filter. For illustrative purposes, the gravimetric dust concentration was chosen arbitrarily. The results for each dust are plotted in two different ways. The dashed lines show the results reported in µm(c) while the solid lines show results reported in µm(b). For any given particle size, µm(b) particle counts tend to be greater than the corresponding µm(c) results. The magnitude of the increase becomes greater as the slope of the particle size distribution becomes steeper (more negative) as per ISO UFTD example.

The revision to ISO 11171 clearly informs users of the underlying basis of particle count data, SRM 2806a or SRM 2806b, and enables accurate interpretations of results to be made. Furthermore, the revision provides for mathematical conversion of particle diameters derived from SRM 2806b calibration, µm(b), to those obtained from SRM 2806a calibration, µm(c). As a result, existing specifications and standards based upon µm(c) can be used without modification, other than to reference the most recent version of ISO 11171.



Key

Y particle size/mL > indicated size

X particle size, µm

1 µm(b) ISO UFTD

2 µm(c) ISO UFTD

3 µm(c) ISO MTD

4 µm(b) ISO MTD

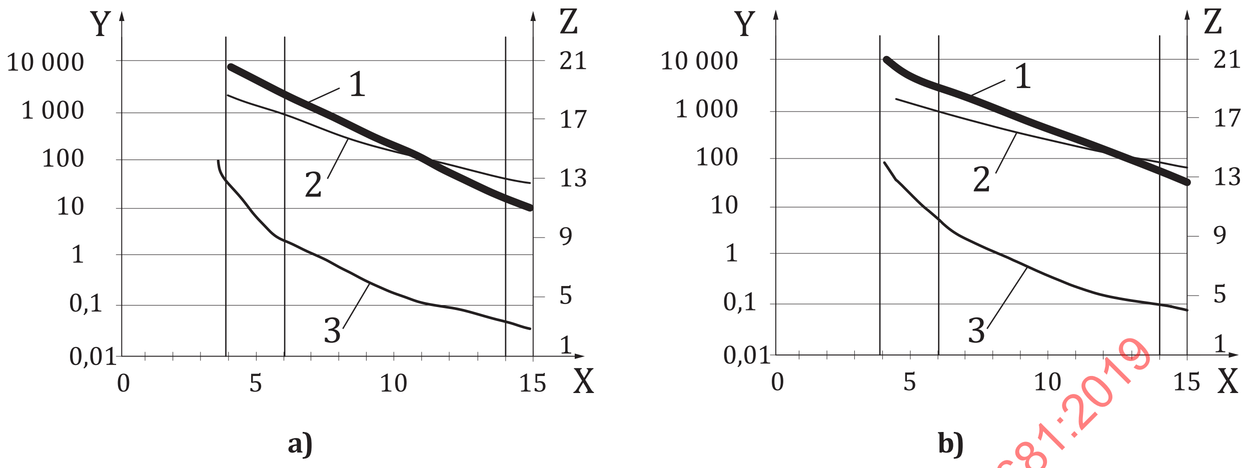
Figure 2 — Impact on revision on particle count results for two different dust size distributions

The magnitude of the impact of the particle size shift on cleanliness levels reported as ISO 4406 Code numbers depends upon the actual particle size distribution of a sample and how near the particle concentration is to cross-over points between ISO Codes. Figures 3 a) and 3 b), and Table 1 are used to illustrate this. Figures 3 a) and 3 b) graphically illustrate the particle size distribution of arbitrary concentrations of ISO MTD and ISO UFTD, and of a sample taken downstream of a filter (Figure 3 a) shows the data reported in µm(c) and Figure 3 b) shows data from the same sample reported in µm(b)).

Table 1 shows this data reported as ISO 4406 codes rather than particle counts. Using the revised ISO 11171, observed ISO 4406 codes do not change provided that µm(c) particle sizes are used as shown in the second column of Table 1. On the other, ISO 4406 cannot be directly used with µm(b) sizes as the code requires µm(c) sizes. Sizes of 4,0 µm(b), 6,0 µm(b) and 14,0 µm(b) correspond to sizes of 3,6 µm(c), 5,4 µm(c) and 14,0 µm(c). If particle sizes of 4,0 µm(b), 6,0 µm(b) and 14,0 µm(b) are erroneously used with the ISO 4406 code, the examples in Table 1 (column 3) show that ISO codes typically increase 1 or 2 code units, depending upon the particle concentration and size distribution.

The following magnitude of the change in ISO code data is dependent upon the particle size distribution. The steeper the particle size distribution, the greater for the change. For this reason, a greater shift could occur with certain field samples such as those collected downstream of fine filters.

In practical terms, such an error could result in systems failing to meet cleanliness recommendations simply due to a failure to use the proper particle size reference, i.e. incorrect use of µm(b) instead of the correct µm(c). This could result in unnecessary service or corrective action being taken to solve problems that don't exist. Prior to the revision, users had no convenient way of determining the basis for calibration, putting them at risk of making inappropriate contamination control decisions.



Key

	a)		b)
Y	particles/mL > indicated size	Y	particles/mL > indicated size
X	particle size, µm(c) S	X	particle size, µm(b)
Z	ISO 4406 code	Z	ISO 4406 code
1	ISO UFTD	1	ISO UFTD
2	ISO MTD	2	ISO MTD
3	Down stream	3	Downstream

Figure 3 — Effect of calibration material on ISO code for various types of samples

NOTE Figure 3 a) shows the data reported in µm(c) and Figure 3 b) shows data from the same sample reported in µm(b)

Table 1 — Effect of calibration material upon reported ISO code[a]

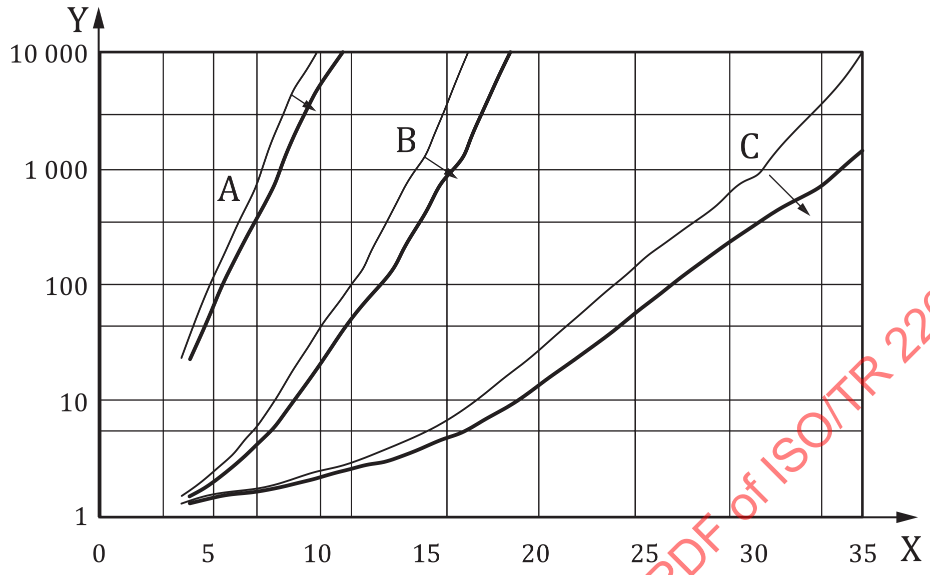
Sample description	ISO Code	
	µm(c)	µm(b)
MTD	18/17/13	19/18/14
UFTD	20/19/11	21/20/13
Downstream of filter	12/9/3	14/10/4

[a] Refer to Figure 3 for particle size distribution of each sample.

The particle size shift also impacts observed filter Beta Ratio data. The magnitude of the impact depends upon the characteristics of the filter in question. When particle size is reported in terms of µm(c) according to the revised ISO 11171, Beta Ratio results are unaffected. New and historical data based upon ISO 11171 can be compared without conversion. On the other hand, direct comparison of µm(c) and µm(b) Beta Ratios is problematic. This is illustrated in Figure 4 using results from three different types of filters, referred to as A, B and C.

Results for each filter are plotted using particle sizes as µm(c) (thin lines) and as µm(b) (**bold lines**) according to the revised ISO 11171. In general Beta Ratios appear smaller and filter performance appears worse using µm(b) sizes because the corresponding µm(c) sizes are numerically 10,2 % smaller. Since the magnitude of the decrease in Beta Ratio depends upon the characteristics of the filter, there is no generic Beta Ratio correction available. Prior to the revision users of Beta Ratio data had no clear indication of the cause of this decrease and would have assumed that filter performance had deteriorated even though no actual change in filter performance had occurred.

The financial implications of this are significant and include potential rejection of filter shipments based upon a perceived failure to meet the specification and extensive troubleshooting efforts to eliminate failure modes that do not exist. The revision provides a means to avoid such problem by providing a clear means to report filter performance using historically consistent µm(c) sizes. This allows filter customers and manufacturers to evaluate products in the context of historic performance. Thus, existing standards and specifications referring to particle size in µm(c) do not require revision and historical data based upon ISO 11171 can be directly compared to µm(c) data obtained using the revised ISO 11171.



Key

Y Beta Ratio

X particle size

——— (thick) µm(b)

——— (thin) µm(c)

Figure 4 — Filter Beta Ratios expressed as function of µm(c) and µm(b)

6 Use of revised ISO 11171

The particle size shift resulting from the introduction of new APC calibration material posed a major challenge for the industry requiring immediate action. In the absence of a standard means for expressing particle size, there was inconsistency in terms of how data was reported and erroneous contamination control decisions made. In response, a minor revision to ISO 11171 affecting the reporting of data was passed by ISO TC 131/SC 6.

Since the supply of SRM 2806a and the shelf life of SRM 2806a secondary calibration samples had expired, it was not possible to revert back to the previous SRM 2806a calibration material. Future calibration according to ISO 11171 must be made using SRM 2806b traceable material. The revision provides the industry with a mathematical method for converting µm(b) sizes obtained from APCs calibrated with SRM 2806b to µm(c) sizes that are traceable to SRM 2806a. There has been no technical change to ISO 11171. Only the reporting method has been revised. The revised ISO 11171 does not require particle size or count data to be expressed in any particular manner. It provides two mathematically related options for reporting sizes. The use µm(c) or µm(b) is at the discretion of user, as is how to implement their choice.

In most instances, organizations will find it least disruptive to continue reporting particle size in units of µm(c). There is no inherent advantage in reporting in units of µm(b), while standards, product and

