An Introduction to Standard Powders in Japan

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1. Preface

The uses of standard powders have increased sharply in the past several years, and industrial tests and studies relevant to them have increased accordingly. The application that once chiefly comprised tests on the filterability of air cleaners in motor vehicles and on the abrasion resistance and antidust ability of automotive engine parts has recently expanded to cover labor hygiene, medicine, pharmacology and the food industry, besides mining and manufacturing industries. The demand has been increasing steadily in diversified uses which now include, calibration in monitoring airborne microfine particles in a clean or bioclean room, contamination control, the examination of dust respirators, durability tests of seat belts in motor vehicles, and experimental administration to mice.

This paper attempts to provide introductory information on standard powders which have hitherto been handled by The Association of Powder Process Industry & Engineering, Japan (APPIE), giving an outline of their properties with the purpose of serving as a reference.

2. Kinds of standard powders

Generally, the properties of a bulk solid may be specified in terms of four elements true density, particle size distribution, chemical composition, and particle shape. Specifications standardizing bulk solids in foreign countries as well as in Japan show that it is an ordinary practice to define their properties in terms of the above-mentioned four elements or three excluding particle shape. It is necessary for the properties of a standard powder to be specified defined, for its constant stable supply to be ensured, and for the material itself to be applicable to the performance tests of instruments and machinery, etc. as a means of evaluating the efficiency of their mechanical operation.

According to the practice by The Association of Powder Process Industry & Engineering, Japan, standard powders are generally divided into three categories on the basis of the properties of bulk solids for convenience, as shown in Table 1; that is, standard particles for basic properties, testing grade standard powders, and dusts for industrial testing.

Table 1 shows the classification of standard powders arranged by Prof. Masafumi Arakawa of Kyoto Institute of Technology, in which a "standard particle for basic properties" refers to one to be used for research on basic properties, having a particle shape and particle size which are ideal in simplifying the complexity that the powder itself essentially has; a "test grade standard powder" refers to one which

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has a particle shape and size both of which are close to uniformity next only to a standard powder in terms of basic properties, to be used for basic research on bulk solids or granular materials, or for the calibration of devices for measuring physical properties of bulk solids; a "dust for industrial testing" refers to one specified by JIS\(^1\) and used for performance tests of apparatuses handling dust in mining or manufacturing industries and corresponding to industrial dusts in particle shape, size and composition.

3. Standard powders

3.1 Standard particles for basic properties

Table 2 shows the mean particle diameter, true density, uses respectively of a standard particle and the basic properties of which are designated by The Association of Powder Process Industry & Engineering, Japan. Figure 1 shows the particle shapes of the standard particles.

As shown clearly in Fig. 1, polystyrene latex is a standard particle that consists of almost perfectly spherical particles. There are many variants with particle diameters ranging from 0.1 \(\mu\)m to 7 \(\mu\)m, each prepared in the form of about 2 ~ 3 mass percent solution and packed in a container of about 5 cm\(^3\) in volume. Some of the uses of this series of polystyrene latex are for calibration in the measurement of airborne particles in a clean room, as a standard

Table 2: Basic properties of standard particles

| Heading            | Mean particle diameter \(D_p (\mu m)\) | True density \(\rho_p (g/cm^3)\) | Uses                                      |
|--------------------|----------------------------------------|---------------------------------|-------------------------------------------|
| 0.1 \(\mu\)m       | 5 \(\mu\)m                              |                                | Calibration of fine particle-measuring devices (for both gases and liquids); as a standard for samples under a microscope |
| 0.2                | 7                                      |                                |                                           |
| 0.3                | 10                                     |                                |                                           |
| Poly-styrene latex | 0.4                                    | 15                              |                                           |
| 0.5                | 20                                     | 1.50                            |                                           |
| 0.6                | 41                                     |                                |                                           |
| 0.7                | 66                                     |                                |                                           |
| 1.1                | 92                                     |                                |                                           |
| 2.0                |                                        |                                |                                           |

Fig. 1: Particle shapes of standard powders

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1. JIS: Japan Industrial Standard
sample in the measurement of surface contamination in a clean room, and for the determination of magnifications or for the comparison of the dimensions with the sample when added to samples for use in electron microscopy.

3.2 Testing grade standard powders

Table 3 shows the properties and uses of the testing grade standard powders designated by The Association of Powder Process Industry & Engineering, Japan. Figure 1 shows the particle shapes of the testing grade standard powders.

(1) Lycopodium powder

Lycopodium powder, besides being a product of nature, is characterized by virtual evenness in particle size and by excellent fluidity. Being a pollen occurring in nature and having an outstanding dispersibility in the air, lycopodium powder has uses in tests on fluidity, clinical tests for pollinosis, and the like.

(2) Precipitated calcium carbonate

As seen in Fig. 1, precipitated calcium carbonate comes in a configuration and size characteristic of the rhombohedron. Such an evenness characterizes a size which makes the crystals useful for basic experiments on devices for measuring powder properties.

(3) Glass beads

Glass beads are transparent spherical particles with evenness in particle size. There are six variants with an average particle size of 10, 20, 30, 40, 60 and 80 μm. They are used for calibration in the measurement of particle sizes of powders and as standard samples in, for example, efficiency tests of filters for hydraulic equipment.

(4) White fused alumina

White fused alumina is a product of refining available in six variants with a mean particle diameter of 2, 5, 10, 20, 40 and 80 μm (each doubles to the next in progression). The properties, i.e. true density, particle size distribution, specific surface area, fluidity, particle shape, and composition etc., are known with respect to each of these variants. The white fused alumina is considered to be most suited for calibration in measuring the properties of bulk solids.

Table 3 Standard powders

| Standard powders | Heading | Mean particle diameter $D_p$ (μm) | Main ingredient (%) | True density $\rho_p$ (g/cm$^3$) | Uses |
|------------------|---------|-------------------------------|---------------------|-------------------------------|------|
| Glass beads      | Lycopodium powder | 30 ~ 40 | Fatty oil about 50 (oleic acid 80, arachic acid 8) | 1.05 | Test on fluidity and diffusion |
|                  | Precipitated calcium carbonate | 12 ~ 15 | CaCO$_3$ | 2.71 | Calibration of particle size measurement |
|                  | No. 1 | 10 | Soda lime | 2.72 | Calibration of a fine particle counter |
|                  | No. 2 | 20 | Silicate glass | | Fluidity test |
|                  | No. 3 | 30 | SiO$_2$ ... 70 ~ 73 | | |
|                  | No. 4 | 40 | Titanium | | |
|                  | No. 5 | 60 | Barium glass | | |
|                  | No. 6 | 100 | TiO$_2$ ... 32 ~ 38, BaO ... 43 ~ 48 | | |
|                  | White fused alumina | No. 1 | 2 | Al$_2$O$_3$ 98 | 3.92 | Calibration of particle size measurement of bulk solid |
|                  | No. 2 | 5 | | 3.94 | Test on wear, durability of machinery |
|                  | No. 3 | 10 | | 3.95 | |
|                  | No. 4 | 20 | | 3.96 | |
|                  | No. 5 | 40 | | 3.97 | |
|                  | No. 6 | 80 | | 3.98 | Test on fluidity |
|                  | Talc | 0.5 | SiO$_2$ ... 60 ~ 63, MgO ... 30 ~ 34 | 2.80 | Performance test of high efficiency filter, etc., Calibration of particle size measurement |
(5) Talc

Talc consists of very minute particles with a mean particle diameter of $0.5 \mu$m, the particle diameter being the smallest of all powders prepared by pulverization and classification. The particle is a flake shaped. Talc is expected to become increasingly in demand for uses in research on the surface contamination of wafers in clean rooms, and for tests on the filterability of fine filters. Talc, together with Class 4 and Class 9 as dusts for industrial testing, comes in three grades of particle sizes, i.e. fine, very fine, and ultrafine.

3. 3 Dusts for industrial testing (JIS Z 8901)

The standardization of dusts for industrial testing dates back to 1958, when the six classes from 1 (silica sand powder) to 6 (cement) were initially designated. In compliance with the desires in various fields of mining and manufacturing industries and in the instrumental control of environmental pollution and labor hygiene, the number of dusts used for industrial testing was increased during the next thirty years, to the present 17 classes, which are shown in Table 4.

The particle size distributions and the particle shapes of the dusts for industrial testing are shown in Fig. 2 and Fig. 3, respectively. A general idea of all 17 dusts used in industrial testing can be obtained from Table 4 which shows the median diameters, principal components and true densities, and from Figs. 2 and 3 which show the particle size distributions and particle shapes.

(1) Classes 1, 2 and 3 (silica sand powder of the coarse, fine, and very fine grades, respectively)

Silica sand powder is composed mainly of SiO$_2$, characterized by hard quality and irregularity in particle shape. The particles become finer in the order of from Class 1 to Class 3. Its characteristic of being able to accelerate abrasion is used in tests on the durability and wear of dust-related instruments and machinery.

(2) Classes 4 and 9 (talc of the very fine and ultrafine grades)

Talc pulverized and prepared to have a specified particle size is used. The particles are fine flakes in shape. The main use is for testing the filter cloth in a dust-collecting system.

(3) Classes 5 and 10 (fly ash of the very fine and ultrafine grades)

Particulates obtained from the pulverized coal-burning furnace of a thermal power plant is used. The collected fly ash is prepared by classification so as to have specified particle size distributions. Most of the particles are spherical in shape, though irregular particles are also included. The main use is for testing dust collectors.

(4) Class 6 (ordinary portland cement)

An ordinary concrete-forming cement is used for tests on the airtightness of lamps in motor vehicles as specified by the SAE-recommended standard$^3$ and JIS$^4$. Care must be taken in handling it because of its hygroscopicity.

(5) Classes 7, 8 and 11 (Kanto loam powder of the fine, very fine, and ultrafine grades)

Also called Kanto loam dust, these classes of dust come from Kanto volcanic ash soil which is distributed widely in the southwestern part of the Kanto district of Japan, and is produced by calcination followed by pulverization. The products have coherency with both “fine” and “coarse” dusts in the SAE-recommended standard$^5$. They are used for testing various dust-collecting devices, for testing the durability of instru-
Table 4 Dusts for industrial testing specified by JIS Z 8901

| Kind    | Substance               | Medium diameter $D_p$ 50 (µm) | Main ingredient (%) | True density $\rho_p$ (g/cm³) | Uses                                    |
|---------|-------------------------|-------------------------------|---------------------|-------------------------------|-----------------------------------------|
| Class 1 | Silica sand powder      | 195                           | SiO₂                | 63 ~ 73                       | Efficiency test of powder apparatus,    |
| Class 2 | Silica sand powder      | 30                            | SiO₂                | 57 ~ 63                       | Tests on the wear and durability of      |
| Class 3 | Silica sand powder      | 8                             | SiO₂                | 34 ~ 40                       | instruments and machinery,              |
| Class 4 | Talc                    | 8                             | SiO₂                | 34 ~ 40                       | Dust collector test                     |
| Class 9 | Talc                    | 4.6                           | MgO                 | 28 ~ 32                       | Dust collector test                     |
| Class 5 | Fly ash                 | 15                            | SiO₂                | 34 ~ 40                       | Machinery wear test                     |
| Class 10| Fly ash                 | 5                             | Al₂O₃               | 26 ~ 32                       | Oil pressure filter test                |
| Class 6 | Ordinary portland cement | 26                           | C₂O                 | 3.1 ~ 3.2                     | Test of the airtightness of motor       |
| Class 7 | Kanto loam powder       | 30                            | SiO₂                | 21 ~ 24                       | vehicle lamps                           |
| Class 8 | Kanto loam powder       | 8                             | Fe₂O₃               | 17 ~ 23                       | Dust collector test                     |
| Class 11| Kanto loam powder       | 1.9                           | Al₂O₃               | 26 ~ 32                       | Machinery wear test                     |
| Class 12| Carbon black            | –                             | DPB absorption      | –                             | Dust elimination test                   |
| Class 13| Aerosol                 | 0.27                          | Dioctyl phthalate   | –                             | Test of high efficiency air filter      |
| Class 14| Aerosol                 | 0.86                          | Stearic acid        | –                             | Calibration of a fine particle counter  |
| Class 15| Dust mixture            | –                             | Dusts for industrial testing Class 8, Class 12 and linters | –                             | Prefilter test                          |
| Class 16| Heavy calcium carbonate | 4.1                           | CaO                 | 54 ~ 56                       | Test of adhesion/aggregation, Dust      |
| Class 17| Heavy calcium carbonate | 2.2                           | Heat reduction      | 2.7 ~ 2.9                     | collector test                          |
Fig. 3 Shapes of dusts used for industrial testing
ments and machinery, etc. This dust is the one most used for testing.

(6) Classes 9, 10 and 11 (talc, fly ash, and Kanto loam powder respectively of an ultrafine grade)

Classes 9, 10 and 11, which have already been referred to, were developed at the request of the Standard Department of the Agency of Industrial Science and Technology in connection with enactment of Notification No. 1 of the Environment Agency and the Health and Welfare Ministry Ordinance in the Public Buildings Sanitary Administration Law. Aptly called “10 μm cut dusts” informally, these three classes of dusts have particle diameters of less than 10 μm and differ in particle shape — Class 9 is flakes, Class 10 is spheres and Class 11 is irregular particles.

(7) Class 12 (carbon black of the ultrafine grade)

This one corresponds to the dust that falls from the smokestacks of a factory and is used in tests on dust collection in a large scale dust collection system. The particles are extremely fine with a particle diameter range of 0.03 ~ 0.20 μm, and they exist as spheres linked together.

(8) Classes 13 and 14 (aerosols of the ultrafine grade)

Two kinds of aerosols are specified in terms of particle size distribution — a monodispersed system and a polydispersed system — with submicron particles as the liquid drops in both cases. Each class of aerosol is produced by using stearic acid or dioctyl phthalate (DOP), as specified in JIS, and by means of an aerosol generator. As currently specified by JIS, the monodisperse aerosol is used for testing the filterability of the air filter, and an polydisperse aerosol is used for the air leakage test of the same air filter.

(9) Class 15 (dust mixture)

The product is a mixture of Class 8 dust (Kanto loam powder corresponding to road dust), Class 12 dust (carbon black corresponding to dust fall), and linters (fibrous particles corresponding to indoor dust), which corresponds to polluted urban air. It is used mainly for testing the filterability of prefilters (filters in advance or for coarse dust).

(10) Classes 16 and 17 (heavy calcium carbonate in very fine and ultrafine grades)

These two classes were added to the dusts for industrial testing in the revised standards in fiscal 1982. They are used for testing dust-collecting devices and as standard samples in testing the adhesive and aggregative properties of bulk solids. A constant stable commercial supply of products characterized by virtual evenness in particle size, though irregular in shape, can be ensured.

3.3.1 Physicochemical properties of dusts for industrial testing

(1) Items of measurement

Table 5 shows the items and methods of measurement with respect to the physicochemical properties of the dusts used in industrial testing. Besides true density, particle size distribution and chemical composition as specified by JIS, the items of measurement included, are bulk density, specific surface area, fluidity and particle shape.

The true density was measured by vacuum deaeration using a pycnometer in accordance with the relevant specification of the JIS.

As a means of determining particle size distributions, the standard sieves are used in the production of Class 1 dust, in the screening of dusts with a particle diameter of over 75 μm in the production of Classes 2, 3, 6, 7 and 8, and in the screening of dusts with a particle diameter of over 106 μm in the production of Classes 5 and 10.

The specific surface area was determined by using a constant pressure air-permeable type of measuring device and the automatic device in the BET method.

The fluidity was measured by using the powder tester, which was a product of Hosokawa Micron Corporation.

As to particle shapes, an optical microscope was mainly employed, but an electron microscope of the scanning type or the transmission type was also employed where the particle size was finer.

The chemical compositions are those
obtained by chemical analyses, and the standards\textsuperscript{1)} of the dusts for industrial testing are shown in the following list.

3. 3. 2 Physicochemical properties

(a) True density

Table 6 shows the results of the actual measurement of the true densities of dusts for industrial testing in comparison with the respective standards. The table shows the conformance of each measured value to the respective standard.

(b) Particle size distribution

To determine the particle size distribution, Class 1 dust was subjected to standard screening\textsuperscript{8)} by introducing standard sieves\textsuperscript{7)}, whereas the Andreasen pipette method was introduced with respect to Classes 2, 3, 4, 5, 7, 8, 9, 10, 11, 16 and 17.

As a result, the particle size distributions of the above-mentioned classes of dusts for industrial testing were all found to conform to the specifications in JIS\textsuperscript{1)} and to satisfy the value of median diameters in Table 4.

Table 6 True density and specific surface areas of dusts for industrial testings

| Dust | Measured value | Standard value | BET method | Air-permeable method |
|------|----------------|----------------|------------|---------------------|
| Class 1 (silica sand powder, coarse) | 2.65 | 2.6 ~ 2.7 | — | 0.0685 |
| Class 2 (silica sand powder, fine) | 2.64 | 2.6 ~ 2.7 | 0.80 | 0.405 |
| Class 3 (silica sand powder, very fine) | 2.7 | 2.6 ~ 2.7 | 1.94 | 0.752 |
| Class 4 (talc, very fine) | 2.74 | 2.7 ~ 2.9 | 7.51 | 1.534 |
| Class 9 (talc, ultrafine) | 2.78 | 2.7 ~ 2.9 | 7.14 | 1.866 |
| Class 5 (fly ash, very fine) | 2.08 | 2.0 ~ 2.3* | 1.51 | 2.664 |
| Class 10 (fly ash, ultrafine) | 2.07 | 2.0 ~ 2.3* | 2.64 | 3.920 |
| Class 6 (cement, very fine) | 3.16 | 3.10 ~ 3.18** | 1.30 | 0.325 |
| Class 7 (Kanto loam powder, fine) | 2.96 | 2.9 ~ 3.1 | 10.6 | 0.513 |
| Class 8 (Kanto loam powder, very fine) | 2.96 | 2.9 ~ 3.1 | 10.4 | 0.897 |
| Class 11 (Kanto loam powder, ultrafine) | 2.9 | — | — | 1.897 |
| Class 16 (heavy calcium carbonate, very fine) | 2.72 | 2.7 ~ 2.8 | 3.74 | 1.110 |
| Class 17 (heavy calcium carbonate, ultrafine) | 2.72 | 2.7 ~ 2.8 | 6.12 | 1.657 |

* Specified in JIS A 6201 (fly ash)
** Specified in JIS R 5210 (portland cement)
and the particle size distributions in Fig. 2.

(c) Specific surface area

Table 6 shows the specific surface areas of dusts for industrial testing.

In the BET method, the specific surface area showed increases with decrease in particle size with respect to the silica sand powder, fly ash and heavy calcium carbonate, whereas the particle size of talc and Kanto loam powder were found to be independent of the specific surface areas. The likely reason for this difference is that talc and Kanto loam powder crumble easier than the others when tapped.

(d) Fluidity

The fluidity of a dust for industrial testing was evaluated in terms of Carr's flowability index\(^{10}\) based on the apparent bulk density, compressibility, angle of repose, angle of spatula, cohesiveness, and uniformity as determined by a Powder Tester (Model PT-E)\(^9\).

Table 7 shows the results of the measurement. From this, it is observed that the fluidity of the dusts for industrial testing is not satisfactory; where dusts with the same composition are compared, there is a tendency for the fluidity to decrease with decrease in particle size.

When Classes 1, 2 and 3 (silica sand powder of the coarse, fine, and very fine grades) are compared, it is seen that the fluidity of Class 1 is good, but it becomes poor with decrease in particle size as shown by Classes 2 and 3.

This degradation of the fluidity influenced by enhancement of the fineness of the particles is also obvious when Classes 4 and 9 (talc of the very fine and ultrafine grades) are compared.

Classes 5 and 10 (fly ash of the very fine and ultrafine grades) are relatively better in fluidity than Class 4; the likely reasons are that fly ash is relatively coarser in particle size than the talc and that fly ash is an aggregate of spherical particles which are easily dispersed.

Of Classes 7, 8, and 11 (Kanto loam powder of the fine, very fine, and ultrafine grades), the fluidity of Class 7 is as good as that of Class 5, but that of Class 8 and Class 11 is unsatisfactory. The fluidity of Class 12 (carbon black of the ultrafine grade) is very poor.

Fluidity is very poor with respect to Classes 16 and 17 (heavy calcium carbonate of very fine and ultrafine grades), differing little independent of the particle size in between.

A glance at the constituent values of the measurement by a Powder Tester reveals that between dusts of the same composition there is a decrease, dependent on particle size, in the apparent bulk density (g/cm\(^3\)), the compressibility, the angle of spatula, the cohesiveness, and the uniformity. An exception is heavy calcium carbonate which has a high cohesiveness and shows little difference in characteristics between Class 16 and Class 17 which differ in particle size.

(e) Particle shape

Figure 3 shows the particle shapes of the dusts for industrial testing which were observed by an optical microscope and electron microscope. Silica sand powder, i.e. Classes 1, 2 and 3, is irregular in particle shape and has rigid angular configurations.

Talc, i.e. Classes 4 and 9, is an aggregate of flake-shaped particles which easily exfoliate. The photograph also shows the talc to be relatively crumbly.

Fly ash, i.e. Classes 5 and 10, consists mostly of spherical particles, although some particles are irregular in shape.

Ordinary portland cement, i.e. Class 6, consists of somewhat roundish particles.

Kanto loam powder, i.e. Classes 7, 8 and 11, consists of particles which are not angular but rather roundish in shape.

Carbon black, i.e. Class 12, is an aggregate of spherical particles. Practically none of the individual particle exist by themselves but rather are linked to one another.

Dust mixture, i.e. Class 15, consists primarily of Class 8 (Kanto loam powder of the very fine grade), contains added linters and Class 12 (carbon black of the ultrafine grade). The particles of Class 12 exist in part separate from one another and in part forming aggregates closely filling the interspaces.

Heavy calcium carbonate, i.e. Class 16 and Class 17, consists of somewhat roundish particles which exist in part separate from
Table 7  Results of the measurement of the fluidity of dusts for industrial testing

| Dust                                      | Apparent bulk density [g/cm³] | Compressibility | Angle of repose | Angle of spatula | Cohesiveness/ | Total flowability index | Evaluation of flowability |
|-------------------------------------------|-------------------------------|-----------------|-----------------|-----------------|---------------|------------------------|--------------------------|
|                                           | loosed packed                 |                 |                 |                 | % points      | deg. points           |                           |
| Class 1 (silica sand powder coarse)       | 1.503                         | 1.612           | 1.577           | 6.8             | 23            | 40 17.5               | 81.5 Good                 |
| Class 2 (silica sand powder, fine)        | 0.992                         | 1.613           | 1.231           | 38.5            | 2             | 52 12                 | 28 Very poor              |
| Class 3 (silica sand powder, very fine)   | 0.650                         | 1.307           | 0.980           | 50.3            | 0             | 41 17                 | 26 Very poor              |
| Class 4 (talc, very fine)                 | 0.288                         | 0.561           | 0.421           | 48.7            | 0             | 50 12                 | 34 Very poor              |
| Class 5 (fly ash, very fine)              | 0.747                         | 1.192           | 0.913           | 37.3            | 5             | 43 16                 | 43 Poor                   |
| Class 6 (cement, very fine)               | 0.926                         | 1.693           | 1.273           | 45.3            | 0             | 54 12                 | 21 Very poor              |
| Class 7 (Kanto loam powder, very fine)    | 0.734                         | 1.142           | 1.008           | 35.7            | 7             | 49 12                 | 43 Poor                   |
| Class 8 (Kanto loam powder, very fine)    | 0.563                         | 1.145           | 0.859           | 50.8            | 0             | 46 14.5               | 28.5 Very poor            |
| Class 9 (talc, ultrafine)                 | 0.258                         | 0.523           | 0.392           | 50.7            | 0             | 49 12                 | 29 Very poor              |
| Class 10 (fly ash, ultrafine)             | 0.595                         | 1.052           | 0.790           | 42.8            | 2             | 47 12                 | 33 Very poor              |
| Class 11 (Kanto loam powder, ultrafine)   | 0.395                         | 0.891           | 0.589           | 46.7            | 0             | 35 20                 | 37 Very poor              |
| Class 12 (carbon black, ultrafine)        | 0.302                         | 0.571           | 0.504           | 47.1            | 0             | 41 17                 | 36 Very poor              |
| Class 16 (heavy calcium carbonate, very fine) | 0.520                   | 1.030           | 0.770           | 49.1            | 0             | 44 16                 | 23 Very poor              |
| Class 17 (heavy calcium carbonate, ultrafine) | 0.480                       | 0.940           | 0.700           | 48.1            | 0             | 45 15                 | 22 Very poor              |

△ Measured degree of uniformity
one another and in part in the form of aggregates. Using a transmission type electron microscope, the contours of the separate particles and aggregates of the particles can be relatively clearly distinguished. However, when using a scanning type electron microscope, the particles overlying one another in an aggregation can be distinguished.

(f) Chemical composition

Table 8 shows the chemical compositions of the dusts for industrial testing.

The silica sand particles forming Classes 1, 2 and 3 are obtained by pulverizing standard Soma sand\(^1\) and preparing it to have specified particle size distributions and a chemical composition of hard SiO\(_2\) particles in a proportion of over 97%.

The talc forming Classes 4 and 9 is obtained by pulverizing natural talc and preparing it to have specified particle size distributions and a chemical composition consisting mainly of SiO\(_2\) and MgO.

The fly ash forming Classes 5 and 10 consists mainly of SiO\(_2\) and Al\(_2\)O\(_3\), and the cement forming Class 6 consists mainly of CaO.

3.4 Dusts used for industrial testing that meet other than JIS specifications

The Association of Powder Process Industry & Engineering, Japan besides specifying standard particles, also specifies testing grade standard powders, dusts for industrial testing JIS Z 8901, and the dusts used for industrial testing, which are shown in Table 9. The particle shapes of these additional dusts are shown in Fig. 4.

(1) Standard Soma sand

The standard Soma sand is silica sand...
| Kind | Class 1, 2 and 3 (silica sand powder) | Class 4, 9 (talc) | Class 5, 10 (fly ash) | Class 6 (ordinary portland cement) | Class 7, 8 and 11 (Kanto loam powder) | Class 12 (carbon black) | Class 13 and 14 (aerosol) | Class 15 (dust mixture) | Class 16 and 17 (heavy calcium carbonate) |
|------|--------------------------------------|------------------|----------------------|-------------------------------|----------------------------------------|--------------------------|---------------------------|----------------------------|----------------------------------|
|      |                                      |                  |                      |                               |                                        |                          |                           |                           |                                  |
|      |                                      |                  |                      |                               |                                        |                          |                           |                           |                                  |

Table 8 Chemical composition of dusts for industrial testing (Unit: %)

| Composition | SiO₂ | Al₂O₃ | Fe₂O₃ | CaO | MgO | TiO₂ | SO₃ | Undissolved residuum | Reduction by heating |
|-------------|------|-------|-------|-----|-----|------|-----|---------------------|---------------------|
| Class 1, 2 and 3 (silica sand powder) | Over 97 | Under 3, including reducing portion by heating | — | — | — | — | — | — | — |
| Class 4, 9 (talc) | 60 ~ 63 | 0 ~ 3 | 0 ~ 3 | 0 ~ 2 | 30 ~ 34 | — | — | 3 ~ 7 | — |
| Class 5, 10 (fly ash) | Over 45 | Over 20 | — | — | — | — | — | — | — |
| Class 6 (ordinary portland cement) | 20.5 ~ 23.7 | 4.0 ~ 7.0 | 2.5 ~ 4.5 | 63.0 ~ 65.6 | 0.6 ~ 3.2 | — | 0.3 ~ 2.0 | 0.1 ~ 1.0 | 0.3 ~ 2.0 |
| Class 7, 8 and 11 (Kanto loam powder) | 34 ~ 40 | 26 ~ 32 | 17 ~ 23 | 0 ~ 3 | 3 ~ 7 | 0 ~ 4 | — | — | 0 ~ 4 |
| Class 12 (carbon black) | — | — | — | — | — | — | — | — | — |
| Class 13 and 14 (aerosol) | — | — | — | — | — | — | — | — | — |
| Class 15 (dust mixture) | — | — | — | — | — | — | — | — | — |
| Class 16 and 17 (heavy calcium carbonate) | 0 ~ 4 | 0 ~ 3 | 0 ~ 1 | 54 ~ 56 | 0 ~ 3 | — | — | — | 42 ~ 45 |

Note 1) physicochemical properties
Note 2) indicates quality
Note 3) indicates quality

Table 9 Dusts used for industrial testing that meet other than JIS specification

| Heading | Medium dia. | Main ingredient | True density | Uses |
|---------|-------------|-----------------|--------------|------|
| Standard Soma sand | 170 | SiO₂ ..... over 97% | 2.63 | — |
| Quarts ultra fine powder | 0.44 | high pure quarts | 2.45 | — |
| Quarts powder | 1.58 | — | — | — |
| Quarts dust | — | — | — | — |
| the three component mixture | — | Class 3 (specified in JIS) 75% | — | — |
| | — | Class 5 (specified in JIS) 16% | — | — |
| | — | Iron powder (under 75μm) 15% | — | — |
| Fine | 8 | SiO₂ ...... 68% | 2.62 | — |
| AC dust | 30 | Al₂O₃ ...... 16% | — | — |
| Coarse | — | Fe₂O₃ ...... 4% | — | — |

Uses:
- Raw material for dusts for industrial testing, classes 1, 2 and 3.
- Efficiency test of powder apparatus
- Performance test of dust respirators
- Durability testing of sent belts (Australian Standard, ASE, Part II)
- Test of a dust collector
- Tests on the durability
- Test of air cleaner
- Tests on the wear of instruments and machinery
naturally occurring in the Soma district of Fukushima Prefecture; the particles do not have an angular configuration but are roundish in shape and are characterized by virtual evenness of particle size with a range of 590 ~ 840 \mu m and very good fluidity. Standard Soma sand is used as the raw material for dusts for industrial testing, namely, Classes 1, 2 and 3, as well as in the manufacture of glass and cement, and in civil engineering, etc. Some of its characteristic uses are for research on comminution, the performance testing of pulverizers, and tests on characteristics such as fluidity in powder-related machinery.

(2) Quartz powder
Quartz powder is produced by pulverizing in a ball mill from high purity quartz naturally occurring in the Ishikawakami district of Fukushima Prefecture and prepared in two grades of particle sizes - very fine and ultrafine.

Very fine grade quartz powder is used for the durability testing of seat belts in motor vehicles, and that of the ultrafine grade is used for the performance test\textsuperscript{12} of dust respirators. The first-mentioned test is being specified in a related Australian standard\textsuperscript{11} and in the latter-mentioned test by the JIS.

(3) The three-component mixture
The three-component mixture is a dust used for industrial testing and prepared by combining Class 3 (silica sand powder of the very fine grade), Class 5 (fly ash of the very fine grade), and iron powder of the ultrafine grade, the first-mentioned two components being dusts for industrial testing specified in JIS Z 8901.

This mixture is unique in that its components differ from each other in true density, particle size distribution, and chemical composition. It is used for tests on wear and on the durability of machinery.

(4) AC Dust
Air cleaner (AC) testing dust consists of natural sand from the Azorean desert and is a typical American testing dust for motor vehicles specified by the SAE-recommended Standard\textsuperscript{5}. ISO Standard\textsuperscript{13} AC Dust has also come into use for performance tests of automotive air cleaners in Europe. The product has always been a high quality dust.

AC Dust is available in two grades – fine and coarse. The fine grade corresponds in particle size distribution to Class 3 (silica sand powder of the very fine grade) and Class 8 (Kanto loam powder of the very fine grade) and the coarse grade corresponds in particle size distribution to Class 2 (silica sand powder of the fine grade) and Class 7 (Kanto loam powder of the fine grade) (the four classes are dusts used for industrial testing specified by JIS).

References
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