

[54] SURGE VOLTAGE ABSORBER
[75] Inventors: Ikuo Takano; Yasutaka Imajyo;
Akira Tanimoto, all of Tokyo, Japan
[73] Assignee: Tokyo Shibaura Electric Co., Ltd.,
Japan
[22] Filed: Nov. 7, 1973
[21] Appl. No.: 413,576

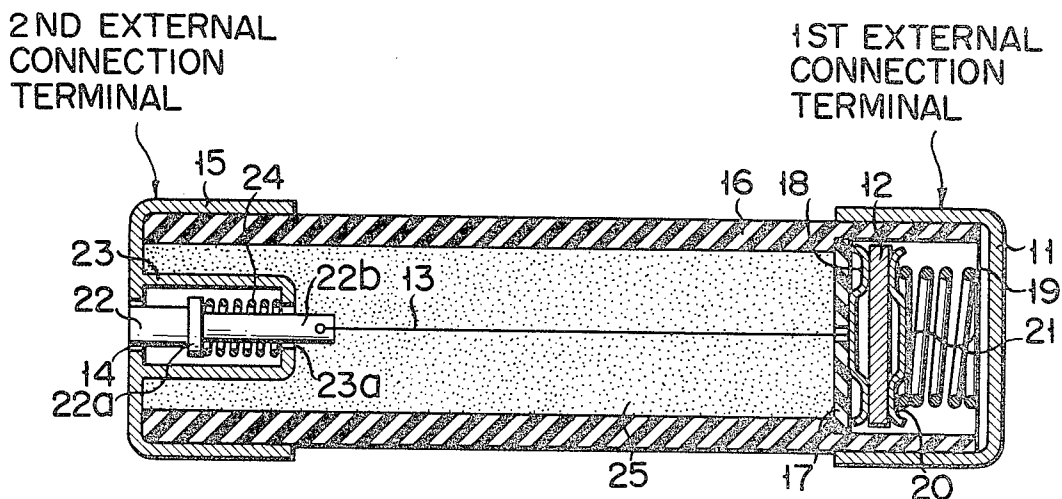
[52] U.S. Cl. 337/244; 317/41; 317/66;
338/21
[51] Int. Cl. H01h 85/30
[58] Field of Search 338/20, 21, 31; 337/244,
337/241, 184, 4; 317/41, 61.5, 50, 66, 31,
32, 40 A

[56] References Cited
UNITED STATES PATENTS
3,255,383 6/1966 Astleford, Jr. 317/41
3,340,430 9/1967 Jenkins 337/244 X
3,450,949 6/1969 Inglis 337/244 UX

3,518,489 6/1970 Musham 317/50 X
3,781,607 12/1973 DiMarco et al. 317/40 A X
Primary Examiner—R. N. Envall, Jr.
Attorney, Agent, or Firm—Oblon, Fisher, Spivak,
McClelland & Maier

[57] ABSTRACT
A surge voltage absorber wherein a first external connection terminal, at least one nonlinear resistance element made of metal oxide, a fusible element and a second external connection terminal bored with a penetrating hole are held by a holding structure so as to form an electrical series circuit; when the surge absorber is broken by surge voltage, a fusible element is melted away; and at this time a display member received in the recess of the second external connection terminal is made to project through the aforesaid penetrating hole by means of a biasing device also disposed in said recess.

7 Claims, 13 Drawing Figures



2ND EXTERNAL
CONNECTION
TERMINAL

FIG. 1

1ST EXTERNAL
CONNECTION
TERMINAL

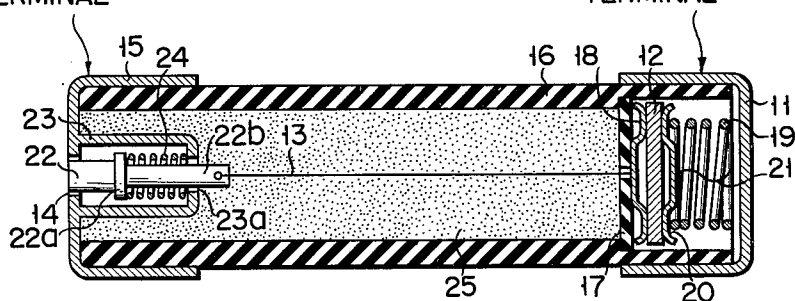


FIG. 2

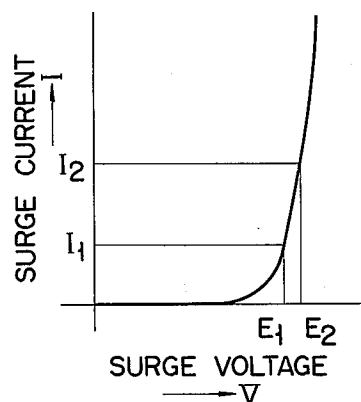


FIG. 3A

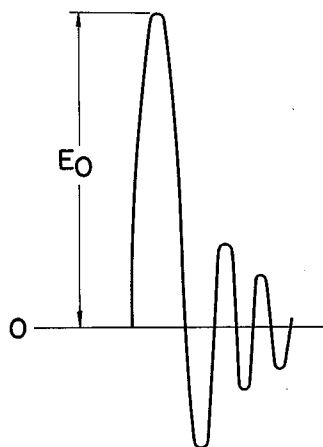


FIG. 3B

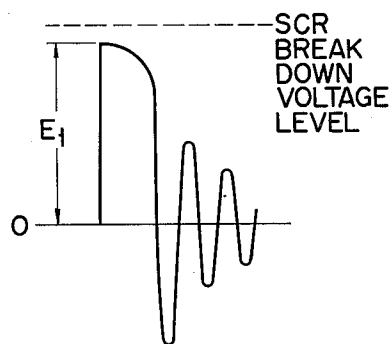


FIG. 4A

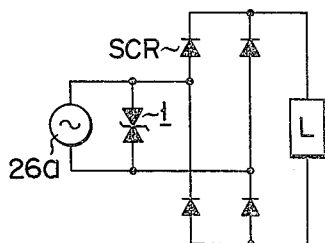


FIG. 4B

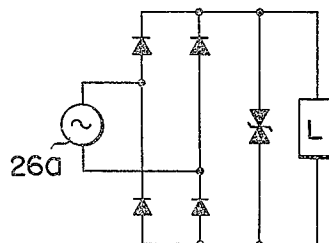


FIG. 4C

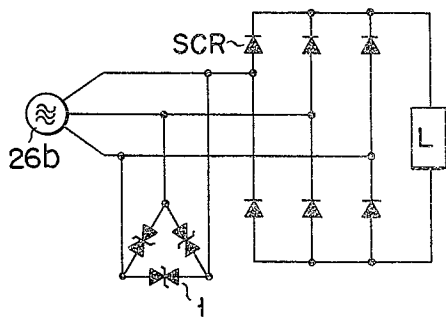


FIG. 4D

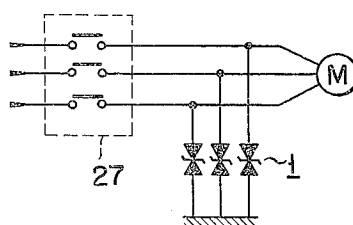


FIG. 5

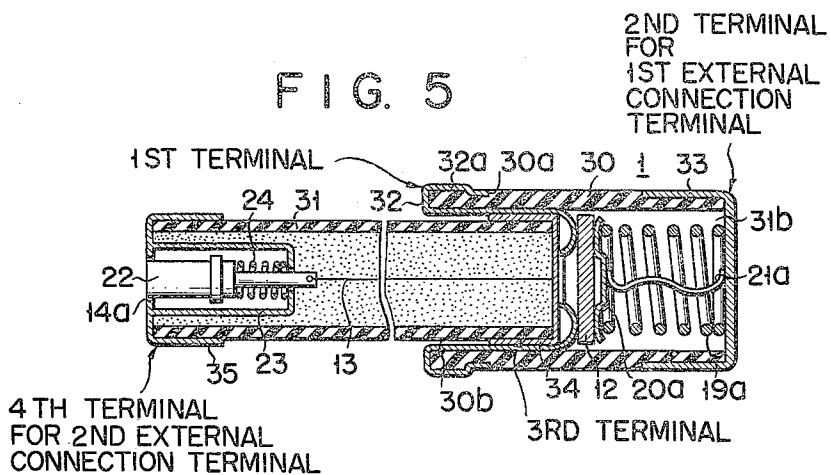


FIG. 6

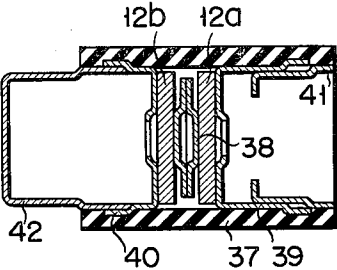


FIG. 7A

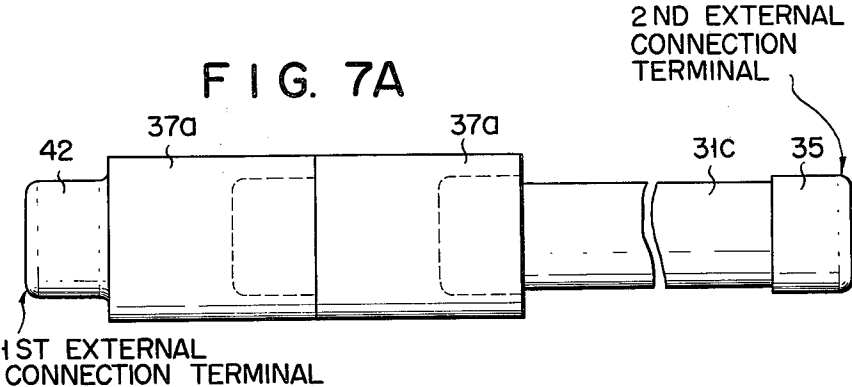
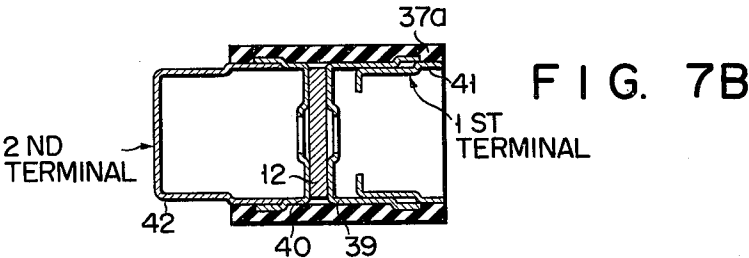
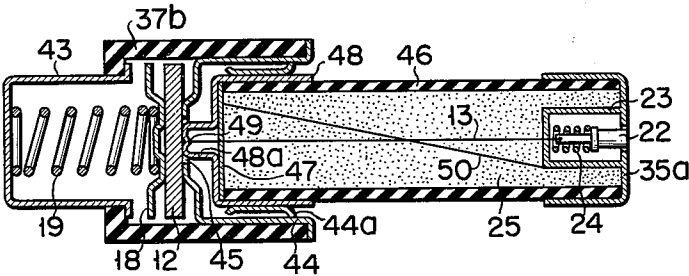


FIG. 7B

FIG. 8



SURGE VOLTAGE ABSORBER

This invention relates to a surge voltage absorber including a nonlinear resistance element made of metal oxide and more particularly to an improved surge voltage absorber miniaturized into an integral body and provided with a built-in display member for immediately indicating the breakage of said surge voltage absorber.

Generally, a circuit including a semiconductor element, for example, a thyristor is provided with a surge voltage absorber to protect the semiconductor element from an abnormal surge voltage resulting from the operation of, for example, a switch or a tremendously large surge voltage originating with thunder lightning. To this end, a condenser or resistor, for example, is connected parallel to a semiconductor element requiring protection. Further, the above-mentioned semiconductor circuit is sometimes provided with a thyristor surge voltage absorber, controlled avalanche rectifier voltage absorber or selenium arrestor element. However, a surge voltage absorber formed of a condenser or resistor and intended to dispose of surge voltage having an extremely large amount of energy would have to be bulky, resulting in high cost. On the other hand, it would be difficult to construct a large capacity surge voltage absorber of a controlled avalanche rectifier element.

A nonlinear resistor element used as a surge voltage absorber should have a large nonlinear coefficient and, moreover, leakage current of said element has to be minimized. However, the thyristor or selenium element undesirably has a small nonlinear coefficient and in consequence gives rise to high leakage current. Further, it is demanded that the breakage of a surge voltage absorber be unfailingly indicated, an element requiring protection be saved from damage which might arise from a second occurrence of surge voltage after the breakage of a surge voltage absorber, and the surge voltage absorber itself be made into a compact integral body so as to be very easily exchanged or handled.

It is accordingly the object of this invention to provide a surge voltage absorber which includes a nonlinear resistance element absorbing a large amount of surge voltage energy and giving rise to little leakage current, admitting of miniaturization into an integral body at low cost and whose breakage is immediately indicated with sufficient clearness.

A surge voltage absorber according to this invention comprises a holding structure for holding a first external connection terminal, at least one nonlinear resistance element made of metal oxide, a first fusible element and a second external connection terminal bored with a penetrating hole such that they constitute an electrical series circuit; a display member disposed in the recess of the second external connection terminal and displaced to the outside through the penetrating hole of the second external connection terminal when the first fusible element does not constitute part of the series circuit; and a biasing device for displacing the display member to the outside when the first fusible element does not constitute part of the series circuit.

The surge voltage absorber of this invention may be modified, as need arises, into the type in which the holding structure consists of a first envelope containing at least one nonlinear resistance element made of metal oxide and a second envelope holding the first fusible

element, display member and the biasing device of said display member, said second envelope being detachably inserted at one end into the first envelope.

In another modification, a plurality of the first envelopes may be separably connected together in series. In still another modification, the first fusible element is attached at one end to a conductor contacting a nonlinear resistance element by means of low melting metal, and when the nonlinear resistance element is deteriorated, the low melting metal is melted by the raised temperature of said element resulting from its deterioration to detach one end of the first fusible element, thereby indicating said deterioration.

It will be understood that the surge voltage absorber of this invention may be applied in many other modifications.

This invention can be more fully understood from the following detailed description when taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a cross sectional view of a surge voltage absorber according to a first embodiment of this invention;

FIG. 2 illustrates the voltage-current characteristics of the nonlinear resistance element of metal oxide shown in FIG. 1;

FIG. 3A shows the wave form example of surge voltage impressed across a surge voltage absorber in general use;

FIG. 3B indicates the wave form of the surge voltage of FIG. 3A appearing across the nonlinear resistance of the surge voltage absorber of this invention;

FIGS. 4A to 4D present the manners in which the surge voltage absorber of the invention is connected to a circuit requiring protection;

FIG. 5 is a cross sectional view of a surge voltage absorber according to a second embodiment of the invention;

FIG. 6 is a cross sectional view of the first envelope of a surge voltage absorber according to a third embodiment of the invention;

FIG. 7A is a plan view of a surge voltage absorber according to a fourth embodiment of the invention;

FIG. 7B is a cross sectional view of one of the first envelopes of FIG. 7A; and

FIG. 8 is a cross sectional view of a surge voltage absorber according to a fifth embodiment of the invention.

Referring to FIG. 1, a cup-shaped external connection terminal 11, a nonlinear resistance element 12 made of metal oxide, a first fusible element 13 and a second cup-shaped external connection terminal 15 bored at the center with a penetrating hole 14 are jointly received in a cylindrical case 16 made of insulating material. The nonlinear resistance element 12 is disposed under pressure between an elastic washer 18 placed on a metal plate 17 provided at the stepped portion of the insulation case 16 and another elastic washer 20 urged to the left of FIG. 1 by a spring 19, one end of which contacts the inner wall of the first external connection terminal 11. The latter elastic washer 20 is connected to the first external connection terminal 11 by a flexible conductor 21. The indicated right side of the first fusible element 13 is either connected to the metal plate 17, or when it is replaced by an insulation plate, connected to the former elastic washer 18. A display member 22 has a section 22b extending to the right through a flange 22a. This extension 22b has its

inner end connected to the other end of the first fusible element 13. The open end of a cylindrical member 23 constituted by a penetrating hole 23a permitting the reciprocation of the extension 22b therethrough is fixed to the inner wall of the second external connection terminal 15, namely, to the periphery of the penetrating hole 14. The display member 22 is mechanically biased by a spring 24 received in the cylindrical member 23 so as to cause the display member 22 to be displaced to the outside when the first fusible element 13 is melted.

Referential numeral 25 denotes a filler such as fine particles of silicon dioxide for assisting extinction of arc when the first fusible element 13 is melted. The nonlinear resistance element 12 of metal oxide consists of a disk prepared by sintering a mixture of 87 to 12 mol % ZnO, 12 to 87 mol % MgO and 1 to 30 mol % Sb_2O_3 , and baking a silver coating to both sides of the disk. This resistance element 12 displays, as in FIG. 2, the prominent nonlinearity of current I (plotted on the ordinate) relative to voltage E (plotted on the abscissa). The resistance element 12 which does not substantially permit the passage of current under lower voltage than prescribed extremely minimizes leakage current when used as an element of a surge voltage absorber. The first fusible element 13 which is always subjected to tension by a spring 24 should have a sufficient rigidity to overcome said tension. To this end, therefore, the fusible element 13 is made of, for example, iron or tungsten end is chosen to have a relatively large amount of resistance, for example, 500 milliohms to 1 ohm, and further a large positive temperature coefficient of resistance. The fusible element 13 acting as a trigger for the display member can also be named as a trigger wire. Since, however, it is melted when impressed with an abnormally large energy of surge voltage, it is referred to as a fusible element in this invention.

In FIG. 2, where currents I_1 and I_2 are conducted through the nonlinear resistance element 12, the levels of voltage impressed across said element 12 are denoted as E_1 and E_2 . The ratio of E_1/I_1 or E_2/I_2 can be varied with the kinds of component elements of the nonlinear resistance element 12 or the mixed proportions thereof. It is therefore easy to select such a resistance element as much as the desired level of voltage appearing across said element with respect to a fixed amount of current. Now let it be assumed that the resistance element 12 is impressed, as shown in FIG. 3A, with surge voltage having a peak value of E_0 , and the current I_1 of FIG. 2 runs through said resistance element 12. Then the voltage therein is limited, as seen from FIG. 2, to the voltage of E_1 volts shown in FIG. 3B. Therefore, an element of a circuit requiring protection, for example, a semiconductor controlled rectifier (SCR) having a higher withstand voltage level than E_1 volts will be fully protected from surge voltage.

FIG. 4 presents the manners in which the surge voltage absorber I of FIG. 1 is connected to a circuit requiring protection. FIG. 4A denotes the case where the surge voltage absorber I is connected parallel to the A.C. supply source 26a of an SCR rectifying circuit to which a load L is connected. FIG. 4B represents the case where the surge voltage absorber I is connected parallel to the load L. FIG. 4C shows the case where three surge voltage absorbers are connected in the delta formation to the 3-phase supply source 26b of the SCR rectifier. FIG. 4D indicates the case where three

surge voltage absorbers are parallel connected in the Y formation to a motor M supplied with power through a 3-phase interrupter 27. Thus, the SCR, load L and motor M are saved from the impression of an unduly high level of surge voltage, preventing the A.C. supply source 26a from being short-circuited.

There will now be described in detail the protective function of the surge voltage absorber of FIG. 1. This absorber continues to act as such, so long as a relatively small amount of surge voltage energy is impressed across the first external connection terminal 11 and the second external connection terminal 15, and almost all the energy is absorbed, thereby preventing the breakage of the resistance element 12 and the melting of the fusible element 13. However, where a tremendous high level of voltage is impressed, and the nonlinear resistance element 12 is unfortunately broken, then said element 12 will be considerably decreased in resistance value and a large amount of current will run through the fusible element 13, resulting in its melting. At this time, the biasing force of the spring 24 acting to the left side of FIG. 2 causes the display member 22 to be moved to the left until the flange 22a of said display member 22 contacts the periphery of the penetrating hole 14 of the second external connection terminal 15. Accordingly, the displacement of the display member 22 can be utilized in effecting remote indication by activating, for example, a microswitch or in operating the associated protective device. Should the nonlinear resistance element 12 be broken, its resistance will be noticeably reduced, leading to the short-circuiting of the A.C. supply source 26a of FIG. 4A. At this time, however, the fusible element 13 is immediately melted to carry out the above-mentioned indication, thereby quickly eliminating the short-circuited condition.

As mentioned above, this invention provides a surge voltage absorber having a large capacity to absorb the energy of surge voltage and capable of immediately indicating the breakage of the nonlinear resistance element and easily admitting of miniaturization. Further, it will be understood that the surge voltage absorber of this invention can be applied in various modifications.

FIG. 5 shows a surge voltage absorber according to a second embodiment of this invention where the holding structure consists of a first and a second envelope 30 and 31, each consisting of a cylindrical member made of insulating material. The first envelope 30 contains a nonlinear resistance element 12 made of metal oxide. The first envelope 30 is provided on the left side with a first terminal 32 and on the right side with a second terminal 33 used as the first external connection terminal. The first terminal 32 has a folded portion 32a, the end of which is elastically fitted into a groove 30a cut out on the outer peripheral surface of the first external envelope 30. Referential number 30b denotes a recess of said first inner connection terminal 32. The second terminal 33 has its end attached to the outer peripheral surface of the first envelope 30 on the indicated right side to constitute a concave section 31b. The nonlinear resistance element 12 is disposed under pressure between the outer surface of the bottom of the first terminal 32 and the elastic washer 20a urged to the left side by the spring 19a. The washer 20a is connected to the second terminal 33 by means of a flexible conductor 21a. Fitted into the right end portion of the second envelope 31 is a third cup-shaped terminal 34. Received in the left end portion of the second envelope 31

is a fourth terminal 35 used as the second external connection terminal bored at the center with a penetrating hole 14a. The fusible element 13 is connected at the right end to the third terminal 34. Since the combination of the display member 22, cylindrical member 23 and spring 24 and the display operation taking place upon the melting of the fusible member 13 has already been described by reference to FIG. 1 description thereof is omitted. As shown in FIG. 5, the third terminal 34 of the second envelope 31 is detachably inserted into the first terminal 32 of the first envelope 30 to constitute a surge voltage absorber. In this case, the inner wall of the first terminal 32 is provided with four elastic inwardly extending cutout projecting strips (not shown) so as to assure the firm insertion of the third terminal 34. Under this arrangement, the second terminal 33 acts as a first external connection terminal and the fourth terminal 35 as a second external connection terminal.

A surge voltage absorber according to a second embodiment of FIG. 5 is characterized by the advantage that the first envelope 30 and second envelope 31 are separably connected together to admit of the easy formation of a surge voltage absorber of different rating and that when the absorber as a whole has lost its function, either the first or second envelope 30 or 31 can be replaced by a fresh one.

FIG. 6 shows a modification of the first envelope 30 of FIG. 5 as a third embodiment of this invention. In this modified first envelope 37, the mutually facing sides of two nonlinear resistance members 12a and 12b abut against the corresponding surfaces of two elastic washers 38. The other side of the resistance element 12a contacts an elastic member 39, and the other side of the resistance element 12b another elastic member 40. A first terminal 41 corresponding to the first terminal 32 of FIG. 5 contacts the elastic member 39. The third terminal 34 of the second envelope 31 of FIG. 5 is detachably inserted into the first terminal 41. A second terminal 42 contacts the elastic member 40 to act as a first external connection terminal. The third embodiment of FIG. 6 is characterized in that the first terminal 41 has an inner diameter equal to the outer diameter of the second terminal 42, and, if necessary, a plurality of the first envelopes 37 can be separably connected in series, thereby providing a surge voltage absorber capable of absorbing a tremendously high level of surge voltage.

FIG. 7 represents a surge voltage absorber according to the fourth embodiment of this invention, in which the first envelope 37a (FIG. 7B) has an arrangement resembling that of the first envelope 37 of FIG. 6 but different in that only one nonlinear element 12 is received. The parts of FIG. 7 the same as those of FIG. 6 are denoted by the same numerals and description thereof is omitted. FIG. 7A shows a surge voltage absorber in which two envelopes 37a shown in FIG. 7B are connected in series and a second envelope 31c having the same construction as the second envelope 31 of FIG. 5 is connected in series to the above-mentioned two envelopes 37a. In this case, the second terminal 42 is used as a first external connection terminal and the fourth terminal 35 as a second external connection terminal. The embodiment of FIG. 7 has the same characteristics as the third embodiment of FIG. 6.

FIG. 8 indicates a surge voltage absorber according to a fifth embodiment of this invention. The first enve-

lope 37b is provided on the left side with a second terminal 43 acting as a first external connection terminal and on the right side with a first terminal 44. This terminal 44 is bored at the center with a penetrating hole 45. The nonlinear resistance element 12 is pressed on one side against the periphery of the hole 45 and on the other side against the elastic washer 18 urged by a spring 19 to the indicated right side. The inner wall of the first terminal 44 is provided with a plurality of elastic projecting strips 44a. A second envelope 46 is provided on the indicated right side with a fourth terminal 35a used as a second external connection terminal having the same construction as the fourth terminal 35 of FIG. 5 and containing the display member 22, cylindrical member 23 and spring 24. Fitted to the left side of the second envelope 46 is a third terminal 48 so as to abut against a metal cover 47. The projecting portion 48a of the third terminal 48 is brought into contact with the nonlinear resistance element 12 when the third terminal 48 is inserted into the first terminal 44 in a state supported by the elastic projecting strips 44a. The first fusible element 13 is fixed at one end to the inside of the projecting portion 48a by means of a metal piece 49 melting at a low temperature, for example, 100°C, and at the other end the display member 22. Further, a second fusible element 50 is connected between the metal cover 47 and cylindrical member 23. The first fusible element 13 is always subjected to a sufficient tension mechanically to withstand the rightward biasing force of the spring 24. The second fusible element 50 has a smaller degree of resistance than the first fusible element 13, namely, such melting property that when an abnormally high level of surge voltage is impressed across the second terminal 43 and fourth terminal 35a to destroy the nonlinear resistance element 12 and a large amount of current runs through said element 12, then the second fusible element 50 melts away prior to or simultaneously with the melting of the first fusible element 13.

Now let it be assumed that in the embodiment of FIG. 8, the nonlinear resistance element 12 is deteriorated due to long use and allows the passage of higher leakage current than prescribed, for example, more than 30 milliamperes even under the normal condition free from surge voltage. Then the surface of the resistance element 12 is heated to higher temperature than 100°C due to Joule heat, causing the low-melting metal piece 49 to melt away and in consequence the first fusible element 13 to be separated from the projecting portion 48a of the third terminal 48. As the result, the display member 22 is pushed to the outside. Where an extremely higher level of surge voltage than the protective voltage limit of the nonlinear resistance element 12 is impressed thereon to destroy said element 12, then a large amount of current runs mainly through the second fusible element 50, which immediately melts away. Almost simultaneously or just slightly later, the first fusible element 13 also melts away to save a circuit requiring protection from any resulting damage or failure. At this time, too, the display member 22 is pushed out of the fourth terminal 35a.

The embodiment of FIG. 8 safely protects the component elements of a circuit even when it is impressed with a tremendously large energy of surge voltage. It has been considered difficult to provide a compact surge voltage absorber fully carrying out three functions of absorbing high surge voltage energy, detecting

the deterioration of the nonlinear resistance element and saving the component elements of a circuit from the harmful effect of the destruction of the nonlinear resistance element. However, this invention has satisfactorily resolved this problem.

In the embodiments of FIGS. 5, 6 and 7, it is obviously possible to form a projecting portion on the third terminal of the second envelope, cause said projecting portion to contact the nonlinear resistance element 12 and fix one end of the first fusible element 12 to the projecting portion by means of a low-melting metal piece.

What we claim is:

1. A surge voltage absorber which comprises a holding structure;

a first external connection terminal provided at one end of said holding structure;

a second external connection terminal having a penetrating hole and provided at the other end of said holding structure;

at least one nonlinear resistance element made of metal oxide and provided within said holding structure so as to be electrically connected to said first external connection terminal at its one end;

a first fusible element arranged so as to be electrically connected at its one end to the other end of said nonlinear resistance element;

a display member disposed in a recess of said second external terminal, connected to the other end of said fusible element and displaceable to the outside through said penetrating hole; and

a biasing device which electrically contacts said second external connection terminal and said display member and causes said display member to project through said penetrating hole when said fusible element is melted away.

2. A surge voltage absorber according to claim 1 wherein the electrical connection between said other end of said nonlinear resistance element and said one end of said fusible element is effected by a conductor contacting said other end of said nonlinear resistance element and a low-melting metal piece for fixing said one end of said first fusible element to said conductor.

3. A surge voltage absorber according to claim 2 further comprising a second fusible element connected at both ends to said conductor contacting said other end of said nonlinear resistance element and said second external connection terminal respectively, said second fusible element having a smaller degree of resistance than said first fusible element.

4. A surge voltage absorber according to claim 1

wherein the holding structure consists of a first envelope containing at least one nonlinear resistance element made of metal oxide, a first terminal electrically connected to one side of the nonlinear resistance element and a second terminal, electrically connected to the other side of the resistance element and a second envelope containing a third terminal electrically connected to one end of the first fusible element, fourth terminal electrically connected to the other end of said first fusible element and bored with the penetrating hole, said display member and biasing device; the third terminal of the second envelope is detachably inserted into the first terminal of the first envelope; and the second terminal is used as the first external connection terminal and the fourth terminal as the second external connection terminal.

5. A surge voltage absorber according to claim 4 wherein the third terminal of the second external envelope has a projecting portion contacting the nonlinear resistance element, the first fusible element being fixed at one end to said projecting portion by means of a low-melting metal piece readily melting when the nonlinear resistance element is raised to a higher temperature than prescribed.

6. A surge voltage absorber according to claim 5 further comprising a second fusible element connected between the third terminal of the second envelope and the fourth terminal, said second fusible element having a smaller degree of resistance than the first fusible element so as to melt away when impressed with surge current prior to or simultaneously with the melting of the first fusible element.

7. A surge voltage absorber according to claim 1 wherein the holding structure consists of a plurality of first envelopes each containing at least one nonlinear resistance element made of metal oxide, a first terminal electrically connected to one side of the nonlinear resistance element and a second terminal electrically connected to the other side of the resistance element and a second envelope containing a third terminal electrically connected to one end of the first fusible element, fourth terminal electrically connected to the other end of said first fusible element and bored with the penetrating hole, said display member and biasing device; said first envelopes are connected in series by inserting the second terminal of a first envelope to the first terminal of another first envelope and said third terminal of second envelope is inserted to the outermost first terminal of said series connected first envelopes.

* * * * *