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(71) Applicant *(for all designated States except US)*: **MEADWESTVACO PACKAGING SYSTEMS LLC** [US/US]; One High Ridge Park, Stamford, 7 06905 (US).

(72) Inventor; and
(75) Inventor/Applicant *(for US only)*: **BATES, Aaron** [US/US]; 4537 Planters Hill Drive, Powder Springs, GA 30127 (US).

(74) Agent: **SUZUKI, Tsugihiko**; MeadWestvaco Corporation, 4850d North Church Lane, Smyrna, Georgia 30080 (US).

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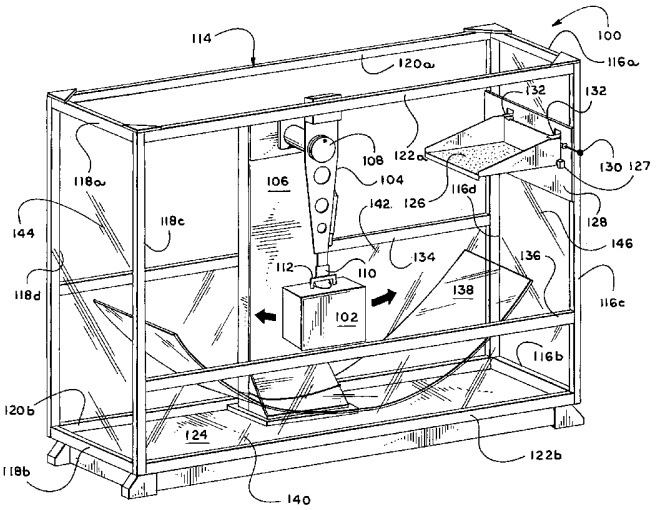
(54) **Title:** APPARATUS AND METHODS FOR TESTING CONTAINERS



(57) **Abstract:** An apparatus automatically tests the effect of pendular motion on the integrity of a carton (102) or other container having a handle (112), by grasping the handle (112) with grasping means (110) connected to a pendulum arm (104), which swings the carton (102) along an arcuate path (600) according to a predefined test protocol. A first test protocol simulates removal of the carton (102) from an elevated shelf (126). A second test protocol simulates the oscillating motion of a human carrying a carton (102) by its handle (112). A third test protocol simulates a human swinging the carton (102) upward to a prescribed elevation. The grasping means (110) may be connected to the pendulum arm (104) by articulation means (204) that allows articulation of the grasping means (110) , thereby approximating the action of a human arm, wrist, and hand. The pendulum arm (104) may be caused to pivot or oscillate by the force of gravity and alternatively, by a mechanical or electromechanical drive system (500).

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APPARATUS AND METHODS FOR TESTING CONTAINERS

TECHNICAL FIELD

This invention relates generally to testing cartons or other containers, and more particularly, to systems and methods for testing a container using periodic and/or non-linear motion.

BACKGROUND OF THE INVENTION

Containers, such as cartons for encasing and dispensing articles, are useful for enabling a user to consolidate, transport, store, and access multiple articles. To facilitate ease of use, a typical container includes a handle or other attached or integral component that enables the articles within to be carried by a user as an article group. Clearly, the carton and the handle must be sufficiently strong to enclose and support the suspended weight of the articles when the container is being moved or carried. Therefore, it is advisable to test new container designs prior to placing the containers in commerce.

Prior art approaches to container testing have focused on the ability of the container to withstand linear forces by simulating a relatively sudden "dead lift" from a resting state or a drop from a certain height, where the dead lift or drop is performed by a machine. However, such tests fail to assess the ability of a container to withstand the more realistic forces imposed by a human user, including removal of a loaded container from a shelf, carriage of the container while the user walks, and placement of the loaded container on a shelf.

There is a need, therefore, for systems and methods for testing the integrity of a container and its handle that simulate more realistic non-linear forces that occur in the course of handling the container by a human user.

SUMMARY OF THE INVENTION

The various embodiments of the present invention overcome the shortcomings of the prior art by providing systems and methods for testing the structural integrity of a container by exposing the container and means for carrying the container to non-linear forces, which simulate or approximate the forces applied by a human user.

Generally, each of the various embodiments of the novel container testing apparatus performs one or more novel methods for testing the performance of a container. The apparatus and methods of the invention generate and apply forces to the container to simulate the forces applied to the container when used by a human user, in particular, by simulating the forces applied to the container as the container is raised, lowered, carried, and/or swung by the user. The apparatus is useful for testing various types of containers that are designed to be carried by one or more human hands, including cartons, cases, bags, purses, sacks, suitcases, packages, and the like. For the purposes of illustration and not of limitation, a container will be described herein as a carton for enclosing and carrying multiply-packaged products such as cans, bottles, or singly-packaged and protectively-covered goods.

More specifically, the apparatus for testing the integrity of a carton includes an approximation of a human arm for lifting, supporting, and carrying the carton. Additionally, the arm includes an approximation of a human hand for grasping the carton. The apparatus causes the carton to follow a range of motion that at least approximates an arcuate or at least partially circular path as defined by the pendulum-like swing of the arm. In certain embodiments of the invention, the container testing apparatus includes a frame comprising a rectangular periphery having four sides and a base. The vertical edges of the four sides are preferably connected one to the next at perpendicular corners. Each of the sides is preferably framed, and the area within the outline created by the frame may be at least partially open.

According to one aspect of the invention, the arm is connected in the manner of a pendulum such that it is pivotably connected at one end to an upright support or other suitable support means, such as a panel, crossbeam, or post that is preferably connected or integral to the frame. The pivotable connection comprises a pivot point about which the arm swings. In certain embodiments, the arm swings along a two-dimensional longitudinally oriented plane having a horizontal axis that is substantially parallel to the base, as well as a vertical axis that is perpendicular to the base. At the distal end of the arm, the simulated hand or other grasping means is connected for engaging or otherwise detachably connecting the arm with the carton, preferably by grasping a handle or other carrying means that is attached or integral to the carton. Once a carton is engaged by the hand, the apparatus serves as a means for testing the integrity of the carton or the carton handle by causing or allowing the carton to move along an arcuate or at least partially circular path along the two dimensional plane. The apparatus can cause the carton to move by applying force via a mechanical or electromechanical means for driving the movement of the arm about the pivot point, such as servo motor, crank, or a weight or spring driven escapement. The apparatus can also allow the force of gravity and the kinetic energy associated with the mass of a carton having been displaced from a position of equilibrium to move the carton along an arcuate path.

According to one aspect of the invention, the apparatus includes an arm that is pivotally attached to and supported by the frame.

According to another aspect of the invention, the arm includes a means for grasping a handle or other carrying means that is integral to or attached to the carton.

According to another aspect of the invention, the grasping means functions as a simulated hand that is connected to the arm by a means for articulation that simulates the action of a human wrist by allowing the grasping means to articulate,

or move with respect to the arm about a movable connection with the arm. The articulation means includes or is associated with a pivot point, a means for self-centering or rectifying the position of the grasping means, and a means for dampening the articulation.

The apparatus of the invention preferably tests carton integrity by performing automated and preferably programmable test protocols that include the various methods of the present invention. According to one aspect of the various methods of the invention, a carton at rest is engaged by the arm, which swings the carton along a two dimensional plane until the carton fails the integrity test, or until swinging ceases by operation of gravity or by assertion of a contravening force. The carton moves or is moved from a resting state at one point on the two dimensional plane to at least one transition point on the two dimensional plane. At each transition point, the carton either fails the integrity test or completely decelerates or otherwise reaches a velocity of zero. In other words, the carton is swung from a resting state at one point to a failure point at which the carton fails the integrity test, or to a transition point at which gravity or a braking force applied by the apparatus causes the carton to completely decelerate at least momentarily. The carton may continue to move to any number of transition points, with its direction preferably reversing between each transition point.

A first embodiment of a method of the invention comprises a shelf drop test, which is intended to simulate removal by a human of a carton from a raised platform such as a shelf, and the ensuing arcuate path along which the carton would travel from the shelf to one side of the human's body. This method is performed by placing the carton on the shelf, which is mounted on an end wall of a container testing apparatus, causing the hand to grasp the carton, and then removing the support provided by the shelf such that the carton swings downward from the level of the shelf, driven by gravitational forces associated at least in part with the weight of the carton and the height of the shelf.

A second embodiment of a method for testing a carton comprises a shelf lift test, which simulates the forces caused by an upswing, such as placement by a human of the carton on a shelf. Accordingly, the carton is engaged by the arm, which is preferably at equilibrium at a first point wherein a hypothetical line connecting the first point to the pivot point is parallel to the vertical axis of the two dimensional plane. A drive system is engaged to cause the arm to rotate to a second point at the height of a hypothetical shelf by causing the arm to pivot from the equilibrium point to the shelf height point.

A third embodiment of a method for testing a carton comprises a swing arm test, which simulates the forces caused by oscillation of the carton, such as when a human user carries a carton with one hand while the user walks and swings the carton back and forth, the carton oscillating about the user's shoulder.

As another aspect of the invention, a human-machine interface permits an operator to specify test parameters such as velocity, acceleration, deceleration, position, number of cycles to be performed, container mass, force, and duration.

The foregoing has broadly outlined some of the aspects and features of the present invention, which should be construed to be merely illustrative of various potential applications of the invention. Other beneficial results can be obtained by applying the disclosed information in a different manner or by modifying the disclosed embodiments. Accordingly, other aspects and a more comprehensive understanding of the invention may be obtained by referring to the detailed description of the exemplary embodiments taken in conjunction with the accompanying drawings, in addition to the scope of the invention defined by the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of an exemplary carton testing apparatus, according to certain embodiments of the present invention.

FIG. 2 is an elevation of an arm of an exemplary carton testing apparatus.

FIG. 3 is an enlarged view of a self-centering means according to certain embodiments of the present invention.

FIG. 4 is a cross-sectional view of a portion of the arm of **FIG. 2**.

FIG. 5 is a cross-sectional view of an exemplary means for controlling an exemplary arm.

FIG. 6 shows the relative positions of a carton and the components of the carton testing apparatus during performance of an exemplary method for testing the container.

FIG. 7 shows the relative positions of a carton and the components of the carton testing apparatus during performance of another exemplary method for testing the container.

FIG. 8 shows the relative positions of a carton and the components of the carton testing apparatus during performance of yet another exemplary method for testing the container.

FIG. 9 is a block diagram showing certain elements of an exemplary human-machine interface according to the present invention.

DETAILED DESCRIPTION

As required, detailed embodiments of the present invention are disclosed herein. It will be understood that the disclosed embodiments are merely examples to illustrate aspects of the invention that may be embodied in various and alternative forms. The figures are not necessarily to scale, and some features may be exaggerated or minimized to show details of particular components. In other instances, well-known materials or methods have not been described in detail to avoid obscuring the present invention. Therefore, specific structural and functional details disclosed herein are not to be interpreted as limiting, but as a basis for the claims and for teaching one skilled in the art to variously employ the present invention.

Referring now to the drawings in which like numerals indicate like elements throughout the several views, the drawings illustrate certain of the various aspects of an exemplary embodiment of a container testing apparatus according to the teachings of the present invention. In the embodiments described herein, the container of the present invention is a carton for enclosing, carrying, and dispensing articles such as beverage cans or bottles. Generally described, the carton is formed from a foldable sheet material such as paperboard, corrugated board, plastic, laminates, any combination thereof, or the like.

FIG. 1 is a perspective view of an exemplary carton testing apparatus **100** that is illustrative of certain of the various aspects of the present invention. The carton testing apparatus **100** is preferably constructed to safely and effectively test a container such as beverage carton **102** in a test environment that is easily monitored either visually or electronically by one or more operators or monitoring devices. According to the testing methods described in more detail below with respect to **FIGs. 6** through **8**, the carton **102** is detachably connected to a pendulum arm **104** that is pivotably connected to a support means such as post **106** such that the pendulum arm **104** can pivot about a pivot point, which is shown as turntable **108**.

The carton testing apparatus **100** applies forces to the carton **102** by causing the carton **102** to swing from pendulum arm **104** according to a predefined test protocol that prescribes the initial position of the pendulum arm **104**, the angle of throw or amplitude of the swing, the acceleration, deceleration, and velocity of the swing, and the extent of arm rotation, among other potential parameters.

The pendulum arm **104** includes a grasping means **110** for grasping the carton **102**, which in certain embodiments simulates a human hand (as best shown in **FIGs. 2** and **4**). The grasping means **110** includes upper digit **224** and lower digit **226** which enable the grasping means **110** to interface with a handle **112** or any other typical carrying means, such as a strap or a hand aperture. The dimensions and materials that define the grasping means **110** are preferably selected to enable the grasping means **110** to engage the carton **102** by taking hold of the carton **102** in approximately the same manner as would a human, such as by grasping the carton **102** by the handle **112** or other carrying means.

To provide additional stability and to safely establish the boundaries of the carton testing environment, certain embodiments of the carton testing apparatus **100** are enclosed within the perimeters of a frame **114**. The frame **114** can include various load bearing, non-load bearing, reinforcing, and non-reinforcing members, which may be arranged in any suitable fashion so as to construct the carton testing apparatus **100** in any suitable configuration, size, or shape. In **FIG. 1**, the carton testing apparatus **100** is rectangular in configuration, having a first end, a second end, a rear side, a front side, and a base. The first end is defined by a horizontal upper beam **116a**, a horizontal lower beam **116b**, a vertical front beam **116c**, and a vertical rear beam **116d**, which are all connected end to end to form a rectangle. The second end of the carton testing apparatus **100** is defined by a horizontal upper beam **118a**, a horizontal lower beam **118b**, a vertical front beam **118c**, and a vertical rear beam **118d**, which are also connected end to end. The rear side of the carton testing apparatus **100** is defined by horizontal upper beam **120a** and horizontal lower

beam **120b**. The front side of the carton testing apparatus **100** is defined by horizontal upper beam **122a** and horizontal lower beam **122b**. The horizontal lower beams **116b**, **118b** are connected end to end with horizontal lower beams **120b**, **122b**, thereby defining the bounds of base **124**, which is constructed of a rigid material such as steel. Base **124** preferably includes a welded steel frame with mounting feet and a steel support panel mounted on the welded frame. Base **124** may be bolted or otherwise anchored to the floor of the test area or adjustably mounted, for instance, on offset bolts, so that carton testing apparatus **100** can be kept level.

The carton testing apparatus **100** also includes a platform **126** that is mounted on a panel **128** that spans the distance between and is connected to vertical front beam **116c** and vertical rear beam **116d**. The platform **126** is pivotally connected to panel **128** by one or more pins **127** for swivel movement between raised and lowered positions. The platform **126** can be locked in the raised position (shown in **FIGs. 1** and **6**) wherein it projects inwardly and generally horizontally from the first end of the carton testing apparatus **100** and is substantially parallel to base **124**. The platform **126** can be lowered or downwardly rotated to the lowered position (shown in **FIGs. 7** and **8**) by deactivating a support mechanism such as by removing or a pin or shifting a lever **130**. Lever **130** controls the position of one or more catches **132** that function either to brace the platform **126** in the raised position or to release platform **126** such that platform **126** assumes the lowered position where platform **126** is disposed substantially perpendicular to base **124**.

The frame **114** may also include additional structural members, including beams **134** and **136**, which serve at least in part to fortify the frame **114** and to further define the test environment. Further the frame 114 may include a shield **138**, which serves at least in part to catch carton **102** or its contents if the carton 102 is dropped or loses structural integrity during a testing protocol. Shield **138** is preferably constructed of a strong, clear material such as LEXAN or PLEXIGLAS so as to reduce obstructions to

operators and monitoring equipment. The frame 114 may include additional shields formed of similar materials to further define and ensure safety of the test environment including, but not limited to, front and rear shields **140** and **142** which enclose the areas below beams **136** and **134**, respectively, as well as end shields **144** and **146** which enclose the entire respective ends of the frame **114**.

FIG. 2 is a plan view of the pendulum arm **104** as viewed from the front side of the exemplary carton testing apparatus **100**. The pendulum arm **104** may be constructed of aluminum, steel, or any material that has sufficient strength and rigidity to transfer and withstand the forces generated by swinging containers of various sizes, shapes, and weights around a pivot point, which is approximated by turntable **108**.

To position the pendulum arm **104** manually rather than by means of a drive system (described in detail below), a removable drive pin **200** (best shown in **FIG. 5**) is inserted through both the turntable **108** and the pendulum arm **104**. To reduce or eliminate the influence of the weight of the arm itself on the test results, or to counterbalance the weight of the loaded carton **102**, an adjustable counterweight **202** is fixed at an end of the pendulum arm **104** opposite the end to which the grasping means **110** is attached. The adjustable counterweight **202** shown comprises a series of plates that are bolted onto the pendulum arm **104**, one or more of which can be removed to yield the necessary weight for counterbalancing.

Certain embodiments of the present invention provide articulation of the connection between the pendulum arm **104** and the grasping means **110**. To that end, the embodiment shown includes articulation means **204** for simulating the flexibility of the human wrist by functioning as an interface between the pendulum arm **104** and the grasping means **110** that allows the grasping means **110** to pivot and flex with respect to the pendulum arm **104**. Preferably, the grasping means **110** moves in a controlled manner as if it were a human hand, the motion of which is limited at least

in part by tendons and bones. Thus, the articulation means **204** functions as an approximation of a human wrist, flexibly connecting pendulum arm **104** to grasping means **110**, which is the approximation of a human hand.

In the embodiment shown, the articulation means **204** pivots about a pivot point such as shoulder screw **206**, or any other fastener that has a shank that can be used to connect and to function as a bearing or pivot surface between pendulum arm **104** and articulation means **204**. The articulation means **204** can be adapted to include a self-centering or rectifying means for automatically centering the grasping means **110**, i.e., to resist and at least partially counteract forces encouraging the grasping means **110** to pivot.

FIG. 3 is an enlarged view of an example of a self-centering means comprising at least the combination of dowel **208**, aperture **210**, and springs **300**. Dowel **208** is connected or integral to articulation means **204** and protrudes at least partially into a depression, groove, or aperture **210**, which is formed in pendulum arm **104**. As grasping means **110** pivots in one direction, dowel **208** moves with respect to aperture **210** in the direction opposite the pivoting of the grasping means **110**. The range of motion of dowel **208** is ultimately limited by the width of aperture **210** and the force required to shift dowel **208** is proportional to the spring constant or the sum of the spring constants of one or more elastic bodies, such as springs **300** or elastomeric rings, which are preferably inserted in aperture **210** and on either side of dowel **208**. Each spring may be connected to dowel **208** and/or to at least one surface of aperture **210**. In certain embodiments, a preload screw is added to control the level of resistance provided by the self-centering means by compressing or decompressing the springs **300** prior to initiation of a test cycle. Alternatively, when pivoting of the grasping means **110** is not desirable at all, a locking pin **212** can be inserted to lock the action of the articulation means **204**.

The rate of motion of the grasping means **110** with respect to the pendulum arm **104** is preferably controlled by a dampening means **214**, which discourages rapid or extreme pivoting of the grasping means **110**. As a non-limiting example, the dampening means **214** shown in **FIG. 2** is a dashpot having a piston that moves within a cylinder containing oil, which is known in the art as one of various means for cushioning or damping movement of a mechanical part to avoid shock. The dampening means **214** shown is connected to pendulum arm **104** and to the articulation means **204** by brackets **216** and **218**.

Articulation means **204** may include an integral or interconnected portion that functions as a rotator cuff **220**. In certain embodiments, the rotator cuff **220** is rotatably associated with a rotator pin **400** to which the grasping means **110** is directly connected. The rotator pin **400** permits the grasping means **110** to swivel around the longitudinal axis of the pendulum arm **104**. To at least temporarily fix the grasping means **110** at a predetermined angle, a spring plunger **402** (best shown in **FIG. 4**) is inserted through the rotator cuff **220** to engage one or more predrilled and prealigned detent marks on the rotator pin **400** as the grasping means **110** is swiveled along with the rotator pin **400**. For example, detent marks disposed at 45 degree intervals around the rotator pin **400** would enable an operator to easily swivel the grasping means **110** either clockwise or counterclockwise from the position shown in **FIG. 2** to relative positions at **45**, **90**, **135**, **180**, **225**, **270**, and **315** degrees. Those skilled in the art will readily recognize controlled rotation of the grasping means **110** can be achieved electromechanically, e.g., via a servo motor.

The total range of pivoting motion of the grasping means **110** is restricted, in certain exemplary embodiments to approximately 30 degrees, at least in part by mechanical interaction between cuff **220** and the distal end of pendulum arm **104**, the width of aperture **210**, and the constraints of dampening means **214**.

FIG. 5 is a cross-sectional view of an exemplary system **500** for driving the motion of an exemplary pendulum arm **104**. The drive system **500** is preferably any suitable manual or automatic means for generating oscillating motion of the pendulum arm **104**, preferably by converting the rotary motion of a shaft **502** to oscillation of the pendulum arm **104**. Examples of suitable drive systems include, but are not limited to, a servo motor and drive, an electric or pneumatic rotary actuator, or a manual crank. The shaft **502** is enclosed and sealed within a housing **504** to prevent the entrance of foreign material. Shaft **502** is associated with turntable **108** via arm hub **506** such that rotation of shaft **502** translates into rotation of turntable **108**. It should be noted that other embodiments of the invention may additionally or alternatively provide reciprocal motion or circular motion of the pendulum arm **104**.

The drive system **500** is preferably controlled by a controller (not shown) that enables an operator to specify test parameters via a human-machine interface (HMI), which is described in more detail below with reference to **FIG. 9**. The controller preferably includes a processor that processes the test parameters and translates the parameters into control signals for controlling the action of the drive system **500**, and a memory for storing and launching executable instructions such as computer programs. Various test parameters can be specified, including but not limited to, the angle or position of rotation of the arm at various times before or during a test protocol, the velocity at which the pendulum arm **104** is rotated, the acceleration at which pendulum arm **104** is rotated, the deceleration of pendulum arm **104** typically at the end of a test protocol, and the velocity and acceleration of each swing cycle of a cyclical test protocol.

The various embodiments of carton testing apparatus **100** described above are utilized to perform the novel carton testing protocols of the invention. Three test protocols will be described in detail below, although the carton testing apparatus **100** can be adapted to perform other testing protocols without departing from the spirit or scope of the invention.

Shelf Drop Test

FIG. 6 is a diagram showing the relative positions of a carton **102** and certain components of the carton testing apparatus **100** during performance of a carton testing protocol that is hereinafter referred to as a Shelf Drop Test. The Shelf Drop Test is designed to simulate a user removing a carton **102** from a platform **126** such as a shelf, wherein the user allows the carton **102** to pivot about the user's shoulder and to swing downward along an arcuate path **600** from the level of the platform **126** to at least the lowest point along arcuate path **600**, which is defined at least in part by the angular range of motion of the extended arm of the user. Accordingly, the pendulum arm **104** of the carton testing apparatus **100** is an approximation of the user's arm, the grasping means **110** is an approximation of the user's hand, and turntable **108** is an approximation of the user's shoulder. As shown, the platform **126** is positioned at the height of the user's shoulder, although its height may be adjusted to simulate removal of carton **102** from shelves having any of various distances from floor level so long as the relative platform height is sufficient to require the pendulum arm **104** to pivot from its equilibrium position (hanging vertical) to engage a carton on the platform **126**.

FIG. 6 illustrates the initial position of certain elements of the carton testing apparatus **100** for performance of the Shelf Drop Test. At the initiation of the shelf drop test, platform **126** is in the raised position, extending generally horizontally from a first end of the carton testing apparatus **100** such that the upper surface between the proximal and distal edges of platform **126** is not perpendicular and is preferably substantially parallel to the base **124**. A carton **102** is placed on the upper surface of the platform **126**, and is preferably positioned such that the carton **102** is on its side with its handle **112** extending beyond the distal edge of the platform **126**. Drive pin **200** is removed to disengage drive system **500**, which is preferably deenergized. The pendulum arm **104** is mechanically or otherwise repositioned to place the

grasping means **104** in association with the handle **112** of the carton **102**. Locking pin **212** may be removed or remain inserted for the Shelf Drop Test.

The Shelf Drop Test is initiated by deactivating the platform support mechanism by operating lever **130**, which causes at least the distal edge of platform **126** to fall away thereby removing support from the carton **102**. The gravitational torque associated with the weight of the carton **102** and of the pendulum arm **104**, either of which may be counterbalanced at least in part by counterweight **202**, causes the unsupported carton **102** to swing from pendulum arm **104** along arcuate path **600** that defines the maximum amplitude of oscillation of the pendulum arm **104**. The protocol of the Shelf Drop Test may allow the carton **102** to oscillate along successively smaller segments of path **600** until the pendulum arm **104** reaches equilibrium in a vertical position. Alternatively, the operator or controller may be required to brake or limit the oscillation to a predefined number of swings. The primary goal of the test is to determine whether the carton **102** and the handle **112** can withstand the various forces generated by the initial removal of the carton **102** from the level of the platform **126**.

Swing Arm Test

FIG. 7 is a diagram showing the relative positions of a carton **102** and the components of the carton testing apparatus **100** during performance of another exemplary method for testing the carton **102**, which is hereinafter referred to as the Swing Arm Test. The goal of the Swing Arm Test is to test the ability of the carton **102** and handle **112** to withstand forces generated when the carton **102** is swung repeatedly back and forth, such as when a human user walks while carrying the carton **102** by its handle **112**. To prepare for performing the Swing Arm Test, the carton testing apparatus **100** is adapted to more closely simulate the oscillating arm swing of a human, and may also simulate the vertical motions that accompany a typical human gait.

With reference to **FIG. 7**, the initial state of the carton testing apparatus **100** is as follows. At initial position A, the pendulum arm **104** is at equilibrium, hanging vertically downward such that the longitudinal axis of pendulum arm **104** is perpendicular to the base **124**. Drive pin **200** is inserted to engage the drive system **500**. Locking pin **212** may be removed or remain inserted for the Swing Arm Test. The removal of locking pin **212** enables articulation of articulation means **204** so as to more accurately approximate the flexibility of a human wrist. Grasping means **110** is rotated such that the length of carton **102** is aligned parallel to the plane of oscillation. Carton **102** is engaged by grasping means **110** by placing handle **112** between upper digit **224** and lower digit **226**. The digits **224**, **226** may be clamped down around or otherwise adjusted to fixedly engage handle **112** to prevent the carton **102** from being dropped in the absence of a failure of the carton **102** or the carton handle **112**. Platform **126** is not needed in the Swing Arm Test, and thus is held in the lowered position.

The controller is programmed with the desired test protocol by inputting or uploading the appropriate control parameters via the HMI. The operator preferably launches a test cycle by pressing a CYCLE START button on the HMI or issuing a voice command. Alternatively, the test cycle begins at a predetermined time or delay interval. The drive system **500** drives the pendulum arm **104** to oscillate through multiple consecutive swing cycles, thereby causing carton **102** to traverse path **700** repeatedly. During each cycle of oscillation, the carton **102** swings between two extreme points **B** and **D** on path **700**, each swing preferably having an amplitude that is substantially equal to the amplitude of each previous and each subsequent swing. It should be noted that when the Swing Arm Test is performed with locking pin **212** removed, the articulation means **104** permits the grasping means **110** to flex somewhat in opposition to the forces generated by swinging the carton **102**. For example, at position **C**, the grasping means **110** may flex at an angle no greater than its maximum range of motion, which for the purposes of illustration and not limitation, is ± 15 degrees from center.

The Swing Arm Test continues until the carton **102** or the carton handle **112** fails, for a predetermined number of swings, for a predetermined duration, or until a predetermined swing velocity/acceleration has been achieved. If the integrity of the carton **102** is preserved until the Swing Arm Test ends, the carton **102** has passed. A carton also may be rated by the number of swings or the velocity/acceleration withstood without failure.

Shelf Lift Test

FIG. 8 illustrates the relative positions of a carton and the components of the carton testing apparatus during performance of yet another exemplary method for testing the container, which is hereinafter referred to as the Shelf Lift Test. The object of the Shelf Lift Test is to simulate functional loads experienced during lifting of the carton **102**, such as when a human user lifts the carton **102** to place it on a relatively high shelf. In particular, the torsional strength of the handle **112** is tested by rotational forces that are generated by the grasping means **110** on the handle **112** as the carton **102** is moved along an arcuate path **800**. In this manner, the propensity for the handle **112** to tear away from the carton **102** can be assessed.

For performance of the Shelf Lift Test, the initial state of the carton testing machine **100** is as follows. Pendulum arm **104** is at equilibrium, hanging vertically downward such that the longitudinal axis of pendulum arm **104** is perpendicular to the base **124**. Drive pin **200** is inserted to engage the drive system **500**. Locking pin **212** is inserted to disable articulation of articulation means **204**. Carton **102** is engaged by grasping means **110**, which grasps handle **112** between upper digit **224** and lower digit **226**. Platform **126** is not needed in the Shelf Lift Test, and thus is held in the lowered position.

The controller is programmed with the desired test protocol by inputting the velocity at which the pendulum arm **104** will be rotated, the extent to which the pendulum arm **104** will be rotated, and the acceleration and deceleration of the rotation of the

pendulum arm **104**. The operator then launches the test cycle, causing the carton testing apparatus **100** to lift carton **102** a single time through path **800**.

If the carton **102** or the carton handle **112** fails during the single lift performed as the Shelf Lift Test, then the carton **102** has failed. If the integrity of the carton **102** is preserved, then the carton **102** has passed.

It is contemplated that the carton testing apparatus may be adapted to perform additional test protocols, including but not limited to a Torsion test that is similar to the Shelf Lift Test, except that the grasping means **110** is caused to rotate a quarter turn, or 90 degrees, while the carton **102** is lifted.

The Human-Machine Interface

The HMI **900** is a user interface that interfaces with the controller, which controls components of the carton testing apparatus **100** according to the program instructions, and/or according to operator inputted parameters received via input/output (I/O) devices associated with the HMI **900**. Suitable I/O devices include any integral or remote combination of keypad, joystick, voice recognition devices, sound generation devices, and viewable display functionality capable of relaying data to or from the controller.

The controller can include any suitable microprocessor circuit, microcontroller, or similar data processing device that executes program instructions stored in a memory, while incorporating the parameters received via the I/O devices. Examples of suitable processing devices include programmed general or special purpose mobile device microprocessor, micro-controller and peripheral integrated circuit elements, ASIC or other integrated circuit, digital signal processor, hardwired electronic or logic circuit such as a discrete element circuit, programmable logic devices such as a PLD, PLA, FPGA or PAL, and the like. In general, the controller is

any device capable of implementing the functionality described herein, and may comprise any combination of hardware, firmware, and software.

The memory can be implemented using any suitable combination of readable, writable, and/or re-writable volatile (e.g., dynamic RAM or static RAM) or non-volatile (e.g., ROM, PROM, EPROM, EEPROM, optical ROM disk, or flash) memory elements. In general, the memory is any device capable of temporarily or permanently storing data.

FIG. 9 is a block diagram showing certain elements of an exemplary HMI **900**. According to this embodiment, the HMI **900** comprises a monitor **902** with a touch screen **904** for displaying the components of a Graphical User Interface (GUI). The GUI includes various user interface controls, including but not limited to buttons, menus, list boxes, text windows, and dialog boxes. The controls may alternatively or exclusively receive or display data and commands. As shown, the HMI **900** controls correspond to the particular test protocol that the carton testing apparatus **100** will perform. For instance, the controls primarily related to the Shelf Drop, Shelf Lift, and Torsion Tests are grouped toward the left of the display screen **904**, and controls primarily related to the Swing Arm Test are grouped toward the right of the screen **904**. Common controls are grouped in the middle of the screen **904**.

To input the parameters corresponding to a particular test, an operator adjusts the state of a variable control, such as text boxes **906** until the variable control indicates the desired value. The variable controls may also function to display the status of the parameters during a test cycle, for example whether the desired swing velocity has been achieved. To position the components of the carton testing apparatus **100**, the operator pushes one or more single-action controls, such as buttons **908** that cause the pendulum arm **104** to reposition itself.

The HMI **900** may also include status indicators **910** that indicate the existence and state of one or more conditions, as well as start/stop controls **912** that initiate or terminate a test. The controller may receive status data from the operator, who may for example, push a button to indicate that the operator has visually detected a failure of the carton. The controller may also receive status data from any number of sensing or metering devices, such as strain gauges, tachometers, optical, auditory, or thermal sensors, motion detectors, or any other means for measuring or detecting an existing test condition, such as motion, heat or light and for converting the condition into an analog or digital representation to be relayed to the controller and displayed via the HMI **900**.

The present invention has been illustrated in relation to a particular embodiment which is intended in all respects to be illustrative rather than restrictive. Those skilled in the art will recognize that the present invention is capable of many modifications and variations without departing from the scope of the invention. For example, as used herein, directional references such as "top", "base", "bottom", "end", "side", "inner", "outer", "upper", "middle", "lower", "front" and "rear" do not limit the respective sides of the carton testing apparatus or carton to such orientation, but merely serve to distinguish these sides from one another. Any reference to pivotable connection should not be construed as necessarily referring to a junction including a single pivot point only; indeed, it is envisaged that pivotable connection can be formed from one or more potentially disparate means for pivotably connecting materials. As used herein, "failure" of a carton or carrying means can be defined according to any industry or custom performance standard or metric.

Those skilled in the art will also appreciate that the shape and size of the apparatus for testing containers represents only one example of the various configurations that will be suitable for implementation of the various embodiments of the invention. For instance, the frame may be oval, round, or square, rather than rectangular. The entire testing apparatus may be open – that is, having no sides at all. Rather, the

arm may be pivotably suspended from or connected to a post or pillar-like structure and the platform **126** may be hingedly or pivotably connected to another post. The size and shape of the container testing apparatus or any of its components may be adjusted to accommodate containers of differing sizes, shapes, weights, contents, and alternative wall structures may be used. The container testing apparatus may include more than one arm such as for testing a container having two handles, one at each of the ends of the container. Accordingly, the scope of the present invention is described by the claims appended hereto and supported by the foregoing.

CLAIMS

1. An apparatus for testing the structural integrity of a container having a handle, comprising:

support means;

a pendulum arm pivotably connected at a first end of said arm to said support means at a pivot point thereof;

grasping means for grasping said handle of said container to load said pendulum arm, said grasping means being connected to a second end of said arm; and

drive means for causing said pendulum arm to pivot about said pivot point.

2. The apparatus of Claim 1, wherein said support means comprises a component of a frame.

3. The apparatus of Claim 1, wherein said support means comprises a post.

4. The apparatus of Claim 1, wherein said support means comprises a panel.

5. The apparatus of Claim 1, wherein said grasping means comprises a simulated hand.

6. The apparatus of Claim 5, wherein said simulated hand comprises at least one projection for engaging said handle.

7. The apparatus of Claim 1, wherein said pendulum arm comprises means for articulation between said grasping means and said pendulum arm, wherein said articulation means movably connects said grasping means to said pendulum arm.

8. The apparatus of Claim 7, wherein said articulation means comprises means for permitting the grasping means to pivot with respect to said pendulum arm.

9. The apparatus of Claim 8, wherein said articulation means comprises means for permitting the grasping means to rotate on a longitudinal axis of said pendulum arm.

10. The apparatus of Claim 7, wherein said articulation means comprises a means for dampening the pivoting of said grasping means.

11. The apparatus of Claim 10, wherein said dampening means is further for dampening the pivoting of said grasping means by providing resistance, wherein the amount of resistance provided is proportional to the velocity at which the grasping means pivots.

12. The apparatus of Claim 10, wherein said dampening means comprises a dashpot.

13. The apparatus of Claim 7, wherein said articulation means includes means for rectifying the orientation of the grasping means such that the grasping means is aligned with said pendulum arm.

14. The apparatus of Claim 13, wherein said rectifying means comprises at least one spring.

15. The apparatus of Claim 13, wherein said rectifying means comprises an elastomeric material.

16. The apparatus of Claim 1, wherein said drive means comprises a mechanical drive system.

17. The apparatus of Claim 16, wherein said mechanical drive system includes at least one of the following: a crank, a weight driven escapement, a spring driven escapement.

18. The apparatus of Claim 1, wherein said drive means comprises an electromechanical drive system.

19. The apparatus of Claim 18, where in said electromechanical drive system includes at least one of the following: a rotary actuator, a servo motor.

20. The apparatus of Claim 1, wherein said pivot point comprises a turntable to which said pendulum arm is connected; and

wherein said drive means generates rotational motion of said turntable.

21. The apparatus of Claim 1, further comprising a controller and a user interface, wherein said controller is programmed to cause said drive means to cause said pendulum arm to pivot according to a predefined test protocol; and

wherein said user interface comprises:

at least one input device for passing to said controller at least one command that controls the performance of said test protocol; and

at least one output device for communicating data to an operator.

22. The apparatus of Claim 1, further comprising a controller and a user interface, wherein said controller is programmed to cause said drive means to cause said pendulum arm to pivot according to a predefined test protocol; and

wherein said user interface comprises:

at least one input device for passing to said controller at least one parameter that controls the performance of said test protocol; and

at least one output device for communicating data to an operator.

23. The apparatus of Claim 22, wherein said at least one parameter is selected from a group of values consisting of: velocity, angular rotation, acceleration, force, mass, deceleration, position, number of cycles, and duration.

24. A method for testing the structural integrity of a container having a handle, the method comprising:

placing said container on a raised platform;

grasping said container by said handle with a grasping means connected to a pendulum arm; and

removing said platform, thereby allowing said pendulum arm to pivot about a fixed pivot point.

25. The method of Claim 24, wherein:

said pendulum arm is pivotably connected at a first end thereof to a support means at said pivot point; and

said grasping means is connected to a second end of said pendulum arm.

26. The method of Claim 24, wherein said pendulum arm comprises means for articulation between said grasping means and said pendulum arm, wherein said articulation means movably connects said grasping means to said pendulum arm.

27. A method for testing the structural integrity of a container having a handle, the method comprising:

positioning a pendulum arm at a position of equilibrium;

grasping said container by said handle with a grasping means connected to said pendulum arm; and

causing said pendulum arm to oscillate at least once about a pivot point by:

swinging said pendulum arm from said equilibrium position to a first extreme angle of rotation; and

swinging said pendulum arm from said first extreme angle of rotation back through the position of equilibrium to a second extreme angle of rotation.

28. The method of Claim 27, wherein causing said pendulum arm to oscillate comprises activating drive means for pivoting said pendulum arm about said pivot point.

29. The method of Claim 27, further comprising causing said grasping means to articulate with respect to said pendulum arm using means for articulation that movably connects said grasping means to said pendulum arm.

30. A method for testing the structural integrity of a container having a handle, the method comprising:

positioning a pendulum arm at a position of equilibrium;

grasping said container by said handle with a grasping means connected to said pendulum arm; and

causing said pendulum arm to pivot at least once about a fixed pivot point by swinging said pendulum arm from said equilibrium position to a predefined extreme angle of rotation.

31. The method of Claim 30, wherein causing said pendulum arm to oscillate comprises activating drive means for pivoting said pendulum arm about said pivot point.

32. The method of Claim 30, further comprising causing said grasping means to articulate with respect to said pendulum arm using means for articulation that movably connects said grasping means to said pendulum arm.

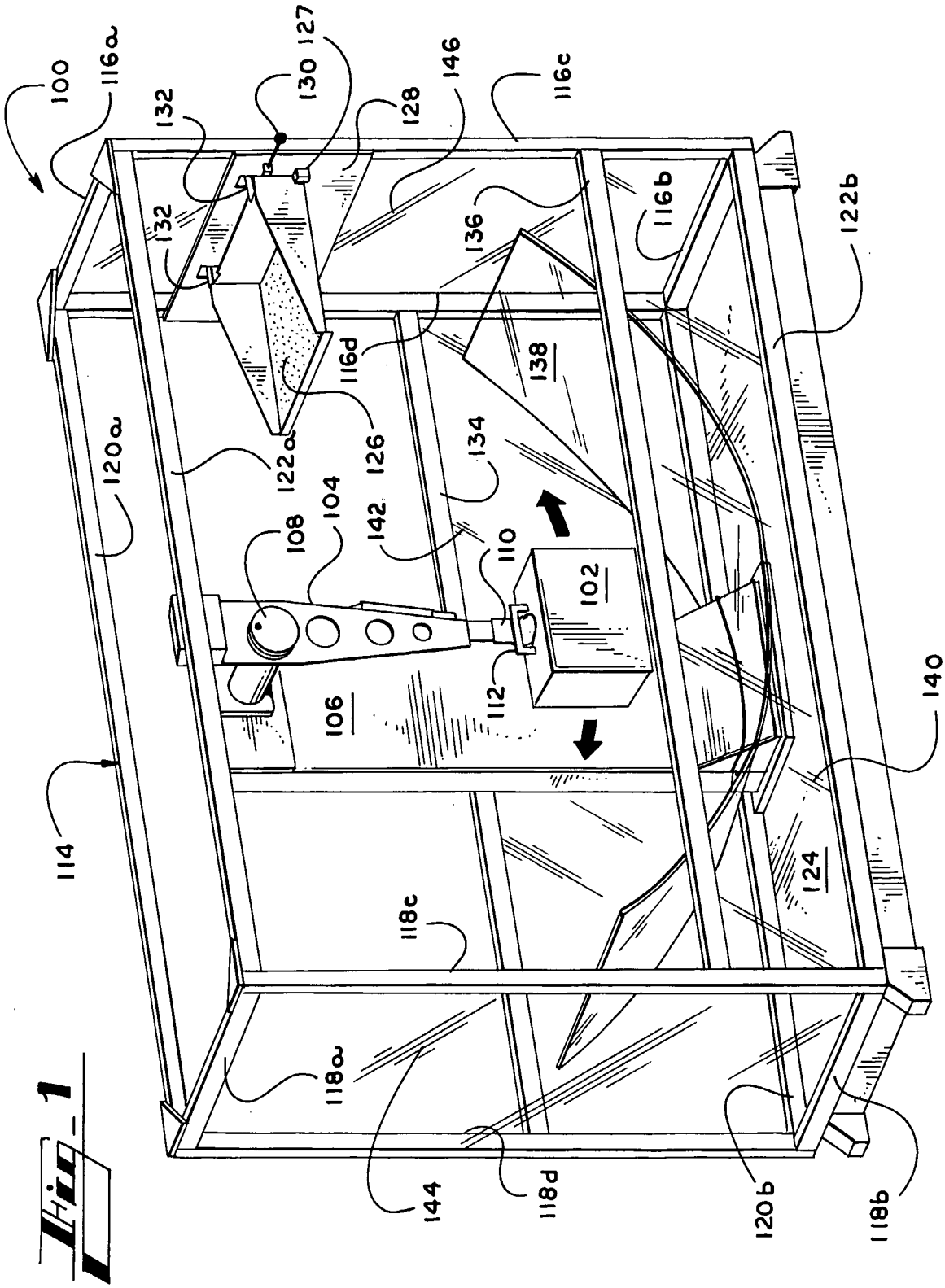
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Fig. 1

Fig_4

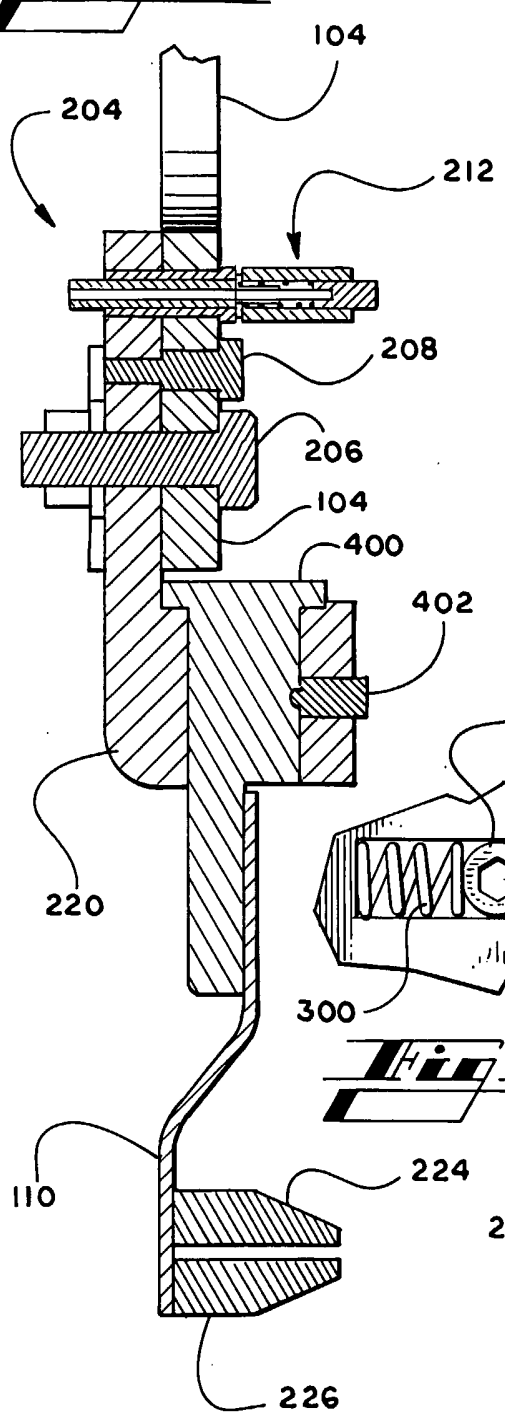

Fig_3

Fig_2

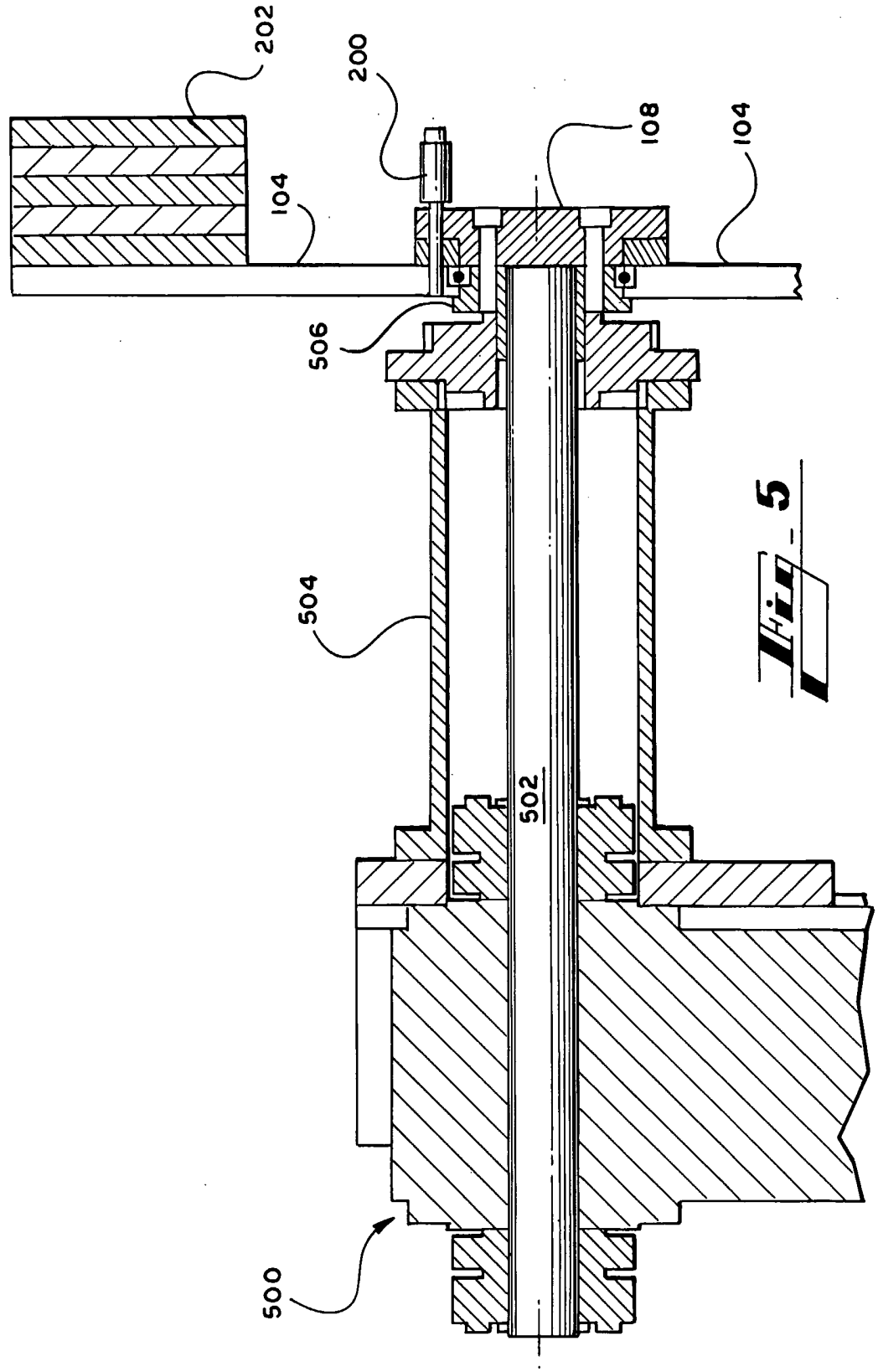

Fig. 5

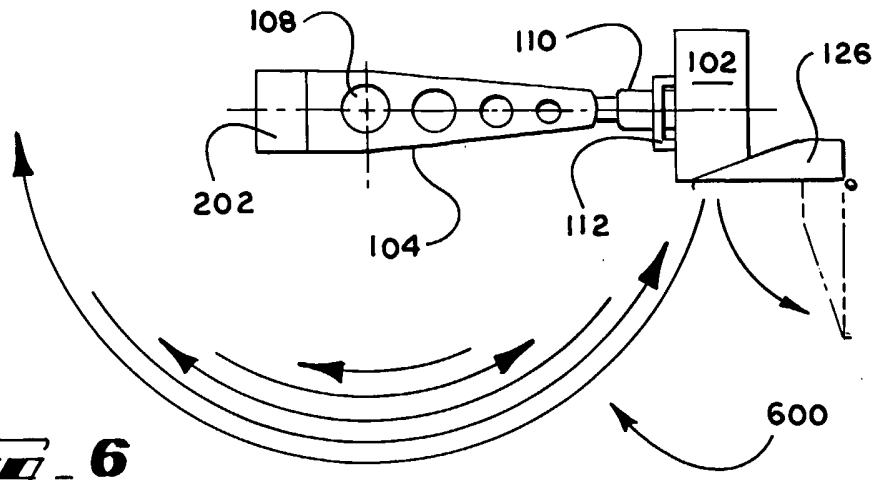

Fig_6

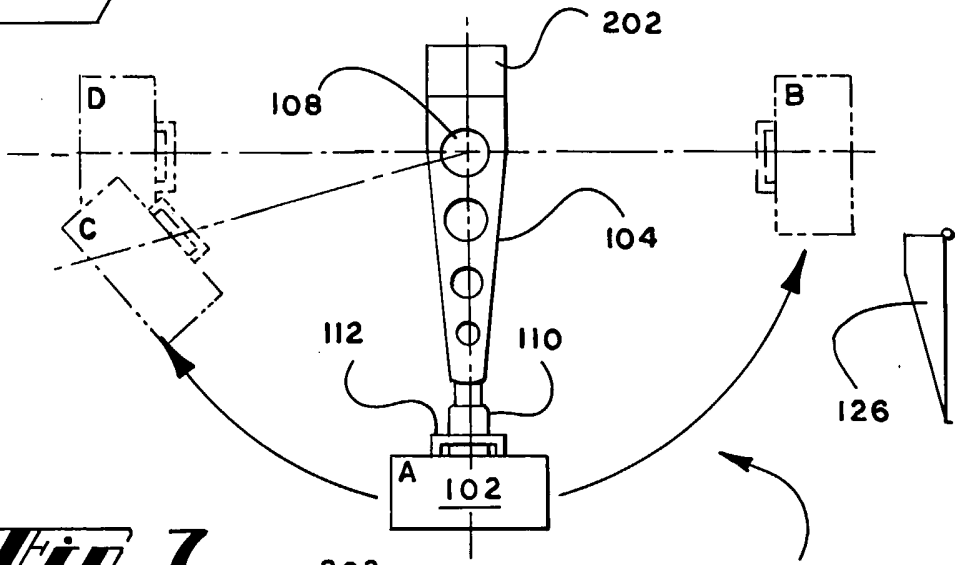

Fig_7

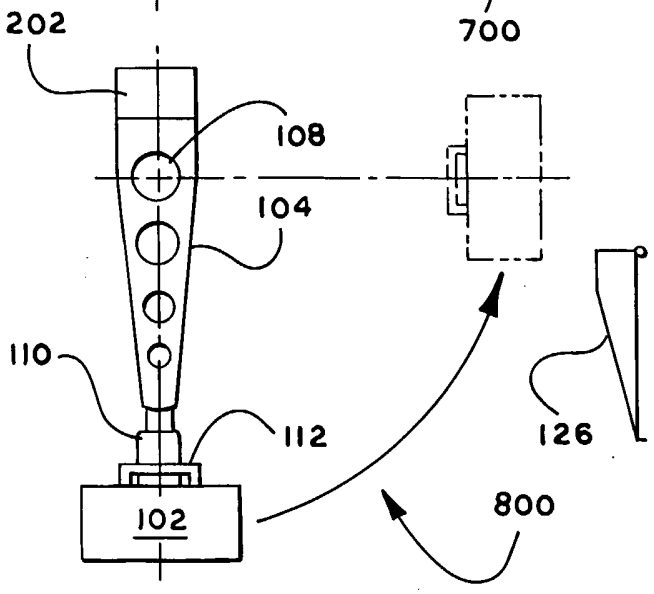

Fig_8

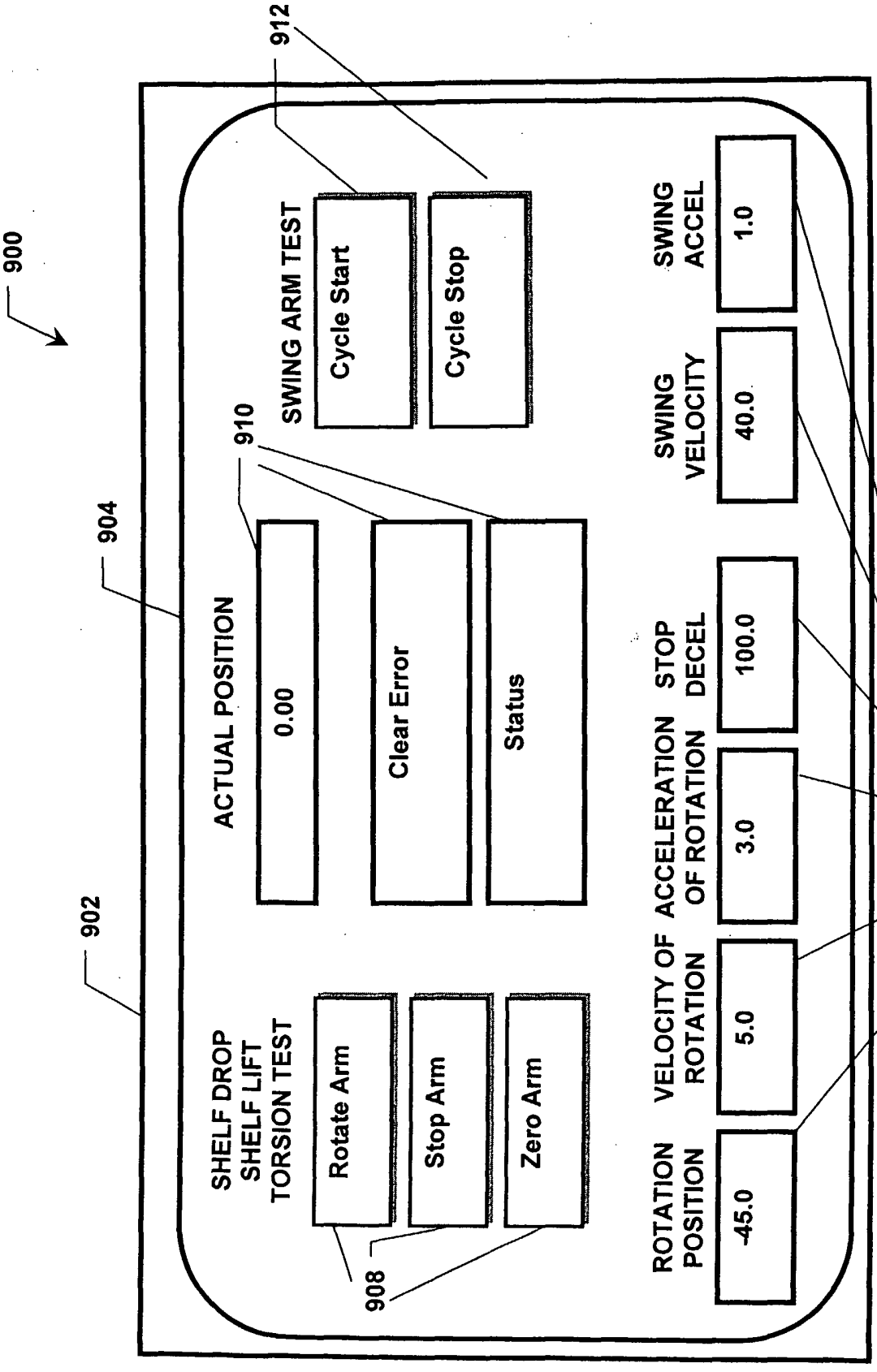
900
902
904
906
908
910
912
SHELF DROP
SHELF LIFT
TORSION TEST
Rotate Arm
Stop Arm
Zero Arm
ACTUAL POSITION
0.00
Clear Error
Status
SWING ARM TEST
Cycle Start
Cycle Stop
ROTATION POSITION
-45.0
VELOCITY OF ROTATION
5.0
ACCELERATION OF ROTATION
3.0
STOP DECEL
100.0
SWING VELOCITY
40.0
SWING ACCEL
1.0

Fig. 9

INTERNATIONAL SEARCH REPORT

Int ıal application No
PCT/US2005/039330

A. CLASSIFICATION OF SUBJECT MATTER
G01N3/32 G01M19/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G01N G01M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4 553 438 A (DAWSON ET AL) 19 November 1985 (1985-11-19) abstract; figures 1-6 column 1, line 20 - column 2, line 40 column 3, line 65 - column 4, line 9 column 4, line 61 - column 5, line 2	1-32
A	US 4 046 000 A (WATKINS ET AL) 6 September 1977 (1977-09-06) abstract; figures 1-3 column 1, line 24 - line 50	1-32

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
1 March 2006	27/03/2006

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Bockstahl, F

INTERNATIONAL SEARCH REPORT

Int ıal application No
PCT/US2005/039330

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 4553438 A	19-11-1985	NONE	
US 4046000 A	06-09-1977	NONE	