Designation: E 959 – 83 (Reapproved 1999)

Standard Test Method for Characterizing the Performance of Refuse Size-Reduction Equipment[1]

This standard is issued under the fixed designation E 959; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers measuring the performance of solid waste size reduction equipment.

1.2 This test method can be used to measure the flow (that is, throughput) of solid waste through the size-reduction equipment, energy usage of the size-reduction device, and particle size of the shredded product.

1.3 This test method includes instructions for measuring energy usage, solid waste throughput, net processing time, and particle size distribution.

1.4 This test method applies only to size reduction equipment that produces a shredded product with a size corresponding to 90 % cumulative passing in the range of 0.5 to 15 cm (0.2–6 in.) on an air-dry weight basis. For material with nominal sizes outside of this range, the precision and bias statements for particle size designation (Section 14) may not apply.

1.5 This test method can be applied to size reduction equipment located anywhere within a processing line.

1.6 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.7 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* See Section 7 for specific hazard information.

2. Referenced Documents

2.1 *ASTM Standards:*

E 828 Test Method for Designating the Size of RDF-3 From Its Sieve Analysis[2]

E 929 Test Method for Measuring Electrical Energy Requirements of Processing Equipment[2]

3. Terminology *Definitions:*

3.1 *characteristic product size*—the screen size corresponding to 63.2 % cumulative passing by weight.

3.2 *discrete throughput method*—the method whereby average throughput is calculated as the average of a number of discrete throughput measurements conducted during a test period.

3.3 *idling time*— time periods during which a size reduction device is freewheeling, that is, not processing refuse.

3.4 *net processing time*—the time during which refuse is processed through the size reduction device.

3.5 *nominal product size*—the screen size corresponding to 90 % cumulative passing by weight.

3.6 *size reduction device or equipment*—a device which size reduces (Synonyms: shredder, grinder, pulverizer, and mill).

3.7 *stationary belt method*—a method of gross sample collection in which the conveyor belt is stopped and the sample of material is removed manually.

3.8 *time-averaged throughput method*—the method whereby the average throughput is calculated by dividing the total mass size reduced by the net processing time.

3.9 *test interval*— a test interval is equal to one-quarter of the test period.

3.10 *test period*— the test period is two to four continuous h of net-processing time.

4. Summary of Test Method

4.1 The duration of the test period is established and refuse is prepared for processing.

4.2 An energy measuring system is installed.

4.3 Solid waste is processed through the size reduction equipment, energy usage and throughput is measured, and samples for analysis of product particle size distribution are collected.

4.4 Average throughput, power requirements, specific energy, and particle size of the shredded product are calculated.

4.5 Two methods (Time-Averaged Throughput Method and Discrete Throughput Method [Section 10]) for measuring the performance of size reduction equipment are described. The selection of a particular method is governed by the layout of the processing equipment, the location of the size-reduction equipment relative to the other processing equipment, and the preference of the parties conducting the test.

5. Significance and Use

5.1 Throughput, power and energy requirements, and product size are key parameters that describe the operation and

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[1] This test method is under the jurisdiction of ASTM Committee D-34 on Waste Management and is the direct responsibility of Subcommittee D34.06 on Recovery and Reuse.

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[2] *Annual Book of ASTM Standards*, Vol 11.04.

performance of solid waste size-reduction equipment.

5.2 This test method can be used to determine if the size-reduction equipment is operating within specifications and meeting performance criteria.

5.3 Having determined the parameters given in 5.1, the equipment that has been subjected to the test may be compared to other equipment similarly tested in order to establish relative levels of performance among equipment.

5.4 The basic test period is a continuous two to four h duration. The use of several test periods may be warranted to assess adequately the performance of size reduction equipment.

6. Apparatus

6.1 *Hand Broom*.

6.2 *Dust Pan*.

6.3 *Wide-mouthed Shovel*.

6.4 *Clock or Stopwatch*, accurate to 0.1 s.

6.5 *Plastic Bags*, large containers, or both.

6.6 *Push-broom*.

6.7 *Ties and Labels*.

6.8 *Electrical Metering System*.

6.9 *Sieving Equipment*, manual or mechanical.

7. Hazards

7.1 The test procedure described in 11.4 requires the removal of shredded material from a stopped conveyor belt by test personnel. Precautions should be taken to ensure that the belt cannot be started while occupied. These precautions consist of lockout of the electrical power to the conveyor, ready access to a safety "stop" cord located on the conveyor, or both.

7.2 This test method requires installation of electrical metering equipment. Consequently, the precautions described in Test Method E 929 should be observed.

7.3 Gross samples should be collected sufficiently far from the size reduction equipment such that test personnel are protected from potential explosions and flying objects from the equipment.

8. Equipment Calibration

8.1 All electrical metering equipment used for energy measurement shall be calibrated in accordance with Test Method E 929.

8.2 All weight-measuring equipment shall be calibrated according to the manufacturer's instructions.

9. Preparation for Test

9.1 *Refuse Preparation and Establishment of Test Intervals*—The duration of the test period is to be a minimum of 2 h and a maximum of 4 of net-processing time. During the test period, collect four gross samples of shredded product from which subsamples for particle size distribution analysis will be taken subsequently. The test period is divided into four equal test intervals (that is, test intervals 1, 2, 3, and 4). Calculate the approximate duration of the test intervals using the following relation:

$$t_i^* \simeq \frac{t_p^*}{4} \tag{1}$$

where:

t_p^* = estimate of the duration of the test interval (h), and

t_p^* = estimated duration of the test period (h), subject to the condition $2\ \text{h} \leq t_p^* \leq 4\ \text{h}$.

Weigh refuse, uniformly mixed as much as possible, and form into four discrete piles, each of which has an approximate (nominal) weight as calculated by the following relation:

$$M_i^* \simeq \frac{\dot{m}^* t_i^*}{4} \tag{2}$$

where:

M_i^* = approximate weight of the refuse pile in Mg,

$\dot{m}^*$ = nominal throughput value (Mg/h) established for the test, and

t_i^* = estimated duration of the test interval (h) derived from Eq 1.

The measured weight of each pile (M_i) is to be within ± 5 % of the nominal weight (M_i^*). Record the weight of each pile on the sample data form shown in Fig. 1.

9.2 *Time Measurements and Logbook*—Keep a time log during the conduct of the test program, the primary purpose of which is to allow the calculation of net-processing time. A sample format for the log is shown in Fig. 2.

9.2.1 The key time recordings for each time interval are as follows:

9.2.1.1 Starting time of the time interval,

9.2.1.2 Starting time of idling periods in which the size reduction device is electrically energized but in which no size reduction of refuse is occurring,

Pile No.	Weight of Pile, M_i(Mg)
1	
2	
4	
Total, M:	
5	
6	
7	
8	
Total, M:	
9	
10	
11	
12	
Total, M:	
13	
14	
15	
16	
Total, M:	
17	
18	
19	
20	
Total, M:	

FIG. 1 Sample Data Sheet for Throughput Measurement Using the Time-Averaged Throughput Method

Site: ______________________________
Type of Size
Reduction Device: ______________________
Model No.: ___________________________
Serial No.: ___________________________

Date: ______________________________
Recorded By: __________________________
Test Period No.: ________________________
Test Interval No.: _______________________

Time	Description of Activity/Reason for Shutdown	(A) Shredding Time, Δt_s(h)	(B) Idling Time, Δt_x[A] (h)	(C) Shredder Shutdown, Δt_y[B] (h)
Totals				

[A] Power on to size reduction equipment, but no processing of material.

[B] Power off to size reduction equipment.

FIG. 2 Time Log for Testing Size Reduction Equipment

9.2.1.3 Starting time of any periods in which the size reduction device is electrically shut down (de-energized), and

9.2.1.4 Finishing time of the test interval.

9.2.2 In order to obtain representative test data, it is recommended that the net-processing time be a minimum of 75 % of the duration of the test period. For example, if a four-h test period is chosen, the net processing time should be equal to or greater than three h.

9.3 *Setup and Use of the Energy Measuring Equipment*—Measure energy usage of the size reduction device during the test period using Test Method E 929. Use a rotating disk-type wattmeter or equivalent as the measuring instrument. Install and test the energy measuring equipment prior to initiating the test period.

10. Time-Averaged Throughput Method Procedure:

10.1 The Time-Averaged Throughput Method may be used in those instances where there is no stream-splitting apparatus upstream of the size-reduction device, for example, there is no pre-trommel screen upstream of the size-reduction device.

10.2 After an initial one-half hour warmup period during which refuse is shredded and the power measuring equipment is functioning, allow the shreading device to empty. Subsequent to its emptying, measure the initial freewheeling power draw while the machine is idling using a rotating disk-type wattmeter, as described in Test Method E 929. Record measurements in accordance with Fig. 2, Energy Measurement Data Sheet of Test Method E 929.

10.3 After completion of the initial freewheeling power measurements and at the onset of the first time interval, note the starting time and record on the time log (Fig. 2). Record the initial wattmeter reading in accordance with Fig. 2, Energy Measurement Data Sheet of Test Method E 929. Simultaneously, initiate the processing of one of the four pre-weighed piles of refuse. Make every reasonable effort to supply a constant flow of refuse into the size-reduction device. The measured duration of the test interval is to be within ±10 % of that estimated for t_i* in Eq 1.

10.4 Approximately midway through the first time interval of the test period, collect a representative gross sample for product particle size analysis downstream of the shredder discharge. The appropriate weight of the gross sample is as indicated in Fig. 3.

10.5 The preferred method of collection for the gross sample is through diversion of the entire cross section of the shredded refuse stream into a collection container or through collection of the entire cross section of the stream at a conveying transition point. Where neither of the two preferred methods of collection can be employed, the collection of a partial stream sample may be substituted. If partial stream sampling is used, make a notation on the data sheet used for recording the weights of gross and laboratory samples (Fig. 4) and the data sheets used to record particle size distribution data (Fig. 5).

10.6 Weigh the gross sample and store in a waterproof container or bag until the representative laboratory samples are chosen. Record weight data on the data sheet shown in Fig. 4.

10.7 At the conclusion of the time interval, note the time and record the reading on the time log.

10.8 Collect the second, third, and fourth gross samples for product particle size analysis approximately midway into the second, third, and fourth test intervals, respectively, of the test period, following the procedures in 10.4 through 10.7 . Note and record on the time logs the starting times of the subsequent test intervals.

10.9 Following the fourth time interval and immediately upon size reducing the remainder of the fourth pile of refuse, note the time and record the final wattmeter reading on Table X4 of Test Method E 929. After the final wattmeter reading has been noted, measure the final freewheeling power draw and record the data in Fig. 2, Energy Measurement Data Sheet of Test Method E 929.

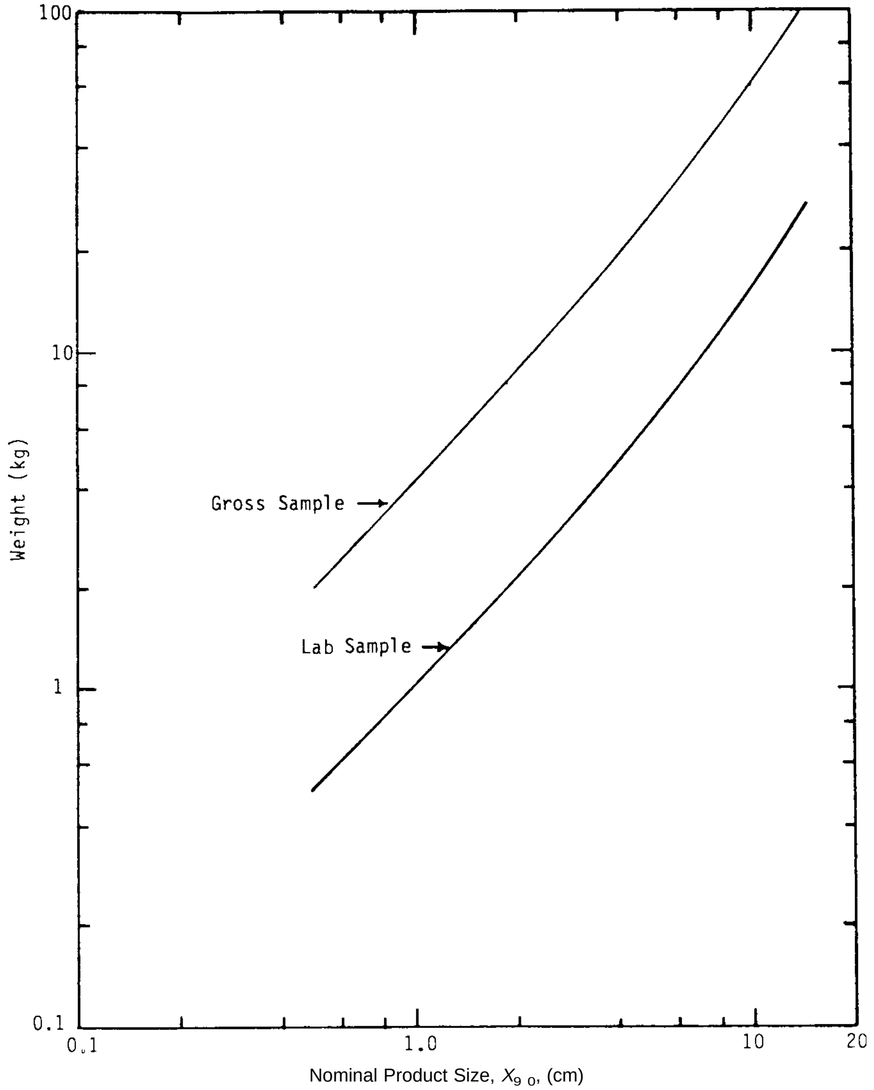

FIG. 3 Weight Requirements for Gross and Lab Samples as a Function of Nominal Product Size

11. Discrete Throughput Method Procedure

11.1 The Discrete Throughput Method is used in those instances where splitting of the raw refuse stream occurs prior to its entering the size-reduction device, for example, in those systems where a pre-trommel screen is located upstream of the size-reduction device.

11.2 Follow the procedures in 10.2 through 10.4 . The preferred method of collection of the gross sample is by diversion of the entire cross section of the shredded refuse stream into a collection container or through collection of the entire cross section of the stream in free fall at a conveying transition point. Use a stopwatch to measure the time during which the throughput sample is being collected.

11.3 Weigh and store the gross sample in a waterproof container or bag until the representative laboratory samples are chosen. Record the weight of the throughput sample and the elapsed time of sample collection on the data sheet shown in Fig. 6.

11.4 Where neither of the methods of 11.2 (that is, diversion of the entire cross section of the process stream) can be employed, collect throughput samples from a suitable length of conveyor belt downstream of the shredder discharge, using the Stationary Belt Method. Simultaneously stop both the shredder infeed conveyor and the belt from which the throughput sample is to be taken. After the conveyors are stopped, collect and remove the shredded material from a measured length of the belt. The weight of material to be removed will be approximately as indicated in Fig. 3.

11.5 Immediately prior to stopping the belt for the purpose of collecting the throughput sample, note the time and record the reading on the time log, Fig. 2.

11.6 Weigh the gross sample and store in a waterproof container or bag until the representative laboratory samples are chosen. Record the weights and conveyor information on the data sheet shown in Fig. 7.

11.7 After removal of the gross sample, start the conveyor and begin shredding refuse. Note the time and record the reading on the time log.

11.8 Repeat the procedures in 11.5 through 11.7 for the second, third, and fourth test intervals.

11.9 Immediately at the conclusion of the fourth test interval, note the final time reading and record it on the time log. In

Test Interval No.	Weight of Gross Sample (kg)	Weight of Laboratory Sample (kg)
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		
23		
24		
25		
26		
27		
28		

FIG. 4 Sample Data Sheet for Recording Weights of Gross and Laboratory Samples

addition, note and record the final wattmeter reading in Fig. 2, Energy Measurement Data Sheet of Test Method E 929. After the final meter reading is recorded, make and record the final freewheeling power measurements in Fig. 2, Energy Measurement Data Sheet of Test Method E 929 in accordance with the procedures described in Test Method E 929.

12. Analyzing Laboratory Samples

12.1 Take the laboratory samples for particle size determinations from the gross samples using the following procedures for cone-and-quartering of the material:

12.1.1 Empty the contents of the container or bag containing the gross sample onto a clean, smooth, and level surface.

12.1.2 Using a wide-mouthed shovel, form the gross sample into a symmetrical cone, uniformly mixing the material as the cone is formed.

12.1.3 Using the blade of the shovel, carefully partition the cone of material into one-quarter segments. Use a vertical as well as a sideways motion of the blade to promote the separation of the one-quarter segments. Cut the cone completely to the bottom of the pile.

12.1.4 Select two one-quarter segments that are 180° opposite each other, weigh and bag each in a waterproof bag, and label them. In collecting the one-quarter segments, take care to gather all of the material, including dirt and glass fines. The weight of the laboratory samples should be approximately as shown in Fig. 3.

12.1.5 Two laboratory samples (that is, twin samples) are subsampled from each gross sample. Subject at least one representative laboratory sample from each test interval to the procedures for particle size analysis. The twin laboratory sample may also be analyzed for particle size distribution. Subject all laboratory samples to air drying to constant weight, label, seal in a waterproof bag, and retain for later analysis in accordance with 12.1.6 and 13.3.1.

12.1.6 The particle size distribution of the laboratory samples are determined using Test Method E 828. A data sheet for recording particle size data is shown in Fig. 5. Conduct the sieve analysis on the shredded material after it has been subjected to air drying. Report the air-dry moisture content on the size distribution data sheet.

12.2 *Reduction of Energy Data*—Calculate the results of the energy measurements using the procedures in the section on Calculations of Test Method E 929.

13. Calculation

13.1 *Time Measurements*:

13.1.1 *Net-Processing Time*—The net-processing time for the test period (T_n) is the sum of the net-processing times for each of the four test intervals:

$$T_n = \sum_{j=1}^{4} \left(\sum_{i=1}^{n} (\Delta t_s)_i \right)_j \tag{3}$$

where:

Δt_s = values that are the time periods during which size reduction occurs, and
n = the number of such periods during any given test interval, j. Calculate and tabulate the Δt_s values in column A of Fig. 2.

13.1.2 *Idling Time*— The idling time for the test period (T_x) is the sum of the idling time periods for each of the four test intervals,

$$T_x = \sum_{j=1}^{4} \left(\sum_{i=1}^{n} (\Delta t_x)_i \right)_j \tag{4}$$

where:

Δt_x = values that are the time periods during which the size reduction device is idling (that is freewheeling), and
n = the number of such periods during any given test interval, j. The Δt_x values are calculated and tabulated in column B of Fig. 2.

13.2 *Throughput*:

13.2.1 *Time-Averaged Throughput Method* (to be used with Section 10): Compute the average throughput ($\bar{\dot{m}}$) using the following relation:

$$\bar{\dot{m}} = \frac{M}{T_n} \tag{5}$$

where:

M = total as-received weight of the refuse processed during the test period, Mg and
T = the net-processing time of the test period in hours.

13.2.2 *Discrete Throughput Method* (to be used with Section 11)— Compute the average throughput ($\bar{\dot{m}}$) for the test period using the following relation:

$$\bar{\dot{m}} = \frac{\sum_{i=1}^{4} \overline{\dot{m}}_i}{4} \tag{6}$$

13.3 *Particle Size Distribution*:

13.3.1 Plot the particle size distribution data for each

Size Distribution Data Sheet

Date: ____________________
Site: ____________________
Test No.: ____________________
Grinder: ____________________
Material: ____________________
Sample Wet Weight: ____________________
Sample Dry Weight: ____________________
Water Content: ____________________
Moisture Content: ____________________
Screening Time: ____________________

Screen Size	Bottom Screen Size ( )	Gross Weight Retained by Bottom Screen ( )	Tare Weight ( )	Net Weight Retained by Bottom Screen ( )	% of Feed on Bottom Screen	Cumulative Weight % Passing Bottom Screen
Pan						

Total Sample Weight:

NOTES: ____
____
____
____
____

FIG. 5 Size Distribution Data Sheet

Test Interval No.	Weight of Throughput Sample, m (kg)	Collection Time, t_c (s)	Calculated Throughput, $\dot{m}_i$[A] (Mg/h)
1			
2			
3			
4			

Average Throughput $(\bar{\dot{m}})$[B] = ________

[A] $\dot{m}_i = 3.6 \dfrac{m}{t_c}$

[B] $\bar{\dot{m}} = \dfrac{\sum_{i=1}^{4} \dot{m}_i}{4}$

FIG. 6 Sample Data Sheet for Throughput Measurements Using Procedure 9.3.2

laboratory sample plotted on Rosin-Rammler coordinates (Fig. 8). Any or all of the twin laboratory samples (see 12.1.5) may be screened and used as additional data. Draw a smooth curve for each of the particle size distributions.

13.3.2 Determine the nominal and characteristic product sizes (corresponding to 90 % and 63.2 % cumulative % passing, respectively) from the Rosin-Rammler plots for each sample and record on the sample data sheet shown in Fig. 9. Calculate the average nominal size ($\bar{X}_{90}$) in centimetres using the following relation:

$$\bar{X}_{90} = \frac{1}{n} \sum_{i=1}^{n} (X_{90})_i \tag{7}$$

Calculate the average characteristic size ($\bar{X}_o$), cm, using the following relation:

$$\bar{X}_o = \frac{1}{n} \sum_{i=1}^{n} (X_o)i \tag{8}$$

13.4 *Energy Usage*:

13.4.1 *Gross Energy Usage*—Calculate the gross energy (E_g) in kWh used for size reduction during the test period using the following relation:

$$E_g = E_{tot} - \bar{P}_{fw} T_x \tag{9}$$

where:

E_{tot} = the energy measured by the wattmeter (kWh),
$\bar{P}_{fw}$ = the average freewheeling power draw (kW), and
T_x = the idling time expressed in hours.

Calculate the average freewheeling power draw, $\bar{P}_{fw}$, in accordance with the procedures given in the section on Calculations of Test Method E 929.

13.4.2 *Net Energy Usage*— Calculate the net energy (E_n) in kWh used the size reduction during the test period using the following relation:

$$E_n = E_g - \bar{P}_{fw} T_n \tag{10}$$

13.5 *Power Requirements*:

13.5.1 *Gross Power Requirements*—Calculate the gross average power requirements ($\bar{P}_g$) of the size reduction device in kW as the quotient of the gross energy (E_g) measured during the test period and the net-processing time (T_n):

$$\bar{P}_g = \frac{E_g}{T_n} \tag{11}$$

The units of E_g and T_n are kW and h, respectively.

13.5.2 *Average Net Power Requirement*—Calculate the average net power requirement ($\bar{P}_n$) of the size reduction device in kW as follows:

$$\bar{P}_n = \frac{E_n}{T_n} \tag{12}$$

The units of E_n and T_n are kWh and h, respectively.

Test Interval No.	Weight Gross Sample, m (kg)	Length of Conveyor Belt Section (l) (m)	Belt Speed of the Conveyor (s) (m/s)	Calculated Throughput ($\dot{m}_i$)^A (Mg/h)
1				
2				
3				
4				

Average Throughput $(\bar{\dot{m}})^B =$ ________

[A] $\dot{m} = 3.6 \frac{ms}{l}$

[B] $\bar{\dot{m}} = \frac{1}{4} \sum_{j=1}^{4} \dot{m}_i$

FIG. 7 Measured Parameters for Gross Samples Collected Using the Stopped Belt Method (11.4)

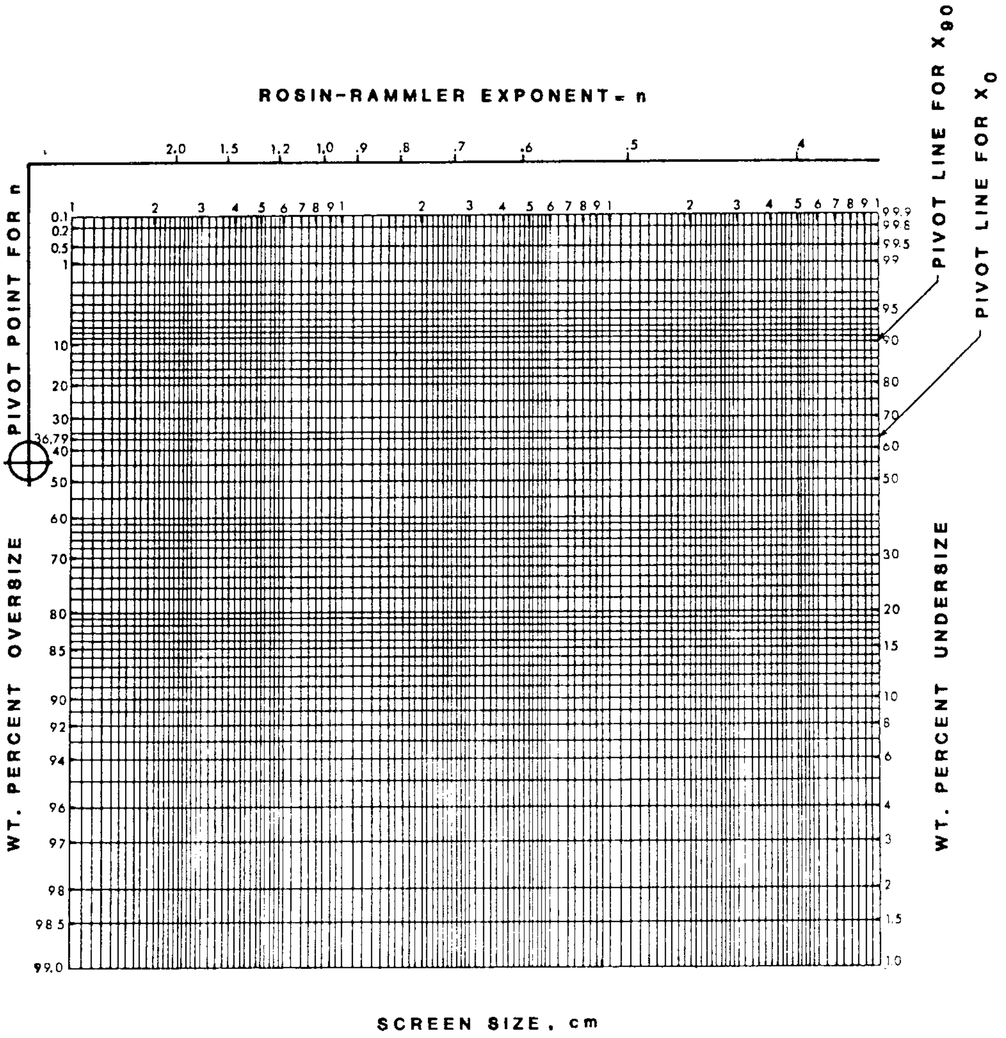

FIG. 8 Rosin-Rammler Paper

13.6 *Specific Energy Requirements*:

13.6.1 *Gross Specific Energy*—Calculate the gross specific energy requirement, $(E_o)_g$, in kWh/Mg using the following relation:

$$(E_o)_g = \frac{E_g}{\bar{\dot{m}}} \quad (13)$$

where:

E_g = the gross energy usage in kWh, and

$\dot{m}$ = the average throughput in Mg/h.

The gross specific energy requirement includes the free-wheeling component.

Test Interval	Product Size (cm)	
	Nominal (X_{90}) (90 %)	Characteristic (X_o) (63.2 %)
1		
2		
3		
4		
Alternative Samples		
1		
2		
3		
4		
Average[A,B]		

[A] Average nominal size ($\bar{X}_{90}$) =

$$1/n \sum_{i=1}^{n} (X_{90})_i$$

[B] Average characteristic size ($\bar{X}_o$) =

$$1/n \sum_{i=1}^{n} (X_o)_i$$

FIG. 9 Summary of Product Size Distribution Data

13.6.2 *Net Specific Energy*—Calculate the net specific energy requirement, E_o, in kWh/Mg using the following relation:

$$E_o = \frac{E_n}{\bar{\dot{m}}} \qquad (14)$$

where:

E_n = the net energy usage in kWh, and

$\dot{m}$ = the average throughput in Mg/h.

13.7 *Recording of Results*:

13.7.1 The calculated results for average throughput ($\bar{\dot{m}}$), average gross ($\bar{P}_g$) and net ($\bar{P}_n$) power requirements, and average nominal ($\bar{X}_{90}$) and characteristic ($\bar{X}_o$) product sizes, and average gross ($(E_o)_g$) and net (E_o) specific energy requirements may be recorded on the sample summary data sheet shown in Fig. 10.

14. Precision and Bias

14.1 The bias of this method has not been established. The following estimates are given as guidelines:

14.1.1 The bias of watthour metres is estimated to be 98.0 to 99.5 %.

14.1.2 The bias of potential and current transformers (0.3 accuracy class) is 99.7 %.

14.1.3 The bias of the particle size designation (X_{90} and X_o) is a function of the number of samples analyzed and the degree of confidence; for example at a 90 % confidence level the following estimates apply:

Number of Samples	Precision (± %)
4	20 to 35
8	10 to 20
16	7 to 15

14.2 The precision of this test method has not been established.

Date: ______________________________
Site: ______________________________

Type of Size
Reduction Device: ______________________________
Model No.: ______________________________
Serial No.: ______________________________
Type of Solid Waste: ______________________________

Test Period No.	Average Throughput (Mg/h)	Average Gross Power Requirement, $\bar{P}_g$(kW)	Average Net Power Requirement, $\bar{P}_n$(kW)	Average Product Size (cm)		Specific Energy Requirement (kWh/Mg)	
				Nominal X_{90}	Characteristic X_o	Gross $(E_o)_g$	Net (E_o)

FIG. 10 Summary of Test Results

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