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(54) **Title**: OPTIMIZING ACOUSTIC EFFICIENCY OF A SONIC FILTER OR SEPARATOR

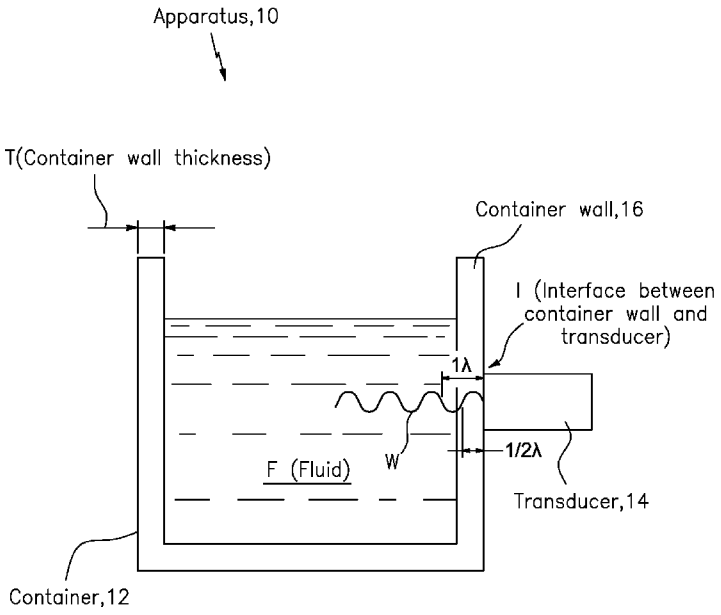

FIG. 1

(57) **Abstract**: Apparatus features a container and a transducer. The container is made of a selected material and has a container wall with a selected thickness, and configured to hold a fluid therein. The transducer is configured on the outside of the container wall, and is also configured to provide a standing wave into the fluid. The selected thickness and material of the container wall is chosen to ensure about a 1 /2 wavelength of a desired frequency exists within the container wall, so as to substantially reduce back reflections toward the transducer due to any mismatch in acoustic impedance at the interface between the container wall and the fluid, and so as to substantially maximize the amount of energy delivered to the fluid, thus improving the operating efficiency of the apparatus.

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OPTIMIZING ACOUSTIC EFFICIENCY OF A SONIC FILTER OR SEPARATOR

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims benefit to provisional patent application serial no. 61/439,540 (CCS-0041), filed 4 February 2011, which is incorporated by reference in their entirety.

BACKGROUND OF THE INVENTION

1. Field of Invention

The present invention relates to a technique for providing a standing wave into fluid in a container.

2. Description of Related Art

Sonic filters and separators based upon standing wave agglomeration are known and have been demonstrated. The efficiency of such filters is determined by the amount of electrical energy required to obtain a specified level of separation.

Typically, a standing wave may be set up in a fluid by acoustically driving the fluid by situating an appropriate transducer to the outside of the container containing the fluid. However, one problem with this type of configuration is that the interface between the fluid and the container wall causes back reflections (toward the transducer) due to the mismatch in acoustic impedance between the container wall and the fluid. This reflection results in less acoustic energy being

imparted to the fluid. Because of this, the maximum amount of energy is not delivered to the fluid, thus reducing the operating efficiency thereof.

There is a need to improve the efficiency of such filters, e.g., by lowering the required acoustic drive power.

The is also a need in the industry to improve the maximum amount of energy delivered to the fluid, thus improving the operating efficiency of these types of devices and processes.

SUMMARY OF THE INVENTION

The present invention provides for a proper selection of the thickness and/or material to ensure that a 1/2 wavelength of a desired frequency exists within the container wall. Under these conditions, a maximum amount of energy is delivered to the fluid, thus improving the operating efficiency.

The present invention also provides an improved excitation method to improve the efficiency by lowering the required acoustic drive power.

According to some embodiments, the present invention may take the form of apparatus featuring a container and a transducer. The container has a container wall characterized by at least one parameter, including being made of a selected type of material or having a selected thickness, and is configured to hold a fluid therein. The transducer is configured on the outside of the container wall, and is also configured to provide a standing wave into the fluid. The at least one parameter of the container wall is selected to ensure about a 1/2 wavelength of a desired frequency exists within the container wall, so as to substantially reduce

back reflections toward the transducer due to any mismatch in acoustic impedance at the interface between the container wall and the fluid, and so as to substantially maximize the amount of energy delivered to the fluid, thus improving the operating efficiency of the apparatus.

According to some embodiments, the present invention may also include some combination of the following features:

- The at least one parameter may include a combination of the selected material and the selected thickness of the container wall.

- The container wall may be a steel plate

- The container wall may have a thickness of about 3/4".

- The transducer may be configured to provide the standing wave into the fluid with a sound speed in the steel plate of about 5,740 meters/sec, so as to produce a first 1/2 wave resonance at about 150.7KHz, a second resonance (first full wave) at about 301.4KHz, and a third resonance at about 452.1KHz.

- The apparatus may include, or take the form of, a sonic filter or separator.

BRIEF DESCRIPTION OF THE DRAWING

The drawing includes Figure 1, which is not necessarily drawn to scale, and which is a diagram showing apparatus according to some embodiments of the present invention.

DETAILED DESCRIPTION OF BEST MODE OF THE INVENTION

By way of example, Figure 1 shows the present invention in the form of apparatus generally indicated as 10 featuring a container 12 in combination with a transducer 14. The container 12 has a container wall 16 characterized by at least one parameter, including being made of a selected type of material or having a selected thickness T. The container 12 is configured to hold a fluid F therein. The transducer 14 is configured on the outside of the container wall 16, and is also configured to provide a standing wave W into the fluid F.

The at least one parameter of the container wall 16 is selected to ensure about a 1/2 wavelength (1/2λ) of a desired frequency exists within the container wall 16, so as to substantially reduce back reflections toward the transducer 14 due to any mismatch in acoustic impedance at the interface I between the container wall 16 and the fluid F, and so as to substantially maximize the amount of energy delivered to the fluid F, thus improving the operating efficiency of the apparatus 10.

According to some embodiments of the present invention, the at least one parameter may be a combination of the selected material and the selected thickness T of the container wall 16.

According to some embodiments of the present invention, the container wall 16 may be a steel plate and/or the container wall 16 may have a thickness of about 3/4".

According to some embodiments of the present invention, the transducer 14 may be configured to provide the standing wave W into the fluid F with a

sound speed in the steel plate of about 5,740 meters/sec, so as to produce a first 1/2 wave resonance at about 150.7KHz, a second resonance (first full wave) at about 301.4KHz, and a third resonance at about 452.1KHz.

According to some embodiments of the present invention, the apparatus 10 may be, or form part of, a sonic filter or separator.

Containers like element 12 are known in the art, and the scope of the invention is not intended to be limited to any particular type or kind thereof either now known or later developed in the future. By way of example, the container may include, or take the form of, a flotation tank, a column, a drum, a tube, a vat, etc.

Transducers like element 14 are known in the art, and the scope of the invention is not intended to be limited to any particular type or kind thereof either now known or later developed in the future.

The scope of the invention is not intended to be limited to the calculated values of the at least one parameters set forth above by way of example. Embodiments are envisioned using other types or kinds of selected materials either now known or later developed in the future, other types or kinds of selected container wall thicknesses either now known or later developed in the future, as well as other types or kinds of combinations of selected materials and selected container wall thicknesses either now known or later developed in the future.

Applications Re Other Industrial Processes

By way of example, in known industrial processes sound passing through a fluid, mixture, gas/vapor of a process flow, e.g. in a pipe or container, may be sensed and used to determine parameters related to the fluid, mixture, gas/vapor. The sound may be generated by equipment operating either in association with the process flow or in close proximity to the process flow. The sound generated by equipment operating in association with the process flow may include sound in the form of a standing wave generated by such an appropriate transducer or other known sound generating device that is coupled or connected, e.g., to the outside of a container wall of a container, a pipe wall of a pipe, a tank wall of a tank, etc. See, e.g., the technology disclosed in PCT patent application serial no. PCT/US/27731, filed 9 March 2011 (Atty docket no. 712-2.338-1 (CCS 33, 35, 40, 45-49)), entitled "Method and apparatus for determining GVF (gas volume fraction) for aerated fluids and liquids in flotation tanks, columns, drums, tubes, vats," which has been assigned to the assignee of the present application, and which is hereby incorporated by reference in its entirety.

Further, the present invention also may be used in, or form part of, or used in conjunction with, SONAR-based entrained air meter and metering technology known in the art taking the form of a SONAR-based meter disclosed, e.g., in whole or in part in United States Patent Nos. 7,165,464; 7,134,320; 7,363,800; 7,367,240; and 7,343,820.

Furthermore, the present invention may also be used in, or form part of, or used in conjunction with, industrial processes like a mineral extraction processing system for extracting minerals from ore either now known or later developed in the future, including any mineral process, such as those related to processing substances or compounds that result from inorganic processes of nature and/or that are mined from the ground, as well as including either other extraction processing systems or other industrial processes, where the sorting, or classification, of product by size is critical to overall industrial process performance.

The Scope of the Invention

While the invention has been described with reference to an exemplary embodiment, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, may modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment(s) disclosed herein as the best mode contemplated for carrying out this invention.

WHAT IS CLAIMED IS:

1. Apparatus comprising:

a container having a container wall characterized by at least one parameter, including being made of a selected type of material or having a selected thickness, the container being configured to hold a fluid therein;

a transducer configured on the outside of the container wall, and also configured to provide a standing wave into the fluid;

the at least one parameter of the container wall being selected to ensure about a 1/2 wavelength of a desired frequency exists within the container wall, so as to substantially reduce back reflections toward the transducer due to any mismatch in acoustic impedance at the interface between the container wall and the fluid, and so as to substantially maximize the amount of energy delivered to the fluid, thus improving the operating efficiency of the apparatus.

2. Apparatus according to claim 1, wherein the at least one parameter is a combination of the selected material and the selected thickness of the container wall.

3. Apparatus according to claim 2, wherein the container wall is a steel plate

4. Apparatus according to claim 2, wherein the selected thickness is about 3/4".

5. Apparatus according to claim 2, wherein the container wall is a steel plate having a thickness of about 3/4".

6. Apparatus according to claim 5, wherein the transducer is configured to provide the standing wave into the fluid with a sound speed in the steel plate of about 5,740 meters/sec, so as to produce a first 1/2 wave resonance at about 150.7KHz, a second resonance (first full wave) at about 301.4KHz, a third resonance is produced at about 452.1KHz, etc.

7. Apparatus according to claim 1, wherein the apparatus is a sonic filter or separator.

8. Apparatus comprising:

a container having a container wall being made of a selected material and having a selected thickness, and being configured to hold a fluid therein;

a transducer configured on the outside of the container wall, and also configured to provide a standing wave into the fluid;

the selected material and the selected thickness of the container wall being chosen to ensure about a 1/2 wavelength of a desired frequency exists within the container wall,

so as to substantially reduce back reflections toward the transducer due to any mismatch in acoustic impedance at the interface between the container wall

and the fluid, and so as to substantially maximize the amount of energy delivered to the fluid, thus improving the operating efficiency of the apparatus.

9. Apparatus according to claim 8, wherein the container wall is a steel plate having a thickness of about 3/4".

10. Apparatus according to claim 9, wherein the transducer is configured to provide the standing wave into the fluid with a sound speed in the steel plate of about 5,740 meters/sec, so as to produce a first 1/2 wave resonance at about 150.7KHz, a second resonance (first full wave) at about 301.4KHz, a third resonance is produced at about 452.1KHz, etc.

12. Apparatus according to claim 8, wherein the apparatus is a sonic filter or separator.

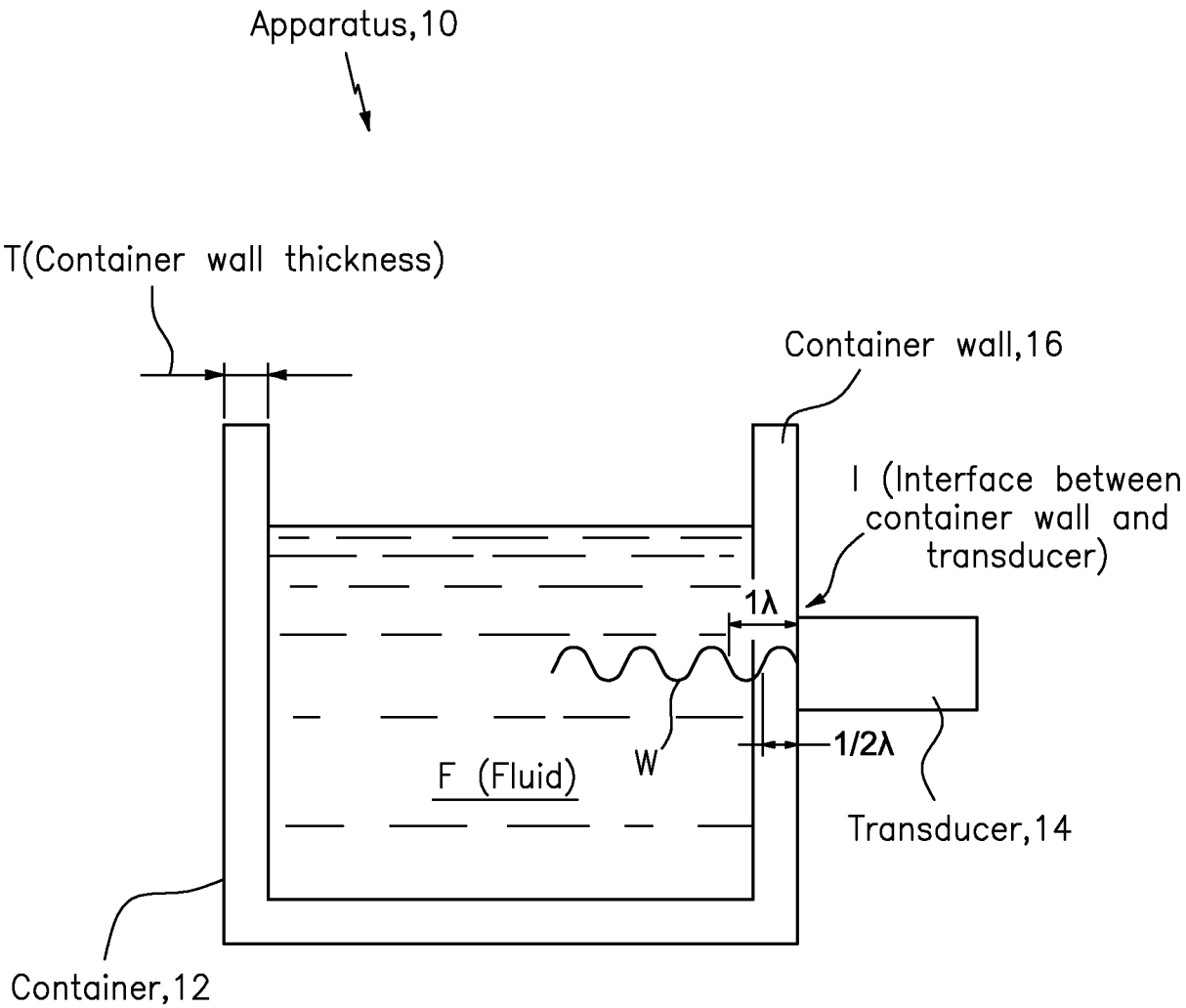
Apparatus,10
T(Container wall thickness)
Container wall,16
I (Interface between container wall and transducer)
1λ
1/2λ
W
F (Fluid)
Transducer,14
Container,12

FIG. 1

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 12/23960

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - G01F 23/00 (2012.01)
USPC - 73/290v
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)
USPC - 73/290v; IPC(8) - G01F 23/00 (2012.01)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
USPC - 73/2902R (Keyword limited; terms below)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
PubWEST(PGPB,USPT,USOC,EPAB,JPAB); Google Scholar TERMS wavelength transducer "standing wave" sonic filter separator reflection fluid acoustic impedance steel container "3/4 inch" wall thickness khz speed velocity sound "150 kHz"

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 6,397,656 B1 (Yamaguchi et al.) 04 June 2002 (04.06.2002) claim 4, col 1, ln 62-63, col 2, ln 6, 22-26, 42-43, col 4, ln 57-59	1-10, 12
Y	US 2004/0173021 A1 (Lizon et al.) 09 September 2004 (09.09.2004) para [0020], [0026], [0028], [0029], [0032], [0033]	1-10, 12
Y	US 2010/0323342 A1 (Gonzalez Gomez et al.) 23 December 2010 (23.12.2010) para [0046], [0049], [0053]	7, 12
	* * * * *	
A	US 2010/0264095 A1 (Hadfield et al.) 21 October 2010 (21.10.2010) para [0014], [0031]	1, 8
A	US 6,936,151 B1 (Gary et al.) 30 August 2005 (30.08.2005) col 5, ln 2, col 8, ln 17-18, 59-63	1, 8
A	US 4,770,038 A (Allan et al.) 13 September 1988 (13.09.1988) col 3, ln 64	6, 10
A	US 4,580,448 A (SKRGATIC) 08 April 1986 (08.04.1986), entire document especially Fig 1; col 2, lns 36-44	1-10, 12
A	US 3,220,258 A (ROD) 30 November 1965 (30.11.1965), entire document especially Figs 1-3, 8; col 5, lns 30-44	1-10, 12

☐ Further documents are listed in the continuation of Box C. ☐

* 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
07 May 2012 (07.05.2012)	23 MAY 2012
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Authorized officer: Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774