

CLAIMS

We claim:

1. A process for heating articles in a heating system, said process comprising:
 - (a) passing an article in a carrier through a heating chamber that is at least partially filled with a liquid medium to form a liquid bath;
 - (b) heating said article in said carrier, wherein said article is at least partially submerged in said liquid bath during said heating, and wherein at least a portion of said heating is performed using microwave energy; and
 - (c) one or more of adding fluid into and removing fluid from at least one location in said heating chamber to maintain a temperature profile across said heating chamber in which a temperature of said liquid bath at an inlet area of said heating chamber is at least 10°C cooler than a temperature of said liquid bath at an outlet area of said heating chamber.
2. The process of claim 1, wherein passing said article in said carrier through said heating chamber includes transporting said carrier including said article using a conveyance system.
3. The process of claim 1, wherein said adding of step (c) occurs simultaneously with at least a portion of said heating of step (b).
4. The process of claim 1, wherein the change in temperature per linear foot of said liquid bath remains substantially constant between said inlet area and said outlet area.
5. The process of claim 1, wherein the change in temperature per linear foot of said liquid bath is at least 0.50°C/ft.
6. The process of claim 1, wherein the temperature of said liquid bath at said inlet area of said heating chamber is at least 50°C.
7. The process of claim 1, wherein the temperature of said liquid bath at said outlet area of said heating chamber is at least 60°C.

8. The process of claim 1, wherein said heating of step (b) is sufficient to increase the temperature of a coldest portion of said article to a temperature at or above a target temperature, and wherein one or more of the temperature of said liquid bath at said inlet area and the temperature of said liquid bath at said outlet area is lower than said target temperature.

9. The process of claim 1, wherein said one or more of adding and removing liquid of step (c) includes discharging a portion of said liquid into said heating chamber and withdrawing a portion of said liquid from said heating chamber, respectively, via a nozzle located along a length of said heating chamber between the inlet area and said outlet area.

10. The process of claim 9, wherein said nozzle is one of plurality of nozzles distributed along said length of said heating chamber between said inlet and said outlet.

11. The process of claim 10, wherein said plurality of nozzles includes at least one nozzle pair, said nozzle pair including a first nozzle for discharging warmed fluid and a second nozzle for discharging cooled fluid into the heating chamber.

12. The process of claim 11, wherein said warmed fluid has a temperature of at least 35°C and wherein said cooled fluid has a temperature of not more than 35°C.

13. The process of claim 10, wherein said plurality of nozzles includes a nozzle pair including an inlet nozzle and an outlet nozzles for respectively discharging fluid into and removing fluid from a portion of said heating chamber.

14. The process of claim 9, wherein said one or more adding and removing of step (c) includes simultaneously discharging fluid into said heating chamber and removing fluid from said heating chamber.

15. The process of claim 14, wherein a ratio of volumetric flow rate of fluid discharged into said heating chamber to volumetric flow rate of fluid removed from said heating chamber near said inlet area is greater than a ratio of volumetric flow rate of fluid discharged into said heating chamber to volumetric flow rate of fluid removed from said heating chamber near said outlet area.

16. The process of claim 1 further comprising, prior to said one or more adding and removing of step (d)–

(i) measuring a fluid temperature selected from the group consisting of an inlet fluid temperature, an outlet fluid temperature, and a combination thereof to provide at least one measured temperature value;

(ii) comparing said at least one measured temperature value to a target value for said liquid temperature measured in step (i) to determine a difference; and

(iii) selectively adding or removing fluid from said heating chamber until said difference is lower than a maximum allowable difference.

17. The process of claim 16, wherein each of steps (i) through (iii) is performed automatically by a computerized control system.

18. The process of claim 1 further comprising prior to said passing of step (a), preheating said article in said carrier in a preheating chamber, wherein said preheating chamber is at least partially filled with another fluid to form a second liquid bath and said article is at least partially submerged in said second liquid bath during said preheating.

19. The process of claim 1 further comprising, subsequent to said heating of step (b), passing said article in said carrier through a holding zone, wherein a temperature of a coldest portion of said article is maintained at or above a target temperature for a period of time in said holding zone.

20. The process of claim 19, wherein said heating of step (c) and said holding are sufficient to at least one of pasteurize and sterilize said article.

21. The process of claim 1, wherein said article comprises packaged foodstuffs or a beverage.

22. The process of claim 1, wherein said heating system has an average production rate of at least 20 packages per minute equivalent.

23. A heating system for heating, said heating system comprising:
a heating chamber for heating articles using microwave energy, wherein said heating chamber is configured to be at least partially filled with a fluid forming a liquid bath; and
a fluid distribution and temperature control system comprising:
at least one heat transfer device for one or more of heating and cooling said fluid;
and
a plurality of nozzles for one or more of discharging fluid into said heating chamber and removing fluid from said heating chamber,
wherein said nozzles are in fluid flow communication with said at least one heat transfer device, and said nozzles are spaced apart from one another along a length of said heating chamber.

24. The heating system of claim 23, wherein said fluid distribution system is configured to maintain a temperature profile along said heating chamber in which a temperature of said liquid bath at an outlet area of said heating chamber is at least 10°C higher than a temperature of said liquid bath at an inlet area of said heating chamber and a change in temperature per linear foot of said liquid bath through said heating chamber remains substantially constant between said inlet area and said outlet area.

25. The heating system of claim 24 further comprising, an automatic control system for selectively regulating a flow of fluid of said plurality of nozzles and said at least one heat transfer device to maintain said temperature profile along said heating chamber.

26. The heating system of claim 23 further comprising a carrier configured to hold said articles.

27. The heating system of claim 26 further comprising a convey line for transporting said carrier in a convey direction.

28. The heating system of claim 23 further comprising a microwave generator for generating said microwave energy and a microwave distribution system for directing said microwave energy from said generator into said heating chamber, wherein said microwave distribution system includes at least one pair of microwave launchers for discharging microwave energy into said heating chamber.

29. The heating system of claim 28, wherein said pair of launchers is disposed on an upper side of said heating chamber.

30. The heating system of claim 28, wherein said pair of microwave launchers includes an upper microwave launcher and a lower microwave launcher, the upper microwave launcher and the lower microwave launcher positioned on opposite sides of said heating chamber.

31. The heating system of claim 23, wherein said plurality of nozzles includes at least two pairs of nozzles spaced apart from one another along the length of said heating chamber, wherein each of said pairs of nozzles includes one discharge nozzle for adding fluid to said heating chamber and one withdraw nozzle for removing fluid from said heating chamber.

32. The heating system of claim 23, wherein the plurality of nozzles includes adjacent pairs of nozzles, the system further comprising a divider disposed between said adjacent pairs of nozzles.

33. The heating system of claim 23, wherein said fluid distribution system comprises a first heat transfer device to provide heated fluid to a first nozzle of said plurality of nozzles and a second heat transfer device to provide cooled fluid to a second nozzle of said plurality of nozzles, said first nozzle and said second nozzle being disposed adjacent to each other along a length of said heating chamber.

34. The heating system of claim 23, wherein said plurality of nozzles includes at least two pairs of nozzles positioned on opposite sides of said heating chamber.

35. The heating system of claim 23 further comprising a preheating chamber located prior to said heating chamber for preheating said articles to a preheat temperature.

37. The heating system of claim 23 further comprising a holding chamber located after said heating chamber for maintaining said articles at a hold temperature such that a coldest portion of each of said articles is at or above a target temperature for a hold time.

38. The heating system of claim 23, wherein said heating system is at least one of a pasteurization or sterilization system.

39. The heating system of claim 23, wherein said heating system has an average production rate of at least 20 packages per minute equivalent.

40. A process for heating articles comprising:

(a) sequentially passing a plurality of loaded carriers in a continuous manner through a first processing section;

(b) sequentially passing said plurality of loaded carriers in an incremental manner through a second processing section using an incremental convey segment, wherein said incremental convey segment comprises a plurality of sequential carrier-receiving slots, each carrier-receiving slot configured to receive one of said loaded carriers, and said incremental convey segment configured to be moved incrementally at multiples of discrete intervals corresponding to said carrier-receiving slots;

(c) sequentially passing said plurality of loaded carriers in a continuous manner through a third processing section; and

(d) heating articles supported by said carriers with microwave energy in at least one of said first, second, and third processing sections, the heating of said articles occurring while said articles are submerged in a liquid bath and at a pressure greater than atmospheric pressure.

41. The process of claim 40 further comprising controlling an average residence time of said loaded carriers in said second processing section relative to an average residence time of said loaded carriers in at least one of said first processing section or said third processing section by varying a movement speed of said incremental convey segment during at least a portion of the incremental movement of said second convey segment.

42. The process of claim 41, wherein said sequential passing of step (b) includes sequentially loading each of said loaded carriers into a respective one of said carrier-receiving slots and said controlling of said average residence times causes at least some of said slots to be skipped during said loading.

43. The process of claim 40, wherein said articles are passed through each of said first, second, and third processing zones at an equivalent respective rate.

44. The process of claim 40, wherein said incremental convey segment transports said loaded carrier in a substantially vertical manner.

45. The process of claim 44, wherein said loaded carriers pass through said first and third processing sections in a substantially horizontal manner.

46. The process of claim 40, wherein said first processing section is a heating section, said heating of step (d) occurs in the first processing section, said second processing section is a hold section, and said third processing section is a high-pressure cooling section.

47. A process for heating articles in a heating system, said process comprising:

(a) passing a first carrier loaded with an article through a first processing section using a first convey segment, said first loaded carrier having a first residence time in said first processing section of τ_1 ;

(b) transferring said first loaded carrier from said first convey segment to a vertical convey segment, wherein said transferring includes loading said first loaded carrier into a carrier slot of said vertical convey segment;

(c) passing said loaded carrier through a second processing section using said vertical convey segment, wherein said passing includes incrementally actuating said vertical convey segment to move said first loaded carrier vertically, said first loaded carrier having a residence time in said second processing section of τ_2 ;

(d) transferring said first loaded carrier from said vertical convey segment to a third convey segment, wherein said transferring includes removing said first loaded carrier from said carrier slot of said vertical convey segment; and

(e) transporting a second loaded carrier through said first and said second processing sections by repeating steps (a) through (d) with said second loaded carrier.

48. The process of claim 47 further comprising, during said transporting of step (e), adjusting a ratio of τ_2 to τ_1 by periodically skipping one or more carrier slots of said vertical convey segment when loading said second loaded carrier into said vertical convey segment.

49. The process of claim 48, wherein said adjusting includes decreasing τ_2 by skipping more carrier slots when loading said second loaded carrier into said vertical convey segment than were skipped during said loading of step (b).

50. The process of claim 48, wherein said adjusting includes increasing τ_2 by skipping fewer carrier slots when loading said another loaded carrier into said vertical convey segment than were skipped during said loading of step (b).

51. The process of claim 48, wherein said adjusting includes either –

(i) skipping more carrier slots when loading said second loaded carrier into said vertical convey segment than were skipped during said loading of step (b), and wherein the ratio of τ_2 to τ_1 of said second loaded carrier is at least 5 percent less than the ratio τ_2 to τ_1 of said first loaded carrier; or

(ii) skipping fewer carrier slots when loading said second loaded carrier into said vertical convey segment than were skipped during said loading of step (b), and wherein the ratio of τ_2 to τ_1 of said second loaded carrier is at least 5 percent more than the ratio τ_2 to τ_1 of said first loaded carrier.

52. The process of claim 47, wherein said vertical convey segment is a first vertical convey segment, the process further comprising subsequent to step (d), passing said first loaded carrier through a third processing section using said third convey segment, wherein:

said third convey segment comprises a second vertical convey segment,

said transferring of step (d) includes introducing said loaded carrier into a second carrier slot of said second vertical convey segment,

said first vertical convey segment moves said first loaded carrier upwardly through said second processing section, and

said second vertical convey segment moves said first loaded carrier downwardly through said third processing section.

53. The process of claim 47, wherein said second processing section is at least partially filled with a first fluid and said third processing section is at least partially filled with a second fluid medium, said first fluid having an average temperature at least 50°C higher than said second fluid.

54. The process of claim 47, wherein said first processing section is a microwave heating section, said second processing section is a hold section, and said third processing section is a high-pressure cooling section.

55. The process of claim 47, wherein a ratio of τ_2 to τ_1 for said first loaded carrier is at least 5 percent different than a ratio τ_2 to τ_1 for said first loaded carrier.

56. The process of claim 47, wherein said first processing section is a microwave heating section and said second processing section is a hold zone.

57. A heating system for heating a plurality of articles, said system comprising:
a heating chamber for heating an article in a carrier using microwave energy;
a cooling chamber for cooling said article in said carrier; and
a holding chamber disposed between said heating chamber and said cooling chamber,
wherein said heating chamber adapted to be at least partially filled with a heating chamber fluid medium and said cooling chamber is adapted to be at least partially filled with a cooling chamber fluid medium.

58. The heating system of claim 57, wherein said holding chamber and at least a portion of said cooling chamber are separated by a carrier transfer chamber configured to permit said carrier to pass between said holding chamber and said cooling chamber, and said transfer chamber is configured to be filled with a transfer chamber fluid medium different than said heating chamber fluid medium and said holding chamber fluid medium.

59. The heating system of claim 57, wherein said holding chamber and said cooling chamber are thermally isolated from one another such that said holding chamber fluid medium in has a temperature at least 20°C higher than a temperature of said cooling chamber fluid medium.

60. The heating system of claim 57, wherein:
said holding chamber includes a first vertical convey segment for moving said carrier through said holding chamber,
said cooling chamber includes a second vertical convey segment for moving said carrier through said cooling chamber, and
said carrier transfer chamber includes a horizontal convey segment for transferring one of said carrier from said holding chamber to said cooling chamber.

61. The heating system of claim 57, wherein each of said holding chamber and said cooling chamber are configured to be pressurized to a pressure of at least 5 psig.

62. The heating system of claim 57 further comprising a preheating chamber prior to said heating chamber, wherein said preheating chamber is configured to be at least partially filled with a preheat chamber fluid medium.

63. The heating system of claim 57, wherein said heating system is at least one of a pasteurization or sterilization system.

64. The heating system of claim 57, wherein said heating system has an average production rate of at least 20 packages per minute equivalent.

65. A heating system for heating articles, said system comprising:
a heating chamber for heating using microwave energy, wherein said heating chamber is configured to be at least partially filled with fluid medium; and
a conveyor system for transporting a carrier holding an article in a convey direction through said heating chamber,
wherein said conveyor system includes at least two spaced apart convey segments disposed within said heating chamber, and wherein said convey segments are spaced apart from one another in said convey direction.

66. The heating system of claim 65, wherein said heating chamber has an internal volume divided into a plurality of temperature zones by baffles extending into the internal volume.

67. The heating system of claim 65, wherein each of the at least two spaced apart convey segments are disposed within a respective temperature zone.

68. The heating system of claim 65, wherein said convey segments are spaced apart from one another by a distance that is less than the length of said carrier.

69. The heating system of claim 65, wherein said heating chamber has an inlet and an outlet, and wherein the overall length of said microwave chamber from its inlet to its outlet is greater than the sum of the lengths of each of said convey segments.

70. The heating system of claim 65, wherein a ratio of a length of the longest convey segment to a length of said heating chamber is not more than about 0.90:1.

71. The heating system of claim 65, wherein said conveyor system includes at least two drivers each driver for independently driving a respective convey segment of said convey segments.

72. The heating system of claim 71, wherein each of said drivers is positioned outside of said heating chamber.

73. The heating system of claim 71, wherein said conveyor system further comprises a synchronization system for coordinating the operation of said drivers.

74. The heating system of claim 65, wherein said heating chamber comprises a plurality of modular chamber units, each modular chamber unit comprising an inlet, an outlet, one of said convey segments disposed within said modular chamber unit, and at least one microwave launcher configured to discharge microwave energy into said modular chamber unit.

75. The heating system of claim 74, wherein said microwave launcher is a first microwave launcher and said modular chamber unit further comprises at least one second microwave launcher configured to discharge microwave energy into said modular chamber unit.

76. The heating system of claim 75, wherein said first microwave launcher and said second microwave launcher are disposed on opposite sides of said modular chamber unit.

77. The heating system of claim 76, wherein said first microwave launcher and said second microwave launcher are disposed opposite from each other.

78. The heating system of claim 74, wherein the plurality of modular chamber units comprises at least three modular chamber units.

79. The heating system of claim 74, wherein the distance between said inlet and said outlet of said modular chamber unit is greater than the length of said convey segment.

80. The heating system of claim 74, wherein each of said modular chamber units is selectively removable from said heating system.

81. The heating system of claim 65, wherein said heating chamber is adapted to be pressurized.

82. The heating system of claim 65 further comprising a thermalization chamber for preheating said article to a thermalization temperature and wherein said thermalization chamber is positioned upstream of said heating chamber and is configured to be at least partially filled with liquid medium.

83. The heating system of claim 65 further comprising a holding chamber for maintaining a temperature of said article at or above a minimum target temperature for a minimum period of time, and wherein said holding chamber is positioned downstream of said heating chamber and is configured to be at least partially filled with second fluid medium.

84. The heating system of claim 65 further comprising a cooling chamber for cooling said article, wherein said cooling chamber is positioned downstream of said heating chamber and is configured to be at least partially filled with second fluid medium.

85. The heating system of claim 65, wherein said heating system is at least one of a pasteurization or sterilization system.

86. The heating system of claim 65, wherein said heating system has an average production rate of at least 20 packages per minute equivalent.

87. A process for heating articles in a heating system, said process comprising:

- (a) introducing a carrier supporting an article into a heating chamber, wherein said article is at least partially submerged in a liquid bath in said heating chamber;
 - (b) passing said carrier by a first microwave launcher of a plurality of microwave launchers along a first convey segment in a convey direction;
 - (c) during at least a portion of said passing of step (b), discharging microwave energy from said first microwave launcher toward said article in said carrier;
 - (d) passing said carrier by a second microwave launcher of said plurality of microwave launchers along a second convey segment in said convey direction; and
 - (e) during at least a portion of said passing of step (d), discharging microwave energy from said second microwave launcher toward said article in said carrier,
- wherein said first convey segment and said second convey segments are spaced apart from one another in said convey direction.

88. The process of claim 87, wherein said first convey segment is driven by a first driver and said second convey segment is driven by a second driver independently operable from said first driver.

89. The process of claim 88, wherein each of said first and second drivers is located outside of said heating chamber.

90. The process of claim 87, wherein the carrier has a carrier length and said first convey segment and said second convey segment are spaced apart from one another by a distance that is less than the carrier length.

91. The process of claim 87, wherein said heating chamber and each of said convey segments has a respective length, the length of the heating chamber being greater than the sum of the lengths of the convey segments.

92. The process of claim 87 further comprising passing said carrier by a third microwave launcher of said plurality of microwave launchers and, during at least a portion of said passing by said third microwave launcher, discharging microwave energy from said third microwave launcher toward said article in said carrier.

93. The process of claim 92, wherein:

said third microwave launcher and at least one of said first microwave launcher and said second microwave launcher are positioned on a same side of said heating chamber,

said passing by said third microwave launcher comprises moving said carrier along a third convey segment in said convey direction, and

said third convey segment is spaced apart from said second convey segment in said convey direction.

94. The process of claim 92, wherein said third microwave launcher is positioned on a

first side of the heating chamber opposite a second side of said heating chamber including at least one of said first microwave launcher and said second microwave launchers.

95. The process of claim 87, wherein:

the heating chamber comprises a plurality of heating chamber modules,

said first convey segment is disposed within a first heating chamber module of said plurality of heating chamber modules, and

said second convey segment is disposed within a second heating chamber module of said plurality of heating chamber modules.

96. The process of claim 95, wherein each of said first and said second microwave

chamber modules further comprise respective microwave launchers of said plurality of microwave launchers.

97. The process of claim 96, wherein each of said first and said second microwave

chamber modules further comprise two or more microwave launchers of said plurality of microwave launchers.

98. The process of claim 87, wherein said heating chamber is pressurized to a

pressure of at least 5 psig during said passing of steps (b) and (d).

99. The process of claim 87, wherein said article comprises packaged foodstuffs.

100. The process of claim 87 further comprising, subsequent to said step (e), passing said carrier through a holding zone to maintain the temperature of a coldest portion of said article at or above a minimum temperature for a hold time.

101. The process of claim 87 further comprising, prior to said introducing of step (a), passing said carrier through a thermalization zone.

102. The process of claim 87, wherein said heating system has an average production rate of at least 15 packages per minute equivalent.

103. A heating system for heating articles, said heating system comprising:
a preheating section for heating an article;
a cooling section for cooling said article; and
a heating section for heating said article using microwave energy, wherein said heating section is disposed between said preheating section and said cooling section and comprises a plurality of heating chamber modules, each of said heating chamber modules comprising:
a vessel segment having an inlet and an outlet;
at least one microwave launcher configured to discharge microwave energy into said vessel segment;
a convey segment disposed within said vessel segment for transporting said article in a convey direction; and
a conveyor driver for driving said convey segment,
wherein said chamber modules are configured to be selectively coupled to and uncoupled from one another.

104. The heating system of claim 103, wherein said convey segment has a first length and said vessel segment has a second length, said first length being less than said second length.

105. The heating system of claim 103, wherein each of said microwave chamber modules comprises a respective pair of microwave launchers.

106. The heating system of claim 105, wherein said pair of microwave launchers includes a first microwave launcher and a second microwave launcher oppositely-facing said first microwave launcher.

107. The heating system of claim 105, wherein each microwave launcher of said pair is oriented at a launch tilt angle of at least 2° and not more than 15° measured from a plane normal to said convey direction.

108. The heating system of claim 103, wherein said heating section comprises a first heating chamber module of said plurality of heating chamber and a second heating chamber module of said plurality of heating chamber modules, the inlet of said second heating chamber module being configured to be selectively coupled to the outlet of said first heating chamber module.

109. The heating system of claim 108, wherein the convey segment of said first heating chamber module and the convey segment of said second heating chamber module are spaced apart from one another when the inlet of said first heating chamber module is coupled to the outlet of said second heating chamber module.

110. The heating system of claim 108, wherein:

the convey driver of said first heating chamber module is disposed outside the vessel segment of said first heating chamber module;

the convey driver of said second heating chamber module is disposed outside the vessel segment of said second heating chamber module; and

the convey driver of said first heating chamber module and the convey driver of said second heating chamber module are independently operable.

111. The heating system of claim 103, wherein each of said preheating section, said cooling section, and said heating section are configured to be at least partially filled with fluid medium.

112. The heating system of claim 103, wherein each of said preheating section, said cooling section, and said heating section are configured to be pressurized.

113. The heating system of claim 103 further comprising a holding section disposed between said heating section and said cooling section, said holding section for maintaining said article at or above a minimum hold temperature for a hold time.

114. The heating system of claim 103, wherein said heating system is at least one of a pasteurization or sterilization system.

115. A process for heating articles in a heating system, said process comprising:

- (a) passing a carrier loaded with an article through a vessel inlet and into a first vessel portion;
- (b) moving the loaded carrier in a first direction through said first vessel portion away from said inlet;
- (c) during at least a portion of said moving of step (b), contacting at least a portion of said articles in said loaded carrier with a first fluid medium;
- (d) moving the loaded carrier in a second direction opposite the first direction through a second vessel portion toward a vessel outlet; and
- (e) during at least a portion of said moving of step (d), contacting at least a portion of said articles in said loaded carrier with a second fluid medium.

116. The process of claim 115 further comprising transferring the loaded carrier to said second vessel portion, wherein said second vessel portion is at least partially fluidly isolated from said first vessel portion.

117. The process of claim 115 further comprising removing said loaded carrier from said second vessel portion via said vessel outlet.

118. The process of claim 115, wherein said first direction and said second direction are vertical.

119. The process of claim 118, wherein said first direction is vertically upward and said second direction is vertically downward.

120. The process of claim 115, wherein said first vessel portion and said second vessel portion are chambers of a split-chamber vessel.

121. The process of claim 115, wherein said contacting of step (c) includes discharging at least a portion of said first fluid medium from a plurality of spray nozzles as a fluid spray, and said article is contacted with said fluid spray during said moving of step (b).

122. The process of claim 121, wherein said first vessel portion is at least partially filled with said first fluid medium forming a liquid bath, and wherein said contacting of step (c) includes at least partially submerging said article in said liquid bath during said moving of step (b).

123. The process of claim 121, wherein at least one of said first vessel portion is not filled with said first fluid medium and said second vessel portion is not filled with said second fluid medium.

124. The process of claim 115, wherein said contacting of step (e) includes discharging at least a portion of said second fluid medium from a plurality of spray nozzles as a fluid spray, wherein said articles are contacted with said fluid spray during said moving of step (d).

125. The process of claim 124, wherein said second vessel portion is at least partially filled said second fluid medium to form a liquid bath, and wherein said contacting of step (e) includes at least partially submerging said article in said second liquid during said moving of step (d).

126. The process of claim 115, wherein said first fluid medium has a first temperature and said second fluid medium has a second temperature, said first temperature and said second temperature being within about 10°C of each other.

127. The process of claim 126, wherein said first temperature and said second temperature are each at least about 35°C.

128. The process of claim 126, wherein said first temperature and said second temperature are each not more than about 45°C.

129. The process of claim 115, wherein said first fluid medium has a first temperature and said second fluid medium has a second temperature, said first temperature being at least 30°C higher than said second temperature.

130. The process of claim 129, wherein said first temperature is at least 75°C.

131. The process of claim 129, wherein said second temperature is not more than 40°C.

132. The process of claim 115, wherein at least one of said first vessel portion and said second vessel portion is pressurized to at least 5 psig.

133. The process of claim 115, wherein at least one of said first vessel portion and said second vessel portion has a pressure of not more than 5 psig.

134. The process of claim 115 further comprising, loading a second article into a second carrier, and, subsequent to said passing of step (a), passing the second loaded carrier through said inlet and into said first vessel portion.

135. The process of claim 134, wherein:

at least a portion of said moving of step (b) includes simultaneously moving the loaded carrier and the second loaded carrier upwardly through said first vessel portion, and

at least a portion of said moving of step (d) includes simultaneously moving the loaded carrier and the second loaded carrier downwardly through said second vessel portion.

136. The process of claim 135 further comprising transferring the loaded carrier and the second loaded carrier one-by-one from said first vessel portion to said second vessel portion.

137. The process of claim 135 further comprising:

removing said loaded carrier from said second vessel portion via said vessel outlet; and

subsequent to removing said loaded carrier, removing said second loaded from said second vessel portion via said vessel outlet.

138. The process of claim 115 further comprising transferring the loaded carrier to said second vessel portion, wherein the loaded carrier is not contacted with said first fluid medium or said second fluid medium during said transferring.

139. The process of claim 115 further comprising removing the loaded carrier from the second vessel portion via said vessel outlet and simultaneously introducing a second loaded carrier into said first vessel portion via said vessel inlet.

140. The process of claim 115, wherein:

said contacting of step (c) includes discharging at least a portion of said first fluid medium from a plurality of spray nozzles as a fluid spray and contacting said article with at least a portion of said fluid spray,

said second vessel portion is at least partially filled with said second fluid medium to form a liquid bath, said contacting of step (e) includes submerging said article in said liquid bath, and

said first fluid medium has a first temperature and said second fluid has a second temperature, each of said first temperature and said second temperature being at least 40°C.

141. The process of claim 115, wherein:

said contacting of step (c) includes submerging said articles in a liquid bath of said first fluid,

said contacting of said step (e) includes discharging at least a portion of said second fluid from a plurality of spray nozzles as a fluid spray and contacting said article with at least a portion of said fluid spray, and

said first fluid has a first temperature and said second fluid medium has a second temperature, each of said first temperature and said second temperature being at least 40°C.

142. The process of claim 115, wherein:

said contacting of step (c) includes submerging said article in a first liquid bath of said first fluid medium,

said contacting of step (e) includes submerging said article in a second liquid bath of said second fluid medium, and

the first liquid bath has a first temperature and the second liquid bath has a second temperature, the first temperature being at least 20°C higher than said second temperature.

143. The process of claim 142, wherein said first temperature is at least 60°C and said second temperature not more than 40°C.

144. The process of claim 115, wherein a coldest portion of said article has a temperature of at least 60°C when passed into said first vessel portion.

145. The process of claim 115, wherein a coldest portion of said article has a temperature of not more than 35°C when passed into said first vessel portion.

146. The process of claim 115 further comprising, passing the loaded carrier along a convey line through a heating chamber and discharging microwave energy into said heating chamber during said passing, wherein at least a portion of the microwave energy is used to heat the article, and wherein said article is at least partially submerged in a liquid bath during said passing along said convey line.

147. The process of claim 146, wherein the loaded carrier is passed through said heating section prior to said passing of step (a).

148. The process of claim 146, wherein the loaded carrier is passed through said heating section subsequent to removing said carrier from said second vessel portion.

149. The process of claim 115, wherein said heating system is a pasteurization or sterilization system.

150. The process of claim 115, wherein said article comprises packaged foodstuffs.

151. A heating system comprising:

a heating chamber configured to heat articles using microwave energy, wherein said heating chamber comprises a chamber adapted to be at least partially filled with a fluid medium;

a conveyor for transporting carriers holding said articles through said heating chamber in a convey direction; and

a vessel comprising:

an inlet side and an outlet side, said inlet side and said outlet side being at least partially fluidly isolated from one another,

a carrier inlet configured to receive one of said carriers into said inlet side;
a carrier outlet configured to discharge one of said carriers out of said outlet side;
a first convey segment located in said inlet side configured to move said carriers vertically away from said carrier inlet; and
a second convey segment located in said outlet side configured to move said carriers vertically toward said carrier outlet.

152. The heating system of claim 151, wherein said vessel is a split-chamber vessel, said inlet side comprises a first chamber of said split-chamber vessel, and said outlet side comprises a second chamber of said split-chamber vessel.

153. The heating system of claim 151, wherein said first convey segment moves said carriers vertically upward and said second convey segment moves said carriers vertically downward.

154. The system of claim 151, wherein:
said first convey segment comprises two pairs of support members spaced apart from one another in a direction parallel to said convey direction,
said support members define a carrier receiving space therebetween, wherein each support member includes a plurality of carrier support members, and
said carrier support members are arranged in an engaged configuration when said carrier support members are located within said carrier receiving space and are arranged in a disengaged configuration when said carrier support members are not located in said carrier receiving space.

155. The system of claim 151, wherein said vessel comprises at least one removable side panel.

156. The system of claim 151, wherein said vessel is configured to be pressurized.

157. The system of claim 151, wherein said vessel is an atmospheric vessel.

158. The system of claim 151 further comprising a plurality of spray nozzles configured to discharge fluid medium toward said carriers in at least one of said inlet side and said outlet side.

159. The system of claim 158, wherein said plurality of spray nozzles comprises a first set of spray nozzles configured to discharge streams of fluid medium toward said carriers in said inlet side and a second set of spray nozzles configured to discharge streams of fluid medium toward said carriers in said outlet side.

160. The system of claim 151, wherein the vessel is a first vessel, the system further comprising a second vessel comprising:

- a second inlet side and a second outlet side, said second inlet side and said second outlet side being at least partially fluidly isolated from one another;

- a second carrier inlet configured to receive one of said carriers at a time into said second inlet side;

- a second carrier outlet configured to discharge one of said carriers at a time out of said second outlet side;

- a third convey segment located in said second inlet side configured to move said carriers away from said second carrier inlet; and

- a fourth convey segment located in said second outlet side configured to move said carriers toward said second carrier outlet.

161. The system of claim 160, wherein said first vessel is located upstream of said heating chamber and said second vessel is located downstream of said heating chamber.

162. The system of claim 161 further comprising a pressure adjustment zone disposed between said heating section and said second vessel.

163. The system of claim 162 further comprising a third vessel comprising:

- a third inlet side and a third outlet side, wherein said third inlet side and said third outlet side are at least partially fluidly isolated from one another;

- a third carrier inlet configured to receive one of said carriers at a time into said third inlet side;

a third carrier outlet configured to discharge one of said carriers at a time out of said third outlet side,

a fifth convey segment located in said third inlet side configured to move said carriers away from said third carrier inlet; and

a sixth convey segment located in said third outlet side and to move said carriers toward said third carrier outlet.

164. The system of claim 163 further comprising a low-pressure cooling chamber for cooling said articles in said carriers, said third vessel positioned between said heating section and said low-pressure cooling chamber.

165. The system of claim 151, wherein said heating chamber is positioned upstream of said vessel.

166. The system of claim 151, wherein said heating chamber is positioned downstream of said vessel.

167. The system of claim 151 further comprising a pressure adjustment zone positioned between said heating chamber and said vessel.

168. The system of claim 151, wherein said vessel comprises a transfer section positioned between said inlet side and said outlet side, the transfer section configured to permit the transfer of one of said carriers at a time from said inlet side to said outlet side.

169. The system of claim 168, wherein said transfer section comprises at least one horizontal convey segment for moving one of said carriers from said inlet side to said outlet side.

170. A process for heating articles in a heating system, said process comprising:

- (a) preheating an article in a carrier in a preheat section;
- (b) after said preheating, heating the article in said carrier in a heating section, wherein at least a portion of said heating is performed using microwave energy;
- (c) passing said article in said carrier through a holding section, wherein a coldest temperature of said article is maintained at or above a hold temperature for a hold time in said holding section; and

(d) cooling said article in said carrier in a cooling section, wherein at least a portion of one or more of said preheating, said passing, and said cooling are performed by moving said carrier at least one of upwardly and downwardly using at least one convey segment, and wherein said article is contacted by at least one fluid medium during said moving.

171. The process of claim 170, wherein said at least one convey segment is a vertical convey segment.

172. The process of claim 170, wherein said holding of step (c) is performed by moving said carrier through a first side of a vessel and contacting said article with warmed fluid medium and at least a portion of said cooling of step (d) is performed by moving said carrier through a second side of said vessel and contacting said article with cooled fluid medium.

173. The process of claim 172, wherein said vessel is pressurized during said holding of step (c) and during at least a portion of said cooling of step (d) to greater than 5 psig.

174. The process of claim 172, wherein said warmed fluid medium has a first temperature and said cooled fluid medium has a second temperature, said first temperature at least 20°C higher than said second temperature.

175. The process of claim 170, wherein said carrier is transferred from said first side to said second side of said vessel one at a time.

176. The process of claim 170, wherein said preheating of step (a) is performed by moving said carrier vertically using one or more vertical convey segments disposed within a vessel.

177. The process of claim 176, wherein said vessel during said preheating of step (a) has a pressure of less than 5 psig.

178. The process of claim 176, wherein:
said preheating of step (a) is performed by moving said carrier upwardly in a first side of said vessel and downwardly in a second side of said vessel,

said article is contacted with a fluid spray comprising said at least one fluid medium in said first side; and

said article is submerged in a liquid bath comprising said at least one fluid medium in said second side.

179. The process of claim 170, wherein at least a portion of said cooling of step (d) is performed by moving said carrier vertically using one or more vertical convey segments disposed within a vessel.

180. The process of claim 179, wherein said vessel has a pressure of less than 5 psig during said at least a portion of said cooling of step (d).

181. The process of claim 179, wherein said at least one fluid medium has a temperature of not more than 35°C.

182. The process of claim 179, wherein:

said at least a portion of said cooling of step (d) is performed by moving said carrier upwardly in a first side of said vessel and downwardly in a second side of said vessel,

said article is submerged in a liquid bath comprising a first fluid medium in said first side, and

said article is contacted with a fluid spray comprising a second fluid medium in said second side.

183. The process of claim 170, wherein said article is contacted by pressurized jets of said fluid medium during said moving of said carrier.

184. The process of claim 170, wherein said article is at least partially submerged in a liquid bath of said fluid medium during said moving of said carrier.

185. The process of claim 170, wherein said fluid medium has a temperature of at least 35°C.

186. The process of claim 170, wherein said fluid medium has a temperature of not more than 35°C.

187. The process of claim 170, wherein said article comprises packaged foodstuffs.

188. The process of claim 170, wherein said heating of step (b) is performed while said article is at least partially submerged in a liquid bath of a second fluid medium.

189. The process of claim 170, wherein said heating of step (b) is sufficient to at least one of pasteurize or sterilize said article.

190. The process of claim 170, wherein said heating system has an average product rate of at least 20 packages per minute equivalent.