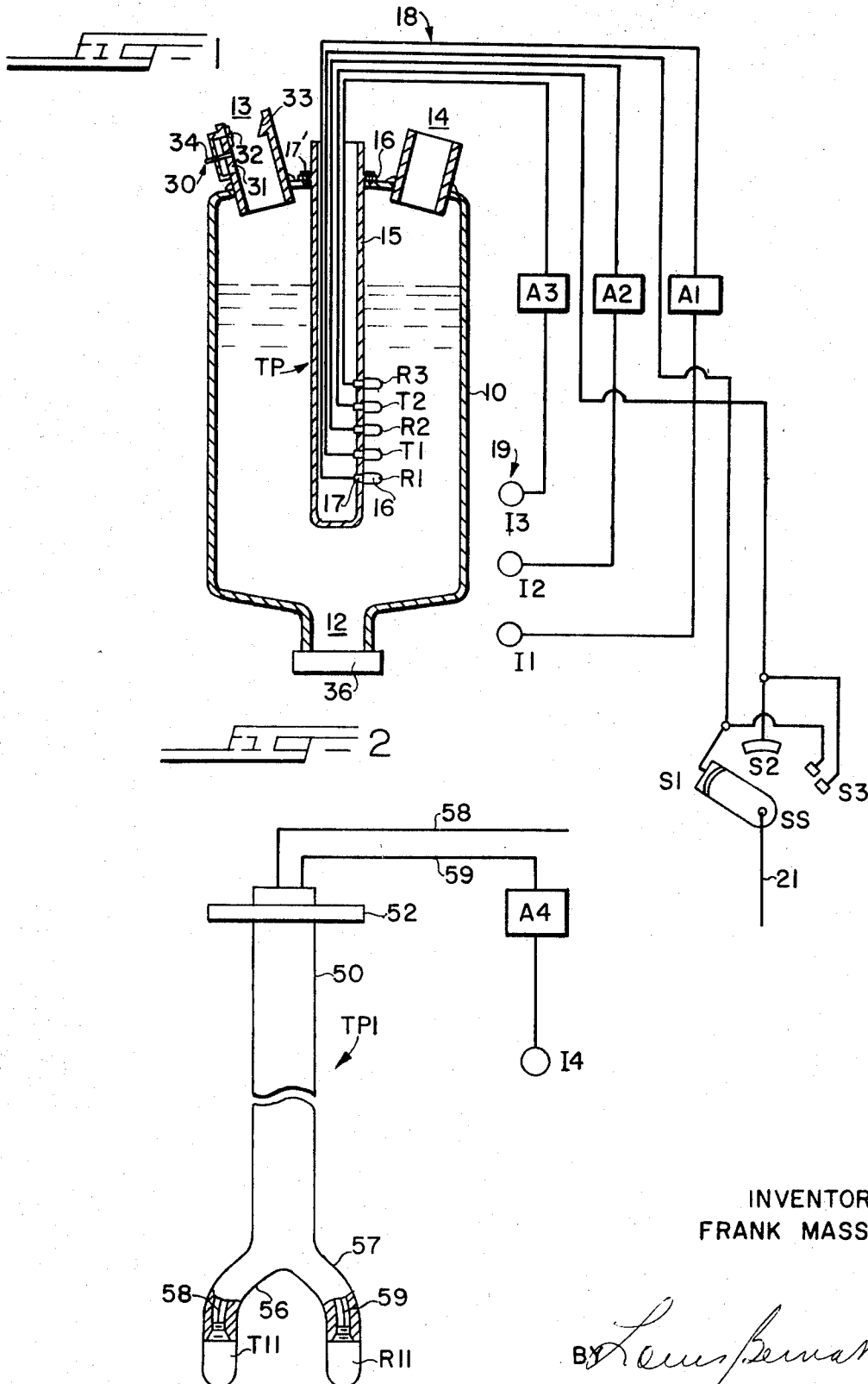


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MONITORING A CHEMICAL PROCESSING SYSTEM BY MEASURING THE
INSTANTANEOUS SOUND TRANSMISSION CHARACTERISTICS THEREIN
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MONITORING A CHEMICAL PROCESSING SYSTEM BY MEASURING THE INSTANTANEOUS SOUND TRANSMISSION CHARACTERISTICS THEREIN

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13 Claims

ABSTRACT OF THE DISCLOSURE

A chemical process is monitored by a system for measuring the instantaneous sound transmission characteristic in a substance being processed. In processes where the substance stratifies, a plurality of measurements are made at different strata of the material while it is being processed. The sound transmission characteristics are measured by a plurality of electroacoustic transmitting and receiving transducers located within separate regions of the material being processed. A source of alternating electric power drives the transmitting transducers and the intensity of sound level produced is picked up by the receiving transducer which records the sound level through appropriate amplifiers and indicators. As applied to wood chip digestion, the instantaneous sound transmitting characteristics indicate the rate and process of the digestion.

This invention relates to apparatus and method for monitoring a chemical processing system, and more particularly to acoustic instruments for automatically observing the physical state of a compound or mixture as it is undergoing a transformation. Although the invention is not limited to the processing of materials which are in a fluid state, the invention is particularly well adapted for this type of process.

Many chemical manufacturing processes involve a change in the physical state of a substance which is being processed. When such a change occurs, there is usually an accompanying change in the sound transmission characteristics of the material. This variation of transmission characteristics is utilized for monitoring and controlling the manufacturing process.

The specific nature of the manufacturing process is not too important to the invention. However, it might be instructive to mention a few exemplary processes so that the invention may be related to specific situations. A first such exemplary process involves the manufacture of plastics having molecular chains of high molecular weight. As the raw materials change in characteristics, toward the desired high weight molecules, there are accompanying changes in the sound transmission characteristics in the chemical mix being processed. The desired characteristics of the processed material occur when a particular size of molecule is reached during the processing. This molecule size provides more or less attenuation to an ultrasonic sound signal of a chosen value of frequency.

Another exemplary process might involve a system used in the continuous manufacture of wood pulp. In this system, wood chips are fed into a digester, which is a large steel tank containing a hot chemical bath for digesting the wood and thereby separating the fibers and forming a wood pulp. Here, it is desirable to control the level of the wood chips within the liquid in order to obtain a satisfactory processing time for completing the chemical action on the wood chips. This control permits the withdrawal of the digested pulp on a continuous basis,

while simultaneously enabling the addition of fresh wood chips to maintain an optimum level within the tank. This continuity is a substantial advance over the batch processing which requires a substantial digester down time after pulp is withdrawn and before each new batch is introduced into the digester.

Still another exemplary process might include the manufacture of fluids or chemicals in which two or more ingredients are added to a processing vat at a controlled rate while the processed combination of the ingredients is withdrawn from the vat on a continuous basis. For controlling and monitoring this continuous system, the invention makes use of the variations in the acoustic transmission properties of the material which occur responsive to the change of state within the combined ingredients. This variation in acoustic transmission characteristics within the processed material is utilized for determining the completion of the process and for controlling the rate of flow of the materials through the processing system.

This invention may be applied to still other types of industrial processing systems. In each case, the acoustic properties of the processed material is utilized to determine when the process is completed. The apparatus which monitors the acoustic transmission characteristic of the material may be used to control the process in any desired manner.

Accordingly, an object of the invention is to monitor or control a chemical processing system by measuring the acoustic properties of the material being processed.

Another object of this invention is to provide an array of electroacoustic transducers which may be immersed within a chemical processing tank for measuring the acoustic properties of the material which is being processed within the tank. Here, an object is to provide such an array which may probe in a corrosive environment.

An additional object of this invention is to provide an array of transmitting electroacoustic transducers interspersed for establishing the sound transmission characteristics within a volume of material in which the transducer array is submerged.

A further object of this invention is to provide a linear array of electroacoustic transducer elements immersed in a material undergoing chemical processing. Here, an object is to determine the sound transmitting characteristics within the material. More particularly, an object is to measure the characteristics from point to point along the length of the electroacoustic transducer array.

Still another object of this invention is to automatically control a chemical process in which one or more ingredients are added within a tank. Here, an object is to control the rate of flow of the materials into and out of the tank.

The novel features which are characteristic of this invention are set forth with particularity in the appended claims. However, the organization, method of operation, and advantages of the invention will be understood best from the following description when taken in connection with the accompanying drawings in which:

FIG. 1 is a schematic representation of a chemical processing apparatus controlled by one form of my invention; and

FIG. 2 is a schematic illustration of another embodiment of my invention.

In FIG. 1, the reference character 10 represents a vertical digester tank shown in cross section and having an outlet 12 at the bottom and two inlets 13 and 14 at the top of the tank. Valves and other mechanisms are provided for controlling the flow of material at both the inlet and outlets of the tank. These valves and mechanisms may be almost any of the structures used in this

type of industrial processing system. They may include remote control means for regulating the valve positions and for controlling the rates of material flow into and out of the tank.

Purely by way of example, an inlet valve is here shown schematically at 30 to control the introduction of raw material into the tank 10. More particularly, this valve comprises a door-like arrangement 31 pivoted at 32 to swing up against a stop 33, and thereby block the flow of raw material. Or, the door 31 may swing down, as shown, to allow passage of the raw material into the tank 10. An actuator 34, for controlling the position of door 31, is automatically moved responsive to the output of the receiving transducers. A similar device 36 is shown at the output 12.

In keeping with an aspect of the invention, an instrumentation test probe TP is inserted into the tank 10 and submerged beneath the surface M of the material being processed within the tank. This test probe measures the sonic characteristics of such material. The probe includes a number of transmitting transducers T1, T2 and receiving transducers R1, R2, R3 located at different vertical heights within the tank.

This test probe is particularly useful as a monitor for a material processing system wherein the processed material tends to form stratified layers. For example, in a wood chip digester tank, the top stratum of the tank tends to be filled with a liquid and floating chip mixture, the center stratum of the tank is filled with water logged chips which have not been completely digested, and the bottom stratum of the tank is filled with digested wood pulp. The receiving transducer R3 measures conditions in the top stratum, the transducer R2 measures conditions in the center stratum, and the transducer R1 measures conditions in the bottom stratum.

In greater detail, a vertical pipe 15 is provided with a flange 16 which is attached to the top of the tank, as by means of bolts 17', for example. The interior of the test probe pipe 15 is hermetically sealed to prevent entry of any liquid contained within the tank 10. Spaced vertical along the length of the pipe 15 are a number of electroacoustic transducers. Receiving transducers are identified as R1, R2 and R3. Interspersed between the receiving transducers are a number of transmitting transducers T1 and T2.

Preferably, the transmitting transducers are omnidirectional along the vertical axis of the pipe 15. Thus, the sound generated by a transmitting transducer, such as T1, for example, is directed simultaneously toward the adjacent receivers R1 and R2.

While the specific structural details of these electroacoustic transducers are not too important and while many well known types may be employed, I presently contemplate the use of transducers comprising a polarized cylindrical ceramic element enclosed in a hermetically sealed housing or chamber 16. The axis of the ceramic cylinder is arranged to lie at right angles to the axis of the test probe pipe 15. The housing or chamber 16 enclosing the cylindrical ceramic elements is terminated at the base end 17 by tapered pipe threads. As the transducer elements are turned into mating threads through the wall of the test probe pipe 15, a hermetic seal is formed between the transducer mounting structure 17 and the wall of the pipe 15.

Electrical cables 18 are individually connected to the transducers R1, T1, R2, T2 and R3. The receiving transducers R1, R2 and R3 are connected to amplifiers A1, A2, and A3 via individually associated wires in the cable 18. The outputs from these amplifiers are connected to indicators 19, individually designated I1, I2 and I3. These indicator elements may be lights, illuminated digits, electrical meters, relays, or any other type of device which is operated or controlled responsive to electrical output signals from the transducers. These indicators may be actuated at predetermined levels of amplifier output sig-

nals. The relays may provide for giving additional control over the process functions, as by operating motors, valves, or the like. Thus, the indicators provide means for controlling the process which is being monitored by the acoustic system.

Electrical wires in the cable 18 also make individual connections between the transmitting transducers T1 and T2 and a selector switch SS, having three circuit making positions S1, S2 and S3 for the common movable arm. The electrical wire 21 supplies power, from a source (not shown), for operating the transmitting transducers. When the selector switch SS is in position S1, only transmitting transducer T1 is activated. At the position S2, only the transmitting transducer T2 is activated. In position S3, both of the transmitting transducers T1 and T2 are activated simultaneously.

In operation, the apparatus measures the characteristics of sound transmission through material contained within the tank 10 and situated between the energized transmitting transducers and the associated receiving transducers. These transducers are placed at intervals, along the height of the tank, which are selected according to the process being monitored. For example, with the selector switch in position S1, the readings on indicators I1 or I2 indicate the transmission of sound characteristics between transmitting transducer T1 and receiving transducers R1, or R2, respectively. Additional sound transmission readings are obtained on indicators I2 and I3 when the selector switch is in position S2. With the switch in position S3, both transmitting transducers T1 and T2 are activated simultaneous to give readings on all indicators.

The information thus obtained on the indicators I1-I3 discloses the chemical state of the material contained within the tank. This information may be utilized by any suitable means for mechanically controlling the processing system. For example, it may control a withdrawing of the completely processed material from the outlet 12 or the addition of raw material through the inlet 13 or 14. If the processing requires an application of a heat cycle, for example, the heating element may also be regulated responsive to the output signals from the amplifiers A1, A2, and A3.

By way of illustration, assume that the tank 10 is processing wood pulp, that the wood chips are admitted through inlet 13, and that the completely processed pulp is withdrawn through the outlet 12. The tank 10 also contains any chemicals which are necessary for treating the wood chips. In a particular situation, the liquid may be heated. Also, the tank 10 may be pressurized, and might contain stirring or other mixing apparatus (not shown) which are well known in the art.

According to the invention, the process of digesting the wood chips to manufacture pulp may be made automatic and continuous. For this, it is necessary to determine when the wood chips have been broken down into their component fiber parts. Then, the processed pulp may be withdrawn from the bottom of the digester, at the proper time and at the correct rate. The wood chips may be added in proportion to the removal of the completely digested chips. This continuous processing also requires the maintenance of an optimum height of the wood chips and the liquid within the tank. The invention automatically monitors this optimum height.

All of these and other monitoring details may be accomplished by a measurement of the characteristic transmission of sound between adjacent transducers located at various points along the vertical axis of the tank. For example, there is a relatively high attenuation of sound in the region within the tank where the fresh wood chips are present. The attenuation is relatively low in the liquid above the chips. The digestion of the chips is completed near the bottom of the tank. There, the absorption of the sound is different from the absorption in other areas where digestion is not yet complete. Thus, the nature of

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the wood pulp material at the various regions may be derived from the several receiving transducers. Upon reflection, it should be apparent that the receiving transducers R1-R3 indicate the conditions and the progress of the chips and pulp product being processed. These receivers may be used to monitor and automatically control the process.

The foregoing description of FIG. 1 relates to a processing system wherein the material tends to stratify. A wood pulp digesting system is cited here, by way of example. Other systems will readily occur to those who are skilled in the art.

Another type of material processing system involves mixtures which are generally homogenous throughout the entire processing cycle. Here, there is no need to monitor any more than one point in the tank. Thus, a test probe TP1 for a homogeneous mixture is shown in FIG. 2.

In greater detail, FIG. 2 schematically illustrates another embodiment of my invention. Here, a pipe 50 has an attached mounting flange 52. This probe TP1 may replace the test probe TP illustrated in FIG. 1. Near its lower end, the pipe 50 is bifurcated to provide two small diameter branches 56 and 57 which are adapted to receive a transmitting transducer T11 and a receiving transducer R11. An electrical cable 58 connects the transmitting transducer T11 to a source of driving alternating current power (not shown). An electrical cable 59 connects the receiving transducer R11 to the input of an amplifier A4. An indicator I4 is connected to the output amplifier A4.

The sonic energy is transmitted from the transmitting transducer T11 through the mixture in the tank to the receiving transducer R11. Thus, the sound transmission characteristics of the mixture affects the sound energy, as it is received. The nature of this received energy is amplified at A4 and indicated at I4. Therefore, the amplifier A4 and indicator I4 provide the function, as described for the corresponding elements A1-A3 and I1-I3, in FIG. 1.

The arrangement of FIG. 2 provides a simpler electroacoustic system since a single transmitter and receiver are employed in the test probe TP1. Therefore, only a single measurement channel is required in FIG. 2, as compared to the multiple channels required in FIG. 1.

The simplified system of FIG. 2 may be employed where a material subjected to a chemical processing is relatively homogeneous and where a change in state results from the processing. This change occurs uniformly throughout the entire volume of the processed material. In such applications, it is only necessary to monitor the acoustic transmission properties at a single point in the material being processed.

The optimum choice of the driving frequency is empirically determined for the type of product that is being processed. The desirable frequency range is easily determined by measuring the absorption of sound transmitted between a pair of transducers immersed within a sample of the product, as it appears at the various stages encountered during the manufacturing process. Thus, the absorption characteristic is experimentally determined for the various samples to enable a selection of the optimum frequency which gives output readings with maximum indications, and thereby achieves maximum precision in the control of the process.

In general, for many chemical processes, it is found that the ultrasonic frequency region gives maximum indications of attenuation changes which occur in the material during the processing operation. If a change in molecular weight is to be detected during a chemical process, it may be necessary to use relatively high ultrasonic frequencies, as in the region of a megacycle or more, for example. In other cases, where large scale changes occur in particle size during such processing, lower ultrasonic frequencies generally give optimum re-

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sults. In still other cases, relatively large pieces of solid materials are mixed or diffused within a liquid, and frequencies in the upper audible range might be more desirable. Therefore, this invention need not operate at any uniquely specific frequency. Rather, the frequency of operation is determined according to the specific process which is to be monitored. The operating frequency is selected so that a maximum differential is obtained in the attenuation characteristic of sonic energy transmitted through the material, as it undergoes its chemical processing.

While the invention has been described in connection with particular embodiments thereof, it should be understood that additional embodiments and modifications thereof may be devised without departing from the spirit and scope of the invention. Therefore, the appended claims are to be construed as covering all equivalents of the invention.

I claim:

1. An apparatus for monitoring a chemical system for processing a substance having a sound transmission capability, said apparatus comprising a container for said substance being processed, electroacoustic instrumentation means for measuring the sound transmission characteristics in each of a plurality of separate regions within the substance, said measuring means including a plurality of electroacoustic receiving transducers and at least one electroacoustic transmitting transducer located at separate points within the separate regions in the substance, a source of alternating electrical power for driving said transmitting transducer, and indicating means connected to said receiving transducers for instantaneously indicating the intensity of sound levels produced by said driven transducer at said separate points in the separate regions within the substance where the receiving transducers are located.

2. The apparatus of claim 1 wherein said substance is in at least a partially liquid state during at least part of said processing, and said indicating means including an amplifier means having an input and an output, and an indicator, the input of said amplifier means being connected selectively to one of said receiving transducers and the output of said amplifier means being connected to said indicator.

3. The apparatus of claim 2 and a test probe comprising a hollow tubular structure having a wall surface, said transducers being vertically mounted along the outside wall surface of said tubular structure, and said transmitting transducer being mounted to transmit sound in directions which are in alignment with a sensitive axis of each of at least two of said receiving transducers.

4. The apparatus of claim 3 and electrical connection means contained within said hollow tubular structure for interconnecting said transducers and said amplifier means.

5. The apparatus of claim 4 and means for sealing said tubular structure whereby the substance cannot pass into the inner region of the hollow tubular structure when the tubular structure is immersed within the substance.

6. A chemical processing system comprising a tank, a fluid substance contained within said tank, said fluid having a sound transmitting characteristic, a plurality of electroacoustic receiving transducers and at least one electroacoustic transmitting transducer mounted in a spaced apart relationship with respect to one another, said transducers being immersed within said fluid substance when so mounted, a source of alternating current electrical power, electrical connection means connecting said source of electrical power to said transmitting transducer means, signal amplification means electrically connected to receive signals from said receiving transducer means, and sensing means responsive to the amplified signal from said signal amplification means for indicating the sound transmission characteristics of said substance.

7. In a chemical processing system, a tank having a vertical axis, test probe means comprising a hollow sealed

pipe having an outer wall surface and also having an axis, means for mounting said probe within said tank with the axis of said pipe arranged approximately parallel to the vertical axis of said tank, a plurality of electroacoustic receiving transducers and at least one electroacoustic transmitting transducer mounted on the outer wall surface of said pipe, said transducers being spaced along the length of said pipe and said transducers being hermetically sealed against an opening in said pipe whereby a watertight enclosure is maintained within said pipe and transducers, and means contained within said sealed pipe and transducer for connecting said plurality of electroacoustic receiving transducers to means for indicating the output of said receiving transducers.

8. An apparatus for controlling a chemical material processing system comprising a container having inlet and outlet openings, means for causing said material to flow into and out of said openings, means for controlling the flow rates of said material through each of said openings, means for detecting sound transmitting characteristics of the material being processed within said container, means for automatically regulating the flow rate control means responsive to the detected sound transmitting characteristic of the material being processed within said container, said detecting means including means for measuring said sound transmitting characteristic comprising a plurality of electroacoustic transducers mounted a fixed distance from each other and suspended within said processed material, wherein the plurality of electroacoustic transducers comprise at least one transducer for generating a sound signal in the material and a plurality of transducers for receiving said sound signal generated in said material at a plurality of separate regions in said material, amplifying means for amplifying said received signal, said amplified signal having a characteristic which is a measure of the sound transmitting characteristic of the material, and means responsive to said amplified signal for regulating said means for controlling said flow control means.

9. The invention in claim 8 and means for hermetically sealing said container and said transducer mounting comprises a rigid fixture which is immersed in the container.

10. The invention in claim 9 wherein said fixture comprises a hollow sealed tubular structure and electrical wiring in said hollow tubular structure to provide transducer connections.

11. A continuous wood pulp digesting process comprising the steps of:

- (a) monitoring the instantaneous sound transmission characteristics in a first stratum in said digester to detect the rate and progress of the digestion of said wood chips;
- (b) selectively admitting a predetermined amount of wood chips to a digester, said predetermined amount being set responsive to the instantaneous transmission of sound characteristics monitored in said first stratum of said digester.
- (c) monitoring the instantaneous sound transmission characteristics in a second stratum in said digester

to detect the rate and progress of the digestion of said wood chips;

- (d) monitoring the instantaneous sound transmission characteristics in a third stratum in said digester to detect the rate and progress of the digestion of said wood chips; and

- (e) selectively withdrawing a predetermined amount of wood pulp from said digester responsive to the instantaneous sound transmission characteristics as monitored at the third stratum in said digester.

12. The process of claim 11 wherein said first stratum is near the top of said digester, said third stratum is near the bottom of said digester, and said second stratum is between said first and third strata; said process comprising the added steps of transmitting sonic energy from at least one transmitting transducer to a receiving transducer mounted in each of said strata.

13. A continuous raw material digesting process comprising the steps of:

- (a) monitoring the instantaneous sound transmission characteristics in a first stratum in said digester to detect the rate and progress of the digestion of said raw material;
- (b) selectively admitting a predetermined amount of raw material to a digester, said predetermined amount being set responsive to the instantaneous transmission of sound characteristics monitored in said first stratum of said digester;
- (c) monitoring the instantaneous sound transmission characteristics in a second stratum in said digester to detect the rate and progress of the digestion of said raw material;
- (d) monitoring the instantaneous sound transmission characteristics in a third stratum in said digester to detect the rate and progress of the digestion of said raw material; and
- (e) selectively withdrawing a predetermined amount of raw material from said digester responsive to the instantaneous sound transmission characteristics as monitored at the third stratum in said digester.

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