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(19) (CA) **CANADIAN PATENT** (12)

(54) Blood Testing Device

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ABSTRACT OF THE DISCLOSURE

Apparatus for the investigation of blood, comprising a columnar reservoir formed from a plastic hypodermic syringe for holding the blood, an elongate tube leading from the reservoir to a waste blood holding vessel, and a pressurisable vessel for holding a blood immiscible fluid. The pressurisable vessel is connected to the columnar reservoir and pressurised so that the immiscible fluid displaces the blood through the tube, while simultaneously stirring the blood in the columnar reservoir. The apparatus includes at least two parallel channels, each channel comprising a columnar reservoir, elongate tube, waste blood holding vessel, and means for introducing a displacing fluid. A single parallel sided punching needle is provided, positioned so as to permit the punching of the respective elongate tube of each channel, or two similar parallel sided punching needles are provided, positioned so as to permit the punching by each of the said needles of a respective one of the said two elongate tubes. A collagen body may be positioned within the elongate tube to enable the investigation of thrombus formation. A pressure transducer is so positioned as to measure pressure in the waste blood holding vessel, so that the process of blood clotting can be followed.

BLOOD TESTING DEVICE

This invention relates to the measurement of various haemostatis, clotting, and the like properties of blood, and specifically to apparatus enabling measurements of such quantities to be made on blood.

A device of this kind is disclosed in European Patent **Publication** No. 129425.

In that specification there is disclosed apparatus for the investigation of blood, comprising a columnar reservoir for holding the blood, an elongate tube leading from the reservoir to a waste blood holding vessel, and means for introducing into the reservoir a fluid immiscible with blood to displace the blood through the tube, while simultaneously stirring the blood in the columnar reservoir (hereinafter referred to as "apparatus of the type described").

I have now discovered a number of modifications and improvements to the apparatus disclosed in European Patent **Publication** No. 129425, which not only enable more reliable and more reproducible measurements to be made of clotting and haemostatis, but also enable a number of other quantities to be measured.

In accordance with a first aspect of the invention, apparatus of the type described includes a

pair of parallel channels, each channel comprising a columnar reservoir, elongate tube, waste blood holding vessel, and means for introducing a displacing fluid, as described above.

The use of two parallel channels enables a number of measurements to be made which are not possible with a simple single channel instrument. For example, in a preferred embodiment of this aspect of the invention, each channel has a punching station, at which, as disclosed in European Patent **Publication** No. 129425, a through-hole is punched through the elongate tube, to simulate bleeding. So that the size of the holes in the two tubes is exactly the same, both holes may be punched by a single parallel-sided punching needle. In an alternative embodiment, two exactly similar needles may be provided at corresponding places in the tubes of the two channels.

The use of parallel channels is particularly advantageous, because it enables measurements of clotting and haemostasis kinds to be carried out on whole blood. Thus, in one embodiment, the columnar reservoir of both channels is filled with native blood, and caused to flow through the respective elongate tube, by displacement. Both channels are pierced, and the time take for haemostatis to occur

(i.e. the formation of a platelet plug in the two holes) is measured in both channels. Because the test is carried out in both channels using whole blood, the platelet plug formed simulates very closely platelet plugs formed in arterial bleeding.

An anticoagulant agent is then introduced in to the blood flowing in one of the channels. This prevents the blood flowing in that channel from clotting, so that thrombolysis of the platelet plug in that channel can be investigated but does not interfere with the haemostatic plug formation because the haemostatic plug has already been formed when the anticoagulant is introduced. A preferred anticoagulant is heparin, because of its low interference with the thrombolytic process.

After a period of time the blood in the channel which is not anticoagulated will clot, and this can be measured by appropriate pressure transducers. In the channel to which the anticoagulant has been added, the platelet plug will eventually dissolve, and therefore thrombolysis time can be measured.

The two-channel instrument of the first embodiment of the present invention is also useful in other clinical diagnostic techniques, for example to determine the effects of various pharmaceuticals substances on clotting, haemostatis and thrombolysis. Native blood containing saline (control) may be utilised in one channel of the apparatus, and identical blood containing the pharmaceutical

substance to be investigated in the other, and thus the effect on the various properties of the blood can be monitored under closely controlled conditions.

In a second aspect, the invention is concerned with the effect of various substances, for example collagen, on haemostasis/thrombosis. For example, a small piece of collagen, such as a piece of a surgical suture, may be placed within the elongate tube leading from the columnar reservoir to the blood holding vessel of apparatus of the type described, and the blood caused to flow over the substance.

The mechanism of platelet thrombus formation on the surface of substances such as collagen is similar to that which occurs during the normal passage of blood through injured blood vessels in the body. Collagen fibres are exposed when blood vessels are ruptured and it is of considerable clinical interest to investigate in detail the effect of collagen during thrombus formation. In particular, it has been established by electron micrography that thrombus formation takes place by means of the build up of a monolayer of platelets on the collagen surface, followed by subsequent platelet adhesion to succeeding layers. Electron micrography is an expensive and time consuming technique, and in a second aspect of the invention, a method and apparatus are provided for

enabling the investigation of platelets on substances such as collagen or other bio-compatible materials to be carried out, using relatively simply apparatus.

In accordance with this aspect of the invention, a piece of the substance such as collagen is provided in the elongate tube of the apparatus, and the progress of thrombus formation is followed by observing blood flow in the tube, for example by the measurement of pressure, as disclosed hereinafter, as the formation of a thrombus on the substance causes a characteristic pattern of occlusion of the tube.

In accordance with a third aspect of the invention, three parallel channels may be provided, to enable the effect of substances such as collagen on thrombus formation to be determined, whilst other measurements are also being performed, for example haemostatis and blood clotting measurements.

A fourth aspect of the invention relates to the method by which blood flow in apparatus of the type described is measured and controlled. In European Patent **Publication** No. 129425, a pressure transducer is utilised, to measure variation of pressure in the blood, as the holes are punched, and subsequently occluded by platelet plugs. The pressure transducer however is positioned upstream of the punching station, so that the only measurement possible with

regarding to clotting in the tube is the point at which blood flow in the tubes ceases completely. In accordance with the fourth aspect of the invention, apparatus of the type described includes a pressure transducer downstream of the elongate tube, and preferably disposed so as to measure pressure in the waste blood holding vessel, whereby the process of blood clotting can be followed. Thus, as the blood clot in the tube grows in size, flow through the tube diminishes steadily, and thus the pressure in the waste blood reservoir falls. As in European Patent **Publication** No. 129425, the waste holding vessel is, in this embodiment, filled with a fluid immiscible with the blood, which is displaced by the entry of the blood.

A fifth aspect of the invention is concerned with the mechanism for causing the blood to pass through the elongate tube. In European Patent **Publication** No. 129425, the blood is displaced by a fluid immiscible therewith, for example paraffin oil, which is supplied to the columnar container using a syringe pump. This arrangement is somewhat disadvantageous in practice, because it tends to result in a pressure profile which varies unacceptably, and is also rather difficult to control.

In accordance with a sixth aspect of the

invention, apparatus of the type described includes means for introducing the immiscible fluid into the columnar container, comprising a pressurisable vessel for the immiscible fluid, means for applying a constant pressure head to the pressurisable container, and a capillary tube leading from the pressurisable vessel to the columnar container, the capillary tube having a resistance to flow substantially greater than that of the tube leading from the columnar container to the waste blood holding vessel. Because in this arrangement, the greater part of the pressure drop across the apparatus takes place across the capillary tube, rather than the tube which is pierced, a constant pressure applied to the pressure vessel results in a substantially contant flow of the displacing fluid into the columnar container. Thus, the flow of blood through the apparatus can be readily controlled, by controlling the pressure in the pressurisable container. This may be applied using, for example, a twin-head pump, or a gas cylinder.

A seventh aspect of the invention relates to the nature of the columnar container itself. In the apparatus disclosed in European Patent **Publication** No. 129425, the columnar container is essentially a tube provided with a fluid inlet and a fluid outlet at its bottom part, for, respectively, introduction of

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the displacing fluid, and the outflow of blood. One disadvantage of this arrangement is that it necessitates transfer of the blood from one container to another, after it has been taken from the patient, and this can result in the initiation of the clotting process. Furthermore, the tube arrangement includes a number of sharp corners over which the blood must flow, and these and the turbulence caused also can initiate the clotting/haemostasis process. In the seventh aspect of the invention, the columnar container is preferably a plastics syringe, which can be used to take a blood sample from a patient in the ordinary way, and from which the hypodermic needle can then be removed, so that the elongate tube leading to the waste blood holding vessel can be attached. The apparatus preferably includes a mounting block for the syringe, which may include temperature control means, for example a water jacket, or a thermostatically controlled heating element. In devices according to the invention having two or three parallel channels, the mounting block will generally be adapted for mounting a syringe for each channel.

The support block may also preferably comprise a port or septum, so that a hypodermic needle may be introduced into the syringe, through its wall, for introduction of the displacement fluid. The

displacement fluid will normally be less dense than blood, and accordingly the port is preferably positioned close to the bottom of the hypodermic syringe, so that introduction of the displacement fluid causes effective stirring of the blood. The elongate tube leading from the syringe to the waste blood vessel is preferably attached by a LUER-type fitting, and by this method virtually all parts of the apparatus which come into contact with blood are rendered disposable. Thus, the syringe, tubing and waste blood holding vessel may all be discarded after use.

It is particularly desirable that the apparatus should be so constructed that all parts which come into contact with blood are easily removed and disposed of, whether or not the apparatus includes a hypodermic syringe as the columnar container.

Yet a further aspect of the invention is concerned with the investigation of thrombolysis. As indicated above, by carrying out the second phase of the measurements on anticoagulated blood, it is possible to follow the progress of thrombolysis in blood, and to investigate the effect of various agents on thrombolysis. Although haemostatis and clotting are relatively quick to occur, thrombolysis will generally require a much longer time for completion, for example from fifteen to forty minutes. If the blood is caused to flow in the elongate tube for the whole of this period, substantial quantities of blood are required. However, once the anticoagulant has been added, it is no longer necessary for the <u>flow</u> of

blood to be maintained in the tube, provided that the pressure of the blood remains constant.

Accordingly, in this further aspect of the invention, there is provided a valve, for example a needle valve, for closing the outlet of the waste blood holding vessel, so that after anticoagulated blood has passed through the whole of the elongate tube, the valve can be closed, such that pressure in the system can be maintained, without the loss of blood therefrom. The progress of thrombolysis can then be measured, as above, using a pressure transducer in the waste blood holding vessel. This arrangement is particularly advantageously used with the arrangement described above of a pressurised vessel for driving the displacement fluid in the columnar blood container. In this preferred embodiment, means may be provided for reducing the pressure applied to the pressurisable vessel, when the valve is closed. Since the internal pressure in the blood-containing parts of the system (the columnar container, elongate tube and waste blood holding vessel) is substantially below that in the pressurisable container, closing of the valve would result in the overall rise in pressure in the system, because of equalisation of the pressure in the blood-containing parts, and the displacement fluid

containing parts. In this preferred embodiment of the invention therefore, means are preferably provided for applying a reduced pressure to the displacement fluid, after closure of the valve. In one embodiment, the means for applying the reduced pressure may take the form of two pressurisable containers, pressurised to different pressures, and alternatively switchable to provide the pressure to drive the displacement fluid.

Although all of the various aspects of the invention are preferably embodied in the same apparatus, it should be understood that each aspect may be utilised independently, or the various aspects may be utilised in any desired combination.

A particularly preferred embodiment of apparatus incorporating all of the above aspects of the invention will now be described, with reference to the accompanying drawings, in which:-

Figure 1 is a schematic diagram showing one channel of a two-channel blood analysis device,

Figure 2 is a schematic diagram of the punching station of a two-channel device,

Figure 3 shows a preferred pressurised vessel arrangement,

Figure 4 shows samples of haemostatis, clotting, and thrombolysis traces obtained with the instrument of Figures 1 and 2, and

Figure 5 illustrates the investigation of platelet, collagen interaction.

Referring first to Figure 1, one channel of a two-channel instrument comprises a columnar container for holding blood, in the form of a 2ml hypodermic syringe 1, made of a disposable plastics material. A elongate polyethylene tube, having an internal diameter of 0.5 mm, and a length of approximately 30 cm is connected to the syringe 1 by means of LUER-type connector 3. The tube 2 is inserted through a pressure-tight rubber seal 4 in a waste blood holding vessel 5. At the commencement of any particular investigation, the waste blood holding vessel 5 is filled with paraffin oil 6, and the level of blood 7 in the vessel rises during the investigation.

The syringe 1 is received in a syringe mounting block 8, provided with an electrical heating element and thermostat (not shown) to maintain the heating block 8 at a constant temperature of 37°C. The plunger 9 of the syringe 1 is secured by a lock (not shown), to prevent its backward movement, on pressurisation of the blood in the syringe.

The polyethylene tube 2 is threaded through a punching station, generally of the kind described in European Patent **Publication** No. 129425, except for

the modification that support is provided for two such polyethylene tubes, and a punching needle 10 is of a sufficient length, and has sufficient movement, to punch through both sides of the tubes 2 of two channels. This is illustrated more clearly in Figure 2. Needle 10 is attached to a plunger 11, which may be manually actuated, but is preferably actuated by means of a solenoid, or hydraulic or pneumatic actuator. The shank of the punching needle 10 has a diameter of 0.15 mm.

Means (not shown) are provided for enabling the supply of warm saline solution to the punching station, surrounding the tubes, to wash away the blood, as simulated bleeding occurs from holes 12 when the tube is punched. An outlet is provided for the saline solution, and means are provided associated with outlet for causing the saline solution to flow between a light-emitting diode, emitting green light, and a silicon photodiode.

The waste blood holding vessel 5 has three parts, a base 5a, a central tubular part 5b and an upper part 5c. The upper 5c has an opening 19 to which is affixed a pressure transducer 20. An outlet 21 for paraffin oil is also provided in the upper part 5c. A valve 22 is provided for closing outlet 21 from the vessel 5.

Parts 5a, 5b and 5c of the vessel 5 are assembled as a push-fit, and are sealed by "O" rings 24 and 25.

Figure 3 illustrates schematically an arrangement for supplying an immiscible fluid (paraffin oil) under pressure to the two channels of the instrument.

The apparatus for Figure 3 includes two pressurisable vessels 30 and 31, and a three-way tap 32. The three-way tap 32 is connected to a low pressure gas supply line 33, and a high pressure gas supply line 34. In the embodiment shown, the pressure in line 33 is arranged to be 60 torr, and that in line 34, 360 torr (all pressures referred to herein are gauge pressures) regulators 35 and 36 respectively are provided to maintain the pressure in lines 33 and 34 of the desired level. The three-way valve 32 can be turned between a first position, as shown, in which pressure line 33 is connected directly to pressure vessel 30, via line 38, and pressure line 34 is connected directly to vessel 31, via line 39, and a second position, in which pressure line 34 is connected to both pressure vessels 30 and 31.

Each of vessel 30 and 31 is filled with paraffin oil, and is provided with a respective capillary tube 40, 41 having an internal diameter of approximately 0.18 mm, and a length of approximately 30 cm, to hypodermic needles 42 and 43 respectively.

Means 46 are provided for applying gas under pressure to both pressure regulators 35 and 36. The means 46 may be a pump, or a cylinder of pressurised gas.

In operation of the apparatus, two blood samples are taken from the patient using respective syringes 1 of the two-channels of the apparatus. The syringes 1 are placed in the heating block 8 of the apparatus, and the luer-lock connector 3 is connected to the syringe outlet. The respective tubes 2 are then passed through the piercing station, and through rubber seals 4 of two waste blood holding vessels 5.

Each of the respective syringes 1 is then pierced through its side with a respective hypodermic needle 42, 43, connected to paraffin oil supplies in pressurised vessels 30 and 31 respectively. A pressure of 360 torr is applied to both pressure vessels 30 and 31, which causes paraffin oil to be displaced into the syringes 1 at a rate of approximately 0.1 m per minute. The inflowing paraffin oil prevent sedimentation of red cells in the blood, and displaces the blood through the tubing 2. The pressure at the pressure transducer 20 is observed, until it is steady, with a steady flow of blood entering vessel 5. The tubes 2 of both channels are then simultaneously pierced with the single needle

10, and the pressure at transducer 20 is observed further. A confirmatory check of bleeding through holes 12 is carried out noting the signal received at the silicon photodiode. Bleeding from holes 12 causes the signal to be much reduced, so that on-set and cessation of bleeding can be noted and confirmed.

Figure 4 illustrates a typical pressure trace obtained for channels I and II of two-channel apparatus.

In Figure 4, the trace shown for channel II illustrates the normal process of haemostatis and clotting, when no anticoagulant is used. Point A is Figure 4 represents the point at which the tubes 2 are pierced, and as can be seen, the pressure in vessel 5 descreased rapidly, and then slowly rises over a period of approximately two minutes, as haemostatic plugs are formed in holes 12. The pressure in channel II then rises again to its original level of 60 torr, until clotting occurs in tube 2. The on-set of clotting can be seen at point B, and clotting is complete at point C.

In channel I of the apparatus, the progress of haemostatis is identical with that in channel II, but after the haemostatic plugs have been formed, at point D in Figure 4, an anticoagulant is introduced into the blood in columnar container 1. In practice, this is

carried out by introducing into the paraffin oil flowing into the syringe 1 an amount of heparin such as to give a final concentration of 5 U/ml in the blood. Following injection of the anticoagulant, the blood in channel I does not clot, but continues to flow in the tube. To minimize wastage of blood therefore, after sufficient time has been allowed for heparin-containing blood to pass through the system, the valve 22 is closed, and valve 32 is operated, so as to reduce the pressure applied to pressure vessel 30 to 60 torr.

By this method, the progress of the breakdown of platelet plugs can be observed, and the effect of various drugs on thrombolysis can also be noted. The breakdown of the haemostatic plugs is shown not only by pressure drop at point E in Figure 4, but also by the silicon photodiode referred to above. The on-set of bleeding, as sensed by the photodiode, at point A is used to start a electronic clock, when blood appearing in the light pathway reaches a pre-set sensitivity threshold, and decreases the photodiode output below that threshold stops the Quartz clock, to show the elapsed (thrombolysis) time.

In the embodiment illustrated in Figure 5, the arrangement is generally the same as illustrated in Figure 1, except that it is not necessary to utilise

he needle 10 to punch the tube 2.

As illustrated in Figure 5, a short piece of collagen fibre (surgical catgut), having a diameter of approximately 0.15 mm is placed within the tube 2, before the blood supply is started. Platelets adhere and aggregate on the surface of the catgut, as illustrated in Figure 5, and eventually occlude the tube. The rate and extent of the decline of the pressure in the vessel 5 indicate the platelet adhesion to the collagen, and subsequent thrombus formation.

This procedure allows the quantative measurement of platelet function which is most characteristically changed in certain disorders (for example Von Willebrand disease, and by drugs, for example aspirin).

In accodance with the invention, apparatus for the determination of the effects of collagen and the like on thrombus formation may omit the punching means 12. It is preferred however that apparatus in accordance with the invention comprises three substantially identical channels, all as illustrated in Figure 1. The tubes 2 of two of the channels pass through the punching station, but the other does not, and is intended to receive the piece of collagen fibre.

The invention also provides methods for the determination of clotting, haemostatis and

thrombolysis factors of blood, using apparatus as described above.

It is a particular advantage of the apparatus described above that in vivo bleeding is simulated very closely, as well as the subsequent restorative processes, i.e. haemostatis, blood clotting, and clot disolution (thrombolysis). The device disclosed enables the simultaneous measurement of these three factors in a simple, reproducable way, under conditions close to those of haemodynamic stress, and in which a large amount of the blood utilised is saved. Furthermore, non-anticoagulated (native) blood can be utilised for all of these measurements, and all of the various measurements can be made from a blood sample of no more than 5 ml. Furthermore, evaluation of drugs which modify any of the three above processes can be carried out in a setting that is much more physiologically relevant than other in vitro methods used previously in haemostatis research, such as platelet aggregometry.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. Apparatus for the measurement of properties of blood, comprising:

a columnar reservoir for holding the blood,

an elongate conduit leading from the reservoir to a waste blood holding vessel,

means either (1) operatively coupled to said conduit or (2) disposed in said conduit, for initiating the process of haemostasis within said conduit,

means for flowing blood through said conduit, including means for introducing into the reservoir a fluid immiscible with blood to displace the blood through the conduit, said means for flowing blood being on an upstream side of said haemostasis initiating means, and

a pressure transducer for monitoring pressure haemostasis in the conduit and means for producing a record of the pressure monitored by said pressure transducer over time, the pressure transducer and record producing means being positioned downstream of said means for initiating the process of haemostasis,

wherein during the process of haemostasis, the flow of blood through the conduit creates pressure fluctuations downstream of the haemostasis initiating means, the monitored and recorded pressure over time thereby providing a measure of the haemostasis characteristics of the blood.

2. Apparatus as claimed in claim 1, wherein the pressure transducer is disposed so as to measure pressure in the waste blood holding vessel, whereby the process of haemostasis can be observed.

3. Apparatus as claimed in claim 1, wherein the columnar reservoir is a plastic syringe.

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4. The apparatus of claim 1 wherein said means for introducing said fluid into said reservoir comprises:

a pressurizable vessel for holding said fluid;

means for applying a constant pressure to said pressurizable vessel; and

a capillary tube leading from said pressurizable vessel to said reservoir, said capillary tube having a resistance to flow greater than that of said conduit, whereby a generally constant flow through said conduit occurs.

5. The apparatus of claim 1, wherein said means for initiating the process of haemostasis comprises a collagen substance disposed within said conduit.

6. The apparatus of claim 5, wherein said collagen substance is a collagen thread mounted to said elongate conduit so as to be disposed in a flow path thereof whereby flood flowing through said elongate conduit flows over and around said collagen thread.

7. The apparatus of claim 1, wherein said means for initiating the process of haemostasis comprises a punching station located along the conduit for punching said conduit to form a hole of determined size in said conduit to permit measurement of properties of the blood in said conduit.

8. Apparatus as claimed in claim 2, further comprising means for introducing a substance, a thrombolytic effect of which is to be measured, into the blood upstream of the means for initiating the process of haemostasis and a valve for closing an outlet of the waste blood holding vessel after introduction of said substance, whereby pressure in the system can be maintained without a loss of blood and whereby thrombolysis can be measured.

9. Apparatus as claimed in claim 8, including means for reducing the pressure to the displacement fluid,

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after closure of the valve, the means for reducing pressure comprising two pressurizable containers, means for pressurizing the containers to different pressures, and means for alternately switching the pressure from the two containers to drive the displacement fluid.

10. Apparatus as claimed in claim 8, wherein the means for introducing the immiscible fluid into the columnar reservoir comprises a pressurizable vessel for the immiscible fluid, means for applying a constant pressure head to said pressurizable vessel, and means for reducing the pressure applied to the pressurizable vessel when the valve is closed.

11. An apparatus for the measurement of properties of blood comprising:

first and second blood carrying channels, said first channel forming a test channel for subjecting blood to a test condition, the second channel comprising a control channel to compare with said test channel, whereby the effects of a test condition introduced in said test channel on blood flowing therethrough can be monitored, each of said channels comprising:

a columnar reservoir for receiving a sample of blood;

an elongate tube connected at one end to said columnar reservoir;

a waste receptacle connected to the second end of said elongate tube for receiving blood flowing from said columnar reservoir through said elongate tube;

means for introducing in said columnar reservoir a fluid immiscible with blood to displace the blood through said elongate tube;

pressure monitoring means located adjacent the second end of said elongate tube for monitoring pressure at a downstream portion of a respective

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channel; and

means for recording monitored pressure over time,

whereby the relative pressure differences in said first and second blood carrying channels indicates the relative effects of a condition introduced into said test channel on blood flowing therethrough.

12. Apparatus as claimed in claim 11, wherein a parallel-sided punching needle is provided, constructed and arranged so as to permit the punching of the elongate tube.

13. An apparatus for the measurement of physical properties of blood comprising:

first and second reservoirs for holding blood;

first and second elongate conduits connected at one end to a respective reservoir;

a punching station located along the first conduit for punching said first conduit to form holes of determined size in said first conduit to permit measurement of blood properties in said first conduit;

the second conduit having a collagen substance disposed therein whereby platelet adhesion to the collagen substance and subsequent haemostasis can be measured;

waste receptacle means connected to the other ends of said first and second conduits for collecting blood flowing therethrough;

means for introducing a displacing medium into the first reservoir for forcing said blood through said first conduit past said punching station; and

means for monitoring pressure downstream of said collagen substance, and for recording the monitored pressure over time thereby to monitor and indicate haemostasis.

14. The apparatus of claim 13 wherein said punching station comprises a punching needle mechanism which

punctures said first conduit, permitting measurement of the haemostasis of blood flowing through said first conduit.

15. The apparatus of claim 14 comprising a pressure transducer located at a point downstream of said punching station for measuring pressure changes in said first conduit following puncture thereof.

16. The apparatus of claim 13 wherein said means for introducing said displacing medium into said first reservoir comprises:

a pressurizable vessel for holding said displacing medium;

means for applying a constant pressure to said pressurizable vessel; and

a capillary tube leading from said pressurizable vessel to said first reservoir, said capillary tube having a resistance to flow greater than that of said first conduit, whereby a generally constant flow through said first conduit occurs.

17. The apparatus of claim 13 wherein each reservoir is a columnar container comprising a plastic syringe.

18. The apparatus of claim 13 further comprising: a three-way tap connected to a source of high pressure and a source of low pressure through first and second regulators; first and second pressurizable vessels, said first vessel having a first inlet connected to said three-way tap, said second vessel having an inlet connected to said source of high pressure; and, first and second capillary tubes connecting said first and second vessels to said first and second reservoirs.

19. The apparatus of claim 13, wherein said collagen substance is a collagen thread mounted to said second conduit so as to be disposed in a flow path thereof whereby blood flowing through said second conduit flows over and around said collagen thread.

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20. An apparatus for the measurement of properties of blood comprising:

a columnar reservoir for holding the blood;

an elongate conduit connected at one end to said reservoir, said elongate conduit having a collagen substance disposed therewithin;

a waste receptacle connected to a second end of said elongate conduit;

blood driving means for driving blood through said elongate conduit, said driving means being disposed on an upstream side of said collagen substance and including means for introducing into said reservoir an immiscible fluid for displacing said blood through said elongate conduit past said collagen substance into said waste receptacle; and,

pressure monitoring means for monitoring pressure and for producing a record of pressure over time in said elongate conduit downstream of said collagen substance for indicating changes in pressure resulting from blood flowing past said collagen substance.

21. The apparatus of claim 20, wherein said collagen substance is a collagen thread mounted to said elongate conduit so as to be disposed in a flow path thereof whereby blood flowing through said elongate conduit flows over and around said collagen thread.

22. A method for the investigation of blood, comprising:

providing a columnar reservoir for holding blood to be investigated,

providing an elongate conduit leading from the reservoir to a waste blood holding vessel,

flowing blood through said conduit, including introducing into the reservoir a fluid immiscible with blood to displace the blood through the conduit, while simultaneously agitating the blood in the columnar

reservoir,

initiating the process of haemostasis within said conduit with haemostasis initiating means that is either (1) operatively coupled to said conduit or (2) disposed in said conduit, and

monitoring pressure downstream of a locus of said initiated haemostasis.

23. A method as in Claim 22, further comprising recording the monitored pressure over time so that the process of haemostasis in the conduit can be evaluated.

24. A method as in Claim 22, wherein said step of flowing blood comprises flowing non-anti-coagulated blood through said conduit.

25. A method for the investigation of blood comprising:

providing a reservoir;

placing blood to be investigated in said reservoir;

connecting an elongate conduit at one end to said reservoir, said elongate conduit having a collagen substance disposed therewithin;

connecting a waste receptacle to a second end of said elongate conduit;

displacing blood through said elongate conduit with displacing means disposed on an upstream side of said collagen substance and including introducing into said reservoir an immiscible fluid to stir blood in said reservoir and displace said blood through said elongate conduit past said collagen substance toward said waste receptacle; and

monitoring pressure in said elongate conduit downstream of said collagen substance to detect changes in pressure resulting from blood flowing past said collagen substance.

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26. A method as in Claim 25, further comprising recording the monitored pressure over time so that a process of haemostasis in the conduit can be evaluated.

27. A method as in Claim 26, wherein said step of placing blood comprises placing non-anti-coagulated blood in said reservoir and said step of displacing comprises displacing said non-anti-coagulated blood through said elongate conduit.

28. A method for the investigation of blood, comprising:

providing a columnar reservoir for holding blood to be investigated,

providing an elongate conduit leading from the reservoir to a waste blood holding vessel,

flowing blood through said conduit, including introducing into the reservoir a fluid immiscible with blood to displace the blood through the conduit, while simultaneously agitating the blood in the columnar reservoir,

initiating the process of haemostasis within said conduit with haemostasis initiating means that is either (1) operatively coupled to said conduit or (2) disposed in said conduit,

after a haemostatic plug has formed in said conduit, introducing an anticoagulant into the blood upstream of the haemostatic plug,

closing an outlet of the waste blood holding vessel, so as to maintain pressure in the system without a loss of blood,

reducing a pressure applied to the immiscible fluid, and

monitoring the breakdown of the haemostatic plug by one of montioring pressure and sensing blood flow downstream of said haemostatic plug.

29. A method as in Claim 28, further comprising introducing a substance, a thrombolytic effect of which is to be investigated, into the blood upstream of the haemostatic plug.

30. A method as claimed in Claim 28, wherein the step of reducing a pressure applied to the immiscible fluid comprises switching between two pressurizable containers pressurized to different pressures, to drive the displacement fluid.

31. A method as claimed in Claim 28, further comprising the steps of:

providing a second columnar reservoir for holding blood,

providing a second elongate conduit leading from the second reservoir to the waste blood holding vessel,

flowing blood through said second conduit, including introducing into the second reservoir a fluid immiscible with blood to displace the blood through the second conduit, while simultaneously agitating the blood in the second reservoir,

initiating the process of haemostasis within said second conduit with haemostasis initiating means that is either (1) operatively coupled to said second conduit or (2) disposed in said second conduit, and

one of monitoring pressure and sensing blood flow downstream of said haemostatic plug in said conduit, thereby to define a control for comparison with the monitored haemostatic plug breakdown.

32. A method for the investigation of blood comprising:

providing first and second blood carrying channels, said first channel forming a test channel for

subjecting blood to a test condition, the second channel comprising a control channel to compare with said test channel, whereby the effects of a test condition on blood flowing through said test channel can be monitored, each of said channels comprising:

a columnar reservoir for receiving a sample of blood;

an elongate conduit connected at one end to said columnar reservoir; and

a waste receptacle connected to a second end of said elongate conduit for receiving blood flowing from said columnar reservoir through said elongate conduit;

introducing non-anti-coagulated blood into each said columnar reservoir;

introducing a fluid immiscible with blood into each said columnar reservoir for agitating the blood in said reservoir and to displace the blood through said respective elongate conduit;

monitoring pressure at a downstream portion of a respective channel with a pressure monitoring means; and,

recording over time the pressure monitored by said pressure monitoring means,

whereby the relative pressure differences in said first and second blood carrying channels indicates the relative effects of said test condition on blood flowing therethrough.

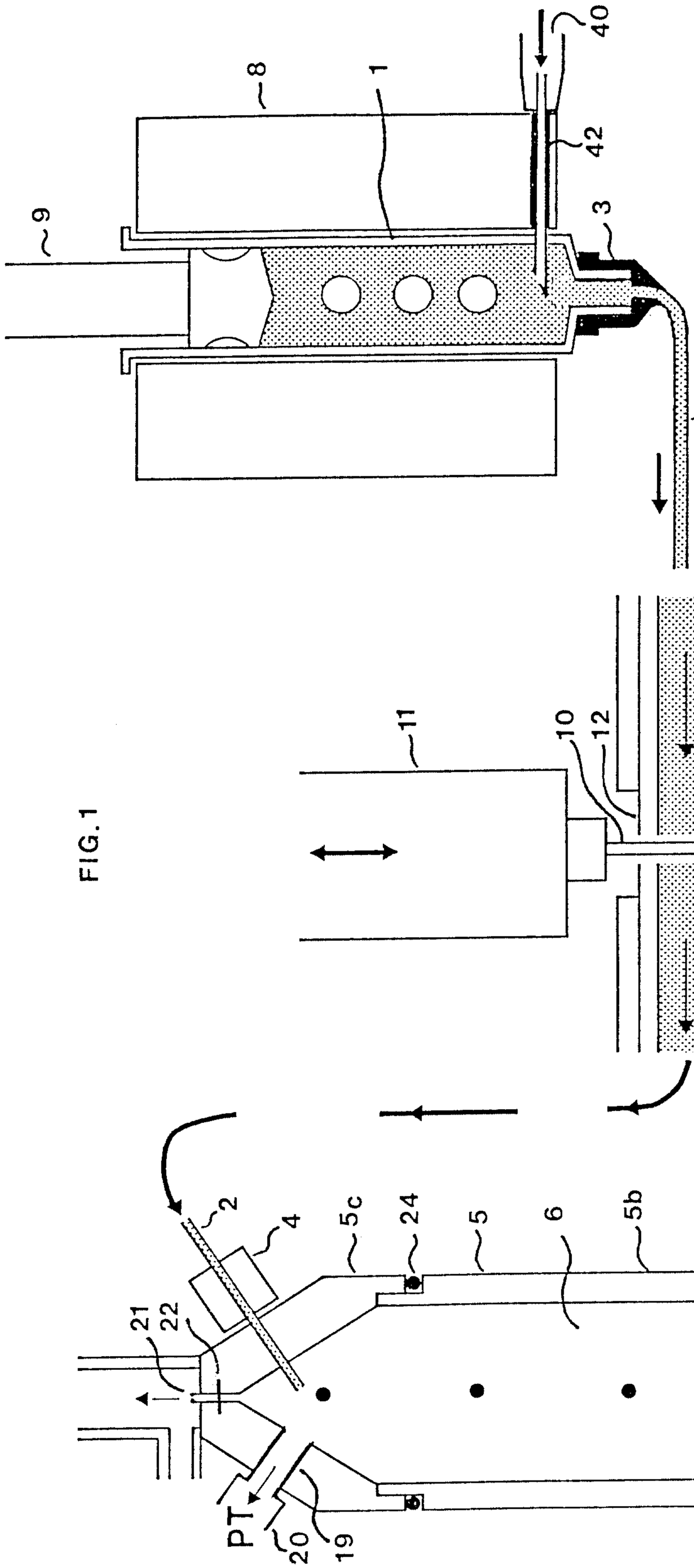


FIG.1

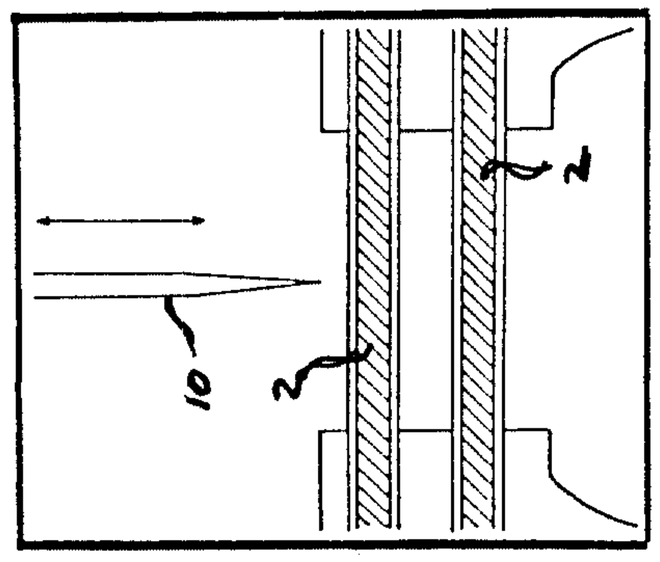


FIG.2

B

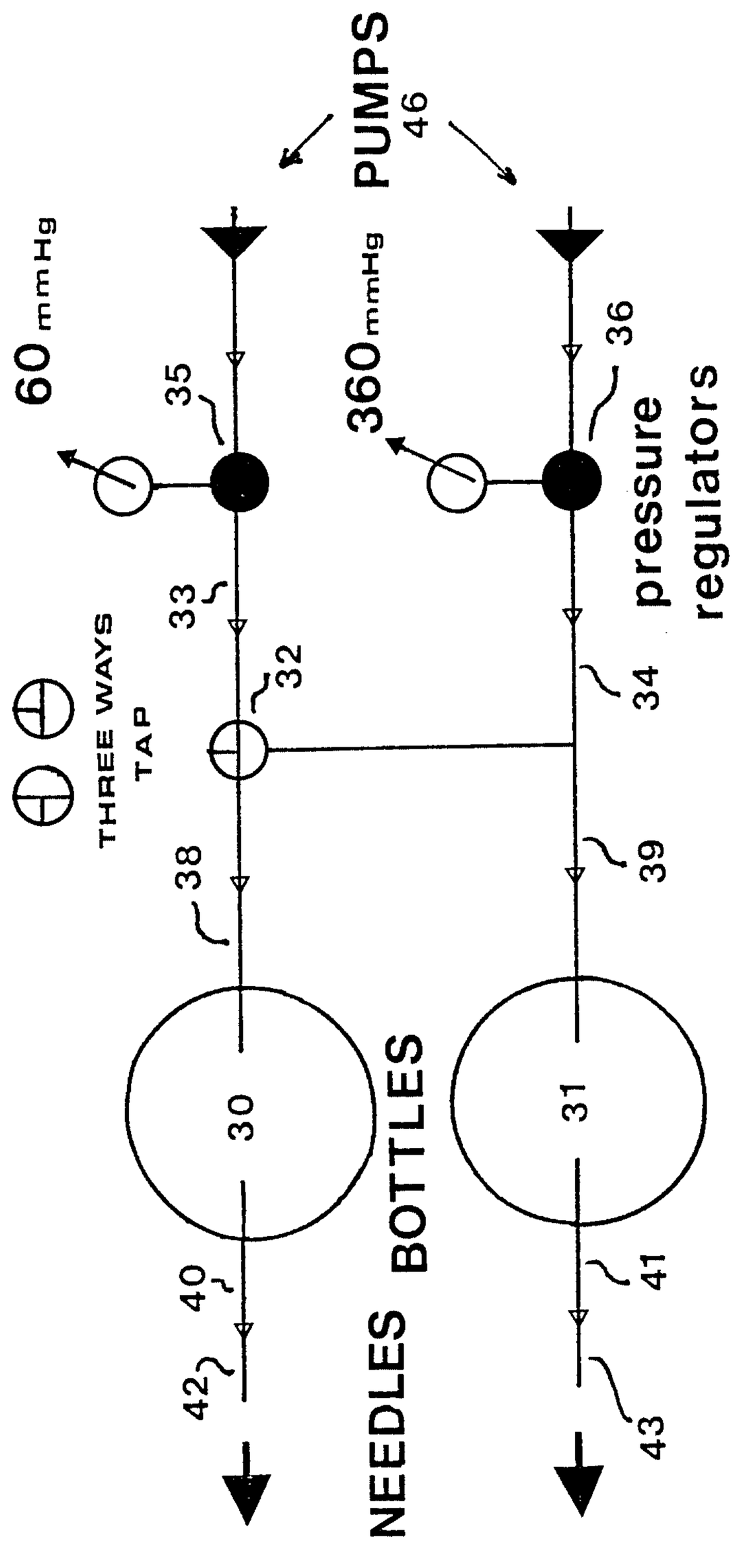

PUMPS
46
60 mmHg
360 mmHg
35
36
pressure regulators
33
32
34
THREE WAYS TAP
38
39
30
31
40
41
42
43
NEEDLES
BOTTLES
Channel I
Channel II

FIG. 3

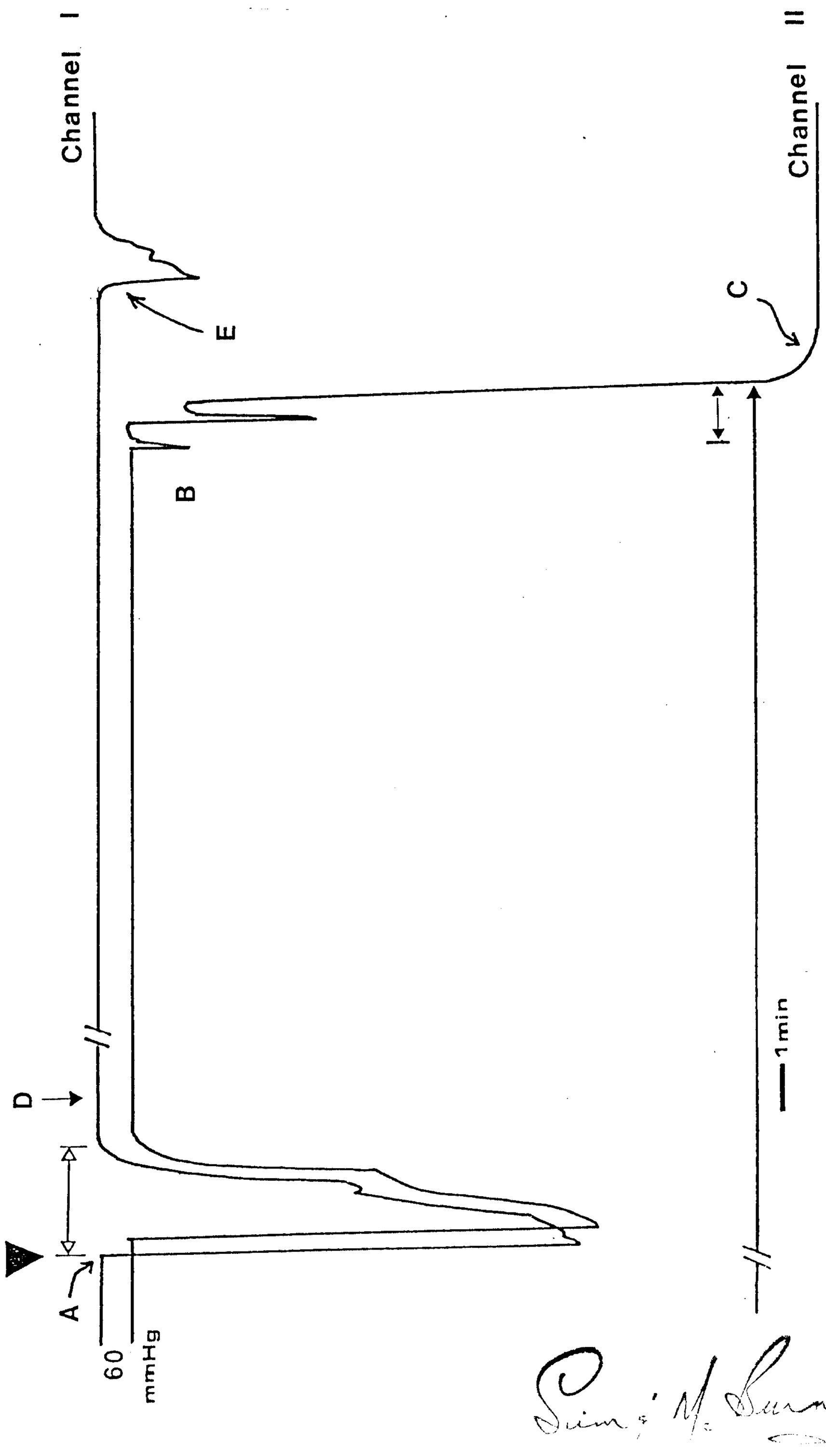
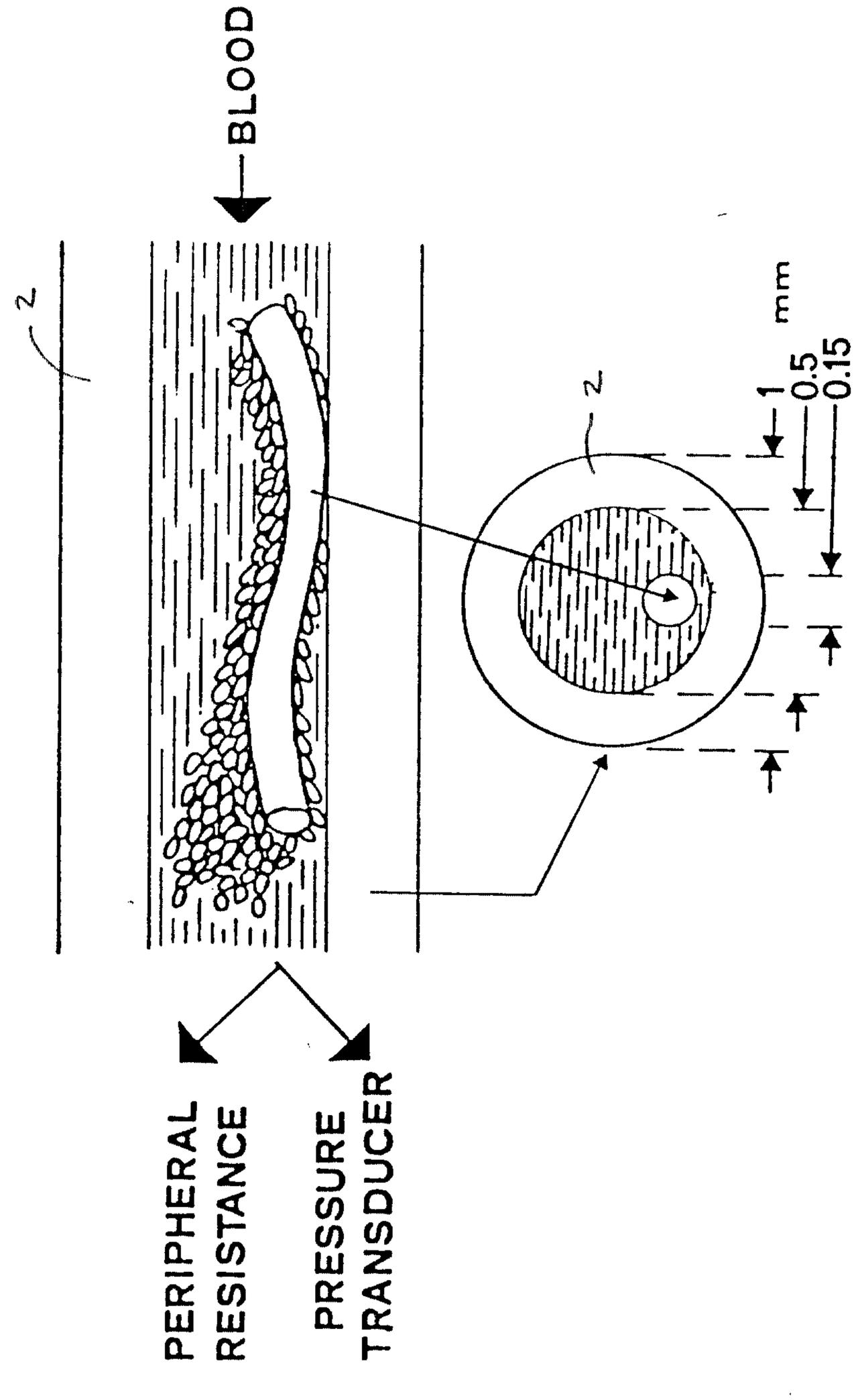


FIG. 4

FIG. 5



B