

## [54] APPARATUS FOR AND METHOD OF GRANULAR MATERIAL TESTING

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[52] U.S. Cl. .... 73/93

[51] Int. Cl. .... G01n 33/24

[58] Field of Search ..... 73/88 R, 93, 81

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Primary Examiner—Jerry W. Myracle

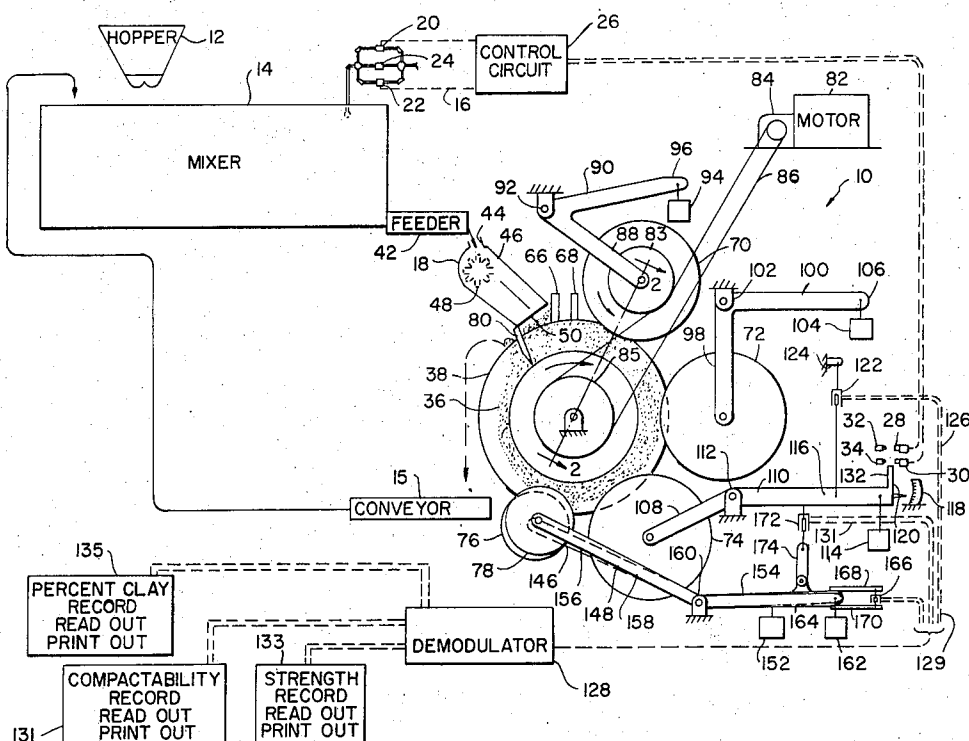
Attorney, Agent, or Firm—Whittemore, Hulbert &amp; Belknap

## [57]

## ABSTRACT

Apparatus for and method of determining the compactibility, strength and effective clay content of granular material such as foundry sand. Both rotary and linear apparatus modifications for continuously determining the compactibility, strength and effective clay content of the foundry sand is specifically disclosed along with novel sample feed structure, foundry sand strength determining structure, and structure for determining the effective clay content of foundry sand from compactibility and strength information, including cam discs constructed in accordance with the relation between the compactibility and the effective clay content of the granular material and in accordance with the relation between the strength of the granular material and the effective clay content thereof. Apparatus for and method of conditioning foundry sand and for directing conditioned foundry sand into automatic molding machines in accordance with one of the determined compactibility, strength and effective clay content is also disclosed.

19 Claims, 19 Drawing Figures



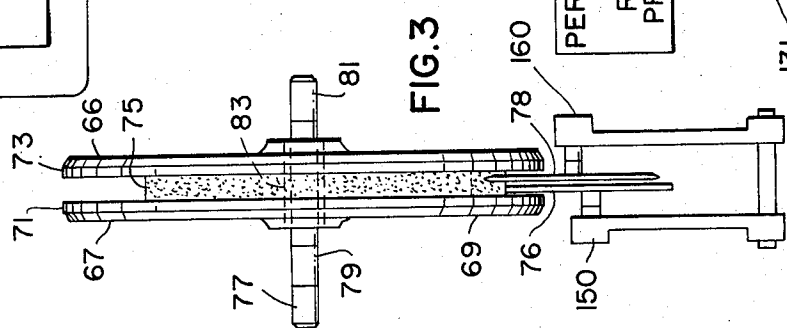
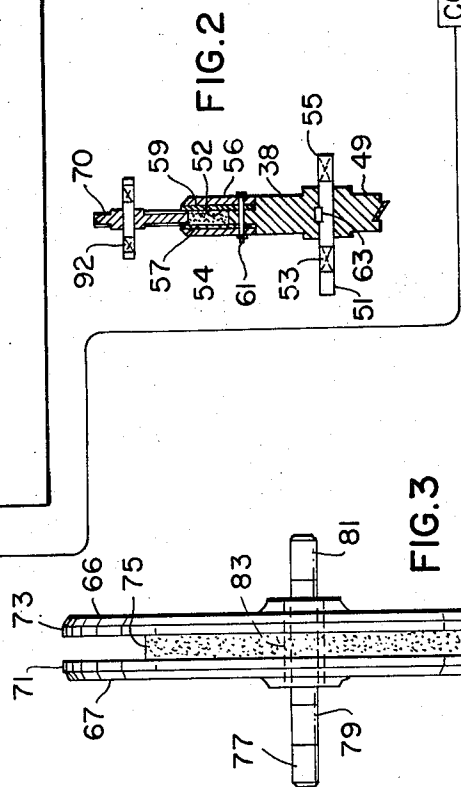
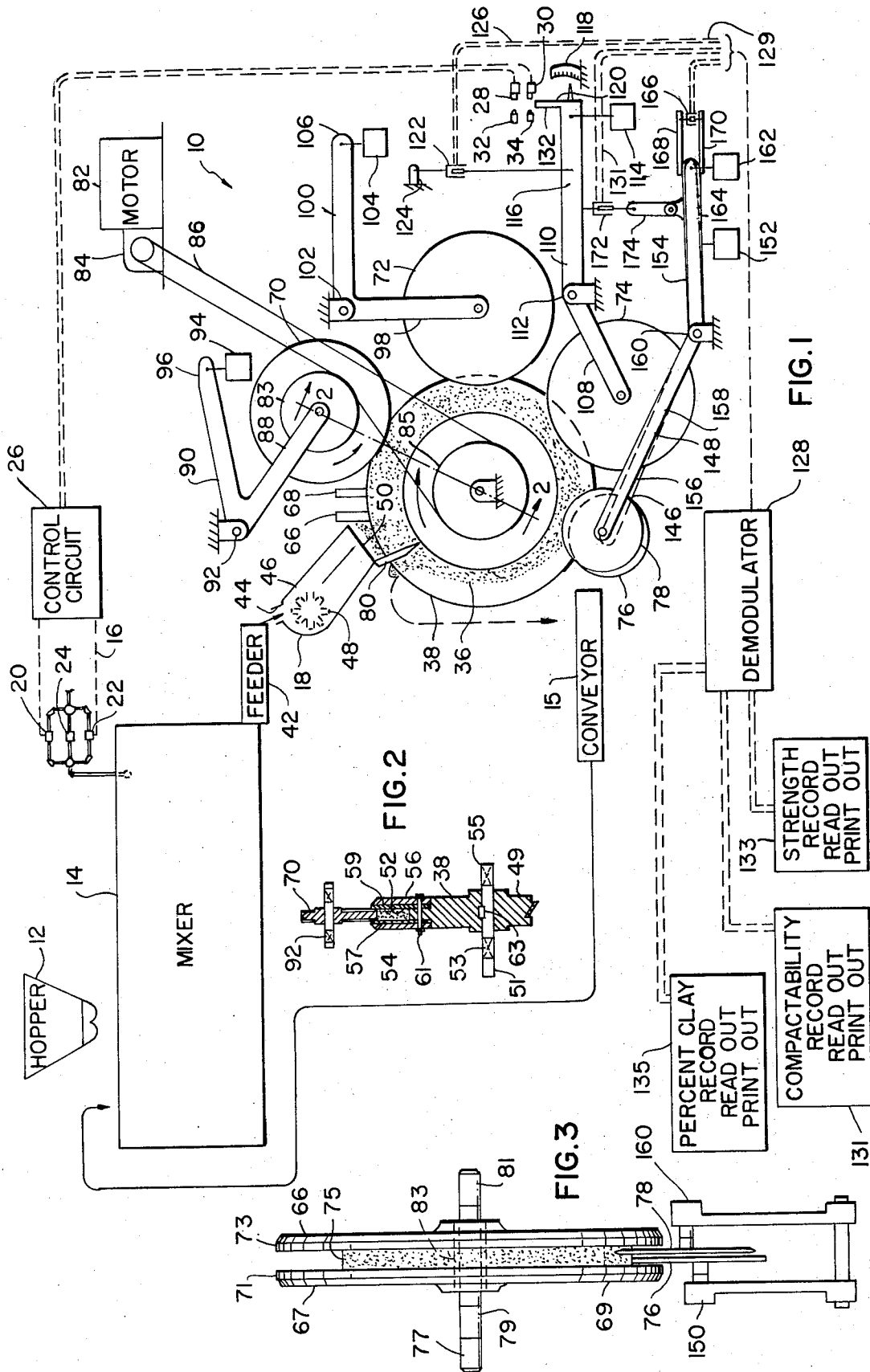


FIG. 8

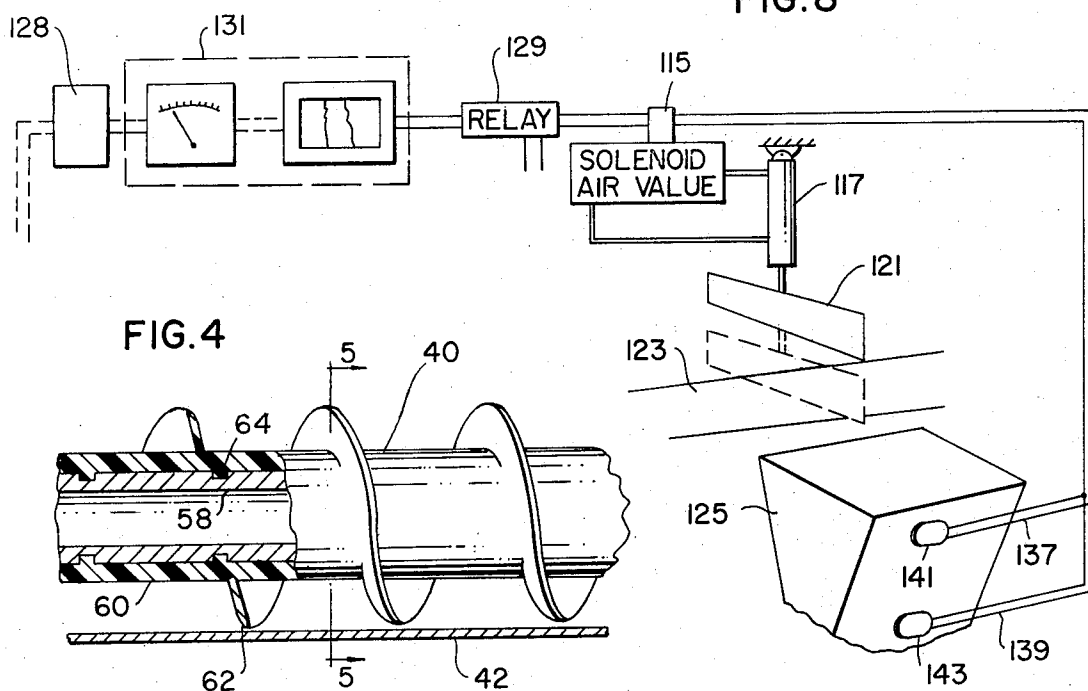


FIG. 4

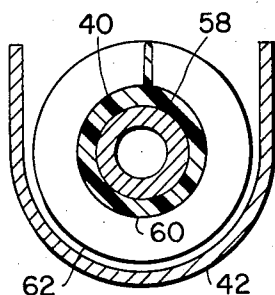
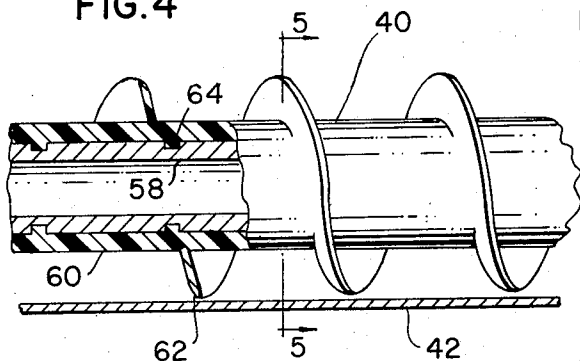


FIG. 5

FIG. 9

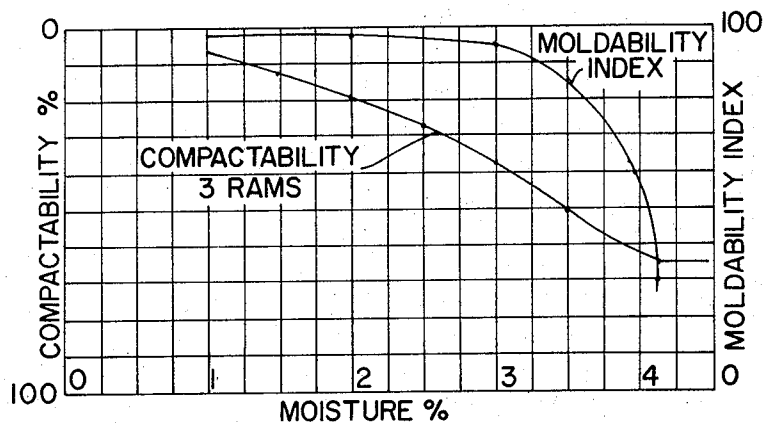


FIG. 6

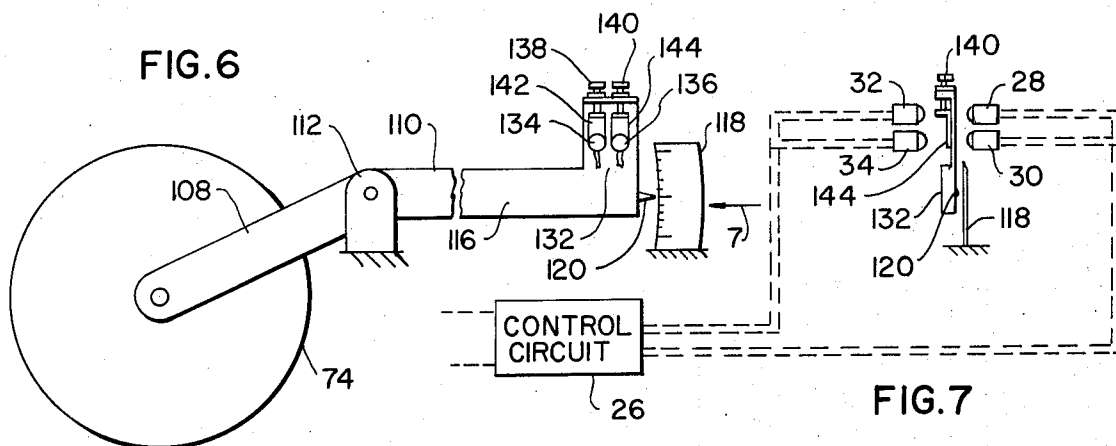
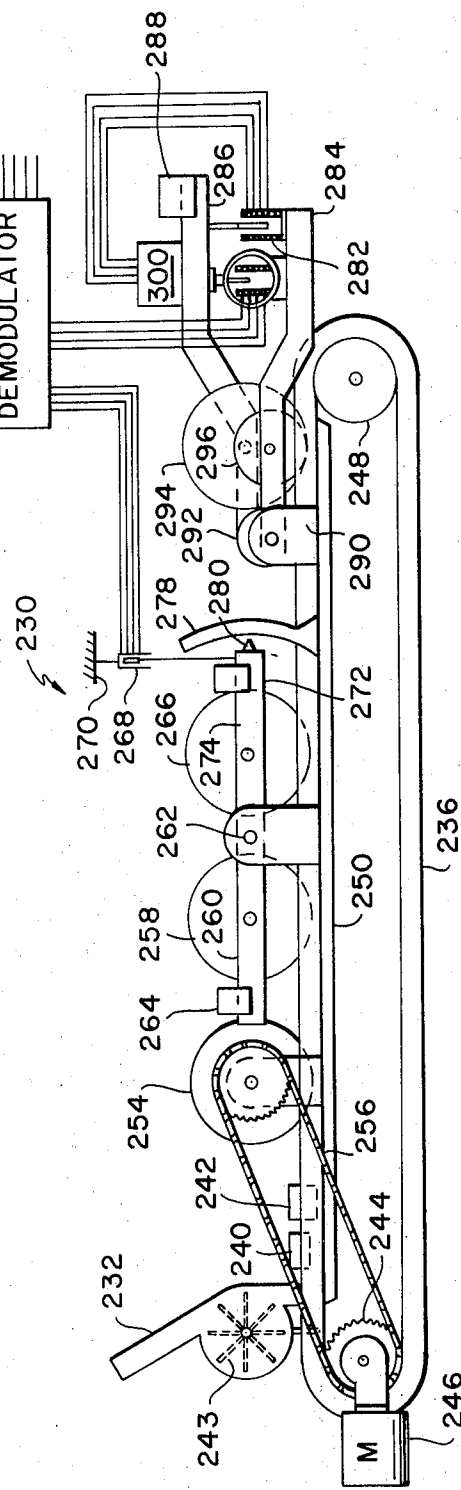
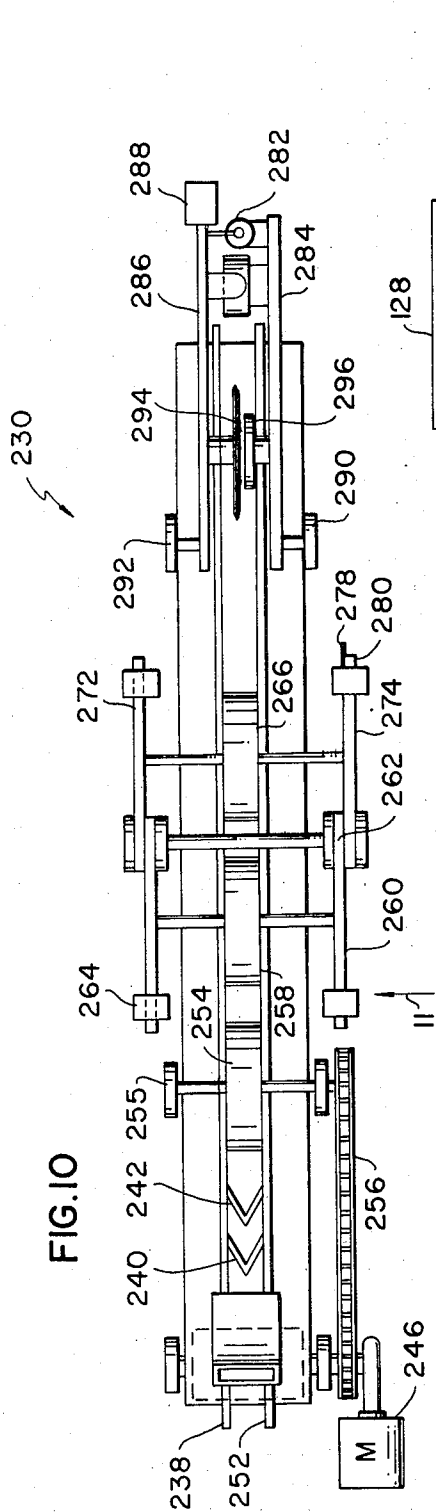
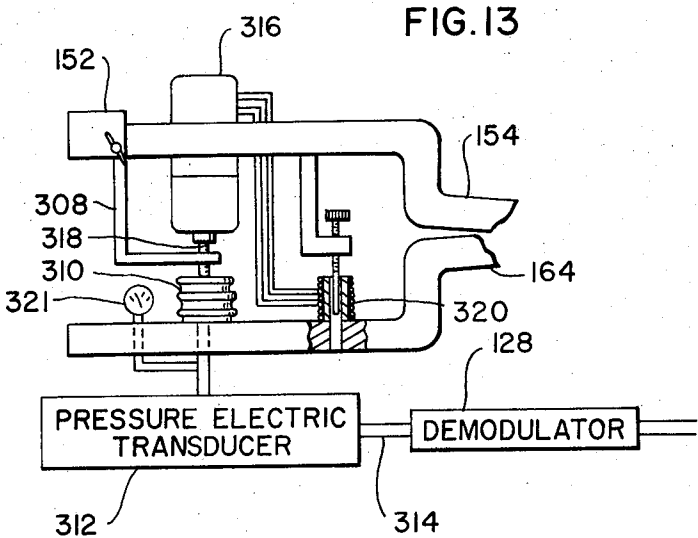
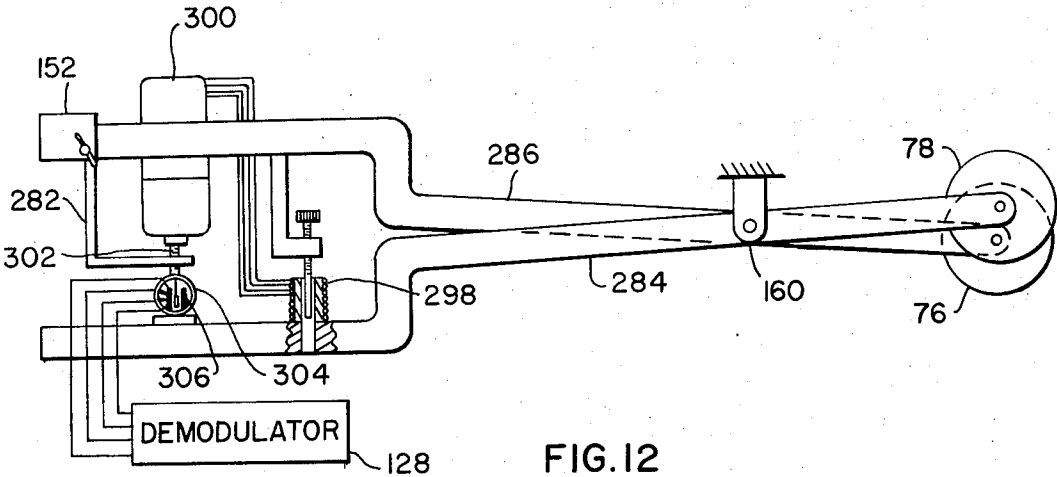


FIG. 7





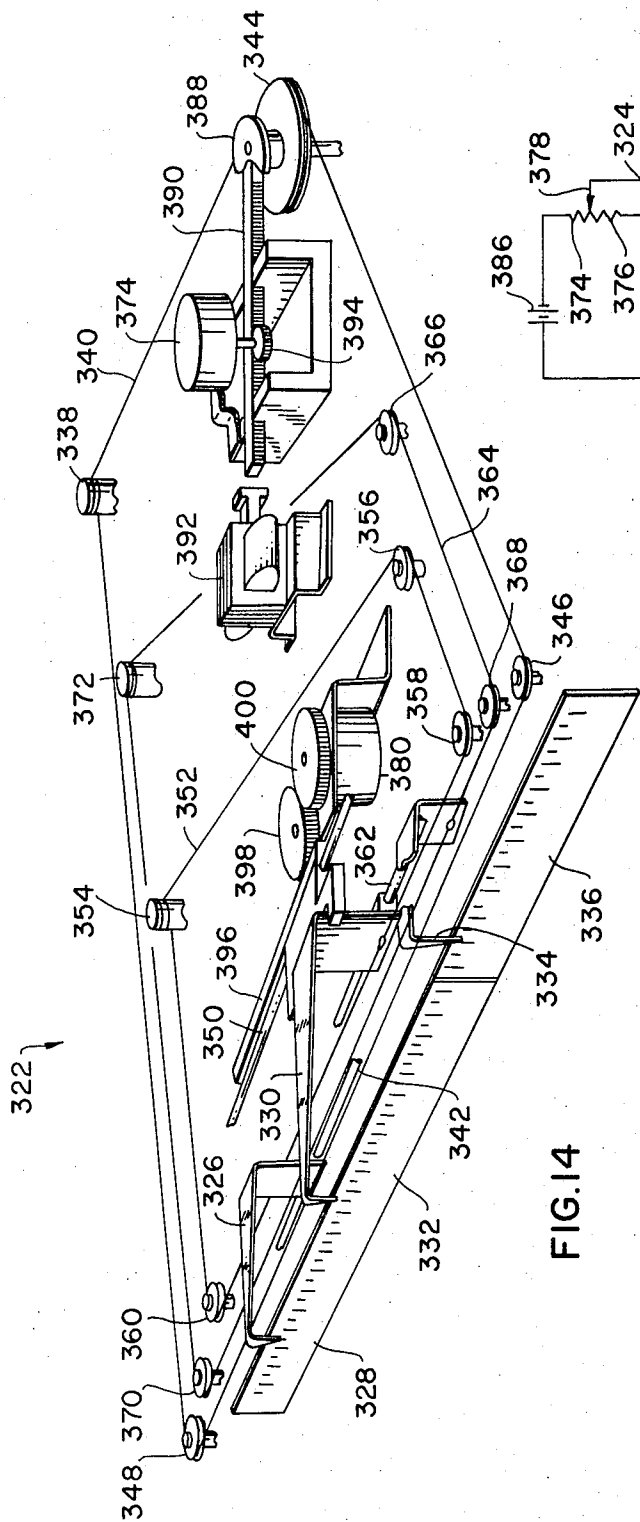


FIG. 14

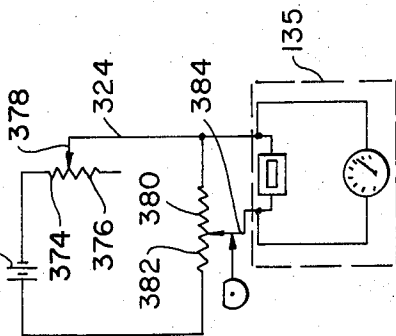
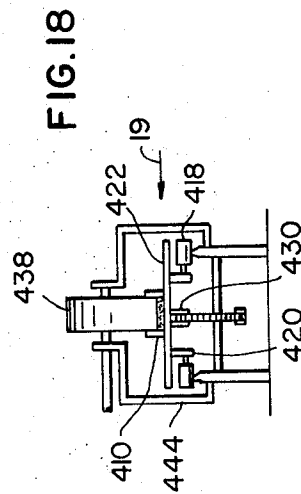
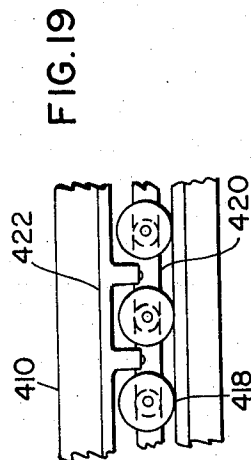
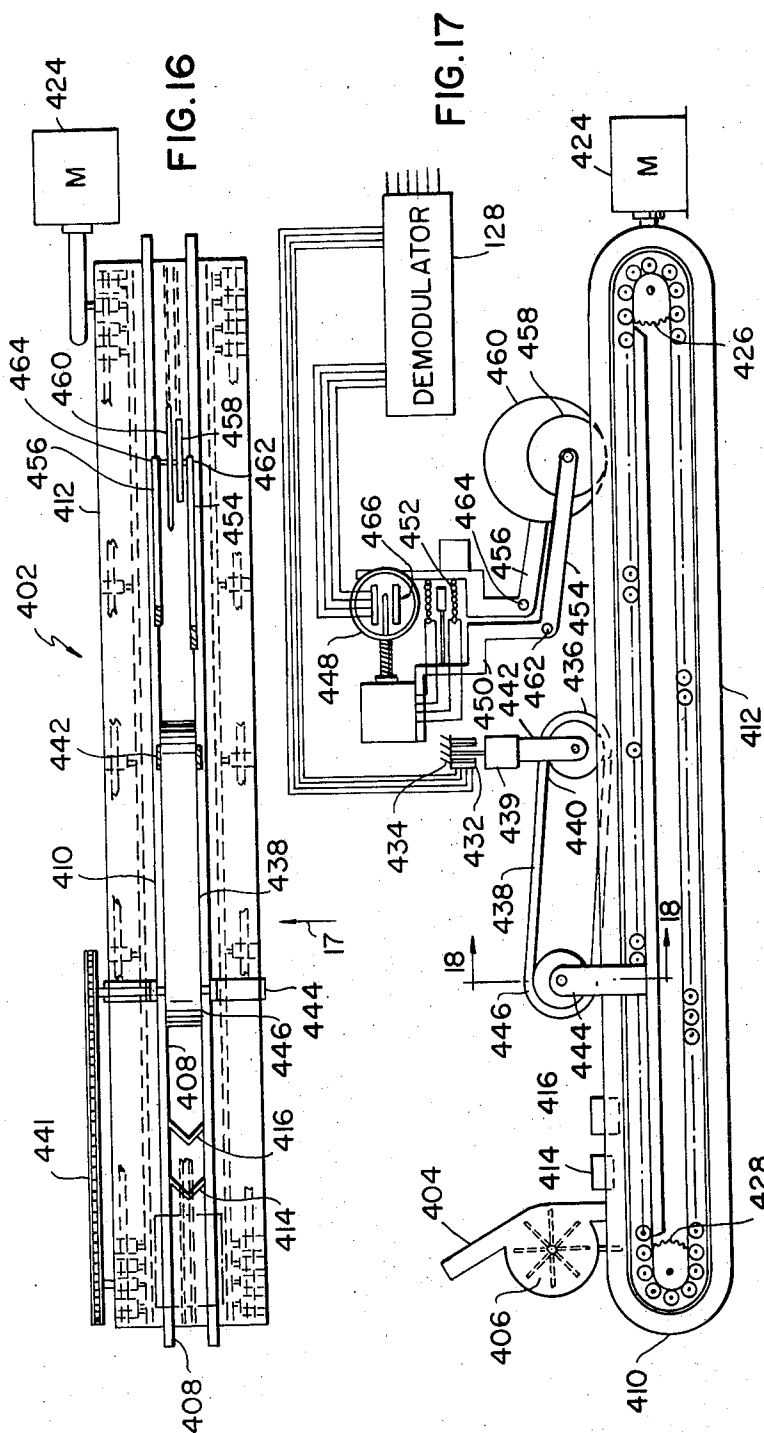


FIG. 15



# APPARATUS FOR AND METHOD OF GRANULAR MATERIAL TESTING

## BACKGROUND OF THE INVENTION

### 1. Field of the Invention

The invention relates to granular material conditioning apparatus and methods and refers more specifically to both a rotary and linear apparatus for and method of continuously determining the compactibility and strength of foundry sand and subsequently determining the effective clay content of the foundry sand in accordance with the compactibility and strength thereof, structure for conditioning the foundry sand in accordance with the compactibility thereof, structure for removing the conditioned foundry sand from a conveyor at a remote molding location in accordance with the compactibility thereof, and sample feed means for the foundry sand.

### 2. Description of the Prior Art

It is essential to the production of acceptable castings to have properly conditioned foundry sand. Initially, the determination of the proper condition of foundry sand was largely an art and consisted of an experienced operator holding a sample of the sand in his hand and compressing it to determine its suitability for use in a particular job. Recently, the conditioning and testing of foundry sand for such suitability has become more of a mechanized science.

In the mechanized testing of foundry sand, the condition of the sand has sometimes been determined by electrically sensing the moisture content thereof. This method of determining the condition of foundry sand has been largely supplanted by moldability control apparatus for sensing and controlling the moldability of the sand in accordance with applicant's prior Patents Nos. 3,136,009 and 3,136,010.

## SUMMARY OF THE INVENTION

In accordance with the present invention, apparatus for and a method of determining the compactability, strength and effective clay content of foundry sand is provided. Both rotary and linear embodiments of the apparatus for determining the compactability, strength and effective clay content of the foundry sand continuously are disclosed.

Further, a circuit for continuously determining the effective clay content of the foundry sand from compactability and strength information is disclosed. The circuit includes cam means contoured in accordance with the relation between the compactability and the effective clay content of the foundry sand and contoured in accordance with the relation between the strength and the effective clay content thereof.

Particular structure is also disclosed for determination of the strength of the foundry sand, including a pair of levers movable in accordance with the strength of the foundry sand having a first linear variable differential transformer positioned therebetween, a servo motor driving a screw, and a force ring in series between the levers with the servo motor being driven in accordance with the signal from the first linear variable differential transformer and a second linear variable differential transformer within the force ring which provides a signal proportional to the strength of the foundry sand.

Additionally, a sample feeder including a feed auger having a flexible radially outer periphery in conjunction with a feed trough which together prevent foreign material from jamming the sample feeder by permitting deformation of the feed auger and thereby permitting the foreign material to pass through the sample feeder is also included in the disclosure along with structure for conditioning the foundry sand in accordance with the compactibility thereof and structure for removing the conditioned granular material from a conveyor at a remote location in accordance with the compactibility thereof.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagrammatic representation of rotary apparatus for continually determining the compactibility, strength and effective clay content of granular material such as foundry sand, controlling the addition of additives to the foundry sand in accordance with the compactibility thereof, and recording the compactibility, strength and effective clay content of the conditioned foundry sand, constructed in accordance with the invention for effecting the method of the invention.

FIG. 2 is a partial section view of the sample wheel of the apparatus illustrated in FIG. 1 taken substantially on the line 2—2 in FIG. 1.

FIG. 3 is an enlarged edge view of a modified sample wheel for the apparatus illustrated in FIG. 1.

FIG. 4 is an enlarged, broken away, partial view of the sample feeder of the apparatus illustrated in FIG. 1.

FIG. 5 is a cross section view of the sample feeder illustrated in FIG. 4 taken substantially on the line 5—5 in FIG. 4.

FIG. 6 is an enlarged broken elevation view of the compactibility structure of the apparatus illustrated in FIG. 1.

FIG. 7 is an elevation view of the compactibility structure illustrated in FIG. 6 taken in the direction of arrow 7 in FIG. 6.

FIG. 8 is a diagrammatic representation of structure for controlling a plow for moving the conditioned foundry sand from the apparatus illustrated in FIG. 1 from a conveyor at a remote molding location in accordance with the condition of the foundry sand.

FIG. 9 is a chart showing the relation between moisture content, moldability and compactibility of a particular type of foundry sand indicating that the conditioning of the foundry sand may be controlled by controlling compactibility of the sand in addition to the known methods of controlling the conditioning of foundry sand by controlling the moisture content or moldability of the sand.

FIG. 10 is a partial top view of a first linear modification of the apparatus illustrated in FIG. 1.

FIG. 11 is an elevation view of the complete modified apparatus illustrated in FIG. 10 taken in the direction of arrow 11 in FIG. 10.

FIG. 12 is an enlarged elevation view of the strength determining structure of the apparatus illustrated in FIG. 10.

FIG. 13 is a partial elevation view of a modification of the strength determining structure illustrated in FIG. 12.

FIG. 14 is a diagrammatic representation of structure for determining effective clay content in foundry sand

from compactibility and strength information in accordance with the invention.

FIG. 15 is a schematic diagram of a circuit for determining the effective clay content of foundry sand in accordance with the structure of FIG. 14.

FIG. 16 is a partial top view of a second linear modification of the apparatus illustrated in FIG. 1.

FIG. 17 is an elevation view of the complete modified apparatus illustrated in FIG. 16, taken in the direction of arrow 17 in FIG. 16.

FIG. 18 is a section view of the modified apparatus illustrated in FIGS. 16 and 17, taken substantially on the line 18-18 in FIG. 17.

FIG. 19 is an enlarged elevation view of a portion of the modified apparatus illustrated in FIG. 18, taken in the direction of arrow 19 in FIG. 18.

#### DESCRIPTION OF THE PREFERRED EMBODIMENTS

As shown best in FIG. 1, the apparatus 10 for determining the compactibility, strength and active clay content of foundry sand is shown in conjunction with a hopper 12 for feeding granular material to be conditioned, the compactibility, strength and active clay content of which it is desired to determine, into the material mixer 14, and the mixer 14. Water addition apparatus 16 and sample feeder structure 18 are shown in conjunction with the apparatus 10, hopper 12 and mixer 14.

The hopper 12 and mixer 14 are well known in the foundry sand conditioning art and will not therefore be considered in detail herein. Similarly, moisture control apparatus including automatically operated fine and coarse water addition valves 20 and 22 and the manual water addition valve 24 connected in parallel as shown are well known. The valves 20 and 22 as shown are operable in response to an electrical signal fed to a control circuit 26 in accordance with the light reception of photoelectric cells 28 and 30 from light sources 32 and 34, respectively. The light reception of the photoelectric cells 28 and 30 is in accordance with the compactibility of the sample of foundry sand 36 on the sample wheel 38, which compactibility is determined in accordance with the invention, as will be considered subsequently.

The sample feeder 18 includes a feed auger 40, best shown in FIGS. 4 and 5, which is rotatably supported in a feed trough 42 and which is operable to pass granular material from an orifice in the mixer 14 into the input opening 44 in the sand chute 46. As shown, an aerator in the form of a rotatable paddle wheel 48 is positioned in the chute 46 to break up any lumps of sand which may find their way through the mixer 14 and the trough 42. The chute 46 is shaped at its lower end 50 to guide the aerated foundry sand sample into the annular recess 52 between the sides 54 and 56 of the sample wheel 38 as shown in detail in FIG. 2.

The feed auger 40, as shown best in FIGS. 4 and 5, includes a metal cylinder 58, adapted to be rotated by conventional means such as a gear (not shown) secured to one end thereof. A plastic sleeve 60 with integral helical auger fins 62 thereon is molded on the cylinder 58. The fins are flexible urethane and as shown are tapered toward the outer periphery thereof. The annular recesses 64 in the cylinder 58 lock the plastic sleeve 60 onto the cylinder 58 against axial movement with respect thereto.

Foundry sand is moved through the trough 42 on rotation of the feed auger 40, and should hard, foreign objects such as nails, bolts or the like be fed from the mixer 14 into the sample feeder 18, they will be passed through the trough 42 without damage to the feed auger 40 or trough 42 due to deformation of the outer periphery of the fins 62 in contact with the hard objects. Thus, no shutdown time is required with the sample feeder 18 due to broken shear pins or actuation of overload relays on the drive motor due to hard objects jammed between the feed auger and trough.

The apparatus 10 for determining the compactibility, strength and active clay content of a sample of granular material from the mixer 14 fed to the sample wheel 38 includes the sample wheel 38, the first and second sample strike-off plates 66 and 68, first, second and third compacting wheels 70, 72 and 74, the strength discs 76 and 78 and their associated mounting and sensing structure, and the foundry sand removal barrier 80 arranged as shown in FIG. 1 about the sample wheel 38. The sample wheel 38 and first compacting wheel 70, as shown, are driven by motor means 82 through gearbox 84 and chain drive 86 in conjunction with sprockets 83 and 85.

More specifically, the sample of granular material fed from the mixer 14 through the trough 42 and chute 46 is deposited on the sample wheel 38 between the sides 54 and 56 before the first and second strike plates 66 and 68 and after the material removal barrier 80 considering movement of the wheel 38 in a clockwise direction. Any excess of the sample of granular material will pass over the sides 54 and 56 of the sample wheel where it can be taken away by suitable conveyor means such as an extension of the conveyor 15.

The function of the strike plates 66 and 68 which are V-shaped in cross section having an apex pointing toward the chute 46, as shown for example in FIGS. 10 and 16, is to provide a uniform cross section of granular material on the sample wheel 38. To this end, it has been found that two strike plates, the first being radially outwardly of the sample wheel 38 with respect to the second, as shown in FIG. 1, are considerably more efficient than a single strike plate at the ultimately desired radial position such as the strike plate 68 by itself.

The sample wheel 38, as shown best in FIG. 2, includes a hub 49 rotatably mounted on the axle 51 in bearings 53 and 55. The sides 54 and 56 along with the hardened steel liners 57 and 59 are secured to the hub 49 by bolts 61. The hub 49 is keyed to the shaft 51 by the key 63.

The alternate sample wheel structure 65, as shown in FIG. 3, is constructed of a plurality of separate discs such as the outer discs 67 and 69, the wearing discs 71 and 73, and the central smaller diameter disc 75. In the structure of FIG. 3, the plurality of discs are mounted for rotation on the axle 77 in the bearings 79 and 81 and are secured to each other and to the axle 77 by key means 83.

The first compacting wheel 70, as shown best in FIG. 1, is rotatably mounted on the end 88 of lever 90. The lever 90 is pivotally mounted centrally thereof on the fixed support 92. The wheel 70 is urged toward the sample 36 of granular material on the wheel 38 by suitable weight 94 suspended from the end 96 of the lever 90.

The first compacting wheel 70 may be positively driven as by the motor 82, gearbox 84 and chain 86 through sprocket 83, as previously indicated and as shown in FIG. 1, or alternatively, the compacting wheel 70 may be rotated only by the frictional contact between the wheel 70 and the sample of foundry sand 36. Wherein the compacting wheel 70 is frictionally driven, the outer periphery of the wheel 70 may be serrated to improve the frictional contact between the wheel 70 and the foundry sand 36. In either case, the function of the first compacting wheel 70 is to provide an initial uniform compaction of the foundry sand sample 36.

The second compacting wheel 72 is similarly rotatably mounted on the end 98 of a lever 100 which is centrally pivotally mounted on the fixed support 102. Again, the second compacting wheel 72 is urged into contact with the sample of granular material 36 between the sides 54 and 56 of the sample wheel 38 by a weight 104 suspended from the end 106 of the lever 100.

The function of the second compacting wheel 72 is to further uniformly compact the sample of granular material 36 on the sample wheel 38.

In this regard, a plurality of compacting wheels have been found to produce more uniform compactibility measurements than a single wheel since the foundry sand is not allowed to build up as high behind the plurality of compacting wheels as it would if a single compacting wheel were providing the entire initial uniform compaction of the foundry sand sample passed by the strike plate 68.

The third compacting wheel 74 is again rotatably mounted on the end 108 of a lever 110, which lever is pivotally mounted on the fixed support 112 centrally thereof. A weight 114 is suspended from the opposite end 116 of the lever 110 to urge the third compacting wheel 74 into engagement with the sample of foundry sand 36 on the sample wheel 38.

The function of the third compacting wheel 74 is to provide information relative to the compactibility of the sample of granular material 36. To this end, the compactibility scale 118 is provided adjacent the end 116 of the lever 110, and a pointer 120 is secured to the end 116 of the lever 110. The pointer 120 in conjunction with the scale 118 provides a direct reading of the compactibility of the sample of foundry sand 36 on the sample wheel 38.

In addition, a linear variable differential transformer 122 is connected between a fixed support 124 and the end 116 of the lever 110. The voltage from the linear variable differential transformer 122 is proportional to the compactibility of the sample of foundry sand 36 and is passed over conductors 126 to a demodulating circuit 128 where the signal is amplified and passed to the compactibility record, read-out and print-out structure 131, as shown. The demodulating circuit and recording and read-out structure are purchased items and are within the skill of the art to provide. They will not, therefore, be considered in detail herein.

Further, the movement of the lever 110 in accordance with the compactibility of the foundry sand sample 36 may be used to control the addition of water or other additive to the mixer 14 in response to the structure illustrated best in FIGS. 6 and 7. The relation between the compactibility control factor and the previously used control factors of moisture content and moldability is as shown in FIG. 9.

As shown in FIG. 1, the coarse, automatic water inlet valve 20 is closed when the light from the light source 34 is cut off from the light sensitive signal element 30, while the water from the fire, automatic water inlet valve 22 is cut off when the light from the light source 32 is prevented from reaching the light sensitive element 28.

Thus, as the compactibility of the sample of granular material 36 on the sample wheel 38 increases, the lever 110 will be rotated counterclockwise so that the portion 132 of the end 116 of lever 110 comes first between the light source 34 and the light sensitive element 30 and then between the light source 32 and light sensitive element 28, the moisture addition to the mixer 14 will be first diminished and then cut off. As shown in more detail in FIG. 6, the location of the critical ends of the openings 134 and 136 through the portion 132 of the lever 110 may be varied by adjusting screws 138 and 140 to move the corresponding light shields 142 and 144.

The strength disc 76, as shown best in FIG. 3, is supported for rotation on the end 146 of the lever 148 which is pivotally mounted on the fixed support 150 centrally thereof. A weight 152 is suspended from the other end 154 of the lever 148 to urge the strength disc 76 toward the sample of foundry sand 36 on the sample wheel 38.

Similarly, the strength disc 78 is rotatably mounted on the end 156 of the lever 158. The lever 158 is pivotally mounted on the fixed support 160 and the counterweight 162 is suspended from the end 164 of the lever 158. Again, and as shown best in FIG. 3, the strength disc 78 is thinner and is provided with a sharper periphery than the disc 76 so as to penetrate the sample of foundry sand 36 deeper than the disc 76 which has a wider periphery.

The difference in penetration of the discs 76 and 78 into the compacted foundry sand sample 36 is proportional to the strength of the foundry sand sample 36 and is measured, as illustrated in the embodiment of the invention illustrated in FIG. 1, by the separation of the ends 154 and 164 of the levers 148 and 158.

Thus, as shown, a linear variable differential transformer 166 is secured between the extensions 168 and 170 of the levers 148 and 158. The linear variable differential transformer 166 is then connected directly to the demodulator 128 through conductors 129 where the signal from the transformer 166 is amplified and prepared for display on the strength record, read-out and print-out structure 133.

A further linear variable differential transformer 172 is connected between the end 116 of lever 110 and a link 174 which is pivoted at one end to the end 154 of the lever 148. The signal from the transformer 172 is similarly fed to the electric circuit 128 through conductors 131 where it is amplified and prepared for presentation in the effective clay record, read-out and print-out structure 135 as effective clay content of the sample of foundry sand 36.

After passing the discs 76 and 78, the sample of granular material 36 on the sample wheel 38 is removed therefrom by the material removal barrier 80 and is passed back to the mixer 14 on a conveyor 15. Thus, a continuous reading of the compactibility, strength and effective clay content of the foundry sand in the mixer 14 is provided with the apparatus 10.

The compactibility signal from the linear variable differential transformer 122 may also be used to lower or raise a plow 121 positioned with respect to a conveyor 123 carrying conditioned sand from the mixer 14 so as to direct the sand on the conveyor 123 into automatic molding equipment 125 at a remote location with the plow in a down position, as shown in phantom in FIG. 8, and to prevent sand from being directed into the automatic molding equipment 125 when the plow 121 is in an up position.

Thus, the signal from transformer 122 is sent through the demodulator 128 and the compactibility recorder, read-out and print-out structure 131 of the relay 129. The relay 129 is actuated when the compactibility of the granular material is in an acceptable range. The relay 129 will then energize the solenoid air valve 115 to permit actuation of the pneumatic cylinder 117 to lower the plow 121 on demand from the control circuit of the molding equipment 125.

When the compactibility is outside of the acceptable range for use in the automatic molding equipment 125, the air solenoid valve 115 cannot be actuated, and the pneumatic cylinder 117 raises the plow 121 to prevent the unacceptable foundry sand from being placed in the automatic molding machine. Electrical signals are provided to the automatic molding equipment 125 over the conductors 137 and 139 to actuate the solenoid valve 115 when the relay 129 is actuated in accordance with the level controls 141 and 143 on the automatic molding equipment 125.

The apparatus 10 for determining the compactibility strength and effective clay content of foundry sand is essentially a rotary structure using a sample wheel. Comparable linear apparatus 230 for determining the compactibility, strength and effective clay content of granular material is shown in FIGS. 10 and 11.

In the apparatus 230 the chute 232 having the aerator 234 therein is similar to the chute 46 and aerator 48

packing wheel 258 is held in contact with the sand sample by a weight 264 on the other end of the lever 260.

The third compacting wheel 266, as with the circular structure 10, provides a compactibility reading in conjunction with a linear variable differential transformer 268 which is secured between a fixed support 270 and the end 272 of lever 274 to which the wheel 266 is rotatably secured and which is pivotally secured at the other end to the fixed supports 262.

Again, the compactibility of the sample of granular material on the conveyor 236 may be read directly from the scale 278 in conjunction with the pointer 280 on the lever 274.

The strength of the sand sample on the conveyor 236 is sensed by the structure 282 positioned between the levers 284 and 286. The levers 284 and 286 are pivotally connected at one end to the fixed supports 290 and 292 and rotatably support the larger diameter, relatively thin strength disc 294 and the relatively wide, smaller diameter disc 296 centrally thereof. The ends of the levers 284 and 286 are biased into contact with the sample of granular material by the weight 288 on the lever 286.

The structure 282 for sensing the strength of the sample of foundry sand on the conveyor 236 in accordance with the movement of the levers 284 and 286 is shown best in FIG. 12. Structure 282 includes a linear variable differential transformer 298 connected between the levers 284 and 286 for providing a signal proportional to the relative movement of the levers 284 and 286 which is representative of the strength of the sample of foundry sand. The electric servo motor 300 fixed on the lever 286 receives the signal from the linear variable differential transformer 298 and drives a loading screw 302 in accordance with the signal from the transformer 298. The loading screw 302 loads a force ring 304. The load on the force ring 304 varies the signal

322 in conjunction with the electric circuit 324 shown in FIGS. 14 and 15, respectively.

In the computer structure 322, compactibility is indicated by the indicator 326 in conjunction with the scale portion 328. The strength of the sample of foundry sand is indicated by the indicator 330 in conjunction with the scale portion 332, and the effective clay content is indicated by the indicator 334 in conjunction with the scale portion 336.

The drive spindle 338 is driven from the demodulator 128 in accordance with the compactibility of the sample of granular material to move the indicator 326 to which the linear member 340 is connected. The indicator 326 moves on the guide rod 342 while the linear member 340 is guided about and rotates the pulleys 344, 346 and 348.

Indicator 330 is moved on the guide rod 350 by the linear member 352 which is driven by the drive spindle 354 in accordance with the strength of the granular material from the demodulator 128. Again, the linear member 352 is guided about and rotates the pulleys 356, 358 and 360.

In the computer structure 322 the effective clay content can be determined by movement of the indicator 344 along the guide rod 362 in accordance with the movement of the linear member 364 guided about the pulleys 366, 368 and 370 in accordance with the rotation of the spindle 372 by a signal from the demodulator 128.

In the case where only the compactibility and strength signals are provided to the demodulator as in the linear modification 230 of the structure 10, the drive signal for the spindle 372 is computed in the circuit 324 by means of the rheostat 374 having the resistance 376 and the movable wiper arm 378 and the potentiometer 380 having the resistance 382 and the movable wiper arm 384.

As shown, the resistance 374 and movable wiper arm 378 of the rheostat 376 are connected in series with the resistance 382 of the potentiometer 380 and the source of electrical energy 386. Thus, in the circuit of FIG. 15, if the movable wiper arm 378 is moved in accordance with the compactibility of a sample of granular material and its relation to the percent effective clay in the sample of foundry sand, and the movable wiper arm 384 of the potentiometer 380 is moved in accordance with the strength of the sample of foundry sand and its relation to the percent effective clay in the sample of foundry sand, the record and read-out and print-out structure 135 will provide the percent of effective clay information desired.

As shown in FIG. 14, the computer structure 322 provides a cam 388 constructed in accordance with the relation between the compactibility and effective clay content which is secured to the pulley 344 for rotation therewith. A rack 390 is biased into engagement with the cam 388 by a preset solenoid or spring means 392. The rack 390 is in mesh with a pinion 394 which moves the wiper arm of the rheostat 374 in accordance with the relation between the compactibility and percent effective clay as required in the circuit 324.

Similarly, a rack 396 is connected to the strength indicator 330 for linear movement therewith which through a gear 398, a cam having a contour proportional to the relation between strength and effective clay content of the foundry sand, and a pinion 400, moves the wiper arm 384 of the potentiometer 380 in

accordance with the relation between the strength and effective clay content of the sample of granular material, again as required in FIG. 15.

Thus, with the structure of computer 322 and the circuit of FIG. 15, with the compactibility and strength of a sample of granular material known and continuously varying, a continuously varying signal proportional to the effective clay content of a sample of granular material may be determined.

Another linear modification 402 of the structure for determining the compactibility, strength and effective clay content of granular material is illustrated in FIGS. 16-19. The linear embodiment of the structure 10 illustrated in FIGS. 16-19 is similar to the linear embodiment of the invention 230 illustrated in FIGS. 10-11.

Thus, a chute 404 having an aerator 406 therein is utilized to place a sample of foundry sand in the channel 408 provided between the parallel retaining walls 410 carried by the sectioned plate conveyor 412.

The strike plates 414 and 416 serve to limit the depth of foundry sand in the channel 408.

The sectioned conveyor 412, as best shown in FIGS. 18 and 19, includes the rollers 418 separated by the links 420 which are pivotally connected to each other at the opposite ends thereof, as shown.

The conveyor sections 422 are secured to the individual links 420, and the walls 410 are secured to the individual conveyor plates 422. Again, the conveyor 412 is driven by motor means 424 and sprockets 426 and 428 at opposite ends thereof in conjunction with centrally located meshing structure 430 secured to the conveyor plates 422.

Compactibility of the sample of foundry sand is measured by the linear variable differential transformer 432 between a fixed support 434 and the end 436 of a sectioned plate conveyor 438 which is connected to the linear variable differential transformer 432 at end 440 by a connecting link 422 pivotally connected to the conveyor 438. The conveyor 438 is connected to the fixed support 444 at the end 446. Again, the conveyor 438 may be weighted by weight 439 and may be driven with conveyor 412 through chain or sprocket drive 441, or may be frictionally driven as desired.

Thus, in operation, the sample of granular material, after passing strike-off plate 416, is gradually compacted beneath the plate conveyor 438 with the ultimate compaction of the sample of granular material being an indication of the compactibility of the sample of granular material.

The strength of the sample of foundry sand is sensed by the strength structure 448 positioned between the ends 450 and 452 of levers 454 and 456 to which the relatively wide disc 458 and the relatively thin disc 460, respectively, are rotatably secured. The levers 454 and 456 are again centrally pivotally mounted on fixed supports 462 and 464 as before.

The strength sensing structure 448 may be as shown in either FIG. 12 or 13 and the strength signal from the linear variable differential transformer 466 as well as the compactibility signal from the linear variable differential transformer 432 are again fed to the demodulator 128 and may be used to actuate a computer such as the computer 322 having the included circuit 324 as desired therein.

While two embodiments of the present invention and modifications thereof have been considered in detail

herein, it will be understood that other embodiments and modifications thereof are contemplated by the inventor. It is, therefore, intended to include all embodiments and modifications as are defined by the appended claims within the scope of the invention.

What I claim as my invention is:

1. Structure for determining the condition of granular material comprising means providing a sample of the granular material, means operably connected to the means providing the sample of granular material for determining the compactibility of the sample of granular material, means operably connected to the means providing the sample of granular material for determining the strength of the sample of granular material, and means operably connected to the means for determining the compactibility and the means for determining the strength of the sample of granular material for determining the effective clay content of the sample of granular material in accordance with the compactibility and strength of the sample of granular material.

2. Structure as set forth in claim 1 wherein the means for determining the compactibility of the granular material comprises a fixed support, a lever pivotally secured to the fixed support, means engageable with the sample of granular material movable in accordance with the compactibility of the granular material connected to the lever for pivoting the lever about the fixed support in accordance with the compactibility of the granular material, and means operably associated with the lever for providing a signal proportional to the compactibility of the granular material in accordance with the pivotal movement of the lever.

3. Structure as set forth in claim 1 wherein the means for determining the strength of the granular material comprises a fixed support, a pair of levers pivotally mounted on the fixed support for pivotal movement with respect to each other, a relatively wider member secured to one of the levers in engagement with the granular material for movement relative thereto in accordance with the strength of the granular material and the width of the member to produce corresponding movement of the one lever, a relatively thin member secured to the other lever in engagement with the granular material for movement relative thereto in accordance with the strength of the granular material and the thickness of the member to produce corresponding movement of the other lever, and means positioned between the levers for indicating the strength of the granular material in accordance with the relative position of the levers.

4. Structure as set forth in claim 3 wherein the means positioned between the levers for indicating the strength of the granular material in accordance with the relative position of the levers comprises a linear variable differential transformer positioned between the levers having a coil secured to one of the levers and a core secured to the other of the levers, an electrical servo motor secured to one of the levers, a force ring secured to the other of the levers, and screw means operable by the servo motor in accordance with an electrical signal produced in the linear variable differential transformer for stressing the force ring and a linear variable differential transformer within the force ring for producing a signal proportional to the stress on the force ring which is proportional to the strength of the granular material.

5. Structure as set forth in claim 4 wherein the means positioned between the levers for indicating the strength of the granular material in accordance with the relative position of the levers comprises a linear variable differential transformer positioned between the levers having a coil secured to one of the levers and a core secured to the other of the levers, an electrical servo motor secured to one of the levers, a bellows secured to the other of the levers, means providing pressure within the bellows, screw means operable by the servo motor in accordance with an electrical signal produced in the linear variable differential transformer for stressing the bellows to vary the pressure in the bellows, and a pressure to electrical transducer connected to the bellows for producing a signal proportional to the pressure in the bellows which is proportional to the strength of the granular material.

6. Structure as set forth in claim 1 wherein the means for determining effective clay content of the granular material includes a potentiometer and a rheostat each including a resistance and a wiper arm, a source of electrical energy in series with the resistance of the potentiometer and the resistance of the rheostat, indicating means for the effective clay content connected in parallel with a portion of the potentiometer resistance through the wiper arm of the potentiometer, cam means for moving the movable wiper arm of the rheostat in accordance with the relation between the compactibility of the granular material and the effective clay content in the granular material, and cam means for moving the wiper arm of the potentiometer in accordance with the relation between the strength of the granular material and the effective clay content of the granular material.

7. Structure as set forth in claim 1 wherein the compactibility, strength and effective clay content are continuously monitored, the means providing a sample of granular material includes a sample wheel having the sample of granular material thereon and the means for determining the compactibility and strength of the granular material includes wheels and discs engaged with the granular material on the sample wheel which are moved radially with respect to the sample wheel in accordance with the compactibility and strength of the granular material.

8. Structure as set forth in claim 1 wherein the means providing a sample of granular material includes, a conveyor and sample confining means movable on the conveyor, the means for determining the compactibility and strength of the granular material includes a compactibility member pivotally mounted adjacent the conveyor and positioned to ride on the sample of granular material on the conveyor and the means for determining the strength of the granular material includes a pair of discs pivotally mounted adjacent the conveyor and positioned to ride on the sample of granular material on the conveyor which discs have different thicknesses so as to penetrate the sample of granular material differently in accordance with the strength of the granular material.

9. Structure as set forth in claim 1 and further including a granular material plow and means for actuating the granular material plow at a remote location in accordance with at least one of the compressibility, strength and effective clay content of the granular material to cam granular material off a conveyor at the remote location in accordance with a demand therefor or

to prevent the camming of the granular material from the conveyor at the remote location if the granular material does not meet required specifications.

10. The method of treating granular material such as foundry sand comprising providing a continuous sample of the granular material, measuring the compactibility of the sample of granular material, measuring the strength of the sample of granular material, and combining the measurement of the compactibility of the sample of granular material and the measurement of the strength of the sample of granular material to measure the effective clay content of the sample of granular material.

11. The method as set forth in claim 10 wherein the step of measuring the compactibility of the granular material comprises placing a measured sample of granular material in sample receiving structure, initially compacting the granular material and subsequently engaging the sample of granular material with a movable member to cause movement of the movable member in accordance with the compactibility of the granular material to provide an indication of the compactibility of the granular material.

12. The method as set forth in claim 10 wherein the measuring of the strength of the granular material comprises initially compacting the granular material, placing a pair of movable members on the sample of granular material, which movable members have different thickness and registering the difference of penetration into the sample of granular material of the different thickness members as an indication of the strength of the granular material.

13. The method as set forth in claim 10 wherein the effective clay content of the granular material is measured by relating the compactibility and effective clay content of the granular material, to provide a compactibility related signal relating the strength and effective clay content of the granular material to provide a strength related signal and combining the compactibility and strength related signals to provide a composite effective clay content signal.

14. Structure for determining the effective clay content of granular material from the compactibility and strength of the granular material comprising an electric circuit including a source of electrical energy in series with the resistance of a potentiometer and a rheostat through the wiper arm of the rheostat, means for indicating the effective clay content of the granular material connected in parallel with a portion of the resistance of the potentiometer through the potentiometer wiper arm, means for moving the rheostat wiper arm in accordance with the compactibility of the granular material, and means for moving the potentiometer wiper arm in accordance with the strength of the granular material.

15. Structure as set forth in claim 14 wherein the means for moving the wiper arm of the rheostat comprises a rack and pinion, the pinion of which is connected to the wiper arm of the rheostat, a cam having a contour proportional to the relation between compactibility and effective clay content of the granular material, means for urging one end of the rack into engagement with the cam and means for rotating the cam in accordance with the compactibility of the granular material.

16. Means for determining the strength of granular material comprising a fixed mounting, a pair of levers pivotally connected to the mounting for pivotal movement with respect to each other, a relatively wide disc secured to one of the levers in engagement with the granular material for movement relative thereto in accordance with the strength of the granular material and the width of the wide disc to produce corresponding movement of the one lever, a relatively thin disc secured to the other lever in engagement with the granular material for movement relative thereto in accordance with the strength of the granular material and the thickness of the thin disc to correspondingly pivot the other lever, and means positioned between the levers for indicating the strength of the granular material in accordance with the relative pivoting of the levers.

17. Structure as set forth in claim 16 wherein the means positioned between the levers for providing a signal for indicating the strength of the granular material comprises a linear variable differential transformer positioned between the levers having a coil secured to one of the levers and a core secured to the other of the levers, an electrical servo motor secured to one of the levers, a force ring secured to the other of the levers, and screw means operable by the servo motor in accordance with the electrical signal in the linear variable differential transformer for stressing the force ring and a second linear variable differential transformer within the force ring for producing a signal proportional to the stress on the force ring which is proportional to the strength of the granular material.

18. Structure as set forth in claim 16 wherein the means positioned between the levers for providing a signal for indicating the strength of the granular material comprises a linear variable differential transformer positioned between the levers having a coil secured to one of the levers and a core secured to the other of the levers, an electrical servo motor secured to one of the levers, a bellows secured to the other of the levers, means providing a predetermined pressure in the bellows, and screw means operable by the servo motor in accordance with the electrical signal in the linear variable differential transformer for stressing the bellows to vary the pressure in the bellows and a pressure to electrical transducer connected to the bellows for producing a signal proportional to the pressure in the bellows which is proportional to the strength of the granular material.

19. Structure for determining at least one physical parameter of a sample of granular material comprising a wheel, a circumferential, radially extending slot in the outer periphery of the wheel, means for rotating the wheel, means for feeding a sample of granular material into the slot in the outer periphery of the wheel, means for compacting the granular material within the slot as the wheel is rotated, means movable into the slot in the wheel as the wheel is rotated in contact with the compacted granular material in the slot and means operably connected to the means movable into the slot for measuring at least one physical parameter of the granular material within the slot in accordance with the movement of the means movable within the slot into the granular material within the slot.

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