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[54] **SPACER-DAMPER FOR BUNDLE CONDUCTORS**

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[52] **U.S. Cl.** **174/42,** 174/146, 267/152, 267/74

[51] **Int. Cl.** **H02g 7/14,** H02g 7/12

[58] **Field of Search** 267/140, 141, 152, 73, 267/74; 174/42

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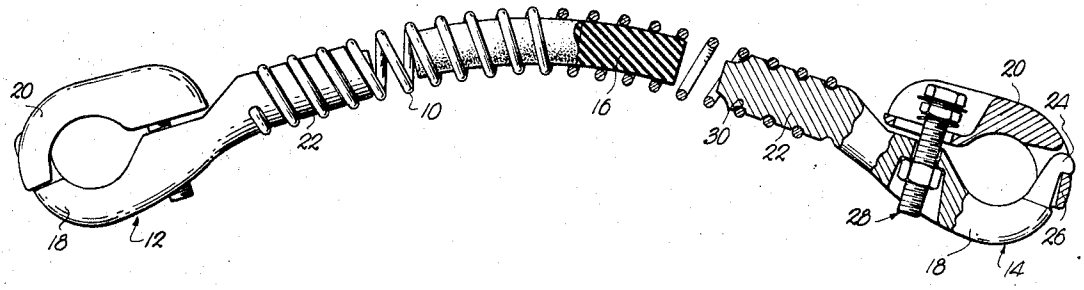
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[57] **ABSTRACT**

Spacer-damper apparatus for bundle conductors includes an elongated, tubular spring member which telescopically receives a yieldable damping element. The damping element is formed from a rubber-like material characterized by the property of absorbing large quantities of energy upon deformation thereof which is released primarily as heat rather than in the rapid restoration of the element to its initial configuration. A pair of conductor gripping components are provided at opposite ends of the spring member for connection to spaced high voltage conductor cables.

23 Claims, 7 Drawing Figures



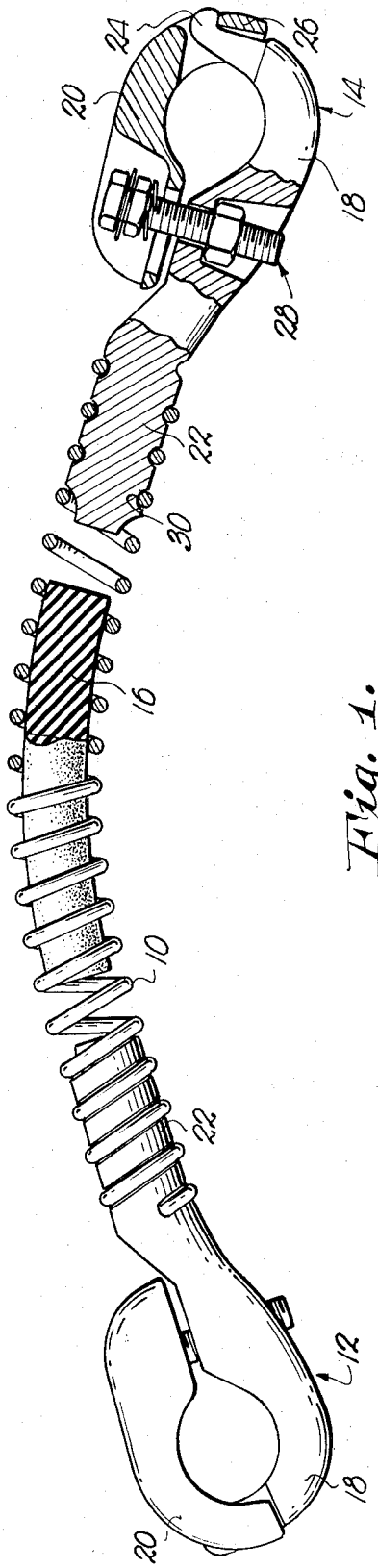


Fig. 1.

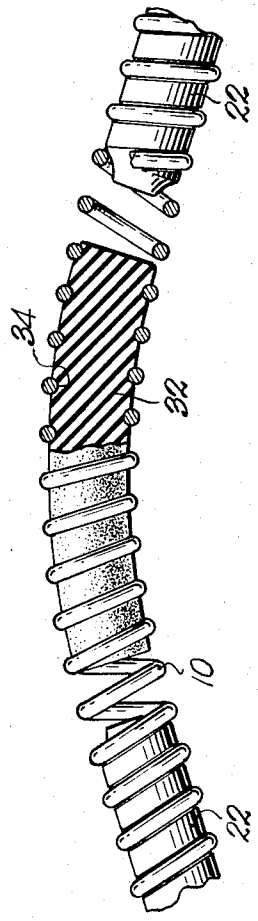


Fig. 2.

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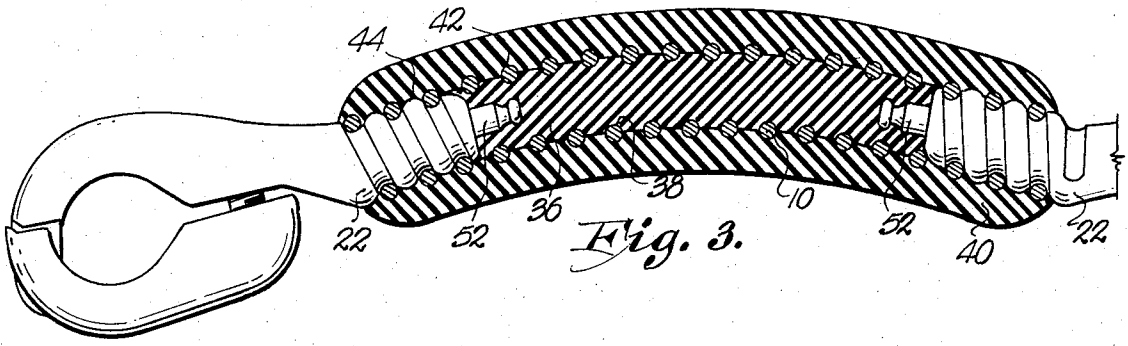


Fig. 3.

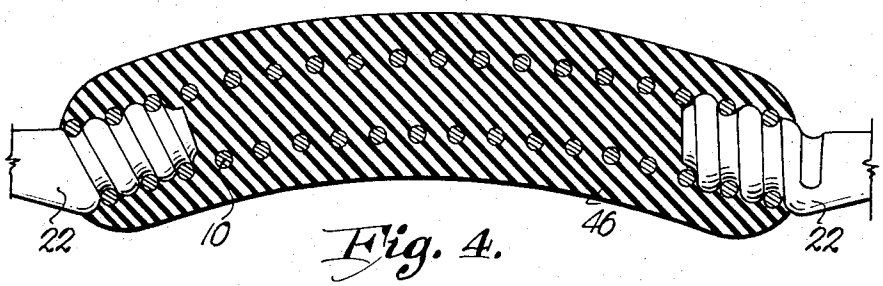


Fig. 4.

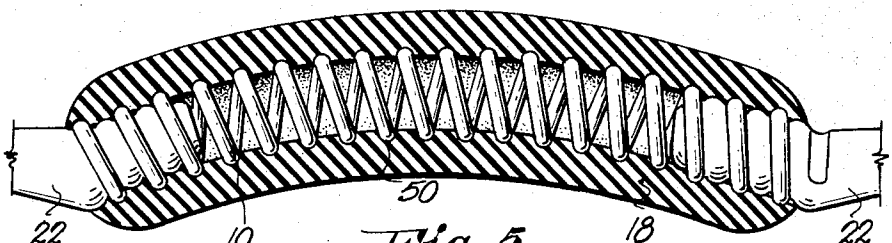


Fig. 5.

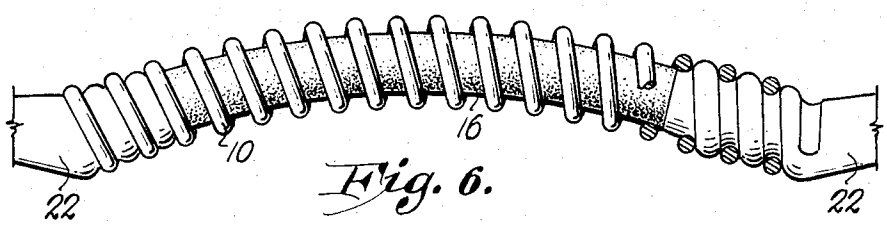


Fig. 6.

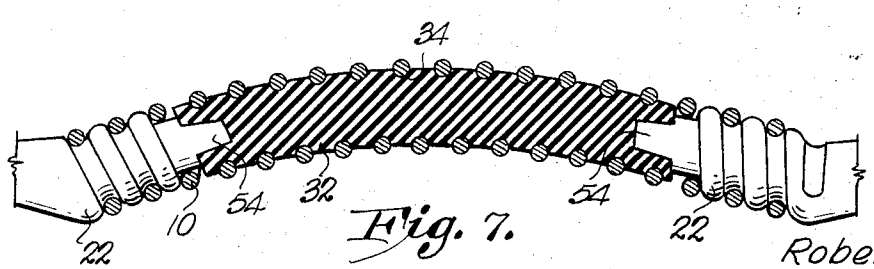


Fig. 7.

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SPACER-DAMPER FOR BUNDLE CONDUCTORS

The present invention relates to high voltage power transmission equipment and particularly to spacer-damper apparatus for bundle conductors.

Wind-induced vibration is one of the most persistent operating hazards of overhead transmission lines. Damaging oscillations traditionally have been divided into two categories, designated for convenience as either aeolian or galloping. The former is far more common and is probably responsible for most line damage. This type of oscillatory motion may be induced by nothing more than a low velocity crosswind. Full-wave amplitudes with aeolian oscillations seldom exceed one or two conductor diameters, and half-loop lengths range from 10 to 30 feet, with frequencies in the range of 10 to 60 cycles per second.

Galloping conductors are far more rare and normally require the buildup of ice on the lee side of a conductor. Such a buildup of ice produces a crude airfoil which, in conjunction with the torsional response of the conductor, can produce a varied assortment of violent wave motions. In extreme cases, amplitudes as high as 50 feet have been observed. With such extreme motions, line outages and damage are inevitable.

Attempts to control aeolian vibrations along conventional single conductor transmission lines has met with moderate success through the use of dampers, conductor clamps with low inertia and high mobility, avoidance of resonant tower elements, and maintenance of low to moderate conductor tension. Control of galloping vibrations has, on the other hand, met with little success.

The introduction of bundle conductor systems in recent years has blurred the distinction between aeolian and galloping vibrations and has generally aggravated the overall problem. Numerous instances have been noted of bundle conductor systems vibrating in large amplitudes which would previously have been called galloping, when there was no ice present. The simple system has become complex through aerodynamic influences and the interchange of energy between subconductors. Spacers and suspension points in bundle conductor systems provide direct communication between the subconductors, multiplying the possible modes of vibration. For example, bundle conductors have been observed vibrating in a horizontal plane, a condition not previously encountered with single conductor systems. Another phenomena observed with bundle conductors is that often the windward conductors will hang quietly, doing little except to set up vortices in the air currents which are carried across to agitate the other conductors into vibration. No general classification of bundle conductor vibration has been established, but the need for an effective damping means is clearly evident.

Prior damping devices have consisted largely of weights that were mounted on a single conductor clamp through flexible wire cables such that during vibration of the conductor, the weight tended to remain stationary or oscillate out of phase with the conductors and the vibration was dissipated through friction in the flexible cables. The effectiveness of such devices was hampered by the fact that their relatively high masses tended to result in the creation of nodal points at the location of the damper thus partially eliminating the energy absorbing action of the damper. Furthermore,

such prior devices performed only a damping function and did not serve to maintain the spatial relationship of bundle conductors.

Spacers previously used with bundle conductors included those constructed from helical rods which were wrapped around adjacent conductor cables and extended therebetween to maintain the cables in spaced relationship. While such devices had the desired low mass, they were not capable of performing a substantial damping function.

Another device previously used was a rigid spacer provided with rubber mounts on the conductor gripping components. Problems associated with increased masses were encountered with this type of device and it also was incapable of performing both a satisfactory spacing and damping function. Both of the spacers described above were incapable of responding to the large scale motions that can occur along a high voltage transmission line because of fault currents or ice dropping from the lines.

It is, therefore, the primary object of this invention to provide a spacer-damper assembly for bundle conductors which not only effectively maintains the conductors in spaced relationship without causing damage to the individual conductors, but also is capable of lessening the tendency of the conductors to vibrate, particularly in the form of damaging oscillations.

Another important object of this invention is to provide a spacer-damper assembly for bundle conductors with the ability to respond to the large scale motions produced by fault currents or ice dropping from the lines.

A further important object of this invention is to provide spacer-damper apparatus for bundle conductors having a spring member for maintaining the conductor cables in the desired spatial relationship and an energy-absorbing, yieldable element for controlling vibrations of the type peculiar to bundle conductor systems.

As a corollary to the above object, it is also an object of this invention to provide spacer-damper apparatus as aforesaid wherein the damping characteristics are enhanced by the provision of a yieldable element characterized by the property of absorbing large quantities of kinetic energy upon deformation thereof which is released primarily as heat rather than in restoration of the element to its initial configuration.

Yet another object of the invention is to provide spacer-damper apparatus for bundle conductors as previously described having a sufficiently low mass such that the apparatus does not tend to create nodal points for the oscillating movements.

Still another object of the invention is to provide spacer-damper apparatus for bundle conductors that is capable of absorbing the energy of large scale motions such as those produced by fault currents, and is also capable of restoring normal spacing following such disturbances.

An object of this invention is also to provide spacer-damper apparatus for bundle conductors that can be inexpensively constructed, thereby permitting incorporation of the apparatus at every needed location and also the provision of energy-absorbing elements at frequent intervals along the conductors.

Still other objects of the invention will become apparent or be made clear from the following specification when read in light of the accompanying drawings, wherein:

FIG. 1 is a side elevational view of one embodiment of the spacer-damper apparatus with portions of the same shown in cross section for purposes of illustration;

FIG. 2 is a fragmentary, side elevational view of the spacer-damper apparatus showing an alternative embodiment of the damping element, portions of the apparatus being shown in cross section for purposes of illustration;

FIG. 3 is a fragmentary, side elevational view of still another form of the spacer-damper apparatus with the damping element being shown in cross section for purposes of illustration;

FIG. 4 is a fragmentary, side elevational view of yet another embodiment of the spacer-damper apparatus with the damping element shown in cross section for purposes of illustration;

FIG. 5 is a fragmentary, side elevational view of another alternative embodiment of the apparatus with the damping element being shown in cross section for clarity;

FIG. 6 is a fragmentary, side elevational view of the spacer-damper apparatus showing an alternative form of the embodiment illustrated in FIG. 1; and

FIG. 7 is a fragmentary, side elevational view of the apparatus with the damping element being shown in cross section and illustrating an alternative form of the embodiment shown in FIG. 2.

Referring to the drawing, and initially to the embodiment illustrated in FIGS. 1 and 6, the spacer-damper apparatus includes an elongated, tubular spring member such as a curvilinear coil spring 10 and a pair of conductor-gripping components 12 and 14 connected to the spring 10 at opposite ends of the latter. An elongated, generally cylindrical, yieldable damping element 16 is telescopically received within the spring 10.

Each of the conductor-gripping components 12 and 14 includes a body portion 18, a keeper 20, and a leg portion 22 integral with the body portion 18. The body portion 18 and the keeper 20 are provided with mating flanges 24 and 26 respectively for cooperating with a conventional breakaway bolt assembly 28 to hold the components 12 and 14 in gripping engagement with a conductor cable (not shown). Bolt assembly 28 is of the breakaway type to not only insure proper tightening of the components 12 and 14 around a pair of conductors but also to prevent excessive tightening which would result in damage to the conductors. A spiral groove 30 along the outer surface of each of the leg portions 22 receives the spiral convolutions of the respective ends of the coil spring 10.

It is preferred that the ends of the damping element 16 be disposed in abutting relationship to the leg portions 22 and bonded thereto by a suitable adhesive (as illustrated in FIG. 6) or otherwise secured to prevent any movement of the element 16 relative to the spring 10. In some cases, however, where the conductor cables are not subjected to extremely excessive line motions, it has been found satisfactory to omit the bond between the damping element 16 and the leg portions 22 and maintain the element 16 in spaced relationship to the leg portions 22, as illustrated in FIG. 1.

In an alternative form of the invention as illustrated in FIGS. 2 and 7, an elongated, generally cylindrical damping element 32 is telescopically received within the coil spring 10, the latter being secured to the leg portions 22 of a pair of conductor-gripping components in the same manner as previously described for the embodiment of FIGS. 1 and 6. In the structure shown in FIGS. 2 and 7 however, the damping element 32 is provided with a spiral groove 34 in the outer surface thereof having a depth less than the diameter of the spiral convolutions of the spring 10 for complementally receiving the convolutions of the spring. This inhibits relative shifting of the spring 10 and the damping element 32 and is particularly desirable when the ends of the damping element are spaced from the leg portions 22 as illustrated in FIG. 2. As shown in FIG. 7 however, the respective ends of the damping element 32 may be disposed in abutting relationship to the leg portions 22 and secured thereto by a suitable adhesive.

A third alternative embodiment of the invention is illustrated in FIG. 3 wherein a damping element 36 is shown telescoped within the coil spring 10 between the leg portions 22 of the conductor-gripping components. The damping element 36 is bonded or otherwise secured to the leg portions 22, and a spiral groove 38 in the outer surface thereof complementally receives the spiral convolutions of the coil spring 10. A second elongated, generally tubular damping element 40 extends substantially the entire length of the spring 10 and has open ends for receiving the respective leg portions 22. The second damping element 40 is cast around the spring 10 with the first damping element 36 disposed therein to provide a configuration having a first spiral groove 42 in the inner surface thereof for receiving the spiral convolutions of the spring 10, and a second groove 44 for mating with the irregular surface of the leg portions 22. It is to be understood, of course, that the second damping element 40 may be preformed around the spring 10 and the first damping element 36 subsequently disposed within the spring.

A fourth alternative embodiment of the invention is illustrated in FIG. 5 wherein the spiral convolutions of the coil spring 10 are received by the leg portions 22 of the conductor-gripping components, and a damping element 46 is cast in and around the coil spring 10 over substantially the entire length of the latter in a manner to receive the leg portions 22 at opposite ends of the element 46.

In the further embodiment of the invention, as illustrated in FIG. 5, the spiral convolutions of the coil spring 10 are received by the grooves 30 in the respective leg portions 22 and a generally tubular damping element 48 is disposed in surrounding relationship to the coil spring 10. The damping element 48 is provided with a spiral groove 50 in its inner surface which receives the spiral convolutions of the spring 10, and the ends of the damping element 48 are open for receiving the respective leg portions 22.

It is important that each of the damping elements 16, 32, 36, 40, 46 and 48 be constructed of a "dead" rubber such as butyl, silicone or other rubber-like material that is characterized by the property of absorbing large quantities of energy upon deformation and which is released primarily as heat rather than in the rapid restoration of the material to its initial configuration. This assures that the apparatus will respond to the large-scale motions produced by fault currents or the like thereby permitting the individual conductor cables to approach each other in a manner not possible with more rigid structures while at the same time assuring the return of

these cables to their normal spaced positions as the kinetic energy is dissipated into heat.

An alternative form for the gripping components **12** and **14** is illustrated in FIGS. **3** and **7**. In FIG. **3** it is seen that each of the leg portions **22** is provided with a longitudinally extending tongue **52** which is embedded within the damping element **36**. A longitudinally extending tongue **54** of slightly different configuration is illustrated projecting from each of the leg portions **22** and embedded in the damping element **32** in FIG. **7**. The tongues **52** and **54** serve to mechanically grade out sharp flexing of the spring **10** in the vicinity of the leg portions **22**.

When the conductor-gripping components **12** and **14** of any of the embodiments of the invention are secured to a pair of adjacent conductors, the combination of the coil spring **10** and the yieldable damping element of rubber-like energy-absorbing material provides spacer-damper apparatus that is particularly effective in not only controlling bundle conductor vibrations but is also capable of responding to the large-scale line motions along the conductors which result from fault currents or ice dropping from the lines to restore normal spacing following such disturbances. The curvilinear configuration of the spring **10** assures that flexing thereof always take place in the same direction. This precludes undesirable slight unwinding of the individual conductor cables which could otherwise occur under certain conditions if the spring **10** was allowed to flex in more than one direction.

When a line motion disturbs the spatial relationship of two or more conductors the kinetic energy is absorbed by the appropriate damping element as the latter is deformed. A large percentage of the energy is dissipated as heat and the remainder of the energy serves to slowly return the damping element to its initial configuration and thereby restore the conductors to their desired spatial positions. A very desirable feature of the invention is the manner in which damping is effectively accomplished without sacrifice in the flexibility of the spacer, i.e., the spring **10**. This permits the conductors to approach each other during a fault current or other disturbance thereby avoiding physical stresses on the conductors which would inherently result with a rigid structure where the conductors are held in spaced relationship by generally unyielding members. Additionally, the inherent lightweightness of the spacer-damper of the present invention avoids the tendency for nodal points to form at the location of the apparatus as is the case with damping structures employing suspended weights.

Having thus described the invention, what is claimed as new and desired to be secured by Letters Patent is:

1. Spacer-damper apparatus for bundle conductors comprising:

an elongated spring member;

a pair of conductor gripping components connected to the spring member at opposite ends of the latter and constructed to be secured to respective conductors in clamping relationship thereto; and

an elongated, yieldable, damping element of a dead rubberlike material disposed between said components, said material being characterized by the property of absorbing the energy of motion imparted thereto by relative movement of said conductors, primarily as heat rather than restoration of the element to its initial configuration.

2. The invention of claim **1**, wherein said element comprises a rubber-like material characterized by the property of absorbing large quantities of kinetic energy upon deformation thereof which is released primarily as heat rather than in restoration of the element to its initial configuration.

3. The invention of claim **2**, wherein said element comprises silicone rubber.

4. The invention of claim **2**, wherein said element comprises butyl rubber.

5. The invention of claim **1**, wherein said spring member is of curvilinear configuration to assure flexing thereof in but one direction.

6. The invention of claim **1**, wherein said member includes an elongated coil spring, said element is received within said spring in abutting relationship to said components, and each of said components includes a leg portion provided with a spiral groove in the outer surface thereof complementally receiving the spiral convolutions of said spring and a longitudinally extending tongue embedded in said element.

7. The invention of claim **1**, wherein said member is generally tubular, and an elongated, generally cylindrical, yieldable damping element is telescoped into the member intermediate said components.

8. The invention of claim **7**, wherein said member comprises an elongated coil spring and said element is provided with a spiral groove in the outer surface thereof which complementally receives the spiral convolutions of said spring.

9. The invention of claim **7**, wherein the respective ends of the element are joined to respective components.

10. The invention of claim **7**, wherein the respective ends of the elements are spaced from the respective components.

11. The invention of claim **7**, wherein said damping element has a smooth uninterrupted surface.

12. The invention of claim **7**, and a second elongated, yieldable damping element disposed in surrounding relationship to said member and the first mentioned damping element.

13. The invention of claim **12**, wherein said member comprises an elongated coil spring and said second element is provided with a spiral groove in the inner surface thereof which complementally receives the spiral convolutions of said spring.

14. The invention of claim **1**, wherein said element is cast around said member.

15. The invention of claim **14**, wherein said member comprises an elongated coil spring and said element is cast within and around said spring.

16. The invention of claim **1**, wherein said element is generally tubular and disposed in surrounding relationship to said member.

17. The invention of claim **16**, wherein said member comprises an elongated coil spring and said element is provided with a spiral groove in the inner surface thereof which complementally receives the spiral convolutions of said spring.

18. Spacer-damper apparatus for bundle conductors comprising:

an elongated coil spring member;

a conductor gripping component secured to each end of the member and constructed to be secured to re-

spective conductors in gripping relationship thereto;

an elongated yieldable damping element of a dead rubber-like material disposed between said components, said material being characterized by the property absorbing the energy of motion imparted thereto by relative movement of said conductors, primarily as heat rather than restoration of the element to its initial configuration.

19. The invention of claim **18,** wherein said spring member is of curvilinear configuration to assure flexing thereof in but one direction.

20. The invention of claim **18,** wherein the element is provided with a spiral groove in one surface thereof which complementally receives the spiral convolutions of said spring member.

21. The invention of claim **18,** wherein each of said conductor gripping components includes a leg portion provided with a spiral groove in the outer surface thereof complementally receiving the spiral convolutions of said spring member.

22. The invention of claim **21,** wherein said leg portion is received within one end of said damping element.

23. The invention of claim **18,** wherein said damping element extends substantially the length of said spring member in surrounding relationship thereto.

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