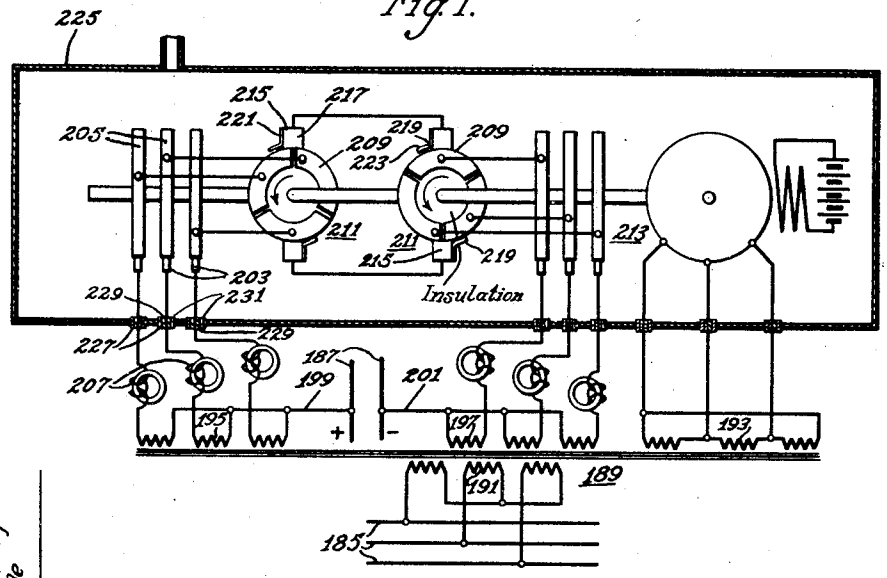
Nov. 20, 1945. J. SLEPIAN 2,389,391

ENERGY CONVERTING APPARATUS

Original Filed Sept. 20, 1939

Fig. 1.



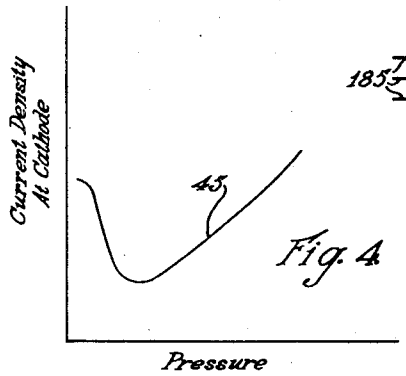


Fig. 4

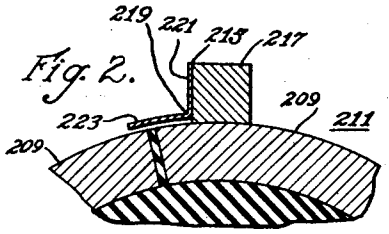
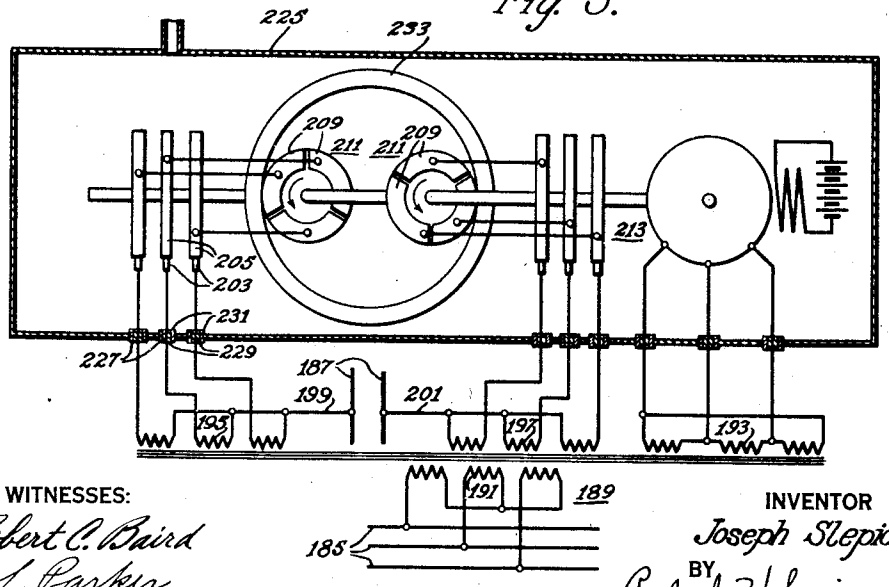


Fig. 2.

Fig. 3.



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UNITED STATES PATENT OFFICE

2,389,391

ENERGY CONVERTING APPARATUS

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Original application September 20, 1939, Serial No. 295,727. Divided and this application December 3, 1942, Serial No. 467,761

2 Claims. (Cl. 175—364)

The invention relates to apparatus involving arc discharges and has particular relation to dynamo-electric machines embodying commutating devices where circuit interruptions take place.

This application is a division of my copending application entitled Circuit interrupters, Serial No. 295,727, filed September 20, 1939, which has matured into Patent No. 2,326,074, patented August 3, 1943, assigned to the Westinghouse Electric & Manufacturing Company.

In circuit interrupters and commutating devices of dynamo-electric machines constructed in accordance with the teachings of the prior art, difficulty is encountered because the contacts are excessively heated. For a semi-infinite solid (which is a solid extending indefinitely in one direction) having specific heat c, thermal-conductivity k, density δ, the rise in temperature T of the surface is given by

$$T=\frac{W}{4.19\sqrt{kc\delta}}\sqrt{t}$$

where W is the power input in watts per square centimeter at the surface and t is the time in seconds. The current density at the cathode for an arc flowing between the customary metal electrodes in air at atmospheric pressures is of the order of 10,000 amperes per square centimeter. Since the cathode drop is of the order of 20 volts, the density of the power developed at the cathode is of the order of 2×10^5 watts per square centimeter. If the electrode in question is assumed to be copper

$$k=1,\ c=1/10,\ \delta=8$$

In such a case,

$$T=3\times10^4\sqrt{t}$$

If the arc burns for ½ period of an ordinary 60 cycle source, $t=1/120$ and $T=2800°$ C. Thus, the surface of a copper electrode functioning as the cathode for an arc in air is raised to a temperature substantially above the boiling point of the copper, even if the arc burns for only ½ period of a 60 cycle source.

In accordance with the prior art, it has been the usual practice to try to reduce the damage caused by arcing at the commutator contacts by designing the machine to produce as nearly sparkless commutation as possible. Machines so designed are relatively complex and expensive to construct and maintain and their efficiency is not as high as is desired.

An object of the invention is the provision of an improved dynamo-electric machine or energy converter in which an excessive rise in temperature shall not occur when the commutator contacts disengage the brush or collector.

Another object of the invention is the provision of a dynamo-electric machine or converter having an improved commutator device in which arcing at the commutator contacts does not result in excessive heat.

Another object of the invention is the provision of an improved energy converting arrangement of the rotary type that shall be capable of satisfactory operation at a substantially higher rating than has heretofore been considered possible for equipment of the same size.

Another object of the invention is the provision of simple and inexpensive arc interrupting means for use in an energy converting system.

My invention arises from the discovery that the heat concentration developed at the cathode of an arc is relatively small when the arc is operated in a gaseous atmosphere at a pressure of the order of several centimeters of mercury. Specifically, I have found that the pressure in which the arc is burning should be of the order of 1 cm. for the most proportious results. However, a material improvement over arcs operating at atmospheric pressure or in high vacua is manifested by an arc operating at a pressure as high as 10 cm., on one hand, and as low as .1 cm. on the other hand. When the pressure is lower than .1 cm. difficulties arise because the arc becomes concentrated over small areas of the electrodes.

In accordance with my invention, I provide a circuit interrupter in which the contacts are disposed in a gaseous medium at a pressure of the order of several centimeters of mercury. The contacts are disposed in a vacuum tight container in which the pressure is of the desired magnitude.

I have found moreover that the energy developed at the contacts may be materially decreased by properly selecting the attenuated gas in which the contacts operate. The current density I of a cold cathode arc I believe is given by

$$I=K\frac{P\sqrt{E_i}}{M}$$

where K is a constant, P is the pressure of the gas, E_i is its ionizing potential, and M is its molecular weight. If gases having a low value of

$$\frac{E_i}{M}$$

are selected the current density is materially re-

duced. Noble gases such as helium, argon, xenon, krypton, and nitron have substantially lower values for

$$\frac{E_i}{M}$$

than ordinary gases. Thus, for xenon the value is .1, while it is .74 for nitrogen and .39 for oxygen. In accordance with my invention therefore the gas within the vacuum tight container is preferably a noble gas such as xenon.

In accordance with my invention, the commutators of an energy converting arrangement are operated in a medium at a pressure of the order of several centimeters of mercury and arcs are produced between the brushes and the commutator segments when the segments are disengaged from the brushes. Since the energy density at the electrodes generated by the arcs is relatively small, the commutators are not deleteriously affected by the arcs and the rating is materially higher than that for equivalent apparatus designed to operate in air. To further improve the energy, conversion arrangement readily saturable chokes may be connected in series with the commutator segments. The chokes of the type preferably used in the practice of my invention saturate at a current of the order of several amperes. Accordingly, during commutation when the current is relatively low, the chokes offer a high impedance to the current flow and decrease the energy developed in the regions in which segments and brushes are separating. When the current is equal to the normal load current, the chokes are saturated and offer substantially no impedance to the current flow.

The novel features that I consider characteristic of my invention are set forth with particularity in the appended claims. The invention itself, however, both as to its organization and its method of operation, together with additional objects and advantages thereof, will best be understood from the following description of specific embodiments when read in connection with the accompanying drawing, in which:

Figure 1 is a diagrammatic view showing a dynamo-electric machine or energy converting arrangement in accordance with the invention;

Fig. 2 is an enlarged view in section showing a part of the commutator arrangement used in the apparatus shown in Fig. 1;

Fig. 3 is a diagrammatic view showing another energy converting arrangement in accordance with the invention; and

Fig. 4 is a graph illustrating the basis of my invention.

Referring first to Figure 4, the relationship between the pressure and the current density at the cathode of an arc is shown graphically. Pressure is plotted horizontally, and current density vertically. As can be seen from the curve **45**, the current density is relatively high for pressures of the order of one atmosphere or more. As the pressure is decreased, the current density decreases until it approaches a minimum in the region of pressures of the order of one centimeter of mercury. As the pressure is now further decreased, the current density increases, and for low pressures approaches the values that it has at one atmosphere. In accordance with my invention, the pressure is maintained at approximately one centimeter of mercury and, therefore, the energy consumed at the cathode when an arc is ignited between the contacts is relatively small.

The invention is particularly applicable to short arc structures and hence to commutator devices, since in the case of a short arc the contact surfaces are available to condense the ionized gases which arise as a result of the arc.

Referring to Figs. 1 and 2, a conversion system constructed in accordance with my invention is shown. While my invention is applicable to the transfer of energy between systems operating at any different frequencies, it is specifically shown as applied to the interchange of power between alternating-current line conductors **185** and direct-current line conductors **187**.

The apparatus comprises a three-phase transformer **189** having a star-connected primary **191** and three secondary sections **193**, **195** and **197**, one of which (**193**) is delta-connected to the motor **213**. The neutral conductors **199** and **201** of the star secondaries **195** and **197** are connected to the direct-current line conductor **187**. At the other terminals, each of the phase windings of the secondary sections **195** and **197** are each connected to a brush **203** which engages a conducting slip ring **205** through a readily saturable choke **207**. The choke is so designed that it becomes saturated when the current flow through it is small compared to the load current. In practice, the saturating current for the choke should be of the order of 1 ampere.

The slip rings **205** are each connected to an insulated segment **209** of one or the other of a pair of commutators **211**. The segments **209** are uniformly spaced around the periphery of the commutators **211**, each commutator having three 120° segments. The commutators **211** and the slip rings **205** are rotated together from a synchronous motor **213** which is supplied from the delta secondary section **193**. With each commutator **211** a pair of oppositely disposed brushes **215** is associated. Each brush associated with one commutator is conductively connected to a corresponding brush associated with the other commutator.

The brushes **215** are of composite structure, each comprising a block **217** of conducting material to which an angle **219** of sheet metal is secured. One surface of the block **217** engages the segments **209** as the corresponding commutator **211** is rotated. One side **221** of each angle **219** is secured to a surface of the block **217** which is perpendicular to the engaging surface in a position such that the other side **223** extends substantially parallel to the segment surface in the region of engagement a short distance above the segments preferably about .1 of a centimeter from the surface of the segments. The angles **219** are so positioned at the block **217** that the end of a receding commutator segment **209** passes under side **223** after it passes the block.

The moving parts of the system including the motor **213**, the slip rings **205**, and the segments **209** are disposed in a container **225** within which a pressure of from one-tenth to ten centimeters of mercury is maintained, the preferred pressure being of the order of one centimeter of mercury. The container may be permanently exhausted or it may be continuously pumped. The supply conductors for the motor and the connecting conductors for the brushes **203** are introduced in the container through eyelets **227**. Each eyelet comprises a central glass plug **229**, through which the conductors are sealed and an outer alloy ring **231** is sealed to the glass and welded to the adjacent wall of the container **225**.

The commutator brushes **215** are so positioned

relative to the segments **209** that the junction region between two segments passes under a brush when the potential of the secondary winding to which one of the segments is connected is passing from a magnitude smaller than the potential of the secondary winding to which the other segment is connected to a magnitude greater than this potential. At this point the connection to the brush is transferred from one of the receding windings to the approaching winding and the current flow through the brush and the receding segment falls to zero, while the current flow through the other segment rises from zero to a predetermined value. For rectification, that is, where the direct-current conductors **187** constitute the load and the alternating-current conductors **185** constitute the source, the system is adjusted for under commutation in accordance with the preferred practice of my invetion. In this case the potential of the receding and the approaching windings become equal after the block **217** disengages the receding segment and the current zero occurs when the receding segment is passing under the angle **219**. An arc is ignited between the receding segment **209** and the angle **219** when the brush first disengages the segment since its potential still predominates over that of the approaching segment and as the current zero is approached and passed, the arc is extinguished. The pressure within the container **225** as previously stated may be from one-tenth to ten centimeters of mercury but is preferably of the order of 1 centimeter of mercury. The gas within the container may be air, but is preferably a gas having a low rate of ionizing potential E_i to molecular weight M. Noble gases such as helium, argon, xenon, krypton and nitron have substantially lower values of

$$\frac{E_i}{M}$$

than ordinary gases. Thus for xenon the value is .1, while it is .74 for nitrogen and ,39 for oxygen. In accordance with my invention therefore the gas within the container **225** is preferably a noble gas such as xenon. Operating in the reduced pressure gaseous medium specified, the brushes **219** and the segments **209** are not deleteriously affected by the arcs. The situation is materially improved by the operation of the chokes **207** which are unsaturated when the commutation occurs, and therefore, absorb a substantial portion of the potential tending to maintain the arc.

Of course, in view of the fact that the current intensity in the arc is small because of the low pressure in the container, the chokes need not in all cases be utilized. In many situations, moreover, a relatively inexpensive choke may be used where a relatively expensive choke would be required in a conversion arrangement constructed in accordance with the teachings of the prior art.

In Fig. 3, a modification of my invention is illustrated. In this case the brushes are replaced by a circular ring **233** which is tangential to the segments **209**. The tangential ring **233** functions as a brush, and when one segment is being disengaged and the succeeding segment is being engaged, the arcing takes place between the circular ring and the receding segment.

As described herein, the containers involved in the various modifications of my invention are merely exhausted until the desired pressure is attained. Improved operation is attained if the residual gas in the containers is xenon. If the improvement is desired, the containers may be first exhausted and treated to produce a high vacuum and then the necessary quantity of xenon may be introduced.

Although I have shown and described certain specific embodiments of my invention, I am fully aware that many modifications thereof are possible. My invention, therefore, is not to be restricted except insofar as is necessitated by the prior art and by the spirit of the appended claims.

I claim as my invention:

1. For use in supplying a load circuit with power from a source of a given frequency the combination comprising a vacuum-tight container, having a gaseous medium at a pressure of the order of one to two centimeters of mercury therein, commutator means within said container, said commutator means including segments and cooperative brush means and said brush means each having an arcing tail parallel to the periphery of said segments and spaced approximately .1 of a centimeter therefrom for striking an arc on the disengagement of said segments and said brush means, a synchronous motor energized from said source of given frequency for rotating said commutator means within said container, and connections for interposing said commutator means between said source and said circuit.

2. For use in supplying a load circuit with power from a source of a given frequency the combination comprising a vacuum-tight container, having a gaseous medium at a pressure of the order of one-tenth of a centimeter to ten centimeters of mercury therein, commutator means within said container, said commutator means including segments and cooperative brush means and said brush means including means for striking and maintaining an arc of the order of .1 centimeter in length on the disengagement of said segments and said brush means, a motor for rotating said commutator means within said container and connections for interposing said commutator means between said source and said circuit.

JOSEPH SLEPIAN.