

**CONTROL SCHEME FOR BEVERAGE COOLERS OPTIMIZED FOR
BEVERAGE QUALITY AND FAST PULLDOWN TIME**

Related Applications

- 5 **[0001]** This application claims the benefit of provisional patent application serial number 63/220,360, filed July 9, 2021, the disclosure of which is hereby incorporated herein by reference in its entirety.

Field of the Disclosure

- 10 **[0002]** The present disclosure relates to systems and methods related to actively cooled containers.

Background

- 15 **[0003]** Current methods for refrigerated product storage in grocery, supply chain, delivery, and other perishable cold chain applications are: Phase-change material (i.e. “ice” packs: Paraffin, water-ice, glycol, Dry-ice, etc.). When items are added to the refrigerated space, the heat needs to be removed from these items. Improved systems and methods for cooled product storage are needed.

20 Summary

- 25 **[0004]** Systems and methods for an actively cooled container comprising: a power subsystem; an active cooling subsystem; and a control subsystem are provided. In some embodiments, the control subsystem is configured to: determine that additional cooling is needed; cause the active cooling subsystem to cool the actively cooled container below a lower limit; determine to end the additional cooling; and cause the active cooling subsystem to cool the actively cooled container at or above the lower limit. In this way, the best balance between a fast cooldown time and not damaging the product load (beverages), through freezing is achieved.
- 30 **[0005]** In some embodiments, determining that additional cooling is needed comprises determining that additional products have been added to the actively cooled container.

[0006] In some embodiments, causing the active cooling subsystem to cool the actively cooled container below the lower limit comprises causing the active cooling subsystem to cool the actively cooled container below zero Celsius.

[0007] In some embodiments, determining to end the additional cooling
5 comprises determining that a door open event has occurred.

[0008] In some embodiments, determining to end the additional cooling comprises determining that a time out event has occurred.

[0009] In some embodiments, the length of the time out event is such that products in the actively cooled container are not spoiled.

10 **[0010]** In some embodiments, the length of the time out event is such that products in the actively cooled container are not frozen.

[0011] In some embodiments, the length of the time out event is based on an ambient temperature of the actively cooled container.

15 **[0012]** In some embodiments, the length of the time out event is longer if the ambient temperature of the actively cooled container is lower.

[0013] In some embodiments, the active cooling subsystem comprises one or more Thermoelectric Coolers

[0014] A time-based (both real-time and elapsed time) control feedback scheme can be used to achieve the best balance between a fast cooldown time
20 and not damaging the product load (beverages), through freezing. To accomplish this, the control system operating mode will not immediately transition from Pull-down (highQ) to a variable capacity (VarQ) or high efficiency steady-state (HighCOP) mode, but will instead enter a temporary, intermediate high-capacity transition mode (referred to herein as LTSoak), that allows the
25 system to remain in a high-capacity mode at a temperature below the actual setpoint but at product temperatures within the allowable range of temperatures for the product. This mode operates for a sufficient time to allow for all of the loaded products to reach the desired temperature, while still protecting them from localized and/or global freezing. After the completion of the LTSoak mode, the
30 control system will revert back to standard mode transitions until LTSoak is triggered again.

[0015] Those skilled in the art will appreciate the scope of the present disclosure and realize additional aspects thereof after reading the following detailed description of the preferred embodiments in association with the accompanying drawing figures.

5

Brief Description of the Drawing Figures

[0016] The accompanying drawing figures incorporated in and forming a part of this specification illustrate several aspects of the disclosure, and together with the description serve to explain the principles of the disclosure.

10 **[0017]** Figure 1 illustrates an example of a refrigerator for storing beverages in which some embodiments can be employed;

[0018] Figure 2 illustrates an example of the operation of a cooling system according to some embodiments of the current disclosure.

15 Detailed Description

[0019] The embodiments set forth below represent the necessary information to enable those skilled in the art to practice the embodiments and illustrate the best mode of practicing the embodiments. Upon reading the following description in light of the accompanying drawing figures, those skilled in the art will understand the concepts of the disclosure and will recognize applications of these concepts not particularly addressed herein. It should be understood that these concepts and applications fall within the scope of the disclosure and the accompanying claims.

20 **[0020]** Beverages are often chilled to temperatures between 1-4 C, which can lead to the product freezing if the refrigeration system temperatures are not controlled properly. Beverage sellers will often also desire a fast cool-down time ensure the best product experience as well as to maximize profits. During normal operation, particularly during high capacity pull-down (HighQ), the control device (thermometer, thermistor, thermocouple, RTD, etc.) will be colder than the
30 average beverage temperature due to differences in thermal mass, and it will itself come to a steady-state temperature faster than the actual product being

cooled. This conflict typically leads to longer real-world cool-down times for the beverages to both protect the product and allow for thermostatic control. If a simple temperature offset is used to compensate for the temperature difference between the control sensor and product load, then the temperature of the beverages risks going below freezing both locally and in bulk, and potentially damaging the product and/or making it unsellable.

[0021] A time-based (both real-time and elapsed time) control feedback scheme can be used to achieve the best balance between a fast cooldown time and not damaging the product load (beverages) through freezing. To accomplish this, the control system operating mode will not immediately transition from Pull-down (highQ) to a variable capacity (VarQ) or high efficiency steady-state (HighCOP) mode. Instead, it will enter a temporary, intermediate, high-capacity transition mode (referred to herein as LTSoak), that allows the system to remain in a high-capacity mode at a temperature below the actual setpoint but at product temperatures within the allowable range of temperatures for the product. This mode operates for a sufficient time to allow for all of the loaded products to reach the desired temperature, while still protecting them from localized and/or global freezing. After the completion of the LTSoak mode, the control system will revert back to standard mode transitions until LTSoak is triggered again.

[0022] A cooler (e.g., for food or other perishable item storage) with active thermoelectric cooling (TEC) to maintain internal temperature within cold chain or customer requirements is disclosed herein. This cooler with active TEC cooling is also referred to herein as an “active cooler”. In some embodiments, the active cooler is used for storage and transportation of refrigerated and frozen food stuffs, medical or biological products, or the like. The active cooler maintains stable and uniform temperature control, powered via wall power, battery, or wireless power transmission.

[0023] Figure 1 illustrates an example of a refrigerator for storing beverages in which some embodiments can be employed. Depicted is one operating example of a control system leveraging LTSoak. The present disclosure relates to an insulated container that features an active cooling system i.e., (thermoelectric,

vapor-compression, Stirling, etc.) installed directly into the cooler in a removable or built-in module). Figure 1 illustrates an example insulated container with active refrigeration system, according to some embodiments of the current disclosure. Additional details can be found in International Patent Application serial number PCT/US2020/067172, filed December 28, 2020, the disclosure of which is hereby incorporated herein by reference in its entirety; and U.S. Patent Application Serial Number 17/135,420, filed on December 28, 2020, the disclosure of which is hereby incorporated herein by reference in its entirety. Both of these claim priority to Provisional Patent Application Serial Number 62/953,771, filed December 26, 2019.

[0024] In some embodiments, the control scheme includes one or more of the control schemes described in U.S. Patent Application Publication US 2013/0291555, U.S. Patent Application Publication US 2015/0075184, U.S. Patent No. 9,581,362, U.S. Patent No. 10,458,683, and U.S. Patent No. 9,593,871, which are incorporated herein by reference. In some embodiments, a thermal module includes a heat pump such as that described in U.S. Patent No. 9,144,180, which is incorporated herein by reference. For heat extraction (i.e., heat accept) and heat rejection, the thermal module may include, for example, a heat accept system (e.g., thermosiphons or other passive or active heat exchange component(s) for transferring heat from an interior of the active cooler to a cold side of the TEC/heat pump) and a heat reject system (e.g., thermosiphons or other active or passive heat exchange components for transferring heat from a hot side of the TEC/heat pump to the ambient environment).

[0025] Figure 2 illustrates an example of the operation of a cooling system according to some embodiments of the current disclosure. When the refrigeration cabinet has been loaded or reloaded with warm beverages and is in a high-capacity pulldown mode (HighQ), then the control system will no longer transition directly to a standard variable capacity (VarQ) or steady-state high efficiency, temperature seek (HighCOP), but instead, it will transition into a reduced temperature, high capacity soak (LTSoak) mode after reaching and then

passing the standard setpoint threshold for transition into VarQ or HighCOP mode. In some embodiments, if the ambient temp is very cold, this moves even faster. If ambient is lower, the system can stay in LTSoak longer. The heat pumping power, in LTSoak mode, may be kept constant as in HighQ mode or
5 may be varied as in VarQ mode to allow the control system to seek a target temperature sensor offset, below the actual setpoint. The duration of the LTSoak transition mode may be fixed or variable and may be determined by, among other things, a simple timeout, the ambient temperature and amount of beverage which was loaded in the unit or through analysis of the rate of temperature
10 change of the entire system.

[0026] Operating in the LTSoak mode instead of HighCOP or VarQ mode will allow the beverages within the refrigerator cabinet to continue to cool at a higher rate than they would otherwise be able to by continuing to operate the refrigeration system in a high-capacity heat removal mode for an extended period
15 instead of throttling the system in lower capacity modes. This will allow the remaining products not at the desired setpoint temperature when the control sensor reaches the target temperature to cool faster to the desired set point before switching the refrigeration system control mode to a variable capacity (VarQ) or high efficiency steady-state seek (HighCOP) mode, which provides
20 maximized efficiency and minimized energy consumption

[0027] Those skilled in the art will recognize improvements and modifications to the preferred embodiments of the present disclosure. All such improvements and modifications are considered within the scope of the concepts disclosed herein and the claims that follow.

Claims

What is claimed is:

1. An actively cooled container comprising:
5 a power subsystem;
an active cooling subsystem; and
a control subsystem;
wherein the control subsystem is configured to:
determine that additional cooling is needed;
10 in response, cause the active cooling subsystem to cool the actively
cooled container below a lower limit;
determine to end the additional cooling;
in response, cause the active cooling subsystem to cool the actively
cooled container at or above the lower limit.
15
2. The actively cooled container of claim 1 wherein being configured to
determine that the additional cooling is needed comprises being configured to
determine that additional products have been added to the actively cooled
container.
20
3. The actively cooled container of any of claims 1-2 wherein being
configured to cause the active cooling subsystem to cool the actively cooled
container below the lower limit comprises being configured to cause the active
cooling subsystem to cool the actively cooled container below zero Celsius.
25
4. The actively cooled container of any of claims 1-3 wherein being
configured to determine to end the additional cooling comprises being configured
to determine that a door open event has occurred.

5. The actively cooled container of any of claims 1-4 wherein being configured to determine to end the additional cooling comprises being configured to determine that a time out event has occurred.
- 5 6. The actively cooled container of any of claims 1-5 wherein the length of the time out event is such that products in the actively cooled container are not spoiled.
7. The actively cooled container of any of claims 1-6 wherein the length of
10 the time out event is such that products in the actively cooled container are not frozen.
8. The actively cooled container of any of claims 1-7 wherein the length of
15 the time out event is based on an ambient temperature of the actively cooled container.
9. The actively cooled container of claim 8 wherein the length of the time out event is longer if the ambient temperature of the actively cooled container is lower.
20
10. The actively cooled container of any of claims 1-9 wherein the active cooling subsystem comprises one or more Thermoelectric Coolers.
11. A method of controlling an actively cooled container comprising:
25 determining that additional cooling is needed;
in response, causing an active cooling subsystem to cool the actively cooled container below a lower limit;
determining to end the additional cooling;
in response, causing the active cooling subsystem to cool the actively
30 cooled container at or above the lower limit.

12. The method of claim 11 wherein determining that the additional cooling is needed comprises determining that additional products have been added to the actively cooled container.
- 5 13. The method of any of claims 11-12 wherein causing the active cooling subsystem to cool the actively cooled container below the lower limit comprises causing the active cooling subsystem to cool the actively cooled container below zero Celsius.
- 10 14. The method of any of claims 11-13 wherein determining to end the additional cooling comprises determining that a door open event has occurred.
- 15 15. The method of any of claims 11-14 wherein determining to end the additional cooling comprises determining that a time out event has occurred.
- 16 16. The method of any of claims 11-15 wherein the length of the time out event is such that products in the actively cooled container are not spoiled.
- 20 17. The method of any of claims 11-16 wherein the length of the time out event is such that products in the actively cooled container are not frozen.
- 25 18. The method of any of claims 11-17 wherein the length of the time out event is based on an ambient temperature of the actively cooled container.
- 30 19. The method of claim 18 wherein the length of the time out event is longer if the ambient temperature of the actively cooled container is lower.
20. The method of any of claims 11-19 wherein the active cooling subsystem comprises one or more Thermoelectric Coolers.