Aug. 20, 1935. A. L. ATHERTON 2,011,605

CENTRAL BLAST RECTIFIER AND WATER TEMPERATURE CONTROLLING MEANS THEREFOR

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Fig. 1.

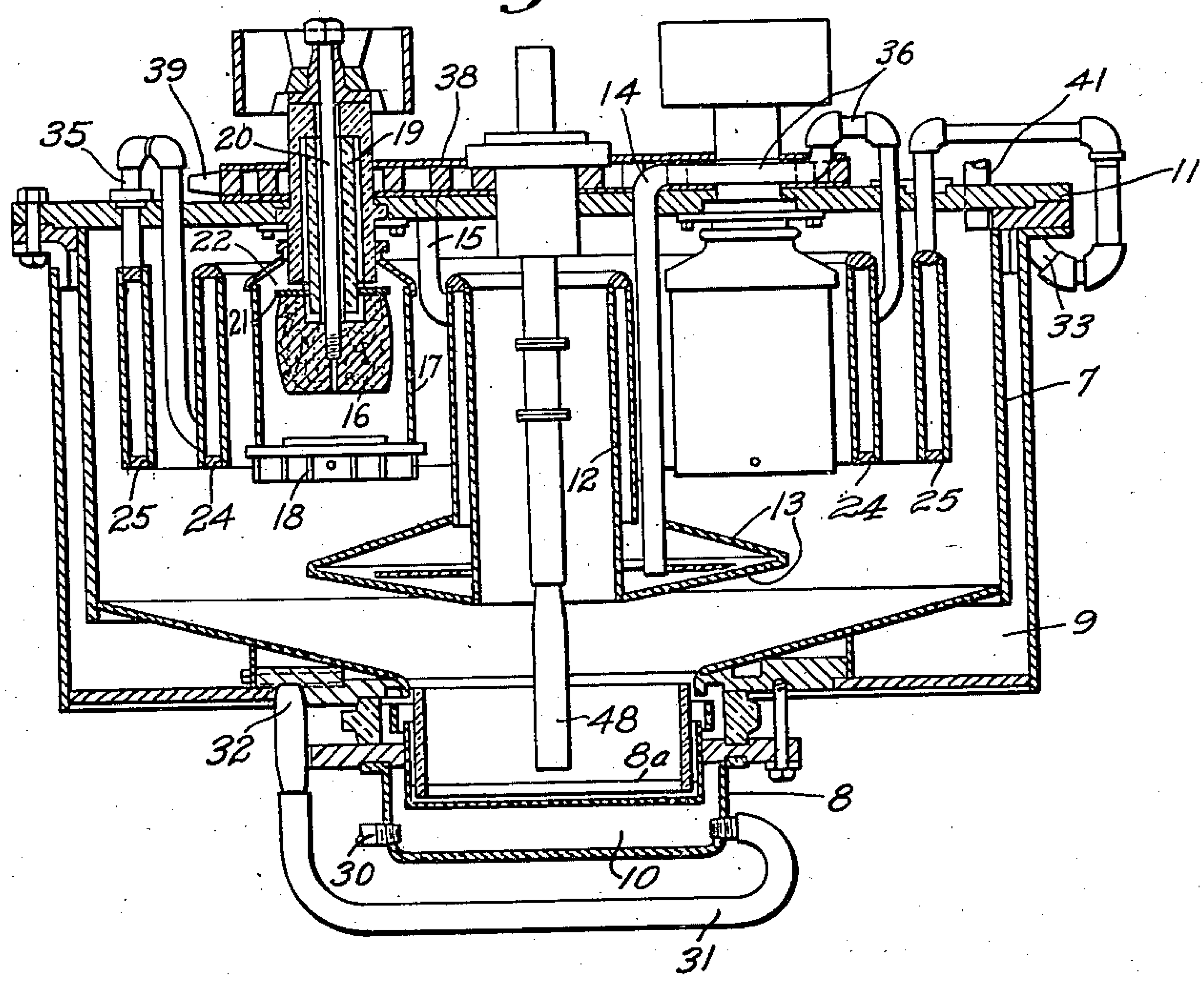
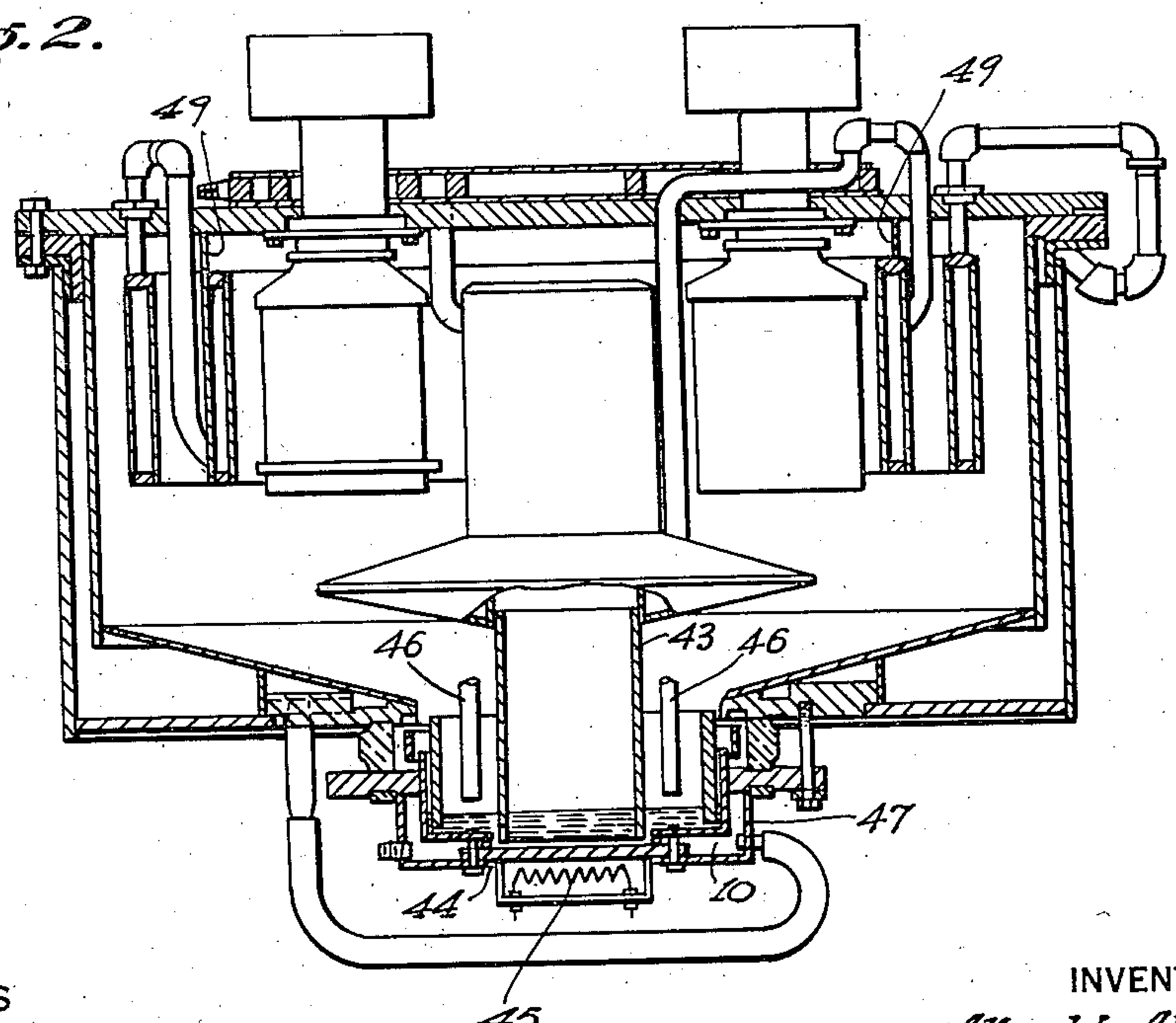


Fig. 2.



WITNESS
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CENTRAL BLAST RECTIFIER AND WATER TEMPERATURE CONTROLLING MEANS THEREFOR

Filed Jan. 28, 1932 2 Sheets-Sheet 2

Fig. 3.

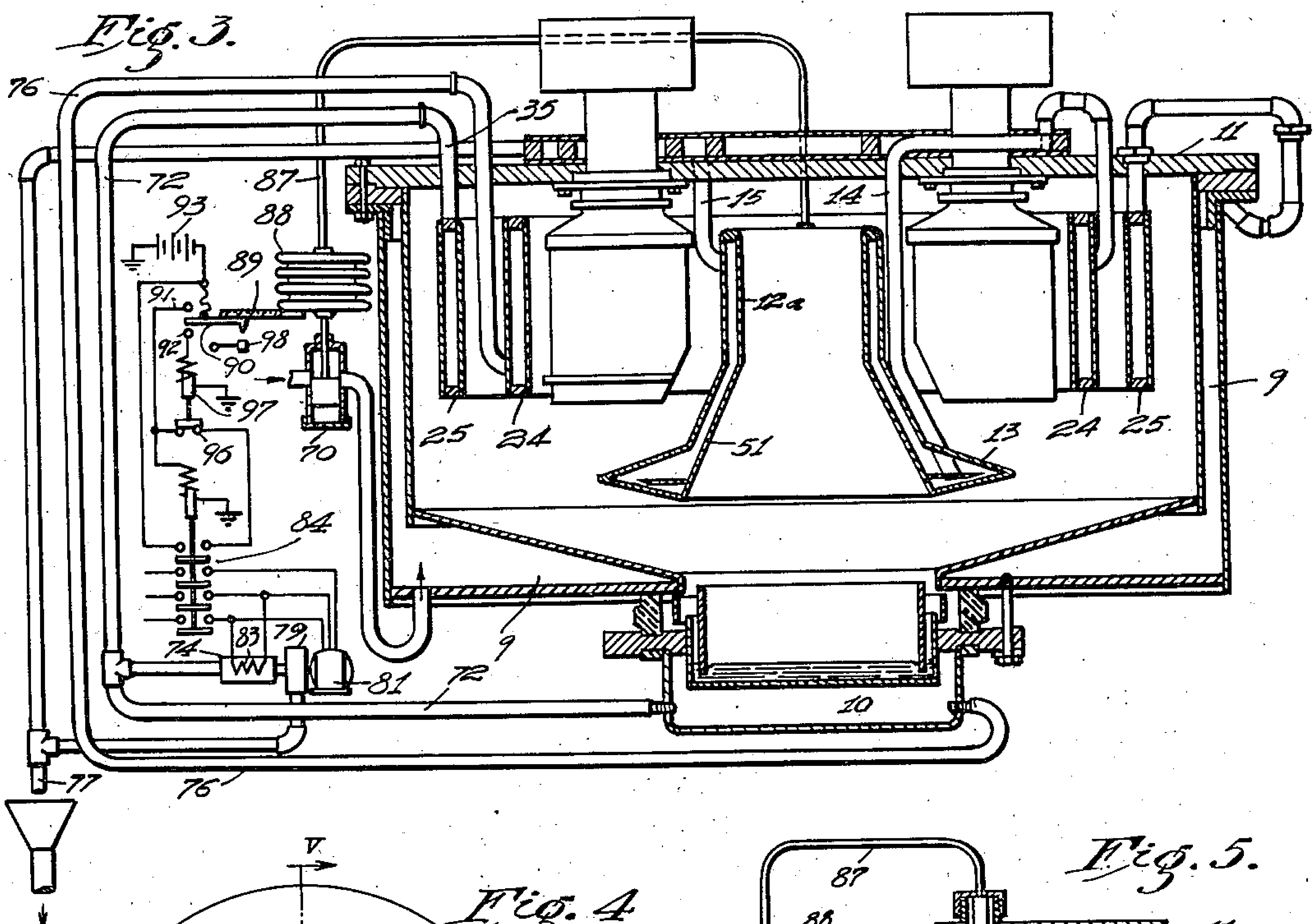


Fig. 4

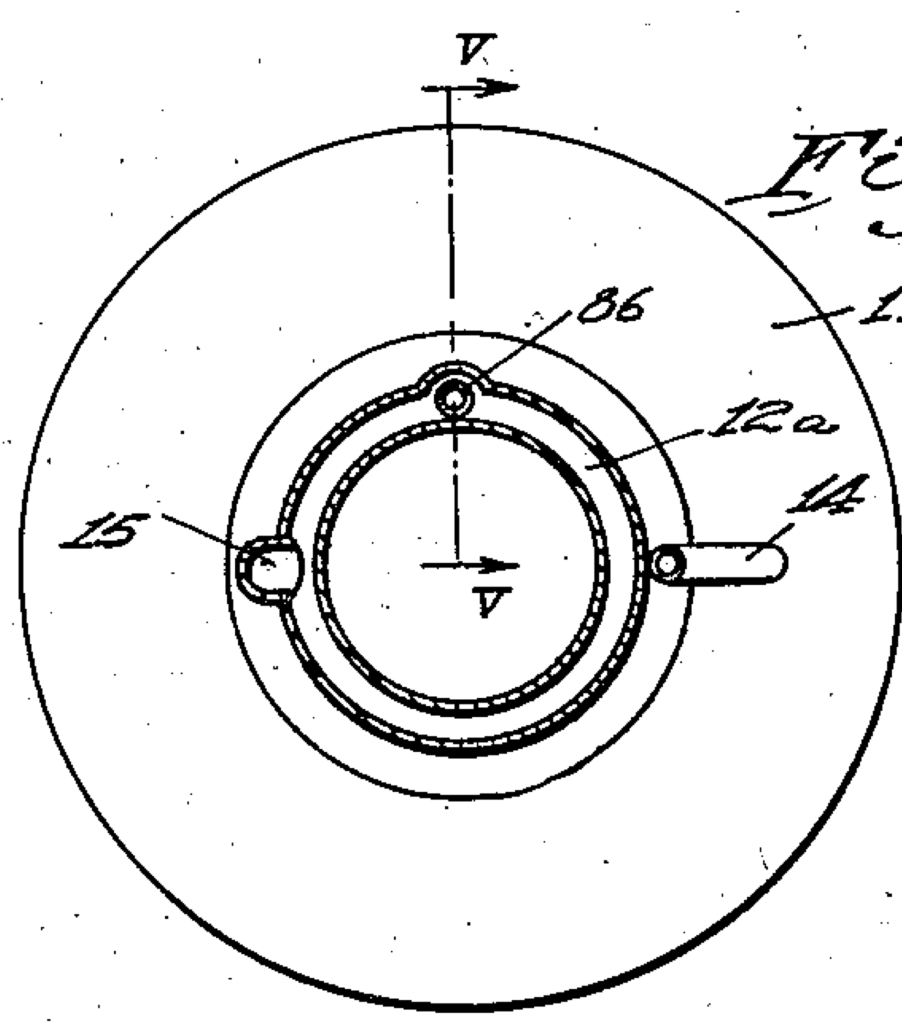


Fig. 5.

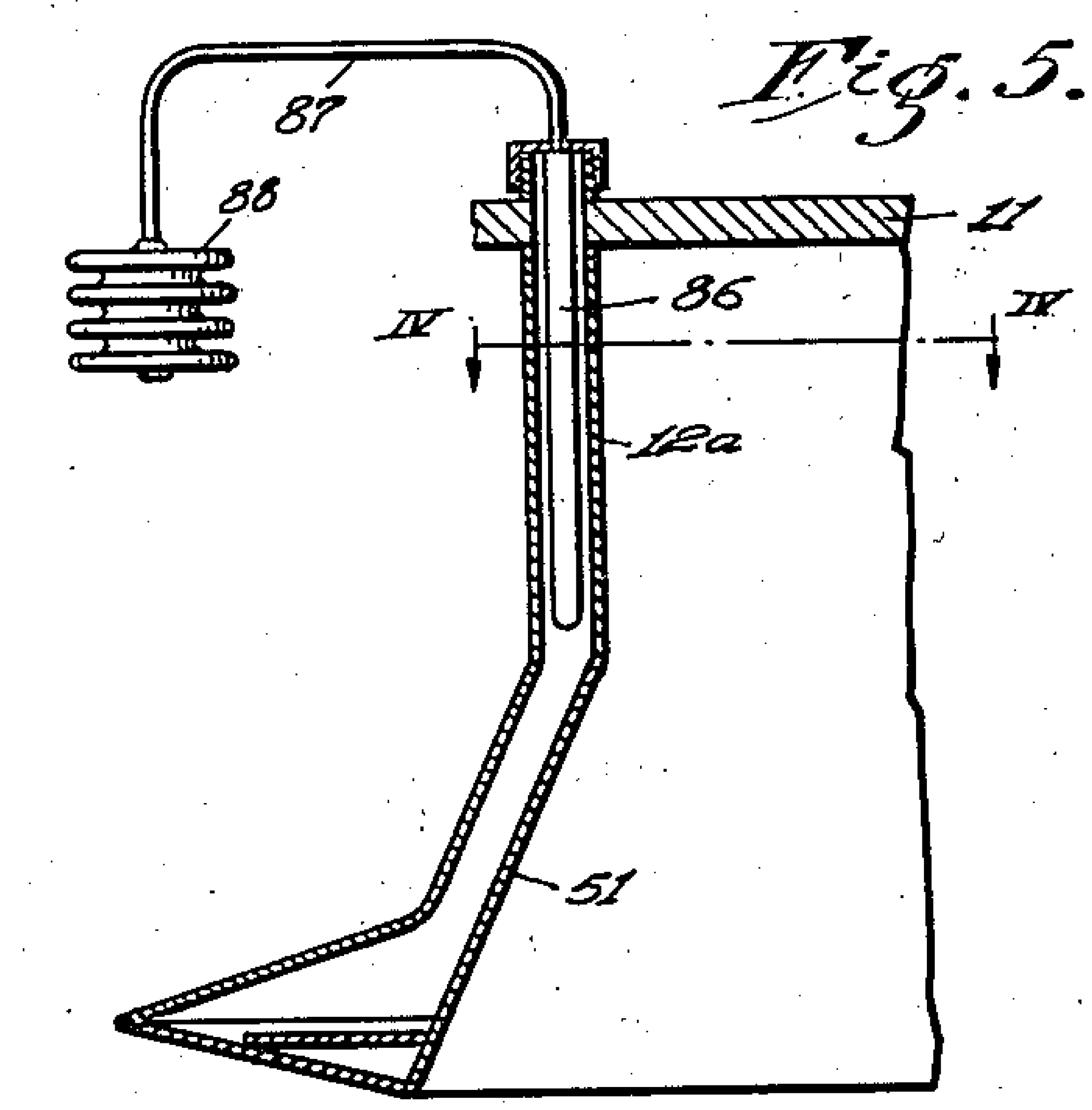
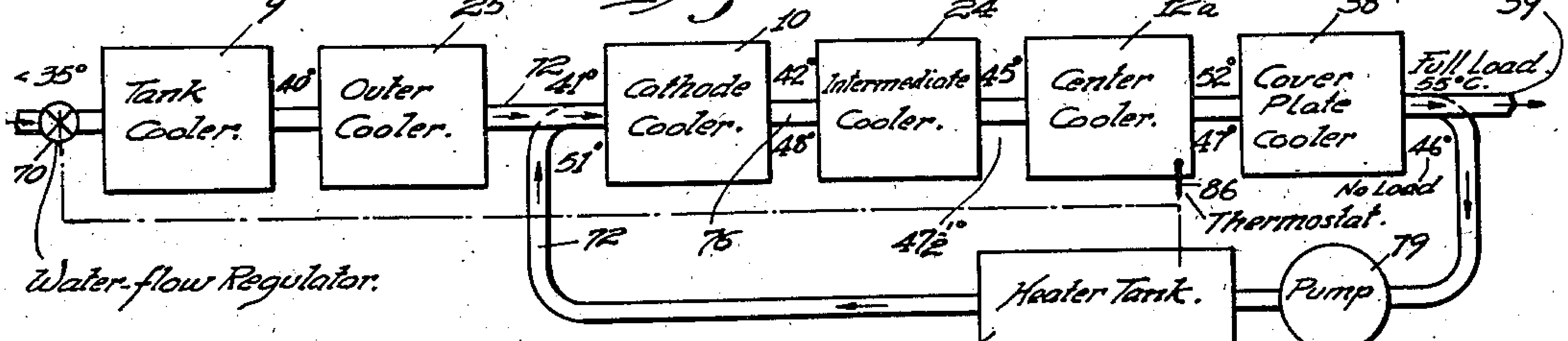


Fig. 6.



WITNESS

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Patented Aug. 20, 1935

2,011,605

UNITED STATES PATENT OFFICE

2,011,605

CENTRAL-BLAST RECTIFIER AND WATER TEMPERATURE CONTROLLING MEANS THEREFOR

Alfred L. Atherton, Verona, Pa., assignor to Westinghouse Electric & Manufacturing Company, a corporation of Pennsylvania

Application January 28, 1932, Serial No. 589,415

17 Claims. (Cl. 250—27.5)

My invention relates to means for improving the operation and reducing the space requirements of mercury-arc metal-tank rectifiers and it has particular relation to means for influencing or controlling the flow of vapor in a multi-anode rectifier tank and for providing a blast of sufficiently deionized vapor in the region of the anodes to prevent arc-backs, while helping to provide sufficient vapor for the main arc path.

The thought behind my invention is to provide means for preventing a phenomenon which constitutes a peculiar difference between the insulating gas paths from the cathode to the anodes (and from one anode to another) when the particular anode is not carrying current but when some other anode is active, on the one hand, and an ordinary insulating gap in a gas, on the other hand. In any rectifier, the object is, of course, to have the gas paths between the inactive anodes and the other parts of the structure perform the function of insulators to prevent current flow to and from said inactive anodes during the portion of the cycle when they are not supposed to carry current. If it were not for the presence of another anode or anodes carrying current, as the terminal of an arc or arcs, in the same tank, these insulating gas paths would normally withstand a potential of somewhere around 10,000 volts, with the spacings, vapor pressures, and materials of the anodes and the gas, commonly met with in metal-tank rectifiers. In such a rectifier, in which the maximum potential difference is of the order of 1000 volts, no back-fire should ever occur, but it is well known that such back-fires, or arc-backs, do occasionally occur. The theory has been suggested that the remanent ionization, which remains in the region of an anode after the termination of this period of activity explains these occasional back-fires, and means have been added with the view of quickly deionizing these remanent ions.

My observation has shown, however, that the back-fire phenomenon is a random phenomenon, and my studies of the distribution of arc-backs during the period of inactivity have not shown any considerable degree of clustering during the initial remanent-ionization period of transition from conductivity to insulation characteristics for a given path, thereby indicating, to my mind, that the remanent ionization, at least in the modern types of rectifiers, as ordinarily constructed, although a contributory cause of back-fire, cannot be a predominant cause of back-fire in the presence of ionization from other simultaneously operating arcs in the same chamber.

The present invention is based upon the theory or belief that the peculiar characteristic of the insulating gas paths in a rectifier, which causes them to break down, occasionally, at voltages of the order of 10%, or less, of their ordinary break-down potential, is attributed to the presence of ionized mercury vapor from the arc-paths of other anodes which are active at the moment. This ionized mercury vapor, according to my present belief, is carried about in a variable and more or less uncontrolled way by the blast of mercury vapor from the cathode, in rectifiers as heretofore constructed. At intervals there will be the combination of a sufficient density of ionization concentrated in the space around an anode on which the reverse potential is applied with sufficient instantaneous potential to cause the breakdown which develops into an arc-back. This combination of circumstances occurs only occasionally because it requires the accumulation of a large number of positive ions at just the right place and at just the right time, and because the movement of the positive ions is controlled by the blast of vapor from the cathode which has a high velocity and which is made to be extremely turbulent and full of eddies by the projection, into the stream of vapor, of a large number of irregularly shaped bodies, such as anode shields, cooling systems, etc. Further complication is introduced by the fact that along the path of flow of the vapor there are portions in which energy losses take place because of the flow of the arc current, which causes local heating, increasing the molecular agitation velocity and tending to set up local vapor movement.

The conception that the source of these occasional breakdowns is the concentration of ionization from an outside source, brought about by the flow, into the high voltage-gradient space, of an abnormally large concentration of positive ions, seems to me to be reasonable. It also seems to me to be reasonable that the extremely varied flow of gas, resulting from the high velocity and extremely irregular path, will explain the long time intervals and the variation in time intervals.

Considerations such as the foregoing lend increased support to the corrective measures disclosed in my application Serial No. 560,722, filed September 2, 1931. If we can introduce such a flow of un-ionized vapor that the ionized vapor cannot enter the high-gradient portion, this source of arcing-back is removed. In the rectifier constructions shown in my copending application just mentioned, use was made of a separate mercury pool, heated by an auxiliary source, to supply the flow of un-ionized vapor.

My present invention is partly in the nature of a continuation, in part, of my above-mentioned application, and, in part, it is directed to modifications and improvements thereon. I have been able, as described in the present application, to obtain a blast of sufficiently un-ionized vapor from the cathode pool itself, without resorting to a separate mercury pool, and I have discovered, more definitely, the nature and importance of the control of the temperature gradients within the rectifier, if the un-ionized blast is to be used effectively, whether it originates from the cathode pool or from an auxiliary mercury pool.

Of course, it is known that there are many other cases of arc-backs, each of which has to be taken care of. For example, the presence of too much foreign gas will cause trouble and it is necessary to get this kind of thing under control, regardless of what other mechanisms of vapor-flow may be set up. The proper design and control of means for providing an un-ionized mercury blast, in accordance with my present invention, affords one of the most effective ways of which I know, for avoiding the troubles due to foreign gas. This may be explained as follows:

The vapor from the cathode may be assumed to be relatively free from foreign gas. The principal sources of foreign gas, assuming that any rubber gaskets which are utilized for vacuum-sealing processes are sufficiently cooled, are the anodes and the hot parts surrounding them. I believe that these gases, which are continually being given off by the hotter parts of the apparatus, are carried along in the general direction of the vapor flow and have accumulated in pockets, in previous constructions, thereby preventing the mercury vapors from reaching the cold walls of the tank, thus lowering the efficiency of the rectifier, but, what is worse, accumulating until some vagary of the vapor flow sends an eddy or puff through such a gas pocket and blows the gas into a region where back-fire may occur. In my vapor-blast control system, a gas-free blast of vapor from the cathode is definitely directed across the anodes, and particularly across the mouths of the anode shields, where such shields are utilized, so as to carry along any foreign gas which is given off, thereby depositing said foreign gas at a portion of the tank to which the vacuum pumping connection is made. This results in freeing the space within the anode shield from entrance of serious quantities of foreign gas.

There is another factor in the behavior of a rectifier which has to be taken into account in determining the amount and density of vapor necessary in the auxiliary stream. When the current flows in an anode shield to the anode head, the vapor in the shield is heated and tends to expand and flow out at the bottom of the shield. When the current flow ceases, the vapor re-enters the anode shield due to the reduced temperature of the gas in the shield. This results in a breathing effect which tends to draw into the shield whatever vapor may surround the opening, just at the time when the negative potential is being applied. It is thus necessary that the vapor surrounding the opening of the anode shield shall be to a sufficient extent un-ionized. Doubtless the only way for us to approach the problem of determining the amount of auxiliary vapor flow which will be required will be by trial, at least for the present.

With the foregoing and other objects in view, my invention consists in the various structures, combinations, methods and arrangements of parts which are hereinafter described and claimed and shown in the accompanying drawings, wherein

Figure 1 is a sectional view of a rectifier embodying my invention in a form which utilizes a central blast from the cathode pool itself, with a series connection of the various coolers for the purpose of obtaining the approximate temperature gradients which are necessary for the proper maintenence of the blast.

Fig. 2 is a similar view showing the use of an auxiliary mercury pool or auxiliary portion of the main pool which is segregated as the source of the un-ionized blast.

Fig. 3 is a view similar to Fig. 1, illustrating a means for increasing the relative strength of the central blast, as compared to the radial blast which lies in the direct arc path between the cathode and the several anodes. This figure also shows what is now my preferred method of controlling the temperatures of the various coolers, with automatic means for this purpose.

Fig. 4 is a sectional view of the center cooler, the section plane being indicated on Fig. 3 by the line IV—IV.

Fig. 5 is a partial vertical, sectional view through the center cooler, showing the temperature-responsive device or thermostat which is associated therewith.

Fig. 6 is a diagrammatic view illustrating the water flow system for the coolers.

In Fig. 1 my invention is shown applied to a metal-tank rectifier comprising a main tank portion 7 having an insulated cathode receptacle 8 in the bottom thereof. A liquid mercury cathode pool 8a is disposed in the bottom of said cathode receptacle 8. The side and bottom walls of the tank are provided with a tank cooler or water jacket 9 and the cathode receptacle is provided with a water jacket or cathode cooler 10. Depending from the central portion of the cover plate 11 of the tank is a central cooler or tubular baffle 12 which terminates, at its lower end, in an annular conical baffle 13. Both the central cooler 12 and the conical baffle 13 are cooled by water which enters through an inlet pipe 14 and leaves through an outlet pipe 15.

A plurality of anodes 16 are disposed in a ring around the upper portion of the central tubular baffle 12 and above the conical baffle 13. Each anode may be provided with an anode shield 17, the bottom of which is protected by a grid 18. Preferably, also, I utilize an anode construction as shown and claimed per se in an application of J. T. Mathews Serial No. 588,915, filed January 26, 1932 and assigned to the Westinghouse Electric & Manufacturing Company. One of the most significant things about this anode construction is the use of a quartz tube 19 surrounding the anode lead or shank 20 and counter-sunk into the anode head 16. Surrounding the quartz tube 19, and resting upon the top of the anode head 16, is a quartz disc or ring 21 which is spaced from the lower end of the anode porcelain 22. This space, as well as the quartz tube 19, seem to be necessary, in addition to the arrangement of the mercury blasts in my present application, in order to secure the fullest measure of freedom from back-fires which has not been attainable heretofore.

The ring of anodes 16 is disposed close in towards the center cooler 12, being much closer to said cooler than to the side walls of the tank 7. Surrounding the ring of anodes is an intermediate cooler 24, and surrounding that there may be an outer cooler 25. The outer cooler 25 and the tank cooler 9 provide what I call the final condensing walls, or walls of which the predominant characteristic is that the mercury condenses and runs as a liquid back to the cathode, as distinguished from a wall on which the mercury condenses and re-evaporates. For brevity, I shall refer to these final condensing walls as the side walls of the tank 7, regarding the outer cooler 25, if it is used, as simply a continuation of the side walls of the tank. To make my meaning more clear, I shall refer next to the temperature gradients which I maintain within the tank, and to the general phenomena of mercury vapor flow.

Mercury vapor leaves the cathode at a high velocity, probably much higher than the velocity corresponding merely to the temperature of the surface of the mercury, although this temperature is the hottest part of the mercury vapor blast. As soon as the mercury vapor leaves the cathode surface, it expands with molecular movements in all directions, but with a preponderance of the molecules or particles moving in the direction of the temperature gradient, or toward the cooler portions of the rectifier. When mercury vapor touches the central cooler, which, according to my invention, is the hottest cooling surface, being intermediate in temperature between the temperature of the surface of the mercury pool and the temperature of the final condensing walls, the vapor approaches the surface of the cooler at the high velocity above described and leaves it at a much lower velocity corresponding to the molecular velocity corresponding to the temperature of the cooler. I describe this process as a condensation and re-evaporation of the mercury on the walls of the cooler. During this process, the vapor also loses the ionization which it had when it left the region of the cathode. In its progress up through the central cooler 12, the mercury vapor thus becomes deionized and it loses much of its velocity and, of course, much of the vapor pressure which goes with the velocity. When the central blast of mercury vapor reaches the top of the central cooler, it again expands, as a free gas which is released, under pressure, in a space, in a manner similar to that which was described for the blast as it first left the mercury cathode. Some of the mercury vapor comes down and condenses on the top walls of the conical baffle 13, and some goes out to the intermediate cooler 24, thereby providing a downwardly and outwardly directed blast of substantially un-ionized mercury vapor which is fairly free of foreign gases, sweeping past the bottom mouths of the anode shields 17, and carrying along with it any foreign gases which are liberated from the anodes 16.

In addition to the central blast which rises from the cathode, there is also a radial blast which passes outwardly under the conical baffle 13 and thence out to the side walls of the tank and to the outer cooler 25, the two blasts joining and condensing, finally, upon the final condensing walls of the tank cooler 9 and the outer cooler 25.

In order to maintain the vapor flow just described, it is essential that the central cooler shall have a temperature cooler than the initial temperature of the vapor blast, so that the mercury vapor will condense on it, and yet warmer than the final condensing walls, so that the expanding vapor, as it loses its velocity and pressure, will re-evaporate and move on as un-ionized vapor. The intermediate cooler 24 should, I believe, have a temperature more nearly like that of the inner cooler 12.

In the particular system shown in Fig. 1, the approximate temperature gradients of the coolers are maintained by introducing the cooling water first into the cathode cooler 10, as indicated by the inlet pipe 30. The water leaves the cathode cooler 10 through a rubber hose connection 31 and enters the inlet pipe 32 of the tank cooler 9. It leaves the tank cooler through the outlet pipe 33 and enters the outer cooler 25. Leaving the outer cooler through the outlet pipe 35, the cooling water then enters the intermediate cooler 24, from which it passes, through pipes 36, to the inlet pipe 14 of the central cooler 12 and conical baffle 13. The water leaves the central cooler 12 through the outlet pipe 15 and enters a cover-plate cooler 38, from which the water is discharged through a suitable outlet or drain pipe 39. In the foregoing system of water connections, it will be observed that the hottest water is at the inner cooler 12 and that the coldest water is in the tank cooler 9 and the outer cooler 25.

The above-described scheme of controlling the temperatures at the various parts of the rectifier so as to produce the conditions necessary for the vapor to flow from the cathode to the cooling surfaces, through paths apart from the danger zones, (the regions of the anodes where back-fires are likely to occur, is very important in reducing the frequency of these back-fires. The particular structure shown in Fig. 1 illustrates the principle, although I do not believe that it carries it out as far as possible. For example, if we make the center baffle hotter by, say, 10 degrees, than the balance of the condensing surface, then the vapor pressure just at the surface of this baffle is approximately twice as high as the vapor pressure at the cooler surfaces. This certainly produces a tendency for vapor to flow from the center baffle to the cooler surfaces and this vapor, flowing in this direction, will carry foreign gases and ionized mercury vapor with it toward the main condensing surfaces and thus into places where less harm is done. It is, of course, necessary that the hot walls be cool enough to ensure condensation, so that saturated mercury vapor will be present.

I also find that the grouping or nesting of the anodes 16, close in towards the center cooler 12, has an important bearing on the freedom from back-fire. In other words, it is important to provide a free radial space between the ring of anodes 16 and the side walls of the tank 7. This is particularly true where an intermediate cooler 24 is utilized, which I prefer in all cases to do, said intermediate cooler being at a temperature higher than the temperature of the side walls of the tank, thereby producing a definite pressure-difference, as just described for the central cooler, producing a definite flow of mercury vapor below the bottom of the intermediate cooler and out to the side and bottom walls of the tank 7.

The main arcing path between the cathode and the several anodes is around the central conical baffle 13, although it must be understood that the arc, taking place, as it does, in an extremely low-pressure gas or vapor, spreads out pretty largely over the whole tank space, some of it probably even passing at least occasionally, through the central blast path hereinabove described.

A further point to be considered is that the vacuum pumping connection should be arranged so as to open into the tank at the point where the gases accumulate. In the present rectifier, as above described, this point is at the top of the side walls of the tank portion 7. I have indicated a vacuum pumping connection 41 in the cover plate 11 near the side walls of the tank, in Fig. 1.

I have found some indication of a tendency of the design shown in Fig. 1 to be sensitive to rapidly applied loads. While the number of arc-backs is relatively small, all of the arc-backs which have occurred so far have occurred at a time when the load was suddenly increased, say, from 25% of full load to 200% of full load, the frequency of back-fires, under such circumstances, being about one in a thousand times. I also find that, for a few minutes, after such an increase in load, the arc drop is considerably higher and is considerably erratic. I attribute these phenomena mainly to the slowness with which the cathode spots on the mercury pool spread out over the surface of the pool, so as to carry the increased load, and to the time which it takes for the average temperature of the top surface of the mercury pool to increase to a value necessary to supply the increased mercury vapor which is necessary to be present in the arc paths. In other words, the central blast, in the particular design shown, does not seem to be large enough to supply a sufficient number of un-ionized mercury molecules or vapor in the region under the anode shields 17, so that there are not sufficient gas particles there to carry the increased load current without excessive arc drops.

There are two ways in which I might correct this defect, according to my present theories. One is to utilize an auxiliary source of mercury vapor, for the un-ionized blast, as I have indicated in Fig. 2. In this case, a tubular quartz baffle 43 is provided between the central cooler 12 and a central portion of the mercury pool, which is heat-insulated from the cathode cooler 10, as indicated at 44. A heater 45 is provided for this central mercury pool, whereby mercury may be boiled off therefrom at any rate which may be desired. In this form of embodiment of my invention, one or more starting anodes 46 are provided, in the outer active annular portion of the mercury pool 47 instead of using a single centrally located starting anode 48 as in the Fig. 1 construction.

Fig. 2 also shows a feature which may be of utility in any of the forms of embodiment of my invention, namely, a depending tubular baffle 49 depending from the cover plate 11 in the region of the ring of anodes 16 for the purpose of assisting in directing the blast downward past the mouths of the anode shields 17.

An additional method of obtaining the increased central mercury blast which I believe to be needed in the particular design shown in Fig. 1, is indicated in Fig. 3, wherein the bottom end of the central cooler 12a is opened out, like a funnel, as indicated at 51, so that it spreads over substantially the whole area of the cathode pool, so as to take instant advantage of the increased mercury ebullition from the regions of the cathode spots, no matter where they are located, upon the occurrence of a sudden increase in load. In this way, it is believed that more mercury vapor will immediately pass up through the central baffle or cooler 12a, without waiting for the temperature of the cathode spots to spread out over the surface of the mercury, upon the occurrence of a sudden increase in load.

Figure 3 also shows what I now believe to be the best water circulating system in the coolers. As in Fig. 1, the coolers are connected in series, although in the broadest aspects of my invention I am not to be limited to a series connection. In Fig. 3, however, the cathode cooler 10 is placed in the third position instead of in the first position in the series of coolers which constitute the path of the cooling water, and I provide means for artificially heating all of the coolers except the tank cooler 9 and the outer cooler 25, during periods of no load, so that the parts are kept at a temperature suitable for immediate assumption of load.

As shown in Fig. 3, as well as in the diagrammatic view of Fig. 6, water is led first through a valve or so-called water-flow regulator 70 and thence to the tank cooler 9 and outer cooler 25. From the discharge pipe 35 of the outer cooler, a hose connection 72 leads both to the cathode cooler 10 and to a heater tank 74. Tracing first the normal path of the water through the cathode cooler, a second hose connection 76 carries the water to the inlet pipe of the intermediate cooler 24, whence it passes through the center cooler and the cover-plate to the outlet pipe 39 which is connected both to the drain 77 and to the inlet side of a pump 79 which, when operating, discharges water into the heater tank 74, from which it is recirculated through the cathode, intermediate, center and cover-plate coolers 10, 24, 12a and 38. The pump 79 is adapted to be driven by a motor 81, which may be energized, whenever current is supplied to an electric heater 83 in the heater tank 74, in response to the operation of a contactor switch 84. It will be understood that, normally, when the rectifier tank is carrying any appreciable load, the electric water heater 83 and the pump 79 will be unenergized, so that no water will flow therethrough.

To give some idea of the temperatures involved, I shall indicate certain temperatures which have been found to be satisfactory, although it will be understood that I am not to be altogether limited to these particular temperatures. Inlet water is supplied, at almost any desirable temperature, which preferably should be less than 35° C., as indicated in Fig. 6. After passing through the tank cooler, a water temperature of as large as 40° C. may be utilized. The water will be slightly further heated in passing through the outer cooler, reaching a temperature of possibly 41°. Subsequently, the water temperatures will be 42°, at the end of the cathode cooler; 45° at the end of the intermediate cooler; 52° at the end of the center cooler and possibly 55° at the discharge terminal 39. These temperatures are merely given for illustrative purposes.

During periods of no-load, or extremely light loads, it is very desirable to prevent the temperatures of the cathode and of the intermediate and center coolers from falling to too low a value. I, therefore, provide means for shutting off the water-flow regulator 70 and starting an intermediate circulation by means of the pump and heater tank, as previously described. In such a case, the inlet water which is fed first to the cathode cooler from the heater tank may have a temperature of about 51° C., after which it is conducted into the intermediate cooler at a temperature of, say, 48° C., then to the center cooler at a temperature of 47½° and finally to the cover-plate at a temperature of 47°, returning to the pump at a temperature of possibly 46° C., from which it is discharged again into the heater tank 74.

It will be observed that, at all times, the intermediate and center coolers are kept at a temperature intermediate between that of the cathode surface and that of the tank cooler and outer cooler, so that the vapor flow, as previously described, may be satisfactorily maintained. It will also be observed that the principal source of heat-interchange during normal operation, is in the center cooler, which is the cooler the most sensitive to load changes.

In devising an automatic heat control system, therefore, I utilize a thermostat or heat-responsive device 86 which is responsive to the water temperature in the center cooler 12a. As shown in Figs. 4 and 5, this heat-responsive element may take the form of a liquid container which is inserted in the center cooler 12a and which is connected, externally of the tank, by means of a pipe-connection 87, to a metallic bellows 88 which expands and contracts in response to temperature changes in the center cooler. This metallic bellows is mounted as an integral part of the water-flow regulator, so that it turns off the water at a temperature of, say, 50° in the center cooler, and turns it open wide at a temperature of 58° C. in the center cooler.

Upon either the same or a duplicate thermostatic device 86, 88, an insulating support 89 carries a contact finger 90 which moves between two stationary spring-contact fingers 91 and 92. Energy is supplied from a relay battery 93 to the movable contact finger 90, so that when the back contact 91 is engaged, at a temperature of, say, 45° C., the contactor switch 84 will be energized in order to turn on the water heater 83 and the pump motor 81. As soon as the contactor switch 84 picks up, a "hold" circuit 95 is energized through the normally closed contacts 96 of an auxiliary relay 97 which is tripped by the engagement of the contact finger 92 at a temperature of, say, 48° C., so that the water heater and pump are cut off at this temperature. When the temperature of the central cooler 12 increases two more degrees, or to 50° C., the thermostatic device begins to turn on the water-flow regulator, as previously described.

If very excessive temperatures should be reached, a final limit-switch contact 98 is reached, by the contact member 90 of the thermostatic device, so that an alarm will be rung and the entire station shut down at a temperature of about 65° C. It will be understood that the foregoing temperatures are illustrative only, and that any temperatures may be utilized which experience shows to be adapted to the particular design-conditions of any given installation.

The rectifier tank which is shown and described in this application is a part of a development which has contributed, in large measure, to the success of a sectionalized-type design which constitutes the subject matter of my copending application Serial No. 589,414, filed January 28, 1932. In this sectionalized design, a large mercury-arc rectifier is built up by utilizing two, four, or more tanks such as herein described, operating them electrically as if they constituted a single tank, suitable means being provided for securing a proper division of the load, notwithstanding the fact that parallel-operating arcs are in different tanks. One of the requisites of a successful sectionalized design is a much smaller size than has heretofore been possible. I feel that it is the herein-described control of the direction and magnitude of the flow of mercury vapor within the rectifier tank, which has made it possible for me to provide a rating of 750 kilowatts at 600 volts in a volume only one-half as great as has previously been required for a 500 kilowatt rating at 600 volts.

While I prefer to utilize an automatically controlled temperature regulation in the various parts of the vapor-flow path, I believe that desirable results may be obtained without any accurate control of the temperatures, so long as the general principles of the temperature gradients are roughly adhered to.

I contemplate that numerous changes will be made within the scope of my invention, such as the possible elimination of a part of the shielding around the anodes, which would result in a further reduction in internal losses. I have also obtained a material gain in efficiency by utilizing a 2'' depth for the cathode receptacle instead of an 8'' depth.

Along with a reduction in the size of the tank, there is inherently a material reduction in the voltage-drop during operation, and this reduction is increased by my vapor-flow means for preventing back-fires, thus making it possible to dispense with many of the shields and other obstructions which have been heretofore needed for the purpose of preventing back-fires and which consume several volts of arc drop. For example, previous Westinghouse designs of 500 kilowatt rectifiers, as well as present competitive designs of the same capacity, have a full-load arc-drop of approximately 21 volts. The design shown in Fig. 1, which is now in service, has a full-load arc-drop of 20 volts, at a 50% increase in rating over the previous and competitive designs of twice the size. An experimental modification, making full use of the principle discussed hereinabove, has been made and tested and found, so far as the restricted tests indicate, to be satisfactory, having a full-load arc-drop of approximately 16 volts. I believe that a reduction in the anode shielding and an increase in the central blast over that shown in Fig. 1 will reduce the full-load losses to possibly 13 volts.

In connection with the disposition of foreign gases, it is necessary to pay particular attention to details in the pre-treatment or processing of the rectifier parts both before and after assembly. My own experience, as well as that of others, has clearly shown that the quality of a rectifier may be determined by the degree of freedom from foreign gases. In building my rectifiers, I go to rather extreme lengths to decrease the amount of foreign gas. One of the most important items in this regard is the practice of high-temperature pre-treatment of the graphite anode-head under vacuum. All other materials which might emit foreign gases are pre-treated before assembly wherever this can reasonably be done.

A practice which I believe is novel in metal-tank rectifiers is to determine the completion of the treating-out process by a measurement of pressure-rise within the rectifier at a maximum contemplated load current for a given period of time, with the pumps not in operation. The previous practice of treating until a given degree of vacuum could be maintained by the pumps did not give complete information as to the condition of the rectifier from the standpoint of freedom from occluded gases. I have found that, even though a high degree of vacuum may be maintained by the operation of the pumps, the presence of foreign gas, flowing through the rectifier from the hot surfaces to the pumping connection, is definitely and seriously detrimental.

The subject-matter of the present application is more or less completely shown and discussed in my paper presented before the American Institute of Electrical Engineers on January 28, 1932.

I claim as my invention:

1. A multi-anode, metal-tank, mercury-arc rectifier characterized by a central tubular baffle over the cathode in spaced relation thereto, an annular baffle mounted around the bottom end of said central tubular baffle, also spaced from the cathode, a plurality of anodes spaced in a circle close to the upper portion of said central tubular baffle and for the most part over said annular baffle, and a second tubular baffle surrounding said circle of anodes.

2. A multi-anode, metal-tank, mercury-arc rectifier characterized by a central tubular baffle over the cathode in spaced relation thereto, an annular baffle mounted around the bottom end of said central tubular baffle, also spaced from the cathode, a plurality of anodes spaced in a circle close to the upper portion of said central tubular baffle and for the most part over said annular baffle, and a liquid-cooled jacket for said central tubular baffle.

3. A multi-anode, metal-tank, mercury-arc rectifier characterized by a central tubular baffle over the cathode in spaced relation thereto, an annular baffle mounted around the bottom end of said central tubular baffle, also spaced from the cathode, a plurality of anodes spaced in a circle close to the upper portion of said central tubular baffle and for the most part over said annular baffle, a tubular liquid-cooled jacket for said central tubular baffle, an annular liquid cooled jacket for the top of said tank, and a tubular liquid-cooled jacket for the side walls of said tank.

4. A multi-anode, metal-tank, mercury-arc rectifier characterized by a central tubular baffle over the cathode in spaced relation thereto, an annular baffle mounted around the bottom end of said central tubular baffle, also spaced from the cathode, a plurality of anodes spaced in a circle close to the upper portion of said central tubular baffle and for the most part over said annular baffle, a second tubular baffle surrounding said circle of anodes, a tubular liquid-cooled jacket for said central tubular baffle, a tubular liquid-cooled jacket for said second tubular baffle, an annular liquid-cooled jacket for the top of said tank, and a tubular liquid-cooled jacket for the side walls of said tank.

5. A multi-anode, metal-tank, mercury-arc rectifier characterized by a central tubular baffle over the cathode in spaced relation thereto, an annular baffle mounted around the bottom end of said central tubular baffle, also spaced from the cathode, a plurality of anodes spaced in a circle close to the upper portion of said central tubular baffle and for the most part over said annular baffle, and an individual shield and grid for each of the anodes.

6. A multi-anode, metal-tank, mercury-arc rectifier comprising a main tank, an insulated, centrally disposed, cathode-receptacle in the bottom thereof, liquid mercury in said cathode-receptacle, a central vertical tubular baffle, an annular baffle mounted around said central tubular baffle in spaced relation to the liquid mercury, a circulating liquid cooling-medium for said annular baffle and at least the top portion of said central tubular baffle, and a plurality of anodes spaced around said central tubular baffle above said annular baffle.

7. A multi-anode, metal-tank, mercury-arc rectifier comprising a main tank, an insulated, centrally disposed, cathode-receptacle in the bottom thereof, liquid mercury in said cathode-receptacle, a plurality of anodes spaced in a circle in said main tank, means, including a circulating-liquid cooling-means disposed in the central space of the main tank, for largely deionizing, as well as reducing the vapor-pressure of, a mercury-vapor flow from the liquid mercury centrally upward and out past the regions of the anodes, and an annular baffle surrounding the central mercury-vapor flow path and disposed between the regions of the anodes and the bottom of the tank for providing a relatively ionized main arc-path under said annular baffle between said regions of said anodes and said centrally disposed liquid mercury.

8. A multi-anode, metal-tank, mercury-arc rectifier characterized by a central tubular baffle over the cathode in spaced relation thereto, an annular baffle mounted around the bottom end of said central tubular baffle, also spaced from the cathode, a plurality of anodes spaced in a circle close to the upper portion of said central tubular baffle and for the most part over said annular baffle, a liquid-cooled jacket for said central tubular baffle and for said annular baffle, and an auxiliary tubular baffle depending from said central liquid-cooled baffle.

9. A multi-anode, metal-tank, mercury-arc rectifier characterized by an insulated cathode receptacle, a mercury cathode therein, a central tubular baffle over the cathode in spaced relation thereto, an annular baffle mounted around the bottom end of said central tubular baffle, also spaced from the cathode, a plurality of anodes spaced in a circle close to the upper portion of said central tubular baffle and for the most part over said annular baffle, a second tubular baffle surrounding said circle of anodes, liquid-cooled jackets for the cathode receptacle, for all of said baffles and for the side walls of the tank, and an auxiliary tubular baffle depending from said central liquid-cooled baffle.

10. A multi-anode, metal-tank, mercury-arc rectifier having a liquid mercury cathode pool, a plurality of anodes, there being a main arc-path between the cathode and the several anodes, means for producing a blast of relatively un-ionized, low-pressure mercury vapor blowing over the regions of said anodes and the arc-back spaces therebetween, from said cathode pool, said blast-producing means comprising a cooler for the outer tank walls, a cooler for the annular space surrounding said anodes, and a cooler for the central space over said cathode pool and within the space occupied by said anodes, said first-annular space occupied by said anodes, said first-mentioned cooler being the coolest and said last-mentioned cooler being the warmest, and an auxiliary tubular baffle depending from said central liquid-cooled baffle.

11. A multi-anode, metal-tank, mercury-arc rectifier characterized by a central tubular baffle over the cathode in spaced relation thereto, an annular baffle mounted around the bottom end of said central tubular baffle, also spaced from

the cathode, a plurality of anodes spaced in a circle close to the upper portion of said central tubular baffle and for the most part over said annular baffle, a liquid-cooled jacket for said central tubular baffle, means for substantially segregating the surface of the central portion of the mercury cathode from the annular outer portion thereof, and a heater for said segregated central portion.

12. A multi-anode, metal-tank, mercury-arc rectifier comprising a main tank, an insulated, centrally disposed, cathode-receptacle in the bottom thereof, liquid mercury in said cathode-receptacle, a central vertical tubular baffle, an annular baffle mounted around said central tubular baffle in spaced relation to the liquid mercury, a circulating liquid cooling-medium for said annular baffle and at least the top portion of said central tubular baffle, a plurality of anodes spaced around said central tubular baffle above said annular baffle, means for substantially segregating the surface of the central portion of the mercury cathode from the annular outer portion thereof, and a heater for said segregating central portion.

13. A multi-anode, metal-tank, mercury-arc rectifier comprising a main tank, an insulated, centrally disposed, cathode-receptacle in the bottom thereof, liquid mercury in said cathode-receptacle, a plurality of anodes spaced in a circle in said main tank, means, including a circulating-liquid cooling-means disposed in the central space of the main tank, for largely deionizing, as well as reducing the vapor-pressure of, a mercury-vapor flow from the central portion of liquid mercury centrally upward and out past the regions of the anodes, an annular baffle surrounding the central mercury-vapor flow path and disposed between the regions of the anodes and the bottom of the tank for providing a relatively ionized main arc-path under said annular baffle between said regions of said anodes and said central portion of the liquid mercury cathode, means for substantially segregating the surface of the central portion of the mercury cathode from the annular outer portion thereof, and a heater for said segregated central portion.

14. A multi-anode, metal-tank, mercury-arc rectifier having a liquid mercury cathode pool, a plurality of anodes, there being a main arc-path between the cathode and the several anodes, and means for producing a blast of relatively un-ionized, low-pressure mercury vapor blowing over the regions of said anodes and the arc-back spaces therebetween, from said cathode, said blast-producing means comprising a cooler for the outer tank walls, a cooler for the annular space surrounding said anodes, and a cooler for the central space over said cathode pool and within the annular space occupied by said anodes, means for substantially segregating the surface of the central portion of the mercury cathode from the annular outer portion thereof, and a heater for said segregated central portion.

15. A multi-anode, metal-tank, mercury-arc rectifier having a liquid mercury cathode pool, a plurality of anodes, there being a main arc-path between the cathode and the several anodes, and means for producing a blast of relatively un-ionized, low-pressure mercury vapor blowing over the regions of said anodes and the arc-back spaces therebetween, said blast-producing means comprising a centrally disposed source of mercury vapor segregated from the active annular cathode surface of the mercury pool, and a succession of coolers in the path of the blast from said mercury-vapor source, past the region of the anodes, and on beyond to the outer walls of the tank, terminating in a cooler at said outer walls, a cooler which is disposed in the path between said mercury-vapor source and the region of the anodes being at a temperature intermediate between the temperature of the outer-wall cooler and the higher temperature of the mercury-vapor source.

16. A multi-anode, metal-tank, mercury-arc rectifier characterized by a central, cylindrically disposed cooler, a ring of anodes surrounding the same, an intermediate, cylindrically disposed cooler surrounding the ring of anodes, a cathode cooler, a tank cooler for the side walls of the tank, a main circulating system for supplying a liquid heat-interchange medium in series through the tank cooler, cathode cooler, intermediate cooler and central cooler, in said order, starting with the tank cooler, a liquid-flow regulator for said main circulating system, and an auxiliary circulating system comprising a heater and means for circulating the liquid heat-interchange medium in series through said heater, the cathode cooler, the intermediate cooler and the central cooler, in said order, starting with the heater.

17. A multi-anode, metal-tank, mercury-arc rectifier characterized by a central, cylindrically disposed cooler, a ring of anodes surrounding the same, an intermediate cylindrically disposed cooler surrounding the ring of anodes, a cathode cooler, a tank cooler for the side walls of the tank, a main circulating system for supplying a liquid heat-interchange medium in series through the tank cooler, cathode cooler and central cooler, in said order, starting with the tank cooler, a liquid-flow regulator for said main circulating system, an auxiliary circulating system comprising a heater and means for circulating the liquid heat-interchange medium in series through said heater, the cathode cooler and the central cooler, in said order, starting with the heater, and automatic thermally responsive regulator-means responsive to successively decreasing temperatures for shutting off the liquid-flow regulator and subsequently turning on said heater and auxiliary circulating system, and vice versa for increasing temperatures.

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