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(54) **INDUCTION COOKER**

(57) An induction cooker is provided, comprising a cooking surface and a heat pump apparatus (30, 32, 34, 36, 38, 40, 42) constructed and arranged to absorb heat from a component (14) of the induction cooker to be cooled and to supply heat to the cooking surface during operation of the induction cooker. The heat pump apparatus (30, 32, 34, 36, 38, 40, 42) comprises a heating section associated with the cooking surface, and a cooling section associated with the component (14) of the induction cooker to be cooled. The heat pump apparatus (30, 32, 34, 36, 38, 40, 42) may be arranged, for example, to cool a switching transistor (14) of a switching circuit (14, 16, 18) arranged to supply a current from a power source to an induction coil (12) of the induction cooker.

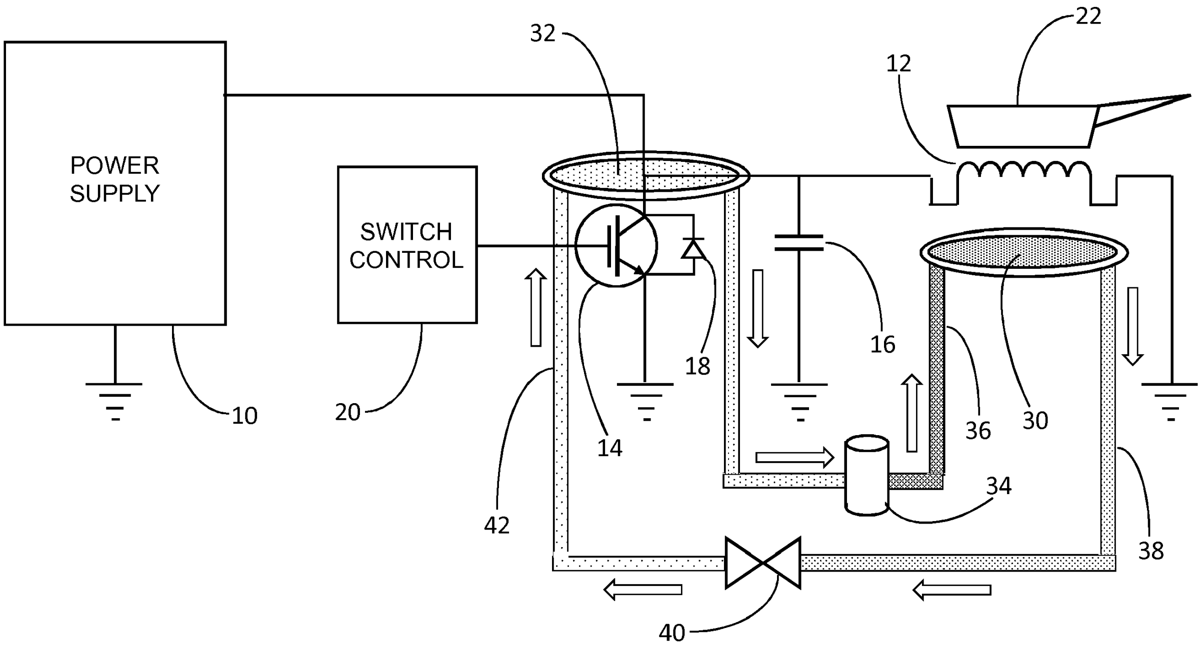

Figure 2

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Description

Technical Field

[0001] The present disclosure relates to induction cookers.

Background

[0002] Induction cookers are known in which pulses of electric current are passed through an induction coil, the coil thereby generating a corresponding varying electromagnetic field. The varying electromagnetic field induces a varying eddy current in a ferromagnetic cooking vessel or the like when the cooking vessel is placed in close proximity to the induction coil, which in turn heats the cooking vessel and therefore the contents of the cooking vessel. A switching circuit comprising one or more high power transistors is provided to vary the width of current pulses supplied to the induction coil to control the power that is provided to the induction coil and so to the cooking vessel.

Summary

[0003] According to a first aspect disclosed herein, there is provided an induction cooker, comprising:

a cooking surface; and
a heat pump apparatus constructed and arranged to absorb heat from a component of the induction cooker to be cooled and to supply heat to the cooking surface during operation of the induction cooker.

[0004] In an example, the induction cooker comprises an induction coil and a switching circuit arranged to supply a current from a power source to the induction coil, and the component to be cooled is a switching transistor of the switching circuit.

[0005] Cooling a switching transistor the switching circuit may be expected to increase the operating efficiency of the switching circuit. For example, the switching circuit may comprise one or more switching transistors, and cooling the switching transistors can increase the current conducting capability of the switching transistors. Furthermore, supplying supplementary heat to the cooking surface enables the induction coil to be operated at a lower power level. The supplementary heat may be recovered from the switching circuit.

[0006] In an example, the heat pump apparatus comprises a closed circuit of tubing containing a refrigerant, the circuit having a heating section associated with the cooking surface and a cooling section associated with the component to be cooled.

[0007] In an example, at least a portion of the cooling section includes one or more heat conducting elements to enable absorption of heat from the switching circuit or from another component to be cooled. The heat conducting elements may include heat-conducting fins, or a heat conducting material providing a heat-conducting path from a component to be cooled to at least a portion of the cooling section.

[0008] Examples described herein provide various ways in which heat conduction from the heating section to the cooking surface may be increased.

[0009] In an example, at least a portion of the heating section includes one or more heat conducting elements to enable conduction of heat from the heating section to the cooking surface.

[0010] In an example, at least a portion of the heating section is embedded into the cooking surface.

[0011] In an example, at least a portion of the heating section forms a part of a structure including an induction coil of the induction cooker. For example, at least a portion of the windings of the induction coil may comprise a coiled section of tubing comprising at least a portion of the heating section.

[0012] In an example, at least a portion of the heating section is thermally coupled to the cooking surface by a heat conducting material.

[0013] In an example, a fan is provided to cause a flow of air between the cooling section and the component to be cooled.

[0014] In an example, a fan is provided to cause a flow of air from the heating section to the cooking surface.

[0015] In an example, a temperature sensor arranged to sense a temperature of the component to be cooled, and a controller arranged to control the heat pump apparatus according to the sensed temperature.

[0016] In an example, a leakage sensor is provided to detect a leakage of a refrigerant from the heat pump apparatus, and a controller is provided to deactivate the heat pump apparatus in the event that the leakage sensor detects a leakage.

[0017] In an example, a temperature sensor arranged to sense a temperature of the cooking surface, and a controller arranged to control a switching circuit to supply a current to an induction coil of the induction cooker taking account of the sensed temperature of the cooking surface.

Brief Description of the Drawings

[0018] To assist understanding of the present disclosure and to show how embodiments may be put into effect, reference is made by way of example to the accompanying drawings in which:

Figure 1 shows schematically a simplified electric circuit of a known induction cooker;

Figure 2 shows schematically the electric circuit of Figure 1 with a heat pump apparatus incorporated according to examples disclosed herein; and

Figure 3 shows schematically a plan view of an induction coil of an induction cooker according to an example disclosed herein.

Detailed Description

[0019] A known example of an induction cooker electric circuit will firstly be described with reference to Figure 1. Example embodiments of an induction cooker according to the present invention will then be described with reference to Figure 2 and Figure 3.

[0020] Referring firstly to Figure 1, there is shown a simplified electric circuit diagram for a known induction cooker. The diagram shows an electric circuit having a direct current (DC) power supply 10 arranged to supply current to an induction coil 12 under the control of a switching circuit comprising a "power" transistor 14, for example a Metal Oxide Semiconductor Field Effect Transistor (MOSFETs) or an Insulated Gate Bipolar Transistor (IGBT). For higher-power induction cookers, two or more switching transistors 14 may be provided. The switching transistor 14 is connected in parallel with a capacitor 16 and a diode 18. The combination of the inductor 12 and the capacitor 16 forms a resonant circuit. The switching transistor 14 is controlled by a switch controller 20, arranged to switch the transistor 14 on and off using a pulse width modulation (PWM) technique at or near to the resonant frequency of the resonant circuit. The switch controller 20 thereby causes the transistor 14 to pass a varying electric current to the induction coil 12. The switch controller 20 adjusts the current level flowing through the inductor 12 by varying the conduction time (pulse width) of the transistor 14, according to the power level required to heat a cooking vessel 22.

[0021] Half-bridge switch topologies and full bridge switch topologies using two or more switching transistors are also known for use in induction cookers as an alternative to the single switch topology shown in Figure 1.

[0022] Due to the power levels involved, for example given that a current level of up to 15A or so may typically be supplied by the switching transistor 14 to the induction coil 12, the temperature of the transistor 14 may rise to a high level. Some form of heat management is therefore required, conventionally in the form of a heat sink and a fan to cause a flow of air past the heat sink.

[0023] According to embodiments of an invention to be described below, an apparatus implementing a heat pump may be included in a known induction cooker, provided both to cool a switching circuit (14) and to provide supplementary heat to the induction coil 12. An example of an induction cooker incorporating a heat pump apparatus, according to the present disclosure, will now be described with reference to Figure 2 and Figure 3.

[0024] Referring to Figure 2 and Figure 3, a representation of a heat pump apparatus is shown overlain upon the electric circuit of Figure 1, initially for the purpose of explaining the principles of operation of an embodiment of the present invention. The apparatus implements a vapour-compression refrigeration cycle or Carnot heat pump. The heat pump apparatus comprises a closed circuit of tubing containing a selected refrigerant. The circuit of tubing includes a heating section 30 which may be incorporated within a central section of the induction coil 12, as shown in Figure 3, and a cooling section 32 which may be positioned close to the switching transistor 14. A fan (not shown in Figure 2) may be positioned to circulate air through the cooling section 32 and through or across a heat sink on which the switching transistor 14 may be mounted to provide a flow of cooled air and so remove heat from the heat sink and so from the switching transistor 14. The cooling section 32 may also be used to cool other components of the induction cooker as required.

[0025] The refrigerant is selected having a temperature of vaporisation such that it will vaporise in the cooling section 32 as it absorbs heat from the switching transistor 14 or other cooled components.

[0026] A compressor 34 is provided to compress the vaporised refrigerant and so raise its temperature significantly. The high pressure high temperature refrigerant vapour passes from the compressor 34 along a 'hot' section 36 of the circuit to the heating section 30. The heating section 30 acts as a condenser in the refrigeration cycle, transferring heat to a cooking surface in the vicinity of the induction coil 12 and so contributing to the heating of the cooking vessel 22. A fan may be provided (not shown in Figure 2) to blow air heated by the heating section 30 towards the cooking surface and so improve the transfer of heat thereto. The transfer of heat causes at least some of the refrigerant vapour in the coiled heating section 30 to condense back to a liquid form.

[0027] The high pressure refrigerant, now slightly cooled and at least partially in liquid form, passes on through a section 38 of the circuit to an expansion valve 40 which allows a portion of the high pressure refrigerant to pass to a low pressure low temperature section 42 of the circuit as a liquid. The reduction in pressure causes a rapid reduction in refrigerant temperature. The cool refrigerant liquid then passes through the section 42 to the cooling section 32, acting as an evaporator in the refrigeration cycle, to absorb heat from the switching transistor 14 or other components of the induction cooker. As a result, the cool refrigerant liquid passing through the cooling section 32 vaporises before passing on to the compressor 34 to complete the refrigeration cycle.

[0028] The compressor 34 may be driven by a low power DC motor, selected according to the refrigerant vapour pressure and temperature required in the hot section 36, 30 of the circuit and the rate of cooling required by the cool section 42, 32 of the circuit. In designing a refrigeration apparatus for a given induction cooker, the refrigeration cycle may be modelled, by a person of ordinary skill in this field, to take account of the rate of cooling required for the switching transistor 14 and other components and therefore the pressure to be achieved by the compressor 34.

[0029] Cooling of the switching transistor 14 increases its current-carrying capacity and therefore contributes to an increase in the efficiency of the induction cooker. Heating of the induction coil 12 provides supplementary heat to the cooking surface of the induction cooker which may be taken into account when operating the switching transistor 14. That is, if there is a supplementary source of heat provided by the heating coil section 30 of the heat pump apparatus, less power needs to be transferred to the cooking vessel 22 by the induction coil 12 and so the switch controller 20 may supply a lower level of current to the induction coil 12 when the heat pump apparatus is operating. It may also be possible to provide an induction coil 12 having a smaller number of turns.

[0030] There are a number of different configurations for the tubing forming the cooling section 32 of the heat pump apparatus, as would be apparent to a person of ordinary skill in the relevant art. For example, the tubing may be coiled or arranged to follow a two-dimensional path. Furthermore, additional heat conducting fixtures may be applied to the tubing to provide a direct heat conducting path to a component to be cooled, for example to a heat sink of the switching transistor 14. Alternatively, the additional fixtures may be applied to the tubing to increase a heat conducting surface area in contact with the tubing and so increase the rate of heat absorption by the cooling section 32 from air flowing through.

[0031] Alternatively, a portion of tubing of the cooling section 32 may be incorporated into a heat sink to which the switching transistor 14 is thermally coupled.

[0032] Similarly, there are a number of different configurations for the tubing forming the heating section 30 of the heat pump apparatus, as would be apparent to the notional skilled person. For example, a section of tubing may be incorporated into the cooking surface itself. Alternatively, the induction coil 12 may be wound in such a way as to leave an open central region in which an arrangement of tubing forming the heating section 30 may be fitted. As a further alternative, the tubing of the heating section 30 may be integrated into the windings of the induction coil 12. In yet another arrangement, at least a portion of the windings of the induction coil 12 may comprise a coiled section of electrically conducting tubing of the heating section 30 to be energised with current supplied by the switching transistor 14. As a further alternative, the tubing of the heating section 30 may be thermally coupled to the cooking surface by means of a thermally conducting material.

[0033] As for the cooling section 32, additional heat conducting fixtures may be applied to tubing forming the heating section 30 to increase the rate of conduction of heat, in this case from the tubing of the heating section 30 to the cooking surface.

[0034] The switch controller 20, or another controller within the induction cooker, may implement control functionality to control the compressor 34 of the heat pump apparatus. A temperature sensor may be provided to sense the temperature of the switching transistor 14 and/or its heat sink, or to sense the temperature of other components of the induction cooker and to control the compressor 34 of the heat pump apparatus to provide a required level of cooling. The temperature sensor may be, for example, a negative temperature coefficient (NTC) thermistor. The compressor 34 may be controlled to maintain the temperature of cooled components within a predetermined temperature range or to maintain a temperature at or below a predetermined threshold temperature. The compressor 34 may be deactivated if the sensed temperature of cooled components is below the threshold.

[0035] Furthermore, a temperature sensor may be provided at the cooking surface to sense a temperature of the cooking surface in the vicinity of the induction coil 12. The switch controller 20 may be arranged to vary the supply of power to the induction coil 12 according to a sensed temperature of the cooking surface. The temperature of the cooking surface may result from heat conducted from the cooking vessel 22 and supplementary heat supplied by the heat pump apparatus. In this way, any contribution to the heating of the cooking vessel 22 by the heat pump apparatus may be taken into account when determining the power to be supplied to the induction coil 12.

[0036] A further sensor may be provided to sense any leakage of refrigerant from the heat pump apparatus. This sensor may be a gas sensor to sense the presence of refrigerant gas within a chassis of the induction cooker. Alternatively, this sensor may be a pressure sensor arranged to sense a pressure, and hence any drop below a predetermined pressure threshold, within the heat pump circuit of the apparatus. The control functionality may deactivate the compressor 34 in the event that a leakage of refrigerant is sensed.

[0037] In an example implementation, a refrigerant such as 1, 1, 1, 2 - Tetrafluoroethane (CF_3CH_2F), also known as R134a, may be selected, having a boiling point of -26.1°C at 1 atmosphere of pressure. However, as would be apparent to a notional skilled person in this art, other refrigerants may be used having properties selected as being most suited to the particular cooling requirements of an application of the present invention.

[0038] The examples described herein are to be understood as illustrative examples of embodiments of the invention. Further embodiments and examples are envisaged. Any feature described in relation to any one example or embodiment may be used alone or in combination with other features. In addition, any feature described in relation to any one example or embodiment may also be used in combination with one or more features of any other of the examples or embodiments, or any combination of any other of the examples or embodiments. Furthermore, equivalents and modifications not described herein may also be employed within the scope of the invention, which is defined in the claims.

Claims

1. An induction cooker, comprising:

   a cooking surface; and
   a heat pump apparatus (30, 32, 34, 36, 38, 40, 42) constructed and arranged to absorb heat from a component (14) of the induction cooker to be cooled and to supply heat to the cooking surface during operation of the induction cooker.

2. The induction cooker according to claim 1, comprising an induction coil (12) and a switching circuit (14, 16, 18) arranged to supply a current from a power source to the induction coil (12), and wherein the component to be cooled is a switching transistor (14) of the switching circuit (14, 16, 18).

3. The induction cooker according to claim 1 or claim 2, wherein the heat pump apparatus (30, 32, 34, 36, 38, 40, 42) comprises a closed circuit (30, 32, 38, 42) of tubing containing a refrigerant, the circuit having a heating section (30) associated with the cooking surface and a cooling section (32) associated with the component (14) to be cooled.

4. The induction cooker according to claim 3, wherein at least a portion of the cooling section (32) includes one or more heat conducting elements to enable absorption of heat from the component (14) to be cooled.

5. The induction cooker according to claim 4, wherein the one or more heat conducting elements comprise heat conducting fins, or a heat conducting material providing a heat-conducting path from the component (14) to be cooled to at least a portion of the cooling section (32).

6. The induction cooker according to any one of claims 3 to 5, wherein at least a portion of the heating section (30) includes one or more heat conducting elements to enable conduction of heat from the heating section (30) to the cooking surface.

7. The induction cooker according to any one of claims 3 to 6, wherein at least a portion of the heating section (30) is embedded into the cooking surface.

8. The induction cooker according to any one of claims 3 to 7, wherein at least a portion of the heating section (30) forms a part of a structure including an induction coil (12) of the induction cooker.

9. The induction cooker according to claim 8, wherein at least a portion of the windings of the induction coil (12) comprises a coiled section of tubing comprising at least a portion of the heating section (30).

10. The induction cooker according to any one of claims 3 to 9, wherein at least a portion of the heating section (30) is thermally coupled to the cooking surface by a heat conducting material.

11. The induction cooker according to any one of claims 3 to 10, comprising a fan to cause a flow of air between the cooling section (32) and the component (14) to be cooled.

12. The induction cooker according to any one of claims 3 to 11, comprising a fan to cause a flow of air from the heating section (30) to the cooking surface.

13. The induction cooker according to any one of claims 1 to 12, comprising a temperature sensor arranged to sense a temperature of the component (14) to be cooled, and a controller arranged to control the heat pump apparatus (30, 32, 34, 36, 38, 40, 42) according to the sensed temperature.

14. The induction cooker according to any one of claims 1 to 13, comprising a leakage sensor arranged to detect a leakage of a refrigerant from the heat pump apparatus (30, 32, 34, 36, 38, 40, 42), and a controller arranged to deactivate the heat pump apparatus (30, 32, 34, 36, 38, 40, 42) in the event that the leakage sensor detects a leakage.

15. The induction cooker according to any one of claims 1 to 14, comprising a temperature sensor arranged to sense a temperature of the cooking surface, and a controller (20) arranged to control a switching circuit (14, 16, 18) to supply a current to an induction coil (12) of the induction cooker taking account of the sensed temperature of the cooking surface.

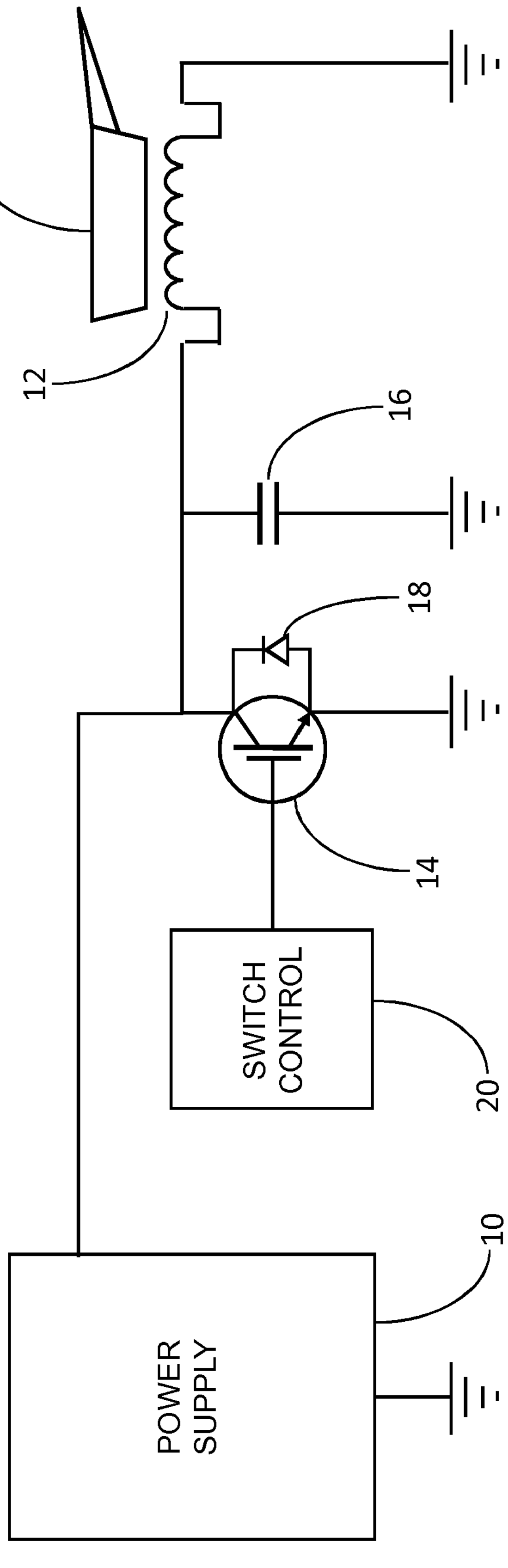
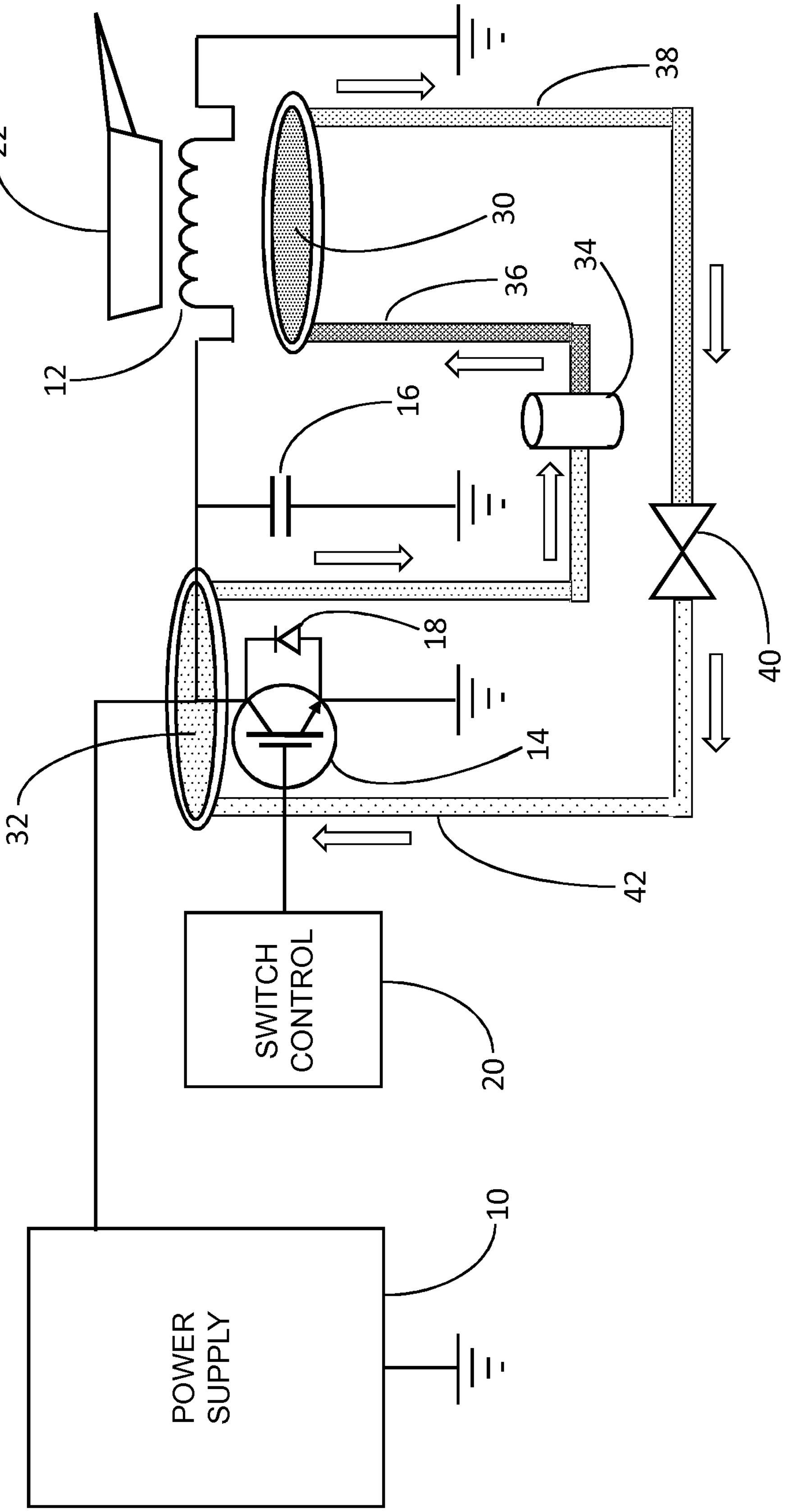


Figure 1



POWER SUPPLY
SWITCH CONTROL
10
12
14
16
18
20
22
30
32
34
36
38
40
42

Figure 2

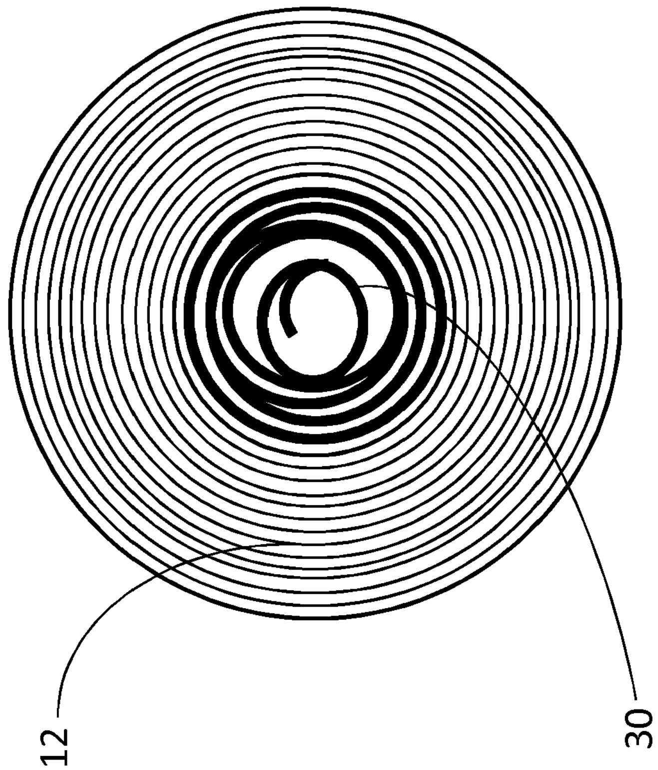


Figure 3

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EUROPEAN SEARCH REPORT

Application Number
EP 17 18 7043

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	US 2007/062513 A1 (GAGAS JOHN M [US]) 22 March 2007 (2007-03-22) * abstract; figures 1-14b * * paragraphs [0072], [0106] * -----	1-15	INV. H05B6/12
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TECHNICAL FIELDS SEARCHED (IPC)
H05B

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	21 February 2018	Garcia, Jesus

CATEGORY OF CITED DOCUMENTS

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