Test Sieving: Principles and Procedures

A Discussion of the Uses, Capabilities, and Limitations of Testing Sieves as Analytical Tools

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Specialists
In Manufacture Of
Sieving Equipment for the
Particle Industries

THE LEADER IN SIEVING TECHNOLOGY®

Foreword

Through ASTM and many industry organizations, standards have been established for particle size for powder, granular and larger sized materials. This manual has been prepared to help guide users of test sieves through the proper procedures as well as provide many additional tips that can enhance the existing procedures.

Our aim is to provide assistance to both the experienced and non- experienced particle technologist in developing comprehensive particle size test results, reduce test variations and enable the user to isolate and identify sources of error or variations in the data.

Advantech Test Sieves, manufactured in the U.S.A., are the most accurate test sieves available in the world today. The use of Advantech Test Sieves will provide more precise and reproducible data, resulting in better product control and a possible reduction of variables.

In preparing this manual, we have drawn from sources in the ASTM publications, ISO Standards and various papers written by some of the most renowned figures in the particle technology world. Additionally, Advantech personnel have contributed sieving technology developments after having logged numerous years of "hands-on " experience with many experts in the field. The result is a melding of standards, research and opinion to provide a solid foundation for your own particle size analysis program.

If additional help is desired in establishing your sieve analysis procedure, or if you desire a list of suppliers of the equipment highlighted in this manual, please contact Advantech Mfg 2450 S Commerce Dr., New Berlin, WI 53151

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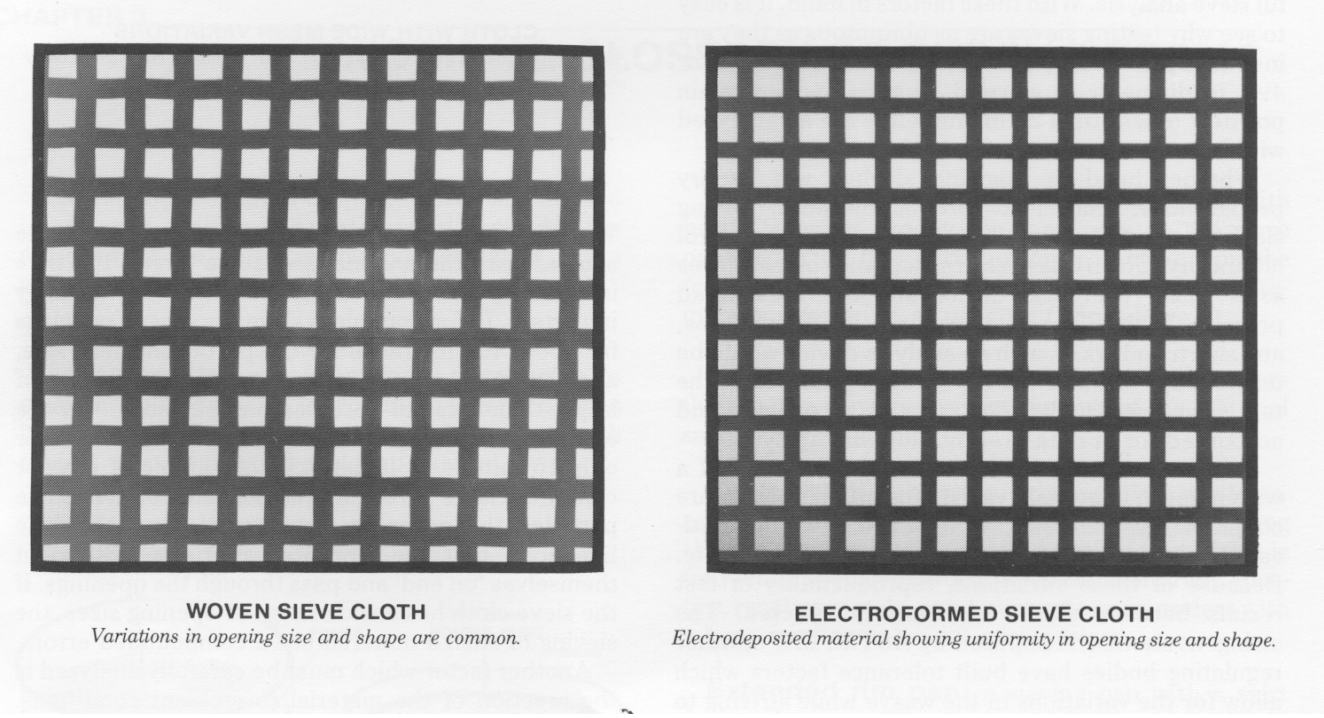
WHAT IS SIEVING?

A simplistic definition of sieving is the separation of fine material from coarse material by means of a meshed or perforated vessel. Professor Terence Allen characterizes sieving as "The aperture of a sieve may be regarded as a series of gauges which reject or pass particles as they are presented to the aperture." [(1)] This theory was actually in practice during the early Egyptian era as grains were sized with 'sieves' of woven reeds and grasses.

The level of sophistication increased with the rise of the industrial revolution and the need for more sophisticated methods for classifying material by their particle size. As requirements for sized material rose, technology in producing uniform sieving media increased. Woven wire cloth was introduced as an alternative, providing greater accuracy and durability. At present, this woven cloth is available in a range of sizes from 125 mm (5") openings to 20 micrometer openings. All mesh sizes are covered by of both national and international standards.

The need for particle size analysis in the finer size ranges (i.e. 38 micrometers and less) prompted the development of the electrodeposited sieve. These sieves, sometimes called electroformed or micromesh, are currently being produced with openings as fine as 3 micrometers. The mesh openings are extremely uniform in both size and shape and maintain exacting tolerances.

While the technology related to sieve analysis has come a long way since the reed sieves of ancient Egypt, few new developments have come along since the 1940's. Professor Kurt Leschonski wrote "Sieve analysis is one of the few methods of particle size analysis which has escaped modernization." [(2)]While the modernization has not come in the actual hardware of sieving, refinements in the application and utilization of existing equipment has proceeded.



WOVEN SIEVE CLOTH
Variations in opening size and shape are common.

ELECTROFORMED SIEVE CLOTH
Electrodeposited material showing uniformity in opening size and shape.

CHAPTER 2

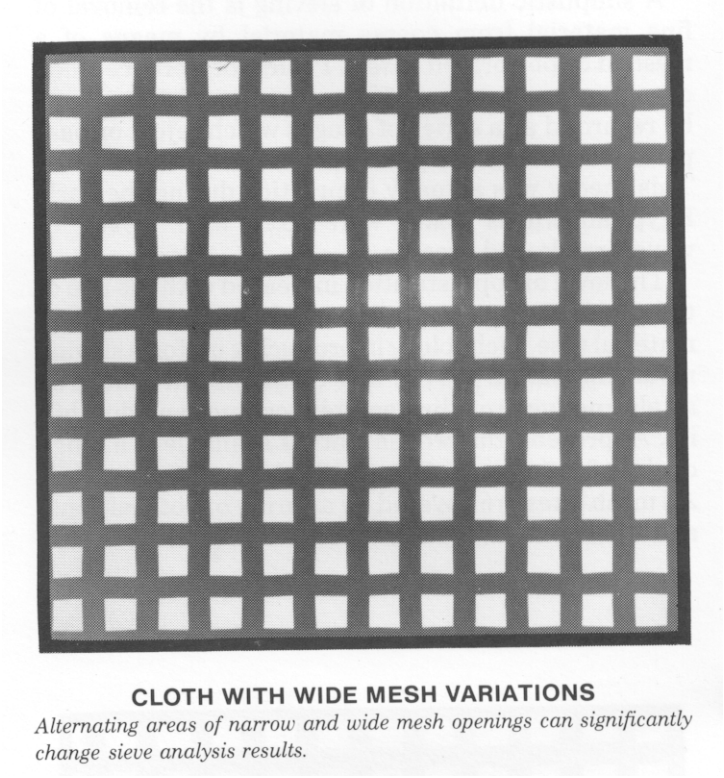
USES, LIMITATIONS AND ADVANTAGES

Harold Heywood wrote "I often refer to sieving as the 'Cinderella' of particle size analysis methods; it does most of the hard work and gets little consideration."[3]

There are numerous reasons for the selection of high quality testing sieves as a first choice in particle size analysis work. Leschonski said "... because of its simplicity - everyone immediately understands the purpose of a stack of sieves and its operation -and its inexpensive- ness." [4] Standard sieve analysis is probably the fastest and most widely used quality control procedure in any powder process control industry. Used frequently as a mediating device between the production and sales divisions of a process corporation or between the sales force and the customer, test sieve analysis work enjoys the universal recognition of being the best 'quick and dirty' test procedure for rapid particle size distribution data. The outcome of the analysis is easily calculated and interpreted for comparison between laboratories. Start-up cost to institute a basic sieving quality control program is minimal, and operators at most levels of training are capable of performing a successful sieve analysis. With these factors in mind, it is easy to see why testing sieves are as ubiquitous as they are in industry. Materials from crushed ore chunks of over 114.3 mm (4 ½”) in diameter to slurred alumina and porcelain powders of less than 20 micrometers are all analyzed with test sieves on a regular basis.

Whether hand or machine sieving, wet or dry preparations, analysis or production work, testing sieves have found a niche in the quality control laboratory. Given this overall acceptance of test sieves as a viable analytical device and the widespread presence of the sieve in laboratories of all industries, any shortcomings of such an analytical device would be magnified. For all of the advantages available to the test sieve user, limitations must be recognized and accounted for in the presentation and analysis of the data.

Test sieves are individuals. Being fabricated of a woven mesh material, variations in the weave are common. The chances of locating two sieves with an identical distribution of opening sizes are extremely remote. Due to these variations, the reproducibility of test results between sieves can be adversely affected. The stringent standards imposed by ASTM, ISO or other regulating bodies have established tolerance factors which allow for the permissible variations in the weave while striving to maintain a level of uniformity in the performance of the 'test grade' sieve cloth. (See Table 1)



CLOTH WITH WIDE MESH VARIATIONS

Alternating areas of narrow and wide mesh openings can significantly change sieve analysis results.

With this variation of opening sizes present, some smaller than the nominal and some larger, the time interval of the sieve analysis becomes extremely important. If, for example, a sieve has several openings far above the nominal opening size for the particular mesh size, and the test is run for 30 minutes, the probability of larger-than-nominal particles finding those oversize openings is much greater than if the test was run for only 15 minutes. Similarly, if the sample of powder contains a large percentage of elongated or needlelike particles, a longer test interval would provide a greater likelihood that the elongated particles will orient themselves 'on end' and pass through the openings. If the sieving cloth has a wide range of opening sizes, the sieving of this type of material has a compounded error.

Another factor which must be considered is the reaction of the material to ambient conditions. The most accurate test sieve available would be of

minimal use if the relative humidity in the test lab was 99%.Extremely dry conditions can cause fine powders to adhere to the sieve components and each other with strong electrostatic charges. Additional types of sieving problems are discussed in the glossary section.

To minimize error caused by wire cloth variation steps must be taken at every stage of fabrication that will assure the uniformity of the woven mesh as well as its compliance with the applicable standards. Both the weaver and the test sieve manufacturer must maintain a constant monitoring program measuring the actual opening sizes of the wire cloth as well as the uniformity of those openings. The loss to the manufacturers in rejected out of specification sieve cloth is a gain to the end-user in uniformity and compliance.

COMPARATOR

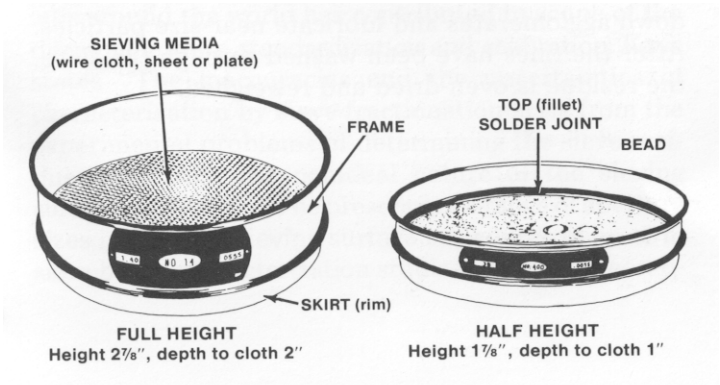
Profile projector specially designed and built for wire cloth and sieve inspection.

CHAPTER 3

GLOSSARY OF SIEVING TERMINOLOGY

Sieving terminology is frequently used and abused in writing specifications for materials. Listed below are some of the most frequently used terms and a general discussion of their meaning:

Agglomerate: natural tendency of materials to clump or ball together. This condition is very common in materials with high moisture, fat or oil content or those with fibrous or extremely irregular topography.



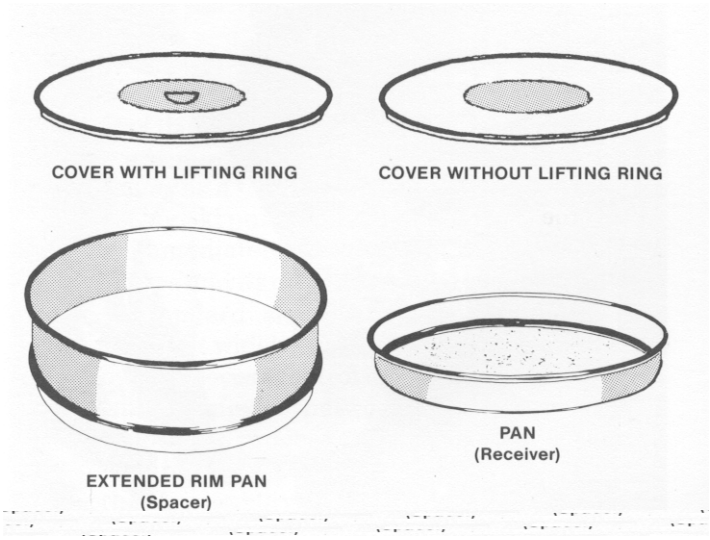
Blinding: plugging of the screen openings with particles either exactly the same size as the sieve opening or by fine particles which build up on the wire mesh and eventually close off the openings. Frequently referred to as pegging. (Photo Page 4)

Cover: stamped or spun lid that tightly covers the top of a sieve to prevent the loss of the material sample during sifting or mechanical agitation.

Electrostatic charges: accumulation of electrical charges on the particles and sieve components causing clinging, agglomeration or blinding. This condition is frequently seen in hydrocarbon-based materials, plastics, reactive metals, paint pigments and powders with a large fraction finer than 20 micrometers.

Extended rim pan: a sieving pan with a skirt designed to nest within a sieve stack, allowing multiple tests to be performed simultaneously. Frequently called a nesting pan or spacer.

WORKING GLOSSARY OF SIEVING TERMS (cont.)



Flow additive: powdered substance added to the sample to reduce agglomeration, neutralize static charges and improve the flow characteristics of the sample. Common additives are fine silica, activated charcoal, talc, and other commercially produced natural or synthetic substances. Generally, the additive is pre- screened to a known average particle size, blended with the sample (approximately 1% additive by weight) and then screened with the additives value removed from the reported data.

Frame: a rigid sidewall used to form the body of the testing sieve. Common depths are 50.8 mm (2" full height) for 8” sieves and 25.4 mm (1" half height). Special application sieves of other depths are also in use.

Mesh: screening medium with openings of uniform size and shape made of woven, punched or electrodeposited material.

Pan: stamped or spun receiver of materials passing through the finest sieve.

Skirt: section of test sieve below the sieve mesh that allows for mating or nesting of the sieves in a test stack.

Support mesh: coarse sieve cloth mounted under fine sieve cloth in a test sieve to provide extra strength. This is widely used in wet sieving operations to protect the fragile fine sieve cloth. Frequently called backing cloth or rolled backing cloth.

Test Sieve: screening medium (mesh) with openings of uniform size and shape mounted on a rigid frame, usually for laboratory testing or small scale production applications. The frames can be made of various materials, the most common of which are brass and stainless steel in a cylindrical configuration, having a diameter of 3", 5", 6", 8", 10", 12" or larger.

Wet sieving: the separation of fines from the coarse portion of a sample while suspended in an aqueous solution introduced to a testing sieve. The liquid medium is used to negate static charges, break down agglomerates and lubricate near-size particles. After the fines have been washed through the sieve, the residue is oven-dried and re-weighed.

CHAPTER 4

SIEVE SPECIFICATIONS -Domestic and International

The U.S. Standard Sieve Series is a metric system based series first suggested by the American Society for Testing and Materials in 1913. The opening sizes in this sieve series are in the ratio of the fourth root of two. This numerical relationship was first suggested by Professor P .R. Rittinger, a German researcher, in 1867.

In the fourth root of two series, every opening size is 1.189 times the opening size of the next smaller sieve. This relationship continues into sieve opening area measurement. The U. S. Sieve Series provides that the area of each sieve opening size is 1 1/2 times the area of the preceding sieve size.

By using every other sieve in this number series, the relationship becomes based on the square root of two (1.414), with the area of the opening being twice that of the preceding sieve size. Thus, by skipping two sizes, you create an area ratio of 3 to 1, or by skipping three sizes, you create a ratio of 4 to 1.

When selecting sieves from this series, any number of sieves can be used for an analysis. Care must be taken in selecting each sieve between two points, every other sieve, every fourth sieve, etc., to keep within the mathematical progression of the series.

After World War II, the International Standards Organization (ISO) was formed in an attempt to establish world standards. Though the U.S. Sieve Series had proven to be effective and was in use throughout the world, members of the ISO would not accept the U.S. Sieve Series as a world standard. The ISO chose to adopt the Preferred Number Series based on the roots of ten. The Preferred Number Series was suggested by Charles Renard of France in 1879. His system is based on the tenth, twentieth and fortieth roots of ten (designated R-10, R-20 and R-40). See Table 2.

A compromise was reached between the ISO and the proponents of the U.S. Sieve Series when it was discovered that every third value in the R-40/3 table is in a step ratio of 1.1885, sufficiently close to the fourth root of two (1.1892) used in the U.S. Sieve Series. In 1970, slight adjustments were made in the U.S. Sieve Series to align the series perfectly with the ISO specifications.

Copies of these tables of specifications can be found in Table 3.

CHAPTER 5

SIEVE CALIBRATION PROCEDURES

Quantifying and accounting for variations in test sieve results have become two of the most important topics in particle technology today. Once again, the ubiquitous nature of stacks of test sieves in powder labs around the world has contributed to the scope of the dilemma in sieve standardization and calibration. Kaye states "The inaccuracies and the uncertainties of characterization by sieve fractionation arise from the experimental problems of determining the sieve residues and from the non-ideal nature of the sieving surfaces." Further, "The presence of a range of aperture sizes in any real sieving surface is a source of error in sieve based characterization studies since the theoretical or nominal size of the sieve is taken to be the boundary limit for the sieve residue." [5]

Not only is the test sieve user plagued with variations in the weave of the cloth, but also confronted with the effects of particle shape on sieving results. Nearly 50 years ago, A.M. Gaudin wrote, "Powders with identical size distributions, densities and chemical composition may behave quite differently as a result of variations in particle shape between samples. For example, powders consisting solely of spherical particles are likely to have good flow properties, while powders containing needlelike particles will not." Further, "In addition, it is

impossible to isolate the concepts of particle size and shape, since the method of size measurement will influence the particle size which is determined." (6)

Numerous approaches have been tried to compensate for the effects of variations in wire cloth and particle shape. The methods have fallen into 3 basic categories: 1) inspection of the mesh to determine opening size, 2) material testing of the sieves to determine if sieves fall within performance specifications, and 3) a combination of methods 1 and 2, assuring compliance with both opening size and performance specifications.

Probably the most elementary of the inspection methods is the use of the etched glass slide. This procedure relies on what is referred to as the 'Moire Effect', which compares the number of wires per inch in the wirecloth sample to the number of lines per inch etched on the glass slide. By microscopically measuring the wire diameters, a rough estimate of the opening size can be approximated. One major shortcoming of this procedure is the assumption that all wire diameters within the sample are the same. A slight variation in wire diameter can translate to a significant change in opening size.

An alternative to this measurement approach is the use of a high-powered optical comparator or profile projector. In this method, powerful light sources illuminate the mesh from both above and below and project the image onto a glass screen. Calibrated micrometer stages move the mesh sample in relation to a reference point allowing measurements with an accuracy of 1 micrometer to be made on both the opening and wire diameter. The results are displayed on a numerical readout. The broad field of view of the comparator allows for the scanning of a large number of sieve openings, facilitating a more comprehensive picture of the nature of the sieve cloth.

In the material testing of sieves, powder samples are run on subject sieves and the residue calculated. These values are then compared with other sieves in selecting what are often referred to as 'matched' sieves. There are a number of shortcomings in this procedure also. The first and foremost problem encountered is that of compliance. Conceivably, it is possible to find hundreds of sieves that will provide the same performance data when tested with a reference material and still not meet ASTM standards.

While the sieves perform comparably, they do not meet the basic criteria of ASTM specifications, which should disqualify them from use as a U.S. Standard Testing sieve. Another problem encountered with material matching is the use of reference samples that are different in shape, size or density than the users' products. For example, a manufacturer of spherical steel shot would yield significantly different results on a sieve that had been matched with an angular ground silica material. In this case, both shape and density are considerably different. The key too proper matching is using the end-users own product or a material that approximates the product most closely.

The final approach is a combination of the first two methods. First, the sieve is inspected optically for compliance with all applicable standards. Openings and wire diameters are measured, not averaged. After the sieve opening distribution has been characterized and evaluated, actual material testing can begin. During the material testing, samples of the user's product are used for the standardization procedure. All tests are run for repeatability and the variation between test results calculated. This procedure yields a testing sieve with known values in the two most essential parameters compliance with specifications and performance under duplicate test conditions.

An alternative that has been used with some success is the use of correction factors between sieves. Once a 'master set' of sieves has been established, a reference sample is tested on the stack. The values are calculated and retained. As new sieves are acquired, the original reference sample is tested on the new set and the values calculated. Any variations between the sieve stacks can be compensated for with correction factors or multipliers. For example, a sieve in stack 3 may retain more or less than the comparable sieve in the master set. A multiplier of magnitude greater than or less than 1 is necessary to calculate the comparable retention value on that sieve when compared to the master set. In this way, every sieve in use can be compared to the master set to standardize sieving results. Whatever method you use, it is essential that your starting point is based on ASTM specifications. This compliance is necessary to assure uniformity between and within industries.

CHAPTER 6

PERFORMING THE SIEVE ANALYSIS

In obtaining meaningful sieve analysis data, six major steps are recommended. 1) Obtain a representative sample of the material to be evaluated. 2) Prepare the sample for evaluation; this may involve washing and/or drying the sample. 3) Reduce the sample to a size suitable for the sieve analysis procedure. 4) Perform the actual sieve analysis procedure. 5) Compute the data and convert the data into a usable format. 6) Organize the data and assemble the information for presentation.

Granular and powder materials are prone to segregation during movement and storage of the products. This segregation can be due to the disparity of the particle sizes and the varied densities for blended products. When forming a stockpile of material, the larger, coarser particles are heavier and tend to roll to the lowest portion and outer perimeter of the cone. The finer particles are lighter and more angular and remain concentrated at the top and through the vertical center of the cone. Obtaining samples from only the outer perimeter or from the top of the cone would not provide a sample which would be representative of the entire batch.

Sample extraction and preparation is the most commonly overlooked variable in sieve standardization programs. Testing bias can be added at many places along the progression from the raw materials received from a supplier, samples taken at each stage of production, sample reduction procedures and samples when the product is ready for shipment to the customer. The way the samples are extracted from the original bulk volume varies with the way the materials are received, produced or stored. The ideal sampling method is one, which provides the most representative sample with the least amount of material required.

The following paragraphs were first published in the ASTM technical publication STP 447 A. The collaborative efforts of the authors have produced a section on sampling technique which will aid in obtaining representative test samples from larger test sources.. [7]

Sampling from a chute or belt

Accuracy in sampling is obtained where material is flowing from a chute or belt conveyor. The ideal place to collect the sample is where the material drops from the chute or belt.If the material stream is small enough, use a pail or other suitable receptacle which can be swung completely across the flowing stream in a brief interval of time and with uniform movement. The sampling receptacle should not be allowed to overflow, because the overflow would tend to reject a higher proportion of the larger particles that exist in a representative sample. Mechanical sampling devices are available for selecting samples automatically from a stream at uniform time intervals.

Sampling from carload shipments of course bulk material

For coarse materials, such as crushed stone and gravel, shipped in railroad cars, a recommended method is to dig three or more trenches at least 30.48 cm (1 foot) deep and approximately 30.48 cm (1 foot)) wide at the bottom. Equal portions are taken at seven equally spaced points along the bottom of the trench by pushing a shovel downward into the material and not by scraping horizontally. Samples from trucks, barges, or boats should be taken in the same manner as from railroad cars, except that the number of trenches should be adjusted to the size of the transportation unit and tonnage involved.

Sampling from carload shipments of fine bulk materials

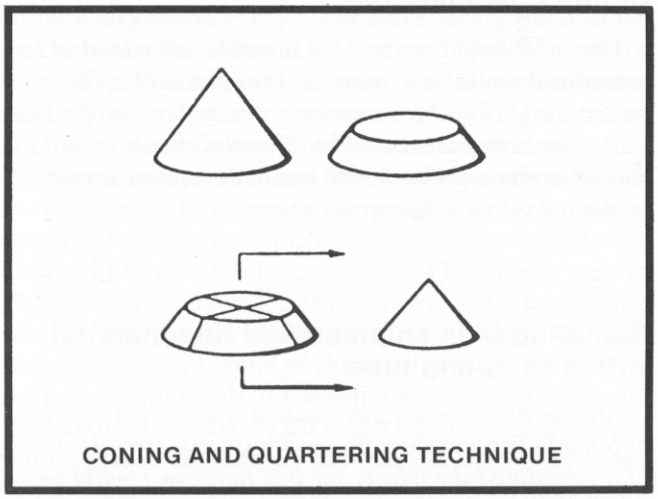
One established method for sampling a carload of bulk granular material is to take eight equal samples, (approximately 700 to 1000 grams each) from the bottom of a 30.48 cm (1 foot)) conical excavation. Samples should be suitably spaced to represent the length and width of the car and then combined into a single gross sample.

Sampling bulk shipments of fine material with a sampling tube

An alternate and simpler method of sampling a carload, or other bulk quantity of fine or granular material is by use of a sampling tube which, for this purpose, should be 38.1 mm (1 1/2 inches) by approximately 1.829 m (6 feet). Five or six insertions of the tube will produce approximately, a 2 pound (907g) sample.

Sampling from a carload of bagged material

One method of sampling a carload of material shipped in bags is to select, at random, a number of bags equal to the cube root of the total number of bags in the car and to take suitable portions (800 to 1000 grams for minus 6 mm material) from each of the selected bags for a combined gross sample.



Sampling from a pile

In sampling from a pile, particularly material like crushed stone or coal containing large particles, it is extremely difficult to secure samples that are truly representative. At the apex of a conical pile, the proportion of fines will be greater, while at the base; the percentage of coarse particles will be greater. Therefore, neither location will be representative of the whole. In a shoveling process, every fifth or tenth shovel, etc., should be taken depending on the amount of the sample desired. The sample should consist of small quantities taken at random from as many parts of the pile as are accessible and taken in a manner that the composite will have the same grading as the larger amount.

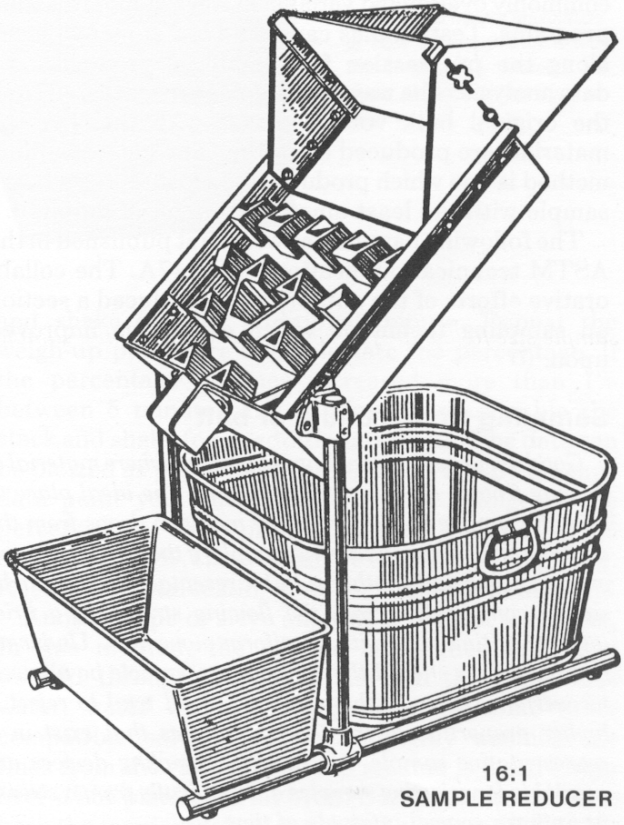
Reduction of gross sample to test size for sieve analysis

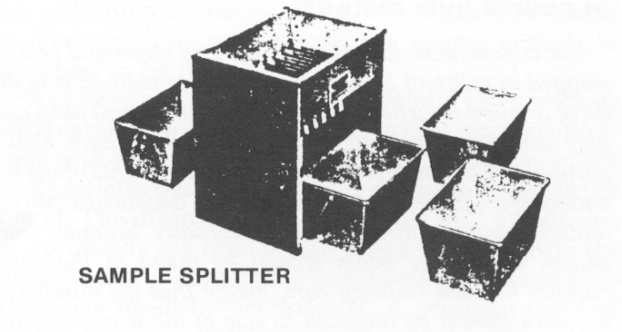
After the gross sample has been properly obtained, the next step is to reduce it to a suitable size for sieve analysis without impairing in any way the particle size distribution characteristics of the original sample. This phase of the operation should follow the applicable procedures described in the succeeding sections and should be performed with as much care as was used in the collection of the gross sample and in performing the sieve test.

Coning and quartering

Pile the gross sample in a cone, place each shovel full at the apex of the cone, and allow it to run down equally in all directions. This will mix the sample. Then spread the sample in a circle and walk around the pile, gradually widening the circle with a shovel until the material is spread to a uniform thickness.

Mark the flat pile into quarters, and reject two opposite quarters. Mix again into a conical pile, taking alternate shovel-fulls from the two quarters saved. Continue the process of piling, flattening, and rejecting two quarters until the sample is reduced to the required size.





Sample splitters and reducers

Gross samples, if not too large, may be reduced to test sample size by one or more passes through a sample splitter or Jones type riffle, which will divide a sample in half while maintaining the particle size distribution of the original sample. By repeated passes, the sample can be split into quarters, eighths, and soon until the size of the sample desired is obtained. For larger gross samples, sample reducers are available which will select a representative 1/16 part with a single pass. After just two passes through such a unit, a representative one pound sample can be obtained from an original 256 pounds. Three passes will give a one pound sample from two tons of material. Always make sure that the passages in the splitter or reducer are at least three times the size of the largest particle in the sample. Do not attempt to arrive at exactly the amount of material specified for the test. If a 50 gram sample is desired, arrive as near to this amount as practicable, because it will make no difference in the test percentage results whether the sample is slightly larger or smaller. In attempting to arrive at an exact weight, the tendency is to discriminate by the removal of sizes that are not representative of the whole, thus destroying the representative quality of the sample.

Size of Sample in the Test

There is a natural tendency, although incorrect, to use an excessively large sample in the test. In most cases, a smaller sample will provide a more accurate analysis. Beware, however, that the more you split, the greater the chance of error. Testing sieves are a go or no go gauge; if the sample is too large it will not permit each of the particles an opportunity to present themselves to the screen surface. Often the limiting factor for reducing the sample size is the accuracy of the weighing device used to determine the amount of material retained on the sieve.

Generally a 25 to 100 gram sample is recommended. However, if it is necessary to establish the correct sample size, utilize the following procedure: Using a sample splitter, reduce samples to weights (i.e. 25, 50, 100, 200 grams). Analyze these various sample sizes on a selected nest of sieves for a period of five minutes preferably using a mechanical sieve shaker. If the test with the 100 gram sample shows approximately the same percentage passing the finest sieve as the 50 gram sample, whereas the 200 gram sample shows a lower percentage, this would indicate that the 200 gram sample is too large and the 100 gram sample would be satisfactory. Then run the 100 gram sample on the same set of sieves for the same time period to see if repetitive results are obtainable.

A useful table of recommended sample sizes for tests with 200 mm or 8" diameter sieves is presented in Table 4. Note that the table gives sample sizes listed by volume. Recommended sample weights in grams can be determined by multiplying the values in Column 3 and 4 by the bulk density (grams per cubic centimeter) of the material to be tested rounded out within a reasonable tolerance. If the actual bulk density of a certain material is not known, the typical density factor for the most nearly similar material listed in Table 5 may be used.

To perform the actual sieve analysis, sieves should be chosen in a sequence as described earlier. Use every sieve, every other sieve, or every third sieve, etc. between the desired size parameters. The use of sieves in this sequential order will allow for better data presentation and a more meaningful analysis of the test results. Care should also be taken in selecting the proper sieves to avoid overloading any sieve with an especially large material peak. For example, a specification may require 96% of the sample be retained above a #50 mesh sieve. The proper way to perform an analysis of this nature is to use 'relief screens', that is, sieves in the 30, 35, 40 and 45 mesh ranges to remove some of the burden from the critical cut point of 50 mesh. If the relief sieves are not used, the particles of exactly 50 mesh size or slightly larger may become wedged in or forced through the sieve openings by the mass of material resting above them. Large concentrations of material on one sieve reduce the opportunity for near size material to pass through the sieve resulting in a larger portion of the material retained on the test sieve. The sieve cut point would

be inaccurate and the sample would not meet the specifications for the test.

The selected sieves should be assembled with the coarsest sieve at the top of the stack, and the balance of the stack in increasing magnitude of fineness (increasing sieve numbers with smaller openings). The stack should include a cover on the top sieve and a pan below the finest sieve. The sieve stack can either be shaken then rapped by hand, or mounted in a sieve shaker with a motorized or electrostatic drive mechanism.

While many applications still use the hand-shaken method for sieving, motor driven shakers have proven to be much more consistent, minimizing variations related to operator procedures. In powder analysis below the 100 mesh range, the sieve shaker should be equipped with a device to impart a shock wave to the sieve stack at regular intervals. This hammer or rapping device is necessary to reorient the particles on the sieve and impart some shear forces to near-size particles blocking the sieve openings.

Recommended Time Intervals

The duration of the sieving interval is usually regulated by industry standards, or by in-house control specifications. Commonly, 10, 15 or 20 minute tests are used as arbitrary sieving intervals. To determine the best interval for a new material, or to double check the accuracy of existing specifications, the following procedure can be used. Select the desired sieves for the analysis. 1) Weigh up a sample of the material to be tested and introduce it to the completed sieve stack. 2) Shake the sieve stack for a period of 5 minutes. 3) Weigh the residue in the pan and calculate the percentage in relation to the starting weight. 4) Reassemble the stack and shake for one additional minute. 5) Repeat the weigh-up procedure and calculate the percentage. If the percentage of fines increased more than 1% between 5 minutes and 6 minutes, reassemble the stack and shake for an additional minute. The data can be plotted as percentage throughput vs. time for each data point you calculate. When the change in the percentage of fines passing in the 1 minute period drops below 1 %, the test can be considered complete. Record the total testing time for subsequent analyses.

Another type of sieve analysis is the wet sieve test. In this method, the sample is weighed and then washed through the finest sieve in the stack with water, a wetting agent (water based), or some other compatible solvent. After thoroughly washing the fines from the raw sample, the residue is dried either over a hot plate or in an oven. The temperature of the sieve should be maintained below 149°C (300°F) to avoid loosening of the sieve cloth or failure of the solder joint. After drying, the residue is then sieved normally on the balance of the sieve stack. The loss in weight not accounted for on the coarse screens is assumed to be fines or soluble material.

Wet sieve analysis is especially helpful when working with naturally agglomerated materials,
Ultra-fine powders with severe static changes, and in samples where fine particles tend to cling to the coarse fractions in the blend. The disadvantages associated with wet sieving are primarily the time period required to perform the analysis due to the additional washing and drying time and the possible damage to the sieve mesh by overloading. A common practice with wet sieving operations is brushing or forcing the sample through the mesh while the liquid medium is directed on the sieve. This pressure can distort the sieve openings or tear the mesh at the solder joint through stress. Therefore, this procedure is not recommended. Once the sieving interval is complete, whether dry or wet sieving is used, the residue on each sieve is removed by pouring the residue into a suitable weighing vessel. To remove material wedged in the sieve's openings, the sieve is inverted over a sheet of paper or suitable collector and the underside of the wire cloth brushed **gently** with a nylon paint brush with bristles cut to a 25.4 mm (1") length. The side of

the sieve frame may be tapped gently with the handle of the brush to dislodge the particles between brush strokes. At no time should a needle or other sharp object be used to remove the particles lodged in the wire cloth. Special care should be taken when brushing sieves finer than 80 mesh. Brushing can cause distortions and irregularities in the sieve openings. The procedure is repeated for each sieve in the stack and contents of the pan.

The individual weights retained on the sieves should be added and compared to the starting sample weight. Wide variations or sample losses should be determined immediately. If the finished sample weight varies more than 2% from the initial weight, the analysis and sample should be discarded and the test performed another sample. If the sample weights are acceptable, complete the calculations and report the individual weights retained on each sieve.

Presentation and analysis of the resulting data is frequently made easier by plotting on one of a number of graph formats. The most common graphic presentation is the plotting of the cumulative percentage of material retained on a sieve (plotted on a logarithmic scale) versus percentage (plotted on a linear scale). The resulting curve allows a quick approximation of the sieve size at the fifty-percentile point of accumulation. The curve also shows the smoothness of the distribution by revealing the presence of bimodal blends in the sample. Other plotting techniques include log-log and direct plotting of micron size versus percentage retained.

Care should be exercised in the analyzing the data in relation to the length of time the test was run. If the sample contains a large amount of elongated or near-size particles, the test results can be misleading. The longer the sieving interval, the greater the opportunity for these problem particles to pass through the sieve's openings. Ideally each fraction should be inspected microscopically after sieving to determine the integrity of the sieve cut point.

Table 6 lists many of the ASTM published standards on sieve analysis procedures for specific materials or industries.

CHAPTER7

SIEVE CARE AND CLEANING

Test sieves, like any other piece of analytical laboratory equipment, require regular care to maintain their performance standards. Sieves should be kept clean and dry at all times, and stored either in the cardboard carton provided or in a suitable cabinet. The wire cloth must be taut and free from variations in opening size. For this reason, cleaning procedures must be clearly delineated as part of a comprehensive sieving program.

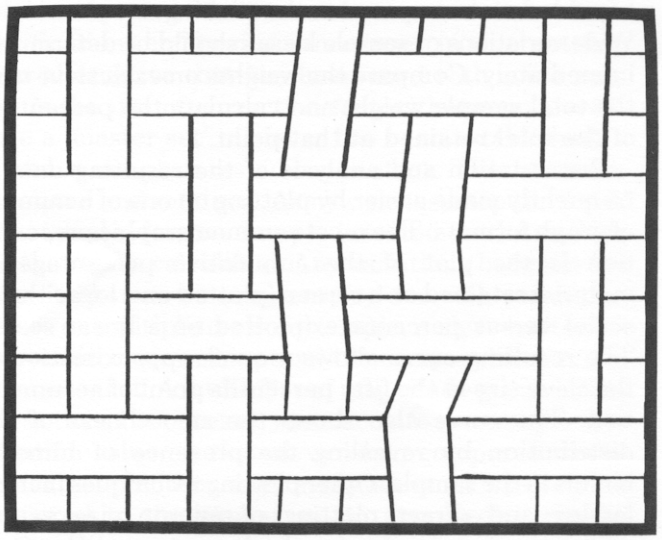
Test sieves should be cleaned ultrasonically on a regular basis. For some installations, this may be done at the end of a shift or at the end of a week, but must be done regularly to assure accurate sieving results. The sieves should be immersed in an ultrasonic cleaner filled with a solution of a mild detergent and water. Prior to reuse, ensure that the test sieves are dried thoroughly. Ultrasonic cleaning prevents the buildup of particles trapped in the sieve openings and prolongs the useful life of the sieve. Between test clean-up, brushing of the mesh, sizes 100 and coarser, is recommended. For best results, use a nylon bristle paint brush with the bristles cut to a length of approximately 25.4 mm (1"). The sieve openings should be brushed from the **underside only** with a gentle circular motion. Vigorous brushing will distort the sieve openings and reduce the effective life of the sieve. Particles lodged in the sieve openings should never be removed with a sharp object. These particles should be removed in an ultrasonic cleaner only. Brushing should be avoided on sieves finer than 100 mesh, as the fine wires are more likely to bend, distort or even break. Brushing can often loosen the wire cloth; the finer mesh sizes are most susceptible to this damage.

Similarly, cleaning sieves with a compressed air jet is common, but this can damage the sieve openings on the finer mesh sieves. The concentrated jet of air can cause severe 'local' damage to the wire cloth, and significantly reduce the accuracy of the sieve mesh.

With proper care, sieves will perform accurately for many years. Typical wear does not usually change the opening sizes, but can abrade the 'knuckles' or crimps

of the wire. A sieve with a noticeable sag of the cloth should be replaced. Fine mesh sieves that are torn should not be re-soldered, as the localized heat of the soldering iron can distort the openings. Epoxies have been used for repairs, but tend to block a large percentage of the openings reducing the opportunity for particles to pass through the openings in the allotted agitation time. Epoxies may become too brittle for the flexing of the wirecloth and can fracture with use.

Good general laboratory procedures should be observed with testing sieves as with any other piece of test equipment. Testing should be performed with clean, uncontaminated sieves, especially when using a sieve for the first time. With proper care and cleaning coupled with a good calibration procedure, any test sieve should provide many years of consistent service.



WIRE CLOTH DAMAGED BY IMPROPER BRUSHING

Note the irregularities in both opening size and shape.

EPILOG

We hope that the characterization of testing sieves and their uses presented in this manual will serve as an enhancement to your current particle size analysis program. By maximizing the analytical advantage potential of testing sieves while minimizing and compensating for shortcomings and inaccuracies, the testing sieve can be a viable and precise testing tool. Care, maintenance and proper test procedures are as critical with a testing sieve as they are with other, more sophisticated particle size analyzers.

Compliance with applicable industry, National and International specifications is essential. The intent of these regulating bodies is the formulation of general standards to assure uniformity in testing standards observed by both the buyer and producer. The accepted specification should be the foundation for the in-house testing procedure.

Testing accuracy is highly dependent on the technique of the operators. Interpretation of data should be neither overstated nor understated in terms of importance. The effects of variables must be understood, accepted and factored into final data analysis to avoid these shortcomings.

By analyzing the total test sieve analysis program as we suggest from sample preparation to data presentation, variations can be reduced, accuracy improved, and productivity increased.

NOTE: To aid in making this manual as understandable and comprehensive as possible, minor changes in spelling and grammar have been made to some of the quoted references. These changes have not altered the statements made but have aided in clarifying the thoughts of the authors.

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U.S.A. Standard Testing Sieves ASTM Specifications E 11-04

Nominal Dimensions, Permissible Variation for Wire Cloth of Standard Testing Sieves (U.S.A.) Standard Series

Sieve Designation		Nominal Sieve Opening, in.	Permissible Variation of Average Opening from the Standard	Opening Dimension Exceeded by not more than 5%	Maximum Individual	Nominal Wire Diameter (mm)
Standard (b)	Alternative	(see c below)	Sieve Designation	of the Openings	Opening	(see a below)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
125 mm	5"	5	±3.70 mm	130.0 mm	130.9 mm	8.00
106 mm	4.24"	4.24	±3.20 mm	110.2 mm	111.1 mm	6.30
100 mm [d]	4"	4	±3.00 mm	104.0 mm	104.8 mm	6.30
90 mm	3 ½"	3.50	±2.70 mm	93.6 mm	94.4 mm	6.30
75 mm	3"	3	±2.20 mm	78.1 mm	78.7 mm	6.30
63 mm	2 ½"	2.50	±1.90 mm	65.6 mm	66.2 mm	5.60
53 mm	2.12"	2.12	±1.60 mm	55.2 mm	55.7 mm	5.00
50 mm [d]	2"	2	±1.50 mm	52.1 mm	52.6 mm	5.00
45 mm	1 ¾"	1.75	±1.40 mm	46.9 mm	47.4 mm	4.50
37.5 mm	1 ½"	1.50	±1.10 mm	39.1 mm	39.5 mm	4.50
31.5 mm	1 ¼"	1.25	±1.00 mm	32.9 mm	33.2 mm	4.00
26.5 mm	1.06"	1.06	±.800 mm	27.7 mm	28.0 mm	3.55
25.0 mm [d]	1.00"	1	±.800 mm	26.1 mm	26.4 mm	3.55
22.4 mm	7/8"	0.875	±.700 mm	23.4 mm	23.7 mm	3.55
19.0 mm	¾"	0.750	±.600 mm	19.9 mm	20.1 mm	3.15
16.0 mm	5/8"	0.625	±.500 mm	16.7 mm	17.0 mm	3.15
13.2 mm	.530"	0.530	±.410 mm	13.83 mm	14.05 mm	2.80
12.5 mm [d]	½"	0.500	±.390 mm	13.10 mm	13.31 mm	2.50
11.2 mm	7/16"	0.438	±.350 mm	11.75 mm	11.94 mm	2.50
9.5 mm	3/8"	0.375	±.300 mm	9.97 mm	10.16 mm	2.24
8.0 mm	5/16"	0.312	±.250 mm	8.41 mm	8.58 mm	2.00
6.7 mm	.265"	0.265	±.210 mm	7.05 mm	7.20 mm	1.80
6.3 mm [d]	¼"	0.250	±.200 mm	6.64 mm	6.78 mm	1.80
5.6 mm	No. 3 ½	0.223	±.180 mm	5.90 mm	6.04 mm	1.60
4.75 mm	No. 4	0.187	±.150 mm	5.02 mm	5.14 mm	1.60
4.00 mm	No. 5	0.157	±.130 mm	4.23 mm	4.35 mm	1.40
3.35 mm	No. 6	0.132	±.110 mm	3.55 mm	3.66 mm	1.25
2.80 mm	No. 7	0.110	±.095 mm	2.975 mm	3.070 mm	1.12
2.36 mm	No. 8	0.0937	±.080 mm	2.515 mm	2.600 mm	1.00
2.00 mm	No. 10	0.0787	±.070 mm	2.135 mm	2.215 mm	0.900
1.70 mm	No. 12	0.0661	±.060 mm	1.820 mm	1.890 mm	0.800
1.40 mm	No. 14	0.0555	±.050 mm	1.505 mm	1.565 mm	0.710
1.18 mm	No. 16	0.0469	±.045 mm	1.270 mm	1.330 mm	0.630
1.00 mm	No. 18	0.0394	±.040 mm	1.080 mm	1.135 mm	0.560
850 µm	No. 20	0.0331	±35 µm	925 µm	970 µm	0.500
710 µm	No. 25	0.0278	±30 µm	775 µm	815 µm	0.450
600 µm	No. 30	0.0234	±25 µm	660 µm	695 µm	0.400
500 µm	No. 35	0.0197	±20 µm	550 µm	585 µm	0.315
425 µm	No. 40	0.0165	±19 µm	471 µm	502 µm	0.280
355 µm	No. 45	0.0139	±16 µm	396 µm	426 µm	0.224
300 µm	No. 50	0.0117	±14 µm	337 µm	363 µm	0.200
250 µm	No. 60	0.0098	±12 µm	283 µm	306 µm	0.160
212 µm	No. 70	0.0083	±10 µm	242 µm	263 µm	0.140
180 µm	No. 80	0.0070	±9 µm	207 µm	227 µm	0.125
150 µm	No. 100	0.0059	±8 µm	174 µm	192 µm	0.100
125 µm	No. 120	0.0049	±7 µm	147 µm	163 µm	0.090
106 µm	No. 140	0.0041	±6 µm	126 µm	141 µm	0.071
90 µm	No. 170	0.0035	±5 µm	108 µm	122 µm	0.063
75 µm	No. 200	0.0029	±5 µm	91 µm	103 µm	0.050
63 µm	No. 230	0.0025	±4 µm	77 µm	89 µm	0.045
53 µm	No. 270	0.0021	±4 µm	66 µm	76 µm	0.036
45 µm	No. 325	0.0017	±3 µm	57 µm	66 µm	0.032
38 µm	No. 400	0.0015	±3 µm	48 µm	57 µm	0.030
32 µm	No. 450	0.0012	±3 µm	42 µm	50 µm	0.028
25 µm [d]	No. 500	0.0010	±3 µm	34 µm	41 µm	0.025
20 µm [d]	No. 635	0.0008	±3 µm	29 µm	35 µm	0.020

a) The average diameter of the wires in the x and y direction, measured separately, of any wire cloth shall not deviate from the nominal values by more than ±15%

(b) These standard designations correspond to the values for test sieve openings recommended by the International Organization for Standardization (ISO) Geneva, Switzerland, except where noted.

(c) Only approximately equivalent to the metric values in column 1.

(d) These sieves are not in the standard series but they have been included because they are in common usage.

Table 1

INTERNATIONAL STANDARDS ORGANIZATION (ISO)
PREFERRED NUMBER SERIES

Values in millimeters unless specified as micron (µ).

R 20/3	R 20	* R 40/3	Equivalent in inches
125	125	125	4.921
	112		4.409
		106	4.173
	100		3.937
90	90	90	3.543
	80		3.150
		75	2.953
	71		2.795
63	63	63	2.480
	56		2.205
		53	2.087
	50		1.969
45	45	45	1.772
	40		1.575
		37.5	1.476
	35.5		1.398
31.5	31.5	31.5	1.240
	28		1.102
		26.5	1.043
	25		0.984
22.4	22.4	22.4	0.882
	20		0.787
		19	0.748
	18		0.709
16	16	16	0.630
	14		0.551
		13.2	0.520
	12.5		0.492
11.2	11.2	11.2	0.441
	10		0.394
		9.5	0.374
	9		0.354
8	8	8	0.315
	7.1		0.280
		6.7	0.264
	6.3		0.248
5.6	5.6	5.6	0.220
	5		0.197
		4.75	0.187
	4.5		0.177
4	4	4	0.157
	3.55		0.140
		3.35	0.132
	3.15		0.124
2.8	2.8	2.8	0.110
	2.5		0.098
		2.36	0.093
	2.24		0.088
2	2	2	0.079
	1.8		0.071

R 20/3	R 20	* R 40/3	Equivalent in inches
		1.7	0.0669
	1.6		0.0630
1.4	1.4	1.4	0.0551
	1.25		0.0492
		1.18	0.0465
	1.12		0.0441
1	1	1	0.0394
	900µ		0.0354
		850µ	0.0335
	800µ		0.0315
710µ	710µ	710µ	0.0280
	630µ		0.0248
		600µ	0.0236
	560µ		0.0220
500µ	500µ	500µ	0.0197
	450µ		0.0177
		425µ	0.0167
	400µ		0.0157
355µ	355µ	355µ	0.0140
	315µ		0.0124
		300µ	0.0118
	280µ		0.0110
250µ	250µ	250µ	0.0098
	224µ		0.0088
		212µ	0.0083
	200µ		0.0079
180µ	180µ	180µ	0.0071
	160µ		0.0063
		150µ	0.0059
	140µ		0.0055
125µ	125µ	125µ	0.0049
	112µ		0.0044
		106µ	0.0042
	100µ		0.0039
90µ	90µ	90µ	0.0035
	80µ		0.0031
		75µ	0.0030
	71µ		0.0028
63µ	63µ	63µ	0.0025
	56µ		0.0022
		53µ	0.0021
	50µ		0.0020
45µ	45µ	45µ	0.0018
	40µ		0.0016
		38µ	0.0015
R'10	36µ		0.0014
32µ			0.0013
25µ			0.0010
20µ			0.0008

***** Same as ASTM E 11 USA Standard Sieve Series
R'10 = Tenth root of ten ratio
R 20 = Twentieth root of ten
R 20/3 = Every third number of R 20 Series
R 40/3 = Every third number of fortieth root of ten series

Table 2

COMPARISON TABLE
INTERNATIONAL TEST SIEVE SERIES

INTERNATIONAL ISO 3310-1:2000	AMERICAN ASTM E 11-01		BRITISH BS410:2000		CANADA CGSB-8.2-M88	FRANCE AFNOR NFX11-501		GERMANY DIN (ISO) 3310-1:2000		JAPAN JIS
Aperture mm	Opening mm	Equiv. inch/No.	Aperture mm	Equiv. BS Mesh	Aperture mm	Aperture mm	Tamis No.	Aperture mm	Approx. DIN No.	Aperture mm
125.00	125.00	5"	125.00							
112.00			112.00							
106.00	106.00	4.24"	106.00							
100.00	100.00	4"	100.00		100.00	100.00		100.00		
90.00	90.00	3 1/2"	90.00		90.00	90.00		90.00		
80.00			80.00							
75.00	75.00	3"	75.00							
71.00			71.00		71.00	71.00		71.00		71.00
63.00	63.00	2 1/2"	63.00		63.00	63.00		63.00		
56.00			56.00							
53.00	53.00	2.12"	53.00		53.00	53.00		53.00		
50.00	50.00	2"	50.00		50.00	50.00		50.00		50.00
45.00	45.00	1 3/4"	45.00		45.00	45.00		45.00		
40.00			40.00							
37.50	37.50	1 1/2"	37.50							
35.50			35.50							
31.50	31.50	1 1/4"	31.50		31.50	31.50		31.50		
28.00			28.00		28.00	28.00		28.00		
26.50	26.50	1.06"	26.50							26.50
25.00	25.00	1.00"	25.00		25.00	25.00		25.00		
22.40	22.40	7/8"	22.40		22.40	22.40		22.40		22.40
20.00			20.00		20.00	20.00		20.00		
19.00	19.00	3/4"	19.00							19.00
18.00			18.00			18.00		18.00		
16.00	16.00	5/8"	16.00		16.00	16.00		16.00		16.00
14.00			14.00		14.00	14.00		14.00		
13.20	13.20	.530"	13.20							
12.50	12.50	1/2"	12.50		12.50	12.50		12.50		12.50
11.20	11.20	7/16"	11.20		11.20	11.20		11.20		11.20
10.00			10.00		10.00	10.00		10.00		
9.50	9.50	3/8"	9.50							9.50
9.00			9.00			9.00		9.00		
8.00	8.00	5/16"	8.00		8.00	8.00		8.00		8.00
7.10			7.10		7.10	7.10		7.10		
6.70	6.70	.265"	6.70							6.70
6.30	6.30	1/4"	6.30		6.30	6.30		6.30		
5.60	5.60	No.3 1/2	5.60	3	5.60	5.60		5.60		
5.00			5.00			5.00	38	5.00		5.00
4.75	4.75	No.4	4.75	3 1/2						
4.50			4.50			4.50		4.50		
4.00	4.00	No.5	4.00	4	4.00	4.00	37	4.00	2E	
3.55			3.55	5		3.55		3.55		
3.35	3.35	No.6	3.35							
3.15			3.15		3.15	3.15	36	3.15		
2.80	2.80	No.7	2.80	6	2.80	2.80		2.80		
2.50			2.50		2.50	2.50	35.00	2.50		
2.36	2.36	No.8	2.36	7						
2.24			2.24			2.24		2.24		
2.00	2.00	No.10	2.00	8	2.00	2.00	34	2.00	3E	
1.80			1.80			1.80		1.80		
1.70	1.70	No.12	1.70	10						
1.60			1.60		1.60	1.60	33	1.60		
1.40	1.40	No.14	1.40	12	1.40	1.40		1.40		1.40
1.25			1.25			1.25	32	1.25		
1.18	1.18	No.16	1.18	14				1.20	5	
1.12			1.12		1.12	1.12		1.12		
1.00	1.00	No.18	1.00	16	1.00	1.00	31	1.00	6	
900µ			900µ			900µ		900µ		
850µ	850µ	No.20	850µ	18						850µ
800µ			800µ		800µ	800µ	30	800µ		
710µ	710µ	No.25	710µ	22	710µ	710µ		710µ		710µ

Table 3

COMPARISON TABLE
INTERNATIONAL TEST SIEVE SERIES

INTERNATIONAL ISO 3310-1:2000	AMERICAN ASTM E 11-01		BRITISH BS410:2000		CANADA CGSB-8.2-M88	FRANCE AFNOR NFX11-501		GERMANY DIN (ISO) 3310-1:2000		JAPAN JIS
Aperture mm	Opening mm	Equiv. inch/No.	Aperture mm	Equiv. BS Mesh	Aperture mm	Aperture mm	Tamis No.	Aperture mm	Approx. DIN No.	Aperture mm
630µ			630µ			630µ	29	630µ		
600µ	600µ	No.30	600µ	25				600µ	10	600µ
560µ			560µ			560µ		560µ		
500µ	500µ	No.35	500µ	30	500µ	500µ	28	500µ	12	500µ
450µ			450µ			450µ		450µ		
425µ	425µ	No.40	425µ	36				430µ	14	425µ
400µ			400µ		400µ	400µ	27	400µ	16	
355µ	355µ	No.45	355µ	44	355µ	355µ		355µ		355µ
315µ			315µ		315µ	315µ	26	315µ		
300µ	300µ	No.50	300µ	52				300µ	20	300µ
280µ			280µ			280µ		280µ		
250µ	250µ	No.60	250µ	60	250µ	250µ	25	250µ	24	250µ
224µ			224µ			224µ		224µ		
212µ	212µ	No.70	212µ	72						212µ
200µ			200µ		200µ	200µ	24	200µ	30	
180µ	180µ	No.80	180µ	85	180µ	180µ		180µ		180µ
160µ			160µ			160µ	23	160µ		
150µ	150µ	No.100	150µ	100				150µ	40	150µ
140µ			140µ		140µ	140µ		140µ		
125µ	125µ	No.120	125µ	120	125µ	125µ	22	125µ	50	125µ
112µ			112µ			112µ		112µ		
106µ	106µ	No.140	106µ	150						106µ
100µ			100µ		100µ	100µ	21	100µ	60	
90µ	90µ	No.170	90µ	170	90µ	90µ		90µ	70	90µ
80µ			80µ			80µ	20	80µ		
75µ	75µ	No.200	75µ	200				75µ	80	75µ
71µ			71µ		71µ	71µ		71µ		
63µ	63µ	No.230	63µ	240	63µ	63µ	19	63µ		63µ
56µ			56µ		56µ	56µ		56µ	110	
53µ	53µ	No.270	53µ	300						53µ
50µ			50µ			50µ	18	50µ	120	
45µ	45µ	No.325	45µ	350	45µ	45µ		45µ		45µ
40µ			40µ			40µ	17	40µ		
38µ	38µ	No.400	38µ	400						38µ
36µ			36µ		36µ	36µ		36µ	130	
32µ	32µ	No.450	32µ	440		32µ		32µ		32µ
25µ	25µ	No.500	25µ			25µ		25µ	200	
20µ	20µ	No.635	20µ			20µ		20µ		

Table 3

RECOMMENDED REPRESENTATIVE BULK VOLUMES OF TEST SAMPLES

Used in 8" (203mm) Testing Sieves

Standard Sieve Designation		Bulk Volume of Material	
Standard	Alternate	Recommended Volume of Material for Test Sample	Maximum Permitted Volume on Sieve on Completion of Sieving
25.0mm	1.00"	1800cm³	900cm³
22.4mm	7/8"	1600cm³	800cm³
19.0mm	3/4"	1400cm³	700cm³
16.0mm	5/8"	1000cm³	500cm³
12.5mm	1/2"	800cm³	400cm³
11.2mm	7/16"	800cm³	400cm³
9.50mm	3/8"	600cm³	300cm³
8.00mm	5/16"	500cm³	250cm³
6.30mm	1/4"	400cm³	200cm³
5.60mm	No. 3 1/2	400cm³	200cm³
4.00mm	No. 5	350cm³	150cm³
2.80mm	No. 7	240cm³	120cm³
2.00mm	No. 10	200cm³	100cm³
1.40mm	No. 14	160cm³	80cm³
1.00mm	No. 18	140cm³	70cm³
710µ	No. 25	120cm³	60cm³
500µ	No. 35	100cm³	50cm³
355µ	No. 45	80cm³	40cm³
250µ	No. 60	70cm³	35cm³
180µ	No. 80	60cm³	30cm³
125µ	No. 120	50cm³	25cm³
90µ	No. 170	40cm³	20cm³
63µ	No. 230	35cm³	17cm³
45µ	No. 325	30cm³	15cm³
38µ	No. 400	25cm³	12cm³

The recommended weight of material for a sieve test sample is calculated by multiplying the bulk volume figure in Column 3 by the particular bulk density in grams per cubic centimeter of the material, rounded out within a tolerance of ±25 percent.

Table 4

BULK DENSITY OF PULVERIZED MATERIALS IN FREELY POURED CONDITION[a]

Material	Average Weight lbs./ft.³	g/cm³	Material	Average Weight lbs./ft.³	g/cm³	Material	Average Weight lbs./ft.³	g/cm³
Alumina	44	1.23	Fullers earth	30 to 40	0.48 to 1.04	Rubber, chopped	36	0.58
Aluminum, calcined	128	2.05	Garnet	168	2.69	Rubber, ground	20	0.32
Aluminum oxide	122	1.96	Glass beads	76	1.22	Phosphate rock	75 to 85	1.20 to 1.36
Aluminum shot	96	1.54	Glass, crushed	66	1.06	Salt, flake	61	0.98
Ammonium nitrate	48	0.77	Glass cullet	93	1.49	Salt, rock	66	1.06
Ammonium - sulfate	61	0.98	Granite, crushed	95 to 100	1.52 to 1.60	Salt, table	75	1.20
Bauxite ore	75 to 85	1.20 to 1.36	Gravel	90 to 100	1.44 to 1.60	Sand	90 to 100	1.44 to 1.60
Bentonite	50 to 65	0.80 to 1.04	Gypsum, calcined	58	0.93	Sand, silica	90 to 100	1.44 to 1.60
Bicarbonate of soda	57	0.91	Gypsum, crushed	90 to 100	1.44 to 1.60	Sawdust	18	0.29
Borax	50 to 61	0.80 to 0.98	Iron ore	120 to 150	1.92 to 2.40	Seacoal	42	0.67
Boric acid	58	0.93	Kaolin	160	2.56	Shale	100	1.60
Calcite	90	1.44 to 1.68	Kyanite	68	1.09	Shot, metal	230	3.69
Calcium carbide	75	1.20	Lime, ground	60	0.96	Silica, flour	27	0.43
Calcium carbonate	49	0.79	Lime, hydrated	25	0.40	Silica, gel	45	0.72
Calcium chloride	64	1.03	Limestone, crushed	85 to 100	1.36 to 1.60	Soapstone, pulverized	40	0.64
Calcium phosphate	57	0.91	Limestone, agricultural	70	1.12	Soda ash, light	25 to 35	0.40 to 0.56
Carbon black	24	0.33	Magnesite	106	1.70	Soda ash, heavy	55 to 65	0.88 to 1.04
Cellulose powder	16	0.26	Magnetite	155	2.49	Soda, bicarbonate	57	0.91
Cement, portland	90 to 100	1.44 to 1.60	Manganese ore	120 to 136	1.92 to 2.18	Sodium nitrate	78	1.25
Cement clinker	75 to 80	1.20 to 1.28	Marble, crushed	90 to 95	1.44 to 1.52	Sodium phosphate	43	0.69
Chrome ore	140	2.25	Metals, powdered			Sodium sulfate	96	1.54
Clay	30 to 75	0.48 to 1.20	Aluminum	80	1.28	Steel grit	228	3.66
Coal, anthracite	55	0.88	Copper	169	2.71	Stone, crushed	85 to 95	1.36 to 1.52
Coal, bituminous	50	0.88	Copper-lead	364	5.84	Sugar, granulated	5	0.80
Coke breeze	25 to 35	0.40	Iron	243	3.90	Sugar, powdered	37	0.59
Coke, petroleum	25 to 40	0.40 to 0.64	Nickel	263	4.22	Sulphur, crushed	50 to 65	0.80 to 1.04
Copper ore	100 to 150	1.60 to 2.40	Stainless steel	240	3.85	Talc, powder	34	0.55
Coquina shell	80	1.28	Tantalum	300	4.80	Talc, granular	44	0.71
Corn starch	40	0.64	Mica	42	0.67	Traprock, crushed	105 to 110	1.68 to 1.76
Diatomaceous earth	31	0.50	Ore, sintered	144	1.83	Triple superphosphate,		
Dicalcium phosphate	64	1.03	Oyster shells, ground	29	0.47	granular	64	1.03
Dolomite, crushed	90 to 100	1.44 to 1.60	Perlite ore	65 to 75	1.04 to 1.20	Tungsten carbide	550	8.82
Feldspar, crushed	65 to 84	1.04 to 1.35	Plaster, calcined	64	1.03	Urea prills	43	0.69
Ferrophosphorous	196	3.14	Polyethylene pellets	36	0.58	Vermiculite ore	80	1.28
Fire clay	80	1.28	Polyethylene powder	18	0.29	Wood chips	13	0.21
Flour, wheat	24	0.38	Poly vinyl chloride	30	0.48	Zinc dust	144	2.31
Flour, maize	37	0.59	Potash	77	1.23	Zirconium oxide	200	3.22
Fluorspar	90 to 120	1.44 to 1.92	Potassium carbonate	79	1.27	Zirconium sand	162	2.60
Fly ash	49	0.79	Pumice	40	0.64			

[a] - Where a single figure is given, it represents an actual weight of a typical average sample of the material recorded by a research laboratory; therefore, the figure can be expected to vary from sample to sample of the same material.

Table 5

LIST OF ASTM PUBLISHED STANDARDS ON SIEVE ANALYSIS PROCEDURES FOR SPECIFIC MATERIAL OR INDUSTRIES

Material	ASTM Designation	Title of Standard	Sieve No. or Size Range
Aggregates	C117-95	Standard Test Method for Materials Finer Than 75-µm (No.200) Sieve in Mineral Aggregates by Washing	No.200
	C136-01	Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates	3½ in. - No.200
	C142-97	Standard Test Method for Clay Lumps and Friable Particles in Aggregates	1½ in. - No.20
	C330-00	Standard Specifications for Lightweight Aggregates for Structural Concrete	1 in. - No.100
	C331-01	Standard Specifications for Lightweight Aggregates for Concrete Masonry Units	¾ in. - No.100
	D4791-99	Standard Test Method for Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate	
	D5821-01	Standard Test Method for Determining the Percentage of Fractured Particles in Coarse Aggregate	
Asbestos	D2589-88 (1997)	Standard Test Method for McNett Wet Classification of Duel Asbestos Fiber	No.4 - No.325
	D2947-88 (1997)	Standard Test Method for Screen Analysis of Asbestos Fibers	
Carbon black	D1508-99	Standard Test Method for Carbon Black, Pelleted-Fines and Attrition	No.100
	D1511-00	Standard Test Method for Carbon Black-Pellet Size Distribution	No.10 - No.120
	D1514-00	Standard Test Method for Carbon Black-Sieve Residue	No.30 - No.325
Cement	C184-94	Standard Test Method for Fineness of Hydraulic Cement by the 150-µm (No.100) and 75-µm (No.200) Sieves	No.100 & No.200
	C430-96	Standard Test Method for Fineness of Hydraulic Cement by the 45-µm (No.325) Sieve	No. 325
	C786-96	Standard Test Method for Fineness of Hydraulic Cement and Raw Materials by the 300-µm (No.50), 150-µm (No.100), and 75-µm (No.200) Sieves by Wet Methods	No.50 - No.200
Ceramic	C325-81 (1997)	Standard Test Method for Wet Sieve Analysis of Ceramic Whiteware Clays	No.100 - No.325
	C371-89 (1999)	Standard Test Method for Wire-Cloth Sieve Analysis of Nonplastic Ceramic Powders	No.70 - No.325
Coal	D197-87 (1994)	Standard Test Method for Sampling and Fineness Test of Pulverized Coal	No.16 - No.200
	D4749-87 (1994)	Standard Test Method for Performing the Sieve Analysis of Coal and Designating Coal Size	5 in. - No.400
Coatings	D3214-96	Standard Test Methods for Coating Powders and Their Coatings Used for Electrical Insulation	
	D3451-01	Standard Guide for Testing Coating Powders and Powder Coatings	
Coke	D293-93 (1999)	Standard Test Method for the Sieve Analysis of Coke	4 in. - No.200
	D5709-95 (2000)	Standard Test Method for Sieve Analysis of Petroleum Coke	3 in. - No.200
Enamel	C285-88 (1999)	Standard Test Methods for Sieve Analysis of Wet-Milled and Dry-Milled Porcelain Enamel	No.40 - No.325
Glass	C429-01	Method for Sieve Analysis of Raw Materials for Glass Manufacture	No.8 - No.200
	D1214-89 (1994)	Test for Sieve Analysis of Glass Spheres	
Magnesium	D2772-90 (1997)	Standard Test Method for Sieve Analysis of Electrical Grade Magnesium Oxide	
Metal Bearing ores	E276-98	Standard Test Method for Particle Size or Screen Analysis at No.4 (4.75-mm) Sieve and Finer for Metal-Bearing Ores and Related Materials	No.4 - No.200
Metal Powders	B214-99	Test for Sieve Analysis of Metal Powders	No.80 - No.325
Mineral	D451-91 (1996)	Standard Test Method for Sieve Analysis of Granular Mineral Surfacing for Asphalt Roofing Products	No.6 - No.100
	D452-91 (1997)	Standard Test Method for Sieve Analysis of Surfacing for Asphalt Products	No.12 - No.200
	D546-99	Standard Test Method for Sieve Analysis of Mineral Filler for Bituminous Paving Mixtures	
Perlite	C549-81 (1995)	Standard Specification for Perlite Loose Fill Insulation	
Pigments and paint	D185-84 (1999)	Standard Test Methods for Coarse Particles in Pigments, Pastes and Paints	No.325
	D480-88 (1999)	Standard Test Methods for Sampling and Testing of Flaked Aluminum Powders and Pastes	No.100 - No.325
Plastic	D1921-01	Standard Test Method for Particle Size (Sieve Analysis) of Plastic Materials	down to No.400
Porcelain	C285-88 (1999)	Standard Test Methods for Sieve Analysis of Wet-Milled and Dry-Milled Porcelain Enamel	No.40 - No.325
Refractories	C92-95 (1999)	Tests for Sieve Analysis and Water Content of Refractory Materials	3 in. - No.200
Resins	D2187-94 (1998)	Standard Test Methods for Physical and Chemical Properties of Particulate Ion-Exchange Resins	No.8 - No.100
Rubber additives	D5461-93 (1998)	Standard Test Method for Rubber Additives-Wet Sieve Analysis of Powdered Rubber Chemicals	
Soap	D502-89 (1995)	Standard Test Method for Particle Size of Soaps and Other Detergents	No.12 - No.100
Soda ash	E359-00	Standard Test Methods for Analysis of Soda Ash (Sodium Carbonate)	
Soil	D421-85 (1998)	Standard Practice for Dry Preparation of Soil Samples for Particle-Size Analysis and Determination of Soil Constants	No.4 - No.40
	D422-63 (1998)	Standard Test Method for Particle-Size Analysis of Soils	3 in. - No.200
	D1140-00	Standard Test Methods for Amount of Material in Soils Finer Than the No.200 (75-µm) Sieve	No.40 - No.200
	D2217-85 (1998)	Standard Practice for Wet Preparation of Soil Samples for Particle-Size Analysis and Determination of Soil Constants	No.10 - No.40
Vermiculite	C516-80 (1996)	Standard Specification for Vermiculite Loose Fill Insulation	¾ in. - No.100

Table 6