United States Patent [19]

Thompson

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[54] **CORIOLIS-TYPE MASS FLOWMETER CIRCUITRY**

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Related U.S. Application Data

[60] Division of Ser. No. 116,257, Oct. 29, 1987, Pat. No. 4,911,020, which is a continuation-in-part of Ser. No. 923,847, Oct. 28, 1986, Pat. No. 4,891,991.

[51] **Int. Cl.⁵** G01F 1/84
[52] **U.S. Cl.** 73/861.38
[58] **Field of Search** 73/861.38, 861.37

[56] **References Cited**

U.S. PATENT DOCUMENTS

Re. 31,450	11/1983	Smith	73/861.38
3,509,767	5/1970	Greer	73/705
3,927,565	12/1975	Pavlin et al.	73/194 M
4,127,028	11/1978	Cox et al.	73/861.38
4,187,721	2/1980	Smith	73/194 B
4,192,184	3/1980	Cox et al.	73/194 B
4,252,028	2/1981	Smith et al.	73/861.38
4,311,054	1/1982	Cox et al.	73/861.38
4,422,338	12/1983	Smith	73/861.38
4,491,009	1/1985	Ruesch	73/32 A
4,655,089	4/1987	Kappelt et al.	73/861.38
4,660,421	4/1987	Dahlin et al.	73/861.38
4,691,578	9/1987	Herzl	73/861.38
4,703,600	11/1987	Brenneman	73/861.38
4,747,312	5/1988	Herzl	73/861.38
4,756,197	7/1988	Herzl	73/861.38
4,759,223	7/1988	Frost	73/861.38
4,777,833	10/1988	Carpenter	73/861.38
4,782,711	11/1988	Pratt	73/861.38
4,817,448	4/1989	Hargarten et al.	73/861.38
4,823,614	4/1989	Dahlin	73/861.38
4,831,855	5/1989	Dahlin	73/861.38

FOREIGN PATENT DOCUMENTS

0212782	3/1987	European Pat. Off. .
WO8505677	12/1985	PCT Int'l Appl. .
WO8600699	1/1986	PCT Int'l Appl. .
WO8702469	4/1987	PCT Int'l Appl. .

Primary Examiner—Herbert Goldstein
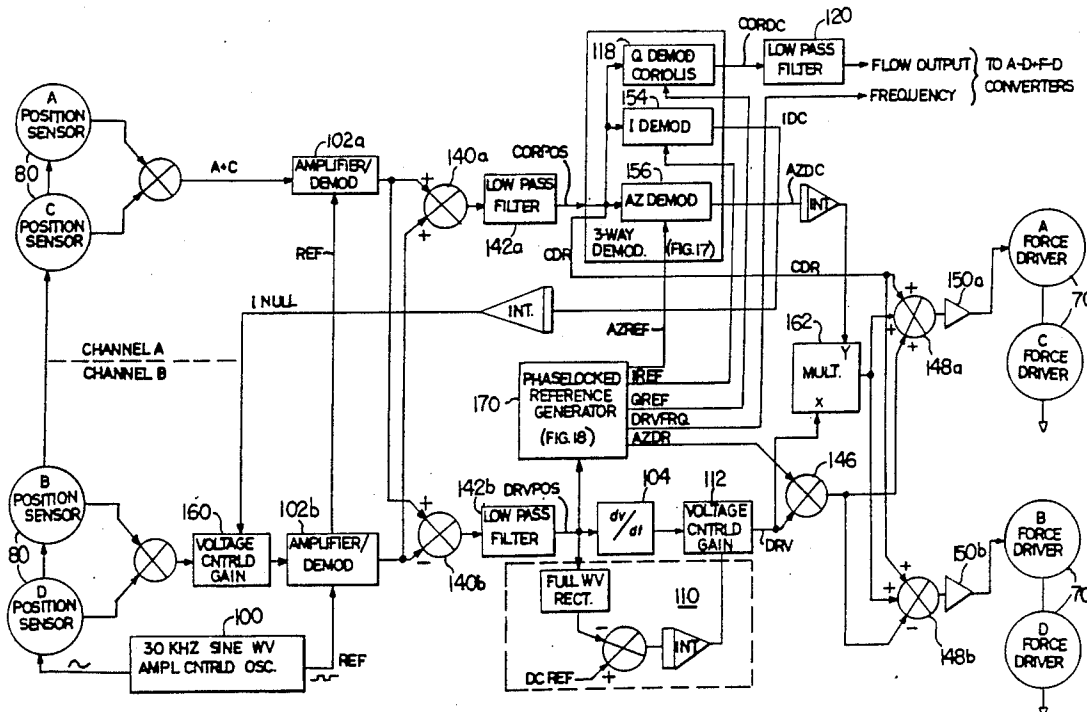*Attorney, Agent, or Firm*—Fish & Richardson

[57] **ABSTRACT**

Displacement sensors at opposite ends of at least one oscillating conduit produce output signals from which the drive component or the Coriolis component, or preferably both, are recovered. An oscillatory drive signal is derived from the drive component, and a mass flow signal is derived from the Coriolis component. The remaining drive component in a combination of the two sensor outputs is nulled by amplitude control of one sensor output. Two force drivers at opposite ends of the conduit are driven by complementary drive signals to which a perturbation signal is added. The remaining perturbation signal in a combination of the two sensor outputs is nulled by adding compensation to both drive signals to eliminate drive force imbalance. Synchronous demodulation is used in the preferred embodiment to detect several parameters in a combination of the sensor outputs. In a dual loop configuration, pairs of sensors and/or force drivers are located at opposite ends of each conduit section.
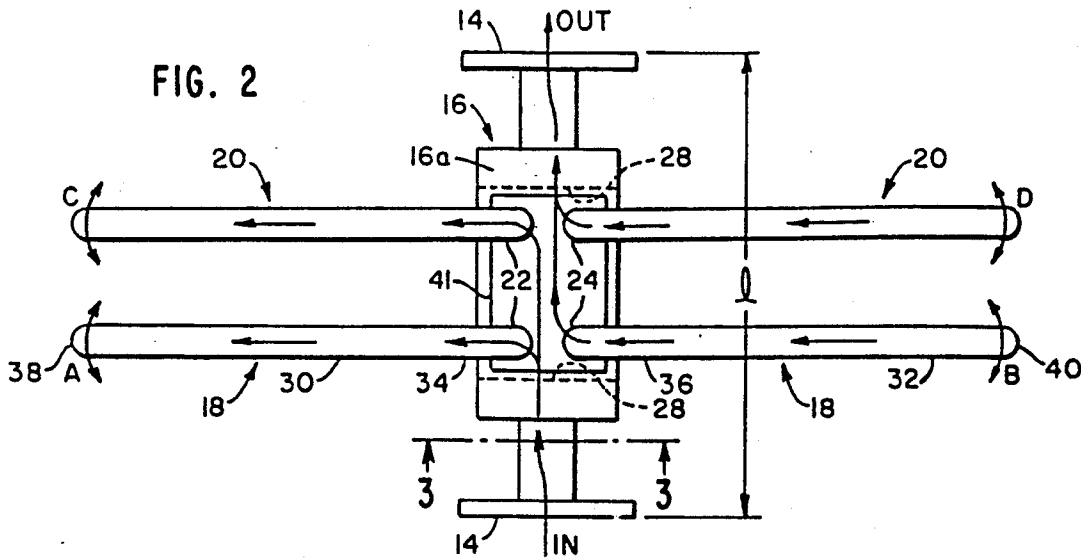
21 Claims, 12 Drawing Sheets

FIG. 1

DRIVER ASSEM., 70

DETECTOR ASSEM., 80

FIG. 2

FIG. 2A
(SERIES FLOW)

FIG. 3

FIG. 4

FIG. 5

FIG. 6

COVER

COIL

TUBE

MAGNET

POLE PIECE

FIG. 6A

FIG. 7

FIG. 8

FIG. 9

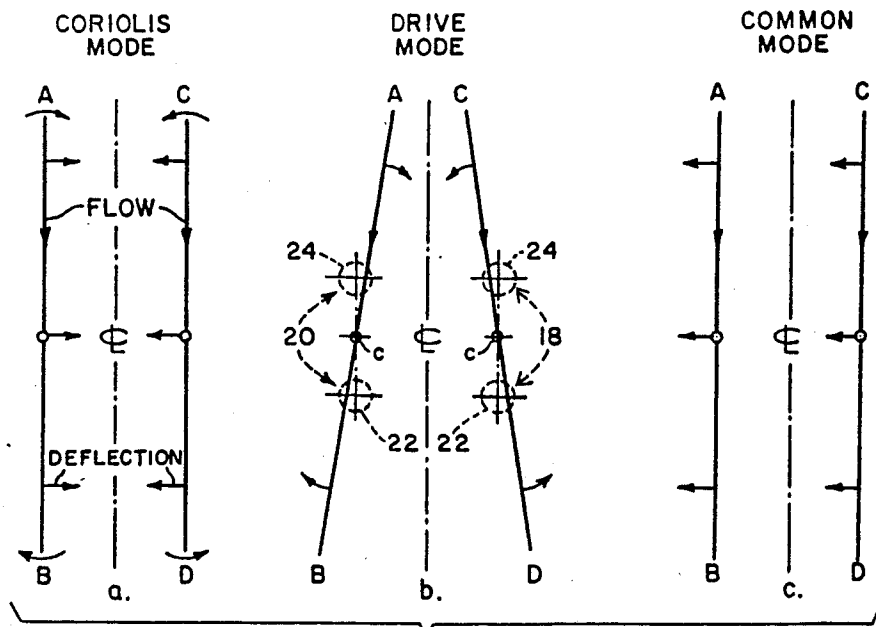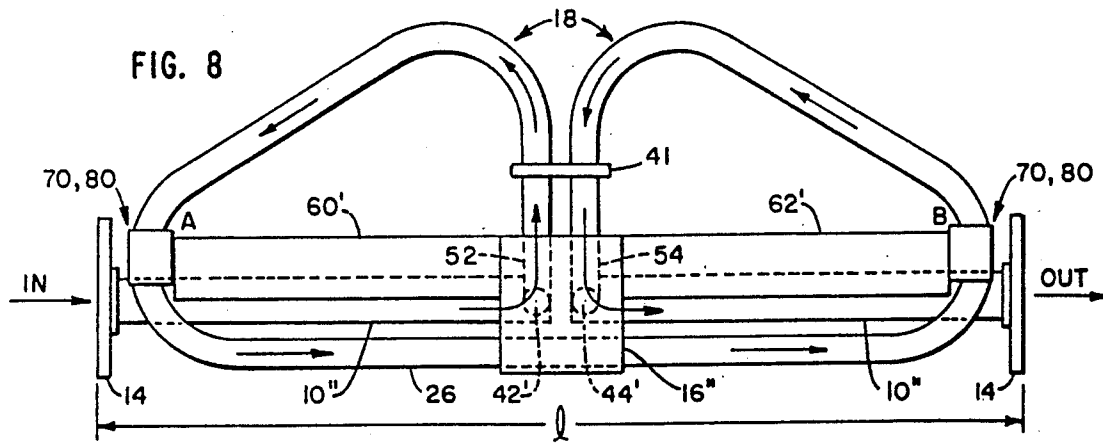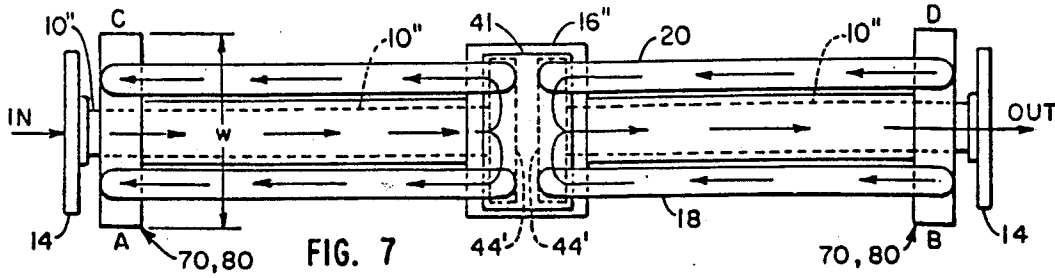CORIOLIS MODE   DRIVE MODE   COMMON MODE
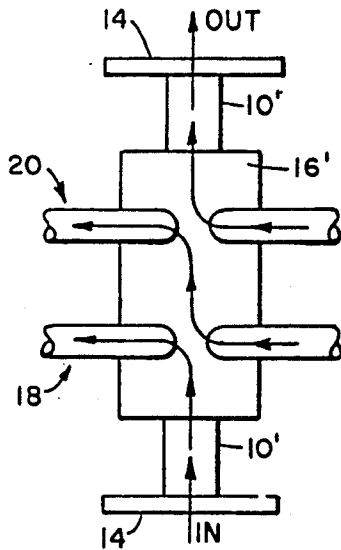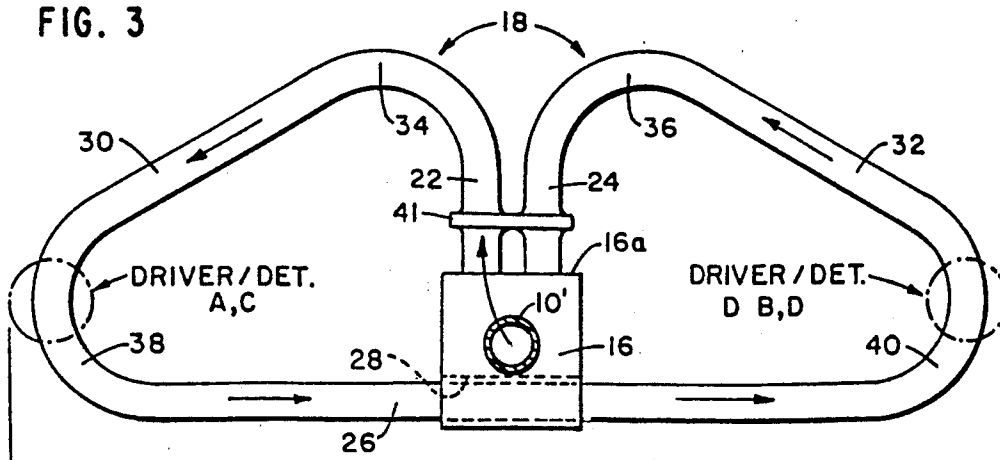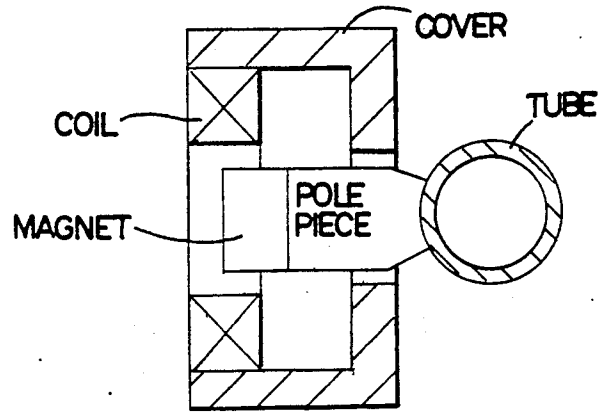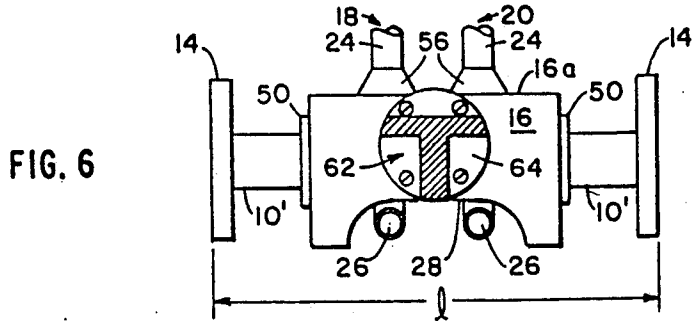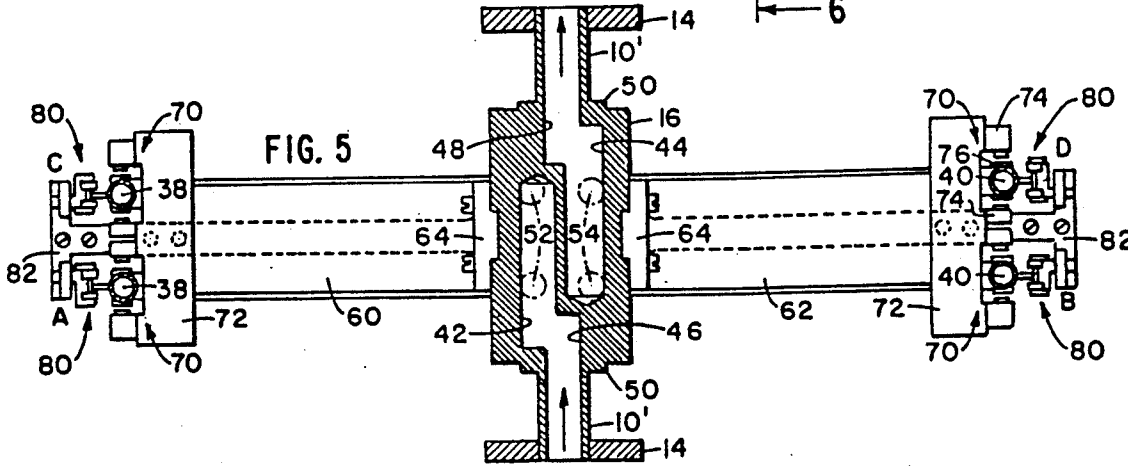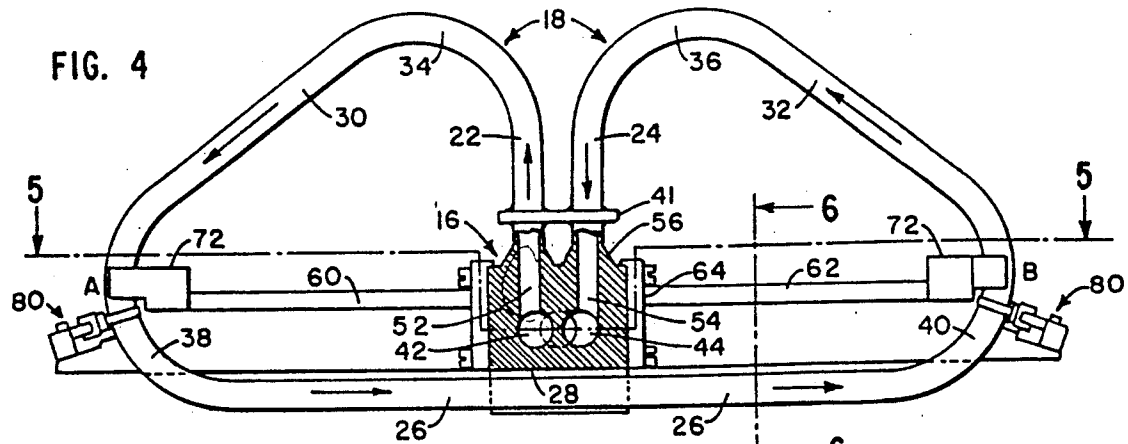
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