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Improved Rotary Sieve for Measuring State and Stability of Dry Soil Structure[1]

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ABSTRACT

An improved rotary sieve designed to overcome the limitations of the original sieve (1) was constructed and thoroughly tested.

The improved apparatus is capable of separating dry soil in one operation into any number of dry soil fractions up to 14. The operation requires little technical skill. The results of sieving are independent of personal judgment.

The apparatus was found useful for determining the relative mechanical stability as well as the state of aggregation of soil in a dry condition. Mechanical stability, as determined from the relative resistance of soil aggregates to breakdown by repeated sieving, varied directly with the resistance of the soil aggregates to abrasion by wind-blown soil materials. Abrasion is one of the serious aspects of erosion of soil by wind.

The rate of breakdown of soil aggregates varied exponentially with the number of sievings. Assuming this type of relationship to extend beyond the experimental range, the amounts of some particular size of aggregates present in soils before sieving were estimated.

The rotary sieve previously described (1) has been indispensable in studies of soil structure as related to erodibility by wind. As the studies progressed it became apparent that for thorough evaluation of erodibility it was necessary to separate the soil into as many as 12 erodible and several nonerodible fractions. That sieve failed in this requirement, since it was capable of separating the soil into a maximum of seven fractions of which only two were erodible. The original apparatus was likewise inadequate for determining the size distribution of soil fractions transported by the wind. Another limitation of the original apparatus was the inadequate feeder device. Hand feeding of the soil into the upper feed opening was time-consuming. The lower feed opening was unsuited for soils which contained large amounts of crop residues.

An improved rotary sieve designed to overcome these limitations was constructed and thoroughly tested. A description of the qualitative performance of the apparatus for measuring the state and stability of soil structure condition is presented.

Description of Rotary Sieve

The rotary sieve is essentially a rotating nest of concentric cylindrical sieves of various diameters. The apparatus is in two sections, one mounted above the other. The upper section can be used alone, or the upper and lower sections can be used together, depending on the number of sieves required. The cylindrical sieves are removable. This enables the operator to make up a nest or nests of sieves containing any desired number of sieves up to seven in either section. Size and other specifications of the sieves are given in table 1. If the maximum number of 13 sieves

Table 1.—Specifications of concentric cylindrical sieves of the rotary sieve apparatus.

Sieve number	Sieve openings	Diameter of cylinder	Length of cylinder: Upper portion	Perforated portion	Lower portion	Total
	mm	inches	inches	inches	inches	inches
			Upper Section			
1	38.1	6⅛	1	3¼	22¾	27
2	12.7	9½	1¼	3¾	18½	23½
3	6.4	11	1½	4¼	15	20¾
4	2.38	12¼	1¾	4¾	11½	18
5	1.19	13¼	2	5¼	8	15¼
6	0.84	14¼	2¼	5¾	4½	12½
7	0.42	15¼	2½	6	1¼	9¾
			Lower Section			
8	0.59	6⅛	1	7	20½	28½
9	0.42	7	1¼	7½	17¼	26
10	0.297	8	1½	8	14	23½
11	0.210	9	1¾	8½	10¾	21
12	0.149	10	2	9	7½	18½
13	0.105	11	2¼	9½	4¼	16
14	0.074	12	2½	10	1	13½

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is to be used, sieve number 7 of the upper section is removed. If only the upper section is used, any or all of the appropriate sieves can be used, including sieve number 7. The apparatus assembled to separate the soil into 13 possible soil fractions is shown in figure 1. The essential features of the apparatus are shown diagrammatically and to scale in figure 2.

Each sieve has a perforated area which extends completely around the circumference of the cylinder. The perforations are square openings placed as close together as possible. The relative position of the perforated area in each cylinder is shown in table 1. Sieve openings of 1/4 inch or greater are actual perforations in a 24-gauge galvanized sheet metal of which the cylinders are composed. Openings smaller than this are composed of wire sieves soldered to the sheet metal and suitably reinforced.

The essential parts common to all rotary sieves can be observed from figure 2. These parts are: a circular flange *A* composed of a metal plate 1/8 inch thick and 18 inches in outer diameter, the upper portion *B*, the perforated area *C*, and the lower portion *D*. Dimensions of each of these parts are given in table 1. A nest of any number of sieves can be made up by stacking the cylinders one outside the other and bolting flange *A* of each cylinder to a circular hub-board *E*. The hub board is composed of plywood 1/2-inch thick and is fastened to a cylindrical hub *F*. The hub rides on two 2-inch diameter idling V-pulleys *G* with centers 4 inches apart. An inverted V-track *H* fastened around the outside of the rotating hub rides on the pulleys and keeps the sieve cylinders in place. Another V-track *H'*, fastened on the outside of the cylindrical hub, acts as a seat for a drive belt. The whole hub section can be removed merely by disengaging the drive belt. An identical hub section is used for the lower sieve section.

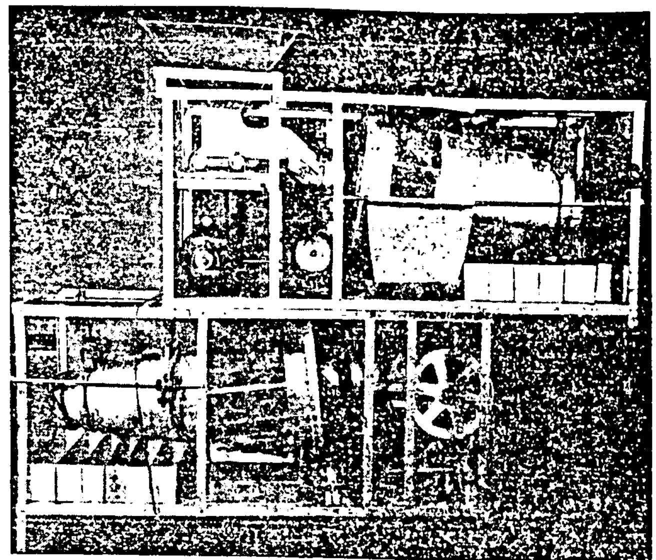

Fig. 1. — Front view of the rotary sieve assembled to separate the soil into 13 possible size-fractions.

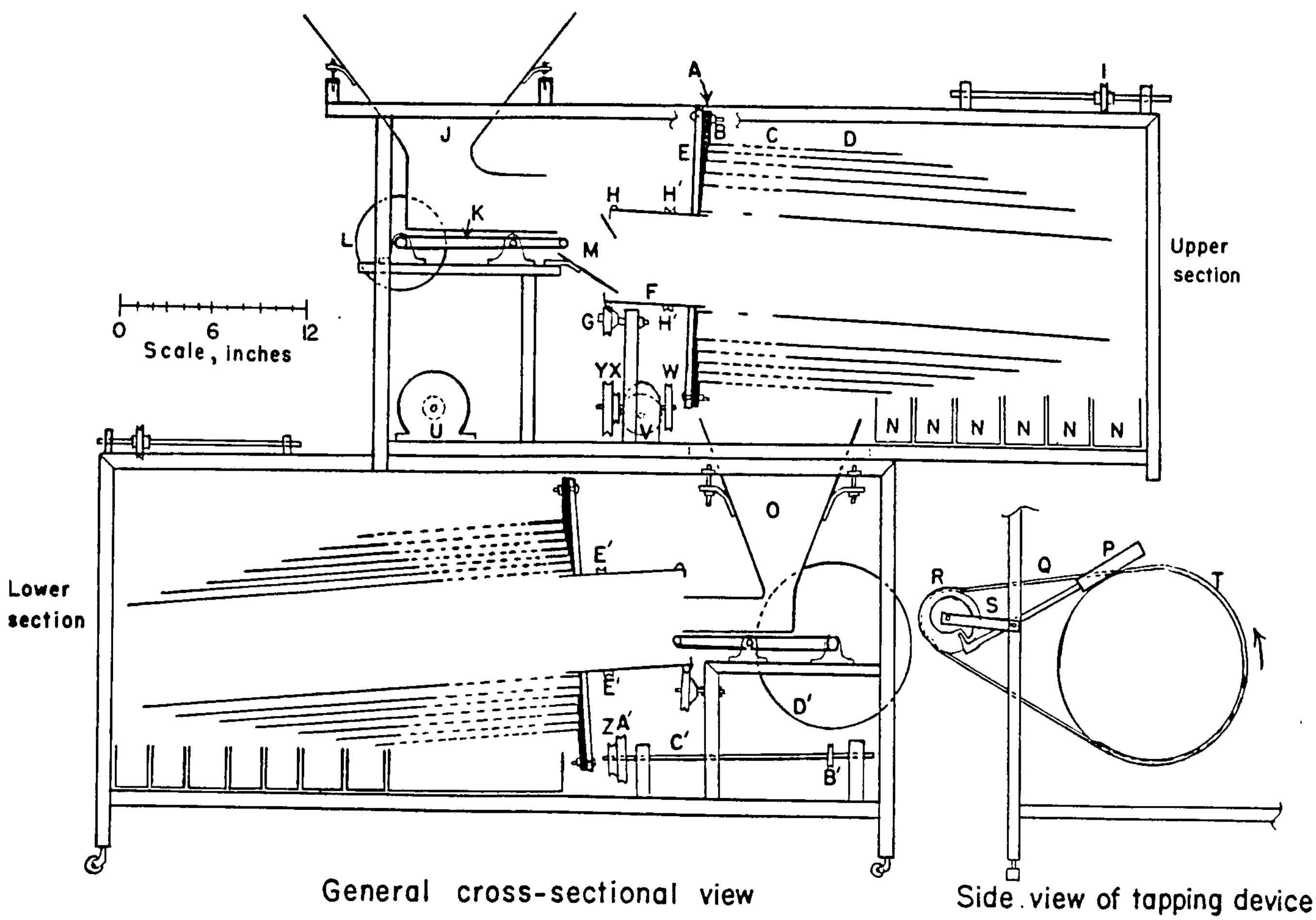

Fig. 2. — Diagrammatic representation of the rotary sieve shown in figure 1.

Spacing of cylindrical sieves is determined on the upper end by the position of the holes in flange *A* through which bolts are inserted. Spacers (not shown in figure 2) are used on the lower end. The spacers are composed of four to eight stove bolts of appropriate length passed through the wall of the larger cylinder and butted against the next smaller one. Nuts tightened against the larger cylinder keep the bolts in place. To replace a cylinder it is necessary to loosen the nuts.

The cylindrical sieves are sloped 4 degrees from the horizontal as in the original apparatus (1). The upper end of the nest of sieves rides on two idling pulleys *G*, and the lower end is suspended on a ¼-inch round leather belt. The belt runs around the outside of any one of the cylindrical sieves and over an idler pulley *I* on top of the apparatus. Two other belts are strung around the cylinder and over idling pulleys (not shown in figure 2) on each side of the apparatus to prevent any side swing that might occur. The pulleys can be slid on a horizontal shaft to any desired position and are held in place by a pair of collars. Belts are removable. Belts of different lengths are available for use, depending on the diameter of the rotary cylinder on which they ride.

A sample of soil to be sieved is placed in a hopper *J*. The hopper has an open bottom. The cross-sectional dimension of this opening is 3½ inches square. The opening fits against a horizontal conveyor belt *K* which carries a stream of soil into the apparatus. The speed of the conveyor is 5 inches per minute so that the volume of soil-flow into the apparatus is about 60 cubic inches per minute. The conveyor is driven by a shaft of 1-inch diameter connected to a drive pulley *L*.

The soil slides through chute *M* and inside the hub section *F*. From there it slides through the rotating sieves, is separated into various size-fractions, and is deposited in trays at *N*. The speed of rotation of sieves of the upper and lower sections is 7 r.p.m. Chute *M* is mounted on a hinge so it can be raised to facilitate insertion and removal of the hub section *F* and the nest of sieves. A spring (not shown in figure 2) holds chute *M* in proper position.

If only the upper section is to be used, the belt which drives the mechanism of the lower section is disengaged and the section is placed on a table. A tray is placed under the finest sieve in place of hopper *O*. If both sections are used the soil fraction passing through the finest sieve of the upper section falls into hopper *O* and passes through a set of still finer sieves of the lower section. Hopper *O* of the lower section has an opening 1-inch wide and 2-inches high. The soil is conveyed into the lower sieve section the same way as into the upper section. The speed of the lower conveyer belt is 5 inches per minute. Speeds greater than this may cause incomplete sieving through the finer sieves. The volume of soil-flow into the lower section is about 10 cubic inches per minute.

Some marginal sizes of soil fractions lodge in the openings of the sieves. Also dust, even when dry, sticks to metal surfaces and does not pass readily, especially through the finer sieves. To facilitate passage of these materials through the sieves, a tapping device (shown separately in figure 2) is used on the upper and the lower sections. The device taps against the lower portion of the outer cylinder of each section. The essential parts of the device are: weight *P*, belt *Q*, and spiral cam and pulley unit *R*. The cam and pulley unit is mounted on a horizontal shaft and is adjustable for position vertically by a pair of arms *S* and horizontally by a pair of shaft collars. Power is supplied from any one of the rotating cylinders *T*. Belt *Q* is replaceable and adjustable for any length, depending on the size of cylinder *T*. The drop on the spiral cam is 0.75 inch and the drop of the weight against the cylinder is 2 inches. The weight *P* weighs approximately 2 pounds.

Power is supplied from an electric motor *U* to a 50:1 speed reducer *V*. Pulley *W* drives the upper sieve section along a track *H′*. Pulley *X* drives the conveyor pulley *L* through a pair of intermediary pulleys fastened to a horizontal shaft not shown in figure 2. Pulley *Y* drives pulleys *Z*, *A′*, and *B′*, which are fastened to the nearly horizontal shaft *C′*. Pulley *B′* drives pulley *D′* by half twist of a belt and through an appropriate belt guide not shown in figure 2. Pulley *Z* drives the lower sieve section along a V-track *E′*.

The hopper openings are large enough to provide a uniform flow of soil containing virtually any amount of crop residue and any proportion of clods up to 2 inches or more in diameter. Clods much larger than 2 inches are picked up by hand and placed directly into the appropriate tray ready for weighing.

A small amount of dust is usually carried away by air currents during sieving. It is important that the soil sample be weighed prior to sieving to determine the amount of dust lost, if any. This amount could be added to the amount of the finest sieve fraction.

Qualitative Performance of the Rotary Sieve

Soils of various textures were oven-dried at 175° F and sieved repeatedly to determine the qualitative performance of the rotary sieve apparatus. Soil samples weighing at least 2,000 grams were used. Samples of very cloddy soils weighed at least 5,000 grams. The size of sample did not influence the qualitative performance of the rotary sieves because the volume of the soil stream in and out of the apparatus was constant. Due to this unique performance of the rotary sieve, the effect of time of sieving as conventionally performed with a nest of flat sieves could not be employed. Instead, sieving was repeated on samples of five widely different soils.

The soil aggregates broke down to some degree under repeated sievings (table 2). Large clods appeared to break down more than the smaller clods. It will be seen also that the degree of breakdown varied widely, depending on soil texture. There was virtually no breakdown of silty clay aggregates during repeated sievings. The coarser the soil texture the greater was the degree of breakdown.

The greatest breakdown of aggregates in all soils occurred during the first sieving. Subsequent sievings broke the aggregates less and less (table 2). By plotting the number of sievings against the logarithm of the percentage weight of aggregates greater than some particular diameter, the distribution curves became straight lines, as shown in figure 3. Evidently the rate of aggregate breakdown under repeated sieving obeys, over the range investigated, the experimental law of decay. This type of relationship seems to permeate the whole subject of erodibility of soil by wind.

The quantity of some particular diameter of soil

Table 2.—Size distribution of dry aggregates after repeated sievings on rotary sieves (averages of duplicated tests).

Soil class	Number of sievings	Aggregate distribution by weight												
		>38.1 mm	38.1–12.7 mm	12.7–6.35 mm	6.35–2.38 mm	2.38–1.19 mm	1.19–0.84 mm	0.84–0.59 mm	0.59–0.42 mm	0.42–0.297 mm	0.297–0.210 mm	0.210–0.149 mm	0.149–0.105 mm	<0.105 mm
		%	%	%	%	%	%	%	%	%	%	%	%	%
Sandy loam	1	9.6	23.8	11.0	7.8	3.8	1.0	0.7	0.7	1.4	1.4	4.9	5.4	28.5
	2	7.8	20.6	10.2	7.2	3.4	0.9	0.6	0.6	1.8	1.4	4.6	7.3	33.6
	3	5.0	19.8	9.8	6.8	3.2	0.9	0.6	0.7	2.3	1.6	5.2	9.8	34.3
	4	4.4	17.4	9.2	6.2	3.0	0.8	0.5	0.6	3.3	1.4	4.9	10.1	38.2
Loam	1	4.2	16.7	8.4	12.6	8.5	5.2	3.4	3.4	6.4	1.9	3.2	4.9	21.2
	2	3.7	16.4	8.5	12.0	8.5	4.0	3.2	3.4	7.0	2.0	3.4	5.0	22.9
	3	3.4	14.0	8.3	11.6	8.2	4.0	3.4	3.4	6.6	2.1	3.6	5.6	25.8
	4	2.6	13.5	8.1	11.2	8.2	4.0	3.4	3.8	7.3	2.0	4.4	4.5	27.0
Silt loam	1	8.9	23.4	12.2	10.0	6.4	2.9	2.8	2.8	4.0	2.2	2.3	2.4	19.7
	2	6.0	24.8	11.9	9.7	6.4	3.0	2.6	3.0	4.0	2.1	2.5	2.8	21.2
	3	6.6	21.0	11.4	9.9	6.5	3.2	2.5	3.0	4.6	2.2	2.6	2.8	23.7
	4	4.0	22.2	11.4	9.6	6.2	3.1	2.5	3.0	4.4	2.1	2.6	3.0	25.9
Silty clay loam	1	16.4	30.8	12.8	11.2	12.2	4.8	3.0	0.9	1.8	0.9	0.8	0.3	4.1
	2	15.9	29.8	12.7	11.3	12.4	4.6	3.0	1.0	1.8	1.0	1.0	0.4	5.1
	3	14.2	30.2	12.6	11.2	12.4	4.8	2.2	1.2	2.1	1.0	0.9	0.4	6.8
	4	15.3	28.4	12.4	11.3	12.6	4.8	2.4	1.4	2.4	1.2	1.2	0.6	6.0
Silty clay	1	1.0	6.9	15.4	19.5	9.5	4.8	18.8	6.4	10.1	3.4	1.8	0.8	1.6
	2	0	6.9	15.0	19.6	9.6	4.8	18.8	7.0	10.0	3.2	1.9	0.6	2.6
	3	0	6.0	15.0	19.7	9.6	4.8	19.0	7.2	9.8	3.2	1.8	0.6	3.3
	4	0	5.6	14.7	19.6	10.0	4.8	18.9	7.4	9.8	3.2	2.0	0.6	3.4

aggregates as determined by sieving represents the original quantity modified to some degree by the amount of aggregated breakdown caused by the sieving. The quantity of aggregates before sieving was estimated by projecting the straight-line curves of figure 3 to the ordinate (zero number of sievings). Some speculation at once arises as to the justification and accuracy of these estimations. The extrapolation of the existing data is based on the assumption that the same law which governs the aggregate breakdown by sieving extends beyond the investigated range. This assumption may well be inapplicable despite the fact that all of the available data seem to fit the law. The accuracy of the estimates, justifiable or otherwise, would depend on how closely the determined values fit straight-line curves. The accuracy may be enhanced by replication. Sieving tests carried in duplicate appeared to be quite sufficient.

The relative resistance of soil aggregates to breakdown by sieving was found previously (3) to vary directly with resistance of the aggregates to abrasion by wind-blown soil material. Abrasion is one of the serious aspects of erosion of soil by wind. Some idea of the relative resistance of soil to abrasion can be obtained from the relative mechanical stability of soil aggregates. The stability as determined from the degree of resistance of soil aggregates to breakdown by sieving can be evaluated from the curves of figure 3. The greater the slope of the curve, the lower is the mechanical stability of the soil aggregates. This stability can be evaluated also from the percentage reduction in weight of dry aggregates due to repeated sieving, as shown in table 3.

The reductions in the weight of dry aggregates under repeated sieving shown in table 3 are based on individual averages of duplicated tests. The experimental errors of measurement are involved in these data. A more accurate set of values can be obtained

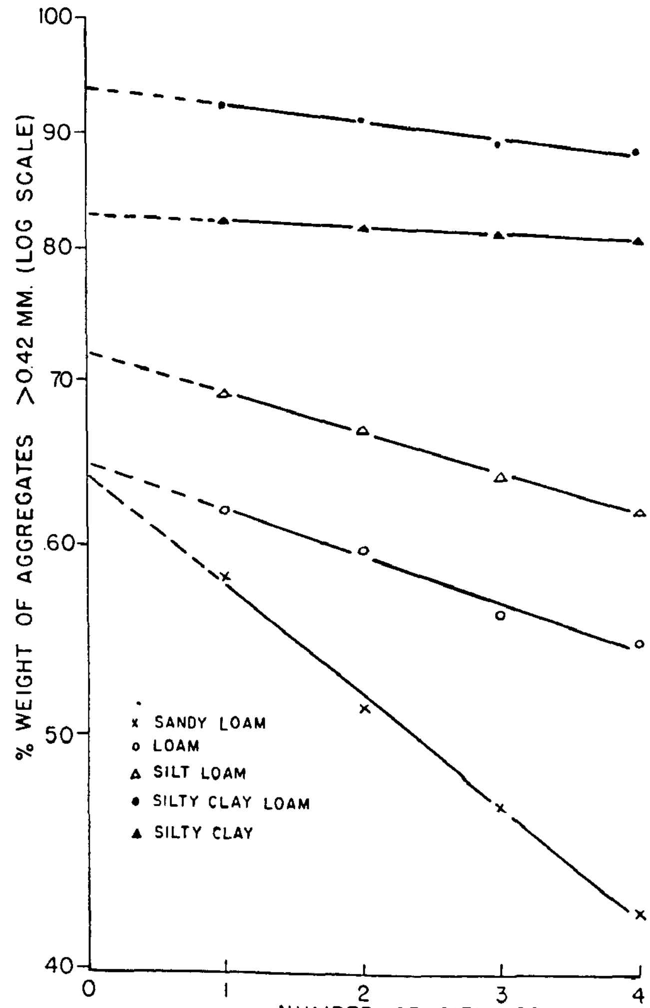

FIG. 3.—Loss in weight of dry aggregates due to repeated sievings on the rotary sieve.

Table 3.—Reduction in weight of dry aggregates due to repeated sieving on rotary sieves.

Soil class	Number of sievings	Reduction in weight of aggregates > 0.42 mm*	
		Nest of 12 sieves†	Nest of 2 sieves‡
		%	%
Sandy loam	1	5.8	3.0
	2	12.9	8.6
	3	17.4	10.4
	4	22.1	12.1
Loam	1	2.7	2.0
	2	5.4	4.1
	3	8.8	5.9
	4	10.3	7.3
Silt loam	1	3.1	1.4
	2	5.1	2.6
	3	8.4	3.8
	4	10.5	5.6
Silty clay loam	1	1.4	1.2
	2	2.8	3.0
	3	4.7	4.2
	4	4.9	4.7
Silty clay	1	0.3	0.1
	2	0.9	0.3
	3	1.3	0.6
	4	1.6	0.8

*Original weight of aggregates >0.42 mm determined by extrapolation as in figure 3.
†All but sieves number 7 and 14.
‡Sieves number 3 and 7.

from the position of the curves of figure 3 rather than from the position of the determined values.

It will be seen from table 3 and also from figure 3 that the order of mechanical stability is more or less the same irrespective of whether it is based on the degree of resistance of soil to breakdown under the first or on that of any of the subsequent sievings. A convenient method of estimating the relative mechanical stability would appear to be to repeat the sieving once and to base the relative stability on the percentage breakdown of soil aggregates due to the second sieving, proper regard being given to the number of replications required for accuracy of the results.

Both the state and the mechanical stability of the dry soil structure have a profound influence on erodibility by wind, and both vary independently with numerous factors as shown by previous studies (2, 3). Thus, repeated dry sieving measurements assume major importance as a means of indirect estimation of the amounts of removal and the amounts of abrasion of the soil by erosive winds.

The number of sieves used in the rotary sieve apparatus also influenced the amount of aggregate breakdown to some degree. As shown in table 3, the amount of breakdown of aggregates greater than 0.42 mm when 12 sieves were used was, on the whole, somewhat greater than when 2 sieves were used. Due to these differences it would seem advisable to use the same number of sieves in all comparable tests.

The results of sieving with 7 sieves of the upper section of the improved apparatus and with the 6 sieves of the original apparatus (1) showed that the improved apparatus broke up the larger aggregates slightly less than did the original, probably due to the shorter cylinders and perforated areas of the improved apparatus. Thus, the proportion of aggregates >0.84 mm in silt loam soil obtained with the improved sieve was 62.4% as compared to 60.5% obtained with the original apparatus. The proportion of fraction <0.42 mm, based on duplicated determinations, was 31.1% with the new apparatus as compared to 31.3% with the original.

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