United States Patent [19]

Ripple et al.

[11] **3,838,716**

[45] **Oct. 1, 1974**

[54] **SYSTEM FOR PACKING PARTICULATE MATERIAL INTO LONG CYLINDRICAL CONTAINERS**

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[22] Filed: **July 24, 1973**

[21] Appl. No.: **382,248**

[52] **U.S. Cl.** .... **141/12,** 141/77, 141/263, 141/270, 141/284, 141/374, 53/124 B

[51] **Int. Cl.** **B65b 1/24**

[58] **Field of Search** .... 141/12, 34, 71–81, 141/374, 270, 271, 272, 273, 274, 280, 284, 263, 264, 172, 181, 182; 29/424; 53/24, 124 B, 124 D, 124 E

[56] **References Cited**

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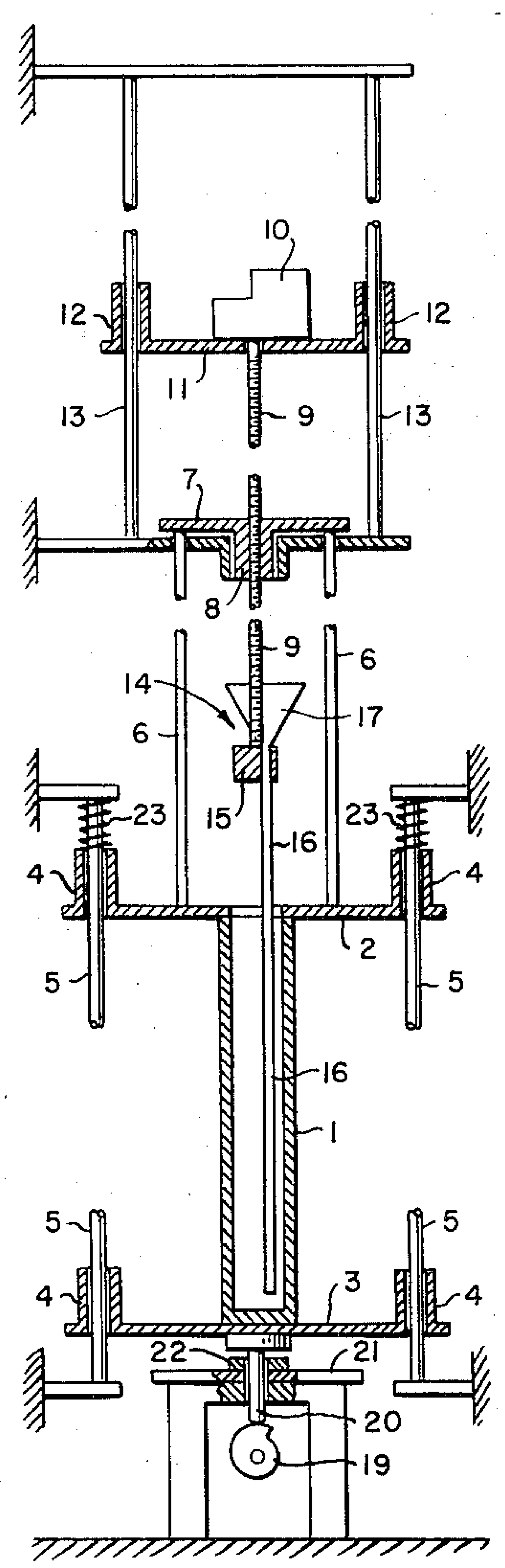
[57] **ABSTRACT**

Particulate material is deposited in an elongated container by continuously and uniformly depositing the material in the container while repeatedly lifting and dropping (and impacting) the container and the particle delivery means. Post-impact vibration and bouncing are damped.

10 Claims, 6 Drawing Figures



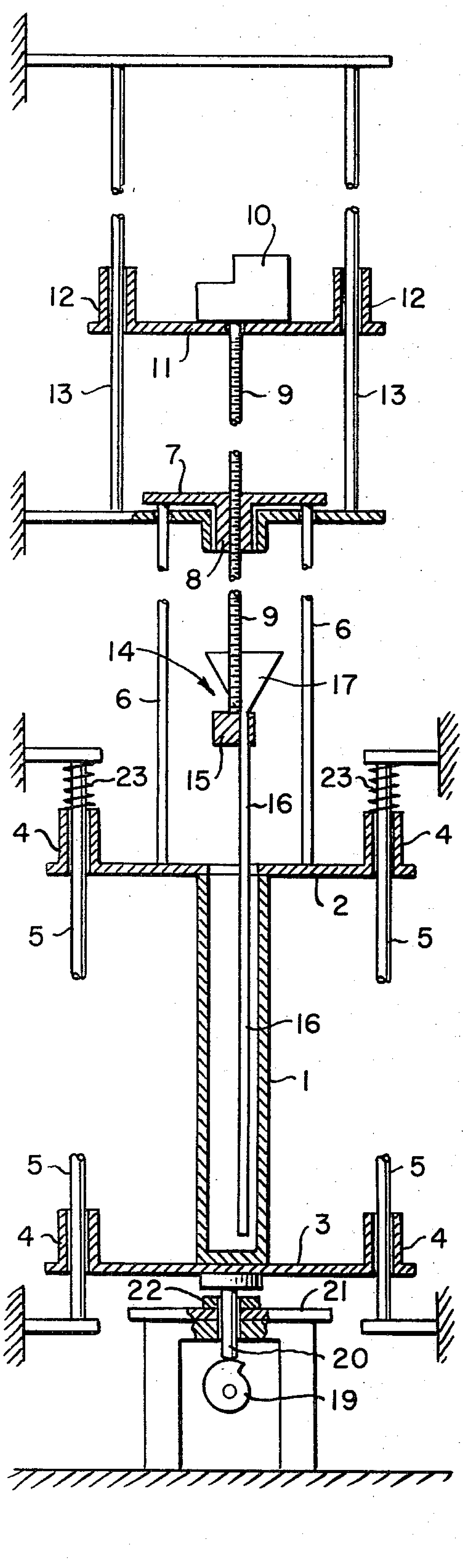


FIG. 1.

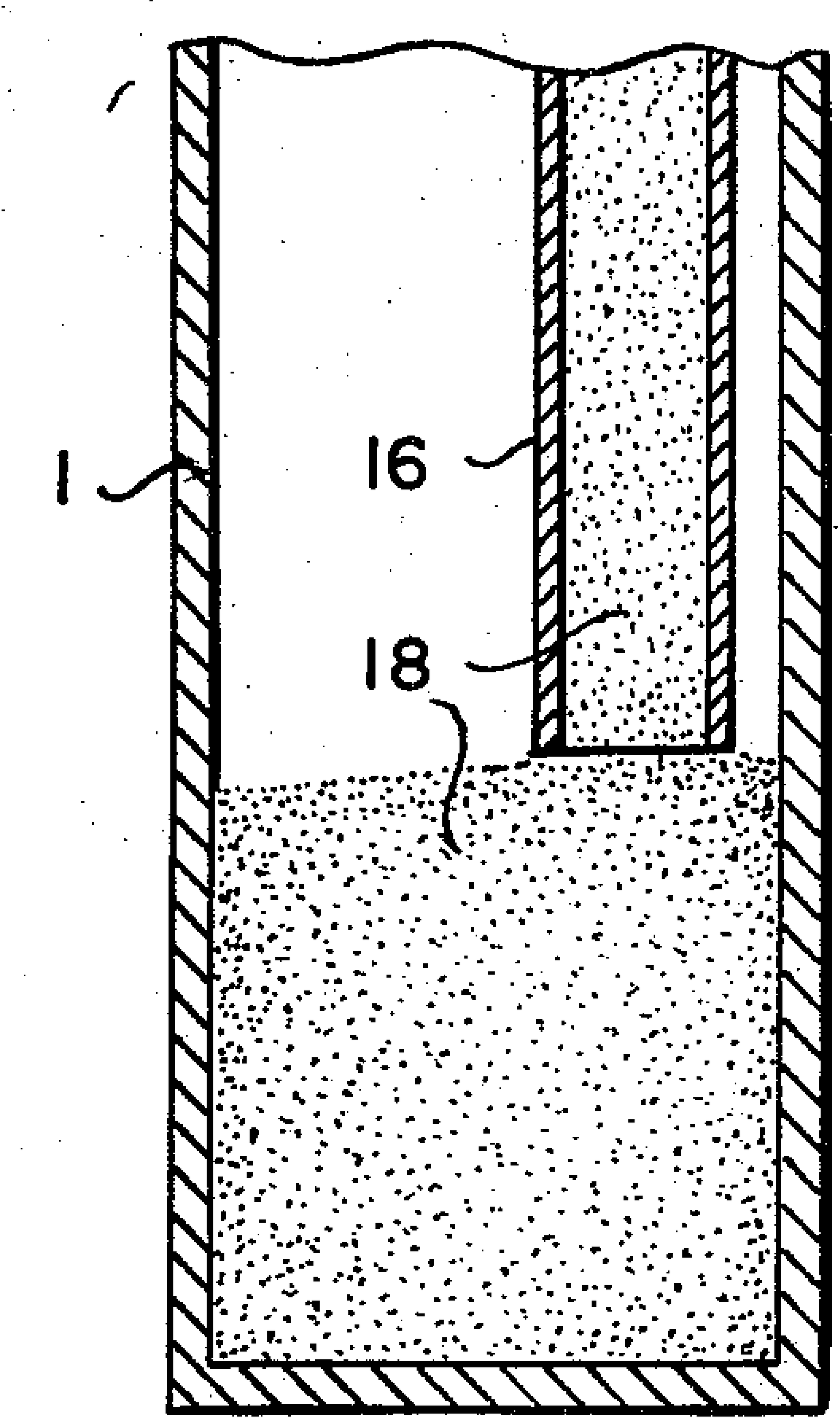


FIG. 2.

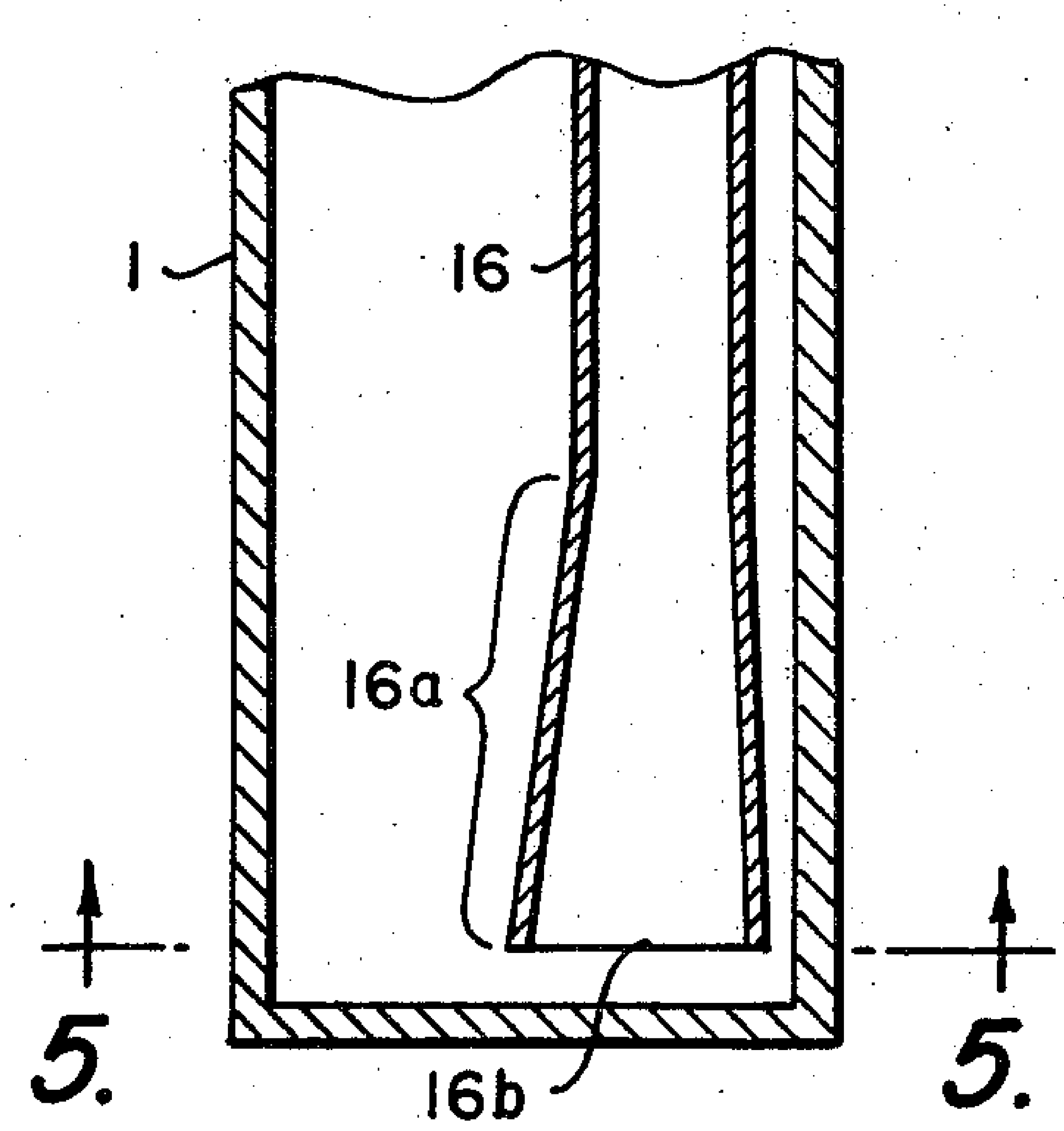


FIG. 3.

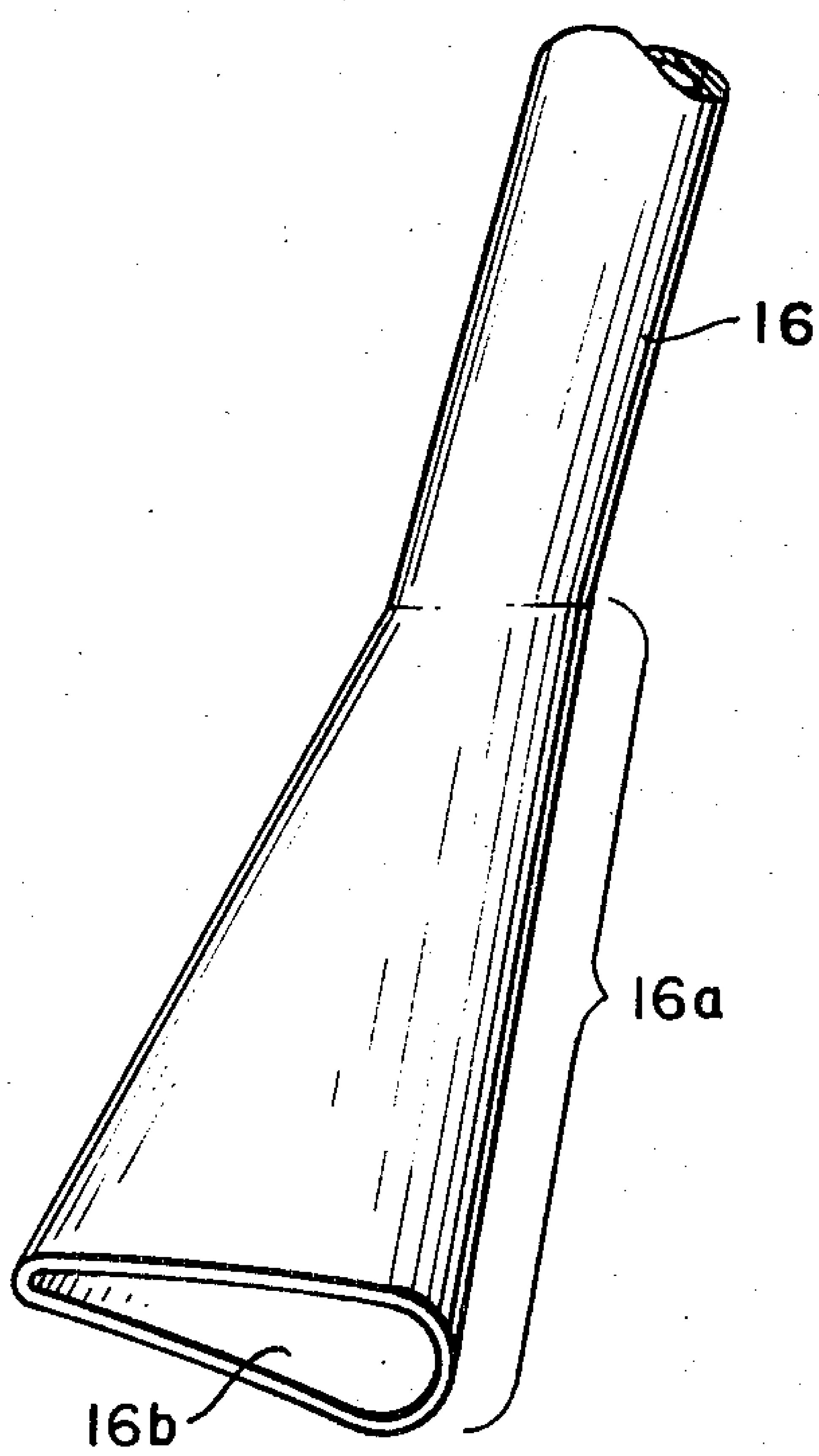


FIG. 4.

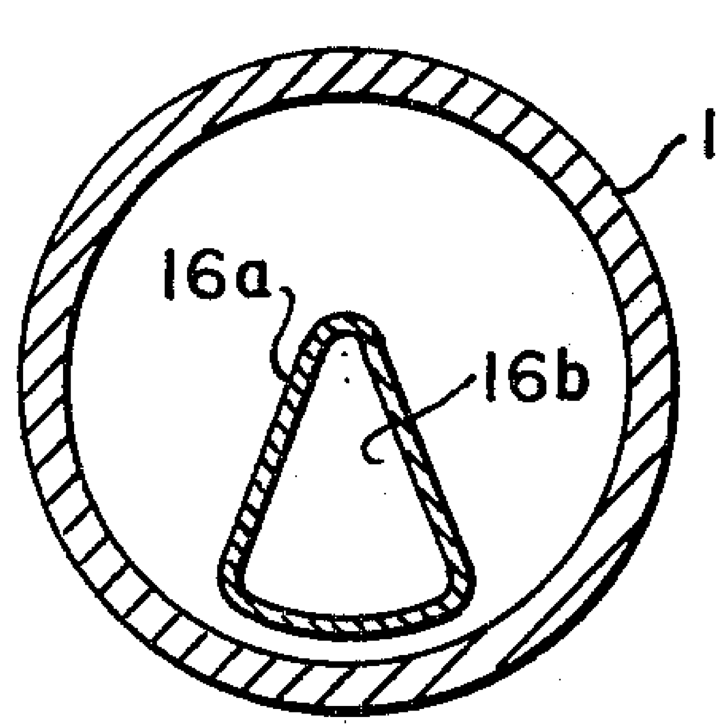


FIG. 5.

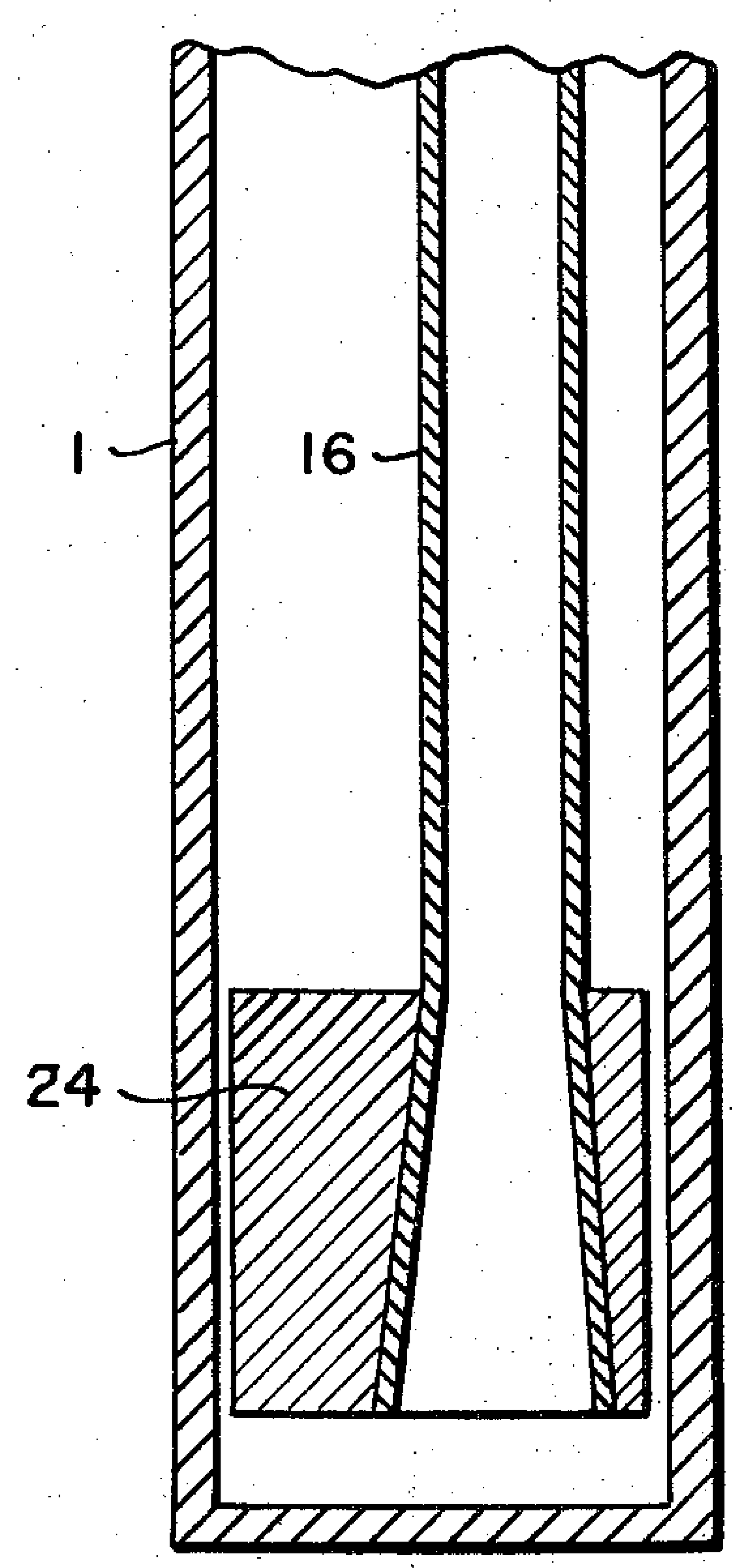


FIG. 6.

SYSTEM FOR PACKING PARTICULATE MATERIAL INTO LONG CYLINDRICAL CONTAINERS

This invention relates to packing particulate materials into cylindrical containers. An important object in such a packing operation is to attain high bulk density and particle size homogeneity throughout the container whereby segregation of coarse and fine particles is minimized or eliminated. Homogeneity is a highly important factor in filling nuclear fuel rods or dies with powder or particulates, or for packing particulate material into cylindrical containers for testing purposes.

Some of the problems encountered with the prior art of packing particulates are as follows: (1) Deposition processes alone are usually unsatisfactory in that further compaction is usually necessary. Even high velocity deposition (free fall of particulates, etc.) usually leads to only moderate bulk densities, and segregation of particles is common. (2) Screw feeds may fracture soft or brittle particles, which is an undesirable feature in certain cases. (3) Tremie feeds alone do not produce segregation, but they produce only moderate bulk densities. (4) Vibratory feeds alone produce only moderate bulk densities, and the chance of segregation exists.

In the art of packing long columns various compaction procedures used alone are unsatisfactory: (1) Pressing alone achieves a high but not necessarily homogeneous bulk density pack, since wall friction alters the pressure fields. Also, soft or brittle particles may be fractured. (2) Impact techniques alone have in the past been used and are satisfactory only for relatively short, already filled columns. Even these display a smaller bulk density and radial particle size segregation in the top layers, which must be discarded. The impact techniques are unsatisfactory for long columns due to the complex locking of the particles in the lowermost regions into a low density pack by the overburden pressure of the upper portion. (3) Vibration techniques have become the most prevalent method of densifying particulates in containers. Their acceptance has been based on (A) ability to achieve a high bulk density pack that (B) displays adequate axial homogeneity. Vibration of short, previously filled columns results in packs of acceptable axial and radial homogeneity as well as high bulk density in the lower portions only. Vibration compaction of previously filled long columns is unsatisfactory in that only the intermediate portions may achieve a reasonably uniform high bulk density. The lowermost particles are locked into a stable, low bulk density configuration by the overburden pressure of the upper layers.

The combination of simultaneous deposition (vibratory or tremie feed) and vibratory compaction is currently much used for packing long columns. The combined technique has resulted in long, high bulk density columns with acceptable axial homogeneity. However, it has been shown that radial particle size segregation (and consequently, radial inhomogeneity) occurs at least in the case of tremie deposition and most likely in the case of vibratory feed deposition. The lack of radial homogeneity makes these long column packs undesirable for many uses.

We have now developed a system for utilizing, in combination, a deposition device and a compaction device for producing axially and radially homogeneous dense packs of particulate materials in long cylindrical containers. An automated tremie device is used to continuously and uniformly deposit material into the cylindrical container in the pattern of a helix. This form of deposition, by itself, produces particulate packs free of axial and radial inhomogeneities, but of unacceptably low bulk density. An impact type compaction device is used concurrently with the deposition device to increase uniformly the bulk density of the pack without degrading the axial or radial homogeneity of the pack. The compaction device consists of an automated impacting mechanism, capable of lifting the pack container a short, precise distance and dropping it on a solid stop at repetitive, predetermined time intervals during the deposition process. An essential feature of the device is thorough damping of the container and accessory apparatus. This eliminates from the system any undesirable vibration and post-impact bounce which have been shown to produce radial segregation of particle sizes.

It is therefore an object of the present invention to prevent radial inhomogeneity in a column packed with particulate material.

Another object is to prevent free vertical oscillation while packing such a column.

Other objects and advantages will be obvious from the following more detailed description of the invention taken in conjunction with the drawings in which

FIGS. **1** and **2** illustrate an embodiment of the present invention;

FIGS. **3–5** show a modification of FIGS. **1** and **2**; and

FIG. **6** illustrates a further modification.

Referring to FIG. **1**, reference numeral **1** designates an elongated cylindrical container or zone to be packed with particulate material. The top and bottom of the container **1** are fixed to plates **2** and **3**, respectively, by, for example, bolting or adhesion. Plates **2** and **3** are provided at their peripheries with bushings **4** which slide on fixed rods **5**.

Attached to the top of plate **2** are supports **6** for platform **7**. A threaded sleeve **8** extends through the top of platform **7** to receive threaded vertical rod **9**. A motor **10** mounted on platform **11** above rod **9** turns the rod. Bushings **12** on platform **11** guide the platform along fixed vertical alignment rods **13**.

At the lower end of rod **9** is a tremie delivery zone or assembly **14** consisting of support member **15**, and a generally cylindrical filling tube **16** with a funnel **17** or other appropriate feed mechanism attached to the top of the tube.

Tube **16** and funnel **17** are axially offset from threaded rod **9**. Under this arrangement, when rod **9** is turned, tube **16** simultaneously moves slowly upwardly and around the relatively fixed vertical axis of container **1** thereby traveling a helical path with the pitch of the threaded rod **9**.

In operation the filling assembly **14** is filled with particulate material, and slowly rotated and lifted by means of rod **9** and motor **10** through a helical path from the bottom of container **1** so as to deposit material helically in the container.

Referring to FIG. **2**, at no time during the filling operation is the material in the exit passageway of tube **16** out of contact with the top surface of the body of material already deposited in the container **1**. Thereby, a continuous mass **18** of material is formed within and between container **1** and tube **16.**

However, throughout the filling operation the bottom of tube **16** merely brushes against the top surface of the continuously enlarging body of material in container **1,** and at no time does the tube actually rest upon or compress the top surface. Such compression-free contact helps to insure axial homogeneity of the deposited material.

During packing operations, tube **16** is kept full of particulate material to insure the prevention of free-fall of particles through the tube onto the body of particulate material in the container. Furthermore, it is also desirable to maintain the height of particles within the tube at a substantially constant level throughout the filling operation to insure that the downward force on particles leaving the bottom of the tube is substantially constant.

Referring again to FIG. **1,** as the filling tube slowly moves upwardly through the container, the entire structure, e.g., container **1,** plates **2** and **3,** platform **7,** tremie assembly **14,** plate **11** and motor **10** are subject to a vertical reciprocating motion by repeatedly being slowly lifted upward a short distance by cam **19** and push rod **20** driven by a geared, variable speed electric motor (not shown), and then allowed to fall back toward and impact upon support table or stop **21** firmly fixed to the floor. Spacers **22** on table **21** are provided to adjust the height of the drop. Typical lifting frequencies range from once every 2.5 seconds to once every 3 minutes. Typical drop heights range from 0.2 cm to **1.0** cm.

As can be seen from the figure, the reciprocating means in no way displaces the container and filling tube from one another. Rather, the container and tube are simultaneously lifted and simultaneously dropped the same height.

Springs **23** mounted at the top of rods **5** oppose upward motion of the assembly, and accomplish a twofold purpose. First, their compression during lifting results in an increase of pre-impact downward acceleration of the assembly. Second, and perhaps more importantly, the springs increase the damping of post-impact vibration and bouncing experienced by container **1.**

FIGS. **3, 4** and **5,** the latter which is a view along viewing plane line **5—5** of FIG. **3,** illustrate a modification of the system which enhances packing homogeneity. Tube **16** is circular in cross-section except at its lowest segment **16*a*.** As shown in the figures, the geometrical shape of **16*a*,** in cross-section is a circle at the top of the segment while the opening **16*b*** at the bottom of **16*a*** is generally sector-shaped (sector of a circle). Furthermore, the cross-sectional area of **16*a*** progressively enlarges from the top to the bottom thereof. Generally, this insures a steady and sufficient flow of material out the bottom of the tube.

As can be seen in FIG. **5,** sector-shaped opening **16*b*,** at its narrowest dimension, is disposed in the axial portion of container **1,** while the widest dimension of the sector is disposed in the peripheral and larger zone of the container. This allows greater volumes of particulate material to pass from the tube **16** directly to the peripheral zone of the container then to the axial zone, which insures that particulate material is equally deposited across the radius of the container, thereby preventing crater-like deposition.

Referring now to FIG. **6,** to further enhance packing homogeneity, a guide **24** can be secured around the lowest segment **16*a*** of tube **16.** The guide prevents undesirable lateral movement of the lowest segment, and thereby prevents misalignment and hence nonuniformity of the filling operation.

Many other mechanical variations can be employed in the system. For example, other damping mechanisms rather than compression springs can be employed such as mechanical locks, an air cylinder or an electrical solenoid control (with feedback). Impact may be effected by periodically striking the container, with damping, rather than by the lift-fall technique. Still further, the container could be placed in motion by low frequency square wave driven and controlled oscillation.

As an alternative to raising the filling tube **16** by means of screw rod **9,** while maintaining the container in a relatively fixed vertical position, the filling tube can be maintained in a relatively fixed vertical position, while the container is positively moved downwardly, away from the tube, through the container's carriage assembly. Lifting and dropping of the container and tube is then accomplished by periodically lifting and dropping the carriage assembly which is also attached to the delivery tube assembly. Under either arrangement, the tube in effect passes toward the top of the container, while the entire assembly is lifted and dropped.

Still further, as an alternative to positively rotating the filling tube about the container's axis while maintaining the container's axis relatively fixed, the tube can be rotationally fixed while the container positively rotates about its own axis. Under either arrangement, the delivery tube in effect passes around the container's axis.

Other modifications include providing separate means for vertical displacement and rotational displacement of the container and filling tube.

We claim:

1. A process for homogeneously and densely packing a vertically oriented, cylindrically elongated collection zone with particulate material comprising

a. inserting a delivery zone into said collection zone adjacent the bottom of said collection zone;

b. feeding particulate material out of the bottom of said delivery zone into said collection zone so as to fill said collection zone;

c. displacing said delivery and collection zones from one another throughout said filling step so that, in effect, said delivery zone passes around the vertical axis of said collection zone, and simultaneously passes toward the top of said collection zone;

d. preventing free-fall flow of particulate material from said delivery zone into said collection zone throughout said filling step by continuously maintaining the bottom of said delivery zone in compression-free contact with the top surface of the continuously-enlarging body of particulate material in said collection zone, so that a continuous mass of particulate material is formed within and between said delivery and collection zones;

e. repeatedly lifting and dropping, with impacting, said collection and delivery zones throughout said filling step; said zones being simultaneously lifted and simultaneously dropped the same height; and

f. damping post-impact vibration and bouncing of said zones throughout said filling step.

2. The process of claim **1** wherein said delivery zone feed particulate material directly toward the axial portion of said collection zone and directly toward the peripheral portion of said collection zone, and wherein larger volumes of particulate material are fed toward said peripheral portion.

3. The process of claim **2** wherein said delivery zone is positively revolved around said vertical axis of said collection zone, and wherein said delivery zone is positively moved upwardly.

4. The process of claim **3** wherein the level of particulate material within said delivery zone is maintained substantially constant throughout said filling step.

5. A device for filling particulate material into a container comprising

a. a vertically disposed, elongated cylindrical container;

b. a vertically disposed filling tube within said container, with an opening at the bottom of said tube;

c. means to displace said tube and container from one another so that, in effect, said tube moves upwardly from the bottom of said container, and rotates about the vertical axis of said container;

d. additional means to repeatedly lift and drop, with impact, said container and filling tube, wherein said container and tube are simultaneously lifted and simultaneously dropped the same height; and

e. means to damp post-impact vibration and bouncing of said container and filling tube.

6. The apparatus of claim **5** wherein said means to displace said tube and container from one another comprises a threaded screw rod parallel to but axially displaced from said filling tube, means connecting said tube to said rod so that said tube revolves around said rod as said rod turns on its axis and so that said tube moves upwardly simultaneously with upward movement of said rod; means to turn said threaded rod through a threaded sleeve; and means to maintain said threaded sleeve at a fixed distance above said container.

7. The apparatus of claim **6** wherein said tube is circular in crosssection throughout most of its length with the exception of its lowest segment; in which its lowest segment is circular in cross-section at the top of its lowest segment, and is generally sector-shaped in cross-section at the bottom of its lowest segment; wherein the cross-sectional area of said lowest segment progressively enlarges from the top of said lowest segment to the bottom of said lowest segment; and wherein, at the bottom of said lowest segment, said sector, at its narrowest dimension, is disposed in the axial section of said container, and wherein said sector, at its widest dimension, is disposed in the peripheral section of said container.

8. The apparatus of claim **7** wherein said lifting and dropping means comprises a vertical push rod below said container; cam means below said push rod to periodically lift said rod so that said rod periodically lifts and drops said container upon a solid stop; and means to rotate said cam means.

9. The apparatus of claim **8** wherein said damping means comprises a horizontal plate fixed to said container throughout said filling operation, said plate provided with bushings to receive fixed vertical guide rods, said guide rods extending through and above said bushings whereby said plate moves up and down said guide rods during said lifting and dropping of said container; springs surrounding each guide rod at the top segment of each rod, said springs fixed adjacent the top of said rods, said springs being in close proximity to said plate so as to essentially prevent vibration and bouncing of said plate.

10. The apparatus of claim **6** wherein said lifting and dropping means comprises a vertical push rod below said container; cam means below said push rod to periodically lift said rod so that said rod periodically lifts and drops said container upon a solid stop; and means to rotate said cam means.

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