US006357671B1

(12) **United States Patent**
Cewers

(10) **Patent No.: US 6,357,671 B1**
(45) **Date of Patent: Mar. 19, 2002**

(54) **ULTRASONIC NEBULIZER**

(75) Inventor: **Göran Cewers**, Lund (SE)

(73) Assignee: **Siemens Elema AB**, Solna (SE)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/489,835**

(22) Filed: **Jan. 24, 2000**

(30) **Foreign Application Priority Data**

Feb. 4, 1999 (SE) 9900369

(51) **Int. Cl.**[7] **B05B 1/08**; A61M 11/06

(52) **U.S. Cl.** **239/102.2**; 239/67; 239/69; 239/71; 239/99; 239/102.1; 239/338

(58) **Field of Search** 239/67, 69, 71, 239/73, 99, 102.1, 102.2, 338

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,839,651	A		10/1974	Michaels
3,918,640	A	*	11/1975	Piccino et al. ..... 239/102.2 X
4,300,131	A		11/1981	Mitsui et al.
4,319,155	A		3/1982	Nakai et al.
4,641,053	A	*	2/1987	Takeda ..... 239/102.2 X
4,776,990	A		10/1988	Verity
5,217,165	A	*	6/1993	Takahashi et al. 239/102.2
5,303,585	A		4/1994	Lichte
5,361,989	A	*	11/1994	Merchat et al. 239/102.2
5,429,302	A	*	7/1995	Abbott 239/102.2

FOREIGN PATENT DOCUMENTS

EP	0 151 753 A2	12/1984
EP	WO 93/09409	5/1993
EP	0 845 663 A1	11/1997
JP	9-173978	7/1997

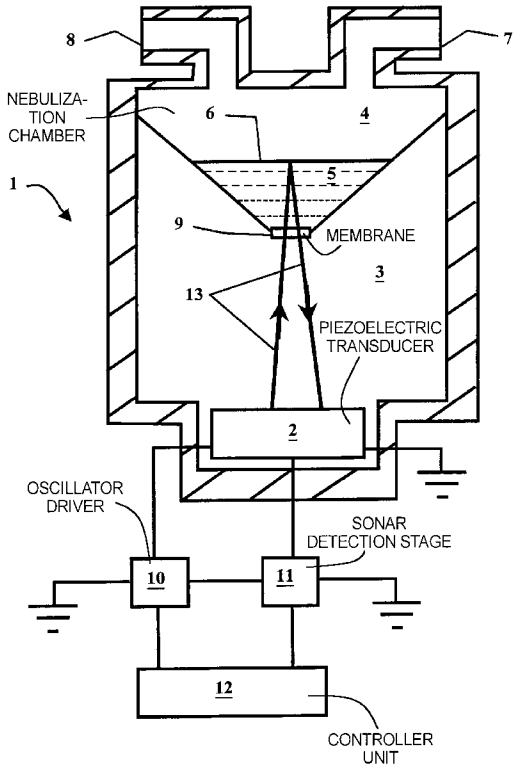
* cited by examiner

Primary Examiner—Robin O. Evans
(74) *Attorney, Agent, or Firm*—Schiff Hardin & Waite

(57) **ABSTRACT**

An ultrasonic nebulizer includes a nebulization chamber for holding a liquid to be nebulized, the liquid being limited by an upper boundary within the chamber, and a nebulization source acoustically couplable to the liquid within the chamber to provide therein an ultrasonic output at an amplitude to cause nebulization. The nebulization source is controllable to vary the amplitude of the ultrasonic output to provide a measurement period during which no nebulization occurs, and a sonar device measures, during the measurement period, a time interval between emission of an acoustic pulse toward the boundary and detection of a component of the emitted acoustic pulse reflected from the boundary, and provides an output signal dependent on the measured time interval for use in determining location information of the boundary within the chamber.

8 Claims, 2 Drawing Sheets



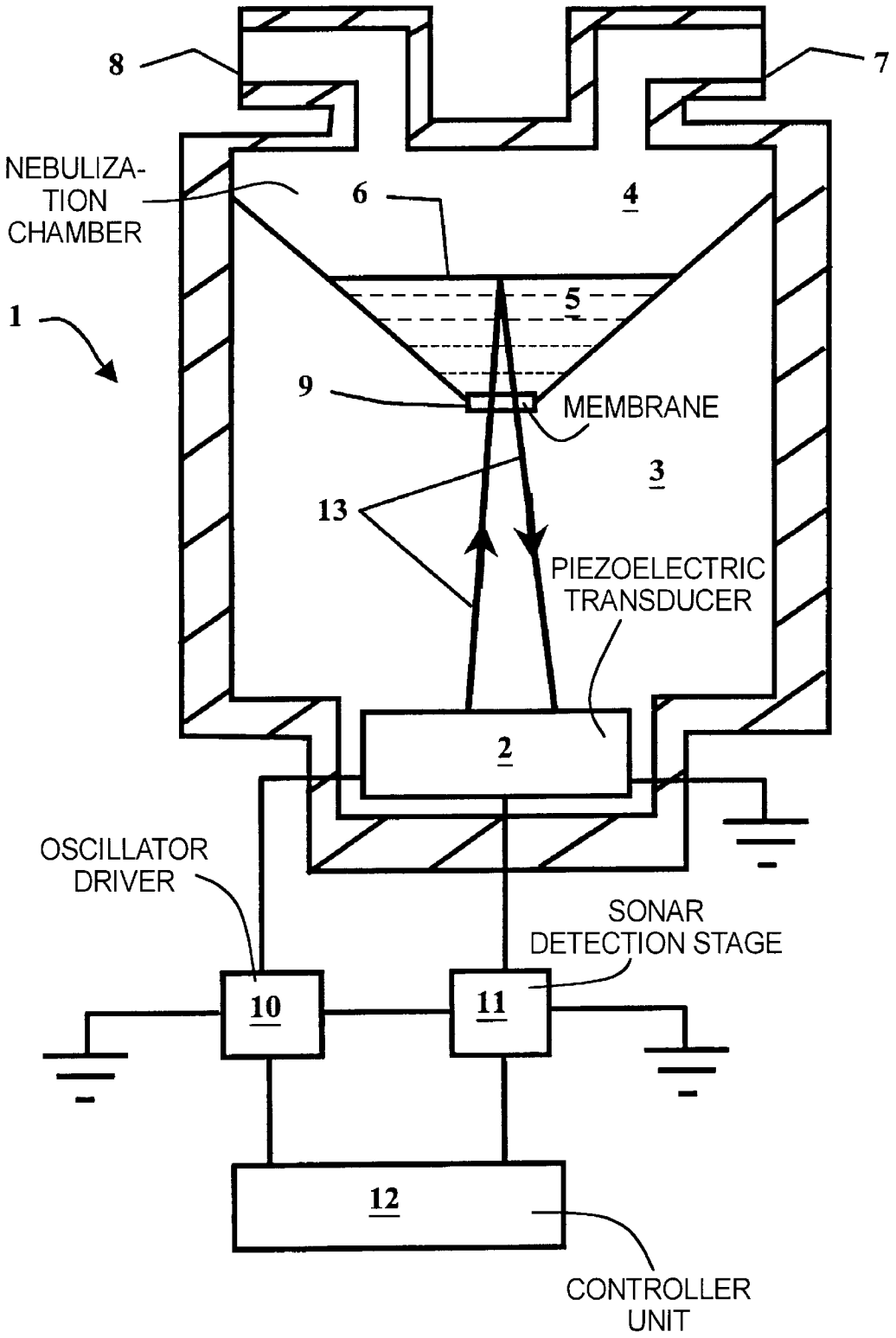


FIG. 1

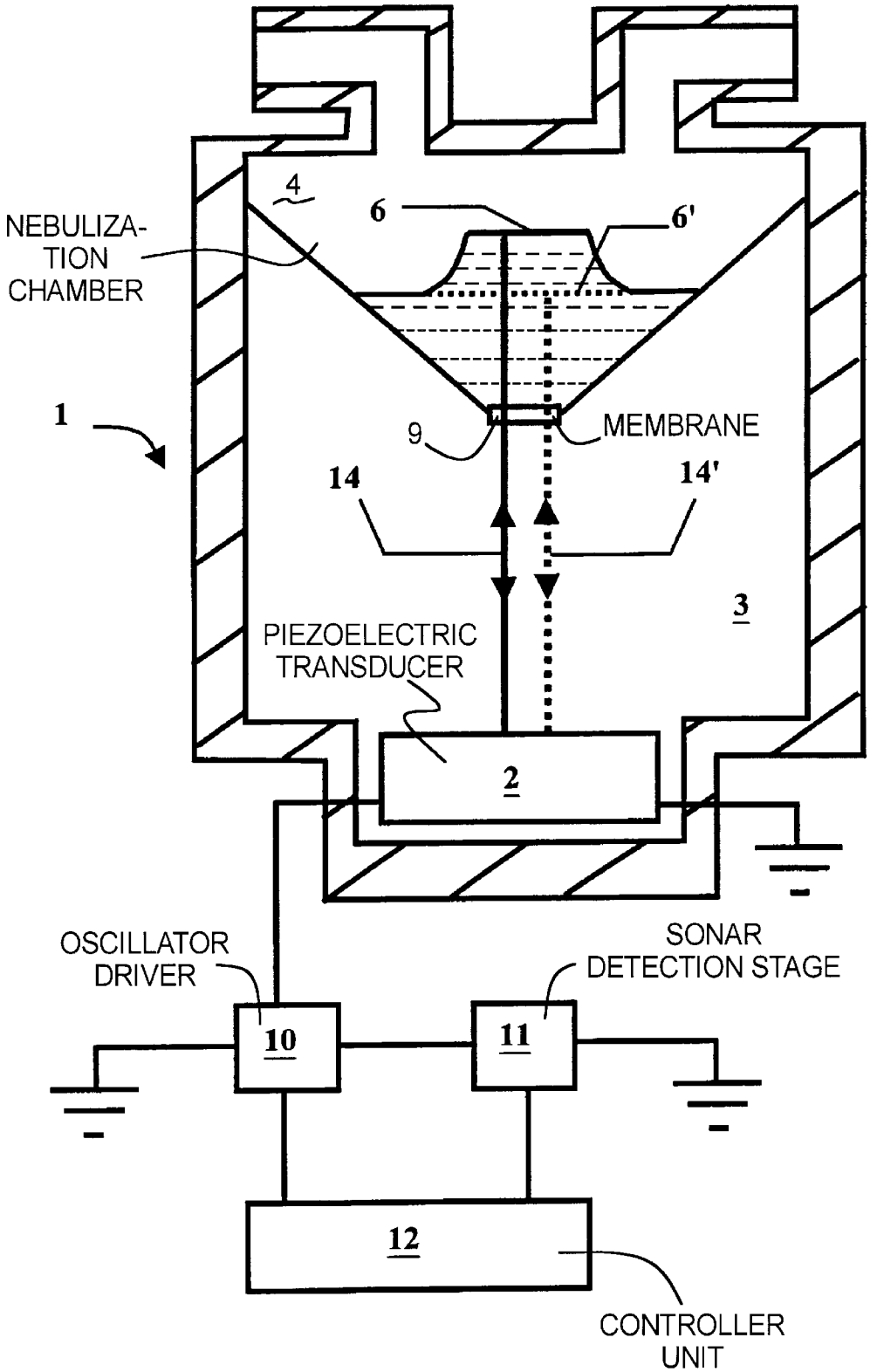


FIG. 2

ULTRASONIC NEBULIZER

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an ultrasonic nebulizer (atomizer) and in particular to a nebulizer of the type having an output controllable dependent on the level of liquid available for nebulization.

2. Description of the Prior Art

Ultrasonic nebulizers are devices which utilize a source of ultrasound, such as for example a piezoelectric crystal oscillator, acoustically coupled to a liquid in a nebulizing chamber in order to generate an aerosol of small liquid droplets in a space above the liquid boundary. The generated aerosol may be used for any desired purpose such as humidification or medication. Such nebulizers are often used as a component in a breathing circuit of a mechanical ventilator, where they are employed in the delivery of controlled doses of anaesthetic or other additive into a breathing gas for supply to a patient.

It is important, particularly in the medical field, to be able to monitor the level of liquid in the nebulizing chamber. This may be for example, in order to maintain a supply of liquid throughout mechanical ventilation or to monitor the dosage of liquid delivered into the breathing gas.

One known ultrasonic nebulizer which is provided with a liquid level indicator is disclosed in U.S. Pat. No. 3,839,651. This nebulizer uses a temperature sensitive resistance element which is thermally coupled to the liquid within the nebulizing chamber. The current in an electrical circuit containing this element is dependent on the amount of liquid within the chamber and is used to decrease power supplied to the oscillator and to provide a visible indication when the liquid level falls to a predetermined minimum. One problem with such a level indicator is that it is relatively insensitive to small changes in liquid level which are likely to occur between successive, or closely spaced, inspiration periods of a patient breathing cycle.

SUMMARY OF THE INVENTION

An object of the present invention is to provide an ultrasonic nebulizer having a level indicator capable of sensing such small changes.

The above object is achieved in accordance with the principles of the present invention in a nebulizer having a nebulization chamber containing a liquid to be nebulized the liquid having an upper boundary within the chamber, and an ultrasonic nebulization source which is acoustically coupled to the liquid to introduce ultrasound into the liquid to nebulizer the liquid, and wherein the ultrasonic nebulization source is operated to emit ultrasound with a variable amplitude so as to provide a measurement period during which no nebulization occurs, and wherein the nebulizer has a sonar device which, during the measurement period, measures a time interval between emission of an acoustic pulse toward said liquid boundary and detection of a component of the emitted acoustic pulse reflected from the boundary so as to produce an output signal dependent on this measured time interval which is indicative of a location of the upper boundary of the liquid within the nebulization chamber.

By controlling the amplitude of the nebulization source to provide periods where no nebulization occurs, possibly by providing periods of zero amplitude output, a sonar device which employs echo ranging techniques may be used to measure the location of the upper boundary of the liquid within the nebulization chamber. This provides a relatively sensitive arrangement for identifying changes in the location of the liquid boundary from which, for example, the amount of liquid within the nebulization chamber may be calculated.

Preferably, a single piezoelectric crystal is employed as both the nebulization source and as the sonar device. This allows existing nebulizing chambers and sources to be used with only modifications to the electronic circuitry used to control the crystal being necessary. Moreover, by using only one crystal, a major component cost saving is achieved compared with employing separate sonar and nebulization sources.

A difference forming circuit is used to enable differences in the location of the liquid boundary to be determined. The determined difference, for example, may be used to monitor the amount of liquid nebulizer between measurement periods or to monitor the effect of different known crystal driving currents on the liquid boundary during a single measurement period. Both of these monitoring modes then may be employed to calibrate the nebulization source and to control the amplitude or duration of the ultrasonic output from the source to, for example, more reliably provide a required amount of nebulization or to remove power from the source if a minimum liquid level is reached.

Particularly useful is the latter mode of monitoring since a calibration of the output of the nebulization source may be made before generating any nebulized liquid.

DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic representation of an embodiment of a nebulizer and illustrates one mode of operation according to the present invention.

FIG. **2** is a schematic representation of a nebulizer illustrating a further mode of operation according to the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In FIGS. **1** and **2** an ultrasonic nebulizer is shown generally at **1**. The nebulizer **1** of FIGS. **1** and **2** has the same basic components but different modes of operation, which modes will be described separately for each of the FIGS. **1** and **2**.

The ultrasonic nebulizer **1** of FIGS. **1** and **2** includes a ultrasonic oscillator **2**, here in the form of a piezoelectric transducer, which is located in a water chamber **3** above which is a nebulization chamber **4**. A liquid **5** for nebulization is held within the nebulization chamber **4** so that in use a space into which nebulized liquid passes remains in the chamber **4** above an upper boundary **6** of the liquid **5**. Gas may be introduced into the nebulization chamber **4**, flowing from an inlet **7** to an outlet **8** through the space above the upper boundary **6**, and removing from the chamber **4** liquid droplets formed during nebulization. A thin membrane **9** separates the water chamber **3** from the nebulization chamber **4** so that ultrasonic energy from the oscillator **2** can pass readily therethrough with the result that the oscillator **2** "sees" essentially only a single body of liquid, terminating at the upper boundary **6**. An oscillator driver **10** is connected in an electrical circuit with the oscillator **2** and is arranged to drive the oscillator **2** to generate a controllable, variable amplitude ultrasonic signal for emission into the water chamber **3**. A sonar detection stage **11** is also provided in electrical connection with the oscillator driver **10** and with the oscillator **2**. The detection stage **11** includes conventional

timer circuitry (not shown) which is arranged to measure the transit time for an ultrasonic sonar pulse to travel from the oscillator **2** to the upper liquid boundary **6** and back again. The detection stage **11** is also adapted to emit a signal representative of this measured transit time.

The driver **10** and the sonar detection stage **11** are readily realizable by those skilled in the art using conventional electrical engineering methodology and an understanding of the principles of their function, as provided herein.

A controller unit **12**, for example in the form of a suitably programmed computer, is operably connected to both the driver **10** and the sonar detection stage **11** and provides control of the driver **10** and calculates the location of the upper liquid boundary **6** within the nebulization chamber **4** from the output signal of the sonar detection stage **11**.

To explain the nebulizer **1** of FIG. **1** and its mode of operation, the arrows **13** show the path of the sonar pulse. In use the controller unit **12** provides control instructions to the driver **10** for generating a periodic variation in the amplitude of the ultrasonic energy emitted by the oscillator **2**. The variation is such that nebulization periods, during which high amplitude ultrasound are emitted which are sufficient to cause nebulization, alternate with measurement periods, during which only ultrasound sonar pulses are emitted having an amplitude, insufficient to affect i.e. disturb, the location of the upper boundary **6** to a measurable extent.

During a measurement period a trigger signal is sent to the sonar detection stage **11**, corresponding to the oscillator **2** being driven, to generate an ultrasonic sonar pulse. The trigger signal, which may conveniently be provided either by the controller unit **12** or the driver **10**, initiates the start of timing by the timer circuitry. The time measurement is stopped when the receipt of a reflected component of the generated ultrasonic pulse is detected at the oscillator **2**. This detection is facilitated by the use of a piezoelectric transducer as the oscillator **2**. It is well known that ultrasonic energy incident on such a piezoelectric transducer **2** can cause detectable changes in the electrical properties of an electrical circuit in which the transducer **2** is included. Thus in the present embodiment the receipt of the reflected pulse is detected using such known circuitry within the detection stage **11**. The pulse emission and detection optionally can be carried out a number of times throughout the measurement period and an average location determination made within the controller unit **12** based on the averaged value of the measured transit times. The determined location may be used within the controller unit **12** to provide a control signal which inhibits the operation of the driver **10** when a location corresponding to a minimum level is detected.

Optionally, the controller unit **12** may be programmed to compare the currently determined location with a previously determined location, having a known temporal relationship to the currently determined location and preferably one made in a consecutive measurement period, so that the amount of liquid nebulized during an intervening nebulization period or periods may be calculated within the controller unit **12** to provide dose information. This dose information may then be used by the controller unit **12** in the control of the driver **10** to regulate one or both of the amplitude of the ultrasound generated for nebulization and the duration of the nebulization period to obtain a desired dose from the nebulizer **1**.

For explaining the nebulizer **1** of FIG. **2** and its mode of operation, solid arrows **14** and dashed arrows **14'** show paths of the sonar pulses. In use the controller unit **12** controls the driver **10** to provide the piezoelectric transducer **2** with a known, variable amplitude driving force to generate a corresponding variable amplitude ultrasonic output into the water chamber **3**. The driver **10** is controlled to provide from the oscillator **2** at least one nebulization period, during which high amplitude ultrasound is emitted sufficient to cause nebulization, and at least one measurement period, during which ultrasound is emitted at amplitudes lower than are capable of causing nebulization.

During each measurement period the controller unit **12** controls the driver **10** to generate at least two different amplitudes of ultrasound to provide distinguishable and different locations of at least part of the upper boundary **6**, **6'**. As illustrated in FIG. **2** one output amplitude is chosen so as not to affect (i.e. disturb) the location of the upper boundary **6'** to a measurable extent, for example a zero amplitude output, and the other output amplitude is chosen to provide a localized change in the upper boundary **6**. The sonar detection stage **11** and the driver **10** operate cooperatively to provide two measurements of transit times; one for a sonar pulse traveling along the path **14** which measures the location of the boundary **6**, and the other for a sonar pulse traveling along the path **14'** which measures the location of the boundary **6'**. These measurements are carried out in a manner analogous to that described for the transit time measurements of FIG. **1**.

The controller unit **12** is operably connected to the sonar detection stage **11** to receive outputs from the detection stage **11** representative of the two measured transit times. A difference calculation between the locations of the boundaries **6**, **6'** is made within the controller unit **12**. The controller unit **12** is further adapted to calculate the rate of change of location of the boundary with supplied driving force using the calculated difference and from the knowledge of the amplitude of the driving force supplied by the driver **10** to generate the two upper boundary locations **6**, **6'**. From this rate of change the controller unit **12** generates an estimate of the driving force required to be provided to the oscillator **2** in order to generate a desired degree of nebulization within the nebulizer **1** and controls the driver **10** accordingly.

Although modifications and changes may be suggested by those skilled in the art, it is the intention of the inventor to embody within the patent warranted hereon all changes and modifications as reasonably and properly come within the scope of his contribution to the art.

I claim as my invention:

1. A nebulizer comprising:

a nebulization chamber containing a liquid to be nebulized, said liquid having an upper boundary within said nebulization chamber;

an ultrasonic nebulization source acoustically coupled to said liquid and operable to nebulize said liquid, said ultrasonic nebulization source including a control unit which varies an amplitude of ultrasound produced by said ultrasonic nebulization source to provide at least a first measurement period and a second measurement period during which no nebulization of said liquid occurs, said first and second measurement periods being separated in time from each other;

a sonar device disposed to measure, during each of said first and second measurement periods, a time interval between emission of an acoustic pulse toward said upper boundary and detection of a component of said acoustic pulse reflected from said boundary, and generating respective output signals dependent on said time interval indicative of a location of said upper

DOCKET ALARM

Explore Litigation Insights

Docket Alarm provides insights to develop a more informed litigation strategy and the peace of mind of knowing you're on top of things.

Real-Time Litigation Alerts

Keep your litigation team up-to-date with **real-time alerts** and advanced team management tools built for the enterprise, all while greatly reducing PACER spend.

Our comprehensive service means we can handle Federal, State, and Administrative courts across the country.

Advanced Docket Research

With over 230 million records, Docket Alarm's cloud-native docket research platform finds what other services can't. Coverage includes Federal, State, plus PTAB, TTAB, ITC and NLRB decisions, all in one place.

Identify arguments that have been successful in the past with full text, pinpoint searching. Link to case law cited within any court document via Fastcase.

Analytics At Your Fingertips

Learn what happened the last time a particular judge, opposing counsel or company faced cases similar to yours.

Advanced out-of-the-box PTAB and TTAB analytics are always at your fingertips.

API

Docket Alarm offers a powerful API (application programming interface) to developers that want to integrate case filings into their apps.

LAW FIRMS
Build custom dashboards for your attorneys and clients with live data direct from the court.

Automate many repetitive legal tasks like conflict checks, document management, and marketing.

FINANCIAL INSTITUTIONS
Litigation and bankruptcy checks for companies and debtors.

E-DISCOVERY AND LEGAL VENDORS
Sync your system to PACER to automate legal marketing.