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Moveable gripper for gripping a container and heating contents of the container through dynamically controlled thermal contact and heat settings

Abstract

Embodiments of the invention are directed to an apparatus that includes a moveable gripper element including a flexible inner sleeve. A mechanical energy source mechanism is communicatively coupled to the moveable gripper element, and a sensor network is communicatively coupled to the moveable gripper. A controller is communicatively coupled to the mechanical energy source mechanism and the sensor network. The flexible inner sleeve defines an adjustable opening. The controller controls the mechanical energy source mechanism to transfer to the moveable gripper element a gripping force configured to move the moveable outer sleeve, reduce a size of the adjustable opening, and bring the flexible inner sleeve into an initial level of thermal contact with a container positioned within the adjustable opening. The controller is configured to, subsequent to establishing the initial level of thermal contact, control the mechanical energy source mechanism to make adjustments to the gripping force.

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Background/Summary

BACKGROUND
(1) The present invention relates in general to heating systems. More specifically, the present invention relates to a heating system having a moveable gripper configured to grip a container and deliver heat to the contents of the container by dynamically controlling thermal contact and heat settings at or near the interface between the moveable gripper and the container. In some aspects of the invention, a gripper sub-assembly is configured to agitate the moveable gripper while the moveable gripper dynamically grips and delivers heat to the contents of the container.
(2) Heaters have been developed to heat the contents of a container. Examples include heaters that use either microwave heating technologies or induction heating technologies. Microwave heaters (commonly referred to as microwave ovens) can heat a container (typically made of plastic or other types of dielectric material) by exposing it to an external heat source in the form of electromagnetic radiation in the microwave frequency range. The electromagnetic radiation effectively penetrates through the container and is absorbed by the stored liquid, thereby heating the liquid. Microwave ovens require non-metallic or polymeric containers so that the microwave radiation is not shielded and can penetrate through to heat the absorbed liquid.
(3) Induction heaters typically include an electromagnet and an electronic oscillator that passes a high-frequency alternating current (AC) through the electromagnet. The alternating magnetic field penetrates the conductive object, generating electric currents within the conductive object. These electric currents (referred to as “eddy currents”) are generated within the conductive object itself and flow through the resistance of the conductive material to induce a Joule heating effect. Unlike microwave heaters, induction heaters generate heat inside the conductive container itself, thereby heating the liquid contained in the conductive object via conduction. Induction heaters require metallic or electrically conductive containers and will not work on polymeric or dielectric containers.
SUMMARY
(4) Embodiments of the invention are directed to an apparatus that includes a moveable gripper element including a flexible inner sleeve. A mechanical energy source mechanism is communicatively coupled to the moveable gripper element, and a sensor network is communicatively coupled to the moveable gripper. A controller is communicatively coupled to the mechanical energy source mechanism and the sensor network. The flexible inner sleeve defines an adjustable opening. The controller controls the mechanical energy source mechanism to transfer to

the moveable gripper element a gripping force configured to move the moveable outer sleeve, reduce a size of the adjustable opening, and bring the flexible inner sleeve into an initial level of thermal contact with a container positioned within the adjustable opening. The controller is configured to, subsequent to establishing the initial level of thermal contact, control the mechanical energy source mechanism to make adjustments to the gripping force, wherein the adjustments to the gripping force increase thermal contact points at an interface between the flexible inner sleeve and the container; and displace air from the interface between the flexible inner sleeve and the container.
(5) Embodiments of the invention are directed to a method of making the above-described apparatus.
(6) Additional features and advantages are realized through the techniques described herein. Other embodiments and aspects of the invention are described in detail herein. For a better understanding, refer to the description and to the drawings.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
(1) The subject matter which is regarded as the present invention is particularly pointed out and distinctly claimed in the claims at the conclusion of the specification. The foregoing and other features and advantages are apparent from the following detailed description taken in conjunction with the accompanying drawings in which:
(2) FIG. **1** depicts a block diagram of a heating apparatus according to non-limiting embodiments of the invention;
(3) FIG. **2** depicts a perspective view of a moveable gripper according to non-limiting embodiments of the invention;
(4) FIG. **3** depicts a perspective view of a moveable gripper according to non-limiting embodiments of the invention;
(5) FIG. **4**A depicts a block diagram showing a Material A in contact with a Material B in accordance with non-limiting embodiments of the invention;
(6) FIG. **4**B depicts a block diagram showing a Material A in contact with a Material B in accordance with non-limiting embodiments of the invention;
(7) FIG. **4**C depicts a block diagram showing a Material A in contact with a Material B in accordance with non-limiting embodiments of the invention;
(8) FIG. **4**D depicts a block diagram showing a Material A in contact with a Material B in accordance with non-limiting embodiments of the invention;
(9) FIG. **5** depicts a table illustrating how various interface-parameters can be dynamically controlled, improved, and/or achieved in accordance with non-limiting embodiments of the invention;
(10) FIG. **6**A depicts a graph and a corresponding block diagram showing a Material A in contact with a Material B in accordance with non-limiting embodiments of the invention;
(11) FIG. **6**B depicts a graph and a corresponding block diagram showing compressed flexible Material A making sufficient thermal contact (i.e., dynamically increased thermal contact points and dynamically displaced air at the interface) with Material B to efficiently transfer and evenly distribute heat through the interface between Material A and Material B in accordance with non-limiting embodiments of the invention;
(12) FIG. **6**C depicts a graph and a corresponding block diagram showing a Material A in contact with a Material B in accordance with non-limiting embodiments of the invention;
(13) FIG. **6**D depicts a graph and a corresponding block diagram showing compressed flexible Material A making sufficient thermal contact (i.e., dynamically increased thermal contact points

and dynamically displaced air at the interface) with Material B to efficiently transfer and evenly distribute heat through the interface between Material A and Material B in accordance with non-limiting embodiments of the invention;

(14) FIG. **6**E depicts an example of how a controller and a sensor network can be used to determine adjustments to the gripping/heating settings, if necessary, to achieve a target interfacial thermal resistance level (i.e., dynamically increased thermal contact points between two materials; and dynamically displaced air at the interface between the two materials), heat transfer efficiency, and/or uniform heat distribution in accordance with non-limiting embodiments of the invention;

(15) FIG. **7**A depicts a table illustrating how various interface-parameters can be dynamically controlled, improved, and/or achieved in accordance with non-limiting embodiments of the invention;

(16) FIG. **7**B depicts a block diagram showing a flexible inner sleeve in uncompressed contact with a container wall having an irregular surface topology in accordance with non-limiting embodiments of the invention;

(17) FIG. **7**C depicts a block diagram showing a flexible inner sleeve in compressed contact with a container wall having an irregular surface topology in accordance with non-limiting embodiments of the invention;

(18) FIG. **7**D depicts a sequence of block diagrams illustrating how a flexible inner sleeve contacts and conforms a container wall having a conformable, irregular surface topology in accordance with non-limiting embodiments of the invention;

(19) FIG. **8**A depicts a perspective view of a flexible inner sleeve heater assembly included in the moveable gripper shown in FIGS. **1-3** rolled into a cylindrical shape according to non-limiting embodiments of the invention;

(20) FIG. **8**B depicts a first selectable heating zone of a flexible inner sleeve heater assembly according to non-limiting embodiments of the invention;

(21) FIG. **8**C depicts a second selectable heating zone of a flexible inner sleeve heater assembly according to non-limiting embodiments of the invention;

(22) FIG. **8**D depicts a third selectable heating zone of a flexible inner sleeve heater assembly according to non-limiting embodiments of the invention;

(23) FIG. **9**A depicts a cross-sectional view of an inner sleeve heater assembly according to non-limiting embodiments of the invention;

(24) FIG. **9**B depicts a cross-sectional view of the inner sleeve heater assembly according to non-limiting embodiments of the invention;

(25) FIG. **9**C depicts a cross-sectional view of the inner sleeve heater assembly according to non-limiting embodiments of the invention;

(26) FIG. **9**D depicts a cross-sectional view of the inner sleeve heater assembly according to non-limiting embodiments of the invention;

(27) FIG. **10**A depicts a cross-sectional view of a flexible inner sleeve heater assembly according to non-limiting embodiments of the invention;

(28) FIG. **10**B depicts a top-down, perspective view of a portion of a flexible inner sleeve heater assembly having a resistive metal foil layer etched to define a serpentine pattern according to non-limiting embodiments of the invention;

(29) FIG. **10**C depicts a top-down view of a portion of a flexible inner sleeve heater assembly having a resistive metal foil layer etched to define multiple serpentine patterns according to non-limiting embodiments of the invention;

(30) FIG. **11**A depicts a flow diagram illustrating a method in accordance with embodiments of the invention;

(31) FIG. **11**B depicts a flow diagram illustrating a method in accordance with embodiments of the invention;

(32) FIG. **11**C depicts a flow diagram illustrating a method in accordance with embodiments of the

invention;
(33) FIG. **12** depicts a machine learning system that can be utilized to implement aspects of the invention;
(34) FIG. **13** depicts a learning phase that can be implemented by the machine learning system shown in FIG. **12**; and
(35) FIG. **14** depicts details of an exemplary computing system capable of implementing various aspects of the invention.
(36) In the accompanying figures and following detailed description of the disclosed embodiments of the invention, the various elements illustrated in the figures are provided with two, three, or four digit reference numbers. In most instances, the leftmost digit(s) of each reference number corresponds to the figure in which its element is first illustrated.

DETAILED DESCRIPTION

(37) For the sake of brevity, conventional techniques related to making and using aspects of the invention may or may not be described in detail herein. In particular, various aspects of the materials, structures, computing systems, and specific computer programs to implement the various technical features described herein are well known. Accordingly, in the interest of brevity, many conventional implementation details are only mentioned briefly herein or are omitted entirely without providing the well-known system and/or process details.
(38) Turning now to an overview of technologies that are more specifically relevant to aspects of the present invention, microwave heaters and induction heaters are known heaters capable of quickly heating a material such as a consumable food or beverage. These conventional technologies, however, suffer from limitations. For instance, induction heaters typically require specific heating equipment and further require that the material to be heated is in or on a container specifically made to operate with a particular induction heating system. Microwave heaters are incapable of heating materials supported in or on metal containers because the metal material reflects the microwave energy, which prohibits it from reaching the material and can cause arcing and damage. In addition, microwave heaters also lack the precision to target specific locations or “zones” of a material.
(39) Turning now to an overview of aspects of the present invention, embodiments of the invention address the above-described shortcomings of known heating systems by providing a heating system having a gripper sub-assembly with a moveable gripper configured to grip containers having various sizes, shapes, flexibility levels, and surface topologies. The heating system is configured to grip and deliver heat to the container in a dynamically-controlled manner that efficiently transfers and evenly distributes heat through the container to the contents of the container. In some aspects of the invention, efficient heat transfer and even heat distribution are enhanced by configuring the moveable gripper to grip containers with a dynamically controlled gripping force that increases and/or maximizes thermal contact points between the movable gripper and the container; and that dynamically displaces air (i.e., reduces air-gaps) at the interface between the moveable gripper and the container to decrease and/or minimize air at the interface between the moveable gripper and the container.
(40) In some embodiments of the invention, the moveable gripper includes a moveable outer sleeve heater assembly physically coupled to a flexible sleeve heater assembly such that the flexible inner sleeve defines an adjustable opening. When a container is positioned within the adjustable opening, the gripper sub-assembly can dynamically apply the above-described gripping force to the moveable outer sleeve, and the gripping force moves the moveable outer sleeve and the flexible inner sleeve in a manner that reduces the size of the adjustable opening and dynamically controls, improves, and/or achieves a predetermined level of thermal contact between the flexible inner sleeve and the container. In accordance with aspects of the invention, the predetermined level of thermal contact is controlled, improved, and/or achieved by dynamically controlling the gripping force to increase the thermal contact points between the flexible inner sleeve and the container; and

by dynamically controlling the gripping force to displace air at the interface between the flexible inner sleeve and the container. In accordance with aspects of the invention, the predetermined level of thermal contact between the flexible inner sleeve and the container can be a maximum (or maximized) level of thermal contact between the flexible inner sleeve and the container. In aspects of the invention, the maximum level of thermal contact can be a thermal contact level at which additional increases in the above-described dynamically controlled gripping force no longer increases the level of thermal contact between the flexible inner sleeve and the container.

(41) In accordance with embodiments of the invention, the terms "thermal contact" (TC) and derivatives thereof are used herein to describe contact at an interface between a first material and a second material that is sufficient to exchange heat between the first material and the second material. The terms "targeted level of thermal contact" (TLTC) and derivatives thereof are used herein to describe a level of thermal contact at an interface between a first material and a second material that achieves a predetermined level of heat exchange at the interface. In accordance with aspects of the invention, the "targeted level" of thermal contact can include a "maximum level" (or maximized level) of thermal contact between a first material and a second material (e.g., the above-described maximum (or maximized) level of thermal contact between the flexible inner sleeve and the container). In accordance with aspects of the invention, the predetermined level of heat exchange at the interface can be achieved by achieving target values and/or ranges for TLTC proxy measurements and/or estimates (measurements/estimates) that include but are not limited to a percentage of the first/second material interface area that is air-gaps between the first material and the second material; a temperature gradient at the first/second material interface; and/or and interfacial thermal resistance level at the first/second material interface. The terms "air-gap percentage" (AG %) are used herein to describe the percentage of the interface area at the interface between first and second materials that has air between the first material and the second material. The terms "interfacial thermal resistance" (ITR) are used herein to describe a measure of the resistance to thermal flow at an interface between a first material and a second material. Where an outer surface of the container is rigid or semi-rigid and includes a topology (e.g., a pattern of ridges, creases, and the like), in some aspects of the invention, the flexible inner sleeve has sufficient flexibility and thickness to enable the surface of the flexible inner sleeve that interfaces with the outer surface of the container to, in response to the gripping force, substantially conform to the topology of the outer surface of the container. Where an outer surface of the container is substantially flexible and includes a topology (e.g., a pattern of ridges, creases, and the like), in some aspects of the invention, the flexible inner sleeve includes an interface surface that is flexible but sufficiently rigid to enable the interface surface to, in response to the gripping force, substantially conform the topology of the substantially flexible container outer surface to the topology of the inner sleeve's interface surface. Accordingly, in embodiments of the invention, thermal contact can be dynamically controlled and/or improved at the interface between the flexible inner sleeve and the container even where the outer surface of the container includes a topology.

(42) The terms "intimate thermal contact" (ITC) and derivatives thereof are used herein to describe a level of thermal contact at an interface between a first material and a second material that achieves an air-gap percentage at the interface that ranges from about zero (0) percent to about ten (10) percent, or that achieves an air-gap percentage at the interface that is less than about five (5) percent. In some embodiment of the invention, TLTC can include ITC. In some embodiments of the invention, ITC can be achieved between the flexible inner sleeve and the container even where the outer surface of the container includes a topology.

(43) In some aspects of the invention, efficient heat delivery and even heat distribution are provided by configuring the flexible inner sleeve to include heating elements thermally coupled to a heat distribution element, wherein the heat distribution element evenly distributes heat generated by the heating element(s) to portions of the container that are in a TLTC with the flexible inner

sleeve. The heat distribution element(s) also prevent excessive heating at particular locations referred to as "hot spots" that can damage the heating element(s) specifically, and/or damage the flexible inner sleeve in general. In some aspects of the invention, efficient heat delivery and even heat distribution are further provided by segmenting the heating element(s) into separate heating zones or regions, where each heating zone can be independently activated or not activated to, in effect, customize how much of the available surface area of flexible inner sleeve is actively delivering heat to the container. In embodiments of the invention, any number of controllable (or addressable) heating zones can be provided, thereby further improving efficient heat transfer and even heat distribution by enabling the size of the active (i.e., heat delivering) portion(s) of the flexible inner sleeve to be more closely matched to the size and shape of the container. In embodiments of the invention, activation/deactivation of the heating zones can be dynamically controlled

(44) In some aspects of the invention, efficient heat transfer and even heat distribution are further enhanced by providing a gripper sub-assembly configured to agitate the moveable gripper while the moveable gripper grips, heats, and makes a TLTC with the container. In aspects of the invention where the gripper sub-assembly and the moveable gripper agitate the container, the gripping force can be further dynamically controlled to ensure that the moveable gripper maintains its grip on the container while agitating the container. In aspects of the invention where the gripper sub-assembly and the moveable gripper agitate the container, the gripping force can be further dynamically controlled to ensure that, while the container is being agitated, the moveable gripper maintains its grip on the container without damaging the container.

(45) In some embodiments of the invention, the gripper sub-assembly includes a controller configured to control various aspects of the heating system to dynamically control the TLTC at the interface between the flexible inner sleeve and the container. More specifically, the controller can be used to dynamically set and/or make adjustments to the gripping and/or heating (gripping/heating) settings of the heating system in order to achieve TLTC at the interface between the flexible inner sleeve and the container, as well as achieve substantially efficient transfer and even distribution of heat through the walls of the container to the contents of the container. In accordance with aspects of the invention, the gripping/heating (or gripper/heat) settings can include one or more of the various system settings involved in the gripping and/or heating operations performed by the heating system. In some aspects of the invention, the gripping/heating settings include, in any combination, the various gripping forces applied to the moveable gripper; the activation and/or deactivation pattern (i.e., heating pattern(s)) applied to the heating zones of the heating element; the power applied to the heating zones; whether the power applied to the heating zones is continuous or pulsed; the duty cycle (duration, pule width, and pulse magnitude) of the pulsed power applied to the heating zones; the initiation of the power applied to the heating zones; and/or whether the heating system agitates the moveable gripper while the moveable gripper is gripping and transferring heat through the container to the contents of the container.

(46) In some embodiments of the invention, the above-described controller is configured to utilize various data types from various data sources to dynamically control, compute, look up, and/or simulate the gripping force that controls, improves, and/or achieves a TLTC between the flexible inner sleeve and the container, as well as achieve substantially efficient transfer and even distribution of heat through the walls of the container to the contents of the container. In some embodiments of the invention, the controller is configured to utilize various data types from various data sources to dynamically control, compute, look up, and/or simulate a maximum level of heat that the heating element generates, wherein the maximum heating element heat level is below a heat level that would damage the container. For example, the data type can be data about the maximum service temperature (Tmax) of the container material, where Tmax is the highest temperature at which a material can be used, for prolonged periods, without significant change in the material's properties, including but not limited to degradation, chemical changes, mechanical

changes, and/or excessive creep. The controller can use this data, along with feedback from a network of temperature sensors, to maintain the maximum heat level generated by the heating element below the Tmax of the container material.
(47) In some embodiments of the invention, the controller is configured to utilize the various data types from the various data sources to compute, look up, and/or simulate gripping force, heating element temperature, and other parameters using a variety of known computer analysis techniques, including but not limited to simulation algorithms, machine learning algorithms, relational databases, and the like. In some embodiments of the invention, the data types/sources can include data about the container gathered from sensors. In some embodiments of the invention, the data types/sources can include data about the container that has been downloaded to the controller from a remote processor over a network (e.g., a cloud computing system). In some embodiments of the invention, the data types/sources can include data about the container received through manual inputs to the controller.
(48) In some embodiments of the invention, the controller is configured to independently activate or not activate the heating zones to, in effect, further improve heat transfer efficiency and evenly distribute heat by customizing how much of the available surface area of flexible inner sleeve is actively passing heat to the container, and by matching the heating zones to the size and shape of the container. In some embodiments of the invention, the controller is configured to evaluate potentially competing constraints on the gripping force to determine whether or not all of the potentially competing constraints can be satisfied. For example in some aspects of the invention, the gripping force needs to be sufficient to dynamically control, improve, and/or achieve a TLTC between the flexible inner sleeve and the container; sufficient to hold the container while the gripper sub-assembly agitates the container; and insufficient to damage the container.
(49) Turning now to a more detailed description of aspects of the invention, FIG. **1** depicts a block diagram illustrating a heating apparatus **100** according to non-limiting embodiments of the invention. In accordance with aspects of the invention, the heating apparatus **100** includes a gripper sub-assembly **102**, a moveable gripper **106**, a power supply **120**, a controller **112**, and a sensor system/network **117**, configured and arranged as shown. In embodiments of the invention, the sensor network **117** can include but is not limited to measurement sensor(s) **116**, image sensor(s) **114**, and/or mechanical energy source sensors **119**. In embodiments of the invention, the gripper sub-assembly **102** includes mechanical energy source(s) **128** and a coupling mechanism **132**, wherein the coupling mechanism **132**, in some embodiments of the invention, can include a gripper actuator **121**, a clamping assembly **123**, and moveable arms **122**. The use of a gripper actuator **121**, a clamping assembly **123**, and moveable arms **122** to implement the coupling mechanism **132** is one example, and embodiments of the invention can utilize other implementations of the coupling mechanism **132**. In embodiments of the invention, the moveable gripper **106** includes flaps **124** physically coupled to a moveable outer sleeve heater element **110**, which is physically and communicatively coupled to a flexible inner sleeve heater element **108**. In embodiments of the invention, the flexible inner sleeve heater element **108** of the moveable gripper **106** defines an adjustable opening **126** that can hold a container **104**. In embodiments of the invention, the container **104** can have a variety of sizes, shapes, flexibility levels, conformability levels, surface topologies, and container materials.
(50) The controller **112** can be located anywhere within the heating apparatus **100**. In some embodiments of the invention, the controller **112** can be located external to the heating apparatus **100**. In embodiments of the invention, the controller **112** is in wired and/or wireless electronic communication with the sensor system/network **117** (including the image sensors **114**, the mechanical energy source sensors **119**, and/or the measurement sensors **116**), a display (e.g., display **1408** shown in FIG. **14**), the gripper sub-assembly **102**, and/or the moveable gripper **106** in order to receive various data types from the sensor system/network **117**, receive various manual inputs **111** from a user, and dynamically control various operations of the heating apparatus **100**.

The controller **112** can also be in wired or wireless communication with additional remote computing resources (not shown) and/or additional remote data sources **115** through a communication path **1425** (shown in FIG. **14**) and/or a cloud computing system **50**. In embodiments of the invention, the remote data sources **115** include remotely stored container data that provides a variety of details about a variety of container sizes, shapes, materials, and/or surface topologies that can be part of the container **104**. In some embodiments of the invention, the remote data sources **115** are integrated with the remote computing resources. In embodiments of the invention, the controller **112** is configured to use the container data to customize for a particular container size, shape, material, and/or surface topology how the gripper sub-assembly **102** and the moveable gripper **106** grip and deliver heat to a container **104**. In some embodiments of the invention, the controller **112** is remotely located and in wired and/or wireless communication with various components of the heating apparatus **100** through the communications path **1425** (shown in FIG. **14**) and/or the cloud computing network **50**.
(51) In accordance with aspects of the invention, the gripper sub-assembly **102** and the moveable gripper **106** are configured to receive the container **104** through the adjustable opening **126**; grip the container **104** in a manner that dynamically controls, improves, and/or achieves a TLTC between portions of the moveable gripper **106** and the container **104**; and apply heat through the container **104** to the contents of the container **104**. In embodiments of the invention, the contents of the container **104** can be a consumable liquid or beverage including but not limited to coffee, tea, soup, and the like. In embodiments of the invention, the heating apparatus **100** is configured to dynamically control the heat transferred through the container **104** such that the heat transferred into the container **104** is below a threshold heat level (e.g., Tmax) that would change the container material's properties, including but not limited to degradation, chemical changes, mechanical changes, and/or excessive creep or deformation. In embodiments of the invention, the container **104** can be any material that has sufficient thickness, thermal conductivity, and mechanical robustness to transfer a predetermined level of heat to contents of the container **104** without degrading the container **104**. In some embodiments of the invention, the container **104** can be a closed or sealed metal container, examples of which include but are not limited to aluminum metal cans or tin plated steel cans. In some embodiments of the invention, the container **104** can be a closed or sealed semi-rigid plastic container. In some embodiments of the invention, the container **104** can be a closed or sealed substantially flexible and/or conformable plastic container. In some embodiments of the invention, the container **104** can be substantially cylindrical or irregular in shape.
(52) In accordance with aspects of the invention, the movable gripper **106** can set the adjustable opening **126** to a size that is large enough to receive the container **104**. After the container **104** is positioned within the adjustable opening **126**, the movable gripper **106** can be moved in a manner that reduces the size of the adjustable opening **126** and brings portions of the moveable gripper **106** (i.e., the flexible inner sleeve heater assembly **108**) into thermal contact with the container **104** in order to dynamically control, improve, and/or achieve a TLTC between the flexible inner sleeve heater assembly **108** and the container **104**. Although not shown in FIG. **1**, the heating apparatus **100** can include additional sub-assemblies such as a container loading sub-assembly and a dispensing tray sub-assembly that could optionally be heated to maintain the desired temperature after the gripper sub assembly **102** and the moveable gripper **106** have finished heating the container **104**. The container loading sub-assembly can contain one or more containers **104**, and can load (e.g., either automatically or manually) an instance of the container **104** into the adjustable opening **126** of the movable gripper **106**. Subsequent to completion of the heating cycle, the heated container **104** can be dispensed (e.g., either automatically or manually) to the dispensing tray sub-assembly where it can be retrieved by a person or another automated sub-assembly.
(53) In embodiments of the invention, the flexible inner sleeve heater assembly **108** is physically coupled to an inner wall of the movable outer sleeve heater assembly **110**. In some embodiments of

the invention, the moveable outer sleeve heater assembly **110** can be formed from (or formed to include) a substantially semi-rigid material. As used herein, the terms “semi-rigid material,” “semi-rigid body,” “semi-rigid structure,” and equivalents thereof refer to a material that, when not being influenced by a force or some other source of pressure, generally maintains a predetermined shape but can be bent, flexed or otherwise deformed in response to an applied force or pressure without cracking, separating, or otherwise compromising the structural integrity of the material. In other words, for semi-rigid materials, the distance between any two given points in or on the material remains substantially constant in time unless and until a sufficient external force is exerted on the material. In some embodiments of the invention, suitable semi-rigid materials for forming the outer sleeve heater assembly **110** can include high-temperature flexible materials such as a high-temperature polymer, a high-temperature plastic material, or other high-temperature engineered plastics including, but not limited to, polyether ether ketone (PEEK) polyamide imide, polyimides, polyetherimide, poly phenylene sulfide, and/or composites thereof. As used herein, the terms “high temperature” when used to modify a material refers to the material having a Tmax greater about 100 degrees Celsius.

(54) As previously noted herein, the flexible inner sleeve heater assembly **108** and the moveable outer sleeve heater assembly **110** are configured to receive the container **104**; grip the container **104** in a manner that dynamically controls, improves, and/or achieves a TLTC between the flexible inner sleeve heater assembly **108** and the container **104**; and apply heat through the container **104** to the contents thereof. In some embodiments of the invention, the flexible inner sleeve heater assembly **108** is formed from a flexible material that allows the flexible inner sleeve heater assembly **108** to flex when the moveable outer sleeve heater assembly **110** is moved. As used herein, the terms “flexible material,” “flexible body,” “flexible structure,” and equivalents thereof refer to a material characterized by the ability to bend or compress easily many times without cracking or delaminating under the material's normal use conditions. In embodiments of the invention, the flexible inner sleeve heater assembly **108** is formed from a flexible material that, when affixed to an inner wall of the movable outer sleeve heater assembly **110**, bends or compresses easily without cracking when the movable outer sleeve assembly **110** is moved. In some embodiments of the invention, the moveable outer sleeve heater assembly **110** can also be formed from, and/or formed to include, flexible materials. The flexibility of the inner sleeve heater assembly **108** and the movability of the moveable outer sleeve heater assembly **110** also allow the moveable gripper **106** to receive and establish a TLTC with containers having a wide variety of sizes, shapes, flexibility levels, conformability levels, and/or surface topologies (e.g., creases, ridges, and the like). In some embodiments of the invention, the flexible inner sleeve heater assembly **108** is configured to include both flexible and compressible material at the interface between the flexible inner sleeve heater assembly **108** and the container **104**, thereby allowing the compressible material to substantially conform to a topology of the container **104** under the influence of the gripping force. Additional details of various component parts of a multi-layered implementation of the flexible inner sleeve heater assembly **108** in accordance with aspects of the invention are depicted in FIGS. **9**A-**10**C and described subsequently herein.

(55) In embodiments of the invention, the controller **112** can be implemented to include the features and functionality of the computing system **1400** (shown in FIG. **14**), which enable the controller **112** to execute a variety of algorithms and computer-readable program instructions stored in various memory elements of the controller **112**. In one or more non-limiting embodiments of the invention, the controller **112** is in signal communication with the sensor network **117** that includes but is not limited to one or more image sensors **114**, the one or more mechanical energy source sensors **119**, and/or the one or more measurement sensors **116**. The measurement sensors **116** can include, but are not limited to, pressure sensors; grip pressure sensors configured to detect the gripping force (e.g., gripping forces **404**, **414** shown in FIGS. **4**A-**4**D) that is applied to the moveable gripper **106** and transferred through the moveable gripper **106** to press an inner surface

of the flexible inner sleeve **108** against the container **104** and form an interface (e.g., interfaces **406**, **416** shown in FIGS. **4**A-**4**D); flexible inner sleeve temperature sensors positioned on the flexible inner sleeve **108** such that they measure temperature at locations on an inner wall of the flexible inner sleeve **108** that contact the container **104**; container temperature sensors positioned on the flexible inner sleeve **108** such that they measure temperature at locations on an outer wall of the container **104** that contact the flexible inner sleeve **108**; ambient/environment temperature sensors; vibration sensors; air-gap sensors configured to detect air at the interface between the flexible inner sleeve **108** and the container **104**; position sensors configured to detect a position of the container **104** within the adjustable opening **126** and/or the with respect to the flexible inner sleeve **108**; accelerometer(s); gyroscope(s); and thermistor(s). The image sensors **114** can include, but are not limited to, a photo diode; a barcode reader; a quick response (QR) code reader; and a visible or IR frequency camera. Image sensors **114** can scan a code included with the container **104**, wherein the code includes a variety of information about characteristics of the container **104**. Image sensors **114** can also capture an image of the container **104**, wherein the image also includes a variety of information about characteristics of the container **104**. The controller **112** can process and analyze the scanned code or captured image (e.g., perform image recognition) to determine various characteristics of the container **104** including, but not limited to, the source of the container **104**, the material of the container **104**, the flexibility of the material of the container **104**, the shape/size/dimensions of the container **104**, the sizes/dimensions/locations of any surface topology (e.g., ridges, creases, and the like) of the container **104**, and/or the contents stored in the container **104** (e.g., soup, coffee, tea, vegetables, and the like).

(56) In some embodiments of the invention, the controller **112** can be configured to calculate an estimate of the temperature(s) at locations on the outer wall of the container **104** based on temperature readings from the flexible inner sleeve temperature sensors; data about characteristics and/or parameters of the flexible inner sleeve **108**; and/or data about characteristics and/or parameters of the container **104**. In some embodiments of the invention, the controller **112** can be configured to calculate an estimate of the level of interface pressure or force applied at the interface (e.g., interfaces **406**, **416** shown in FIGS. **4**A-**4**D) between the flexible inner sleeve **108** and the container **104** based on gripping force readings from the gripping force sensors; data about characteristics and/or parameters of the moveable gripper **106**; and data about characteristics and/or parameters of the container **104**.

(57) In embodiments of the invention, the mechanical energy source sensors **119** can include a mechanical energy source temperature sensor, a mechanical energy source vibration sensor, a mechanical energy source accelerometer, and/or a mechanical energy source gyroscope. In embodiments of the invention, the controller **112** is in signal communication with the mechanical energy source sensors **119**, the power supply **120** and/or the mechanical energy source(s) **128**. Accordingly, the controller **112** can dynamically control the power supply **120** and/or the mechanical energy source(s) **128** in response to data or measurements output from the mechanical energy source sensors **119**. Additionally, the controller **112** can dynamically control the power supply **120** and/or the mechanical energy source(s) **128** in response to outputs from the image sensors **114**, the measurement sensors **116** (including grip pressure sensors), the manual inputs **111**, and/or the remote data sources **115**. In one or more non-limiting embodiments of the invention, the measurement sensors **116** can include grip pressure sensors configured and arranged to sense a gripping pressure applied by coupling mechanism **132** to the flaps **124** of the moveable gripper **106**. The controller **112** can dynamically control the coupling mechanism **132** to adjust the first and second moveable arms **122** based on the sensed gripping pressure. In some embodiments of the invention, for example, the controller **112** can dynamically control the coupling mechanism **132** to increase the gripping pressure applied to the moveable gripper **106** until the gripping pressure reaches or exceeds a gripping pressure threshold value that is sufficient to dynamically control, improve, and/or achieve a TLTC between the flexible inner heater assembly **108** and the container

104.

(58) In embodiments of the invention, the controller **112** can receive various manual inputs **111** from an operator of the heating system **100**. In embodiments of the invention, the manual inputs **111** can include inputs that are best sourced from the user/operator, including but not limited to a target temperature for the contents of the container **104**. In embodiments of the invention, the manual inputs **111** can include the same types of inputs generated by the sensor network **117**, including for example a container type (e.g., type of container material), a container size, and/or details about the contents of the container **104**.

(59) In embodiments of the invention, the controller **112** can access the remote data sources **115** over the communication path **1425** (shown in FIG. **14**) and/or the cloud computing system **50** to download remotely stored container data that provides a variety of details about a variety of container types that can be utilized as the container **104**. For example, the controller **112** can receive data from the sensor network **117** (e.g., **114**, **116**) and/or the manual inputs **111** identifying the container **104** that is currently within the adjustable opening **126** as a 12-ounce single serving can of chicken noodle soup sold by Company A. The controller **112** can query the data source **115** to determine whether the data source **115** has container data about a 12-ounce single serving cans of chicken noodle soup sold by Company A. In some aspects of the invention, the query sent by the controller **112** can include tradenames, label images, and other container identifying information/data that can be compared with the remotely stored container data to assist with identifying the specific remotely stored container data that matches the query. When the remote data source **115** has identified a match, the data source **115** transmits the matching container data over the communication path **1425** and/or the cloud computing system **50** to the controller **112**. In the previously-described example query, the matching container data for the 12-ounce single serving can of chicken noodle soup sold by Company A can include the same types of inputs generated by the sensor network **117**, including for example a container type (e.g., type of container material), a container size and shape, and/or details about the contents of the container **104**. In some embodiments of the invention, the matching container data can include information about the container **104** that is not easily determined by the sensor network **117**, including for example a variety of details about the robustness of the container material. Examples of details about the robustness of the container material include the container material's thickness, melting point, Tmax, flexibility, rigidity, conformability, softening point, glass transition temperature, burst pressure, and the like. In embodiments of the invention, the controller **112** is configured to use the downloaded matching container data to customize for that container (e.g., the 12-ounce single serving can of chicken noodle soup sold by Company A) how the gripper sub-assembly **102** carries out the various features and functionality of aspects of the invention, including but not limited to how the gripper sub-assembly **102** and the moveable gripper **106** grip and deliver heat to the container **104**.

(60) In embodiments of the invention, the controller **112** can also include a data interface (e.g., wireless interface—not shown separately from the controller **112**) that facilitates data exchange with the communication path **1425** (shown in FIG. **14**) and/or the cloud computing system **50**. In this manner, the controller **112** can actively obtain various types of data in real-time including, but not limited to, local weather data, container data (e.g., container size, container shape, container material type, etc.), customer profile data, customer preferences, customer product purchase requests, etc. In some embodiments of the invention, the controller **112** can adjust the heating characteristics (e.g., power applied to the thermal film heater **208** shown in FIG. **8**C; a target temperature to be achieved for the contents of the container; etc.) of the heating cycle based on the weather data, product data, customer profile data and/or customer product purchase requests.

(61) In accordance with aspects of the invention, the controller **112** is configured to utilize the container data obtained from the measurement sensors **116**, the image sensors **114**, the manual inputs **111**, and/or the remote data sources **115** to perform various functions and operations described herein, including, but not limited to, dynamically controlling operations (e.g., gripping

force, heat delivery settings, agitation, etc.) of the gripper sub-assembly **102** and/or dynamically controlling operations of the moveable gripper **106**. To execute these functions and operations, the controller **112** is configured to include computer hardware, algorithms, and computer-readable program instructions stored in various memory elements of the controller **112**. For example, the controller **112** is configured to utilize various computer control techniques and features, including simulation algorithms, machine learning (ML) algorithms, look-up tables (e.g., relational databases), and other computational techniques to assist with dynamically controlling the gripper sub-assembly **102** and the moveable gripper **106** to generate and supply heat to the container **104** disposed in the adjustable opening **126** of the moveable gripper **106**.

(62) In some embodiments of the invention, the controller **112** is configured to base the above-described dynamically controlled operations and/or functions at least in part on received information (e.g., sensor data, downloaded data, manually input data, and the like) and/or estimates or calculations based on the received information. For example, in some embodiments of the invention, the information used (or needed) by the controller **112** to perform an operation or function can be difficult to measure directly using sensors, or the information used or needed by the controller **112** is not readily available for download or manual inputs. In such situations, the controller **112** can be configured to calculate an estimate of the necessary information. An example of such a calculation is depicted in FIG. **6**E. In some aspects of the invention, the information used or needed by the controller **112** to perform the operations and/or function described herein can be estimated and/or calculated, regardless of whether or not the information is available from other sources. Accordingly, any of the embodiments of the invention described herein where the controller **112** is described as relying on a particular type of information source (e.g., sensor readings), it is understood that the particular type of information source can be substituted with other types of information sources (e.g., sensor readings, downloaded data, manual inputs, and/or estimates/calculations). Additional details of how the controller **112** utilizes various types of data sources and control techniques in accordance with aspects of the invention are described in greater detail subsequently herein.

(63) In accordance with some embodiments of the invention, the gripper sub-assembly **102** includes a mechanical energy mechanism formed as the mechanical energy source(s) **128** attached to the coupling mechanism **132**. The coupling mechanism **132** is configured to convert mechanical energy generated by the source **128** to a gripping force and apply it to the flaps **124** of the moveable gripper **106**. In accordance with aspects of the invention, the gripping force is dynamically controlled such that it is sufficient to move the moveable gripper **106** and dynamically control, improve, and/or achieve a TLTC between the flexible inner sleeve heater assembly **108** and the container **104**. In accordance with embodiments of the invention, the mechanical energy mechanism **128**, **132** of the gripper sub-assembly **102** is further configured to, under certain circumstances, agitate the moveable gripper **106** while the moveable gripper **106** is gripping a container **104** and delivering heat to the contents of the container **104**. A variety of coupling mechanisms **132** are suitable for performing the coupling mechanism operations described herein. In some embodiments of the invention, the coupling mechanism includes the gripper actuator **121**, the clamping assembly **123**, and the moveable arms **122**. The mechanical energy sources **128** are operable in response to receiving power from a power supply **120**.

(64) The gripper actuator **121** includes a first end and an opposing second end, wherein the first end is moveably coupled to the mechanical energy source(s) **128**, and wherein the opposing second end is coupled to the clamping assembly **123**. The clamping assembly **123** is configured to apply the adjustable gripping force in response to operation of the gripper actuator **121**. The clamping assembly **123** can include various gripping mechanism configurations capable of applying the adjustable gripping force. Suitable gripping mechanism configurations include, but are not limited to, the one or more moveable arms **122**, one or more moveable cables, a biased hinge, a spring clamp, a lead screw clamp, a hose clamp, or combinations thereof. In some embodiments of the

invention, the mechanical energy source(s) **128** can include electronic solenoids and/or pneumatic elements configured and arranged to generate the gripping force. In some embodiments of the invention, the mechanical energy source(s) **128** can include one or more electronically controlled motors configured and arranged to move and/or agitate the moveable gripper **106** in a variety of directions along the X/Y/Z axes **102**. In some embodiments of the invention, any combination of the previously-described example iterations of the mechanical energy source(s) **128** can be used to generate the gripping force (e.g., gripping forces **404**, **414** shown in FIGS. **4**A-**4**D). In some embodiments of the invention, any combination of the previously-described example iterations of the mechanical energy source(s) **128** can be used to move and/or agitate the moveable gripper **106** in a variety of directions along the X/Y/Z axes **102**.

(65) In some embodiments of the invention, the moveable gripper **106** can be configured to include a ledge, an offset, and/or other support structure that supports the container **104** in the adjustable opening **126** prior to when the gripping force moves the moveable gripper **106** a sufficient distance to reduce the size of the adjustable opening **126** and bring the flexible inner sleeve heater assembly **108** into a TLTC with the container **104**. After the container **104** is positioned within the adjustable opening **126**, the controller **112** can then dynamically control the mechanical energy mechanism (e.g., the mechanical energy source(s) **128**, the gripper actuator **121**, the clamping assembly **123**, and the movable arms **122**) to apply a gripping force to the flaps **124** of the moveable outer sleeve heater assembly **110**, wherein the applied gripping force reduces the size of the adjustable opening **126** and brings the flexible inner sleeve **108** into a TLTC with the container **104**.

(66) In embodiments of the invention, the gripper actuator **121** can include a pneumatic system configured to adjust the clamping assembly **123** and the moveable arms **122** in response to a varying air pressure delivered from an external source, such as an air compressor or replaceable supply tank (not shown). The gripper actuator **121** can also include other types of systems or configurations capable of moving or adjusting the clamping assembly **123**. For example, the gripper actuator **121** can include, but is not limited to, a screw or scroll mechanism; a rod and gear arrangement driven by the mechanical energy source(s) **128** (e.g., an electric motor); and/or an electromagnetic solenoid clamping arrangement. A rod and gear assembly, for example, can be rotatably coupled through the clamping assembly **123** to the moveable arms **122** such that rotationally adjusting the rod (e.g., via the mechanical energy source(s) **128**) adjusts the positions of the moveable arms **122**.

(67) In one or more non-limiting embodiments of the invention, the characteristics of the agitation operations (e.g., agitation frequency, agitation speed, range of rotation, and duration of agitation) performed by the system **100** are actively and dynamically controlled using, for example, the subsystem **610**, which is shown in FIG. **6**E and described in greater detail subsequently herein. In some embodiments of the invention, the characteristics of the agitation operations performed by the system are dynamically controlled based on feedback from temperature sensors that are included among the measurement sensors **116**. In some embodiments of the invention, the temperature sensors that are included among the measurement sensors **116** are configured to generate various types of temperature gradient data. In some embodiments of the invention, the temperature gradient data represents a gradient (or difference) between a temperature measured at a first position on the container **104** and a temperature measured at a second position on the container **104**, wherein distance between the first and second positions on the container **104** are sufficient to provide an indication of how well the heat transferred to the container **104** from the flexible inner sleeve heater assembly **108** is being evenly distributed along a height and/or width dimension of the container **104**. In this instance, temperature gradient data above a threshold represents a level of uneven heat distribution when the flexible inner sleeve heating element **108** transfers heat to the container **104**. In accordance with aspects of the invention, this type of temperature gradient data can be used by the controller **112** to determine that the level of heat distribution along a height and/or width dimension of the container **104** is sufficiently uneven to trigger the controller **112** to initiate an

agitation operation during the heating cycle in order to more evenly distribute the heat that is being transferred from the flexible inner sleeve heater assembly **108** to the container **104** that is being gripped by the moveable gripper **106**.

(68) In embodiments of the invention, the characteristics of the agitation (e.g., agitation frequency, agitation speed, range of rotation, and duration of agitation) performed by the system **100** (e.g., using the subsystem **610** shown in FIG. **6**E) are actively and dynamically controlled based on feedback from temperature sensors that are included among the measurement sensors **116**, along with simulations and/or modeling operations performed by the controller **112** to estimate a temperature gradient from the container **104** to a midpoint of the contents of the container (e.g., other estimated parameters **613** of the subsystem **610** shown in FIG. **6**E). In some embodiments of the invention, the estimated temperature gradient provides an indication of how well the heat transferred to the container **104** from the flexible inner sleeve heater assembly **108** is being evenly distributed to the contents of the container **104**. In this instance, the estimated temperature gradient data above a threshold represents a level of uneven heat distribution when the flexible inner sleeve heating element **108** transfers heat to the container **104**. In accordance with aspects of the invention, this type of estimated temperature gradient data can be used by the controller **112** to determine that the level of heat distribution among the contents of the container **104** is sufficiently uneven to trigger the controller **112** to initiate an agitation operation in order to more evenly distribute the heat that is being transferred from the flexible inner sleeve heater assembly **108** to the container **104** while the container **104** is being gripped by the moveable gripper **106**. In accordance with aspects of the invention, the controller **112** is further configured to dynamically control the gripping force such that it is sufficient to enable the movable gripper **106** to also hold the container **104** with sufficient force to not drop the container **104** during the agitation operation.

(69) The moveable gripper **106** is illustrated in greater detail in FIGS. **2** and **3** in accordance with embodiments of the invention. More specifically, FIGS. **2** and **3** depict examples of how the gripping force can be applied to the movable outer sleeve heater assembly **110** of the moveable gripper **106** in accordance with aspects of the invention. In some embodiments of the invention, the moveable gripper **106** includes first and second opposing flaps **124** coupled to the moveable outer sleeve heater assembly **110**. A first one of the flaps **124** is coupled to a first one of the moveable arms **122** and a second one of the flaps **124** is coupled to a second one of the moveable arms **122**. Although first and second opposing flaps **124** and first and second moveable arms **122** are described, it should be appreciated that the other configurations for coupling the moveable gripper **106** to the clamping assembly **123** can be envisioned without departing from the scope of the invention. Accordingly, the moveable gripper **106**, which in some embodiments of the invention is formed from semi-rigid material, is flexed into a cylindrical or substantially cylindrical shape corresponding to the shape of the adjustable opening **126**. In one or more non-limiting embodiments of the invention, the moveable gripper **106** can have a vertical height ranging, for example, from about, 100 millimeter (mm) to about 180 mm. The adjustable opening **126** can define a varying diameter that can range, for example, from about 50 millimeters (mm) to about 85 mm.

(70) As shown in FIG. **2**, by adjusting the first and second moveable flaps **124** (e.g., laterally as indicated by directional arrows **129**), the moveable gripper **106** can be compressed (as indicated by directional arrows **129**) and the diameter or size of the adjustable opening **126** can be varied to accommodate a wide variety of sizes and shapes of the container **104**. For example, in some embodiments of the invention, the diameter or size of the adjustable opening **126** can be varied between from about 50 millimeters (mm) to about 85 mm. In some embodiments of the invention, the diameter or size of the adjustable opening **126** can be varied between from about 90 mm to about 100 mm. In this manner, the moveable gripper **106** can receive containers having a wide variety of shapes and sizes. Although the moveable gripper **106** is described herein as having a cylindrical profile, the moveable gripper **106** can be constructed to have other shapes and profiles

without departing from the scope of the invention.
(71) As shown in FIG. **3**, rather than applying a gripping force (e.g., a squeezing force) that compresses the flaps **124** together, the flaps **124** shown in FIG. **3** are configured such that the gripping force (e.g., a pulling force) applies a tensile force (indicated by the directional arrows **130**) on the flaps **124**. Accordingly, the moveable gripper **106** applies a tension on the container **104** (shown in FIGS. **1-3**) inserted in the adjustable opening **126**.
(72) In embodiments of the invention, the mechanical energy source(s) **128** are part of the mechanical energy source mechanism that physically couples to the moveable outer sleeve heater assembly **110** and operates under the influence of the controller **112** to initiate and dynamically control an agitation operation that imparts agitation to the moveable gripper **106** and a container **104** being gripped by the moveable gripper **106**. In some embodiments of the invention, the motor mechanism includes the mechanical energy source(s) **128** and the coupling mechanism **132** configured to convert mechanical energy generated by the mechanical energy source(s) **128** to movement by moveable gripper **106**, wherein the movement includes movement in any direction along the X/Y/Z axes **102** that agitates the moveable gripper **106**. In some embodiments of the invention, the coupling mechanism can be implemented as the gripper actuator **121**, the clamping assembly **123**, and the moveable arms **122**. In response to receiving a command to enhance or improve how evenly (or uniformly) heat is being distributed to the contents of the container **104** disposed in the moveable gripper **106**, or based on a determination that the heat is not being evenly (or uniformly) distributed to the contents of the container **104** disposed in the moveable gripper **106**, the controller **112** can dynamically control the mechanical energy source(s) **128** to repeatedly or continuously agitate the moveable gripper **106**. In some embodiments of the invention, the agitation can be performed during a selected portion of a heating process or cycle, while in some embodiments of the invention the agitation can be continuously performed over the full duration of a heating process or cycle.
(73) In one or more embodiments of the invention, the controller **112** can dynamically control the agitation duration, agitation frequency, agitation speed, acceleration and/or range of rotation at which the mechanical energy source(s) **128** move the gripper actuator **121** in any direction along the X/Y/Z axes **102** based on feedback data (e.g., rotational frequency or speed) provided by the mechanical energy source sensors **119**. In embodiments of the invention, the characteristics of the agitation (e.g., agitation frequency, agitation speed, range of rotation, and/or duration of agitation) can be actively determined by the controller **112** based on a manual input **111** and/or container data corresponding to the container **104** disposed in the moveable gripper **106**. The container data includes, for example, the manufacturer (or source) of the container **104**, the container contents, the material of the container **104**, the shape of the container **104**, the size/dimensions of the container **104**, and the like. In one or more non-limiting embodiments of the invention, the characteristics of the agitation (e.g., agitation frequency, agitation speed, range of rotation, and duration of agitation) performed by the system **100** is actively and dynamically controlled based on feedback from temperature sensors that are included among the measurement sensors **116**.
(74) FIGS. **4**A-**6**E depict graphs and block diagrams that illustrate how, in accordance with embodiments of the invention, efficient heat transfer between the flexible inner sleeve heater assembly **108** (e.g., Material A) and the walls of the container **104** (e.g., Material B) is provided by dynamically controlling the gripping forces **404**, **414** (shown in FIGS. **4**A-**4**D and **6**A-**6**D) applied to the movable outer sleeve **110** (shown in FIG. **1**) such that the gripping force **414** is sufficient to dynamically control, improve, and/or achieve a targeted level of a TLTC between the flexible inner sleeve heater assembly **108** (e.g., Material A) and the container **104** (e.g., Material B).
(75) Turning first to FIGS. **4**A-**4**D, block diagrams are shown that illustrate a portion of a Material A (corresponds to the flexible inner sleeve heater assembly **108**) in contact with a portion of a Material B (corresponds to a wall of the container **104**). In FIG. **4**A, in accordance with aspects of the invention, Material A can be a flexible material having varying levels of conformability and/or

compressibility, and Material B can be a rigid and/or semi-rigid material. As used herein, the term "compressible" is used to define a material having the characteristic whereby its volume can change as a response to a pressure (or mean stress) change. As used herein, the term "conformable" is used to define a first material having the characteristic whereby its shape (and/or its surface topology) can conform to or track the topology of a second material when the first and second materials are pressed into contact with one another. As used herein, a compressible material is understood to be both flexible and conformable. However, a flexible material may or may not be compressible depending on the specific physical characteristics of the flexible material; and a flexible material may or may not be conformable depending on the specific physical characteristics of the flexible material. Similarly, as used herein, a "conformable" material is understood to be flexible. However, a conformable material may or may not be compressible depending on the specific physical characteristics of the conformable material. In some embodiments of the invention, Material B can be a rigid material, a semi-rigid material, and/or a material having varying levels of conformability. In some embodiments of the invention, Material A can be multi-layered. In some embodiments of the invention, Material B can be multi-layered (e.g., a wall of the container **104** plus a layer of label material).

(76) In FIG. **4**A, a gripping force **404** has been applied to flexible Material A at distance **1** to bring flexible Material A into contact with Material B at an interface **406** at distance **2**. In embodiments of the invention, the gripping force **404** is dynamically controlled, which means that the controller **112** is configured to automatically and/or continuously adjust the value of the gripping force **404** based at least in part of various parameters and/or characteristics of the moveable gripper **106**, the container **104**, and/or the interface **406**. Accordingly, the value of the gripping force **404** determined by the controller **112** for a first type of the container **104** can be different from the value of the gripping force **404** determined by the controller **112** for a second type of the container **104**. In embodiments of the invention where flexible Material A includes conformable and/or compressible regions, the gripping force **404** is sufficient to bring flexible Material A into contact with Material B without substantially compressing and/or conforming flexible Material A and/or Material B at the interface **406**. In embodiments of the invention, no adhesive is present at the interface **406**, so only the gripping force **404** maintains Material A in contact with Material B. In aspects of the invention, position sensors included among the measurement sensors **116** can be used by the controller **112** to determine that the flexible inner sleeve **108** has made contact with the container **104** to form the interface **406**; and the pressure sensors included among the measurement sensors **116** can be used by the controller **112** to determine the gripping force **404** that maintains the flexible inner sleeve **108** in contact with the container **104** to form the interface **406**.

(77) In FIG. **4**B, in accordance with aspects of the invention, a gripping force **414** has been applied to flexible Material A at distance **1** to press flexible Material A against Material B, thereby creating interface **416** at distance **2**. In embodiments of the invention, the gripping force **414** is dynamically controlled, which means that the controller **112** is configured to automatically and/or continuously adjust the value of the gripping force **414** based at least in part of various parameters and/or characteristics of the moveable gripper **106**, the container **104**, and/or the interface **416**. Accordingly, the value of the gripping force **414** determined by the controller **112** for a first type of the container **104** can be different from the value of the gripping force **414** determined by the controller **112** for a second type of the container **104**. In FIG. **4**B, in accordance with aspects of the invention, Material A is non-conformal and not compressed at the interface **416**, and Material B is (or includes) rigid material, semi-rigid material, and/or material having varying levels of conformability. In embodiments of the invention, and depending on whether or not Material A and Material B shown in FIGS. **4**B-**4**D are conformable and/or compressible, the gripping force **414** is sufficient to dynamically control, improve, and/or achieve a TLTC between Material A and Material B at the interface **416**. In some embodiments of the invention, Material B is not conformable and its outer surface at the interface **416** does not have a topology. In embodiments of

the invention where Material B is conformable and its outer surface at the interface **416** has a conformable topology, the gripping force **414** is sufficient to conform the conformable topology of the outer surface of Material B at the interface **416** to the outer surface of Material A at the interface **416**.

(78) In FIG. **4**C, in accordance with aspects of the invention, Material A is conformable but not compressible at the interface **416**, and Material B is (or includes) rigid material, semi-rigid material, and/or material having varying levels of conformability. In embodiments of the invention, the gripping force **414** is sufficient to dynamically control, improve, and/or achieve a TLTC between Material A and Material B at the interface **416**. In embodiments of the invention where Material B is not conformable and its outer surface at the interface **416** has a topology, the gripping force **414** is sufficient to conform the conformable outer surface of Material A at the interface **416** to the topology of the outer surface of Material B at the interface **416**. In embodiments of the invention where Material B is conformable and its outer surface at the interface **416** has a topology, the gripping force **414** is sufficient to conform the conformable outer surface of Material A at the interface **416** and the conformable topology of the outer surface of Material B at the interface **416** to one another.

(79) In FIG. **4**D, in accordance with aspects of the invention, Material A is conformable and compressible at the interface **416**, and Material B is (or includes) rigid material, semi-rigid material, and/or material having varying levels of conformability. In accordance with aspects of the invention, a gripping force **414** has been applied to flexible Material A at distance **1** to compress flexible Material A against Material B at an interface **416** at distance **2**. In embodiments of the invention where Material B is not conformable and its outer surface at the interface **416** has a non-conformable topology, the gripping force **414** is sufficient to conform the compressible and conformable outer surface of Material A at the interface **416** to the non-conformable topology of the outer surface of Material B at the interface **416**. In embodiments of the invention where Material B is conformable and its outer surface at the interface **416** has a conformable topology, the gripping force **414** is sufficient to conform the conformable/compressible outer surface of Material A at the interface **416** and the conformable topology of the outer surface of Material B at the interface **416** to one another.

(80) As previously noted herein, the terms "thermal contact" (TC) and derivatives thereof are used herein to describe contact at an interface between a first material and a second material that is sufficient to exchange heat between the first material and the second material. Additionally, the terms "targeted level of thermal contact" (TLTC) and derivatives thereof are used herein to describe a level of thermal contact at an interface between a first material and a second material that achieves a predetermined level of heat exchange at the interface. In accordance with aspects of the invention, the "targeted level" of thermal contact can include a "maximum level" (or maximized level) of thermal contact between a first material and a second material (e.g., the previously-described maximum (or maximized) level of thermal contact between the flexible inner sleeve and the container). In FIGS. **4**B-**4**D and **5**, in accordance with aspects of the invention, the predetermined level of heat exchange at the interface **416** can be achieved by achieving target values and/or ranges for TLTC proxy measurements that include but are not limited to a percentage of air-gaps (i.e., the previously-described AG %) at the interface **416**; a temperature gradient at the interface **416**; and/or and an interfacial thermal resistance (ITR) level at the interface **416**.

(81) FIG. **5** depicts a table **500** illustrating some of the relationships between the dynamically controlled gripping force **414** (shown in FIGS. **4**B-**4**D) and various parameters at the interface **416** (shown in FIGS. **4**B-**4**D) that can be dynamically controlled, improved, and/or achieved using the embodiments of the invention described and illustrated herein. More specifically, the table **500** depicts relationships between the gripping force **414** (first column going from left to right); the interface-parameter at the interface **416** to be dynamically controlled, improved, and/or achieved by the gripping force **414** (second column going from left to right); various proxy measurements

and/or estimates (measurement/estimate) for assessing the level of the interface-parameter at the interface **416** (third column going from left to right); and various target values and/or target ranges for the interface-parameter proxy measurements/estimates (fourth column going from left to right). Example relationships are shown in rows **502**, **504**, **506**, **508**, **510**, **512**, **514** for multiple instances of the gripping force **414**, namely GF**1**-A, GF**1**-B, GF**1**-C, GF**2**-A, GF**2**-B, GF**3**-A, and GF**3**-B, along with multiple instances of the interface-parameter, namely a TLTC at the interface **416**. In some embodiments of the invention, based on the conformability and/or compressibility of Material A and/or Material B (shown in FIGS. **4**A-**4**D), the TLTC can be maximized.

(82) For row **502**, the gripping force **414** is GF**1**-A; the interface-parameter is a targeted level of thermal contact (TLTC-**1** shown in FIG. **6**B) at the interface **416**; the interface-parameter proxy measurement/estimate is the air-gap percentage (AG %) at the interface **416** that results from GF**1**-A; and the target values/ranges of the AG % at the interface **416** that can be achieved using aspects of the invention includes a AG % that ranges from about zero (0) percent to about ten (10) percent, or less than about five (5) percent. In accordance with aspects of the invention, the TLTC achieved using GF**1**-A can be considered "intimate thermal contact." As previously noted herein, the terms "intimate thermal contact" (ITC) and derivatives thereof are used herein to describe a level of thermal contact at an interface between a first material and a second material that achieves an air-gap percentage at the interface that ranges from about zero (0) percent to about ten (10) percent, or that achieves an air-gap percentage at the interface that is less than about five (5) percent. For row **504**, the gripping force **414** is GF**1**-B; the interface-parameter is the TLTC at the interface **416**; the interface-parameter proxy measurement/estimate is the AG % at the interface **416** that results from GF**1**-B (AG %-GF**1**-B); and the target values/ranges of AG %-GF**1**-B that can be achieved using aspects of the invention includes AG %-GF**1**-B being less than AG %-preGF**1**-B, wherein AG %-preGF**1**-B is the AG % at the interface **416** prior to the application of GF**1**-B. For row **506**, the gripping force **414** is GF**1**-C; the interface-parameter is the TLTC at the interface **416**; the interface-parameter proxy measurement/estimate is the AG % at the interface **416** that results from GF**1**-C (AG %-GF**1**-C); and the target values/ranges of AG %-GF**1**-C that can be achieved using aspects of the invention includes minimizing AG %-GF**1**-C and/or bringing AG %-GF**1**-C below a target AG %-preGF**1**-C, wherein AG %-preGF**1**-C is the AG % at the interface **416** prior to the application of GF**1**-C.

(83) For row **508**, the gripping force **414** is GF**2**; the interface-parameter is the TLTC at the interface **416**; the interface-parameter proxy measurement/estimate is ΔT (change in temperature) at the interface **416** that results from GF**2** (ΔT-GF**2**); and the target values/ranges of ΔT-GF**2** that can be achieved using aspects of the invention include ΔT-GF**2** being less than ΔT-preGF**2**, wherein ΔT-preGF**2** is the ΔT at the interface **416** prior to the application of GF**2**. For row **510**, the gripping force **414** is GF**2**; the interface-parameter is the TLTC at the interface **416**; the interface-parameter proxy measurement/estimate is ΔT at the interface **416** that results from GF**2** (ΔT-GF**2**); and the target values/ranges of ΔT-GF**2** that can be achieved using aspects of the invention include minimizing ΔT-GF**2** and/or bringing ΔT-GF**2** below a target ΔT-GF**2** threshold value.

(84) For row **512**, the gripping force **414** is GF**3**; the interface-parameter is the TLTC at the interface **416**; the interface-parameter proxy measurement/estimate is the Material A parameters, the Material B parameters, and parameters of the interface parameters **416** that can be used to calculate/estimate interfacial thermal resistance (ITR) at the interface **416** under the influence of GF**3** (ITR-GF**3**); and the target values/ranges of ITR-GF**3** that can be achieved using aspects of the invention include ITR-GF**3** being less than ITR-preGF**3**, wherein ITR-preGF**3** is the ITR at the interface **416** prior to the application of GF**3**. For row **514**, the gripping force **414** is GF**3**; the interface parameter is the TLTC at the interface **416**; the interface parameter proxy measurement/estimate is the Material A parameters, the Material B parameters, and parameters of the interface **416** that can be used to calculate/estimate the ITR at the interface **416** under the influence of GF**3** (ITR-GF**3**); and the target values/ranges of ITR-GF**3** that can be achieved using

aspects of the invention include minimizing ITR-GF**3** and/or bringing ITR-GF**3** below a target ITR-GF**3** threshold.

(85) FIGS. **6**A-**6**D depict graphs and block diagrams (corresponding to the block diagrams shown in FIGS. **4**A and **4**D) that further illustrate the relationships depicted in FIGS. **4**A, **4**D, and **5** in accordance with aspects of the invention. More specifically, FIGS. **6**A-**6**D depict embodiments of the invention where the interface-parameter proxy measurement/estimate is the air-gap percentage (AG %) at the interface **416** (FIGS. **6**A and **6**B), as well as where the interface-parameter proxy measurement/estimate is a temperature change at the interface **416** (FIGS. **6**C and **6**D). The graphs and block diagrams in FIGS. **6**A-**6**D focus on the pair of examples shown in FIGS. **4**A and **4**D. However, graphs and block diagrams similar to those shown in FIGS. **6**A-**6**D can be developed for the pair of examples shown in FIGS. **4**A and **4**B, as well as the pair of examples shown in FIGS. **4**A and **4**C. Because FIGS. **6**A-**6**D convey the essential concepts applicable to all of the example pairs shown in FIGS. **4**A-**4**D (specifically, FIGS. **4**A and **4**B; FIGS. **4**A and **4**C; and FIGS. **4**A and **4**D), graphs and block diagrams that correspond to the pair of examples shown in FIGS. **4**A and **4**B, as well as the pair of examples shown in FIGS. **4**A and **4**C, have been omitted in the interest of brevity.

(86) FIGS. **6**A and **6**B depict graphs and block diagrams that illustrate the relationships depicted at rows **502**, **504**, **506** of the table **500** (shown in FIG. **5**). Turning first to FIG. **6**A there is depicted a graph **602**, along with a corresponding block diagram, which is the same block diagram shown in FIG. **4**A. The block diagram in FIG. **6**A shows a portion of a Material A in contact with a portion of a Material B. In accordance with aspects of the invention, Material A is a flexible material, and Material B is a rigid, semi-rigid, and/or conformable material. In accordance with aspects of the invention, Material A can be a flexible material having varying levels of conformability and/or compressibility, and Material B can be a rigid and/or semi-rigid material. In some embodiments of the invention, Material B can be a rigid material or a semi-rigid material having varying levels of conformability. A gripping force **404** has been applied to flexible Material A at distance **1** to bring flexible Material A into contact with Material B at an interface **406** at distance **2**. In embodiments of the invention where flexible Material A is conformable and/or compressible at the interface **406**, the gripping force **404** is sufficient to bring flexible Material A into contact with Material B without substantially compressing and/or conforming flexible Material A and/or Material B at the interface **406**.

(87) In accordance with aspects of the invention, flexible Material A includes heat generating elements (e.g., elements **208**, **208**′ shown in FIGS. **8**A-**10**C) configured to generate heat that propagates through flexible Material A, the Material A/Material B interface (can be **406** and/or **416**), and Material B. In embodiments of the invention where Material B corresponds to the container **104**, the heat that propagates through the container **104** and goes into the contents of the container **104** to heat the contents of the container **104**. In embodiments of the invention, the controller **112** can be configured to activate or initiate the heat generating elements at selected power levels and time(s) during the application of the various values for the gripping forces **404**, **414**. For example, the controller **112** can be configured to initiate/activate the heat generating elements at selected power levels around the time (e.g., just before or just after) a determination that flexible Material A has contacted Material B under the gripping force **404** to form the interface **406**. Adjustments to the gripping force that are applied subsequent to establishing the gripping force **406** are considered adjustments to the gripping force **414**. Subsequent to establishing the gripping force **404**, the controller **112** is configured to dynamically control the gripping force **414**, which means that the controller **112** is configured to automatically and/or continuously adjust the value of the gripping force **414** based at least in part of various parameters and/or characteristics (measured, estimated, downloaded, input, and the like) of the moveable gripper **106**, the container **104**, the contents of the container **104**, and/or the interface **416**. For example, the controller **112** can be configured dynamically control the gripping force **414** toward the goal of minimizing the AG %

at the interface **416**. Accordingly, the controller **112** can determine the AG % at the interface **416** at Time**1** (e.g., through sensor data and/or calculations); adjust the gripping force **414** at Time**2**; determine the AG % at the interface **416** at Time**3**; and compare the AG % at Time**1** with the AG % at Time**3**. If the AG % at Time**1** is not greater than the AG % at Time**3**, the controller **112** concludes that the gripping force **414** applied at Time**2** did not reduce the AG %, and the controller **112** further concludes that the AG % has been minimized. On the other hand, if the AG % at Time**1** is greater than the AG % at Time**3**, the controller **112** concludes that the gripping force **414** applied at Time**2** reduced the AG %. The controller **112** continues the pattern of operations used at Time**1**, Time**2**, and Time**3** until adjustments to the griping force **414** no longer result in reductions to the AG %, and the controller **112** thereby concludes that the AG % has been minimized. Additional similar examples can be generated for the other interface-parameter measurements/estimates depicted in the table **500** (shown in FIG. **5**).

(88) In another example, the controller **112** can be configured to delay initiating/activating the heat generating elements at selected power levels until after the controller **112** has selected and applied an initial value for the gripping force **414**. In some aspects of the invention, the initial value of the gripping force **414** can be randomly selected. In some aspects of the invention, the initial value of the gripping force **414** can be based on an estimate of what the final value of the gripping force **414** should be in order to achieve the TLTC goal for the interface **416**. As previously noted herein, subsequent to setting the gripping force **404** that brings flexible Material A into contact with Material B to form the interface **406**, additional adjustments to the gripping force are considered adjustments to the gripping force **414**. Subsequent to establishing the initial value of the gripping force **414**, the controller **112** is configured to dynamically control the gripping force **414**, which means that the controller **112** is configured to automatically and/or continuously adjust the value of the gripping force **414** based at least in part of various parameters and/or characteristics (measured, estimated, downloaded, input, and the like) of the moveable gripper **106**, the container **104**, the contents of the container **104**, and/or the interface **416**. For example, the controller **112** can be configured to dynamically control the gripping force **414** toward the goal of minimizing the AG % at the interface **416**. Accordingly, the controller **112** can determine the AG % at the interface **416** at Time**1** (e.g., through sensor data and/or calculations); adjust the gripping force **414** at Time**2**; determine the AG % at the interface **416** at Time**3**; and compare the AG % at Time**1** with the AG % at Time**3**. If the AG % at Time**1** is not greater than the AG % at Time**3**, the controller **112** concludes that the gripping force **414** applied at Time**2** did not reduce the AG %, and the controller **112** further concludes that the AG % has been minimized. On the other hand, if the AG % at Time**1** is greater than the AG % at Time**3**, the controller **112** concludes that the gripping force **414** applied at Time**2** reduced the AG %. The controller **112** continues the pattern of operations used at Time**1**, Time**2**, and Time**3** until adjustments to the griping force **414** no longer result in reductions to the AG %, and the controller **112** thereby concludes that the AG % has been minimized. Additional similar examples can be generated for the other interface-parameter measurements/estimates depicted in the table **500** (shown in FIG. **5**).

(89) In embodiments of the invention where the controller **112** activates or initiates the heat generating elements at selected power levels around the time (e.g., just before or just after) a determination that flexible Material A has contacted Material B under the gripping force **404** to form the interface **406**, the heat generating elements of the flexible Material A impart heat to flexible Material A and raise a temperature of flexible Material A at distance **1**. Due to the intrinsic thermal conductivity characteristics of flexible Material A, as the heat passes through flexible Material A there is some heat transfer, which results in the temperature of flexible Material A changing from an initial temperature level at distance **1** to a lower temperature level at distance **2**. As the heat generated in flexible Material A crosses the interface **406** between flexible Material A and Material B at distance **2**, the temperature at the interface drops again from the lower temperature level at distance **2** moving across the interface **416** at distance **2**. This temperature drop

across the interface **406** at distance **2** represents an initial level of thermal contact (TC-**1**) between Material A and Material B under the influence of gripping force **404**, as well as an initial level of the interfacial thermal resistance (ITR-**1**) between flexible Material A and Material B under the influence of gripping force **404**.

(90) There are two modes of heat transfer through the interface **406** between flexible Material A and Material B at distance **2**. The first heat transfer mode is through points of solid-to-solid contact between flexible Material A and Material B, and the second heat transfer mode is through the gas-filled (e.g., air-filled) gaps between flexible Material A and Material B. By selecting a flexible Material A having a relatively high thermal conductivity, the heat transfer at solid-to-solid contact between flexible Material A and Material B is relatively efficient. However, heat transfer at gas/air-filled gaps between flexible Material A and Material B is inherently inefficient because of the low thermal conductivity of gas/air in comparison to flexible Material A and Material B. Even in instances where two surfaces have been processed for smoothness, there will be post-processing surface roughness due to machining and other process limitations that results in a relatively large number of tiny gas/air-gaps between the surfaces when they are placed in contact with one another.

(91) Referring still to FIG. **6**A, the graph **602** is a plot of the air gap % (AG %) versus distance for Material A in contact with Material B under the influence of gripping force **404**. As shown at distance **2**, AG %-a represents a relatively high level of gas/air-gaps between flexible Material A and Material B and results in a relatively low initial level of thermal contact (TC-**1**) between flexible Material A and Material B at the interface **406** under the influence of gripping force **404**. Additionally, in accordance with embodiments of the invention, Material B can have a topology (e.g., ridges, creases, and the like) based on aesthetic and/or functional requirements of Material B (e.g., where Material B is a wall of the container **104**). The presence of a surface topology on Material B at distance **2** further increases gas/air-gaps between flexible Material A and Material B under the influence of gripping force **404**, thereby further decreasing the level of TC-**1** between flexible Material A and Material B at the interface **406** under the influence of gripping force **404**.

(92) FIG. **6**B depicts a graph **602**A, along with a corresponding block diagram showing compressed flexible Material A in contact with Material B at the interface **416** under the influence of gripping force **414** in accordance with aspects of the invention. The graph **602**A is substantially the same as the graph **602** (shown in FIG. **6**A) except graph **602**A shows the AG % at an interface **416** that results from a gripping force **414** being applied to flexible Material A to compress flexible Material A against Material B, which results in the distance from distance **1** to distance **2**′ shown in FIG. **6**B being less than the distance from distance **1** to distance **2** shown in FIG. **6**A. The block diagram shown in FIG. **6**B is the same block diagram shown in FIG. **4**D. In accordance with aspects of the invention, the gripping force **414** and the flexibility of compressed flexible Material A are sufficient to push compressed flexible Material A at the Material A/Material B interface **416** into the previously-described gas/air-filled spaces that result from the roughness and/or topology on the contacting surfaces of Material A and/or Material B, thereby reducing and/or substantially eliminating gas/air-gaps at the Material A/Material B interface **416** (shown as AG %-a′ in FIG. **6**B). Accordingly, FIG. **6**B depicts that AG %-a is greater than AG %-a′; and further depicts that the TLTC-**1** that results from AG %-a′ is greater than the TC-**1** that results from AG %-a.

(93) FIGS. **6**C and **6**D depict graphs and block diagrams (corresponding to the block diagrams shown in FIGS. **4**A and **4**D) that further illustrate the relationships depicted at rows **508**, **510** of the table **500** (shown in FIG. **5**). Turning first to FIG. **6**C there is depicted a graph **604**, along with a corresponding block diagram showing a portion of a Material A in contact with a portion of a Material B. The graph **604** is a plot of temperature versus distance for Material A in contact with Material B, and the block diagram shown in FIG. **6**C is the same as the block diagram shown in FIG. **4**A. In accordance with aspects of the invention, the block diagram in FIG. **6**C shows Material A as a flexible material, and Material B as a rigid, semi-rigid, and/or conformable material. In accordance with aspects of the invention, Material A can be a flexible material having varying

levels of conformability and/or compressibility, and Material B can be a rigid and/or semi-rigid material. In some embodiments of the invention, Material B can be a rigid material or a semi-rigid material having varying levels of conformability. A gripping force **404** has been applied to flexible Material A at distance **1** to bring flexible Material A into contact with Material B at an interface **406** at distance **2**. In embodiments of the invention where flexible Material A is conformable and/or compressible, the gripping force **404** is sufficient to bring flexible Material A into contact with Material B without substantially compressing and/or conforming flexible Material A and/or Material B at the interface **406**. In accordance with aspects of the invention, flexible Material A includes heat generating elements that impart heat to flexible Material A and raise a temperature of flexible Material A to T**1** at distance **1**. Due to the intrinsic thermal conductivity characteristics of flexible Material A, as the heat passes through flexible Material A there is some heat loss, which results in the temperature of flexible Material A changing from T**1** at distance **1** to T**2***a* at distance **2**. As the heat generated in flexible Material A crosses the interface **406** between flexible Material A and Material B at distance **2**, the temperature at the interface drops from T**2***a* to T**2***b*, and this drop is the interfacial thermal resistance (ITR-**1**) between flexible Material A and Material B.

(94) As previously described herein, there are two modes of heat transfer through the interface **406** between flexible Material A and Material B at distance **2**. The first heat transfer mode is through points of solid-to-solid contact between flexible Material A and Material B, and the second heat transfer mode is through the gas-filled (e.g., air-filled) gaps between flexible Material A and Material B. By selecting a flexible Material A having a relatively high thermal conductivity, the heat transfer at solid-to-solid contact between flexible Material A and Material B is relatively efficient. However, heat transfer at gas/air-filled gaps between flexible Material A and Material B is inherently inefficient because of the low thermal conductivity of gas/air in comparison to flexible Material A and Material B. Even in instances where two surface have been processed for smoothness, due to machining and other process limitations, there will be post-processing surface roughness that results in a relatively large number of tiny gas/air-gaps between the surfaces when they are placed in contact with one another. Accordingly, at distance **2**, the presence of gas/air-gaps between flexible Material A and Material B results in the temperature drop from T**2***a* to T**2***b*, and this temperature drop reflects the level of initial thermal contact (TC-**2**) between flexible Material A and Material B. Additionally, in accordance with embodiments of the invention, Material B can have a topology (e.g., ridges, creases, and the like) based on aesthetic and/or functional requirements of Material B (e.g., where Material B is a wall of the container **104**). The presence of a surface topology on Material B at distance **2** further increases gas/air-gaps between flexible Material A and Material B, thereby further increasing TC-**1**. As the heat at the Material A/Material B interface **406** moves through Material B, the temperature changes from T**2***b* at distance **2** to T**3** at distance **3**, and the change from T**2***b* to T**3** is substantially due to intrinsic thermal conductivity characteristics of Material B.

(95) FIG. **6**D depicts a graph **604**A, along with a corresponding block diagram showing compressed flexible Material A in a TLTC with Material B at the interface **416** in accordance with aspects of the invention. The graph **604**A is a plot of temperature versus distance for compressed flexible Material A in contact with Material B. Material B in FIG. **6**D is substantially the same as Material B in FIG. **6**C. Compressed flexible Material A in FIG. **6**D is substantially the same as flexible Material A in FIG. **6**C, except, in accordance with aspects of the invention, a gripping force **414** has been applied to flexible Material A in FIG. **6**D to compress flexible Material A against Material B, which results in the distance from distance **1** to distance **2**′ shown in FIG. **6**D being less than the distance from distance **1** to distance **2** shown in FIG. **6**C.

(96) In accordance with aspects of the invention, the gripping force **414** and the flexibility of compressed flexible Material A at the interface **416** are sufficient to push compressed flexible Material A at the Material A/Material B interface **416** into the previously-described gas/air-filled spaces that result from the roughness and/or topology on the contacting surfaces of Material A and

Material B, thereby reducing and/or substantially eliminating gas/air-gaps at the Material A/Material B interface **416**. In accordance with aspects of the invention, as the heat generated in compressed flexible Material A crosses the interface **416** between compressed flexible Material A and Material B at distance **2**′, the temperature at the interface drops from T**2***a*′ to T**2***b*′, and this temperature drop represents the targeted thermal contact (TLTC-**2**) between compressed flexible Material A and Material B. In accordance with embodiments of the invention, the difference between T**2***a*′ and T**2***b*′ (which can be detected using the measurement sensors **116**) is less than the difference between T**2***a* and T**2***b* (which can be detected using the measurement sensors **116**), and TLTC-**2** is greater than TC-**2**. In accordance with aspects of the invention, the gripping force **414** and the flexibility of compressed flexible Material A are sufficient to result in the difference between T**2***a*′ and T**2***b*′ being less than a predetermined threshold, which reflects that TLTC-**2** is greater than a predetermined threshold. As the heat at the Material A/Material B interface moves through Material B, the temperature changes from T**2***b*′ at distance **2**′ to T**3**′ at distance **3**′, and the change from T**2***b*′ to T**3**′ is substantially due to intrinsic thermal conductivity characteristics of Material B.

(97) FIG. **6**E depicts a block diagram that further illustrates a supporting system **610**, which is a subset of the system **100**. The supporting system **610** can be used to control various aspects of the system **100** to dynamically control thermal contact at the interface **416**. More specifically, the system **610** can be used to dynamically set and/or make adjustments to the gripping and/or heating (gripping/heating) settings **614** of the system **100** in order to achieve TLTC at the interface **416**, as well as achieve substantially efficient transfer and even distribution of heat through the walls of the container **104** to the contents of the container **104**. In accordance with aspects of the invention, the gripping/heating settings **614** can include one or more of the various system settings involved in the gripping and/or heating operations performed by the system **100**. In some aspects of the invention, the gripping/heating settings **614** include the gripping forces **404**, **414**; the activation and/or deactivation pattern (i.e., heating pattern(s)) applied to the heating zones A, B (**208**A, **208**B, **208**′ shown in FIGS. **8**A-**10**C); the power applied to the heating zones A, B; whether the power applied to the heating zones A, B is continuous or pulsed; the duty cycle (duration, pule width, and pulse magnitude) of the pulsed power applied to the heating zones A, B; the initiation of the power applied to the heating zones A, B; and/or whether the system **100** agitates the moveable gripper **106** while the moveable gripper **106** is gripping and transferring heat through the container **104** to the contents of the container **104**. In aspects of the invention, TLTC at the interface **416** can be determined based on the relationships depicted at rows **502**-**514** of the table **500** (shown in FIG. **5**).

(98) The supporting system **610** includes the controller **112** communicatively coupled to the sensor network **117**. The sensor network **117** is configured to receive data from the system **100** (shown in FIG. **1**) about interface-parameter proxy measurements/estimates **612**; other estimated parameters **613**; and values of the heating/gripping settings **614**. The interface-parameter proxy measurements/estimates **612** include Material A parameters (where Material A corresponds to the flexible inner sleeve **108**); Material B parameters (where Material B corresponds to the container **104**); and parameters of the interface **416**. The other estimated parameters **613** can include a variety of parameters that are not easily detected and/or cannot easily be accessed (e.g., through manual inputs **111** or additional data source(s) **115**), an example of which includes estimating a temperature at various points along a centerline of the contents of the container **104** (where the container **104** corresponds to Material B), which provides feedback on how evenly or uniformly heat is being delivered to the contents of the container **104**. The controller **112** is configured to include machine learning algorithms **615**, simulation algorithms **616**, and/or relational databases **618**, which can be used individually or in any combination to perform task **620** based at least in part on the interface-parameter proxy measurements/estimates **612**; the other estimated parameters **613**; and/or the values/settings of the gripping/heating settings **614**. In embodiments of the invention, the task **620** includes generating dynamic adjustments to the gripping/heating settings **614**, if necessary, to

achieve TLTC at the interface **416**, as well as achieve substantially efficient transfer and even distribution of heat through the walls of the container **104** to the contents of the container **104**. In some aspects of the invention, TLTC is represented by the interface-parameter proxy measurements/estimates shown in the table **500** (shown in FIG. **5**), which can include predictions of the target interfacial thermal resistance (ITR) levels made by the controller **112** using the machine learning algorithms **615**, the simulation algorithms **616**, and/or the relational database **618**.
(99) In some embodiments of the invention, the controller **112** can be configured to perform task **620** by utilizing the machine learning algorithm **615** to generate and train a model of the gripper sub-assembly **102**, the movable gripper **106**, the container **104**, and/or the contents of the container **104**. More specifically, the model can be trained to classify and/or predict the nature of the interface between the flexible inner sleeve heater assembly **108** and the container **104** (e.g., as depicted in the tables **500**, **700** shown in FIGS. **5** and **7**A; and using the techniques used in FIGS. **6**A-**6**E) in response to the gripping/heating settings **614** applied to the system **100**.
(100) In some embodiments of the invention, the controller **112** can be configured to perform the task **620** by utilizing the simulation algorithm(s) **616** to simulate the characteristics of the gripper sub-assembly **102**, the movable gripper **106**, and/or the container **104**. More specifically, the simulation algorithm(s) **616** can be known simulation algorithms configured and arranged to simulate the nature of the interface between the flexible inner sleeve heater assembly **108** and outer walls of the container **104** (e.g., as depicted in the tables **500**, **700** shown in FIGS. **5** and **7**A; and using the techniques used in FIGS. **6**A-**6**E) in response to the gripping/heating settings **614** applied to the system **100**.
(101) In some embodiments of the invention, the controller **112** can be configured to perform the task **620** by dynamically controlling and accessing a relational database **618** stored in a memory location of the controller **112**. A suitable relational database **618** that can be used in connection with embodiments of the invention is any relational database configured to provide a means of storing related information (e.g., the interface-parameter proxy measurements/estimates **612**, the other estimated settings **613**, and/or the gripping/heating settings **614**) in such a way that the information and the relationships between the information can be retrieved from it. The data in a relational database can be related according to common keys or concepts, and the ability to retrieve related data from a table is the basis for the term relational database. A relational database management system (RDBMS) of the controller **112** performs the tasks of determining the way data and other information are stored, maintained and retrieved from the relational database of the controller **112**. For example, where the targeted ITR is a value denoted by X, the relational database **618** can be used to determine that, based on the current interface-parameter proxy measurements/estimates **612**, the gripping force **414** to achieve the targeted ITR value of X should be a gripping force **414** of value Y. The controller **112** would then evaluate the current values of the gripping force **414** and output control signals that make whatever adjustments are necessary to the gripping force **414** to achieve and maintain a gripping force value of Y.
(102) In some embodiments of the invention, the dynamic adjustments performed as part of the task **620** can be considered mitigation strategies that the controller **112** selects and initiates based on the current status of the interface **416**. For example, where the other estimated parameters **613** indicate that an upper region of the contents of the container **104** is heating faster (or to a higher temperature) than a lower region of the contents of the container **104**, the controller **112** can be configure to perform the dynamic adjustments of task **620** by selecting from a suite of mitigation operations configured to make the heat distribution between the upper and lower regions of the contents of the container **104** more uniform. For example, the controller **112** can be configured to use a model of the system **100**, the interface **416**, the container **104**, and the contents of the container **104** to determine that the mitigation operation or combination of mitigation operations that are most likely the be effective at making the heat distribution between the upper and lower regions of the contents of the container **104** more uniform. In embodiments of the invention, the

mitigation operations can include changing the activation and/or deactivation pattern (i.e., heating pattern(s)) applied to the heating zones of the thermal film heater **208**, **208**′; adjusting the power applied to the heating zones of the thermal film heater **208**, **208**′; determining whether the power applied to the heating zones is continuous or pulsed; adjusting the duty cycle (duration, pule width, and pulse magnitude) of the pulsed power applied to the heating zones; and determining whether the system **100** agitates the moveable gripper **106** while the moveable gripper **106** is gripping and transferring heat through the container **104** to the contents of the container **104**.

(103) FIG. **7**A depicts a table **700** illustrating relationships between the gripping force **414** (shown in FIGS. **4**B-**4**D); the nature of Material A at the interface **416** (shown in FIGS. **4**B-**4**D); the nature of Material B at the interface **416**; the nature of the topology (e.g., ridges, creases, and the like) of Material B at the interface **416** (shown in FIGS. **4**B-**4**D); and the interface-parameters that can be dynamically controlled, improved, and/or achieved using the embodiments of the invention. In some embodiments of the invention, Material A can be compressible at the interface **416**, and rows **702**, **704**, **706**, **708** of the table **700** depict the interface-parameters that can be dynamically controlled, improved, and/or achieved based on various combinations of Material B at the interface **416** and the topology of Material B at the interface **416**. As shown, where Material A is compressible at the interface **416**, a gripping force **414** (GF**4**, GF**5**, GF**6**, GF**7**) can be applied that will dynamically control, improve, and/or achieve a TLTC (e.g., TLTC-**1** shown in FIG. **6**B) that can include ITC. In accordance with aspects of the invention, TLTC can be evaluated using any of the applicable interface-parameter proxy measurements/estimates shown in table **500** (shown in FIG. **5**) and the applicable techniques shown in FIGS. **6**A-**6**E.

(104) In some embodiments of the invention, Material A can be conformable at the interface **416**, and rows **710**, **712**, **714**, **716** of the table **700** depict the interface-parameters that can be dynamically controlled, improved, and/or achieved based on various combinations of Material B at the interface **416** and the topology of Material B at the interface **416**. As shown at rows **710**, **712**, **716**, where Material A is conformable at the interface **416**, and for the combinations of Material B at the interface **416** and the Material B topology at the interface **416**, a gripping force **414** (GF**8**, GF**9**, GF**11**) can be applied that will dynamically control, improve, and/or achieve a TLTC at the interface **416** (e.g., TLTC-**1** shown in FIG. **6**B) that can include ITC. In accordance with aspects of the invention, TLTC can be evaluated using any of the interface-parameter proxy measurements/estimates shown in table **500** (shown in FIG. **5**) and the applicable techniques shown in FIGS. **6**A-**6**E. As shown at row **714**, where Material A is conformable at the interface **416** and Material B at the interface **416** is a rigid material having a topology, a gripping force **414** (GF**10**) can be applied that will dynamically control, improve, and/or achieve a TLTC at the interface **416**. In accordance with embodiments of the invention, TLTC at the interface **416** can include ITC where Material A is sufficiently flexible to fill in depressions at the interface **416** that result from the Material B topology. In accordance with aspects of the invention, TLTC at the interface **416** can be evaluated using any of the applicable interface-parameter proxy measurements/estimates shown in table **500** and the applicable techniques shown in FIGS. **6**A-**6**E.

(105) In some embodiments of the invention, Material A can be flexible but not conformable at the interface **416**, and rows **718**, **720**, **722**, **724** of the table **700** depict the interface-parameters that can be dynamically controlled, improved, and/or achieved based on various combinations of Material B at the interface **416** and the topology of Material B at the interface **416**. As shown at rows **718**, **720**, **724**, where Material A is flexible but not conformable at the interface **416**, and for the combinations of Material B at the interface **416** and the Material B topology at the interface **416**, a gripping force **414** (GF**12**, GF**13**, GF**15**) can be applied that will dynamically control, improve, and/or achieve a TLTC (e.g., TLTC-**1** shown in FIG. **6**B) that can include ITC. In accordance with aspects of the invention, TLTC can be evaluated using any of the interface-parameter proxy measurements/estimates shown in table **500** (shown in FIG. **5**) and the applicable techniques shown in FIGS. **6**A-**6**E. As shown at row **722**, where Material A is flexible but not conformable at the

interface **416** and Material B at the interface **416** is a rigid material having a topology, a gripping force **414** (GF**14**) can be applied that will dynamically control, improve, and/or achieve a TLTC at the interface **416** (e.g., TLTC-**1** shown in FIG. **6**B). However, TLTC at row **722** will not be sufficient to include ITC because Material A, albeit flexible, is not sufficiently flexible to fill in depressions at the interface **416** that result from the Material B topology. In accordance with aspects of the invention, TLTC at the interface **416** can be evaluated using any of the applicable interface-parameter proxy measurements/estimates shown in table **500** and the applicable techniques shown in FIGS. **6**A-**6**E.

(106) FIGS. **7**B, **7**C, and **7**D depict cross-sectional views of structures that further illustrate some of the relationships depicted in the table **700**, where Material A corresponds to the flexible inner sleeve heater assembly **108**, and where Material B corresponds to an outer wall of the container **104**. FIGS. **7**B and **7**C depict an example of an interaction between the flexible inner sleeve heater assembly **108** and a wall **104**A of the container **104** that illustrates the relationships depicted in rows **702**, **704**, **706**, **708** of the table **700** (shown in FIG. **7**A) in accordance with aspects of the invention. For ease of illustration and explanation, the flexible inner sleeve **108** and the container wall **104**A are each substantially planar in FIGS. **7**B and **7**C. However, it is understood that, in practice, the flexible inner sleeve **108** and the container wall **104**A can each be substantially non-planar. The flexible inner sleeve heater assembly **108** includes a region **108**A having one or more layers, along with a compressible interface layer **108**B. In some embodiments of the invention, the compressible interface layer **108**B can be an elastomer material. In some embodiments of the invention, the compressible interface layer **108**B can be a filled elastomer or composite material with thermally conductive particles for enhanced thermal conductivity. In some embodiments of the invention, the thermally conductive particles are configured such that compression of the interface layer **108**B creates a percolated network of thermally conductive particles that improve the thermal conductivity of the filled elastomer or composite material of the compressible interface layer **108**B while having a sufficient thickness that allows the compressible interface layer **108**B to conform to whatever height (or depth) irregularities exist based on the presence of a non-conformable container wall topology **104**B. In some embodiments of the invention, the compressible interface layer **108**B can be a silicone elastomer material. In some embodiments of the invention, the compressible interface layer **108**B can be a silicone elastomer material having the thermally conductive particles. The non-conformable container wall topology **104**B (e.g., ridges, creases, depressions, and the like) can be provided based on aesthetic and/or functional requirements of the container wall **104**A or can be roughness that results from manufacturing or processing of the outer surface of the container wall **104**A.

(107) FIG. **7**B depicts the flexible inner sleeve heater assembly **108** having a thickness D**1** under influence of the gripping force **404** that brings the flexible inner sleeve heater assembly **108** into contact with the container wall **104**A but does not compress the inner flexible inner sleeve heater assembly **108**. FIG. **7**C depicts the flexible inner sleeve heater assembly **108** under the influence of the gripping force **414** that presses the compressible interface layer **108**B against the container wall **104**A. In accordance with embodiments of the invention, the compressible interface layer **108**B has sufficient flexibility and thickness to enable the surface of the compressible interface layer **108**B that interfaces with the non-conformable container wall topology **104**B to, in response to the gripping force **414**, substantially conform to the container wall topology **104**B of the container wall **104**A. Accordingly, in embodiments of the invention, a TLTC can be dynamically controlled, improved, and/or achieved between the flexible inner sleeve heater assembly **108** and the container **104** in accordance with the relationships depicted in the table **500** even where the outer surface of the container wall **104**A includes a topology **104**B. Under the influence of the gripping force **414**, the thickness of the flexible inner sleeve heater assembly **108** is reduced to D**2**, which is less than D**1**.

(108) FIG. **7**D depicts a sequence of block diagrams showing top-down, cross-sectional views of

how a moveable gripper **106** having a flexible inner sleeve **108** contacts and conforms a container wall **104**A of a container **104** in accordance with non-limiting embodiments of the invention, where the container wall **104**A includes a conformable, irregular surface topology. The example depicted in FIG. **7**D is an example of the relationships defined at row **724** of the table **700** (shown in FIG. **7**A). The leftmost image depicts the container **104** within the adjustable opening **126** defined by the moveable gripper **106** but prior to the application of the gripping force **414**. The center image depicts the container **104** and the moveable gripper **106** during application of the gripping force **414**, wherein the flexible inner sleeve **108** of the moveable gripper **106** has contacted the container wall **104**B and started the process of conforming the conformable topology of the container wall **104**B to the shape of the moveable gripper **106**. The rightmost image depicts the container **104** and the moveable gripper **106** where the gripping force **414** has urged the moveable gripper **106** to conform the conformable topology of the container wall **104**B to the shape of the moveable gripper **106**, thereby substantially reducing the air gaps and substantially improving the thermal transfer.
(109) FIGS. **8**A, **8**B, **8**C, and **8**D, depict additional details of how the flexible inner sleeve heater assembly **108** can be implemented according to embodiments of the invention. More specifically, FIG. **8**A depicts the flexible inner sleeve heater assembly **108** in a substantially cylindrical shape. In embodiments of the invention, the flexible inner sleeve heater assembly **108** is held in the substantially cylindrical shape shown in FIG. **8**A when the flexible inner sleeve heater assembly **108** is coupled to the moveable outer sleeve heater assembly **110** (best shown in FIGS. **2** and **3**). Various component parts of the flexible inner sleeve **108** are shown diagrammatically in FIG. **8**A as dotted line structures. FIGS. **8**B, **8**C, **8**D depict the flexible inner sleeve heater assembly **108** operating according to different selectable heating zones, which are also referred to herein as selectable heating patterns. Although three heating zones **250***a* (shown in FIG. **8**B), **250***b* (shown in FIG. **8**C), **250***c* (shown in FIG. **8**D) are depicted, it should be appreciated that any number of heating zones can be provided.
(110) As best shown in FIG. **8**A, in aspects of the invention, the flexible inner sleeve heater assembly **108** includes a thermal film heater **208** configured to generate heat in response to receiving an applied voltage. In one or more non-limiting embodiments of the invention, the thermal film heater **208** and the busbars **211** are included in a stacked arrangement of individual flexible layers, sheets and/or thin films, examples of which are shown in FIGS. **9**A-**9**D and **10**A-**10**C and described in greater detail subsequently herein. In embodiments of the invention, the busbars **211** pass current to the thermal film heater **208**, which generates heat in response to the received current. In embodiments of the invention, the busbars **211** are formed by depositing a layer of conductive material then selectively etching the layer of conductive material to define the busbars **211**. The thermal film heater layer **208** serves as the thin film heater and can include various thermal generating materials including, but not limited to, a carbon-filled polyimide (e.g., element **208** shown in FIGS. **9**A-**9**D. In some embodiments of the invention, the busbars **211** can be eliminated and the thermal film heater layer **208** can be a resistive metal and/or an etched resistive metal foil (e.g., element **208**′ shown in FIGS. **10**A-**10**C). The thickness of the thermal film heater layer **208** can range, for example, from about 12.5 microns (μm) to 75 μm. In some embodiments of the invention, a thermally conductive layer **200** (shown in FIGS. **9**A-**9**D and **10**A) is positioned between the thermal film heater **208** and the container **104** (shown in FIGS. **1-3**) and serves to assist with uniformly transferring the heat generated by the thermal film heater layer **208** to the container **104** disposed in the adjustable opening **126** so as to assist with uniformly distributing heat to the contents of the container **104**.
(111) The individual heating zones A and B can be selectively activated and deactivated independently from one another, which provides the capability to uniformly heat containers of different sizes, shapes, and/or materials received by the inner sleeve heater assembly **108**. In addition, a first temperature of a first activated heating zone can be controlled independently from a second temperature of a second activated heating zone. Accordingly, temperatures at different

locations of the inner sleeve heater assembly **108** can be independently adjusted to improve the precision of the heat applied to the container. For instance, a lower-portion heating zone can be utilized to heat shorter containers so as to concentrate the heat accordingly. In another example, a lower portion of the moveable gripper **106** can be heated at a first temperature while the upper portion of the moveable gripper **106** can be heated at a different second temperature to properly heat containers having a different material at the container bottom compared to the container top. In another example, the measurement sensors **116** can detect that heat is being delivered unevenly to the container **104**, and the heat delivered to each heating zones (i.e., the heating zone pattern) can be controlled (e.g., by the controller **112**) in a manner configured to compensate for and correct the uneven heat distribution. In embodiments of the invention, the uneven heat distribution can be detected by using the measurement sensors **116** to determine that the difference between a temperature at a first predetermined location on the container **104** and a temperature at a second predetermined location on the container **104** exceeds a threshold. In embodiments of the invention, the uneven heat distribution can be detected by using the measurement sensors **116** to determine that the difference between a temperature at a first end of the container **104** and a temperature at a second and opposite end of the container **104** exceeds a threshold. In embodiments of the invention, the uneven heat distribution can be detected by using the measurement sensors **116** and the controller **112** to estimate temperature differences between the locations on the container **104** and center-points of the contents of the container **104**.

(112) Electrical terminals **213** are attached to the busbars **211**, and electric wires (not shown) can be coupled to the electrical terminals **213** to deliver power to the busbars **211**. Multiple types of measurement sensors **116** are positioned in various locations on the flexible inner sleeve heater assembly **108** to provide inputs to various control processes executed by the controller **112** (shown in FIGS. **1**, and **6**E). As previously noted herein, the measurement sensors **116** can include, but are not limited to, a pressure sensor, a container temperature sensor, an ambient/environment temperature sensor, a vibration sensor, an accelerometer, gyroscope, a thermistor, and the like. The measurement sensors **116** can be individually coupled to various locations of the flexible inner sleeve heater assembly **108**. In some embodiments of the invention, the measurement sensors **116** can be printed (e.g., using additive manufacturing techniques) on one or more of the individual flexible layers, sheets and/or thin films that form the flexible inner sleeve heater assembly **108**. For example, rather than coupling a single individual measurement sensor **116** at a particular location on the flexible inner sleeve heater assembly **108**, an array of measurement sensors **116** can be printed on one or more of the individual flexible layers (e.g., a first electrically insulative layer that forms the electrical insulator region **204** shown in FIG. **9**B).

(113) The flexible layers that make up the flexible inner sleeve heater assembly **108** are sufficiently flexible to be folded or rolled about a vertically extending center Y-axis (shown at reference axes **102**). Accordingly, the flexible inner sleeve heater assembly **108** when attached to the moveable outer sleeve heater assembly **110** is sufficiently flexible to track the movement of the moveable outer sleeve heater assembly **110** while also tracking the cylindrical shape defined by the moveable outer sleeve heater assembly **110**. Thus, the moveable outer sleeve heater assembly **110** and the flexible inner sleeve heater assembly **108** define the adjustable opening **126**. The adjustable opening **126** allows for a container (e.g., container **104**) having a variety of sizes, shapes, and exterior surface topologies to be disposed therein.

(114) FIG. **8**B depicts the selectable heating zone **250***a* of the flexible inner sleeve heater assembly **108** according to embodiments of the invention. The heating zone **250***a* effectively includes the entire flexible inner sleeve heater assembly **108** spanning from a first busbar **211***a* of the flexible inner sleeve heater assembly **108** to a second busbar **211***b*. The heating zone **250***a* can be selected and activated by applying a first voltage potential (e.g., a positive voltage) to the first busbar **211***a* via a first terminal **213***a* and a second voltage potential (e.g., a negative voltage or ground potential) to the second busbar **211***b* via a second terminal **213***b*. In this manner, a voltage potential

is applied across the entire thermal film heater **208** of the flexible inner sleeve heater assembly **108**, which in turn induces current flow through the entire thermal film heater layer **208**. Electrical lead wires can then be attached (e.g., via soldering or electrical terminals **213***a*, **213***b*, **213***c*) to the busbars **211** to deliver power to the busbars **211**, which deliver their power to thermal film heater layer **208**. In this manner, the thermal film heater layer **208** can generate heat in response to a voltage being applied to one or more of the defined busbars **211**.

(115) FIG. **8**C depicts the selectable heating zone **250***b* of the flexible inner sleeve heater assembly **108** according to an embodiments of the invention. The heating zone **250***b* includes a lower portion of the flexible inner sleeve heater assembly **108** (e.g., heater zone B shown in FIGS. **8**B and **8**C) spanning from a third busbar **211***c* to the second busbar **211***b*, while excluding an upper portion of the flexible inner sleeve heater assembly **108** (e.g., heater zone A shown in FIGS. **8**B and **8**C) spanning from the third busbar **211***c* to the first busbar **211***a* (shown in phantom). The heating zone **250***b* can be selected and activated by applying a first voltage (e.g., a positive voltage) to the third busbar **211***c* via a third terminal **213***c* and a second voltage (e.g., a negative voltage or ground potential) to the second busbar **211***b* via the second terminal **213***b*. In this manner, a voltage potential is applied across only a portion of the thermal film heater layer **208** of the inner sleeve heater assembly **108**. As a result, current flows through the thermal film heater layer **208** from the third busbar **211***c* to the second busbar **211***b*, rather than through the entire thermal film heater layer **208**.

(116) FIG. **8**D depicts the selectable heating zone **250***c* of the flexible inner sleeve heater assembly **108** according to embodiments of the invention. The heating zone **250***b* includes the upper portion of the flexible inner sleeve heater assembly **108** (e.g., heater zone A shown in FIGS. **8**B and **8**C) spanning from the first busbar **211***a* to the third busbar **211***c*, while excluding the lower portion of the flexible inner sleeve heater assembly **108** (e.g., heater zone B shown in FIGS. **8**B and **8**C) spanning from the third busbar **211***c* to the second busbar **211***b* (shown in phantom). The third heating zone **250***c* can be selected and activated by applying a first voltage (e.g., a positive voltage) to the first busbar **211***a* via the first terminal **213***a* and a second voltage (e.g., a negative voltage or ground potential) to the third busbar **211***c* via the third terminal **213***c*. Again, the voltage potential is applied across only a portion of the thermal film heater layer **208** of the inner sleeve heater assembly **108**. In this scenario, however, the current flows through the thermal film heater layer **208** from the first busbar **211***a* to the third busbar **211***c*.

(117) Referring still to FIGS. **8**B, **8**C, **8**D, the controller **112** can be in signal communication with the power supply **120**, along with measurement sensors **116***a* and **116***b* coupled to the flexible inner sleeve heater assembly **108**. The controller **112** can control the power supply **120** to control the voltages the power supply **120** applies to the busbars **211***a*, **211***b*, **211***c* to select and activate a targeted one of the heating zones **250***a*, **250***b*, **250***c*. In embodiments of the invention, the controller **112** can also monitor the measured data (e.g., temperatures) output from the measurement sensors **116***a*, **116***b*, **116***c* located at respective heating zones **250***a*, **250***b* **250***c*. The measurement sensors **116***a*, **116***b*, **116***c* are specific instances of the measurement sensors **116** (e.g., the measurement sensors **116** shown in FIG. **8**A). In this manner, the controller **112** can automatically activate and deactivate selected heating zones and/or actively adjust the temperatures of each heating zone **250***a*, **250***b*, **250***c* independently from one another based on the measured temperature data output from the measurement sensors **116***a*, **116***b*, **116***c* located at their respected heating zone **250***a*, **250***b*, **250***c*. In embodiments of the invention, the controller **112** can detect one or more hot spots forming while heating an inserted container **104** and can automatically deactivate one or more of the heating zones **250***a*, **250***b*, **250***c* to avoid damaging the thermal film heater layer **208**.

(118) FIGS. **9**A-**9**D depict a cross-sectional views of example multi-layered implementations of the flexible inner sleeve heater assembly **108**, wherein FIGS. **9**A and **9**B depict an implementation of the flexible inner sleeve **108** as a multi-layered flexible inner sleeve heater assembly **108**C, and wherein FIGS. **9**B and **9**C depict an implementation of the flexible inner sleeve **108** as a multi-

layered flexible inner sleeve heater assembly **108**D. For ease of illustration, the flexible inner sleeves **108**C, **108**D are depicted as substantially planar. However, it is understood that, in practice, the flexible inner sleeves **108**C, **108**D can be substantially non-planar. The individual flexible layers of the flexible inner sleeve heater assembly **108**C shown in FIG. **9**A include a thermally conductive layer **200**, an electrical insulator region **204**, a thermal film heater layer Zone A **208**A, a thermal film heater layer Zone B **208**B, and an electrically conductive layer formed as multiple spaced apart busbars **211**, configure and arranged as shown. Some or all of the layers shown in FIG. **9**A can be secured in place using any suitable adhesive or bonding material (not shown separately). In embodiments of the invention, the bonding material can include, for example, various adhesive materials including, but not limited to, polyimide adhesive, epoxy adhesive, pressure sensitive adhesives, acrylic adhesive, and/or fluoropolymer adhesive, using in any combination. The thickness of each individual region of bonding material can range, for example, from about 12.5 microns (μm) to about 125 μm

(119) The thermally conductive layer **200** can include, for example, various thermally conductive metal materials including, but not limited to, aluminum, copper, gold, or silver. The thickness of the thermally conductive layer **200** can range, for example, from about 0.76 mm (0.030 inches) to about 1 mm (about 0.035 inches).

(120) The electrical insulator region **204** can include various electrically insulative materials including, but not limited to, a polyimide film, a polyester (PET) film, a fluoropolymer film, and a silicone elastomer. The thickness of the electrical insulator region **204** can range, for example, from about 25 microns (μm) to 50 μm. The electrical insulator region **204** protects against the electrical shorting of the thermal film heater layer **208** and the busbars **211** to the thermally conductive layer **200** and to the surrounding environment. The electrical insulator region **204** serves as an electrical protective layer to protect the thermal film heater layer **208** from electrically shorting against any metal in the thermally conductive layer **200** or to the moveable outer sleeve heater assembly **110** or other components that can touch the heater film **208** through the cutouts of the moveable outer sleeve heater assembly **110**. In some embodiments of the invention, the electrical insulator region **204** can be omitted if the bonding materials that join the various layers shown in FIG. **9**A provide sufficient electrical insulation.

(121) The multiple spaced apart busbars **211**, can include various electrically conductive materials including, but not limited to, copper (Cu), gold (Au), silver (Ag), tin (Sn), and aluminum (Al). The thickness of the busbars **211** along the vertical Y-axis can range, for example, from about 12.5 microns (μm) to about 75 μm. In embodiments of the invention where the thermal film heater layer **208** is implemented as a layer of carbon-filled polyimide, the conductive layer from which the busbars **211** are formed can be permanently bonded with the thermal film heater layer **208** to form a permanent bond.

(122) In FIG. **9**B, the multi-layered flexible inner sleeve heater assembly **108**D is substantially the same as the flexible inner sleeve heater assembly **108**C except the flexible inner sleeve heater assembly **108**D includes a compressible interface layer **108**B having substantially the same features and functionality as the compressible interface layer **108**B shown in FIGS. **7**B and **7**C. In some embodiments of the invention, the compressible interface layer **108**B can be an elastomer material. In some embodiments of the invention, the compressible interface layer **108**B can be a filled elastomer or composite material with thermally conductive particles for enhanced thermal conductivity. In some embodiments of the invention, the thermally conductive particles are configured such that compression of the interface layer **108**B creates a percolated network of thermally conductive particles that improve the thermal conductivity of the filled elastomer or composite material of the compressible interface layer **108**B while having a sufficient thickness that allows the compressible interface layer **108**B to conform to whatever height (or depth) irregularities exist based on the presence of a non-conformable container wall topology **104**B. In some embodiments of the invention, the compressible interface layer **108**B can be a silicone

elastomer material. In some embodiments of the invention, the compressible interface layer **108**B can be a silicone elastomer material having the thermally conductive particles. Similar to the compressible interface layer **108**B shown in FIGS. **7**B and **7**C, the compressible interface layer **108**B in FIG. **9**B, under the influence of the gripping force **414**, is pressed against the container wall **104**A and an adjacent container **104**. In accordance with embodiments of the invention, the compressible interface layer **108**B has sufficient flexibility and thickness to enable the surface of the compressible interface layer **108**B that interfaces with a non-conformable container wall topology (e.g., **104**B shown in FIGS. **7**B and **7**C) to, in response to the gripping force **414**, substantially conform to the container wall topology. Accordingly, in embodiments of the invention, a TLTC can be dynamically controlled, improved, and/or achieved between the flexible inner sleeve heater assembly **108**D and the container **104** in accordance with the relationships depicted in the table **500** even where the outer surface of the container wall **104**A includes a topology

(123) FIGS. **9**C and **9**D depict examples of how heat is transmitted from the thermal film heating zone A **208**A through the electrical insulator region **204**, the thermally conductive layer **200**, and, optionally, the compressible interface layer **108**B in accordance with aspects of the invention. A similar heat transmission path can be generated for heating zone B **208**B alone and/or for heating zones A & B **208**A, **208**B taken in combination. Referring collectively to FIGS. **9**A and **9**B, heat is generated by the thermal film heating zone A **208**A when an electric potential is applied across heating zone A **208**A through the busbar **211** due to the joule heating phenomenon. As shown in FIGS. **9**C and **9**D, heating zone A **208**A has been activated while heating zone B **208**B is not activated. Heat generated in heating zone A **208**A will propagate upward (e.g., along the y-axis in the positive direction), downward (e.g., along the y-axis in the negative direction) and laterally (e.g., along the x-axis and the z-axis in positive and negative directions) but will propagate preferentially or selectively along the path of least resistance (i.e., the shortest or “thinnest” path), which is shown in FIGS. **9**C and **9**D as preferential heating paths **206**B (e.g., along the y-axis in the negative direction). The terms “preferential,” “preferentially,” “selective,” “selectively,” and equivalents thereof, such as, for example, “preferentially propagate heat along a targeted path,” means that the heat propagates along the targeted path at a faster rate than the heat propagates along the available non-targeted paths. Accordingly, the thicknesses of the various layers/regions **204**, **200**, **108**B of the flexible inner sleeve **108**C, **108**D are selected such that the preferential path **206**B is from the thermal film heater **208** to the container **104**, and are further selected such that a targeted (or maximized) percentage of the heat emanating from the thermal film heater **208** is along the preferential path **206**B. More specifically, the portion of region **204** that is below the thermal film heater **208** and any intervening bonding materials are very thin, typically measured in microns of thickness, whereas the lateral distances (along the x-axis) are measured in centimeters. Additionally, the thickness of the portion of the region **204** that is above the thermal film heater **208** and the thickness of the busbars **211** are larger than the thickness of the portion of region **204** that is below the thermal film heater **208** and any intervening bonding materials. Accordingly, the preferential heating path **206**B (i.e., the path of least thermal resistance) becomes the most direct path between the heating zone A **208**A and the thermally conductive layer **200**, and/or between the heating zone A **208**A and the compressible interface layer **108**B, both of which are also the shortest distance for heat to travel from the heating zone A **208**A to container **104** that is in contact with the thermally conductive layer **200** and/or the compressible interface layer **108**B.

(124) FIG. **10**A depicts an example cross-sectional view of the flexible inner sleeve heater assembly **108** implemented as a flexible inner sleeve heater assembly **108**E, wherein the thermal film heater layer **208** is implemented as an etched resistive metal foil **208**′. The resistive metal foil **208**′ is bonded (e.g., using the aforementioned types of bonding materials) above and below to a first electrically insulative layer **204** and a second electrically insulative layer **214**. In embodiments of the invention, the resistive metal foil **208**′ can be formed from various resistive metal materials

including, but not limited to, cupronickel (CuNi) and various types of oxidation-corrosion-resistant materials. Cupronickel is an alloy of copper that contains nickel and strengthening elements, such as iron and manganese.

(125) FIG. **10**B depicts a region **1002**A coupled to the power supply **120** and the controller **112**. The region **1002**A is an exploded and tilted view of a region **1002** of the flexible inner sleeve heater layer **108**E shown in FIG. **10**A. The region **1002**A depicts that, in embodiments of the invention, the resistive metal foil **208**′ can be etched to define a narrow strip of resistive metal foil in a serpentine pattern **220** that traverses from a first terminal **213***d* to a second terminal **213***e*. In embodiments of the invention, the terms "serpentine pattern" and equivalents thereof refer to a pattern that is sinuous and curves in alternate directions. A first voltage polarity (e.g., a positive voltage) can be applied to the first terminal **213***d* and while a second voltage polarity (e.g., a negative voltage or ground) can be applied to the second terminal **213***e*. The voltage applied across the resistive metal foil **208**′ in the serpentine pattern **220** generates a current flow through the resistive metal foil **208**′, which in turn induces heat that is efficiently and preferentially (e.g., using the same preferential heating paths **206**B shown in FIGS. **9**C and **9**D) passed through the remaining layers (**204**, **200**, and optionally **108**B) of the flexible inner sleeve heater assembly **108**E to deliver heat to the container **104** (shown in FIGS. **1-3**) that is being maintained by the gripping force **414** at a TLTC with the flexible inner sleeve heater assembly **108**E.

(126) FIG. **10**C depicts a region **1002**B coupled to the power supply **120** and the controller **112**. The region **1002**B is an exploded top-down view of the region **1002** of the flexible inner sleeve heater layer **108**E shown in FIG. **10**A. The region **1002**B depicts that, in embodiments of the invention, the resistive metal foil **208**′ can be etched to define multiple serpentine patterns **220***a*, **220***b*. Although two serpentine patterns **220***a*, **220***b* are shown in FIG. **10**C, any number of serpentine patterns **220** can be provided. In accordance with embodiments of the invention, the serpentine pattern **220***a* traverses from the first terminal **213***d* to the second terminal **213***e*; and the serpentine pattern **220***b* traverses from a third terminal **213***f* to a fourth terminal **213***g*. In embodiments of the invention, the resistive metal foil **208**′ is etched to define the multiple individual serpentine patterns **220***a*, **220***b*. The serpentine patterns **220***a*, **220***b* when **213***d* and **213***f* are electrically connected define a first heater zone corresponding to the heater zone **250***a* shown in FIG. **8**B. The serpentine pattern **220***a* defines a second heater zone corresponding to heater zone **250***c* shown in FIG. **8**D. The serpentine pattern **220***b* defines a third heater zone corresponding to heater zone **250***b* shown in FIG. **8**C. In embodiments of the invention, current can be induced to flow through a given serpentine pattern **220***a*, **220***b* by using the controller **112** to dynamically control the power supply **120** to selectively apply voltages to the serpentine patterns **220***a*, **220***b* independent from one another. In this manner, multiple heating zones can be effected as described herein.

(127) In embodiments of the invention, the first heating zone **220***a*, **220***b* can be effected by applying a voltage across both of the serpentine patterns **220***a* and **220***b* (terminals **213***e* and **213***f* can be electrically coupled to create one larger heater). The first heating zone **220***a*, **220***b*, therefore, can effectively generate heat from substantially the entire flexible inner sleeve heater assembly **108**E. The second heating zone **220***a* can be effected by applying a voltage across the serpentine pattern **220***a*, while disconnecting voltage from the serpentine pattern **220***b*. Accordingly, heat is effectively generated from a first portion of the flexible inner sleeve heater assembly **108**E including the activated serpentine pattern **220***a*. The third heating zone **220***b* can be effected by applying a voltage across the serpentine pattern **220***b*, while disconnecting voltage from the serpentine pattern **220***a*. Accordingly, heat is effectively generated from a second portion of the flexible inner sleeve heater assembly **108**E including the activated second serpentine pattern **220***b*. Although not illustrated in FIGS. **10**A-**10**C, measurement sensors **116** can also be implemented allowing the controller **112** to monitor the flexible inner sleeve heater assembly **108**E (e.g., using the subsystem **610** shown in FIG. **6**E to perform the task **620**). Accordingly, the controller **112** can

actively and dynamically control the individual serpentine patterns **220**, **220***a*, **220***b* and the heating zones as described in detail herein to dynamically control how heat is transferred from the flexible inner sleeve **108**E to the container **104** in accordance with the various aspects of the invention described herein.

(128) FIG. **11**A depicts a flow diagram illustrating a computer-implemented method **1100** in accordance with aspects of the invention. In accordance with aspects of the invention, multiple iterations of the method **1100** can be implemented by the controller **112** to control the gripper sub-assembly **102** to apply a dynamically controlled gripping force **414** to the moveable outer sleeve heater assembly **110**. In embodiments of the invention, the gripper sub-assembly **102** is configured to apply the gripping force **414** (shown in FIGS. **4**B, **4**C, **4**D, **6**B, **6**D, **6**E) using a mechanical energy source mechanism of the gripper sub-assembly **102**. In accordance with some embodiments of the invention, the mechanical energy source mechanism includes the mechanical energy source(s) **128** physically coupled to coupling elements. In aspects of the invention, the coupling elements are configured to convert mechanical energy (or force) generated by the mechanical energy source(s) **128** to the gripping force **414** and apply the gripping force **414** to the moveable outer sleeve heater assembly **110**. In some embodiments of the invention, a wide variety of coupling mechanisms can be used to convert the mechanical energy generated by the mechanical energy source(s) **128** to the gripping force **414**. In some embodiments of the invention, the coupling elements are implemented as the gripper actuator **121**, the clamping assembly **123**, and the moveable arms **122**, configured and arranged as shown in FIG. **1**. Accordingly, in some embodiments of the invention, the controller **112** can implement the method **1100** by dynamically controlling the mechanical energy source(s) **128**, the gripper actuator **121**, the clamping assembly **123**, and the moveable arms **122** in a manner that generates the gripping force **414** and uses the moveable arms **122** to apply the gripping force to the moveable outer sleeve heater assembly **110**. In some embodiments of the invention as illustrated by the method **1100**, the controller **112** dynamically controls the gripping force **414** such that the gripping force **414** is sufficient to dynamically control, improve, and/or achieve TLTC (in the manners depicted in the table **500** shown in FIG. **5**) between the flexible inner sleeve heater assembly **108** of the moveable outer sleeve heater assembly **110** and the container **104**. In some embodiments of the invention as illustrated by the method **1130** (shown in FIG. **11**B), the controller **112** dynamically controls the gripping force **414** such that the gripping force **414** is sufficient to dynamically control, improve, and/or achieve TLTC (in the manners depicted in the table **500**) between the flexible inner sleeve heater assembly **108** of the moveable outer sleeve heater assembly **110** and the container **104**; hold the container while the gripper sub-assembly **102** agitates the container **104**; and not damage the container **104**. In some embodiments of the invention as illustrated by the method **1160** (shown in FIG. **11**C), the controller **112** dynamically controls the gripping force **414** such that the gripping force **414** is sufficient to dynamically control, improve, and/or achieve TLTC (in the manners depicted in the table **500**) between the flexible inner sleeve heater assembly **108** of the moveable outer sleeve heater assembly **110** and the container **104** without damaging the container **104**.

(129) As shown in FIG. **11**A, the method **1100** begins by using the controller **112** to execute the operations at blocks **1102**, **1103**, **1104**. At block **1102**, the controller **112** is used to access data from the sensors **114**, **116**. At block **1103**, the controller **112** is used to download container data, wherein the container data includes characteristics of a wide variety of known containers, including but not limited to the source(s) of known containers, the material of known containers, the shape/size/dimensions of known containers, the surface topologies of known containers, the contents stored in the known containers, and/or the recommended temperature for safely consuming the contents of the container. At block **1104**, the controller **112** is used to access the manual inputs **111**. The sensors **114**, **116** can include the previously described image sensors **114** and measurement sensors **116**. The manual inputs **111** can include the previously described details about a variety of characteristics of the container **104** that have been entered into the controller **112**

by a user, or that have been selected by a user from a menu of option presented to the user by the controller **112**. In some embodiments of the invention, the sensors **114**, **116** are optional and details about the container **104** are determined completely from the downloaded container data and/or the manual inputs **111**. In some embodiments of the invention, the downloaded container data is optional and details about the container **104** are determined completely from the sensors **114**, **116** and the manual inputs **111**. In some embodiments of the invention, the manual inputs **111** are optional and the details about the container **104** are determined completely from the downloaded container data and/or the sensors **114**, **116**. In some embodiments of the invention, the sensors **114**, **116**, the downloaded container data, and the manual inputs **111** are used to provide data about the details of the container **104**.

(130) At block **1106**, the controller **112** uses outputs from blocks **1102**, **1103**, and/or **1104** to determine the location and characteristics of the container **104**. In embodiments of the invention, the location of the container **104** is the location of the container within the adjustable opening **126**. In embodiments of the invention, the characteristics of the container include but are not limited to the source of the container **104**, the material of the container **104**, the shape/size/dimensions of the container **104**, and/or the contents stored in the container **104**. For example, the controller **112** can receive container image data from the image sensors **114** and process the container image data to determine that the container **104** is a substantially cylindrical can of brewed coffee having a 16 ounce volume, a 7 inch height dimension, a 4 inch circumference dimension, and a 16 ounce weight.

(131) At block **1108**, the controller **112** optionally accesses parameters of the gripper sub-assembly **102** and/or the moveable gripper **106** that are relevant to estimating a gripping force applied to the moveable arms **122**, including, for example, the overall thickness of the flexible inner sleeve heater assembly **108**, the various individual thicknesses of the individual layers of the flexible inner sleeve heater assembly **108**, the various materials that form the various layers of the flexible inner sleeve heater assembly **108**, the flexibility of each of the various layers of the flexible inner sleeve heater assembly **108**, the flexibility of the semi-rigid material of the moveable outer sleeve heater assembly **110**, and the like. In accordance with aspects of the invention, the output of block **1108** is optionally provided to block **1109** and/or block **1110**.

(132) At block **1109**, the controller **112** optionally uses the container location and/or characteristics determined at block **1106**, along with, optionally, parameters of the gripper sub-assembly **102** determined at block **1108**, to determine a heating zone pattern for the flexible inner sleeve heater element **108**. According to one or more non-limiting embodiments of the invention, the flexible inner sleeve heater element **108** can be segmented into an array having any number of individually addressable heating zones (e.g., zone A and zone B of the thermal film heater **208** shown in FIG. **9**A or zone A and zone B of the thermal film heater **208** shown in FIG. **10**C). In accordance with aspects of the invention, each heating zone of the flexible inner sleeve heater element **108** is individually addressable in that each heating zone can be thermally activated independently of the other heating zones in the heating zone array, thereby creating a heating zone pattern formed from the thermally activated heating zones of the heating zone array. In aspects of the invention where the flexible inner sleeve heating element **108** is configured to include an array of individually addressable heating zones, the controller **112** can be programmed to selectively activate and deactivate the addressable heating zones to selectively target heat generation operations to those portions of the flexible inner sleeve heater assembly **108** that are determined by the controller **112** to be in contact with the container **104**. In embodiments of the invention, the determination by the controller **112** what portions of the container **104** are in contact with the container **104** can made in any suitable manner. For example, in some embodiments of the invention, the controller **112** can determine the portions of the flexible inner sleeve heater assembly **108** that are (or will be) in contact with the container **104** by receiving from block **1106** the location and characteristics of the container **104** that have been determined at block **1106** through an analysis of various types of data

about the container **104** generated by operations at blocks **1102**, **1103**, **1104**.
(133) As an example of how block **1109** can be implemented, where a height dimension of the flexible inner sleeve heater assembly **108** is configured to accommodate a container having a height dimension of about 10 inches, and where the container **104** in the adjustable opening **126** (shown in FIGS. **1** and **8**A) has a height dimension of about 5 inches, the controller **112** is configured to generate and implement a heating zone pattern, wherein the heating zone pattern activates only the heating zones of the flexible inner sleeve heater assembly **108** that deliver heat to the portions of the flexible inner sleeve heater assembly **108** that are (or will be) in contact with the container **104** when the container **104** is within the adjustable opening **126** and the controller **112** has dynamically controlled the mechanical energy source mechanism to bring the flexible inner sleeve heater assembly **108** into contact with the container **104**. As another example of how block **1109** can be implemented, where a bottom portion of the container **104** has a circumference of about 6 inches, and a top portion of the container **104** tapers to a circumference of about 3 inches, when the container **104** is within the adjustable opening **126**, the flexible inner sleeve heater assembly **108** when moved will contact the bottom portion of the container **104** but not the top portion of the container **104**. In this example, the controller **112** is configured to generate and implement a heating zone pattern, wherein the heating zone pattern activates only the heating zones of the flexible inner sleeve heater assembly **108** that deliver heat to the bottom portion of the flexible inner sleeve heater assembly **108** that is (or will be) in contact with the container **104** when the container **104** is within the adjustable opening **126** and the controller **112** has dynamically controlled the mechanical energy source mechanism to bring the flexible inner sleeve heater assembly **108** into contact with the container **104**.
(134) At block **1110**, the controller **112** uses outputs from blocks **1106**, **1108**, and/or **1109** to generate an estimate of a gripping force **414** required to dynamically control, improve, and/or achieve a TLTC between a surface of the inner sleeve heater assembly **108** and exterior walls of the container **104**. In embodiments of the invention, block **1110** can utilize the various interface-parameter proxy measurements/estimates shown in FIGS. **5**, **7**A as a proxy or substitute for the TLTC at the interface between the flexible inner sleeve heater assembly **108** and the outer walls of the container **104**. Accordingly, it is understood that the estimates of thermal contact depicted in the flow diagrams depicted in FIGS. **11**A, **11**B can be implemented in accordance with the interface-parameter proxy measurement relationships and target values/ranges shown in the table **500** (shown in FIG. **5**) and/or the table **700** (shown in FIG. **7**A) using the techniques depicted in FIGS. **6**A-**6**E.
(135) In some embodiments of the invention, the controller **112** can be configured to implement the determinations at blocks **1106**, **1109**, as well as the estimate determined at block **1110** using a variety of computer-implemented analysis methods, including but not limited to machine learning algorithms, simulation algorithms, relational databases, and the like (examples of which are shown in FIG. **6**E). Using the operations at block **1110** as an example, the controller **112** can be configured to implement block **1110** by utilizing a machine learning algorithm (e.g., classifier **1210** shown in FIG. **12**) configured to generate and train a model of the gripper sub-assembly **102**, the movable gripper **106**, and/or the container **104**. More specifically, the model can be trained to classify the nature of the interface between the flexible inner sleeve heater assembly **108** and the container **104** (e.g., as depicted in the tables **500**, **700** shown in FIGS. **5** and **7**A; and using the techniques used in FIGS. **6**A-**6**E) in response to gripping forces **414** applied to the moveable outer sleeve heater assembly **110**.
(136) In some embodiments of the invention, the determining and/or estimating operations of the method **1100** (e.g., blocks **1106**, **1109**, **1110**) can be performed by utilizing a known simulation algorithm to simulate the characteristics of the gripper sub-assembly **102**, the movable gripper **106**, and/or the container **104**. More specifically, the simulation algorithm can be used to simulate the nature of the interface between the flexible inner sleeve heater assembly **108** and outer walls of the container **104** (e.g., as depicted in the tables **500**, **700** shown in FIGS. **5** and **7**A; and using the

techniques used in FIGS. **6**A-**6**E) in response to gripping forces **414** applied to the moveable outer sleeve heater assembly **110**.

(137) In embodiments of the invention that perform the determining and/or estimating operations of the method **1100** (e.g., blocks **1106**, **1109**, **1110**) by controlling and accessing a relational database stored in a memory location of the controller **112**, a suitable relational database that can be used in connection with embodiments of the invention is any relational database configured to provide a means of storing related information in such a way that information and the relationships between information can be retrieved from it. Data in a relational database can be related according to common keys or concepts, and the ability to retrieve related data from a table is the basis for the term relational database. A relational database management system (RDBMS) of the controller **112** performs the tasks of determining the way data and other information are stored, maintained and retrieved from the relational database of the controller **112**. In accordance with aspects of the invention, the examples of how machine learning algorithms, simulation algorithms, and/or relational databases can be used to implement block **1110** apply equally to blocks **1106**, **1109**.

(138) Decision block **1112** receives from block **1110** the estimated gripping force **414** that will dynamically control, improve, and/or achieve a TLTC between a surface of the inner sleeve heater assembly **108** and the container **104**. Decision block **1112** determines whether or not the estimated gripping force **414** generated at block **1110** is above or below a threshold for maintaining the physical integrity of the container **104**. The gripping force threshold used in decision block **1112** is dynamic in that it is determined for the particular size, shape, weight, surface topology, and material of the container **104** as determined using the data generated at blocks **1102**, **1103**, and/or **1104**. Similar to block **1110**, the dynamic gripping force threshold used in decision block **1112** can be generated using a simulation algorithm and/or a machine learning algorithm (or model) configured and arranged to estimate the dynamic gripping force threshold that enables gripping the container **104** without compromising the physical integrity of the container **104**. Examples of compromising the physical integrity of the container **104** includes denting, puncturing, cracking or crushing the container **104**. If the answer to the inquiry at decision block **1112** is no, the method **1100** moves to block **1114** and generates an error message that communicates (e.g., to a user) that TLTC cannot be controlled, improved, and/or achieved between the flexible inner sleeve heater assembly **108** and the container **104** without compromising the physical integrity of the container. If the answer to the inquiry at decision block **1112** is yes, the method **1100** passes the estimated gripping force **414** determined at block **1110** to block **1116**. At block **1116**, the controller **112** determines and applies the necessary controls to the gripper sub-assembly **102** (e.g., settings and controls for the mechanical energy source(s) **128**) that will apply the gripping force **414** determined at block **1110** to the movable outer sleeve heater assembly **110**.

(139) In decision block **1118**, the controller **112** uses sensor data from the various sensors (e.g., grip presser sensors among the sensors **116**) of the gripper sub-assembly **102** and the movable gripper **106** to evaluate whether or not the gripping force **414** determined at block **1110** has controlled, improved, and/or achieved TLTC at the interface between the flexible inner sleeve heater assembly **108** and the container **104**. In some embodiments of the invention, the evaluation determined at decision block **1118** can be performed using the relationships reflected in the table **500**, along with the techniques shown in FIGS. **6**A-**6**F.

(140) If the answer to the inquiry at decision block **1118** is yes, the method **1100** moves to block **1122** and ends. If the answer to the inquiry at decision block **1118** is no, the method **1100** moves to block **1120**; analyzes the determinations made at decision block **1118**; makes recommendations for adjustments to the determinations made at block **1110** in a last (or in prior) iterations of the method **1100**; and returns to block **1110** for a next partial iteration of the method **1100** that takes into account the change recommendations developed at block **1120**. In some embodiments of the invention, the recommendations made at block **1120** leverage the simulation and/or machine learning algorithms utilized to make the determinations at block **1110** in the last (or in prior)

iterations of the method **1100**. In some embodiments of the invention, the operations at block **1120** can include using the measurement sensors **116** (including grip pressure sensors) to capture the current actual gripping force and compare it to the currently computed estimated gripping force determined at block **1110**. If there is a difference between the estimated gripping force and the current actual gripping force, that difference can be incorporate in the recommendation generated at block **1120**. For example, block **1120** can determine that the actual current gripping force is 10% less than the estimated gripping force, and the recommendation generated at block **1120** can include increasing the estimated gripping force by 10%.
(141) FIG. **11**B depicts a flow diagram illustrating a computer-implemented method **1130** in accordance with aspects of the invention. In accordance with aspects of the invention, multiple iterations of the method **1130** can be implemented, whereby the controller **112** dynamically controls the gripping force **414** such that the gripping force **414** is sufficient to satisfy one (1), two (2), or all three (3) of a set of constraints, namely dynamically control, improve, and/or achieve TLTC (in the manners depicted in the table **500**) between the flexible inner sleeve heater assembly **108** and the container **104** (block **1136**); hold the container while the gripper sub-assembly **102** agitates the container **104** (block **1138**); and/or not damage the container **104** (block **1134**). In some embodiments of the invention, the method **1130** can modify and/or supplement the method **1100** shown in FIG. **11**A. More specifically, in some embodiments of the invention, the method **1100** can be modified by replacing blocks **1112**, **1114**, and **1116** of the method **1100** with blocks **1140**, **1142**, **1144** of the method **1130**. In addition, block **1110** of the method **1100** is substantially the same as the constraint defined at block **1136**, while blocks **1134** and **1138** of the method **1130** provide additional constraints that are input to decision block **1140**. In addition, in some embodiments of the invention, block **1132** can be implemented in substantially the same manner with substantially the same inputs as block **1109** of the method **1100**. In some embodiments of the invention, the method **1130** is integrated within the method **1100**. In some embodiments of the invention, the method **1130** is implemented as a stand-alone method. In the interest of brevity, the subsequent descriptions of the method **1130** are in the context of how the method **1130** functions as a stand-alone method. However, it will be understood by those skilled in the relevant arts that all of the features and functionality described in connection with the method **1130** apply equally to embodiments of the invention where the method **1130** is integrated into the method **1100**.
(142) In embodiments of the invention, the controller **112** implements the method **1130** by dynamically controlling how the mechanical energy source mechanism **128**, **132** of the gripper sub-assembly **102** applies a gripping force **414** to the movable outer sleeve heater assembly **110**. In embodiments of the invention, the mechanical energy source mechanism is configured to include the mechanical energy source(s) **128**, the gripper actuator **121**, the clamping assembly **123**, and the moveable arms **122**, configured and arranged as shown in FIGS. **2** and **3**. In accordance with some aspects of the invention, the controller **112** dynamically controls the gripping force **414** applied to the moveable outer sleeve heater assembly **110** such that the gripping force **414** is sufficient to satisfy three constraints defined at blocks **1134**, **1136**, **1138** of the method **1130**.
(143) At block **1134**, the controller **112** generates an estimate of a gripping force that is insufficient to damage the container **104**. In some embodiments of the invention, block **1134** is configured to generate an estimate of a maximum gripping force that will not damage the container **104**. The gripping force estimated at block **1134** is dynamic in that it is determined for the particular size, shape, weight, surface topology, and/or material of the container **104**. In embodiments of the invention, data from which the size, shape, weight, surface topology, and/or material of the container **104** can be determined is provided to block **1134** using, for example, the operations depicted at blocks **1102**, **1103**, and/or **1104** of the method **1100** shown in FIG. **11**A. At block **1134**, the controller **112** determines the location and/or characteristics of the container **104**, including but not limited to the location of the container **104** within the adjustable opening **126**; the source of the container **104**; the material of the container **104**; the shape/size/dimensions of the container **104**;

the topologies of exterior surfaces of the container **104**; and/or the contents stored in the container **104**. In some aspects of the invention, at block **1134** the controller **112** can make its determination about the location and/or characteristics of the container **104** in substantially the same manner as block **1106** of the method **1100** shown in FIG. **11**A. In some aspects of the invention, at block **1134** the controller **112** can make its determination about the location and/or characteristics of the container **104** by optionally taking into account various parameters of the gripper sub-assembly **102** that are relevant to estimating gripper form in general. In some embodiments of the invention, block **1134** can receive outputs from operations that corresponds to the operations performed at block **1108** of the method **1100** shown in FIG. **11**A. As previously noted herein, the operations at block **1108** include accessing parameters of the gripper sub-assembly **102** that include the overall thickness of the flexible inner sleeve heater assembly **108**, the thicknesses of the various layers of the flexible inner sleeve heater assembly **108**, the various materials that form the various layers of the flexible inner sleeve heater assembly **108**, the flexibility of each of the various layers of the flexible inner sleeve heater assembly **108**, the flexibility of the semi-rigid material of the moveable outer sleeve heater assembly **110**, and the like.

(144) In some embodiments of the invention, the controller **112** can be configured to perform the estimate defined at block **1134** by utilizing a known simulation algorithm to simulate the characteristics of the container **104** and how the container **104** would respond to various gripping forces applied to the container **104** by the gripper sub-assembly **102**. More specifically, the known simulation algorithm can be configured to simulate whether or not a particular gripping force will compromise the physical integrity of the container **104**. Examples of how the physical integrity of the container **104** can be compromised includes denting, puncturing, cracking or crushing the container **104**.

(145) In some embodiments of the invention, the controller **112** can be configured to perform the estimate defined at block **1134** by utilizing known machine learning algorithms to create and train one or more models that represent the characteristics of the container **104** and how the container **104** would respond to various gripping forces applied to the container **104** by the gripper sub-assembly **102**. More specifically, the machine learning models can be configured to classify whether or not a particular gripping force will compromise the physical integrity of the container **104**. Examples of compromising the physical integrity of the container **104** includes denting, puncturing, cracking or crushing the container **104**.

(146) In some embodiments of the invention, the controller **112** can be configured to perform the estimate defined at block **1134** by dynamically controlling and accessing a relational database stored in a memory location of the controller **112**, wherein the relational database is configured to store characteristics of a variety of containers, a variety of gripping forces, and the impact that the variety of gripping forces has on the integrity of the containers. Once the controller **112** determines the characteristics of the container-under-investigation, the controller **112** can access the relational database to determine the gripping forces and integrity impacts associated with the container-under-investigation. For example, if the controller **112** determines that the container-under-investigation is a cylindrically shaped 12 ounce aluminum can of chicken noodle soup having a certain can height and can diameter, the relational database can be used to in effect look up a maximum gripping force that can be applied to a corresponding known 12 ounce can of chicken noodle soup without compromising the integrity of the known 12 ounce can. A suitable relational database that can be used in connection with embodiments of the invention is any relational database configured to provide a means of storing related information in such a way that information and the relationships between information can be retrieved from it. Data in a relational database can be related according to common keys or concepts, and the ability to retrieve related data from a table is the basis for the term relational database. A relational database management system (RDBMS) of the controller **112** performs the tasks of determining the way data and other information are stored, maintained and retrieved from the relational database of the controller **112**.

(147) At block **1136**, the controller **112** generates an estimate of a gripping force that dynamically controls, improves, and/or achieves TLTC (using the relationships shown in the table **500** shown in FIG. **5**) between the flexible inner sleeve **108** and the container **104**. As previously noted herein, block **1136** can be implemented in substantially the same manner as block **1110** of the method **1100** (shown in FIG. **11**A), and can utilize outputs from substantially the same operations as performed at blocks **1102**, **1103**, **1104**, **1106**, **1108** of the method **1100**. Similar to block **1110**, block **1136** can be implemented using computer analysis techniques (e.g., simulation algorithms, machine learning algorithms, relational databases, and the like) that do not require specialized computer functionality.

(148) At block **1138**, the controller **112** generates an estimate of a gripping force that is insufficient to hold the container **104** while the gripper sub-assembly **102** is agitating the container **104**. In some embodiments of the invention, block **1136** is configured to generate an estimate of a minimum gripping force that will hold the container while the gripper sub-assembly **102** is agitating the container **104**. The gripping force estimated at block **1138** is dynamic in that it is determined for the particular size, shape, weight, surface topology, and/or material of the container **104**. In embodiments of the invention, data from which the size, shape, weight, surface topology, and/or material of the container **104** can be determined is provided to block **1138** using, for example, the operations depicted at blocks **1102**, **1103**, and/or **1104** of the method **1100** shown in FIG. **11**A. At block **1138**, the controller **112** determines characteristics of the container **104**, including but not limited to the source of the container **104**; the material of the container **104**; the shape/size/dimensions of the container **104**; the topologies of exterior surfaces of the container **104**; and/or the contents stored in the container **104**. In some aspects of the invention, at block **1138** the controller **112** can make its determination by optionally taking into account various parameters of the gripper sub-assembly **102** that are relevant to estimating gripper form in general. In some embodiments of the invention, block **1138** can receive outputs from operations that corresponds to the operations performed at block **1108** of the method **1100** shown in FIG. **11**A. As previously noted herein, the operations at block **1108** include accessing parameters of the gripper sub-assembly **102** that include the overall thickness of the flexible inner sleeve heater assembly **108**, the individual thicknesses of the various individual layers of the flexible inner sleeve heater assembly **108**, the various materials that form the various layers of the flexible inner sleeve heater assembly **108**, the flexibility of each of the various layers of the flexible inner sleeve heater assembly **108**, the flexibility of the semi-rigid material of the moveable outer sleeve heater assembly **110**, and the like.

(149) In some embodiments of the invention, the controller **112** can be configured to perform the estimate defined at block **1138** by utilizing a known simulation algorithm to simulate the characteristics of the container **104** and how the container **104** would respond to various gripping forces applied to the container **104** by the gripper sub-assembly **102** while the gripper sub-assembly **102** is agitating the container **104**. More specifically, the known simulation algorithm can be configured to simulate whether or not a particular gripping force will hold the container **104** while the gripper sub-assembly **102** is agitating the container **104**. In some embodiments of the invention, the known simulation algorithm can be configured to determine a minimum gripping force that will hold the container **104** while the gripper sub-assembly **102** is agitating the container **104**.

(150) In some embodiments of the invention, the controller **112** can be configured to perform the estimate defined at block **1138** by utilizing known machine learning algorithms to create and train one or more models that represent the characteristics of the container **104** and how the container **104** would respond to various gripping forces applied to the container **104** by the gripper sub-assembly **102** while the gripper sub-assembly **102** is agitating the container **104**. More specifically, the machine learning models can be configured to classify whether or not a particular gripping force will hold the container **104** while the gripper sub-assembly **102** is agitating the container **104**.

In some embodiments of the invention, the machine learning models can be configured to determine a minimum gripping force that will hold the container **104** while the gripper sub-assembly **102** is agitating the container **104**.

(151) In some embodiments of the invention, the controller **112** can be configured to perform the estimate defined at block **1138** by dynamically controlling and accessing a relational database stored in a memory location of the controller **112**, wherein the relational database is configured to store characteristics of a variety of containers, a variety of gripping forces, and the ability of the variety of gripping forces to hold the container **104** while the gripper sub-assembly **102** is agitating the container **104**. Once the controller **112** determines the characteristics of the container-under-investigation, the controller **112** can access the relational database to determine the gripping forces and container holding ability associated with the container-under-investigation. For example, if the controller **112** determines that the container-under-investigation is a cylindrically shaped 12 ounce aluminum can of chicken noodle soup having a certain can weight, can height, and can diameter, the relational database can be used to in effect look up a minimum gripping force that can be applied to a corresponding known 12 ounce can of chicken noodle soup in order to hold the corresponding known 12 ounce can of chicken noodle soup while the gripper sub-assembly **102** is agitating the corresponding known 12 ounce can of chicken noodle soup. As previously noted herein, a suitable relational database that can be used in connection with embodiments of the invention is any relational database configured to provide a means of storing related information in such a way that information and the relationships between information can be retrieved from it.

(152) Decision block **1140** receives from blocks **1134**, **1136**, **1138** the estimated gripping forces that satisfy each of the constraints defined at blocks **1134**, **1136**, **1138**. Decision block **1140** determines whether or not there is a single gripping force **414** that satisfies all of the constraints defined at blocks **1134**, **1136**, **1138**. If the answer to the inquiry at decision block **1140** is no, the method **1130** moves to block **1142** and generates an error message that communicates (e.g., to a user) that all three of the constraints defined at blocks **1134**, **1136**, **1138** cannot be satisfied. If the answer to the inquiry at decision block **1140** is yes, the method **1130** passes the single gripping force determined at decision block **1140** to block **1144**. At block **1144**, the controller **112** applies the necessary controls to the gripper sub-assembly **102** (e.g., settings and controls for the mechanical energy source(s) **128**) that will apply the single gripping force **414** determined at decision block **1140** to the movable outer sleeve heater assembly **110**.

(153) In embodiments of the invention, all of the operations performed in the method **1130** can be executed using known computer analysis techniques (e.g., simulation algorithms, machine learning algorithms, relational databases, and the like) that do not require specialized computer functionality. In embodiments of the invention, the method **1130** can be implemented to include any combination of the operations depicted at blocks **1132-1144**.

(154) FIG. **11**C depicts a flow diagram illustrating a computer-implemented method **1160** in accordance with aspects of the invention. In accordance with aspects of the invention, multiple iterations of the method **1160** can be implemented by the controller **112** to dynamically control the gripper sub-assembly **102** to apply a level of heat to the container **104** that is below a temperature that will damage the container **104**. In embodiments of the invention, portions of the method **1160** are implemented in substantially the same way as portions of the method **1100** shown in FIG. **11**A. More specifically, blocks **1162**, **1164**, **1166**, **1168**, **1170**, **1172** of the method **1160** can be implemented in substantially the same way as blocks **1102**, **1103**, **1104**, **1106**, **1108**, **1109** of the method **1100** shown in FIG. **11**A.

(155) At block **1174**, the controller **112** uses outputs from blocks **1168**, **1172**, and/or **1170** to generate an estimate of a maximum container temperature (MCT) that will not damage the container **104**, and to control or adjust the temperature(s) output by the flexible inner sleeve heater assembly **108** (e.g., heating element temperature (HET)) to be less than or equal to the estimated MCT. In embodiments of the invention, block **1174** can estimate MCT using substantially the same

computer control features and functions used in block **1110** of the method **1100** (shown in FIG. **11**A) to estimate the gripping force required to achieve and maintain TLTC between a surface of the inner sleeve heater assembly **108** and the container **104**. In embodiments of the invention, block **1174** can dynamically control or adjust HET to be less than or equal to the estimated MCT using substantially the same computer control features and functions used in block **1116** of the method **1100** (shown in FIG. **11**A) apply controls to the gripper sub-assembly **102** to apply and maintain the gripping force determined at block **1110** to the movable outer sleeve heater assembly **110**.

(156) Decision block **1176** receives from block **1174** the estimated MCT that will not damage the container **104**. Decision block **1176** determines whether or not the actual temperature(s) of the container **104** are above or below the estimated MCT generated at block **1174**. The estimated MCT threshold used in decision block **1176** is dynamic in that it is determined for the particular size, shape, weight, surface topology, and material of the container **104** as determined using the data generated at blocks **1162**, **1164**, and/or **1166**. The dynamic MCT threshold used in decision block **1176** can be generated using a simulation algorithm and/or a machine learning algorithm (or model) configured and arranged to estimate the MCT threshold that will not compromise the physical integrity of the container **104**. Examples of compromising the physical integrity of the container **104** include exceeding Tmax for some or all of the container **104**. If the answer to the inquiry at decision block **1176** is yes, the method **1160** moves to decision block **1178** and determines whether the heating cycle being applied to the container **104** by the gripper sub-assembly **102** has ended. If the answer to the inquiry at decision block **1178** is yes, the method **1160** move to block **1182** and ends. If the answer to the inquiry at decision block **1178** is no, the method **1160** returns to the input to decision block **1176**. If the answer to the inquiry at decision block **1176** is no, the method **1160** moves to block **1180**; analyzes the determinations made at decision block **1174**; makes recommendations for adjustments to the determinations made at block **1174** in a last (or in prior) iterations of the method **1160**; and returns to block **1174** for a next partial iteration of the method **1160** that takes into account the change recommendations developed at block **1180**. In some embodiments of the invention, the recommendations made at block **1180** leverage the computer analysis techniques used by the controller **112** to make the determinations at block **1174** in the last (or in prior) iterations of the method **1160**. In some embodiments of the invention, the operations at block **1180** can include using the measurement sensors **116** to capture the current actual temperature being applied to the container **104** and compare it to the currently computed HET determined at block **1174**. If there is a difference between the currently computed HET and the currently sensed actual temperature at the container **104**, that difference can be incorporate in the recommendation generated at block **1180**. For example, block **1180** can determine that the currently sensed actual temperature at the container **104** is 10% less than the currently computed HET, and the recommendation generated at block **1180** can include increasing the currently computed HET by 10%. Similar to the methods **1100**, **1130** shown in FIGS. **11**A and **11**B, the controller **112** can implement the method **1160** using machine learning algorithms, simulation algorithms, relational databases, and the like in substantially the same ways previously described herein.

(157) Additional details of machine learning techniques that can be used to implement portions of the controller **112** will now be provided. The various types of computer control functionality (e.g., estimates, determinations, decisions, recommendations, and the like of the controller **112**) described herein can be implemented using machine learning and/or natural language processing techniques. In general, machine learning techniques are run on so-called “neural networks,” which can be implemented as programmable computers configured to run a set of machine learning algorithms. Neural networks incorporate knowledge from a variety of disciplines, including neurophysiology, cognitive science/psychology, physics (statistical mechanics), control theory, computer science, artificial intelligence, statistics/mathematics, pattern recognition, computer vision, parallel processing and hardware (e.g., digital/analog/VLSI/optical).

(158) The basic function of neural networks and their machine learning algorithms is to recognize

patterns by interpreting unstructured sensor data through a kind of machine perception. Unstructured real-world data in its native form (e.g., images, sound, text, or time series data) is converted to a numerical form (e.g., a vector having magnitude and direction) that can be understood and manipulated by a computer. The machine learning algorithm performs multiple iterations of learning-based analysis on the real-world data vectors until patterns (or relationships) contained in the real-world data vectors are uncovered and learned. The learned patterns/relationships function as predictive models that can be used to perform a variety of tasks, including, for example, classification (or labeling) of real-world data and clustering of real-world data. Classification tasks often depend on the use of labeled datasets to train the neural network (i.e., the model) to recognize the correlation between labels and data. This is known as supervised learning. Examples of classification tasks include detecting people/faces in images, recognizing facial expressions (e.g., angry, joyful, etc.) in an image, identifying objects in images (e.g., stop signs, pedestrians, lane markers, etc.), recognizing gestures in video, detecting voices, detecting voices in audio, identifying particular speakers, transcribing speech into text, and the like. Clustering tasks identify similarities between objects, which it groups according to those characteristics in common and which differentiate them from other groups of objects. These groups are known as "clusters."

(159) An example of machine learning techniques that can be used to implement aspects of the invention will be described with reference to FIGS. **12** and **13**. Machine learning models configured and arranged according to embodiments of the invention will be described with reference to FIG. **12**. Detailed descriptions of an example computing system and network architecture capable of implementing one or more of the embodiments of the invention described herein will be provided with reference to FIG. **14**.

(160) FIG. **12** depicts a block diagram showing a classifier system **1200** capable of implementing various aspects of the invention described herein. More specifically, the functionality of the system **1200** is used in embodiments of the invention to generate various models and sub-models that can be used to implement computer functionality in embodiments of the invention. The system **1200** includes multiple data sources **1202** in communication through a network **1204** with a classifier **1210**. In some aspects of the invention, the data sources **1202** can bypass the network **1204** and feed directly into the classifier **1210**. The data sources **1202** provide data/information inputs that will be evaluated by the classifier **1210** in accordance with embodiments of the invention. The data sources **1202** also provide data/information inputs that can be used by the classifier **1210** to train and/or update model(s) **1216** created by the classifier **1210**. The data sources **1202** can be implemented as a wide variety of data sources, including but not limited to, sensors configured to gather real time data, data repositories (including training data repositories), and outputs from other classifiers. The network **1204** can be any type of communications network, including but not limited to local networks, wide area networks, private networks, the Internet, and the like.

(161) The classifier **1210** can be implemented as algorithms executed by a programmable computer such as a processing system **1400** (shown in FIG. **14**). As shown in FIG. **12**, the classifier **1210** includes a suite of machine learning (ML) algorithms **1212**; natural language processing (NLP) algorithms **1214**; and model(s) **1216** that are relationship (or prediction) algorithms generated (or learned) by the ML algorithms **1212**. The algorithms **1212**, **1214**, **1216** of the classifier **1210** are depicted separately for ease of illustration and explanation. In embodiments of the invention, the functions performed by the various algorithms **1212**, **1214**, **1216** of the classifier **1210** can be distributed differently than shown. For example, where the classifier **1210** is configured to perform an overall task having sub-tasks, the suite of ML algorithms **1212** can be segmented such a portion of the ML algorithms **1212** executes each sub-task and a portion of the ML algorithms **1212** executes the overall task. Additionally, in some embodiments of the invention, the NLP algorithms **1214** can be integrated within the ML algorithms **1212**.

(162) The NLP algorithms **1214** include speech recognition functionality that allows the classifier

1210, and more specifically the ML algorithms **1212**, to receive natural language data (text and audio) and apply elements of language processing, information retrieval, and machine learning to derive meaning from the natural language inputs and potentially take action based on the derived meaning. The NLP algorithms **1214** used in accordance with aspects of the invention can also include speech synthesis functionality that allows the classifier **1210** to translate the result(s) **1220** into natural language (text and audio) to communicate aspects of the result(s) **1220** as natural language communications.

(163) The NLP and ML algorithms **1214**, **1212** receive and evaluate input data (i.e., training data and data-under-analysis) from the data sources **1202**. The ML algorithms **1212** includes functionality that is necessary to interpret and utilize the input data's format. For example, where the data sources **1202** include image data, the ML algorithms **1212** can include visual recognition software configured to interpret image data. The ML algorithms **1212** apply machine learning techniques to received training data (e.g., data received from one or more of the data sources **1202**) in order to, over time, create/train/update one or more models **1216** that model the overall task and the sub-tasks that the classifier **1210** is designed to complete.

(164) Referring now to FIGS. **12** and **13** collectively, FIG. **13** depicts an example of a learning phase **1300** performed by the ML algorithms **1212** to generate the above-described models **1216**. In the learning phase **1300**, the classifier **1210** extracts features from the training data and coverts the features to vector representations that can be recognized and analyzed by the ML algorithms **1212**. The features vectors are analyzed by the ML algorithm **1212** to “classify” the training data against the target model (or the model's task) and uncover relationships between and among the classified training data. Examples of suitable implementations of the ML algorithms **1212** include but are not limited to neural networks, support vector machines (SVMs), logistic regression, decision trees, hidden Markov Models (HMMs), etc. The learning or training performed by the ML algorithms **1212** can be supervised, unsupervised, or a hybrid that includes aspects of supervised and unsupervised learning. Supervised learning is when training data is already available and classified/labeled. Unsupervised learning is when training data is not classified/labeled so must be developed through iterations of the classifier **1210** and the ML algorithms **1212**. Unsupervised learning can utilize additional learning/training methods including, for example, clustering, anomaly detection, neural networks, deep learning, and the like.

(165) When the models **1216** are sufficiently trained by the ML algorithms **1212**, the data sources **1202** that generate “real world” data are accessed, and the “real world” data is applied to the models **1216** to generate usable versions of the results **1220**. In some embodiments of the invention, the results **1220** can be fed back to the classifier **1210** and used by the ML algorithms **1212** as additional training data for updating and/or refining the models **1216**.

(166) In aspects of the invention, the ML algorithms **1212** and the models **1216** can be configured to apply confidence levels (CLs) to various ones of their results/determinations (including the results **1220**) in order to improve the overall accuracy of the particular result/determination. When the ML algorithms **1212** and/or the models **1216** make a determination or generate a result for which the value of CL is below a predetermined threshold (TH) (i.e., CL<TH), the result/determination can be classified as having sufficiently low “confidence” to justify a conclusion that the determination/result is not valid, and this conclusion can be used to determine when, how, and/or if the determinations/results are handled in downstream processing. If CL>TH, the determination/result can be considered valid, and this conclusion can be used to determine when, how, and/or if the determinations/results are handled in downstream processing. Many different predetermined TH levels can be provided. The determinations/results with CL>TH can be ranked from the highest CL>TH to the lowest CL>TH in order to prioritize when, how, and/or if the determinations/results are handled in downstream processing.

(167) In aspects of the invention, the classifier **1210** can be configured to apply confidence levels (CLs) to the results **1220**. When the classifier **1210** determines that a CL in the results **1220** is

below a predetermined threshold (TH) (i.e., CL<TH), the results **1220** can be classified as sufficiently low to justify a classification of “no confidence” in the results **1220**. If CL>TH, the results **1220** can be classified as sufficiently high to justify a determination that the results **1220** are valid. Many different predetermined TH levels can be provided such that the results **1220** with CL>TH can be ranked from the highest CL>TH to the lowest CL>TH.

(168) The functions performed by the classifier **1210**, and more specifically by the ML algorithm **1212**, can be organized as a weighted directed graph, wherein the nodes are artificial neurons (e.g. modeled after neurons of the human brain), and wherein weighted directed edges connect the nodes. The directed graph of the classifier **1210** can be organized such that certain nodes form input layer nodes, certain nodes form hidden layer nodes, and certain nodes form output layer nodes. The input layer nodes couple to the hidden layer nodes, which couple to the output layer nodes. Each node is connected to every node in the adjacent layer by connection pathways, which can be depicted as directional arrows that each has a connection strength. Multiple input layers, multiple hidden layers, and multiple output layers can be provided. When multiple hidden layers are provided, the classifier **1210** can perform unsupervised deep-learning for executing the assigned task(s) of the classifier **1210**.

(169) Similar to the functionality of a human brain, each input layer node receives inputs with no connection strength adjustments and no node summations. Each hidden layer node receives its inputs from all input layer nodes according to the connection strengths associated with the relevant connection pathways. A similar connection strength multiplication and node summation is performed for the hidden layer nodes and the output layer nodes.

(170) The weighted directed graph of the classifier **1210** processes data records (e.g., outputs from the data sources **1202**) one at a time, and it “learns” by comparing an initially arbitrary classification of the record with the known actual classification of the record. Using a training methodology knows as “back-propagation” (i.e., “backward propagation of errors”), the errors from the initial classification of the first record are fed back into the weighted directed graphs of the classifier **1210** and used to modify the weighted directed graph's weighted connections the second time around, and this feedback process continues for many iterations. In the training phase of a weighted directed graph of the classifier **1210**, the correct classification for each record is known, and the output nodes can therefore be assigned “correct” values. For example, a node value of “1” (or 0.9) for the node corresponding to the correct class, and a node value of “0” (or 0.1) for the others. It is thus possible to compare the weighted directed graph's calculated values for the output nodes to these “correct” values, and to calculate an error term for each node (i.e., the “delta” rule). These error terms are then used to adjust the weights in the hidden layers so that in the next iteration the output values will be closer to the “correct” values.

(171) FIG. **14** depicts a high level block diagram of the computer system **1400**, which can be used to implement one or more computer processing operations in accordance with aspects of the present invention. Although one exemplary computer system **1400** is shown, computer system **1400** includes a communication path **1425**, which connects computer system **1400** to additional systems (not depicted) and can include one or more wide area networks (WANs) and/or local area networks (LANs) such as the Internet, intranet(s), and/or wireless communication network(s). Computer system **1400** and the additional systems are in communication via communication path **1425**, e.g., to communicate data between them. In some embodiments of the invention, the additional systems can be implemented as one or more cloud computing systems **50**. The cloud computing system **50** can supplement, support or replace some or all of the functionality (in any combination) of the computer system **1400**, including any and all computing systems described in this detailed description that can be implemented using the computer system **1400**. Additionally, some or all of the functionality of the various computing systems described in this detailed description can be implemented as a node of the cloud computing system **50**.

(172) Computer system **1400** includes one or more processors, such as processor **1402**. Processor

1402 is connected to a communication infrastructure **1404** (e.g., a communications bus, cross-over bar, or network). Computer system **1400** can include a display interface **1406** that forwards graphics, text, and other data from communication infrastructure **1404** (or from a frame buffer not shown) for display on a display unit **1408**. Computer system **1400** also includes a main memory **1410**, preferably random access memory (RAM), and can also include a secondary memory **1412**. Secondary memory **1412** can include, for example, a hard disk drive **1414** and/or a removable storage drive **1416**, representing, for example, a floppy disk drive, a magnetic tape drive, or an optical disk drive. Removable storage drive **1416** reads from and/or writes to a removable storage unit **1418** in a manner well known to those having ordinary skill in the art. Removable storage unit **1418** represents, for example, a floppy disk, a compact disc, a magnetic tape, or an optical disk, flash drive, solid state memory, etc. which is read by and written to by removable storage drive **1416**. As will be appreciated, removable storage unit **1418** includes a computer readable medium having stored therein computer software and/or data.

(173) In alternative embodiments of the invention, secondary memory **1412** can include other similar means for allowing computer programs or other instructions to be loaded into the computer system. Such means can include, for example, a removable storage unit **1420** and an interface **1422**. Examples of such means can include a program package and package interface (such as that found in video game devices), a removable memory chip (such as an EPROM, or PROM) and associated socket, and other removable storage units **1420** and interfaces **1422** which allow software and data to be transferred from the removable storage unit **1420** to computer system **1400**.

(174) Computer system **1400** can also include a communications interface **1424**. Communications interface **1424** allows software and data to be transferred between the computer system and external devices. Examples of communications interface **1424** can include a modem, a network interface (such as an Ethernet card), a communications port, or a PCM-CIA slot and card, etcetera. Software and data transferred via communications interface **1424** are in the form of signals which can be, for example, electronic, electromagnetic, optical, or other signals capable of being received by communications interface **1424**. These signals are provided to communications interface **1424** via communication path (i.e., channel) **1425**. Communication path **1425** carries signals and can be implemented using wire or cable, fiber optics, a phone line, a cellular phone link, an RF link, and/or other communications channels.

(175) In the present description, the terms “computer program medium,” “computer usable medium,” “computer program product,” and “computer readable medium” are used to generally refer to media such as memory. Computer programs (also called computer control logic) are stored in memory. Such computer programs, when run, enable the computer system to perform the features of the present invention as discussed herein. In particular, the computer programs, when run, enable the controller to perform the features and operations described herein. Accordingly, such computer programs can controllers of the computer system.

(176) The computer readable storage medium can be a tangible device that can retain and store instructions for use by an instruction execution device. The computer readable storage medium may be, for example, but is not limited to, an electronic storage device, a magnetic storage device, an optical storage device, an electromagnetic storage device, a semiconductor storage device, or any suitable combination of the foregoing. A non-exhaustive list of more specific examples of the computer readable storage medium includes the following: a portable computer diskette, a hard disk, a random access memory (RAM), a read-only memory (ROM), an erasable programmable read-only memory (EPROM or Flash memory), a static random access memory (SRAM), a portable compact disc read-only memory (CD-ROM), a digital versatile disk (DVD), a memory stick, a floppy disk, a mechanically encoded device such as punch-cards or raised structures in a groove having instructions recorded thereon, and any suitable combination of the foregoing. A computer readable storage medium, as used herein, is not to be construed as being transitory signals per se, such as radio waves or other freely propagating electromagnetic waves,

electromagnetic waves propagating through a waveguide or other transmission media (e.g., light pulses passing through a fiber-optic cable), or electrical signals transmitted through a wire.

(177) Many of the functional units described in this specification have been labeled as modules. Embodiments of the present invention apply to a wide variety of module implementations. For example, a module can be implemented as a hardware circuit comprising custom VLSI circuits or gate arrays, off-the-shelf semiconductors such as logic chips, transistors, or other discrete components. A module can also be implemented in programmable hardware devices such as field programmable gate arrays, programmable array logic, programmable logic devices or the like.

(178) Modules can also be implemented in software for execution by various types of processors. An identified module of executable code can, for instance, include one or more physical or logical blocks of computer instructions which can, for instance, be organized as an object, procedure, or function. Nevertheless, the executables of an identified module need not be physically located together but can include disparate instructions stored in different locations which, when joined logically together, comprise the module and achieve the stated purpose for the module.

(179) The following definitions and abbreviations are to be used for the interpretation of the claims and the specification. As used herein, the terms “comprises,” “comprising,” “includes,” “including,” “has,” “having,” “contains” or “containing,” or any other variation thereof, are intended to cover a non-exclusive inclusion. For example, a composition, a mixture, a process, a method, an article, or an apparatus that comprises a list of elements is not necessarily limited to only those elements but can include other elements not expressly listed or inherent to such composition, mixture, process, method, article, or apparatus.

(180) The terminology used herein is for the purpose of describing particular embodiments of the invention only and is not intended to be limiting of the present invention. As used herein, the singular forms “a”, “an” and “the” are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms “comprises” and/or “comprising,” when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, element components, and/or groups thereof.

(181) Additionally, the term “exemplary” and variations thereof are used herein to mean “serving as an example, instance or illustration.” Any embodiment or design described herein as “exemplary” is not necessarily to be construed as preferred or advantageous over other embodiments or designs. The terms “at least one,” “one or more,” and variations thereof, can include any integer number greater than or equal to one, i.e. one, two, three, four, etc. The terms “a plurality” and variations thereof can include any integer number greater than or equal to two, i.e., two, three, four, five, etc. The term “connection” and variations thereof can include both an indirect “connection” and a direct “connection.”

(182) The terms “about,” “substantially,” “approximately,” and variations thereof, are intended to include the degree of error associated with measurement of the particular quantity based upon the equipment available at the time of filing the application. For example, “about” can include a range of ±8% or 5%, or 2% of a given value.

(183) The phrases “in signal communication”, “in communication with,” “communicatively coupled to,” and variations thereof can be used interchangeably herein and can refer to any coupling, connection, or interaction using electrical signals to exchange information or data, using any system, hardware, software, protocol, or format, regardless of whether the exchange occurs wirelessly or over a wired connection.

(184) Aspects of the present invention are described herein with reference to flowchart illustrations and/or block diagrams of methods, apparatus (systems), and computer program products according to embodiments of the invention. It will be understood that each block of the flowchart illustrations and/or block diagrams, and combinations of blocks in the flowchart illustrations and/or block diagrams, can be implemented by computer readable program instructions.

(185) The flowchart and block diagrams in the Figures illustrate the architecture, functionality, and operation of possible implementations of systems, methods, and computer program products according to various embodiments of the present invention. In this regard, each block in the flowchart or block diagrams may represent a module, segment, or portion of instructions, which comprises one or more executable instructions for implementing the specified logical function(s). In some alternative implementations, the functions noted in the block may occur out of the order noted in the figures. For example, two blocks shown in succession may, in fact, be executed substantially concurrently, or the blocks may sometimes be executed in the reverse order, depending upon the functionality involved. It will also be noted that each block of the block diagrams and/or flowchart illustration, and combinations of blocks in the block diagrams and/or flowchart illustration, can be implemented by special purpose hardware-based systems that perform the specified functions or acts or carry out combinations of special purpose hardware and computer instructions.
(186) The corresponding structures, materials, acts, and equivalents of all means or step plus function elements in the claims below are intended to include any structure, material, or act for performing the function in combination with other claimed elements as specifically claimed. The description of the present invention has been presented for purposes of illustration and description but is not intended to be exhaustive or limited to the invention in the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art without departing from the scope and spirit of the invention. The embodiment of the invention was chosen and described in order to best explain the principles of the invention and the practical application, and to enable others of ordinary skill in the art to understand the invention for various embodiments with various modifications as are suited to the particular use contemplated.
(187) It will be understood that those skilled in the art, both now and in the future, may make various improvements and enhancements which fall within the scope of the claims which follow.

Claims

1. An apparatus comprising: a moveable gripper element comprising a flexible inner sleeve; a mechanical energy source mechanism communicatively coupled to the moveable gripper element; a sensor network communicatively coupled to the moveable gripper element; and a controller communicatively coupled to the mechanical energy source mechanism and the sensor network; wherein the flexible inner sleeve defines an adjustable opening; wherein the controller controls the mechanical energy source mechanism to transfer to the moveable gripper element a gripping force configured to move the moveable gripper element, reduce a size of the adjustable opening, and bring the flexible inner sleeve into an initial level of thermal contact with a container positioned within the adjustable opening; wherein the controller is configured to perform heat exchange control operations to achieve a predetermined level of heat exchange at an interface between the flexible inner sleeve and the container; wherein the heat exchange control operations comprise: subsequent to establishing the initial level of thermal contact, controlling the mechanical energy source mechanism to, responsive to one or more interface parameters, make adjustments to the gripping force that bring the flexible inner sleeve into a targeted level of thermal contact with the container; and controlling a heater assembly to, responsive to one or more of the interface parameters, make adjustments to heating settings applied to the heater assembly to distribute heat to portions of the flexible inner sleeve that are in thermal contact with the container; and wherein the adjustments to the gripping force: increase thermal contact points at the interface between the flexible inner sleeve and the container; and displace air from the interface between the flexible inner sleeve and the container.
2. The apparatus of claim 1, wherein: the heat exchange control operations further comprise, responsive to temperature gradient information, controlling the moveable gripper element to

perform agitation operations that agitate the moveable gripper in multiple directions while the moveable gripper grips and delivers heat to contents of the container; and the temperature gradient information comprises a difference between a temperature at a first position on the container and a temperature at a second position on the container.
3. The apparatus of claim 1, wherein: an interface-parameter proxy measurement or estimate (measurement/estimate) represents the interface parameters; and the interface-parameter proxy measurement/estimate comprises an air-gap percentage at the interface between the flexible inner sleeve and the container.
4. The apparatus of claim 1, wherein: an interface-parameter proxy measurement or estimate (measurement/estimate) represents the interface parameters; the interface-parameter proxy measurement/estimate comprises a prediction of an interfacial thermal resistance at the interface between the flexible inner sleeve and the container; and the controller comprises a machine learning algorithm trained to generate the prediction of the interfacial thermal resistance at the interface between the flexible inner sleeve and the container.
5. The apparatus of claim 1, wherein: an interface-parameter proxy measurement or estimate (measurement/estimate) represents the interface parameters; and the interface-parameter proxy measurement/estimate comprises a difference between: a temperature of the flexible inner sleeve at a location of the interface between the flexible inner sleeve and the container; and a temperature of the container at the location at the interface between the flexible inner sleeve and the container.
6. The apparatus of claim 1, wherein: an interface-parameter proxy measurement or estimate (measurement/estimate) represents the interface parameters; and the interface-parameter proxy measurement/estimate comprises an estimate of the difference between: an estimate of a first temperature at a first location of the contents of the container; and an estimate of a second temperature at a second location of the contents of the container.
7. The apparatus of claim 1, wherein: the flexible inner sleeve comprises the heater assembly; the heater assembly comprises a thermal heating element configured to generate the heat; the thermal heating element is configured to include heating zones; the controller is configured to, based at least in part on container data, individually activate or deactivate each of the heating zones to generate a pattern of the heat; and the container data is selected from the group consisting of: a material of the container; a size of the container; a shape of the container; a surface topology of the container; and a position of the container within the adjustable opening.
8. The apparatus of claim 1, wherein: the flexible inner sleeve comprises the heater assembly; the heater assembly comprises a thermal heating element configured to generate the heat; the adjustments to the heating settings are such that the heat that reaches the container has a substantially uniform distribution along a height dimension of the container; and the substantially uniform distribution of the heat comprises a temperature differential between a first end of the container and a second opposite end of the container being within a predetermined temperature range.
9. The apparatus of claim 1, wherein the adjustments to the gripping force are insufficient to enable the gripping force to damage the container.
10. The apparatus of claim 1, wherein: the flexible inner sleeve comprises the heater assembly; the heater assembly comprises a thermal heating element configured to generate the heat; the heating settings control aspects of how the thermal heating element generates the heat; and the adjustments to the heating settings are such that the heat that reaches the container is insufficient to damage the container.
11. A method of making an apparatus, the method comprising: providing a moveable gripper element comprising a flexible inner sleeve that defines an adjustable opening; providing a mechanical energy source mechanism; communicatively coupling the mechanical energy source mechanism to the moveable gripper element; configuring the mechanical energy source mechanism to, responsive to a controller, transfer to the moveable gripper element a gripping force configured

to move the moveable gripper element, reduce a size of the adjustable opening, and bring the flexible inner sleeve into an initial level of thermal contact with a container positioned within the adjustable opening; and further configuring the mechanical energy source mechanism is configured to, responsive to the controller, perform heat exchange control operations to achieve a predetermined level of heat exchange at an interface between the flexible inner sleeve and the container; wherein the heat exchange control operations comprise: subsequent to establishing the initial level of thermal contact, and responsive to one or more interface parameters, making adjustments to the gripping force that bring the flexible inner sleeve into a targeted level of thermal contact with the container; and using a heater assembly to, responsive to one or more of the interface parameters, make adjustments to heat settings applied to the heater assembly to distribute heat to portions of the flexible inner sleeve that are in thermal contact with the container; and wherein the adjustments to the gripping force: increase thermal contact points at the interface between the flexible inner sleeve and the container; and displace air from the interface between the flexible inner sleeve and the container.

12. The method of claim 11, wherein: the heat exchange control operations further comprise, responsive to temperature gradient information, controlling the moveable gripper element to perform agitation operations that agitate the moveable gripper in multiple directions while the moveable gripper grips and delivers heat to contents of the container; and the temperature gradient information comprises a difference between a temperature at a first position on the container and a temperature at a second position on the container.

13. The method of claim 1, wherein: an interface-parameter proxy measurement or estimate (measurement/estimate) represents the interface parameters; and the interface-parameter proxy measurement/estimate comprises an air-gap percentage at the interface between the flexible inner sleeve and the container.

14. The method of claim 11, wherein: an interface-parameter proxy measurement or estimate (measurement/estimate) represents the interface parameters; the interface-parameter proxy measurement/estimate comprises a prediction of an interfacial thermal resistance at the interface between the flexible inner sleeve and the container; and the controller comprises a machine learning algorithm is used to generate the prediction of the interfacial thermal resistance at the interface between the flexible inner sleeve and the container.

15. The method of claim 11, wherein: an interface-parameter proxy measurement or estimate (measurement/estimate) represents the interface parameters; and the interface-parameter proxy measurement/estimate comprises a difference between: a temperature of the flexible inner sleeve at a location of the interface between the flexible inner sleeve and the container; and a temperature of the container at the location at the interface between the flexible inner sleeve and the container.

16. The method of claim 11, wherein: an interface-parameter proxy measurement or estimate (measurement/estimate) represents the interface parameters; and the interface-parameter proxy measurement/estimate comprises an estimate of the difference between: an estimate of a first temperature at a first location of the contents of the container; and an estimate of a second temperature at a second location of the contents of the container.

17. The method of claim 11, wherein: the flexible inner sleeve comprises the heater assembly; the heater assembly comprises a thermal heating element configured to generate heat; the thermal heating element is configured to include heating zones; the adjustments to the heating settings comprise, based at least in part on container data, individually activate or deactivate each of the heating zones to generate a pattern of the heat; and the container data is selected from the group consisting of: a material of the container; a size of the container; a shape of the container; a surface topology of the container; and a position of the container within the adjustable opening.

18. The method of claim 11, wherein: the flexible inner sleeve comprises the heater assembly; the heater assembly comprises a thermal heating element configured to generate the heat; the heating settings are configured to control aspects of how the thermal heating element generates the heat;

the adjustments to the heating settings are such that the heat that reaches the container has a substantially uniform distribution along a height dimension of the container; and the substantially uniform distribution of the heat comprises a temperature differential between a first end of the container and a second opposite end of the container being within a predetermined temperature range.

19. The method of claim 11, wherein the adjustments to the gripping force are insufficient to enable the gripping force to damage the container.

20. The method of claim 11, wherein: the flexible inner sleeve comprises the heater assembly; the heater assembly comprise a thermal heating element configured to generate heat; the heating settings are configured to control aspects of how the thermal heating element generates the heat; and the adjustments to the heating settings are such that the heat that reaches the container is insufficient to damage the container.