

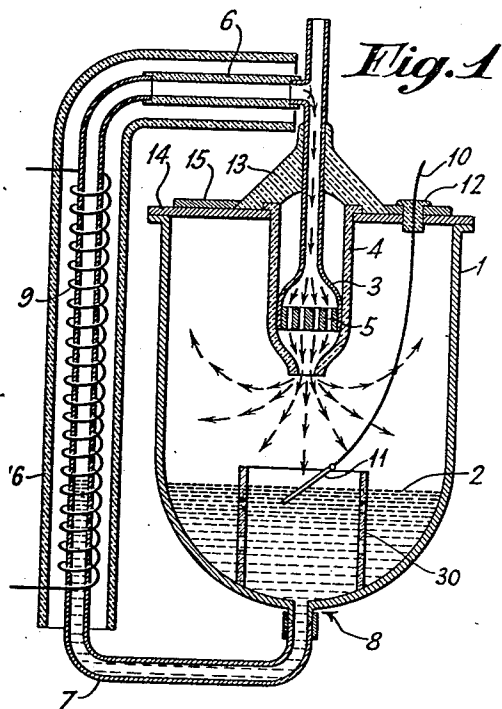
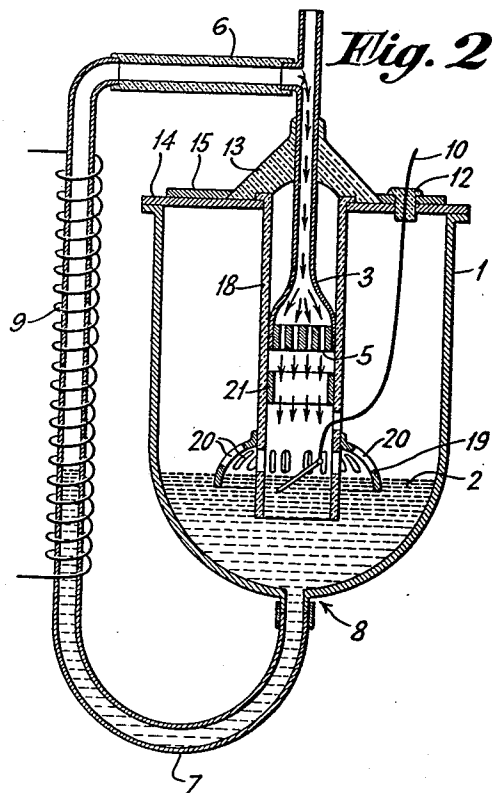
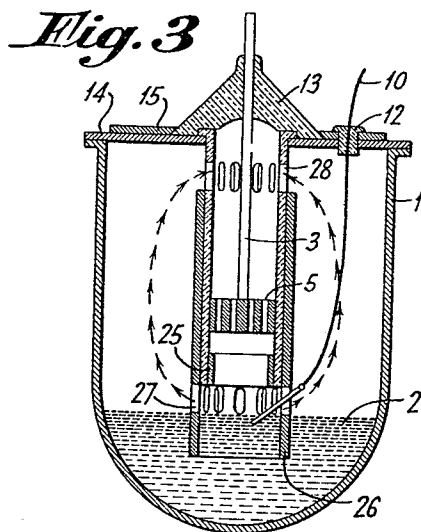
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2,179,929

MERCURY ARC RECTIFIER

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MERCURY ARC RECTIFIER

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9 Claims. (Cl. 250—27.5)

This invention relates to novel improvements in vapor discharge devices such as mercury arc rectifiers and similar devices for converting alternating electrical current into direct current or for converting direct current into alternating current. It may also be applied to vapor discharge devices used to control the flow of alternating and direct current.

An object of this invention is to improve upon the present form of mercury arc converters in a manner to reduce the probability of backfires, or passage of electrical current in the wrong direction.

Another object is to increase the current and voltage limits of converters of given dimensions or to make possible a reduction in dimensions of converters of given current and voltage rating.

A further object is to forcibly supply mercury vapor in the path of the arc discharge in a rectifier, or other arc discharge device, in a manner to stabilize the arc and increase the current carrying capacity of the arc, by eliminating the possibility of excessively low vapor density near the anode produced by electrical pumping of the kind described in my U. S. Pat. #2,022,465, issued Nov. 26, 1935.

Still a further object is to forcibly deionize the arc path near the anode, by means of a blast of rapidly moving vapor which prevents formation of an arc discharge in the wrong direction.

Another object is to heat the anode, control grid, shields, etc., with superheated vapor which will prevent condensation of mercury on these parts but at the same time provide cooling of the parts when, in operation, their temperatures tend to rise above the temperature of the vapor.

Other objects and advantages will become apparent as the description of the invention proceeds.

The conventional arc discharge converters, such as mercury arc rectifiers, are subject to flashback or backfires, or passage of current in unwanted directions, primarily due to ionization in the rectifier during the time that the anode voltage is applied in the reverse direction. When, in the course of its operation, a positive potential drives a current through the rectifier, in the forward or normal direction, the active space is filled with partially ionized vapor. If the potential is reversed instantly the positively ionized mercury molecules will be pulled toward the anode. If the reversed potential is great enough, the mercury ions will strike the anode with sufficient velocity to cause electron emission. The electrons emitted from

the anode due to ion bombardment will be drawn toward the cathode and on the way may produce additional ionization by collision with neutral molecules. In addition, the ions left in the rectifier upon reversal of the potential will collide with neutral molecules enroute to the anode and so increase the ionization. If the increase in ionization due to bombardment of anode and neutral molecules becomes greater than the rate of natural deionization in the tube, we at once have an unstable condition which will result in the vapor becoming highly ionized and fully conducting in the reverse direction. This is the condition of flashback which limits the maximum voltage on all mercury or gaseous rectifiers and causes so much trouble in the rectifiers of radio transmitters.

If the vapor can be allowed to become fully deionized before the reverse voltage is applied, it will withstand very much greater reverse voltage before flashing back. According to this invention, I hasten deionization when the potential across the rectifier is reversing and causing the current to pass through a zero value, thereby permitting operation of the rectifier at higher current and voltage. In addition, my invention provides means for deionizing the vapor space near an anode, and preventing or reducing reverse currents which may grow into backfires, even when the anode is one of several in a single chamber containing continuous ionization. This condition is met with in polyphase rectifiers having one cathode for two or more anodes.

In my United States Patent 2,163,785, issued June 27, 1939, and my U. S. Pat. #2,022,465, issued Nov. 26, 1935, I have called attention to and made use of the pumping action which accompanies a vapor or gaseous electrical discharge. I believe this pumping action is responsible for much of the effectiveness of anode shields in reducing flashbacks in some forms of commercial mercury vapor rectifiers. The pumping action is also partly responsible for improved operation in old style mercury rectifiers having the anodes at the ends of long bent glass arms or tubes.

The lower gas pressures near the anode brought about by the pumping action results in greater mobility for the ions in the space and so brings about quicker collision between an ion and a wall or other part of the rectifier which can give the ion an electron and make it neutral, or hold the ion from further movement. Also, the probability of an ion or electron colliding with a neutral molecule and increasing

the total ionization, in traveling a given distance, is decreased.

The difficulty with using the pumping action alone is that the chamber surrounding the anode is insufficiently evacuated for low currents and too highly evacuated for high currents. In other words, under steady state conditions, there is only one optimum value of current for best compromise between voltage drop in the arc and flashback voltage. Also, the vapor pressure around the anode will vary with the length of time during which the current flows. Further, with high currents, the pumping is likely to be accompanied by sudden large fluctuations in arc drop, due to surging of the vapor, resulting in excessive and oscillatory potentials which may cause failures and arcover both in the rectifier and in associated equipment.

By my invention a means is provided for forcefully sweeping ions out of the space around the anode, or between anode and cathode, without changing the vapor or gas pressure in the process, and in a manner which tends to suppress surging of the vapor and excessive potentials. This will result in a better converter. The arc drop may always be small and still flashbacks may be avoided.

This invention will best be understood by referring to the accompanying drawing, in which:

Fig. 1 shows a sectional view of a mercury arc rectifier of the ignition liquid cathode type with external means for producing and circulating mercury vapor;

Fig. 2 shows a sectional view of a modification of a rectifier having external means for circulating the mercury vapor; and

Fig. 3 shows a sectional view of a mercury arc rectifier in which electrical pumping alone is relied upon to provide internal circulation of the mercury.

Referring now to Fig. 1 of the drawing, a mercury pool ignition type rectifier is shown in which a metallic casing 1 contains a pool of mercury 2 which serves as a cathode. An anode 3 is partially enclosed in a shield 4, the anode being in the form of a hollow electrically conducting tube flared out at the end and equipped with a plurality of openings 5 on the side toward the open end of the shield 4. From these openings, streams of mercury vapor issue forth which set up a rapidly moving vapor stream from the anode through the end of the shield toward the mercury cathode 2, as indicated by the arrows. This vapor stream tends to sweep out the space between the anode and the end of the shield, thus increasing the speed of deionization near the anode. The decreased deionization time reduces the probability of flashbacks. The effect is very similar to that obtained when a stream of air is blown through the contacts of relays handling alternating current of substantially high voltages. In order to produce a circulating stream of mercury vapor from anode 2, I provide a pipe connection 6, preferably of insulating material, to the hollow anode stem around the outside of casing or tank 1, and connect the same with a metallic pipe 7 which connects with tank again at point 8 below the mercury surface. It will be noted that the pipe 7 is partly filled with liquid mercury and partly with vapor. Pipe 7 is heated by an insulated resistance wire 9 through which electrical current is passed from any suitable source, so as to maintain a higher temperature of mercury and vapor in the pipe than in the main tank. As a result a higher vapor pressure

exists in the pipe than in the tank. The difference in the vapor pressure produces the stream of mercury vapor from the anode. This principle of producing a mercury vapor stream is similar to that used in the well known Langmuir mercury vapor pump disclosed in U. S. Pat. #1,393,550, issued Oct. 11, 1921.

In order to prevent condensation of vapor in the pipe and anode the heater is arranged to superheat the vapor. The pipe and anode will therefore be held at a temperature higher than that corresponding to the vapor pressure existing at any point in the pipe and anode. It may be noted that, when losses at the anode from passage of electrical current through the rectifier raise the anode temperature, the anode will transfer heat to the mercury vapor passing through it. In other words, the anode is vapor cooled and will be capable of withstanding rather heavy power dissipation without water cooling. In addition, increasing anode temperatures, by increasing the temperature of the vapor, expand the volume of vapor and increase the vapor velocity. Thus, there is a tendency for increasing rectifier loads to make an automatic improvement in vapor velocity and speed of deionization.

The movement of mercury ions, and of molecules which they carry with them, from the vicinity of the anode toward the cathode, constitutes an additional pumping action the force of which varies with the load on the rectifier. If the electrical pumping and the transfer of heat from the anode to the vapor is made to have an effect in correct proportion to the pumping by evaporation in the pipe, the vapor stream velocity may be made to vary in about the correct proportion to compensate for fluctuations in load.

A still further improvement in automatic control of vapor velocity may be made by causing the load current to vary the energy input to heater 9 or to vary the energy dissipated in another heater operated in cooperation with heater 9.

A rectifier similar to Fig. 1 has an advantage that the arc may take place through the stream of vapor which may have a considerably higher temperature and pressure than that existing in the main body of the tank. Therefore, the arc drop may be kept small even when the tank temperature is low. The rectifier shown in Fig. 1 also comprises an igniter lead 10 having a tip 11 of resistance material, preferably a carborundum composition, such as "Thyrity", which is a mixture of silicon carbide and carbon with clay as a binder, made as specified in a U. S. Pat. 1,822,742, issued Sept. 8, 1931, to K. B. McEachron, which contacts the mercury, an insulating bushing 12 and a bushing 13 which is retained on cover 14 by a clamping ring and seal 15. In order, that the heat may be retained around pipes 6 and 7, a sleeve such as 16 may be provided which is made of any suitable heat insulating material, such as asbestos, glass wool, etc.

Although I have shown only one anode in Fig. 1, it will be understood that any number of anodes may be used and provided with superheated mercury vapor from either individual sources or a common source through insulating tubes.

The modification shown in Fig. 2 also has an external mercury circulating system, the active portion of the rectifier being confined to the inside of an insulating tube 18, where the effect of the forced vapor stream is present throughout the whole active space. It is intended that the

vapor stream in the active part of the rectifier have a density corresponding very approximately to about 0.1 millimeter pressure at 80 degrees C. (The actual temperature and pressure are considered to be of little importance in comparison to the density. The number of gas molecules per cubic centimeter is believed to be the important thing.) It is intended that the main body of the rectifier tank be maintained at a temperature of perhaps not more than 60 degrees C. Since considerable expansion of the mercury vapor may be allowed to take place as the vapor passes through the anode, the mercury to produce the stream may be evaporated at a considerably higher temperature and corresponding pressure than 80 degrees. This is desirable to make variations in temperature of the main tank have less effect upon the vapor flow through the anode.

In practice, the correct amount of power to obtain optimum energy dissipation in heater 9 will be determined by trial under service conditions in each case.

In the construction shown in Fig. 2, a deionizing metal shield 19 is connected to the mercury pool. This shield will allow the mercury vapor to escape through a large number of holes or slits 20 with length great enough compared to the width of opening to assure substantially complete deionization of the gas before it reaches the main chamber. Such an arrangement permits several polyphase anodes to be operated in the one tank without danger of the path to one anode being ignited by ionization from another anode. It also permits operation of the device with higher vapor pressure and density in the arc path than exists in the main body of the tank.

Also, in Fig. 2, I have shown a baffle 21 between the anode and mercury pool. This baffle, which may be either insulating material or metal, preferably metal, serves to restrict the arc path and increase the electrical pumping effect. When correctly designed, the baffle and the electrical pumping effect counteract the variations in rate of evaporation at the cathode, with variations in load, which might otherwise cause the gas pressure near the anode to fluctuate adversely with the load. The baffle also assists in speeding up deionization of the vapor passing through it and so tends to reduce flashbacks. Preferably, the baffle should be connected to the anode over a high resistance path formed on the inside of the insulating cylinder. This allows the baffle to serve as an anode in initiating the arc but the resistance limits the current flow to the baffle, forcing the main anode to carry nearly all the current after the arc is started. As a result, the baffle will not heat up as the anode does. When the voltage reverses, the relatively cool baffle, serving temporarily as an anode, is much less liable to allow starting of an arc in the wrong direction because of its low temperature and because of limitation in reverse current flow to it caused by the high resistance connection to the main anode.

By the use of a "Thyritye" rod for an igniter which has one end dipped in the mercury pool and the other end connected to a source of ignition current, the resistance dipping into the mercury pool causes a high current concentration at the mercury surface where it touches the mercury, and the drop in resistivity with increasing current density will tend to increase the current concentration at the junction of the mercury surface which is a desirable feature.

I have also found that it is not essential for

the ignition rod to dip into the mercury pool. I have used ignition points, ending near the surface of the mercury, to form spark gaps across which momentary high voltages were applied to cause a spark in a manner very similar to the spark plug in a gasoline engine. The sparks initiated the main arc without difficulty.

Fig. 3 shows another form of rectifier, in which electrical pumping alone is relied upon to provide a circulation of mercury vapor from anode to cathode. In this arrangement, the pumping action increases with increasing current so that the normal tendency for flashbacks to increase with increasing load is counteracted by an increased vapor circulation and blow-out effect. To obtain proper action in this case, the area of the path between anode and cathode must be restricted to decrease diffusion back against the electrical pumping action. A baffle 25 is provided between the anode and cathode for accomplishing the pumping action. The cross-sectional area of openings through the baffle, for carrying the arc should be of the order of magnitude of 0.25 square centimeter per ampere of maximum direct current allowed to flow between the anode and cathode. I have also indicated a shield and baffle 26 extending from below the surface of the mercury up to a point outside the anode insulator near the top of the tank. This shield and baffle and the anode insulator will be provided with many holes or slits 27 and 28, each slit of narrow cross-section, for allowing passage of the vapor into the anode insulator through holes or slits 28 and out into the main chamber through holes or slits 27 and for deionizing this gas as it passes through. This serves to prevent ignition from the top of the anode stem, through the vapor and the main tank to the mercury pool. Thus, the arc and all ionized gas is confined to a small enclosed volume between anode and cathode. This allows other anodes of different phase to operate in the same tank, without increased probability of backfires and decreases the deionization time.

One very interesting feature of rectifiers or converters with mercury vapor circulation, such as that shown in Figs. 1 and 2 is that the arc takes place in pure mercury vapor regardless of leakage into the tank. The constant distillation of the mercury forces all foreign gases out of the active portion of the rectifier and this alone is an important factor in preventing backfires and preventing deterioration of the anode and baffles. Likewise, there is a tendency for the blast to remove all molecules of anode material released by sputtering and removal of all material particles which might start a cathode spot on the anode.

Although I have shown only one anode in each of the rectifiers shown in Figs. 1, 2 and 3, the invention is, of course, not limited to single anode rectifiers. I may use any number of anodes in a single evacuated chamber. For single phase full wave rectification, I may use two anodes; for three phase full wave rectification, I may use six anodes and so on.

It will likewise be understood that my vapor blast suppression of backfires is applicable to multianode rectifiers having a single cathode serving for all anodes. It is not essential that the rectifiers have ignition type arc starters but any other known means of starting arcs may be used including the use of hot cathodes. In other words, my invention includes the application of vapor blast suppression of backfires in any known type of vapor or gaseous rectifier or power converter or

inverter. The rectifiers, converters or inverters may, of course, be equipped with control electrodes by means of which the discharge current may be controlled for purposes of converting alternating current to direct current, direct current to alternating current, or for control of power as in high current, short time electric welding, etc.

Obviously, also all auxiliary devices, such as vacuum pumps, vacuum gages, water cooling systems, relay protective systems, etc., associated with previously known arc converters and control devices may be a part of the devices employing my invention. In other words, my invention is an improvement upon vapor discharge devices of any kind in the art represented by the publications and patent applications which have been cited.

The heater wire 9 of Fig. 1 may be dispensed with by passing relatively large electrical currents through a portion of the pipe 7 so that the pipe, itself, becomes the electrical resistance of the heater. Furthermore, the heating current may be obtained partly from a transformer whose primary winding is in series with the input circuit of a rectifier or the output circuit of an inverter in order that the heating may readily be made to vary with the load on the device.

Although in the figures I have shown the pool of mercury resting in the bottom of the main tank, or metallic casing, in practice I prefer to insulate the pool from the main tank as an aid to prevention of arcs to the tank and for confining the arc to the pool. In Fig. 1, I have also indicated an arc confining insulator 30 for the purpose of confining the cathode spot on the mercury surface to the area enclosed by the confining insulator. Otherwise, the cathode spot, or negative terminal of the arc may wander to the main metallic casing or to other parts inside the casing where it may cause damage or be cooled sufficiently to extinguish the arc.

To obtain an indication of the vapor pressures required and the vapor velocities which may be expected in the path of the vapor blast in the confined portion of the space between anode and cathode in rectifiers and direct current to alternating current converters utilizing my invention, assume, for example, that the confined space between anode and cathode, through which the arc passes, has a diameter of ten centimeters, giving a cross-sectional area of 78.6 square centimeters and a length of twenty centimeters. At a pressure of one bar and a temperature of 20° C., air will flow through the tube at the rate of about 370,000 cubic centimeters per second. Under about the same conditions of temperature and pressure, the rate of flow of mercury vapor would be approximately

$$\text{Flow} = 370,000 \sqrt{\frac{28.9}{200.61}} = 140,000 \text{ cubic centimeters}$$

per second

giving an input velocity to the space of

$$V = \frac{140,000}{78.6} = 1,780 \text{ centimeters per second}$$

and an output velocity as much higher as the change in volume of the vapor due to difference in pressure.

From this, it will be seen that a difference of vapor pressure of one bar between ends of the tube will cause mercury vapor to sweep out ions from the entire space within about 0.0005 second or less. In practice, the velocity at the center of the tube will be higher than the average and

the walls of the tube will deionize the outer part of the arc path. This, combined with increasing velocity due to expansion of the vapor, will in practice probably give a time for complete deionization more on the order of 0.001 second. Higher deionization speeds may be obtained with higher vapor pressure differences.

It is evident that, when vapor velocities exceed the rate of motion of ions in the arc, it becomes impossible either to initiate or maintain an arc requiring motion of the ions against the vapor blast.

What is claimed is:

1. A mercury vapor rectifier comprising a container, a mercury pool cathode at the bottom of said container, an apertured anode within said container, an insulating shield supported by said container and surrounding said anode, said shield extending beyond said anode and having a constricted portion between said anode and cathode whereby the arc discharge path therebetween is restricted and means for establishing fluid communication from said cathode through the apertures in said anode.

2. A mercury vapor rectifier comprising a container, a mercury pool cathode at the bottom of said container, an apertured anode within said container, an insulating tubular shield supported by said container and surrounding said anode, said shield extending beyond said anode and having a constricted portion between said anode and cathode whereby the arc discharge path therebetween is restricted, and means for establishing fluid communication from said cathode through the apertures in said anode.

3. A mercury vapor rectifier comprising a container, a mercury pool cathode at the bottom of said container, an apertured anode within said container, an insulating tubular shield supported by said container and surrounding said anode, said shield extending beyond said anode and having a constricted portion between said anode and cathode whereby the arc discharge path therebetween is restricted, and means independent of the discharge space between said anode and cathode for establishing fluid communication from said cathode through the apertures in said anode.

4. A mercury vapor rectifier comprising a container, a mercury pool cathode at the bottom of said container, an apertured anode within said container, an insulating tubular shield supported by said container and surrounding said anode, said shield extending beyond said anode and having a constricted portion between said anode and cathode whereby the arc discharge path therebetween is restricted and means independent of the discharge space between said anode and cathode for establishing fluid communication from said cathode through the apertures in said anode, said means comprising a pipe extending from the bottom of said anode.

5. A mercury vapor rectifier comprising a container, a mercury pool cathode at the bottom of said container, an apertured anode within said container, an insulated shield supported by said container and surrounding said anode, said shield extending beyond said anode and having a constricted portion between said anode and cathode whereby the arc discharge path therebetween is restricted and means for establishing fluid communication from said cathode through the apertures in said anode, said means comprising a pipe extending from the bottom of said container to the top of said anode and means for heating said pipe outside of said container.

6. A mercury vapor rectifier comprising a container, a mercury pool cathode at the bottom of said container, an apertured anode within said container, an insulating shield supported by said container and surrounding said anode, said shield extending beyond said anode and having a constricted portion between said anode and cathode whereby the arc discharge path therebetween is restricted and means for establishing fluid communication from said cathode through the apertures in said anode, said means comprising a pipe extending from the bottom of said container to the top of said anode and an electrical heating coil surrounding said pipe for heating said pipe outside of said container.

7. A mercury vapor rectifier comprising a container, a mercury pool cathode at the bottom of said container, an apertured anode within said container, a tubular insulating shield inside said container and surrounding said anode, and means outside the direct discharge path between said anode and said cathode for supplying mercury vapor under pressure to the rear of said anode and inside said shield, said tubular shield extending beyond said anode toward said cathode and having in its wall between said anode and said cathode a constricted outlet through which mercury vapor inside said shield may escape into said container above the surface of said cathode and out of said direct discharge path.

8. A mercury vapor rectifier comprising a con-

tainer, a mercury pool cathode at the bottom of said container, an apertured anode within said container, means for producing from the mercury of said cathode a stream of mercury vapor passing through said anode and directed away from the active side of said anode facing said cathode, and a tubular insulating shield surrounding said anode and extending away from the active side of said anode toward said cathode, said shield being smaller in diameter than said cathode and having in its wall between said anode and said cathode a constricted outlet for producing between said anode and said cathode a flow of mercury vapor out of the discharge path.

9. A mercury vapor rectifier comprising a container, a mercury pool cathode at the bottom of said container, an apertured anode within said container, means for producing from the mercury of said cathode a stream of mercury vapor passing through said anode and directed away from the active side of said anode facing said cathode, and a tubular insulating shield surrounding said anode and extending away from the active side of said anode toward said cathode to make the arc discharge over a portion of its path near the anode smaller than said container, said shield having between said portion of the arc discharge path and said cathode an outlet to produce a flow of mercury vapor out of said shield and out of the remaining portion of the arc discharge path.

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