Dec. 23, 1958 W. ROTH 2,865,201

GYROSCOPIC MASS FLOWMETER

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FIG. 1

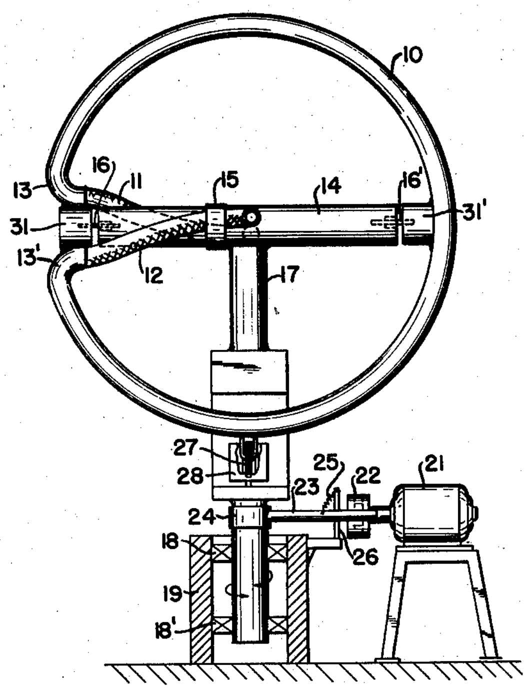


FIG. 2

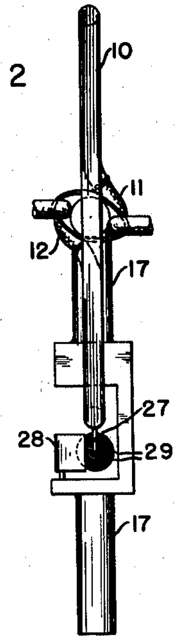


FIG. 3

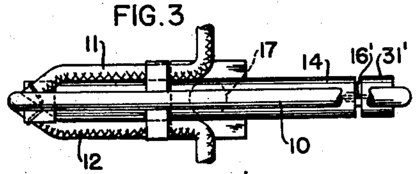
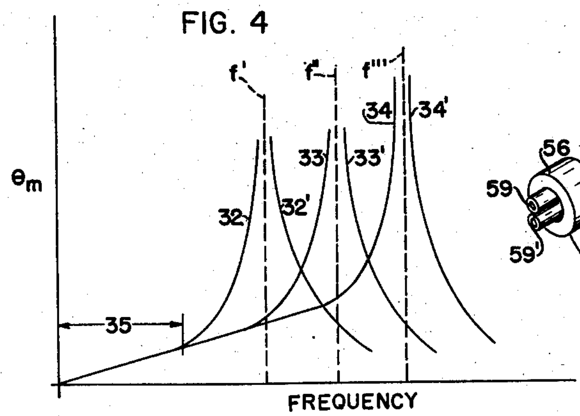


FIG. 4



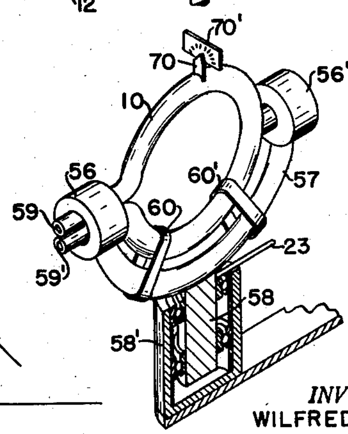


FIG. 6

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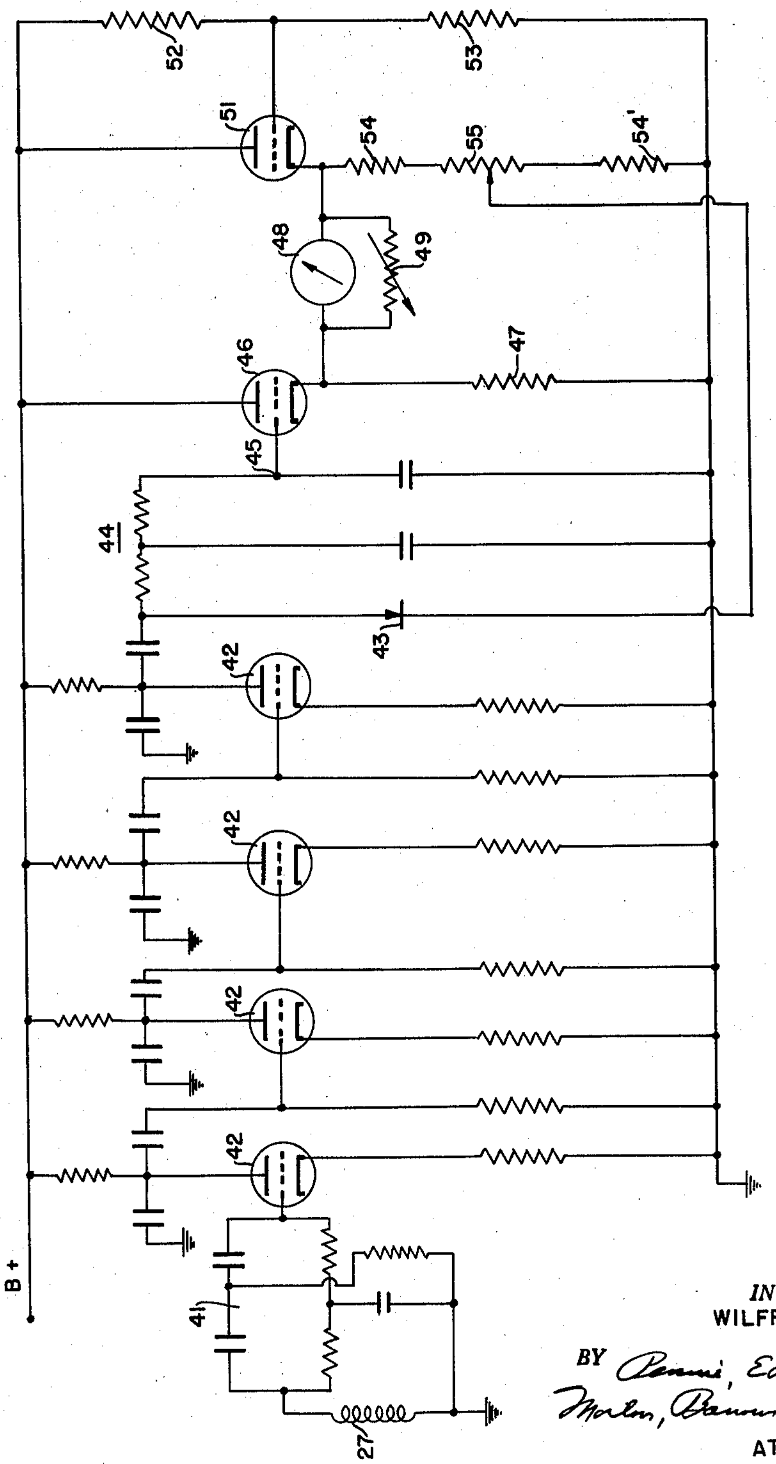

FIG. 5

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FIG. 7

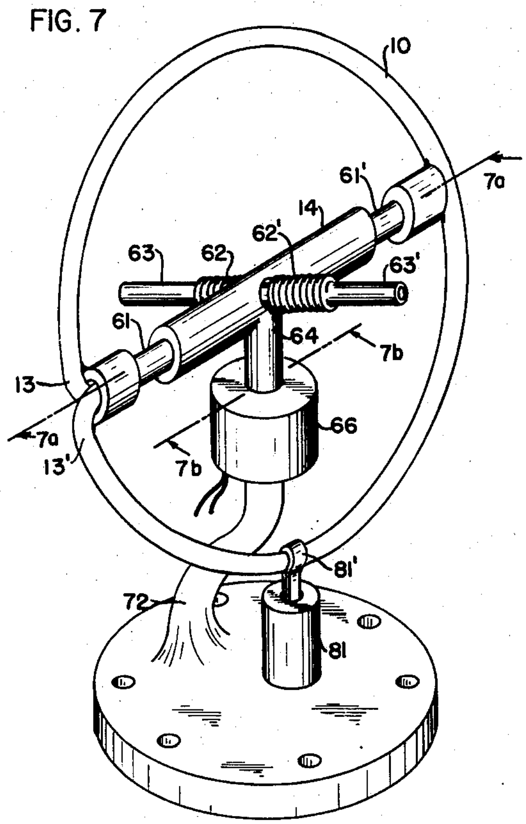

FIG. 7b

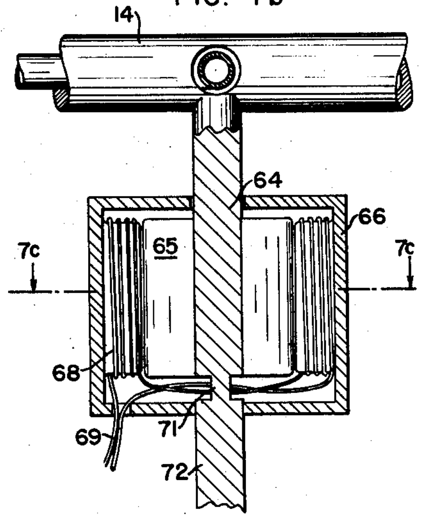

FIG. 7c

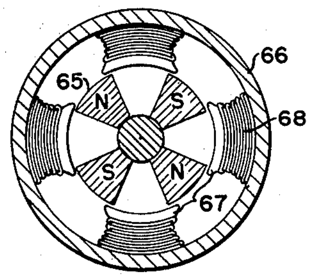

FIG. 7a

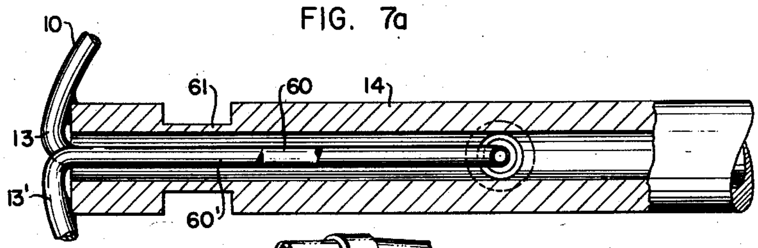

FIG. 1a

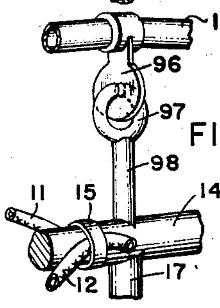

FIG. 1b

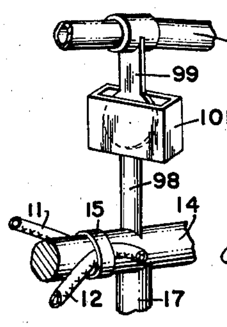

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FIG. 8

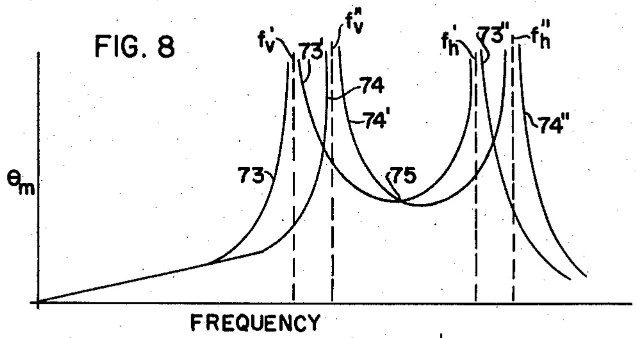


FIG. 9

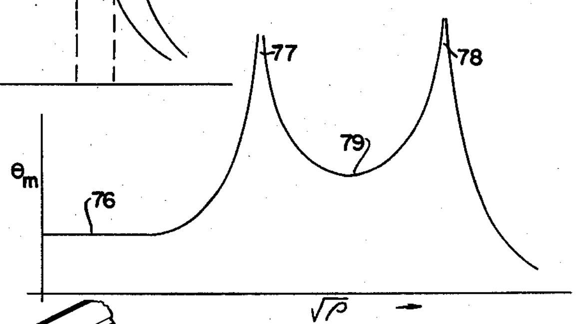


FIG. 10

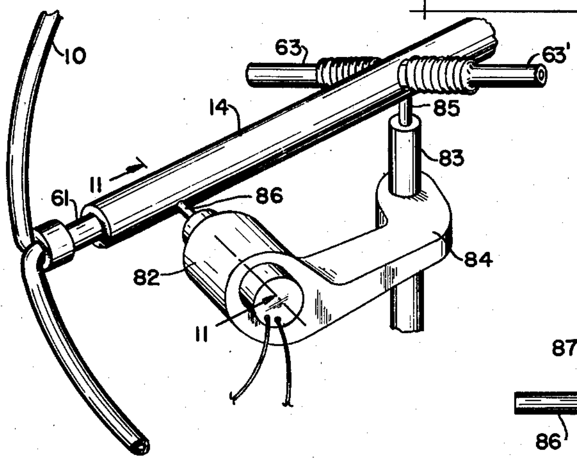


FIG. 11

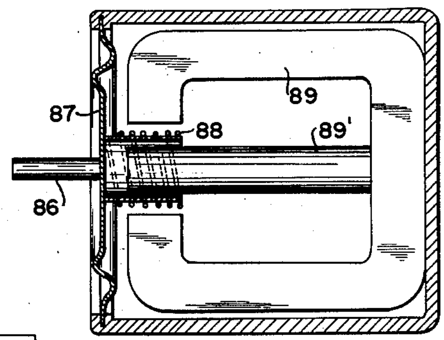
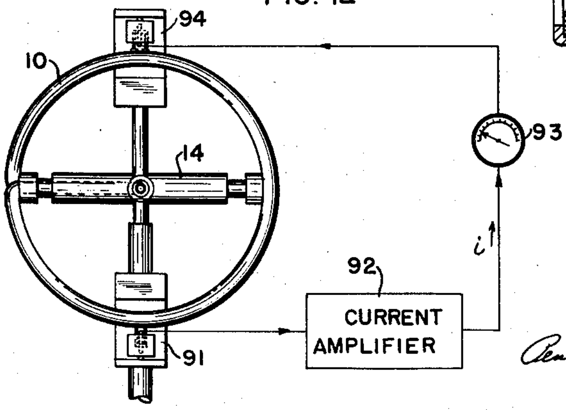


FIG. 12



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United States Patent Office

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Patented Dec. 23, 1958

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GYROSCOPIC MASS FLOWMETER

Wilfred Roth, West Hartford, Conn.

Application August 26, 1954, Serial No. 452,437

30 Claims. (Cl. 73—194)

This invention relates to mass flowmeters utilizing the gyroscopic principle. The invention is especially directed to the provision of satisfactory A.-C. or oscillating flowmeters, as distinguished from those of the D.-C. or continuously rotating type, although certain features are applicable to the latter.

There is a considerable need in industry for an instrument which will measure mass flow, as distinguished from volume flow. In many industrial processes it is the mass of a reagent that is important, rather than merely volume. Also, it is often advantageous to market fluid-like materials according to their mass rather than volume. While mass flow is the product of volume flow and density, the density may vary depending upon the exact constituents of the material, and usually varies considerably with temperature. Thus the conversion of volume flow to mass flow is often difficult. Even when such conversion is possible, it is advantageous to have an instrument which indicates mass flow directly.

It has been suggested to employ the gyroscopic principle in order to measure mass flow directly. In such an instrument the fluid-like material is caused to flow in a curved conduit, specifically a conduit in the form of a loop. For a given fluid and conduit, the angular momentum varies with the rate of flow of the fluid through the conduit. By virtue of the flowing fluid, the conduit is equivalent to the rotor of an ordinary gyroscope. If the loop is caused to rotate about an axis perpendicular to that of the angular momentum, a torque will be produced about the mutually orthogonal axis. If, for example, the loop is circular and is caused to rotate about a diameter thereof by a drive source, a torque or couple will be produced about an axis mutually perpendicular to the axis of rotation and the axis of the loop. The instantaneous value of this torque will be proportional to the instantaneous value of the angular momentum as determined by the rate of mass flow of the fluid, and the instantaneous value of the angular velocity of the loop about the drive axis.

In one instrument of this general type which has been proposed, continuous rotation of the loop about one axis has been employed, and a rotating mass mounted concentrically with the axis of the loop has been driven at an angular velocity controlled by gyroscopic couples produced by the flowing liquid, but in a counter direction, so that the angular momentum of the flowing liquid is counteracted by the angular momentum of the rotating mass. This produces a null type instrument. The use of a rotating mass in this manner is considered undesirable because of the added weight and complexity involved, together with the need for careful maintenance. Furthermore, a continuously rotating loop requires sealed rotating bearings which are relatively expensive, require careful maintenance and may be troublesome with chemically active fluids or fluids at high pressure.

It has also been proposed to oscillate the loop, and

strument, as described above. While the oscillation removes the need for rotating joints, the rotating flywheel is considered highly undesirable for the reasons given above.

It is a primary object of the present invention to provide a mass flowmeter of the gyroscopic type, wherein the loop is oscillated so as to avoid the need for rotating joints, and in which the need for a rotating flywheel is avoided. An oscillating instrument is here termed the A.-C. type. Certain features of the invention, however, are applicable to a continuously rotating instrument, here termed the D.-C. type. Although the apparatus of the invention is particularly useful in measuring the mass flow of fluids, generally speaking it is capable, with suitable design parameters, of measuring the mass flow of any fluid-like material. Such materials include emulsions, slurries of solid particles in a liquid or gaseous carrier, multi-phase mixtures of liquids or gases, etc.

The invention will be explained in conjunction with the accompanying drawings, and certain features will in part be pointed out and in part be evident from the drawings and description thereof.

In the drawings:

Fig. 1 is a side view of an A.-C. mass flowmeter; Figs. 1*a* and 1*b* are details illustrating suitable damping means;

Fig. 2 is a view at right angles to that of Fig. 1;

Fig. 3 is a detail showing the arrangement of the inlet and outlet conduit sections;

Fig. 4 shows curves to explain the non-resonant operation of the apparatus of Figs. 1–3;

Fig. 5 is a circuit diagram of an indicating device which may be used with the apparatus of Figs. 1–3;

Fig. 6 is another embodiment of an A.-C. mass flowmeter with simplified indication;

Fig. 7 is a further embodiment of an A.-C. mass flowmeter;

Fig. 7*a* is a detail showing the inlet and outlet conduit sections;

Figs. 7*b* and 7*c* are details of a torque drive which may be employed with the apparatus of Fig. 7;

Figs. 8 and 9 show curves illustrating the resonant operation of the apparatus of Fig. 7;

Figs. 10 and 11 are details of an alternative form of torque drive which may be employed in the apparatus of Fig. 7; and

Fig. 12 is a diagram showing a torque feedback system in accordance with the invention.

Referring now to Fig. 1, a fluid conduit **10** is arranged in the form of a loop and attached to support members **31**, **31'**. As specifically shown the loop is circular, but other configurations could be employed if desired. Inlet and outlet fluid conduit sections **11** and **12** extend from adjacent points **13**, **13'** of the loop to approximately the center of the loop. As here shown, conduit sections **11** and **12** are of flexible hose and secured to the horizontal support member **14** by a band **15**. Or, the sections **11**, **12** can be extensions of the tubing of loop **10**, extending inwardly to the loop axis in the manner shown but without the restraining band **15**, and flexible couplings attached to the tube sections near the center of the loop.

The loop **10** is mounted for angular movement with respect to member **14** by suitable means which are here shown as short lengths of music wire **16**, **16'**. Thus, the loop **10** is mounted for angular movement about an axis approximately in the plane of the loop, and the lengths of music wire form torsional springs which produce a restoring moment when the loop **10** is angularly deflected on either side of the central position illustrated.

The loop and its associated support member **14** is mounted for rotation about an axis approximately per-

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