

AN IMPROVED FLEXIBLE ELONGATE BODY

This invention relates to flexible elongate bodies of the kind which comprise a plurality of bare elongate elements of metal or metal alloy and which are adapted to be freely supported from spaced supports in long
5 lengths. The invention is especially, but not exclusively, concerned with overhead electric conductors of the kind which comprise one or more than one layer of bare elongate elements of electrically conductive metal or metal alloy but it is to be understood that the
10 invention does not exclude flexible elongate bodies not normally intended to carry electric current, for instance, wire ropes.

In the Complete Specification of our Patent No: 1598438 there is described and claimed a flexible
15 stranded body comprising at least one layer of helically wound bare elongate elements of metal or metal alloy, at least one elongate compartment within and extending throughout the length of the stranded body and, loosely housed in the elongate compartment or at least one of
20 the elongate compartments, at least one separate optical fibre and/or at least one optical bundle.

It is an object of the present invention to provide
— an improved flexible elongate body which is especially suitable for use as an overhead electric conductor.

According to the invention, the improved flexible elongate body comprises at least one layer of helically wound bare elongate elements of metal or metal alloy, at least one elongate compartment within and extending
 5 throughout the length of the elongate body and, loosely housed in the elongate compartment or at least one of the elongate compartments, at least one optical fibre element comprising a flexible tube having a bore in which at least one optical fibre is so loosely housed
 10 that, when the tube is bent or otherwise flexed, the or each optical fibre is free to move to a limited extent transversely of and with respect to the tube, wherein the flexible tube is resiliently set in such a form that the central longitudinal axis of the tube follows a
 15 longitudinally extending path which, between any two longitudinally spaced positions, is greater in length than the rectilinear distance between said two positions, the arrangement being such that, when the resiliently set tube is subjected to a longitudinally
 20 applied tensile force, the tube will tend to straighten in a lengthwise direction against the action of its resilient set thereby to reduce the tensile force applied to the or each optical fibre and, when the tensile force is removed, the tube will return under the action of its resilient set towards its original form.

Preferably, the flexible tube of the optical fibre element is resiliently set in such a form that the central longitudinal axis of the tube follows a path of smoothly curved undulations, the axes of curvature of the undulations preferably lying parallel to one another and substantially normal to the longitudinally axis of the tube. By virtue of the smoothly curved undulations, when the resilient set tube is subjected to a longitudinally applied tensile force, the tube will tend to straighten against the action of its resilient set; that is to say, the length of the radii of the smoothly curved undulations will gradually increase.

Alternatively, the flexible tube of the optical fibre element may be resiliently set in such a form that the central longitudinal axis of the tube follows a substantially helical path, the lay of the helically extending path preferably lying in the range 5° to 15° to the central rectilinear axis of the helically extending tube.

The flexible tube of the optical fibre element may be of circular or non-circular cross-section and, in each case, preferably the radial thickness of the tube wall is substantially constant at all transverse cross-sections of the tube. Where the flexible tube is of non-circular cross-section, preferably it has a transverse cross-section of elongate form, e.g. of an elongate form having two major parallel sides joined by ends of approximately semi-circular shape, and in this

case preferably the flexible tube is resiliently set in such a form that the central longitudinal axis of the tube follows a path of smoothly curved undulations whose axes of curvature lie substantially parallel to the major transverse axes of the flexible tube.

The flexible tube of the optical fibre element is preferably of a plastics material or plastics materials which can be readily resiliently set so that its central longitudinal axis follows a path of the required form but it is to be understood that, in some circumstances, the tube may be of resilient metal or metal alloy.

One or each optical fibre loosely housed in the resiliently set flexible tube preferably is unsupported but, in some circumstances and especially when the tube follows a path of smoothly curved undulations, two or more optical fibres of the optical fibre element may be component parts of at least one optical fibre ribbon structure loosely housed in the bore of the tube. In this case, the optical fibres, and if desired one or more than one flexible elongate reinforcing element, of an optical fibre ribbon structure preferably are arranged side by side and are wholly or partially embedded in a flexible elongate body of plastics material or are arranged side by side and are secured to one major surface of a flexible tape.

In all cases, the flexible tube of the optical fibre element may be substantially filled throughout its length with a water-impermeable medium of a grease like nature which is of such a consistency that the or each 5 optical fibre or the or each optical fibre ribbon structure is free to move relative to the tube when the flexible elongate body vibrates, oscillates or is otherwise flexed. The greasy water-impermeable medium may consist of, or may comprise as a major constituent, 10 silicone gel.

The optical fibre element as above described is the subject of our co-pending Patent Application No: 85/06468 filed on the same day as the present application.

15 By virtue of being housed loosely in the elongate compartment, limited relative movement between the or each optical fibre element and the flexible elongate body can take place when the flexible elongate body vibrates, oscillates or is otherwise flexed as may, for 20 example, occur in the case when an overhead electric conductor or other freely supported flexible elongate body is subjected to winds. Limited relative movement between the or each optical fibre element and the flexible elongate body can also occur when the body is 25 subjected to a changing tensile load during and after its installation due to forces imposed on it by winches and brakes, etc. which are used in tensioning the body

to obtain a predetermined sagging condition; after installation, changes in tensile load in the flexible elongate body can also occur due to changes in external loading and in temperature. Limited relative movement 5 between the or each optical fibre element and the flexible elongate body can also occur whilst the body is in service and creep gives rise to non-elastic extension of the body. In any of these situations, in the unlikely event that a tensile force applied to the 10 flexible elongate body, may be transferred, at least in part, to the or any loosely housed optical fibre element, the flexible tube of the element will straighten in a lengthwise direction against the action of its resilient set thereby to reduce any tensile force 15 that might otherwise be applied to the or any optical fibre and, when the tensile force is removed, the tube will return under the action of its resilient set towards its original form.

In one preferred aspect of the invention, an 20 elongate compartment is within and extends throughout the length of a substantially circumferentially rigid central core and the or each layer of helically wound bare elongate elements of metal or metal alloy surrounds the central core. In one preferred embodiment of this 25 aspect of the invention, the central core is a single elongate member having a central bore which constitutes

the elongate compartment. The single elongate member initially may be of substantially U-shaped transverse cross-section, one or each of the limbs of the U being folded inwardly so that the gap between the free ends of 5 the limbs is at least partially closed, the space between the limbs and the base of the U constituting the elongate compartment; alternatively, the single elongate member initially may be a tape of metal or metal alloy transversely folded to form a tube, the abutting 10 longitudinally extending edges of the tape being welded or otherwise secured together. In all cases, preferably the central core is of substantially circular transverse cross-section.

Alternatively, the central core may be in the form 15 of any one or more of the optional constructions described and illustrated in the Complete Specification of our Patent No: 1598438.

In another aspect of the invention, the central core may consist of two separately formed parts 20 comprising an inner solid elongate member of metal or metal alloy having in its outer surface at least one longitudinally extending recess and, surrounding the inner elongate member, a longitudinally applied transversely folded tape of metal or metal alloy, which 25 tape overlies the or each longitudinally extending recess to form an elongate compartment.

In a further aspect of the present invention, the central core is of aluminium or an aluminium-based alloy; at least one layer of bare elongate elements of steel surrounds the central core; and at least one substantially circumferentially continuous outer layer of aluminium or an aluminium-based alloy surrounds the layer or layers of steel bare elongate elements, aluminium or aluminium-based alloy of the central core and/or of the outer layer at least partially filling interstices between the steel bare elongate elements. In this case, the central core may comprise at least one layer of bare elongate elements of aluminium or an aluminium-based alloy, each element having a transverse cross-section approximating to a sector of an annulus or having a transverse cross-section of such a shape that, when the flexible elongate body is in tension, said element is in interfacial engagement with adjacent bare elongate elements.

In all cases, those parts of the elongate compartment not occupied by the optical fibre element or elements may be substantially filled with a silicone gel or other water-impermeable medium of a grease like nature, the silicone gel or other greasy water-impermeable medium being of such a consistency that the or each optical fibre element is free to move relative to the flexible elongate body when the flexible

elongate body vibrates, oscillates or is otherwise flexed. Another greasy water-impermeable medium may consist of, or may comprise as a major constituent, petroleum jelly.

5 When the improved flexible elongate body is an overhead electric conductor, e.g. an earth conductor of an overhead electric transmission or distribution system, in some circumstances an electric current flowing for a limited period along the conductor, as may
10 occur as a result of a fault or lightning, may be of such a value that there is the risk that heat generated during passage of the current will be conducted to the optical fibre element and to the or any optical fibre and will result in damage to the optical fibre element
15 or such damage to the optical fibre that its light-transmission efficiency is reduced to an undesirable extent. For example, the generated heat may cause plastics material of the flexible tube of the optical fibre element to soften and exert such pressure
20 on the or any loosely housed optical fibre as to reduce its light-transmission efficiency to an undesirable extent.

Accordingly, in some circumstances, the flexible tube of the or each optical fibre element may be of
25 polyethersulphone, polyetherimide or other plastics material capable of withstanding temperatures in the

order of 300°C for a short period and/or a layer of thermally insulating material may be housed in the elongate compartment and surround the optical fibre element or elements. Preferably, the thermally

5 insulating layer is a circumferentially continuous layer which is bonded or otherwise adheres to the boundary surface of the elongate compartment. The layer of thermally insulating material may be firmly bonded to substantially the whole of the boundary surface area of

10 the elongate compartment, or the layer of thermally insulating material may be bonded to mutually spaced portions of the boundary surface area, any air between the thermally insulating layer and the boundary surface serving as additional thermal insulation. The layer of

15 thermally insulating material is preferably a coating of plastics thermally insulating material such as silicone rubber, polytetrafluoroethylene and other fluoroethylene polymers and co-polymers, polyetheretherketone, polycarbonates, polysulphones, polyesters and the

20 aromatic polyamide sold under the Registered Trade Mark "Kevlar". For enhanced thermal insulation, these plastics materials may be in cellular form.

The invention is further illustrated by a description, by way of example, of three preferred forms

25 of optical fibre element suitable for use in an overhead flexible electric conductor and of four preferred forms

of overhead flexible electric conductor incorporating an optical fibre element, with reference to the accompanying drawings, in which:-

Figures 1 to 3 are isometric diagrammatic views,
5 drawn on an enlarged scale, of the three forms of optical fibre element, and

Figures 4 to 7 are transverse cross-sectional views of the four preferred forms of overhead flexible electric conductor.

10 Referring to Figure 1, the first form of optical fibre element 1 comprises eight optical fibres 4 each of which has an overall diameter of 250 μ m and which is loosely housed in the bore of a flexible tube 7 of orientated polyethylene teraphthalate, which tube is of
15 substantially constant circular cross-section throughout its length and has a radially wall thickness of 0.4mm and an internal diameter of 1.8mm. Each of the optical fibres 4 may have a coating of a colour different from that of a coating on each of the other optical fibres.
20 The flexible central longitudinal axis of the tube, and hence the tube, 7 is resiliently set in such a form that the tube follows a path of smoothly curved undulations 8 which have radii of curvature of approximately 60mm and whose axes of curvature lie parallel to one another and
25 substantially normal to the longitudinal axis of the tube.

The second form of optical fibre element 11 shown in Figure 2 comprises an optical fibre ribbon structure 12 comprising eight optical fibres 14 arranged side by side and embedded in an elongate body 16 of silicone acrylate. Each of the optical fibres 14 has an overall diameter of 250 μm and may have a coating of a colour different from that of the coating on each of the other optical fibres. The optical fibre ribbon structure 12 is loosely housed in the bore of a flexible tube 17 which is made of orientated polyethylene terephthalate and which has a transverse cross-section of an elongate form having two major parallel sides joined by ends of approximately semi-circular shape. The flexible tube 17 has a substantially constant wall thickness of 0.3mm, an internal major transverse dimension of 2.5mm and internal minor transverse dimension of 1.0mm; the optical fibre ribbon structure 12 has a major transverse dimension of 2.2mm and a minor transverse dimension of 0.3mm. The flexible tube 17 is resiliently set in such a form that the central longitudinal axis of the tube, and hence the tube, follows a path of smoothly curved undulations 18 which have radii of curvature of approximately 60mm and whose axes of curvature lie substantially parallel to the major transverse axes of the flexible tube.

Referring to Figure 3, the third form of optical fibre element 21 comprises an elongate body 27 which is made of a thermoplastics material and which has a transverse cross-section of elongate form having two major parallel sides joined by ends of approximately semi-circular shape. The elongate body 27 has a major transverse dimension of 6.0mm and a minor transverse dimension of 2.0mm. Extending throughout the length of the elongate body 27 is a bore 29 which has a transverse cross-section of similar shape to that of the body and, embedded in the body on opposite sides of the bore 29, are a pair of resilient copper wires 25. Loosely housed in the bore 29 are two optical fibre ribbon structures 22 each comprising eight optical fibres 24 arranged side by side and embedded in an elongate body 26 of silicone acrylate, each of which optical fibres has an overall diameter of 250 μ m. Each copper wire 25 is set in such a form that the central longitudinal axis of the elongate body 27, and hence the body, itself follows a path of smoothly curved undulations 28 which have radii of curvature of approximately 60mm and whose axes of curvature lie parallel to one another and to the major transverse axes of the elongate body.

When the optical fibre elements 1, 11, 21 shown in Figures 1 to 3 are subjected to a tensile force, the flexible tube 7 and 17 and the elongate body 27 will

tend to straighten in a lengthwise direction against the action of the resilient set in the tubes or in the copper wires 25 thereby reducing the tensile force that would otherwise be applied to the optical fibres 4 and optical fibre ribbons 12 and 22. After the tensile force is removed, the resilient set in the tubes 7 and 17 and in the copper wires 25 will cause the optical fibre elements 1, 11, 21 to return towards their original undulating form.

The overhead flexible electric conductor shown in Figure 4 comprises a central core 41 constituted by a single extruded elongate aluminium member 42 of substantially U-shaped transverse cross-section, the space 46 between the limbs of the U constituting an elongate compartment. The central core 41 is surrounded by three layers 45 of helically wound round wires of aluminium-based alloy, the directions of lay of adjacent layers being of opposite hand. Loosely housed in the elongate compartment 46 is an undulating optical fibre element 11 as shown in Figure 2.

The overhead flexible electric conductors shown in Figures 5 and 6 are similar in construction to the overhead flexible electric conductor shown in Figure 4 except for the form of the central core and, for convenience, components of the flexible conductors shown in Figures 5 and 6, respectively, that are similar to

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those of the overhead conductor shown in Figure 4 have been given references greater by 10 and by 20 than the references of the corresponding components of the flexible conductor shown in Figure 4. In the overhead electric conductor shown in Figure 5, the central core 51 is a tube 52 formed by transversely folding a strip of aluminium-based alloy. In the flexible conductor shown in Figure 6, the central core 61 is constituted by a single extruded elongate aluminium member 62 of substantially U-shaped cross-section, the gap between the free ends of the limbs of the U being partially closed to retain the undulating optical fibre element 11 in the elongate compartment 66.

The overhead flexible electric conductor shown in Figure 7 has a central core 71 consisting of two separately formed parts comprising an inner extruded elongate member 72 of aluminium having in its outer surface four circumferentially spaced, longitudinally extending recesses 76 and, surrounding the inner elongate member, a longitudinally applied transversely folded tape 73 of aluminium, which tape overlies the longitudinally extending recesses to form circumferentially spaced elongate compartments. Loosely housed in each of the elongate compartments 76 is an undulating optical fibre element 11 as shown in Figure 2. The central core 71 is surrounded by three layers 75

of helically wound round wires of aluminium-based alloy, the directions of lay of adjacent layers being of opposite hand.

In each of the flexible conductors shown in Figures 5 4 to 7, the or each elongate compartment may be substantially filled throughout its length with a silicone gel or other greasy water-impermeable medium.

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CLAIMS:

1. A flexible elongate body comprising at least one layer of helically wound bare elongate elements of metal or metal alloy, at least one elongate compartment within and extending throughout the length of the elongate body and, loosely housed in the elongate compartment or at least one of the elongate compartments, at least one optical fibre element comprising a flexible tube having a bore in which at least one optical fibre is so loosely housed that, when the tube is bent or otherwise flexed, the or each optical fibre is free to move to a limited extent transversely of and with respect to the tube, wherein the flexible tube is resiliently set in such a form that the central longitudinal axis of the tube follows a longitudinally extending path which, between any two longitudinally spaced positions, is greater in length than the rectilinear distance between said two positions, the arrangement being such that, when the resiliently set tube is subjected to a longitudinally applied tensile force, the tube will will tend to straighten in a lengthwise direction against the action of its resilient set thereby to reduce the tensile force applied to the or each optical fibre and, when the tensile force is removed, the tube will return under the action of its resilient set towards its original form.
2. A flexible elongate body comprising at least one layer of helically wound bare elongate elements of metal



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or metal alloy, at least one elongate compartment within and extending throughout the length of the elongate body and, loosely housed in the elongate compartment or at least one of the elongate compartments, at least one
5 optical fibre element comprising a flexible tube having a bore in which at least one optical fibre is so loosely housed that, when the tube is bent or otherwise flexed, the or each optical fibre is free to move to a limited extent transversely of and with respect to the tube,
10 wherein the flexible tube is resiliently set in such a form that the central longitudinal axis of the tube follows a path of smoothly curved undulations whose axes of curvature lie parallel to one another and substantially normal to the longitudinal axis of the
15 tube, the arrangement being such that, when the undulating flexible tube is subjected to a longitudinally applied tensile force, the tube will tend to straighten in a lengthwise direction against the action of the undulating resilient set thereby to reduce
20 the tensile force applied to the or each optical fibre and, when the tensile force is removed, the tube will return under the action of its undulating resilient set towards its original form.

3. A flexible elongate body as claimed in Claim 1,
25 wherein the flexible tube of the optical fibre element is resiliently set in such a form that the central



longitudinal axis of the tube follows a substantially helical path, the lay of the helically extending path lying in the range 5° to 15° to the central rectilinear axis of the helically extending tube.

4. A flexible elongate body as claimed in any one of the preceding Claims, wherein the flexible tube of the optical fibre element is of non-circular cross-section and the radial thickness of the tube wall is substantially constant at all transverse cross-sections of the tube.

5. A flexible elongate body as claimed in Claim 2, wherein the flexible tube of the optical fibre element has a transverse cross-section of an elongate form having two major parallel sides joined by ends of approximately semi-circular shape, the flexible tube being resiliently set in such a form that the axes of curvature of the smoothly curved undulations lie substantially parallel to the major transverse axes of the flexible tube.

6. A flexible elongate body as claimed in any one of the preceding Claims, wherein the flexible tube of the optical fibre element is made of a plastics material or materials.

7. A flexible elongate body as claimed in Claim 6, wherein the flexible tube of the optical fibre element is made of orientated polyethylene terephthalate.



8. A flexible elongate body as claimed in Claim 6, wherein the flexible tube of the optical fibre element is made of polyether sulphone or of polyether imide.

9. A flexible elongate body as claimed in Claim 6, wherein the flexible tube of the optical fibre element has embedded in the tube wall at mutually spaced postions a plurality of resilient elongate reinforcing elements, each of which is so resiliently set as to cause the tube to follow the path of required form.

10. A flexible elongate body as claimed in any one of Claims 1 to 5, wherein the flexible tube of the optical fibre element is made of a resilient metal or metal alloy.

11. A flexible elongate body as claimed in any one of the preceding Claims, wherein the or each optical fibre loosely housed in the resiliently set flexible tube of the optical fibre element is unsupported.

12. A flexible elongate body as claimed in any one of Claims 1 to 10, wherein two or more optical fibres are component parts of at least one optical fibre ribbon structure loosely housed in the bore of the resiliently set flexible tube of the optical fibre element.

13. A flexible elongate body as claimed in Claim 12, wherein the or each optical fibre ribbon structure of the optical fibre element comprises two or more optical fibres and one or more than one flexible elongate reinforcing element arranged side by side and wholly or



partially embedded in a flexible elongate body of plastics material or arranged side by side and secured to one major surface of a flexible tape.

14. A flexible elongate body as claimed in any one of
5 the preceding Claims, wherein the resiliently set flexible tube of the optical fibre element is substantially filled throughout its length with a water-impermeable medium of a grease like nature that is of such a consistency that the or each optical fibre or
10 the or each optical fibre ribbon structure is free to move relative to the tube when the tube is bent or otherwise flexed.

15. A flexible elongate body as claimed in Claim 14, wherein the greasy water-impermeable medium in the
15 optical fibre element consists of, or comprises as a major constituent, silicone gel.

16. A flexible elongate body as claimed in any one of the preceding Claims, wherein the elongate compartment is the bore of a substantially circumferentially rigid
20 central core which is surrounded by the layer or layers of helically wound bare elongate elements of metal or metal alloy.

17. A flexible elongate body as claimed in Claim 16, wherein the central core is a single extruded elongate
25 member having a central bore which constitutes the elongate compartment.



18. A flexible elongate body as claimed in Claim 16,
wherein the central core is a single elongate member of
substantially U-shaped transverse cross-section, the
space between the limbs and the base of the U
5 constituting the elongate compartment.

19. A flexible elongate body as claimed in Claim 18,
wherein one or each of the limbs of the U is folded
inwardly so that the gap between the free ends of the
limbs is at least partially closed.

10 20. A flexible elongate body as claimed in any one of
Claims 17 to 19, wherein the single extruded elongate
body is of metal or metal alloy.

21. A flexible elongate body as claimed in Claim 16,
wherein the central core is a longitudinally extending
15 tape of metal or metal alloy which is transversely
folded to form a tube, the abutting longitudinally
extending edges of the tape being welded or otherwise
secured together.

22. A flexible elongate body as claimed in Claim 16,
20 wherein the central core consists of two separately
formed parts comprising an inner solid elongate member
of metal or metal alloy having in its outer surface at
least one longitudinally extending recess and,
surrounding the inner elongate member, a longitudinally
25 applied transversely folded tape of metal or metal
alloy, which tape overlies the or each longitudinally



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extending recess to form an elongate compartment.

23. A flexible elongate body as claimed in Claim 16,
wherein the central core is of aluminium or an
aluminium-based alloy; at least one layer of bare
5 elongate elements of steel surrounds the central core;
and at least one substantially circumferentially
continuous outer layer of aluminium or aluminium-based
alloy surrounds the layer or layers of steel bare
elongate elements, aluminium or aluminium-based alloy of
10 the central core and/or of the outer layer at least
partially filling the interstices between the steel bare
elongate elements.

24. A flexible elongate body as claimed in Claim 23,
wherein the central core comprises at least one layer of
15 bare elongate elements of aluminium or an
aluminium-based alloy, each element having a transverse
cross-section approximating to a sector of an annulus or
having a transverse cross-section of such a shape that,
when the flexible elongate body is in tension, said
20 element is in interfacial engagement with adjacent bare
elongate elements.

25. A flexible elongate body as claimed in any one of
Claims 16 to 24, wherein the central core is of
substantially circular transverse cross-section.

26. A flexible elongate body as claimed in any one of
the preceding Claims, wherein those parts of the or each



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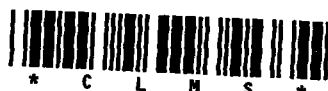
elongate compartment not occupied by the optical fibre element are substantially filled with a silicone gel or other water-impermeable medium of a grease like nature the silicone gel or other water-impermeable medium being
5 of such a consistency that the or each optical fibre element is free to move relative to the flexible elongate body when the flexible elongate body vibrates, oscillates or is otherwise flexed.

27. A flexible elongate body as claimed in any one of
10 the preceding Claims, wherein a layer of thermally insulating material is housed in the or each elongate compartment and surrounds the optical fibre element loosely housed therein.

28. A flexible elongate body as claimed in Claim 27,
15 wherein the thermally insulating layer in the or each elongate compartment is a circumferentially continuous layer which is bonded or otherwise adheres to the boundary surface of the elongate compartment.

29. A flexible elongate body as claimed in any one of
20 the preceding Claims, wherein the flexible elongate body is an overhead electric conductor.

30. An overhead flexible electric conductor
substantially as hereinbefore described with reference
to and as shown in any one of Figures 4 to 7 of the
25 accompanying drawings.



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31. An overhead electric transmission or distribution system including at least one overhead flexible electric conductor as claimed in Claim 29 or 30.

32. An overhead electric transmission or distribution
5 system as claimed in Claim 31, wherein the overhead flexible electric conductor is an earth conductor of the system.



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