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(54) Title: RAPID PULSE ELECTROHYDRAULIC (EH) SHOCKWAVE GENERATOR APPARATUS WITH IMPROVED ELECTRODE LIFETIME

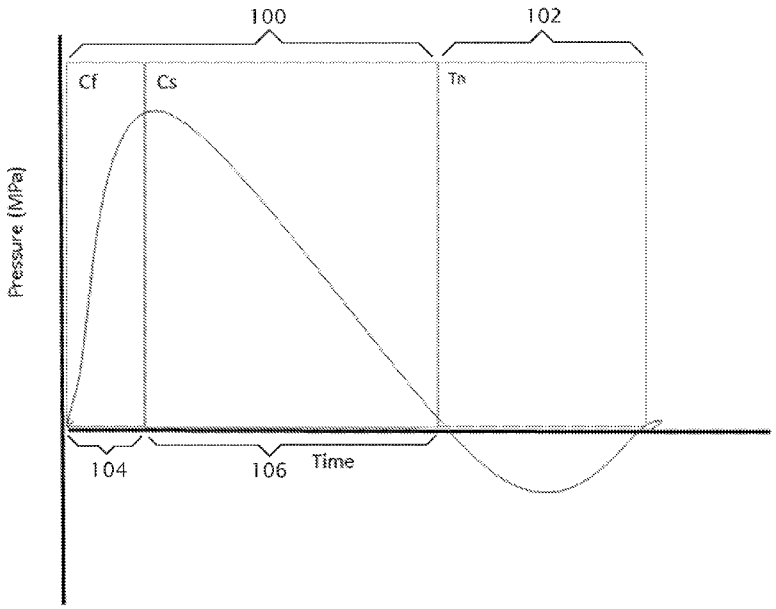

FIG. 1

(57) Abstract: Apparatuses, capacitor arrays, and methods for generating therapeutic compressed acoustic waves (e.g., shock waves). In the apparatuses and at least some of the methods, a plurality of electrodes can disposed in a chamber that is defined by a housing and configured to be filled with liquid, and a plurality of capacitors can be electrically connected to the electrodes and can be carried by (e.g., physically coupled to) the housing. Voltage pulses can be applied simultaneously to the plurality of electrodes (e.g., to begin to vaporize and ionize portions of the liquid to provide at least one inter-electrode conductive path between the plurality of electrodes) and to the capacitors to charge the plurality of capacitors). The plurality of capacitors can be configured to, upon reaching a threshold charge, discharge to the plurality of electrodes (e.g., to generate one or more arcs along the one or more inter- electrode conductive paths to vaporize additional portions of the liquid and generate one or more acoustic shock waves). In the capacitor arrays, a plurality

WO 2018/017414 A3

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Published:

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— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

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01 March 2018 (01.03.2018)

of capacitors can be coupled to the one or more circuit boards with a first portion of the capacitors arranged in a first pattern defined by a plurality of capacitor sets, a second portion of the plurality of capacitors can be arranged in a second pattern defined by a plurality of capacitor sets, with the sets defining the first pattern connected in parallel, the sets defining the second pattern connected in parallel, and the circuit board(s) can be configured to be coupled to an electrode such that the electrode is in electrical communication with the capacitors and is fixed in at least two degrees of freedom relative to the one or more circuit boards.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2017/042122

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - A61B 17/00; A61B 17/22; A61H 23/00; A61N 7/00 (2017.01)
CPC - A61B 17/22004; A61B 17/225; A61B 17/2258; A61H 23/008 (2017.08)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
See Search History document

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
USPC - 361/301.1; 601/1; 601/2; 607/2 (keyword delimited)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
See Search History document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 2014/0257144 A1 (BOARD OF REGENTS THE UNIVERSITY OF TEXAS SYSTEM et al) 11 September 2014 (11.09.2014) entire document	1-3, 9, 22-24, 44-46 --- 4-8
Y	US 2015/0217111 A1 (GREATBATCH LTD) 06 August 2015 (06.08.2015) entire document	4-8
A	US 6,515,842 B1 (HAYWORTH et al) 04 February 2003 (04.02.2003) entire document	10-21, 25-43
A	CN 100530868 C (SICHUAN ZHONGGUANG LIGHTENING PROTECTION SCIENCE AND TECHNOLOGY CO LTD) 19 August 2009 (19.08.2009) machine translation	1-46
A	US 2016/0016013 A1 (SOLITON INC et al) 21 January 2016 (21.01.2016) entire document	1-46

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
04 December 2017	09 JAN 2018
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, VA 22313-1450 Facsimile No. 571-273-8300	Authorized officer Blaine R. Copenheaver PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2017/042122

Continued from Box No. III Observations where unity of invention is lacking

This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fees need to be paid.

Group I, claims 1-24, 44-46 are drawn to a system including electrodes for generating an arc discharge.
Group II, claims 25-43 are drawn to a capacitor arrangement.

The inventions listed in Groups I and II do not relate to a single general inventive concept under PCT Rule 13.1, because under PCT Rule 13.2 they lack the same or corresponding special technical features for the following reasons:

The special technical features of Group I, a housing defining a chamber and a shockwave outlet; a liquid disposed in the chamber; a plurality of electrodes configured to be disposed in the chamber to define one or more spark gaps, a pulse-generation system configured to be coupled to the plurality of electrodes such that: (i) the housing is movable relative to the pulse-generation system, and (ii) the pulse-generation system is in electrical communication with the plurality of electrodes and the plurality of capacitors; where the pulse-generation system is configured to apply voltage pulses simultaneously to: the plurality of electrodes to begin to vaporize and ionize portions of the liquid to provide at least one inter-electrode conductive path between the plurality of electrodes, and the plurality of capacitors to charge the plurality of capacitors; where the plurality of capacitors are configured to, upon reaching a threshold charge, discharge to the plurality of electrodes to generate one or more arcs along the one or more inter-electrode conductive paths to vaporize additional portions of the liquid and generate one or more acoustic shock waves, applying voltage pulses to a plurality of electrodes in a chamber defined by a housing and filled with liquid such that portions of the liquid begin to vaporize and ionize to provide an inter-electrode conductive path, upon the plurality of capacitors reaching a threshold charge, discharging the plurality of capacitors to the electrodes to generate an inter-electrode arc along the established inter-electrode conductive path and thereby generate of at least one acoustic shock wave, are not present in Group II; and the special technical features of Group II, where a first portion of the capacitors is arranged in a first pattern defined by a plurality of capacitor sets, a second portion of the plurality of capacitors is arranged in a second pattern defined by a plurality of capacitor sets, each capacitor set comprises two or more of the capacitors connected in series; the capacitor sets defining the first pattern are connected in parallel, and the capacitor sets defining the second pattern are connected in parallel; and where the one or more circuit boards are configured to be coupled to an electrode such that the electrode is in electrical communication with the capacitors and is fixed in at least two degrees of freedom relative to the one or more circuit boards, are not present in Group I.

Groups I and II share the technical features of a system for generating therapeutic shockwaves comprising one or more circuit boards, and a plurality of capacitors coupled to the one or more circuit boards, and where the one or more circuit boards are configured to be coupled to an electrode such that the electrode is in electrical communication with the capacitors. However, these shared technical features do not represent a contribution over the prior art. Specifically, US 2014/0257144 A1 to Board of Regents, The University of Texas System et al. teaches of a system for generating therapeutic shockwaves (Abstract) comprising one or more circuit boards (Fig. 5, a circuit 400, para. [0098]), and a plurality of capacitors coupled to the one or more circuit boards (Fig. 5, capacitors 424a-424c within the circuit 400, para. [0099]), and where the one or more circuit boards are configured to be coupled to an electrode such that the electrode is in electrical communication with the capacitors (Fig. 5, wherein the capacitors 424a-424c are in communication with spark gaps 412a-412c, the spark gaps defined by a pair of electrodes each, para. [0098]-[0099]).

Since none of the special technical features of the Group I and II inventions are found in more than one of the inventions, unity is lacking.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2017/042122

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:
See extra sheet(s).

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☒ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2017/042122

Box No. I Nucleotide and/or amino acid sequence(s) (Continuation of item 1.c of the first sheet)

1. With regard to any nucleotide and/or amino acid sequence disclosed in the international application, the international search was carried out on the basis of a sequence listing:

   a. ☐ forming part of the international application as filed:

      ☐ in the form of an Annex C/ST.25 text file.

      ☐ on paper or in the form of an image file.

   b. ☐ furnished together with the international application under PCT Rule 13*ter*.1(a) for the purposes of international search only in the form of an Annex C/ST.25 text file.

   c. ☒ furnished subsequent to the international filing date for the purposes of international search only:

      ☒ in the form of an Annex C/ST.25 text file (Rule 13*ter*.1(a)).

      ☐ on paper or in the form of an image file (Rule 13*ter*.1(b) and Administrative Instructions, Section 713).

2. ☐ In addition, in the case that more than one version or copy of a sequence listing has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that forming part of the application as filed or does not go beyond the application as filed, as appropriate, were furnished.

3. Additional comments: