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ARC-QUENCHING ELECTRODE ASSEMBLY FOR HIGH-POWER CIRCUIT BREAKERS AND SWITCHES

Filed April 13, 1967 8 Sheets-Sheet 1

Fig. 1

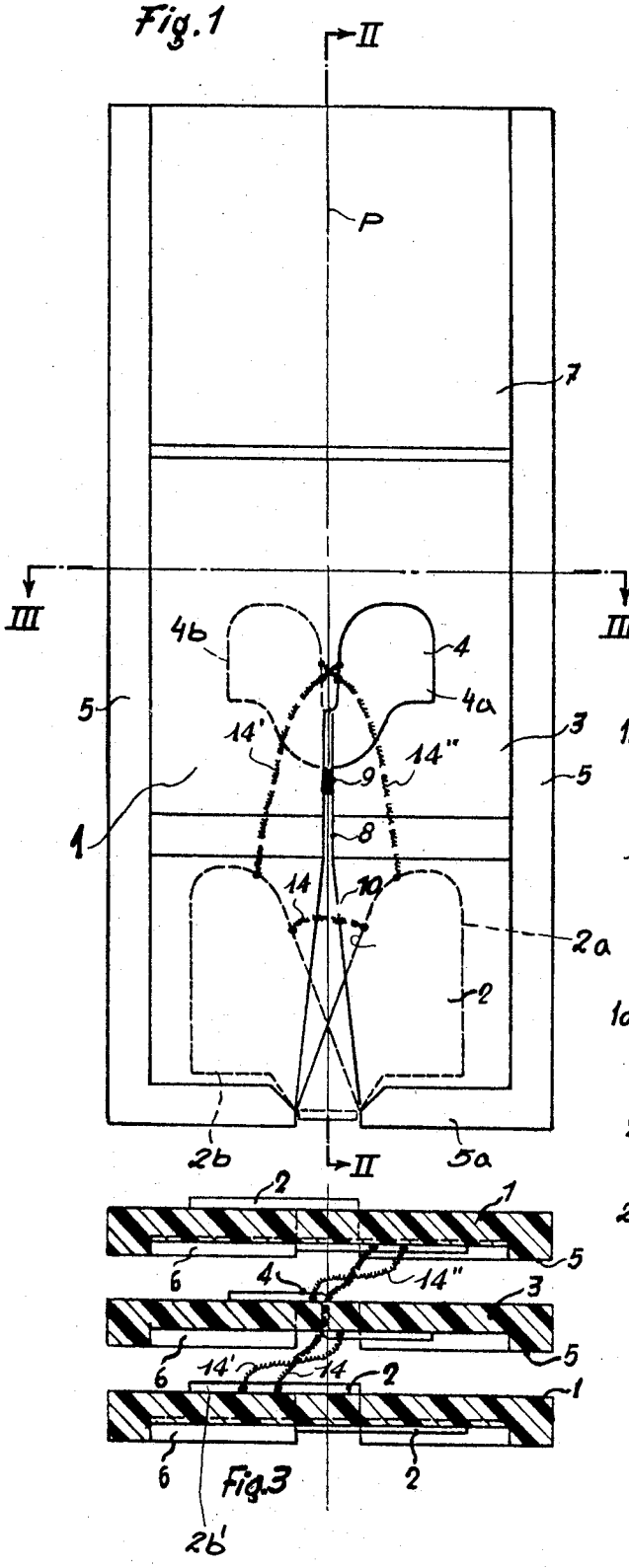


Fig. 3

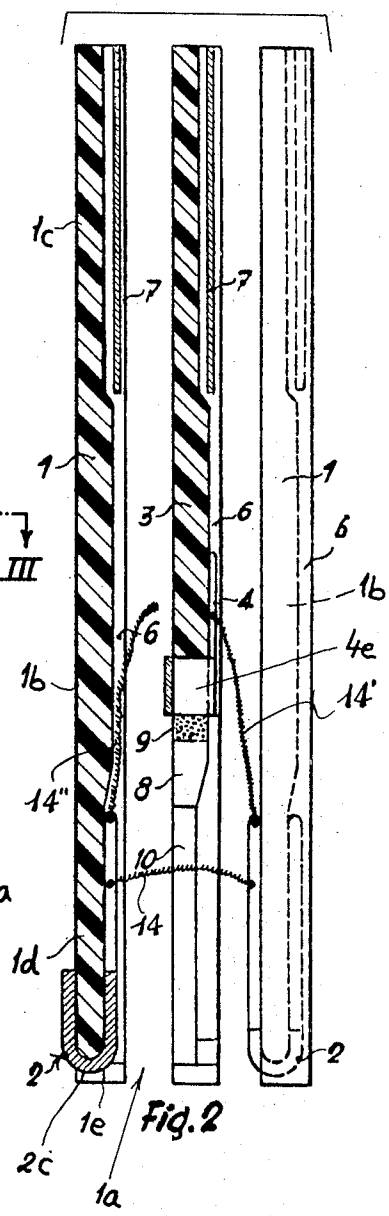


Fig. 2

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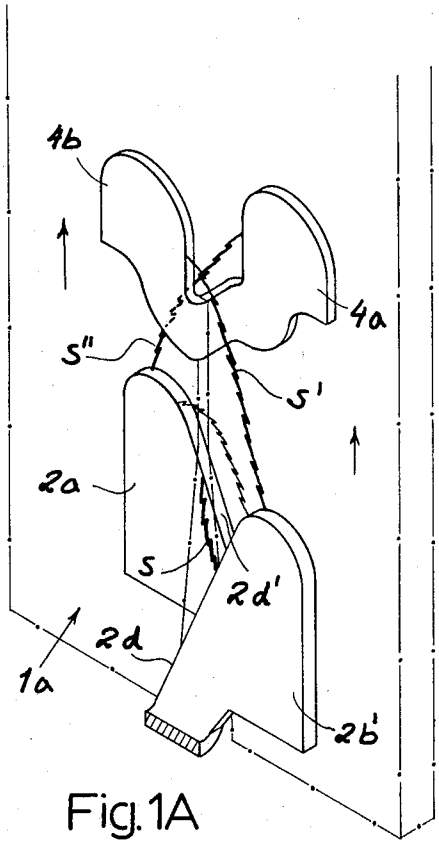


Fig. 1A

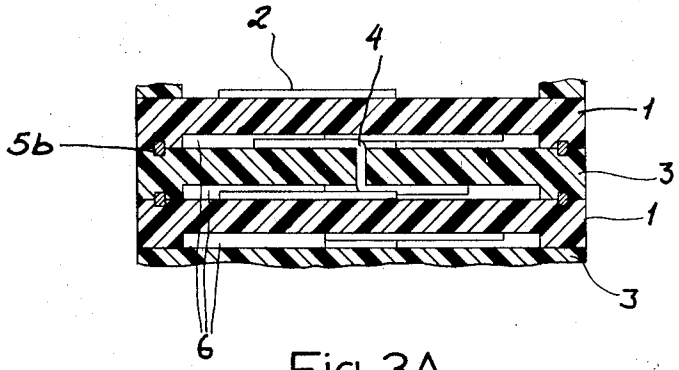


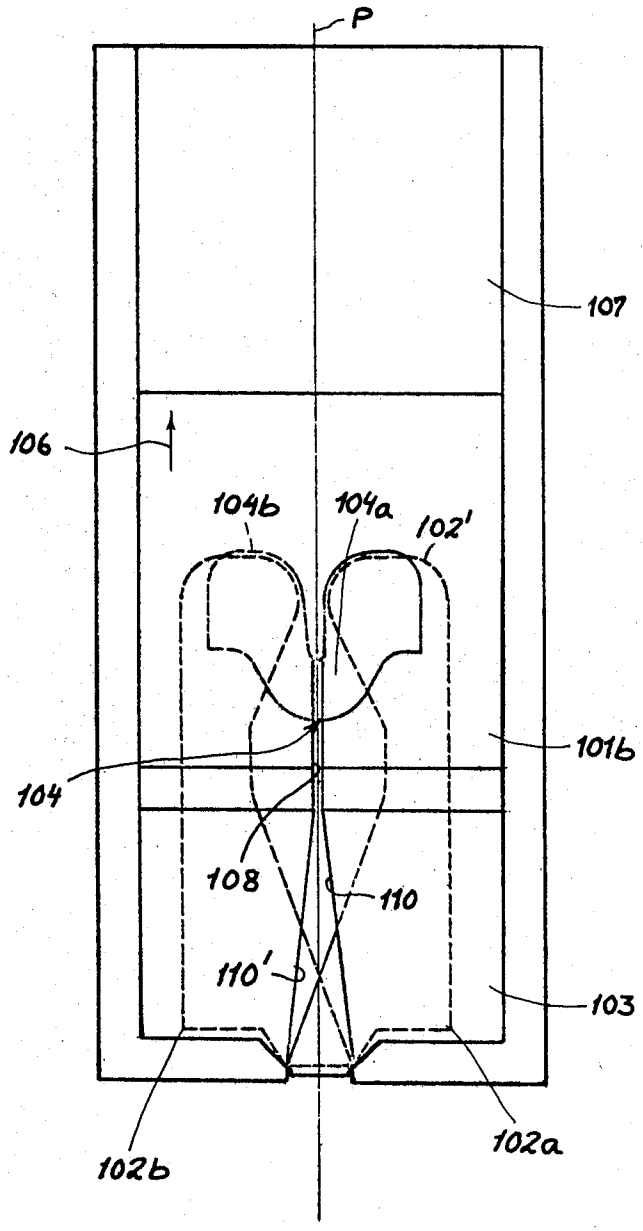
Fig. 3A

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Fig. 4

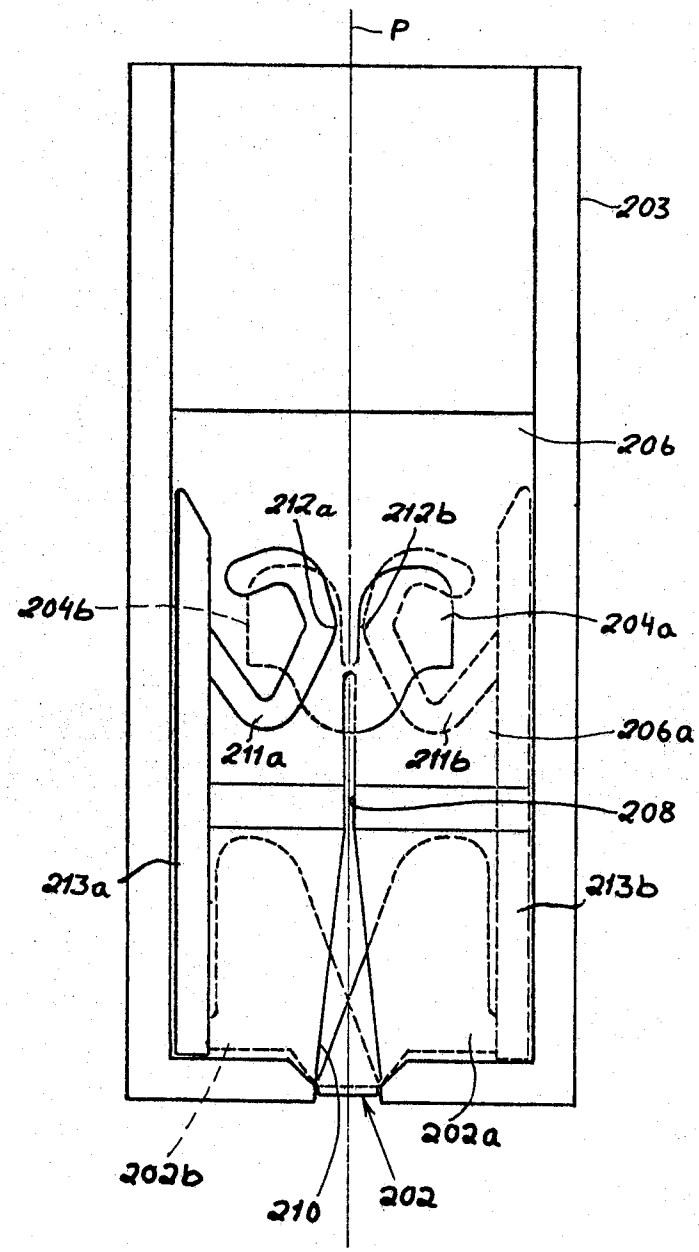


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Fig. 5

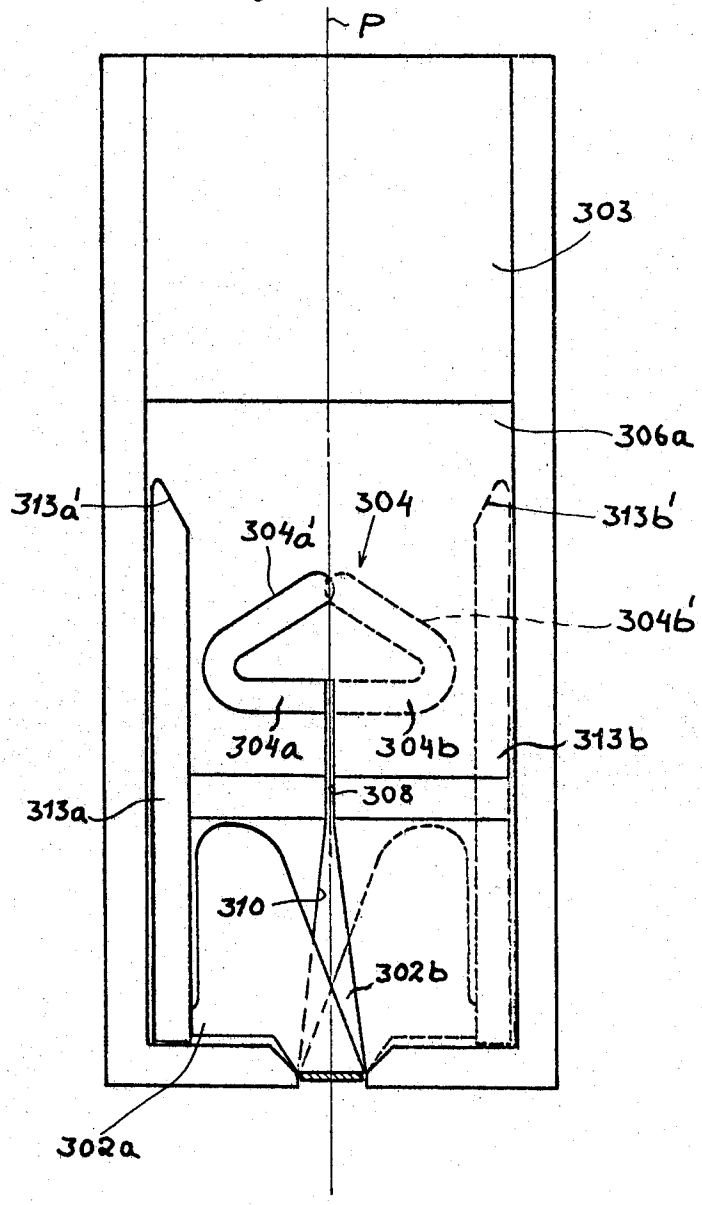


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Fig. 6

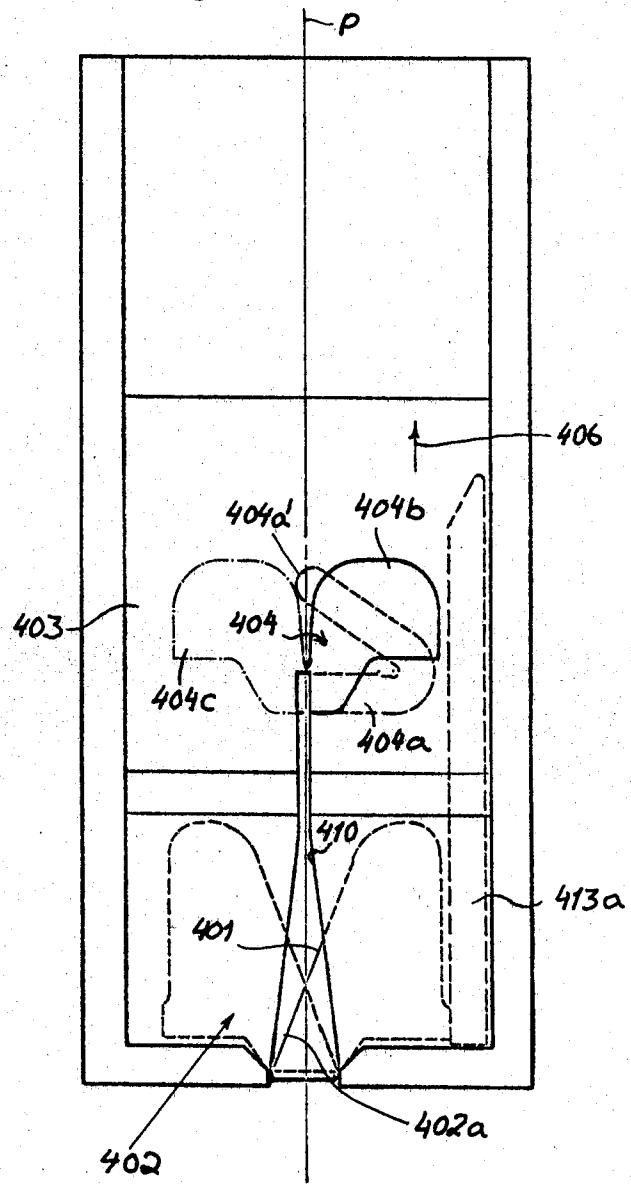


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Fig. 7



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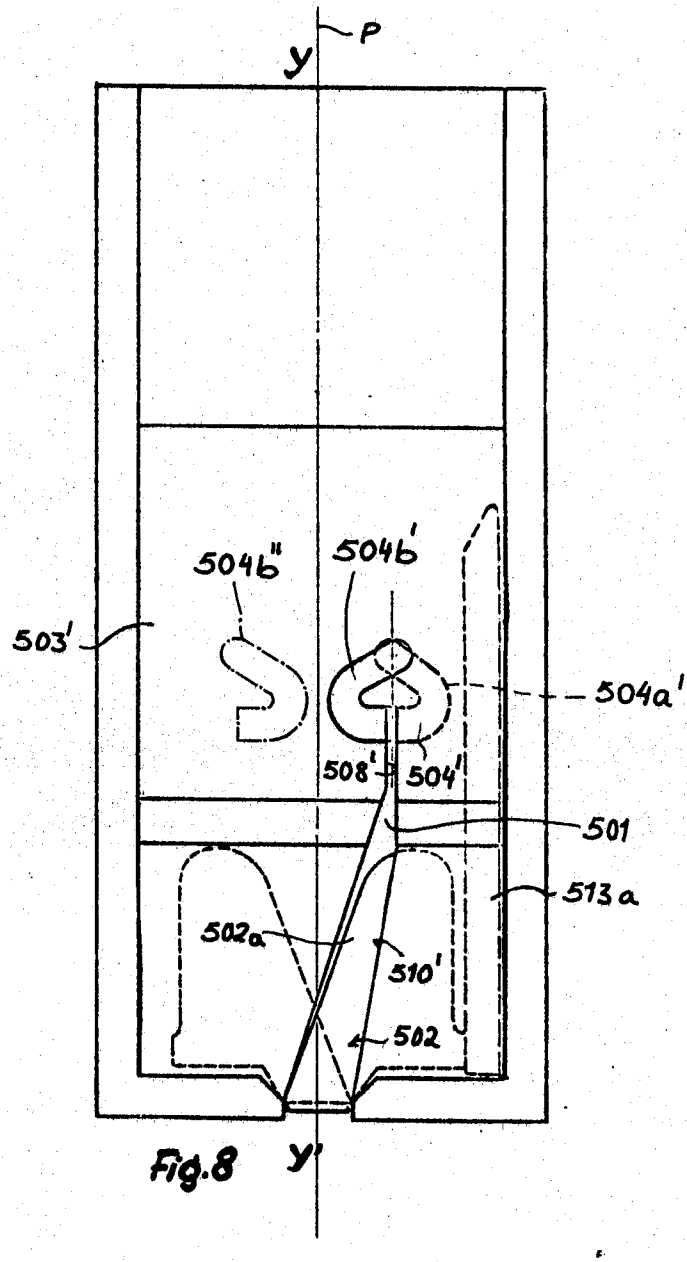


Fig.8

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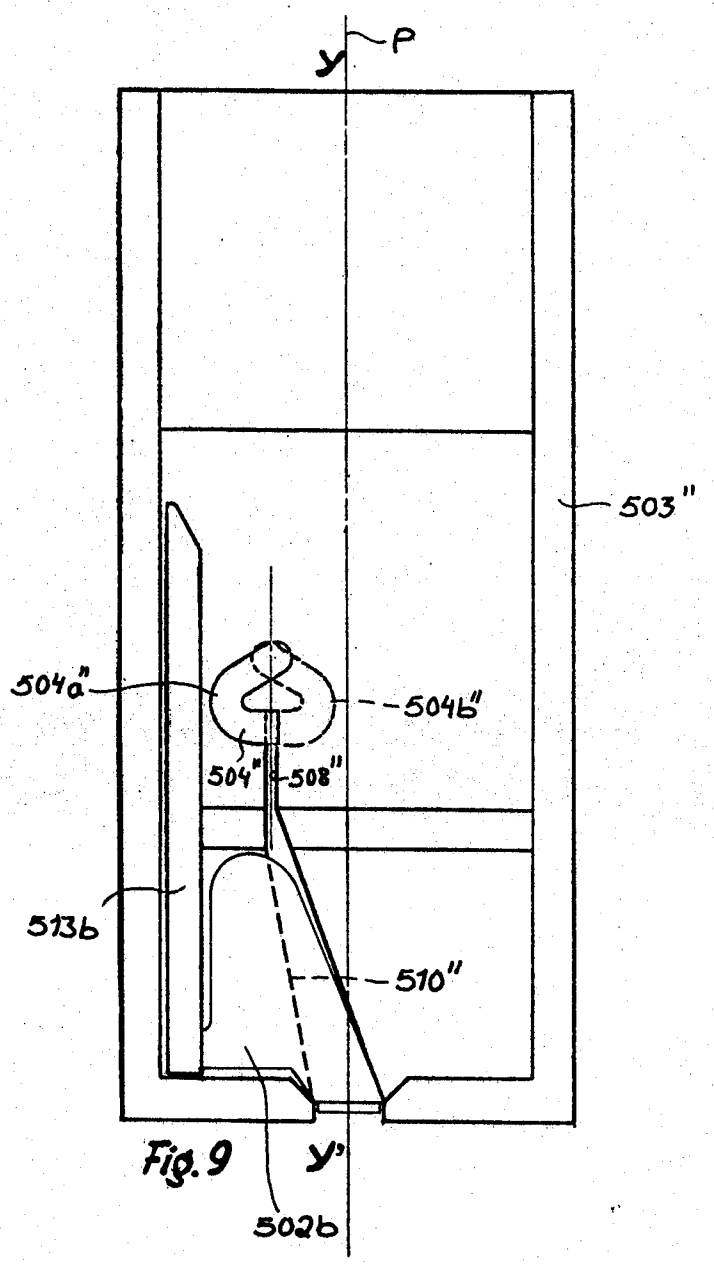


Fig. 9

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ARC-QUENCHING ELECTRODE ASSEMBLY FOR HIGH-POWER CIRCUIT BREAKERS AND SWITCHES

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Filed Apr. 13, 1967, Ser. No. 630,592
Claims priority, application France, Apr. 14, 1966, 57,551
Int. Cl. H01h 9/30, 33/00
U.S. Cl. 200—144 12 Claims

ABSTRACT OF THE DISCLOSURE

Arc-quenching electrode assembly for high-power circuit breakers and switches which has a plurality of mutually parallel, transversely spaced primary plates carrying respective relatively large primary electrodes across which the breaker arc is applied and forming arc chutes for the deionization of the breaker arcs, and at least one secondary plate between each pair of primary plates and having a pair of secondary electrodes of dimensions smaller than those of the primary electrodes for subdividing each primary fractional arc into a number of secondary arcs. The secondary plates are formed with upwardly narrowing throttling slots forming a progressively constricted aperture between each pair of primary blast electrodes or horns for limiting the movement of the primary arc between them toward the secondary electrodes until the amplitude of the primary discharge falls off in its periodic sinusoidal cycle, the upwardly converging slot having a relatively narrow gap adapted to pass only a relatively thin spark and terminating substantially at the secondary electrodes. The primary electrodes and secondary electrodes are mutually offset and offset from the corresponding electrodes of an adjoining arc chute and the arc loops between the electrodes are maximalized to provide a multi-convolution configuration for the current flow which promotes the magnetic-field effect upon the discharge. The primary electrodes have extensions reaching toward the secondary electrodes and of a specific resistivity dimensioned to attenuate the current flow as the arcs move toward the secondary electrodes.

My present invention relates to an arc-quenching arrangement for high-power circuit breakers and switches and, more particularly, to a system wherein a flow of air is utilized to deionize, by cooling, a circuit-breaking arc in conjunction with an arc-splitting system of electrodes.

State of the art

It has already been proposed, in connection with circuit breakers, switches and the like to provide, in addition to a mechanism for disconnecting a pair of contacts at the current-input and current-output sides of the switch, various means designed to quench the arc formed upon open-circuiting these contacts. In general, several systems have been proposed for use individually or in combination to achieve this result. It has, for example, been suggested to provide between the main contacts a number of divergent linearly extending electrodes which subdivide the arc into a plurality of smaller arcs and thereby permit easier dissipation of the heat and evenual arc quenching;

commonly these electrodes are provided above the main electrodes in a so-called "arc chute" or duct through which a convection current of air is induced upwardly in the direction past an array of arc-splitting electrodes. It is also possible, together with arc-splitting electrodes, to provide air-blast arc-quenching means for augmenting the cool-gas flow upwardly through the arc chute. In both cases, and where heat conductors or heat sinks are provided in the arc chute or duct, a decrease in the temperature of the gas has the effect of deionizing the arc. To this end, the arc chute or horns are determined and configured to increase the effective length of the breaker opening and facilitate dissipation or subdivision of the discharges. Finally, a magnetic-blowout system can be used in conjunction with the arc chute to effect a magnetic shaping of the arc and its eventual dissipation.

Object of the invention

It is the principal object of this invention to provide an improved system for the subdivision of a circuit-breaking arc which is of economical and simple construction, conserves space, affords better heat-dissipation and faster arc quenching, and which is more easily assembled and repaired than prior arc-quenching arrangements for circuit breakers and the like.

Brief summary of the invention

I have found that this object can be attained, and that improvements in the magnetic control of the arc in other aspects achieved, when the arc-quenching arrangement comprises a stack of plates against which the circuit-breaking arc is applied and which run perpendicularly to this arc and parallel to one another, preferably in vertical planes, these planes being provided with rider contacts or blast electrodes (blast horns) which subdivide the breaker discharge into a plurality of elementary arcs which are angularly offset or rotated with respect to one another with angles of approximately 90°. The angular offset of the effective electrodes and the loops of the arcs bridging same form convolutions of electric-current flow whose magnetic field is in effect that of a solenoid and shapes or controls the duration of the discharge while a cooling flow of air through the arc chutes between these plates and the dissipation of heat through the walls of chutes deionizes the discharge region and causes quenching of the arc. According to the principal features of this invention, between each pair of these primary plates, there is disposed at least one intermediate plate having an arc-throttling aperture converging in the direction of gas movement through the arc chute and adapted to control the upward movement of the respective discharge between the primary-electrode lobes or horn on opposite sides of the intermediate or secondary plates, the throttling slot terminating substantially at a pair of secondary electrodes above the primary electrodes at which the elemental arc between each pair of primary electrodes is subdivided into at least two secondary arcs which are offset from one another and thereby increase the magnetic or solenoidal effect.

While it has already been proposed to orient a number of arc-splitting electrodes between respective plates in the general manner described and thereby obtain a magnetic lengthening of the arc loop and, consequently, a greater heat dissipation for early quenching of the arc, the conventional arrangements have been of limited utility

because the primary electrodes were required to be relatively close together for spatial considerations and such proximity impeded the gas flow through the arc chute. As a consequence, the arc frequently hung between the primary electrodes without forming the loops which were a requisite to the lengthening of the arc and the increased magnetic-field effect. Earlier systems in which slotted partitions were provided between the primary electrodes were ineffective because they limited the length of the arc within each arc chute. By providing at the narrow end of an upwardly converging V-shaped aperture in the intermediate plate or partition, a pair of electrodes which lie alongside the faces of this intermediate plate and are adapted to form a conductive bridge between the secondary arcs formed upon subdivision of each of the elementary or primary arcs, it has been possible to avoid the disadvantages of the earlier systems and rapidly provide the solenoid effect without increasing the volume of the unit and the number of primary electrode cells. Thus, according to a feature of this invention, the converging aperture terminates in a narrow gap through which the arc of an A.C. breaker discharge can pass only when the "fatness" of the arc or its intensity decreases during the passage of the sinusoidal waveform through the null or zero condition in the amplitude versus time characteristic, the secondary electrodes being disposed above the main blast electrodes or primary horns in the region of this narrow gap and having a surface area and size which is less than that of the corresponding pair of primary electrodes.

While the invention will be described hereinafter in connection with a single secondary plate and pair of secondary electrodes between each pair of primary electrodes, it will be understood that a plurality of secondary or intermediate plates may be stacked between each pair of primary plates and all of these intermediate or secondary plates may have a respective upwardly convergent throttling slot and secondary electrode pair previously described.

The lobes of each pair of secondary electrodes, which are interconnected by a web and are preferably unitary with one another, lie generally on opposite sides of a longitudinal median plate through the narrow gap so that the secondary arcs, formed between each lobe and a respective primary electrode or between each lobe and a respective lobe of the secondary electrode of an adjoining plate, are also angularly offset from one another whereby the secondary arcs, when taken with the secondary electrodes, form effective convolutions whose magnetic field operates in the solenoid manner previously described. Thus, the subdivision of each primary arc into at least two, but generally a greater number of, secondary arcs, permits the heating effect of the discharge between the primary electrodes to be distributed to a larger number of secondary electrodes and thereby allows the metal plates constituting the secondary electrodes to be dimensioned smaller than the primary electrodes while nevertheless serving to dissipate the discharge energy. The length of the secondary arc extending to each lobe of a secondary electrode and the length of the primary arc as controlled by the throttling slot may, therefore, be increased by comparison with earlier systems so that the effective space between the primary electrodes is increased without increasing the gap between the primary plates and, therefore, reducing the air-flow velocity which is conducive to arc quenching.

Furthermore, the present system has the advantage that the intensive heating and damage to the electrodes is avoided by ensuring a transformation of the primary arc into a number of secondary arcs only during the transition period at which the discharge-current intensity is minimum, i.e. in the period in which the sine characteristic passes through zero. It is important to note, in this regard, that the rapidity with which the solenoid effect is generated is directly related to the effectiveness of the so-called blast coil formed thereby. The optimum effectiveness is achieved with a minimum number of convolutions during the high-intensity current periods and a multiplication in the number of convolutions when the intensity of the discharge passes through its null value. By combining the secondary electrodes and throttling aperture slots in the manner described, a synchronization of the number of convolutions with the intensity of the discharge is achieved. The arc-splitting arrangement of this invention is thus characterized by a primary-arc chamber with a minimum number of loops and convolutions, the discharge then passing into a secondary arc chamber in which the number of convolutions and loops is at least doubled, i.e. increased geometrically.

A key advantage of this invention is that a minimum number of primary electrodes can be used with a maximum spacing and relatively large dimensions without endangering the thermal and electrodynamic effectiveness while a large number of secondary electrodes are operable with currents of lesser intensity and may be of smaller dimensions whereby a more rapid deionization can occur.

According to a further feature of this invention, as is particularly desirable for the synchronization of the system as previously described, the secondary electrodes are provided above constrictions in the outlet cross-section of the primary chamber so that a throttling of the gas flow is effected and high intensity breakage arcs are prevented from prematurely entering the secondary chamber. This constriction also increases the gas velocity through the secondary chamber and facilitates the final quenching of the arc.

I have found it advantageous to provide in the narrow gap or throat of the throttling aperture a body of a heat-resistant, insulating material which may be formed as a refractory cement for holding the secondary electrode in place and which resists premature passage of the primary discharge until the null-region of its sinusoidal wave form is reached and prevents damage to this secondary plate in this region of high thermal stress.

Brief description of the views of the drawing

The above and other objects, features and advantages of the present invention will become more readily apparent from the following description, reference being made to the accompanying drawing in which:

FIG. 1 is an elevational view of a group of plates in an arc-splitting arrangement, in accordance with the present invention, adapted to be used with high-power circuit-breaker mechanisms in the usual manner, the primary front plate of the assembly being removed to reveal the underlying secondary plate;

FIG. 1A is a perspective view diagrammatically illustrating the relationship between a pair of primary electrodes of one arc duct and the related secondary electrodes and plate, the members of this portion of the assembly being shown with exaggerated spacing and represented in a stylized form;

FIG. 2 is a cross-sectional view taken generally along the line II—II of FIG. 1 with the plates of one spark duct separated to indicate details of their configurations;

FIG. 3 is a cross-sectional view taken generally along the line III—III of FIG. 1, with the plates in their separated condition corresponding to FIG. 2.

FIG. 3A is a cross-sectional view along the line III—III, of this portion of the apparatus, with the plates properly positioned;

FIG. 4 is a view similar to FIG. 1 of another arc-divider assembly wherein the primary electrodes have a modified configuration;

FIG. 5 is a view similar to FIG. 1 of a system in which the primary electrodes have upwardly extending longitudinal portions and bent members co-operating with the secondary electrodes, according to this invention;

FIG. 6 is another elevational view with the front

primary plate removed, corresponding to FIG. 1 of an arc-splitting arrangement in which the secondary electrode has a modified configuration;

FIG. 7 is an elevational view corresponding to FIG. 1 of a system whose secondary electrodes have still other configurations;

FIG. 8 is an elevational view of a secondary plate of one arc chute of a splitting arrangement having an inclined throttling slot; and

FIG. 9 is an elevational view of another secondary plate adapted to be mounted upon the assembly of FIG. 8 or to be used in conjunction therewith.

Specific description

In FIGS. 1, 1A, 2, 3 and 3A, I show one arc chute of an arc-splitter arrangement having a plurality of such arc chutes in horizontally stacked or cascade arrangement. It will be understood that this arrangement is designed to be substituted for any conventional arc-splitting arrangement having upwardly extending arc chutes and a multiplicity of electrodes across which the circuit-breaking arc is distributed and which are adapted to propagate the arc upwardly in forced or convected air streams with eventual break-off of the secondary arcs. The system may be used with any conventional breaker mechanism in which the current-input and current-output terminals may be bridged by a movable contact via any actuating mechanism and the assembly of arc-splitting primary electrodes is connected at its ends with the operating terminals or contacts of the circuit-opening mechanism. Consequently, the circuit-breaking spark, which would normally extend between the operating contacts, is transferred to the primary arc-splitting electrode array and is there subdivided into a multiplicity of smaller arcs, each jumping between a pair of such primary arc-splitting electrodes through an air space. The actuating mechanism and the method of connecting the arc-splitter thereto may be, as indicated, of a conventional type, e.g. see Standard Handbook for Electrical Engineers, Knowlton, Ninth Edition, McGraw-Hill Publishing Company, New York, 1957, pages 1011–1025 and 1026ff. While only one pair of primary electrodes and the related secondary plates and electrodes will be described in connection with each of the specific embodiments illustrated, it will be understood that each pair of primary plates forms a respective air space across which a respective arc may jump between the primary electrodes. The primary plates will in general, be stacked, with each supporting a pair of electrically connected primary electrodes which are exposed to the air spaces on either side of the primary plate, while respective secondary plates are sandwiched between the primary plates and subdivide the arc chutes or air spaces of each pair of them.

Thus, a pair of primary plates **1** are disposed in mutually parallel, spaced-apart horizontally-stacked relationship and define between them respective air chutes which are represented generally at **1***a*. The plates **1** are composed of a heat-resistant, electrically insulating material and have relatively thick central portions **1***b* which subdivide the air chute into a lower primary arc chamber and an upper secondary arc chamber at the upper and lower ends **1***c* and **1***d* of each plate. These chambers are separated by a constriction which limits upward movement of high-energy "fat" arcs. Each plate **1** carries, moreover, a pair of primary arc-splitting horns or primary electrodes designated at **2**. The primary electrodes **2**, in this embodiment, each have a pair of flat lobes or leaves **2***a* and **2***b* which extend parallel to one another on opposite sides of the lower portion **1***d* of the respective primary plate **1** and are connected electrically and mechanically by a bight **2***c* extending along the lower end of each plate **1** through a gap **1***e* in a marginal rim **5***a* provided along the bottom portion of each plate **1**. Thus the lobes **2***a* and **2***b* of each electrode **2** are exposed to the gas space in one of the arc chutes **1***a*, etc. In the system illustrated in FIGS. 1 through 3, the lobes **2***a* and **2***b* of each pair of mechanically and electrically connected primary electrodes **2** have downwardly inclined edges **2***d* which cross the vertical median plane of symmetry P through the arrangement so that the edges **2***d* and **2***d'* of the lobes **2***a* and **2***b'* of each pair of electrodes in the respective arc chute **1***a* and generate a respective relatively fat and energetic spark discharge S across the airgap between them.

According to the principles of this invention, between each pair of successive primary plates **1**, a secondary plate **3** of heat-resistant electrically insulating material is interposed, the primary and secondary plates being mutually parallel. The secondary plates **3** (see FIGS. 1 through 3) subdivide the arc chutes **1***a* between the pair of primary plates **1** and carry a secondary horn or secondary electrode **4** whose structural function will become more apparent hereinafter. As previously indicated, the plates **1** and **3** illustrated in FIGS. 2 and 3 are spaced apart somewhat while, in FIG. 1, the foremost primary plate **1** has been removed. In FIG. 3A, it is possible to see the plate assembly when the primary and secondary plates are properly positioned whereas FIG. 1A illustrates the relationship of the primary electrodes **2** and the secondary electrodes **4** during the spark-splitting operation. By removing the foremost primary plate in the illustration of FIG. 1, the forward half or lobe **4***a* of the secondary electrode **4** has been made completely visible. Thus the secondary electrode **4** comprises a pair of lobes **4***a* and **4***b* which are of a smaller dimension then the primary electrodes and extend laterally of the vertical median plane P on opposite sides of the thickened central portion of the secondary plate **3** and are interconnected by a web **4***c* extending through this plate in the plane P. The lobes **4***a* and **4***b* of the secondary electrode **4**, like the lobes **2***a* and **2***b* of each primary electrode **2**, are generally planar and lie in respective planes parallel to the plates **1** and **3** and to each other. The primary and secondary plates **1** and **3** are provided along their vertical longitudinal edges with spacing rims **5** integral with the plates and with a bottom rim **5***a* which is split by an opening **5***b* through which the bight portion **2***c* of the primary electrodes extends. The split in the secondary plates **3** is unoccupied. The rims **5** sealingly engage the adjoining plates to form generally flat outlet ducts or chutes **6** which open upwardly and contain a flame protector or shield **7** or other conventional cooling means for lowering the gas pressure as the gas passes through these ducts. Thus the ducts **6** may be provided at their upper end, in addition to the flame shields **7** or in place of the latter, with cooling surfaces having ribs, baffles or the like for conducting heat away from the gases and effecting an indirect heat exchange between the gas and a heat sink. The flame shields **7** are, however, metallic and have high thermal conductivity so that they also form a cooling means for the gases passing upwardly through the arc chutes or ducts **6**. The rims **5** and **5***a* may also be provided with gaskets **5***b* which engage the adjacent plates **1** or **3** and thereby form a sealed conduit for the gases when the plates are horizontally stacked and brought into abutting relationship.

Each secondary plate **3** is provided with a relatively large upwardly converging wedge-shaped aperture or window whose flanks extend symmetrically on opposite sides of the median plane P and converge to a narrow gap **8** just above the primary electrodes **2**. The web portion **4***c* of each secondary electrode **4** extends to an upper part of this gap above a plug **9** of an electrically insulating and refractory material. This plug **9** can be composed of a hardenable cementitious substance which also serves to bond the secondary electrode **4** in place in the upper portion of the narrow gap or throat **8**. A suitable cementitious material for this purpose may be the refractory cement formed by mixing sodium silicate and asbestos powder to a paste and permitting the resulting cement to dry. Another cement

of this type is the refractory material formed by mixing barium sulfate, water glass and asbestos.

Referring now generally to FIG. 1A, the operation of the system will be readily apparent. During the period in which the current intensity remains relatively high, the "fat" circuit-breaking arc, because of its relatively large diameter and in spite of the blast field arising from the primary windings, is held back by the narrow gap **8** of the upwardly converging throttling slot **10** or by the combined effect of this narrow gap and the constricted cross-section of the duct **6** with the effectiveness of this retardation being increased when the plug **9** is provided. During this period, as represented in FIG. 1A, the heavy discharge S jumps directly between the two lobes of the primary horns or electrodes **2** in the respective arc chute **1***a*. Thus, while the spark remains relatively "fat," it can burn only over a relatively short spark length in the wide portion of the upwardly converging opening **10**. In the case of alternating-current circuit breakers, the current characteristic with time has a sinusoidal relationship and each current peak is followed by a passage of the current amplitude through its null value, the arc thins and is guided by the flanks of the throttle slot **10** upwardly into the throat **8** onto the secondary electrodes **4**. In this manner, the discharge between each pair of primary electrodes is split into a pair of secondary discharges represented at S′ and S″ in FIG. 1A.

In this manner it is possible to obtain a device which originally has n primary convolutions in the hypothetical solenoid, formed by the arcs and electrodes during the discharge in the primary chambers below the constriction **1***b* and, in the region of the null point of the sinusoidal characteristic of the intensity of breaking current with time, is transformed into $2 \cdot n$ arc bridges or loops and, accordingly, into $2 \cdot n$ convolutions of the hypothetical solenoid. Furthermore, a plurality of such intermediate plates **3** with respective secondary-electrode pairs can be provided between each primary plate and, when m such plates are employed, the hypothetical solenoid will be made up of $m \cdot n$ bridges or convolutions, a system which is highly satisfactory from the point of view of energy dissipation and quenching of the multiplied number of arcs formed during the final stages of the operation of the device.

According to a further feature of this invention, the transistion region between the active sections of the primary and secondary electrodes of each gas duct is constricted in the manner illustrated with the thickened portions **1***b* of the plates **1** and **3**. In order to promote the transformation of the primary arc passing through the relatively wide part **110′** of the upwardly converging throttling gap **110** of a secondary plate **103**, I provide electrodes **102***a* and **102***b* having projections **102′** reaching beyond the constricted region **101***b* of the duct **106** substantially to the region of the lobes **104***a* and **104***b* of the secondary electrode **104**. The latter may be mounted in the throat **108** via a plug of refractory cement in the manner previously described. In this case, the transition between the primary arc and a pair of secondary arcs is promoted because the extensions **102′** reach substantially toward the lobes of the secondary electrodes which are located on opposite sides of the vertical median plane P of the throat **108** and the slot **110**. The co-operating primary and secondary lobes may, in each of the chamber partitions by the secondary plate **103**, be disposed on opposite sides of this plane P although they are multiparallel and may even be coplanar, thereby ensuring a sufficient gap, however small, for the secondary arcs. At the upper or outlet end of the arc-quenching duct **106**, a flame shield or cooling arrangement **107** is provided in the manner previously described. To prevent excessive restriction of the gas-throughflow opening by the portions **102′** of the primary electrodes extending into the constricted portions of the duct **106** housing the secondary electrodes **104**, I prefer to make the primary-electrode extensions of limited width.

An arrangement of this type is readily apparent from FIG. 5. In this embodiment the secondary plate **203**, which is provided with the upwardly converging throttling slot **210**, narrow throat **208** and a pair of secondary-electrode lobes **204***a* and **204***b* on opposite sides of the median plane P and flush along the faces of the plate **203**, co-operates with primary electrode plates (not shown) whose primary-electrode lobes **202***a* and **202***b* have the configuration described with respect to FIG. 1 but are provided with electrically conductive longitudinal extensions **213***a* and **213***b* which lie along the vertical flanks of the duct **206**. The primary electrode, generally represented at **202**, are in electrical contact with the longitudinal extensions **213***a* and **213***b* which reach upwardly toward the outlet of this duct and extend into the constricted portion **206***a* of this duct. Each of the extensions **213***a* and **213***b* is provided with a hook-shaped finger **211***a*, **211***b*, which has a leading edge **212***a*, **212***b* approaching the active section of the respective lobe **204***a* and **204***b* on the corresponding side of the plate **203**. The extensions **203***a* and **203***b* and the electrode fingers **211***a*, **212***a* and **211***b*, **212***b* are composed of a material of reduced thickness so that they form no barrier to the throughflow of gases and have a specific resistivity calculated, in view of their length, to attenuate the current flow and thereby diminish the arc intensity as the secondary arc is delivered to the secondary electrodes **204***a* and **204***b*.

In all of the aforedescribed embodiments, the secondary electrode lobes and horns have their active sections upon the side of plane P opposite the active side of the corresponding other electrode with which they form the secondary arc. This "other electrode" is the primary-electrode lobe in the gas duct containing the secondary and primary lobes bridged by any secondary arc, although the use of a plurality of secondary plates between any pair of primary plates will constitute some of the secondary-electrode lobes, the co-operating other electrodes for the purpose of this description.

It is, however, also possible and an important feature of this invention in view of the simplicity of the system, to dispose each secondary lobe and the co-operating other electrode within the respective arc chute on the same side of the median plane perpendicular to the plates and passing through this throat and slot. In FIG. 6, therefore, I show an arrangement of this type and it will be noted that the lobe **304***a* of the secondary electrode **304** of the secondary plate **303** co-operates with the upwardly extending portion **313***a* of the primary electrode **302***a* and that the extension **303***a*, which reaches into the region of the secondary electrodes **304** at the throttled duct section **306***a* lies on the same side of the median plane P through the slot **310** and its throat **308** as the secondary lobe **304***a* with which it co-operates. Behind the plate **303**, the other lobe **304***b* of the secondary electrode **304** co-operates with the similarly disposed extension **313***b* of the primary electrode **302***b*. In FIG. 6, the primary electrode **302***a* forwardly of the plate **303** has been represented in solid lines for convenience of explanation although it will be understood that this lobe is carried by the primary plate which is removed here. Thus, the general form of the secondary electrode **304** is that of an isosceles triangle (which may be equilateral) and the assembly of primary-electrode extensions and secondary electrode is of H-configuration. Advantageously, the secondary electrode has shanks whose free ends **304***a′* bend away from the region of closest approach to the extensions **313***a*, etc.

The H-configuration, which also is found in the system of FIG. 5, has an important advantage in that the secondary arcs climb upwardly by a Jacob's-ladder effect between the free end of the extensions **313***a* and **313***b* which can be beveled outwardly at **313***a′* and **313***b′* and the free ends **304***a′* and **304***b′* of the auxiliary electrodes which diverge from the extensions **313***a* and **313***b*. The resistance of the extensions tends to attenuate these secondary arcs as they climb upwardly because of the increasing ohmic-resist-

ance encountered by the arc current and promoting the quenching of the arc. When it is desired to provide more than two secondary electrodes **404** upon respective secondary plates **403** between each pair of primary electrodes **402** within a particular duct **406**, I prefer to use the system generally illustrated in FIG. 7 which shows a primary plate whose primary electrode **402***a* is provided with an upward extension **413***a* of the type described in connection with FIG. 6. When this primary plate **401** is covered by the secondary plate **403** carrying the secondary electrode **404**, the upwardly converging throttling slot **410** is disposed between the partially hidden electrode lobe **402***a* and the foremost lobe which has been removed in this figure, but is positioned by analogy to the system of FIG. 6. The secondary electrode **404** has a bent portion **404***a* beyond the plate **403** and integral with the wing-shaped lobe **404***b* which overlies the front face of the plate **403**. The lobe **404***a* has a configuration similar to that described and illustrated with respect to FIG. 6 while the front lobe **404***b* is constituted as illustrated in FIGS. 1–5. Thus the rear lobe **404***a* co-operates with the extension **413***a* of the blast electrode **402***a* while the forward lobe **404***b* co-operates with the rearmost lobe of an identical secondary electrode upon a plate **403** (positioned in front of the plate illustrated but of a symmetrical configuration with respect to the plane P and thus as represented in dot-dash lines at **404***c* in this figure). Thus, two secondary plates are employed in this system between each pair of primary plates and a single primary arc is subdivided into three secondary arcs. Alternatively, the secondary plates may have the configuration illustrated in FIG. 1 and, therefore, the lobes on opposite faces of each primary plate bent in opposing directions with respect to the plate P. In this case, the stacked plates need not be mirror-symmetrical with respect to one another but may be identical. The bent portion **404***a* has a free arm **404***a'* diverging from the extension **413***a*.

Furthermore, as represented in FIGS. 8 and 9, the arc length can be increased still further and a greater throttle effect achieved when the vertically stacked secondary plates, when a number of them are provided, have upwardly converging slots directed to opposite sides of the axis of symmetry Y–Y' and plane P through the assembly. Thus, immediately in front of the primary plate **501** of FIG. 8, which carries the primary electrode **502** whose lobe **502***a* has an extension **513***a*, there is provided the secondary plate **503'** carrying the secondary electrodes **504'** which have been described in greater detail in connection with FIGS. 6 and 7. The rearmost lobe **504***a'* of this secondary electrode co-operates with the extension **513***a* as already described while the frontmost lobe **504***b'* co-operates with the lobe **504***b''* (shown in dot-dash lines in FIG. 8) of a further secondary plate **503''** disposed forwardly of the plate shown in FIG. 8 and as illustrated in FIG. 9. The secondary plate **503'** has an upwardly converging throttle slot **510'** which is directed to the right of the plane P and converges in the direction of a throat **508'** which is parallel to the plane P and extends from the slot **510'** to the secondary electrode **504'** and can be filled with a plug of refractory material as represented at **9**. The next plate **503''**, however, has its upwardly converging slot **510''** directed to the left of plane P and terminating in the throat **508''**, laterally offset from the throat **508'**, above which is disposed the secondary electrode **504''** whose rearmost lobe **504***b''* co-operates with the lobe **504***b'* as mentioned earlier. The lobe **504***a''* of the secondary electrode **504''** overlies the forward face of the plate **503''** and co-operates with the extension **513***b* of a primary electrode **502***b* carried by the primary plate (not seen in FIG. 9) which overlies the plate **503''**. When the extensions **513***a* and **513***b* are composed of material having a high specific resistivity, the secondary arcs which jump between the upper ends of these extensions and the free ends of the lobes **504***a''* etc. diverging therefrom are rapidly quenched.

I claim:

1. In an arc-quenching arrangement for circuit breakers, switches and the like adapted to generate a circuit-breaking arc, in combination:

a plurality of horizontally stacked upright mutually parallel electrically insulating primary plates defining at least one upright primary arc-extinction chamber between them;

respective primary electrodes on each of said plates and connected in the path of said circuit-breaking arc and formed with primary-electrode lobes along faces of said plate confronting one another across said primary extinction chamber to sustain a primary arc thereacross whereby the passage of electric current across said stack generates a magnetic field inducing movement of said primary arc upwardly in said primary arc-extinction chamber;

at least one intermediate insulating plate defining a window between said primary plates at least along lower portions of said primary-electrode lobes while partitioning said chamber above said lower portions of said primary-electrode lobes into a plurality of downwardly open upright secondary arc-extinction chambers;

a secondary electrode on said intermediate plate formed with arc-splitting secondary lobes on opposite sides thereof for intercepting the rising primary arc and subdividing it into two arcs together forming at least part of a solenoid-type convolution further inducing the upward movement of said primary and secondary arcs, said secondary lobes lying above said primary lobes, said intermediate plate being formed with a throttling slot running upwardly from said window to said secondary electrode and of a width limiting the passage of said primary arc therethrough; and

an electrically insulating body received in said slot at a location spaced above said window and below said secondary electrode for preventing premature passage of the primary arc onto said secondary electrode.

2. The combination defined in claim **1**, further comprising constriction means between said primary-arc chamber and said secondary-arc chambers for impeding the passage of discharges of excessively high energy into said secondary-arc chambers.

3. The combination defined in claim **2** wherein said body is composed of refractory material.

4. The combination defined in claim **2** wherein said lobes of each of said secondary plates are disposed with respect to a median plane through the respective slot toward the side of said plane at which the active region of the cooperating other electrode is located.

5. The combination defined in claim **2** wherein the lobes of the secondary electrode are disposed on the same side of a median plane through said slot.

6. The combination defined in claim **2** wherein a plurality of such intermediate plates are disposed between each pair of primary plates, and the throttling slots of the successive secondary plates between each pair of primary plates are inclined alternately in opposite directions with respect to a median plane through the plates perpendicular thereto.

7. The combination defined in claim **1** wherein each of said primary electrodes is provided with a respective extension reaching toward a respective secondary electrode for effecting a transition of each primary arc to the respective secondary arcs.

8. The combination defined in claim **7** wherein said extensions have respective specific resistivities dimensioned to attenuate the discharges emanating from them upon their application to the respective secondary electrode.

9. The combination defined in claim **7** wherein said extensions of each pair of primary electrodes form an H configuration with the respective secondary electrode.

10. The combination defined in claim **1** wherein said secondary electrode has the configuration of isosceles triangles with rounded vertices.

11. The combination defined in claim 1 wherein a plurality of such intermediate plates is provided between each pair of said primary plates, the lobes of the secondary electrodes on each side of a respective secondary chamber being positioned to one side of a median plane through the stack perpendicular to the plates from the other secondary lobe of the secondary chamber, said window being of upwardly convergent triangular configuration, terminating in said slot.

12. The combination defined in claim 1 wherein said secondary electrode is located wholly above said primary electrodes, said primary electrodes each having lobes formed as wings on opposite sides of the respective

primary plate and said secondary electrode having its secondary lobes formed as unitarily connected wings on opposite sides of said intermediate plate, said secondary electrode further having a web received in said slot above said insulating body.

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