

COOLING DEVICE

This invention relates to the field of temperature regulation and, in particular, to a device for cooling enclosed or confined spaces.

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Cooling devices for maintaining a room, car or other enclosed space at a comfortable temperature are well known. The majority are based on forced air systems that may incorporate some form of cooling of the air. Cooling is generally based on the thermodynamics of condensation and evaporation of a refrigerant gas. On condensation of a gas to a liquid, heat is rejected to the environment and on evaporation of a liquid, heat is absorbed. The evaporation / condensation cycle is driven by compression. In conventional air conditioning units the compression is driven by mechanical work that is normally provided by an electrical motor. Alternatively, sorption devices are driven by the adsorption or absorption of the refrigerant gas (or sorbate), such as ammonia, by a solid or solid / liquid sorbent.

A major problem with these prior art air-conditioning systems is that they are relatively power-hungry to operate. Effective operation usually requires a large amount of electricity, which itself is likely to have been generated at some cost to the environment. Although devices based on a sorption cycle offer some improvement, this technology is by no means mature and very few practical devices have been developed. With the substantial growth in demand for air conditioning units in warm developing countries such as China and India, the burden placed on the electricity supply is becoming critical. There is accordingly an increasing need to improve the energy efficiency of air-conditioning devices. In particular, a more energy-efficient system offers the possibility that it may be operated independently of the infrastructure of an electricity grid. This makes it suitable not only for use in more remote areas but also in a moving environment such as the carriages of an underground railway.

- 2 -

A further problem presented by prior art cooling devices is the potentially hazardous nature of the refrigerant gas used. Ammonia, alcohols, hydrogen, hydrocarbons, hydrofluorocarbons and carbon dioxide have all
5 been used in cooling systems. The potential risks from employing such substances are of course more significant if using in a confined space, such as an underground room or carriage. Most prior art cooling devices also suffer from high CO₂ emissions, which further harm the environment.

10 There is accordingly a growing need to provide an alternative form of cooling device, which is more environmentally-friendly than those known in the prior art.

The present invention provides a cooling device comprising a high voltage
15 source connected to a spark gap and controlled by a timing means, wherein the source and timing means are arranged to generate unidirectional high voltage pulses which are discharged in short and regular impulses across the spark gap and the device also includes an emitter located in the vicinity of an electrode of the spark gap and electrically
20 isolated therefrom.

A device according to the present invention creates a source of high voltage direct current pulses which are discharged in very short impulses, preferably less than 100 ns duration, through a spark gap. As a result of
25 this process, heat is withdrawn from the atmosphere surrounding the spark gap. The cooling effect is highly localised around the discharge spark and so the emitter is used to provide a means of delocalisation. That is, the emitter distributes the cooling effect over a larger volume.

- 3 -

A cooling device that operates according to this principle is radically different from those known in the prior art. Whereas prior art devices are based on a refrigerant condensation / evaporation cycle, the present device is based on a cooling effect produced by a high voltage electrical
5 discharge.

It is known that a high voltage electrical discharge can induce cooling. In nature, atmospheric cooling in the region of a lightning strike has been observed. Temperature drops have also been measured in a large coil of
10 wire connected to a cold cathode arc switch. It is believed that such effects result from organising (or cohering) fluctuation energy such as thermal or quantum zero point fluctuation energy (the Zero Point Energy Field). The pulsed disruption of a high voltage supply will perturb the ZPEF of a system, which results in heat being absorbed from its surroundings. That is,
15 a cooling effect is stimulated from the ZPEF. A device harnessing this effect may be used to cool the space in which it is located.

A cooling device based on this principle advantageously achieves cooling without the use of potentially hazardous refrigerant. Moreover, the power
20 required to generate a suitable electrical discharge is far less than that required to operate conventional cooling devices. A device can readily be constructed that consumes less than 1% of the energy used by current air cooling technology to achieve the same effect.

25 Such a device has numerous applications, primarily in the field of air conditioning. In addition to its environmental credentials, the device of the present invention may be far smaller than currently available air conditioning units. This renders it even more attractive to applications on mobile or non-permanent locations such as trains, cars, boats and
30 caravans.

- 4 -

In order to provide the cooling effect, it is preferred that the high voltage source is arranged to provide a voltage of at least 3 kV and, more preferably, at least 4 kV.

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The high voltage source may comprise a medium voltage source, timing control means for timing power output from said source in medium voltage pulses, a transformer arranged to convert the medium voltage pulses to high voltage pulses and a rectifier arranged to convert the high voltage pulses to a unidirectional signal. Such an arrangement means that the majority of pulse-shaping and manipulation is carried out in the medium voltage regime. Components that are capable of controlling high voltage are far more expensive to produce and suffer from problems with reliability. By operating primarily in the medium voltage regime therefore cheaper, more reliable, electronic components are readily available, which makes the cooling device more reliable to operate and more economic to build.

The medium voltage source itself may comprise a storage device for storing charge at medium voltage and which is discharged by operation of the timing control means. The storage device may be a capacitor or a bank of capacitors. A suitable capacitance may be in the region of 50 μF , and preferably around 47 μF . It may alternatively be an inductor.

The capacitor is preferably charged by a circuit comprising a low voltage source, a pulse generator arranged to produce an alternating signal from the low voltage source, a second transformer arranged to convert low voltage input to a medium voltage output and a rectifier arranged to rectify alternating signal input to direct current output.

- 5 -

The spark gap preferably comprises first and second electrodes sealed within a chamber and separated by an insulating gap. The sealing chamber prevents the electrodes from becoming contaminated, which may inhibit generation of a discharge spark.

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The electrodes are preferably dome shaped, which discourages localisation of spark emissions at a particular point on their surface and hence may prolong their useable life.

- 10 It is further preferred that the electrodes are made of chrome- or nickel-coated steel. The chamber may be filled with argon or other suitably inert gas.

- 15 The emitter may comprise inner and outer thin-walled coaxial tubes, which are coaxially mounted about an electrode connection lead. The tubes should be good electrical conductors and are therefore preferably metallic or made from ceramic materials with high conductivity. Metals are generally cheaper and therefore preferred.

- 20 The tubes preferably have internal diameters in the range 6 mm to 14 mm and lengths in the range 7 mm to 20 mm.

In a second aspect, the present invention provides a method of generating a cooling effect, the method comprising the steps of:-

- 25 (a) Repeatedly applying a high-voltage, unidirectional pulse of electricity between a pair of electrodes in a gaseous environment, thereby causing sparking between the electrodes; and
(b) Diffusing a cooling effect resulting from the sparking by means of an emitter located in the vicinity of the electrodes.

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- 6 -

The pulse is preferably of voltage higher than 4 kV and of duration shorter than 100 ns.

By way of example only, a cooling device made according to the present
5 invention will now be described in detail, reference being made to the accompanying drawings, in which:

Figure 1 is an overview of the process by which a spark that is capable of effecting an environmental cooling is generated.
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Figure 2 is a schematic of a circuit design, suitable for generating a cooling discharge.

Figure 3 is a detailed drawing of a spark gap and emitter.
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Figure 4 is a detailed circuit design for generating a spark that is suitable for effecting cooling.

Referring initially to Figures 1 and 2, the steps carried out by and
20 components of an electrical circuit for a cooling device in accordance with the present invention are shown. At a first step 1, a unidirectional medium direct current voltage, of around 225V, is created and stored in a control capacitor 2-6 (Figure 2). Alternatively, a bank of capacitors may be used.

25 At step 2, the capacitor 2-6 is discharged into the primary coil of a first step up transformer 2-9 (Figure 2) under control of a timer circuit 2-8 to create alternating pulses at around 4500 V.

At step 3, the 4.5 kV output from the first step up transformer 2-9 is rectified
30 to create high voltage unidirectional pulses.

- 7 -

At step 4, the pulses are discharged in very short impulses, of less than 100 ns duration, through a spark gap 2-13 located in the vicinity of an emitter 2-12. The emitter 2-12 spreads or extends a cooling effect that is stimulated by the impulsed discharge. This therefore withdraws heat from the emitter / spark gap environment, which lowers the surrounding temperature. In a typical application, a device containing the emitter 2-12 and spark gap 2-13 would be placed in a room and the effect used to cool the air within the room.

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The electronic components used to generate unidirectional high voltage impulses, which give rise to the cooling effect, will now be described in more detail with reference to Figure 2. Figure 2 illustrates a schematic of a circuit design, suitable for generating a spark in conjunction with an emitter that may be used to produce a cooling device in accordance with this invention. It is the discharging of the control capacitor 2-6 that is central to the generation of a suitable discharge spark.

A low voltage direct current power supply, 2-1, such as a regulated mains adaptor or battery, powers a square wave generator 2-2 whose output is in turn connected to a second step up transformer 2-3. A bridge rectifier 2-4 takes its input from the transformer 2-3 output, and has a diode 2-5 and the control capacitor 2-6 connected in parallel across its output.

These components are used to charge the capacitor 2-6 as follows. The low voltage direct current supply 2-1 typically provides around 500mA at 9V. The square wave generator 2-2 converts this signal to a square wave, which is applied across the second step up transformer 2-3. This transformer 2-3 is arranged to convert 9V input to a medium voltage output of around 225V. The output signal from the transformer 2-3 is therefore an

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- 8 -

alternating signal, at around 225V. The bridge rectifier 2-4 converts this signal to a direct current, maintaining the medium voltage level, reversals of current being prevented by the diode 2-5. The medium voltage unidirectional direct current is stored in the capacitor (or bank of capacitors) 2-6. Typically, the capacitance provided by this capacitor or bank is around 47 μ F.

Once the energy is stored in capacitor 2-6, the discharging of this capacitor at the medium voltage level is the next step 2 (Figure 1) in the process. A timing control circuit 2-8 and the input to the first transformer 2-9 are connected in series across the output of the capacitor 2-6. The timing circuit 2-8 thereby regulates the capacitor discharge into the primary coil of the transformer 2-9. If the timing circuit 2-8 is on, current is discharged from the capacitor 2-6 and input to the first step up transformer 2-9. If the timing circuit 2-8 is off, the control capacitor 2-6 is allowed to recharge, as described above. The timing circuit 2-8 is typically a transistor switch with on / off timing controlled by an integrated circuit timer, which is set to permit discharging of the capacitor 2-6 for a period of the order 15 μ s or less. The first step up transformer 2-9 is arranged to raise the medium level input voltage to a high voltage output of around 4500 V. Under control of the timing circuit 2-8, this output is pulsed.

Moving on to step 3, as shown in Figure 1, the high voltage alternating current pulses, output from the second step up transformer 2-9 are input to a second rectifier 2-10, which in this embodiment is a diode. The pulses are thereby converted into a high-voltage dc signal, in the region of 4.5 kV. The spark gap 2-13 is connected across the rectified output from the first transformer 2-9 in parallel with a second capacitor 2-11. The rectified signal is then discharged into the spark gap 2-13 in short impulses, whose duration is controlled by circuit parameters, primarily the inductance of the

- 9 -

transformer 2-9 and the value of capacitor 2-11. The impulse duration should be no more than 100 ns. Giving due consideration to less-flexible factors such as transformer inductance, it is found that the capacitor 2-11 should have capacitance in the region of 22 pF for satisfactory operation.

- 5 The emitter 2-12 is located in the vicinity of the spark gap 2-13 and electrically isolated therefrom. As a result of the discharging impulses in the spark gap 2-13, the emitter experiences electro-static energy fluctuations, and the surrounding area is cooled.
- 10 Figure 3 is a diagram showing suitable designs of spark gap 2-13 and emitter 2-12 for use with this invention. Figure 3a shows a side illustration, Figure 3b a cross-section along line AA and Figure 3c a cross-section along line BB. The spark gap 2-13 is formed by first 3-1a and second 3-1b electrodes separated by a gap, which is typically in the region of 0.7 mm.
- 15 The electrodes 3-1a, b are dome-shaped and typically made of steel and coated with nickel or chrome. In a preferred embodiment of the invention, the electrodes are sealed in a ceramic chamber containing an argon environment. Other inert gases, in addition to air, are also suitable. The spark gap should however be hermetically sealed in order to prevent the
- 20 accumulation of material on the electrodes, which may impede the discharge of impulses. With this, or similar, electrode arrangement, a voltage of over 3000V is required to cause a discharge current to flow through the surrounding gas, resulting in a sparking between the ends of the electrodes 3-1a,b. The dome shape is advantageous as it allows
- 25 sparks to extend across the gap between the electrodes without being restricted to a base position on the electrode. This extends the life of the electrodes.

The emitter 2-12 abuts the first electrode 3-1a and is electrically isolated

30 therefrom. It consists of inner 3-2 and outer 3-4 thin-walled metal tubes

- 10 -

that are coaxially mounted about the electrode lead, at the opposite side of the electrode to the spark gap 2-13. Plastic end caps 3-3 located at both ends of the tubes 3-2, 3-4 serve to isolate electrically the tubes from the electrode and its lead. The tubes 3-2 and 3-4 are typically made from electro-plated copper or stainless steel. The inner tube 3-2 has an external diameter of around 8mm and length of around 9mm. The outer tube 3-4 has an external diameter of around 12mm and length of about 13mm. The radial gap between the electrode 3-1a and the internal walls of inner tube 3-2 is usually at least 2mm to prevent sparks developing within the emitter.

5 The plastic end caps 3-3 extend beyond the circumference of the outer metal tube 3-4 to prevent sparks developing between the outer walls of the emitter and the dome shaped head of the electrode 3-1a.

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During operation of the device, the emitter tubes 3-2 and 3-4 become charged electro-statically as a result of the impulse discharges across the spark gap 2-13. As a result of the fluctuating electro-static charge, the tubes produce a cooling effect that withdraws natural heat from the surrounding environment, typically air.

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In order for the emitter to produce its effect, it is important that the impulse voltage applied across the spark gap 2-13 has certain properties. In particular it must be a direct current impulse of at least 3 kV and preferably 4 kV. This voltage should be discharged in a timescale of not longer than 100 ns. With these characteristics an impulse will electro-statically charge an emitter 2-12 located in the vicinity of, but electrically isolated from, the spark gap 2-13.

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Figure 4 is a detailed circuit design for a printed circuit board for the cooling device of this invention. The low voltage direct current power supply 2-1 may be connected to this circuit at CN2. As stated previously, this supply

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- 11 -

is conveniently provided by a regulated switched mode mains adaptor or by batteries. Pads P1 and P2 allow an external switch to be fitted to control the power to the circuit. The square wave generator is indicated by integrated circuit U1. Resistors R1, R2, R3 and R4, capacitors C1, C3 and C4, diodes D3 and D4 and transistor Q1 control the square wave produced by U1. As will be apparent to one skilled in the art, if the values of these components are selected appropriately, transistor Q1 will not overheat. The values indicated in Figure 4 provide one example of a suitable combination that ensures transistor Q1 will not normally overheat. The second step up transformer 2-3 is represented in this circuit diagram by T1, which is a 1:25 step up transformer. The square wave generated by U1 is therefore raised (step 1, Figure 1) to medium voltage by T1. The medium voltage current is rectified by bridge rectifier BR1 (2-4). Current reversals are prevented by diode D1 (2-5). These components, enclosed in the diagram by box 4-1 govern the charging, at medium voltage, of control capacitor 2-6 (C7 in Figure 4).

The medium voltage unidirectional direct current is stored in capacitor(s) C7 and converted into short pulses of energy at a regular frequency by switch circuit 2-8, transistor Q2 of Figure 4. Resistors 2-7 (R8 and R9) ensure that capacitor 2-6 (C7) is discharged when the circuit is switched off. Integrated circuits U2 and U3, resistors R5, R6 and R7, capacitors C4, C5, C8, C9 and C10, diodes D9 and D10 control the switching of transistor Q2. This corresponds to step 2, as shown in Figure 1.

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The short pulses (of around 15 μ s duration) discharged from the capacitor 2-6 (C7) are raised to high voltage by the first step up transformer 2-9 (T2), which, in this embodiment, is a 1:20 transformer. The high voltage current is half rectified by diode 2-10 (D2) to create high voltage pulses. The high voltage pulses are discharged in impulses, controlled by capacitor 2-11

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- 12 -

(C6), of less than 100 ns in spark gap 2-13 (FS1). The discharging of capacitor 2-6 (C7) and subsequent raising to high voltage impulses is controlled by the components shown in box 4-2 in Figure 4.

- 5 Diode D2 should be encapsulated in a polyurethane or silicone sealant to prevent the development of high voltage coronas.

In constructing a cooling device in accordance with this invention, the circuit shown in Figure 4 is encased and connected to a source of power.

- 10 Once the device is operated, impulses are discharged across the spark gap 2-13 at a rate of around 300 Hz.

It will be clear to one skilled in the art that circuit parameters can be adjusted to vary the spark discharge characteristics, which in turn affects the cooling that can be achieved. It is important however in considering changes to the circuit to ensure that there is enough energy stored in the control capacitor 2-6 to drive the spark emissions at the rate and voltages required. That is, the charging part of the circuit 4-1 must be capable of providing the energy demanded by the discharging part 4-2. For example, increasing the discharge frequency across the spark gap should increase the cooling that can be achieved. As a consequence however of the control capacitor 2-6 being required to power the discharge sparks more frequently the total energy stored ($\frac{1}{2}CV^2$) should be increased. Care must be taken in increasing this energy that the transformers 2-3, 2-9 are not saturated, with consequent reduction in performance. As a second example, it has been found that a threshold voltage of at least 3 kV is required to generate a spark that is capable of providing cooling. Increasing this voltage generally improves cooling performance, but this effect appears to become saturated at around 4.5 – 5 kV.

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CLAIMS

1. A cooling device comprising a high voltage source connected to a spark gap (2-13) and controlled by a timing means (2-11), wherein the source and timing means (2-11) are arranged to generate unidirectional high voltage pulses which are discharged in short and regular impulses across the spark gap (2-13) and the device also includes an emitter (2-12) located in the vicinity of an electrode (3-1a) of the spark gap and electrically isolated therefrom.
2. A cooling device according to claim 1 wherein the high voltage source is arranged to provide a voltage of at least 3 kV.
3. A cooling device according to claim 2 wherein the high voltage source is arranged to provide a voltage of at least 4 kV.
4. A cooling device according to any preceding claim wherein the timing means (2-11) is arranged to limit the discharge to a timescale of less than 100 ns.
5. A cooling device according to any preceding claim wherein the high voltage source comprises a medium voltage source, timing control means (2-8) for timing power output from said source in medium voltage pulses, a transformer (2-9) arranged to convert the medium voltage pulses to high voltage pulses and a rectifier (2-10) arranged to convert the high voltage pulses to a unidirectional signal.
6. A cooling device according to claim 5 wherein the timing control means comprises a transistor (Q2).

- 14 -

7. A cooling device according to claim 5 or 6 wherein the medium voltage source comprises a storage device (2-6) for storing charge at medium voltage and which is discharged by operation of the timing control means (2-8).
8. A cooling device according to claim 7 wherein the storage device is a capacitor (2-6).
9. A cooling device according to claim 7 wherein the storage device is a bank of capacitors (2-6).
10. A cooling device according to claim 8 or 9 wherein the capacitor (2-6) is charged by a circuit comprising a low voltage source (2-1), a pulse generator (2-2) arranged to produce an alternating signal from the low voltage source, a second transformer (2-3) arranged to convert low voltage input to a medium voltage output and a rectifier (2-4, 2-5) arranged to rectify alternating signal input to direct current output.
11. A cooling device according to any preceding claim wherein the spark gap (2-13) comprises first (3-1a) and second (3-1b) electrodes sealed within a chamber and separated by an insulating gap.
12. A cooling device according to claim 11 wherein the electrodes (3-1a, b) are dome shaped.
13. A cooling device according to claim 11 or 12 wherein the electrodes are made of chrome- or nickel-coated steel.
14. A cooling device according to any one of claims 11 to 13 wherein the chamber is filled with an inert gas.
15. A cooling device according to claim 14 wherein the inert gas is argon.

- 15 -

16. A cooling device according to any preceding claim wherein the emitter (2-12) comprises inner (3-2) and outer (3-4) thin-walled coaxial tubes.
17. A cooling device according to claim 16 wherein the coaxial tubes (3-2, 3-4) are made from materials with good electrical conductivity, such as a ceramic or metallic material, and coaxially mounted about an electrode connection lead.
18. A cooling device according to claim 16 or 17 wherein the tubes have internal diameters in the range 6 mm to 14 mm.
19. A cooling device according to claim 18 wherein the tubes have lengths in the range 7 mm to 20 mm.
20. A method of generating a cooling effect, the method comprising the steps of:-
 - (a) Repeatedly applying a high-voltage, unidirectional pulse of electricity between a pair of electrodes in a gaseous environment, thereby causing sparking between the electrodes; and
 - (b) Diffusing a cooling effect resulting from the sparking by means of an emitter located in the vicinity of the electrodes.
21. A method according to claim 20 wherein the pulse is of duration less than 100 ns and of voltage higher than 3 kV.