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(54) EVAPORATOR WITH INTEGRATED HEATING ELEMENT

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(57) **ABSTRACT**

An evaporator coil includes a conduit having an interior passageway that provides a pathway for a flow of refrigerant. An outer wall of the conduit forms a channel having a longitudinal opening. The channel extends lengthwise adjacent to the interior passageway. The channel contains an electrical heating element that is in thermal contact with the conduit. The electrical heating element periodically provides heat to defrost the evaporator coil during an evaporator defrost cycle. The electrical heating element may be coupled directly to the channel or be housed within a second conduit that is at least partially contained within the channel.

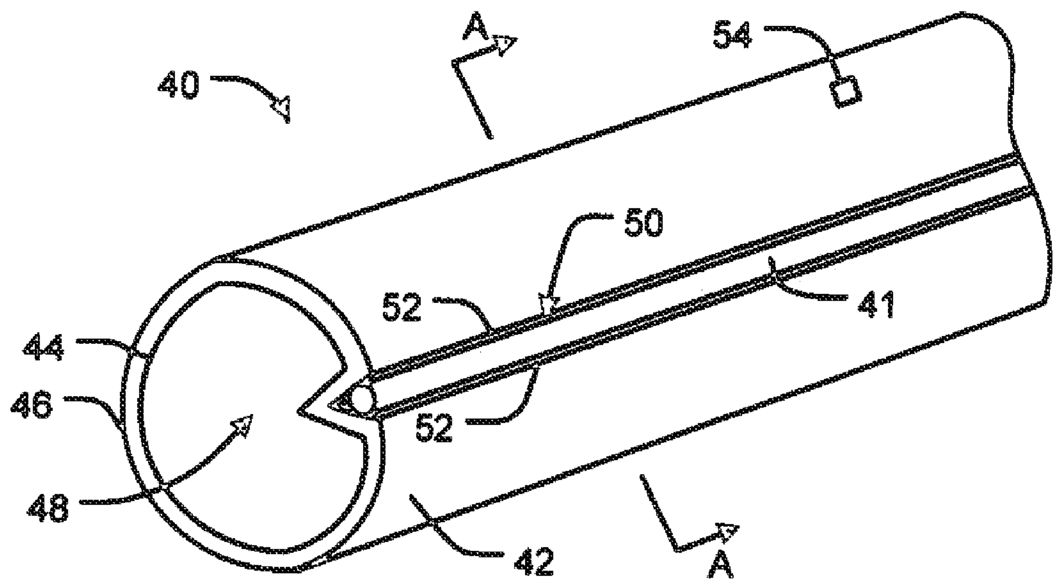


FIG. 1

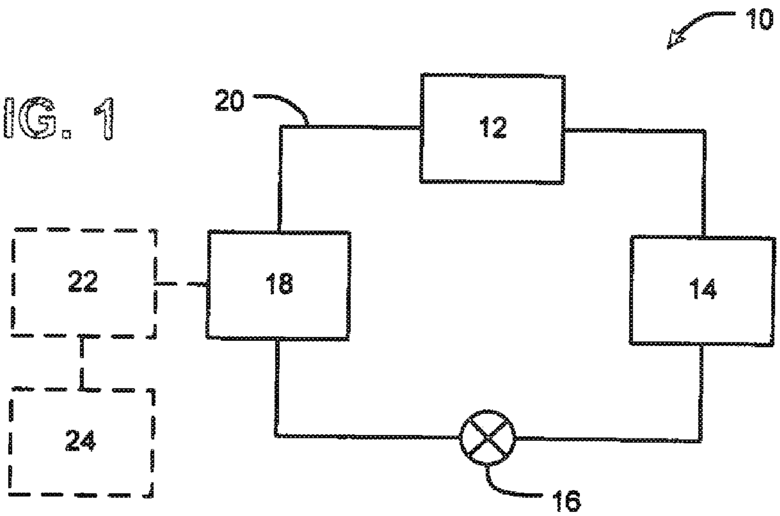
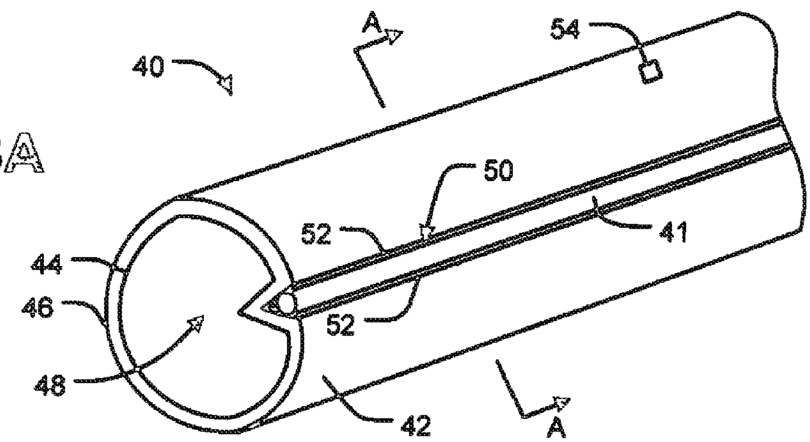


FIG. 3A



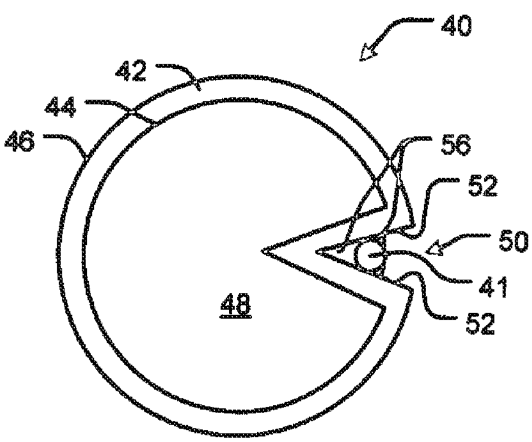


FIG. 3B

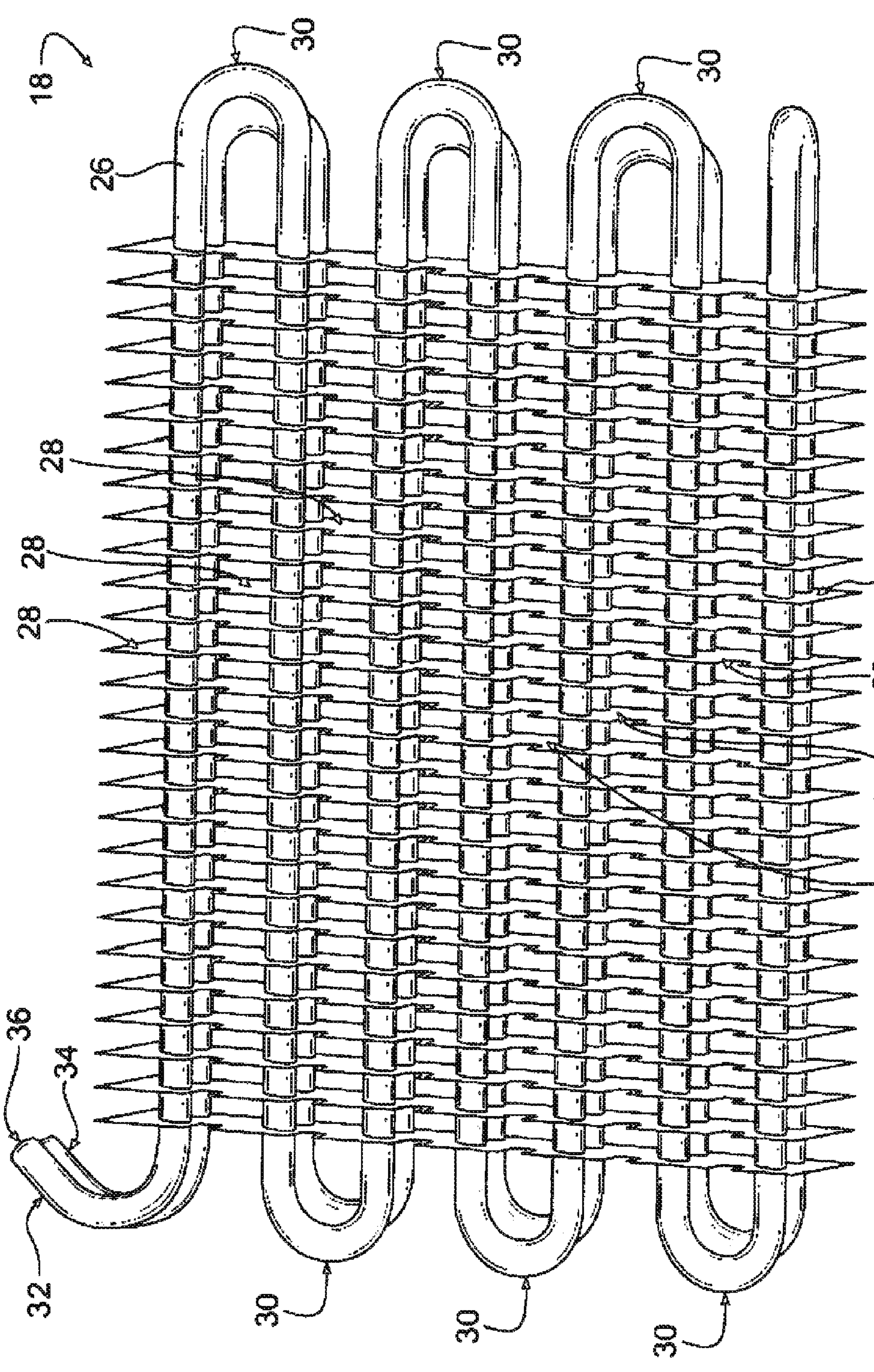


FIG. 2

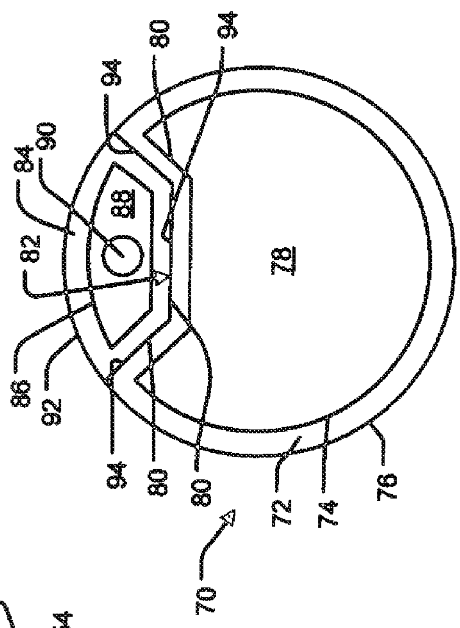


FIG. 4B

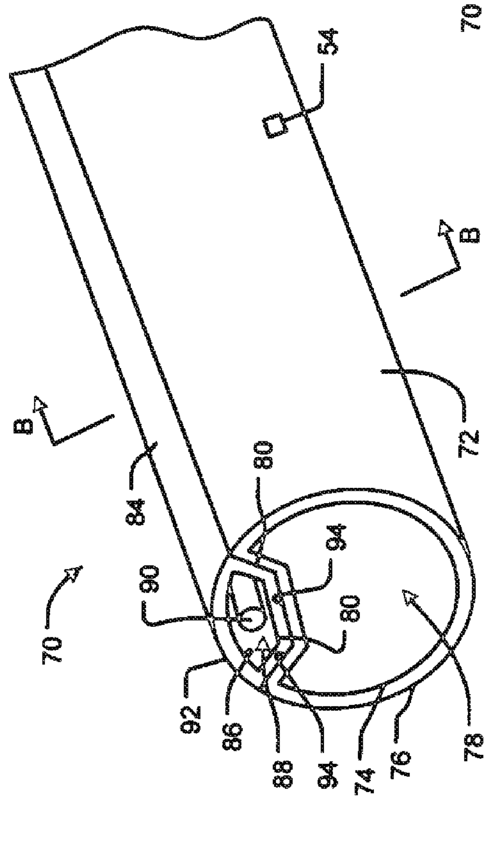


FIG. 4A

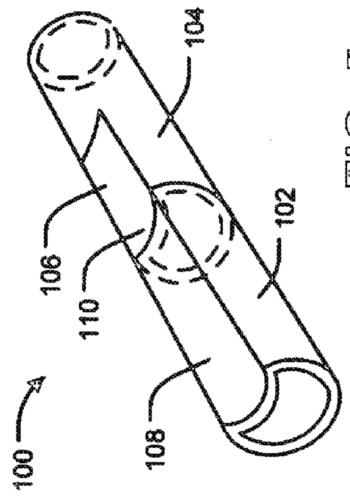


FIG. 5

EVAPORATOR WITH INTEGRATED HEATING ELEMENT

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims the benefit of the filing date of U.S. Provisional Patent Application Ser. No. 61/367,902, file Jul. 27, 2010, the disclosure of which is incorporated herein by reference in its entirety.

BACKGROUND

[0002] Heat exchangers serve to transfer heat between thermal masses. In one heat exchanger configuration, air circulates adjacent to heat exchanger surfaces that are cooled by a circulating coolant and the air gives up heat to the coolant. When temperature of the coolant is low enough, ice may form on the surfaces and impede heat exchange between the surfaces and the air. It is desirable to remove such ice with a minimum of added heat, since a surface that is heated must be re-cooled in order to resume heat exchange with the air.

[0003] Pulse heating is one method of removing ice build-up from the evaporator. Pulse heating is a method of melting a boundary layer of ice between the ice and the refrigerant conduit. In effect, pulse heating supplies a low voltage current through the wall of the refrigeration conduit, thereby utilizing the conduit as a conductor. The conduit is typically made from an inductive material such as stainless steel, which may be undesirable due to its weight and expense.

SUMMARY

[0004] The present invention provides an evaporator coil that has an integrated heating element. When ice builds up on the surfaces of the evaporator, an evaporator defrost cycle can be initiated in which heat from the integrated heating element can be used to melt the ice. Integrating the heating element with the refrigerant conduit can greatly reduce the heat required to defrost the evaporator, and can provide lower power defrosts that can be run with increased frequency and efficiency over other evaporator/heater arrangements.

[0005] For example, the evaporator disclosed herein may provide energy and efficiency savings over an evaporator that has a heater that is spaced from and/or that is in poor thermal contact with the refrigerant conduit and which typically requires excessive heating (overheating) to melt ice on the evaporator coil. Additionally, the evaporator may be less expensive to manufacture, maintain, and operate than pulse cooling systems.

[0006] According to one aspect, the present invention provides an evaporator coil having a conduit with an interior passageway that provides a pathway for a flow of refrigerant. An outer wall of the conduit forms a channel having a longitudinal opening that extends lengthwise adjacent to the interior passageway. The channel contains an electrical heating element that is in thermal contact with the conduit. The electrical heating element periodically provides heat to defrost the evaporator coil during an evaporator defrost cycle.

[0007] According to another aspect, the evaporator coil can include a second conduit having an interior passageway that provides a pathway for the electrical heating element. The second conduit can be at least partially contained within the channel of the first conduit.

[0008] According to another aspect, the evaporator coil can be part of an evaporator in a refrigeration system and the system can be controlled by a controller that alternates between a refrigeration cycle and the evaporator defrost cycle.

[0009] To the accomplishment of the foregoing and related ends, the invention comprises the features hereinafter fully described and particularly pointed out in the claims. The following description and the annexed drawings set forth in detail certain illustrative embodiments of the invention. These embodiments are indicative, however, of but a few of the various ways in which the principles of the invention may be employed. Other objects, advantages and novel features of the invention will become apparent from the following detailed description of the invention when considered in conjunction with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] The appended drawings show various features of embodiments of the invention.

[0011] FIG. **1** is a schematic diagram of a refrigeration system in accordance with aspects of the invention;

[0012] FIG. **2** is an exemplary evaporator having an integrated heating element as may be used in the system of FIG. **1**;

[0013] FIG. **3**A is a perspective view of a segment of an evaporator coil in accordance with aspects of the invention;

[0014] FIG. **3**B is a cross-sectional view of the evaporator coil of FIG. **3**A taken along lines A-A;

[0015] FIG. **4**A is a perspective view of a segment of an evaporator coil in accordance with aspects of the invention;

[0016] FIG. **4**B is a cross-sectional view of the evaporator coil of FIG. **4**A taken along lines B-B; and

[0017] FIG. **5** is a detailed view of a transition region between the evaporator coil and a conduit of the refrigeration system.

DETAILED DESCRIPTION

[0018] Referring to FIG. **1**, an exemplary refrigeration system **10** is shown. A circulating refrigerant enters a compressor **12** as a vapor and is compressed such that it exits the compressor as a vapor at a higher temperature. The vapor travels through a condenser **14** which cools the vapor until it starts condensing into a liquid. The liquid refrigerant then passes through an expansion valve **16** where its pressure abruptly decreases, causing flash evaporation of some of the refrigerant. This results in a mixture of liquid and vapor at a lower temperature and pressure. The low temperature liquid-vapor mixture then travels through an evaporator **18**. In the evaporator, the liquid-vapor mixture is completely vaporized by blowing the warm air from the space to be cooled across the evaporator coil or tubes. The refrigerant cools the air by removing the heat, and the resulting vapor refrigerant then returns to the compressor **12** to complete the cycle. The various components of the refrigeration system can be connected via one or more conduits **20**.

[0019] The system may include a controller **22**. The controller **22** can be configured to control the various components of the system including the compressor, the expansion valve and the evaporator. For example, the evaporator can be controlled to alternate between the aforementioned refrigeration cycle and a defrost cycle for removing ice that may build up on the evaporator. The controller **22** can be coupled to a power supply **24**, and can control the flow of electricity to the evaporator during the evaporator defrost cycle.

[0020] The evaporator **18** can take a variety of forms. For example, the evaporator **18** may be a tube evaporator with fins, a coiled evaporator, a flat evaporator, a bottle brush evaporator, etc. FIG. **2** shows one exemplary embodiment of an evaporator **18** having a coil **26** that has a plurality of longitudinal sections **28** and curved sections **30**. The evaporator coil **26** has an inlet portion **32** configured to interface with a conduit **20** of a refrigeration system **10**, and an outlet portion **34** configured to interface with another conduit **20** of the refrigeration system **10**. The evaporator **18** has an integrated heating element **36** for defrosting the evaporator during an evaporator defrost cycle. Further, the inlet portion **32** and outlet portion **34** may include a transition region as shown and described with respect to FIG. **5**.

[0021] FIG. **3**A shows a segment of an evaporator coil **40** with an integrated heating element **41**, and FIG. **3**B shows a cross-sectional view of the evaporator coil **40** taken along lines A-A. The evaporator coil **40** includes a conduit **42** having an inner wall **44** and an outer wall **46**. The inner wall **44** defines an interior passageway **48** that provides a pathway for a flow of refrigerant.

[0022] A channel **50** is formed by one or more portions **52** of the outer wall **46**. As shown in FIG. **3**A, the channel **50** extends lengthwise along the evaporator coil adjacent to the interior passageway **48** and has a longitudinal opening. The channel **50** may extend parallel to a central axis of the interior passageway **48**. Alternatively, the channel may be angled relative to the central axis of the interior passageway **48**, for example, the channel **50** may extend helically about the center axis of the interior passageway **48** as it extends along a length of the outer wall.

[0023] The channel **50** may consume a relatively small portion of the interior passageway **48**. In the exemplary embodiment of FIGS. **3**A and **3**B, the channel **50** is in the general shape of a "V", however, the channel may have a different shape. For example, the channel may have a "U" shape, a "C" shape, a curve shape or another shape.

[0024] The heating element **41** is integrated into the evaporator **18**. The heating element **41** is at least partially contained within the channel **50**. In the illustrated embodiment, the heating element **41** is completely contained within the channel **50**. The heating element **41** may be a resistive heating element and may be coupled to a low voltage power source, for example, a 120-volt or 220-volt power source. In one embodiment, the heating element **41** is an electric heating cable (e.g., an insulated wire).

[0025] The heating element **41** is in thermal contact with the conduit **42** via the portions **52** of the outer wall **46** that form the channel **50**. The heating element **41** can be in direct physical contact with the portions **52** of the outer wall **46** that form the channel **50**, or alternatively, the heating element **41** can be held in thermal and/or physical contact with the channel **50** by a thermally conductive material **56**, such as a thermally conductive adhesive. Alternatively, the heating element **41** may be welded directly to the channel **50** or held in place by a retaining element such as a strap or other mechanical implement. As shown in FIGS. **4**A and **4**B and described below, the heating element also can be contained in a separate conduit that is coupled to the channel.

[0026] The heating element **41** can be controlled (e.g., manually controlled or automatically controlled with the controller **22**) to provide heat to defrost the surfaces of the evaporator **18**, including the outer wall **46** of the conduit **42**, during the evaporator defrost cycle. The controller **22** can be programmed or otherwise configured to periodically enter an evaporator defrost cycle in which the refrigeration cycle is stopped and electricity is provided to the heating element **41**. As used herein, periodically can mean regular or irregular time intervals. For example, the system can be configured to enter the defrost cycle on a regular basis such as hourly, twice a day, daily, or at any combination of regular or irregular time intervals.

[0027] Additionally or alternatively, the evaporator can be configured to enter the defrost cycle whenever a buildup of ice is detected by sensors or other feedback mechanisms in the system, such as sensor **54** that may be operatively coupled to the controller **22**. The system may include functionality to allow an operator to manually switch the system to the defrost mode.

[0028] Referring to FIGS. **4**A and **4**B, another embodiment of an evaporator coil **70**, with an integrated heating element **90** is shown. The evaporator coil **70** includes a conduit **72** having an inner wall **74** and an outer wall **76**. The inner wall **74** defines an interior passageway **78** that provides a pathway for a flow of refrigerant. One or more portions **80** of the outer wall **76** form a channel **82** that extends longitudinally along the evaporator coil **70** adjacent to the interior passageway **78**. The channel **82** has a longitudinal opening. As noted above, the channel **82** need not be parallel to the axis of the passageway **78**.

[0029] A second conduit **84** is coupled to the first conduit **72** at the channel **82**. The second conduit **84** has an inner wall **86** that provides a passageway **88** for the heating element **90** as described above with respect to FIGS. **3**A and **3**B. The heating element **90** is shown in the illustrated embodiment as being spaced from the inner wall **86** of the passageway **88**, however, the heating element may be in contact with the inner wall **86**, which can improve the efficiency of the heat transfer for defrosting the evaporator. Additionally or alternatively, the second conduit **84** may be filled with a medium to aid heat transfer between the conduit and the heating element. For example, the second conduit **84** may be filled with grease or another medium, such as a gas or liquid. The second conduit **84** may provide physical and environmental protection for the heating element **90**.

[0030] The second conduit **84** has an outer wall **92**. Portions **94** of the outer wall **92** are shaped to substantially match the contour of the channel **82** formed by portions **80** of the outer wall **76** of the first conduit **72**. The second conduit **84** is at least partially contained within the channel **82** and an interface is formed between the portions **80** of the outer wall **76** of the first conduit **72** and portions **94** of the outer wall **92** of the second conduit **84**. As shown best in FIG. **4**B, the shape of the channel **82** and the shape of the portions **94** of the outer wall **92** of the second conduit **84** can be complementary to one another, with the first conduit **72** and the second conduit **84** fitting together. As shown in FIG. **4**B, the conduits **72** and **84** can form an evaporator coil with an integrated heating element that has a substantially circular cross-sectional shape.

[0031] The conduits may be coupled and held together by an adhesive, weld, or other type of attachment. Alternatively, the conduits may be integrally formed with one another, for example, by coextruding the conduits. The conduits may be formed from the same or different materials. Some exemplary suitable materials include aluminum, copper, stainless steel, and the like.

[0032] An advantage of the evaporator coil disclosed herein is that it can be used to defrost an evaporator without using the evaporator coil as a conductor to melt the boundary layer of ice on the evaporator coil. Accordingly, the evaporator can be formed from cheaper materials, which may provide a cost and/or weight savings. Additionally, an evaporator with the evaporator coil disclosed herein can be have a defrost cycle without complicated and expensive electronics, such as transformers and the like.

[0033] FIG. **6** shows an exemplary embodiment of a transition region **100** between an evaporator coil **102** and a conduit **104** of a refrigeration system (e.g., refrigeration system **10**). The conduit **104** has a channel **106** that is aligned with channel **108** in the evaporator coil **102**. The conduit channel **106** may be tapered such that the channel **106** is deeper at the end **110** that is connected to the evaporator coil **102**. The tapered channel can facilitate assembly and integration of the heating element into the evaporator coil and/or may provide an area to connect the heating element to a power supply or controller. The evaporator coil **102** and conduit **104** may be welded at the interface and may be made from different materials (e.g., the evaporator coil may be formed from aluminum and the conduit may be formed from copper).

[0034] Although the principles, embodiments and operation of the present invention have been described in detail herein, this is not to be construed as being limited to the particular illustrative forms disclosed. They will thus become apparent to those skilled in the art that various modifications of the embodiments herein can be made without departing from the spirit or scope of the invention.

What is claimed is:

1. An evaporator coil comprising:

a conduit having an interior passageway that provides a pathway for a flow of refrigerant and an outer wall that forms a channel having a longitudinal opening, the channel extending lengthwise adjacent to the interior passageway; and

an electrical heating element in the channel and in thermal contact with the conduit, the electrical heating element periodically providing heat to defrost the evaporator coil during an evaporator defrost cycle.

2. The evaporator coil of claim **1**, wherein the electrical heating element is coupled to the channel.

3. The evaporator coil of claim **2**, wherein the electrical heating element is coupled to the outer wall by a thermally conductive adhesive or by a weld between the electrical heating element and the channel.

4. The evaporator coil of claim **1**, further comprising a second conduit at least partially contained within the channel, wherein the electrical heating element is contained within the second conduit.

5. The evaporator coil of claim **4**, wherein the second conduit has an outer wall that is contoured to fit in the channel.

6. The system of claim **5**, further comprising a medium in the second conduit that facilitates heat transfer between the electrical heating element and the second conduit.

7. The evaporator coil of claim **4**, wherein the first conduit and the second conduit are formed from different materials.

8. The evaporator coil of claim **1**, wherein the electrical heating element is a resistive heating element.

9. The evaporator coil of claim **1**, wherein the first conduit and the second conduit are extruded.

10. The evaporator coil of claim **1**, wherein the conduit has longitudinal and curved portions and the channel extends substantially the full length of the conduit.

11. The evaporator coil of claim **1** in an evaporator that is part of a refrigeration system having an evaporator defrost cycle, wherein the evaporator coil has an inlet portion configured to interface with a first conduit of a refrigeration system, and an outlet portion configured to interface with a second conduit of a refrigeration system.

12. The system of claim **11**, wherein at least one of the first conduit of the refrigeration system and the second conduit of the refrigeration system has a tapered channel that corresponds to one of the channels in the evaporator coil.

13. The system of claim **12**, further comprising a controller that controls the refrigeration system to alternate between operation of the refrigeration system and an evaporator defrost cycle.

14. An evaporator coil comprising:

a first conduit having an interior passageway that provides a pathway for a flow of refrigerant and an outer wall that forms a channel having a longitudinal opening, the channel extending lengthwise adjacent to the interior passageway;

a second conduit having an interior passageway that provides a pathway for an electrical heating element, the second conduit at least partially contained within the channel of the first conduit; and

an electrical heating element in the second channel, the electrical heating element periodically providing heat to defrost the evaporator coil during an evaporator defrost cycle.

* * * * *