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(54) REFRIGERATED DISPLAY CABINET

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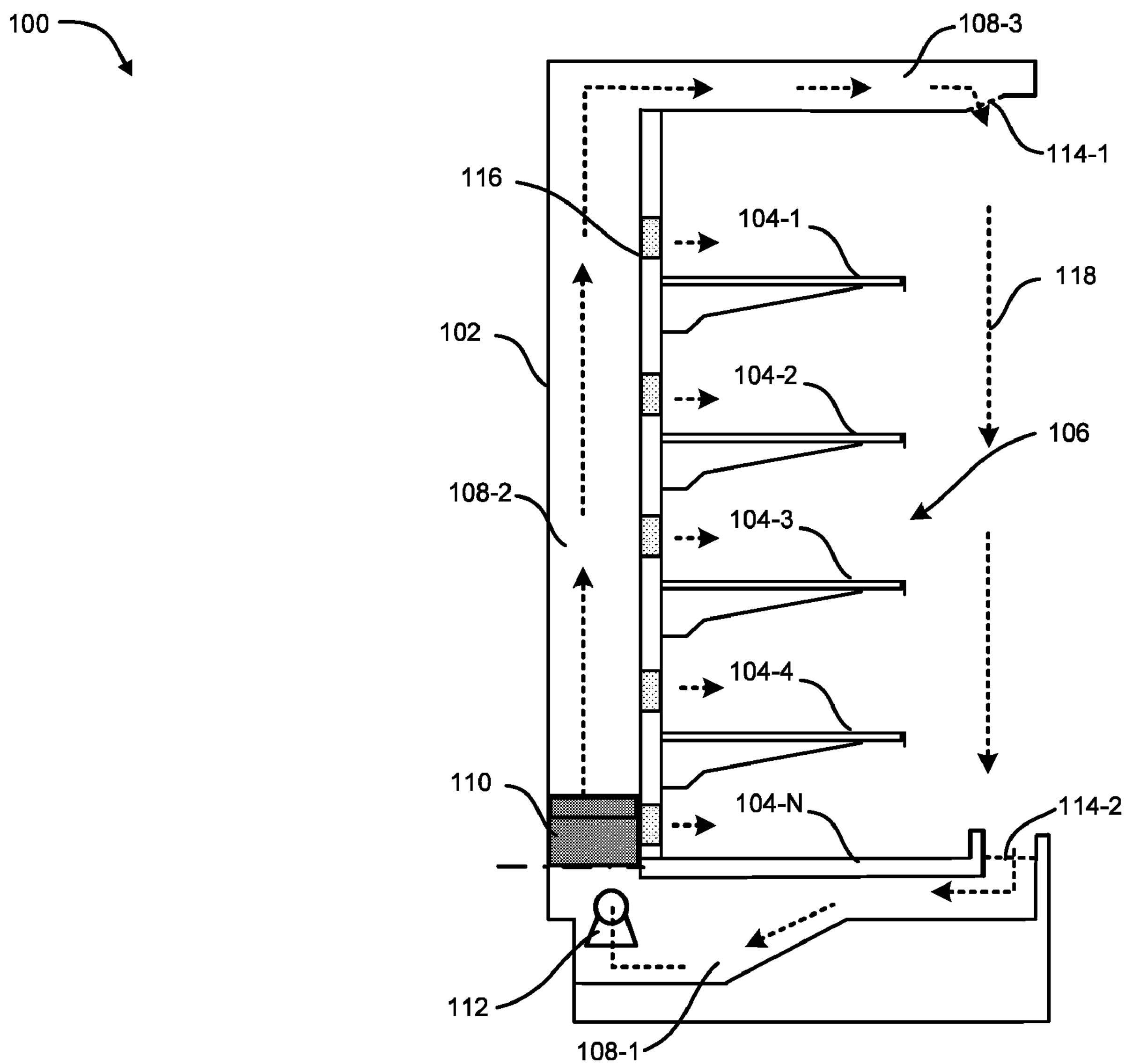
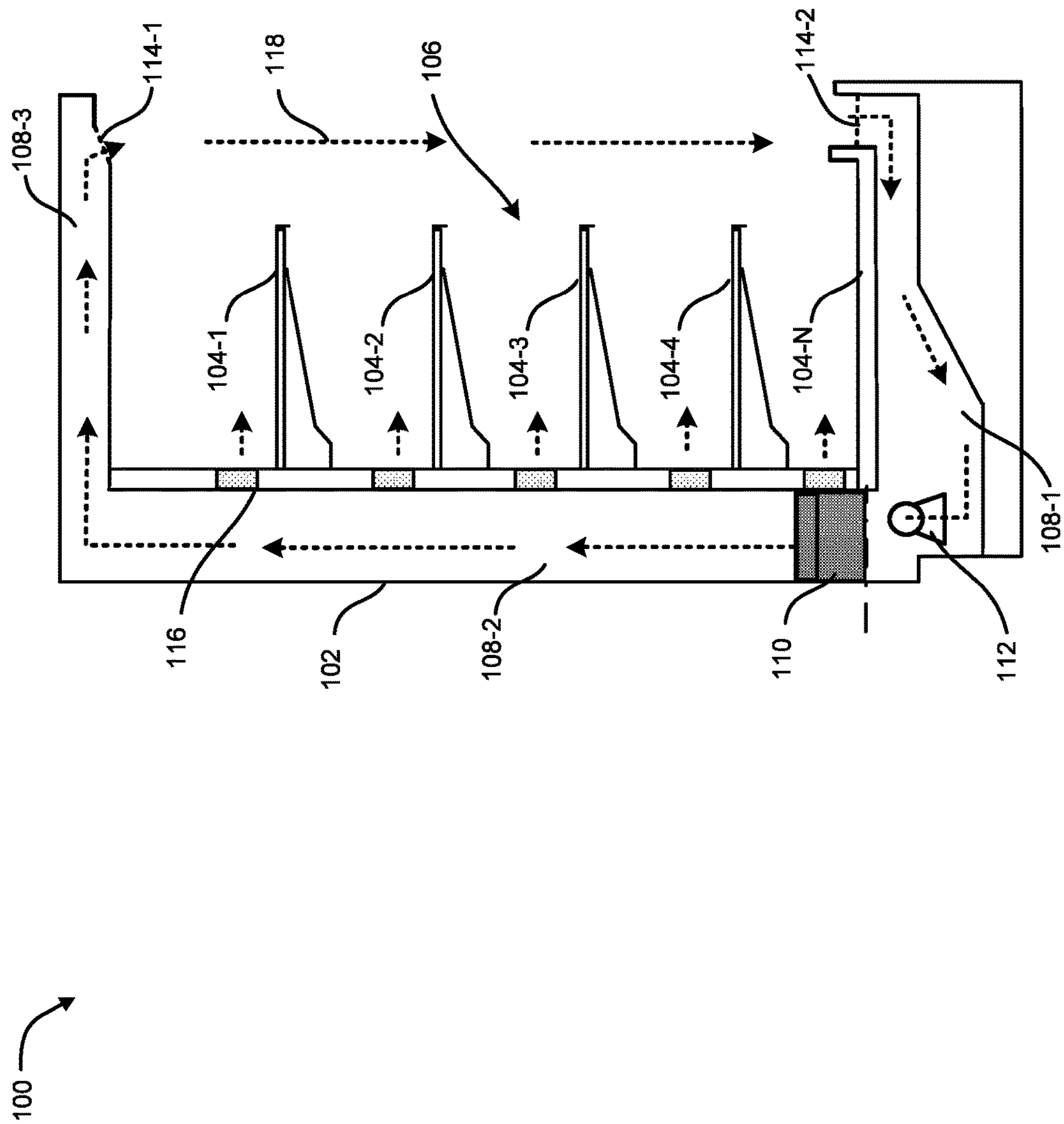
(57) **ABSTRACT**

Described herein is a refrigerated display cabinet. The cabinet comprises a case comprising shelves disposed between side walls of the case to form a conservation space to store products therewithin, a duct extending from a bottom front side of the cabinet to a top front side of the cabinet via a rear side of the cabinet, and at least one heat exchanger, each comprising one or more headers and a plurality of heat exchange tubes extending between the headers. The heat exchange tubes comprise at least one bend formed along a length of the heat exchange tubes to define at least two sections of the heat exchange tubes. The heat exchanger is disposed within the duct of the cabinet such that the headers remain at one lateral end of the rear side and at least one of the bends of the heat exchange tubes remains opposite to the headers.

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102
104-1
104-2
104-3
104-4
104-N
106
108-1
108-2
108-3
110
112
114-1
114-2
116
118

FIG. 1A

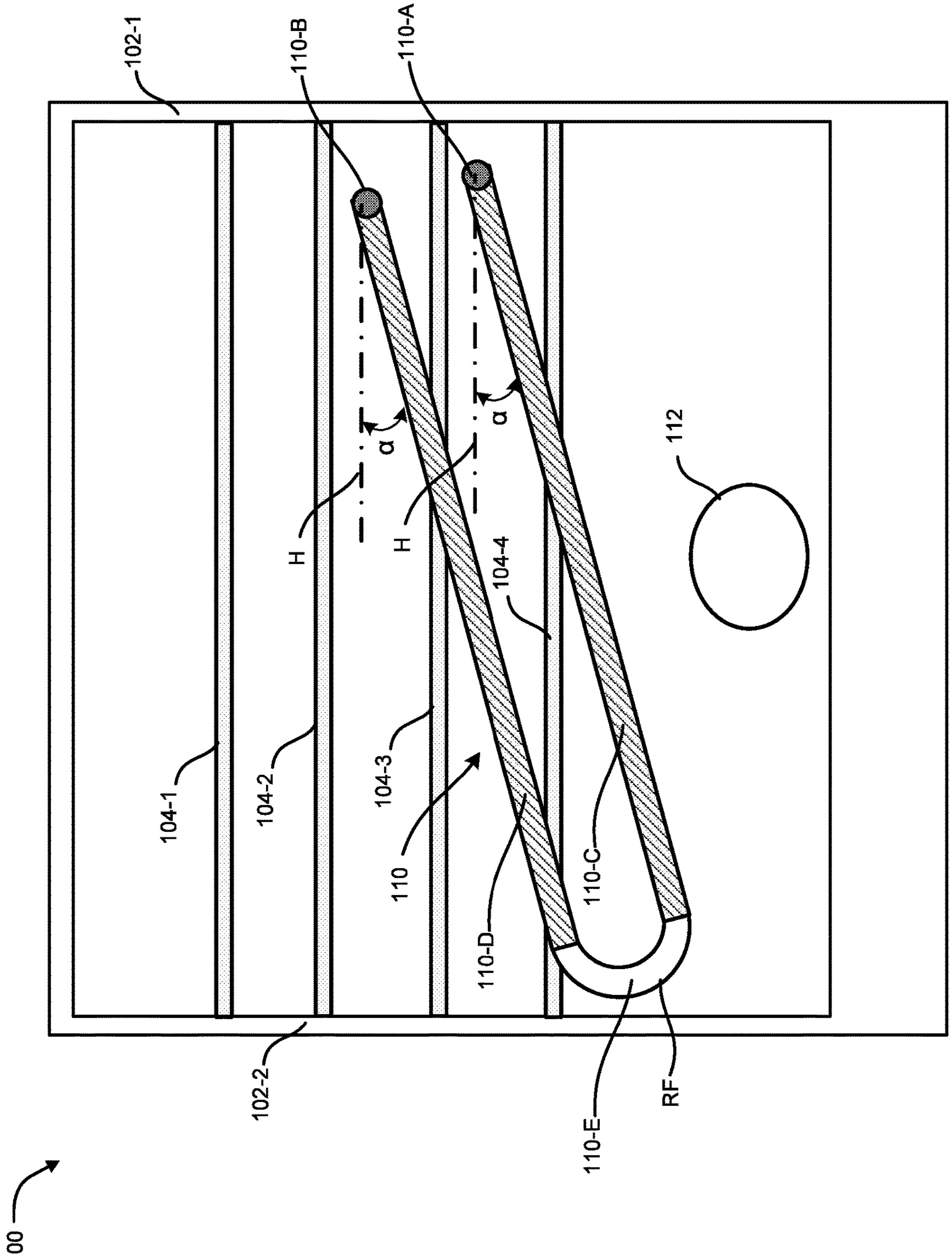
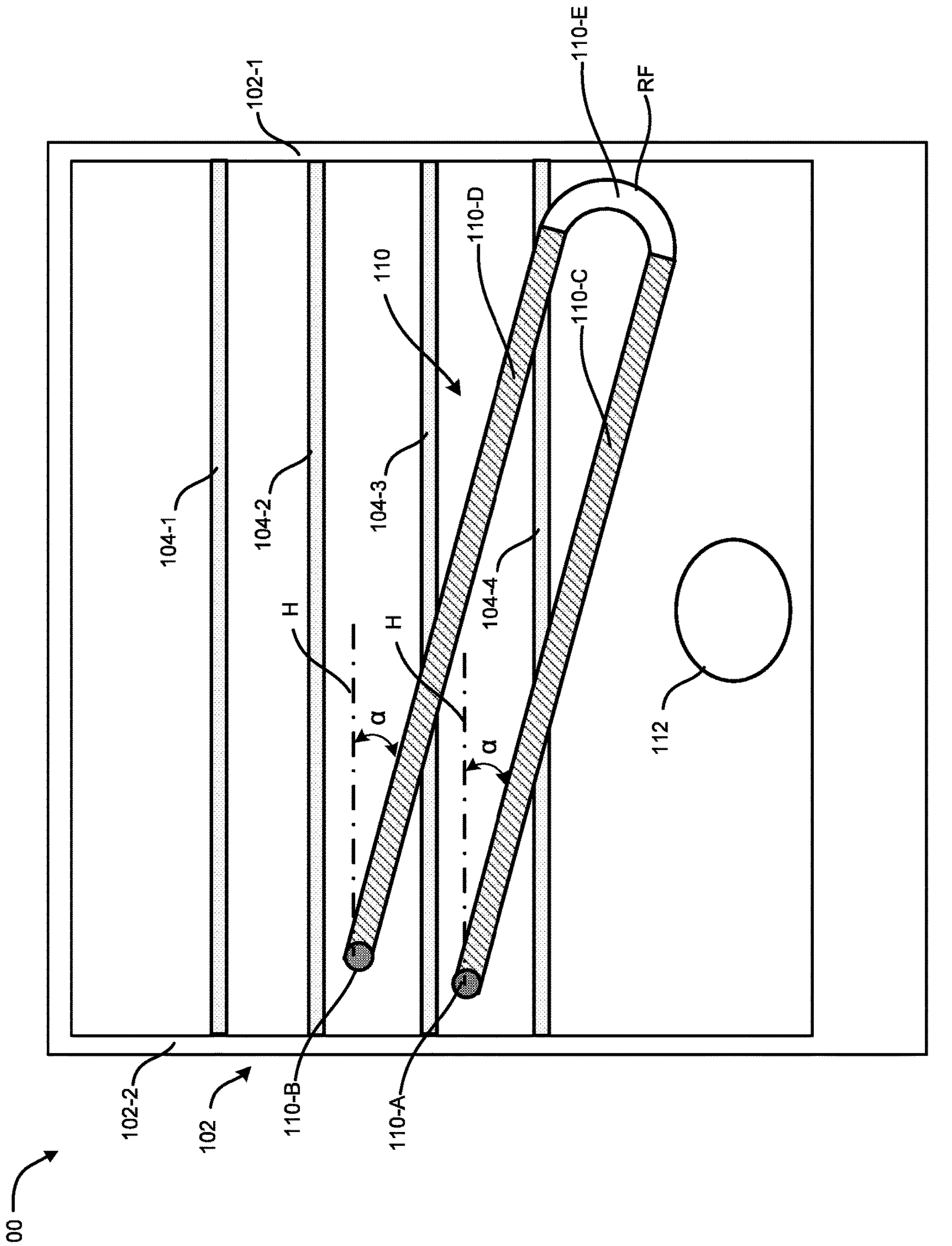

102-1
110-B
110-A
112
H
H
α
α
104-4
104-1
104-2
104-3
110
110-C
110-D
102-2
110-E
RF
100

FIG. 1B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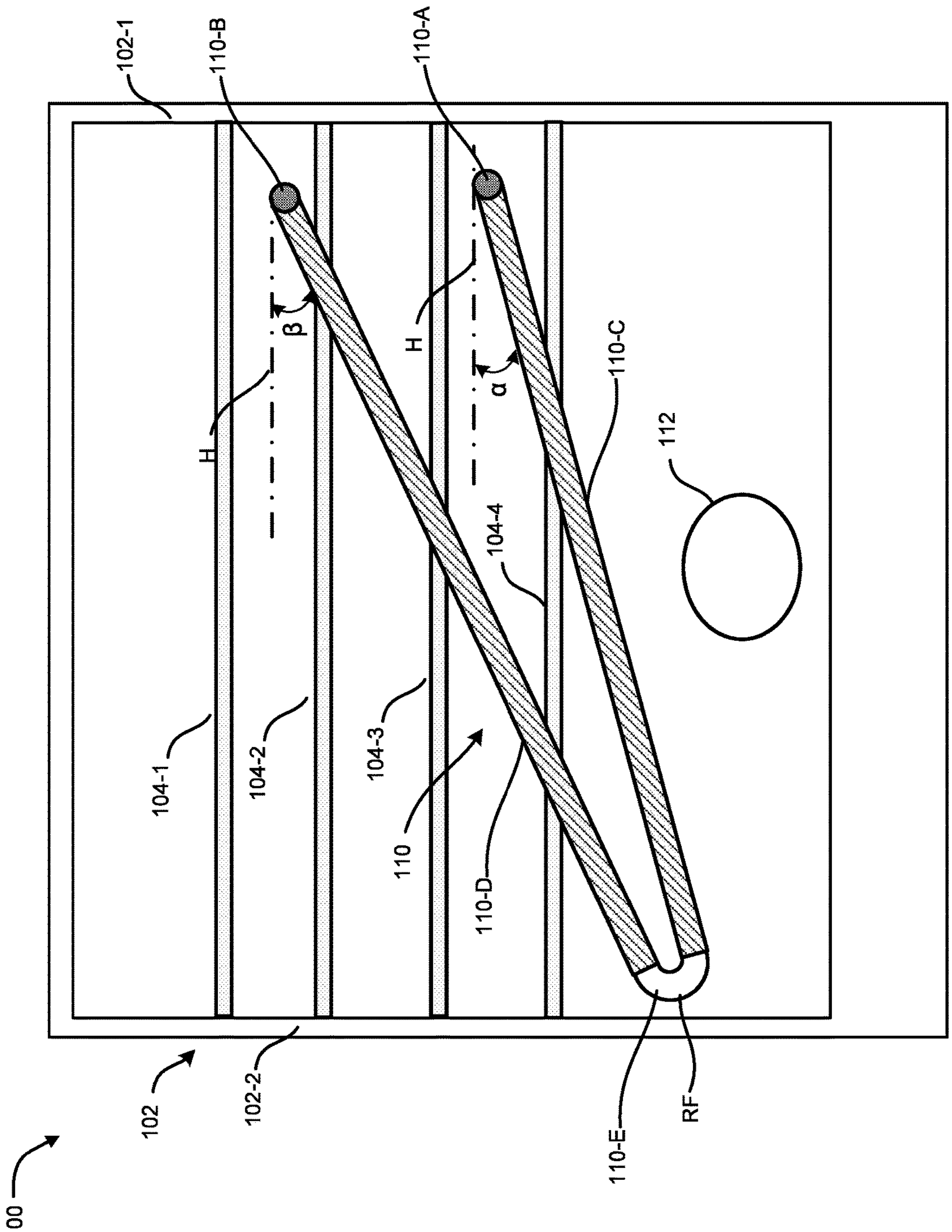
102
102-1
102-2
104-1
104-2
104-3
104-4
110
110-A
110-B
110-C
110-D
110-E
RF
H
H
α
α
112

FIG. 1C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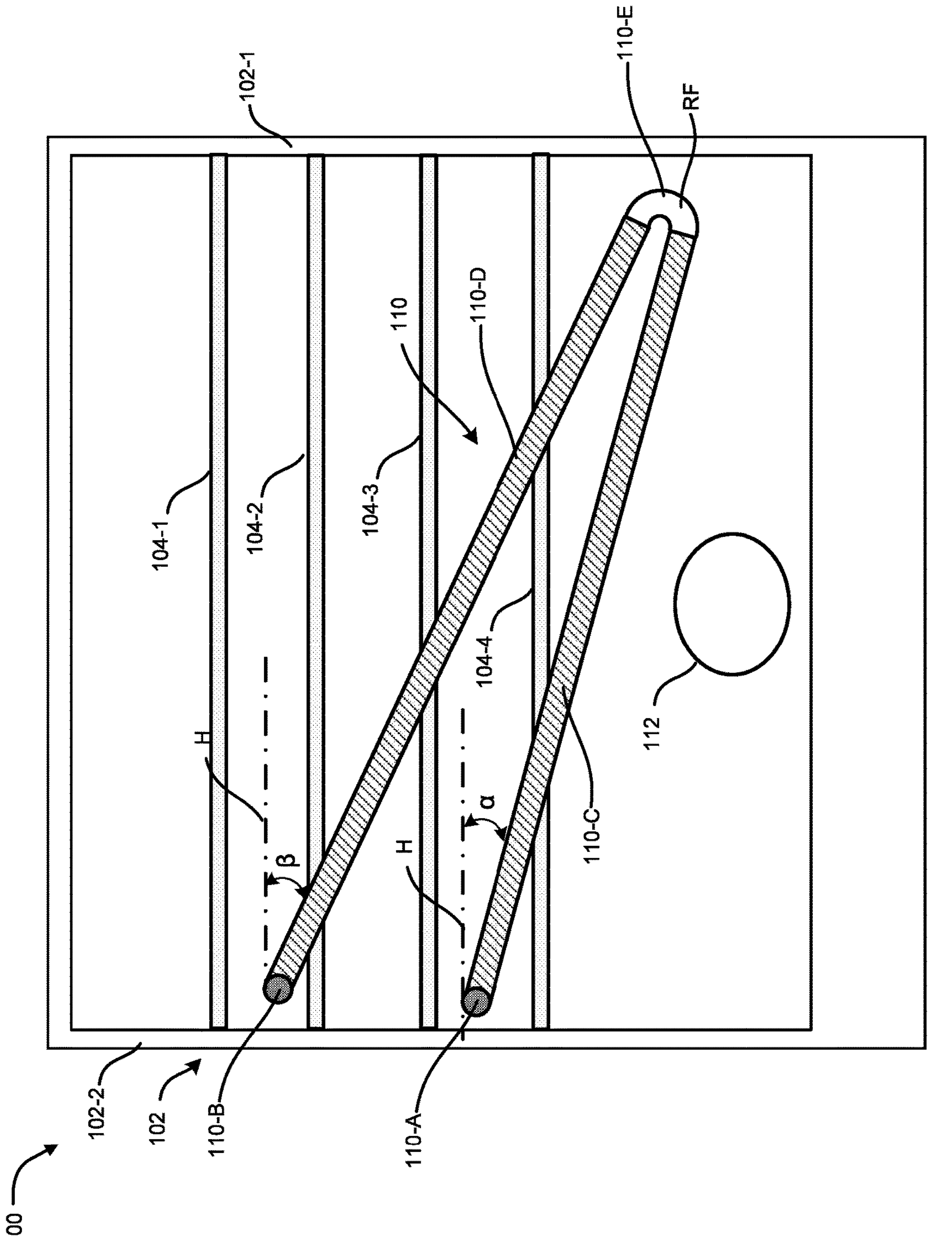
102
102-1
102-2
104-1
104-2
104-3
104-4
110
110-A
110-B
110-C
110-D
110-E
H
H
α
β
112
RF

FIG. 1D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102
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102-2
104-1
104-2
104-3
104-4
110
110-A
110-B
110-C
110-D
110-E
RF
112
H
H
α
β

FIG. 1E

5/7

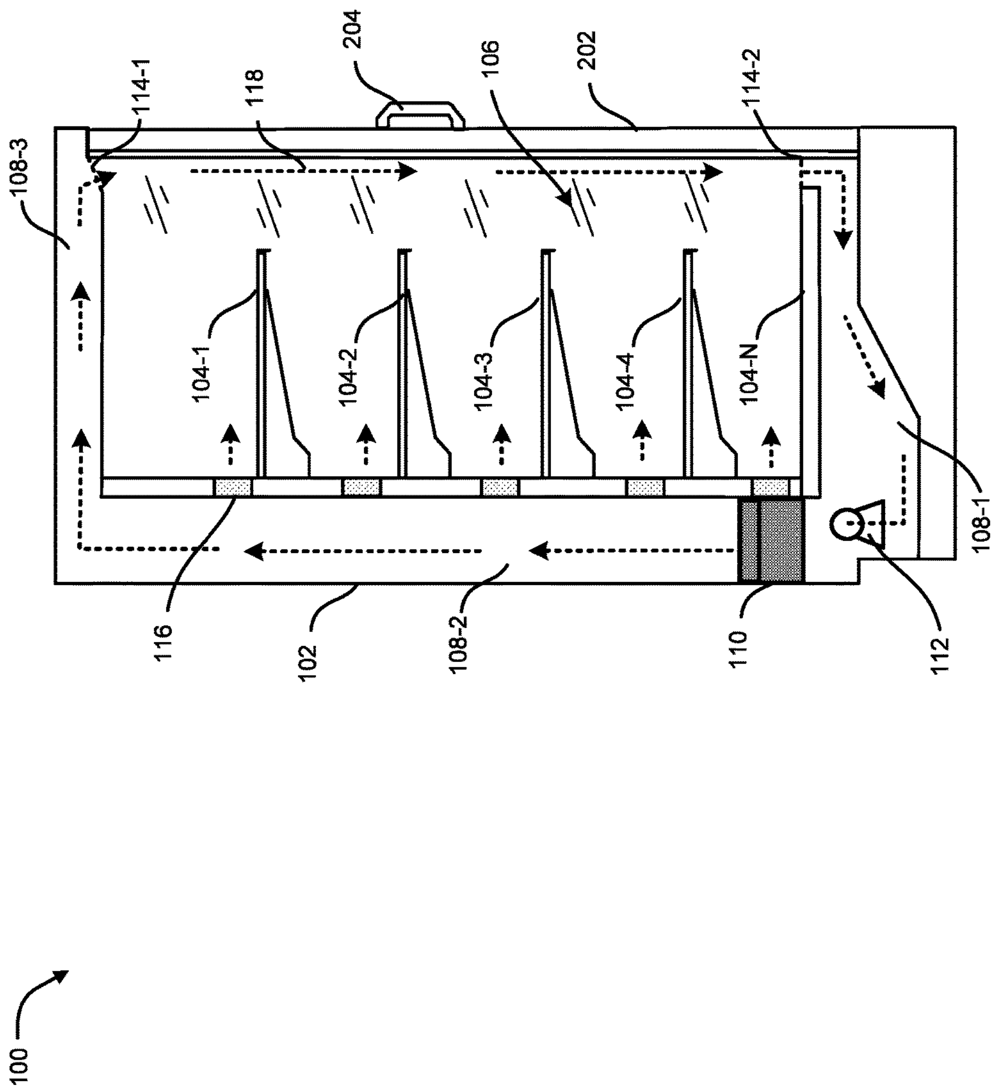
204
106
202
114-1
118
114-2
108-3
104-1
104-2
104-3
104-4
104-N
108-1
116
102
108-2
110
112
100

FIG. 2

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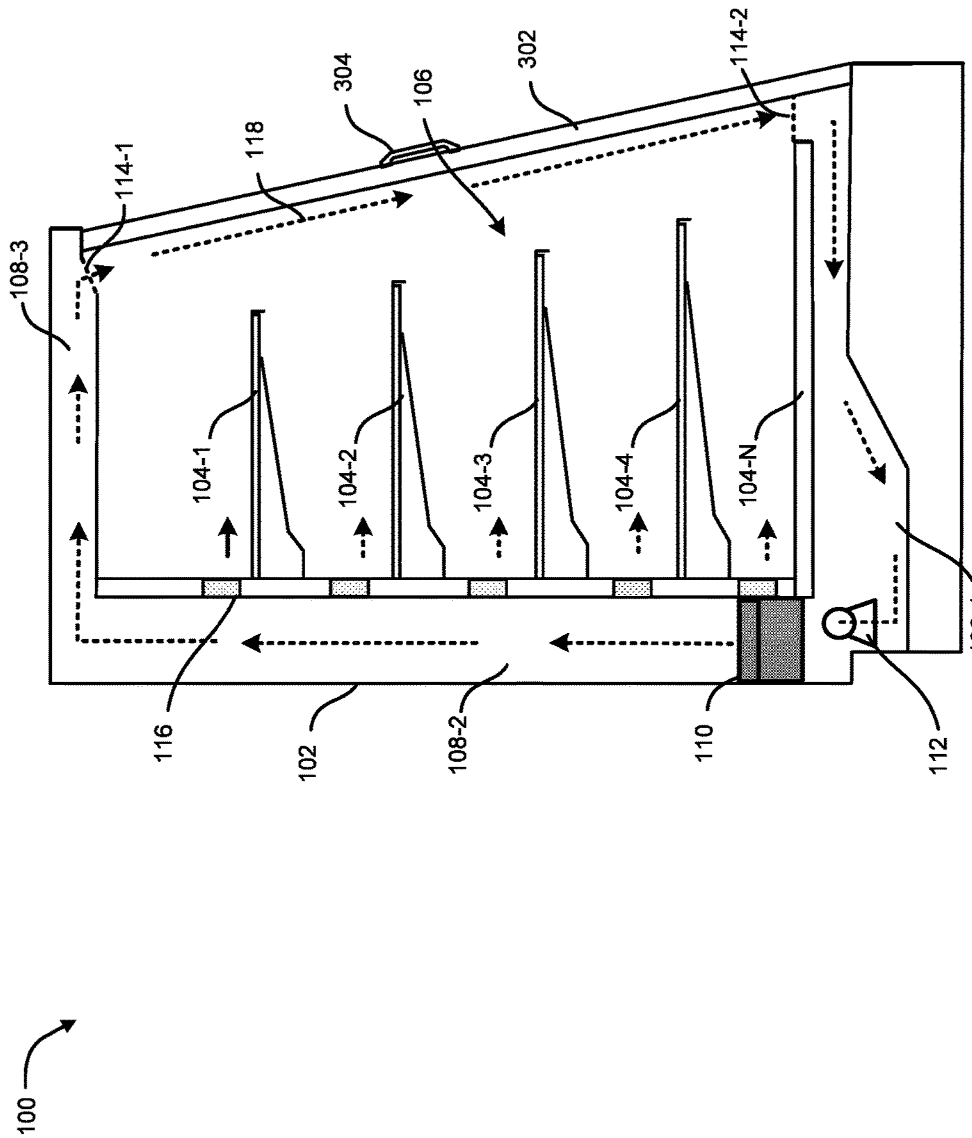
100
102
104-1
104-2
104-3
104-4
104-N
106
108-1
108-2
108-3
110
112
114-1
114-2
116
118
302
304

FIG. 3

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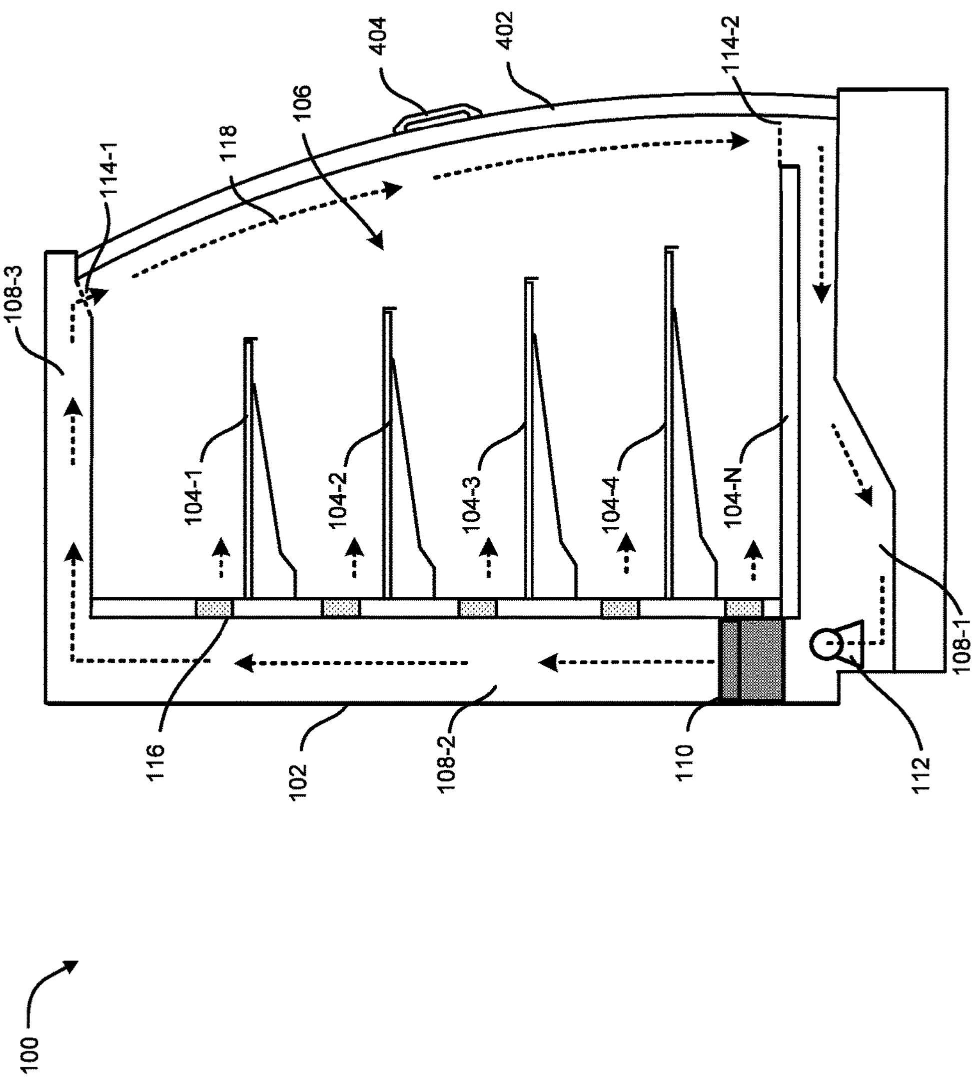

404
402
114-2
106
118
114-1
108-3
104-1
104-2
104-3
104-4
104-N
108-1
116
102
108-2
110
112
100


FIG. 4

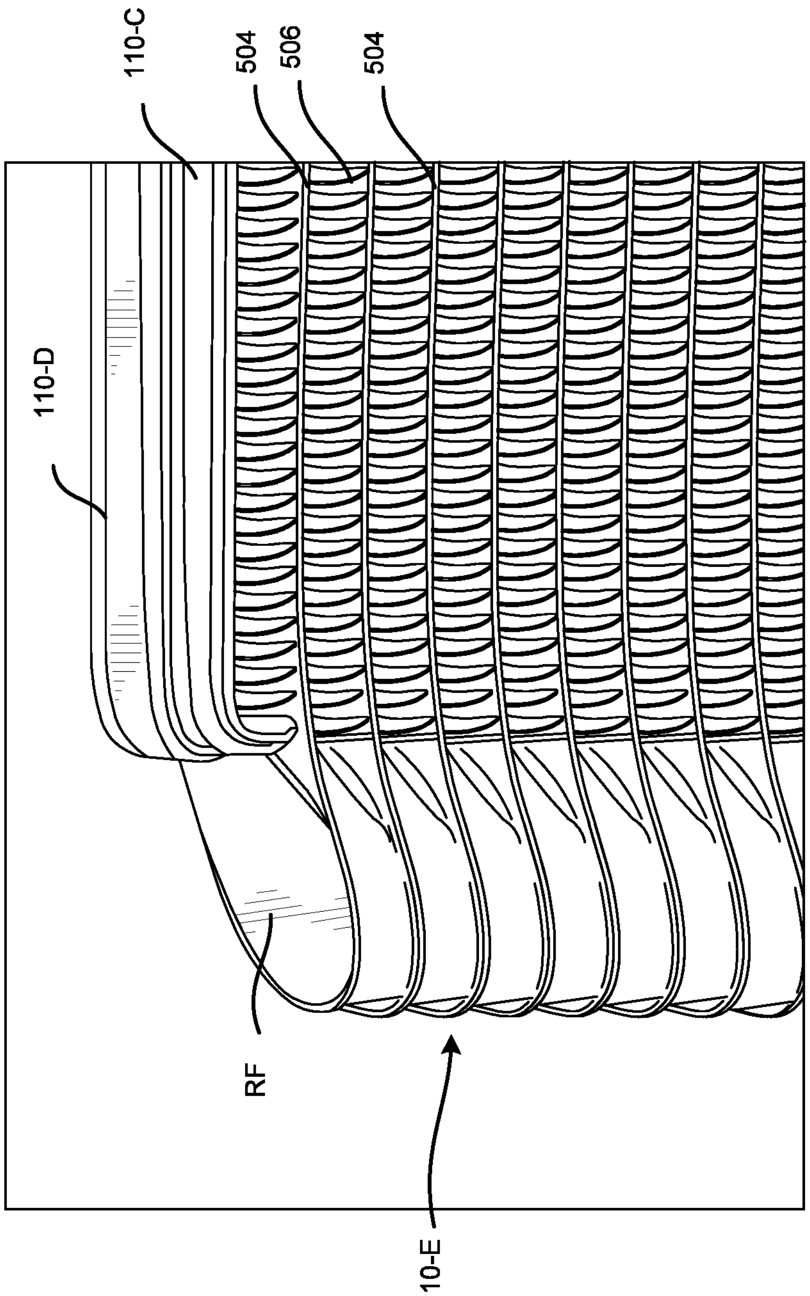


FIG. 5

# REFRIGERATED DISPLAY CABINET

## CROSS-REFERENCE TO RELATED APPLICATION

**[0001]** This patent application claims the benefit of U.S. Provisional Patent Application No. 63/497,541, filed on Apr. 21, 2023, which is incorporated by reference herein in its entirety.

## BACKGROUND

**[0002]** This invention relates to the field of refrigerated display cabinets.

## SUMMARY

**[0003]** Described herein is a refrigerated display cabinet. The cabinet comprises a case comprising one or more shelves disposed between side walls of the case to form a conservation space to support and store one or more products therewithin, a duct extending from a bottom front side of the cabinet to a top front side of the cabinet via a rear side of the cabinet, and at least one heat exchanger, each comprising one or more headers and a plurality of heat exchange tubes extending between the one or more headers. The plurality of heat exchange tubes comprises at least one bend formed along a length of the heat exchange tubes to define at least two sections of the heat exchange tubes, wherein the at least one heat exchanger is disposed within the duct on the rear side of the cabinet such that the one or more headers remain at one lateral end of the rear side and at least one of the bends of the plurality of heat exchange tubes remains opposite to the headers.

**[0004]** In one or more embodiments, the plurality of heat exchange tubes comprises a bend defining a first section and a second section of the heat exchange tubes, wherein the at least one heat exchanger is disposed within the duct on the rear side of the cabinet such that the one or more headers remain at one lateral end of the rear side and the bend of the plurality of heat exchange tubes remains opposite to the headers.

**[0005]** In one or more embodiments, the at least one bend is a ribbon fold formed by bending and twisting the plurality of heat exchange tubes, wherein the at least one bend is formed about an axis extending substantially perpendicular to a longitudinal axis of the plurality of heat exchange tubes.

**[0006]** In one or more embodiments, the first section and the second section are substantially parallel with a predefined gap therebetween.

**[0007]** In one or more embodiments, a longitudinal axis of the first section and the second section is inclined at a first predefined angle with respect to a horizontal plane such that the one or more headers at one lateral end of the rear side remain at a different elevation than the at least one bend of the plurality of heat exchange tubes at an end opposite to the one or more headers.

**[0008]** In one or more embodiments, the first section and the second section are non-parallel to each other.

**[0009]** In one or more embodiments, a longitudinal axis of the first section is inclined at a first predefined angle with respect to a horizontal plane, and a longitudinal axis of the second section is inclined at a second predefined angle with respect to the horizontal plane such that the one or more headers remain at different elevations at the same lateral end of the rear side of the cabinet and such that the one or more headers remain at different elevations than the at least one bend of the plurality of heat exchange tubes at an end opposite to the one or more headers.

**[0010]** In one or more embodiments, the first predefined angle or the second predefined angle is of at least 10° to 15° to the horizontal plane.

**[0011]** In one or more embodiments, the at least one heat exchanger comprises a first header and a second header, each disposed at a left end or a right end of a rear airflow zone of the cabinet, and extending longitudinally between a front end and a rear end of the rear airflow zone, wherein the plurality of heat exchange tubes with the bend fluidically connect the first header and the second header.

**[0012]** In one or more embodiments, the first header and the second header are oriented parallel to the horizontal plane, extending between a front end and a rear end of a rear airflow zone of the cabinet, wherein the second header remains at a predefined height above the first header and such that both the headers remain at different elevations than the bend of the plurality of heat exchange tubes at an end opposite to the headers.

**[0013]** In one or more embodiments, the first header and the second header are oriented at a third predefined angle from the horizontal plane, extending between a front end and a rear end of the rear airflow zone.

**[0014]** In one or more embodiments, the at least one heat exchanger comprises a plurality of fins extending between at least some of the plurality of heat exchange tubes, wherein the plurality of fins extending between at least some of the plurality of heat exchange tubes is louvered such that a louver airflow path is formed between the adjacent louvers.

**[0015]** In one or more embodiments, the cabinet comprises at least one fan positioned upstream or downstream of the at least one heat exchanger within the duct, wherein the at least one fan is configured to facilitate the inflow of air within the duct through the bottom front side of the cabinet, pass the received air through the at least one heat exchanger to cool the received air, and pump out the cool air from the top front side of the cabinet, and wherein the cool air pumped out by the top front side of the cabinet is received by the bottom front side of the cabinet such that an aerothermodynamic barrier or air curtain is formed in front of the one or more shelves or behind the doors of the cabinet.

**[0016]** In one or more embodiments, the heat exchanger is disposed within the rear airflow zone such that the at least one heat exchanger remains at least partially below a bottom-most shelf among the one or more shelves in order to discharge a portion of the cool through a perforated wall panel (PWP), configured with the duct in the rear airflow zone, to the conservation space below the bottom-most shelf and above a bottom airflow zone of the cabinet.

**[0017]** In one or more embodiments, the cabinet is any of an open-front type display cabinet, or a door-type display cabinet comprising one or more doors movably coupled to a front end of the case.

**[0018]** Further described herein is a heat exchanger for a refrigerated display cabinet. The heat exchanger comprises a first header and a second header disposed within a rear side of a duct associated with the cabinet such that both the first header and second header remain disposed at same lateral end of the rear side of the cabinet, wherein the duct extends from a bottom front side of the cabinet to a top front side of the cabinet via the rear side of the cabinet. The heat exchanger further comprises a plurality of heat exchange tubes extending between the first header and the second header. The plurality of heat exchange tubes comprises a bend formed along a length of the heat exchange tubes to define a first section and a second section of the heat exchange tubes, wherein the at least one heat exchanger is configured within the duct such that the bend of the plurality of heat exchange tubes remains opposite to the first header and the second header.

**[0019]** In one or more embodiments, the bend is a ribbon fold formed by bending and twisting the plurality of heat exchange tubes, wherein the bend is formed about an axis extending substantially perpendicular to a longitudinal axis of the plurality of heat exchange tubes.

**[0020]** In one or more embodiments, a longitudinal axis of the first section and the second section is inclined at a first predefined angle with respect to a horizontal plane such that the one or more headers remains at different elevations at same lateral end of the rear side of the cabinet and such that the one or more headers remain at different elevations than the bend of the plurality of heat exchange tubes at an end opposite to the one or more headers.

**[0021]** In one or more embodiments, a longitudinal axis of the first section is inclined at a first predefined angle with respect to a horizontal plane and a longitudinal axis of the second section is inclined at a second predefined angle with respect to the horizontal plane such that the first and second headers remain at different elevations at same lateral end of the rear side of the cabinet and such that the one or more headers remain at different elevations than the bend of the plurality of heat exchange tubes at an end opposite to the one or more headers.

**[0022]** In one or more embodiments, the heat exchanger comprises a plurality of fins extending between at least some of the plurality of heat exchange tubes, wherein the plurality of fins extending between at least some of the plurality of heat exchange tubes is louvered such that a louver airflow path is formed between the adjacent louvers.

**[0023]** The foregoing summary is illustrative only and is not intended to be in any way limiting. In addition to the illustrative aspects, embodiments, and features described above, further aspects, embodiments, features, and techniques of the invention will become more apparent from the following description taken in conjunction with the drawings.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0024]** The accompanying drawings are included to provide a further of the invention and are incorporated in and constitute a part of this specification. The drawings illustrate exemplary embodiments and, together with the description, serve to explain the principles of the invention.

**[0025]** In the drawings, similar components and/or features may have the same reference label. Further, various components of the same type may be distinguished by following the reference label with a second label that distinguishes among the similar components. If only the first reference label is used in the specification, the description is applicable to any one of the similar components having the same first reference label irrespective of the second reference label.

**[0026]** FIG. **1**A illustrates an exemplary diagram depicting a side view of an open-type vertical refrigerated display cabinet, in accordance with one or more embodiments of the invention.

**[0027]** FIGS. **1**B and **1**C illustrate an exemplary front internal view of the refrigerated display cabinet where the first and second sections are non-parallel and inclined with respect to a horizontal plane such that the headers at one lateral end remain at a different elevation than the bend of the heat exchange tubes, in accordance with one or more embodiments of the invention.

**[0028]** FIGS. **1**D and **1**E illustrate an exemplary front internal view of the refrigerated display cabinet where the first and second sections are non-parallel and inclined with respect to a horizontal plane such that the headers at one lateral end remain at a different elevation than the bend of the heat exchange tubes, in accordance with one or more embodiments of the invention.

**[0029]** FIG. **2** illustrates an exemplary diagram depicting a side view of a door-type vertical refrigerated display cabinet, in accordance with one or more embodiments of the invention.

**[0030]** FIG. **3** illustrates an exemplary diagram depicting a side view of a door-type semi-vertical refrigerated display cabinet with flat doors in accordance with one or more embodiments of the invention.

**[0031]** FIG. **4** illustrates an exemplary diagram depicting a side view of a door-type semi-vertical refrigerated display cabinet with curved doors, in accordance with one or more embodiments of the invention.

**[0032]** FIG. **5** illustrates an exemplary view of the microchannel heat exchanger associated with FIGS. **1**A to **4**, depicting the ribbon folds forming the bend between the first and second sections and the heat exchange fins extending between the adjacent microchannel tubes, in accordance with one or more embodiments of the invention.

## DETAILED DESCRIPTION

**[0033]** The following is a detailed description of embodiments of the disclosure. The embodiments are in such detail as to clearly communicate the disclosure. However, the amount of detail offered is not intended to limit the anticipated variations of embodiments; on the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the disclosure.

**[0034]** Various terms are used herein. To the extent a term used in a claim is not defined below, it should be given the broadest definition persons in the pertinent art have given that term as reflected in printed publications and issued patents at the time of filing.

**[0035]** In the specification, reference may be made to the spatial relationships between various components and to the spatial orientation of various aspects of components as the devices are depicted in the attached drawings. However, as will be recognized by those skilled in the art after a complete reading of the subject disclosure, the components of this invention described herein may be positioned in any desired orientation. Thus, the use of terms such as "above," "below," "upper," "lower," "first", "second" or other like terms to describe a spatial relationship between various components or to describe the spatial orientation of aspects of such components should be understood to describe a relative relationship between the components or a spatial orientation of aspects of such components, respectively, as the heat exchanger, flat microchannel tubes, heat dissipating fins, shelves, and corresponding components of the refrigerated cabinet, described herein may be oriented in any desired direction.

**[0036]** The refrigerated display cabinet (sometimes referred to as "cabinet" herein) includes a heat exchanger (evaporator) installed in an airflow path provided in the cabinet to facilitate cooling of a conservation space associated with the cabinet and keep the stored products or goods in the conservation space conditioned. Existing cabinets may include a microchannel heat exchanger for improved heat transfer or cooling performance and frost-free operation of the cabinet. However, there is a need to further improve the cooling performance and efficiency of the refrigerated cabinet while maintaining a frost-free operation and reduced air pressure drop in the cabinet.

**[0037]** This invention provides a compact, improved, and efficient refrigerated cabinet that has improved cooling performance with frost-free operation and reduced air pressure drop.

**[0038]** Referring to FIGS. **1**A to **4**, the refrigerated display cabinet **100** (also referred to as cabinet **100**, hereinafter) is disclosed. The cabinet **100** may include a case **102** comprising one or more shelves **104-1** to **104**-N (collectively referred to as shelves **104**, herein) extending between the side walls **102-1**, **102-2** of case **102**, thereby forming a conservation space **106** to support and store products or goods therewithin. The cabinet **100** may further include a duct **108** or airflow passage extending from the bottom front side of cabinet **100** to the top front side of cabinet **100** via a rear side of cabinet **100**. The duct **108** may include a bottom airflow zone **108-1** extending from the bottom front side to the bottom rear side of cabinet **100**, a rear airflow zone **108-2** extending on the rear side of the cabinet **100** from the bottom rear side to a top rear side of the cabinet **100** and fluidically connected to the bottom airflow zone **108-1**, and a top airflow zone **108-3** extending from the top rear side to the top front side of the cabinet and fluidically connected the rear airflow zone **108-2**.

**[0039]** In one or more embodiments, the cabinet **100** may be an open-type cabinet **100** (without any doors) as shown in FIG. **1**A where an aerothermodynamic barrier may be created in front of cabinet **100** by a recirculating air curtain **118** that may keep the conservation space **106** and the surrounding environment thermally separated from each other In other embodiments, the cabinet **100** may be a door-type cabinet **100** as shown in FIG. **2** to **4** which may include multiple doors (collectively referred to as doors, herein) movably coupled to the front of case **102**. The doors may be adapted to move between an open position and a closed position. The doors and/or the aerothermodynamic barrier created in front of the cabinet **100** by a recirculating air curtain **118** may keep the conservation space **106** and the environment thermally separated.

**[0040]** The cabinet **100** may include a refrigeration system or cooling unit to maintain a predefined temperature in the conservation space **106** of cabinet **100** and also create a recirculating air curtain **118** in front of the shelves **104** or behind the doors of the cabinet **100** in order to create an aerothermodynamic barrier between the conservation space **106** and environment. The refrigeration system may involve the duct **108** extending from the bottom front side of the cabinet **100** to the top front side of the cabinet **100** via the rear side of the cabinet **100**. Further, an opening of the top front side of duct **108** may be configured with a discharge air grille (DAG) **114-1** and an opening of the bottom front side of duct **108** may be configured with a return air grille (RAG) **114-2**. The DAG **114-1** and the RAG **114-2** may control air directivity and facilitate the creation of the air curtain **118** in front of the shelves **104** or behind the doors of the cabinet **100**. The DAG **114-1** and RAG **114-2** may further restrict the entry of undesired objects within duct **108**. As illustrated, the bottom airflow zone **108-1** of duct **108** may extend horizontally from RAG **114-2** to the bottom rear side of the cabinet **100**, the rear airflow zone **108-2** of duct **108** may extend vertically from the bottom rear side to the top rear side of the cabinet **100**, and the top airflow zone **108-3** of the duct **108** may extend horizontally from the top rear side to the DAG **114-1**.

**[0041]** The refrigeration system may further include an evaporator disposed within duct **108** and comprising a heat exchanger **110** that may include one or more headers **110**-A, **110**-B and a plurality of flat microchannel tubes extending between the headers **110**-A, **110**-B. Further, the plurality of heat exchange tubes may include at least one bend **110**-E formed along a length of the heat exchange tubes to define at least two sections **110**-C, **110**-D (also referred to as slabs **110**-C, **110**-D, herein) of the heat exchange tubes. The heat exchanger **110** may be disposed within the duct **108** on the rear side of the cabinet **100** such that the headers **110**-A, **110**-B remain at one lateral end of the rear side and the bend(s) **110**-E of the heat exchange tubes remain opposite to the headers **110**-A, **110**-B. The evaporator/heat exchanger **110** may be operable to enable heat exchange between the cool refrigerant and incoming air stream entering within duct **108** to cool the air to a predefined temperature, which may be supplied to the conservation space **106** and/or create the cool air curtain **118** in front of the shelves **104**.

**[0042]** In one or more embodiments, the heat exchanger **110** may further include a first header **110**-A and a second header **110**-B extending longitudinally between a front end and a rear end of the rear airflow zone **108-2**. In one or more embodiments, the first and second headers **110**-A, **110**-B may be disposed at a left side adjacent to the left side wall **102-1** of the rear airflow zone **108-2** as shown in FIGS. **1**B and **1**D. Further, in one or more embodiments, the first and second headers **110**-A, **110**-B may be disposed at a right side adjacent to the right side wall **102-2** of the rear airflow zone **108-2** as shown in FIGS. **1**C and **1**E.

**[0043]** Accordingly, at least one of the bends **110**-E of the heat exchange tubes may remain at a right side adjacent to the right side wall **102-1** of the rear airflow zone **108-2** as shown in FIGS. **1**B and **1**D, or a left side adjacent to left side wall **102-2** of the rear airflow zone **108-2** as shown in FIGS. **1**C and **1**E. In one or more embodiments, the heat exchange tubes may include one bend **110**-E defining a first section (first slab) **110**-C and a second section **110**-D (second slab) of the heat exchange tubes. The heat exchanger **110** may be disposed within the duct **108** such that the headers **110**-A, **110**-B remain at one lateral end of the rear side and the bend **110**-E remains at the other end opposite to the headers **110**-A, **110**-B.

**[0044]** In one or more embodiments, the bend **110**-E may be a ribbon fold (RF) (designated as **502** in FIG. **5**) that may be formed by bending and twisting the heat exchange tubes about an axis extending substantially perpendicular to a longitudinal axis of the heat exchange tubes. In addition, in one or more embodiments, the heat exchanger **110** may comprise a plurality of fins **506** or louvered fins (not shown) extending between at least some of the plurality of flat microchannel tubes **504** as shown in FIG. **5** such that a louvered airflow path or an inter-louver gap is formed between the adjacent louvers, where the condensate may drain through the louvered airflow path.

**[0045]** Referring to FIGS. **1**B and **1**C, in one or more embodiments, the first section **110**-C and the second section **110**-D of the heat exchange tubes may be substantially parallel to each other with a predefined gap therebetween. The heat exchanger **110** may be disposed within the rear airflow zone **108-2** of duct **108** such that the first and second sections **110**-C, **110**-D of the heat exchange tubes remain inclined at a first predefined angle (α) with respect to a horizontal plane (H). In one or more embodiments, the first predefined angle may be in a range of 10° to 15°. Further, in one or more embodiments, there may be a gap of 1-2 mm between the first section and the second section of the heat exchange tubes.

**[0046]** In one or more embodiments, the first header **110**-A and the second header **110**-B may be positioned at different elevations at one end than the bend **110**-E of the heat exchange tubes at the other end within the rear airflow zone **108-2**. For instance, as shown in FIG. **1**B, the first header **110**-A may be at a lower elevation from the second header **110**-B on the left end of the rear airflow zone **108-2** such that a longitudinal axis of the first section **110**-A and a longitudinal axis of the second section **110**-B remain inclined at the first predefined angle (α) from the horizontal plane H, with the bend **110**-E formed at a right end and a substantially lower or equal elevation than the first header **110**-A within the rear airflow zone **108-2**. In other instances, as shown in FIG. **1**C, the first header **110**-A may be at a lower elevation from the second header **110**-B on the right end of the rear airflow zone **108-2** such that a longitudinal axis of the first section **110**-A and a longitudinal axis of the second section **110**-B of the heat exchange tubes remain inclined at the first predefined angle (α) from the horizontal plane H, with the bend **110**-E formed at a left end and a substantially lower or equal elevation than the first header **110**-A within the rear airflow zone **108-2**.

**[0047]** However, in other embodiments, the first header **110**-A may also be at a higher or equal elevation from the second header **110**-B at one of the lateral ends of the rear airflow zone **108-2**. Further, in one or more embodiments, the first header **110**-A may be at a lower elevation from the second header **110**-B on one of the lateral end of the rear airflow zone **108-2**, with the bend **110**-E formed at the other end at an elevation between the first header **110**-A and the second header **110**-B.

**[0048]** Referring to FIGS. **1**D and **1**E, in one or more embodiments, the first section **110**-C and the second section **110**-D of the heat exchange tubes may be non-parallel to each other. The heat exchanger **110** may be disposed within the rear airflow zone **108-2** of duct **108** such that the first section **110**-C of the heat exchange tubes remains inclined at a first predefined angle (α) with respect to a horizontal plane (H), and the second section **110**-D of the heat exchange tubes remains inclined at a second predefined angle (p) from the horizontal plane H. The first predefined angle (α) and the second predefined angle (p) may be different and in a range of 10° to 15° to the horizontal plane H, but are not limited to the like.

**[0049]** In one or more embodiments, the first header **110**-A and the second header **110**-B may be positioned at different elevations at one end than the bend **110**-E of the heat exchange tubes at another end within the rear airflow zone **108-2**. For instance, as shown in FIG. **1**D, the first header **110**-A may be at a lower elevation from the second header **110**-B on the left end of the rear airflow zone **108-2** such that a longitudinal axis of the first section **110**-C remains inclined at a first predefined angle (α) with respect to the horizontal plane H and a longitudinal axis of the second section **110**-D of the heat exchange tubes remain inclined a second predefined angle (β) from the horizontal plane H, with the bend **110**-E formed at a right end and at a substantially lower or equal elevation than the first header **110**-A within the rear airflow zone **108-2**. In other instances, as shown in FIG. **1**E, the first header **110**-A may be at a lower elevation from the second header **110**-B on the right end of the rear airflow zone **108-2** such that a longitudinal axis of the first section **110**-C of the heat exchange tubes remains inclined at a first predefined angle (α) from the horizontal plane H and a longitudinal axis of the second section **110**-D of the heat exchange tubes remain inclined a second predefined angle (p) from the horizontal plane H, with the bend **110**-E formed at a left end and a substantially lower or equal elevation than the first header **110**-A within the rear airflow zone **108-2**.

**[0050]** However, in other embodiments, the first header **110**-A may also be at a higher or equal elevation from the second header **110**-B at one of the lateral ends of the rear airflow zone **108-2**. Further, in one or more embodiments, the first header **110**-A may be at a lower elevation from the second header **110**-B on one of the lateral end of the rear airflow zone **108-2**, with the bend **110**-E formed at the other end at an elevation between the first header **110**-A and the second header **110**-B

**[0051]** In one or more embodiments, the first header **110**-A and the second header **110**-B may be oriented parallel to the horizontal plane H, extending longitudinally between a front end and a rear end of the rear airflow zone **108-2**. However, the first header **110**-A and the second header **110**-B may also be oriented at a third predefined angle (non-parallel) in a range of 10° to 75° from the horizontal plane H, extending longitudinally between a front end and a rear end of the rear airflow zone **108-2**.

**[0052]** Referring back to FIGS. **1**A to **4**, in one or more embodiments, the heat exchanger **110** may be disposed within the rear airflow zone **108-2** such that the heat exchanger **110** remains at least partially below a bottom-most shelf **104**-N among the shelves **104-1** to **104**-N. However, the heat exchanger **110** may also be disposed of at any other position in the rear airflow zone **108-2** of the cabinet **100**, without any limitation.

**[0053]** Further, the refrigeration system may include a fan **112** that may be positioned adjacent (upstream or downstream) to the heat exchanger **110** within duct **108**. The fan **112** may be configured to facilitate the inflow of air within duct **108** through the RAG **114-2**, pass the received air through the flat microchannel tubes **110**-C of the heat exchanger **110** that cools the received air, and pump out the cool air from the DAG **114-1** of the cabinet **100**. Accordingly, the cool air pumped out by the DAG **114-1** (on the top front side of cabinet **100**) may be received by the RAG **114-2** (on the bottom front side of cabinet **100**) to create a curtain **118** of cool air in front of the shelves **104** or behind the doors of the cabinet **100**, which acts as an aerothermodynamic barrier between the conservation space **106** and environment. In addition, the rear airflow zone **108-2** on the rear side of cabinet **100** may include perforated wall panels (PWP) **116** behind the shelves **104**, which may discharge a portion of the cool air, passing through duct **108**, into the conservation space **106** to maintain the predefined temperature within the cabinet **100**. It would be obvious to understand that the number of PWPs **116** used in cabinet **100** can be selected based on the number of shelves **104**, and the size and cooling capacity required in the cabinet **100**.

**[0054]** The evaporator or heat exchanger **110** associated with the refrigeration system of cabinet **100** may be disposed in the rear airflow zone **108-2** of cabinet **100** with the sections of the heat exchange tubes inclined at the first or second predefined angle (αt least 10° to 15° angle) with respect to the horizontal plane as described in detail in above paragraphs. Additional components of the refrigeration system, such as a compressor, a condenser, an expansion device, and the like (not shown) may be installed in any of the rear airflow zone **108-2**, or the bottom airflow zone **108-1** of the duct **108** or below the cabinet **100** as well. Alternatively, one or more of these components, in particular, the compressor and/or the condenser, may be located outside cabinet **100**, for example in a machine room or on the outside/on the roof of a building (not shown) housing the cabinet **100**.

**[0055]** Further, the bottom airflow zone **108-1** of duct **108** may act as a return air duct that may extend substantially along a horizontal axis and is formed below the lowest shelf of cabinet **100**. The bottom airflow zone **108-1** or the rear airflow zone **108-2** may house the fan **112** that may be configured to suck air from the conservation space **106** through a return air opening located at the bottom of the conservation space **106** into the bottom airflow zone **108-1** and deliver the received air to the evaporator/heat exchanger **110** where it is cooled. The return air opening may be covered by RAG **114-2** which may prevent the products, packaging, or spillage from falling into duct **108** or bottom airflow zone **108-1**.

**[0056]** Cooled air leaving the evaporator/heat exchanger **110** may be delivered to flow vertically through the rear airflow zone **108-2** along the rear wall of cabinet **100**. The vertical cold air duct (rear airflow zone **108-2**) provided with the perforated wall panels **116** having openings may allow cold air to flow from the vertical cold air duct (rear airflow zone **108-2**) into the conservation space **106**.

**[0057]** The top airflow zone **108-3** may be fluidly connected with an upper end of the rear airflow zone **108-2** in order to deliver cold air from the rear airflow zone **108-2** to the front side of the conservation space **106**. A front end of the top airflow zone **108-3** may be provided with the DAG **114-1** that may discharge cold air from the top airflow zone **108-3** into an upper front area of conservation space **106**. The cold air that is discharged through the DAG **114-1** into the upper front area of the conservation space **106** may provide a flow of cold air, creating a cold air curtain **118** flowing substantially along the back of the doors and/or front of the shelves **104** from the top to the bottom of the conservation space **106**.

**[0058]** In one or more embodiments, as shown in FIG. **2**, cabinet **100** may be a vertical refrigerated display cabinet **100** with flat doors. Shelves **104** may extend between the side walls of case **102** with the front end of the shelves **104** in line with each other, thereby forming a conservation space **106** to support and store products therewithin. Further, multiple flat glass doors or transparent doors **202** (collectively referred to as vertical doors, herein) may be movably coupled to the front of case **102** in a vertical orientation, which may be adapted to move between an open position and a closed position. The vertical door **202** may be provided with at least one handle **204** to allow the user to slide or rotate door **202** to open or close cabinet **100**.

**[0059]** In one or more embodiments, as shown in FIG. **3**, cabinet **100** may be a semi-vertical refrigerated display cabinet **100** with flat doors is disclosed. Shelves **104** may extend between the side walls of case **102** with a front end of shelves **104** extending in a step-wise manner from top to bottom of cabinet **100**, thereby forming a conservation space **106** to support and store products therewithin. Further, multiple flat glass doors **302** may be movably coupled to the front of case **102** in an inclined orientation from a vertical axis, which may be adapted to move between an open position and a closed position. The inclined door **302** may be provided with at least one handle **304** to allow the user to slide or rotate door **302** to open or close cabinet **100**.

**[0060]** In one or more embodiments, as shown in FIG. **4**, cabinet **100** may be a semi-vertical refrigerated display cabinet **100** with curved doors is disclosed. Shelves **104** may extend between the side walls of case **102** with a front end of shelves **104** extending in a step-wise manner from top to bottom of cabinet **100**, thereby forming a conservation space **106** to support and store products therewithin. Further, multiple curved doors **402**, in particular, curved glass doors or transparent doors (collectively referred to as curved doors **402**, herein) may be slidably coupled to the front of case **102**, which may be adapted to move between an open position and a closed position. The curved door **402** may be provided with at least one handle **404** to allow the user to slide the curved door **402** to open or close cabinet **100**.

**[0061]** Further, in one or more embodiments, (not shown) channels (or brackets or guide rails) may be provided in front of case **102**, which may extend horizontally along the top front end, and bottom front end of case **102**. The channels may be provided with ball bearings and the top and bottom sides of the glass doors (**202**, **302**, **402**) may be slidably configured in the channels on the top front end, and bottom front end of case **102**. Further, the handle (**204**, **304**, **404**) may be provided on one of the sides of the glass door (**202**, **302**, **402**) to allow users to open or close cabinet **100** as required.

**[0062]** Those skilled in the art will appreciate that as the microchannel heat exchanger is installed on the rear airflow zone on the back side of the cabinet with the heat exchange section having a bend **110**-E and multiple sections (slabs) **110**-C, **110**-D, the number of refrigerant passes may be reduced as the size of the microchannel tubes is approximately divided by 2 and the length of the heat exchange section may be doubled compared to designs where the heat exchanger is installed within a bottom airflow zone of the cabinet. In addition, as the (inlet and outlet) headers **110**-A, **110**-B are placed on the same side, any lack of refrigerant in some heat exchange tubes happening along one of the sections (slab) may be at least partly compensated by the full cooling capacity available in the other section (slab) of the heat exchange tubes. This improved temperature distribution inside the cabinet may allow for a decrease in the fan speed and/or the number of fans in the cabinet, which may reduce the energy consumption of the overall cabinet.

**[0063]** In addition, as the heat exchange tubes/sections **110**-C, **110**-D in this invention are inclined (by an angle of at least 10° to 15°) to the horizontal plane H, the inclined heat exchange tubes may enable automated drainage of any condensate towards the bottom of the rear airflow zone for further removal or extraction.

**[0064]** Thus, this invention overcomes the limitations, shortcomings, and drawbacks associated with existing cabinets by providing a compact, improved, and efficient refrigerated cabinet that has improved cooling performance with frost-free operation and reduced air pressure drop.

**[0065]** While the subject disclosure has been described with reference to exemplary embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the subject disclosure as defined by the appended claims. Modifications may be made to adopt a particular situation or material to the teachings of the subject disclosure without departing from the scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed, but that the subject disclosure includes all embodiments falling within the scope of the subject disclosure as defined by the appended claims.

**[0066]** In interpreting the specification, all terms should be interpreted in the broadest possible manner consistent with the context. In particular, the terms "comprises" and "comprising" should be interpreted as referring to elements, components, or steps in a non-exclusive manner, indicating that the referenced elements, components, or steps may be present, or utilized, or combined with other elements, components, or steps that are not expressly referenced. Where the specification claims refer to at least one of something selected from the group consisting of A, B, C . . . and N, the text should be interpreted as requiring only one element from the group, not A plus N, or B plus N, etc.

**1**. A refrigerated display cabinet comprising:

a case comprising one or more shelves disposed between side walls of the case to form a conservation space to support and store one or more products therewithin;

a duct extending from a bottom front side of the cabinet to a top front side of the cabinet via a rear side of the cabinet; and

at least one heat exchanger, each comprising one or more headers and a plurality of heat exchange tubes extending between the one or more headers, the plurality of heat exchange tubes comprising at least one bend formed along a length of the heat exchange tubes to define at least two sections of the heat exchange tubes,

wherein the at least one heat exchanger is disposed within the duct on the rear side of the cabinet such that the one or more headers remain at one lateral end of the rear side and at least one of the bends of the plurality of heat exchange tubes remains opposite to the headers.

**2**. The refrigerated display cabinet of claim **1**, wherein the plurality of heat exchange tubes comprises a bend defining a first section and a second section of the heat exchange tubes,

wherein the at least one heat exchanger is disposed within the duct on the rear side of the cabinet such that the one or more headers remain at one lateral end of the rear side and the bend of the plurality of heat exchange tubes remains opposite to the headers.

**3**. The refrigerated display cabinet of claim **1**, wherein the at least one bend is a ribbon fold formed by bending and twisting the plurality of heat exchange tubes, wherein the at least one bend is formed about an axis extending substantially perpendicular to a longitudinal axis of the plurality of heat exchange tubes.

**4**. The refrigerated display cabinet of claim **1**, wherein the first section and the second section are substantially parallel with a predefined gap therebetween.

**5**. The refrigerated display cabinet of claim **4**, wherein a longitudinal axis of the first section and the second section is inclined at a first predefined angle with respect to a horizontal plane such that the one or more headers at one lateral end of the rear side remain at a different elevation than the at least one bend of the plurality of heat exchange tubes at an end opposite to the one or more headers.

**6**. The refrigerated display cabinet of claim **1**, wherein the first section and the second section are non-parallel to each other.

**7**. The refrigerated display cabinet of claim **6**, wherein a longitudinal axis of the first section is inclined at a first predefined angle with respect to a horizontal plane and a longitudinal axis of the second section is inclined at a second predefined angle with respect to the horizontal plane such that the one or more headers remain at different elevations at the same lateral end of the rear side of the cabinet and such that the one or more headers remain at different elevations than the at least one bend of the plurality of heat exchange tubes at an end opposite to the one or more headers.

**8**. The refrigerated display cabinet of claim **5**, wherein the first predefined angle or the second predefined angle is of at least 10° to 15° to the horizontal plane.

**9**. The refrigerated display cabinet of claim **1**, wherein the at least one heat exchanger comprises a first header and a second header, each disposed at a left end or a right end of a rear airflow zone of the cabinet, and extending longitudinally between a front end and a rear end of the rear airflow zone, wherein the plurality of heat exchange tubes with the bend fluidically connect the first header and the second header.

**10**. The refrigerated display cabinet of claim **1**, wherein the first header and the second header are oriented parallel to the horizontal plane, extending between a front end and a rear end of a rear airflow zone of the cabinet, wherein the second header remains at a predefined height above the first header and such that both the headers remain at different elevations than the bend of the plurality of heat exchange tubes at an end opposite to the headers.

**11**. The refrigerated display cabinet of claim **10**, wherein the first header and the second header are oriented at a third predefined angle from the horizontal plane, extending between a front end and a rear end of the rear airflow zone.

**12**. The refrigerated display cabinet of claim **1**, wherein the at least one heat exchanger comprises a plurality of fins extending between at least some of the plurality of heat exchange tubes, wherein the plurality of fins extending between at least some of the plurality of heat exchange tubes is louvered such that a louver airflow path is formed between the adjacent louvers.

**13**. The refrigerated display cabinet of claim **1**, wherein the cabinet comprises at least one fan positioned upstream or downstream of the at least one heat exchanger within the duct, wherein the at least one fan is configured to facilitate the inflow of air within the duct through the bottom front side of the cabinet, pass the received air through the at least one heat exchanger to cool the received air, and pump out the cool air from the top front side of the cabinet, and wherein the cool air pumped out by the top front side of the cabinet is received by the bottom front side of the cabinet such that an aerothermodynamic barrier or air curtain is formed in front of the one or more shelves or behind the doors of the cabinet.

**14**. The refrigerated display cabinet of claim **1**, wherein the heat exchanger is disposed within the rear airflow zone such that the at least one heat exchanger remains at least partially below a bottom-most shelf among the one or more shelves in order to discharge a portion of the cool through a perforated wall panel (PWP), configured with the duct in the rear airflow zone, to the conservation space below the bottom-most shelf and above a bottom airflow zone of the cabinet.

**15**. The refrigerated display cabinet of claim **1**, wherein the cabinet is any of an open-front type display cabinet, or a door-type display cabinet comprising one or more doors movably coupled to a front end of the case.

**16**. A heat exchanger for a refrigerated display cabinet, the heat exchanger comprising:

a first header and a second header disposed within a rear side of a duct associated with the cabinet such that both the first header and second header remain disposed at same lateral end of the rear side of the cabinet, wherein the duct extends from a bottom front side of the cabinet to a top front side of the cabinet via the rear side of the cabinet; and

a plurality of heat exchange tubes extending between the first header and the second header, the plurality of heat exchange tubes comprising a bend formed along a length of the heat exchange tubes to define a first section and a second section of the heat exchange tubes, wherein the at least one heat exchanger is configured within the duct such that the bend of the plurality of heat exchange tubes remains opposite to the first header and the second header.

**17**. The heat exchanger of claim **16**, wherein the bend is a ribbon fold formed by bending and twisting the plurality of heat exchange tubes, wherein the bend is formed about an axis extending substantially perpendicular to a longitudinal axis of the plurality of heat exchange tubes.

**18**. The heat exchanger of claim **16**, wherein a longitudinal axis of the first section and the second section is inclined at a first predefined angle with respect to a horizontal plane such that the one or more headers remain at different elevations at same lateral end of the rear side of the cabinet and such that the one or more headers remain at different elevations than the bend of the plurality of heat exchange tubes at an end opposite to the one or more headers.

**19**. The heat exchanger of claim **16**, wherein a longitudinal axis of the first section is inclined at a first predefined angle with respect to a horizontal plane and a longitudinal axis of the second section is inclined at a second predefined angle with respect to the horizontal plane such that the first and second headers remain at different elevations at same lateral end of the rear side of the cabinet and such that the one or more headers remain at different elevations than the bend of the plurality of heat exchange tubes at an end opposite to the one or more headers.

**20**. The heat exchanger of claim **16**, wherein the heat exchanger comprises a plurality of fins extending between at least some of the plurality of heat exchange tubes, wherein the plurality of fins extending between at least some of the plurality of heat exchange tubes is louvered such that a louver airflow path is formed between the adjacent louvers.

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