

# TECHNICAL REPORT

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## **Forage harvesters — Method of determining by screening and expressing particle size of chopped forage materials**

*Récolteuses de fourrage — Méthode pour déterminer par tamisage et  
exprimer la dimension particulaire des matériaux de fourrage haché*



Reference number  
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## Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The main task of technical committees is to prepare International Standards, but in exceptional circumstances a technical committee may propose the publication of a Technical Report of one of the following types:

- type 1, when the required support cannot be obtained for the publication of an International Standard, despite repeated efforts;
- type 2, when the subject is still under technical development or where for any other reason there is the future but not immediate possibility of an agreement on an International Standard;
- type 3, when a technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example).

Technical Reports of types 1 and 2 are subject to review within three years of publication, to decide whether they can be transformed into International Standards. Technical Reports of type 3 do not necessarily have to be reviewed until the data they provide are considered to be no longer valid or useful.

ISO/TR 10391, which is a Technical Report of type 2, was prepared by Technical Committee ISO/TC 23, *Tractors and machinery for agriculture and forestry*, Sub-Committee SC 7, *Equipment for harvesting and conservation*.

The reasons which led to the decision to publish this document in the form of a Technical Report of Type 2 are the following.

- The different organizations which deal with this problem already have their test methods.

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- Alignment of their methods with the one proposed will thus facilitate exchange and comparison.

This document is being issued in the type 2 Technical Report series of publications (according to subclause G.6.2.2 of part 1 of the IEC/ISO Directives) as a “prospective standard for provisional application” in the field of harvesting because there is an urgent need for guidance on how standards in this field should be used to meet an identified need.

This document is not to be regarded as an “International Standard”. It is proposed for provisional application so that information and experience of its use in practice may be gathered. Comments on the content of this document should be sent to the ISO Central Secretariat.

A review of this type 2 Technical Report will be carried out not later than two years after its publication with the options of: extension for another two years; conversion into an International Standard; or withdrawal.

Annex A of this Technical Report is for information only.

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# Forage harvesters — Method of determining by screening and expressing particle size of chopped forage materials

## 1 Scope

1.1 This Technical Report gives a test method to determine the particle size distribution of chopped forage materials and a method of expressing the particle length of the material. The determined particle size distribution can be used to evaluate forage harvesting machine and handling equipment variables, and to define forage physical length in animal feeding trials.

1.2 This Technical Report may be used to determine the particle size of chopped forage materials where the reduction process yields particles such as that material produced by shear-bar type forage harvesters. It is not intended for use on material produced by flail-type harvesters where substantial fractions of the material may be extremely long.

1.3 This Technical Report is intended for use in the field as well as in the laboratory. It is intended to separate chopped forage samples without drying them first.

NOTE 1 Other methods of determining and expressing particle size of chopped forage materials exist: annex A gives a list of these methods.

## 2 Test equipment

2.1 For particle-measuring purposes, a set of square-hole screens having widths of 406 mm, lengths of 565 mm and specifications as shown in table 1 shall be used. The screens shall be supported in frames with depths of 63,5 mm and arranged horizontally in a stack such that the screen with the largest opening size is at the top. Those with smaller openings shall be arranged with progressively smaller hole sizes below each other. If screens with different size openings from those listed in table 1 are used, the actual dimensions for the openings shall be used in the data analysis and shall be reported.

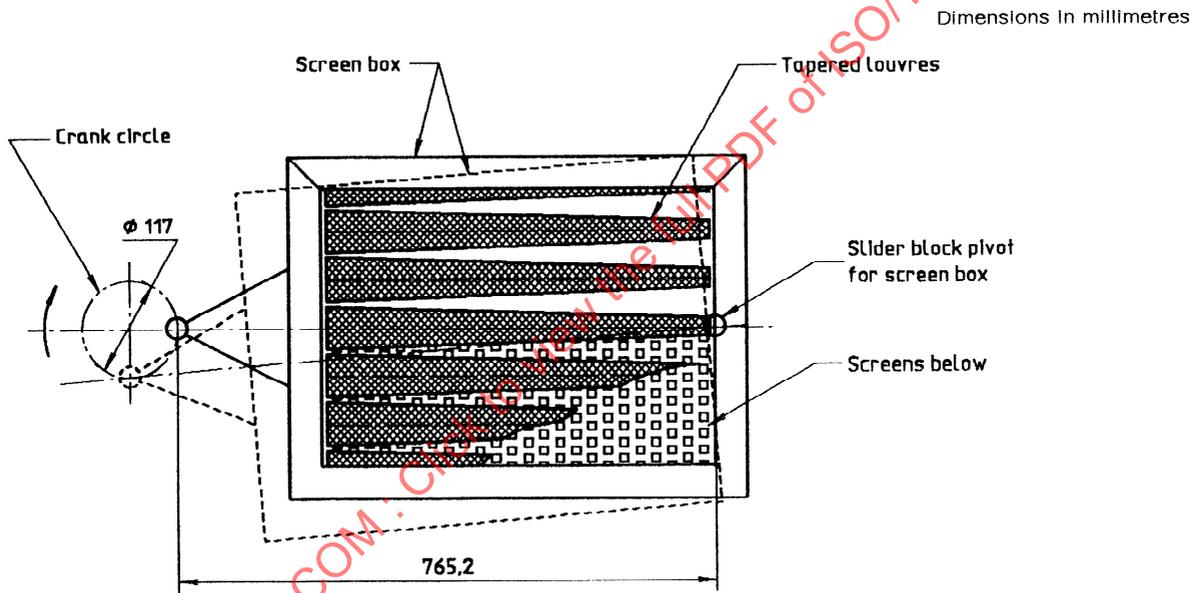
2.2 A suitable screen shaker is required. The shaker shall oscillate the screen stack in a horizontal plane. The centre of one side of the screen stack shall have a pivot and shall oscillate in a straight horizontal line on a slider block. The opposite side of the screen stack shall be supported on and moved by a horizontal crank arm, the crank-end centre of which is located 765,2 mm from the centre of the slider block pivot located on the other side of the screen stack. The centre of the arm shall travel in a horizontal circle with a diameter of 117 mm (see figures 1 and 2).

NOTE 2 Information on plans for constructing such a screen shaker may be obtained from the American Society of Agricultural Engineers.

**Table 1 — Dimensions of square-hole screens for test purposes**

Screen No. <sup>1)</sup>	Nominal size opening mm	Square hole diagonal mm	Screen thickness mm	Open area %
1	19	26,9	12,7	45
2	12,7	18	9,6	33
3	6,3	8,98	4,8	33
4	3,96	5,61	3,1	39
5	1,17	1,65	0,64	41,5
Pan	—	—	—	—

1) All screens are aluminium sheets or plates, except screen No. 5 which has 14 mesh woven wire cloth with 0,64 mm diameter wires.



**Figure 1 — Top view of forage particle separator showing screen motion and feeder position**

Dimensions in millimetres

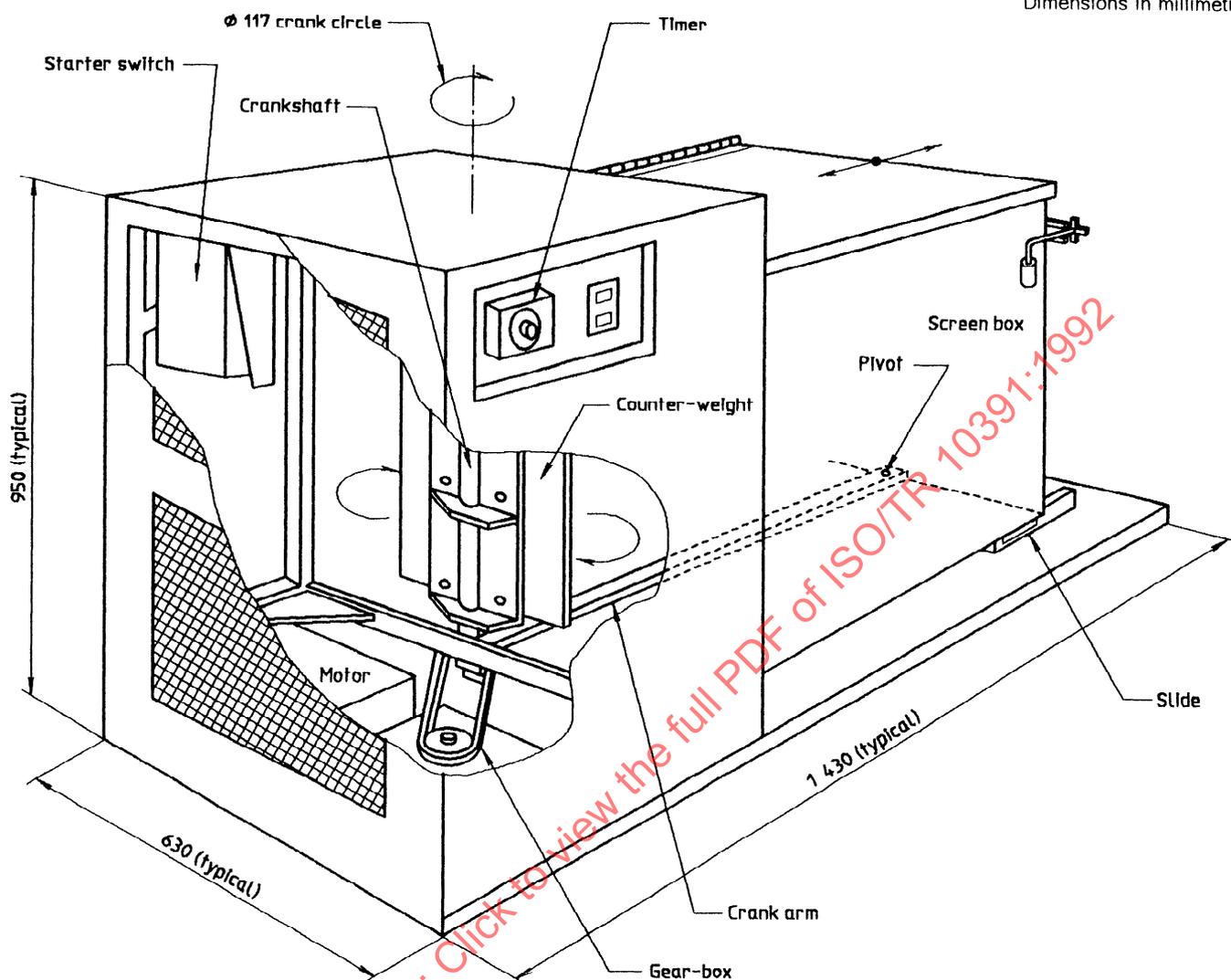


Figure 2 — Schematic diagram of forage particle separator

- 2.3 The screen shaker shall drive the screen stack at a frequency of  $2,4 \text{ Hz} \pm 0,08 \text{ Hz}$ .
- 2.4 The shaker should be operated with the screens level.
- 2.5 A weighing balance having an accuracy of at least  $\pm 0,5 \text{ g}$  shall be used for weighing the product.

### 3 Method of screening

3.1 Uncompressed samples of  $9 \text{ dm}^3$  to  $10 \text{ dm}^3$  of forage should be used. Samples of  $2 \text{ dm}^3$  to  $3 \text{ dm}^3$  of material may be used if extra care is taken to recover the material from each screen. For field work, the larger samples are usually preferred. The sample volume size should be reported with the data.

3.2 Place the sample on the top of the sample feeder (near the closed end) above the top screen of the screen set and operate the shaker for 120 s.

3.3 The tapered louvres on the feeder should be preset to feed the sample to the top screen in 20 s to 30 s. The louvres may be inclined to change the feeding time. This adjustment is made using successive trials with practice samples similar to the crop material to be evaluated for particle size distribution.

**3.4** Material on each screen and bottom pan shall be weighed and recorded.

**3.5** If the amount retained on the top screen exceeds 1 % of the total sample mass, representative sub-samples should be obtained from this screen and measured manually. The average length may then be used in the data analysis as geometric mean length  $\bar{x}_1$ .

**3.6** The screening process should be repeated to produce three sets of data. These data sets may be averaged or analysed separately with the procedure specified in this Technical Report.

**3.7** A representative sample of the unscreened material shall be used for moisture content determination. Moisture content (wet basis) shall be reported along with particle size data.

**3.8** Screen openings shall be kept free of forage particles so that effective screening can be accomplished. A stiff bristle cleaning brush, or compressed air, is useful for cleaning screens which have become clogged with forage particles. Screens may need to be cleaned periodically to remove plant residue materials. Plant residues may be removed by washing with water containing a detergent. Screens and the particle separator shall be air-dried before use.

**3.9** If static electricity becomes a problem when separating dry forage materials, liquid laundry static control may be sprayed lightly onto the sample before separating.

## 4 Data analysis

### 4.1 Mass distribution

Analysis of mass distribution of all chopped forage materials is based on the assumption that these distributions are logarithmic normally distributed.

### 4.2 Calculation of particle size

**4.2.1** The size of particles shall be reported in terms of geometric mean length,  $\bar{x}$ , and standard deviation,  $\sigma$ , by mass.

**4.2.2** Calculated values are obtained as follows:

$$\ln \bar{x} = \frac{\sum (m_i \ln \bar{x}_i)}{\sum m_i} \quad \dots (1)$$

$$(\ln \sigma)^2 = \frac{\sum m_i (\ln \bar{x}_i - \ln \bar{x})^2}{\sum m_i} \quad \dots (2)$$

where

$\bar{x}_i$  is the geometric mean length of particles on  $i^{\text{th}}$  screen:

$$\bar{x}_i = \sqrt{x_i \cdot x_{(i-1)}} \quad \dots (3)$$

in which

$x_i$  is the diagonal of screen openings of the  $i^{\text{th}}$  screen;

$x_{(i-1)}$  is the diagonal of screen openings in next larger than the  $i^{\text{th}}$  screen (just above in a set);

NOTE 3  $\bar{x}_1$  is measured manually as described in 3.5. If it is less than 1 % of the total, it is treated as zero.

$m_i$  is the mass on  $i^{\text{th}}$  screen (actual  $m_i$  or percent of total, decimal or percent form).

4.2.3 Material passing through screen No. 5 and collected in the pan shall be considered to have a geometric mean length of 0,81 mm. This becomes  $\bar{x}_6$  in equations (1) and (2).

4.2.4 An example of how the equations may be used to find geometric mean particle length and standard deviation for a sample data set (see table 2) follows.

Table 2 — Percent mass distribution of chopped alfalfa sample

Screen No.	Screen diagonal mm	Percent total mass on screens %	Cumulative undersize %
1	26,9	3,8	96,2
2	18,0	8,1	88,1
3	8,98	25,1	63,0
4	5,61	26,9	36,1
5	1,65	34,2	1,9
Pan	—	1,9	
		100,0	

The average measured length of the particles on the top screen (No. 1) was 48 mm. This becomes  $\bar{x}_1$  in equations (1) and (2). Equation (3) and the above information are used to obtain the following mean lengths for particles in each fraction:

$$\bar{x}_1 = 48 \text{ mm}$$

$$\bar{x}_2 = \sqrt{18,0 \times 26,9} = 22 \text{ mm}$$

$$\bar{x}_3 = \sqrt{8,98 \times 18,0} = 12,7 \text{ mm}$$

$$\bar{x}_4 = \sqrt{5,61 \times 8,98} = 7,1 \text{ mm}$$

$$\bar{x}_5 = \sqrt{1,65 \times 5,61} = 3,04 \text{ mm}$$

$$\bar{x}_6 = 0,82 \text{ mm}$$

Equations (1) and (2) are used to obtain

$$\bar{x} = \exp \left[ \frac{0,038 \ln(48) + 0,081 \ln(22) + 0,251 \ln(12,7) + 0,269 \ln(7,1) + 0,342 \ln(3,04) + 0,019 \ln(0,82)}{0,038 + 0,081 + 0,251 + 0,269 + 0,342 + 0,019} \right] = 6,95 \text{ m}$$

$$\sigma = \exp \left[ \frac{0,038 \ln^2 \left( \frac{48}{6,95} \right) + 0,081 \ln^2 \left( \frac{22}{6,95} \right) + 0,251 \ln^2 \left( \frac{12,7}{6,95} \right)}{0,038 + 0,081 + 0,251 + 0,269 + 0,342 + 0,019} + \frac{0,269 \ln^2 \left( \frac{7,1}{6,95} \right) + 0,342 \ln^2 \left( \frac{3,04}{6,95} \right) + 0,019 \ln^2 \left( \frac{0,82}{6,95} \right)}{0,038 + 0,081 + 0,251 + 0,269 + 0,342 + 0,019} \right]^{1/2} = 2,26$$

4.2.5 Graphical solutions for geometric mean length and standard deviation may be obtained by plotting the results on logarithmic normal probability graph paper. Figure 3 shows an example of a plot of the data from 4.2.4, where

$\bar{x} = x_{50}$  is the particle length at the 50<sup>th</sup> percentile;

$x_{84}$  is the particle length at the 84<sup>th</sup> percentile;

$\sigma = \frac{x_{84} - x_{50}}{x_{50}}$  is the standard deviation.