

[54] **COMPRESSION TESTING MACHINE**

[75] Inventors: **Russell T. Korolyshun, Derby; P. Mark Rehnborg, Bethany, both of Conn.**

[73] Assignee: **The B. F. Goodrich Company, New York, N.Y.**

[22] Filed: **Oct. 18, 1972**

[21] Appl. No.: **298,567**

[52] U.S. Cl. **73/94**

[51] Int. Cl. **G01n 3/00**

[58] Field of Search **73/94**

[56] **References Cited**

UNITED STATES PATENTS

2,697,347 12/1954 Moore **73/94**

OTHER PUBLICATIONS

S. W. Herwald, Fundamentals of Serromechanisms,

from Product Engineering for June, 1946.

Primary Examiner—Donald O. Woodiel
Assistant Examiner—Anthony V. Ciarlante
Attorney, Agent, or Firm—James R. Lindsay

[57] **ABSTRACT**

A machine for automatically carrying out an indentation load deflection test on cushioning material such as latex foam rubber mattresses and cushions deposits a foot plate on the article being tested, stores an electric signal indicating thickness, utilizes the signal to advance the foot plate until a null point is reached at the predetermined percentage of compression, reads and displays the compressive force, and retracts from the article.

10 Claims, 8 Drawing Figures

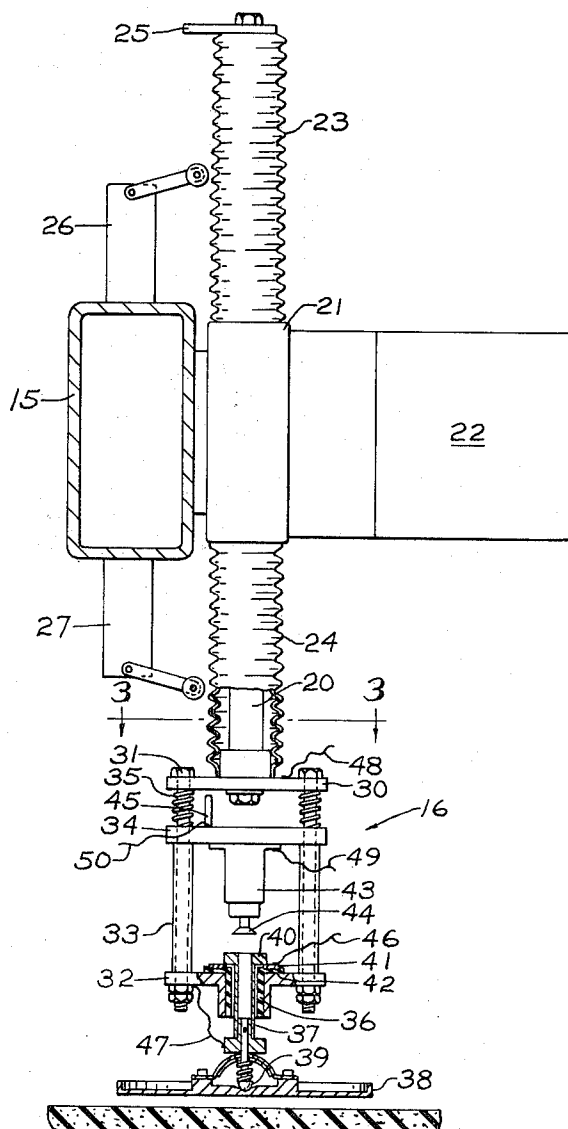


FIG. 1

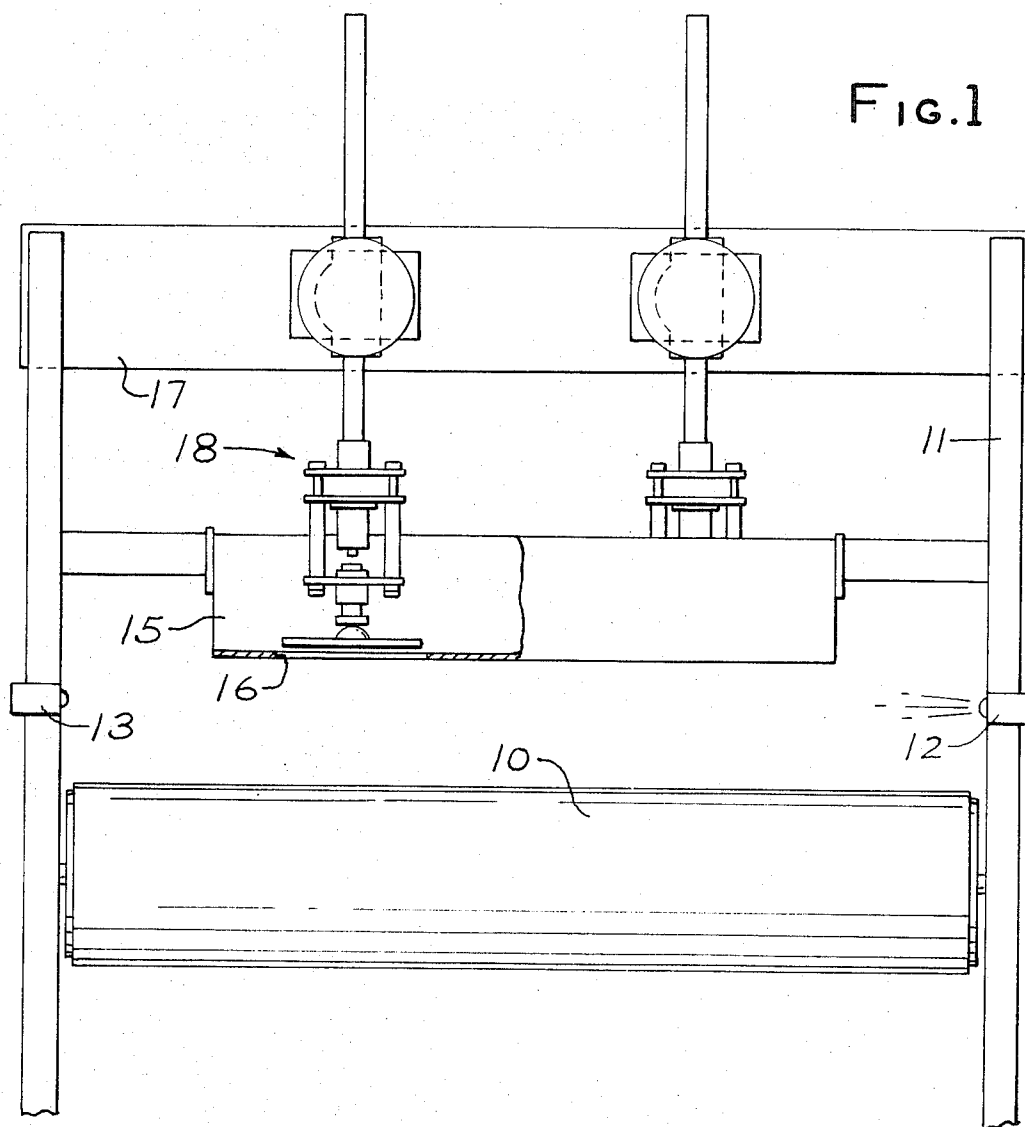


FIG. 2

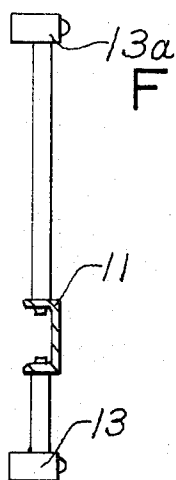
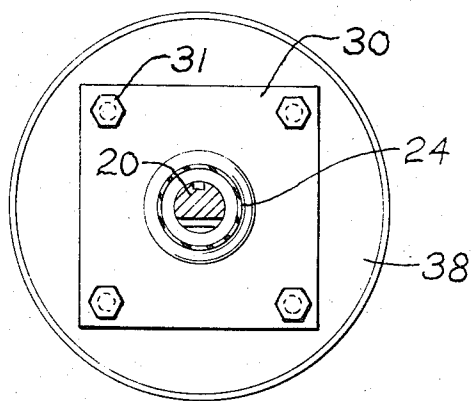


FIG. 3



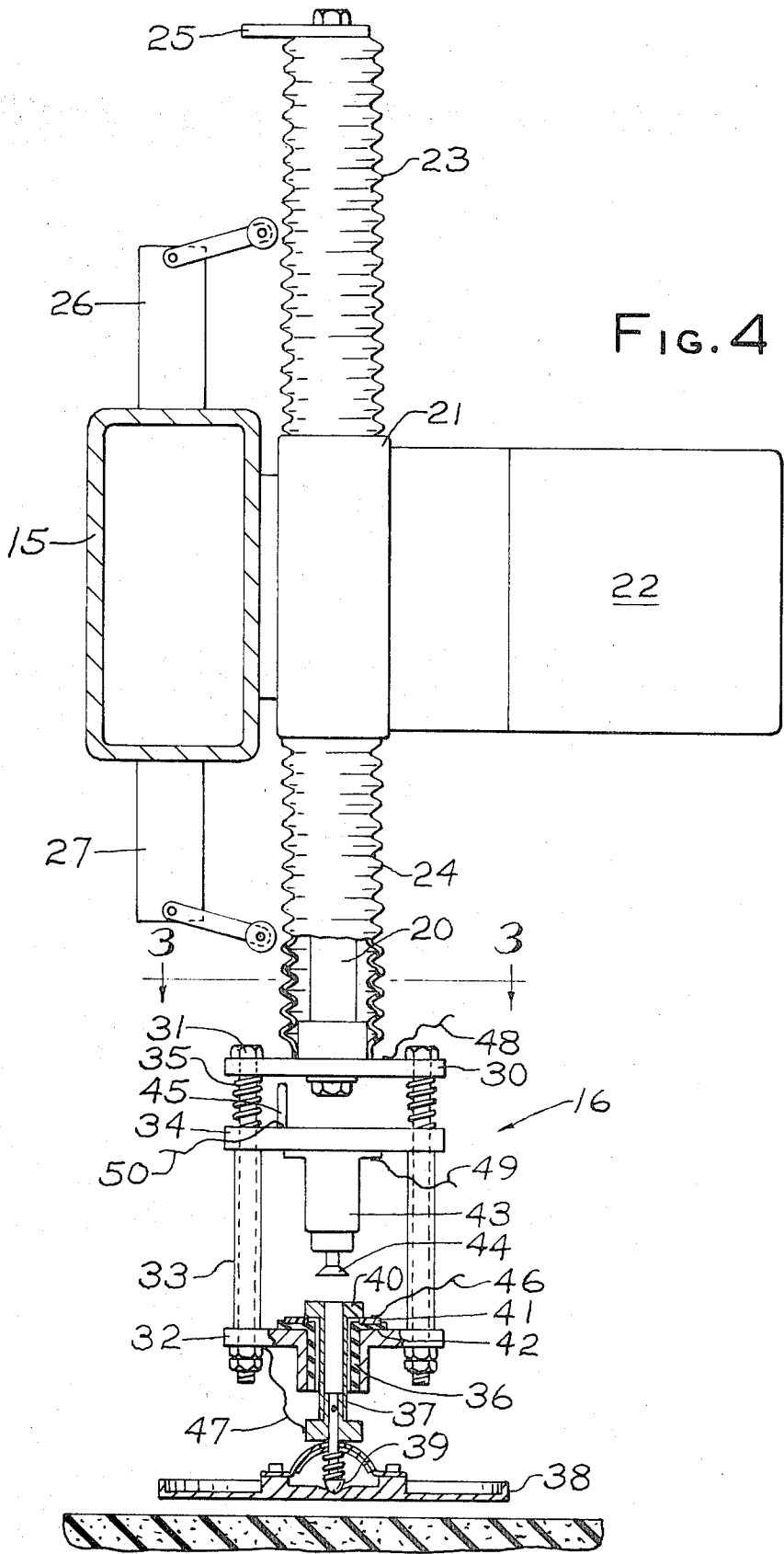


FIG. 5

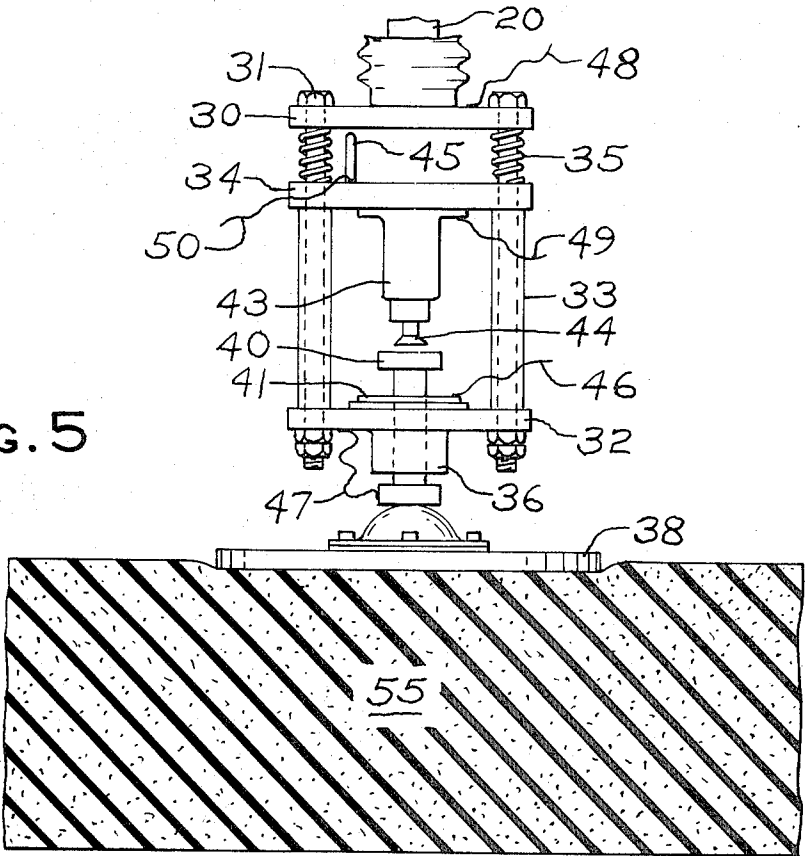


FIG. 6

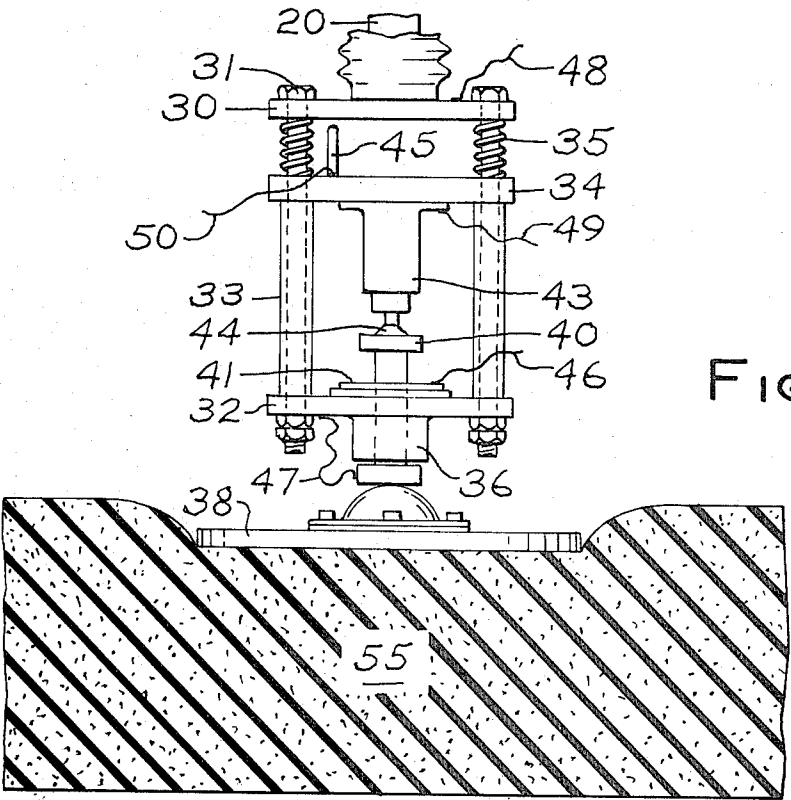
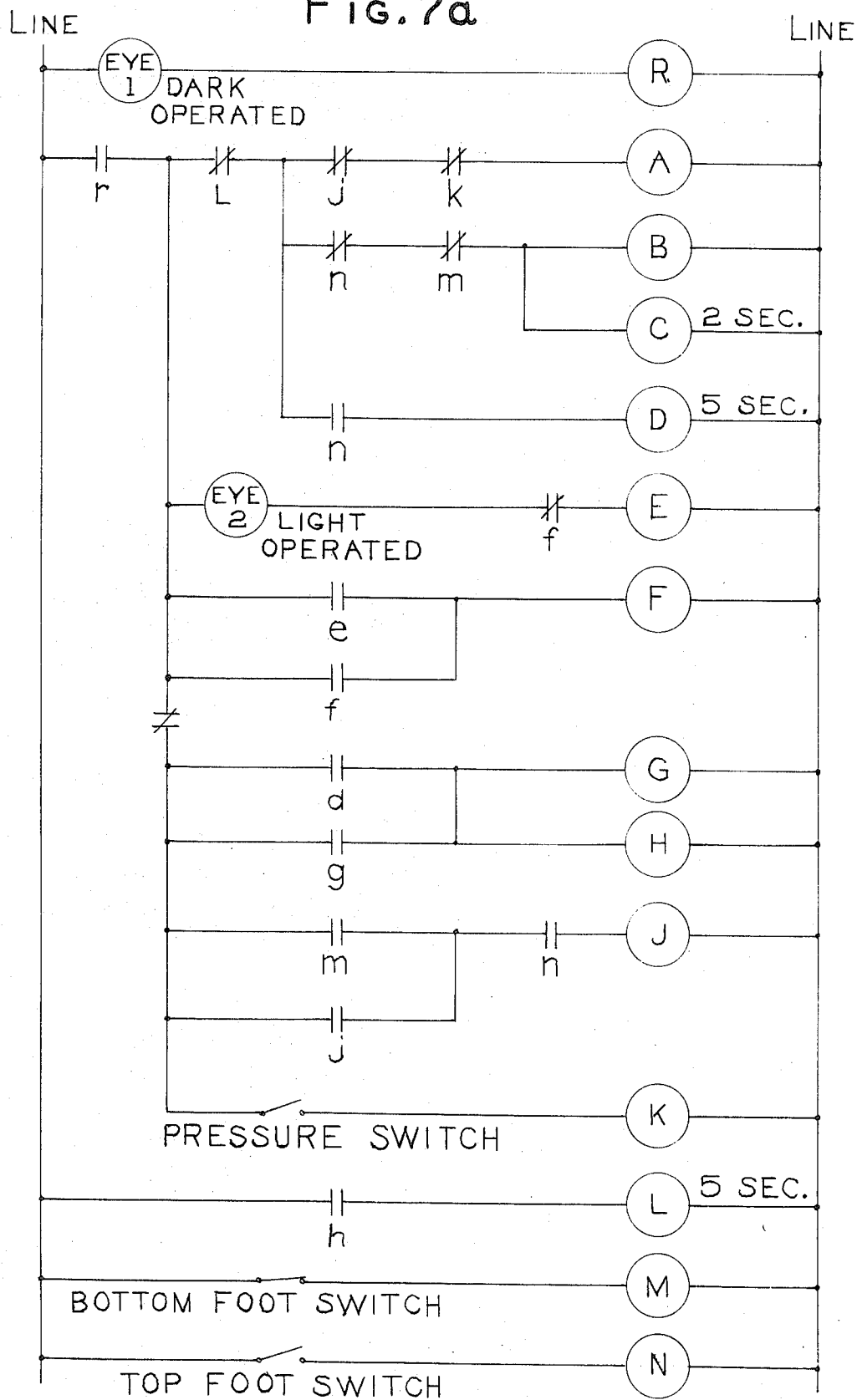


Fig. 7a



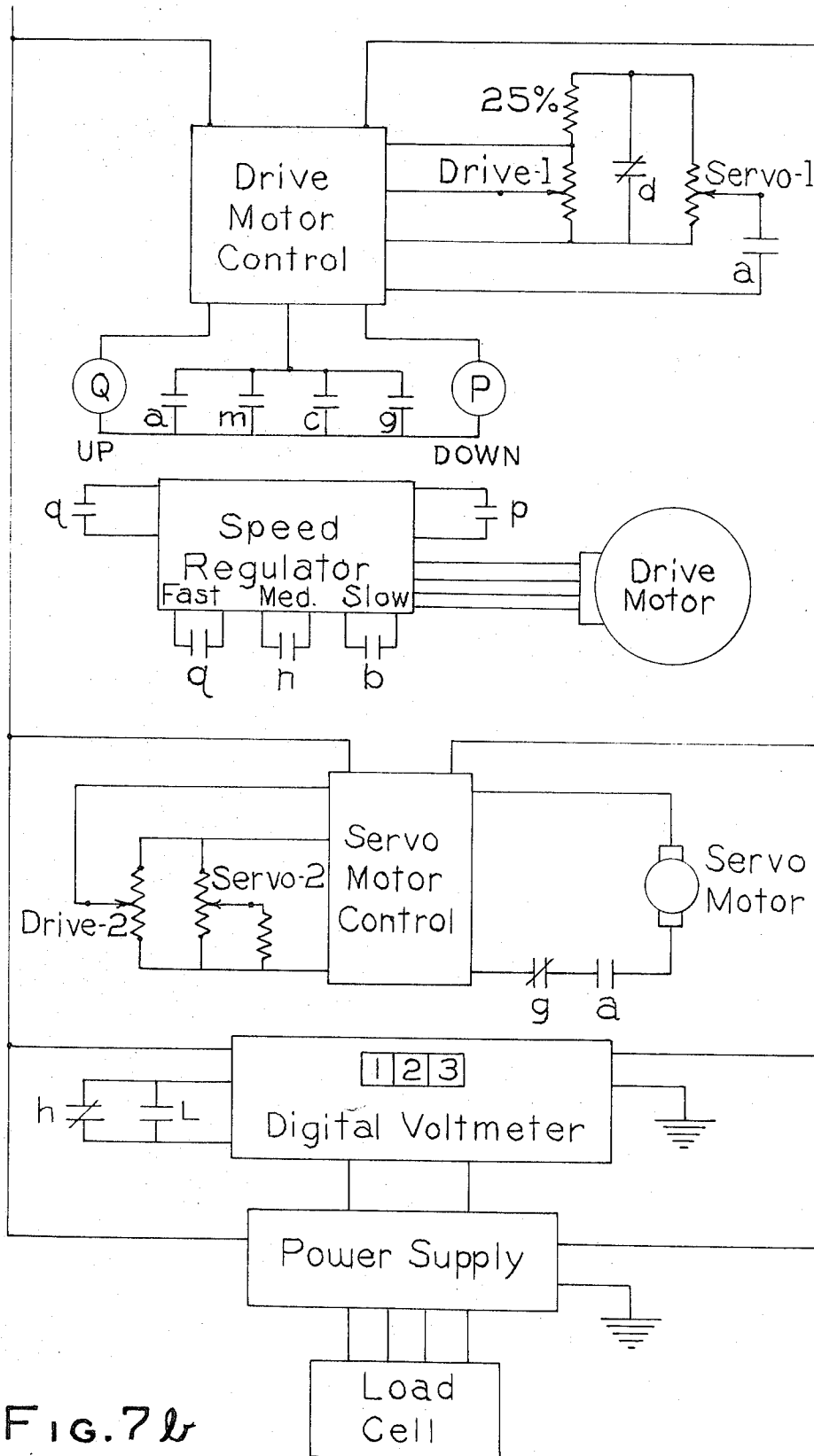


FIG. 7b

COMPRESSION TESTING MACHINE

BACKGROUND

In the manufacture, sale, specification for purchase, and use of cushioning materials such as latex foam rubber or polyurethane foam, it is important that the firmness or load-supporting ability of the material be known, and that this essential property be capable of expression in terms having the same meaning to the manufacturer, middleman, and final user.

The Rubber Manufacturers Association has established a test specification and the American Society for Testing and Materials has adopted an almost identical specification for what is commonly referred to as the Compression Test or Indentation Load Deflection Test. The common features of these tests as applied to latex foam rubber mattresses are:

A flat circular indenter foot with an area of 50 square inches and a weight of 1 pound is placed on the latex foam rubber, and the distance from the foot to the support on which the product rests is determined. The foot is depressed at a rate of 25 inches per minute until it has compressed the product 25 percent of the dimension determined as above. After a rest period of about 5 seconds, the total force on the product (including the 1 pound weight of the foot) is determined, and reported as total force or pounds per square inch which is the total force divided by 50.

For other products, or for products from other materials, different indentations, or different rates, or different rest periods may be prescribed.

The machines used for carrying out this compression test have either been essentially manual instruments requiring the constant attention of an operator, or have been complex mechanisms containing a great many moving parts subject to wear and needing frequent maintenance and adjustment. Moreover, they have not been easily adaptable to changes in test procedures or specifications.

It is accordingly an object of this invention to provide a compression testing machine which will carry out the prescribed test rapidly and automatically, with high precision and reproducibility, with a minimum of attention of any kind.

Another object is to provide a testing machine which is easily adaptable to changes in test conditions or specifications.

SUMMARY OF THE INVENTION

In accordance with this invention a compression test machine for latex foam mattresses or cushions or similar soft, resilient products is provided, having a minimum of moving parts subject to wear, and being completely automatic in operation, functioning so rapidly that it is adapted for 100 percent factory control testing of such products.

This machine deposits the prescribed 1 pound foot plate on the product, senses its distance from the support, presses it at a constant rate until the product is compressed by exactly the prescribed portion of its original thickness, reads the compressive force and displays it, and immediately prepares to make another similar measurement on another like or unlike specimen.

In its preferred form, the machine moves the foot plate by a pinion drive on rack teeth in a vertical sup-

porting rod, using a reversible three speed electric motor. Potentiometers are driven by the motor, and are electrically connected to other potentiometers driven by a servo motor. Suitable circuitry causes the two motors to balance circuits with a first null point indicating thickness of the product being tested, and a second null point indicating exactly three-fourths of that thickness (that is, the 25 percent compression prescribed for the test) or with minor changes any other desired portion of that thickness.

The compressive force is determined by a load cell, and may be displayed visually, or recorded graphically or on magnetic tape, or be used automatically for further handling, as by sorting the output into categories of different degrees of firmness.

THE DRAWINGS

In the accompanying drawings,

FIG. 1 is a view along a belt conveyor, showing a pair of testing machines mounted on a bridge structure over the conveyor.

FIG. 2 is a vertical downward view of the electric eyes on the frame.

FIG. 3 is a vertical downward view on a larger scale of the work-engaging portion of one testing machine as seen from a section along line 3,3 of FIG. 4.

FIG. 4 is a side view of one machine.

FIGS. 5 and 6 show successive stages in the operation of the machine.

FIGS. 7a and 7b are simplified wiring diagrams showing the manner in which the principal components are electrically interconnected.

DETAILED DESCRIPTION

As indicated above, the invention may be used in 100 percent inspection of products, and is illustrated by an arrangement of compression measuring machines in a conveyor line handling the output of a latex foam rubber mattress factory.

Referring to FIG. 1, a belt conveyor 10 is drawn over a solid apron supported in part by a frame 11, so that the surface of the belt provides a fixed reference plane for the required thickness measurement.

An "electric eye," consisting of a miniature projector 12 and light sensitive cell 13 in the path of the light beam, is mounted on frame 11. This is on the far side of the measuring devices, as the articles are carried on the conveyor 10, so that the interruption of the light beam can indirectly stop the conveyor to leave an article under the measuring devices.

On the frame 11 is a guard 15 of stiff sheet metal with openings 16 slightly larger than the prescribed 50 square inch foot plate. The guard 15 is spaced from the conveyor by a distance somewhat greater than the maximum thickness of product to be measured, and is curved so as to tend to guide accidentally misplaced articles into position under the measuring devices.

A cross beam 17 supports the measuring devices 18, of which two are shown, for simultaneous measurement in two locations on a mattress, or simultaneous measurement of two small cushions. One, two, or more may be used as preferred. For articles as large as a mattress, it may be desirable to make arrangements in three or more locations to determine not only firmness but also uniformity from one end to the other.

Each compression measuring device 18, as shown in detail in FIG. 4, includes a vertical supporting rod 20,

sliding in a guideway in a gear housing 21, to which is attached a reversible three speed electric drive motor 22. The motor is coupled to rod 20 by conventional reduction gears terminating in a pinion meshing with rack teeth cut in rod 20. The two ends of rod 20 are sealed against dust and moisture by rubber bellows 23, 24.

Also coupled to the drive motor, and enclosed within its sealed housing, are a pair of identical potentiometers, illustrated diagrammatically in FIG. 7b as Drive-1 and Drive-2. The moving contacts of these potentiometers accordingly move in exact synchronism with the up and down motion of rod 20.

A projecting finger 25 on the top of rod 20 controls the extent of downward motion by engaging a down limit switch 26. An up limit switch 27 similarly controls the extent of upward motion, and also connects the drive motor operating the belt conveyor 10.

Fixed to the bottom of rod 20 is a square plate 30. Bolts 31 pass downward through holes in its corners and have their lower ends solidly fastened by nuts to a lower square plate 32. Spacer tubes 33 on the bolts support an intermediate insulating plate 34 made of a hard plastic. On bolts 31 between the upper plate 30 and the plastic plate 34 are springs 35 compressed to exert a collective force somewhat greater than the normal compression resistance of the articles tested. For cored mattress slabs, springs have an aggregate compressive force of 80 or 100 pounds give adequate protection against damage resulting from accidental contact with an unyielding surface.

The lower plate 32 contains a central cylindrical sleeve 36 in which slides the stem 37 of the foot plate 38. The foot plate 38 is the prescribed disc of 50 square inch area, pivoting loosely on the pointed end 39 of stem 37, with a spring-supported pair of spherical segments to exclude dirt and keep the foot plate 38 in constant contact with the pointed end 39. The stem 37 has an enlarged head 40 resting on a metal ring 41 serving as an electrical contact and therefore supported by an insulating ring 42. The foot plate 38, stem 37 and associated parts are adjusted to the prescribed weight of one pound.

On the bottom of the insulating plate 34 is mounted a load cell 43, the electrical properties of which vary in accordance with the sustained load. Projecting from the bottom of the load cell is a metal contact 44.

Lowering of the rod 20 with its associated group of upper plate 30, lower plate 32 and insulating plate 34, together with loosely supported foot plate 38, will have the consequence that when the foot plate is resting on a supporting surface, such as mattress 55, as shown in FIG. 5, the head 40 of its stem will be lifted from its contact ring 41, functioning as the opening of an electric switch, which is designated "bottom foot switch" in the wiring diagram FIG. 7a. Further lowering of the rod 40, as shown in FIG. 6, will cause head 40 to touch the contact 44 on the load cell, functioning as the closing of an electric switch, which is designated "top foot switch" in FIG. 7a.

As a safety device, in conjunction with springs 35, a metal finger 45 is mounted on insulating plate 34, with its tip spaced by a small distance from upper plate 30. When the compressive force on the foot plate 38 exceeds the aggregate compression of springs 35, the finger 45 will touch plate 30, and since the finger 45 is on an insulating support this will function as the closing of an electric switch to actuate a withdrawal of the entire

measuring foot as will be described below. This is designated as "pressure switch" in FIG. 7a.

Each of the electric switches mentioned above is provided with suitable electric connections. Thus the bottom foot switch has a wire 46 attached to contact ring 41. The other contact element is the head 40 of foot stem 37 which is grounded by a flexible wire 47, from which the connection is made through bolts 31 to another wire 48. The top foot switch similarly is provided with a wire 49 attached to the body of the load cell, with the switch circuit again established through the head 40 of foot stem 37, flexible wire 47, bolts 31, and wire 48. The pressure switch is connected through a wire 50 attached to safety finger 45, and the ground wire 48.

Suitable wiring connections, not shown, are provided for the drive motor 22, the potentiometers coupled to it, the limit switches 26 and 27, and the load cell 43, to connect them to the actuating devices, readout equipment, and control circuits.

In the schematic wiring diagram of FIG. 7a and 7b, in addition to the three switches already mentioned, the motor 22 is designated "drive motor" and the potentiometers coupled to it are designated "Drive-1" and "Drive-2." The several relay coils are identified by capital letters and their contacts by lower case letters. A servo motor is coupled to a pair of identical potentiometers designated as "Servo-1" and "Servo-2." Each motor is provided with a control unit and the drive motor in addition has a speed control unit permitting it to be operated downward at three speeds.

The load cell is connected through a suitable power unit to a digital voltmeter calibrated to display compressive force in pounds.

A relay R actuated by the light receiver 13 of the "electric eye" designated as "Eye 1" in FIG. 7a starts and stops the operation of the machine through a compression measuring cycle.

Drive-1 and Servo-1 potentiometers are connected so that out-of-balance conditions will cause the drive motor control to drive the motor in a direction to move the foot plate 38 downward until the circuit is balanced. Drive-2 and Servo-2 potentiometers are connected so that out-of-balance conditions will cause the servo motor to track the drive motor.

The relays are connected as follows. Relay R actuates relay A to start the cycle. Relay A connects Servo-1 potentiometer to the drive motor control for initiating downward motion of the rod 20, and connects the servo motor to its control, and also opens one of four shunts in the motor actuating circuits of the drive motor control. Relay B closes the slow speed circuit of the drive motor speed regulator, and actuates time delay relay C. Relay C closes one of the four shunts in the motor actuating circuits of the drive motor control to restart the motor in slow speed. Time delay relay D actuates relays G and H, and opens the short circuit of Servo-1 potentiometer. Relay G latches itself and relay H to the power supply, disconnects the servo motor, and closes one of the four shunts in the motor actuating circuits of the drive motor control to restart the motor in medium speed. Time delay relay H actuates time delay relay L and opens a ground circuit to cause display of the compressive force on the digital voltmeter. Relay J operates only if top foot switch fails to function 7 seconds after bottom foot switch, and then disconnects relay A to interrupt and terminate the operating

cycle. Relay K operates only if the pressure switch is closed, and then disconnects relay A to interrupt and terminate the operating cycle. Time delay relay L operates at the normal end of the operating cycle to disconnect relays A, B, C, and D, and to close a ground circuit in the digital voltmeter to freeze the readout of the last digits displayed. Relay M actuates relays B and J and opens one of the four shunts in the motor actuating circuits of the drive motor control to stop the motor. Relay N actuates relay D and disconnects relays B and J, and closes the medium speed circuit of the drive motor in the downward direction. Relay Q starts the drive motor in the upward direction and in addition closes the fast speed circuit of the drive motor speed regulator. The speed regulator is so wired that fast speed stays connected until either slow or medium is connected.

The electric eye is connected to the usual switching device which senses a change in resistivity without significant flow of electric current and operates a self contained relay designated as R. Relays K, M, and N are preferably the same kind of switch, functioning without flow of sufficient current to cause any arcing or oxidation of the electric contact surfaces. For the sake of simplicity, the special wiring connections for this type of switch are not shown, and they are indicated as though they were simple relays, as they might be. Relays K and N are connected to normally open contacts and operate when the contacts are closed. Relay M is connected to normally closed contacts and operates when the contacts are opened.

OPERATION OF THE MACHINE

A cushioning article such as mattress 55 advancing on conveyor belt 10 under the measuring device or devices 18 interrupts the light beam of the electric eye, Eye 1, and actuates its relay R. This actuates relay A which connects the servo motor and starts the drive motor in the downward direction at fast speed. The top limit switch opens, which stops conveyor 10 with the mattress 55 under the measuring devices 18.

Near the end of a previous cycle, the servo motor was disconnected in a position corresponding to a partly down position of the foot plate 38. When the servo motor is reconnected at the beginning of a new cycle, as just stated, the potentiometers which control the servo motor, namely, Drive-2 and Servo-2, are in non-corresponding positions so that the control circuit is unbalanced. The servo motor operates in the direction corresponding to upward motion of the drive motor until the two motors pass one another (that is, until these two potentiometers pass a null point and the polarity of the servo motor drive circuit is reversed) after which the servo motor reverses direction and tracks the drive motor in its downward operation.

When the downward motion of the drive motor reaches the point at which foot plate 38 rests on a mattress 55, the continued downward motion of rod 20 separates contact ring 41 from the head 40 of stem 37 of foot plate 38, as shown in FIG. 4. That is, the bottom foot switch opens, operating relay M which immediately stops the drive motor. Relay M also actuates relay B which changes the motor to slow speed, and actuates time delay relay C. The foot plate 38 settles into position on the mattress 55 during the delay.

After 2 seconds, relay C restarts the motor in the downward direction, at its slowest speed, and the servo

motor tracks the drive motor closely during this motion. After a slight downward motion of rod 20 and the associated parts including load cell 43 with respect to stationary head 40 of stem 37 of foot plate 38, the contact 44 on the load cell 43 will touch head 40. That is, the top foot switch closes, operating relay N which disconnects relays B and C, immediately stopping the drive motor. Relay N also changes the drive motor to medium speed, and actuates time delay relay D.

After 5 seconds, relay D opens the short circuit of potentiometer Servo-1 to permit the drive motor control to go for null. Relay D also actuates relay G and time delay relay H. Relay G, through one set of contacts, latches itself to the power supply, and through another set of contacts disconnects the servo motor, thereby leaving Servo-1 potentiometer in a position corresponding to the thickness of mattress 55 between foot plate 38 and the surface of conveyor belt 10, that is, with a stored signal indicating mattress thickness. Relay G also restarts the drive motor for downward motion at medium speed, which is the 25 inches per minute speed of compression prescribed in the test specification.

After 1 second, relay H opens the ground circuit of the digital voltmeter, permitting it to display the total force on load cell 43 plus the one pound weight of foot plate 38. Relay H also actuates time delay relay L.

The drive motor control at this part of the operating cycle includes a control circuit involving potentiometers Drive-1 and Servo-1 and resistor accurately adjusted to 25 percent of the total of its own resistance and that of Servo-1. This circuit will balance when Drive-1 potentiometer arm is in a position corresponding to the position which Servo-1 potentiometer arm would have if moved 25 percent of the way toward one terminal. Accordingly, if the terminal position of the potentiometer arm corresponds to zero thickness, the circuit directs the drive motor to operate until the mattress is compressed 25 percent of its original thickness, and then stops the motor. This takes only 2 or 3 seconds.

After 5 seconds, relay L operates. Since its actuation is after a 1 second time delay of relay H, following the beginning of compression, several seconds of rest will follow stopping of the drive motor before operation of the contacts of relay L. This rest period permits escape of air from the compressed spaces in the mattress or other cushion being tested, so that the compressive force is that of the solid resilient material only. During this brief period of adjustment, the readout of compressive force on the digital voltmeter changes, first rapidly and then slowly to a steady figure.

The operation of relay L opens the lines to relays A, B, C, and D. Opening of relay A eliminates the down command to the drive motor control, causing the drive motor to operate in the upward direction. When the top limit switch is reached, the limit switch opens the up circuit and starts the conveyor belt to carry away the mattress. The mattress can then be marked to indicate its firmness, or can be directed to packaging or finishing or storage locations as may be appropriate. When the mattress leaves the location of the electric eye 13, the relay R opens, disconnecting relays G, H, J, and K, and through H, relay L, ending the machine cycle.

The machine contains a number of special safety features. In the first place, it will not operate unless there is an article in the proper location to interrupt the light beam of the electric eye to actuate the relay R.

If the machine encounters an object and the bottom foot switch fails to function, the pressure switch would soon be closed, actuating relay K and disconnecting relay A to cause the drive motor to lift the measuring device. The pressure switch functions in the same way if an incompressible object or no object other than the conveyor belt is present.

If the top foot switch fails to function, time delay relay J, after 7 seconds from the opening of the bottom foot switch, disconnects relay A to cause the drive motor to lift the measuring device.

The compression measuring machine described above has been found to be almost trouble free and to permit rapid and accurate indication of the resistance to compression, or firmness, of mattresses or cushions of widely varying thickness, length, and breadth.

On articles as large as mattresses, it is preferred to have three measuring devices in a row, to measure resistance to compression at each end and the middle, simultaneously. In this instance the safety switches are interconnected so that operation of any one of them will cause all the measuring devices to be lifted out of harms way.

The foregoing description refers to operation with relatively narrow mattresses or cushions, which stop in a position approximately centered under the measuring devices if electric eye 13 is about a foot past the center of the measuring devices.

The larger the size, the greater the chance of non-uniform distribution of material and therefore of substantial variation in firmness over the area of the article. Accordingly, the machine can be made to test first one edge of the article and then the other edge.

This is accomplished by use of two electric eyes as shown in FIG. 2. The light detector 13 of one of them is about a foot past the location of the measuring devices, as already explained, and functions to start operation, which results in stopping the conveyor. It is the one designated in FIG. 7a as "Eye 1."

The second electric eye has its light detector 13a on the advance side of the machine, about 4 feet from the other, and is designated in FIG. 7a as "Eye 2."

If an ordinary size mattress interrupts Eye-1 and starts the machine, the mattress will have passed Eye-2 when the conveyor belt 10 stops. Relay E, actuated by Eye-2, will actuate Relay F, which will latch on to the power line and disconnect Relay E during the remainder of the cycle so that it will have no effect.

If an extra wide mattress, such as a "King" size mattress, is on the conveyor, both light beams will be interrupted when the mattress is halted under the measuring devices by stoppage of the conveyor belt. Eye-2, which is light-operated, will be inactive until the measurement is completed, the measuring devices are raised, and the top limit switch starts the conveyor belt again. Then when the mattress is carried to the point where the light beam operates Eye-2, it in turn will actuate relay E, which will temporarily interrupt the power to relays G, H, J, and K. Relay H will then release relay L which will result in closing the circuit again to relay A to start another cycle of operations.

In the new cycle, the downward motion, releasing the top limit switch, will again stop the conveyor belt 10 during the measuring operation. At the conclusion of the measuring operation, Eye-2 can have no effect since it is disconnected from its relay E, and the conveyor belt 10 will carry the mattress away.

The degree or percentage of indentation at which the compression measurement is taken can be set at any desired value by an appropriate choice of the resistance interposed between the appropriate terminal of Servo-1 potentiometer and the connection of the Drive Motor Control circuits. If a choice is desired, two resistors in series can be provided, with a switch to short circuit one when it is not needed.

If two readings are desired on a single specimen at different degrees of indentation, two resistors in series can be provided, one being initially short circuited, with additional relays to restart the downward motion after opening the short circuit.

The compression measuring machine has been described above with reference to particular kinds of electric instruments for sensing thickness, for computing the amount of compression, for commanding a motor to compress by the computed amount, for measuring compressive force, and particular kinds of interconnections of these instruments, and it is not intended that the invention be considered to be limited to the particular embodiment shown and described.

I claim:

1. A compression testing machine for testing cushioning material comprising:

a foot plate with support means and driving means for mechanically placing the foot plate in an unloaded position where the weight of the foot plate is detached from the machine and is completely supported by the material,

means for sensing the thickness of the material from the surface on which it rests to the bottom of the unloaded foot plate,

means for transmitting a signal to modify an electric property indicating the thickness,

means for utilizing the electric property to compel the foot plate to compress the material by a predetermined proportion of the sensed thickness, and

means for indicating the compressive force of the material against the foot plate.

2. A machine as in claim 1, in which the foot plate is moved by a reversible electric drive motor and the means for sensing the thickness is a potentiometer coupled to the motor.

3. A machine as in claim 2, in which the electric property indicative of thickness is the resistance of one branch of a second potentiometer induced to track the potentiometer coupled to the foot plate drive motor.

4. A machine as in claim 3, in which the extent of movement of the foot plate to compress the material is determined by a fixed resistance added to that of the second potentiometer.

5. A machine as in claim 1, including means for automatically halting a conveyor carrying material to be tested with the material under the foot plate and means for automatically lifting the foot plate and restarting the conveyor after the compressive force is indicated.

6. A machine as in claim 5, including means for automatically halting said conveyor a second time for determination of compressive force in a second location.

7. A machine as in claim 1, in which the foot plate is loosely supported and capable of being lifted a small distance from its support when placed in contact with the material, and in which an electric switch is located for transmission of an electric signal to indicate thick-

9

10

ness of the material on completion of the small distance of lift of the foot plate from its support.

8. A machine as in claim 7, in which the means for placing the foot plate in contact with the material is connected for lowering the foot plate support at a fast speed until the foot plate is lifted from its support, and is connected to drive at a much slower speed thereafter until completion of lift of the foot plate from its support.

9. A machine as in claim 8, in which the means for placing the foot plate in contact with the material is connected to drive at an intermediate speed during compression of the material by the foot plate.

10. A machine as in claim 4, in which the foot plate is loosely supported and capable of being lifted a small distance from its support when placed in contact with

the material, an electric switch is located for transmission of an electric signal terminating adjustment of the second potentiometer on completion of the small distance of lift of the foot plate from its support, the foot plate drive is connected for lowering the foot plate at a fast speed until the foot plate is lifted from its support, at a much slower speed thereafter until completion of lift of the foot plate from its support, and at an intermediate speed during compression of the material by the foot plate, and the machine includes means for automatically halting a conveyor when material carried by the conveyor is under the foot plate and means for automatically raising the foot plate and restarting the conveyor after the compressive force is indicated.

* * * * *

20

25

30

35

40

45

50

55

60

65