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(54) **SYSTEM AND METHOD FOR FORMING AND CONTROLLING ELECTRIC ARCS**

(76) Inventor: **Jeffrey Messer**, San Bernardino, CA (US)

Correspondence Address:
MILBANK, TWEED, HADLEY & MCCLOY
1 CHASE MANHATTAN PLAZA
NEW YORK, NY 10005-1413 (US)

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(57) **ABSTRACT**

A system and method for growing and controlling an electric arc from an electro-magnetic field generator is described. The arc may be formed substantially straight by growing from successively generated electric fields from electro-magnetic generator, such as a waveform-controlled solid state Tesla coil. The growth and direction of the arc may be controlled by forming a low impedance channel created by an area of focused laser light in the path of the growing arc.

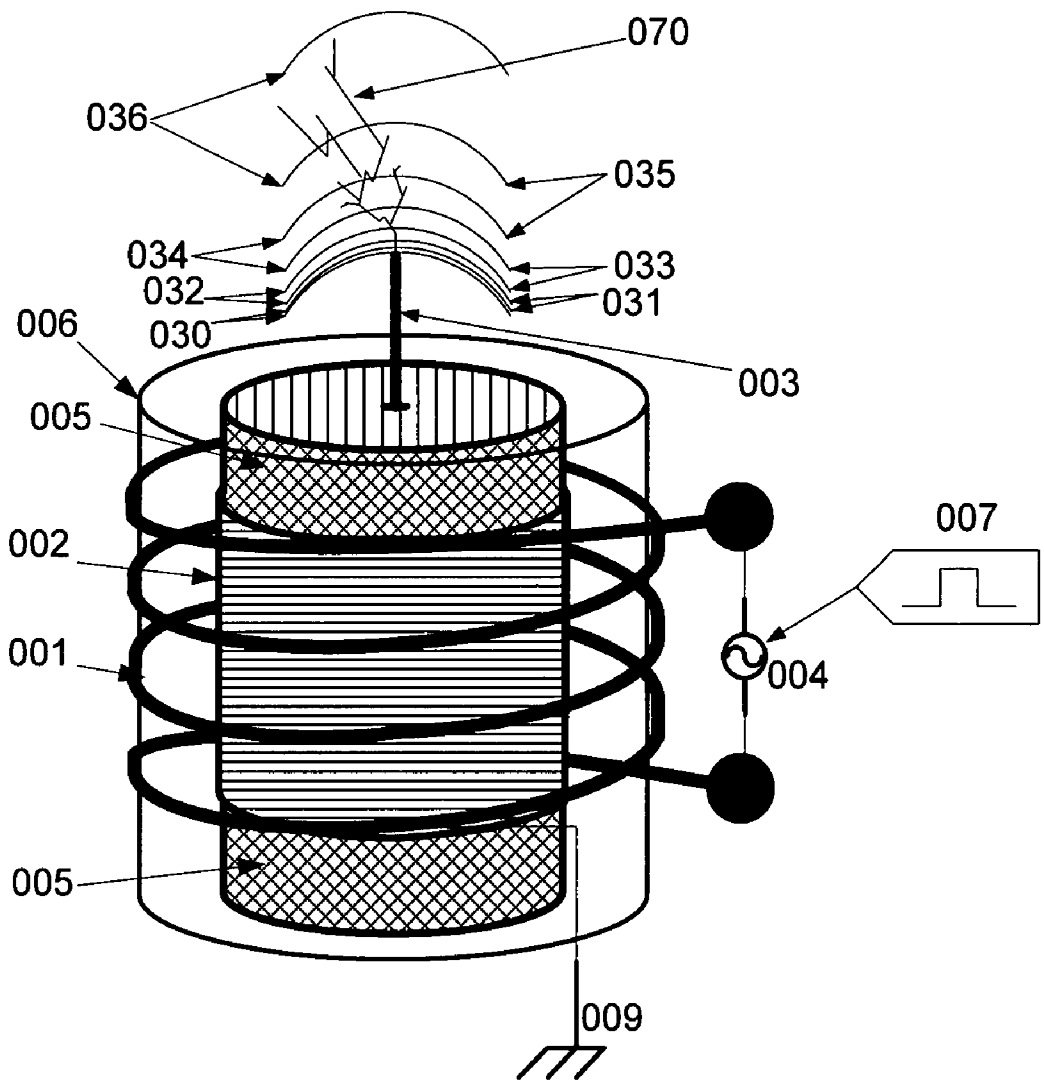
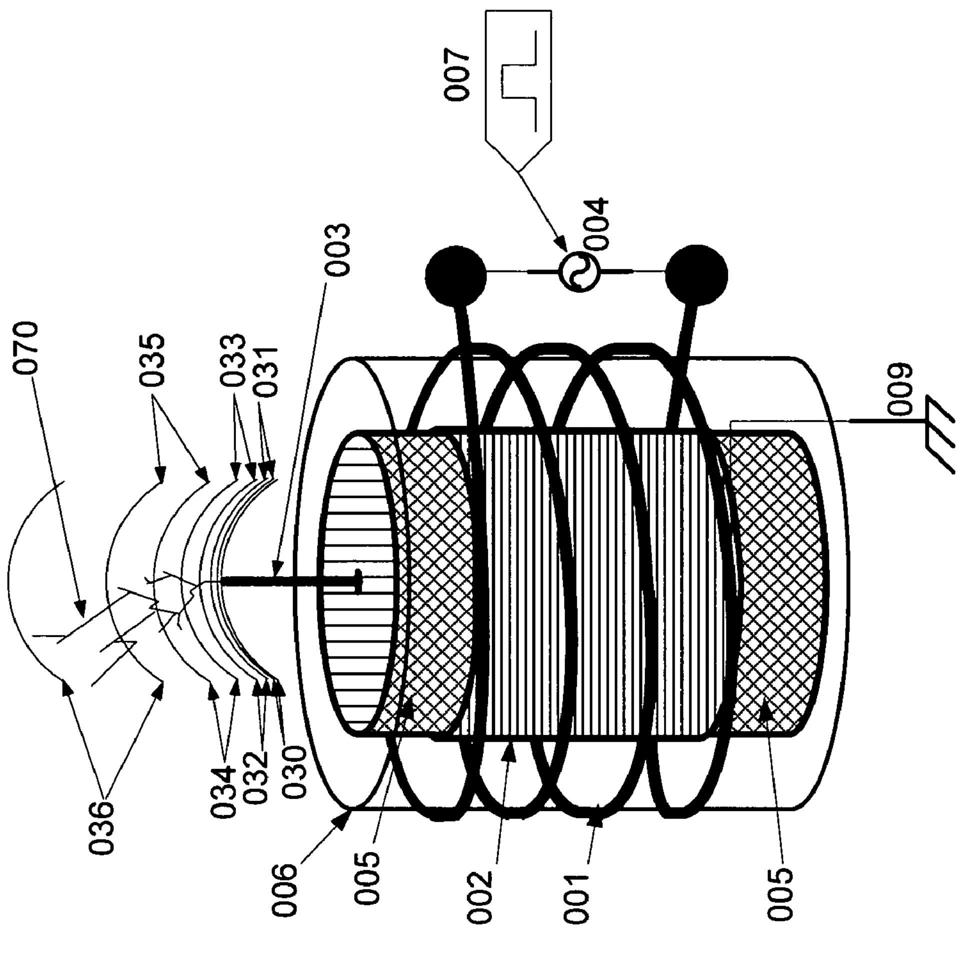


FIG. 1



070
035
033
031
003
007
004
036
034
032
030
009
006
005
002
001
005

FIG. 2b.

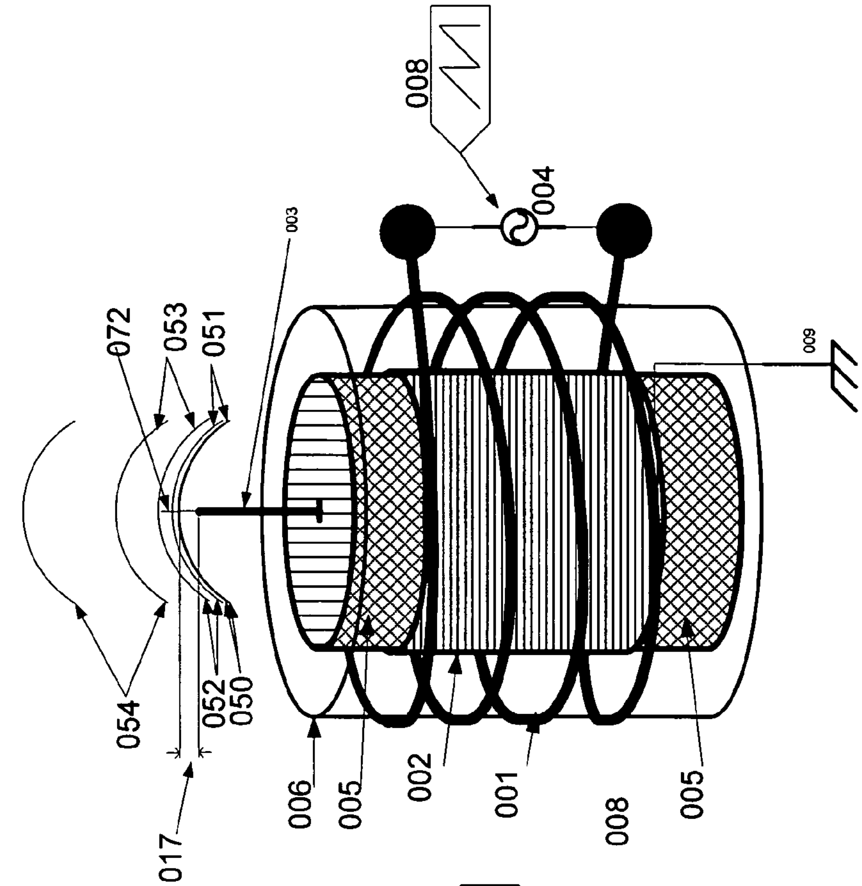

072
053
051
003
008
004
009
054
052
050
017
006
005
002
001
008
005

FIG. 2a.

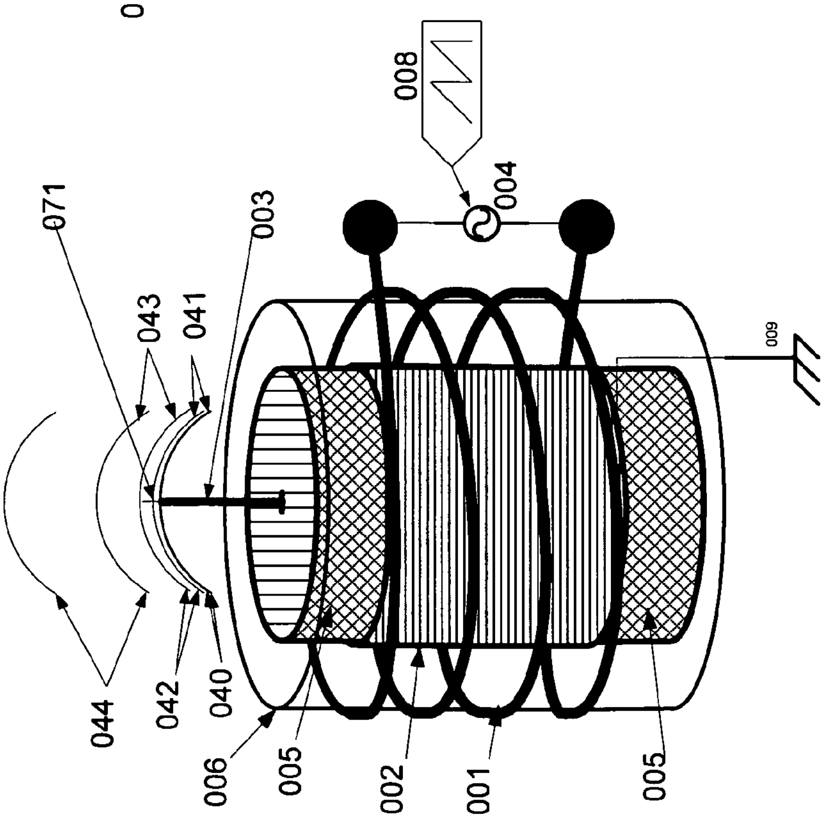

071
003
043
041
008
004
009
044
042
040
006
005
002
001
005

FIG. 3a

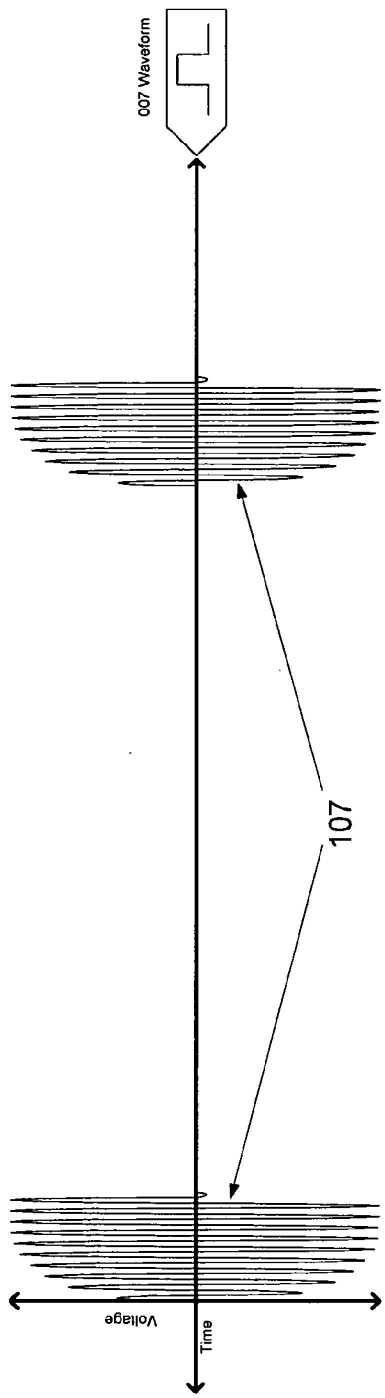

007 Waveform
107
Voltage
Time

FIG. 3b

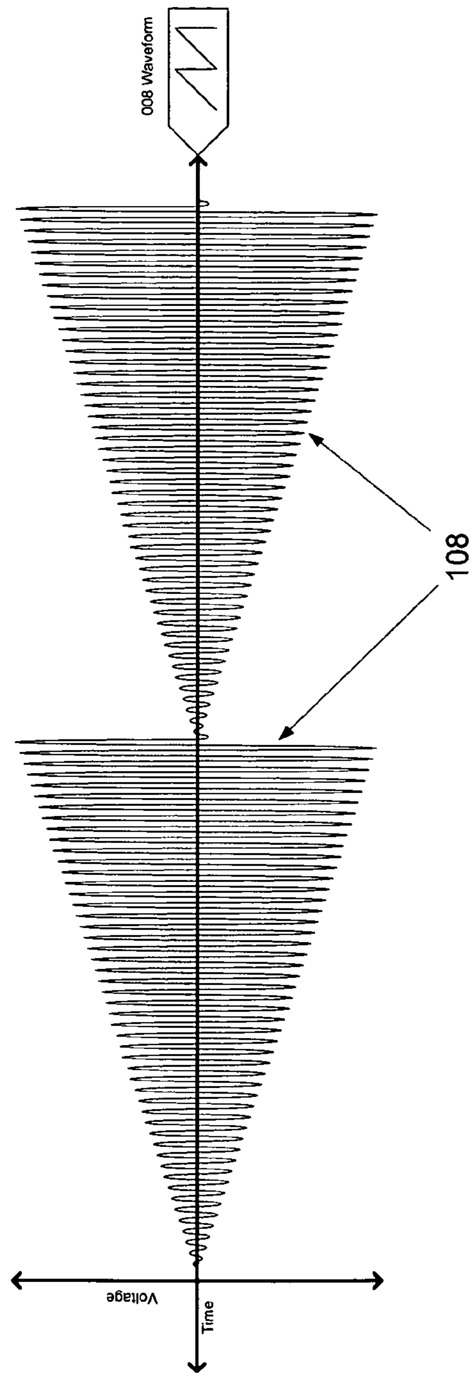
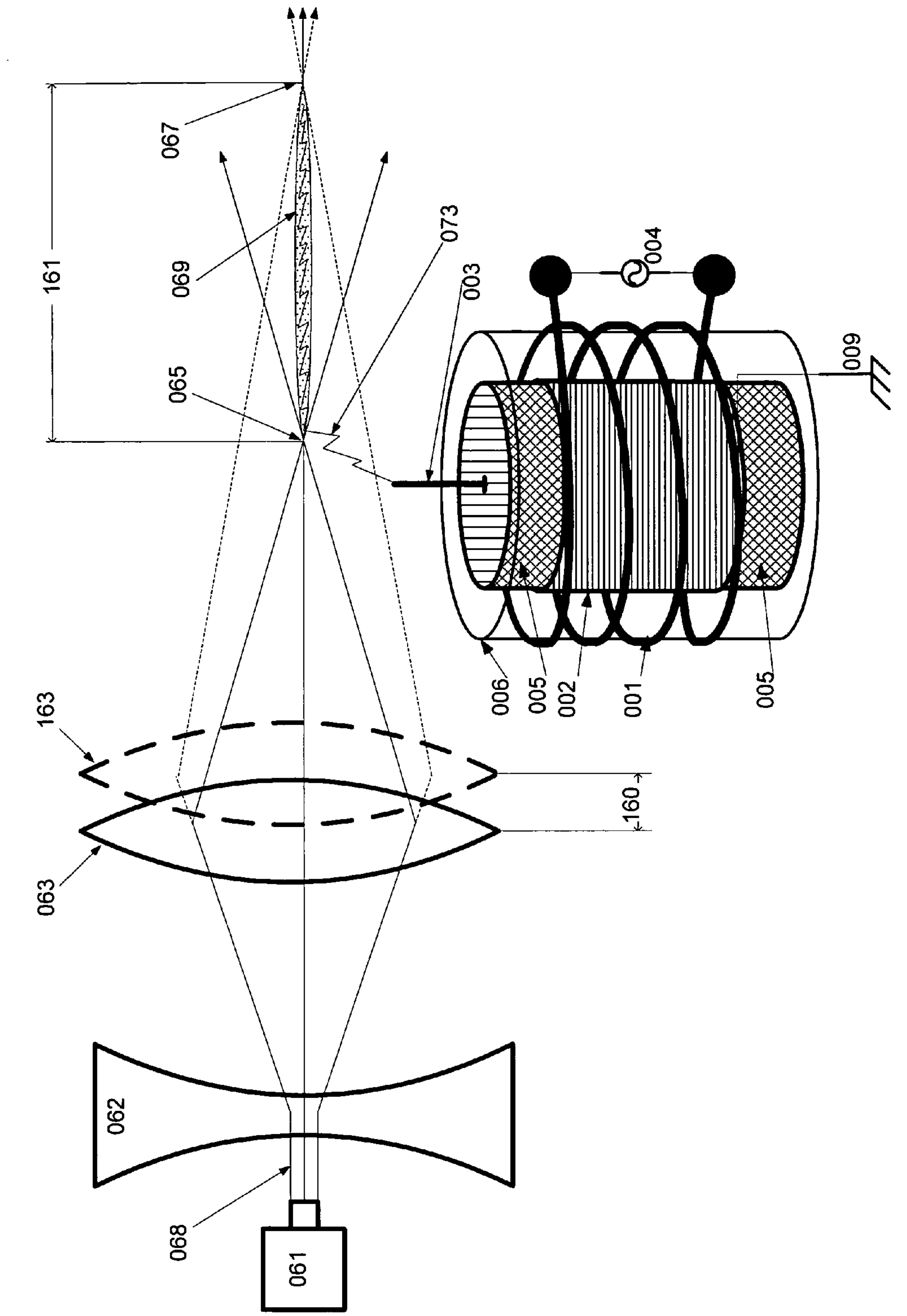

008 Waveform
108
Voltage
Time

FIG. 4


161
067
069
065
073
003
004
009
006
005
002
001
005
163
160
063
062
068
061

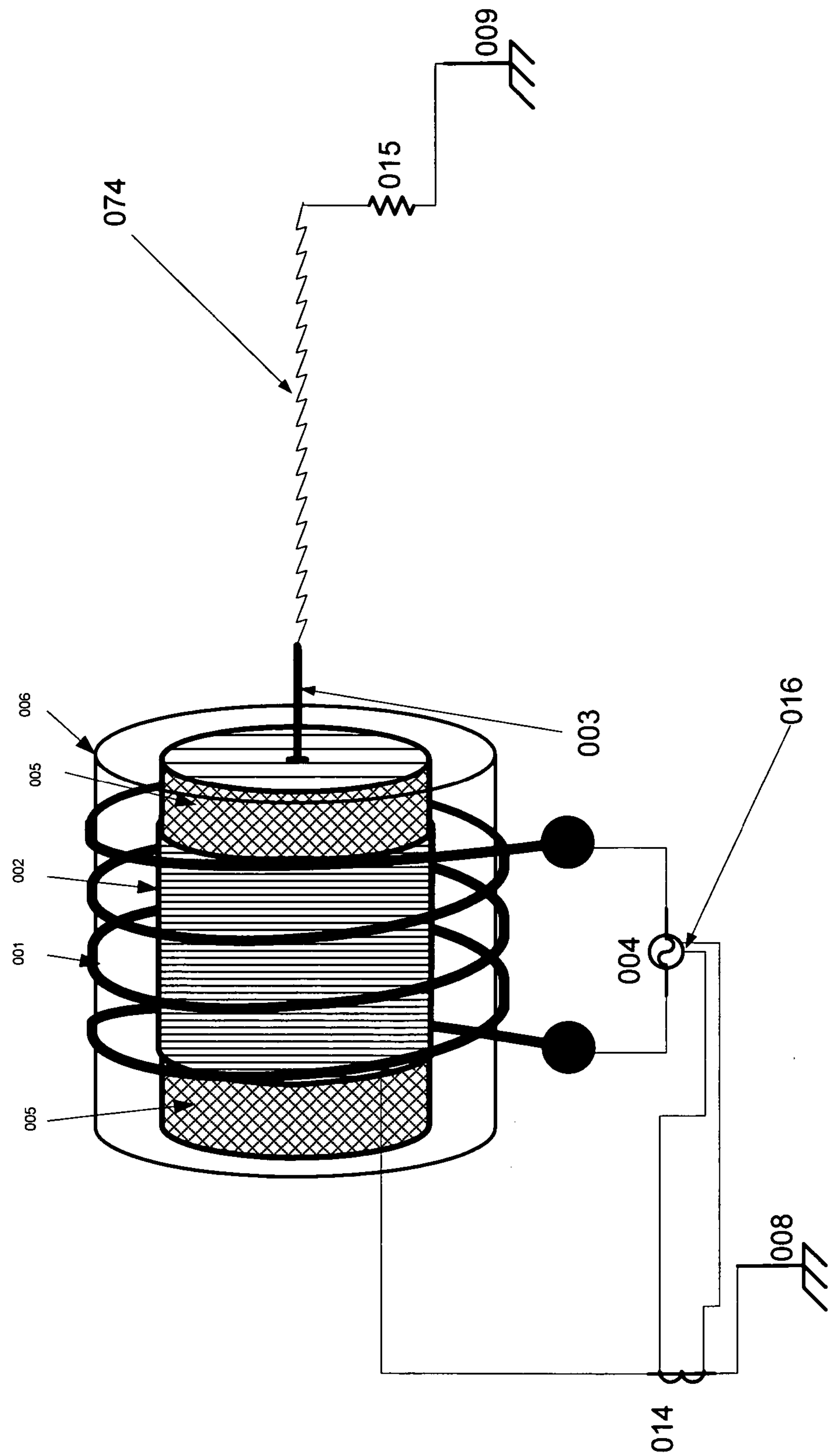


FIG. 5

SYSTEM AND METHOD FOR FORMING AND CONTROLLING ELECTRIC ARCS

[0001] This application claims the benefit of U.S. provisional patent application Ser. No. 60/930,221, filed May 15, 2007, the entire contents of which are hereby incorporated by reference into the present disclosure. This application further hereby incorporates by reference U.S. nonprovisional patent application Ser. No. ______, titled "System and Method for Controlling an Electromagnetic Field Generator," filed May 15, 2008.

FIELD OF THE INVENTION

[0002] The present invention relates to a system and method for forming and controlling electrical discharges or arcs from an electro-magnetic field generator.

BACKGROUND OF THE INVENTION

[0003] Various types of electro-magnetic field generators capable of forming electrical discharges are known. For example, a type of air core transformer known as a solid-state Tesla coil (SSTC) is capable of forming such electric arcs. A SSTC is a well-known resonant transformer that typically uses an alternating current power source and at least two coils to generate a high-voltage at an electrode where electric arcs may be formed.

[0004] Some previous efforts have attempted to control the path of such electric arcs by having the arcs travel down the path of a laser. Such prior efforts have been unsuccessful at least in part because lasers have sufficient power to create an area between the source and the target of low impedance, which is simply too minute in time to be useful. In most cases, any laser strong enough to ionize a sizable path in air would do more damage to a target than an arc.

[0005] Also, these previous efforts have attempted to use a high voltage DC source to create these electric arcs, leaving no direct control over the waveform itself because it is a pulse of DC current. Such a short pulse duration period severely limits the time in which an electrical current can be delivered to a target.

[0006] This problem can also be seen with the use of TASERS, which use a straight and direct line of low electrical impedance to pulse controlled waveforms of current and voltage to a target for a desired period of time.

SUMMARY OF THE INVENTION

[0007] In certain embodiments, the present invention may provide a system for controlling the formation of an electric arc, comprising: an electro-magnetic field generator that generates a first portion of an electric arc having a beginning at a discharge electrode and a second portion of the electric arc having a beginning at an end of the first portion of the electric arc, wherein the first portion and the second portion of the electric arc are substantially straight. The first portion of the electric arc is formed from a first electric field created by the electro-magnetic field generator and the second portion of the electric arc is formed from a second electric field created by the electro-magnetic field generator. The system further comprises a laser source emitting laser light that is focused to create a low impedance path for the electric arc, wherein the low impedance path is formed to grow or change the direction of the electric arc. The second portion of the electric arc has an end at a desired target and the electric arc has a path between the discharge electrode and the desired target that is substantially straight. The system further comprises an alternating current drive system is connected to the electro-magnetic field generator, wherein the alternating current drive system has a saw-tooth waveform output.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] Features and other aspects of embodiments of the present invention are explained in the following description taken in conjunction with the accompanying drawings, wherein like references numerals refer to like components, and wherein:

[0009] FIG. **1** illustrates in perspective view a system for forming a typical electric arc from an electro-magnetic field generator; and

[0010] FIGS. **2**A and **2**B illustrate in perspective view a system for forming a substantially straight electric arc from an electro-magnetic field generator in accordance with an embodiment of the present invention.

[0011] FIG. **3**A shows a graph of voltage output from a standard square alternating current waveform over time.

[0012] FIG. **3**B shows a graph of increasing voltage output from a sawtooth alternating current waveform over time.

[0013] FIG. **4** illustrates in perspective view a system for controlling an electric arc formed by an electro-magnetic field generator in accordance with an embodiment of the present invention

[0014] FIG. **5** illustrates in perspective view a system for forming a substantially straight electric arc from a current drive controlled electro-magnetic field generator in accordance with an embodiment of the present invention

[0015] The drawings are exemplary, not limiting.

DETAILED DESCRIPTION

[0016] Various embodiments of the present invention will now be described in greater detail with reference to the drawings.

[0017] As shown in FIG. **1**, a solid state alternating current driving system **004** is disclosed with a square waveform output **007** driving primary coil **001**, which induces a current into Tesla resonator **002**, thus energizing the Tesla coil. Primary coil **001** is on non-conducting form **006** and secondary coil **002** is on non-conductive form **005**.

[0018] Primary coil **001** and secondary coil **002** together create a SSTC or air-core resonance transformer that, when driven by driving system **004**, produces a relatively high voltage at discharge electrode **003** with respect to ground **009**. Secondary coil **002** is connected to discharge electrode **003** (not pictured). The voltage potential between discharge electrode **003** and ground **009** creates an electrical field that drops off as 1/r with respect to discharge electrode **003** where r is the distance from discharge electrode **003**. This electric field also creates equal voltage potentials as shown in FIG. **1** by equal voltage potential lines **030-036**. These voltage potentials, when strong enough, can rip electrons from the nucleus of atoms, creating an arc or plasma formations. Upon energizing the SSTC shown in FIG. **1**, arc **070** is created as it passes through voltage potentials **030-036**. As illustrated in FIG. **1**, arc **070** starts out growing substantially straight in regions denoted by equal voltage potentials **030** and **031**, where the electric field generated by SSTC is relatively strong. However, as arc **070** passes into increasing weaker parts of the electric field denoted by equal potential lines **033**, **034**, **035**, and **036**, arc **070** is not substantially straight and its path becomes more random. As the outer edge of arc **070** becomes further away from discharge electrode **003** and as arc **070** grows, the voltage potential lines spread as a function of 1/r. Thus, the electric field strength at equal potential lines **035** and **036** are considerably weaker than at equal potential lines **030** and **031**.

[0019] In accordance with an embodiment of the present invention, FIGS. **2***a* and **2***b* disclose an apparatus for forming a substantially straight arc. As will be understood with reference to the following description, FIG. **2**A discloses an apparatus for forming a substantially straight arc in an initial stage and FIG. **2**B discloses an apparatus for forming a substantially straight arc in a stage subsequent to that shown in FIG. **2**A.

[0020] With reference to FIG. **2***a*, a solid state alternating current driving system **004** is disclosed with saw tooth waveform output **008** driving primary coil **001**, which induces current into Tesla resonator **002**, thus energizing the SSTC. Primary coil **001** is on a non-conducting form **006** and secondary coil **002** is on a non-conductive form **005**. Secondary coil **002** is connected to discharge electrode **003** (not pictured). Primary coil **001** and secondary coil **002** together create a SSTC or air core resonance transformer and when driven by driving system **004** a relatively high voltage at discharge electrode **003** with respect to ground **009** is created. This voltage potential between discharge electrode **003** and ground **009** creates an electrical field that drops off as 1/r with respect to discharge electrode **003** where r is the distance away from discharge electrode **003**. This electric field creates equal voltage potentials as shown by equal potential line **040**-**044**. One of ordinary skill in the art recognizes that there are not as many equal voltage potential lines in FIG. **2***a* and FIG. **2***b* as in FIG. **1** because square waveform output **007** generates higher voltage potential than sawtooth waveform output **008** due to the instantaneous jump in input power due to square waveform **007**.

[0021] Upon energizing the SSTC shown in FIG. **2***a*, arc **071** is formed. Initially, arc **071** is small but substantially straight because it is created in an area denoted by equal voltage potentials lines **040**, **041**, and **042** where the electric field is relatively strong and consistent. The constantly growing input waveform **008** supplies arc **071** with sufficient electric field to sustain plasma formation around arc **071**, but does not give arc **071** enough power to grow substantially in physical length, which would result in arc **071** growing into a weaker part of the electric field. Instead, an appropriate amount of power is generated such that arc **071** is maintained until a next electric field peak in Tesla resonator **002** creates a new electric field around arc **071**. For a description of the generation of this next electric field, see U.S. patent application Ser. No. ______, filed on May 15, 2008 entitled "System and Method for Controlling an Electromagnetic Field Generator," the entire disclosure of which is hereby incorporated by reference.

[0022] When a new electric field around arc **071** is generated by SSTC, new equal voltage potential lines **050**-**054** illustrated in FIG. **2***b* are created around arc **071**. As denoted by distance **17** in FIG. **2***b*, under the new electric field, the arc itself in FIG. **2***b* acts as discharge electrode **003** from FIG. **2***a*. This allows another straight arc to be grown off the end of arc **071** from FIG. **2***a* to create arc **072** as shown in FIG. **2***b*. As with arc **071** in FIG. **2***a*, arc **072** is substantially straight because it is grown in the strong part of the electric field. Furthermore, because the portion of arc **072** nearest to discharge electrode **003** created by the forming of arc **071** is substantially straight, it should be clear that the entire length of arc **072** is substantially straight. This straight arc growing process, as seen from the combination of FIG. **2***a* and FIG. **2***b*, can be repeated until the resultant arc reaches its desired length and at that point saw-tooth wave output **008** drops back down to zero from its maximum potential. With reference to FIG. **2***b*, secondary coil **002** is connected to discharge electrode **003** (not pictured).

[0023] FIG. **3***a* shows a graph of the voltage of a square waveform **007** of an alternating voltage output **107** as a function of time for a typical SSTC. As seen in FIG. **3***a*, the amplitude of the voltage increases to a maximum value within a few AC cycles. Therefore, the result would be an arc that is formed in areas where the electric field generated by a SSTC is inconsistent or weak or both. Under these circumstances, the arc would be created almost instantaneously and would reach its full arc length in just a few cycles. It should be noted that the energy needed to create this arc is high, and therefore a SSTC that generates such waveforms may be pulsing with a duty cycle in the range of from approximately 0.5% to approximately 5%. For example, FIG. **3***a* may represent a voltage graph associated with an arc formation generated from a SSTC illustrated in FIG. **1**.

[0024] FIG. **3***b* illustrates a graph of the voltage of a sawtooth waveform of an alternating voltage output **108** as a function of time. As shown in FIG. **3***b*, the amplitude of the voltage slowly increases over time. In fact, the amplitude of the voltage increases to a maximum value after numerous AC cycles. Such a wave may be created by sending a **008** waveform into a SSTC such that more power per unit of time is sent into the Tesla resonator as time passes. For example, FIG. **3***b* may represent a voltage graph associated with the arc formation from a SSTC illustrated in FIGS. **2***a* and **2***b*.

[0025] Another embodiment of the present invention is disclosed with reference to FIG. **4**. In FIG. **4**, laser source **061** emits laser light **068**, which is diverged by lens **062** and then converged by lens **063**. Secondary coil **002** is connected to discharge electrode **003** (not pictured). After traveling through lens **62** and lens **63**, laser light **068** then converges to focal point **065**. At focal point **65** is a small and localized area of relatively high electric field where electrons are ripped away from the nucleus of atoms that serves to make a low impedance carrier of electrical current.

[0026] It should be appreciated that lens **063** in FIG. **4** can move a distance **160** thus allowing lens **063** to be moved to position **163**. By moving lens **063** to position **163** while laser **061** emits laser light **068** results in converging laser light **068** along a substantially straight line between focal point **065** and focal point **067**. The area between focal points **65** and **67** forms a low impedance channel **069** of broken down air. One of ordinary skill in the art will understand that different laser and lens arrangements are possible to form low impedance channel **69**.

[0027] With reference to FIG. **4**, it may be seen that arc **073** created by SSTC may then be used in conjunction with low impedance channel **69**. In particular, by forming low impedance channel **69** near arc **073**, it is possible to correct or change the path of arc **073** or control its path to a desired target.

[0028] FIG. **5** discloses another embodiment of the present invention. FIG. **5** illustrates a substantially straight arc **074**

formed by a SSTC, such as the SSTC discussed with reference to FIGS. **2***a* and **2***b*. In FIG. **5**, arc **074** generated by a SSTC grows such that it hits resistive target **015** connected to ground **009**. Secondary coil **002** is connected to discharge electrode **003** (not pictured).

[0029] In FIG. **5**, current drive transformer **014** connected between ground **008** and the **002** Tesla resonator can detect and measure the amount of current flow in real time and can give constant feedback signals via path **016** to driving system **004**. Such an arrangement permits the current flowing through current drive transformer **014** to be the same as, or close to, the current traveling through resistive target **015** connected to ground **009**. Thus direct and real time current levels through target **015** can be controlled and measured via current drive transformer **014** and driving system **004** disclosed in FIG. **5**.

[0030] In one example of this embodiment, one may set driving system **004** to shut down for a few cycles if the current rises above a specified value, such as one milliamp, thus creating a less than lethal arc that could be used to provide an electrical shock to a human target. At such time when the target is engaged, pulsed waveforms could be sent to incapacitate the target. Because a high frequency waveform cannot be felt due to neurons that cannot close and open fast enough, a lower frequency pulsing of the waveform controlled by driver **004** would interact with the neurons of the human body, incapacitating the target if needed. Thus, it is possible to send a harmless or painless arc to a human target as a warning. Alternatively, for a more harmful approach, it would be possible to disregard current monitoring input **016** such that driver **004** could be set for maximum beats per seconds to send a more harmful arc to a target for a desired period of time.

[0031] Although illustrative embodiments have been shown and described herein in detail, it should be noted and will be appreciated by those skilled in the art that there may be numerous variations and other embodiments that may be equivalent to those explicitly shown and described. For example, the scope of the present invention is not necessarily limited in all cases to execution of the aforementioned steps in the order discussed. Unless otherwise specifically stated, terms and expressions have been used herein as terms of description, not of limitation. Accordingly, the invention is not to be limited by the specific illustrated and described embodiments (or the terms or expressions used to describe them) but only by the scope of claims.

What is claimed is:

1. A system for controlling the formation of an electric arc, comprising:
- an electro-magnetic field generator that generates a first portion of an electric arc having a beginning at a discharge electrode and a second portion of the electric arc having a beginning at an end of the first portion of the electric arc,
- wherein the first portion and the second portion of the electric arc are substantially straight.

2. The system of claim **1**, wherein the first portion of the electric arc is formed from a first electric field created by the electro-magnetic field generator and the second portion of the electric arc is formed from a second electric field created by the electro-magnetic field generator.

3. The system of claim **1**, further comprising.
- a laser source emitting laser light that is focused to create a low impedance path for the electric arc.

4. The system of claim **3**, wherein the low impedance path is formed to grow or change the direction of the electric arc.

5. The system of claim **3**, wherein the laser light is focused by an optical lens.

6. The system of claim **1**, wherein the second portion of the electric arc has an end at a desired target.

7. The system of claim **6**, wherein the electric arc has a path between the discharge electrode and the desired target that is substantially straight.

8. The system of claim **6**, further comprising:
- an alternating current drive system is connected to the electro-magnetic field generator.

9. The system of claim **8**, wherein the alternating current drive system has a saw-tooth waveform output.

10. A system for controlling the formation of an electric arc, comprising:
- a laser source that emits laser light to create a low impedance channel; and
- an electro-magnetic field generator that forms a substantially straight electric arc, a portion of which is located in the low impedance channel.

11. The system of claim **10**, wherein the electric arc has a beginning at a discharge electrode and an end at a desired target.

12. The system of claim **10**, wherein first or second electric arc portion are formed in a low impedance channel.

13. The system of claim **10**, wherein the low impedance channel is formed by focusing the laser light.

14. The system of claim **10**, wherein the electro-magnetic field generator is driven by an alternating current drive system having a saw-tooth waveform output.

15. The system of claim **10**, wherein the electro-magnetic field generator is a solid state Tesla coil.

16. A method of forming a substantially straight electric arc, comprising the steps of:
- generating a first electric field emanating from a discharge electrode;
- growing a substantially straight first electric arc portion having a beginning at the discharge electrode;
- generating a second electric field emanating from the first electric arc portion; and
- growing a substantially straight second electric arc portion having a beginning at an end of the first electric arc portion to form a substantially straight electric arc.

17. The method of claim **16**, wherein first or second electric arc portion are formed in a low impedance channel.

18. The method of claim **16**, wherein the substantially straight electric arc connects the discharge electrode to a desired target.

19. The method of claim **16**, further comprising:
- repeating the generating and growing steps to form a third electric arc portion
- having a beginning at an end of the second electric arc portion.

20. The method of claim **16**, wherein the first electric field is generated by an electro-magnetic field generator that is driven by an alternating current drive system having a saw-tooth waveform output.

* * * * *