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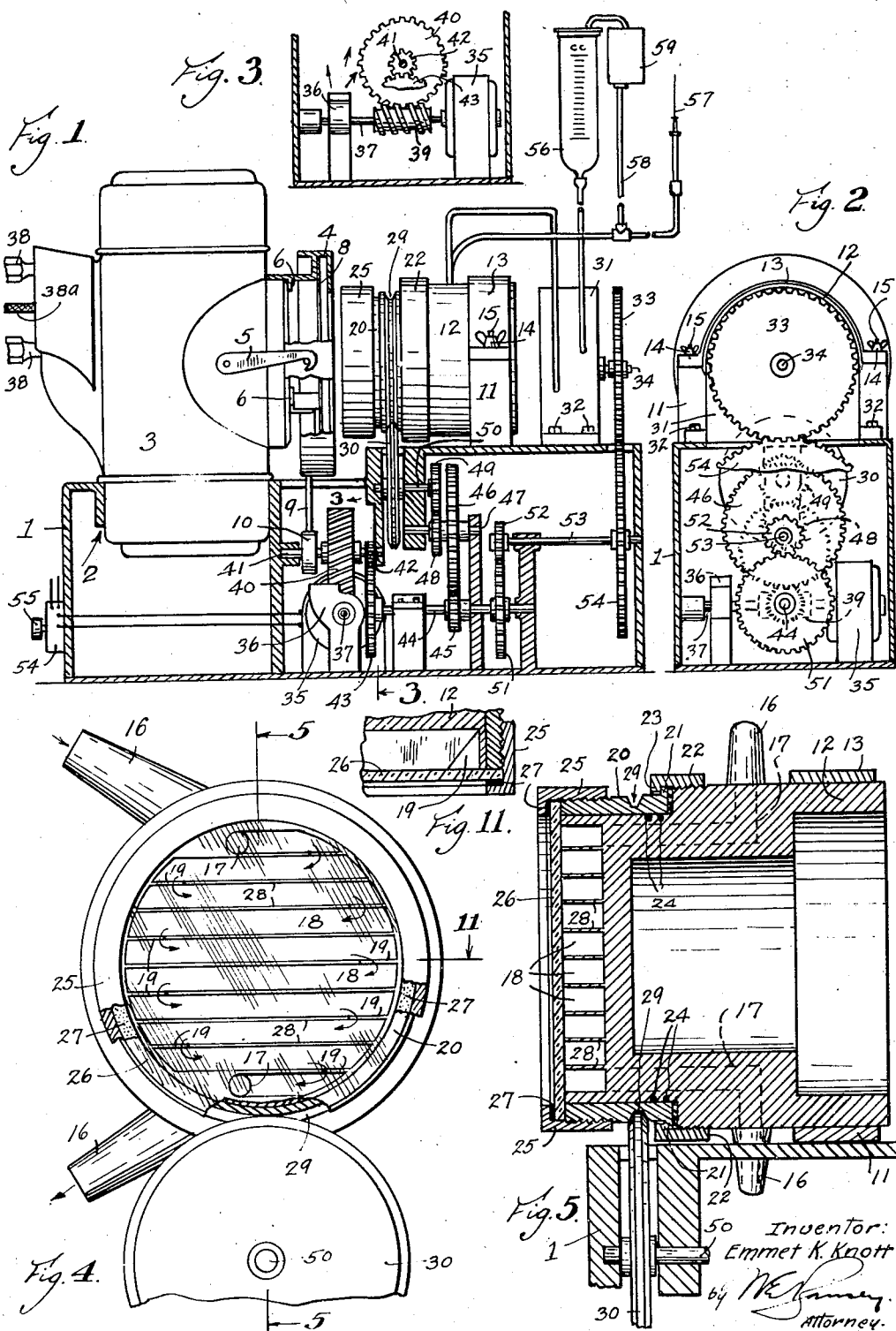
E. K. KNOTT

2,308,516

METHOD AND MEANS FOR IRRADIATING BLOOD

Filed May 1, 1939

2 Sheets-Sheet 1



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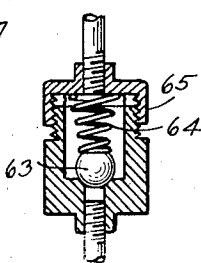
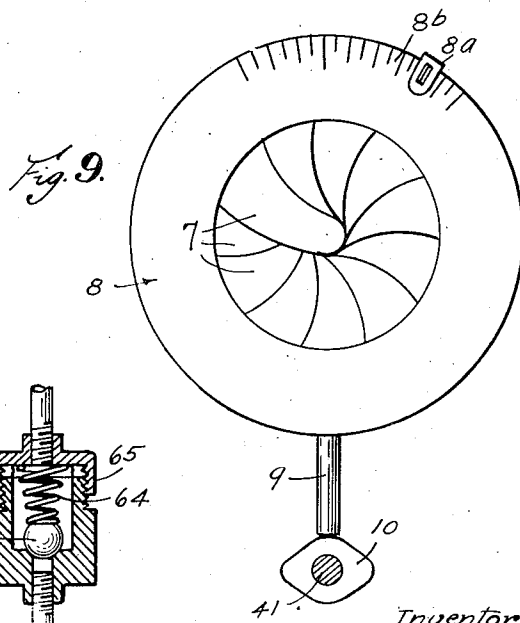
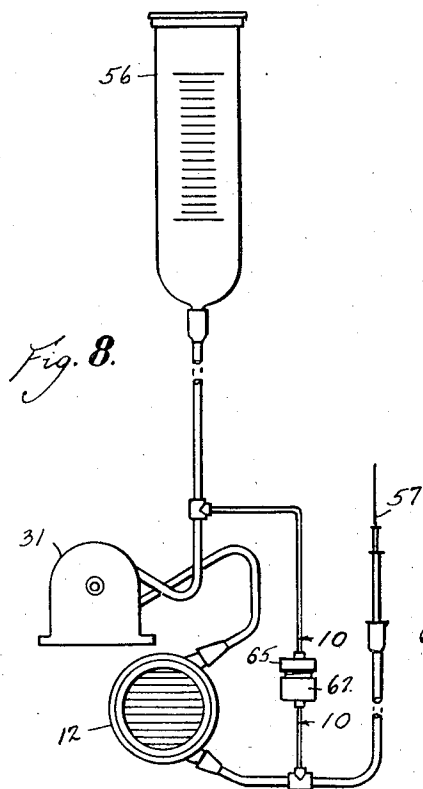
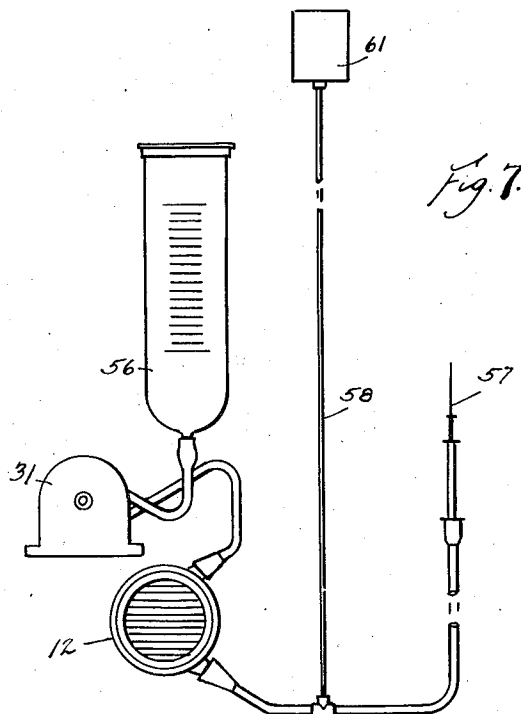
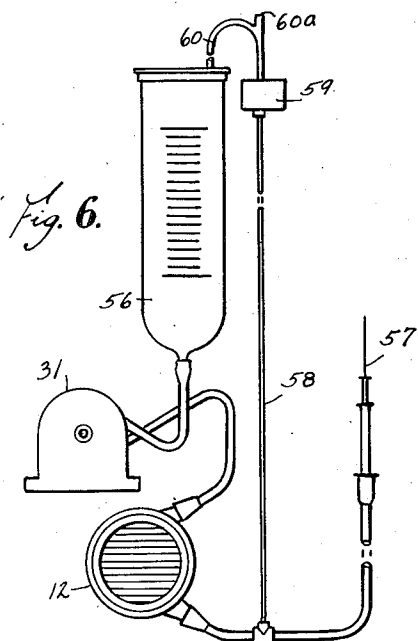
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METHOD AND MEANS FOR IRRADIATING BLOOD

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2 Sheets-Sheet 2



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UNITED STATES PATENT OFFICE

2,308,516

METHOD AND MEANS FOR IRRADIATING
BLOOD

Emmet K. Knott, Seattle, Wash.

Application May 1, 1939, Serial No. 271,072

23 Claims. (Cl. 128—395)

My invention relates to physical therapy and has for its object the correction of pathological conditions of men or beasts by providing stimulation of and giving energy to the constituent serum and cell structure of the blood and the tissue affected thereby by irradiating a quantity of said blood with energy of the ultra-violet portion of the radiant energy spectrum. The objects and advantages of my present invention will be discussed with reference to United States Patent No. 1,683,877, for Means for treating bloodstream infections, issued to Lester A. Edblom and myself, September 11, 1928, in order to distinguish said invention from the prior art.

It has heretofore been known that beneficial results flowed generally from the destruction of infectious bacteria and from inactivation of toxins. A measure of stimulation sometimes followed blood irradiation provided primarily for destruction of infectious bacteria and inactivation of toxins, but said beneficial stimulation has been more or less inconsistent and has occasionally been accompanied by such deleterious effects as to render ultra-violet blood irradiation therapy inadvisable in certain cases. By the method and means hereinafter described, said beneficial stimulative results are increased and are achieved with remarkable consistency, the deleterious effects are wholly avoided, and the range of beneficial results is extended.

In carrying out my invention, I remove a quantity of blood from the circulatory system of a patient, pass it thru a chamber in which it is exposed to ultra-violet radiation for a brief, accurately controlled period of time, and return it to said circulatory system. The technique includes several important details which will be discussed hereinafter. The most obvious effect of this procedure would seem to be the killing of bacteria and inactivation of toxins in the blood stream, and heretofore destruction of bacteria and inactivation of toxins have been the principal objects of blood irradiation. However, I have found that better results will be obtained in most cases if the blood is exposed for a period of time less than that necessary directly to kill bacteria. Furthermore, many pathological conditions not accompanied by bacteria, or not caused by bacteria at all, are thereby corrected, whereas they would not be corrected if an exposure sufficient to kill bacteria directly were used.

The results of irradiating blood according to my present invention may conveniently be divided into three groups, classified according to the speed of the reaction. First, within a few min-

utes there is noticeable a pink glow of the skin of the face of those patients who are at all pallid, and the time required for the temporary pallor resulting from pinching the skin to disappear is usually reduced in those patients where this reaction has become sluggish. This appears to be an entirely new phenomenon; it is not produced by the methods of irradiation heretofore known, wherein the blood was overexposed. Its significance, insofar as I am presently aware, is merely that it is a favorable sign; its presence seemingly indicates that other results of the irradiation are to follow in due time, and meanwhile the treatment of the patient may be planned accordingly. However, this pinking, which results from a relaxation of the peripheral circulatory system, probably indicates that there is an immediate response by the central nervous system to irradiation of the blood, and said response may have further significance not yet fully understood.

Concurrently with the aforesaid pinking, those patients who are rational ordinarily experience an increased feeling of well-being immediately following irradiation according to my invention that does not occur with the over-irradiation heretofore practiced. The significance of this phenomenon is far greater than is indicated by the mere comfort of a patient who is only mildly ill, and it should not be confused with the psychological effect commonly produced by minor surgical operations on naturally optimistic patients. Said stimulative effect permits treatment of critically ill patients.

In the treatment of disease, in general, promptness is an important factor; many remedies and treatments are effective only in the early stages of a disease. But early diagnosis and treatment are, unfortunately, not always possible. My invention is adapted to the treatment of cases in which a disease has reached an advanced stage. The patient may be so weakened that any depressive treatment would be fatal. As heretofore practiced, blood irradiation has occasionally resulted in shock and a condition of lowered resistance of the patient, evidenced by a tired feeling and drowsiness. The effect has been similar to, but more persistent than, the well known protein reaction that sometimes follows the injection of serum into the blood stream. Such treatment is not suitable for a critically ill patient. On the other hand, there are few contraindications for treatment according to my invention; in nearly every case, the patient's chance of living will be increased by said treatment. The immediate sense of well-being following treatment accord-

ing to my invention is in strong contrast to the tired feeling and drowsiness occasionally following the older method, yet the difference in the methods is seemingly a rather narrow one, consisting chiefly in the difference of time of exposure, which is highly critical.

The second group of results of my invention take effect in a few hours, rather than a few minutes. The most noticeable of these results is the reduction of body temperature in patients having fever. In those diseases which are caused by bacteria, and particularly in cases of bacteremia, in which there are bacteria in the blood stream, it would seem that the older method in which the blood is exposed to ultra-violet radiation for sufficient time to kill directly the bacteria in the blood stream would be more effective than the method of my present invention. However, experience has shown that, with few exceptions, the contrary is true; in most bacterial diseases better results will be achieved by the shorter exposure. In certain cases, the direct lethal action of ultra-violet of the older method may be used advantageously provided the patient has sufficient vitality to withstand any depressive action thereof.

Indicative of the way in which the short exposure method of my present invention is effective in bacterial diseases is the fact that the opsonic index of the blood is thereby markedly increased, that is, the rate of destruction of bacteria by certain white blood cells is increased. Coincidental with this phenomenon, and probably causative thereof, the oxygen content of the blood is almost invariably increased in those patients in which said oxygen content was below normal. Again, this effect is in strong contrast to that sometimes produced by the older method in which a portion of the blood was over-exposed, in which case the increased oxygen content is not only absent, but a contrary result is produced in that the hemoglobin of the blood is thereby converted into methemoglobin. Hemoglobin is a chemically active substance having the ability to absorb oxygen, when the pressure thereof is increased above a certain value as it normally is in the lungs, and of giving up said oxygen when the pressure is lower, as it normally is in other parts of the body. On the other hand, methemoglobin is an inert substance that will not absorb or give up oxygen under varying pressure. Under conditions comparable to those herein described, the change from hemoglobin to methemoglobin has been observed spectroscopically to take place after an exposure of less than one minute, the exact minimum exposure not being known.

Another result of irradiation that occurs consistently when the method of the present invention is used is an increased red cell count in those patients in which this count is below normal, that is, the number of red cells per cubic millimeter of blood is increased. This effect will usually be noticeable with 24 hours after irradiation, although this immediate effect may be somewhat obscured by the natural periodic variation in said red cell count, and ordinarily will continue to increase for several days. Here again, the result is in sharp contrast to that produced by the older method; over-irradiation, when present, has been observed consistently to result in a decrease in the red cell count beginning usually within 24 hours and continuing for a few days, after which said red cell count might increase if the disease were overcome.

A somewhat less prompt result is the normal-

izing of the white cell count, which usually requires several days. If the white cell count is low, it will gradually increase whereas if it is high it will decrease, probably as certain bacteria are overcome.

The third group of results of my invention require several months for their full effect, although it is not necessary that treatments be continued during this period. By way of example, patients having arthritis of long duration and whose joints are badly deformed by calcium deposits have been given a series of 3 irradiations a few days apart. Improvement in subjective symptoms, pain and stiffness, frequently were observed within 2 or 3 weeks, and in about 3 months objective improvement was shown by X-ray photographs. Complete recovery of many of these cases resulted in 4 to 6 months after treatment. I am aware that spontaneous recovery of some cases of arthritis have been reported, so that the effectiveness of a treatment cannot be judged by a few recoveries. A substantial number of patients have been treated by my method and complete recovery has resulted in more than 67 per cent of all cases, a result never before attained by any other treatment with which I am familiar. The reason for the failures is not apparent; they have not been limited to the more severe cases of long duration.

The aforesaid recovery of arthritic patients is believed to be due to the increased activity of those white blood cells that are adapted to remove and transport solid matter, such as bone, from one location within the body to another. This activity, like the increased phagocytic power of other white cells, may be due directly to the increased oxygen content of the blood.

Apparatus for irradiating blood is described in said United States Patent No. 1,683,877 for Means for treating blood stream infections, issued to Lester A. Edblom and myself September 11, 1928. The method of my present invention differs, in one respect, from that disclosed in said patent in that I now remove a quantity of blood from a patient, irradiate it, and return it, preferably thru the same hollow needle thru which it was removed.

A further difference between my present invention and the method described in said patent is in the time of exposure. Said patent teaches that the blood should be exposed for sufficient time to kill bacteria, that exposures of 5 to 10 seconds are insufficient for this purpose, and that no harmful results will ensue unless exposures of more than a minute are given. I now regard the optimum exposure to be only a fraction of a second, although I realize that infectious bacteria may not thereby be directly killed, and I consider exposures of 5 seconds or more to be detrimental and to be used with caution.

It should be understood that the word "exposure," as used herein, means the time that an individual particle of blood is effectively exposed to ultra-violet radiation, and not to the time required for a particle of blood to pass through an exposure chamber. Inasmuch as the ultra-violet radiations penetrate blood only to a relatively slight depth, it is evident that only those particles immediately adjacent that surface of said blood toward the source of radiations will be exposed, and that each individual particle will remain in this region of effective exposure only a small fraction of the time required for it to pass thru the chamber. Thus, an exposure of a small fraction of a second in the exposure chamber

hereinafter described will be achieved if the blood passes thru said chamber in 4 to 5 seconds. I have obtained better results by thus controlling the average exposure of a large number of individual blood particles, rather than by attempting to control the actual exposure of each individual particle.

The principal object of my invention is to treat pathological conditions of the body by removing a quantity of blood therefrom, irradiating said blood for a period of time sufficiently long to achieve a maximum of beneficial results, and returning said blood to said body.

A further object of my invention is to treat pathological conditions of the body by intermittently exposing a portion of the blood thereof to ultra-violet radiations. I have found that the time of exposure of each blood particle can be more accurately controlled, and the over-exposure of any particle can more certainly be avoided by giving a quantity of blood a series of short exposures rather than one continuous exposure.

A further object of my invention is to provide means for controlling automatically the time of exposure of blood as it passes into the circulatory system of a patient. Due to spasmodic contraction of the muscles of the veins, or the muscles surrounding them, the rate of flow of blood thru a hollow needle into said veins may vary over a wide range; at times said flow is reduced to the extent that a long period of time is required for the blood to flow into the vein. Said hollow needle may become plugged by a blood clot or tissue, in which case the flow of blood must be interrupted temporarily until said needle is cleaned. Heretofore, the ultra-violet generator has been manually removed from the exposure chamber periodically to avoid overexposure of the blood. This is objectionable for one reason, because it requires the careful attention of a highly skilled operator to time the exposure at all satisfactorily in this way, and, for another reason, even with the most highly skilled operators, the exposure cannot be timed as accurately as is desirable.

A further object of my invention is to provide a mechanically operated cleaning device for cleaning the interior wall of the transparent crystal or window of an exposure chamber. I have found that, especially if the process of irradiating blood is prolonged, a film of blood or blood serum tends to accumulate on said crystal, thereby absorbing part of the radiant energy that would otherwise be absorbed by the blood flowing thru said chamber. Said film makes the actual effective time of exposure uncertain, and it also probably has a selective effect, that is, it probably absorbs some of the shorter wave length radiations. In order that a quantity of blood may be uniformly exposed throughout the exposure process, I prefer continuously to clean the interior surface of the crystal of the exposure chamber.

Other objects and advantages of my invention will be described hereinafter with reference to the accompanying drawings, in which:

Fig. 1 is a side elevation of blood exposure apparatus embodying my invention, one of the side walls of the base member thereof being shown broken away to disclose the parts arranged within said base;

Fig. 2 is an end elevation of said apparatus, portions of the end wall of the base member and of one of the gears being shown broken away to disclose parts posterior thereto;

Fig. 3 is a fragmentary sectional detail view taken substantially on the line 3—3 of Fig. 1, a portion of one of the gears being shown broken away;

Fig. 4 is a more or less diagrammatic enlarged end view of the exposure chamber of said apparatus, portions thereof being shown broken away to disclose the interior structure, a portion of the friction drive wheel therefor being shown;

Fig. 5 is a longitudinal sectional view taken substantially on the line 5—5 of Fig. 4;

Fig. 6 is a diagrammatic view showing the arrangement which I prefer of those parts shown in Fig. 1 thru which the blood flows;

Fig. 7 is a view similar to Fig. 6 showing an alternative arrangement of said parts;

Fig. 8 is a view similar to Fig. 6 showing a modification of my invention;

Fig. 9 is a more or less diagrammatic enlarged side view of the shutter and cam for operating the same shown in Fig. 1; and

Fig. 10 is an enlarged sectional detail view taken along the line 10—10 in Fig. 8.

Blood irradiating apparatus embodying my invention may be mounted upon a base 1 having an aperture 2 adapted to receive and firmly hold an ultra-violet generator 3. I prefer to use a water-cooled type of generator such as a Burdick casing No. W910-1 equipped with a Uviarc burner No. W986, and I prefer to operate said burner at 50 volts. A shutter 4 is removably attached to said generator by clips 5, arranged on either side of said generator, and spaced therefrom by lugs 6. Three of said lugs may be provided, spaced substantially equidistant around said shutter, to hold said shutter laterally as well as to space it from the generator in order that the generator and shutter may be removed from said base as a unit.

Said shutter may be of any convenient type, such as the well known iris type used on cameras. It should be adapted to open, when tripped, for a predetermined time interval, and it is desirable that said interval be readily variable. Said variability may be accomplished in the usual way by moving timer 8a along scale 8b. As is shown more clearly in Fig. 9, blades 7 are adapted to fold into annular space 8 when pin 9 is pressed, and cam 10 is adapted to press said pin when rotated.

A pillow block 11 fixedly secured to the top of base 1 is adapted to support an exposure chamber 12. Cap 13 for said pillow block may be held in place to firmly hold said chamber by means of wing nuts 14 threaded on studs 15, thereby providing for the ready removal of said chamber. Said chamber comprises a body member having fittings 16 adapted to engage rubber tubing to conduct blood to and from said chamber. Said fittings lead to passageways 17 which lead to opposite ends of exposure channel 18 which consists of a series of short, straight ways interconnected by triangular apertures 19 in such a way that blood will flow back and forth across the face of said chamber as it passes therethru. It will be understood that some other configuration of exposure channel might be used. However, I deem it important that said channel be of such shape that a moderate turbulence, especially in the direction toward and away from the face of said chamber, be produced, and that said channel be so designed that it have no pockets in which blood may stagnate and thus become overexposed. Said triangular apertures help produce the proper turbulence, as is explained

more fully in my copending application for United States Patent, Serial No. 191,468, for Ultra-violet exposure device for blood, filed Feb. 19, 1938.

A sleeve 20 rotatably mounted on said chamber and provided with a lip 21 is adapted to be held in place by bushing 22 threaded on said chamber and provided with an internal lip 23 for engaging said lip 21. Said sleeve should fit snugly on said chamber in order to prevent blood flowing therebetween, and to assure that blood shall not so flow I prefer to provide grooves 24 in said chamber to contain packing material. A clamping ring 25 threaded on sleeve 20 is adapted to hold crystal 26 firmly across the end of said sleeve, a resilient packing ring 27 preferably being positioned between said crystal and said clamping ring to prevent leakage of blood therethru, and to minimize the danger of breaking said crystal. Said crystal should be made of quartz, or some other material similarly transparent to ultra-violet radiations.

Bushing 22 may be turned to draw said crystal firmly against the face of said chamber thereby to prevent leakage of blood between said crystal and partitions 28. I prefer to accurately grind the face of said chamber, including the edges of said partitions, to a flat plane in order that said crystal may fit closely thereon. It is important that as few as possible of the blood cells be squeezed between said crystal, as it rotates, and said stationary partitions. The blood cells are rather easily ruptured by mechanical pressure, and, when the hemoglobin from within the red cells is permitted to flow out into the blood serum, undesirable shock symptoms are produced in the patient. The effect of rupturing red blood cells mechanically seemingly is the same as that of rupturing them by overexposure to ultra-violet radiation.

To minimize the aforesaid rupturing of blood cells, I prefer to rotate said crystal at a very slow speed, say, for example, one revolution per minute. This will ordinarily be sufficiently fast to keep said crystal clean by rubbing or scraping against said partitions, which is the object of said rotation. I prefer that said crystal rotate slowly but continually in order that no large amount of deposit shall be scraped loose suddenly, as might occur if said crystal were rotated intermittently by hand, thereby tending to clog the needle thru which the blood is returned to the patient's circulatory system. Rotation of said crystal may be conveniently produced by a friction wheel 30 engaging a groove 29 in sleeve 20. Means for rotating said wheel will be hereinafter described.

In order that blood flowing into the circulatory system of a patient may be exposed for the correct period of time, notwithstanding that the rate of flow of said blood may vary, I prefer that said blood shall be forced thru the exposure chamber by a positive displacement pump, so that the rate of flow of said blood will be proportional to the speed of said pump. Means for preventing undue pressure of said blood where it flows into the patient will be hereinafter described. A positive displacement pump 31 adapted for pumping said blood may be removably mounted on base 1 by cap screws 32. Said pump may be driven by means of gear 33 affixed to pump shaft 34. Said pump should be readily disassembled for cleaning, and it should be so designed that blood cells will not be crushed by its operation, for reasons hereinbefore men-

tioned. A suitable pump for this purpose is described in United States Patent No. 1,845,479, for Blood transfusion apparatus, issued Feb. 16, 1932, to John W. Carpenter.

A motor 35 carries a fan 36 on its shaft 37 for blowing air between generator 3 and chamber 12. I prefer to space said members a short distance apart to allow said air to be blown between them in order that the blood in said chamber shall not be unduly heated, especially when the flow of said blood is temporarily obstructed so that it remains within said chamber for a substantial period of time. Although said generator is preferably of the water cooled type, having tubes 38 for carrying cooling water, and suitable electrical connections 38a, its temperature will ordinarily be higher than that to which blood should be subjected. A further result of said spacing is that no substantial amount of ozone will accumulate between said generator and said chamber. With the means for irradiating blood heretofore used, the generator and the exposure chamber have been held closely together, with only a relatively small body of stagnant air between. A substantial amount of the oxygen of said stagnant air was converted to ozone by the ultra-violet radiations, and said ozone absorbs ultra-violet energy in the neighborhood of 2250 to 2750 Angstrom units to a high degree. I have not accurately determined the effect of eliminating the aforesaid ozone, but the best results I have retained have occurred under conditions in which little, if any, ozone was present.

Said motor also carries on its shaft 37 a worm gear 39 adapted to rotatably engage gear 40 affixed to shaft 41 which carries cam 10, hereinbefore mentioned, affixed thereto. Said shaft 41 also carries a pinion 42 adapted to engage gear 43, fixedly secured to shaft 44. From said shaft 44 two trains of gears are driven. The first, including gear 45 meshing with gear 46 fixed to shaft 47 as is gear 48 which means with gear 49 fixedly secured to shaft 50, is for the purpose of driving friction wheel 30, hereinbefore described, said friction wheel being secured to said shaft 50. The other gear train, including gear 51 meshing with gear 52 affixed to shaft 53 to which is secured gear 54 adapted to mesh with gear 33, hereinbefore described, is for the purpose of operating pump 31.

Other gear arrangements might be used to drive the aforesaid members, but I prefer that pump 31 and shutter 4 be operated by some positive means in order that said shutter may be caused to expose the blood in chamber 12 for a predetermined time when said pump has caused a predetermined amount of blood to flow thru said chamber. I have found that pump 31 should usually be operated at a speed of about one revolution per second, whereas it may be desired to trip shutter 4 twice per second. Thus shafts 53 and 41 may be caused to rotate at about the same speed if cam 10 is provided with 2 protuberances, as is shown in Fig. 9. However, the speeds of various parts may vary widely under different conditions, and more or fewer protuberances may be provided on cam 10. I prefer motor 35 to be of some variable speed type, and it may be supplied with electric power from any suitable source thru control box 54. The speed of said motor may then be varied by turning knob 55 of said control box.

In carrying out the irradiation of blood according to my invention, I prefer to remove from the patient an amount of blood amounting to sub-

stantially $1\frac{1}{2}$ cc. per pound of body weight and treating said blood with citrate, or other reagent, to prevent coagulation thereof. Said blood may be removed from a vein in a manner well known to surgeons, the usual aseptic precautions being taken. If desired, pump 31 may be used to draw said blood out the vein. After said blood has been citrated, it should be placed in a graduated container 56. Said container may be supported by any suitable means, not shown. A rubber tube should be connected from the bottom of said container to the intake of pump 31; another tube should connect the outlet of said pump to chamber 12; and another tube should connect said chamber to a suitable hollow needle 57 adapted to be inserted in a vein of the patient.

With said chamber in position before the ultraviolet generator, after the latter has been properly warmed up and operating properly, motor 35 may be started slowly, forcing blood from the graduated container thru the pump and chamber and into the patient's vein. When the pump has caused a predetermined quantity of blood to flow into the chamber, shutter 4 will be tripped by cam 10 engaging pin 9 and said blood will be exposed for a predetermined time, depending upon the adjustment of said shutter. By way of example, if pump 31 forces 5 cubic centimeters of blood thru said chamber in 10 seconds, shutter 4 might be tripped at intervals of $\frac{1}{2}$ second, and it might remain open $\frac{1}{4}$ second each time it is tripped. Thus, the blood would be exposed for a total of 5 seconds during its passage thru the chamber, although each particle thereof might be exposed for only a fraction of a second.

The use of a positive displacement pump to force blood into the patient's circulatory system after it has been irradiated is highly desirable in that said pump thereby acts as a meter to aid in timing the exposure of said blood. However, the pressure developed by said pump must be limited in some way to avoid injury to the patient in case the blood vessel into which the blood is being forced should be obstructed in some way. I prefer to limit said pressure by means of a standpipe 58 interposed in the tube connecting the aforesaid exposure chamber with needle 57. Said standpipe should be of sufficient height to provide adequate pressure to force blood into a blood vessel as fast as desired, but it should be open at the top to prevent greater pressure. I prefer to make said standpipe of glass in order that an attendant may observe the height to which blood rises therein, said height being a measure of the pressure under which blood is forced into the vein.

Said attendant may slow down motor 35, thereby reducing the rate at which pump 31 forces blood thru exposure chamber 12, if he sees said blood rise too high in standpipe 58; he may thus prevent overflow of blood from said standpipe. However, I prefer to provide a small reservoir 59 adapted to contain a small quantity of blood, and an inverted U-tube 60 having a vent 60a leading from said reservoir to graduated container 56, shown more clearly in Fig. 6. Thus, in case said attendant neglects to slow down motor 35 when the flow of blood into a blood vessel becomes obstructed, the overflow will be returned to said graduated chamber, instead of being spilled. However, this return of blood to said graduated chamber will result in its re-exposure, which is objectionable and should be prevented insofar as possible.

In order to prevent re-exposure of any blood

that might overflow in the apparatus hereinbefore described, I provide, alternatively, the arrangement of parts shown in Fig. 7 wherein the aforesaid U-tube is dispensed with and a somewhat larger reservoir 61 is provided instead of reservoir 59. However, I deem it important that the blood be returned immediately to the patient's circulatory system after it has been irradiated. Accordingly, I do not wish any more blood to be stored in standpipe 58, or the reservoir at its top, than necessary. I, therefore, make the inner diameter of said standpipe no larger than is necessary to control the pressure of the blood flowing into a blood vessel, and I so control the speed of pump 31 that no blood ordinarily overflows from said standpipe.

In the art of blood transfusion, it has heretofore been determined that blood may be forced into a vein under pressure somewhat higher than can be conveniently attained by gravity. In some cases, blood flows into a vein readily under a gravity head of from 3 to 6 feet. In other cases, a somewhat greater pressure is desirable, although said higher pressure should be used with care. To provide said higher pressure, where its use is desired, I provide an adjustable relief valve 62 having a movable member 63 adapted to seat therein, and a spring 64 for causing said member to seat. The tension of said spring may be adjusted by rotating cap 65 threaded on said valve, as is shown in Figs. 8 and 10, thereby adjusting the pressure under which said valve will release.

I interpose said valve 62 in a tube, preferably made of glass, one end of which is connected to the tubing leading from the exposure chamber to the needle, and the other end of which is connected to the tubing leading from graduated container 56 to pump 31. Thus, if the pressure at said needle exceeds a predetermined value, blood will flow thru said relief valve preventing a further increase in said pressure. However, blood flowing thru said valve will be re-exposed, and care should be taken to prevent any substantial quantity from so flowing. Said flow may be prevented by slowing motor 35, as hereinbefore described. The use of valve 62 will greatly expedite the treatment in those cases where blood tends to flow into a vein slowly. Frequently, cap 65 may be screwed down sufficiently to permit the blood to be pumped at a constant rate—without varying the speed of motor 35. Furthermore, the use of said valve 62 makes unnecessary the use of a tall standpipe, and the support therefor.

While I have described my invention in connection with autotransfusions of blood, it may be used advantageously with heterotransfusions; the blood to be irradiated may be taken from another person instead of being returned to the same person. With heterotransfusions, no extra precautions are required because of the irradiation, and the time of exposure should be the same as with autotransfusions. Even where the patient has no disease that requires treatment by irradiation, said irradiation is worth while as a precautionary measure with any transfusion.

My invention is also useful as a preoperative treatment in many cases in which it is necessary to improve the condition of the patient, particularly where it is desired to improve the blood count. Where the time of exposure is so short that each particle of blood is exposed only a fraction of a second, irradiation of the blood is so safe that it may be used as a routine pre-

operative treatment for minor operations, such as tonsillectomies, where it is desired to reduce hemorrhage. For this purpose, said irradiation should precede the operation by about 24 hours.

I claim:

1. In blood transfusion therapy, the method of treating a quantity of removed blood immediately prior to its insertion into a patient's circulatory system comprising producing turbulence of said blood to cause the particles thereof to move towards and from a surface, exposing said surface to a beam of radiant energy of the ultra-violet portion of the spectrum for a time less than that required directly to kill infectious bacteria in said blood.

2. In blood transfusion therapy, the method of treating a quantity of removed blood immediately prior to its insertion into a patient's circulatory system comprising producing turbulence of said blood to cause the particles thereof to move towards and from a surface, exposing said surface to a beam of radiant energy of the ultra-violet portion of the spectrum intermittently for a total time less than that required directly to kill infectious bacteria in said blood.

3. In blood transfusion therapy, the method of treating a quantity of removed blood immediately prior to its insertion into a patient's circulatory system comprising producing turbulence of said blood to cause the particles thereof to move towards and from a surface, exposing said surface to a beam of radiant energy of the ultra-violet portion of the spectrum for a time such that said particles remain in said beam adjacent said surface for less than one second.

4. In blood transfusion therapy, the method of treating a quantity of removed blood immediately prior to its insertion into a patient's circulatory system comprising producing turbulence of said blood to cause the particles thereof to move towards and from a surface, exposing said surface to a beam of radiant energy of the ultra-violet portion of the spectrum intermittently for a total time such that said particles remain in said beam adjacent said surface for less than one second.

5. In blood transfusion therapy, the method of treating a quantity of removed blood immediately prior to its insertion into a patient's circulatory system comprising flowing said blood across a surface in a stratum of substantial depth, producing turbulence of said blood to cause the particles thereof to move towards and from said surface, exposing said surface to a beam of radiant energy of the ultra-violet portion of the spectrum for a time such that said particles remain in said beam adjacent said surface for less than one second.

6. In apparatus for irradiating blood and immediately returning it to the circulatory system, which apparatus comprises a conduit adapted to have a quantity of blood to be irradiated passed therethrough and discharged therefrom, and an exposure chamber communicating therewith, said chamber provided with a window permeable to ultra-violet radiation, the combination therewith of means for producing flow thru said chamber at a constant rate, a by-pass channel communicating with said conduit intermediate said chamber and the point of discharge from said conduit, and means arranged in said by-pass for preserving a predetermined maximum pressure in said conduit at said point of discharge.

7. In apparatus for irradiating blood and immediately returning it to the circulatory system,

which apparatus comprises a conduit adapted to have a quantity of blood to be irradiated passed therethrough and discharged therefrom, and an exposure chamber communicating therewith, said chamber provided with a window permeable to ultra-violet radiation, the combination therewith of a by-pass channel communicating with said conduit intermediate said chamber and the point of discharge from said conduit, and a stand pipe arranged in said by-pass for preserving a predetermined maximum pressure in said conduit at said point of discharge.

8. In apparatus for irradiating blood and immediately returning it to the circulatory system, which apparatus comprises a conduit adapted to have a quantity of blood to be irradiated passed therethrough and discharged therefrom, and an exposure chamber communicating therewith, said chamber provided with a window permeable to ultra-violet radiation, the combination therewith of a by-pass channel communicating with said conduit intermediate said chamber and the point of discharge from said conduit, and means including a pressure relief valve arranged in said by-pass for preserving a predetermined maximum pressure in said conduit at said point of discharge.

9. In apparatus for irradiating blood and immediately returning it to the circulatory system, which apparatus comprises a conduit adapted to have a quantity of blood to be irradiated passed therethrough and discharged therefrom, and an exposure chamber communicating therewith, said chamber provided with a window permeable to ultra-violet radiation, the combination therewith of a by-pass channel communicating with said conduit intermediate said chamber and the point of discharge from said conduit, and a stand pipe arranged in said by-pass for preserving a predetermined maximum pressure in said conduit at said point of discharge, said pressure controlling means including a chamber in said stand pipe of substantially greater cross-sectional area than said stand pipe connected thereto for retaining a substantial quantity of blood.

10. In apparatus for irradiating blood and immediately returning it to the circulatory system, which apparatus comprises a conduit adapted to have a quantity of blood to be irradiated passed therethrough and discharged therefrom, and an exposure chamber communicating therewith, said chamber provided with a window permeable to ultra-violet radiation, the combination therewith of a by-pass channel communicating with said conduit intermediate said chamber and the point of discharge from said conduit, and a stand pipe arranged in said by-pass for preserving a predetermined maximum pressure in said conduit at said point of discharge, said stand pipe having a transparent wall section of substantial length to permit observation of the presence of blood in said stand pipe.

11. In apparatus for irradiating blood and immediately returning it to the circulatory system, which apparatus comprises a generator of ultra-violet irradiation, a conduit adapted to have a quantity of blood to be irradiated passed therethrough and discharged therefrom, and an exposure chamber communicating therewith, said chamber provided with a window permeable to ultra-violet radiation, the combination therewith of means for interrupting periodically the beam directed by said generator through said chamber window.

12. In apparatus for irradiating blood and im-

mediately returning it to the circulatory system, which apparatus comprises a generator of ultra-violet irradiation, a conduit adapted to have a quantity of blood to be irradiated passed therethrough and discharged therefrom, and an exposure chamber communicating therewith, said chamber provided with a window permeable to ultra-violet radiation, the combination therewith of a shutter having a relatively fixed speed of operation for interrupting periodically the beam directed by said generator through said chamber window.

13. In apparatus for irradiating blood and immediately returning it to the circulatory system, which apparatus comprises a generator of ultra-violet irradiation, a generator of ultra-violet radiation, a conduit adapted to have a quantity of blood to be irradiated passed therethrough and discharged therefrom, and exposure chamber communicating therewith, said chamber provided with a window permeable to ultra-violet radiation, said window adapted to be arranged adjacent and facing said generator and to have ultra-violet radiation directed therethrough, the combination therewith of means for interrupting periodically the beam directed by said generator through said chamber window.

14. In apparatus for irradiating blood and immediately returning it to the circulatory system, which apparatus comprises a generator of ultra-violet irradiation, a conduit adapted to have a quantity of blood to be irradiated passed therethrough and discharged therefrom, and an exposure chamber communicating therewith, said chamber provided with a window permeable to ultra-violet radiation, the combination therewith of means for interrupting periodically the beam directed by said generator through said chamber window, and means for varying said means to vary the number of actuations of the latter per unit of time.

15. In apparatus for irradiating blood and immediately returning it to the circulatory system, which apparatus comprises a conduit adapted to have a quantity of blood to be irradiated passed therethrough and discharged therefrom, and an exposure chamber communicating therewith, said chamber provided with a window pane permeable to ultra-violet radiation, said chamber comprising a cup-shaped body having a plurality of transverse partitions extending through the cup of said body, said window pane extending across and bearing upon said partitions, the combination therewith of means for cleaning the inner surface of said window pane including means for moving said pane relatively across said partitions.

16. In apparatus for irradiating blood and immediately returning it to the circulatory system, which apparatus comprises a conduit adapted to have a quantity of blood to be irradiated passed therethrough and discharged therefrom and an exposure chamber communicating therewith, said chamber provided with a window pane permeable to ultra-violet radiation, said chamber comprising a cup-shaped body having a plurality of transverse partitions extending through the cup of said body, said window pane extending across and bearing upon said partitions, the combination therewith of means for cleaning the inner surface of said window pane including means for moving said pane relatively across said partitions, said means being arranged externally of said chamber.

17. In apparatus for irradiating blood and im-

mediately returning it to the circulatory system, which apparatus comprises a generator of ultra-violet radiation, a conduit adapted to have a quantity of blood to be irradiated passed therethrough and discharged therefrom, and an exposure chamber communicating therewith, said chamber provided with a window permeable to ultra-violet radiation, said window adapted to be arranged adjacent and facing said generator and to have ultra-violet radiation directed therethrough, the combination therewith of means arranged adjacent the window of said exposure chamber adapted to direct a current of air across said window and intermediate the latter and said ultra-violet generator.

18. In apparatus for irradiating blood and immediately returning it to the circulatory system, which apparatus comprises a generator of ultra-violet radiation, a conduit adapted to have a quantity of blood to be irradiated passed therethrough and discharged therefrom, and an exposure chamber communicating therewith, said chamber provided with a window permeable to ultra-violet radiation, said window adapted to be arranged adjacent and facing said generator and to have ultra-violet radiation directed therethrough, the combination therewith of means arranged adjacent the window of said exposure chamber adapted to direct a current of air across said window and intermediate the latter and said ultra-violet generator in such quantities as to maintain said window substantially below body heat and to remove rapidly and prevent the accumulation of ozone generated by said ultra-violet radiation.

19. In apparatus for irradiating blood and immediately returning it to the circulatory system, which apparatus comprises a generator of ultra-violet radiation, a conduit adapted to have a quantity of blood to be irradiated passed therethrough and discharged therefrom, and an exposure chamber communicating therewith, said chamber being provided with a window permeable to ultra-violet radiation, the combination therewith of adjustable means for producing a selected rate of flow thru said chamber, and means for interrupting periodically and rapidly the beam directed by said generator thru said chamber window, said latter means being operatively connected with the means for producing flow thru said chamber so as to correlate the frequencies of interruption of said beam with the rate of flow thru said exposure chamber.

20. In apparatus for irradiating blood and immediately returning it to the circulatory system, which apparatus comprises a generator of ultra-violet radiation, a conduit adapted to have a quantity of blood to be irradiated passed therethrough and discharged therefrom, and an exposure chamber communicating therewith, said chamber being provided with a window permeable to ultra-violet radiation, the combination therewith of adjustable means for producing a selected rate of flow thru said chamber, means for interrupting periodically and rapidly the beam directed by said generator thru said chamber window, said latter means being operatively connected with the means for producing flow thru said chamber so as to correlate the frequencies of interruption of said beam with the rate of flow thru said exposure chamber, a by-pass channel communicating with said conduit intermediate said chamber and the point of discharge from said conduit, and a stand pipe arranged in said by-pass for preserving a predetermined max-

imum pressure in said conduit at said point of discharge, said stand pipe having a transparent wall section of substantial length to permit observation of the presence of blood in said stand pipe.

21. In apparatus for irradiating blood and immediately returning it to the circulatory system, which apparatus comprises a conduit adapted to have a quantity of blood to be irradiated passed therethru and discharged therefrom, and an exposure chamber communicating therewith, said chamber being provided with a window permeable to ultra-violet radiation, the combination therewith of a shutter adapted periodically to interrupt a beam of ultra-violet radiation directed through said window, and a power driven cam for actuating said shutter.

22. In apparatus for irradiating blood and immediately returning it to the circulatory system, which apparatus comprises a conduit adapted to have a quantity of blood to be irradiated passed therethrough and discharged therefrom, and an exposure chamber communicating therewith, said chamber being provided with a window pane permeable to ultra-violet radiation, said cham-

ber comprising a cup-shaped body having a plurality of transverse partitions, said window pane extending across and bearing upon said partitions, the combination therewith of rotary friction means for rotating said pane thereby to clean the inner surface of said pane.

23. In apparatus for irradiating blood and immediately returning it to the circulatory system, which apparatus comprises a conduit adapted to have a quantity of blood to be irradiated passed therethrough and discharged therefrom, and an exposure chamber communicating therewith, said chamber being provided with a window pane permeable to ultra-violet radiation, said chamber comprising a cup-shaped body having a plurality of transverse partitions, said window pane extending across and bearing upon said partitions, the combination therewith of rotary friction means for rotating said pane thereby to clean the inner surface of said pane, a shutter adapted to interrupt periodically a beam of ultra-violet radiation directed through said window pane, and a power driven cam for actuating said shutter.

EMMET K. KNOTT.