April 22, 1952

O. ACKERMANN

2,593,955

LIGHTNING ARRESTER

Filed Aug. 19, 1950

Fig.1.

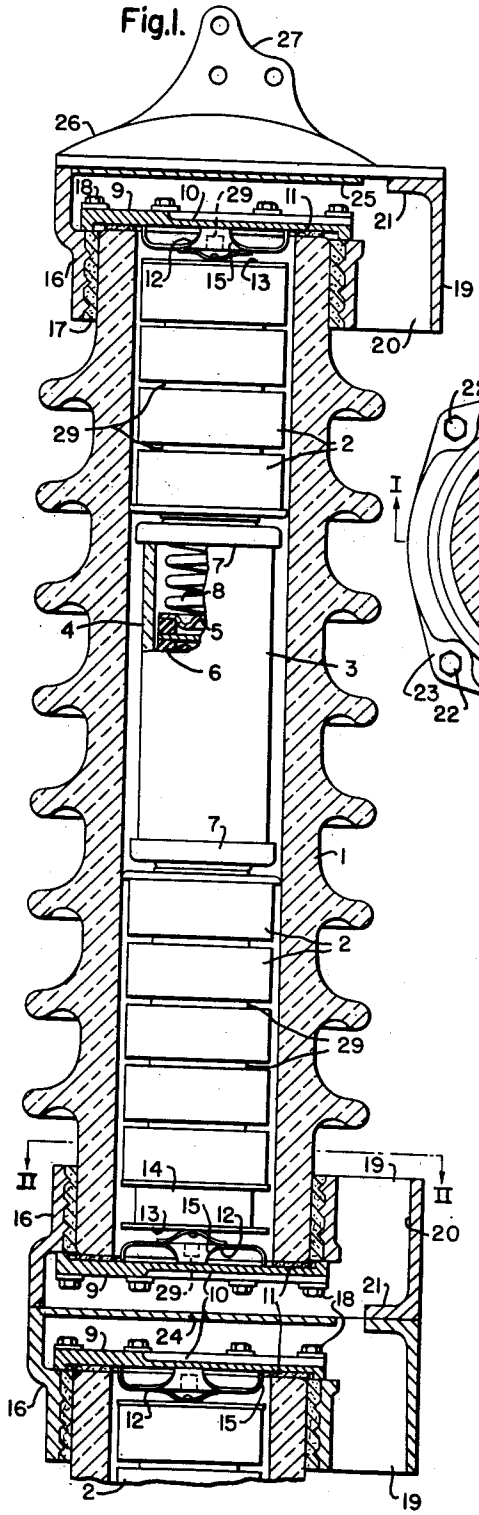


Fig.2.

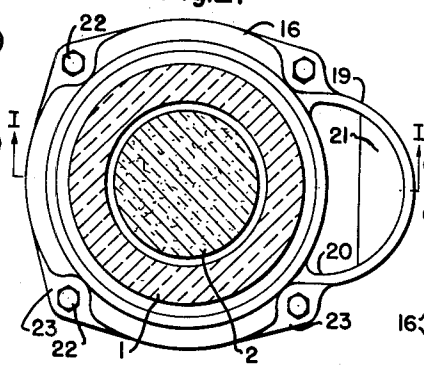
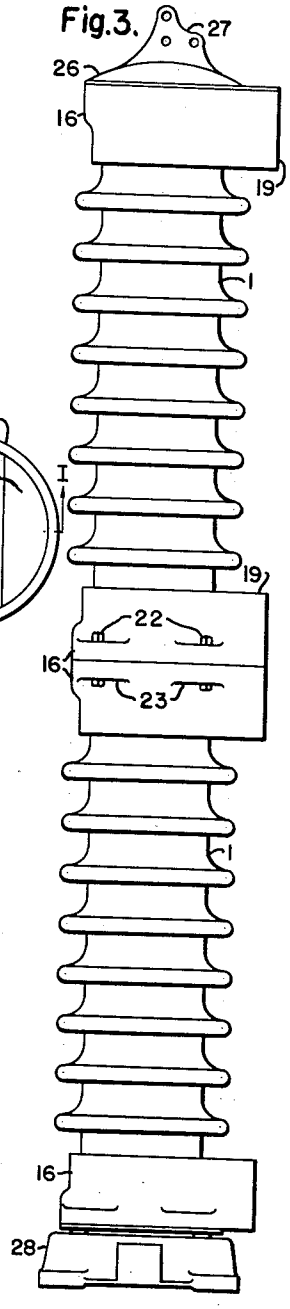


Fig.3.



INVENTOR

Otto Ackermann.

BY J. P. Lyle

ATTORNEY

Patented Apr. 22, 1952

2,593,955

UNITED STATES PATENT OFFICE

2,593,955

LIGHTNING ARRESTER

Otto Ackermann, Irwin, Pa., assignor to Westinghouse Electric Corporation, East Pittsburgh, Pa., a corporation of Pennsylvania

Application August 19, 1950, Serial No. 180,391

6 Claims. (Cl. 175—30)

1

The present invention relates to lightning arresters and, more particularly, to means for preventing shattering or explosion of valve-type lightning arresters in case of failure of the arrester from any cause whatever.

Lightning arresters of the valve type consist essentially of a plurality of spark gap devices and a plurality of valve-type resistance elements or blocks, disposed in series relation in a housing. The spark gaps normally isolate the arrester from the line to which it is connected, but these gaps spark over, under excess-voltage conditions, such as a lightning surge, to permit the surge to be discharged to ground through the valve blocks, which have low resistance under excess-voltage conditions so that the discharge voltage is low. After discharge of the surge, the blocks, because of their valve characteristics, reduce the power-follow current to a relatively small value, which can readily be interrupted by the series gaps.

In the normal operation of lightning arresters of this type, no gas is generated, and the housing can, therefore, be tightly sealed to exclude moisture, which has a very detrimental effect on the electrical characteristics of the blocks and the series gaps. If the arrester fails to interrupt the power current, however, for any reason, after a surge has been discharged, and the blocks lose their current-limiting or valve characteristics, the full short-circuit current of the system to which the arrester is connected flows through the arrester to ground. This results in excessive heating and burning, and arcing over, of the arrester elements, and thus causes the evolution of a large quantity of gas in the housing, by volatilization of the material of the arrester. Since the housing is tightly sealed, the production of this large amount of gas at high temperature causes the pressure in the housing to build up very rapidly to very high values, and may cause shattering of the porcelain housing with explosive force, endangering adjacent apparatus or persons who may be in the vicinity.

In my copending application, Serial No. 93,261, filed May 14, 1949, now Patent No. 2,586,285, and assigned to Westinghouse Electric Corporation, there is disclosed and claimed a construction for preventing such explosions in case of failure of a valve-type lightning arrester. In this construction, the internal gas pressure within the arrester, which is exerted axially through the column of arrester elements, is utilized for rupturing diaphragms closing the ends of the housing, so as to vent the interior of the housing to relieve the pressure, and means are provided for

2

directing the gas escaping from each end of the arrester toward the opposite end, so as to cause an external flashover, thus transferring the internal arc to the outside of the arrester and stopping the further generation of gas within the housing. This construction has been quite successful, but it has been found that there are certain conditions under which the arc cannot be transferred to the outside of the housing fast enough to prevent the development of explosive pressures. These conditions occur when the elements of the arrester are already at a high temperature at the time the flow of short-circuit current is initiated, which is a condition that may occasionally occur.

The internal pressure in the housing, which is caused by the generation and heating of gases within the housing, is dependent on the available arc energy when short-circuit current flows through the arrester. The arc energy is used up in several effects, including heating and chemical change of solid materials in the arrester, conversion of solids into gases, chemical changes in the gases, and heating of the gases. The latter three effects are responsible for the development of explosive pressures. If the arrester is relatively cool when short-circuit current starts to flow, a large part of the energy is initially dissipated in raising the temperature of the solid material in the arrester, while the remainder of the energy is used up in heating the air or the gas already present in the housing, thus raising the pressure. If the arrester material is already highly heated at the instant when short-circuit current starts to flow, however, most of the arc energy goes into volatilization of the solid material and heating the gases thus formed, and the pressure increases much more rapidly. The rate of rise of the pressure in the housing after short-circuit current starts to flow, therefore, depends upon the relative amounts of the arc energy used in heating the solid material and in forming and heating gas, and thus depends to a large extent upon whether the arrester is already heated or not.

The transition from normal power-follow current to short-circuit current, upon failure of the arrester, does not necessarily take place suddenly. Conditions may sometimes occur under which the arrester is unable to interrupt the current but maintains its valve, or current-limiting, characteristic. When this occurs, current continues to flow after discharge of a surge, but the magnitude of the current is limited by the resistance of the valve blocks. This current will heat the valve

blocks rather uniformly until they lose their valve characteristic and finally permit full system short-circuit current to flow. This heating takes an appreciable time, which may be as long as one minute, and the valve blocks may reach a temperature of the order of 800 C. before losing their valve characteristic. Under these conditions, therefore, the blocks are highly heated before short-circuit current starts to flow, and most of the energy goes immediately into volatilizing the block material and heating the gas, so that the rate of pressure rise in the housing is extremely fast.

The effectiveness of transferring the internal arc to the outside of the housing, as described in the above-mentioned application, depends on the ability of the streams of gas discharged from opposite ends of the arrester to meet and cause an external flashover before the internal gas pressure reaches the bursting strength of the housing. The velocity of the gas streams has a definite limit, however, so that for a given length of the housing, the minimum time in which an external flashover can occur is fixed. If the rate of pressure-rise in the housing is high, therefore, it is obvious that a small variation in the rate of pressure-rise may make the difference between preventing an explosion and failure to prevent it. Thus, if the arrester is highly heated by continued current flow before short-circuit current starts to flow, the arc may not always be transferred to the outside of the housing fast enough to prevent an explosion in the arrester-construction of the prior application.

The principal object of the present invention is to provide a valve-type lightning arrester which will not shatter or explode in case of failure of the arrester from any cause whatever, and under any conditions which may exist in the arrester.

Another object of the invention is to provide a valve-type lightning arrester having means for relieving internal gas pressure and means for transferring an internal arc to the outside, and in which provision is made for causing an internal flashover within the arrester, whenever the power current is not interrupted after a discharge, and as soon as it is evident that the arrester cannot regain control of the power flow, thus insuring that the arc will be transferred to the outside soon enough to prevent an explosion under any conditions.

A further object of the invention is to provide a valve-type lightning arrester which includes fusible elements, preferably in the form of discs of a low melting-point metal disposed between the valve blocks, which will melt and induce a flashover of the blocks in response to excessive heating of the blocks, together with means for venting the housing to relieve the internal gas pressure and for inducing an external flashover to transfer the internal arc to the outside of the housing.

Other objects and advantages of the invention will be apparent from the following detailed description, taken in connection with the accompanying drawing, in which:

Figure 1 is a vertical sectional view of a lightning-arrester unit embodying the invention; the section being taken approximately on the line I—I of Figure 2;

Figure 2 is a transverse sectional view approximately on the line II—II of Figure 1; and

Figure 3 is a view in elevation of a complete station-type lightning arrester.

The invention is shown in the drawing embodied in a valve-type lightning arrester unit such as is used in high-voltage, station-type lightning arresters of unit construction, although it will be obvious that the invention is not necessarily restricted to this particular type of lightning arrester. Figure 1 shows in detail one unit of a multi-unit, station-type arrester. The arrester-unit is contained in a hollow, generally cylindrical or tubular porcelain housing 1 and includes a plurality of valve-type resistance elements or blocks 2 and a spark gap assembly 3, disposed in series relation in a vertical column within the housing 1. In the particular construction illustrated, the column of valve blocks is divided into two parts with the spark gap assembly 3 between them, but it will be understood that any other suitable arrangement may be utilized.

The blocks 2 may be made of any suitable resistance material having valve or non-linear characteristics, that is, a material which has very high resistance, or is semi-conducting, under normal voltages, but which sharply reduces its resistance under high surge voltages to permit discharge of the surge with a low discharge voltage across the arrester, and which again increases its resistance after the discharge so as to reduce the power current to a small value, which can readily be interrupted by the gap assembly 3 at the first current zero. The blocks 2 are preferably made of granular silicon carbide mixed with a suitable binder, such as sodium silicate, molded to the desired size and shape, and baked. A conducting contact coating of zinc or copper is preferably applied to the end surfaces of each block to facilitate making electrical contact to the block, and insulating coatings may be applied to the side surfaces of the blocks. Such valve blocks are well known in themselves, and it is to be understood that any suitable type of valve blocks or non-linear resistance elements may be used.

The spark gap assembly 3 is shown as a sealed, multi-gap assembly enclosed in a porcelain tube 4. The gaps are formed by a plurality of metal electrodes 5 separated by annular spacers 6 of high-resistance or insulating material. The gaps are assembled in a column in the porcelain tube 4, and the ends of the tube are closed by metal end caps 7, which are sealed to the tube 4 in any suitable manner, as by soldering them to a metallic glaze on the tube. The column of gaps rests on the lower end cap 7, and a compression spring 8 is placed between the top of the column of gaps and the upper end cap 7 to hold the gaps firmly in place and to effect electrical contact with the upper end cap.

The housing 1 of the arrester-unit is closed at top and bottom by metal end closure-plates 9, which have relatively thin or frangible diaphragm portions 10 closing the housing. Gaskets 11 are placed between the plates 9 and the ends of the housing to substantially hermetically seal the interior of the housing to exclude moisture. As described in my copending application, metal spacers 12 are placed between the top and bottom of the column of arrester elements and the adjacent diaphragms 10, and metal spring-plates 13 are disposed between the spacers 12 and the ends of the column to hold the column of arrester elements firmly in place and to provide sufficient pressure to insure good electrical contact between the elements of the arrester, and also to hold the spacers 12 in firm contact with the diaphragms 10. If desired or necessary, the bottom of the column of arrester elements may

include a conducting spacer 14. Each of the end spacers 12 is provided with axially extending legs 15 which engage the adjacent diaphragm, and each of said spacers may have a central projection 29, which is normally spaced from the diaphragm but adapted to engage it when a high axial pressure is applied to the spacer, as more fully explained in the above-mentioned copending application.

Identical metal end-fitting or castings 16 are placed at the top and bottom of the housing and secured to the housing by cementing, as indicated at 17, or in any other suitable manner. The end-fittings 16 are generally annular, and the end closure-plates 9 are secured to the end-fittings by bolts 18. Each of the end-fittings 16 has an enlargement or projection 19 at one side thereof which has an axially extending opening or passage 20 communicating with the central part of the end-fitting directly adjacent to the diaphragm 10. A ledge 21 closes the end of the opening 20.

The end-fittings 16 of adjacent arrester-units are bolted together by means of bolts 22 extending through openings provided in lugs 23 spaced around the peripheries of the end castings, in order to connect adjacent arrester-units together both electrically and mechanically. The end-fittings 16 are provided with annular internal shoulders for receiving a circular plate or baffle 24, or other redirecting means for redirecting expelled gases. Each of the baffles 24 is clamped between adjacent end fittings of a complete arrester-assembly to prevent gas escaping from the end of an arrester-unit from striking the adjacent end of the next arrester-unit, and to redirect the escaping gas into the opening 20 of the enlargement 19. The top end fitting 16 of the uppermost arrester unit of a multi-unit assembly, such as is shown in Figure 3, is closed by a round plate 25 held in place by a top casting 26, which has suitable line terminal means 27 secured to it or formed integrally with it. The bottom end fitting of the lowermost arrester-unit of a multi-unit assembly may be closed by a similar plate held in place by a base 28 of any suitable construction on which the arrester is supported.

The operation of the structure so far described is similar to that described in the copending application mentioned above. In case of failure of the arrester to interrupt the power-follow current after discharge of a surge, for any reason, such as a lightning surge of abnormal magnitude, or the application of a dynamic voltage in excess of the arrester rating, the full system short-circuit current will flow through the arrester, accompanied by arcing over of the valve blocks, and frequently a puncture of some or all of the blocks. The gas thus generated causes a high pressure to be developed very rapidly in the housing, and this pressure is applied axially through the column of arrester elements to the spacers 12 at both ends, and thus to the diaphragms 10. This excessive axial pressure causes rupture of the diaphragms 10 by the spacers 12, permitting the gas to escape from the housing 1, and thus relieving the internal pressure.

The gas escaping from each end of each arrester-unit is directed by the adjacent baffle plate into the enlargement 19 of the end-fitting 16, from which the gas is directed in a concentrated stream towards the opposite end of the same arrester unit. The end fittings at opposite ends of each arrester unit are mounted with their enlargements in axial alignment, so that the two

concentrated streams of hot, ionized gas escaping from the arrester are directed towards each other, and an external flashover occurs very rapidly after the diaphragms are ruptured, transferring the current to the outside of the arrester, so that production of gas within the housing stops and the development of dangerous internal pressures is prevented.

As previously explained, however, it may occasionally happen that the arrester will fail to interrupt the power current after a discharge, without immediate loss of the valve characteristic, and current of less than short-circuit magnitude will continue to flow through the valve blocks 2 for an appreciable length of time. This condition may last for as long as one minute and results in the blocks being heated to extremely high temperatures, which may be as high as 800° C., before they entirely lose their current-limiting ability and permit full system short-circuit current to flow through the arrester. Under these conditions, the sudden increase of the energy flowing into the arrester when the blocks lose their current-limiting ability causes almost immediate volatilization of a large part of the highly heated block material, and results in a very high rate of pressure-rise.

The effectiveness of the external shunting-arc, outside of the porcelain housing 1, depends upon the ability of the redirected expelled gases to merge before the inside gas-pressure has reached the bursting-strength of the housing. The speed of the expelled gases has a definite limit equal to the speed of sound, and therefore, for a given arrester-length, the shortest time in which an outside gas-merger can be effected is fixed. For example, with a three-foot length of porcelain housing, the time required to form an external arc is about 40% of the time in which a 60-cycle current rises from zero to the symmetrical crest-value. Even without the use of the redirecting means for causing the escaping gases to form an external arc, the rate of pressure-rise within the housing is of the same order as the rate of increase of the current. It is evident, therefore, that a critical condition may be produced by even a small delay in the breaking of the diaphragms 10, for venting the inside of the porcelain housing 1, or a small delay in the formation of the external arc, or a small change in the rate of gas generation in the housing.

In order to prevent explosion of the housing 1 under such conditions, in accordance with the present invention, means are provided for inducing an internal flashover of the arrester blocks if the power current is not interrupted, as soon as it is apparent that the arrester will not be able to reduce or interrupt the current. For this purpose, I place, between the valve-blocks 2, discs 29 of fusible material, such as lead or other metal of low melting point; or other thermally responsive means are provided for producing a deliberate fault or short-circuit on a part of the internal discharge-path within the housing 1. The low-melting-point discs 29 have no effect on the normal operation of the arrester, but if the power current is not interrupted after a discharge, and the valve blocks 2 are heated above their normal discharging-temperatures, the discs 29 will melt, and the molten metal of the discs will flow over the edges of the valve blocks and induce flashovers of the blocks within the arrester housing, thus precipitating a power arc inside the housing. The melting point of the discs 29 will be reached a substantial time before the

blocks are heated to the point of losing their valve characteristic, so that the block material does not reach the extreme temperature it would otherwise attain.

As soon as an arc is formed in the space between the housing-wall and the blocks, the air in this space will be heated and its pressure will quickly increase sufficiently to cause rupture of the diaphragms 10. The pressure of the gas within the housing will continue to increase, but the rate of rise of the pressure will be very much less than if gas were being evolved by a more or less sudden volatilization of highly heated block material. Thus, the gas escaping through the ruptured diaphragms can induce an external flashover to transfer the arc to the outside of the housing before the internal pressure can reach dangerous values.

It has been found by test that the time interval between the incipience of arrester failure and the development of a power arc in the housing can be reduced by the use of the fusible discs 29 to about one-eighth of the time required without the discs. It will be obvious, therefore, that the temperature of the valve blocks and the internal gas pressure attained in the period preceding arc formation are very much reduced from what they would be if no arc occurred until the blocks had been heated to the point of loss of their valve characteristic. The danger of the development of explosive pressures before the arc can be transferred to the outside of the housing is, therefore, substantially eliminated.

It should now be apparent that a valve-type lightning arrester has been provided, which is positively protected against the risk of shattering or explosion of the housing in case of an arrester-failure from any cause whatever.

A particular preferred embodiment of the invention has been shown and described for the purpose of illustration, but it will be apparent that various modifications may be made, and the invention is not limited to the specific arrangement and details of construction shown, but in its broadest aspects it includes all equivalent modifications and embodiments which come within the scope of the appended claims.

I claim as my invention:

1. A lightning arrester comprising an insulating housing, a plurality of spark gap devices and a plurality of valve-type resistance blocks disposed in a column in the housing, fusible metal discs disposed between the resistance blocks in said column for effecting flashover of the resistance blocks in response to heating of the blocks to a temperature above the highest temperature reached by the blocks during normal operation, means for closing the ends of the housing, means for rupturing the closing means upon the occurrence of excessive gas pressure within the housing, and baffle means for directing gas escaping from each end of the housing axially of the housing toward the other end.

2. A lightning arrester comprising an insulating housing, a plurality of spark gap devices and a plurality of valve-type resistance blocks disposed in a column in the housing, fusible metal discs disposed between the resistance blocks in said column for effecting flashover of the resistance blocks in response to heating of the blocks to a temperature above the highest temperature reached by the blocks during normal operation, diaphragms closing both ends of the housing, means for rupturing the diaphragms in response to excessive gas pressure within the housing, and baffle means for directing gas escaping from each end of the housing axially of the housing toward the other end.

3. A lightning arrester comprising an insulating housing, a plurality of spark gap devices and a plurality of valve-type resistance blocks disposed in a column in the housing, fusible metal discs disposed between the resistance blocks in said column for effecting flashover of the resistance blocks in response to heating of the blocks to a temperature above the highest temperature reached by the blocks during normal operation, diaphragms closing both ends of the housing, means for rupturing the diaphragms in response to excessive gas pressure within the housing, and baffle means at each end of the housing for directing gas escaping from the end of the housing in a concentrated stream axially of the housing toward the other end of the housing.

4. A lightning arrester comprising an insulating housing, a plurality of spark gap devices and a plurality of valve-type resistance blocks disposed in a column in the housing, fusible metal discs disposed between the resistance blocks in said column for effecting flashover of the resistance blocks in response to heating of the blocks to a temperature above the highest temperature reached by the blocks during normal operation, diaphragms closing both ends of the housing, means for rupturing the diaphragms in response to excessive gas pressure within the housing, end members at each end of the housing outside of the diaphragms, each of said end members having an enlargement at one side thereof and baffle means for directing gas escaping from the housing into said enlargement and toward the other end of the housing in a concentrated, substantially axial stream, the end members at the opposite ends of the housing being disposed with their enlargements in alignment.

5. A lightning arrester unit comprising an insulating housing, a plurality of valve-type resistance blocks and a spark gap device disposed in series relation within said insulating housing, a frangible closure member substantially hermetically secured to each end of said insulating housing, said closure members being frangible in response to internal forces before the bursting of the housing due to internal pressures, in the event of a failure of the arrester unit in service, and low-melting-point metal elements interposed between adjacent surfaces of at least some of said resistance blocks, said metal elements being adapted to melt and short-circuit at least a part of the discharge path within the housing at a temperature which is higher than any temperature reached by the resistance blocks during normal operation.

6. A lightning arrester unit comprising an insulating housing, a plurality of valve-type resistance blocks and a spark gap device disposed in series relation within said insulating housing, a frangible closure member substantially hermetically secured to each end of said insulating housing, said closure members being frangible in response to internal forces before the bursting of the housing due to internal pressures, in the event of a failure of the arrester unit in service, gas-redirecting baffle means outside the housing adjacent each of said frangible closure members for redirecting the escaping gases from each end of the housing axially of the housing toward the other end thereof, outside of the housing, and low-melting-point metal elements

interposed between adjacent surfaces of at least some of said resistance blocks, said metal elements being adapted to melt and short-circuit at least a part of the discharge path within the housing at a temperature which is higher than any temperature reached by the resistance blocks during normal operation.

OTTO ACKERMANN.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,271,573	Sands	Feb. 3, 1942
2,291,175	Stroup	July 28, 1942
2,422,978	Olsen	June 24, 1947