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(71) Applicant: **Schlumberger Limited, 277 Park Avenue, New York, N.Y. 10172 (US)**
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(71) Applicant: **SOCIETE DE PROSPECTION ELECTRIQUE SCHLUMBERGER, 42, rue Saint-Dominique, F-75340 Paris Cedex 07 (FR)**
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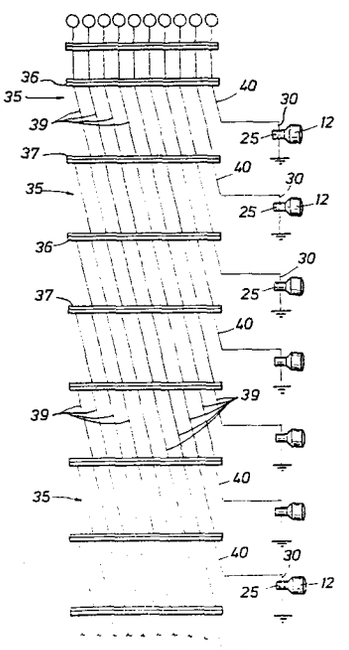
(72) Inventor: **Zimmerman, Thomas H., 14926 Flowerwood, Houston Texas 77058 (US)**

(74) Representative: **Chareyron, Lucien et al, Schlumberger Limited 42, rue Saint-Dominique, F-75340 Paris Cedex 07 (FR)**

(54) Perforating gun indexed wiring harness.

(57) A wiring harness for selective perforating guns uses a single harness configuration for all connections. Each harness increments the relative positions of the harness conductors, while the conductor used in each ha ness for firing its associated detonator is the same. With diode-steering, two harnesses are used, one which increments and one which does not.



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PERFORATING GUN INDEXED WIRING HARNESS

Background of the Invention

The present invention relates to perforating guns for wells, and more particularly to a wiring harness for selective firing systems for oil and gas well perforating guns.

Prior art selective firing systems commonly connect the perforating guns to the firing control system (at the surface of the earth) on a single conductor, using, typically, an addressing device downhole which responds to coded signals on the conductor for selecting the particular gun which is to be actuated. In the simplest case, the guns are simply fired in sequence. In more complex systems, provision is made (such as in a downhole control cartridge) for controllably addressing specific guns from the surface. However, the latter usually requires a plurality of conductors ("multi-wire" harness system) for connecting the guns to the control cartridge, with each gun typically connected to its own unique controlling wire. (An economical alternative is to use each wire for controlling two guns by means of "diode-steering", in which a firing signal of one polarity fires one of the guns and the opposite polarity the other.)

A principal disadvantage of such a multi-wire harness selective firing system is the necessity to connect each gun to a specific wire. That is, as the perforating guns are being assembled on the tool carrier, they are positioned according to the particular perforation pattern which is to be effected. The individual guns are usually identical and drawn from a common inventory, but the electrical connections are not. For convenience and efficiency, the guns are

electrically connected by a series of pre-assembled wiring harnesses. The harnesses have standardized mateable connectors on each end for rapid assembly, so the gun string is assembled by literally plugging the guns and wiring harnesses into one another. For the first gun in the string, a wiring harness is selected having a coupling wire spliced to the electrical harness conductor representing the first gun; for the second gun the second harness conductor is spliced; and so forth. Thus, although the guns themselves may be identical and interchangeable, the wiring harnesses are not, and considerable care must be used to be sure that the correct wiring harnesses are used in the proper sequence. It also means that a large inventory of wiring harnesses, each unique to a specific position on the gun string, must be inventoried.

A need thus remains for a multi-conductor well perforating gun selective firing system in which not only standardized and identical perforating guns, but also standardized and identical wiring harnesses may be used, to minimize inventory requirements, simplify assembly of the gun string, and minimize the chances of miswiring through the inadvertent use of an incorrect harness at a particular location.

Summary of the Invention

Briefly, the present invention meets the above needs and purposes with a multi-conductor well perforating gun selective firing system in which identical harnesses are used throughout, each harness incrementing or indexing the relative positions of the conductors therein. In a variation in which diode-steering is used, two harnesses are used, one which increments and one which does not, since one conductor will serve for two guns. (Alternatively, a

single harness for adjacent pairs of guns could be provided.)

Thus, in the preferred embodiment, a vertically spaced array of selectively actuatable perforating guns is assembled on a carrier for subsequent lowering and positioning within a well bore. Individual electrical firing means, typically electrical detonators, are associated with (attached to) each perforating gun for individually firing that particular gun. A cable and downhole control cartridge are connected between the array of guns and a firing control means at the surface of the earth. The firing control means and downhole control cartridge selectively address each of the individual detonators by providing the proper electrical signal on the particular conductor of a multi-conductor wiring harness which connects to the selected perforating gun. Where diode-steering is employed, the guns may be arranged in subsets, each subset being connected to a single conductor in the wiring harness. Where each gun has its own individual conductor, the subsets may be thought of as consisting of a single gun each.

Contrary to the above prior art devices, however, the subsets of gun(s) in the array according to this invention are electrically connected to one another by identical stepped wiring harness assemblies, one for each of the subsets. The assemblies are connectable in series, and the first or topmost harness is connected to the downhole control cartridge. In the preferred embodiment, the assemblies have suitable matching connectors, one for receiving the electrical signals and one for passing or transmitting them on to the next harness assembly. The harness assemblies also each have internal connecting wires arranged to increment the connections, preferably by one position each, between

the respective connectors thereon.

In addition, each harness assembly has a coupling means responsive to an electrical addressing signal on a particular connecting wire therein for connecting to and controllably energizing the electrical detonator associated with the perforating gun for that particular harness assembly. As indicated, the harness assemblies are identical, and thus the coupling means in each harness assembly is the same, and is connected to the same particular connecting wire. However, although connected to the same particular connecting wire in each harness assembly, the various coupling means in the series connected harnesses are not connected electrically to the same terminals in the control cartridge due to the incrementing of the conductors by each wiring harness.

Therefore, since each wiring harness electrically increments all succeeding conductors in the series, the firing control means at the surface can address the guns uniquely associated with any one of the identical wiring harness assemblies by causing the control cartridge to address the particular electrical conductor in the first wiring harness which, through the series of wiring harness assemblies, is cumulatively indexed thereto.

It is therefore an object of the present invention to provide a well perforating gun selective firing system in which multiple conductors are individually connected to individual subsets of perforating guns through identical wiring harness assemblies, one for each subset; in which the wiring harness assemblies are connectable in series; and in which each wiring harness assembly increments the electrical position of the conductors connected therethrough.

These and other objects are attained in accordance with one aspect of the invention directed to a well perforating gun stepped wiring harness assembly for a well perforating gun selective firing system having a vertically spaced array of selectively actuatable perforating guns adapted for lowering and positioning within a well bore, characterized by: a stepped wiring harness assembly for a predetermined subset of the perforating guns and connectable in a series configuration to other such assemblies, said harness assembly having a receiving connector and a matching transmitting connector for connecting to other such wiring harness assemblies in a series configuration, and having internal connecting wires arranged to increment the connections between the respective connectors thereon, and coupling means in said harness assembly responsive to an electrical addressing signal on a predetermined said connecting wire for controllably energizing the perforating guns associated therewith, said incremented connecting wires thereby electrically incrementing all succeeding conductors in such a series, such that the guns uniquely associated with any one such assembly in a series of identical such wiring harness assemblies can be addressed by addressing the particular electrical conductor which is cumulatively indexed by such harness assemblies thereto.

Another aspect of the invention is directed to a method for assembling a well perforating gun, comprising: assembling a vertically spaced array of selectively actuatable perforating guns adapted for lowering and positioning within a well bore, associating individual electrical firing means with each perforating gun for actuating the particular gun associated therewith, connecting an electrical conductor to each of said firing means adapted to actuate a particular gun when suitably addressed by a controller, and characterized by: connecting a plurality of identical wiring harness assemblies, one for each predetermined subset of the perforating guns, in a series configuration, each harness assembly having a receiving connector and an identical transmitting connector with internal connecting electrical

conductors arranged between said connectors to increment the connections therebetween; and connecting to the electrical firing means an identical coupling means in each harness assembly, responsive to an electrical addressing signal on the same electrical conductor in each assembly, for controllably energizing the electrical firing means associated therewith, the incremented conductors thereby electrically incrementing all succeeding conductors in the series, such that the guns uniquely associated with any one of the identical wiring harness assemblies can be addressed by addressing the particular electrical conductor which is cumulatively indexed by the harness assemblies thereto.

Brief Description of the Drawings

Fig. 1 is a somewhat figurative illustration of a well perforating gun system;

Fig. 2 is a schematic illustration of a first wiring harness assembly embodiment according to the present invention; and

Fig. 3 illustrates an alternative embodiment similar to Fig. 2.

Description of the Preferred Embodiments

With reference to the drawings, Fig. 1 shows a vertically spaced array 10 of selectively actuatable perforating guns 12 connected by a downhole control cartridge 14 and cable 15 to a firing control means, such as a control panel 20, located at the surface of the earth. In use, the array 10 is lowered on cable 15 into a well bore, and when properly positioned by the cable 15, the various guns 12 are individually actuated to perforate the well.

In the embodiment shown in Fig. 2, the individual guns are each fired by individual electrical firing means such as detonators 25. The detonators individually fire the particular gun associated therewith upon receiving the proper electrical signal on a coupling wire 30 (Fig. 2) connected to th associated wiring harness assembly 35.

The individual electrical wiring harness

assemblies 35 are identical, one for each gun 12. In order to connect them in series, each has a receiving connector 36 and a complimentary transmitting connector 37. Each harness assembly also has internal connecting wires 39 which, as shown in Fig. 2, increment or advance the connections between the respective connectors 36 and 37. That is, the wire connected to terminal one on the receiving connector will be connected, for example, to terminal two on the transmitting connector, and so forth.

Each wiring harness assembly also has a coupling means, such as a wire 40, which is connected to a particular one of the connecting wires 39, for responding to an electrical addressing signal on that particular wire, under the control of the firing control panel 20 and downhole control cartridge 14, to energize the detonator 25 associated therewith. Therefore, due to the incrementing of the connecting wires 39 by the harnesses 35, control panel 20 can directly address the guns 12 individually, even though the coupling means or wires 40 are identically connected within each of the identical wiring harness assemblies 35.

The selective firing system illustrated in Fig. 3 differs from that of Fig. 2 in that the perforating guns are generally arranged in subset pairs rather than individually. Likewise, the wiring harness assemblies are arranged in pairs, one an indexed wiring harness 35 as in Fig. 2, and the other a straight-through (non-incrementing) wiring harness 55. In the preferred embodiment, harness 55 includes a pair of diodes 57 for selectably actuating one of the detonators 25 in the pair of guns 58a, 58b energized on the same conductor line from cartridge 14. The selection depends upon whether the energizing signal is positive or negative. A negative signal will fire gun 58a by causing current

to flow in the coupling wire 60 on the straight-through harness 55. A positive signal will fire gun 58b by causing current to flow on the coupling means 40 associated with the incrementing wiring harness 35. Thus the diode pair 57 in each harness 55 functions as a steering means between the particular connecting wire 61 to which they are attached in each of the harnesses 55 and the pair of guns connected to be fired thereby. This provides for selectively energizing the detonators 25 on the gun pairs as a function of the signal which is ultimately placed on that particular connecting wire 61 under the control of panel 20.

As may be seen, therefore, the present invention has numerous advantages. Principally, it is no longer necessary to stock a large number of harness assemblies, each unique to a specific gun location. Instead, identical harness assemblies can be used throughout. This makes assembly of the perforating gun array much easier and quicker, and substantially reduces the likelihood of miswiring. When the harness assembly is made up of two harnesses, such as harnesses 35 and 55 in the diode-steering embodiment shown in Fig. 3, the harness connectors can be polarized, so that the straight-through wiring harnesses 55 cannot be plugged directly into one another, but must be connected through the stepped wiring harnesses 35.

While the forms of apparatus herein described constitute preferred embodiments of this invention, it is to be understood that the invention is not limited to these precise forms of apparatus, and that changes may be made therein without departing from the scope of the invention.

CLAIMS

1. A well perforating gun stepped wiring harness assembly for a well perforating gun selective firing system having a vertically spaced array of selectively actuatable perforating guns adapted for lowering and positioning within a well bore, characterized by:

a stepped wiring harness assembly for a predetermined subset of the perforating guns and connectable in a series configuration to other such assemblies,

said harness assembly having a receiving connector and a matching transmitting connector for connecting to other such wiring harness assemblies in a series configuration, and having internal connecting wires arranged to increment the connections between the respective connectors thereon, and

coupling means in said harness assembly responsive to an electrical addressing signal on a predetermined said connecting wire for controllably energizing the perforating guns associated therewith, said incremented connecting wires thereby electrically incrementing all succeeding conductors in such a series, such that the guns uniquely associated with any one such assembly in a series of identical such wiring harness assemblies can be addressed by addressing the particular electrical conductor which is cumulatively indexed by such harness aseemblies thereto.

2. The system of claim 1 characterized in that the subset is a single gun and said coupling means is a wire for coupling a predetermined said connecting wire to that perforating gun.

3. The system of claim 1 characterized in that:

the subset is a plurality of guns,

said wiring harness assembly comprises at least one indexed harness and at least one straight-through harness, and said coupling means is a steering means coupled between said connecting wire and that plurality of guns for selectively energizing those guns as a function of the signal placed on said connecting wire.

4. The system of claim 3 characterized in that each said harness is for a pair of the perforating guns and has a polarized receiving connector and a matching polarized transmitting connector for connecting said harness to one another in such a series configuration, and

said steering means of said coupling means comprising diode-steering means responsive to an electrical addressing signal on a predetermined connecting wire for controllably energizing, as a function of the polarity of the addressing signal, a predetermined one of the perforating guns associated therewith.

5. A method for assembling a well perforating gun, comprising:

a) assembling a vertically spaced array of selectively actuatable perforating guns adapted for lowering and positioning within a well bore,

b) associating individual electrical firing means with each perforating gun for actuating the particular gun associated therewith,

c) connecting an electrical conductor to each of said firing means adapted to actuate a particular gun when suitably addressed by a controller, and characterized by:

d) connecting a plurality of identical wiring harness assemblies, one for each predetermined subset of the perforating guns, in a series configuration, each harness assembly having a receiving connector and an identical transmitting connector with internal connecting electrical conductors arranged between said connectors to increment the connections therebetween; and

e) connecting to the electrical firing means an identical coupling means in each harness assembly, responsive to an electrical addressing signal on the same electrical conductor in each assembly, for controllably energizing the electrical firing means associated therewith, the incremented conductors thereby electrically incrementing all succeeding conductors in the series, such that the guns uniquely associated with any one of the identical wiring harness assemblies can be addressed by addressing the particular electrical conductor which is cumulatively indexed by the harness assemblies thereto.

FIG.1

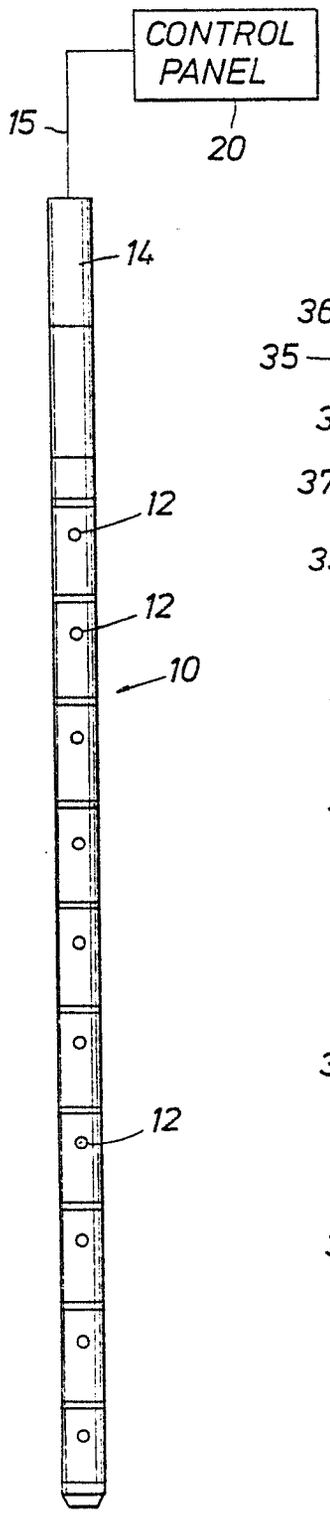
CONTROL PANEL
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FIG.2

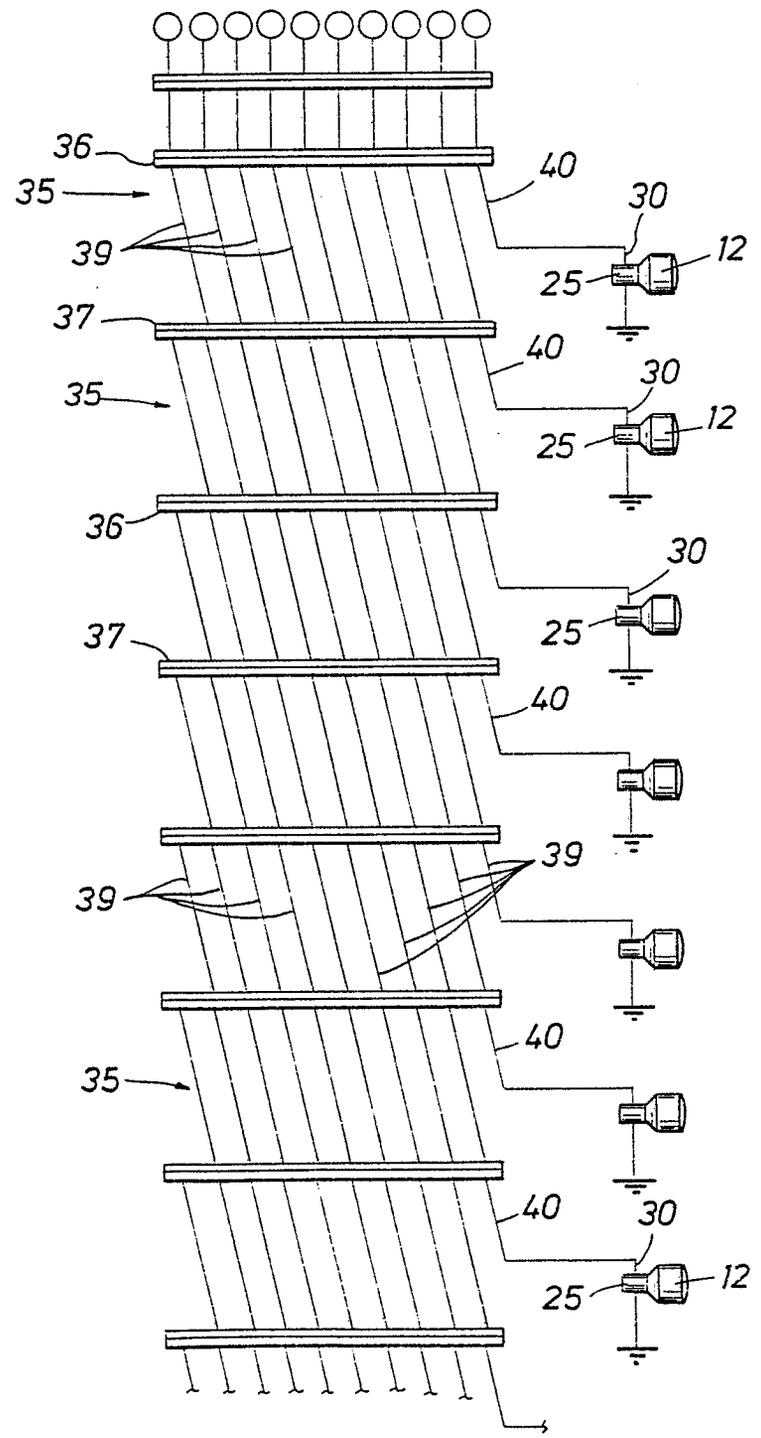
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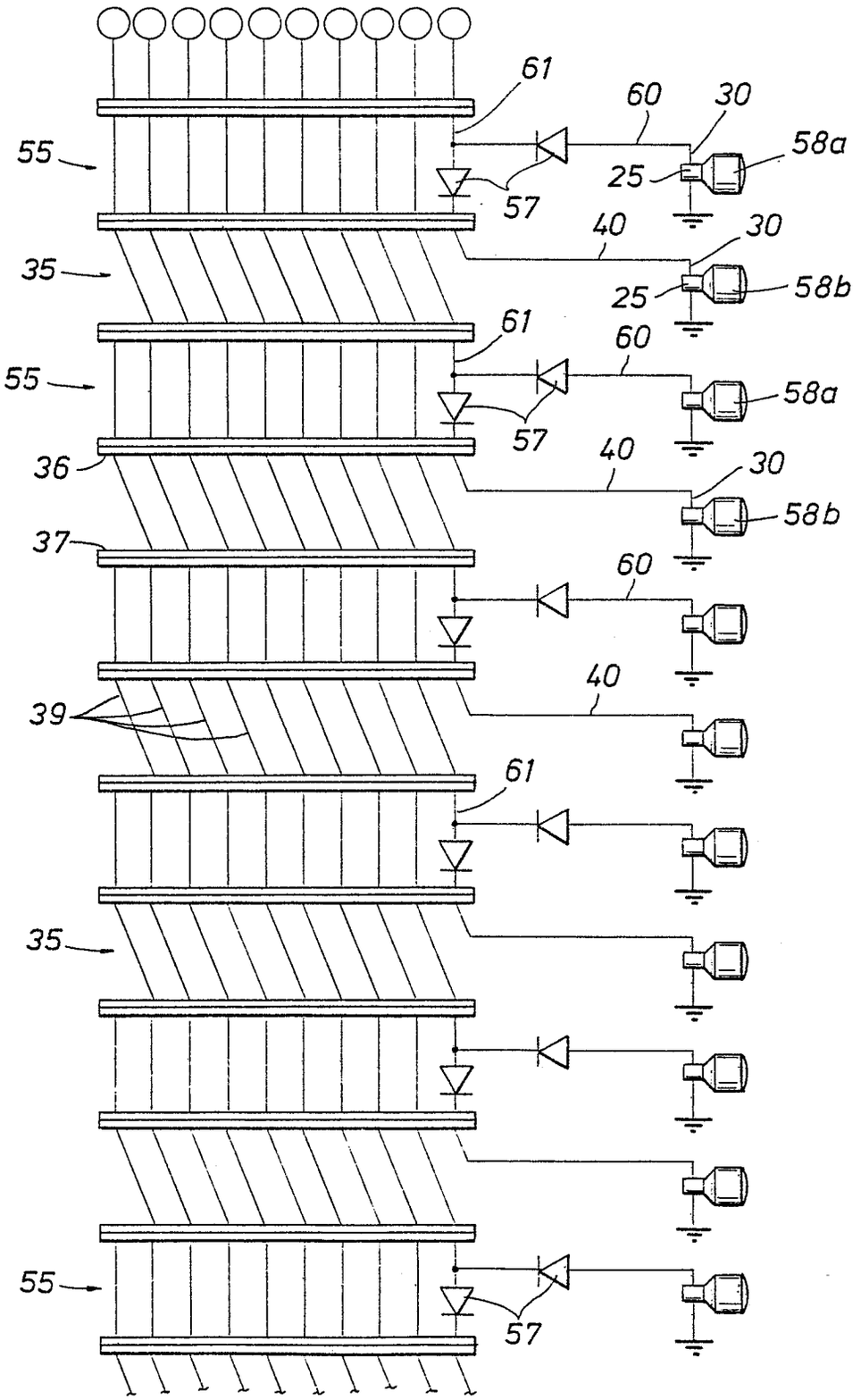
FIG. 3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