Dec. 20, 1938. W. S. COLLENS ET AL 2,140,898

METHOD OF AND APPARATUS FOR PRODUCING INTERMITTENT VENOUS OCCLUSION

Filed Nov. 7, 1935 2 Sheets-Sheet 1

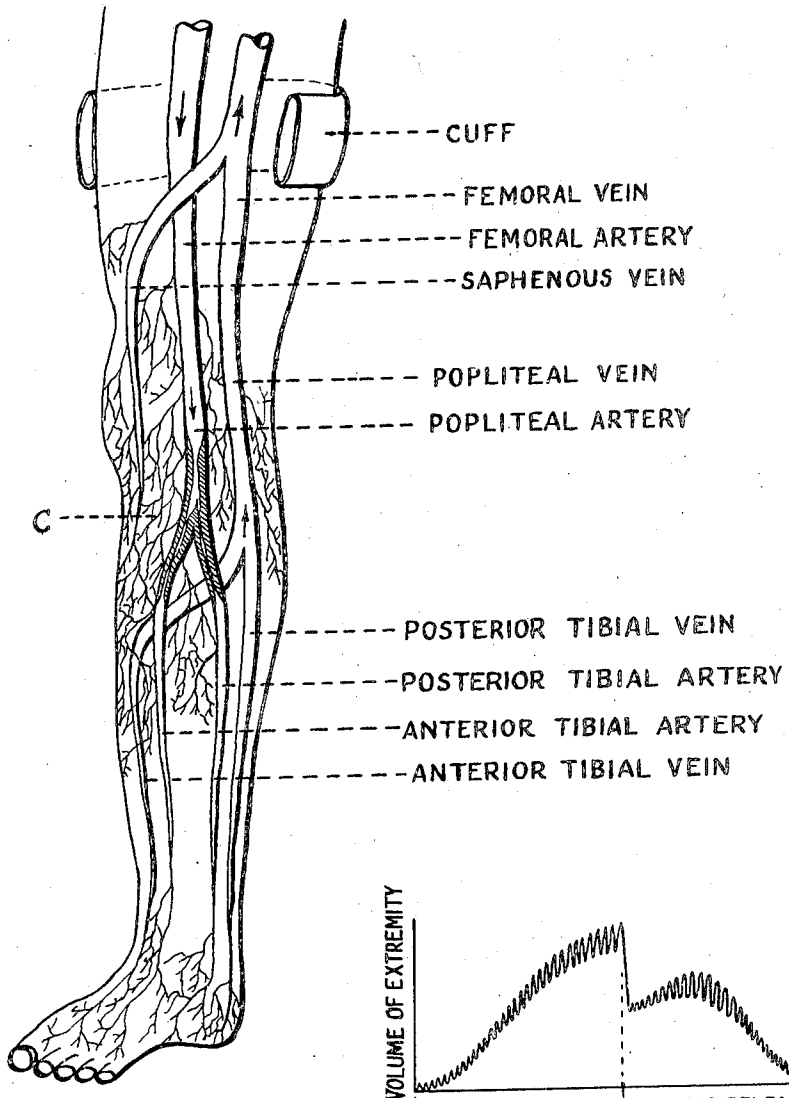


FIG. 1

FIG. 2

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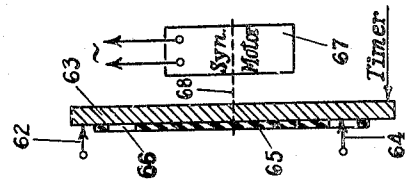


Fig. 4

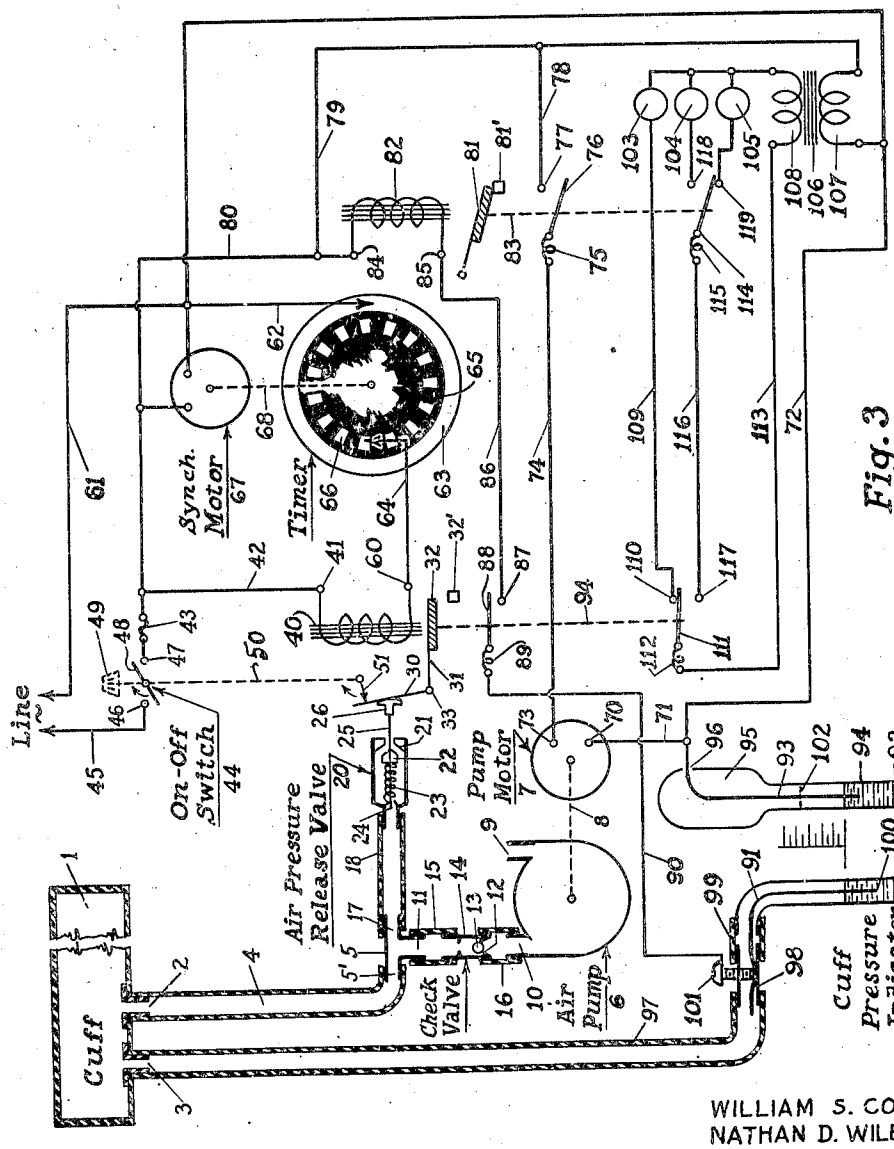


Fig. 3

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2,140,898

METHOD OF AND APPARATUS FOR PRODUCING INTERMITTENT VENOUS OCCLUSION

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Application November 7, 1935, Serial No. 48,748

8 Claims. (Cl. 128—299)

Our present invention relates generally to a method of increasing collateral circulation in the treatment of peripheral vascular disease, and more particularly it relates to a novel method of, and apparatus for, producing intermittent venous occlusion in an extremity wherein there exists deficient circulation.

In the past it has been proposed to treat peripheral vascular disease in a wide variety of ways. The treatments have all sought this common goal: to stimulate the circulation in the diseased extremity in such a manner that the effect of obstructed arterial flow is compensated for. Such prior procedures not only utilize drugs and surgery, but also employ postural exercises; physiotherapy; and mechanical methods. It cannot be said that any of these earlier proposals is adequate.

It is self-evident that for any treatment to be adequate and offer relief, it must be consistent in action when repeated with different patients; it should, additionally, impose a minimum amount of danger, discomfort or pain upon the patient; it should be productive of a substantial improvement in the collateral circulation of the diseased extremity over a usefully wide period of time. The various measures proposed in the past have failed to accomplish one or more of these objects.

It may, therefore, be stated that it is one of the main objects of the present invention to adequately meet the above requirements in the treatment of peripheral vascular diseases of the type wherein deficient circulation, either temporary or permanent, is the offending factor, the present treatment employing a novel mechanical method of stimulating and increasing collateral circulation in the diseased extremity.

Another important object of the invention may be stated to reside in the provision of a method of, and apparatus for, producing intermittent venous occlusion in an extremity and consequent active vaso-dilatation of the arterioles, thereby achieving marked increase in collateral circulation.

Another object of this invention is to provide, from a generic viewpoint, a method of, and means for, obstructing the returning venous blood in the diseased extremity in peripheral vascular disease without in any manner interfering with the arterial flow; maintaining the obstruction active over a predetermined period of time sufficient in duration to result in a substantial reactive hyperemia upon release of the obstruction; releasing the obstruction to develop thereby a highly marked arterial flow through the collateral arterial network of the diseased and blocked artery; and then repeating this cycle of alternate venous obstruction and release over a period of time sufficient to produce alleviation of pain and increase vascular capacity as determined by functional tests.

Still another object of our present invention is to provide an apparatus for automatically producing alternate venous obstruction and release in an extremity, the apparatus, in its broadest aspect, comprising a means for obstructing the flow of venous blood; a device for positively maintaining the said obstruction means operative for a predetermined period of time; the obstruction means being rendered inoperative at the end of the period whereby the venous flow is resumed; the aforesaid device being further constructed to prevent actuation of the obstruction means for a predetermined period of time, and there being provided a time-responsive mechanism for permitting repetition of this cycle as many times as is required.

Still other objects of the invention may be stated to reside in the general improvement of mechanical devices for treating peripheral vascular diseases, and more especially to provide a device which is not only mechanically reliable, durable and efficient in operation, but is further characterized by its relative simplicity of assembly and manipulation.

The novel features which we believe to be characteristic of our invention are set forth particularly in the appended claims; the invention itself, however, as to both its organization and method of operation will best be understood by reference to the following description taken in connection with the drawings in which we have indicated diagrammatically a construction whereby our invention may be carried into effect.

In the drawings:—

Fig. 1 is a schematic representation of a diseased extremity under treatment,

Fig. 2 is a graphic analysis of the effect of the present apparatus on the arterial flow,

Fig. 3 shows schematically an apparatus adapted to perform the functions provided by this invention,

Fig. 4 shows a sectional detail of the timing device.

Referring now to the accompanying drawing, attention is first directed to Fig. 1 which schematically illustrates the relation between the venous and arterial networks in an extremity whose circulation is impaired by peripheral vas-

cular disease. In general, impaired circulation occurs in such diseases as: arteriosclerosis; thrombo-angiitis obliterans; Raynaud's disease; scleroderma; endarteritis obliterans; embolus; and arteritis as occurring in typhoid or typhus fever.

Deficient circulation not only results in pain and interference with normal use of the affected extremity, but creates a dangerous vulnerability to a gangrenous condition. Regardless of the pathological cause of the deficient circulation, the latter condition results from the development in the main artery of an obstruction to normal flow. Without in any way intending to show any particular case, the representation in Fig. 1 illustrates a general state of obstruction in the popliteal artery. The shaded portion within the popliteal artery designates a thickening of the vessel wall, or perhaps a deposit on the inner walls; the normal flow of arterial blood (in the direction of the arrows) has been obstructed. As a result of this obstruction, the disturbances mentioned above follow. The main artery is shown dividing into the anterior and posterior tibial arteries; the anterior and posterior tibial veins are seen joining to form the deep saphenous vein which subsequently empties into the general circulation. The sense of venous flow is shown by the arrows directed upwards.

The small arteries branching off from the main trunks are not shown in detail; it is to be understood, however, that the reference letter C denotes the condition existent when the small arteries unite, or anastomose, with others near them very freely. This condition is well known to occur to such an extent, that when even a large artery is blocked a certain degree of collateral circulation is carried on by the communications between the arterial branches above and below the obstruction in the normal channel. In peripheral vascular diseases, however, this collateral circulation is inadequate to provide sufficient circulation to replace the normal arterial flow. The problem, then, is to restore circulation, and, if possible, to utilize the collateral circulation, thus by-passing the obstructed main artery.

In the past various expedients have been proposed and tried to solve the problem. For example, and without detailed discussion, there have been proposed bed rest; physiotherapy of different types; postural exercises; elimination of spasm-producing substances, such as ergot foods and tobacco; vaso-dilatation by drugs, heat and surgery; fluid injections of different types; mechanical methods of improving circulation through the obstructed artery itself by alternate suction and pressure; femoral vein ligation.

To appreciate the functioning of the present method of treatment, let it first be assumed that a pneumatic cuff is applied at mid-thigh position; the cuff is there positioned so that when inflated it prevents the returning flow of venous blood. If, now, the cuff is inflated to a pressure above intravenous pressure, for example 40 mm. of mercury pressure and maintained at this pressure for a period of time, an increase in arterial circulation occurs in the extremity, and more extensively during the release of this pressure. The pressure employed during occlusion is preferably below the normal arterial pressure (120 mm. mercury), and is above the venous pressure (10 mm). It is to be understood that since reactive hyperemia can also be produced at the release of pressures above arterial pressure, therefore, the use of venous occlusion pressure above arterial pressure is encompassed within the scope of this invention. It has been found that during the release of the venous occlusion there occurs an active vaso-dilatation of the arteries and an increase in arterial flow of as much as 600 per cent, depending upon the degree and duration of the applied venous congestion.

Observation shows an increase in arterial flow, during release of the venous occlusion, in the collateral circulation C from 10 c. c. per 100 c. c. tissue per minute to a value of 60 c. c. per 100 c. c. tissue per minute. This action results in a highly satisfactory improvement in circulation of the extremity when utilized in the manner to be further described.

It is not thought necessary for the purposes of this application to enter into a detailed discussion, or analysis, of the physiological relation between the venous occlusion and release, and increase in the collateral circulation C. It is believed sufficient to point out that plethysmographic methods show an increase in the volume of the extremity upon application of a cuff for venous occlusion; the degree of increase in volume being directly proportional to the pressure increase. After maintaining the pressure for a period of time, release of the pressure results in a fall of volume followed by a secondary rise. The secondary rise, followed by a final decrease in extremity volume, represents an actual increase in arterial flow far above normal flow. Fig. 2 graphically portrays the increase in extremity volume as the cuff pressure is maintained; the initial drop of volume upon release of the pressure; and the "hump" with its increased amplitude of arterial oscillation thereby showing a greatly increased arterial flow.

This cycle of venous occlusion and release is repeated over and over again with the result that an arterial flow is developed in the collateral circulation C, see Fig. 1, sufficient to compensate for the effects of the obstructed main artery. We have found that sustained venous compression at 30 to 60 mm. of mercury for two minutes, followed by a release of this pressure for another two minutes, resulted in highly satisfactory clinical reports. Preferably, the technique consists in applying venous compression with a pneumatic cuff, at mid-thigh or mid-arm, at a pressure of 40 mm. of mercury, alternating with release at two minutes each over periods as long as 12 hours a day continuously. Of course, the pressure employed in the cuff, the duration of the treatment, as well as the period of alternation, is variable; it will depend to a great extent upon the clinical picture presented by the patient prior to treatment.

This routine not only produces alleviation of pain in the diseased extremity and increase of vascular capacity, but is performed by an apparatus, to be hereinafter disclosed, imposing a minimum of discomfort and inconvenience to the patient. Further, consistent use of the method is followed by restoration of the impaired circulation to a point where normal activities may be resumed. In cases where a gangrenous condition exists, the latter is arrested thereby limiting surgical treatment. This method of applying intermittent venous occlusion to provide a substitute for the obstructed main artery, is accomplished in an automatic manner by employing the mechanism schematically shown in Fig. 3.

Since the system employed is purely illustrative in nature, the various mechanical, as well as

electrical circuit, elements are conventionally represented. It is to be clearly understood, furthermore, that many variations of the different components of the system are possible. What is essential in the construction of the present apparatus is that the elements of the system cooperate to perform, in a continuous and automatic manner, the successive steps of the method described above.

From a generic aspect the apparatus shown in Fig. 3 comprises a means for rendering operative a venous occlusion device, the pressure applied to produce occlusion being substantially above normal venous pressure; a time-controlled mechanism functioning to render the occlusion device inoperative upon the elapse of a predetermined period of time and operative again upon the passage of a predetermined period of time, and the timing mechanism being constructed and arranged to repeat the cycle of occlusion and release over a desired treatment period.

More specifically the system shown in Fig. 3 comprises a pneumatic, or balloon, cuff 1 of usual design. The cuff is customarily a hollow body of rubber, or other suitable elastic material, and is band-like in design. As is the case when employed in connection with blood pressure measuring apparatus, the cuff is usually provided with a binder (not shown) for securing the cuff in operative encircling position (see Fig. 1) on the extremity under treatment. The cuff is provided with a pair of ports 2 and 3, the port 2 being coupled, through rubber tubing 4, to an arm 5' of the three way coupling 5. The port 2 of the cuff is the intake, or inflation, port, inflation of the cuff being accomplished through the agency of an air pump, or compressor, 6.

The latter is shown arranged to be operated by a motor 7. The dotted line 8 is to be understood as designating the mechanical drive between the motor and pump 6. The pump itself need only be of conventional design, provided with air inlet 9 and outlet 10. The air outlet 10 is coupled to the arm 11 of coupling 5 through a check valve device comprising a valve seat 12, ball valve 13 and guard cage 14. A rubber tubing 15 couples the outlet of the check valve to arm 11; rubber tubing 16 connects the pump outlet 10 to valve seat 12.

The third arm 17 is coupled, through rubber tubing 18, to the inlet end of the air pressure release valve. The latter may be of any desired conventional type, the type shown being usually employed in automobile tires, is well known to those skilled in the art. It comprises, as usually constructed, a tubular casing 20 having a valve seat 21 at one end thereof; a valve member 22 is normally biased into engagement with the seat 21 by spring 23. The end of the spring 23 opposite to valve member 22 is fixedly secured to a sleeve, or bushing, and the latter is provided with an opening through which stem 24 extends to be guided thereby. The valve member 22 is provided with a stem 25 terminating in a head 26, which stem extends through a bore in the valve seat 21. Thus, when the head 26 is pushed towards the spring 23, the valve member 22 is moved out of contact with seat 21 and the bore in the seat permits the air in the cuff to escape. Normally, that is, with no pressure on head 26, the member 22 is in bore-closure position on seat 21. Of course, all rubber tubing may be replaced by metal or glass tubing, or any other material.

As shown in Fig. 3, the head 26 is urged into air pressure release position by the arm 30 of relay armature 31—32. The latter is of the weight-polarized type, and, as commonly used, comprises a pivoted arm 30 adapted to be moved through an arc by metallic armature 32. The latter is normally pulled downward against a stop by the force of gravity, being secured at one end to the pivoted end of arm 30, as at 33. When the armature 32 is in its normal position against stop 32' the arm 30 is pulled away from contact with head 26. Conversely, when the armature 32 is in its uppermost position, it forces arm 30 against head 26 and causes the pressure release action to take place.

The armature 32 is pulled into its pressure-release position by an electro-magnet 40, the latter being energized for this purpose by current derived from an electrical circuit now to be described. Terminal 41 of the electro-magnet is connected to one side of the 60 cycle A. C. source through a path including lead 42, fuse 43, an "on-off" switch, lead 45. The 60 cycle A. C. source is the usual lighting mains, but it is to be clearly understood that any other current source may be utilized in this connection. For example, a direct current source may be used; and the source may be of the power line or battery type.

The "on-off" switch 44 may be of any conventional snap, or toggle, switch construction. For the purposes of the present disclosure it is sufficient to point out that it comprises a pair of contacts 46 and 47, and a contactor 48. The latter element is mechanically coupled to a manually manipulable member 49 in a manner such that adjustment of member 49 in the direction of the arrow results in electrical connection between contacts 46 and 47.

The mechanical coupling between member 49 and contactor 48 is represented by a dotted line. This coupling is extended to simultaneously actuate a pin, or lever arm, 51. The arm 51 is rigidly affixed to coupling 50, (which may, for example, be a rod extending from the contactor adjusting stub and fixedly carrying the member 51), but is movable in unison therewith. Further, the member 51 is constructed and arranged so that as the "on-off" switch is moved to open position, the member 51 is adjusted to push the element 30 against head 26 and thus unseat valve member 22.

In other words, when the adjusting knob 49 is actuated (as by rotation) in the direction of the arrow (adjacent contact 46) to close the circuit, the pin 51 is simultaneously moved, (in the direction of the arrow adjacent arm 30) out of contact with arm 30. Hence, there is provided a device for insuring actuation of the release valve to "release" position whenever the "on-off" switch is in open-circuit position.

Returning now to the remainder of the circuit which includes magnet 40, the alternating current source is connected to terminal 60 of the magnet through a path including lead 61, contact blade 62, metallic disc 63, contact blade 64. The disc 63 has affixed to a face thereof a concentric insulation disc 65. The latter is of a diameter sufficiently less than that of the disc 63 to provide a peripheral exposed margin on disc 53, the blade 62 being in slidable electrical contact with this margin. A circle of spaced openings 66 is provided around the periphery of insulation disc 65. These openings 66 may be substantially square, or rectangularly, shaped, as shown in Fig. 3.

The openings 66 are dimensioned so as to be readily capable of receiving the free, or contact end, of contactor blade 64 within the four sides

of each opening. Further, the width of each opening 66, along the circle of rotation is so chosen as to permit the contactor 64 to be in electrical connection with contactor 62, through disc 63, for the predetermined period of time desired for venous occlusion, and the latter may be, for example, two minutes. To break the electrical connection between the contactors 62 and 64, the discs 63 and 65 are simultaneously rotated until the contactor 64 is out of a given opening 66 and rests on the insulation disc between the last opening and the succeeding one. The spaces between openings are dimensioned so as to keep the electrical connection between contactors 62 and 64 open for a period of time equal to the occlusion "release" period. As stated previously, this release period may be, by way of example, two minutes in duration.

Accordingly, it will be seen that discs 63 and 65, with flexible slidable contactors 62 and 64, function as a timing mechanism to control the inflation and deflation of balloon cuff 1. Again, the control is carried out in a periodic manner by rotation of the discs. This is most effectively accomplished by means of a synchronous motor 67 which is operated from the A. C. source. Any other type of constant speed device, as a spring clock movement, may be used. The synchronous motor may be of any well known type employed in clocks of the type energized from a 60 cycle A. C. source. For example, such a clock is known by the trade-mark "Telechron"; the synchronous motor of this type of clock is self-starting. The motor 67 rotates the discs 63, 65 one complete revolution in 60 minutes; a mechanical coupling indicated by dotted line 68 between the discs and the motor 67 serves to produce this rotation.

It will be seen that synchronous motor 67 produces relative movement between contactors 62, 64 and the discs 63, 65; due to the contactors being in fixed position, the rotation of the discs 63, 65 cause slidable contact of the free ends of the contactors with the contacted disc faces. The motor 67 is connected in shunt across the A. C. source by connecting one terminal of the motor to lead 61, and the other terminal being connected to contact 47 of the "on-off" switch. Thus, the motor 67 is not energized to rotate the discs 63, 65 until the contactor 48 is in electrical contact with elements 46 and 47.

Fig. 4 shows in a sectional view, the details of the timing mechanism. The insulation disc 65 can be fabricated of paper of good wearing resistance, a phenol condensation product, hard rubber or any other suitable material; it may be cemented to the metallic disc 63, or affixed thereto in any other desired manner. The disc 63 is, of course, very much thicker than the insulation disc so as to furnish a rigid foundation. In general, the composition of the disc 65 should be such that it withstands wear due to sliding contact with contactor 64, and is electrically non-conductive. The disc 63 should be electrically conductive, and be composed of a metal such as copper in order to have good electrical and wearing qualities, and be rigid. For a four minute cycle of occlusion and release, and a period of rotation of discs 63, 65 of 1 R. P. H., there will be provided fifteen spaced openings 66 in the disc 65. The contactor 64, which is sufficiently flexible to readily ride into and out of an opening 66, will then be in contact with disc 63 for a period of two minutes in every four minute cycle.

Assuming, now, that the member 49 has been actuated to "on" position, synchronous motor 67 will begin to rotate the timer discs. If the contactor 64 is positioned in the space between two openings 66, the magnet 40 remains unenergized. Hence, metallic armature 32 is not attracted and the arm 30 remains out of contact with head 26, thereby leaving the release valve closed. (Of course, the pin 51 has been moved out of contact with arm 30, leaving arm 30 solely under control of magnet 40.) In the meanwhile, and upon adjustment of the "on-off" switch to "on" position, the pump motor 7 has been energized to actuate the air pump 6 for the purpose of inflating cuff 1.

The motor 7, adapted to be operated from an A. C. source, has one terminal 70 thereof connected to one side of the A. C. source through a path including lead 71, lead 72, lead 61. The terminal 73 of the motor connects to the other side of the A. C. source through the following path: lead 74, pig-tail connection 75, pivotal contactor 76, contact 77, lead 78, lead 79, lead 80, and to lead 45 through the "on-off" switch. The contactor 76 is adjusted to motor-energizing position when the metallic armature 81 of electro-magnet 82 is attracted towards the latter. The magnetic relay 82—81 may be of the same type as relay 40—32; normally the pivoted armature rests against stop 81' due to the force of gravity. The dotted line 83 designates the mechanical coupling between contactor 76 and armature 81; that is, the contactor moves in unison with armature 81, but is not in electrical connection therewith. Electro-magnetic relay constructions of this type are well known to those skilled in the art, and therefore no further description is believed necessary.

The energization of electro-magnet 82 depends in turn upon armature 32, and whether or not it has been attracted by coil 40. The circuit including electro-magnet 82 may be traced in the following manner: terminal 84 connects to one side of the A. C. source through a path including lead 80, the "on-off" switch and lead 45, Terminal 85 of the magnet connects to the other side of the A. C. source through a path including lead 86, contact 87, contactor 88, flexible pig-tail connection 89, lead 90, adjustable lead 91, mercury column 92, lead 93, lead 72, lead 61. The contactor 88 is constructed, as in the case of contactor 76, to be movable in unison with armature 32. The dotted line 94 denotes the mechanical coupling between armature 22 and contactor 88; the construction is such that when armature 32 is attracted towards electro-magnet 50, by energization of the latter, the contactor 88 is pulled away from contact 87. Therefore, it will be seen that when the release valve is actuated to deflate the cuff, then the pump motor circuit is automatically maintained in de-energized state.

As soon as the member 64 leaves an opening 66 in disc 65, however, the coil 40 is de-energized. This results in a falling of the armature 32, and a simultaneous closing of the pump motor circuit. The pump 6 is rendered operative, and inflation of the balloon cuff commences. In this state of connections the valve seat 21, thereby preventing escape of air through tubing 18. The motor 7 is maintained energized until the contactor 64 slides into an opening 66, whereupon the pump motor circuit is broken at 88—87.

It has been previously explained that the venous occlusion pressure is of the order of 40 mm. of mercury. That is, the cuff is inflated,

while in treatment position as shown in Fig. 1, to a point such that the desired pressure is exerted on the vein. In order to visually indicate this pressure during inflation, and also to positively prevent the inflation from exceeding this maximum pressure, there is provided the usual glass U tube 94 in the legs of which is disposed the mercury column 92. One leg of the U tube terminates in a bulb 95 provided with an aperture 96 thus establishing the bulb interior at atmospheric pressure. The lead, or conductor wire, 93 has one end thereof disposed below the surface of the mercury column, the opposite end of conductor 93 protruding through aperture 96, and being electrically connected to leads 71 and 72.

The other leg of the U tube is coupled to the port 3 of the balloon cuff. A rubber tubing 97 has one end thereof coupled to port 3, the opposite end being coupled to a short, tubular, metallic connector 98. The outlet end of connector 98 is coupled, by rubber tubing 99, to the pressure leg of the U tube. The lead, or conductor wire, 91 has one end 100 thereof disposed below the mercury surface a predetermined distance. The opposite end of the wire is gripped between an adjustable tap screw 101 and the inner surface of connector 98 as shown. The screw 101 is in threaded engagement with the connector 98, and is electrically connected to lead 90. By releasing the pressure of screw 101 on wire 91, and moving the exposed end of the wire, the submersion distance of end 100 may be readily adjusted. The diameter of screw 101 is not, of course, sufficiently great to obstruct the air flow through connector 98. Also, the shank portion of the screw 101 disposed in the connector bore could be provided with a transverse air passage.

It will now be seen that as the cuff is inflated, the column of mercury is shifted in position. The mercury surface above terminal 100 falls; the other surface rises. A scale, calibrated in mm. of mercury pressure is disposed in parallel relation to the leg containing wire 93; thus the pressure in the cuff can be readily determined. Assuming that the dotted line 102 represents the height to which the mercury surface rises at 40 mm. pressure, the operator of apparatus will, therefore, initially adjust wire 91 in such a manner that the mercury breaks contact with terminal 100 when the mercury surface in the other leg rises to height 102. This results in immediate opening of the pump motor circuit, since the latter must be completed through terminal 100. It is to be clearly understood, however, that the indicator and maximum pressure mercury limiter switch can be omitted, if it is desired, or any other type of pressure indicating device, as a diaphragm type of gauge, may be used. In that case the pump motor, or pump itself, could be provided with any well known type of governing mechanism to keep the inflation pressure from exceeding a desired maximum occlusion pressure.

An additional visual indicator device which may be employed, if desired, is shown in the system. Three illumination devices, such as incandescent lamps, are connected into the different circuits at proper times. To energize the lamps there is provided a step-down transformer 106; the primary winding 107 of the latter is connected across the A. C. source between leads 79 and 72. The secondary winding 108 has one terminal thereof connected, in common, to one side of each of lamps 103, 104 and 105, each lamp being arranged, when in circuit, in series with the secondary winding. The circuit to lamp 103 is completed through lead 109, contact 110, contactor 111, flexible pig-tail 112, lead 113.

The contactor 111 is mechanically coupled with armature 32 and contactor 88; the dotted line 94 is extended through contactor 111 to denote the fact that the contactor 111 moves in unison with the other two elements, and functions to close the electrical circuit through lamp 103 when the pump motor circuit is open and the pressure in the cuff is released. In the same way the contactor 114 is mechanically coupled with armature 81 so as to be movable in unison therewith; the dotted line 83 is extended through contactor 114 to denote the fact that the latter is pulled into position to close the electrical circuit through lamp 104 when the pump motor circuit is closed.

The contactor 111 cooperates with contacts 110 and 117; the contactor 114 cooperates with contacts 118 and 119. When the contactor 64 leaves an opening 66 and breaks the magnetic pull on armature 32, the contactor 88 falls therewith and closes the circuit through electro-magnet 82 thereby attracting armature 81 and closing the pump motor circuit through contactor 76. Simultaneously the contactor 111 engages contact 117, and contactor 114 is pulled up to engage contact 118. Lamp 104 is, as a consequence, energized through a path which is traced from contact 118 through contactor 114, through flexible pig-tail 115, lead 117, contact 117, contactor 111, pig-tail 112, lead 113, winding 108. The lamp 103, of course, is de-energized; hence the operator is informed that the pump motor circuit is closed and the cuff is inflating.

Should, now, the pump motor circuit be opened, as when the mercury surface falls below terminal 100, and the release valve still be closed, (the electro-magnet 82 is de-energized and armature 81 causes contactor 76 to disengage contact 77) then contactor 114 would be moved into engagement with contact 119. In this case the lamp 105 is energized, and it informs the operator that the pump is not operating, the cuff is inflated, and mercury limiter switch has operated to open the pump motor circuit. Lamps 103, 104 and 105 could be colored, as for example green, yellow and red respectively. Of course, glow lamps emitting different colored lights (as neon, argon, helium, mercury gas filled) may be employed. While this auxiliary indicating mechanism is highly desirable because of its utility when treatment is applied by non-technical operators, yet it may be dispensed with if an economical type of apparatus is the object.

While we have indicated and described a construction for carrying our invention into effect, it will be apparent to one skilled in the art that our invention is by no means limited to the particular construction shown and described, but that many modifications may be made without departing from the scope of our invention, as set forth in the appended claims.

What is claimed is:

1. A method of increasing the blood circulation through an extremity whose arterial flow is insufficient, which includes the steps of obstructing the venous flow solely at a relatively narrow zone of the proximal portion of said extremity for a relatively short period of time without interfering with the arterial flow therethrough, removing the obstruction at the end of said period, restoring the said venous flow obstruction at said zone after the expiration of a

relatively short period of time, and alternating the said obstruction removal and restoration at said zone at a predetermined frequency over a relatively long period of time.

2. A method of increasing the collateral arterial circulation in an extremity whose main arterial flow is impaired, which consists in applying pressure of between 10 and 120 mm. of mercury solely at a narrow zone of the proximal portion of the extremity thereby to produce only venous occlusion in the extremity, withdrawing said pressure at the end of a predetermined time interval which has a duration sufficiently long to cause substantial hyperemia when the pressure is released, permitting normal venous flow in the extremity for a predetermined time interval after said pressure withdrawal, and repeating said cycle of pressure application and withdrawal for a period of time sufficient to produce said increased collateral circulation.

3. A method which includes the steps of applying a narrow inflatable cuff across the proximal portion of an extremity, inflating the cuff to a pressure well above the venous pressure but substantially below the arterial pressure and in the region of 40 to 60 mm. of mercury thereby obstructing the venous flow through the extremity, maintaining the cuff inflated at said obstruction pressure for a relatively short period of time, then deflating the cuff for a corresponding time period, and continuously repeating the said cycle of cuff inflation and deflation at said frequency for a relatively long period of time.

4. A method of producing an increased arterial circulation in a leg having deficient arterial circulation which includes the steps of compressing the extremity at the mid-thigh section only and to an extent sufficient substantially to prevent only venous flow, maintaining the section compressed for a substantial period of time, ending the compressing action at the termination of said period, and continuously and periodically repeating the aforesaid cycle of compression and compression-withdrawal over a period of time which is relatively long compared to said first period.

5. In a method as described in claim 4, said compressing action being performed at a pressure which is intermediate the arterial and venous pressures, and said first period of time being of the order of two minutes.

6. In a method as defined in claim 4, said first period of time being of the order of two minutes, and said second period being of the order of twelve hours.

7. A method of operating an intermittent venous occlusion apparatus to increase the collateral blood circulation in an extremity of the human body, the apparatus including an inflatable narrow cuff which is adapted to encircle solely a proximal portion of the extremity, the method comprising periodically inflating and deflating said cuff at predetermined short time intervals, maintaining the cuff inflated with air under a pressure sufficient to cut off solely the venous blood return through said proximal portion and without affecting the arterial flow therethrough, alternately deflating the cuff at all times to atmospheric pressure, and automatically carrying on said deflation and inflation cycles over a relatively long period of time as compared to said short time intervals.

8. A method of operating an intermittent venous occlusion apparatus to increase the collateral blood circulation in an extremity of the human body, the apparatus including an inflatable cuff which is adapted to encircle a proximal portion of the extremity, the method comprising periodically inflating and deflating said cuff at predetermined short time intervals, maintaining the cuff inflated with air under a pressure of approximately 40 to 60 mm. of mercury and which is sufficient to cut off solely the venous blood return through said proximal portion and without affecting the arterial flow therethrough, alternately deflating the cuff at all times to atmospheric pressure, and automatically carrying on said deflation and inflation cycles over a relatively long period of time as compared to said short time intervals.

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