United States Patent

Gosling et al.

[15] **3,641,994**

[45] **Feb. 15, 1972**

[54] TURBULENCE-SENSING BLOOD FLOWMETER

[72] Inventors: **Raymond George Gosling**, Hartron, Oldfield Road, Bickley, Kent; **David Henry King**, 14, Aldersey Gardens, Barking, Essex, both of England

[22] Filed: **July 22, 1969**

[21] Appl. No.: **843,602**

[30] **Foreign Application Priority Data**

July 19, 1968 Great Britain 34,537/68

[52] **U.S. Cl.** ..... **128/2.05 F**, 73/194 A, 128/2.05 S

[51] **Int. Cl.** **A61b 5/02**

[58] **Field of Search** ..... 128/2.05 D, 2.05 E, 2.05 F, 128/2.05 N, 2.05 P, 2.05 R, 2.05 S, 2.05 V; 73/94 A, 94 B, 67.2, 69, 70, 56, 70.1, 1

[56] **References Cited**

UNITED STATES PATENTS

2,658,505	11/1953	Sheer	128/2.05 P
2,936,619	5/1960	Gibney	73/194 B
3,002,185	9/1961	Bases	128/2.05 S
3,017,885	1/1962	Robicsek	128/2.05 F
3,189,023	6/1965	Salz et al.	128/2.05 E
3,403,672	10/1968	Curtis	128/2.05 F

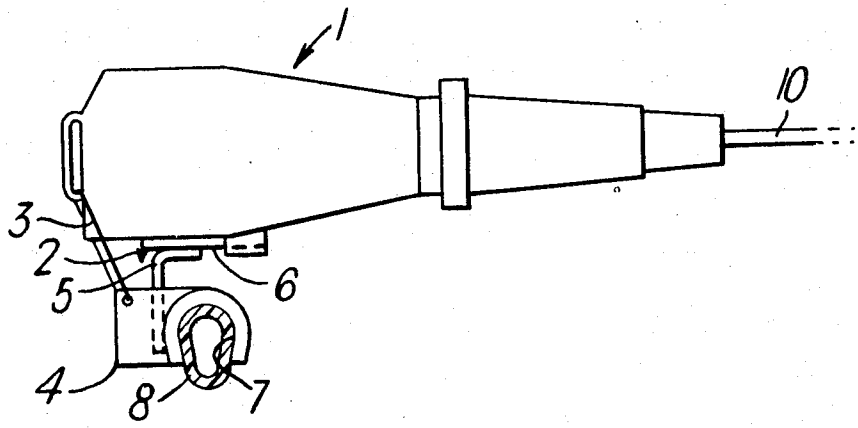
Primary Examiner—William E. Kamm

Attorney—Beveridge and DeGrandi

[57] **ABSTRACT**

An apparatus which evaluates and signals a characteristic which is interdependent with a rate of flow of the bloodstream in an animal vascular system, by detecting and signalling undular alternations of pressure in the blood which alternations are the consequence of turbulence in the flow and are characteristically related to the flow rate. The invention includes the provision of means artificially to create the turbulence and may include adaptation to use in a surgical bypass duct. A C-shaped member fits onto the surgical bypass duct and turbulence in the duct which is indicative of flow rate is transmitted to the C-shaped member and to an acoustic transducer means mechanically connected to the C-shaped member which generates an electrical signal indicative of flow rate.

8 Claims, 4 Drawing Figures



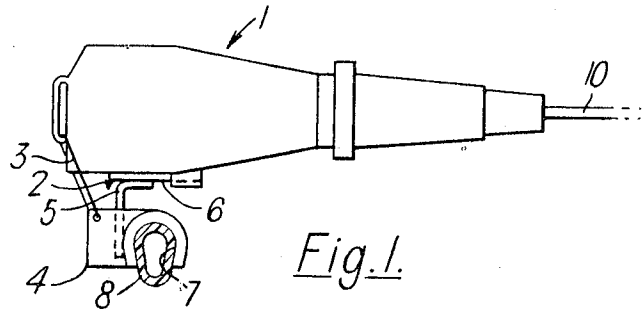


Fig. 1.

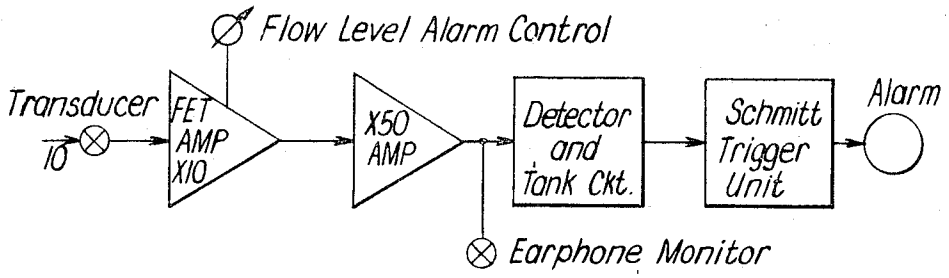


Fig. 3.

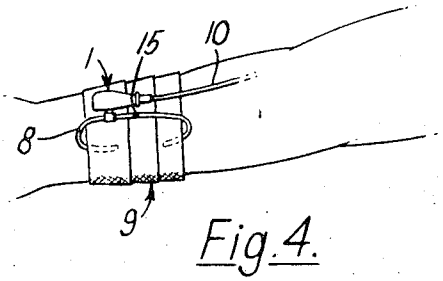


Fig. 4.

Inventor
RAYMOND GEORGE GOSLING
DAVID HENRY KING
By Beveridge & DeGrandi
Attorney

PATENTED FEB 15 1972

3,641,994

SHEET 2 OF 2

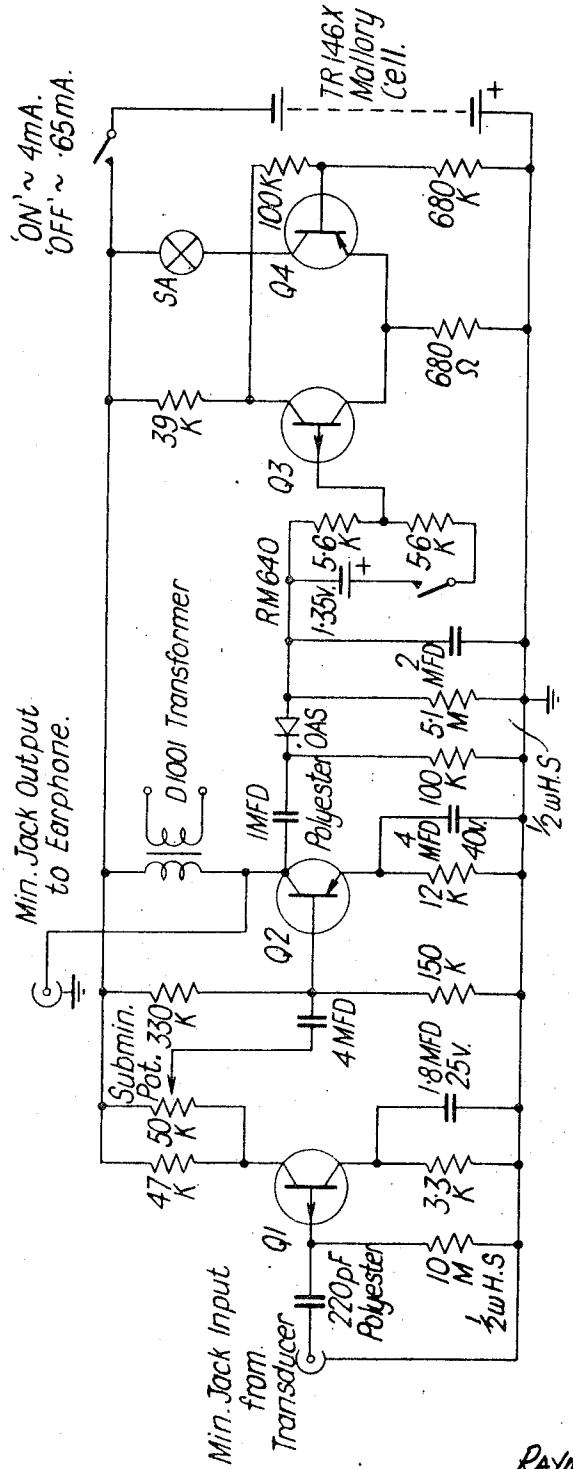


Fig. 2.

Inventor
RAYMOND GEORGE GOSLING
DAVID HENRY KING
By Beveridge & DeGrandi
Attorney

TURBULENCE-SENSING BLOOD FLOWMETER

This invention relates to an apparatus for signalling change of blood flow in an animal vascular system. In its broadest aspect it is concerned with change in rate of flow.

The problem which the invention primarily seeks to solve is the monitoring of blood flow in a renal dialysis shunt in which are used an arterial cannula, a silicone rubber duct or "segment," and a venous cannula. It is desirable continuously to monitor the flow of blood in such a shunt because there can be change due to clotting, which builds up and not only impedes the proper circulation but may (if not anticipated by washing out or other steps) shed emboli which may of course be dangerous. The monitoring to which we refer, may be in either or both of two respects; it may be as to rate of flow itself, or as to a characteristic related to the rate, i.e., turbulence. It is pointed out that blood clotting may produce a detectable decrease in turbulence before it causes detectable change of means rate of flow—particularly because the rate of flow which is susceptible to monitoring is the peak rate.

In surgical applications of the invention, regard must be had to possible interferences in function, or examples due to rustle of clothing, change of posture, change of mean pressure (raising or lowering a peak pressure) temporary strangulation of arterial flow, and so on.

However the apparatus is not restricted in its application, to monitoring a blood flow. As will be seen from what follows, it is widely applicable to signalling change of fluid flow in various circumstances in which the change to be signalled is one which is associated with the promotion of turbulence. Thus, the apparatus may be used as a flowmeter or indicator, in connection with a duct or channel in which it is ascertained that a change in flow rate results in a change in the detectable frequency or amplitude or both, or pressure waves set up by turbulence. To apply such a device it may therefore be that the invention includes the provision of means to promote turbulence and means to signal a resulting train of compression waves. The invention may go even further; it includes a device which may be used to minimize turbulence in circumstances otherwise unduly promoting it, thus actually deferring or shifting a critical flow condition which would otherwise be signalled. That is, the threshold at which a signal is given may be raised, and further, the possible causation of the defect which is monitored, namely turbulence causing clotting, may be avoided or abated. Moreover, by using appropriate signalling means, for instance with a response or indication quantitatively related to a quantitatively varying change, the apparatus may be used (e.g.) to signal a change of or actually to indicate as a reading, a flow velocity. If it be uneconomic to provide a variable signalling device, then a tuner may be used to vary the set operating value to the signal. For instance, the speed of a boat in water, or of a flying aircraft, may be indicated (or evaluated) by creating or selecting a location on the skin boundary whereat turbulence is generated with an undular frequency which is a function of the speed, and then "listening to" and signalling the frequency of sound waves thus caused. The signal may then be read off as a quantity in terms of speed, or the device may be knob turned until a signal is given, and the speed read from the knob setting. In simplified terms this makes practical use of the "singing" which is sometimes heard when there is a turbulent flow, by observing the pitch of the singing.

According to one aspect, there is a method of evaluating rate of flow which comprises detecting turbulence in the flow, which turbulence results in alternations of fluid pressure at a point or in a region in the flow which alternations are characteristically related to the rate of flow; and signalling a variation of or the value of a so related characteristic. Thus, there being a place in the flow whereat turbulence is manifested by a train of pressure waves (usually within the acoustic range) when a certain rate of flow occurs or when an occurrence takes place (such as clotting of blood) which may reduce the rate of flow, the method will reside in detecting either the frequency or the amplitude (or both) of such waves and signalling a significant variation of the detected parameter.

The method may include synthesizing or deliberately causing the turbulence by introducing in the flow an artificial disturbing factor; that is to say, any of the physical factors which are known to result in turbulence, such as a critical transition point, a surface which will critically cause a breakaway from laminar to turbulent flow, an obstruction, as abrupt changes of section of a duct, or a bend especially if in a diffusing (i.e., divergent-section) duct or channel.

The invention includes apparatus in the form of means for evaluating rate of flow in a duct, comprising a sensor of pressure waves responsive to frequency, amplitude, or form of the waves, a transducer actuated by, or itself being the sensor and having an output of electrical energy, and an indicator actuated by such output, the sensor being of such nature—for example being stethoscopic or microphonic—that it can be associated with the duct or other surface whereon the turbulence exists (for example being held in contact with an elastic wall of the duct) so as to be sensitive to waves set up by turbulence in the duct or other surface in a location whereat turbulence is related to the rate of flow.

The invention further includes a monitoring apparatus for human use, comprising an acoustic pickup adapted to press upon a natural or prosthetic blood vessel or duct and to be retained in such relationship; and a transducer, amplifier, and frequency filter arrangement arranged to operate a signalling device (e.g., to make a distinctive noise) preferably after a timelag, when a decrease of flow in the bloodstream occurs. Such apparatus may be battery driven by a small dry battery, and may be adjustable or originally set so as to be insensitive to background or fortuitous noise (such as rustle of clothing), to frequencies which are irrelevant to the condition to be monitored; it may also be so set as to operate outside a sufficiently wide threshold of rate of flow as to leave it unoperated if a change of position results in a change of flow. Indeed, it appears to be shown experimentally that it suffices (to give warning of blood clotting) to indicate a drop in flow rate of say 40 percent from normal. The invention in this form, resides in means for detecting and signalling a change in the peak rate of flow in the blood stream in a surgical arteriovenous bypass or "shunt" duct, comprising an acoustic wave pickup adapted to contact and respond to acoustic pressure wave alternations by a determined level in the bypass duct in such a location as to respond to waves caused by turbulence in the duct such turbulence itself being the result of obstructions of, or changed form of, the bypass.

The invention may also include provision for reducing acoustic frequency turbulence in the blood, to the benefit of a monitor or (as can be medically important) to abate clotting, when such turbulence is caused by the usually tapered distal tip of a venous cannula; this provision resides in one or more holes or apertures formed in the wall of the cannula to afford a blood passage between the base of the cannula and such sinus as may exist peripherally between the tip of the cannula and the vein.

The invention, as will be seen from the following description of an example of apparatus, also includes an acoustic pickup and electrical circuitry which provides the required amplification filtering, timelag, and audible signal, all arranged as a monitor device for a person who has a renal dialysis shunt.

The accompanying drawings illustrate by way of example, a pickup and a circuit suitable for use therewith.

FIG. 1 diagrammatically illustrates the pickup and

FIG. 2 the circuit, of which

FIG. 3 is the block diagram.

FIG. 4 illustrates how the pickup is attached to an arm shunt, between artery and vein.

In FIG. 1 is illustrated conventional phonograph pickup 1 using a piezoelectric crystal and the conventional stylus seen at 2. Attached by a tension loop 3 of nylon is a C-shaped plastics body 4, into which is molded a metal arm 5, soldered to a spring lead 6 an end of which is anchored to the body of the pickup 1. The other end of the leaf engages the stylus 2. The body 4 has a C-shaped formation at 7, forming a reentrant channel so dimensioned that it will retain and firmly contact

the wall of the silicone rubber tube 8 which is part of the dialysis shunt. The firm contact of the C-shaped member on the tube promotes turbulence. This arrangement is used as illustrated by FIG. 4; in this, the pickup 1 is seen positioned so that the body 4 is fitted on to the silicone rubber shunt section 8 of which one end is cannulated into the artery and the other into the vein of the patient's arm (in this example). The body 4 is arranged at the venous end. The whole site is secured by a bandage 9. From the pickup 1, the electrical lead 10 connects to the electrical unit. This comprises a self-contained pack with its own housed battery. As may be seen by reference to FIG. 4 in one embodiment of the invention an obstruction 15 may be situated upstream of the detection means to promote turbulence.

The circuit is based on the block diagram (FIG. 3) and the actual connections and components are to be discerned from FIG. 2. The following describes the functions and the device.

In the turbulence detector (i.e., adapted pickup), the piezoelectric element converts alternations of pressure into an electrical signal in the audio range which is amplified by a P-channel diffused-silicon field effect transistor (Texas Instruments type 2N2497) Q1 giving a voltage gain of 10.

A potentiometer is employed as the load and the adjustable output from this is used to drive a low-noise germanium transistor amplifier (Mullard type GET 880) Q2 giving an approximate gain of 50. A subminiature transformer (type D1001) provides the collector load and a crystal earphone monitor may also be driven from the collector. A swing up to 10 volts peak to peak may be measured at this point.

The AC signal appearing at the collector of Q2 is capacitor coupled to a diode detector followed by an R.C. tank circuit. The DC output derived from this is summed with a voltage derived from a separate "floating" bias cell and used to control the condition of a two-transistor Schmitt trigger circuit. The input is a field effect transistor (Q3) which is coupled to a germanium transistor (Q4) including in its load an alarm module (Sonalert Alarm Unit Type SC628 marketed by Highland Electronics Ltd.) which when energized provides a loud 2.5 kc./s. audio warning signal. The field effect transistor Q3 is normally biassed "ON" and hence drives Q4 "OFF" i.e., the alarm is held off.

When a decrease in flow below a chosen level persists for more than 5 seconds, as determined by the tank circuit, the DC bias on the gate of Q3 reduces to a point where Q3 is switched "OFF" and Q4 is therefore switched "ON" and the alarm sounds. The level is set by varying the potentiometer setting and hence the system sensitivity.

The circuit has an audio band-pass characteristic adjusted to reject 50Hz. mains pickup frequencies and low-frequency signals generated by the transducer as a result of arm movements, rubbing of clothing etc. It accentuates however the response to frequencies indicative of satisfactory flow, estimated from sonograms taken from shunts in patients to be in the range 500 Hz. to 2 kHz.

The circuit uses miniaturized components and has been designed for low power consumption. The total current drain under normal monitoring conditions (i.e., alarm off) is approximately 0.65 milliamps. This is supplied by an 8.4-volt mercury cell (Mallory TR146X) which has a 650 ma./hour capacity.

The complete unit therefore has 1,000 hours life of possible continuous monitoring. The pack dimensions are 13×5×2 cm. and its weight is 190 grams.

It will be clear from the foregoing that by suitable adaption, a similar arrangement may be used to monitor other fluid flows; and by modification of the specific elements involved, the various uses of the invention previously indicated may be practiced. For example the acoustic pickup may be secured within a thin and flexible area coplanar with the skin of an aircraft or that of a boat and if required a small obstruction of negligible drag—such as a rivet head—may be positioned just upstream of that area so that turbulence which it promotes may be "listened to" and monitored so as to signal speed, stalling, shift of a boundary transition locality, or any similarly related characteristic or effect.

We claim:

1. Apparatus for monitoring the rate of flow of blood within a duct having a pliable wall comprising,
   - displacement transmission means positioned in external communication with said pliable wall of said duct and displaceable in accordance with movements of said pliable wall for transmitting movements indicative of turbulence in said duct,
   - acoustic transducer means mechanically connected to said transmission means for generating an electrical signal proportional to said movements indicative of turbulence,
   - amplifier means for applying said electrical signal,
   - detection means for generating an alarm signal when said electrical signal and hence said turbulence and said rate of flow changes by a predetermined amount.

2. Apparatus according to claim 1 wherein said detection means includes a time delay means which allows said alarm signal to be generated only after said change by said predetermined amount takes place for a predetermined minimum period of time.

3. The apparatus of claim 1 further including obstruction means positioned in said duct for creating said turbulence.

4. The apparatus of claim 1 wherein said duct is an artificial shunt connecting two blood vessels.

5. The apparatus of claim 4 wherein said transmission means includes a C-shaped body which grips said artificial shunt around part of its curved surface.

6. The apparatus of claim 5 wherein the gripping of said artificial shunt by said C-shaped member promotes said turbulence.

7. The apparatus of claim 6 wherein said transmission means further includes two separate members attached at one end to said C-shaped member and at the other end to said acoustic transducer means.

8. The apparatus of claim 7 wherein said detection means further includes means for providing a continuous indication of flow rate.

* * * * *