IS 8425 (1977): Code of practice for determination of specific surface area of powders by air permeability methods [CED 2: Cement and Concrete]

BLANK PAGE

IS : 8425 - 1977
(Reaffirmed 2005)

Indian Standard

CODE OF PRACTICE FOR DETERMINATION OF SPECIFIC SURFACE AREA OF POWDERS BY AIR PERMEABILITY METHODS

UDC 620·168·36 : 666·9-492

INDIAN STANDARDS INSTITUTION
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

Price Rs 6·00

August 1977

Indian Standard

CODE OF PRACTICE FOR DETERMINATION OF SPECIFIC SURFACE AREA OF POWDERS BY AIR PERMEABILITY METHODS

Sieves, Sieving and Other Sizing Methods Sectional Committee, BDC 19

Chairman	*Representing*
DR M. PANCHOLY	National Physical Laboratory (CSIR), New Delhi
Members	
DR P. T. JOHN (*Alternate* to Dr M. Pancholy)	
SHRI V. K. AGARWAL	Ministry of Railways
SHRI A. K. MUKHERJEE (*Alternate*)	
SHRI P. N. ARORA	All India Wire Netting Manufacturers Association
SHRI S. N. ARORA	Shalimar Wires & Industries Ltd, Distt Hooghly
SHRI S. KUMAR (*Alternate*)	
SHRI S. K. BAJORIA	Krishanlal Thirani & Co Ltd, Calcutta
SHRI S. K. GANDHI (*Alternate*)	
SHRI R. K. CHOURARIA	Messrs Jeetmul Jaichandlall, Calcutta
DR R. K. DATTA	Central Building Research Institute (CSIR), Roorkee
SHRI KISHAN LAL (*Alternate*)	
DR R. R. HATTIANGADI	The Associated Cement Companies Ltd, Bombay
SHRI D. S. JOSHI	Hindustan Boilers, Bombay
SHRI A. R. A. KRISHNAN	Directorate of Standardization, Ministry of Defence (DGI)
SHRI B. K. SINGH (*Alternate*)	
SHRI R. C. MAHAJAN	The Indian Steel & Wire Products Ltd, Jamshedpur
SHRI G. H. MARWAH	Hindustan Wire Netting Co Ltd, Bombay
SHRI K. RANGANATHAN (*Alternate*)	
SHRI D. K. MEHTA	Tata-Robins-Fraser Ltd, Jamshedpur
LT-COL C. A. RODRIGUES (*Alternate*)	
SHRI R. S. MELKOTE	Central Water Commission, New Delhi
SHRI A. B. JOSHI (*Alternate*)	
SHRI J. MENDONCA	All India Instrument Mfrs & Dealers Association (Bombay Region)
SHRI C. P. SOOD (*Alternate*)	
SHRI E. K. RAMACHANDRAN	National Test House, Calcutta

(*Continued on page 2*)

(*Continued from page* 1)

Members	*Representing*
SHRI K. K. SENGUPTA	Hindustan Steel Ltd, Ranchi
SHRI A. K. SEN (*Alternate*)	
SHRI HASMUKH C. SHAH	Standard Wire Products, Bombay
SHRI C. M. P. SINHA	Directorate General of Technical Development, New Delhi
SHRI C. P. SOOD	All India Instrument Manufacturers' and Dealers Association (Delhi Region), Delhi
SHRI K. C. TOSHINWAL	All India Instrument Manufacturers and Dealers Association (Calcutta Region), Calcutta
SHRI H. C. VERMA	Associated Instrument Manufacturers (India) Pvt Ltd, New Delhi
SHRI A. V. S. R. A. SASTRY (*Alternate*)	
SHRI D. AJITHA SIMHA, Director (Civ Engg)	Director General, ISI (*Ex-officio Member*)

Secretary

SHRI VINOD KUMAR
Deputy Director (Civ Engg), ISI

Sizing by Methods Other Than Sieving Subcommittee, BDC 19 : 2

Convener	
DR BH V. RAMANAMURTY	Indian Institute of Tropical Meteorology, Pune
Members	
SHRI B. H. BAJINA	Tata Chemicals Ltd, Mithapur (Gujarat)
SHRI K. C. BANERJEE	The Fertilizer Corporation of India Ltd, P.O. Sindri
SHRI S. K. GHOSH (*Alternate*)	
SHRI A. B. BISWAS	Indian Institute of Technology, Bombay
DR P. T. JOHN	National Physical Laboratory (CSIR), New Delhi
SHRI B. S. KEDARE	Standard Batteries Ltd, Bombay
SHRI R. S. MANI (*Alternate*)	
SHRI S. L. MUKHERJEE	Incheck Tyres Ltd, Calcutta
SHRI M. D. NAIR	Associated Instrument Manufacturers (India) Pvt Ltd, New Delhi
SHRI A. V. A. SHASTRI (*Alternate*)	
SHRI V. C. PANCHAMIYA	Kamani Metallic Oxides Pvt Ltd, Bombay
SHRI RAM SINGH	Central Scientific Instrument Organization (CSIR), Chandigarh
REPRESENTATIVE	The Associated Cement Companies Ltd, Bombay

Indian Standard

CODE OF PRACTICE FOR DETERMINATION OF SPECIFIC SURFACE AREA OF POWDERS BY AIR PERMEABILITY METHODS

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 25 April 1977, after the draft finalized by the Sieves, Sieving and Other Sizing Methods Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 This standard lays down the procedure for finding the specific surface area of powders in the sub-sieve range. The various methods described in this standard are applicable to powders whose specific surface areas lie within the range of 500 to 40 000 cm^2/g. For fine powders the method given in this standard are not valid since there will be molecular flow (known also as 'slip flow') in addition to viscous flow and it becomes significant in comparison with viscous flow. Since small quantities of material are used in these tests, accurate sampling of the material is very essential. For accurate sampling of the material *see* IS : 4879-1968*.

0.3 In the formulation of this standard due weightage has been given to international co-ordination among the standards and practices prevailing in different countries in addition to relating it to the practices in the field in this country.

---

1. SCOPE

1.1 This standard describes the following methods for the determination of specific surface area of powders. These methods are applicable to powders whose surface areas lie within the range of 500 to 40 000 cm^2/g:

a) Constant flow type air permeability method (Lea and Nurse Type),
b) Variable flow type air permeability method (Blaine Type), and
c) Variable flow type air permeability method (Rigden Type).

1.2 The methods described in **1.1** differ basically in the way in which the flow resistance is measured.

*Method of sub-division of gross sample of powder used for determination of particle size.

2. PRINCIPLE

2.1 The following equation is used to find the specific surface area of powders:

$$S_w = [(e^3 \triangle p\ g\ At)/d^2_o\ (1-e)^2\ Lq\ K\eta]^{\frac{1}{2}}$$

where

S_w = surface area of powder in cm²/g,
e = porosity cm³/cm³,
$\triangle p$ = pressure difference in gf/cm²,
A = cross-sectional area of the sample on which the pressure is acting in cm²,
L = length of the sample in cm,
d_o = true density of the sample g/cm³,
K = constant (which is generally $5 \pm 0{\cdot}5$ for particles that are approximately spherical in shape),
η = viscosity in poise,
q = total flow in cm³, and
t = time of flow for q cm³ to pass through the sample in seconds.

NOTE — This equation is valid in a statistical sense for the passage of an incompressible fluid through a homogeneous bed of powder. The particles of powder have been assumed to be free from pores.

2.2 Use of Compressible Fluid — In general air or gas is used as the fluid for the permeability methods. Since air is a compressible fluid some modification to the above equation is required. If p_e is the entry pressure and p_o is the exit pressure and if q_o is the volume rate of flow *from* the powder bed, the q in equation mentioned under **2.1** is given by:

$$q = q_o\ (P_e - \triangle p)/(p_e - \triangle p/2) \text{ or}$$
$$q = q_o p_o/(p_o + \triangle p/2).$$

Alternatively, if the flow rate *into* the bed is q_e the volume of q in equation given under **2.1** is given by:

$$q = q_e\ p_e/(p_e - \triangle p/2) \text{ or}$$
$$q = q_e\ (p_o + \triangle p)/(p_o + \triangle p/2).$$

These corrections known as 'mass flow corrections' in many practical conditions have values very near to unity so that they can be ignored.

2.3 Non-spherical Particles — When the particles are non-spherical and possess a high specific surface, the value of the constant K may depart considerably from 5. Such a departure may also occur with powders of specific surface where particle size is extreme. Where there is sufficient reason to believe that it is advantageous to adopt some other value for K, this is permissible, but the value adopted should be stated when the results are reported. Otherwise K should be taken as 5.

3. PERMEABILITY CELL

3.1 The cell shall have a circular internal cross-sectional area which is accurately known. The compacting device should be able to produce a

uniform bed of known height with a known weight of powder. Care should be taken to avoid wall effect of the cell.

4. CONSTANT FLOW TYPE AIR PERMEABILITY METHOD (LEA AND NURSE TYPE)

4.1 The details of the method are the same as given in IS : 5536-1969*.

4.2 A worked out example of this method is given in Appendix A.

5. VARIABLE FLOW TYPE AIR PERMEABILITY METHODS

5.1 Blaine Type

5.1.1 *Apparatus* — The apparatus shall be the same as specified in IS : 5516-1969†.

5.1.2 *Procedure* — The cell is joined to the coupling to fit the bottom of the cell. The liquid level in the U-tube initially at zero level is displaced by reducing pressure in the liquid arm fixed to the permeameter cell to a height of 11 cm above zero level. The suction pressure is applied *via* side tube having valve or clamp. When the valve is closed after raising the liquid level, the liquid will start to fall. The time taken for the liquid level to fall from 7 cm to 1·5 cm above zero level is noted.

5.1.3 *Calculations* — The specific surface area of the powder shall be calculated from the following equation. The equation is simplified form of equation under **2.1**.

$$S_w = (14/d_o)\ [e^3/(1-e)^2\ K_1]^{\frac{1}{2}}$$

where

S_w = specific surface area (cm^2/g),

d_o = true density of the material in g/cm^3,

e = porosity (cm^3/cm^3),

K_1 = permeability constant which can be calculated from the following formula :

$$K_1 = \eta\ A_m\ L \ln (h_1/h_2)/(d\ A_c\ t)$$

η = viscosity of air in poise,

L = depth of powder bed in cm,

A_m = Average cross-sectional area of the manometer tube in cm^2,

h_1 = height of the liquid level in manometer above zero level at zero time in cm,

h_2 = height of the liquid level in manometer above zero level in cm at time t seconds,

d = density of manometric liquid in g/cm^3,

A_c = cross-sectional area of powder bed (that is area of cell) in cm^2,

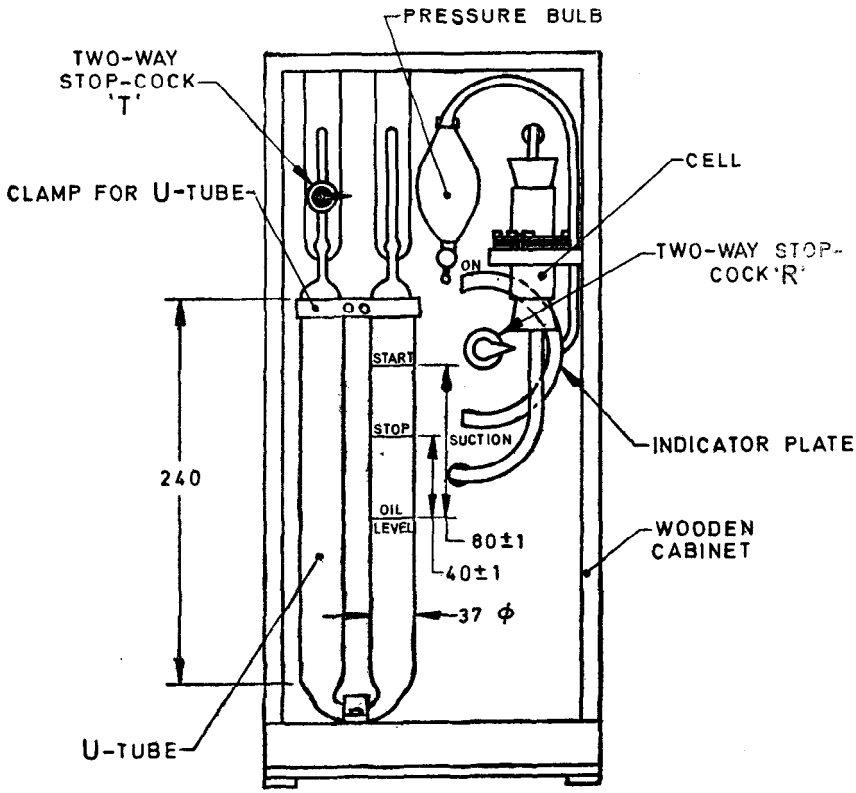
t = time taken for the manometric liquid level to fall from height h_1 to h_2 in seconds.

*Specification for constant flow type air-permeability apparatus (Lea and Nurse type).
†Specification for variable flow type air-permeability apparatus (Blaine type).

5.1.4 A worked out example using this method is given in Appendix B.

5.2 Rigden Type

5.2.1 *Apparatus* — Apparatus is as shown in Fig. 1.



All dimensions in millimetres.

FIG. 1A TYPICAL VARIABLE FLOW TYPE AIR PERMEABILITY APPARATUS (RIGDEN TYPE) (FRONT VIEW)

5.2.1.1 *Permeability cell* — The permeability cell shall consist of two flanged cylindrical units of brass or stainless steel which can be bolted together. A rubber or other suitable gasket shall be used between the flanges to render the joint airtight. The bottom half of the cell shall have a suitable recess for supporting the perforated plate and the gasket. Dimensions and tolerances shall be as detailed in Fig. 2.

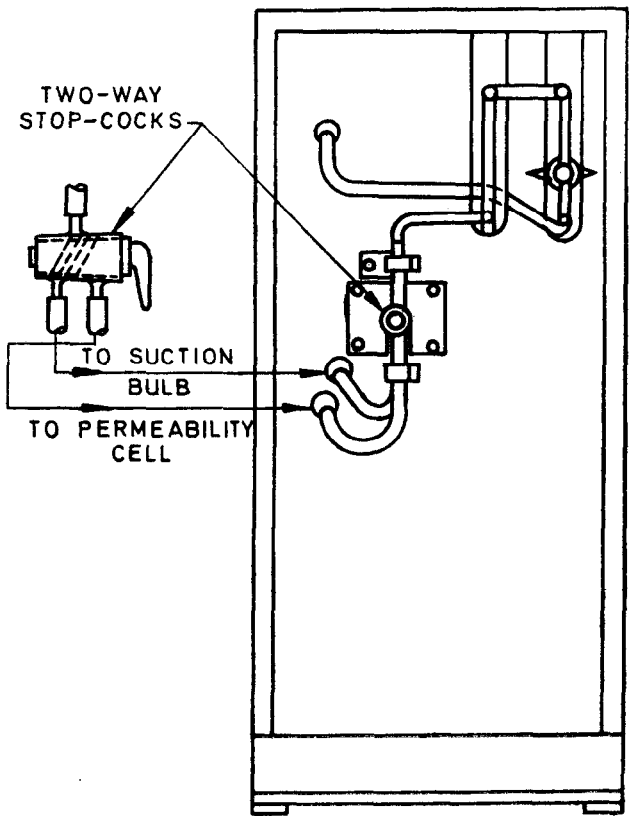
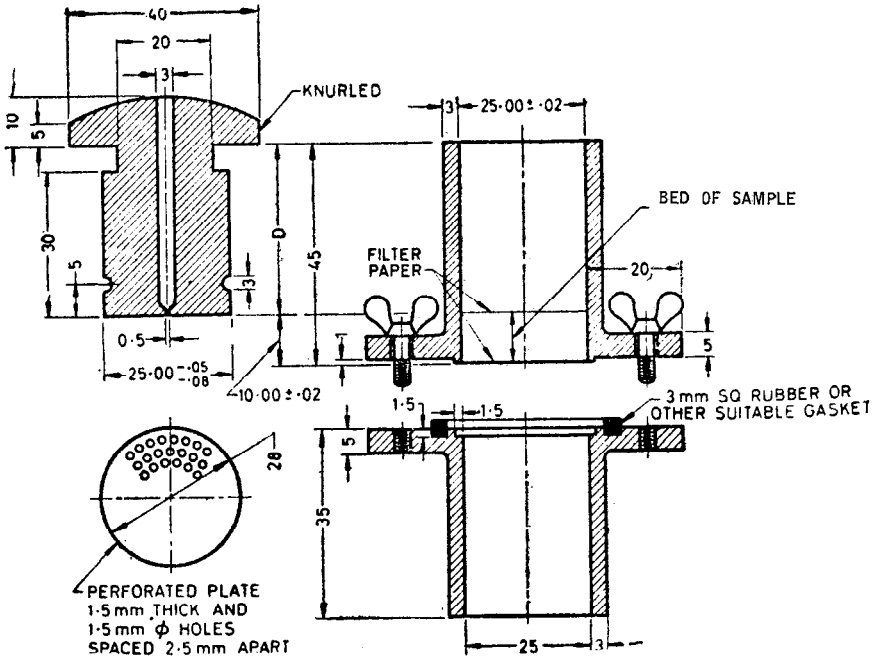


FIG. 1B TYPICAL VARIABLE FLOW TYPE AIR PERMEABILITY APPARATUS (RIGDEN TYPE) (REAR VIEW)

5.2.1.2 *Plunger* — The plunger, of brass or stainless steel, shall have a knurled head, air event and circular recess as detailed in Fig. 2. The bottom of the plunger shall have sharp square edges and shall be at right angles to the principal axis. The dimension *D* of the plunger in Fig. 2 shall be so adjusted that when the plunger is placed in the cell and the knurled head brought in contact with the top of the cell, a bed of powder sample of thickness $10 \pm 0{\cdot}05$ mm is formed over the filter paper kept on top of the perforated plate. The plunger shall also fit snugly into the cell (clearance between the plunger and the cell should not be more than 0·1 mm).



All dimensions in millimetres.

FIG. 2 DETAILS OF PERMEABILITY CELL

5.2.1.3 *Perforated plates* — The plate shall be of brass or stainless steel, with a number of circular perforations. The plate shall be plane and shall fit snugly in the recess in the permeability cell.

5.2.1.4 *Manometer* — The manometer shall be constructed of clear borosilicate glass or equivalent material. The dimension shall generally be as shown in Fig. 1. The manometer shall be of standard wall glass tubing. The manometer shall be filled to the mid-point with a nonvolatile, nonhygroscopic liquid of low viscosity and density, such as dibutylphthalate (dibutyl 1, 2 benzene-dicarboxylate or kerosene).

5.2.1.5 *Manometer stand* — The entire apparatus shall be mounted on a stand of well-seasoned teak or suitable hardwood or pressed steel sheets. For convenience in handling, the manometer and the cell shall be mounted on the front panel, with the cell assembly on one side. The mounting shall be secured by clamps. The rubber tubings and rubber corks for linking the cell and manometer shall be of good quality to resist frequent reconnections.

5.2.1.6 A measuring scale may either be fixed or be etched to record

the levels of manometric liquid conveniently. All connections shall be airtight.

5.2.1.7 *Filter paper* — The filter paper shall be medium retentive (corresponding to Whatman No. 40). The filter paper discs shall be circular, with smooth edges, and shall have the same diameter as the inside of the cell.

NOTE — Filter paper discs that are too small may leave part of the sample adhering to the inner wall of the cell above the top disc. When too large in diameter, the discs have tendency to buckle and cause erratic results.

5.2.2 *Procedure* — Insert the upper bung of the permeability cell. Operate the stop-cock T on the left limb of the U-tube opening it to atmosphere. Operate the stop-cock R so that the indicator line is on to pressure. Press the pressure bulb when the oil level in the right limb is well past the mark, start turn the stop-cock R to 'off'. Close the stop-cock T on the left limb. Turn the stop-cock R to 'on'. Insert the lower rubber bung taking care to avoid forcing air through the powder in the wrong direction. Measure the time of the passage of the liquid level in the U-tube between two marks.

5.2.3 *Calculations* — The specific surface area of the powder shall be calculated from the following equation:

$$S_w^2 = \frac{Mte^3}{(1-e)^2 d_0^2 L}$$

where

S_w = specific surface area (cm^2/g),

t = time of flow of the manometric liquid between two marks in seconds,

d_0 = true density of the material in g/cm^3,

e = porosity of the bed cm^3/cm^3,

L = depth of powder bed in cm,

M = constant of the apparatus and is given by the following formula:

$$M = \frac{196\ A_c\ d}{\eta\ A_m \ln h_1/h_2}$$

η = viscosity of air in poise,

A_c = cross-sectional area of powder bed, that is, area of cell in cm^2,

A_m = average cross-sectional area of the manometer tube in cm^2,

h_1 = height of the liquid level in manometer above zero level at zero time in cm,

h_2 = height of the liquid level in manometer above zero level in cm after t seconds, and

d = density of manometric liquid in g/cm^3.

5.2.4 A worked out example using this method is given in Appendix C.

APPENDIX A

(*Clause* 4.2)

WORKED OUT EXAMPLE USING LEA AND NURSE TYPE APPARATUS

A-1. SPECIFIC SURFACE AREA OF CEMENT

Density d_0 of cement=3·15 g/cm^3
Diameter of cell=2·5 cm
Cross-sectional area of cell= π (2·5/2)^2=4·908 cm^2
Volume of bed=4·908 cm^3 (since the height of bed is 1 cm)
Porosity=0·475
Mass of powder in the bed
= 8·118 g (*see* Table 2, IS : 5536-1969*)
C = $2{\cdot}23 \times 10^{-6}$ (cgs units)
h_1 = 16·6 cm
h_2 = 31·7 cm
Substituting the above values in equation given in **5.6** of IS : 5536-1969*.
S_w = 2 975 cm^2/g.

APPENDIX B

(*Clause* 5.1.4)

WORKED OUT EXAMPLE USING BLAINE'S TYPE APPARATUS

B-1. SPECIFIC SURFACE AREA OF LIME POWDER

Density of the powder=2·4 g/cm^3
Diameter of the cell=1·27 cm
Cross-sectional area of the cell (powder bed) = π (1·27/2)^2=1·267 cm^2
Depth of powder bed=1·5 cm
Volume of the powder bed=1·267×1·5=1·90 cm^3
Mass of powder used=1·377 3 g
Apparent density of powder bed=1·377 3/1·90=0·724 7 g/cm^3
Porosity = 1−(apparent density/true density)
= 1−(0·724 7/2·4)=0·698 1
Internal diameter of manometer tube=0·75 cm
Cross-sectional area of manometer tube= π (0·75/2)^2= 0·441 5 cm^2
Viscosity of air at 27°C=$1{\cdot}842 \times 10^{-4}$ poise
Density of manometer liquid=0·89 g/cm^3

*Constant flow type air-permeability apparatus (Lea and Nurse type).

h_1 = 7 cm h_2=1·5 cm
t = 214 seconds

K_1 is found by using equation given under **5.1.3.**

K_1 = (1·842 × 10^{-4}) (0·441 5) (1·5) (1n 7/1·5)/(0·89) (1·267) (214)
= 7·807 × 10^{-7}

Surface area of powder is found using equation given under **5.1.3.**

S_w = (14/2·4) [(0·698 1)^3/(1−0·698 1)^2 (7·807 × 10^{-7})]$^{\frac{1}{2}}$
= 1·276 × 10^4 cm^2/g.

APPENDIX C

(*Clause* 5.2.4)

WORKED OUT EXAMPLE USING RIGDEN TYPE APPARATUS

C-1. SPECIFIC SURFACE AREA OF FERRIC OXIDE POWDER

Density of ferric oxide=5·1 g/cm^2
Diameter of the cell=2·5 cm
Cross-sectional area of the cell (powder bed)

$$= \pi \left(\frac{2{\cdot}5}{2}\right)^2 = 4{\cdot}908 \text{ cm}^2$$

Depth of the powder bed=1 cm
Volume of the bed=4·908 cm^3
Mass of the powder=8·260 g

$$\text{Apparent density of powder} = \frac{8{\cdot}260}{4{\cdot}908} = 1{\cdot}68 \text{ g/cm}^3$$

Porosity=1−(1·68/5·1)=1−0·329 4=0·670 6

$$\text{Internal area of manometer tube} = \pi \left(\frac{3{\cdot}7}{2}\right)^2 = 10{\cdot}75 \text{ cm}^2$$

Density of manometric liquid=0·89 g/cm^3
Viscosity of air at 27°C=1·842 × 10^{-4} poise
h_1 = 8 cm h_2=4 cm
t = 603 seconds

M = (196 × 4·908 × 0·89)/(1·842 × 10^{-4} × 10·75 × 1n 2)
= 62·4 × 10^{+4}

S_w = [{62·4 × 603 × (0·670 6)^3/(1−0·670 6)^2 × (5·1)^2 × 1}]$^{\frac{1}{2}}$
= 6 343 cm^2/g.

INDIAN STANDARDS

ON

SIEVES, SIEVING AND SIZING METHODS

IS:

460-1962 Test sieves (*first revision*)
1568-1970 Wire cloth for general purposes (*first revision*)
1607-1977 Methods for test sieving (*first revision*)
2405-1963 Wire cloth and perforated plates for industrial sieves
3150-1966 Hexagonal wire netting for general purposes
4124-1967 Glossary of terms relating to powders
4879-1968 Method of sub-division of gross sample of powder used for determination of particle size
4961-1968 Determination of particle size of powders by air elutriation methods
5257-1969 Eyepiece and screen graticule for determination of particle size of powders
5258-1969 Determination of particle size of powders by optical microscope method
5282-1969 Liquid sedimentation methods for determination of particle size of powders
5421-1969 Glossary of terms relating to test sieves and test sieving
5742 (Part I)-1970 Terms and symbols for screen bottoms: Part I Woven and welded wire screens
5742 (Part II)-1970 Terms and symbols for screen bottoms: Part II Perforated plates