3,545,281

METHOD AND APPARATUS FOR ANALYZING A PARTICULATE MATERIAL

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ABSTRACT OF THE DISCLOSURE

A method and apparatus may be used to determine the percentage of a fraction of a particular size or range of sizes for a particulate material from a weighed, discrete sample of the particulate material. An automatically operated apparatus is controlled by a programmer to automatically weigh a sample, transfer the discrete weighed sample to a size separating means, and to automatically weigh and determine the percentage of the particles of a given size or sizes in the sample. At a given time in the cycle as determined by the programmer, the fraction is released and a new sample is formed and/or transferred for subsequent one of a series of analyses.

This invention relates to a method of and apparatus for screening automatically a sample of particulate material into fractions based on size and comparing at least one of the fractions to the total sample.

A number of particulate materials such as grains and oil seeds or the like are sold and bought on the basis of grading for numerous factors, one of which is the amount of foreign material or dockage or both in the particulate material. While the terms “foreign material” and “dockage” in a general sense refer to material in the sample other than the grain being tested, the terms actually differ in meaning from one type of grain to the next. Definitions of these terms and grading factors for grain are specified in the Official Grain Standards of the United States and the Grain Inspection Manual of the United States Department of Agriculture. To simplify the description of the invention, the term “dockage” is used hereinafter in a generic sense to include not only dockage as defined in the above mentioned Government publications, but also to include foreign material or a combination of dockage and foreign material.

When grading corn, for example by sieving, one grading factor is the percentage of particles smaller than the normal size range for corn particles. Typically, the smaller than grain size particles are termed “unders” or “fines” and will include dirt, chaff, weed seeds or the like. The larger than grain size particles called “overs” often include clumps of grain, pieces of dirt, straw sticks, cobs and other larger foreign grains.

Present commercial methods of taking grain samples and ascertaining percentage of dockage in a grain are relatively slow and cumbersome in that the grain samples are usually weighed manually and introduced into a dockage testing machine which separates the sample into fractions to determine the dockage fraction. A person then must calculate the percentage of the dockage by dividing the weight of the dockage fraction by the total weight of the sample and multiplying the dividend by 100. Such a slow, inefficient, costly system is inappropriate for analysis of large and quickly moving streams of grain as may pass to or from a railroad car, barge or ship. Such a system is manifestly too slow to allow adding and blending of other grades of grain or cleaning, as the case may be, with the sampled grain so as to assure that certain grading standards are being met by the composite mixture of the grains.

Accordingly, an object of the present invention is to provide a fast, efficient and more economical sampling and analysis of a size distribution of a particulate material of the foregoing kind.

Other objects and advantages of the invention will become apparent from the detailed description taken in connection with the accompanying drawings in which:

FIG. 1 is a diagrammatic illustration of an apparatus for practicing the invention;

FIG. 2 is a perspective view of a dockage tester provided with the preferred apparatus for handling samples and breaking the same into fractions;

FIG. 3 is a schematic electrical diagram of an electrical control circuit for operation of the preferred apparatus;

FIG. 4 is a schematic electrical diagram of an automatic weighing device; and

FIG. 5 is a perspective view of a valve controlled catch pan for use with the dockage tester of FIG. 2.

Generally, as shown in the drawings for purposes of illustration, the invention is embodied in a method of and an apparatus for collecting and analyzing the size distribution of particles in samples taken from a particulate material such as, for example, a load of grain. Often, samples are taken from a continuously moving stream of grain such as occurs during loading or unloading of a grain carrier. On the other hand, a large number of samples may be taken from a very large static mass of grain to ascertain an average grade for the grain mass. In either event, the samples are usually desired to be analyzed quickly so that the grain may be graded and, if desired, other grains mixed with it or cleaned to meet the standards for a given grade. Very generally, samples are obtained, analyzed and fractions of the sample expressed as a percent of the total sample automatically and in the following manner. An aliquot sample of grain from a moving stream of grain is collected in a hopper 11 and is transferred to a weighing station 13 at which a preselected weight of sample is collected. This predetermined weight of sample is automatically discharged into a separating means 15 having at least one separating screen, generally designated at 17, which screens the sample into fractions based on size of particles in the sample. As will be described, the preferred apparatus has a plurality of separating screens for separating both the “overs” and “fines” from the normal size range of grain particles.

At least one of the fractions is conducted as by a channel 23 to a fraction weighing station 19 at which an automatic weighing mechanism including a scale 20 weighs the fraction, the weighed fraction usually representing the dockage or the “fines” or “overs” portion thereof. Since the weight of the dockage fraction is directly proportional to the weight of the sample, the fraction weight may be computed easily and automatically as a percentage of the weight of the original sample and is automatically recorded by a recorder 21 to provide a permanent record of the dockage in the sample. At an appropriate time, the weighed fraction is automatically discharged from the scale 20 and a new cycle of operation is automatically instituted for analyzing the next grain sample.

Referring now to more detail of the preferred apparatus, the supply hopper 11 is connected to an apparatus similar to that disclosed in U.S. Pat. No. 3,384,420 which supplies a continuous aliquot stream of grain from a ship, barge, railroad car or other grain carrier or storage device, although samples may be taken manually and fed into the hopper 11. The grain discharges from the hopper 11 onto the inlet end of a feeding means in the form of a vibratory feeder 23 which conveys the grain to the left in FIG. 1 to its discharge end 25 from which the grain drops into a vertically aligned, automatic weighing mechanism 27 at the sample weighing station 13. As will be
explained in greater detail, the preferred vibratory feeder feeds grain at a fast rate when its motor 39 is operated at a high power input and feeds grain at a much slower rate when the motor 39 is operated at a second lower power input. To stop feed of grain, the motor 39 is operated at a still much slower speed or is shut off.

The preferred weighing mechanism 27 is a “Model 610 NW Scale” commercially available from the Exact Weight Scale Company of Columbus, Ohio although other automatic weighing mechanisms may be substituted for this preferred mechanism. The automatic, pneumatic mechanism 27 is provided with a grain receiver in the form of a hopper 31 having an open top disposed immediately beneath and vertically aligned with the discharge end 25 of the vibratory feeder 23. The hopper is generally box shaped with four vertical side walls 32 and with a gate 33 in the form of an inclined bottom wall which is pivotally mounted for swinging from a closed position, indicated in solid lines in FIG. 1, in which the grain falling from the discharge end 25 of the vibratory feeder is collected and weighed by an attached scale 35 to an open position, as shown by the dotted line position for the gate 33. When the gate swings to the open position, the weighed sample in the hopper 31 transfers by dropping and automatically flowing into an aligned inlet chute of the separating means 15. The gate 33 is positioned by operation of a solenoid valve 36 which admits air pressure into an air cylinder causing a displacement of a piston in the air cylinder and movement thereby of an arm mechanism 37 to pivot the gate to its open position. Upon being de-energized, the solenoid valve exhausts the air pressure permitting a spring to pivot the gate 33 to the closed position.

In accordance with an important aspect of the invention, each aliquot sample is substantially identical in weight to simplify the conversion of the successive sample fractions all into percentages automatically and with simple equipment. To this end, the solenoid valve 36 opens the gate 33 to discharge the grain from the hopper only when a predetermined amount of grain has been accumulated in the hopper 31, e.g., a sample of 1,000 grams. To assure that the vibratory feeder 23 does not deliver additional grain into the hopper 31 at the time of transfer of the weighed sample to the separating means 15, the vibratory feeder motor 39, as will be explained in greater detail along with the electrical circuitry in the dockage tester motor, is electrically controlled and turned off and grain is no longer fed to the hopper. More specifically, the feeder motor 39 is under the control of the weighing mechanism 35 so that once it has a predetermined weight sample therein, such as 1,000 grams, the electrical control circuit switches the vibratory feeder motor off. As the same predetermined weight is attained for each sample, the weight of the fractions collected for each of the samples is directly proportional to the sample weight. Thus, the weight of the dockage fraction may be expressed directly as a percentage of the total sample weight.

In the separating means 15, the sample flows downward to contribute to a multiscreen separator 15 such as, for example, a Carter Dockage Tester 40 (FIG. 3) sold by Carter-Day Company of Minneapolis, Minn. The Carter Dockage Tester is provided with hoppers for an upper riddle or screen 41 and a vertically spaced trio of sieves or screens 42, 43 and 44, each of which screen is given a given size of sieve media and passes particles of a size smaller than its screen openings. The commercial Carter Dockage Tester collects the fractions in catch pans, to be further described, disposed at the right end of the dockage tester in FIG. 2. Heretofore, the fractions were then removed manually and weighed.

However, it is within the spirit of the present invention that means are provided to transfer the fractions from the catch pans and automatically to weigh a selected one or ones of the fractions and express the same as a percentage of the predetermined sample weight. As the grain sample falls in the dockage tester 40, an air stream blows through the falling sample and removes light dust and chaff which is considered waste and is, in this instance, not weighed. Alternatively, the light dust and chaff may be collected, weighed and expressed as a percentage of the predetermined sample weight. From the inlet chute, the grain sample falls onto the top surface of the riddle 41 which may or may not be used depending on the type of grain being tested. When the riddle 41 is not being used, it is removed and the grain falls directly to the next sieve 42. In this particular instance being described, a riddle is being used and it has sufficiently large openings to pass the grain size particles and the smaller “fines” or “unders” through to the next sieve 42. As will be understood by those familiar with the Carter Dockage Tester, the riddle 41 is vibrated, and this results in the larger size particles thereof to travel up and over the top of the riddle 41 to discharge into a deflecting funnel 47 at the back of the tester. As the openings in the riddle are quite large in size, the large particle sizes it screens from the sample are, in this instance, not included as part of the dockage fraction. These particles collected in the riddle deflecting funnel 47 are discharged into a downwardly inclined chute 49 which has its lower end connected to a vertically disposed collector in the form of a hollow tube or channel 51 for conveying the particles therein down to a waste discharge collector or basket 73.

The particles passing through the riddle 41 are redirected by an imperforate return box 48 which slopes to return the particles to the left end of the sieves, as seen in FIG. 2. In this instance, the top sieve 42 is not used and has been removed from the Carter Dockage Tester with the result that the grain size particles and smaller “fines” or “unders” fall directly to the center sieve 43. The top sieve 42, however, is used for some types of grain.

If the top sieve 42 should be used, it will screen the “overs” from the grain sample. These “overs” particles on the upper side of the top sieve 42 will be collected in a catch pan 52 which is attached an inclined chute leading to a hollow collecting channel 53 through which the “overs” may flow to a lower discharge end 55 and into a hopper 57 of the fraction scaling 20 at the fraction weighing station 19. The collecting channel 53 is vertically disposed and attached to the frame of the dockage tester 40 along one side of the dockage tester and is disposed generally opposite and parallel to the collecting channel 51 on the other side of the dockage tester, if used, the particles passing through it are returned by a return box 48 to the front (left) end of the center sieve 43.

When the top sieve 42 is not used, the particles fall directly from the riddle onto the top of the center sieve 43. The grain size particles are screened from the “unders” and are collected on the upper side of the center sieve 43. All the particles collected on the center sieve 43 are regarded as “grain” and are collected in a catch pan 59 which discharges this fraction into an inclined chute 61 which leads to the discharge channel 51. The “unders” which pass through the center sieve 43 are returned by a return box 48 to the front (left) end of the bottom sieve 44. The “unders” from sieve 43 are reclaimed on sieve 44. The grain size particles collected on the upper side of sieve 44 are regarded as “grain” and are collected in a catch pan 62 which discharges this fraction into the discharge collector or basket 73. The “unders” which pass through the bottom sieve 44 are collected in a lower catch pan and chute 63 which convey and discharge the “unders” into the weighing hopper 57 of the fraction scale.

In the illustrated embodiment of the invention, only the “unders” are collected in the fraction by the hopper 57 and weighed by the fraction scale 20. The “overs” from the riddle 41 and the grain size particles from the center sieve 43 and bottom sieve 44 constitute another fraction of the sample and this fraction is discharged directly into a container 73 at the bottom of the channel 51 without being weighed.
If it is desired to collect and weigh both the "unders" and the "waste" as a fraction, the inclined chute 49 from the riddle is disconnected from an inlet fitting 65 in the channel 51 and is turned through 180° and inserted into an inlet fitting 64 in the opposite waste channel 53. On the other hand, if it is desired to weigh only the "waste" as the dockage fraction, then the "unders" chute 63 is turned to discharge adjacent the outlet end of the channel 51 so that it no longer discharges into the fraction scale hopper 57.

If it is desired to provide a faster manner of changing the makeup of the fraction which is weighed and recorded, the chute from the riddle 49 to the inclined chute 67 and 68 having passageways which are gated selectively to deliver particles to either of the channels 51 and 53. Within the catch pan 66 is a gate means in the form of a butterfly valve 70 which may be turned by a suitable handle between positions in which it blocks one outlet leg passageway and opens another outlet leg passageway. The respective outlet leg passageways are connected to the inlet fittings 64 and 65, respectively, so that particles may be directed in a selective manner to either channel 51 or 53.

The fraction weighing scale is preferably of the same kind as that employed at the sampling weighing station and of the kind previously identified. In a manner similar to the hopper 31, the fraction hopper 57 has a pivoted mounted gate 69 serving as an inclined bottom wall; and the gate 69 may be swung from the closed, weighing position, illustrated in solid lines, to an open discharging position, as illustrated in dotted lines. A suitable solenoid valve 71 controls an air piston cylinder actuator, in the manner described for the scale mechanism 27, to operate an arm mechanism 72 to pivot the gate 69 to and from the respective open and closed positions at appropriate times in the analyzing cycle.

For the purpose of recording the weight of the dockage fraction, the fraction weighing scale 20 is provided with a suitable means for converting the fraction weight into a suitable signal for operating the recorder 21. In this instance, the fraction scale 20 has a movable indicator or arm 74 which is connected to a differential transformer (not shown) such as sold by Atcotran Corporation of King of Prussia, Pa. The differential transformer is preferred as it has the required sensitivity to detect small movements of the scale indicator arm 74 and allows full movement thereof, so that the weight can be read directly from the scale. The differential transformer provides an alternating current electrical signal which is then translated by an Atcotran demodulator to operate the recorder 21 which records the weight of the dockage fraction directly as a percentage due to the fact that the weight of dockage fraction is a directly proportional part of the 1,000 gram sample. The recorder 21 may be of any conventional type such as an A601C sold by Esterline Angus Instrument Co. of Indianapolis, Ind.

The discharge of the weighed and recorded dockage fraction and institution of the next cycle is under the control of a programmer 75. The preferred programmer 75 includes an electrical circuit, such as shown in FIG. 3, and a timer which is herein in the form of an electric motor 77 (FIG. 3) which rotates a series of cams which operate electrical contacts at predetermined times and for a predetermined period of time. All of the switches illustrated in FIG. 3 are shown in a condition prior to initiation of any operation.

When it is desired to render the system operable, a main control, manually operable switch SW1 is moved from an open position to the closed position whereby conventional 115 volt, sixty cycle AC current is connected to the system from a power source and leads 1 through now closed contacts SW1-1 and SW1-2 and the respective leads L1 and L2. Lead L1 is connected to a normally closed contact SW6-1 of a manually operated switch SW6 and lead L3 to supply current to lead L4. The operating motor 39 for driving the vibrating feeder 23 has power connected across it between leads L4 and L2 through a conventional solid state control device 81 which is a conventional part of the vibratory feed motor drive and is not described in detail herein. The feed rate of the vibrating feeder is proportional to the power supplied to the vibrating feeder motor 39 by the control device 81.

The amount of power supplied to motor 39 is determined by the bias of control device 81. The bias is determined by manually adjustable resistor 91 and closed contacts CR1-1 or manually adjustable resistor 93 and closed contacts CR1-3 and CR2-4. When CR1-1 and CR2-4 are open no bias occurs and power is shut off to motor 39 and no feeding takes place. Lead L4 also supplies power thru contacts SW4-1 of manual switch SW4 to control relay CR1.

Because the scale is empty, a magnet 87 (FIG. 4) carried by scale arm 89 is positioned in the proximity of magnetically operated switches MMS1 and MMS2. The magnet 87 closes normally open contacts of MMS1 and MMS2. Contacts MMS1 and MMS2 complete the return circuits of CR1 and CR2 respectively to lead L2.

Operation of control relay CR1 causes contacts CR1-2 to close and energize control relay CR2. Operation of control relay CR2 causes contacts CR2-3 to close and hold relay CR2 energized until MMS2 contacts open. As control relays CR1 and CR2 are now energized, contacts CR1-1 and CR2-4 are closed and contacts CR1-3 and CR2-4 are opened. The now open contacts CR1-3 prevent bias thru variable resistor 93. A bias is now supplied to control device 81 thru closed contacts CR1-1 and variable resistor 91 causing the vibrating feeder to operate.

Preferably the bias is set by adjustable resistor 91 to feed slightly less than 1,000 grams into the sample weighing hopper 31 in a period of about 50 seconds or less. As the weight in the scale hopper 31 approaches 1,000 grams, the scale arm 89 with attached magnet 87 moves to the right (FIG. 4) past magnetic switch MMS1 causing its contacts MMS1 to open and de-energize control relay CR1. Preferably the position of magnetic switch MMS1 is manually adjustable relative to a position 90 (FIG. 4) on the scale 35 indicating a weight of 1,000 grams, and is adjusted so that magnetic switch MMS1 contacts open as scale arm 89 approaches but before it reaches the 1,000 gram position 90. Release of control relay CR1 causes contacts CR1 to open and remove bias to control device 81 thru variable resistor 91. Simultaneously, contacts CR1-3 close completing a bias path thru still closed contacts CR2-4 and variable resistor 93, causing a second slower feed rate into scale hopper 31. A second slower feed rate is preferred because there is less possibility of excessive grain being fed into scale hopper 31 in the interval between the scale reaching the predetermined weight of 1,000 grams and the stopping of the grain feed.

As magnet 87 on scale arm 89 reaches the position 90 indicating 1,000 grams, the magnet 87 has left the proximity of magnetic switch MMS2 causing contacts MMS2 to open and release control relay CR2.

Preferably the position of magnetic switch MMS2 is manually adjustable relative to position 90 and switch MMS2 is adjusted so that its contacts open just as scale arm 89 reaches position 90.

The now opened contacts CR2-3 prevent further operation of control relay CR2 that might occur because of oscillation of scale arm 89 caused by the stopping of the feed to scale hopper 31.

Power across leads L4 and L2 causes the timing motor 77 to operate and turn five cams, each of which is associated with one of a set of contacts TM-1 to TM-5. The timing motor 77 is operated through a circuit in-
cluding now closed contacts CR2-1 of relay CR2 and closed contacts SW4-2 of manual switch SW4. The timing motor then closes its own holding circuit by rotating a first cam (not shown) to close its normally open contacts TM1 to provide a holding circuit for the timer motor. The timer motor 77 then opens contacts TM3 to dump a second sample into the Carter Dockage Tester and turns on dockage tester motor 95 repeating the cycle as previously described.

The control relay CR2 is de-energized and contacts CR2-1 are closed causing the timer motor 77 to continue operating so it again closes its holding contacts TM1.

The timer motor 77 then opens contacts TM3 to dump a second sample into the Carter Dockage Tester and turns on dockage tester motor 95 repeating the cycle as previously described.

The dockage tester motor 95 has been described as being energized and de-energized by the switch contacts TM3 once each cycle, which is usually about 63 seconds in duration, and this is the preferred manner of operation where automatic operation is desired. When it is desired to operate the Carter Dockage Tester in the conventional manner by manually weighing and introducing samples to the Carter Dockage Tester, a manual switch SW6 must be operated to close contacts SW6-2 and open contacts SW6-1 causing the Carter Dockage Tester motor 95 to run. Contacts SW6-1 being open, remove power from L3 and L4 thus preventing operation of the timer and scales. Also, if, it is desired to bypass the operation of the timing motor 77, a manually operated clearing switch 97 may be provided for clearing obvious parallel paths in the circuits for the solid state device 81, sample dumping solenoid 36 and fraction scale dumping solenoid 71.

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at a predetermined period of time after said transfer of said sample weighing at least one of the separated fractions, comparing the weight of the weighed fraction to said sample weight and indicating the percentage of said fraction in said sample, and at a predetermined time after transfer of said sample automatically discharging the fractions and then at a subsequent time instituting another sample analysis.

2. The method of claim 1 including the further steps of providing a moving stream of particulate material and continually taking an aliquot thereof and feeding said particulate material for weighing at a first rate until said predetermined weight is approached and then feeding said material at a rate slower than said first rate.

3. An apparatus for automatically determining the percentage of particles of a given size range in a particulate material comprising, selectively operable means for feeding the particulate material to a weighing station, weighing means at the weighing station for collecting a sample of a predetermined weight, means operable by said weighing means to terminate feeding of particulate material to said weighing means when said predetermined weight of sample is obtained, means for automatically transferring said predetermined weight of sample to a separating station, separating means at said separating station receiving said weighed sample and separating said sample into fractions based on particle size, means for weighing at least one of said fractions and expressing said fraction weight as a percentage of the sample weight, and program means operable at a predetermined period of time to discharge said weighed fraction and to initiate subsequent weighing and separating operations thereby providing a series of weighed discrete samples each of substantial identical weight and each analyzed as to a weighed fraction size therein.

4. An apparatus in accordance with claim 3 in which said selectively operable feeding means has fast and slow feeding rates and in which said control means operates said feeding means at a high speed to feed said particulate material into said receiving means until approaching the predetermined sample weight and then operates said feeding means to feed said particulate material at a slower rate.

5. An apparatus in accordance with claim 3 in which said means at said weighing station includes a hopper and an automatic weighing scale mechanism for weighing the material in said hopper and for discharging the material from said hopper under the control of said program means at a time when said separating means has separated a previous sample into fractions.

6. An apparatus in accordance with claim 3 in which said separating means includes a plurality of vibrating screens for separating said sample into fractions of "unders," "overs" and normal size particles and in which means are connected to said vibrating screens for conveying at least one of said fractions to said fraction weighing means.

7. An apparatus in accordance with claim 3 in which said fraction weighing means includes a hopper and an automatic scale mechanism associated with said hopper for weighing the fraction collected within said hopper and means operable by said program means to discharge said fraction from said hopper.

8. An apparatus in accordance with claim 3 in which said program means includes an electrical circuit for causing said feeding means to feed at one rate of feed until the weight of material in said weighing means approaches said predetermined weight.

9. An apparatus in accordance with claim 3 in which said means operable by said weighing means includes switch means operable when the sample weight approaches said predetermined weight to cause said feed means to feed at a rate slower than said one rate and in which further switch means are operable when said sample reaches said predetermined weight to terminate feeding.

10. An apparatus for determining particle size distribution in a particulate material by running a series of sample analyses, comprising means for providing a continuous aliquot stream of particulate material, a vibratory feeder for receiving said aliquot stream and for conveying the same to a weighing station, an automatic scale mechanism at said weighing station for weighing material being fed from said feeding means, a control circuit including means operable by said scale to stop operation of said feeding means when a predetermined weight of particulate material is in said scale and for causing said sample to be transferred to a separating station, screening means at said separating station for screening said particulate material into fractions of a normal range of particle size, "unders," and "overs," means for conveying at least one of said fractions from said screening means to a fraction weighing station, means including an automatic scale mechanism at said weighing station for weighing said conveyed fraction and expressing said fraction weight as a direct and proportional percentage of said sample weight, and means operable by said control circuit to discharge said weighed fraction and to cause another sample to be weighed to substantially the same weight and to be analyzed in a similar manner.

11. An apparatus in accordance with claim 10 in which a recorder is connected to said fraction scale mechanism for recording as a percentage the weight of the fraction, and in which said control circuit institutes a new cycle for analyzing a subsequent sample after recording the said percentage of the preceding fraction.

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