

TITLE

SYSTEMS AND METHODS FOR THE APPLICATION AND SEALING OF END CLOSURES ON CONTAINERS

CROSS REFERENCE APPLICATION

[0001] This application claims priority to U.S. Patent Application No. 63/071,069 filed August 27, 2020, which is incorporated by reference in its entirety herein.

FIELD OF THE INVENTION

[0002] The present invention relates generally to systems and methods for formation and sealing of containers with closures.

BACKGROUND OF THE INVENTION

[0003] The present disclosure relates generally to containers and methods of sealing such containers. Paper-based or composite containers are often used for snack foods and similar products. Such containers often have a peelable/removable membrane sealed to a top rim of the container, a removable/replaceable overcap or end cap covering the membrane, and a metal closure seamed onto a bottom rim of the container. Typically, the membrane is first sealed to the top rim. The container is then filled with the products through the open bottom end of the container and the metal closure is seamed onto the bottom rim of the container.

[0004] The process described above, using metal bottom ends, interferes with the recyclability of the container, as seaming the metal closure to the bottom of the container makes it very difficult to separate the metal closure from the container itself

after use. Without the ability to separate the paper-based body of the container from the metal bottom, the container assembly is unable to enter either the paper or metal recycling stream. This may result in unnecessary waste and negative environmental impacts. There exists a need for recyclable containers in order to increase the sustainability of the end product.

[0005] One solution to the need for recyclability is to produce containers with paper-based end closures rather than metal ends. However, the existing equipment for seaming metal ends to containers is built specifically for metal ends, and simply swapping out metal closures for paper-based end closures is incompatible with the current metal end seaming process, as paper-based end closures introduce unique challenges not present with metal ends (*e.g.*, flexibility of the closures, separating the closures from a stack of closures, feeding the closures, folding the closures, fusing the non-metal closures). Through ingenuity and hard work, the inventors have not only developed systems and methods for applying paper-based end closures to containers, but have developed systems and methods that operate at high speeds (*e.g.*, over 250 containers per minute).

SUMMARY OF THE INVENTION

[0006] In an embodiment, the invention comprises a sealing system for sealing a closure to a container comprising a die assembly, a mandrel assembly, and a gas evacuation assembly. The die assembly may comprise a die having a positioning portion configured to retain a disc and a die opening adjacent the positioning portion and at least one sealing member configured to provide heat to seal the disc to the container. The mandrel assembly may have a recessed position and an extended position and may

comprise: an outer mandrel comprising an extending portion which is sized to fit within an inner circumference of the positioning portion in its extended position, adjacent a peripheral portion of the retained disc; an inner mandrel configured to translate through an inner circumference of the extending portion of the outer mandrel and the die opening to its extended position, wherein the sealing member is disposed opposite the mandrel assembly when the mandrel assembly is in its retracted position. The gas evacuation assembly may comprise at least one hollow channel disposed at least partially circumferentially within the die; at least one channel opening disposed in the die which connects the at least one channel to an interior of the die, wherein the at least one channel opening is disposed between the positioning portion of the die and the sealing member; and a means for suctioning gas from the interior of the die, the at least one channel opening, and the at least one channel to an exterior of the die.

[0007] In certain methods of the invention, the method may comprise positioning the disc in the positioning portion of the die; axially aligning the container with the positioning portion of the die; positioning the container such that a peripheral edge of the container is in contact with a lower surface of the die; translating the outer mandrel such that it constrains the disc in the positioning portion of the die; suctioning gas from an interior of the container, the at least one channel opening, and the at least one channel to an exterior of the die; translating the inner mandrel such that it pushes the disc into the container and deforms the disc into a container end; and sealing the container end to the container.

[0008] In some embodiments, the system comprises a plurality of channel openings. In some embodiments, the system comprises at least one valve disposed within the die,

connecting the at least one channel to the exterior of the die. In some embodiments, the system additionally comprises at least one tube connecting the at least one valve to the means for suctioning gas. In some embodiments, the means for suctioning gas comprises a side channel pump or a vacuum pump. In some embodiments, the system comprises a plurality of valves are disposed within the die, connecting the at least one channel to the exterior of the die. In some embodiments, the channel openings are disposed between the retained disc and the container to which it is to be sealed. In some embodiments, the vertically extending portion of the outer mandrel has a greater circumference than that of the die opening. In some embodiments, the vertically extending portion of the outer mandrel constrains the disc in the positioning portion of the die.

[0009] In some embodiments of the method, when the outer mandrel constrains the disc in the positioning portion of the die, the interior of the container is sealed off from access to the atmosphere. In some embodiments of the method, the suctioning step and the vertically translating the inner mandrel step occur simultaneously or nearly simultaneously.

[0010] In an embodiment, the outer mandrel, the inner mandrel, and the ejectors extend, translate, and retract parallel to one another. In an embodiment, the outer mandrel extends and retracts vertically, the inner mandrel translates and retracts vertically, and the ejector translates and retracts vertically.

[0011] The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate one or more embodiments of the invention and, together with the description, serve to explain the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[00012] A full and enabling disclosure of the present invention, including the best mode thereof directed to one of ordinary skill in the art, is set forth in the specification, which makes reference to the appended drawings, in which:

[00013] Figure 1 illustrates a cross-section of an exemplary sealing system in accordance with an embodiment of the invention;

[00014] Figure 2 illustrates a cross-section of an exemplary sealing system in accordance with an embodiment of the invention;

[00015] Figure 3 illustrates a cross-section of an exemplary sealing system in accordance with an embodiment of the invention;

[00016] Figure 4 illustrates a cross-section of an exemplary sealing system in accordance with an embodiment of the invention;

[00017] Figure 5 illustrates a cross-section of an exemplary sealing system in accordance with an embodiment of the invention;

[00018] Figure 6 illustrates a cross-section of an exemplary sealing system in accordance with an embodiment of the invention;

[00019] Figure 7 illustrates a cross-section of an exemplary sealing system in accordance with an embodiment of the invention;

[00020] Figure 8 illustrates a cross-section of an exemplary sealing system in accordance with an embodiment of the invention;

[00021] Figure 9 illustrates a cross-section of an exemplary sealing system in accordance with an embodiment of the invention;

[00022] Figure 10 illustrates a cross-section of an exemplary sealing system in accordance with an embodiment of the invention;

[00023] Figure 11 illustrates a cross-section of an exemplary sealing system in accordance with an embodiment of the invention;

[00024] Figure 12 illustrates a cross-section of an exemplary sealing system in accordance with an embodiment of the invention;

[00025] Figure 13 illustrates a cross-section of an exemplary sealing system in accordance with an embodiment of the invention;

[00026] Figure 14 illustrates a cross-section of an exemplary die and gas evacuation system in accordance with an embodiment of the invention;

[00027] Figure 15 illustrates an exemplary die and gas evacuation system in accordance with an embodiment of the invention;

[00028] Figure 16 illustrates an exemplary die and gas evacuation system in accordance with an embodiment of the invention;

[00029] Figure 17 illustrates an exemplary sealing system in accordance with an embodiment of the invention;

[00030] Figure 18 illustrates an exemplary sealing system in accordance with an embodiment of the invention;

[00031] Figure 19 illustrates an exemplary sealing system in accordance with an embodiment of the invention;

[00032] Figure 20 illustrates an exemplary sealing system in accordance with an embodiment of the invention;

[00033] Figure 21 illustrates an exemplary sealing system in accordance with an embodiment of the invention;

[00034] Figure 22 illustrates an exemplary die and gas evacuation system in accordance with an embodiment of the invention;

[00035] Figure 23 illustrates an exemplary die and gas evacuation system in accordance with an embodiment of the invention;

[00036] Figures 24-31 illustrate an exemplary die and gas evacuation system in accordance with an embodiment of the invention;

[00037] Figures 32A-32F illustrate an exemplary die and gas evacuation system in accordance with an embodiment of the invention;

[00038] Figure 33 illustrate an exemplary die and gas evacuation system in accordance with an embodiment of the invention; and

[00039] Figure 34 illustrates a graph comparison of leak detection in inventive paper bottom closures as compared to metal bottom closures.

[00040] Repeated use of reference characters in the present specification and drawings is intended to represent the same or analogous features or elements of the invention.

DETAILED DESCRIPTION

[00041] Reference will now be made in detail to embodiments of the invention, one or more examples of which are illustrated in the accompanying drawings. Each example is provided by way of explanation of the invention, not limitation of the invention. In fact, it will be apparent to those skilled in the art that modifications and variations can be made in the present invention without departing from the scope or spirit thereof. For instance,

features illustrated or described as part of one embodiment may be used on another embodiment to yield a still further embodiment. Thus, it is intended that the present invention covers such modifications and variations as come within the scope of the appended claims and their equivalents.

[00042] In an embodiment, the invention comprises a device and method for manufacture of high barrier packages for perishable products, such as hermetically closed containers for packaging humidity- and oxygen-sensitive solid food products. The containers produced according to the devices and methods described herein may be capable of sustaining a variety of atmospheric conditions when filled and closed. More specifically, the hermetically closed containers may be suitable for maintaining the freshness of crisp food products such as, for example, potato chips, processed potato snacks, nuts, and the like. As used herein, the term "hermetic" refers to the property of sustaining an oxygen (O₂) level with a barrier such as, for example, a seal, a surface or a container.

[00043] In an embodiment, the systems and methods described herein may produce hermetically sealed containers having a wholly paper, paper-based, or composite bottom (though the methods described herein should not be so limited may be applicable to polymeric, metallic, or other types of bottoms known in the art) which is shaped and/or sealed (e.g., via a heated pressing tool) without causing pin holes, pleats, cuts or cracking of the barrier layer, the closed container and/or bottom.

[00044] In an embodiment, the systems and methods described herein may produce hermetically sealed containers having a paper-based, composite bottom which is inserted into a composite container and sealed in a recessed position without causing

doming of the membrane seal (i.e. on the top end). In a typical insertion process which results in a recessed bottom, increased pressure on the interior of the container, caused by the insertion process itself, causes the membrane closures to expand outwardly or “dome.” That is, when the end closure is inserted and sealed in place, it pushes the air within the container into a smaller space to accommodate the recessed end closure. That increased pressure expands outwardly into the most flexible component, which is typically the membrane lid.

[00045] The domed membrane lid is aesthetically unpleasing, but also causes certain manufacturing issues. For example, the domed membrane causes instability – the container cannot stably stand on its membrane end (upside down) as it is being conveyed to a downstream packaging process (i.e. from the sealing machine to the case packer). Further, an overcap may not fit onto the container if the membrane lid is domed, making the package unacceptable for sale.

[00046] Thus, the inventive systems and methods provide a mechanism for applying a recessed paper-based bottom closure onto a paper-based container without an unacceptable level of doming of the flexible membrane closure. More particularly, the invention allows gas evacuation simultaneously with or just before the sealing process occurs. In an embodiment, the inventive method and systems allow an adjustably defined volume of gas to be evacuated from the container. In some embodiments, this defined volume of gas is directly correlated to the depth of the recessed end closure, avoiding an overpressure situation within the container.

[00047] Furthermore, such hermetically sealed containers may be transported worldwide via, for example, shipping, air transport or rail, subjected to varying

atmospheric conditions (e.g., caused by variations in temperature, variations in humidity, and variations in altitude), without unacceptable doming of the membrane lid. As is understood in the art, such conditions may cause a significant pressure difference between the interior and the exterior of the hermetically closed container. Moreover, the atmospheric conditions may cycle between relatively high and relatively low values. The systems and methods for producing hermetically sealed containers described herein may provide a container that can be transported and/or stored under widely differing climate conditions (i.e., temperature, humidity and/or pressure) without unacceptable doming of the membrane lid. Further, in embodiments set forth herein, the hermetically closed containers may be formed from material having sufficient strength, surface friction, and heat stability for rapid manufacturing (i.e., high cycle output machine types and/or manufacturing lines).

[00048] As noted, the hermetically sealed containers produced using the systems and methods described herein may include a paper-based composite bottom. Likewise, the container body may comprise a paper-based composite material, allowing the entire container to be recycled in a single stream (opposed to similar containers with metal bottoms, for example). The bottoms and/or container bodies of the invention may comprise any paper known in the art such, as for example, a fiber based and/or pulpable material, such as cardboard, paperboard, cupboard stock, cupstock, litho paper, or even molded fiber. In some embodiments, the bottoms and/or container bodies of the invention may be 100% paper. In some embodiments, the container assemblies may be about 90% or more paper content by mass. In some embodiments, the container assemblies may be about 95% or more paper content by mass. These

paper content percentages may advantageously qualify the container assemblies as mono material in certain countries, allowing them to be accepted in the recycling streams of most countries globally. In some embodiments, the term “mono-material” includes any material that can be collected and enter a waste management flow to obtain raw material from a residue for a different application. In other embodiments, the bottoms and/or container bodies of the invention may be composite materials.

[00049] The Sealing System

[00050] Referring to FIGS. 1-11, the containers described herein may be formed using the following sealing systems 100 and/or according to the following methods. In one embodiment, the paper-based bottom may begin as a sheet or disc. While the paper bottom discussed herein is referred to as being round or a disc, the invention should not be so limited. The paper bottom may comprise any shape known in the art and may correlate to the shape of the container. For example, if the container has a square, rectangular, triangular, or irregular cross section, the paper bottom may have a correlated shape (square, rectangular, triangular, or irregular).

[00051] For example, a composite sheet or paper-based disc 50 may be shaped to conform to a composite container body 60 via a mandrel assembly 200, a die assembly 300, and a container support assembly (not shown) operating in cooperation. The mandrel assembly 200 may be utilized to stamp or press a paper-based disc 50 to form it into a composite bottom 51 (shown in FIG. 10-11).

[00052] The mandrel assembly 200 may include an outer mandrel 210 (sometimes referred to as a “downholder” due to its purpose of holding the disc 50 downwardly, against the die assembly 300) and an inner mandrel 220 (sometimes referred to as a

“sealing punch” due to its purpose of punch drawing the disc 50 into a container 60 and sealing the disc 50 against the sidewall of the container 60). The outer mandrel 210 and inner mandrel 220 may each move along the Y-axis independent of one another. The inner mandrel 220 may translate with respect to the outer mandrel 210 to form a paper-based disc 50 into a bottom closure 51. Further, the die assembly 300 may cooperate with the mandrel assembly 200 to shape the paper-based disc 50 into the bottom closure 51, simultaneously or nearly simultaneously inserting the closure 51 into the bottom end 62 of a composite body 60. The die assembly 300 may generally comprise a die 80 having a top surface 97, a positioning portion 90, a die opening 98 and sealing member(s) 40, also known as the die bush ring. The tube assembly may be configured to retain and move the composite body 60, relative to the mandrel assembly 200 and die assembly 300. For example, the tube assembly may move the composite body laterally to align the axis of the container body 60 with the axis of the mandrel assembly 200 and die assembly 300 and/or vertically along the axis of the mandrel assembly 200 and die assembly 300.

[00053] In an embodiment, the mandrel assembly 200, the die assembly 300, and the container support assembly may be aligned along the Y-axis, at least during the methods described herein, such that a paper-based disc 50 may be urged through the die opening 98 by the inner mandrel 220 and inserted into the bottom end 62 of a composite body 60 held by the tube support member.

[00054] The Die Assembly

[00055] The die assembly 300 may be configured to receive and retain the paper-based disc 50 prior to insertion of the disc 50 through the die opening 98 and into the

container body 60. In some embodiments, the disc 50 is received from a separate disc feeding assembly (not shown). In an embodiment, the die assembly 300 may be configured to mate or otherwise align with the feeding assembly. For example, the die 80 may comprise notches, ridges, or other alignment features 302 on its upper end (see FIG. 27) which allow it to mate with, align with, or receive a corresponding mechanical element of the feeding assembly. This allows for proper placement of the disc 50 within the die 80.

[00056] More specifically, the die assembly 300 may comprise a die 80 (*i.e.*, die bush ring) having a positioning portion 90 (*i.e.*, collet seat), configured to accept and align a paper-based disc 50 within the die 80 prior to forming the disc 50 into a recessed end 51. The positioning portion 90 may be disposed adjacent the die opening 98 in order to align a paper-based disc 50 with the die opening 98.

[00057] The positioning portion 90 may comprise a sloped surface 96 that connects a top surface 97 of the die 80 to a sidewall 94 of the positioning portion 90. The sloped surface 96 may slope downwardly, toward the die opening 98 and axis of the die assembly 300. In an embodiment, the sloped surface 96 may allow the disc 50 to be guided into the positioning portion 90.

[00058] The sidewall 94 of the positioning portion 90 may be vertical or substantially vertical, in an embodiment. The sidewall 94 of the positioning portion 90 may be longer than the thickness of the disc 50, in an embodiment. The outer diameter of the sidewall 94 of the positioning portion 90 may be substantially similar to the diameter of the disc 50, in an embodiment. In another embodiment, the outer diameter of the sidewall 94 of the positioning portion 90 may be slightly larger than the diameter of the disc 50.

[00059] In an embodiment, the sloped surface 96 of the positioning portion 90 may have a larger perimeter nearest to the top surface 97 of the die 80 and a smaller perimeter nearest to sidewall 94. In some embodiments, the circumference of the outer edge of the sloped surface 96 of the positioning portion 90 may be larger than the paper-based disc 50. The sloped surface 96 may be tapered downwardly to allow gravitational assistance for the alignment of the paper-based disc 50 within the positioning portion 90. Once seated, the paper-based disc 50 may be positioned adjacent the disc support surface 92 and the sidewall 94 of the positioning portion 90. In an embodiment, the disc support surface 92 and the sidewall 94 of the positioning portion 90 connect at a ninety-degree angle or substantially a ninety-degree angle. In an embodiment, the disc support surface 92 may be horizontal or substantially horizontal. In an embodiment, the seated disc 50 is positioned such that its lower surface 54 (see Fig. 2) is adjacent (i.e. seated atop) the disc support surface 92. In an embodiment, the seated disc 50 is positioned such that its thickness is adjacent the sidewall 94 of the positioning portion 90.

[00060] In an embodiment, the inner circumference of the disc support surface 92 is smaller than the circumference of the disc 50. In an embodiment, the inner circumference of the disc support surface 92 adjacent the die opening 98. In an embodiment, the disc support surface 92 is disposed adjacent a die opening inner surface 99. The die opening inner surface 99 may be vertical or substantially vertical, in an embodiment. In an embodiment, the disc support surface 92 is disposed at a right angle or a nearly right angle to the die opening inner surface 99.

[00061] In use, a disc 50 is inserted into the die assembly 300, positioned within the positioning portion 90, and seated on the disc support surface 92. In an embodiment, vacuum pressure may be applied to the paper-based disc 50, from underneath, to align it within the positioning portion 90 of the die 80.

[00062] While the die opening 98 is depicted as having a substantially circular cross-section, the die opening 98 may have a cross-section that is substantially circular, triangular, rectangular, quadrangular, pentagonal, hexagonal or elliptical. In an embodiment, the die opening 98 may be configured to accept the inner mandrel 220, discussed below. In an embodiment, the die opening 98 may have a substantially similar cross-section as that of the inner mandrel 220.

[00063] The Gas Evacuation Assembly

[00064] In an embodiment, a gas evacuation assembly 400 is included in the present system. In an embodiment, the gas evacuation assembly 400 is disposed at least partially within the die assembly 300. The gas evacuation assembly 400 may be designed to suction or vacuum a defined volume of gas out of the interior container space prior to or simultaneously with insertion of the disc 50 into the container 60.

[00065] The gas evacuation assembly 400 may comprise one or more valves 420 which are integral in the die assembly 300. In an embodiment, the valves 420 are disposed within the die 80. More particularly, there may be a port or a bore 82 through the interior of the die 80 which connects the die outer surface 89 to an internal channel 430. The valve 420 may be disposed within said port or bore 82. The port or bore 82 may connect the internal channel 430 to an upper surface of the die, a lower surface of the die, or a side/lateral surface of the die. That is the valve(s) 420 may extend laterally

within the die and/or may extend vertically upwardly or downwardly within the die. In an embodiment, the bore 82 may be configured generally horizontally within the die 80.

[00066] In an embodiment, the bore 82 may be disposed in an upper section 87 of the die 80. In an embodiment, at least a portion of the bore 82 and valve 420 may be disposed above the channel 430. In an embodiment, the valve 420 may have an opening that is directed downwardly, within the bore 82, toward the channel 430. That is, there may be direct gaseous communication between the valve 420 and the channel 430. In an embodiment, air may be suctioned from the channel 430 via the valve 420.

[00067] In an embodiment, the valve 420 may comprise any suction or vacuum valve known in the art. In an embodiment, the valve 420 may have an open position and a closed position. In the open position, the valve 420 may allow the exchange of gasses and in the closed position, the valve 420 may not allow exchange of gasses. In an embodiment, the valve 420 may comprise an elongated tube or pipe that extends generally horizontally or vertically through the upper section 87 of the die 80 with a through hole 422 disposed at its proximal end (with reference to the interior of the die 80). In this embodiment, the through hole 422 may be disposed adjacent the internal channel 430. In some embodiments, a manifold connection 426 may connect the bore 82 and the channel 430. In a particular embodiment, the through hole 422 may be disposed directly above at least a portion of the internal channel 430. In an embodiment, the through hole 422 may connect to and communicate with the internal channel 430. The through hole 422 may take any shape known in the art. In an exemplary embodiment, the through hole 422 is circular, but may be ovular, square, rectangular, or any other shape known in the art.

[00068] The internal channel 430 may be hollow in an embodiment. The channel 430 may be shaped or configured as desired, but in an embodiment, may be square, rectangular, circular, or semi-circular in cross-section. The channel 430 may be disposed circumferentially or partially circumferentially within the die 80 in an embodiment. In a particular embodiment, the channel 430 may comprise a recessed portion of the upper section 87 of the die 80. In this embodiment, the channel 430 may comprise at least one sidewall 432. In an embodiment, the channel 430 may comprise two opposing sidewalls 432, 434 and a top wall 436. In an embodiment, the bottom wall of the channel 430 may comprise the top surface 42 of the sealing member(s) 40. That is, if the upper section 87 of the die 80 were separated from the sealing member(s) 40, the channel 430 would have an open bottom end.

[00069] The channel 430 may have one or more channel openings 440 disposed between the channel 430 and the die opening inner surface 99. In an embodiment, the channel openings 440 are disposed laterally inward of the channel 430, nearer to the central axis of the container 60 which will be sealed. In an embodiment, the channel openings 440 may connect the channel 430 to the interior of the die 80 such that gasses may be exchanged therebetween. That is, the channel openings 440 may provide for gaseous communication between the channel 430 and the interior of the die 80. The channel openings 440 may be shaped as desired, but in an embodiment, may be square, rectangular, circular, ovular, or semi-circular in cross-section. In a particular embodiment, the channel openings 440 into the interior of the die 80 may be square or rectangular. The number, size, and arrangement of the channel openings 440 may vary based upon the amount of gas that must be evacuated.

[00070] In an embodiment shown in FIGS. 22 and 23, the channel 430 may comprise a single channel opening 440. The channel opening 440 may extend circumferentially, between the channel 430 and the die opening inner surface 99. In an embodiment, the channel opening 440 may extend partially or fully circumferentially about the die 80.

[00071] In other embodiments, the channel 430 may comprise a plurality of channel openings 440 (see FIGS. 14, 25). For example, six channel openings 440 are shown in FIG. 25. The channel openings 440 may vary in size, one to another. The channel openings 440 may be spaced equidistance from each other or may be spread out in any other manner known in the art. In an embodiment, the channel openings 440 may be disposed on only one side of the die assembly.

[00072] In an embodiment, the channel openings 440 may be disposed below the positioning portion 90 of the die 80. More particularly, the channel openings 440 may be disposed below the disc support surface 92 of the positioning portion 90. As such, when the disc 50 is in position, before insertion into the container 60, the channel openings 440 may be disposed below the disc 50 (see FIG. 33). In an embodiment, the channel openings 440 may be disposed within the die opening inner surface 99. In an embodiment, the channel 430 and channel openings 440 may disposed adjacent the bottom surface 85 of the upper section 87 of the die 80.

[00073] In an embodiment, the channel 430 is fully circumferential within the die 80. In another embodiment, the channel 430 is partially circumferential within the die 80. In an embodiment, the channel 430 comprises a plurality of discontinuous channels within the die 80.

[00074] In an embodiment, the channel 430 may be sealed off from access to the atmosphere when the disc 50 is positioned within the positioning portion 90 of the die 80. In an embodiment, the vertically extending portion 212 of the outer mandrel 210 (discussed below) constrains the paper-based disc 50 (see Fig. 4) during the bottom end formation. In an embodiment, the pressure that the vertically extending portion 212 of the outer mandrel 210 places on the the paper-based disc 50 may seal the channel 430 off from access to the atmosphere. At such point, the gas evacuation assembly 400 may suction or vacuum gas from the interior of the container, as will be further explained herein.

[00075] In an embodiment, the valves 420 may connect via piping or tubing 424 (see FIG. 31) to a side channel pump, blower, or fan or a vacuum pump (not shown). Any side channel pump or vacuum pump or other suction device known in the art may be utilized. The valves 420 may connect to the tubing via a coupling connection 410. The coupling connection 410 may be integral to the die 80. Alternatively, the coupling connection 410 may be screwed into the die 80. That is, there may be screw threads on at least a portion of the internal surface of the bore 82 which may align with and interconnect with threads on an external surface of the coupling connection 410.

[00076] The coupling connection 410 may have a distal end 412 which is configured to connect to a hose or tube. The connection may be a snap-fit, twist, or any other configuration known in the art. In an embodiment, the coupling connection 410 may comprise an elbow joint, allowing the tubing to attach and hang in a vertical, horizontal, or any other position. In an embodiment, the coupling connection 410 may rotate about its axis to prevent tangling of the tubing.

[00077] In an embodiment, the evacuation assembly 400 comprises a plurality of valves 420, coupling connections 410, and tubes. In a particular embodiment, the evacuation assembly 400 comprises three valves 420 and three corresponding coupling connections 410 and tubes. In an embodiment, the number of valves 420 corresponds to the number of sealing member(s) 40 (discussed below). In this embodiment, if there are three sealing member(s) 40, three valves 420 are present, each disposed in one of the sealing member(s) 40. In other embodiments, the number of valves 420 may be greater than the number of sealing member(s) 40. For example, the sealing member 40 may comprise a single, unitary sealing member 40 but may have two or three valves 420 disposed therein. In an embodiment, a certain number of channel openings 440 are disposed in each valve section 414, 416, 418. For example, three, four, five, or six channel openings 440 may be disposed in each valve section.

[00078] In an embodiment, the gas evacuation mechanism is operated in a vacuum chamber which has been depressurized. In another embodiment, however, the gas evacuation mechanism is operated under standard atmospheric conditions, without use of a vacuum chamber.

[00079] The Mandrel Assembly

[00080] As noted above, the mandrel assembly 200 may comprise an inner mandrel 220 and an outer mandrel 210. The inner mandrel 220 and the outer mandrel 210 may be vertically translatable, separately from one another. In an embodiment, the inner mandrel 220 and the outer mandrel 210 translate parallel to one another, which may be vertically but need not necessarily be vertically. For example, the system may provide an inner mandrel 220 and outer mandrel 210 that translate horizontally or angularly.

[00081] In an embodiment, the inner mandrel 220 may move a first distance and the outer mandrel 210 may move a second distance, wherein the first and second distances are different from one another. Likewise, the inner mandrel 220 may move at a first time and the outer mandrel 210 may move at a second time, wherein the first and second times are different from one another. In an embodiment, the inner mandrel 220 and the outer mandrel 210 may move in unison during a first time period. In an embodiment, the inner mandrel 220 may have a first extension length and the outer mandrel 210 may have a second extension length, wherein the first and second extension lengths are different from one another. In an embodiment, the outer mandrel 210 may move in unison with both the inner mandrel 210 and the ejector 30 until such time as the mandrel assembly 200 contacts the die assembly 300. Each of the outer mandrel 210, the inner mandrel 210 and the ejector 30 may contact the die assembly 300 simultaneously in an embodiment.

[00082] The outer mandrel 210 may be generally cylindrical, in an embodiment. In this embodiment, the container may be cylindrical. However, if the container is not cylindrical (i.e. square, triangular, rectangular, irregular, etc. cross-section), the outer mandrel 210 may have a shape and configuration which correlates to that of the container.

[00083] In another embodiment, the outer mandrel 210 may comprise a vertically extending (i.e. downwardly) portion 212 and a radially-outwardly directed flange 214. The flange 214 may not be present in some embodiments (see FIG. 19). The vertically extending portion 212, in an embodiment, may be perforated and/or may have through holes 216 disposed therein. In an embodiment, the vertically extending portion 212 and

the radially-outwardly directed flange 214 may join in a right angle or a nearly right angle.

[00084] In an embodiment, the vertically extending portion 212 of the outer mandrel 210 may be sized to fit within the circumference of the positioning portion 90. In an embodiment, the vertically extending portion 212 of the outer mandrel 210 has a greater circumference than that of the die opening 98, such that the vertically extending portion 212 of the outer mandrel 210 cannot extend into the die opening. More specifically, the vertically extending portion 212 of the outer mandrel 210 may be sized and/or configured such that, when fully extended, it is disposed adjacent the positioning portion sidewall 94 and the disc support surface 92 of the positioning portion 90. In an embodiment, the vertically extending portion 212 of the outer mandrel 210 may be extended after the disc 50 is seated within the positioning portion 90 and may be configured to secure the disc 50 in place (see Fig. 4).

[00085] As shown in Fig. 12, the inner mandrel 220 may be generally cylindrical. As noted above with regard to the outer mandrel, the inner mandrel 220 may be shaped and configured to correlate to the shape and configuration of the container. For example, if a container has a square-cross section, the inner mandrel 220 may have a square shape and configuration.

[00086] In an embodiment, the inner mandrel 220 may be sized to fit within the inner circumference of the vertically extending portion 212 of the outer mandrel 210. In an embodiment, the inner mandrel 220 may be configured to extend vertically lower than the vertically extending portion 212 of the outer mandrel 210. In this embodiment, once the disc 50 is seated within the positioning portion 90 and constrained by the fully

extended vertically extending portion 212 of the outer mandrel 210, the inner mandrel 220 may continue to move vertically downwardly, extending beyond the base of the vertically extending portion 212 of the outer mandrel 210, and pushing/urging the disc 50 into the open end 62 of the container 60 (see Fig. 6).

[00087] The inner mandrel 220 may comprise a first mandrel surface 222 adjacent a second mandrel surface 224, together configured to insert and shape a paper-based disc 50 (see Fig. 12). In an embodiment, the first mandrel surface 222 may join the second mandrel surface 224 in an angle of between about 92° and 94°. In an embodiment, the first mandrel surface 222 may be horizontal or substantially horizontal and may be disposed adjacent the top surface of the disc 50 when fully extended. In an embodiment, the second mandrel surface 224 may be vertical or substantially vertical and may be configured to be adjacent an inner surface of the vertically extending portion 212 of the outer mandrel 210 as the inner mandrel 220 passes through the outer mandrel 210. That is, the circumference of the second mandrel surface 224 may be less than the inner circumference of the vertically extending portion 212 of the outer mandrel 210. In an embodiment, the second mandrel surface 224 is parallel to the inner surface of the vertically extending portion 212 of the outer mandrel 210.

[00088] It is noted that while the first mandrel surface 222 and the second mandrel surface 224 are depicted in the figures as being substantially flat (horizontal and vertical), the first mandrel surface 222 and the second mandrel surface 224 may be curved, contoured or shaped. The inner mandrel 220 may further comprise a shaped portion that is disposed between the first mandrel surface 222 and the second mandrel surface 224. The shaped portion may be curved, chamfered, or comprise any other

contour. It is noted that, while the inner mandrel 220 is depicted as having a substantially circular cross-section, the inner mandrel 220 may have a cross-section that is substantially circular, triangular, rectangular, quadrangular, pentagonal, hexagonal or elliptical.

[00089] As the inner mandrel 220 pushes the disc 50 into the container 60 (see Figs. 5-6), the disc is released from between the outer mandrel 210 and the positioning portion 90 of the die assembly 300. The central portion 56 of the disc 50 may be pushed downwardly, through the die opening 98, into the open end 62 of the container 60, such that the central portion 56 (the first deformed surface 53) remains flat or substantially flat (i.e. horizontal). During insertion of the disc 50 into the container 60, in an embodiment, the peripheral portion 58 of the disc 50 may be bent at a right angle or a near-right angle, shown as the second deformed surface 55 in Fig. 11. In this embodiment, the peripheral portion 58 of the disc 50 (becoming the second deformed surface 55) may be forced adjacent the second mandrel surface 224, passing through the die opening 98. The resulting second deformed surface 55 (previously the peripheral portion 58) of the disc 50 may be disposed vertically or nearly vertically, adjacent the inner sidewall 66 of the container 60, at the open end 62.

[00090] The disc 50 may be pushed into the container 60 any distance that would be practical in the art. In an embodiment, the disc 50 becomes a recessed composite bottom 51 (Fig. 11). In an embodiment, the peripheral edge 57 of the disc 50 is flush with the edge of the sidewall of the container 60. In another embodiment, the peripheral edge 57 of the disc 50 is disposed inward, in relation to the container 60, of the edge of the sidewall of the container 60. In an embodiment, the first deformed surface 53 and

the second deformed surface 55 are joined in a right angle or a near-right angle, within the container body 60.

[00091] In an embodiment, a mandrel heater may be configured to heat the first mandrel surface 222 and/or the second mandrel surface 224 of the inner mandrel 220, in an embodiment. In an embodiment, the mandrel heater may be disposed within the inner mandrel 220. The inner mandrel 220 may, in an embodiment, further comprise an insulated portion formed from a heat insulating material that is configured to mitigate heat transfer.

[00092] The Sealing Members

[00093] The sealing member(s) 40 may be configured to provide heat and pressure for heat sealing. The sealing member(s) 40 may be positionable between a sealing position (FIGS. 1-6) and an open position (FIGS. 7-11). When in the sealing position, sealing member(s) 40 are in contact with the outer surface 64 of the container 60 and when in the open position, the sealing member(s) 40 are not in contact with the container 60. In an embodiment, the sealing member(s) 40 comprise segmented clamping brackets (see FIGS. 1-16 generally).

[00094] In other embodiments, the sealing member 40 comprises a non-segmented clamping ring (see FIGS. 17-33). FIG. 17 illustrates the inventive system with a non-segmented clamping ring, wherein the system is in its initial state. In FIG. 18, the system moves into position with a disc clamped in place. In FIG. 19, the system moves into the sealing position. FIG. 20 illustrates the removal of the sealing punch while the ejector supports the paper bottom in place. Finally, FIG. 21 illustrates the ejector moving away from the container. FIGS. 17-23 additionally illustrate the connections to

the evacuation line. In this embodiment, the sealing member may comprise a static die bush ring. This type of sealing member may be particularly useful in ready-to-eat food processing equipment, which has a high focus on food safety.

[00095] In an embodiment, for example a segmented clamping bracket embodiment, the sealing member(s) 40 may be rotatably coupled to the die assembly 300. The sealing member(s) 40 may be complementarily shaped to one another such that, when the sealing member(s) 40 are in the sealing position, the sealing member(s) 40 substantially surround the work piece in a puzzle-like manner. In other embodiments, the sealing member 40 may comprise a single, unitary member (i.e. a closed ring) which surrounds the container body 60 when the container is in position. When sealing a paper-based disc 50 to a composite body 60, the sealing member(s) 40 may compress the bottom end 62 of the composite body 10 along a substantially complete perimeter of the exterior surface 64. When the composite body 60 has a substantially circular cross-section, a circumference of the composite body 60 may be compressed substantially evenly by the sealing member(s) 40. In an embodiment, three sealing member(s) 40 are present. In other embodiments, one sealing member 40 is present (i.e. a non-segmented clamping ring). It is noted that any number of sealing member(s) 40 may be utilized, however. For example, the sealing system may comprise from about one to about ten sealing member(s) 40. Moreover, the sealing member(s) 40 may each cover substantially equal segments of the composite body or may cover substantially non-equal segments.

[00096] The sealing member(s) 40 may be utilized to compress and heat a work piece in order to perform a heat-sealing operation. Each sealing member 40 may provide

conductive heating to a container of up to about 300° C. Moreover, the sealing member(s) 40 may apply a pressure of up to about 30 MPa to a container. The sealing member(s) 40 may be adjacent to one another.

[00097] As the sealing member(s) 40 contact the exterior surface 64 of the container body 60, the container body 60 and the composite closure 51 may be compressed between the second mandrel surface 224 and the sealing member(s) 40. After compression and heat has been applied for a sufficient dwell time, the sealing member(s) 40 may be moved away from the bottom end 62 of the container body 60 such that the sealing member(s) 40 are not in contact with the container body 60 (FIG. 7) after the dwell time expires.

[00098] Ejector

[00099] Once the sealing process is complete, in an embodiment, the mandrel assembly 200 is removed from the container body 60. In an embodiment, the outer mandrel 210 releases and is translated away from the die assembly 300 prior to movement of the inner mandrel 220. In other embodiments, the outer mandrel 210 and inner mandrel 220 simultaneously release and translate away from the die assembly 300.

[000100] In an embodiment, an ejector 30 is disposed interior of the inner mandrel 220 to aid in the removal of the mandrel assembly 200 from the container 60. The ejector 30 may be spring-loaded, in an embodiment. In other embodiments, the ejector 30 may not be spring loaded. In some embodiments, the inner mandrel 220 may or may not be spring loaded. In a further embodiment, the outer mandrel 210 may or may not be spring loaded. In a particular embodiment, only the outer mandrel 210 is spring loaded.

[000101] The ejector 30 may have a circumference on its lower end 32 which is less than the circumference of the inner mandrel 220. In this respect, the ejector 30 may be fitted within the inner circumference of the inner mandrel 220 in its retracted position (shown in Fig. 12, for example). In an embodiment, the base of the ejector 30 may comprise a cylindrical pyramid. In such an embodiment, the interior of the inner mandrel 220 may comprise a recess which is cylindrically pyramidal, such that the ejector 30 can be fitted into the inner mandrel 220. In an embodiment, the ejector 30 may be perforated and/or may have through holes disposed therein, as shown in FIGS. 20 and 28.

[000102] In another embodiment, the base of the ejector 30 may comprise a plurality of disc contact sections, each contacting the bottom closure 51, but separated from one another. For example, the ejector may comprise three or four prongs that are flattened at the contact surface with the closure 51, to avoid damage to the closure 51.

[000103] In an embodiment, the ejector has a bottom surface 34 designed to contact the bottom closure 51. The ejector 30 may be solid across its bottom surface 34, from one side of the diameter to the other side of the diameter, in an embodiment. In another embodiment, the ejector 30 may have a hollow interior portion, as shown in the figures. In this embodiment, the bottom contact surface 34 may be circular in cross-section. In any embodiment, the bottom surface 34 of the ejector 30 may contact at least a portion of the first deformed surface 53 of the composite closure 51. In an embodiment, the first deformed surface 53 of the closure 51 may comprise a countersink portion of the closure 51. In a particular embodiment, the bottom surface 34 of the ejector 30 is

circumferential and positioned near the second deformed surface 55 of the composite closure 51 when in its extended position (shown in Fig. 13, for example).

[000104] In one embodiment, the bottom surface 34 of the ejector 30 may be flush with the first (lower) surface 222 of the inner mandrel 220 when the ejector 30 is in its recessed position (shown, for example in Fig. 12). In another embodiment, the ejector 30 may be recessed slightly within the inner mandrel 220 such that the bottom surface 34 of the ejector 30 is higher than the first (lower) surface 222 of the inner mandrel 220 when the ejector is in its recessed position.

[000105] In an embodiment, the ejector 30 and the inner mandrel 220 (and/or outer mandrel 210) may each translate vertically, separately from one another. That is, the inner mandrel 220 may move a first distance and the ejector 30 may move a second distance, wherein the first and second distances are different from one another.

Likewise, the inner mandrel 220 may move at a first time and the ejector 30 may move at a second time, wherein the first and second times are different from one another. In an embodiment, the inner mandrel 220 and the ejector 30 may move in unison during a first time period. In an embodiment, the inner mandrel 220 may have a first extension length and the ejector 30 may have a second extension length, wherein the first and second extension lengths are different from one another.

[000106] In a particular embodiment, the inner mandrel 220 (and/or outer mandrel 210) is initially vertically retracted from the container 60, while the ejector 30 remains positioned adjacent the composite closure 51 (shown in Figs. 8 and 13), retaining the position of the paper-based closure 51 within the container 60. In this embodiment, a space may be disposed between the outer circumference of the lower end 32 of the

ejector 30 and the deformed portion 55 of the closure 51. This position (Figs. 8 and 13) may be referred to as the extended position of the ejector 30. In this embodiment, once the inner mandrel 220 is retracted beyond the peripheral edge of the container 60, in an embodiment, the ejector 30 is then retracted vertically upward, back into the interior of the inner mandrel 220.

[000107] In another embodiment (see FIG. 28E), after the sealing process is complete, the ejector 30 may extend further downwardly than it extended during the sealing process in order to aid in removal of the container 60 from the die assembly 300. That is, the ejector 30 may push the container 60 downwardly via pressure on the closure 51. Alternatively, the ejector 30 may not add pressure to the closure 51, but may translate downwardly with the container 60 and closure 51, in concern with the movement of the container assembly. In this embodiment, the ejector 30 may then retract from contact with the closure 51 and retract into the mandrel assembly 200.

[000108] In an embodiment, the ejector 30 comprises a means for delivering a controlled blast of air directed toward the closure 51 concurrent with or just before retraction of the ejector 30 from the closure 51. In an embodiment, the delivery of pressurized air may comprise a shower head mechanism disposed within the ejector 30. In an embodiment, the mandrel assembly 200 comprises an ejector coupling 201 and a mandrel or sealing head coupling 202 (see FIG. 19).

[000109] The ejector 30 of the invention avoids the issue caused by a standard mandrel retraction process. That is, a standard mandrel retraction involves dragging the mandrel out of the container (or vice versa), causing friction between the mandrel and the paper-based closure. As the mandrel and the container are separated, any

relative movement of the paper-based closure can cause folds, wrinkles, and/or bubbles to form in the seal, reducing or destroying the hermeticity of the container. The ejector 30 of the present invention allows stabilization of the position of the paper-based closure within the container body during the process of removing the mandrel (i.e. during outfeed). The ejector 30 helps to ensure the hermeticity of the seal between the closure 51 and the container 60, over the complete cycle of the paper bottom sealing process.

[000110] After retraction of both the inner mandrel 220 and the ejector 30, the container may be removed from the die assembly 300 and the mandrel assembly 200, optionally in a vertically downward manner (Fig. 10). In an embodiment, the movement of the inner mandrel 220, the ejector 30, and container may be synchronous. In an embodiment, the inner mandrel 220 and outer mandrel 210 may then fully retract vertically upwardly from the die assembly 300, optionally in a unitary manner (Fig. 11). In an embodiment, the mandrel assembly 200 and the die assembly 300 are then positioned for another insertion, bottom closure formation, and sealing process.

[000111] Container support assembly

[000112] The container support assembly may be configured to retrieve and/or retain a composite body 60 and hold the composite body 60 in a desired location. The container support assembly may comprise a tube support member that is shaped to accept the composite body 60. In an embodiment, the tube support member may lift the container 60 upwardly vertically to meet the die assembly 300 and the mandrel assembly 200.

[000113] In an embodiment, the container 60 will be inserted into the die assembly by lifting upwardly and will be fixed in the vertical position in the die assembly by contacting

the rim or edge of the container 60 with the lower surface of the die opening 98 (see FIG. 2-3). The container 60 will be in a secured position to avoid relative vertical movements of the container 60 while the inner mandrel 220 moves in and out of the container assembly.

[000114] Closure

[000115] As shown in Fig. 2, in an embodiment, the paper-based disc 50 may have an upper surface 52 and a lower surface 54 that define a sheet thickness. The paper-based disc 50 may comprise a layered structure in an embodiment, i.e., a fiber layer, an oxygen barrier layer and a sealant layer. The paper-based disc 50 may comprise a central portion 56 and a peripheral portion 58. The central portion 56 and the peripheral portion 58 may be substantially flat, in an embodiment. For example, the paper-based disc 50 may be cut or shaped into a circular disc. In other examples, the paper-based disc 50 may be cut or formed into a domed disc (not depicted) such that the central portion 56 is offset along the Y-axis from the perimeter portion 58.

[000116] After formation, the paper-based disc 50 becomes a bottom closure 51 (Fig. 11). The bottom closure 51 may have a first deformed surface 53 and a second deformed surface 55. The first deformed surface 53 may be substantially horizontal, in an embodiment. In an embodiment, the first deformed surface 53 comprises the central portion 56 of the paper-based disc. In another embodiment, the second deformed surface 55 may be substantially vertical and/or may comprise the peripheral portion 58 of the paper-based disc. In an embodiment, the first deformed surface 53 may be adjacent the interior cavity of the container 60 and the second deformed surface 55 may be adjacent the interior surface 66 of the container 60 sidewall.

[000117] Methods

[000118] In use, the sealing system 100 accepts a disc 50 and seats the disc 50 within the positioning portion 90 of the die assembly 300, optionally using vacuum pressure to properly seat the disc. In an embodiment, a container 60 is then lifted via lifting plates toward the die assembly 300 until the peripheral edge of the container 60 contacts the lower surface of the die 80. In this embodiment, the container inner sidewall 66 may be flush with the die opening 98. The outer mandrel 210, in an embodiment, is then vertically translated downwardly toward the disc 50 until the outer mandrel 210 contacts the peripheral portion 58 of the disc 50, constraining it in place. More particularly, the vertically extending portion 212 of the outer mandrel 210 may be configured to secure the disc 50 in place (see Fig. 4).

[1] Once the disc 50 is clamped in place via the outer mandrel 210 (i.e. the vertically extending portion 212 thereof), the open end (bottom) of the container 60 is isolated from the surrounding atmosphere. The force of the outer mandrel 210 against the disc 50 may create an airtight or nearly airtight condition within the container 60, between the container 60 and the disc 50. The gas valve(s) are then opened, if necessary, and air is vacuumed out of the container interior, through the channel openings 440 and channel 430, thus creating an underpressure condition within the container 60. More particularly, the side channel pump or vacuum pump may be designed to suction a defined volume of gas from the interior of the container. The defined volume of gas may be related to the size and volume of the container 60 and the depth to which the disc 50

is to be inserted into the container 60 for sealing thereto. More particularly, the defined volume of gas may be defined as the insertion depth of the paper bottom multiplied by the interior volume of the container. In any embodiment, the volume of gas which is evacuated should be less than that which would cause collapse of the container 60. In some embodiments, the speed at which gas is evacuated from the container may be adjusted. For example, some containers, such as containers having a larger interior volume, may have a greater risk of collapse using a high speed gas evacuation process. In some cases, the vacuum level may be adjusted. For example, a process using a higher vacuum pressure may require a lower flow rate for the gas evacuation process. A process using a lower vacuum pressure may require a higher flow rate for the gas evacuation process. One of skill in the art would understand these variations.

[000119] In some embodiments, the gas evacuation process may occur over a period of about 60 msec or less. In other embodiments, the gas evacuation process may occur over a period of about 40 msec to about 50msec. In some embodiments, the gas evacuation process may occur over a period of about 200 msec or less.

[000120] When the side channel pump or vacuum pump is triggered, air within the tubes, connector 410, and valve 420 may be suctioned into the side channel pump or vacuum pump. Further, air within the channel 430, channel openings 440 and interior of the container may be suctioned into the side channel pump or vacuum pump. Without releasing the pressure between the outer mandrel 210 and the disc 50, the paper disc 50 is then immediately inserted into (or punched into) the container 60 in a recessed fashion via the inner mandrel 220. The suction and insertion steps may occur simultaneously or nearly simultaneously. That is, the air may be suctioned from the

interior of the container a fraction of a second prior to insertion of the disc 50 into the container 60.

[000121] In an embodiment, insertion of the disc 50 into the container 60 is accomplished via the inner mandrel 220. In this embodiment, the inner mandrel 220 and the ejector 30 may continue to translate vertically downward toward the disc 50. The inner mandrel 220 and the ejector may then contact the disc 50 and urge the disc 50 downwardly, through the die opening 98, until the disc 50 becomes deformed such that it has a flat central portion and a deformed sidewall 55 adjacent the inner sidewall 66 of the container 60. In one embodiment, pressure may be applied to the disc by the first mandrel surface 222 and/or second mandrel surface 224 of the inner mandrel 220 (e.g., by actuating the inner mandrel 220 along the Y-direction).

[000122] The deformed composite closure 51 may then be hermetically sealed to the container body 60. In an embodiment, this occurs without releasing the inner mandrel and die pressures which maintain the underpressure condition within the container. Compression and heat may be applied to the deformed composite closure 51 and/or the container body 60 such that their respective sealant layers form a hermetic seal. In an embodiment, heat is provided via at least the sealing members 40. Likewise, the sealing members 40 and the second mandrel surface 224 of the inner mandrel 220 may provide opposing pressure to the exterior surface 64 of the container 60 and/or the deformed sidewall 55 of the closure 51.

[000123] Hermetic seals, according to the present disclosure, may be formed by sealing members 40 at a temperature greater than about 90° C such as, for example, 120° C to about 280° C or from about 140° C to about 260° C. Suitable hermetic seals

may be formed by keeping the sealing member(s) 40 in contact with the bottom end 62 of the composite body 60 for any dwell time sufficient to heat a sealant layer to a temperature suitable for forming a hermetic seal such as, for example, less than about 5 seconds, from about 0.8 seconds to about 5.0 seconds or from about 1 second to about 4 seconds. The bottom closure 51 and the bottom end 62 of the composite body 60 may be compressed between the sealing members 40 and the inner mandrel 220 with any pressure less than about 30 MPa such as a pressure from about 1 MPa to about 22 MPa.

[000124] After compression and/or heat has been applied for a sufficient dwell time, the sealing members 40 may be moved away from the bottom end 62 of the container 60 such that the sealing members 40 are not in contact with the composite body 10 (FIG. 7) after the dwell time expires. The inner mandrel 220 may then be retracted from the closure 51, while the ejector 30 remains in place. Once the inner mandrel 220 at least clears the peripheral edge of the container 60, the ejector 30 is then retracted, optionally accompanied by a blast of pressurized air to aid in a smooth retraction process. The ejector 30 is then fully retracted into the interior of the inner mandrel 220. The container 60 is then moved away from the die assembly 300 and mandrel assembly 200, prior to, during, or after the full retraction of the mandrel assembly 200 from the die assembly 300.

[000125] In an embodiment, the systems and methods described herein may produce hermetically sealed containers having a paper-based, composite bottom which is inserted into a composite container and sealed in a recessed position without causing doming of the membrane seal (i.e. the membrane seal on the top end) due to

overpressure within the container. Because the top seal membrane is not domed, there are no instability issues. The container can stably stand on its membrane end (upside down) as it is being conveyed to a downstream packaging process (i.e. from the sealing machine to the case packer). Further, an overcap will easily fit onto the container if the membrane lid because the membrane lid is not domed.

[000126] Further, the hermetically sealed containers of the invention may be transported worldwide via, for example, shipping, air transport or rail, subjected to varying atmospheric conditions (e.g., caused by variations in temperature, variations in humidity, and variations in altitude), without unacceptable doming of the membrane lid.

[000127] In certain embodiments, a plurality of composite containers may be formed by a system or device suitable for processing multiple paper-based discs, bottom closures and composite containers in a synchronized manner. For example, a manufacturing system may include a plurality of mandrel assemblies, a plurality of die assemblies, a plurality of gas evacuation assemblies and a plurality of tube support assemblies operating in a coordinated manner. Specifically, a turreted device with a plurality of sub-assemblies wherein each sub-assembly comprises a mandrel assembly, a die assembly, a gas evacuation assembly and a tube assembly may accept discs and process the discs simultaneously or synchronously. Depending upon the complexity of the turreted device, hundreds of separate composite containers may be manufactured per cycle in a coordinated manner. Thus, any of the processes described herein may be performed contemporaneously. For example, when each sub-assembly operates in a synchronous manner, each of the following may be performed contemporaneously: a first paper-based disc may be positioned above a die opening; a second paper-based

disc may be constrained between a mandrel assembly and a die assembly; a third paper-based disc may be formed into a first bottom closure via insertion into a first composite body; and a third bottom closure may be hermetically sealed to a second composite body. Alternatively, any of the operations described herein may be performed simultaneously such as, for example, by a device having a plurality of sub-assemblies.

[000128] In an embodiment, the systems and methods of the present invention allow sealing system to operate at high speeds (*e.g.*, over 300 containers per minute). In another embodiment, the systems and methods of the present invention allow sealing system to operate at a speed of at least 400 containers per minute. In still another embodiment, the systems and methods of the present invention allow sealing system to operate at a speed of at least 500 containers per minute.

[000129] It should be understood that the present disclosure provides for hermetically closed containers for packaging humidity-sensitive and/or oxygen-sensitive solid food products such as, for example, crisp carbohydrate-based food products, salted food products, crisp food products, potato chips, processed potato snacks, nuts, and the like. Such hermetically closed containers may provide a hermetic closure under widely varying climate conditions of high and low temperature, high and low humidity, and high and low pressure. Moreover, the hermetically closed containers can be manufactured according to the methods described herein via processes involving conductive heating technology with relatively low environmental pollution. The hermetically closed containers described herein may have high structural stability at low weight and be suitable for recycling.

Examples

[000130] In the following examples, paper-bottom containers of the invention (composite container, paper bottom, membrane cover, and overcap) were tested for various characteristics. The paper bottom of the tested containers comprised a flexible board (i.e. cup stock) as the paper layer (195 g/m² (0.3 mm thickness)), a tie layer, aluminum foil (8µm) as a barrier layer, and an ionomer layer (32 g/m²) as a sealant layer. In some containers, a PET layer was included to protect the aluminum barrier layer. In other embodiments, an aluminum barrier layer was not included. All versions passed the testing, as indicated below.

[000131] Example 1

[000132] In the high altitude testing, the inventive containers were placed into a sealed chamber and the pressure within the chamber was increased to at least 11 inHg over a period of about 10 minutes. If the containers can withstand up to 10 inHg (simulating the atmospheric pressure as containers travel over the Rocky Mountains) for at least 10 minutes, the containers passed the test. If not, the containers are listed as “missed”. As used herein, “Rocker Bottoms Observed” means during the vacuum chamber confinement, the membrane and/or paper bottom domed due to the overpressure conditions, which is normal under such conditions. After removal from the container, the doming returned to neutral. Doming may constitute the membrane or paper bottom moving outwardly from the interior of the container such that it extends beyond the relevant cut edge of the container. A miss or failure includes a leak, a peeling membrane or paper bottom, a retained distortion after pressure is released, a split or delamination of a seam, a bursting of a membrane or paper bottom, and/or another other failure that would prevent the container from meeting hermeticity standards. If a membrane or paper

bottom domes inwardly into the can upon pressure release, this may indicate a leakage failure. The test results are set forth below.

[000133] Table 1a. High Altitude Testing (“HAT”) Results.

Batch #	Batch Size	HAT (10” Hg/10 min)	Rocker Bottom Observed
1	1027 containers	0 missed	~ -11 inHg
2	558 containers	0 missed	~-11 inHg
3	435 containers	0 missed	~-11 inHg
4	550 containers	0 missed	~-11 inHg
5	232 containers	7 missed	~-11 inHg
6	258 containers	1 missed	~-11 inHg
7	1667 containers	16 missed	~-11 inHg
8	193 containers	5 missed	~-11 inHg

[000134] The testing indicated a 99.4% success rate for the paper bottoms as described herein, which is acceptable.

[000135] Table 1b. High Altitude Testing Results

Batch #	Batch Size	HAT Failure	Rocker Bottom Observed
Standard Laminates			
1	20 containers	0 missed Failure at -15.8 in Hg	~-13 inHg
2	20 containers	0 missed Failure at -15.4 in Hg	-13 to -14 inHg
3	25 containers	1 missed Failure at -14.5 in Hg	n/a

4	25 containers	2 missed Failure at -13.5 in Hg	n/a
5	25 containers	0 missed Failure at -14.8 in Hg	-12 to -13 inHg
6	25 containers	0 missed Failure at -14.8 in Hg	-13 to -14 inHg
7	10 containers	0 missed Failure at -14.5 in Hg	-11.6 inHg AVG
8	10 containers	0 missed Failure at -15.7 in Hg	-11.4 inHg AVG
Light Weight Laminates			
11	10 containers	0 missed Failure at -16.2 in Hg	-9.8 inHg
12	10 containers	0 missed Failure at -16.4 in Hg	-9.5 inHg
13	10 containers	0 missed Failure at -14.7 in Hg	-9.5 inHg
14	10 containers	0 missed Failure at -13.8 in Hg	-8.8 inHg

[000136] The testing indicated a 98% success rate for standard laminates and a 100% success rate for lightweight paper bottoms as described herein, which is acceptable.

[000137] Example 2

[000138] In this example, inventive containers were subjected to helium leak testing. Helium can be used as a tracer gas to detect leaks because it constitutes only about 5 ppm in the atmosphere, so background levels are very low. Helium has also relatively low mass so that it is mobile and is completely inert/non-reactive. The sealed inventive containers were placed in a sealed vacuum chamber and the vacuum chamber was then flooded with helium at 130 mbar. A sniffer/leak detector was connected to the container so that a sample of gas from within the container could be drawn off and passed through

a mass spectrometer to read increases over the background reading of helium levels in the container. In this example, the helium leakage limit was 2.3×10^{-4} mbar*/l/sec. A success rate of 99.8% was observed. This result is acceptable.

[000139] Table 2. Helium Leak Testing (“HLT”) Results

Batch #	Batch Size	HLT (130 mbar); limit: 2.3×10^{-4} mbar*/l/sec	Rocker Bottom Observed
1	1027 containers	2 missed	None
2	558 containers	2 missed	None

[000140] Example 3.

[000141] In this example, inventive containers were subjected to container integrity testing. The containers were placed under 200 mbar pressure in a vacuum chamber and vacuum decay was measured over a 20 second period. The method uses a pressure change measurement to indirectly determine the flow from the container into the fixed volume chamber. The mass extraction variant measures the flow required to maintain the vacuum at a fixed level (ASTM F2338 and ASTM F 3287). If the container has a leak, it will reduce the expected vacuum inside the vacuum chamber. The vacuum drop or decay was measured per second. The success/failure threshold was set at 42 Pa/s. A success rate of 98.6% was observed. This result is acceptable.

[000142] Table 3. Container Integrity Test (“CIT”) Results

Batch #	Batch Size	CIT (200 mbar, 20 sec)	Rocker Bottom Observed	Failure Type
1	10 containers	0 missed	none	none
2	10 containers	0 missed	none	none
3	14 containers	0 missed	none	none
4	14 containers	0 missed	none	none
5	60 containers	2 missed	none	none
6	35 containers	0 missed	none	none
7	3247 containers	44 missed	none	none

[000143] Example 4.

[000144] In this example, inventive containers were subjected to container Periodic Test Interval (“PTI”) testing. The containers were placed under 700 mbar pressure in a vacuum chamber and vacuum decay was measured over a 20 second period. The vacuum drop or decay was measured per second. The success/failure threshold was set at 20 Pa/s. A success rate of 96% was observed. This result is acceptable.

[000145] Table 4. PTI Testing Results

Batch #	Batch Size	PTI (700 mbar, 20 sec)	Rocker Bottom Observed	Failure Type
1	26 containers	1 missed	none	none
2	25 containers	1 missed	none	none

[000146] Example 5.

[000147] In this example, the inventors analyzed simulated shelf life of the inventive containers. The containers were filled, sealed, and stored having a residual oxygen level of 0.0%. The containers were then tested for residual oxygen levels after 6 months and 9 months. The success/failure threshold was set at less than or equal to 2.0% residual oxygen over these time periods (a threshold of 4.0% - 4.5% may be acceptable after about 18 months). A success rate of 92% was observed. This result is acceptable.

[000148] Table 5. Simulated Shelf Life Results

Container Age	Batch Size	Measured Residual Oxygen in Containers that Passed	Failures
6 months	19 containers	Between 0.32% and 0.34%	3 missed (due to mechanical damage to the container)
6 months	39 containers	0.0%	4 missed
9 months	39 containers	0.0%	1 missed

[000149] Example 6.

[000150] In this example, the inventors compared the leakage of containers having the inventive paper bottom closures to containers having a metal bottom closure using the vacuum decay methods described herein. The drop in pressure was measured in Pa/s for the cans. The “blue” and “green” cans are paper bottom containers while the “Reference with metal end” comprises metal bottom containers. As can be seen, the paper bottom containers have overall less pressure drop during the vacuum decay than

the containers having metal bottom ends. FIG. 34 illustrates a graph of the results. Overall, the paper bottoms of the invention outperformed the metal bottoms in terms of consistency of avoiding leaks.

CLAIMS

What is claimed is:

1. A sealing system for sealing a closure to a container comprising:
 - a die assembly comprising:
 - a die having a positioning portion configured to retain a disc and a die opening adjacent the positioning portion; and
 - at least one sealing member configured to provide heat to seal the disc to the container; and
 - a mandrel assembly having a recessed position and an extended position and comprising:
 - an outer mandrel comprising an extending portion which is sized to fit within an inner circumference of the positioning portion in its extended position, adjacent a peripheral portion of the retained disc;
 - an inner mandrel configured to translate through an inner circumference of the extending portion of the outer mandrel and the die opening to its extended position,
 - wherein the sealing member is disposed opposite the mandrel assembly when the mandrel assembly is in its retracted position; and
 - a gas evacuation assembly comprising:
 - at least one hollow channel disposed at least partially circumferentially within the die;
 - at least one channel opening disposed in the die which connects the at least one channel to an interior of the die, wherein the at least one channel

opening is disposed between the positioning portion of the die and the sealing member; and

a means for suctioning gas from the interior of the die, the at least one channel opening, and the at least one channel to an exterior of the die.

2. The system of claim 1 comprising a plurality of channel openings.
3. The system of claim 1 additionally comprising at least one valve disposed within the die, connecting the at least one channel to the exterior of the die.
4. The system of claim 3 additionally comprising at least one tube connecting the at least one valve to the means for suctioning gas.
5. The system of claim 1 wherein the means for suctioning gas comprises a side channel pump.
6. The system of claim 1 additionally comprising a plurality of valves disposed within the die, connecting the at least one channel to the exterior of the die.
7. The system of claim 1 wherein the channel openings are disposed between the retained disc and the container to which it is to be sealed.
8. The system of claim 1 wherein the extending portion of the outer mandrel has a greater circumference than that of the die opening.
9. The system of claim 1 wherein the extending portion of the outer mandrel constrains the disc in the positioning portion of the die.
10. The system of claim 1 wherein the at least one channel opening is vertically disposed between the positioning portion of the die and the sealing member.
11. The system of claim 1, wherein the outer mandrel, the inner mandrel, and the ejectors extend, translate, and retract parallel to one another.

12. The system of claim 1, wherein:

- the outer mandrel extends vertically;
- the inner mandrel translates vertically; and
- the ejector translates vertically.

13. The system of claim 1 wherein the closure is paper-based.

14. A method for sealing a closure to a container comprising:

providing a die assembly comprising:

a die having a positioning portion configured to retain a disc and a die opening adjacent the positioning portion; and

at least one sealing member configured to provide heat to seal the disc to the container; and

providing a mandrel assembly having a recessed position and an extended position and comprising:

an outer mandrel comprising an extending portion which is sized to fit within an inner circumference of the positioning portion in its extended position, adjacent a peripheral portion of the retained disc;

an inner mandrel configured to translate through an inner circumference of the extending portion of the outer mandrel and the die opening to its extended position,

wherein the sealing member is disposed opposite the mandrel assembly when the mandrel assembly is in its retracted position; and

providing a gas evacuation assembly comprising:

at least one hollow channel disposed at least partially circumferentially within the die;

at least one channel opening disposed in the die which connects the at least one channel to an interior of the die, wherein the at least one channel opening is disposed between the positioning portion of the die and the sealing member; and

a means for suctioning gas from the interior of the die, the at least one channel opening, and the at least one channel to an exterior of the die;

positioning the disc in the positioning portion of the die;

axially aligning the container with the positioning portion of the die;

positioning the container such that a peripheral edge of the container is in contact with a lower surface of the die;

translating the outer mandrel such that it constrains the disc in the positioning portion of the die;

suctioning gas from an interior of the container, the at least one channel opening, and the at least one channel to an exterior of the die;

translating the inner mandrel such that it pushes the disc into the container and deforms the disc into a container end; and

sealing the container end to the container.

15. The method of claim 14 wherein when the outer mandrel constrains the disc in the positioning portion of the die, the interior of the container is sealed off from access to the atmosphere.

16. The method of claim 14 wherein when suctioning step and the translating the inner mandrel step occur simultaneously.

17. The method of claim 14 wherein when suctioning step and the translating the inner mandrel step occur nearly simultaneously.

18. The method of claim 14 comprising a plurality of channel openings.

19. The method of claim 14 additionally comprising at least one valve disposed within the die, connecting the at least one channel to the exterior of the die.

20. The method of claim 19 additionally comprising at least one tube connecting the at least one valve to the means for suctioning gas.

21. The method of claim 14 wherein the means for suctioning gas comprises a side channel pump.

22. The method of claim 14 additionally comprising a plurality of valves disposed within the die, connecting the at least one channel to the exterior of the die.

23. The method of claim 14 wherein the channel openings are disposed between the retained disc and the container to which it is to be sealed.

24. The method of claim 14 wherein the extending portion of the outer mandrel has a greater circumference than that of the die opening.

25. The method of claim 14, wherein the outer mandrel, the inner mandrel, and the ejectors extend, translate, and retract parallel to one another.

26. The method of claim 14, wherein:

the outer mandrel extends vertically;

the inner mandrel translates vertically; and

the ejector translates vertically.

27. The method of claim 14, wherein the sealing member is disposed vertically opposite the mandrel assembly when the mandrel assembly is in its retracted position.

28. The method of claim 14, wherein the at least one channel opening is vertically disposed between the positioning portion of the die and the sealing member.

29. The method of claim 14 wherein the closure is paper-based.