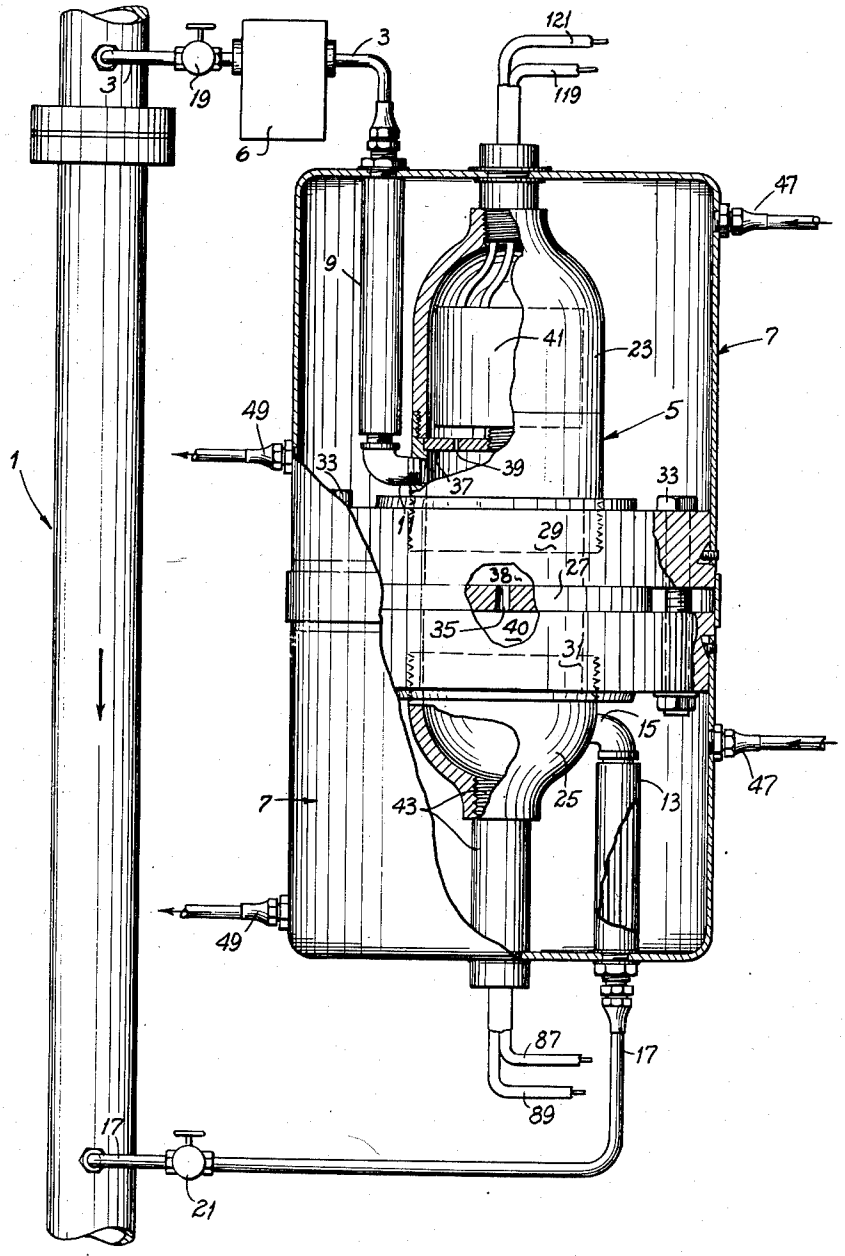
March 19, 1957 F. M. POOLE ET AL 2,785,567

DENSIMETER

Filed March 17, 1954



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United States Patent Office

2,785,567

Patented Mar. 19, 1957

2,785,567

DENSIMETER

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Application March 17, 1954, Serial No. 416,930

6 Claims. (Cl. 73—24)

This invention relates to a densimeter and more particularly to apparatus for determining the densities of gases.

Among the several objects of the invention may be noted the provision of a densimeter for accurately and continuously determining the densities of gases; the provision of a densimeter which will determine the density of gases at various operating pressures and temperatures; the provision of a densimeter of the class described which is useful in density-indicating and control apparatus; and the provision of a densimeter which is reliable in operation. Other objects and features will be in part apparent and in part pointed out hereinafter.

Briefly, this invention is directed to a sonic capsule body employed in combination with apparatus for determining the density of gases. This sonic capsule body defines first and second chambers connected through a throat and containing a gas. The chambers are provided with a gas inlet and an outlet. The throat is of small cross-sectional area relative to its length while the volume of the chambers is large relative to the volume of the throat. A transducer and pick-up means are mounted in acoustic communication with the chambers and the mass of gas in the throat acts as a piston to set into sonic oscillation the gas contained in the chambers at a natural resonant frequency which is a function of the density of the gas therein.

The invention accordingly comprises the construction hereinafter described, the scope of the invention being indicated in the following claims.

In the accompanying drawing, in which one of various possible embodiments of the invention is illustrated, the single figure is a side elevation of a sonic capsule unit of the present invention with portions being broken away. Corresponding reference characters indicate corresponding parts throughout the drawing.

In accordance with the present invention, apparatus is provided which will continuously determine the density of gases with a high degree of accuracy (in the order of one part in ten thousand to fifty thousand parts). This apparatus includes a sonic capsule which has a natural resonant frequency dependent upon the density of the gas contained therein. This resonant frequency is independent of the pressure of the gas within the limits of deviation from Boyle-Mariotte's law. Thus, where a change of the density of the gas is due solely to pressure variations, the apparatus of this invention functions so that such pressure-induced density changes are automatically compensated and the oscillatory frequency of the capsule is unaffected. If elimination of the effect of the temperature variations on the gas density is desirable, the temperature of the gas being tested and the sonic capsule may be maintained constant or means may be provided for compensating for any temperature-induced gas density variations.

Referring now to the drawing, a pipeline adapted to carry a gas, the density of which is to be determined, is shown at reference numeral 1. A sample tube 3 interconnects pipeline 1 with a sonic capsule unit 5 of the present invention. A preheater 6 is connected in tube 3 so that the gas sample may be maintained at a constant temperature. Sonic capsule 5 is contained in a housing 7 to which sample tube 3 is connected. A sonic or acoustic filter 9 is interposed between tube 3 and a gas inlet 11. A second and similar acoustic filter 13 interconnects the gas outlet 15 to a tube 17 which conducts the effluent gas from sonic capsule 5 back to pipeline 1. The acoustic filters 9 and 13 serve to muffle the sonic vibrations or oscillations set up in the capsule and to thus isolate them and effectively prevent their transmission out of housing 7 and along tubes 3 and 17. The construction of an exemplary filter is shown by the broken-away portion of filter 13 to comprise a plurality of small parallel-aligned tubes which block the sound waves produced in capsule 5. A gas inlet valve 19 and a gas outlet valve 21 are provided for controlling the velocity of gas flow through the sonic capsule, or, if desired, for introducing test gases intermittently.

Sonic capsule 5 comprises a pair of opposed cups 23 and 25 separated by an orifice plate 27. The inner ends of cups 23 and 25 are threaded into a pair of flanges 29 and 31 which are held in fixed alignment with orifice plate 27 by means of bolts 33. A transducer mounting plate 37 divides the interior of cup 23 into two portions, the lower one of which constitutes a first chamber (indicated by the reference numeral 38), and the second of which serves as a transducer housing. A transducer 41 is carried in the housing portion affixed to mounting plate 37 so as to be in acoustic and gaseous communication with the first or upper chamber 38. A small aperture 39 provides gaseous communication between the upper chamber and the transducer housing so that the respective pressures are essentially the same in each portion. Thus, the sonic capsule body, made up of cups 23 and 25, flanges 29 and 31 and orifice plate 27, defines a pair of chambers 38 and 40, the volume of which is large relative to the volume of a throat 35 in the orifice plate. The cross-sectional area of throat 35 is small relative to its length.

An exemplary pick-up means, for example a microphone 43, is mounted in acoustic communication with the chambers, such as by mechanically affixing it to cup 25. Housing 7 is provided with a pair of heating-medium inlets 47 and a pair of heating-medium outlets 49 so that it may be filled with a fluid heated to a predetermined temperature.

This sonic capsule body 5 is adapted to be connected in combination with apparatus which utilizes the electrical output of microphone 43 to drive transducer 41 in a regenerative circuit and which provides a signal the frequency of which indicates gas density. This may be readily accomplished by replacing vibratory element 1 of Fig. 4 of U. S. Patent 2,635,462 with sonic capsule 5. Microphone wires 87 and 89 herein are connected to similarly referenced wires of this Fig. 4 apparatus. The transducer 41 is energized via wires 119 and 121 by the amplifier vacuum tube 109 of Fig. 4 of said patent. If temperature-induced variations are undesirable, then a temperature-compensating unit (such as is illustrated at reference numeral 83 of Fig. 4 of said patent) may be connected in tube 17 and/or the constant temperature auxiliary heater 6 may be used. Density is indicated by the calibrated dial 175 of selsyn 167 in said patent.

An alternate arrangement for interconnecting sonic capsule 5 in a density-measuring system is to employ the master and sample amplifiers, etc., of Fig. 1 of U. S. Patent 2,666,326. By disconnecting wires 16, 18, 26 and 28 of Fig. 1 of that patent from their respective transducers and microphones, and by then connecting these wires to transducers 41 and microphones 43 of two

of the sonic capsules 5 as described above, the indicator X will indicate gas density.

Also, another way to utilize the present invention is in conjunction with the apparatus of Fig. 9 of U. S. Patent 2,666,326 in which wires 439 and 441 are connected to transducer 41 of capsule 5 (rather than to transducer 425) and wires 435 and 437 are connected to microphone 43 of capsule 5 (instead of to microphone 433). Indicator O would provide density indications.

Operation is as follows:

In order to determine the density of a gas flowing through pipeline 1, valves 19 and 21 are opened. The differential pressure between the points where valves 19 and 21 are connected to line 1 will cause gas to course through the tube 3, acoustic filter 9, capsule 5, filter 13 and tube 17. Any casual ambient noise will energize microphone 43 and an electrical signal will be developed across wires 87 and 89. By connecting this electrical signal to the input circuit of an amplifier (e. g., amplifier I as described in Patent 2,635,462 or the amplifier and associated components H—L as described in conjunction with Fig. 9 of Patent 2,666,326) and connecting an output thereof to transducer 41, an oscillatory circuit is set up in which transducer 41 is energized in response to the amplified signal developed by microphone 43. The volume of gas in the upper chamber 38 will be compressed and expanded in response to this signal. This action will be coupled through the throat 35 to the volume of gas contained in the other or lower chamber (interior of cup 25). An acoustic or sonic oscillation is thereby set up in capsule 5 in which the gas mass contained in throat 35 acts as a slug or piston and moves as a whole to alternately compress and expand the volumes of gas in the chambers at a natural resonant frequency. It is preferred that an automatic volume-control or signal-limiter unit be interposed (as shown in Patents 2,635,462 and 2,666,326) between the microphone and the transducer to maintain the output level of the transducer at a predetermined substantially constant level. The frequency of the electrical signal present at an amplifier output corresponds to that of the resonant acoustic oscillation set up in the capsule between the volumes of the gas in the two chambers (acting as acoustic compliances) through the gas in the throat (acting as an acoustic mass). The natural resonant frequency of this system differs with each different density gas. By using any conventional frequency-responsive means, such as a frequency meter or any of other devices such as the various comparator arrangements of Patents 2,635,462 and 2,666,326, the density of the gas in pipeline 1 is indicated as a function of the natural resonant frequency of the capsule 5.

In a second manner of using the present invention (as described in connection with Fig. 1 of Patent 2,666,326) the sonic capsule connected with master amplifier D would not be connected to pipeline 1, but would contain a standard gas or one of known density. A gas of unknown density from pipeline 1 is fed to the other sonic capsule 5 which is connected to sample amplifier A. The compression indicator is calibrated in density units or is calibrated to indicate the difference in density of the sample gas from that of the standard gas.

In utilizing the present invention in conjunction with the apparatus of Fig. 9 of Patent 2,666,326 a gas of unknown density is fed to sonic capsule 5 and the density thereof is read from indicator O which is calibrated in gas density units.

Thus it can be seen that a single capsule 5 may be used in association with an amplifier (having an input connected to microphone 43 and one output connected to transducer 41) having an output connected to a frequency-indicating means calibrated in density units. Also, a single capsule 5 may be employed with an amplifier output connected to a servo-amplifier device arrangement (as in Fig. 4 of U. S. Patent 2,635,462). In such arrangements, the indicating means would be initially calibrated by first charging capsule 5 with a standard gas or any gas of known density. Further, a pair of capsules 5 may be employed to energize a pair of amplifier outputs which are differentiated to produce indication of density (as in Fig. 1 of U. S. Patent 2,666,326).

The temperature of sonic capsule 5 may be maintained constant at the same temperature as the input gas (optionally heated by unit 6) by transmitting a heating medium through housing 7 as indicated by connections 47 and 49.

It will be understood that the term gas includes a mixture of gases as well as pure gases, and that the electrical output from the microphone 43 or associated amplifier could be used for control purposes such as the operation of valves to mix other gases so as to maintain the density of any gas flowing through the line 1 at a predetermined value.

In view of the above, it will be seen that the several objects of the invention are achieved and other advantageous results attained.

As various changes could be made in the above constructions without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawing shall be interpreted as illustrative and not in a limiting sense.

We claim:

1. In apparatus for determining the density of gases, a sonic capsule comprising a body constituted by two opposed cups secured to opposite sides of an orifice member to define first and second chambers connected through a throat and containing a gas, a gas inlet for one chamber and a gas outlet for the other chamber, said throat being of small cross-sectional area relative to its length, the volume of said chambers being large relative to the volume of said throat, an electroacoustic transducer in gaseous and acoustic communication with said first chamber, and an electroacoustic pick-up means in acoustic communication with said second chamber, the mass of the gas in the throat acting as a piston to set into sonic oscillation the gas contained in said chambers at a natural resonant frequency which is a function of the density of the gas therein.

2. A sonic capsule as set forth in claim 1 wherein one of said cups is divided into two portions, one of which constitutes said first chamber and the second of which serves as a transducer housing.

3. A sonic capsule as set forth in claim 2 wherein there is an opening between said two portions to provide gaseous communication therebetween whereby the pressures in said portions are maintained substantially equal.

4. A sonic capsule as set forth in claim 1 which further includes acoustical filters in said gas inlet and outlet.

5. A sonic capsule as set forth in claim 1 which further includes means for maintaining the contained gas at a substantially constant temperature.

6. A sonic capsule as set forth in claim 1 which further includes means for maintaining the temperature of said body substantially constant.

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