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(54) **CONVEYOR SYSTEM AND MEASURING DEVICE FOR DETERMINING WATER CONTENT OF A CONSTRUCTION MATERIAL**

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(Continued)

(51) **Int. Cl.**

G01N 23/06 (2018.01)
B65G 15/08 (2006.01)

(Continued)

(52) **U.S. Cl.**

CPC ***G01N 23/06*** (2013.01); ***B65G 15/08*** (2013.01); ***B65G 43/08*** (2013.01); ***G01B 15/02*** (2013.01); ***G01B 15/025*** (2013.01); ***G01N 23/083*** (2013.01); ***G01N 23/09*** (2013.01); ***G01N 23/12*** (2013.01); ***G01N 33/383*** (2013.01);

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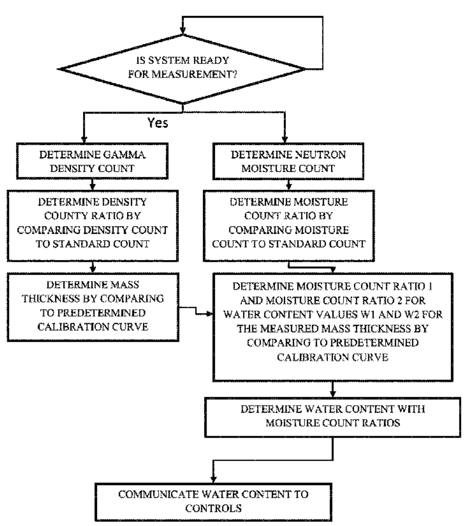
(57) **ABSTRACT**

A system is provided. The system includes a conveyor apparatus configured for conveying a material and a water content measurement system positioned about the conveyor apparatus for determining water content in the material. A dimension characteristic measurement system for detecting one or more dimension characteristics of the material is provided and a computer device is configured to manipulate data received from the water content measurement system and the dimension characteristic measurement system to determine a water content of the material.

18 Claims, 6 Drawing Sheets



Related U.S. Application Data

continuation of application No. 16/748,490, filed on Jan. 21, 2020, now Pat. No. 11,280,748, which is a continuation of application No. 15/155,056, filed on May 15, 2016, now Pat. No. 10,539,415, which is a continuation of application No. 13/656,918, filed on Oct. 22, 2012, now Pat. No. 9,389,191.

(51) **Int. Cl.**

B65G 43/08	(2006.01)
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G01N 23/083	(2018.01)
G01N 23/09	(2018.01)
G01N 23/12	(2018.01)
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(52) **U.S. Cl.**

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(58) **Field of Classification Search**

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See application file for complete search history.

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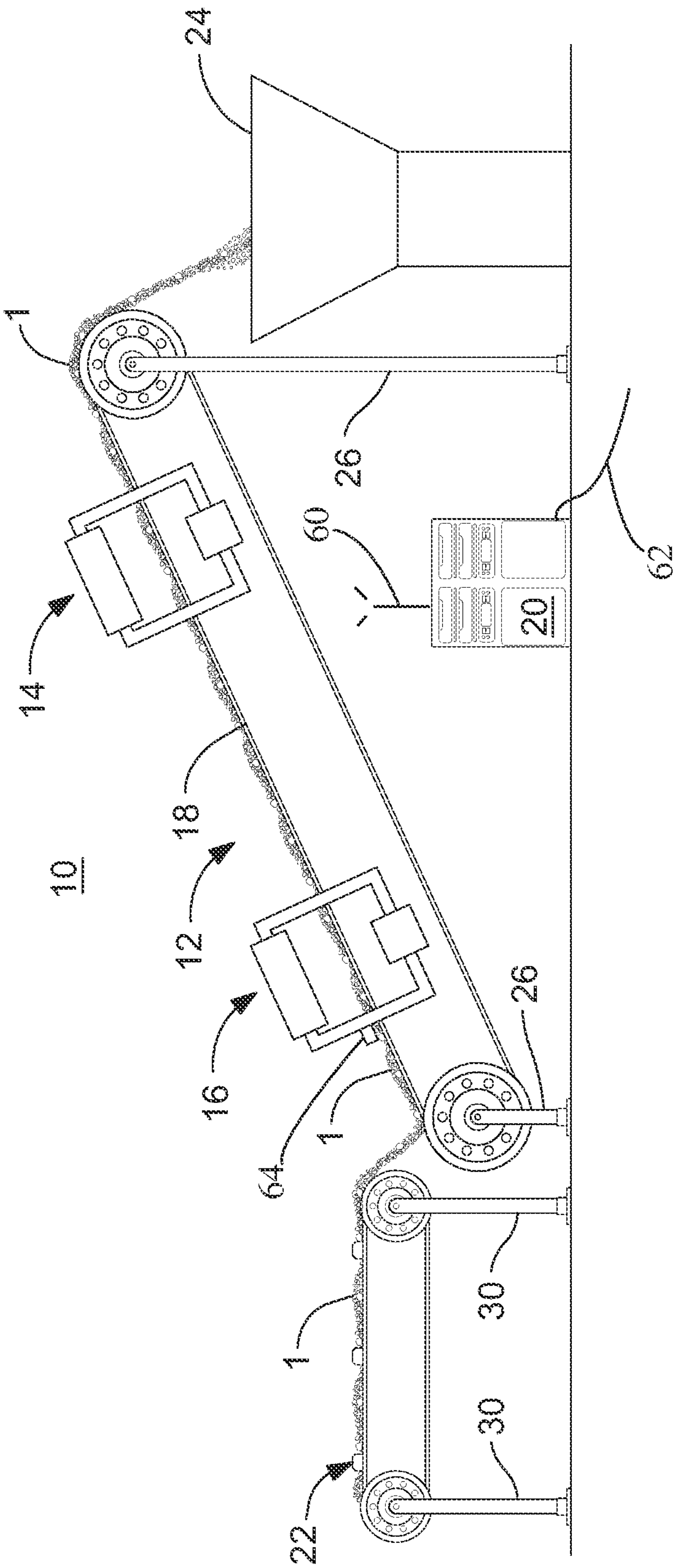


FIG. 1

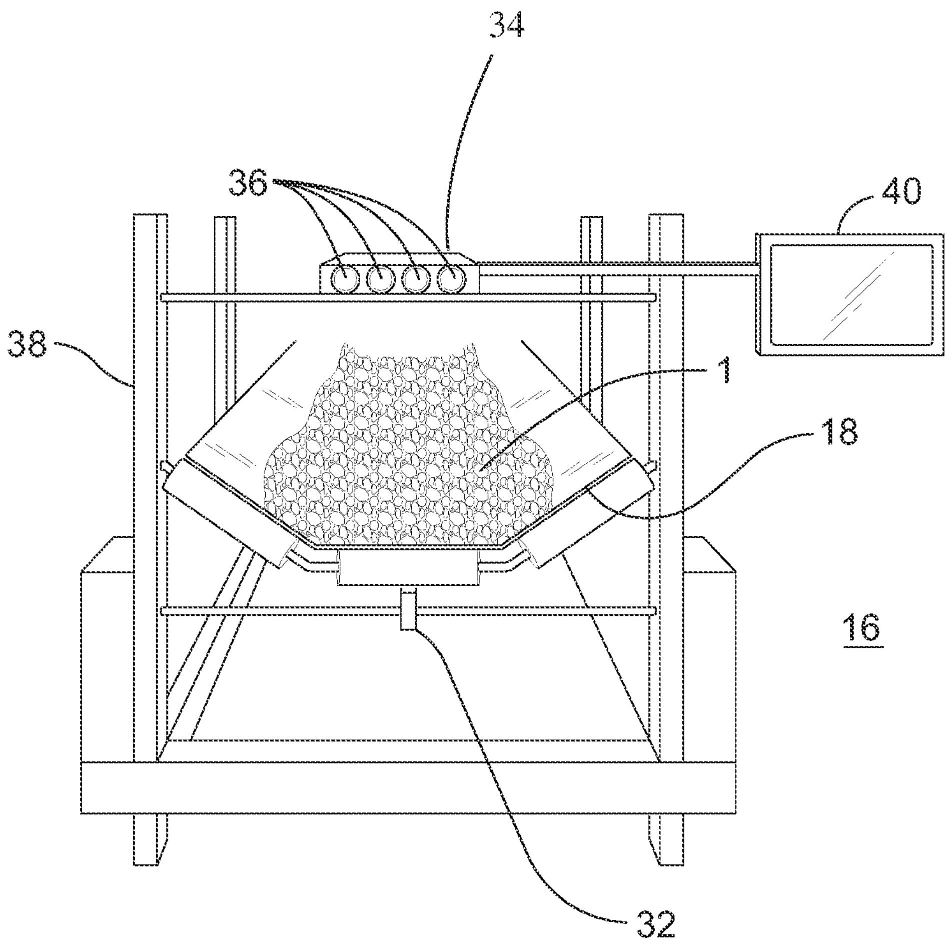


FIG. 2

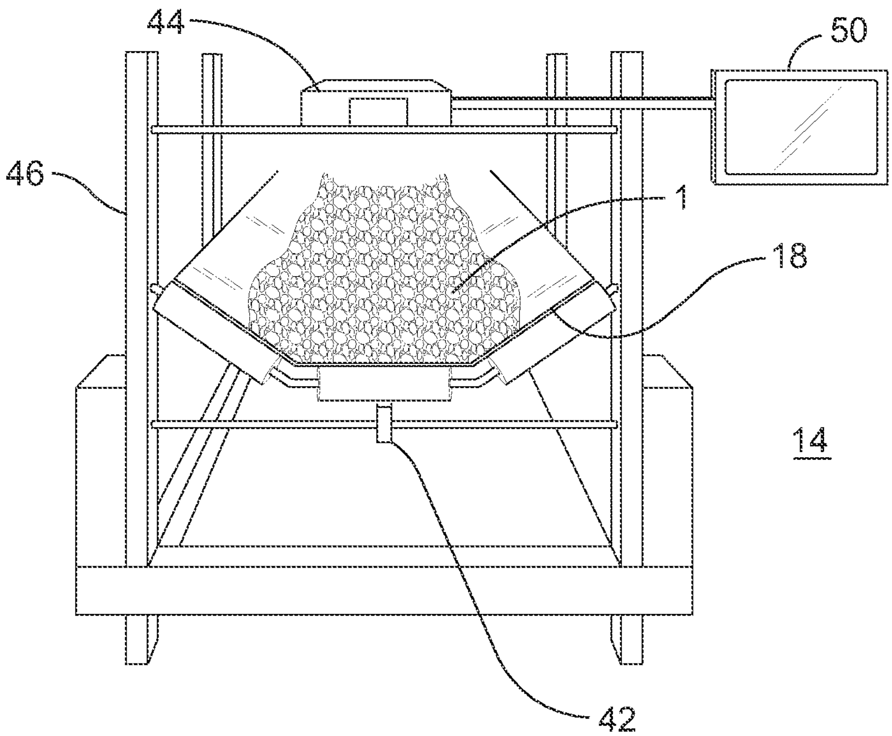
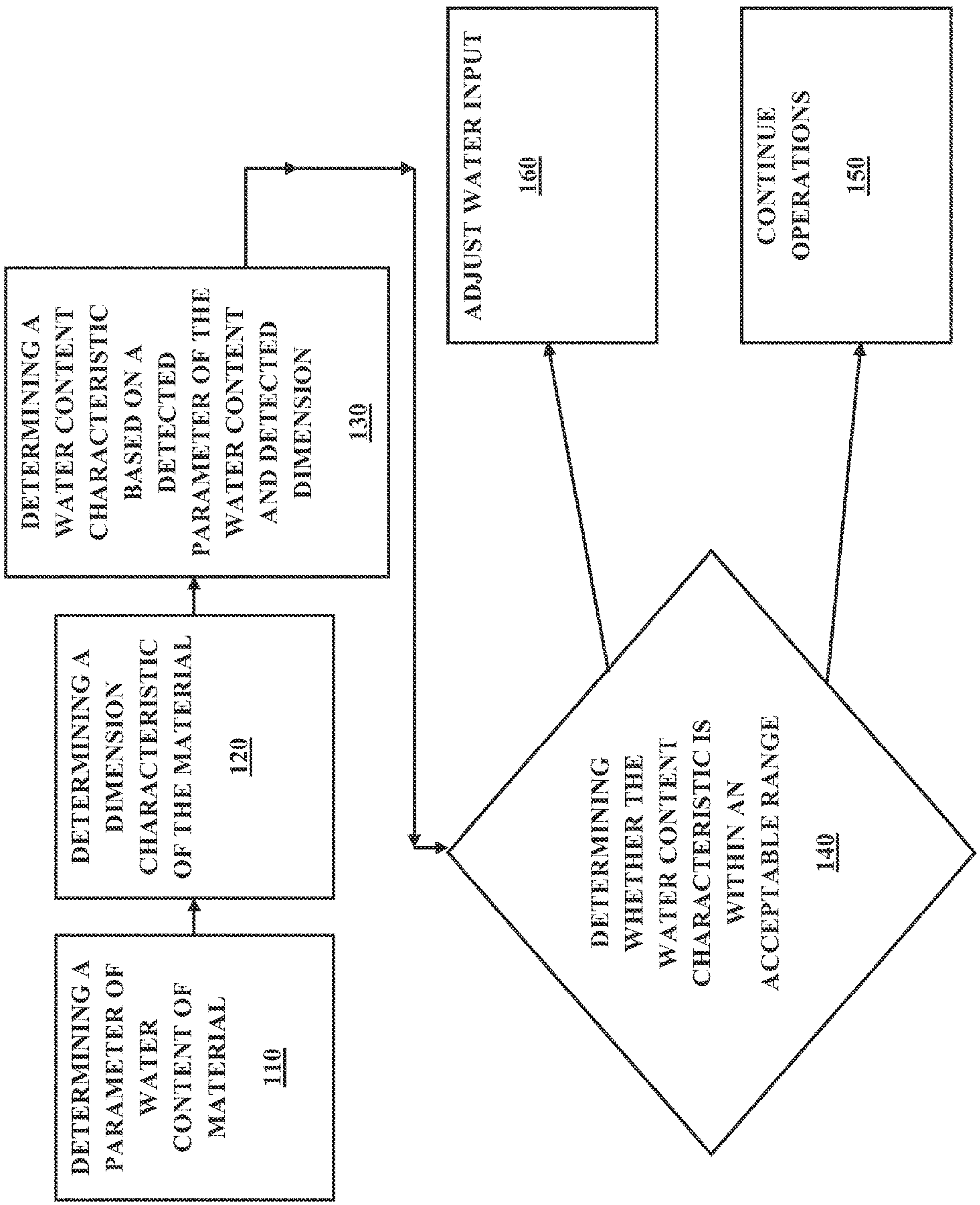


FIG. 3

FIG. 4


DETERMINING A PARAMETER OF WATER CONTENT OF MATERIAL
110
DETERMINING A DIMENSION CHARACTERISTIC OF THE MATERIAL
120
DETERMINING A WATER CONTENT CHARACTERISTIC BASED ON A DETECTED PARAMETER OF THE WATER CONTENT AND DETECTED DIMENSION
130
DETERMINING WHETHER THE WATER CONTENT CHARACTERISTIC IS WITHIN AN ACCEPTABLE RANGE
140
ADJUST WATER INPUT
160
CONTINUE OPERATIONS
150

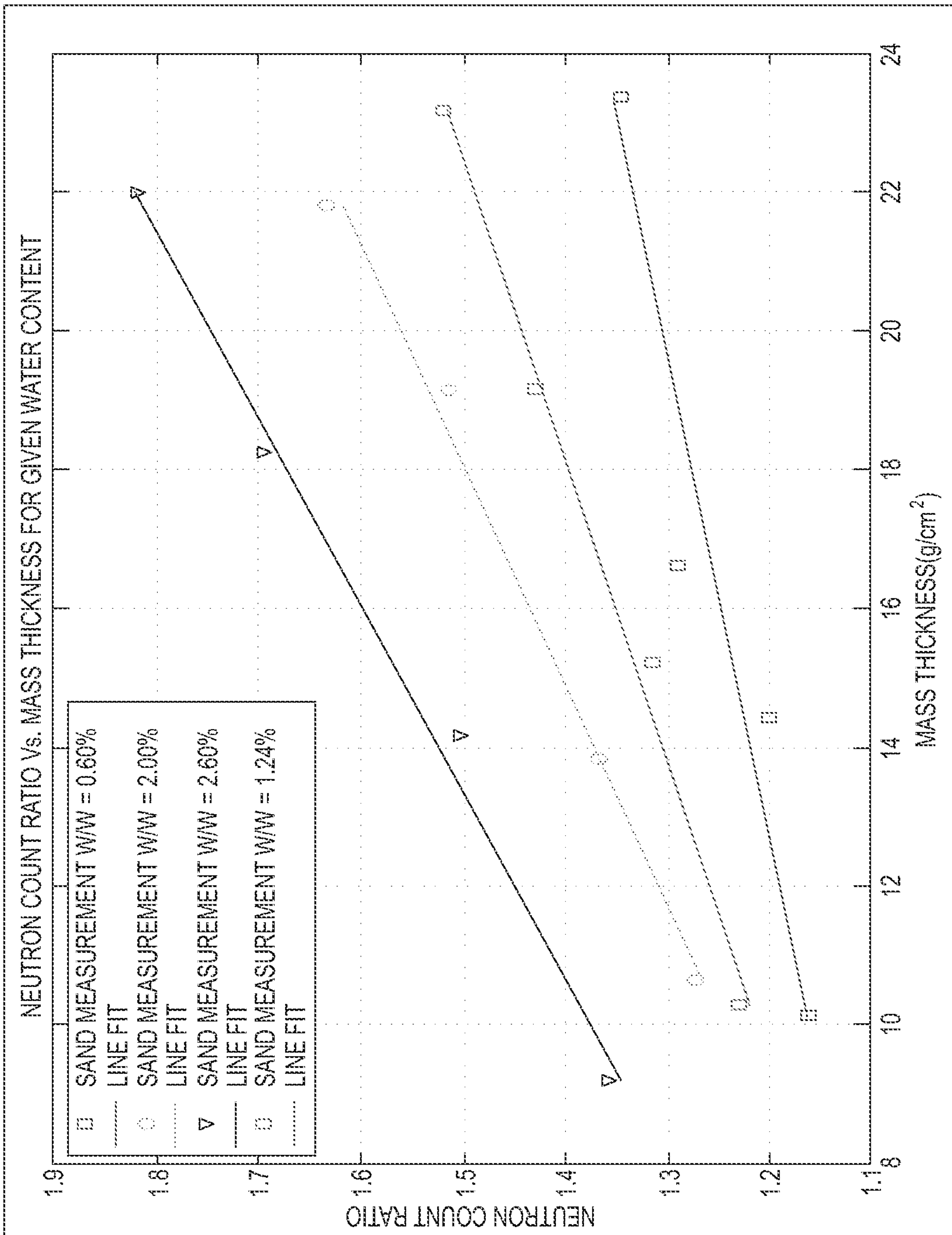

NEUTRON COUNT RATIO Vs. MASS THICKNESS FOR GIVEN WATER CONTENT
SAND MEASUREMENT W/W = 0.60%
LINE FIT
SAND MEASUREMENT W/W = 2.00%
LINE FIT
SAND MEASUREMENT W/W = 2.60%
LINE FIT
SAND MEASUREMENT W/W = 1.24%
LINE FIT
NEUTRON COUNT RATIO
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
8
10
12
14
16
18
20
22
24
MASS THICKNESS(g/cm²)

FIG. 5

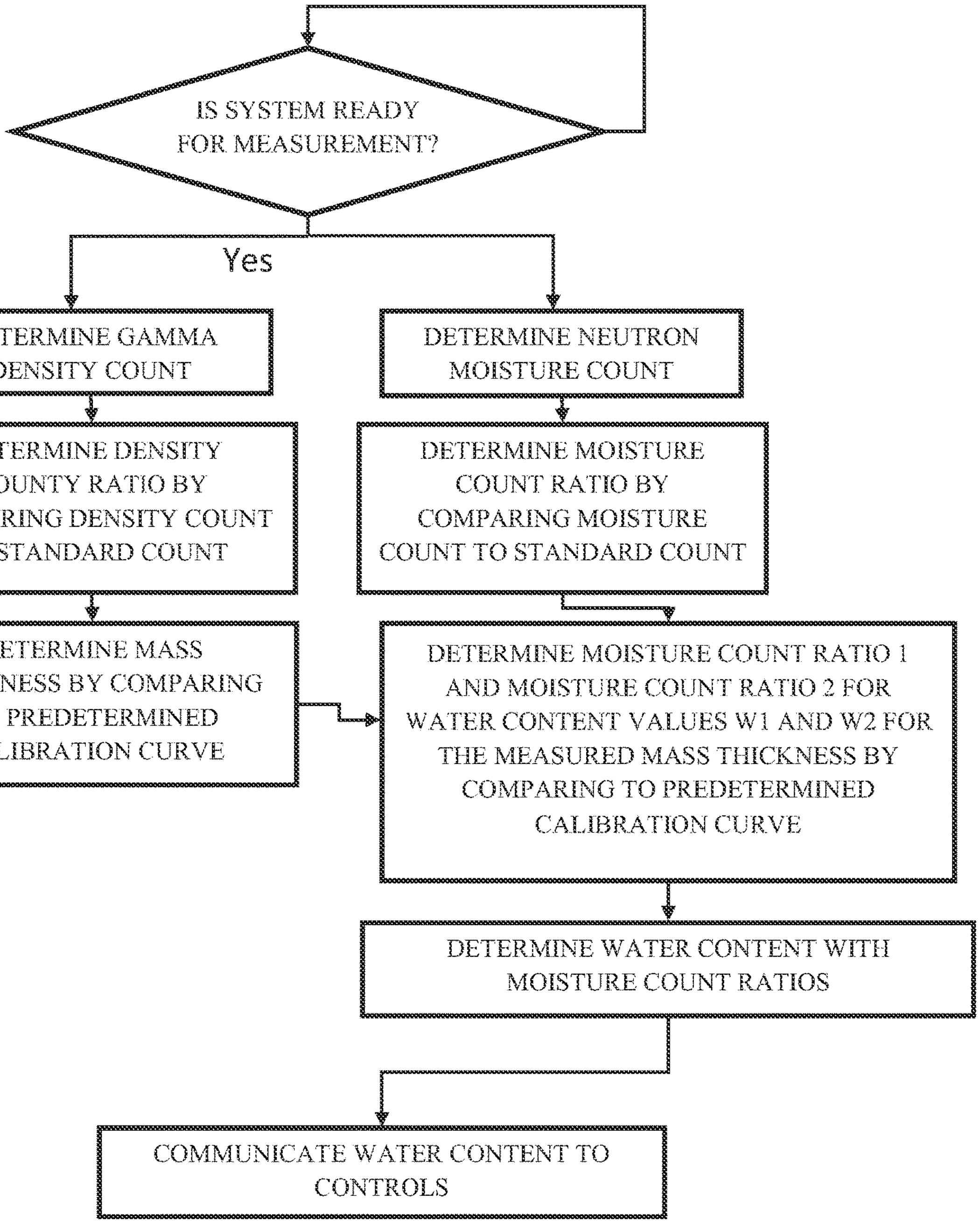

IS SYSTEM READY
FOR MEASUREMENT?
Yes
DETERMINE GAMMA
DENSITY COUNT
DETERMINE NEUTRON
MOISTURE COUNT
DETERMINE DENSITY
COUNTY RATIO BY
COMPARING DENSITY COUNT
TO STANDARD COUNT
DETERMINE MOISTURE
COUNT RATIO BY
COMPARING MOISTURE
COUNT TO STANDARD COUNT
DETERMINE MASS
THICKNESS BY COMPARING
TO PREDETERMINED
CALIBRATION CURVE
DETERMINE MOISTURE COUNT RATIO 1
AND MOISTURE COUNT RATIO 2 FOR
WATER CONTENT VALUES W1 AND W2 FOR
THE MEASURED MASS THICKNESS BY
COMPARING TO PREDETERMINED
CALIBRATION CURVE
DETERMINE WATER CONTENT WITH
MOISTURE COUNT RATIOS
COMMUNICATE WATER CONTENT TO
CONTROLS

FIG. 6

CONVEYOR SYSTEM AND MEASURING DEVICE FOR DETERMINING WATER CONTENT OF A CONSTRUCTION MATERIAL

CROSS REFERENCE TO RELATED APPLICATION

This is a continuation patent application of U.S. patent application Ser. No. 17/696,256, filed Mar. 16, 2022 and titled "CONVEYOR SYSTEM AND MEASURING DEVICE FOR DETERMINING WATER CONTENT OF A CONSTRUCTION MATERIAL", being issued as U.S. Pat. No. 11,714,053 on Aug. 1, 2023, which is a continuation patent application of U.S. patent application Ser. No. 16/748,490, filed Jan. 21, 2020 and titled "CONVEYOR SYSTEM AND MEASURING DEVICE FOR DETERMINING WATER CONTENT OF A CONSTRUCTION MATERIAL", now U.S. Pat. No. 11,280,748 issued on Mar. 22, 2022, which is a continuation patent application of U.S. patent application Ser. No. 15/155,056, filed May 15, 2016 and titled "CONVEYOR SYSTEM AND MEASURING DEVICE FOR DETERMINING WATER CONTENT OF A CONSTRUCTION MATERIAL", now U.S. Pat. No. 10,539,415 issued on Jan. 21, 2020, which is a continuation patent application of U.S. patent application Ser. No. 13/656,918, filed Oct. 22, 2012 and titled "CONVEYOR SYSTEM AND MEASURING DEVICE FOR DETERMINING WATER CONTENT OF A CONSTRUCTION MATERIAL", now U.S. Pat. No. 9,389,191 issued on Jul. 12, 2016, the contents of which are all incorporated herein by reference in their entireties.

TECHNICAL FIELD

This disclosure is related to a conveyor system and measuring system for determining water content of a construction material, and, more particularly, towards a measuring device that determines water content of a concrete and/or aggregate mixture while the mixture travels on a conveyor assembly. The system is high speed and corrects for thickness and density and may do so in real-time.

BACKGROUND

Concrete mixture is made of one or more of sand, aggregate, cement, pozzolans, and other materials and is transported on a conveyor assembly from bins or silos to an area where water and other additives are incorporated into the concrete mixture to homogenize the mixture in preparation for installation and curing. The sand and other aggregates naturally contain a varying amount of water and determining the amount of water already existing in the concrete mixture is important so that the proper amounts of water can be added later during homogenization. Itis well known that the water to cement ratio is directly related to the concrete product strength. Improper amounts of water added during the mixing process can impact the curing time, strength, durability, and appearance of the cured concrete. In some instances, entire batches of concrete must be destroyed or sold as cull product if the water content is not appropriately controlled.

Under current methods, water content of the mixture moving on the conveyor is estimated by random sampling on the run and by direct measurement of water in sand and aggregate stockpiles. Usually, such measurements are made once or twice a day and cannot estimate the variability of the water in the stock pile from surface drying during the day and/or rainfall that may occur. Such measurements also take a longer time, usually requiring about half an hour or more. Typically, the operator takes a select amount from the stock pile, weighs the amount, dries it on an electric or gas stove top and finds the mass lost to evaporation. The mass lost is determined as a gravimetrical percent moisture based on dry or wet mass of initial total aggregate.

In another method widely used in industry for determining water content, a probe is directly buried in sand or sand and aggregate within bins and/or hoppers. The material may be held stationary or may flow out of the bin past the probe or hopper to a conveyor belt. The method relies on the correlation of the dielectric properties of the water content of the material. The probe measures the dielectric properties of the material, and, based on a calibration, the water content of the material is determined. This method has limited accuracy in estimating the bulk water content of the material due to following draw backs: 1) when the material is stationary, the measurement volume of the probe is small compared to the majority of the material volume, resulting in an inaccurate detection of water in the bulk volume of the sample and 2) when material is flowing past the probe, the flow characteristics such as random air pockets, density variations, and turbulent material flow significantly increase the variance, reducing the average values, and leading to inaccurate water content data.

Nuclear and non-nuclear methods have been used to measure water content of construction materials for more than five decades. One such method described in U.S. Pat. No. 3,213,280 incorporates a neutron source and a slow neutron detector that utilized the fast neutron thermalizing effect or slowing down effect of hydrogen to measure water content in sand. The method described there was to measure the water content of sand used for molds and cores. The neutron source and the detector were placed inside a cylindrical probe. In calibration, the probe was buried in a container of carefully measured dimensions filled with sand so that the measurement volume of the probe covers most of the volume of sand in the container. Although this method is good for that particular application, the measurement volume is still a small fraction of the volume of bins and hoppers used in concrete plants. Chemical composition errors remained in the systems as well as density errors associated with moisture values.

Methods that determine water content of a concrete mixture when the mixture is moving on a conveyor belt have the advantage of estimating water content of a large integral fraction of the mixture. When the mixture has water distributed non-uniformly, water content estimate for the bulk volume has better accuracy with "on the run" averaging. Furthermore, due to the nature of concrete plant operation, at a given measurement position or location, height, mass, and density of the mixture moving on the belt varies with time. When determining the water content, methods should be used to compensate for such variations.

To compensate moisture measurements for the variation in height and mass of the mixture moving on the belt with time, one practice may be to use two or more independent methods for determining the height or mass thickness, and a quantity related to the water content of the mixture. Thereafter, physical relationships between the height or mass thickness, and a quantity related to water content are used to estimate or obtain direct measurements of the water content of mixture.

In nuclear techniques based on this proposed method, gamma-ray techniques are used to measure height or mass thickness and neutron techniques are used to measure a quantity related to water content of the mixture. Such methods are described in a report by Muller, R. H. (1963), Anal. Chem., Vol. 35(1), pp 99A-101A, and US patents such as U.S. Pat. Nos. 3,255,975, 3,431,415, 3,748,473, 3,955,087, 4,362,939, and 4,884,288. Problems with the previous such methods is that they use nuclear radiation sources of large strength or activity, may have mechanical constraints to keep the mixture passing near the gauge at a constant height, and use specialized nuclear radiation detectors and sources, and complex electronic circuitry that were problematic for plant maintenance. Furthermore, error corrections on the fly associated with chemical composition, real-time corrections to flow discontinuities associated with random material height, thickness, density, and mass thickness, linked to belt speed and separation of detectors, are not fully described in previous art.

A need therefore exists for a method or solution that addresses these disadvantages and provides a real-time assessment of the concrete mixture. This solution can produce real time or near real time data, averaged, integral, and filtered results instantaneously.

SUMMARY

This Summary is provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description of Illustrative Embodiments. This Summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used to limit the scope of the claimed subject matter.

Disclosed herein is a system for use with a construction material. The system may include a conveyor apparatus configured for conveying a material. A water content detector is positioned about the conveyor apparatus for detecting moisture in the material and a dimension or quantity characteristic detector for detecting one or more dimension characteristics of the material. A computer device is configured to manipulate data received from the water content detector and the dimension characteristic detector to determine a corrected water content of the material. Quantity characteristic may mean a thickness (m), mass (kg), volume (m^3), mass thickness (kg-m), area (m^2), density (kg/m^3), linear length (m), mass per length (kg/m), mass per area (kg/m^2), time (s), speed (m/s), conveyor rate (1/s) and various combinations of the units or other dimensional characteristics. Mass thickness may be defined as a ratio such as mass per meter or mass per square meter. Water content may be relative, volumetric or gravimetric, based on wet or dry product, and/or converted from one set of units to another.

According to one or more embodiments, the water content detector and the dimension characteristic detector may be spaced-apart about the conveyor apparatus to eliminate relative cross-talk therebetween.

According to one or more embodiments, the water content detector includes a neutron source spaced-apart from one side of the conveyor apparatus and neutron detector spaced-apart from an opposing side of the conveyor.

According to one or more embodiments, the neutron source is Cf-252 and the neutron detector is an He-3 neutron or other detector.

According to one or more embodiments, the dimension characteristic detector is configured to determine one of a height or mass thickness of the material. A gravimetric or volumetric determination may be made.

According to one or more embodiments, the dimension characteristic detector includes a gamma-ray source spaced-apart from one side of the conveyor apparatus and a gamma-ray detector spaced-apart from an opposing side of the conveyor apparatus. Back scatter may also be employed.

According to one or more embodiments, the gamma-ray source is Cs-137 and the gamma-ray detector is a scintillation detector.

According to one or more embodiments, the water content detector is positioned downstream of the dimension detector.

According to one or more embodiments, the material is one of a concrete, bituminous mixture, sand, aggregate, concrete additives, water or a combination thereof.

According to one or more embodiments, the dimension characteristic detector uses one of acoustics, ultrasonic, structured light, lasers, optical, and combinations thereof for determining one of more dimension characteristics. A gravimetric or volumetric determination may be made.

According to one or more embodiments, the computer device is further configured to determine whether the water content characteristic is within an acceptable range and provide adjustments to water input of the material based on the determination.

According to one or more embodiments, a method for determining the water content of a material being transported on a conveyor apparatus is provided. The method includes detecting water content in the material, detecting a dimension characteristic of the material, and determining a water content of the material based on the detected water content and detected dimension of the material.

According to one or more embodiments, detecting water content in the material includes counting neutrons on one side of the conveyor apparatus emitted from a neutron source from an opposing side of the conveyor apparatus.

According to one or more embodiments, detecting a dimension characteristic of the material includes using one of acoustics, ultrasonic, structured light, lasers, optics, radar principles, and combinations thereof for determining one or more dimension characteristics.

According to one or more embodiments, detecting a dimension characteristic of the material includes counting gamma-rays (photons) on one side of the conveyor apparatus emitted from a gamma-ray source from an opposing side of the conveyor apparatus.

According to one or more embodiments, detecting a dimension characteristic of the material includes detecting one of a height or mass thickness of the material.

According to one or more embodiments, a density correction may occur.

According to one or more embodiments, a device for determining a characteristic of a construction material being transported by a conveyor apparatus is provided. The device includes one of a gamma-ray and a neutron source positioned about one or opposing sides of the conveyor apparatus and at least one detector positioned about the opposing side of the conveyor apparatus configured for detecting one of the gamma-ray and neutron source. A computer device is configured to manipulate data received from the detector to determine a characteristic of the construction material.

According to one or more embodiments, the detector is configured for detecting water content in the material.

According to one or more embodiments, the detector is configured for detecting a height, density, or a mass thickness of the material.

According to one or more embodiments, a mechanical device may be provided to scrape or otherwise form the material to a predetermined dimensional characteristic.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing summary, as well as the following detailed description of preferred embodiments, is better understood when read in conjunction with the appended drawings. For the purposes of illustration, there is shown in the drawings exemplary embodiments; however, the presently disclosed invention is not limited to the specific methods and instrumentalities disclosed. In the drawings:

FIG. **1** is a side view of a conveyor system in accordance with one or more embodiments disclosed herein;

FIG. **2** is a front view of a water content detector for use with a conveyor system in accordance with one or more embodiments disclosed herein;

FIG. **3** is a front view of a dimension characteristic detector for use with a conveyor system in accordance with one or more embodiments disclosed herein;

FIG. **4** is a flow chart of a method for determining a water characteristic of a material according to one or more embodiments disclosed herein;

FIG. **5** is a chart showing experimental results for determining a water characteristic according to one or more embodiments disclosed herein; and

FIG. **6** is a flow chart of a method for determining a water content within a material and communicating that content to a computer device according to one or more embodiments disclosed herein.

DETAILED DESCRIPTION

The presently disclosed invention is described with specificity to meet statutory requirements. However, the description itself is not intended to limit the scope of the one or more embodiments shown and described herein. Rather, the inventors have contemplated that the claimed invention might also be embodied in other ways, to include different steps or elements similar to the ones described in this document, in conjunction with other present or future technologies.

FIG. **1** illustrates a system **10** for processing concrete or other construction materials. The system **10** includes a conveyor apparatus **12** configured for conveying a material **1** about a conveyor track **18**. The material **1** may contain any one of a concrete, bituminous mixture, sand, aggregate, concrete additives, water, air, or a combination thereof. In one or more embodiments, material **1** may also be coal or other ore based materials. The material flow in the conveyor apparatus **12** as illustrated is from left to right. A dimension characteristic measurement system **14** may be positioned about the conveyor apparatus **12** for detecting one or more dimension characteristics of the material **1**. A water content measurement system **16** may be positioned about the conveyor apparatus **12** for detecting water content in the material. A material scraping device **64** may be provided about the water content measurement system **16** in order to remove excess amounts of material **1** before being interacted with by the water content measurement system **16**. The speed of the web at the conveyor apparatus **12** may be monitored.

A computer device **20** is in communication with the water content measurement system **16** and dimension characteristic measurement system **14** and is configured to manipulate data received therefrom to determine a water content of the material **1**. The water content may be a function of the detected water and the detected material dimensions. For example, a material having an otherwise increased thickness will thereby have an associated increase in detected neutrons, which may be read as an increased water content if the thickness of the material is not taken into consideration. The computer device **20** may be configured to normalize water content with the determined mass thickness. Communication with the computer device **20** may be wireless or hard wired, such as, for example, through the use of transmitter **60** or hardwire **62**. The computer device **20** may be further configured to include one or more aspects of a global positioning system (GPS) for providing identification, mix properties, and location tracking services and information about the system **10** to either the on-site operator or a remote operator or to a customer. The conveyor **12** may be a mobile system or permanently placed at a plant.

The water content measurement system **16** may also be configured for detecting water or moisture by use of Boron-10 isotopes, coated gas tubes, BF3 filled gas tubes, lithium, solid state measures, and other detector types.

The conveyor apparatus **12** may be in further communication with an additional conveyor apparatus **22** and bin assembly **24**. Bin assembly **24** could also be a homogenization tank for addition of water to the material **1**. Additionally, moisture or water detection may occur in conveyor apparatus **22** or bin assembly **24**. A frame member **26** may be provided for elevating the conveyor apparatus **12**. Similarly, a frame member **30** may be provided for elevating additional conveyor apparatus **22**.

The water measurement system **16** and the dimension characteristic measurement system **14** are illustrated in a spaced-apart arrangement about the conveyor apparatus **12** to eliminate cross-talk therebetween. In one or more embodiments, there may be about six (6) feet of spacing between the dimension characteristic measurement system **14** and the water content measurement system **16**. Shields or additional structures may be employed for further limiting cross-talk between the dimension characteristic detector **14** and the water content detector **16** and may allow for more closely-spaced arrangement of the two measurement systems. Source and detector positions may be on opposing sides of the conveyor apparatus **12** or may be on the same side in a back scatter configuration.

Alternatively, the water content measurement system **16** may be configured for determining water content by using an electromagnetic source and detecting one or more characteristics such as impedance or scattering parameters. Exemplary techniques for use in determining a water property include using fringing field capacitors to produce an electromagnetic field; time domain reflectometry techniques; single-frequency moisture techniques; sweeping-frequency moisture techniques; microwave absorption techniques; radar reflection techniques; transmission techniques; and/or amplitude and microwave phase shift techniques. Further, suitable moisture signal detectors include detectors operable to measure the real and imaginary parts of a dielectric constant at a single frequency, multiple frequencies, continuous sweeps of frequencies, and/or chirps of frequency content, or involve time domain pulse analysis. An electromagnetic source may result in electromagnetic radiation or non-radiative fields in contact or not in contact with the material **1** or conveyor apparatus **12**.

The water content measurement system **16** is illustrated more closely in FIG. **2**. The water content measurement system **16** may include a neutron source **32** spaced-apart from one side of the conveyor track **18** and neutron detector **34** spaced-apart from an opposing side of the conveyor track **18**. In this manner, neutron source **32** is configured for emitting neutrons into material **1** and the neutron detector **34** is configured for determining the counting statistics and/or energy state of neutrons passing through the material **1**. In one or more embodiments, the neutron source **32** may be a 100 micro Curie source of Cf-252 having a half life of about 2.64 years. However, other suitable neutron sources may be employed, such as an Am-241/Be or any other suitable isotope/chemical or accelerator-based neutron sources for example. In one or more embodiments, a preferred configuration is transmission.

The neutron detector **34** may include one or more He-3 detectors **36** for detecting moderated neutrons. The He-3 detectors may include a gas tube with He-3. A frame **38** may be provided for supporting the neutron source **32** and the neutron detector **34**. A display screen **40** may be communicatively coupled or remotely coupled visually interfacing the control operator to the water content measurement system **16** for displaying one or more measurements thereof. The water content measurement system **16** may be configured to provide a reading over a predetermined period of time. For example, the water content detector **16** may be configured to provide a reading of water content at specific times or at timed intervals. The water content measurement system **16** may be further configured to detect water over a predetermined number of occurrences, and the computer device **20** may be configured to average or filter the readings of the predetermined number of occurrences.

The neutron detector **34** may be operatively configured to detect moisture by determining the amount of hydrogen in material **1**. Specifically, fast neutrons emitted by the neutron source **32** pass through the material **1** and undergo collisions with atomic nuclei in the material, thereby losing energy and slowing down. Hydrogen that is present within the water has a mass similar in magnitude to the neutron. Collisions of the neutrons with hydrogen atoms slow the neutrons down. By counting the number of slowed neutrons passing through, this may give an indicator as to the amount of hydrogen, and therefore water content present. However, the thickness of material **1** present on the conveyor track **18** can vary from measurement to measurement, so determining the amount of material **1** present may be necessary for converting the neutron count into a water content. Neutron count may be dependent on the density of the material **1** and the thickness of the material **1**.

The dimension characteristic measurement system **14** is illustrated more closely in FIG. **3**. The dimension characteristic measurement system **14** may be configured to determine one of a height and mass thickness of the material **1**. A volumetric and gravimetric determination may be made. The dimension characteristic measurement system **14** includes a gamma-ray source **42** spaced-apart from one side of the conveyor track **18** and a gamma-ray detector **44** spaced-apart from the opposing side of the conveyor track **18**. The gamma-ray detector **44** may be configured for counting gamma rays (photons) of various energies, or counting gamma rays of any energy. In one or more embodiments, the gamma-ray source **42** is Cs-137 and may have a 300 micro Curie strength. However, other suitable gamma radiation sources with different primary energy levels may be employed, such as a Co-60, or any other suitable isotope gamma radiation source for example. In one or more embodiments, the gamma-ray detector **44** is a scintillation detector. In one or more embodiments, the scintillation detector may be an NaI or PMT detector. A frame **46** may be provided for carrying the gamma-ray source **42** and gamma-ray detector **44**. A computer device having a display screen **50** may be communicatively coupled or remotely coupled to a central operator and the dimension characteristic measurement system **14** for displaying one or more measurements thereof. Alternatively, computer device **20** may be communicatively coupled to the water measurement system **16** and the dimension characteristic measurement system **14**.

Additionally, in one or more embodiments, the dimension characteristic measurement system **14** may be configured to determine a dimension using one of acoustics, ultrasonic, structured light, lasers, optics, radar techniques, mechanical feelers, and combinations thereof methods.

The dimension characteristic measurement system **14** may be further configured for taking a first measurement at the beginning of a production run with an empty conveyor track **18**. In this manner, the thickness of the conveyor track **18** and surrounding hydrogen can be measured and accounted for when determining a dimension of the material **1**.

One or more methods for determining a water content of a material being transported on a conveyor apparatus are illustrated in the flowchart of FIG. **4** and generally designated **100**. The one or more methods **100** include determining a quantity or parameter of water related to water content in the material **110**. Determining a quantity or parameter of water related to water content in the material **110** may include counting neutrons on one side of the conveyor apparatus emitted from a neutron source from an opposing side of the conveyor apparatus. Determining a quantity or parameter of water related to water content in the material **110** may be effectuated by utilization of the one or more water content measurement systems **16** disclosed herein.

The one or more methods **100** may include determining a dimension characteristic of the material **120**. Determining a dimension characteristic of the material **120** may include using one of acoustics, ultrasonic, structured light, lasers, optics, radar, and combinations thereof for determining one or more dimension characteristics. Determining a dimension characteristic of the material **120** may include counting using a gamma-ray source and a scintillation detector. Determining a dimension characteristic **120** of the material may include detecting one of a height or mass thickness of the material. Determining a dimension characteristic of the material **120** may be effectuated by utilization of the one or more material dimension characteristic measurement systems **14** disclosed herein.

The one or more methods **100** may include determining a water content characteristic of the material based on the detected water parameter and detected dimension characteristic of the material **130**. Determining a water content characteristic **130** may include using a computing module to analyze and determine the water characteristic based on the detected water parameter and dimensions of the material. The water characteristic may be, for example, a percentage of water or Hydrogen in the material **1** by weight, mass, or volume. A density may also be computed. In one or more embodiments, computer **20** may be configured to synchronize measurements of the dimension characteristic detector **14** and water content detector **16** based on the velocity of conveyor belt **18** so that respective measurements are being taken of the same portion of material **1**. Detecting water content may use one or more normalizing variables, such as water content and density. Synchronizing measurements may also depend on material flow characteristics. For example, the speed and mass thickness of the material may be used to synchronize measurements of the dimension characteristic detector **14**. A delay may be introduced between measurements based on the speed of the conveyor belt **18**.

The one or more methods **100** may include determining whether the water content characteristic is within an acceptable or predetermined range **140**. For example, if water content is supposed to be below 3.0% in a given material, the desired range may be predetermined to be between 2.5% and 3.0% water content. The computer device **20** may be configured for communicating with the water content measurement system **16** and dimension characteristic measurement system **14** for determining whether the detected water content characteristic is within the acceptable range.

If the water content characteristic is within an acceptable range, operation of the system **10** may continue with continuous monitoring of the material characteristics **150**. If the water content characteristic is not within an acceptable range, the system **10** may adjust the water input **160** of the material. This may be accomplished instantaneously with the system **10** continuing to operate so that there is no down-time, or, alternatively, the system **10** can cease production while adjustments are made to water input. This adjustment to water input may be accomplished by addition of water, removal of water through pressing or other mechanical processes, thermal application, addition or removal of material, and combinations thereof.

The computer device **20** illustrated in FIG. **1** may include computer control code configured for carrying out the one or more methods **100** disclosed herein. For example, the computer control code may be configured for communicating with moisture **16** and dimensional **14** apparatus, instrumentation on the hopper **24** and conveyors **12** and **22**, display screens **40** and **50** for outputting one or more data parameters. The computer control code may be configured for comparing the detected water content and the detected dimension characteristic to determine a water property of the material. Computer may be directly linked to a control room, hardware controller, or operator in a separate location.

The computer device **20** may be configured to provide an algorithm or other computer control code for displaying information such as the experimental results illustrated in the chart of FIG. **5**. As illustrated in FIG. **5**, the experimental results show a generally linear correlation between neutron count ratio and material thickness for a given control material having a known water content. Similar experimental results may be established showing a linear arrangement for concrete mixtures and by comparing the detecting water characteristic with the detected mass thickness, a water content of the material may be determined. The computer device **20** may be configured to provide a printout of various data and characteristics determined. The system **10** may further include global positioning system (GPS) capabilities.

The relationship between count ratio and material thickness or mass thickness may also be correlated to the speed of the additional conveyor and a known mass of the material as a function of time being applied to belt **22**. Count ratio applies to either neutron or gamma system and refers the actual material measurement count as related to a standard count. Standard count may be a daily count using standard hydrogenous materials or dense materials such as Mg. Al, Mg—Al, Polypropylene or combinations of these materials. Standard count may simply be an empty belt count, or air count, at a particular position of the conveyor, or several points on the conveyor or an integral average of a running conveyor.

FIG. **6** illustrates a method for determining water content and communicating the water content to the computer device. The system first determines if it is ready for measurement **210**. If yes, then the system may, either simultaneously or at an offset time, determine a gamma density count of the material **212** and determine a neutron moisture count **220**. This determination may be made over a predetermined interval, such as, for example, one second. The method may include determining a density country ratio by comparing the density count to a standard count **214**, meaning a count when no material is on the conveyor. The method may include determining a moisture count ratio by comparing moisture count to a standard count **222**. The density count ratio step **214** and moisture count ratio **222** may be performed simultaneously or at offset times thereof. The method may include determining mass thickness by comparing to a predetermined calibration curve **216**. The method may then include determining a moisture count ratio 1 and a moisture count ratio 2 for water content values w1 and w2 by comparing the moisture count ratio and the calibration curve **224**. The method may include determining a water content with the moisture count ratios **226**. The method may include communicating the water content to a computer device **230**. The method may include digital filtering the data or simple averaging or a video or running average technique.

While the embodiments have been described in connection with the preferred embodiments of the various figures, it is to be understood that other similar embodiments may be used or modifications and additions may be made to the described embodiment for performing the same function without deviating therefrom. Therefore, the disclosed embodiments should not be limited to any single embodiment, but rather should be construed in breadth and scope in accordance with the appended claims.

What is claimed:

1. A system comprising:

a conveyor apparatus configured for conveying a material, wherein the material includes at least one of: concrete, bituminous mixture, air voids, sand, aggregate, concrete additives, coal, ore-based materials, and water;

a water content measurement system positioned about the conveyor apparatus for detecting water content in the material;

a dimension characteristic measurement system for detecting one or more dimension characteristics of the material,

wherein dimension characteristic measurement system is further configured for taking a first measurement with an empty conveyor to determine thickness and hydrogen effects of the conveyor and adjusting the one or more dimension characteristics of the material based on the determined thickness and hydrogen effects of the conveyor; and

a computer device configured to:

manipulate data received from the water content measurement system and the dimension characteristic measurement system to determine a water content of the material,

determine whether the water content characteristic is within an acceptable range;

and

provide adjustments to the water content of the material based on the determination.

2. The system according to claim **1**, wherein the water content measurement system comprises a neutron source spaced-apart from one side of the conveyor apparatus and neutron detector spaced-apart from an opposing side of the conveyor.

3. The system according to claim **2**, wherein the neutron source is at least one of: Cf-252 and Am-241: Be, and the neutron detector is at least one of: an He-3 neutron detector, Boron 10 based detector, coated gas tubes, lithium detectors, solid state measures, BF 3 based detector and combinations.

4. The system according to claim **1**, wherein the dimension characteristic measurement system is configured to determine at least one of a height and mass thickness of the material.

5. The system according to claim **1**, wherein the dimension characteristic measurement system comprises a gamma-ray source spaced-apart from one side of the conveyor apparatus and a gamma-ray detector spaced-apart from an opposing side of the conveyor apparatus and is configured for detecting a mass thickness.

6. The system according to claim **5**, wherein the gamma-ray source is Cs-137 and the gamma-ray detector is a scintillation detector.

7. The system according to claim **1**, wherein one of the water content measurement system and the dimension characteristic measurement system is positioned downstream of one of the dimension measurement system and the water content measurement system.

8. The system according to claim **1**, wherein the dimension characteristic measurement system uses one of acoustics, ultrasonic, structured light, lasers, optics, radar and microwave techniques, gamma ray, and combinations thereof methods for determining one of more dimension characteristics.

9. The system according to claim **1**, wherein the computer device is configured to determine the water content of the material based on the permittivity of the material detecting by at least one of an electromagnetic absorption and phase or time delay measurement.

10. The system according to claim **9**, wherein the system is configured to determine the water content electromagnetically by measuring impedance and scattering parameters.

11. The system according to claim **10**, wherein determining the water content electromagnetically includes using at least one of: fringing field capacitance devices, time domain reflectometry, frequency domain reflectometry, microwave transmission and reflection, sweeping frequency, radar reflection or transmission, microwave measurements of amplitude and phase shift, and detectors measuring the real and imaginary permittivity at single, multiple, and continuous frequencies.

12. The system according to claim **1**, wherein the system is configured to use one of: thermal neutrons, radar, microwaves, optics to determine the water content characteristic or the parameter of water.

13. A method for determining the water content of a material being transported on a conveyor apparatus, the method comprising:

detecting a parameter of water in the material,

wherein the material is one of a concrete, bituminous mixture, air voids, sand, aggregate, concrete additives, coal, ore based materials, water or a combination thereof;

detecting a dimension characteristic of the material including taking a first measurement with an empty conveyor to determine thickness and hydrogen effects of the conveyor and adjusting the dimension and hydrogen effects characteristic of the material based on the determined thickness of the conveyor; and

determining a water content of the material based on the detected parameter of water and detected dimension of the material,

determining whether the water content characteristic is within an acceptable range; and

providing adjustments to the water content of the material based on the determination.

14. The method according to claim **13**, wherein detecting water content in the material comprises counting neutrons on one side of the conveyor apparatus emitted from a neutron source from an opposing side of the conveyor apparatus.

15. The method according to claim **13**, wherein determining a dimension characteristic of the material comprises using one of acoustics, ultrasonic, structured light, lasers, optics, radar and microwave techniques, gamma ray, and combinations thereof for determining one or more dimension characteristics.

16. The method according to claim **13**, wherein determining a dimension characteristic of the material comprises counting gamma-rays (photons) using a gamma-rays source and a scintillation detector.

17. The method according to claim **13**, wherein determining a dimension characteristic of the material comprises determining one of a height or mass thickness of the material.

18. A device for determining a characteristic of a construction material being transported by a conveyor apparatus, the device comprising:

one of a gamma-ray and a neutron source positioned about one side of the conveyor apparatus;

a detector positioned about the opposing side of the conveyor apparatus configured for detecting one of the gamma-rays and neutrons;

a water content measurement system positioned about the conveyor apparatus for detecting water content in the material; and

a computer device configured to;

manipulate data received from the detectors to determine a characteristic of the construction material including taking a first measurement with an empty conveyor to determine at least one of a thickness and hydrogen content of the empty conveyor and adjusting the measured characteristics of the material based on the determined thickness and hydrogen content of the conveyor;

determine whether the water content characteristic is within an acceptable range; and

provide adjustments to water content of the material based on the determination.

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