

JAPANESE
INDUSTRIAL
STANDARD

Translated and Published by
Japanese Standards Association

JIS M 8801 : 2004

(CCUJ/JSA)

Coal—Testing methods

ICS 73.040

Reference number : JIS M 8801 : 2004 (E)

PROTECTED BY COPYRIGHT

Foreword

This translation has been made based on the original Japanese Industrial Standard revised by the Minister of Economy, Trade and Industry through deliberations at the Japanese Industrial Standards Committee, as the result of proposal for revision of Japanese Industrial Standard submitted by Center for Coal Utilization, Japan (CCUJ)/Japanese Standards Association (JSA) with the draft being attached, based on the provision of Article 12 Clause 1 of the Industrial Standardization Law applicable to the case of revision by the provision of Article 14. Consequently **JIS M 8801 : 1993** is replaced with this Standard.

This revision has been made based on **ISO 335 : 1974** *Hard coal—Determination of caking power—Roga test*, **ISO 501 : 1981** *Coal—Determination of the crucible swelling number*, **ISO 1953 : 1994** *Hard coal—Size analysis by sieving*, **ISO 5074 : 1994** *Hard coal—Determination of Hardgrove grindability index*, **ISO 7936 : 1992** *Hard coal—Determination and presentation of float and sink characteristics—General directions for apparatus and procedures* and **ISO 8264 : 1989** *Hard coal—Determination of the swelling properties using a dilatometer* for the purposes of making it easier to compare this Standard with International Standards; to prepare Japanese Industrial Standard conforming with International Standards; and to propose a draft of an International Standard which is based on Japanese Industrial Standard.

Attention is drawn to the possibility that some parts of this Standard may conflict with a patent right, application for a patent after opening to the public, utility model right or application for registration of utility model after opening to the public which have technical properties. The relevant Minister and the Japanese Industrial Standards Committee are not responsible for identifying the patent right, application for a patent after opening to the public, utility model right or application for registration of utility model after opening to the public which have the said technical properties.

Date of Establishment: 1951-01-30

Date of Revision: 2004-03-20

Date of Public Notice in Official Gazette: 2004-03-22

Investigated by: Japanese Industrial Standards Committee
Standards Board

Technical Committee on Chemical Products

JIS M 8801 : 2004, First English edition published in 2005-04

Translated and published by: Japanese Standards Association
4-1-24, Akasaka, Minato-ku, Tokyo, 107-8440 JAPAN

In the event of any doubts arising as to the contents,
the original JIS is to be the final authority.

© JSA 2005

All rights reserved. No part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from the publisher.

Printed in Japan

PROTECTED BY COPYRIGHT

Contents

	Page
Introduction	1
1 Scope	1
2 Normative references	1
3 General matter	2
3.1 Scale	2
3.2 Handling of sample	2
3.3 Rules for rounding of numerical values	2
3.4 Report	2
4 Definitions	2
5 Method for particle-size analysis	2
5.1 Principle of test and measurement	3
5.2 Sieve	3
5.3 Sampling, preparation and drying	3
5.4 Procedure	4
5.5 Expression of result	5
5.6 Test report	6
6 Method for determination of float and sink characteristics	9
6.1 Principle of test and measurement	9
6.2 Sample	9
6.3 Heavy liquid	10
6.4 Apparatus	11
6.5 Procedure	11
6.6 Washability curve	12
7 Method for determination of Hardgrove grindability indices (Hardgrove method)	19
7.1 Principle of test and measurement	19
7.2 Sample	19
7.3 Apparatus	19

7.4	Procedure	20
7.5	Calculation of measured value	21
7.6	Number of times for tests	21
7.7	Repeatability limit.....	21
7.8	Report value	21
8	Method for determination of crucible swelling number	23
8.1	Principle of test and measurement	23
8.2	Gas heating method	23
8.3	Electrical heating method	26
9	Method for determination of swelling properties (dilatometer method).....	29
9.1	Principle of test and measurement	29
9.2	Softening fusion characteristic value.....	30
9.3	Sample	30
9.4	Apparatus	30
9.5	Procedure	32
9.6	Number of times for tests	34
9.7	Calculation of measured value and preparation of graph	34
9.8	Repeatability	35
9.9	Report value	35
10	Method for determination of fluidity properties (Giessler plastometer method)	45
10.1	Principle of test and measurement	45
10.2	Softening and fusion characteristic value.....	45
10.3	Sample	45
10.4	Apparatus	45
10.5	Procedure	47
10.6	Number of times for tests	48
10.7	Calculation of measured value and preparation of graph	48
10.8	Tolerance	48
10.9	Expression of measured value.....	49

11	Method for determination of coking properties	57
11.1	Classification of method	57
11.2	Small retort method	57
11.3	Can carbonization method	59
11.4	Report value	60
12	Method for determination of fusibility of ash	61
12.1	Summary	61
12.2	Fusion-characteristic temperature	61
12.3	Sample	62
12.4	Apparatus	62
12.5	Procedure	63
12.6	Calculation of measured value	64
12.7	Number of times for tests	64
12.8	Tolerance	64
12.9	Report value	65
13	Method for determination of Roga indices	67
13.1	Principle of test and measurement	67
13.2	Standard anthracite	67
13.3	Sample	68
13.4	Apparatus	68
13.5	Procedure	69
13.6	Calculation of measured value	70
13.7	Number of times for tests	70
13.8	Repeatability	70
13.9	Report value	71
Annex (informative)	Comparison table between JIS and corresponding International Standards	74

Coal—Testing methods

Introduction This Japanese Industrial Standard has been prepared based on **ISO 335 : 1974** *Hard coal—Determination of caking power—Roga test*, **ISO 501 : 1981** *Coal—Determination of the crucible swelling number*, **ISO 1953 : 1994** *Hard coal—Size analysis by sieving*, **ISO 5074 : 1994** *Hard coal—Determination of Hardgrove grindability index*, **ISO 7936 : 1992** *Hard coal—Determination and presentation of float and sink characteristics—General directions for apparatus and procedures* and **ISO 8264 : 1989** *Hard coal—Determination of the swelling properties using a dilatometer* with some modifications of the technical contents.

Portions given sidelines or dotted underlines are the matters modified from the original International Standards. A list of modifications with the explanations is given in annex (informative).

1 Scope This Standard specifies the method for the particle-size analysis, the method for determination of the float and sink characteristics, the method for determination of Hardgrove grindability indices, the method for determination of the crucible swelling number, the method for determination of the swelling properties, the method for determination of the fluidity properties, the method for determination of the coking properties, the method for determination of the fusibility of ash, and the method for determination of Roga indices of coal.

Remarks : The International Standards corresponding to this Standard are as follows.

In addition, symbols which denote the degree of correspondence in the contents between the relevant International Standard and **JIS** are IDT (identical), MOD (modified), and NEQ (not equivalent) according to **ISO/IEC Guide 21**.

ISO 335 : 1974 *Hard coal—Determination of caking power—Roga test* (MOD)

ISO 501 : 1981 *Coal—Determination of the crucible swelling number* (MOD)

ISO 1953 : 1994 *Hard coal—Size analysis by sieving* (MOD)

ISO 5074 : 1994 *Hard coal—Determination of Hardgrove grindability index* (MOD)

ISO 7936 : 1992 *Hard coal—Determination and presentation of float and sink characteristics—General directions for apparatus and procedures* (MOD)

ISO 8264 : 1989 *Hard coal—Determination of the swelling properties using a dilatometer* (MOD)

2 Normative references The following standards contain provisions which, through reference in this Standard, constitute provisions of this Standard. The most recent editions of the standards (including amendments) indicated below shall be applied.

JIS K 2151	<i>Coke—Methods for testing</i>
JIS M 0104	<i>Technical terms used in coal utilization</i>
JIS M 8810	<i>Coal and coke—General rules for sampling, analysis and testing</i>
JIS M 8811	<i>Coal and coke—Sampling and sample preparation</i>
JIS M 8812	<i>Coal and coke—Methods for proximate analysis</i>
JIS M 8813	<i>Coal and coke—Methods for ultimate analysis</i>
JIS M 8814	<i>Coal and coke—Determination of gross calorific value by the bomb calorimetric method, and calculation of net calorific value</i>
JIS M 8815	<i>Methods for analysis of coal ash and coke ash</i>
JIS Z 8401	<i>Guide to the rounding of numbers</i>
JIS Z 8801-1	<i>Test sieves—Part 1 : Test sieves of metal wire cloth</i>
JIS Z 8801-2	<i>Test sieves—Part 2 : Test sieves of perforated metal plate</i>

3 General matter

3.1 Scale The reciprocal sensibility of a scale, unless otherwise specified, shall be taken as 1/1 000 of weighing capacity. The scale which is near the weighing capacity according to the amount of sample should be preferably used.

3.2 Handling of sample In accordance with clause 5 of JIS M 8810.

3.3 Rules for rounding of numerical values The calculation of measured value and the report value in each test shall be rounded in accordance with JIS Z 8401.

3.4 Report In accordance with clause 12 of JIS M 8810.

4 Definitions For the purpose of this Standard, the definitions given in JIS M 0104 and the following definitions apply:

- a) **gross sample** a sample which collected all increments taken from the sub-lot or the lot which is not divided
- b) **partial sample** a sample which collected two or more increments taken from the sub-lot or the lot which is not divided in order to measure the total moisture
- c) **increment** a part of the lot sampled in one action of a sampler or a part of the sample taken in accordance with the increment reduction method
- d) **nominal top size** the size of the minimum sieve opening (nominal size) of the test sieve (see square hole, JIS Z 8801-2) of which the oversize residual percentage of a sample becomes not more than 5 %

5 Method for particle-size analysis

5.1 Principle of test and measurement A sample is screened with the predetermined sieve, and the oversize residual amount on each sieve and the amount passing through the minimum hole size are weighed, and the particle size of the sample is expressed by the percentage mass (%) to the sample.

5.2 Sieve The required sieves selected from the sieves specified in **JIS M 8801-1** and **JIS Z 8801-2** are determined and used in accordance with the agreement between the parties concerned with delivery.

5.3 Sampling, preparation and drying

5.3.1 Sampling The primary increment of the mass specified in table 5.4 [Nominal top size and absolute minimum mass (average mass) of increment] of **JIS M 8811** shall be taken by not less than the number of pieces (for coal, the numerical value of less than 15 % of ash content is applied.) specified in table 5.1 (Minimum required number of pieces of increment sampled from the lot which is not divided) of **JIS M 8811**.

Remarks : The confirmation of the precision should be performed in accordance with clause 11 of **JIS M 8811**.

5.3.2 Preparation of sample Usually, the whole quantity of every increment, every partial sample, or without carrying out the reduction of gross sample as it shall be taken as the particle-size measurement sample. However, when the mass of the sample for particle-size analysis exceeds twice the mass specified in table 5.1, it may be reduced to the mass in table 5.1 (generally, the numerical value of precision of $\pm 2\%$ may be applied.). That is to say, in the case of the gross sample, it may be reduced to the mass in table 5.1. In the case of a partial sample and an increment, they may be reduced to m_P and m_I which are obtained from the formula (1) and the formula (2).

$$n_P m_P = m_G \quad \dots\dots\dots (1)$$

$$n_I m_I = m_G \quad \dots\dots\dots (2)$$

where, m_P : mass of partial sample after reduction (kg)
 n_P : number of partial sample
 m_G : mass of gross sample specified in table 5.1 (kg)
 m_I : mass of increment after reduction (kg)
 n_I : number of pieces of increment

5.3.3 Drying of sample The sample which is taken and prepared in accordance with 5.3.1 and 5.3.2 shall be dried at 40°C or lower in such a degree that there is no harm in screening.

Table 5.1 Minimum mass of gross sample for particle-size analysis

Unit: kg

Nominal top size of coal mm	Reduction precision and minimum mass of sample	
	$\pm 1 \%$	$\pm 2 \%$
125	4 000	1 000
90	1 500	400
63	500	125
45	200	50
31.5	65	15
22.4	25	6
16	8	2
11.2	3	0.70
8	1	0.25
5.6	0.50	0.25
4	0.25	0.25
2.8	0.25	0.25

Remarks : The minimum mass is calculated with respect to the precision which measures the amount of coal of oversize, i.e. larger than nominal top size. The precision of other size fraction is normally better than this.

5.4 Procedure

5.4.1 Manual sieving The procedure shall be performed as follows:

- a) Weigh the mass of a sample to the nearest 0.1 g, and put the sample on the sieve of the predetermined maximum hole size.

In this case, one time amount of insertion shall be under the amount of such a degree that all particles directly touch the sieve holes for each sieve when the sieving procedure is ended.

- b) The sieving shall be performed by shaking the sieve by hand horizontally.
- 1) **In the case of the sieve of 45 mm or over in hole size** Make the sample which can pass in any direction pass, and there shall be no omission in passage.
 - 2) **In the case of the sieve of 4 mm or over to and excluding 45 mm in hole size** Shake the sieve 8 times horizontally in a distance of about 100 mm with a speed required for the rotation movement of the oversize particles.
 - 3) **In the case of the sieve of under 4 mm in hole size** Perform the horizontal shaking repeatedly so that the sample does not fly in all directions, sieve continuously for 5 min, and weigh the mass of the sample remained on the sieve. Return this to the same sieve, and perform the sieving procedure repeatedly. Weigh the mass again, and stop this procedure when the difference before and after sieving becomes 0.2 % or less of the first mass.

- c) **Wet sieving**

- 1) Apply the wet sieving to coal which is easy to solidify.
- 2) Hold the sieve of the maximum hole size on a receiver, put about 30 g of the sample, and wash within a jet of water. Add about 30 g of all samples at a time, and wash them. Put the sieve on which the oversize remains on a plate, and dry at 40 °C or lower. After drying, weigh the oversize.
- 3) Hold the second sieve on the receiver, pour the first wash liquid on it, and wash within a jet of water. Weigh the oversize after drying.
- 4) Repeat the procedure of 3) also for the remaining sieves.
- 5) When the wash liquid increases in large quantity, the supernatant liquid may be discarded.
- 6) Add a coagulant to the last wash liquid, and a solid matter may be made to settle. After discarding water as much as possible, filter it, dry the filter paper and filtrate at 105 °C to 110 °C until it becomes a constant mass, and obtain the mass of the last undersize.

5.4.2 Machine sieving When a machine is used for a sieving operation, the procedure shall be performed in accordance with 5.4.1. In this case, confirm that the same result as that of the manual sieving is obtained. For that purpose, it is necessary to perform the experiment for confirmation with regard to the amount of the sample to be charged, the mechanical shaking condition, etc., and to determine a proper procedure standard.

5.5 Expression of result

5.5.1 Calculation Calculate the mass of the size fraction retained on each of the different sieves as the percentage mass (%) of the total mass of the test sample. Record the percentages, to the nearest 0.1 %, both fractionally and cumulatively. In most cases it will be most convenient to commence with the fraction of largest size, but for a sample for which there is particular interest in the amount passing through the sieves, it may be preferred to start with the fraction of smallest size. If the analysis has been performed on a number of replicate samples, calculate the mean percentage of each size fraction. The style of expression of the particle-size analysis shall be as given in table 5.2.

Table 5.2 Style of expression of particle-size analysis

Shape of hole	Size fraction mm	Fractional mass		Cumulative mass	
		kg	%	kg	%
	+A -A+B -B+C -C				
Error					100.0
Total			100.0		

Remarks : A, B, and C are the hole size of the used sieve.

Adjust the mass of the smallest size fraction to take account of any loss or gain in the total mass of the test sample after sieving. If, however, in any test the loss or gain in mass exceeds 1 % of the total mass of the test sample, reject the results of that test.

If, during the course of a size analysis, the mass of undersize is reduced by sample division, calculate the mass of each of the subsequent fractions as the percentage mass of the total mass of undersize at the time of division. An example of the calculation of a size analysis involving sample division is given in table 5.3 and the sieving procedure is shown schematically in figure 5.1.

5.5.2 Graphical presentation The presentation of fractional size analyses in graphical form presents difficulties in interpretation, in that the size range of each fraction is seldom uniform. If graphical presentation is required, it is recommended that the cumulative percentage of material remaining on each sieve is plotted, as ordinate, against sieve aperture size, as abscissa.

Linear scales are not usually satisfactory except when the size range is less than two orders of 10. A logarithmic abscissa scale or a Rosin—Rammler type of plot should be used whenever possible. The ordinate for a Rosin—Rammler plot is $1 \log (1 \log 100 - 1 \log R)$, where R is the cumulative percentage of material remaining on each sieve, and the abscissa is the logarithm to base 10 of the sieve aperture size. None of the graphs should be extrapolated outside the experimental range. An example of a Rosin—Rammler plot, using the data in table 5.3, is given in figure 5.2.

5.6 Test report The test report shall include the following information:

- a) The identification and mass of the sample
- b) The standard title
- c) Details of any sample preparation carried out
- d) Details of the test sieves used
- e) The sieving [manual sieving (whether dry sieving or wet sieving was carried out), machine sieving]
- f) The percentage mass, or the mean percentage mass, in each size fraction
- g) If replicate sampling of an isolated consignment has been carried out, the precision achieved
- h) Any operation not included in this Standard, or regarded as optional
- i) The date of test

Table 5.3 Example of the calculation of a size analysis involving sample division

Sieve aperture size mm	Initial sample		First sample division		Second sample division		Third sample division		Size analysis	
	Mass kg	% of test sample	Mass kg	% of test sub- sample (1) (2)	Mass kg	% of test sub- sample (3) (4)	Mass kg	% of test sub- sample (5) (6)	Fractional %	Cumulative oversize %
63	19.5	3.1							3.1	3.1
45	32.1	5.1							5.1	8.2
31.5			8.0	8.3					7.6	15.8
22.4			13.1	13.6					12.5	28.3
16			10.8	11.2					10.3	38.6
11.2			14.0	14.5					13.3	51.9
8					561.7	21.8			10.5	62.4
5.6					545.6	21.2			10.2	72.6
4					379.8	14.8			7.1	79.7
2.8							88.7	32.5	6.6	86.3
2							56.4	20.7	4.2	90.5
1.4							41.7	15.3	3.1	93.6
1							34.9	12.8	2.6	96.2
<1									3.8	100.0
Total retained on sieves (A)	51.6	8.2	45.9	47.7	1 487.1	57.8	221.7	81.3	16.5	
Passing finest sieve (B)	576.4	91.5	50.2	52.1	1 079.7	42.0	50.0	18.3	3.7	
Sample used (C)	629.7	100.0	96.3	100.0	2 573.0	100.0	272.8	100.0	20.3	
Loss (D)	1.7	0.3	0.2	0.2	6.2	0.2	1.1	0.4	0.1	
Passing + loss (B + D)		91.8		48.1		20.3			3.8	
Reduction factor $F = (B + D) / 100$	$F_1 = 0.918$		$F_2 = 0.481$		$F_3 = 0.203$					

Remarks : The data in columns (2), (4) and (6) are obtained by multiplying the corresponding data in columns (1), (3) and (5), respectively, by the reduction factors F_1 , F_2 and F_3 .

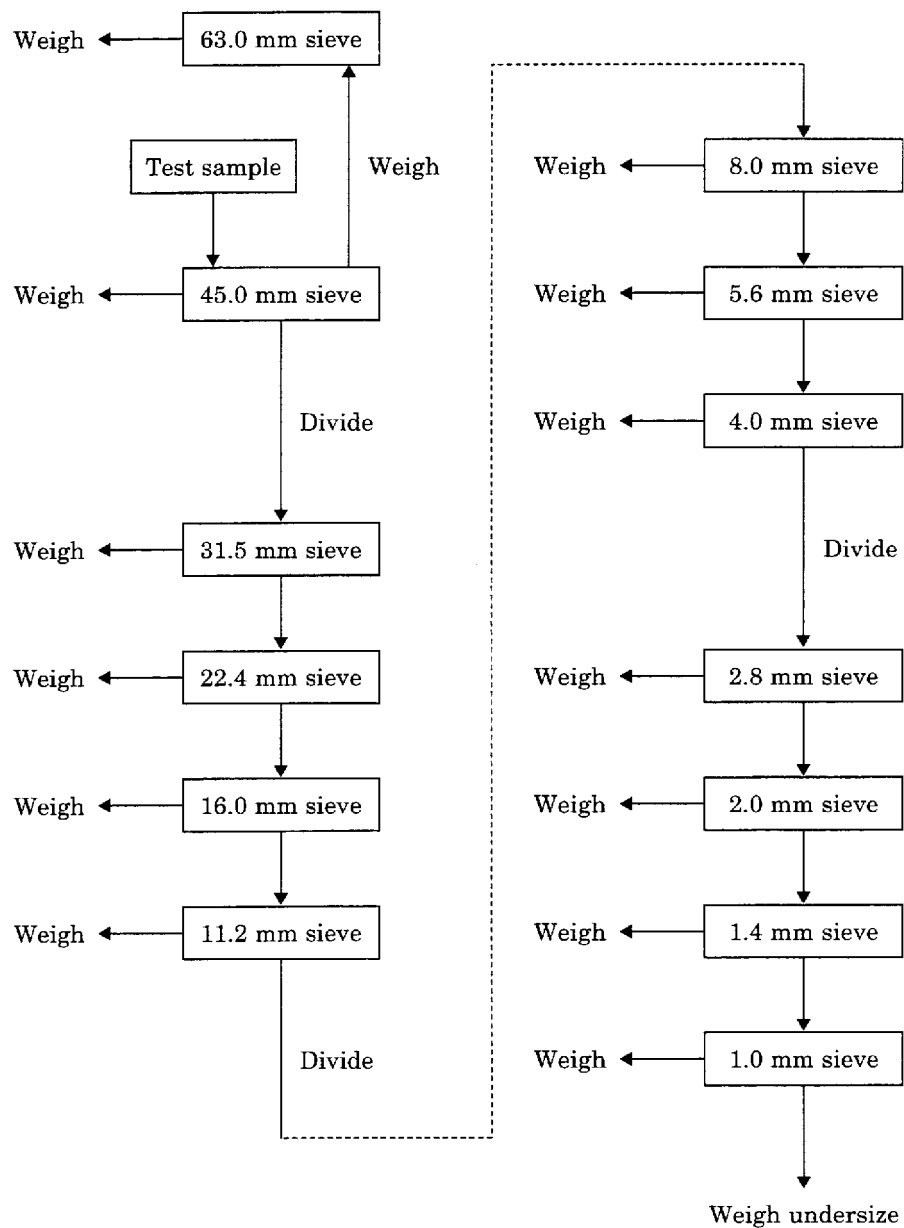


Figure 5.1 Schematic diagram of a sieving procedure including division

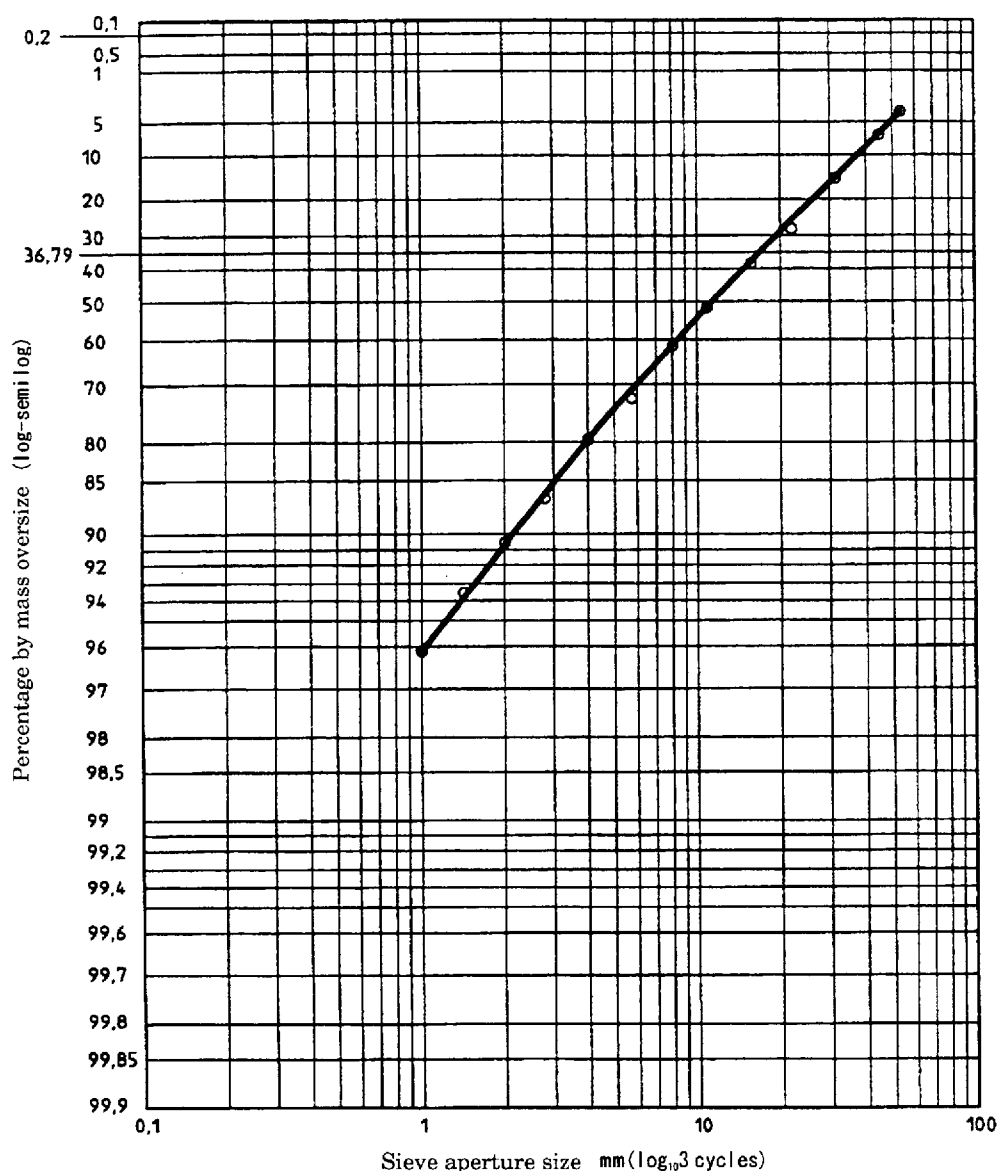


Figure 5.2 Rosin–Rammler plot

6 Method for determination of float and sink characteristics

6.1 Principle of test and measurement The sample is sequentially processed with the heavy liquid arranged according to the predetermined density, is separated into the float material and the sink material, respectively, and after dried, the mass is weighed and the component is measured, and the result is expressed as the washability curve.

6.2 Sample The sample shall be taken in accordance with JIS M 8811.

The sample which is taken shall be sieved, and usually tested every particle size. For the amount provided for the float and sink test, the amount of not less than that given in table 6.1 shall be used according to the particle size.

Table 6.1 Amount of sample

Particle size mm	250 to 125	125 to 63	63 to 31.5	31.5 to 16	16 to 8	8 to 4	4 to 2	2 to 1	1 to 0.5	0.5 to 0.063
Amount of sample kg	1 000	350	180	90	33	7	3	1.5	1.0	0.5

Remarks : The range of particle size is to be “not less than” the first figure and “less than” the latter.

6.3 Heavy liquid The relative density of heavy liquid shall be usually taken as the following eight kinds⁽¹⁾.

1.30, 1.40, 1.50, 1.60, 1.70, 1.80, 1.90, 2.0

An example of heavy liquid shall be given in table 6.2.

Table 6.2 An example of heavy liquid

Name of heavy liquid		Density	Viscosity at 20 °C mPa · s	Vapor pressure at 20 °C kPa	Flammable
Organic	Gasoline	0.73	0.548	25.33	Yes
	Kerosine	0.75	1.365	0.11	Yes
	Toluene	0.87	0.588	2.93	Yes
	Benzene	0.87	0.65	11.20	Yes
	Tetrachloroethylene	1.62	0.88	1.83	No
	1,1,2,2 tetra-bromoethane	2.96	12.0	0.01	No
Inorganic	Zinc chloride aqueous solution	1.96 (max.)	—	—	No

Note ⁽¹⁾ For a heavy liquid, 1.25, 1.35, 1.45, 1.55, 1.65, 1.75, etc. except for the above may be added as necessary.

- Remarks
- 1 When using an organic heavy liquid, attention shall be given to dissolution of coal.
 - 2 An organic heavy liquid and an inorganic heavy liquid shall not be used together for the same test.
 - 3 When reporting, the name of heavy liquid used shall be described together.
 - 4 Since benzene, tetrachloroethylene, and 1,1,2,2 tetra-bromoethane have environmental problems and are highly toxic, they should not be used as much as possible. Highly toxic carbon tetrachloride (density 1.59) was excluded from the example.
 - 5 It shall be note that the zinc chloride aqueous solution is corrosive, and when it enters pores of the sample, it becomes difficult to remove it.
 - 6 The setting of density shall be adjusted according to the mixing ratio of two liquids in the case of an organic heavy liquid, and the concentration in the case of an inorganic aqueous solution.

6.4 Apparatus The apparatus shall be as follows:

- a) **Densimeter** Capable of measuring the difference of density of 0.002.
- b) **Heavy liquid container** Unaffected by the heavy liquid, and convenient for use.
- c) **Scoop net** Unaffected by the heavy liquid, and convenient for use.

6.5 Procedure

6.5.1 Sieving test Prior to the float and sink test, the sample shall be sieved in accordance with clause 5. The sieve aperture at that time shall be in accordance with the specification given in table 6.1. However, this can be changed according to the purpose of test.

Remarks : All or part of the sample are crushed beforehand, and they can be taken as the sample under test. In that case, that is entered in the remarks column of sieving test result. For example, it is entered that +63 mm in the sample is ground to -63 mm and sieved, the arrival sample is ground to -250 mm and sieved, etc.

6.5.2 Float and sink test The float and sink test shall be as follows:

- a) Perform the procedure of a heavy liquid in order of as continuous density as possible.
- b) Perform the procedure of a heavy liquid at one density as follows⁽²⁾:
 - 1) Put the sample in a heavy liquid, stir calmly, and leave it standing until the float material and the sink material are separated.
 - 2) Separate the sink material from the heavy liquid after scooping the float material up.
 - 3) For the float material and the sink material necessary for processing with the next heavy liquid, repeat the procedure of 1) and 2) successively.
- c) For the float material and the sink material which finished the procedure of b), wash out the heavy liquid adhering to the sample, weigh the mass after drying at 35 °C or lower, and measure the ash content in accordance with clause 6 of **JIS M 8812**.

Note ⁽²⁾ For the procedure order of heavy liquid, the sample is easy to process if the procedure is performed in ascending order of relative density in the case of the sample with much low relative density matter, and in descending order of relative density in the case of the sample with much high relative density matter.

When the distribution of relative density of the sample is not known, after, to begin with, the sample is processed with the heavy liquid of middle relative density, the sample is easy to process if the procedure is performed in ascending order of relative density for the float material, and in descending order of relative density for processing the sink material.

- Remarks
- 1 For the cleaning of heavy liquid in the procedure of c), gasoline or toluene in the case of an organic heavy liquid, and hot water in the case of an inorganic heavy liquid are suitable.
 - 2 Since relative density will change if the heavy liquid is continuously used, it shall be checked every test with a specific gravimeter, and the range of the predetermined relative density shall be maintained within ± 0.002 .
 - 3 In the case of the sample of particle size of 4 mm or under, the sample is easy to process if the apparatus as shown in figure 6.1 is used.
 - 4 In the case of the sample of particle size of especially 0.5 mm or under, a centrifugal machine should be used.
 - 5 Care is needed in handling the heavy liquids since there are many heavy liquids which are harmful to a human body, and cannot be discarded as they are for environmental protection.

6.6 Washability curve

6.6.1 Kind of washability curve The float and sink test result shall be expressed with a washability curve. The washability curve has a HR curve and an M curve.

6.6.2 Calculation for plotting washability curve For the float and sink test result, the percentage mass (%) and the ash fraction (%) shall be calculated to be rounded to one decimal place together on the same base according to the procedure in table 6.3.

Table 6.3 Calculation table

Relative density fractions	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)
	Mass	Mass	Ash	Proportion of ash	Relative density	Cumulative floats			Cumulative sinks			Cumulative percentage mass until the middle point of mass every relative density fraction (%)
	kg	Percentage (%)	Percentage (%)	(b) × (c)		Proportion of ash	Mass	Percentage ash (%)	Proportion of ash	Mass	Percentage ash (%)	
						↓ Σ (d)	↓ Σ (b)	(f)/(g)	↑ Σ (d)	↑ Σ (b)	(i)/(j)	(g) - (b)/2
under 1.30					1.30							
1.30 to 1.40					1.40							
1.40 to 1.50					1.50							
1.50 to 1.60					1.60							
1.60 to 1.70					1.70							
1.70 to 1.80					1.80							
1.80 or over												
Total		100.0										

Remarks 1 (a) column to (l) column in the table shall be as follows:

- (a) Mass kg ... Actual measurement value
- (b) Percentage mass (%) ... Percentage of (a) (%)
- (c) Percentage ash (%) ... Actual measurement value
- (d) Proportion of ash ... (b) × (c)
Proportion of ash under the relative density fraction concerned per total sample 10 000 (% × %)
- (e) Relative density ... Set value
- (f) Proportion of ash of cumulative floats ... ↓ Σ (d)
Proportion of ash of cumulative floats at the relative density concerned (per total sample 10 000)
- (g) Percentage mass of cumulative floats (%) ... ↓ Σ (b)
Percentage mass of cumulative floats at the relative density concerned (%)
- (h) Percentage ash of cumulative floats (%) ... (f)/(g)
Percentage ash of cumulative floats at the relative density concerned (%)

- (i) Proportion of ash of cumulative sinks ... $\uparrow \Sigma(d)$
Proportion of ash of cumulative sinks at the relative density concerned (per total sample 10 000)
- (j) Mass of cumulative sinks ... $\uparrow \Sigma(b)$
Percentage mass of cumulative sinks at the relative density concerned (%)
- (k) Percentage ash of cumulative sinks (%) ... $(i)/(j)$
Percentage ash of cumulative sinks at the relative density concerned (%)
- (l) Middle point of mass every relative density fraction ... $(g)-(b)/2$
Median value of mass of the relative density concerned [cumulative percentage mass from the cumulative floats side (%)]

2 In the symbol in the table, $\downarrow \Sigma$ means summation from the top, and $\uparrow \Sigma$ means summation from the bottom.

6.6.3 Method for plotting HR curve The HR curve consists of a characteristic ash curve, a cumulative floats curve, a cumulative sinks curve, a densimetric curve, and a ± 0.1 relative density distribution curve (see figure 6.2). Take percentage ash (%) as the abscissas showing these curves with the left end set as 0 and the right end set as 100, percentage mass (%) of cumulative floats as the ordinate with the top end set as 0 and the bottom end as 100 in the left end, percentage mass (%) of cumulative sinks as the ordinate with the top end set as 0 and the bottom end as 100 in the right end.

- a) The characteristic ash curve ① is the curve connecting many points which show the relation between (c) and (l) of table 6.3 and indicates the percentage ash (%) of the maximum ash particle contained in the cumulative floats.
- b) The cumulative floats curve ② is the curve connecting many points which show the relation between (g) and (h) of table 6.3 and indicates the mean percentage ash (%) to the percentage mass (%) of cumulative floats.
- c) The cumulative sinks curve ③ is the curve connecting many points which show the relation between (j) and (k) of table 6.3 and indicates the mean percentage ash (%) to the percentage mass (%) of cumulative sinks.
- d) The densimetric curve ④ is the curve connecting many points which show the relation between (e) and (g) of table 6.3 and indicates the percentage mass (%) of cumulative floats and cumulative sinks at an arbitrary relative density.
- e) The ± 0.1 relative density distribution curve ⑤ is the curve connecting many points which show the relation between relative density (e) and the percentage mass (%) within the range of ± 0.1 of that relative density and the magnitude of the percentage mass (%) expresses the degree of difficulty of selection.

Remarks 1 The characteristic ash curve and the cumulative floats curve draw a curve so that they converge on one point at mass 0 of cumulative floats, and the characteristic ash curve and the cumulative sinks curve draw a curve so that they converge on one point at mass 0 of cumulative sinks.

- 2 ○ mark is put on many points obtained by the calculation table on each curve.

6.6.4 Method for plotting M curve (see figure 6.3) The M curve expresses the mass and the ash every relative density fraction with a vector. Although the percentage ash (%) is taken as the abscissas with the left end set as 0 and the right end set as 100, since it is inconvenient for handling to graduate until 100 % on the abscissas, the area ahead of the suitable graduation (however, the point of not less than the mean percentage ash of the sample) is folded back in the upper direction of the graph.

The cumulative mass is taken as the ordinate with the top end set as 0 and the bottom end set as 100.

The M curve is the curve which shows the relation between (f) [actually, (f)/100] and (g).

Remarks 1 The intersection of the M curve and the abscissa axis expresses the mean percentage ash of the sample.

2 ○ mark is put on many points obtained by the calculation table on each curve.

6.6.5 Presentation of test results The presentation of test results shall be as follows:

- a) The example of presentation of sieving test results shall be shown in table 6.4.
- b) The example of float and sink test results shall be shown in figure 6.2 and figure 6.3.

Table 6.4 Example of presentation of sieving test results

Sieving test results

Sample name	△△ coal preparation plant acceptance sample
Sampling date	May 27, 1987, From 9:00 a.m. to 3:00 p.m.
Test implementation date	May 28, 1987
Base	Air dry
Remarks	Crush +63 mm to -63 mm, and screen.

Size fraction mm	Percentage mass %	Percentage ash %	Cumulative value	
			Percentage mass %	Percentage ash %
63 to 31.5	24.7	45.6	24.7	45.6
31.5 to 16	27.5	36.4	53.5	40.8
16 to 8	24.2	29.0	76.4	37.0
8 to 4	9.4	27.9	85.8	36.0
4 to 2	4.3	25.8	90.1	35.5
2 to 1	4.3	20.9	94.4	34.9
1 to 0.5	3.3	21.2	97.7	34.4
-0.5	2.3	25.7	100.0	34.2
Total	100.0	34.2	—	—

Unit: mm

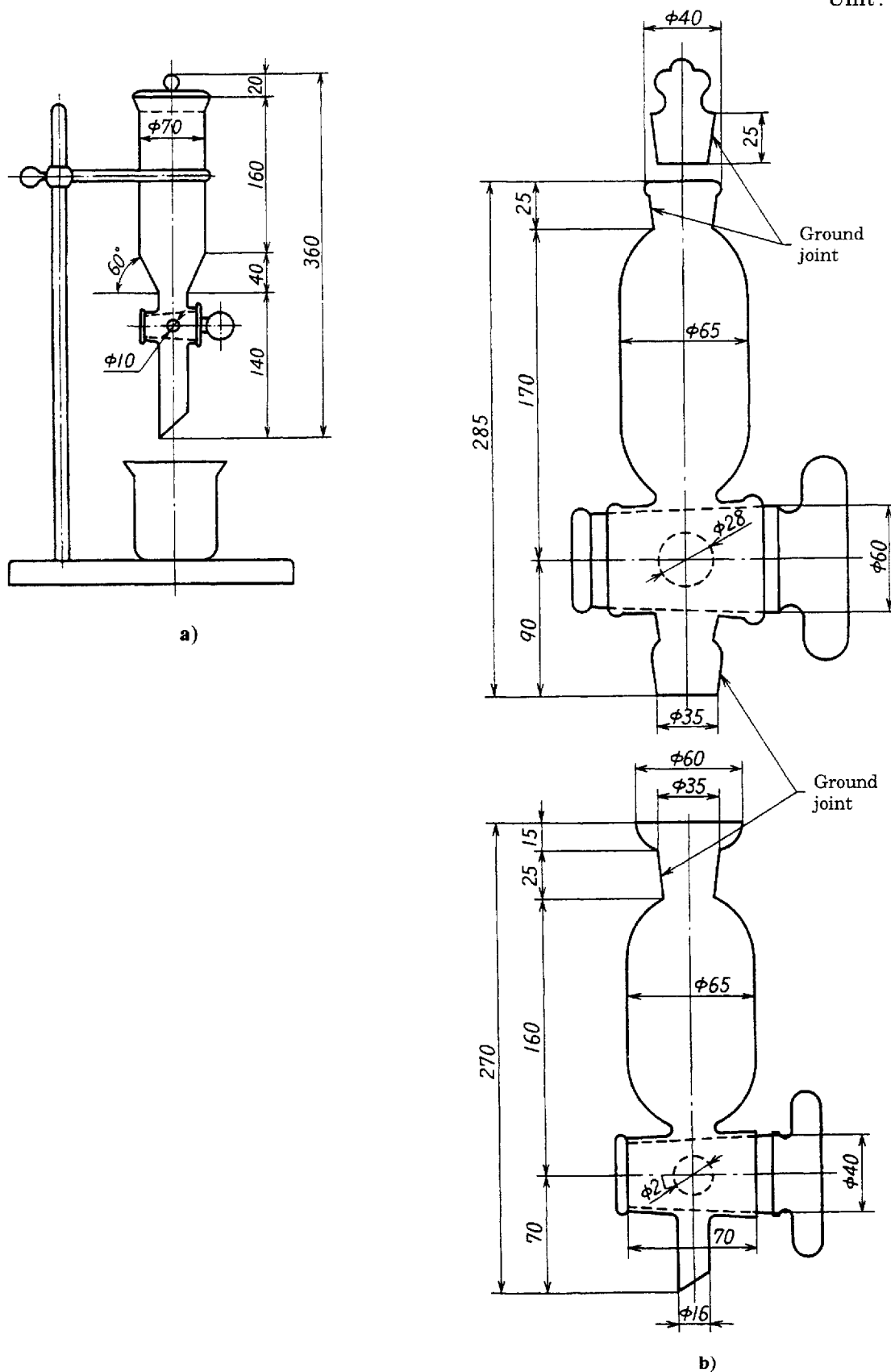
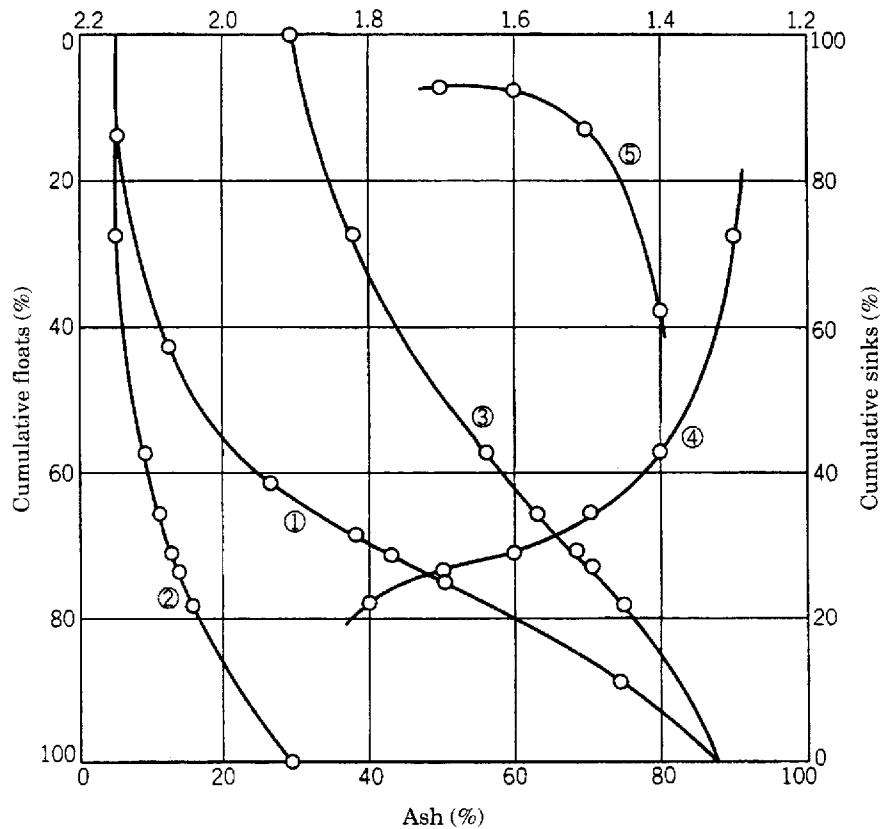


Figure 6.1 Float and sink test apparatus (example)

Float and sink test result

Sample name	△△ coal preparation plant acceptance sample		
Sampling date	May 27, 1987	Test date	Jun 5, 1987
Particle size	16 mm to 8 mm	Base	Air dry
Remarks	Heavy liquid: tetrachloroethylene, gasoline, 1,1,2,2 tetra-bromoethane		



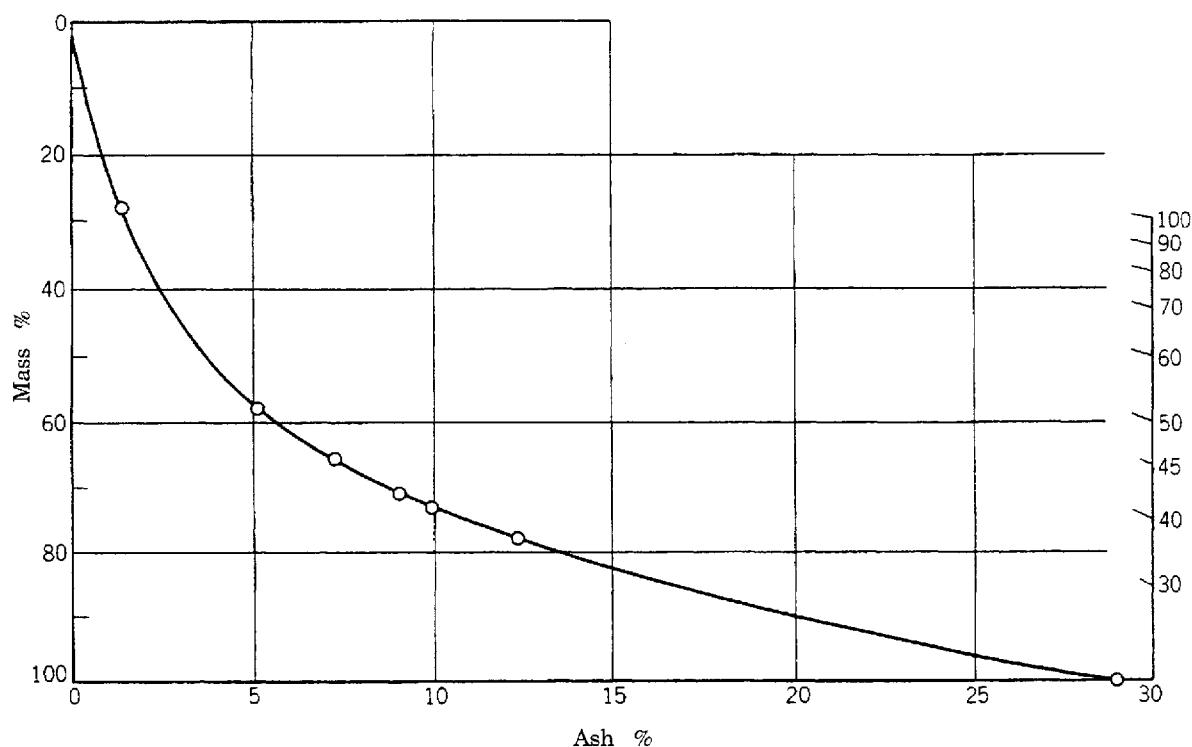
- ① Characteristic ash curve ② Cumulative floats curve ③ Cumulative sinks curve
④ Densimetric curve ⑤ ± 0.1 relative density distribution curve

Relative density fractions	Mass kg	Percent- age mass %	Percent- age ash %	Cumulative floats		Cumulative sinks		Cumulative percentage mass until the middle point of mass every relative density fraction %
				Percent- age mass %	Percent- age ash %	Percent- age mass %	Percent- age ash %	
under 1.30	10.54	27.6	5.1	27.6	5.1	72.4	38.1	13.8
1.30 to 1.40	11.50	30.1	12.4	57.7	8.9	42.3	56.3	42.7
1.40 to 1.50	3.02	7.9	26.3	65.6	11.0	34.4	63.2	61.7
1.50 to 1.60	1.95	5.1	34.1	70.7	12.7	29.3	68.3	68.2
1.60 to 1.70	0.88	2.3	41.3	73.0	13.6	27.0	70.6	71.9
1.70 to 1.80	1.80	4.7	50.7	77.7	15.8	22.3	74.8	75.4
1.80 or over	8.51	22.3	74.8	100.0	29.0	—	—	88.9
Total	38.20	100.0	29.0					

Figure 6.2 Example of presentation of float and sink test result (HR curve)

Float and sink test result

Sample name	△△ coal preparation plant acceptance sample		
Sampling date	May 27, 1987	Test date	Jun 5, 1987
Particle size	16 mm to 8 mm	Base	Air dry
Remarks	Heavy liquid: tetrachloroethylene, gasoline, 1,1,2,2 tetra-bromoethane		



Relative density fractions	Mass kg	Percent- age mass (a) %	Percent- age ash (b) %	Proportion of ash (a) × (b)	Cumulative floats		
					Proportion of ash	Percent- age mass %	Percent- age ash %
under 1.30	10.54	27.6	5.1	140.76	140.76	27.6	5.1
1.30 to 1.40	11.50	30.1	12.4	373.24	514.00	57.7	8.9
1.40 to 1.50	3.02	7.9	26.3	207.77	721.77	65.6	11.0
1.50 to 1.60	1.95	5.1	34.1	173.91	895.68	70.7	12.7
1.60 to 1.70	0.88	2.3	41.3	94.99	990.67	73.0	13.6
1.70 to 1.80	1.80	4.7	50.7	238.29	1 228.96	77.7	15.8
1.80 or over	8.51	22.3	74.8	1 668.04	2 697.00	100.0	29.0
Total	38.20	100.0	29.0	2 897.00			

Figure 6.3 Example of presentation of float and sink test result (M curve)

7 Method for determination of Hardgrove grindability indices (Hardgrove method)

7.1 Principle of test and measurement After the predetermined sample is ground with a testing machine, it is screened with the predetermined sieve, the mass of undersize is weighed, and the value calculated according to the empirical formula is expressed as Hardgrove grindability index (abbreviation: HGI).

7.2 Sample The sample prepared by sampling and drying in accordance with JIS M 8811, or by preliminarily grinding⁽³⁾ the sample reduced in accordance with JIS M 8811 to a size of 4.75 mm or less and then grinding to a size of 1.18 mm to 600 μm and screening⁽⁴⁾ shall be taken as the sample under test.

Notes ⁽³⁾ This grinding is for preventing the overgrinding of a sample, and a non-impact type grinder should be used.

⁽⁴⁾ Even for the particle-sized grinding, the non-impact type grinder should be used. In that case, the gap between grinding gear teeth shall be able to be adjusted. Grind the sample by adjusting the gap between grinding gear teeth to 2 to 3 steps (for example, 3 mm, 2 mm, 1 mm), screen with sieves of 1.18 mm and 600 μm in each case, next grind the oversize remained on a sieve of 1.18 mm repeatedly, and grind and screen repeatedly with the gap between grinding gear teeth in the final step (for example, 1 mm) until all samples pass the sieve of 1.18 mm. The sample of a size of $-1.18 \text{ mm} + 600 \mu\text{m}$ shall be taken as the sample under test, and the undersize passing a sieve of 600 μm shall be discarded.

Furthermore, for screening on this occasion, the time required for screening shall be 2 min or so in the case of machine sieving.

Remarks : For the particle-sized grinding, the desktop small coffee mill type grinder, the Brown crusher, etc. are suitable as a non-impact type grinder.

7.3 Apparatus

7.3.1 Hardgrove grindability machine (see figure 7.1) The test shall be performed using the standard sample in information of **7.3.3**, and the machine having the function in which the measured value becomes the value shown in the sample shall be used.

- a) **Grinding bowl and top grinding ring** (see figure 7.2) The hardness of material of the shaded portion shown in the figure of grinding bowl and top grinding ring shall be equivalent to that of the ball of **b)**, and the near dimensions and the wall surface finishing shall be as shown figure 7.2.
- b) **Ball** A steel ball of 25.4 mm in diameter. Eight pieces are used for the test.
- c) **Load** The mass of each part equivalent to the load of not less than the sum of $284 \text{ N} \pm 2 \text{ N}$ shall be as follows.

Dead weight (made of lead or iron) 26.0 kg

Gear and shaft	2.0 kg
Top grinding ring	1.0 kg

d) **Number of revolutions and rotation speed**

Number of revolutions	60 revolutions (allowable number of revolutions: 1/4 revolutions)
Rotation speed	15 rev/min to 20 rev/min

- e) **Counter** It shall be actuated so that it is capable of stopping automatically at 60 revolutions.

7.3.2 Sieve The sieve of 4.75 mm, 1.18 mm, 600 μm , and 75 μm of which each internal diameter above the sieve surface is usually 200 mm specified in attached table 1 and attached table 2 of **JIS Z 8801-1**, and each height of frame from the sieve surface is 45 mm shall be used.

In addition, the sieve of 75 μm of which the gap between the sieve surface and the frame is filled with solder and suitable synthetic resin adhesives shall be used.

7.3.3 Sieving machine The low tap shaker with the following approximate performance shall be used.

Horizontal movement	About 300 times per min
Stroke width	25 mm to 30 mm
Number of times of stroke	About 150 times per min
Mass of hammer	1.9 kg
Stroke height	About 28 mm

Information : The standard sample of not less than 80 of Hardgrove grindability index given in **ISO 5074 : 1980** is used as the standard sample for inspection of the testing machine. The above-mentioned standard sample is also given in **ASTM D-409-71**.

7.4 Procedure The procedure shall be performed as follows:

- Take 50 g from the sample prepared in **7.2**, put it into the grinding bowl in which eight balls were put beforehand, and level off the sample surface.
- Next, put the top ring on the ball, and fix the grinding bowl to the testing machine with two screw threads with the bottom end of shaft in agreement with the cross groove of top grinding ring.
- Set so that the counter stops at 60 revolutions, and turn on the starter switch.
- After the machine stops automatically at 60 revolutions, put the sample into the oversize on the 75 μm sieve⁽⁵⁾.
- Perform the sieving of the ground sample for 20 min of a total of 10 min plus 5 min plus 5 min using the sieving machine with the 75 μm sieve⁽⁶⁾.

- f) For the sieved sample, weigh the mass of the oversize remaining on the 75 μm sieve to the nearest 0.01 g⁽⁷⁾, subtract this value from 50 g to take as the undersize passing the 75 μm sieve, and take it as W .

Notes ⁽⁵⁾ The operation becomes easy to perform if the sieve of larger hole size (about 4.75 mm used on the occasion of sample preparation) is laid on top of the 75 μm sieve beforehand, the balls and the ground sample are directly inserted on it, and the balls are separated from the sample.

In addition, at this time, the sample remained in the grinding bowl, and the sample adhered to the balls on the sieve, the overlaid sieve, etc. are transferred on the 75 μm sieve.

- ⁽⁶⁾ After performing sieving for 10 min at first, clean the 75 μm sieve with the brush, again perform sieving for 5 min, clean the sieve, and perform sieving for 5 min once again.
- ⁽⁷⁾ Especially, promptly weigh coal containing much moisture of the analysis sample.

7.5 Calculation of measured value The Hardgrove grindability index (HGI) shall be calculated to one decimal place according to the following formula, and rounded to an integer in accordance with JIS Z 8401.

$$\text{HGI} = 13 + 6.93W$$

7.6 Number of times of tests The test shall be performed repeatedly twice in the same laboratory, and when the difference between the measured values of 2 pieces is within the tolerance ($n = 2$) in 7.7, the measured values of 2 pieces shall be taken. However, when the difference between the measured values of 2 pieces is more than the tolerance ($n = 2$), further the one-time test shall be additionally performed.

7.7 Repeatability limit The repeatability limit in the same laboratory shall be as given in table 7.1.

Table 7.1 Tolerance

Hardgrove grindability index (average value)	$n = 2$	$n = 3$
Under 50	1.0	1.2
50 or over to and excl. 75	1.5	1.8
75 or over	2.0	2.4

7.8 Report value For the report value, when the range (the maximum value – the minimum value) of measured values of 2 pieces or 3 pieces repeatedly tested is within the tolerance ($n = 2$) or ($n = 3$) in 7.7, the average value of measured values of 2 pieces or 3 pieces shall be rounded to one decimal place and expressed as HGI. However, when the range (the maximum value – the minimum value) of the measured values of 3 pieces is more than the tolerance ($n = 3$), the median value of the measured values of 3 pieces shall be expressed in the same way as the above leaving the one decimal digit as it is and that (median value) shall be described together.

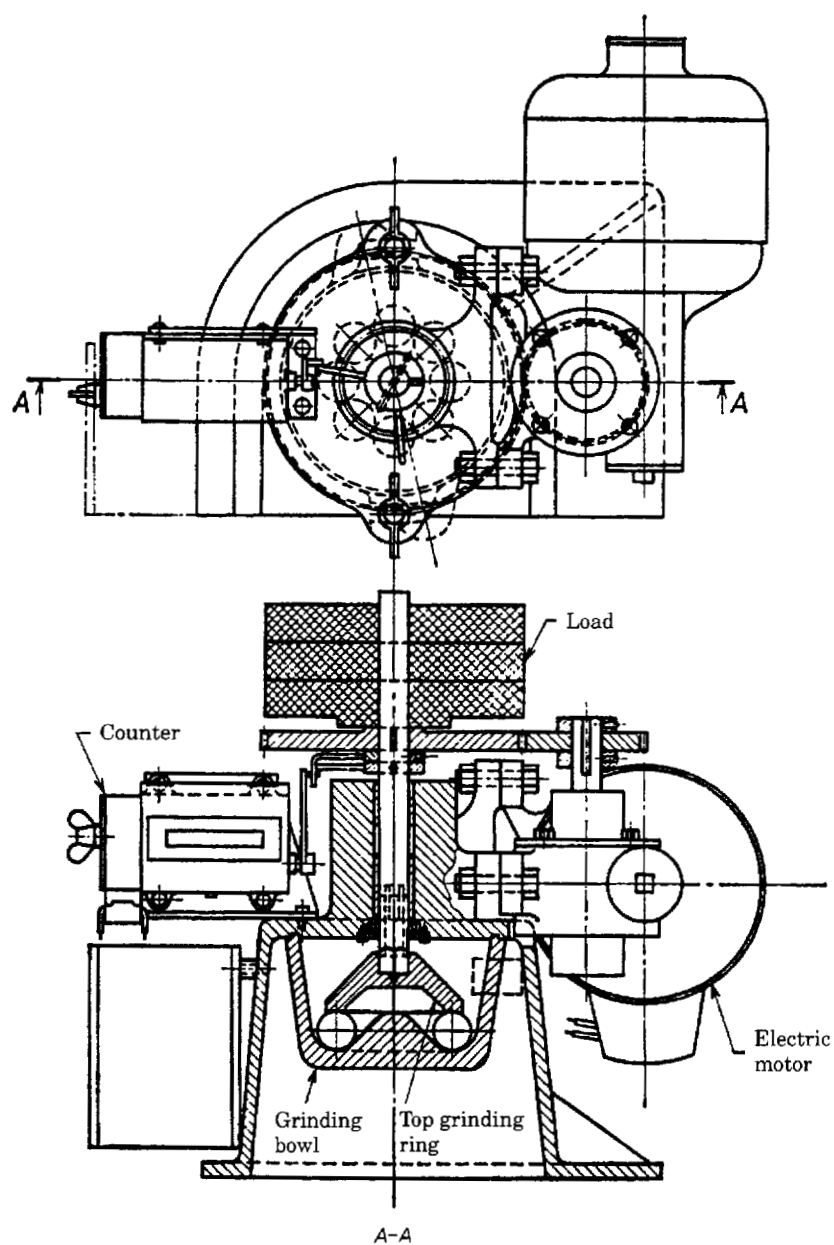


Figure 7.1 Hardgrove grindability machine