Apparatus is described for determining the weight of a moisture-free, compressible material in a given volume of fluid suspension. The given volume of the suspension is confined and the material in the confined suspension is compressed with a movable porous surface at a predetermined pressure to form a mat of the material. The thickness of the mat thus formed is measured and the weight of the material is determined therefrom from a known relationship. Means are provided to flush out the apparatus, and control valve means are provided to effect selective sequential operation.

13 Claims, 4 Drawing Figures
Fig. 1
**Fig. 4**

**Sequence of Events**

<table>
<thead>
<tr>
<th>Step Number</th>
<th>Operational Functions and Associated Control Valves</th>
<th>Time Interval (If Applicable)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Close Chamber Valve</td>
<td>2s</td>
</tr>
<tr>
<td>2</td>
<td>Fill Chamber Supply Line</td>
<td>3s</td>
</tr>
<tr>
<td>3</td>
<td>Take Chamber Sample</td>
<td>4s</td>
</tr>
<tr>
<td>4</td>
<td>Lower Piston Partially</td>
<td>5s</td>
</tr>
<tr>
<td>5</td>
<td>Read Consistency Measure</td>
<td>6s</td>
</tr>
<tr>
<td>6</td>
<td>Raise Piston</td>
<td>7s</td>
</tr>
<tr>
<td>7</td>
<td>Back Flush Chamber</td>
<td>8s</td>
</tr>
<tr>
<td>8</td>
<td>Stop Back Flush</td>
<td>9s</td>
</tr>
<tr>
<td>9</td>
<td>Back Flush Chamber</td>
<td>10s</td>
</tr>
<tr>
<td>10</td>
<td>Stop Back Piston</td>
<td>11s</td>
</tr>
<tr>
<td>11</td>
<td>Stop Back Flush</td>
<td>12s</td>
</tr>
<tr>
<td>12</td>
<td>Raise Piston</td>
<td>13s</td>
</tr>
<tr>
<td>13</td>
<td>Back Flush Chamber</td>
<td>14s</td>
</tr>
<tr>
<td>14</td>
<td>Stop Back Piston</td>
<td>15s</td>
</tr>
<tr>
<td>15</td>
<td>Stop Back Flush</td>
<td>16s</td>
</tr>
<tr>
<td>16</td>
<td>Raise Piston</td>
<td>17s</td>
</tr>
<tr>
<td>17</td>
<td>Back Flush Chamber</td>
<td>18s</td>
</tr>
<tr>
<td></td>
<td>Level Drain</td>
<td></td>
</tr>
</tbody>
</table>

**Operational Functions and Associated Control Valves**

- Purge Vent 31B
- Purge Air 312
- Purge Water 310
- Shaft Seal 306
- Chamber Valve 284a.4b
- Chamber Drain 32B
- Level Drain 330
- Chamber Back Flush 326
- Chamber Sample Feed 269a.4b
- Feed Line Flush 276
- Chamber Air Flush 320
- Measurement Output
- Controlled Rate PSI, PROP 296.300
- Lower Piston 292a.4b

**No No enabling sw.

- Dilution Tank Wash In.
- Wash Cycle Sel. (Auto.)
- Event or Time Sel.
- Add or Sub. Switch

- 1 Sec. Add 100 Sec. Sub.
- 2 Sec. Add 200 Sec. Sub.
- 4 Sec. Add 400 Sec. Sub.
- 8 Sec. Add 800 Sec. Sub.
- 10 Seconds Add or Sub.
- 20 Seconds Add or Sub.
- 40 Seconds Add or Sub.
- 80 Seconds Add or Sub.
This application is a continuation-in-part from Ser. No. 75,967, filed Sept. 28, 1970, now U.S. Pat. No. 3,718,030, and relates generally to the analysis of fluid suspension and, more particularly, to an improved apparatus for determining the weight of a moisture-free compressible material in a given volume of fluid suspension. The invention has particular applicability to the art of paper making, but is not limited thereto.

In the manufacture of certain products, such as paper, it is advantageous to provide instrumentation for monitoring various physical properties of a slurry or suspension while it is being processed. For example, in paper making it is important to monitor the so-called consistency or dry fiber content of the pulp suspension being processed. Consistency or dry fiber content is defined by usage in the pulp and paper industry as the weight of dry fiber per unit volume of aqueous suspension or slurry, and such terms are commonly expressed in percentage terms. In addition to the consistency, it may be desirable to obtain small amounts of solid materials from the suspension for the purpose of performing chemical tests on such materials.

In many manufacturing operations using fluid suspensions of compressible fibrous materials, measurement of the consistency has frequently necessitated a periodic manual sampling and laboratory analysis of each sample. Although providing the necessary data with high accuracy, manual sampling is undesirable because it is time consuming and does not lend itself readily to automatic servosystem process control. Moreover, manual sampling is unsuited to the automation of chemical tests on solid materials in liquid suspension for purposes of process control.

Accordingly, it is an object of the present invention to provide apparatus for automatically determining the weight of a moisture-free, compressible material in a given volume of fluid suspension.

Another object of the invention is to provide apparatus for automatically obtaining and measuring accurately a desired amount of solid from a fluid suspension for performing tests thereon.

It is another object of the invention to provide apparatus for automatically monitoring the consistency of aqueous suspensions or slurries.

A further object of the present invention is to provide apparatus capable of acting as a consistency regulator for aqueous suspensions or slurries in paper making operations.

Still another object of the invention is to provide improved apparatus for measuring consistencies of suspensions used in pulping and paper making over a relatively wide range of values as compared with known apparatus.

Further objects and advantages of the invention will become apparent from the following detailed description, taken in connection with the accompanying drawings wherein like reference numerals designate like elements throughout the several views, and wherein:

FIG. 1 schematically illustrates one embodiment of apparatus in accordance with the present invention connected in a control system;

FIG. 2 is a longitudinal view, partially in section, of an alternative embodiment of an apparatus for determining the weight of a moisture-free, compressible ma-

material in a given volume of fluid suspension in accordance with the present invention;

FIG. 3 is a schematic flow diagram illustrating the apparatus of FIG. 2 connected in a control circuit; and

FIG. 4 is a chart setting forth the sequence of operational steps and the various control elements operative during each step.

Very generally, in determining the weight of a moisture-free, compressible material in a given volume of fluid suspension in accordance with the present invention, the given volume of fluid suspension is first confined within a sample chamber. The solids therein are compressed with a porous surface or piston at a predetermined pressure to form a mat of the material. The thickness of the mat thus formed is measured and the weight of the material determined therefrom. In one embodiment of a testing apparatus in accordance with the present invention, the sample chamber may be flushed after formation of a fibrous mat by lowering a non-porous piston at the bottom of the chamber to open a port whereupon a fluid is introduced into the chamber to flush the material out through the port. In another embodiment of a testing apparatus in accordance with the present invention, a chamber piston is movable to seal the sample chamber after introducing and compressing the fluid suspension, and is movable to allow flushing of the sample chamber after each sample consistency.

As previously mentioned, consistency as used in the pulp and paper industry is the weight of dry fiber per unit volume of aqueous suspension or slurry. A physical property of pulp fibers, often referred to as the compressibility, may be derived from values in the following formula:

\[ \log C = \log m + n \log P \]

where,

\[ C = \text{mass of dry fiber in a web compressed mat} \]

\[ P = \text{the compressing pressure} \]

and

\[ m \] and \[ n \] = experimental constants.

In the paper making art, a manual technique is often used for measuring compressibility. The value thus determined for compressibility is then used in order to perform calculations of specific surface area and specific volume of paper making fibers. Apparatus for accomplishing this manual technique includes a cylinder or chamber which is filled with slurry. A piston is then inserted into the chamber and is lowered to form the fibers in the slurry into a loose mat, the piston being porous to permit the liquid to pass therethrough. Readings are then taken of the distance which the mat is compressed under known pressure in given time periods. Subsequently, the mat of fibers is removed and dried and then weighed. From the data gathered, that is, the known pressure, the pad thickness, and the final dried mat weight, the solids concentration of the mat may be determined as a function of the compactive pressure in accordance with the equation:

\[ C_p = \frac{W}{(1/L)} \]

where,

\[ C_p = \text{the solids at pressure P in weight per volume} \]

\[ W = \text{dried pad weight} \]

\[ A = \text{empirical constant} \]

and

\[ L = \text{measured pad thickness} \]

The foregoing procedure, although capable of determining the compressibility of a liquid suspension or slurry, is not of much practical value where it is desired to obtain a quick determination of consistency during
processing. Rather, the procedure is principally of value as a tool for laboratory investigation of certain pulp properties. It is unsuited to on-line production analysis of liquid suspensions due to the length of time required to perform the procedure. In fact, the amount of fiber used is measured subsequent to the test, by removing the mat from the apparatus, drying it, and weighing it.

The present invention makes use of the fact that the weight of dry fiber in a compressed, water-saturated pad or mat at constant compressing pressure and constant cross sectional area is a direct linear function of the mat or pad thickness. A relationship of pad weight to pad thickness may be seen from the previously set forth equation \( W = C_p AL \) which can be arranged in the form \( W = C_p AL \). The empirical constant \( A \) is a constant reflecting the geometry of the particular system in which the fiber pad or mat is compressed, the fiber structure and composition thereof, and certain physical and mechanical conditions under which the test is made. Since the value of \( C \) is by definition a constant at a given pressure, the constants \( A \) and \( C_p \) may be combined into a new constant \( K \) to yield the equation:

\[
W = KL.
\]

Thus, the relationship between fiber weight and pad thickness is a linear one. Experimental data has confirmed the foregoing mathematically derived relationship. Moreover, it has been experimentally determined that the above relationship between pad thickness and pad weight is fixed for temperature variations of as much as 60°C, and it has also been determined that such relationships are valid for paper pulps of greatly different character.

To summarize, it has been demonstrated mathematically and experimentally that, over a wide range of conditions related to sample size, temperature, sample character, pad diameter, and compressing pressure, the amount of dry fiber in a water-saturated compressed pad of compressible, fibrous material is a simple linear function of the pad thickness at a fixed compressing pressure. The apparatus of the present invention is operated on the basis of such relationships to determine the weight of a moisture-free compressible material by producing a pad or mat from a suspension of such material under certain known conditions. By the term "moisture-free," it is meant the equivalent weight obtained by drying to constant weight at 105°C.

In particular, in accordance with the present invention, a given volume of fluid suspension is confined in a sample chamber or cylinder. The material in the confined fluid suspension is then compressed with a porous surface, such as a porous piston, to form a mat of the material. The force on the piston is regulated so that the pressure at which the material is compressed is known. This is done in one embodiment of the apparatus by attaching a suitable known weight to the piston. In another embodiment, the force on the piston is controlled by a differential pressure operated, double acting, pneumatic cylinder.

After the material is compressed and formed into a mat, the thickness of the mat or pad thus formed is measured. From relationships between the pad thickness and the weight of the material, which are readily determined empirically beforehand, the weight of the material for a given pad thickness may be determined.

Moreover, as will be explained subsequently, the apparatus of the present invention may be suitably calibrated to provide a direct reading of pad weight.

The present invention will be more clearly understood from the following descriptions of preferred embodiments of apparatus in accordance with the invention as illustrated in the accompanying drawings. One embodiment of the apparatus is illustrated in FIG. 1 and includes a supportive base 11 having an opening 12 therein. A block 13 of a corrosion resistant material, such as polysulfone, is supported by the base and has a locating projection 14 on its underside which mates in the opening 12 in the base for locating and positioning the block 13. A pneumatic cylinder 16 having an upper flange 17 is suitably secured to the projection 14 on the block 13 at the flange 17, with the flange mating within the opening 12 in the base 11.

The block 13 is provided with a lower piston passage 18 in which a solid piston 19 is capable of vertical movement. An annular seal 21 surrounds the periphery of the piston 19 and seals the region between the piston and the wall of the passage 18. The piston 19 is moved up and down vertically by a piston rod 22 which extends from the pneumatic actuator 16 through a suitable opening in the block 13 and which is moved by the actuator 16.

The piston 19 is shown in FIG. 1 in its lower or retracted position. In this position, the top surface of the piston 19 is below the level of a pair of passages 23 and 24 provided in the block 13. The passages 23 and 24 are horizontal passages communicating with the passage 18 from appropriate connections described subsequently. The passage 23, as will be explained, serves as an inlet passage for both flush water and slurry, whereas the passage 24 serves as an outlet passage for the aforesaid fluids.

The upper end of the piston passage 18 is provided with an annular enlarged region 26 in which the lower end of a hollow cylinder 27 is accommodated. An annular seal 28 surrounds the lower end of the cylinder 27 between the outer wall of the cylinder and the inner wall of the block 13 to form a seal therewith. Thus, the hollow interior of the cylinder 27 forms a chamber 29 communicating with the piston passage 18 and the inlet and outlet passages 23 and 24. The piston 19 is movable from the illustrated position to a position where the piston at least partially extends within the cylinder 27 and seals the bottom end of the cylinder to seal the chamber 29. Preferably, the piston 19 is a solid plug of polysulfone plastic and the piston rod 22 is of solid stainless steel. To provide a liquid-tight seal between the piston rod 22 and the block 13, a suitable annular seal, not illustrated, may be provided. The function of the piston 19 when in its upper position or unretracted position is to provide a solid base or reference point from which the distance between the upper surface of the piston and the upper surface of the pad being compressed is measured. The piston also serves to support the pad and to contain the slurry in the chamber 29.

The tube 27 is preferably comprised of pyrex or an equivalent material.

The upper piston 31 is provided within the chamber 29 and is movable axially within the chamber. The upper piston 31 includes a plurality of holes 32 bored therein parallel with the axis thereof to allow liquid to pass from the region below the piston to the region above the piston as the piston moves downwardly in the
chamber 29. Preferably, the upper piston 31 is comprised of polysulfone plastic and preferably the lower face thereof is faced with a disc of 80-mesh stainless steel woven screen (not shown).

In order to move the piston 31 vertically within the chamber 29, the piston is attached to a hollow piston rod 33 that has a pair of holes 34 drilled through its wall at diametrically opposed positions just above the piston 31. The piston rod 33 passes upwardly through a plug 36 secured to and sealed on the upper end of the cylinder 27. The piston rod 33 is suitably sealed in a central bore in the plug 36. The plug 36 is provided with an annular flange 37 by which it is secured to the underside of a support disc 38. The support disc 38 is provided with a central opening 39 therein which is substantially larger in diameter than the outer diameter of the piston rod 33. The central portion of the disc 38 through which the opening 39 is provided is raised in the form of a boss 41. A plurality of tie rods 42 extend upwardly from the block 13 to the periphery of the disc 38 and serve to secure and stabilize the disc as well as to secure the plug 36 at the upper end of the cylinder 27. A level sensing probe 43 extends downwardly through the plug 36 within the opening 39. The level sensing probe is connected to a suitable electrical device, as will be explained below, in order to sense the level of slurry within the chamber 29.

The upper end of the piston rod 33 terminates in and is attached to an assembly 44 and, in particular, to a downwardly extending nipple 46 thereof. A tube 47 extends transversely of the nipple 46 and communicates with the hollow interior of the piston 33 therein. The upper surface of the disc 44 carries a weight 48 selected to provide a desired amount of pressure in the compressed material in the chamber 29.

In order to raise the piston 31, a pneumatic stroke cylinder 61 is provided. The stroke cylinder 61 is supported at its lower end by a plate 62 which, in turn, is supported on and movable by the actuator rod of a pneumatic gauge cylinder 63. The gauge cylinder 63 is supported on a horizontal plate or bracket 64 which extends outwardly at the upper end of a support rod 66. The support rod 66 is mounted on the base 11 and extends vertically upward therefrom adjacent the cylinder 51. The rod 66 continues vertically upward through a slide bearing 67 on the plate 62 which maintains the plate 62 in a horizontal position but which enables vertical displacement of the plate with respect to the base 11. Two other guide rods identical with the rod 66 are provided extending upwardly from the base 11 parallel with each other and spaced at 120° intervals around the axis of the cylinder 27. A disc 71 is slidably supported in a horizontal position on the rods 66 by slide bearings 72. The piston of the stroke cylinder 61 is attached to the disc 71 and is capable of moving the disc vertically on the rods 66 in response to actuation of the cylinder 61. A pair of vertical rods 73 extend downwardly from the plate 71 parallel with the rods 66. The rods 73 pass through openings 74 in the plate 44 and terminate in stops 76 provided at the lower ends of the rods 73.

When the cylinder 61 is actuated to raise the disc 71, the disc moves upwardly in its horizontal position on the rods 66. The rods 73 move upwardly with the disc 71 until the stops 76 engage the underside of the disc 44. When this occurs, the disc 44 is supported by the stops 76 and is raised therewith. This moves the piston rod 33 vertically upwardly and consequently effects a movement of the piston 31 within the chamber 29. Similarly, when the stroke cylinder 61 is retracted, the disc 71 moves downwardly, moving the rods 73 downwardly and thus lowering the disc 44. Since the disc 44 is not secured to the stops 76, the piston 31 is allowed to move downwardly in the chamber 29 under the force of the weight 48.

The gauge cylinder 63 permits variation in the operation of the apparatus at retracted and extended positions of the stroke cylinder 61. For example, if it is desired to recycle the apparatus without flushing the pad, a signal from the operator or a programmed controller (described below) to the gauge cylinder causes the latter to extend. This raises the upper piston 31 off the pad slightly. By reciprocating the stroke cylinder 61 when the gauge cylinder is in such a position, the upper piston 31 acts as a stirrer, recirculating the fibers into suspension without compressing them.

In order to provide for automated operation of the apparatus thus far described, a valve 81 connects the tube 47 to a vacuum system, not shown, thus enabling withdrawal of the contents of the chamber 29 above the piston 31 through the hollow piston rod 33 and the tube 47. In addition, a valve 82 is connected between the tube 47 and a pressurized water system, not shown, enabling the flushing of the hollow piston rod 33 and of the region of the chamber 29 above the piston 31.

A valve 83 is coupled to the inlet passage 23 and operates a source of pressurized water (not shown) for flushing the passage 23 and the portion of the chamber 29 below the piston 31. Also connected to the inlet passage 23 is a valve 84 which operates between the inlet passage and a source of slurry or suspension to be analyzed. Preferably, the valve 84 connects a constant head reservoir to the inlet passage 23 for providing slurry for the chamber 29. A valve 86 is connected to the outlet passage 24 and may be closed when it is desired to pass slurry into the chamber 29. When the chamber is to be flushed, the valve 86 is opened, the valve 84 is closed, and the valves 82 and 83 are opened.

In order to automatically operate the valves 81, 82, 83, 84 and 86, and in order to automatically operate the cylinders 61, 63 and 16, a control system 87 is provided. The control system may be of any suitable construction for properly programming the operation of the various automated elements. For example, a stepping drum programmer may be provided with appropriate timers, relays, counters, and electrical and pneumatic switches.

In order to provide an indication of the position of the face of the upper piston 31, the disc 44 is attached to the lower end of the core 88 of a linear position transducer 89. The transducer may be of any suitable construction and in the illustrated embodiment provides a direct current output proportional to the position of the piston 31. One type of transducer which is satisfactory for this purpose is available from Schaeveit Engineering Co., Pennsauken, New Jersey, and consists of three coils wound equally spaced on a cylindrical form. When alternating current is applied to the center coil, voltages are induced across the other two coils. A rod-shaped magnetic core moves axially within the coil assembly, providing a low reluctance path for magnetic flux linking the two outer coils. With the end coils connected in series opposed, and with the core centered,
the combined output of the end coils is zero. When the core is displaced from its centered position, the net output increases proportionally.

The output of the transducer 89 is applied to a recorder 91. The recorder 91 is optional and is merely provided for the purpose of recording the particular consistency values over a given period of time, such as on a moving chart. Naturally, the output signal derived by the transducer 89 may be fed back to suitable relays, servo mechanisms, gauges, etc., depending upon a particular control response desired.

In order to operate the apparatus illustrated in FIG. 1, the control system operates the lower piston 19 to the retracted position as shown in the drawing. The upper piston 31 is then raised to just below the level of the sensing probe 43. The outlet valve 86 is closed, the water valves 82 and 83 are closed, the vacuum valve 81 is closed, and the slurry valve 84 is open. Slurry then flows from the constant head reservoir, not shown, into the apparatus through the inlet passage 23 to fill the cylinder 27. When the slurry level reaches the sensing probe 43, an electrical signal causes the valve 84 to close. A further electrical signal at the same time causes the pneumatic device 16 to move the lower piston 19 up into the tube 27, sealing the bottom of the tube. The sensing probe is set to allow the liquid level to rise the necessary amount when the piston 19 is raised into position without overflowing. (The liquid passes through the upper piston 31 and the fibers are retained below it.) The apparatus is now ready for the compressing operation.

In order to compress the material in the slurry or suspension and form a pad or mat, the stroke cylinder 61 is actuated to return to its retracted position. The rate of return is such that the piston 31 is prevented from falling freely, that is, that the piston 31 is lowered at a rate which is substantially slower than the rate at which it would lower solely in response to the action of gravity on the weight 48 coupled with the resistance of the fluid within the chamber 29. When the stroke cylinder 61 is in its fully retracted position, the upper piston 31 rests freely upon a pad of fibers straining from the slurry by the downward movement of the porous piston. The pad is supported by the lower piston 19.

When the stroke cylinder 61 reaches its retracted position, an electrical signal actuates a suitable time delay relay in the control system 81, preferably set for about three minutes. This allows the pad to reach a constant rate of compression before measuring its thickness. At the end of this time delay period, the transducer 89 is activated. After a time delay sufficient to enable the transducer output voltage to stabilize, typically about five seconds, the recorder 91 is actuated and responds to the transducer dc voltage output to record the signal level. This signal is proportional to the distance between the faces of the upper and lower pistons, thus measuring the thickness of the pad of compressed fibers. The thickness is, of course, proportional to the dry fiber content of the pad.

The procedure thereby yields a series of readings for pad weight versus pad thickness.

After the compressing and recording operation is complete, the apparatus is placed in a condition to begin another cycle. To accomplish this, the recorder 91 is turned off after the recording period and returns to an appropriate position for the next record. The outlet valve 86 is open and the lower pneumatic cylinder 16 is operated to retract the piston 19 to the illustrated position. This allows the upper piston 31 to move downwardly in the chamber 29 until the stops 76 engage the underside of the plate 44. The apparatus is adjusted, through the gauge cylinder 63, such that the lower surface of the upper piston 31 is in the stop position flush with the upper edges of the passages 23 and 24. The water valve 83 is then opened and water flushes through the passages 23 and 24, removing the compressed pad and water from the chamber 27 through the valve 86 to a suitable waste disposal system. During this flushing period, which may last, for example, two minutes, the vacuum valve 81 is periodically opened to withdraw liquid and any suspended fibers from above the upper piston. Upon completion of the flushing period, the water valve 83 is closed, the outlet valve 86 is closed, the stroke cylinder 61 raises the upper piston 33 to the starting position just below the level of the sensing probe, and the sequence of operations is repeated.

FIGS. 2 and 3 illustrate an alternative embodiment of an apparatus in accordance with the present invention for determining the weight of a moisture-free compressible material in a given or predetermined unit volume of fluid suspension. The alternative embodiment of the apparatus illustrated in FIGS. 2 and 3 is indicated generally at 100. The apparatus 100 includes housing means, indicated generally at 102, having a lower base portion 104, an upper support block portion 106, a plurality of support columns 108 which serve to support the block 106 above the base 104, and a tubular cylinder 110. The tubular cylinder 110 is preferably made of a high strength transparent glass material and has a precision finished axial bore 112 therethrough which defines a sample chamber for the apparatus 100.

The lower end of the tubular cylinder 110 is snugly received over an upwardly extending boss 114 on the base portion 104. The upper end of the cylinder 110 is fixedly received within a suitable bore in the support block 106 which has an annular lip 116 adapted to engage the upper end surface of the cylinder 110. The support columns 108 are secured to and between the upper support block 106 and the lower base 104 to effect a fixed mounting of the tubular cylinder 110, an annular mounting ring 118 being disposed intermediate the lengths of the columns 108 and engaging the outer peripheral surface of the cylinder 110 intermediate its length to provide additional stabilizing support therefor.

The housing means 102 further includes a valve body 120 which has an internal bore 122 adapted to be firmly received over a corresponding outer peripheral surface of the support block 106. The valve body 120 has a circular chamber 124 therein axially aligned with the longitudinal axis of the bore 112 of the cylinder 110. The valve body 120 has a pair of threaded flow passage openings 126 and 128 therein which communicate with the chamber 124 and are adapted for selec-
tive communication with the chamber defined by the bore 112 of the cylinder 110. As will become more apparent hereinafter, the threaded flow passage 126 provides means for connecting a sample input line for introducing a fluid suspension sample into the chamber within the cylinder 110, while the threaded passage 128 provides means for connecting the sample chamber 112 to a drain or to a Nu No monitor.

The valve body 120 includes an upper cap portion 130 which is suitably secured to the lower portion of the valve body and has an axial stepped bore 132 therethrough coaxial with the cylindrical bore 112 in the cylinder 110. The stepped bore 132 has an enlarged diameter portion 132a which is coaxextensive with an enlarged diameter portion 122a of the bore 122 in the valve block 120. The enlarged diameter portions 122a and 132a cooperate to receive an annular sleeve bearing 134 which slidingly receives first piston means comprising a cylindrical chamber piston 136. Suitable annular packing seals, such as indicated at 138, are disposed between the stepped bore 122a and the outer peripheral surface of the piston 136 to prevent passage of fluid upwardly between the peripheral surface of the piston 136 and the bearing 134.

The piston 136 is longitudinally movable within the valve block 120 between an upper position allowing communication between the sample chamber 112 and the threaded flow passages 126 and 128 in the valve block, and a downward closed position preventing flow communication between the passages 126 and 128 and the sample chamber 112. To this end, the piston 136 is secured to the lower end of a cylindrical actuating rod 140 which has its lower end secured within a suitable recess 142 in the upper end of the piston 136. The upper end of the actuating rod 140 is affixed to a circular actuating piston 144 disposed within a cylindrical chamber defined by an annular wall 146 supported on the upper cap portion 130 and having an end block 148 secured thereon. The actuating piston 144 has a pair of annular sealing rings 150 disposed on its outer peripheral surface which engage the inner peripheral surface of the annular wall 146 in sealing relation. The piston 144 has an annular recess 152 therein which receives a depending sleeve 154 secured to and supported by the upper end block 148. An annular sealing member 156 is supported by the piston 144 for sliding engagement with the outer peripheral surface of the sleeve 154.

The upper end block 148 has a flow passage 158 therein adapted for connection to a pneumatic control circuit for supplying air pressure against or exhausting air pressure from the upper side of the piston 144. The upper cap portion 130 of the valve block 120 has a similar flow passage 160 therein adapted for connection in the same pneumatic control circuit as the flow passage 158 so as to allow the introduction of fluid pressure against or provide exhaust of fluid pressure from the lower side of the actuating piston 144. In this fashion, it can be seen that the piston 144 may be pneumatically actuated longitudinally relative to the housing means 102 so as to effect a corresponding longitudinal movement of the chamber piston 136 within the chamber 124 in the valve block 120. The chamber piston 136 has an annular flexible beveled sealing ring 162 supported on the lower end thereof for sealing engagement with an annular beveled surface 164 on the upper end of the support block 106 when the chamber piston 136 is moved to its lowered position.

The apparatus 100 includes second piston means comprising a piston rod 170 secured on the lower end of an elongated piston rod 172. The upper end of the piston rod 172 has a cylindrical piston 174 secured thereon which is longitudinally slidably within a tubular operating cylinder 176. The tubular cylinder 176 is secured between upper and lower end members 180 and 182, respectively, which are maintained in assembled relation with the cylinder 176 by longitudinally extending rods 184 secured to and between the upper and lower end members 180 and 182. Each of the upper and lower end members 182 has a flow passage, 186 and 188 respectively, provided therein and adapted for connection to a pneumatic control circuit for effecting double acting longitudinal sliding movement of the piston 174, as will be described more fully hereinafter.

The lower end member 182 is secured to the upper end of the connecting rod 190 which extends downwardly through a bore 192 in the block 148 and is formed integral with or otherwise suitably secured to the upper surface of the actuating piston 144. In this fashion, movement of the actuating piston 144 will effect a corresponding longitudinal movement of the cylinder 176, the piston rod 172 and the piston head 170 independent of any movement of the piston 174 relative to the cylinder 176. The piston rod 172 extends downwardly through suitable axial bores in the end members 182, the connecting rod 190, the actuating piston 144, the actuating rod 140 and the chamber piston 136. The chamber piston 136 has a circular recess 194 in the lower end thereof adapted to receive the piston head 170 when the piston head is in its uppermost position as effected by the actuating cylinder 176.

The chamber piston 136 further has a stepped axial bore 196 which has mounted therein an annular flexible rubber seal member 198. The seal member 198 has an axial cylindrical opening 200 therethrough the peripheral surface of which is normally spaced radially outwardly from the piston 192. The seal member 198 has an outer cylindrical surface 202 spaced radially inwardly from the annular surface of the bore 196. The chamber defined between the outer surface 202 of the seal member 198 and the inner surface of the bore 196 communicates with a flow passage 204 in the chamber piston 136. The flow passage 204 receives a tubular sleeve 206 downwardly therein, the sleeve 206 having its upper end secured in a bore 208 and being in flow communication with a flow passage 210 in the upper end cap 130. The flow passage 210 is adapted for connection to a source of air pressure so as to effect selective inward compression of the seal member 198 against the peripheral surface of the piston rod 172. A sealing ring 212 is supported by the chamber piston 136 about the upper end of the tubular sleeve 206.

The chamber piston 136 has an annular bearing 214 supported in the lower end of the stepped bore 196 adjacent the circular recess 194. The bearing 214 serves to engage the outer peripheral surface of a cylindrical magnetic core 216 mounted on the lower end of the piston rod 172 adjacent the piston head 170 for a purpose to be described more fully below.

The chamber piston 136 has a flow passage 218 which extends generally longitudinally of the chamber piston and communicates between the circular recess
and the upper surface of the chamber piston. The flow passage 218 receives a depending sleeve 220 therein similar to the aforesaid sleeve 206. The upper end of the sleeve 220 is secured within a bore 222 in the cap portion 130 of the flow communication with a flow passage 224 in the end cap 130. As will be described more fully hereinbelow, the flow passage 224 is adapted for connection in a control circuit for effecting selective communication between the portion of the sample chamber 112 above the piston head 170 and external air pressure, purge water, or drain when the piston head is in its downward position within the chamber 112.

The piston head 170 has a plurality of bleed holes or openings 226 extending therethrough parallel to the longitudinal axis of the piston head. The piston head 170 also has a shallow circular recess 228 in its lower surface which receives a disc of 80-mesh stainless steel woven screen similar to the lower surface of the upper piston 31 described hereinbefore with reference to FIG. 1.

A circular porous piston 232 is supported on the upper end of a tubular stem 234 having a threaded lower end portion secured within a threaded opening 236 in the base 104, the opening 236 being axially aligned with a threaded connecting opening 238 in the base 104. The piston 232 engages the upper end surface of the boss 114 and has a plurality of longitudinally extending openings 240 therethrough one of which is in flow communication with the axial passage of the tubular stem 234. The piston 232 supports an 80-mesh stainless steel screen 242 on its surface to allow bleed-off of fluid through the openings 240 while preventing the passage therethrough of fibrous material suspended in the fluid suspension to be introduced into the chamber 112.

The base 104 and upstanding boss 114 have a generally conically shaped recess 244 therein which underlies the piston 232 and provides a fluid receiving chamber about the stem 234. A flow passage 246 is provided in the base block 104 in communication with the chamber 244 and is adapted for connection to a source of pneumatic pressure to aid in cleaning the apparatus, as will become more apparent hereinbelow. The base block 104 also has a transverse flow passage 248 therethrough which intersects the lower end of the chamber 244. One end of the transverse flow passage 248 is adapted for connection to a source of water for flushing the chamber, and the other end of the flow passage 248 is adapted for connection to a drain. The axial passage within the tubular stem 234 permits draining of excess water from the cylinder 110 during compressing of fluid suspension therein while keeping the chamber 244 below the porous piston 232 filled with liquid during an operating cycle so as to maintain constant sample quantity.

In order to provide an indication of the position of the lower surface of the piston head 170, a linear position transducer, indicated generally at 250, is supported by the base block 104 adjacent the lower end of the sample chamber 112 within the cylinder 110. The linear position transducer 250 comprises the aforesaid magnetic core 206 on the lower end of the piston rod 172 adjacent the piston head 170 and an annular coil assembly 252. The coil assembly 252 is supported on the base block 104 and extends peripherally about the lower end of the cylinder 110 as shown in FIG. 2. The coil assembly 252 is connected in a circuit, to be described below, to provide an output signal proportional to the position of the core 216 and thus the position of the piston head 170. The linear position transducer means 250 operates generally in accordance with the above described linear position transducer 89 of FIG. 1, and is commercially available from the Schaevitz Engineering Co., Pennsauken, New Jersey. The coil assembly 252 consists of three coils wound equally spaced on a cylindrical form such that when alternating current is applied to the center coil, voltages are induced across the other two coils. The rod-shaped magnetic core 216 moves axially within the coil assembly 252 providing a low reluctance path for the magnetic flux linking the two outer coils. The end coils are connected in series opposed such that when the core 216 is positioned with the lower surface of the piston head 170 and engaging the lower surface of the fixed piston 232, the combined output of the end coils of the coil assembly 252 is zero. When the core 216 is displaced from its zero position the net output from the coil assembly increases proportionally so as to provide a signal which is a function of the position of the piston head 170. As was explained above with position of the piston head 170. As was explained above with respect to the linear position transducer 89 of FIG. 1, the output of the position transducer 250 may be applied to a recorder (not shown) for the purpose of recording the particular consistency values over a period of time. Similarly, the output signal derived from the linear position transducer means 250 may be fed to suitable relays, servo mechanisms, gauges, etc. depending upon the particular control response desired.

FIGS. 3 and 4 illustrate, respectively, a schematic control diagram for use with the apparatus 100 and a sequence chart which indicates the sequence of operating events as determined by programming the control elements shown in FIG. 3. The apparatus 100 lends itself to full automation and provides reliable and accurate means for on-line analysis of fluid suspensions in process, such as found in the paper making industry.

With particular reference to FIG. 3, a flow conduit 254 is connected on-line with a source of fluid suspension to be tested, such as a paper making machine. The flow conduit 254 is connected to a sample dilution tank 256 having a mixing means 258 therein which may comprise a pneumatically controlled agitator. The dilution tank 256 is adapted for connection through a 2-way ball valve 260 to drain or, alternatively, through a pump 262 to a 3-way ball valve 264 from which the fluid sample from the dilution tank may be introduced into the inlet flow conduit 126 of the valve body 120 or directed back into the dilution tank 256 through a flow conduit 266. The 3-way ball valve 264 is controlled by a pair of interconnected 3-way solenoid operated diverter valves 268a and 268b. The solenoid operated diverter valve 268a is normally de-energized and connects an air pressure supply through a cross-over flow conduit 270 and through the normally energized diverter valve 268b to the 3-way ball valve 264 to cause the fluid suspension sample from the dilution tank 256 to be diverted back to the dilution tank through the conduit 266. When the diverter valve 268a is energized and the valve 268b is de-energized, air pressure is supplied to the 3-way valve 264 directly from the valve 268a and the valve 268b is open to atmosphere so that the valve 264 effects flow of fluid suspension from the
dilution tank 256 into the chamber 124 within the valve body 120 of the apparatus 100. As will be more fully described below, the diverter valves 268a and 268b are programmed for a predetermined sequence of operation in accordance with the chart of FIG. 4.

The valve 260 is controlled by a pair of interconnected solenoid actuated diverter valves 272a and 272b interconnected by a cross-over conduit 274. The diverter valve 272a is normally de-energized and the diverter valve 272b is normally energized such that an air pressure supply connected to the valve 272a is passed through the valve 272b to close the valve 260. Energizing the diverter valve 272a and de-energizing the valve 272b effects air pressure supply through the valve 272a directly to the valve 260 to open valve 260, valve 272b when de-energized being open to exhaust. The diverter valves 272a and 272b are controlled in a pre-programmed sequence as indicated in FIG. 4.

A normally closed solenoid operated valve 276 is connected between a pressurized water supply 278 and the outlet of the valve 264 such that energizing the solenoid of the valve 276 effects water flow through the valve 264 and assists in back-flushing the flow conduit 266 to the dilution tank 256. A manually operable control valve 280 is connected in line with the valve 276 and is manually adjustable to control the volume of water during the back-flushing operation. A second normally closed solenoid operated valve 282 is connected between the water supply 278 and the control valve 260 and is selectively energized to assist in flushing the contents of the dilution tank 256 to drain through the valve 260 during a tank draining cycle when the valve 260 is open to drain.

As noted, the chamber piston 136 is connected in a control circuit for lowering the chamber piston 136 to a sealing position wherein the sealing ring 162 engages the upper beveled surface 164 on the upper support block 106. To this end, a pair of interconnected 3-way diverter valves 284a and 284b are connected in circuit to control the introduction of pressurized air from a source 286 to either side of the piston 144 through the flow conduits 158 or 160. The valve 284a is normally de-energized and diverts air pressure from the source 286 through a cross-over conduit 288 and through the normally energized valve 284b to the lower side of the piston 144 to maintain the chamber piston 136 in a raised position. The valves 284a and 284b are connected in a programmed control circuit so as to be energized and de-energized, respectively, to effect air pressure supply through the flow passage 158 and connect the flow passage 160 to atmosphere so that the chamber valve 136 is selectively moved downwardly to confine the fluid suspension introduced into the chamber 112.

The effect of longitudinal movement of the piston head 170 between an upper position wherein it is disposed within the recess 194 in the chamber piston 136 and a lowered position wherein it is moved downwardly within the sample chamber 112 to compress fluid suspension disposed within the sample chamber, the flow passages 186 and 188 are adapted for connection to a source of air pressure 290 such as 60 psi. The flow passages 188 and 186 are connected, respectively, to 3-way solenoid operated diverter valves 292a and 292b which are interconnected by a cross-over conduit 294. The input side of the valve 292b is connected to the output of a solenoid operated 3-way valve 296. The 3-way valve 296 has one input connected directly to the air pressure supply 290 and has a second input connected to the air pressure supply 290 through a differential pressure regulator 298. The valve 296 is normally energized to allow direct flow of air pressure from the source 290 to the diverter valve 292a which, in its normally de-energized state, causes the air pressure to pass through the cross-over conduit 294 and through the normally energized valve 292a to the flow passage 218 to maintain the piston 174 in its raised position within the cylinder 176.

The diverter valve 292a, when de-energized, is adapted for connection to exhaust through a normally energized 3-way solenoid operated valve 300. The valve 300 is also adapted for connection to the differential pressure regulator 298 and to exhaust through a manually controlled needle valve 302. When energized, the valve 300 blocks air flow from valve 292a directly to exhaust but allows air flow through the needle valve 302 to atmosphere. Adjustment of the needle valve 302 establishes the pressure differential at the differential pressure regulator 298 as indicated by a differential pressure gauge 304. It will be understood that with the valves 296 and 300 normally de-energized, energizing the valve 292a and de-energizing the valve 292a will effect a rapid downward movement of the piston 174 with the cylinder 176, the valve 292a being connected directly to atmosphere through the valve 300. Energizing the valves 296 and 300 serves to effect a controlled downward movement of the piston 174 and associated piston head 170 at a rate as determined by the differential pressure regulator 298 in accordance with known techniques. The valves 292a, 292b, 296 and 300 are connected in a programmed electrical control circuit to effect a predetermined sequence of operation as set forth in the table of FIG. 4.

To effect sealing contact of the seal member 198 about the piston rod 172, a normally de-energized closed solenoid operated 3-way valve 306 is provided to control flow of air pressure from an air pressure source 308 into the flow passage 210 and about the peripheral surface of the seal member 198 to expand it against the piston rod 172.

A pair of normally de-energized closed solenoid actuated control valves 310 and 312 are connected in flow communication with the flow passage 224 in the cap block 130 and, respectively, serve to selectively control the introduction of water from a source 314 or the flow of air from an air supply source 316 into the flow passage 218 in the chamber valve 136 for water flushing or air purging of the chamber 112 when the piston is moved downwardly within the chamber during an operating cycle. The flow passage 224 may also be selectively connected to drain through a normally de-energized closed solenoid control valve 318 to vent the flow passage 224.

The flow passage 246 in the base block 104 is connected through a normally de-energized closed solenoid operated valve 320 to an air pressure supply 322 to allow selective introduction of air into the chamber 244 to assist in clean-up after compressing a fluid suspension sample within the chamber 112. The flow passage 248 extends through the base block 104 and has one end adapted for connection to a source of water pressure 324 through a normally de-energized closed solenoid operated valve 326 to assist in flushing the chamber 244. The other end of the flow passage 248 is
adapted for connection to a drain through a normally de-energized closed solenoid operated valve 328. The flow passage 238 in the base block 104 is adapted for connection to drain under the control of a normally de-energized closed solenoid operated valve 330 to permit draining of excess water from the sample chamber 112 while maintaining the chamber 244 below the porous fixed piston 252 filled with water to maintain constant sample quantity.

FIG. 4 sets forth a table showing the sequence of operational events or functions which take place during a cycle of operation of the apparatus 100. The particular operational functions are indicated in the vertical columns along with the time interval for each event, and the particular control valves operated to effect the individual functions are indicated in the horizontal columns by solid squares.

During a cycle of operation, the valve 318 is energized to vent the flow passage 218 in the chamber valve 136 to atmosphere simultaneously with energizing the solenoid of valve 284a and de-energizing the solenoid of valve 284b of the chamber valve 136. The fluid supply line to the inlet opening 126 in the valve body 120 is then filled with fluid suspension from the tank 256 by energizing the solenoid valve 268a while de-energizing the solenoid valve 268b. Simultaneously, the seal 198 is caused to seal against the piston rod 172 by energizing the solenoid valve 306. A fluid suspension sample is then introduced into the chamber 112 within the cylinder 110 by raising the chamber valve 136, as by de-energizing the valve 284a while energizing the solenoid valve 284b. The chamber valve 136 is then again closed against the beveled surface 164 to confine the fluid suspension sample within the chamber 112.

After confining the fluid sample within the sample chamber 112, the sample chamber is partially drained by energizing the solenoid valve 312 to introduce air into passage 218, and the flow passage 248 in the base block 104 is connected to drain by energizing the solenoid valve 328. Simultaneously, the valve 264 is caused to divert fluid suspension from the tank 256 back into the tank, and the valve 276 is energized to introduce water into the sample supply line to back-flush the line into the tank 256. With the sample chamber 112, the piston 170 is initially lowered a predetermined distance at a relatively rapid rate by energizing the solenoid valve 292a and de-energizing the solenoid valve 292b for a period of three seconds. After this three second period, the solenoid valves 296 and 300 are energized to effect a controlled lowering of the piston 170 in accordance with the setting of the differential pressure regulator 298. After the piston 170 has been lowered at the controlled rate for a period of approximately four minutes to compress the fluid suspension, a measurement output signal is generated by the linear position transducer means 250 which indicates the position of the core 216, and thereby the piston 170, relative to its zero position within the annular core 252. This output signal is taken over a period of five seconds and may be recorded graphically in a known manner. The output signal from the transducer means 250 indicates the thickness of the pad of fibers created from the fluid suspension between the movable piston 170 and the fixed lower piston 232. Thereafter, the piston 170 is raised as above described and the sample chamber 112 is back-flushed by raising the chamber piston 136 and opening the valve 310 while the shaft seal 198 is in sealing relation with the piston rod 172. Simultaneously the valve 326 is energized to allow introduction of water into the lower flow passage 248 in the base block 104, and the valve 320 is energized to introduce air into the flow passage 246. Thereafter, the piston 170 is again lowered and the chamber 244 back-flushed by a suitable timed wash cycle control, the piston 170 being then again raised and the sample chamber 112 flushed and drained.

Suitable control means (not shown) may be connected to the outlet flow passage 128 in the valve body 120 to allow passage of the contents of the sample chamber 112 after compressing a fluid suspension sample therein to either drain or to a Nu No monitor.

To accomplish automatic sequential operation of the apparatus 100 and its associated control circuitry in accordance with the operational sequence chart of FIG. 4, the solenoids of the various control valves may be connected in any suitable control system for obtaining the desired sequence of operation. For example, a drum programmer, such as commercially available from the Tenor Company of New Berlin, Wisconsin, may be connected in circuit with a programmable timer of the type available from Tenor Company and suitable electrical relays to sequentially control the above described solenoid valves in accordance with the chart of FIG. 4.

The embodiments of the present invention, as above described, have application as consistency measuring devices and, if provided with an appropriate control function, such as the opening or closing of a valve in a water feed line to a reservoir or tank such as conduit 254 in FIG. 3, the invention can further act as a consistency regulator. A distinct advantage of the above-described devices in measuring consistency over other known devices is that the range of consistency values that the instant devices are capable of measuring is limited on the high side only by that which can be handled and transported as a fluid, and on the low side by practical limitations in size of the compressing sample chamber to handle a sufficient volume of slurry that will contain enough fiber to form a compressible pad. Thus, the device is applicable to the full range of consistencies encountered in pulping and paper making, normally from about 0.2 to 6.0 percent consistency. Other devices cover only narrow portions of this range.

An additional advantage of the present invention is that it makes possible the measuring of a sample of solid compressible material in a liquid suspension in order to obtain a desired amount of solid for automated chemical testing. The measurement is accomplished accurately by the relationship established between the weight of the compressed pad and the pad thickness at a fixed compressing pressure. The approximately desired amount may be readily obtained by selecting an appropriate volume of slurry for entry into the device. By withdrawing the water from the compressed pad, the sample may be obtained in a form usable for testing in a chemical testing apparatus.

By appropriately selecting the materials of construction of the above described apparatuses, and by the provision of means for maintaining the temperature of the slurry at a fixed temperature, many forms of chemical testing may be performed in the apparatuses. For example, the hollow upper piston rod of the apparatus
of FIG. 1 may be utilized for the introduction and removal of reagents and solutions to and from the compression chamber and, where required, the upper piston may be used as an agitator by programming the stroke or the gauge cylinders to move the piston up and down at a required rate and for a required stroke length. Examples of chemical tests which may be performed on pulp samples contained within the apparatuses of the invention are the Kappa number or permanganate number test, the Na number, and the viscosity after dissolution of the sample in the device. Such tests are well known to those skilled in the paper making art.

It may therefore be seen that the present invention provides apparatus for determining the weight of the moisture-free, compressible material in a given volume of fluid suspension. The apparatus of the invention readily lend themselves to automation and provide a simple and reliable means for on-line analysis of suspensions in process, such as may be extremely useful in the art of paper making.

Various modifications of the invention in addition to those shown and described herein will become apparent to those skilled in the art from the foregoing discussion and accompanying drawing. Such modifications are intended to fall within the scope of the appended claims.

What is claimed:

1. Apparatus for determining the weight of a moisture-free, compressible material in a given volume of fluid suspension, comprising, in combination, housing means defining a sample chamber adapted to receive a volume of the fluid suspension therein, said housing means having first passage means therein adapted for communicating relation with said chamber for introducing the fluid suspension into said chamber, first piston means supported by said housing means for movement between a position allowing the introduction of fluid suspension into said chamber and a position preventing flow from said first passage means into said chamber and confining the fluid introduced into said chamber, second piston means supported by said housing means and having a porous surface movable into said chamber for compressing the fluid suspension confined therein to form a mat of the material, first fluid pressure means operatively associated with said first piston means to effect selective movement thereof to said position preventing flow from said first passage means to said chamber, second fluid pressure means operatively associated with said second piston means to effect longitudinal movement thereof into said chamber for compressing the fluid suspension confined therein, control means for actuating said first and second fluid pressure means to move said first piston means to said position blocking said first flow passage prior to movement of said second piston means longitudinally into said chamber, and means for automatically measuring the thickness of the mat formed, the weight of said mat being determined from a predetermined known relationship of mat thickness to weight for the particular fluid suspension employed.

4. Apparatus as defined in claim 3 wherein said control means includes means for effecting a rapid longitudinal movement of said second piston means within said chamber for a predetermined distance and thereafter effecting said longitudinal movement at a predetermined slower controlled rate of travel.

5. Apparatus as defined in claim 3 wherein said second piston means includes an elongated piston rod longitudinally movable within said chamber, and wherein said apparatus includes linear position transducer means having a core and an annular coil, said core being supported on said elongated piston rod, and said annular coil being disposed about said chamber, said core and said coil cooperating to produce a signal proportional to the relative positions of said core and coil during compressing of said fluid suspension.

6. Apparatus as defined in claim 5 wherein said core and said annular coil are positioned such that a zero output signal is produced when said second piston means is in a fully extended position within said chamber.

7. Apparatus as defined in claim 3 wherein said control means is adapted to effect automatic sequential introduction of a fluid suspension sample into said chamber, move said first piston means into said position preventing flow of fluid from said first passage means into said chamber, and move said second piston means into said chamber for compressing said fluid suspension confined therein to form a mat of material from said fluid suspension.

8. Apparatus as defined in claim 7 wherein said control means is adapted to move said second piston means outwardly of said chamber after compressing the fluid suspension confined therein, thereafter move said first piston means to its said position allowing the introduction of fluid suspension into said chamber, and thereafter effect flushing of said chamber in a manner to remove the compressed pad formed therein.

9. Apparatus as defined in claim 3, including second flow passage means within said housing means and said first piston means, said second passage means being
adapted for selective communication with said chamber to allow the introduction of fluids into said chamber when said second piston means is moved longitudinally into said chamber.

10. Apparatus for determining the weight of a moisture-free compressible material in a given volume of fluid suspension, comprising, housing means including a lower block portion defining a chamber for confining the given volume of the fluid suspension and having a piston passage communicating with said chamber, a movable solid piston at one end of said chamber operable between a first position wherein said one end of said chamber is open for draining the contents thereof and a second position wherein said one end of said chamber is sealed, said lower block portion further having an inlet passage and an outlet passage communicating with said piston passage and opening thereinto with said solid piston in said first position, a porous piston at the end of said chamber opposite said solid piston, said porous piston being movable toward said solid piston for compressing the material in the confined fluid suspension to form a mat of the material, means for measuring the thickness of the mat of material thus formed, means for automatically actuating said solid piston and said porous piston in accordance with a predetermined sequence, and means for introducing a fluid into said inlet passage with said solid piston in said first position in order to flush material from said chamber through said outlet passage.

11. Apparatus according to claim 10 wherein means are connected to said inlet passage for introducing the fluid suspension into said chamber with said solid piston in said first position thereof, and wherein a valve is provided coupled to said outlet passage for closing same during introduction of the fluid suspension.

12. Apparatus according to claim 10 wherein said porous piston is actuated by a hollow piston rod, wherein said hollow piston rod is provided with openings therein communicating between the hollow interior thereof and said chamber, and wherein means are coupled to the hollow piston rod exteriorly of said chamber for introducing fluids and removing fluids therefrom.

13. Apparatus according to claim 10 wherein said thickness measuring means comprises a transducer for converting the mechanical movement of said porous piston into a corresponding electrical signal.

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