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Kim et al.

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(54) **BREAKAWAY MECHANISM FOR CHARGING CABLES OF ELECTRIC VEHICLE CHARGING STATIONS**

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(51) **Int. Cl.**
H02G 3/22 (2006.01)

(52) **U.S. Cl.** ..... **174/153 G**; 439/475; 439/923

(58) **Field of Classification Search** ..... 439/475, 439/474, 180, 923; 174/153 G, 152 G
See application file for complete search history.

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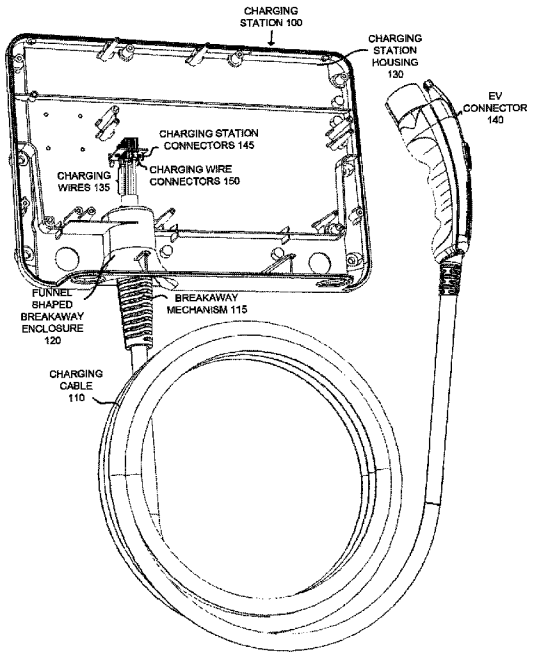
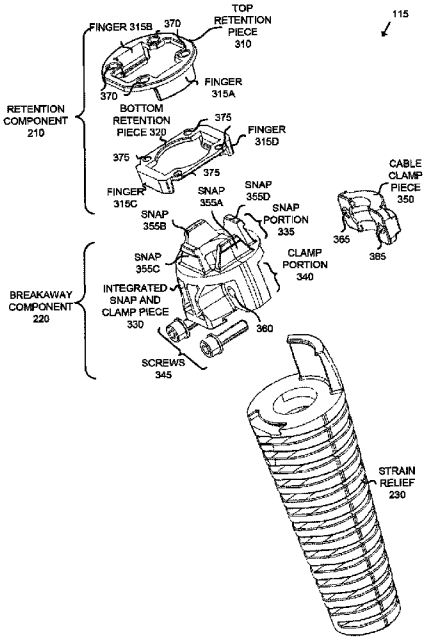
(57) **ABSTRACT**

A breakaway mechanism for a charging cable of an electric vehicle charging station includes a retention component and a breakaway component. The retention component is secured to the charging station and the breakaway component is secured to the charging cable. The charging cable passes through the breakaway component and includes charging wires that connect to connectors on the charging station. The breakaway component is adapted to disengage from the retention component at a predetermined pull force thereby causing the charging wires to disconnect from the connectors on the charging station.

15 Claims, 14 Drawing Sheets





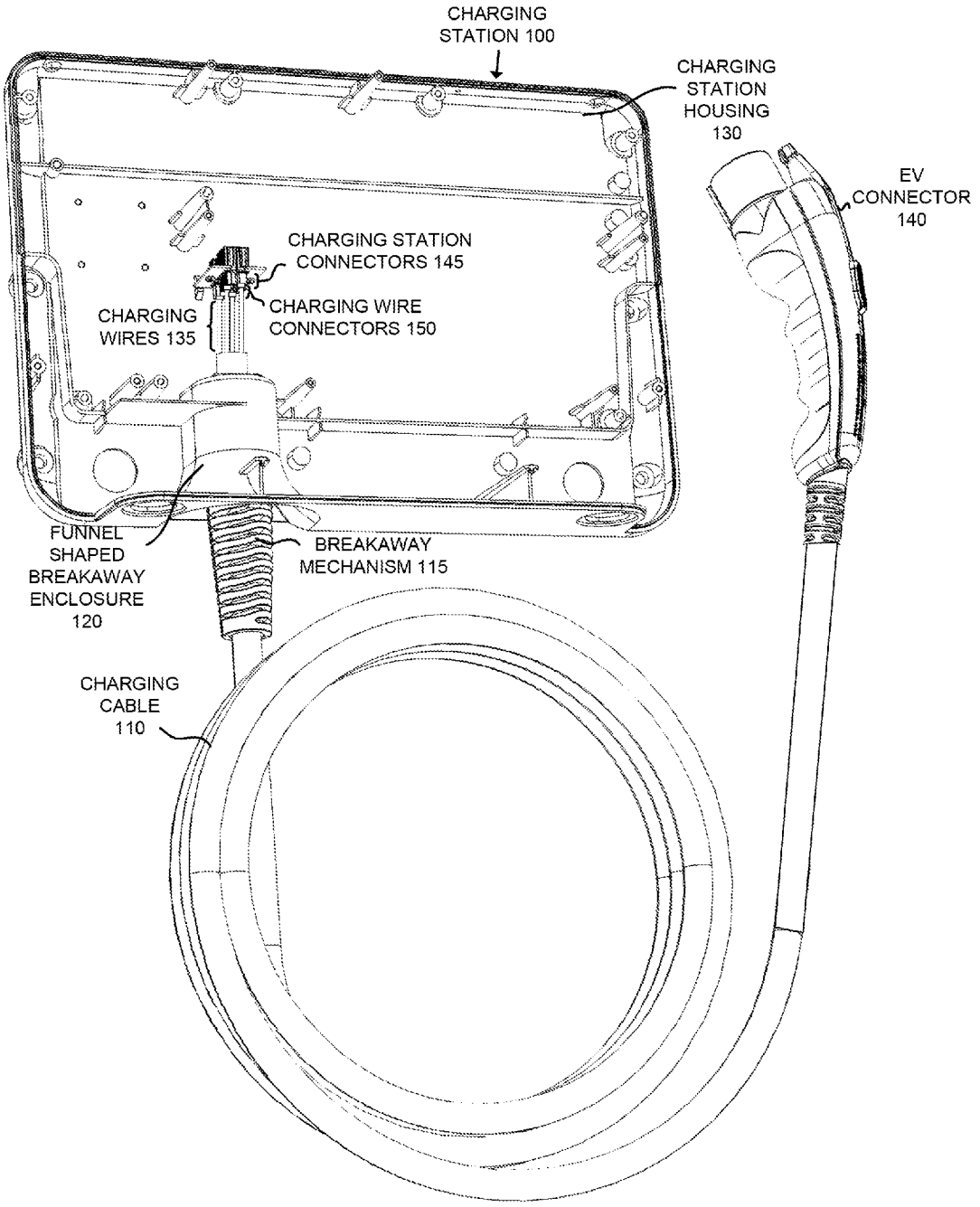

CHARGING STATION 100
CHARGING STATION HOUSING 130
EV CONNECTOR 140
CHARGING STATION CONNECTORS 145
CHARGING WIRE CONNECTORS 150
CHARGING WIRES 135
FUNNEL SHAPED BREAKAWAY ENCLOSURE 120
BREAKAWAY MECHANISM 115
CHARGING CABLE 110

FIG. 1

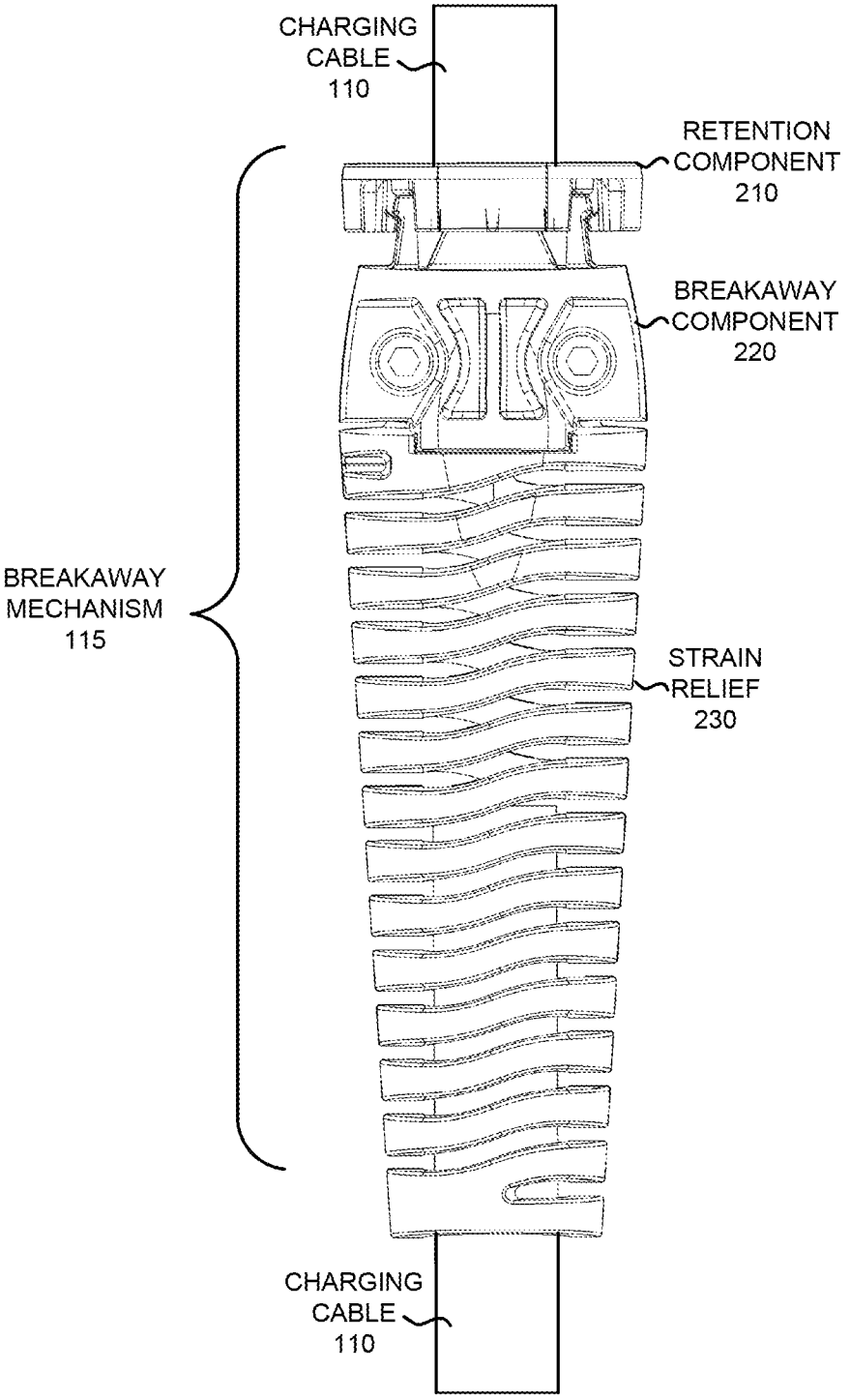

CHARGING CABLE 110
RETENTION COMPONENT 210
BREAKAWAY COMPONENT 220
BREAKAWAY MECHANISM 115
STRAIN RELIEF 230
CHARGING CABLE 110

FIG. 2

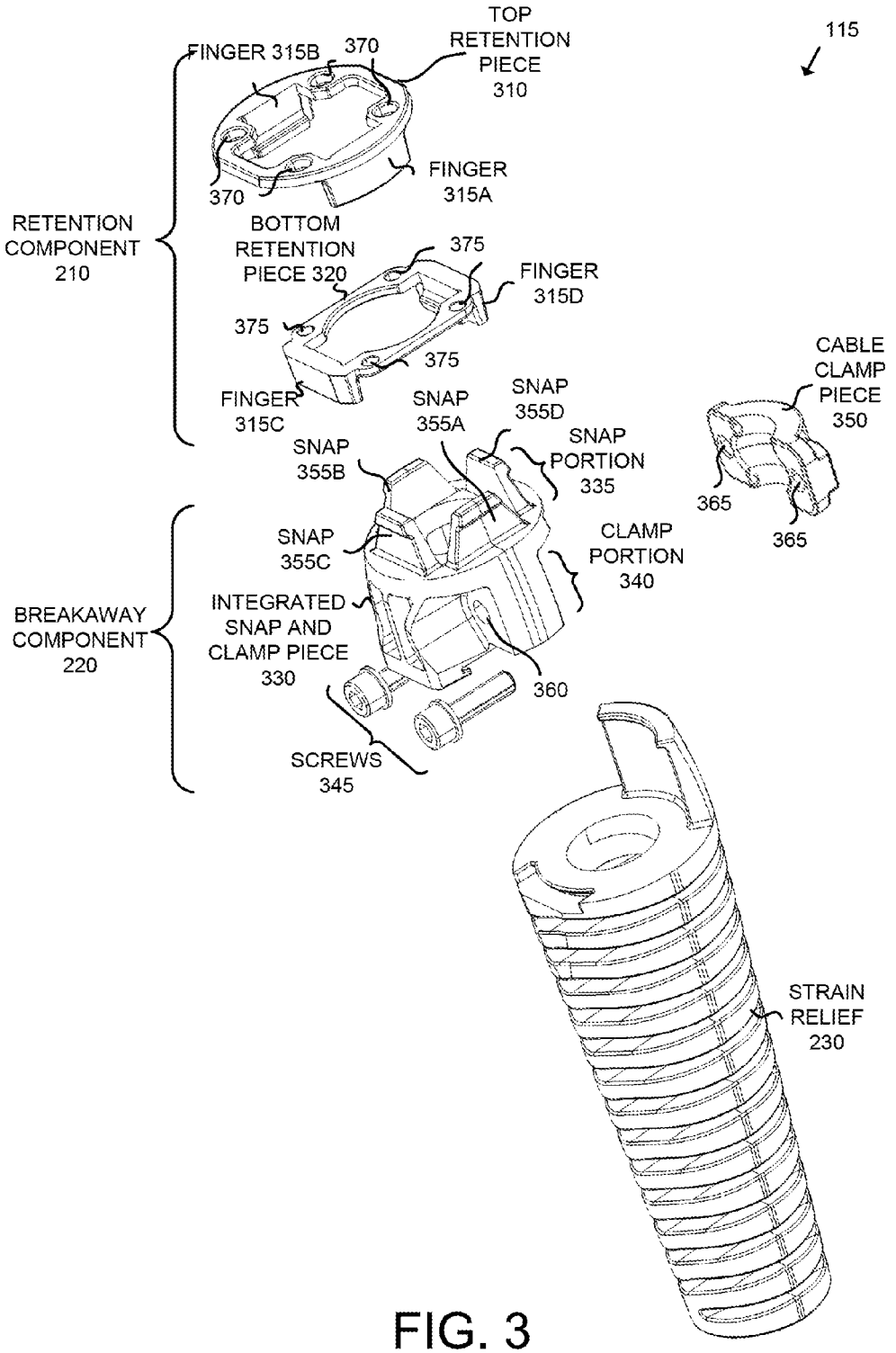

115
TOP RETENTION PIECE 310
FINGER 315B
370
370
FINGER 315A
RETENTION COMPONENT 210
BOTTOM RETENTION PIECE 320
375
FINGER 315D
375
375
FINGER 315C
SNAP 355A
SNAP 355D
SNAP 355B
SNAP PORTION 335
CABLE CLAMP PIECE 350
365
365
SNAP 355C
CLAMP PORTION 340
BREAKAWAY COMPONENT 220
INTEGRATED SNAP AND CLAMP PIECE 330
360
SCREWS 345
STRAIN RELIEF 230

FIG. 3

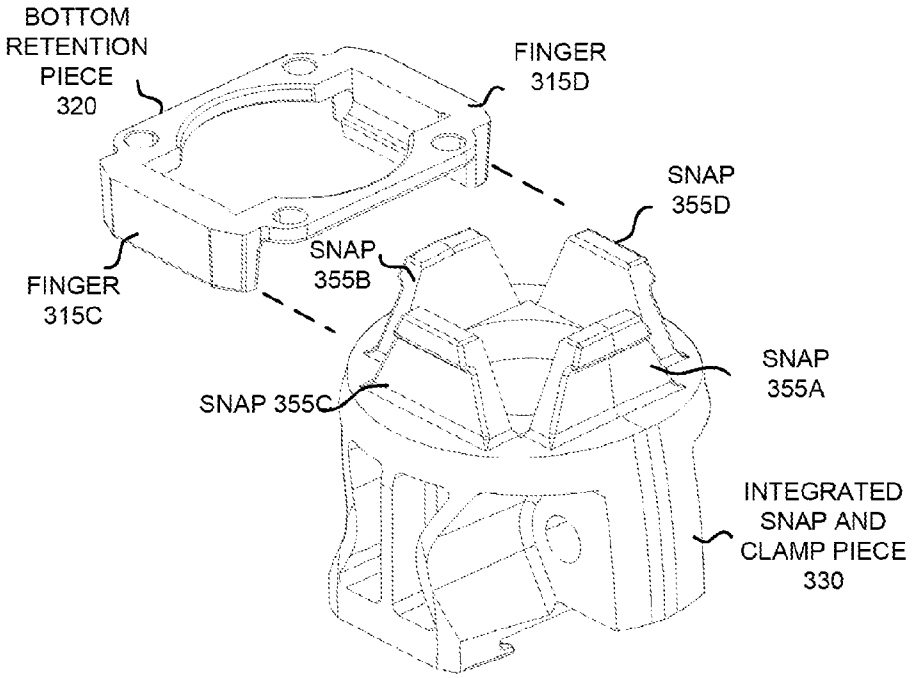

BOTTOM RETENTION PIECE 320
FINGER 315D
SNAP 355D
SNAP 355B
FINGER 315C
SNAP 355A
SNAP 355C
INTEGRATED SNAP AND CLAMP PIECE 330

FIG. 4

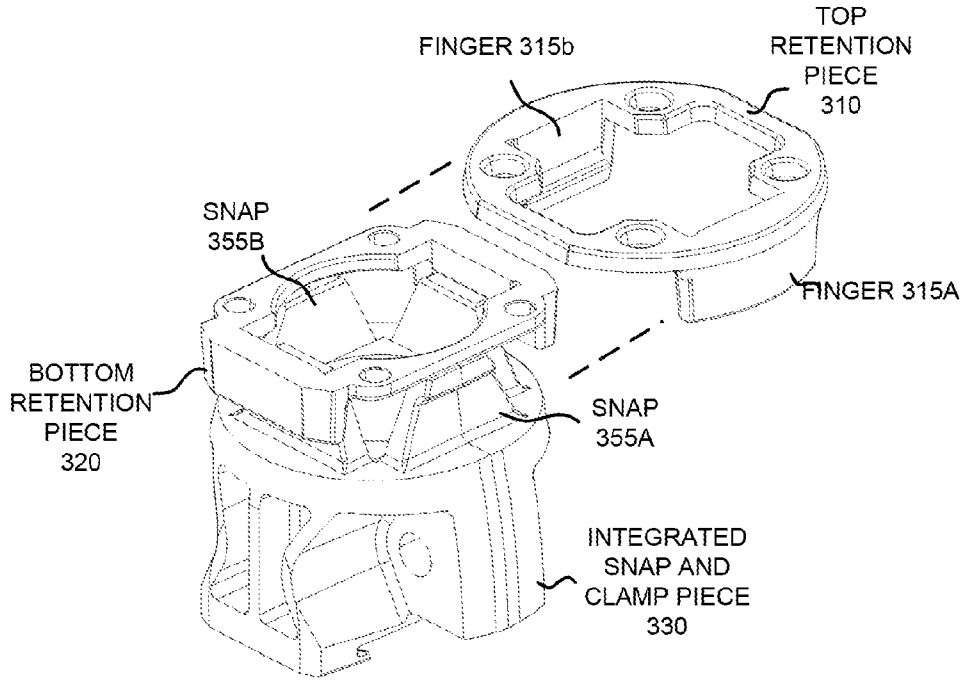

FINGER 315b
TOP RETENTION PIECE 310
SNAP 355B
FINGER 315A
BOTTOM RETENTION PIECE 320
SNAP 355A
INTEGRATED SNAP AND CLAMP PIECE 330

FIG. 5

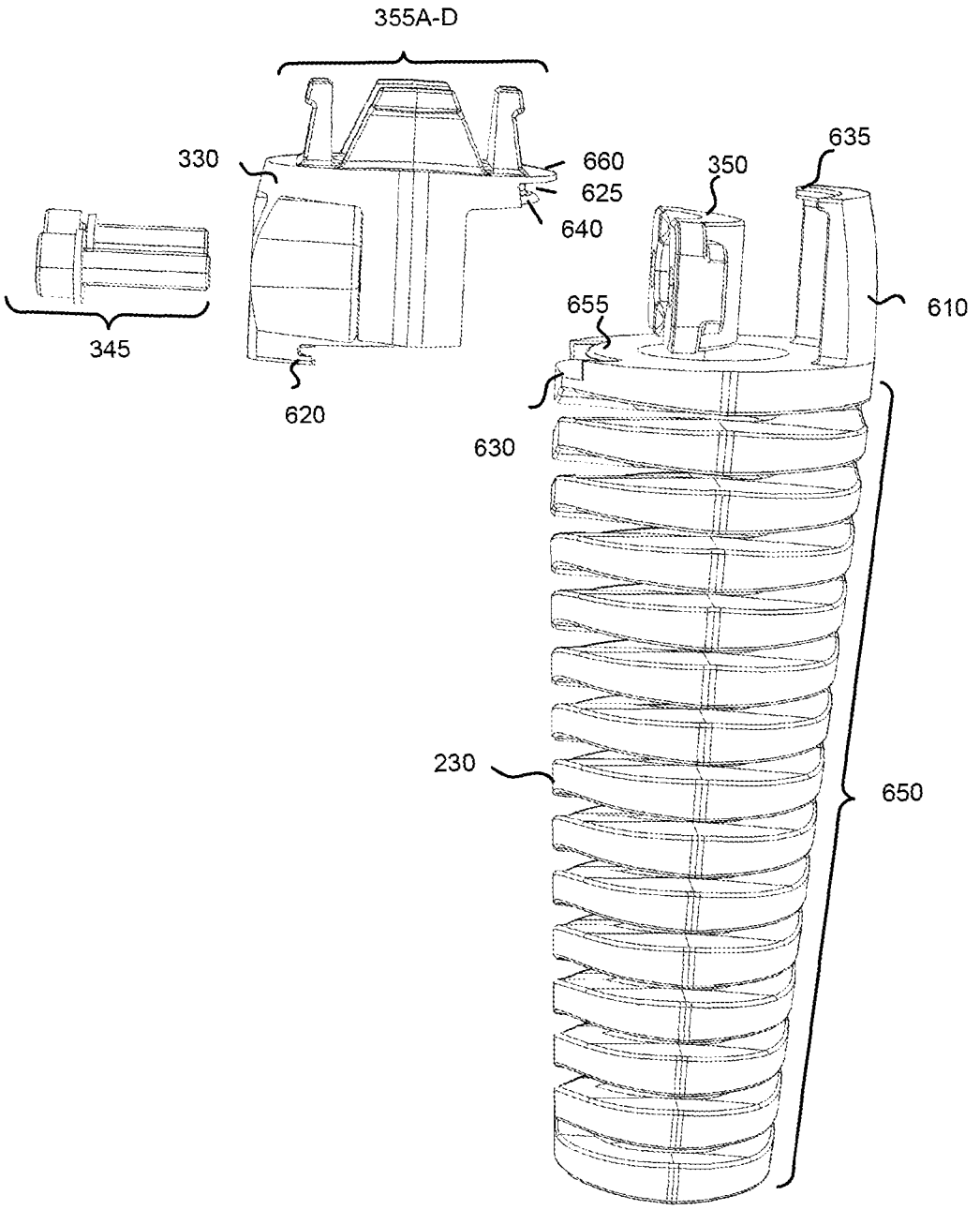


FIG. 6

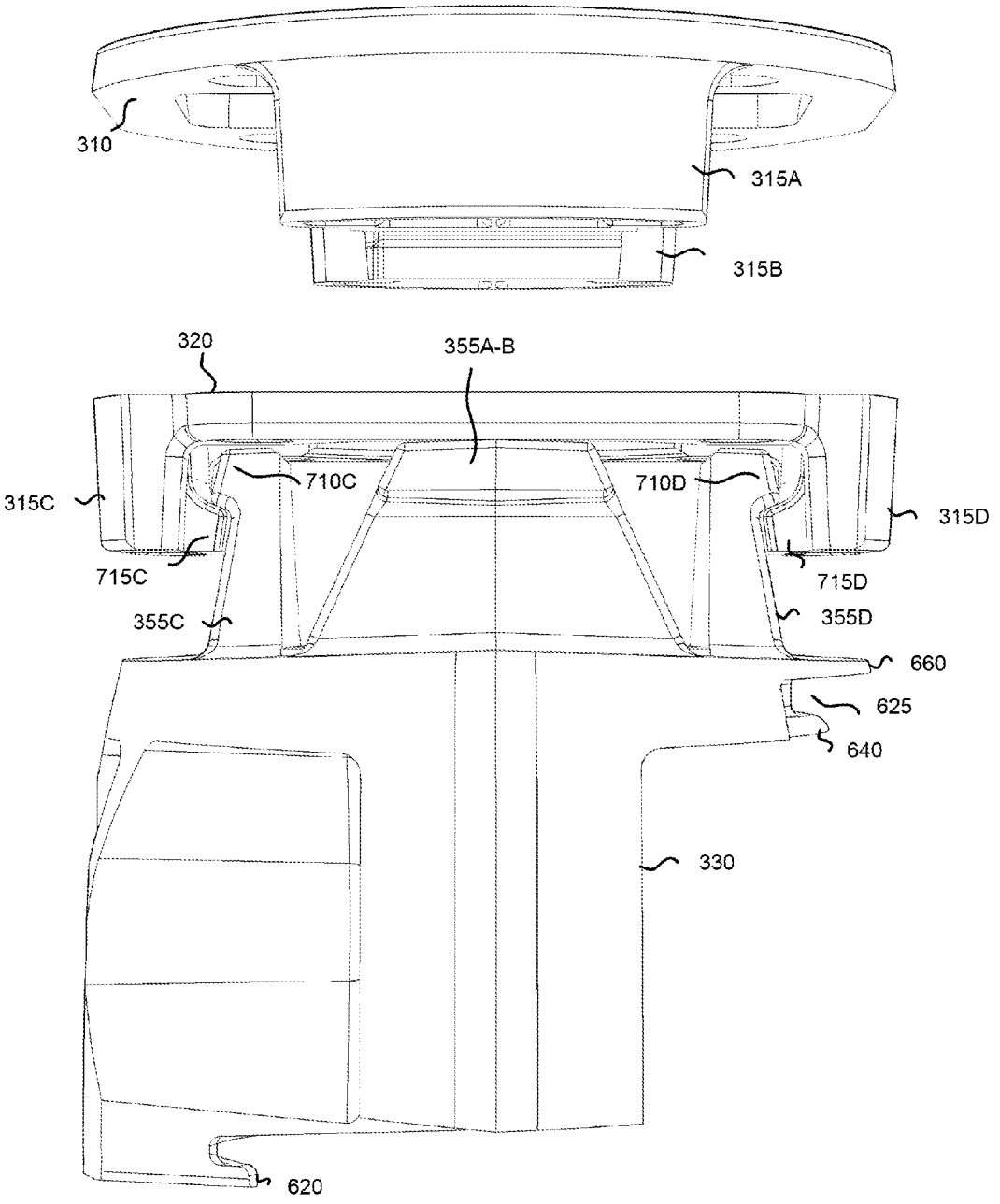

310
315A
315B
320
355A-B
315C
710C
710D
315D
715C
715D
355C
355D
660
625
640
330
620

FIG. 7

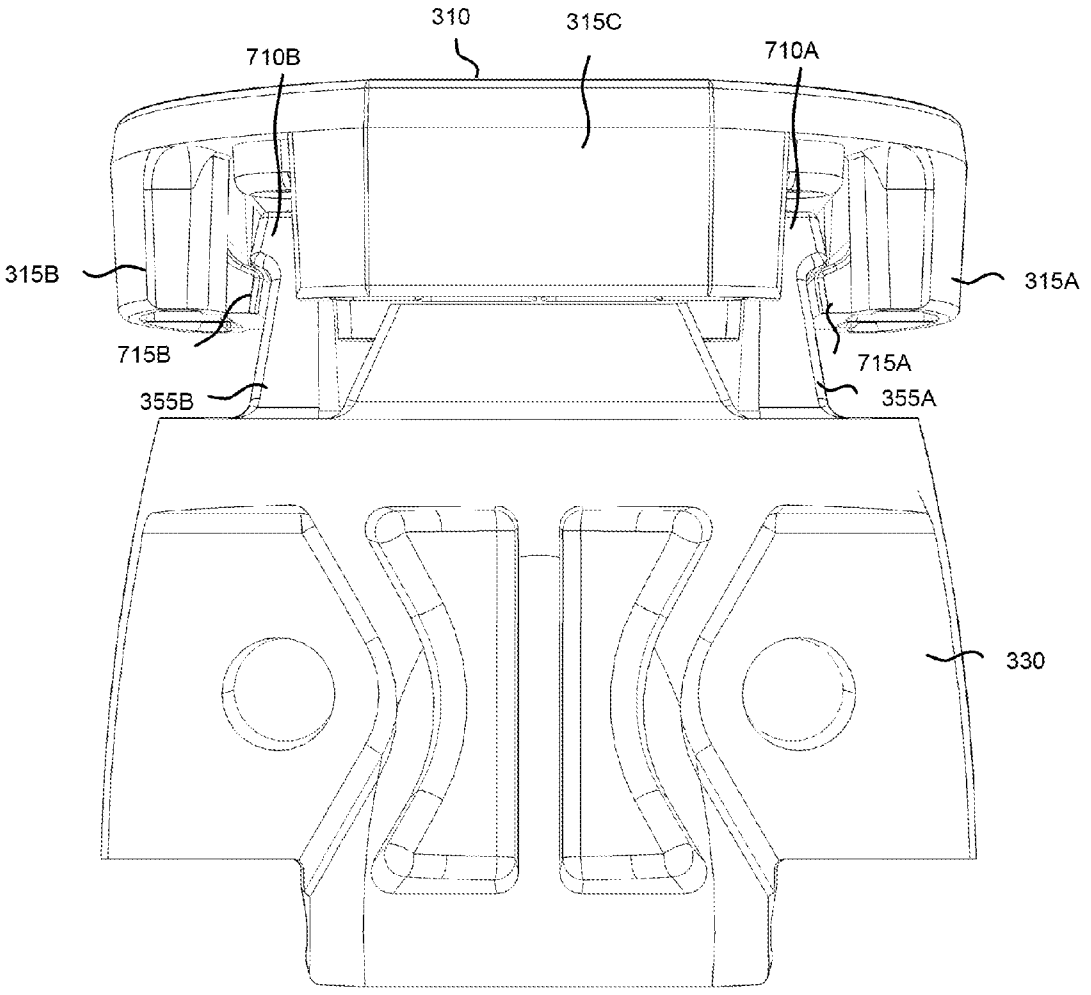


FIG. 8

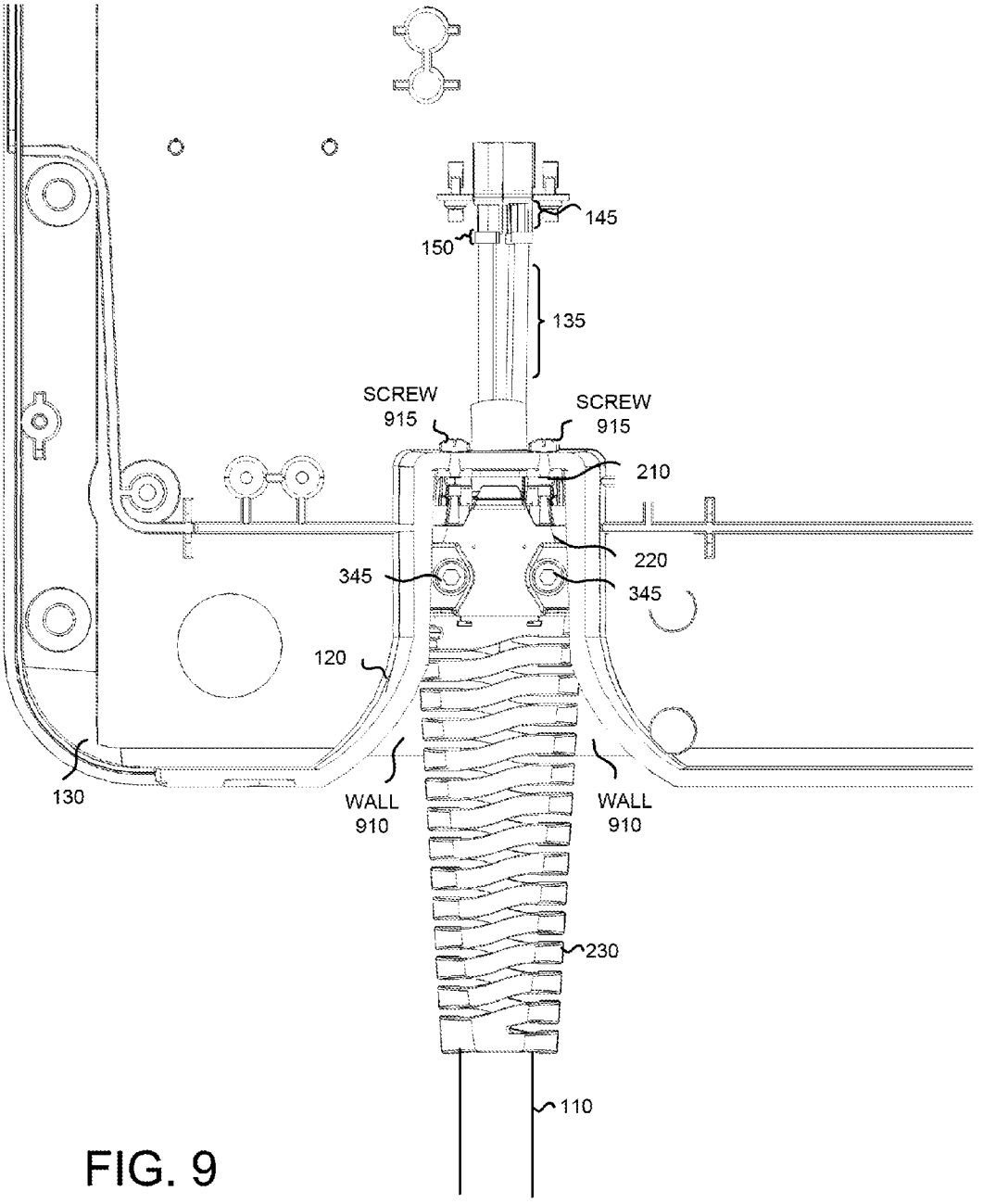

145
150
135
SCREW
915
SCREW
915
210
220
345
345
120
130
WALL
910
WALL
910
230
110

FIG. 9

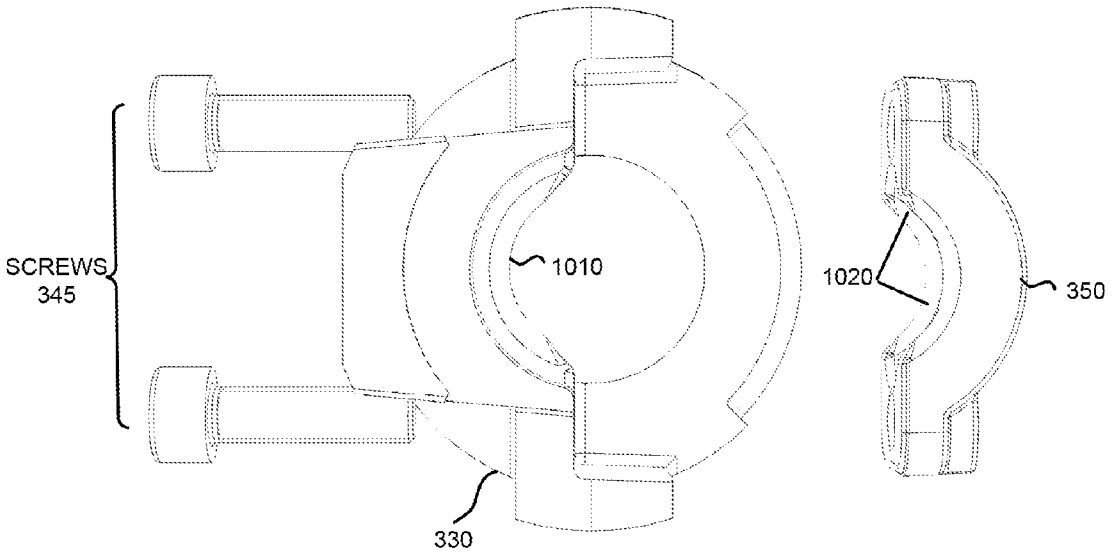


FIG. 10

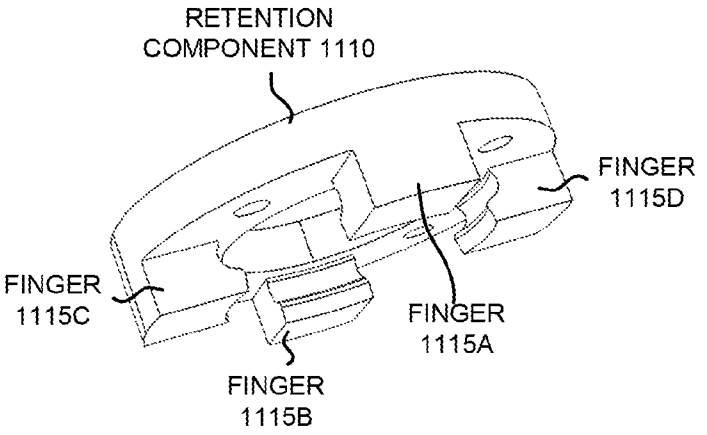

RETENTION
COMPONENT 1110
FINGER
1115D
FINGER
1115C
FINGER
1115A
FINGER
1115B

FIG. 11

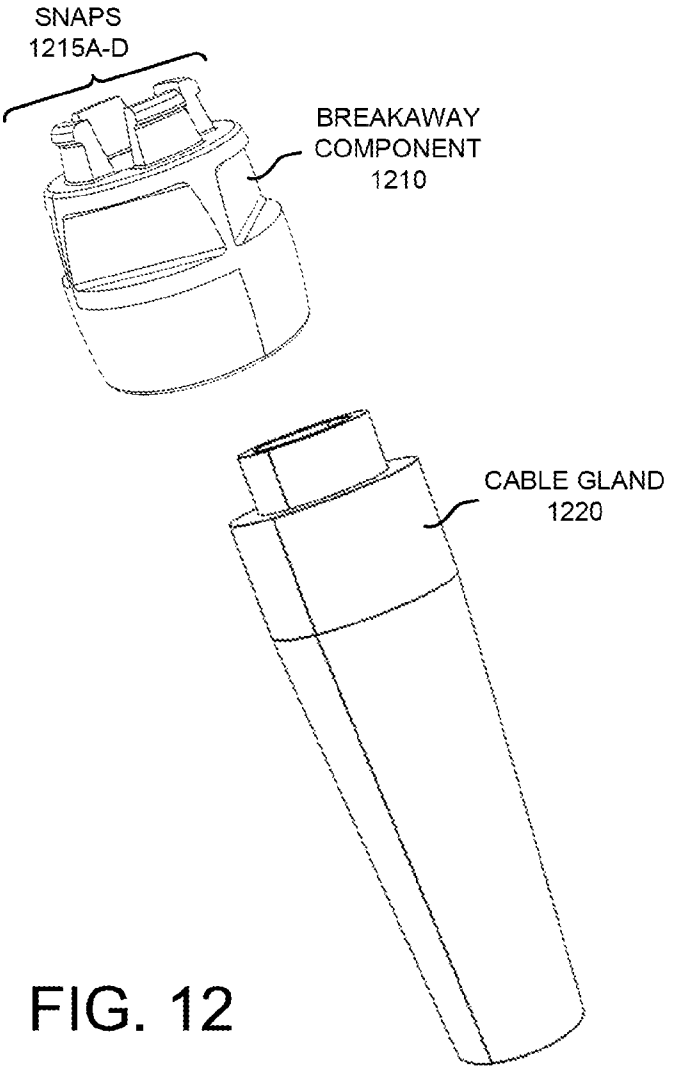

SNAPS
1215A-D
BREAKAWAY
COMPONENT
1210
CABLE GLAND
1220

FIG. 12

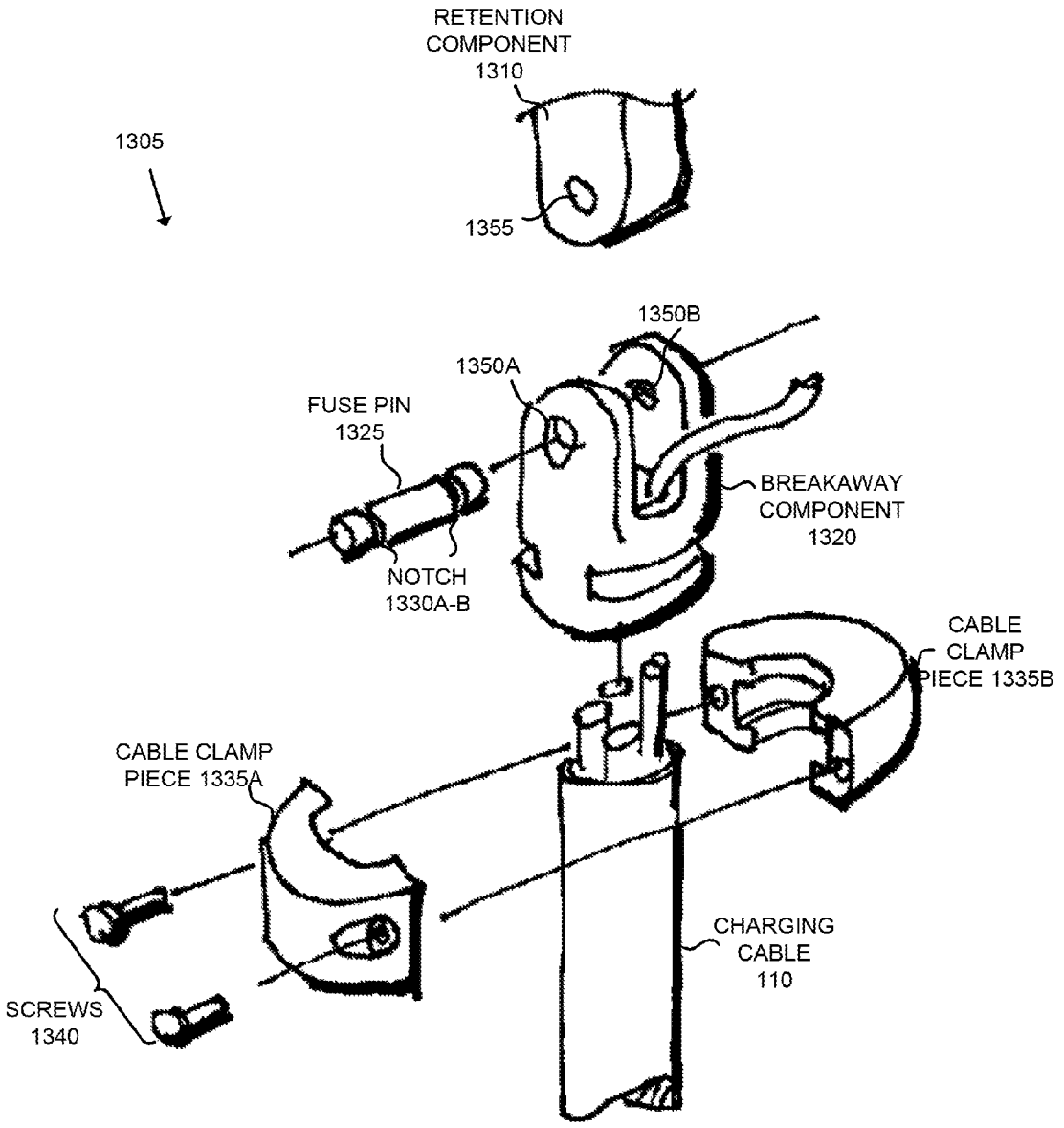

RETENTION COMPONENT 1310
1305
1355
1350B
1350A
FUSE PIN 1325
BREAKAWAY COMPONENT 1320
NOTCH 1330A-B
CABLE CLAMP PIECE 1335B
CABLE CLAMP PIECE 1335A
CHARGING CABLE 110
SCREWS 1340

FIG. 13

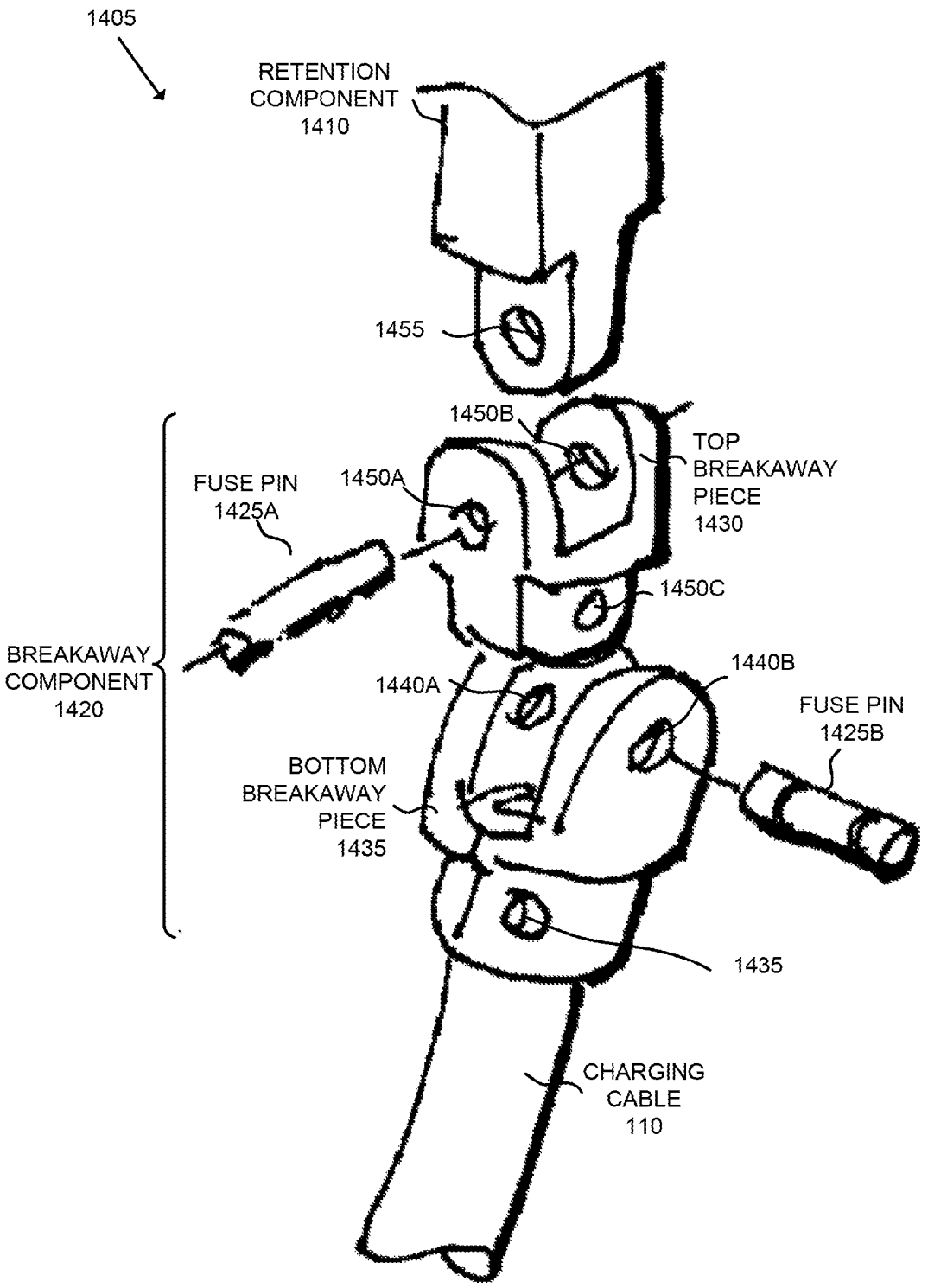

1405
RETENTION COMPONENT 1410
1455
1450B
TOP BREAKAWAY PIECE 1430
FUSE PIN 1425A
1450A
1450C
BREAKAWAY COMPONENT 1420
1440A
1440B
FUSE PIN 1425B
BOTTOM BREAKAWAY PIECE 1435
1435
CHARGING CABLE 110

FIG. 14

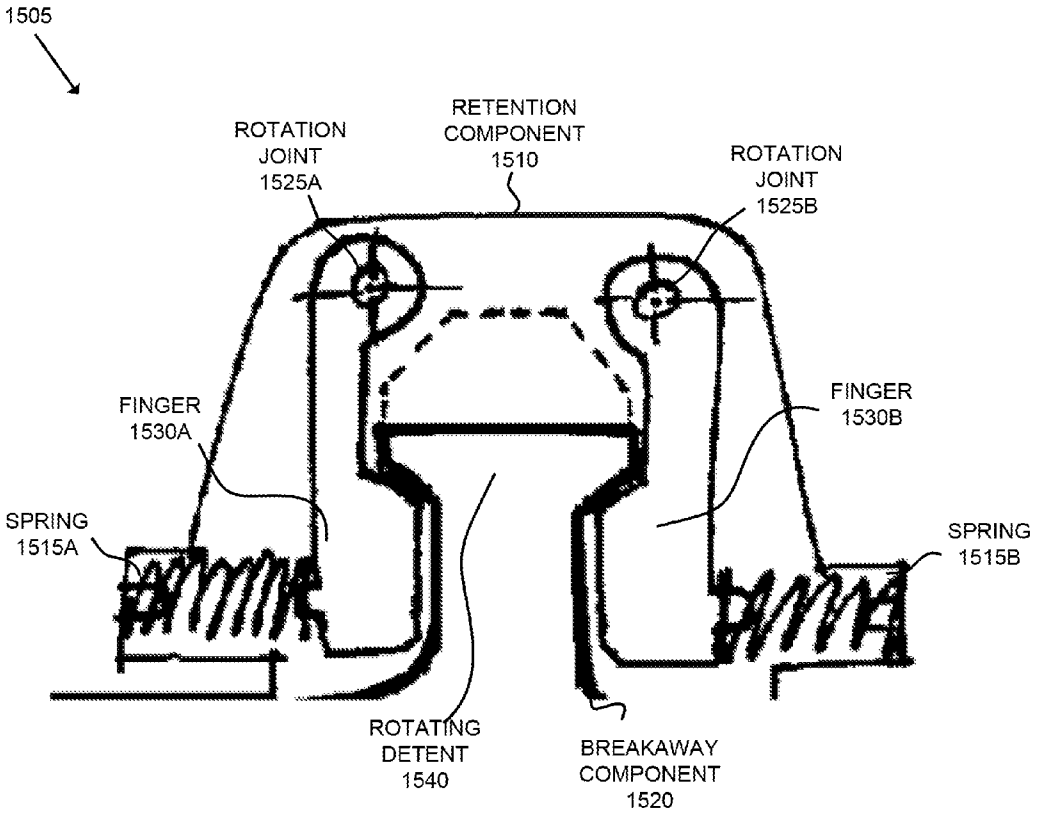

1505
ROTATION JOINT 1525A
RETENTION COMPONENT 1510
ROTATION JOINT 1525B
FINGER 1530A
FINGER 1530B
SPRING 1515A
SPRING 1515B
ROTATING DETENT 1540
BREAKAWAY COMPONENT 1520

FIG. 15

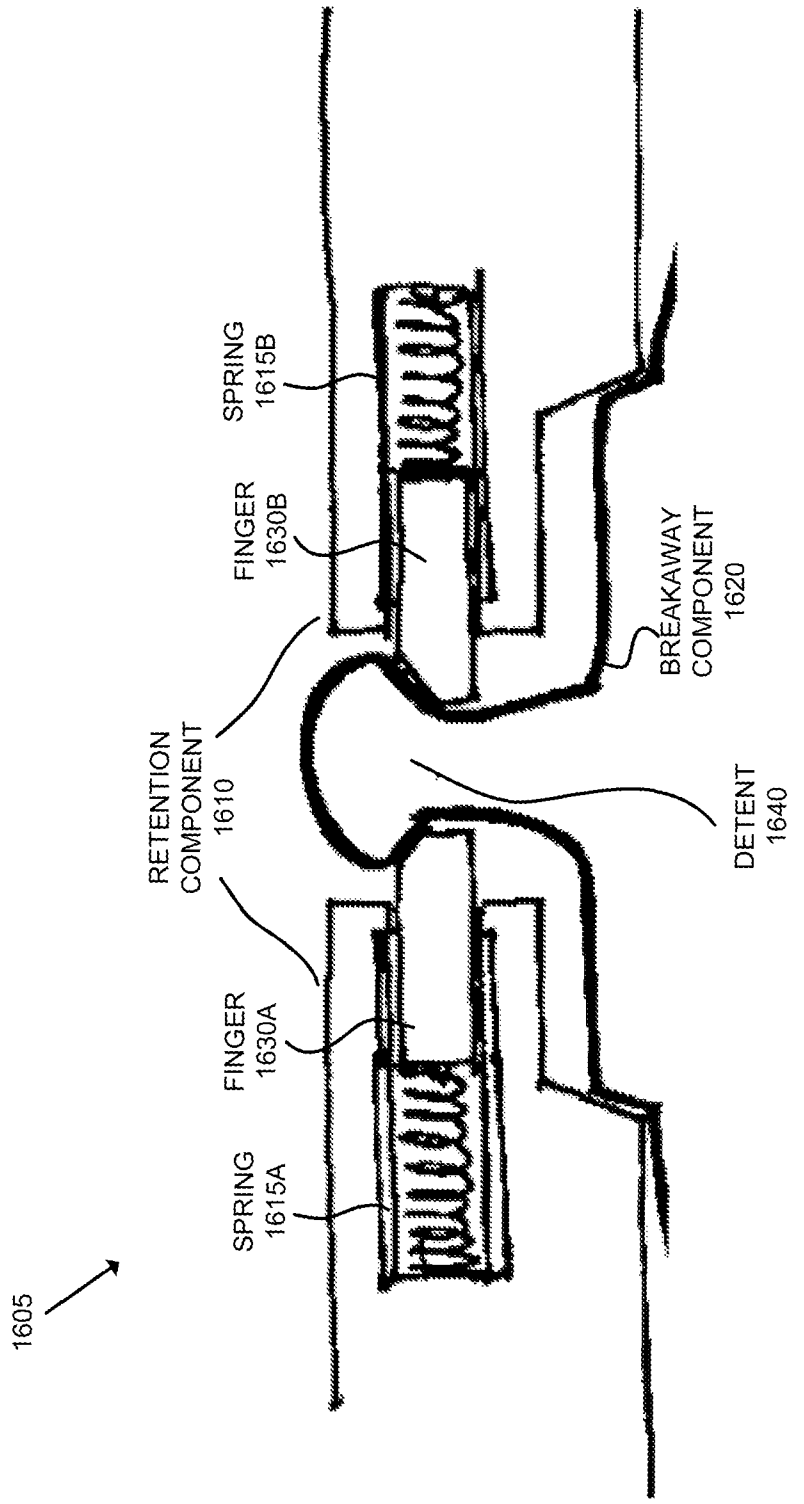

1605
SPRING 1615A
FINGER 1630A
RETENTION COMPONENT 1610
SPRING 1615B
FINGER 1630B
BREAKAWAY COMPONENT 1620
DETENT 1640

FIG. 16

BREAKAWAY MECHANISM FOR CHARGING CABLES OF ELECTRIC VEHICLE CHARGING STATIONS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of U.S. Provisional Application No. 61/363,168, filed Jul. 9, 2010, which is hereby incorporated by reference.

FIELD

Embodiments of the invention relate to the field of electric vehicle charging stations; and more specifically to a breakaway mechanism for a charging cable of electric vehicle charging stations.

BACKGROUND

Electric vehicle charging stations charge electric vehicles (e.g., electric battery powered vehicles, gasoline/electric battery powered hybrid vehicles, etc.). Energy is provided through a charging cable where one end is connected at the charging station and the other end connects to on-board charging circuitry of an electric vehicle. The charging cable and/or connectors (at the connection point at the charging station and/or at the electric vehicle) are subject to damage in case of unexpected vehicle runaway or other high force that is applied to the charging cable. Certain standards (e.g., NFPA (National Fire Protection Association) 70: National Electrical Code 2008, Article 625, (specifically 625.19 "Automatic De-Energization of Cable"), and UL (Underwriters Laboratories) 2594, Electric Vehicle Supply Equipment, November 2009, (specifically paragraph 13.1.14)) require that the charging cable be de-energized when there is an amount of cable strain that could result in either the charging cable rupturing or separation of the charging cable from the electric vehicle connector and exposure of live parts.

SUMMARY

A breakaway mechanism for a charging cable of an electric vehicle charging station is described. In one embodiment, an electric vehicle charging station ("charging station") includes a set of connectors to connect to a set of one or more charging wires of a charging cable (e.g., power wire(s), signaling wire(s), etc.). A breakaway mechanism includes a retention component that is secured to housing of the charging station and a breakaway component that is secured to the charging cable. The breakaway component is adapted to connect to the retention component and disconnect from the retention component at a predetermined force thereby causing the charging wires to disconnect from the set of connectors.

In one embodiment, the retention component includes a set of finger members that engage with a set of snap members of the breakaway component. The snap members are sized to flex and unsnap from the set of finger members at a predetermined pull force.

In one embodiment, the breakaway component includes an integrated snap and clamp piece that includes the set of snap members and a portion of a clamp to secure the breakaway component to the charging cable. The other portion of the clamp is a separate cable clamp piece that is fastened to the integrated snap and clamp piece by one or more fasteners to secure the breakaway component to the charging cable. The breakaway component may also include a strain relief to constrain the charging cable to a minimum bend radius,

In one embodiment the breakaway mechanism works in conjunction with a funnel shaped breakaway enclosure of housing of the charging station. The walls of the funnel shaped enclosure translate the pull force from multiple directions into a one dimensional pull force along the line of axis of the breakaway component. The strain relief also assists in translating the pull force from multiple directions into a one dimensional pull force along the line of axis of the breakaway component. The breakaway component and strain relief (if included) are shaped to allow the detached cable portion and breakaway component to fall unencumbered along the funnel shaped breakaway enclosure so that the wires can easily fall out of the charging station without causing damage to the charging station or wires.

Other embodiments are also described.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention may best be understood by referring to the following description and accompanying drawings that are used to illustrate embodiments of the invention. In the drawings:

FIG. **1** illustrates an exemplary electric vehicle charging station with an exemplary breakaway mechanism according to one embodiment;

FIG. **2** illustrates the breakaway mechanism of FIG. **1** in more detail according to one embodiment;

FIG. **3** illustrates an exploded view of the breakaway mechanism of FIG. **1** according to one embodiment;

FIG. **4** illustrates a bottom retention piece of a retention component sliding onto an integrated snap and clamp piece of a breakaway component of the breakaway mechanism according to one embodiment;

FIG. **5** illustrates a top retention piece of the retention component sliding onto the integrated snap and clamp piece of the breakaway component after the bottom piece retention piece has been slid into position according to one embodiment;

FIG. **6** illustrates an exploded view of the strain relief and the breakaway component of the breakaway mechanism according to one embodiment;

FIG. **7** illustrates the bottom retention piece of the retention component secured to the integrated snap and clamp piece of the breakaway component according to one embodiment;

FIG. **8** illustrates the top retention piece and the bottom retention piece of the retention component secured to the integrated snap and clamp piece of the breakaway component according to one embodiment;

FIG. **9** illustrates a cross section view of the funnel shaped breakaway enclosure of the charging station housing when the charging cable is connected to the charging station according to one embodiment;

FIG. **10** illustrates a view of the cable clamp portion and the cable clamp piece according to one embodiment;

FIG. **11** illustrates an exemplary one piece retention component according to one embodiment;

FIG. **12** illustrates an exemplary one piece breakaway component and cable gland according to one embodiment;

FIG. **13** illustrates a breakaway mechanism that uses a fuse pin disengagement mechanism according to one embodiment;

FIG. **14** illustrates a breakaway mechanism that uses an alternative fuse pin disengagement mechanism according to one embodiment;

FIG. **15** illustrates a breakaway mechanism that uses a rotating detent disengagement mechanism according to one embodiment; and

FIG. **16** illustrates a breakaway mechanism that uses a sliding detent disengagement mechanism according to one embodiment.

DESCRIPTION OF EMBODIMENTS

In the following description, numerous specific details are set forth. However, it is understood that embodiments of the invention may be practiced without these specific details. In other instances, well-known circuits, structures and/or techniques have not been shown in detail in order not to obscure the understanding of this description. Those of ordinary skill in the art, with the included descriptions, will be able to implement appropriate functionality without undue experimentation.

References in the specification to "one embodiment," "an embodiment," "an example embodiment," etc., indicate that the embodiment described may include a particular feature, structure, or characteristic, but every embodiment may not necessarily include the particular feature, structure, or characteristic. Moreover, such phrases are not necessarily referring to the same embodiment. Further, when a particular feature, structure, or characteristic is described in connection with an embodiment, it is submitted that it is within the knowledge of one skilled in the art to effect such feature, structure, or characteristic in connection with other embodiments whether or not explicitly described.

In the following description and claims, the term "coupled" along with its derivatives, may be used. "Coupled" is used to indicate that two or more elements, which may or may not be in direct physical or electrical contact with each other, cooperate or interact with each other.

An apparatus for a breakaway mechanism for an electric vehicle charging cable of an electric vehicle charging station is described. In one embodiment, the breakaway mechanism includes a retention component coupled with a breakaway component. The retention component is secured to an electric vehicle charging station (hereinafter "charging station") and the breakaway component is secured to an electric vehicle charging cable (hereinafter "charging cable"). The charging cable includes a set of charging wires that connect to a set of connectors in the charging station, which are inaccessible by users of the charging station. The breakaway component is adapted to disconnect from retention component when a breakaway force at a predetermined pull force is applied to the breakaway component.

In one embodiment, the retention component includes finger members that slip onto snap members of the breakaway component. The snap members of the breakaway component flex and slip off the finger members of the retention component at a predetermined pull force, causing the charging cable to detach from the charging station (including the set of charging wires disconnecting from the connectors).

In one embodiment, the breakaway mechanism works in conjunction with a funnel shaped enclosure at the charging station. The walls of the funnel shaped enclosure translate the pull force from multiple directions into a one dimensional pull force along the line of axis of the breakaway component.

FIG. **1** illustrates an exemplary electric vehicle charging station with an exemplary breakaway mechanism according to one embodiment. The charging station **100** is used to charge electric vehicles (e.g., electric battery powered vehicles, gasoline/electric battery powered hybrid vehicles, etc.). For example, an operator of an electric vehicle connects the electric vehicle connector **140** connected with the charging cable **110** to on-board charging circuitry of their electric vehicle to transfer energy to the electricity storage device of the electric vehicle.

The charging station **100** includes the charging station housing **130** that includes the funnel shaped breakaway enclosure **120**. The charging station housing **130** houses the charging station connectors **145**. The charging station connectors **145** connect to the charging wire connectors **150** of the charging wires **135** of the charging cable **110** and provide connections to one or more components (not illustrated) (e.g., power, control pilot circuitry, GFCI (ground fault circuit interrupter), etc.) that allow the charging station **100** to transfer energy to electric vehicles. It should be understood that the charging station **100** includes other components that are not directly coupled with the connectors **145** and are not illustrated in order not to obscure understanding of the invention.

The charging cable **110** passes through the breakaway shaped funnel enclosure **120**. The charging cable **110** includes the charging wires **135** and terminates at one end with the electric vehicle connector **140**, and terminates at the other end with the charging wire connectors **150** (e.g., male connectors) that are capable of being connected to the charging station connectors **145** of the charging station (e.g., female connectors). As illustrated in FIG. **1**, the charging wire connectors **150** are connected to the charging station connectors **145**. In one embodiment, the charging station connectors **145** are quick disconnect connectors that allow the charging wire connectors **150** to be quickly and easily disconnected (e.g., with a minimal amount of force). For example, upon a breakaway event, the charging wire connectors **150** disconnect from the charging station connectors **145**.

In one embodiment, the charging wires **135** include one or more wires for power, a ground wire, and a wire for signaling (e.g., a wire carrying a control pilot signal). In some embodiments, the charging station **100** includes control pilot circuitry (not illustrated) that processes control pilot signals. The control pilot allows charging stations to ensure proper operation when charging electric vehicles. For example, the control pilot can verify that an electric vehicle is connected (e.g., the electric vehicle connector **140** is properly connected to on-board charging circuitry of an electric vehicle) and whether the electric vehicle is ready to accept energy. The charging station **100** further includes an electricity control device to energize and de-energize the charging cable **110**. The charging station **100** will de-energize the charging cable **110** or prevent it from being energized when the signal from the control pilot indicates that an electric vehicle is not connected, not ready to accept energy, or there is some other problem. Of course, if the control pilot circuitry does not receive a control pilot signal, the charging station **100** will de-energize the charging cable **110** or prevent it from being energized. Thus, if the charging wire carrying the control pilot signal is disconnected from its charging station connector, the charging cable **110** will not be energized. In such embodiments, the charging wire carrying the control pilot signal may be shorter than the other charging wires so that the charging wire carrying the control pilot signal will be the first charging wire to be disconnected upon a breakaway event causing the charging station **100** to de-energize the charging cable **110**.

The charging cable **110** is coupled with the breakaway mechanism **115**. The breakaway mechanism **115**, which will be described in greater detail later herein, causes the charging cable **110**, along with the charging wire connectors **150**, to detach from the charging station **100** at a predetermined pull force. For example, the charging wire connectors **150** release

from the charging station connectors **145** and the charging cable **110** is allowed to fall through the funnel shaped breakaway enclosure **120**. The predetermined pull force is less than what would rupture the charging cable **110** (that is, the breakaway component **220** is designed to separate from the retention component **210** at a force less than would be sufficient to rupture the charging cable **110**).

The funnel shaped breakaway enclosure **120** houses at least part of the breakaway mechanism **115** and works in conjunction with the breakaway mechanism to translate pull on the charging cable **110** from multiple directions into a one dimensional pull along the line of axis of the breakaway component of the breakaway mechanism **115**. The funnel shaped breakaway enclosure **120** also prevents access to the charging wire connectors **150** and charging station connectors **145** (e.g., a user cannot manually disconnect the charging wire connectors **150**). While FIG. **1** illustrates the funnel shaped breakaway enclosure **120** towards the bottom of the charging station housing, embodiments are not so limited as the funnel shaped breakaway enclosure may be in different locations (e.g., extending from the side of the charging station housing **130**, extending from the middle of the charging station housing **130**, etc.).

FIG. **2** illustrates the breakaway mechanism **115** in more detail according to one embodiment. The breakaway mechanism **115** includes a retention component **210**, a breakaway component **220**, and the strain relief **230**. The retention component **210** is secured to the charging station **100**. For example, the retention component **210** is screwed or otherwise fastened to the funnel shaped breakaway enclosure **120**. The breakaway component **220** is secured to the charging cable **110** (e.g., is clamped to the charging cable **110**) and is coupled with the strain relief **230**. The charging cable **110** passes through the breakaway component **220** and the retention component **210**. The breakaway component **220** is adapted to break away from the retention component **210** at a predetermined pull force. The retention component **210** typically remains secured to the charging station **100** when the breakaway component **220** disconnects. It should be understood that while the breakaway component **220** is secured to the retention component **210** and the charging cable **110**, substantially all of the pull force on the charging cable **110** is applied to the breakaway component **220**. Thus, until the breakaway component **220** separates from the retention component **210**, the charging wire connectors **150** of the charging wires **135** will typically remain connected to the charging station connectors **145**.

The charging cable **110** passes through the strain relief **230** through the breakaway component **220** and the retention component **210**. The strain relief **230** constrains the charging cable **110** to a minimum bend radius. This protects the charging cable **110** from damage as well as assisting in translating a pull force from multiple directions into a one dimensional pull force along the axis of the breakaway component **220**. The strain relief **230** is secured to the breakaway component **220**, as will be described in greater detail with respect to FIG. **3**. The strain relief **230** may be different in different embodiments (e.g., a one piece molded polycarbonate strain relief, a linked strain relief (glass filled plastic or aluminum links that attach together), etc.). The breakaway component **220** and strain relief **230** are shaped with gentle, curved profile to not catch or bind to the funnel side walls of the funnel shaped breakaway enclosure **120** during the breakaway disengagement and release from the charging station **100**. Thus, after the breakaway disengagement the breakaway component **220** and strain relief **230** fall unencumbered from the charging station **100**.

FIG. **3** illustrates an exploded view of the breakaway mechanism **115** according to one embodiment. The breakaway component **220** includes the integrated snap and clamp piece **330**, the cable clamp piece **350**, and the screws **345** (which may be socket screws or other screw type and that secure the integrated snap and clamp piece **330** and the cable clamp piece **350** to the charging cable **110**). The integrated snap and clamp piece **330** includes a snap portion **335** and a clamp portion **340**. The snap portion **335** includes the snap members **355**A-D that extend from the top of the integrated snap and clamp piece **330** and are used secure the breakaway component **220** with the retention component **210**. Although four snap members are illustrated, in other embodiments the integrated snap and clamp piece includes more snap members or less snap members.

The clamp portion **340**, along with the cable clamp piece **350**, secures the breakaway component **220** to the charging cable **110** through use of the screws **345**. For example, the integrated snap and clamp piece **330** includes the openings **360** and the cable clamp piece **350** includes the threaded openings **365** that allow the screws **345** to fasten the integrated snap and clamp piece **330** and the cable clamp piece **350** together thereby clamping the charging cable **110** to the breakaway component **220**. Thus, the integrated snap and clamp piece **330** provides part of the clamp and the cable clamp piece **350** provides the other part of the clamp. While screws are illustrated, in other embodiments a different type of fastener is used to secure the integrated snap and clamp piece **330** and the cable clamp piece **350** to the charging cable **110**. Moreover, while two screws are illustrated, in some embodiments there is more or less screws that fasten the integrated snap and clamp piece **330** and the cable clamp piece **350** to the charging cable **110**. The strain relief **230** is secured to the breakaway component **220** as the two clamp parts (the integrated snap and clamp piece **330** and the cable clamp piece **350**) are fastened together by the screws **345**.

FIG. **10** illustrates a different view of the cable clamp portion **340** and the cable clamp piece **350**. The clamp portion **340** includes the raised surface **1010** and the cable clamp piece includes the surface **1020**. The surfaces **1010** and **1020** are textured, knurled, and/or patterned to produce better gripping surfaces for greater cable retention since the cable jacket may be smooth and may slip under large forces. In another embodiment, the filler fibers in the charging cable **110** are peeled back and sandwiched between the cable jacket and the clamp surfaces **1010** and **1020** for greater cable retention.

The retention component **210** includes a top retention piece **310** and a bottom retention piece **320**. The top retention piece **310** and bottom retention piece **320** include the fastener openings **370** and **375** (threaded) respectively in order to secure the retention component **210** to the charging station (e.g., screw the retention component **210** into a housing of the charging station). The top retention piece **310** includes the downwardly extending finger members **315**A-B at opposite ends and the bottom retention piece **320** includes the downwardly extending finger members **315**C-D at opposite ends. When the top retention piece **310** and the bottom retention piece **320** are connected to the breakaway component **220**, the finger members **315**A-D are substantially 90 degrees apart. In one embodiment, the top retention piece **310** and the bottom retention piece **320** are die cast metal pieces, while in other embodiments the construction material is different (e.g., sheet metal, glass fiber reinforced injection molded plastic, etc.).

The finger members **315**A-D are adapted to be coupled with the snap members **355**A-D of the integrated snap and clamp piece **330** respectively to secure the breakaway com-

ponent **220** to the retention component **210**. For example, each of the snap members **355**A-D has an outwardly facing portion that is shaped to snap onto an inwardly facing portion of the finger members **315**A-D respectively. In one embodiment, the snap members **355**A-D have a relatively high deflection force (e.g., 200-300 pounds), which prevents the finger members **315**A-D from being easily snapped onto the snap members **355**A-D. In such an embodiment, the top retention piece **310** and the bottom retention piece **320** slide onto the breakaway component such that they are nested at a 90 degree orientation over the snap members **355**A-D. For example, FIG. **4** illustrates the bottom retention piece **320** sliding onto the integrated snap and clamp piece **330**. Specifically, the finger members **315**C-D slide in a position to snap to the snap members **355**C-D respectively. FIG. **5** illustrates the top retention piece **310** sliding onto the integrated snap and clamp piece **330** after the bottom piece retention piece **320** has been slid into position. Specifically, the finger members **315**A-B slide in a position to snap to the snap members **355**A-B respectively.

The snap members **355**A-D flex and unsnap from the finger members **315**A-D at a predetermined pull force, causing the breakaway component **220** (along with the attached charging cable **110**) to separate from the retention component **210**. For example, the outwardly facing portion of a snap **355** slides down the inwardly facing portion of a finger member **315** until it separates from the finger member **315**. When the breakaway component **220** disconnects from the retention component **210**, the charging wire connectors **150** will disconnect from the charging station connectors **145** and typically will fall through the opening of the retention component **210**. Thus, when the breakaway component **220** disconnects from the retention component **210**, the breakaway component **220** disconnects and falls out of the charging station housing **130**.

FIG. **6** illustrates an exploded view of the strain relief **230** and the breakaway component **220** in more detail to illustrate the fit of the breakaway component **220** and the strain relief **230** in one embodiment. The strain relief **230** includes the support portion **610** and the cutout portion **630**. The integrated snap and clamp piece **330** fits with the strain relief **230** through the support portion **610** and the cutout portion **630**. The support portion **610** extends from the body **650** of the strain relief **230** and is curved to allow the curved cable clamp piece **350** to fit against it. The support portion **610** further includes a ridge **635** that fits within the groove **625** between the upper lip **660** and the lower lip **640** of the integrated snap and clamp piece **330**. The upper lip **660**, which is longer than the lower lip **640**, fits over the ridge **635** and the lower lip **640** fits beneath the ridge **635**. The cable clamp piece **350** also fits below the ridge **635** and the lip **640**. The cutout portion **630** is opposite the support portion **610** and forms the ridge **655**. The integrated snap and clamp piece **330** further includes the notch **620** that runs across the bottom of the integrated snap and clamp piece **330**. The bottom of the notch **620** fits into the cutout portion **630** and the ridge **655** fits into the opening of the notch **620**. It should be understood that fit of the breakaway component **220** with the strain relief **230** is relatively loose until the clamp parts of the breakaway component **220** (the clamp portion **340** and the cable clamp piece **350**) are fastened together and clamping the charging cable **110**. Thus, the charging cable **110** acts on the strain relief **230** to tightly bind the strain relief **230** to the breakaway component **220** without the use of additional fastener hardware.

FIG. **7** illustrates the bottom retention piece **320** secured to the integrated snap and clamp piece **330**. Specifically, the finger members **315**C-D are slipped onto the snap members **355**C-D respectively. The snap member **355**C has an outwardly facing portion **710**C that snaps with the inwardly facing portion **715**C of the finger member **315**C and the snap member **355**D has an outwardly facing portion **710**D that snaps with the inwardly facing portion **715**D of the finger member **315**D. The snap members **355**C-D flex and unsnap from the finger members **315**C-D at a predetermined pull force. For example, at a predetermined pull force, the outwardly facing portions **710**C-D of the snap members **355**C-D slide down the inwardly facing portions **715**C-D of the finger members **315**C-D until the snap members **355**C-D are released from the finger members **315**C-D.

FIG. **8** illustrates the top retention piece **310** and the bottom retention piece **320** secured to the integrated snap and clamp piece **330**. The snap member **355**A has an outwardly facing portion **710**A that snaps with the inwardly facing portion **715**A of the finger member **315**A and the snap member **355**B has an outwardly facing portion **710**B that snaps with the inwardly facing portion **715**B of the finger member **315**B. The snap members **355**A-B flex and unsnap from the finger members **715**A-B at a predetermined pull force. For example, at a predetermined pull force, the outwardly facing portions **710**A-B of the snap members **355**A-B slide down the inwardly facing portions **715**A-B of the finger members **315**A-B until the snap members **355**A-B are released from the finger members **315**A-B.

FIG. **9** illustrates a cross section view of the funnel shaped breakaway enclosure **120** of the charging station housing **130** when the charging cable **110** is connected to the charging station according to one embodiment. The breakaway component **220** is secured to the funnel shaped breakaway enclosure by the screws **915**. The funnel shaped breakaway enclosure **120** translates the pull force to the breakaway component **220** when the charging cable **110** is pulled in a direction that causes the strain relief **230** to press against the inner wall **910** of the funnel shaped breakaway enclosure **120**. Thus, regardless of the direction of the pull force (whether substantially on the axis of the breakaway component **220** or from another direction), the force will be applied to the breakaway component **220**.

The funnel shaped breakaway enclosure **120** also encloses at least a portion of the breakaway mechanism **115** (e.g., the retention component **210**, the breakaway component **220**, and at least a portion of the strain relief **230**). This prevents access to the charging wire connectors **150** and the charging station connectors **145**, as well as the breakaway components. For example, a user cannot reach into the charging station and disconnect the charging wire connectors **150** from the charging station connectors **145**. In addition, the funnel shaped breakaway enclosure **120** prevents a user from being able to unscrew the screws **345** that secure the breakaway component **220** to the charging cable **110** or otherwise tamper with the breakaway component **220** or the retention component **210**.

After a breakaway event and the charging cable **110** has separated from the charging station **100**, a service technician will need to be called to re-connect the charging wire connectors **150** to the charging station connectors **145**. The service technician will need to open the charging station in order to access the retention component **210**. Typically the service technician will need to unfasten the retention component **210** and secure the breakaway component **220** (e.g., as described with respect to FIGS. **4-5**) to the retention component. The service technician then can connect the charging wire connectors **150** to the charging station connectors **145** and secure the retention component **210** to the funnel shaped breakaway enclosure **120**. Thus an electric vehicle operator cannot by

themselves re-connect the charging wire connectors **150** to the charging station connectors **145**.

In some embodiments, after a breakaway event has occurred, the charging station causes a notification message (e.g., an email, a text message) to be transmitted to the owner and/or operator of the charging station **100** that indicates that a breakaway event has occurred (a breakaway notification message). In some embodiments the charging station **100** generates and transmits the breakaway notification message to the owner and/or operator while in other embodiments the charging station **100** transmits a notification message request or a breakaway event indicator message to a separate device (e.g., a remote server coupled to the charging station **100**) that generates and transmits the breakaway notification message to the owner and/or operator. Different ways of sensing a breakaway event can be used in different embodiments. For example, in one embodiment, the breakaway component includes a magnet that is sensed by a Hall-effect device that is attached to the retention component. If the breakaway component separates from the retention component, the Hall-effect device changes state. The state change is communicated to a set of one or more control modules of the charging station that cause a breakaway notification message to be transmitted to the owner and/or operator of the charging station.

ALTERNATIVE EMBODIMENTS

While embodiments have been described with respect to a two piece retention component (e.g., the top retention **310** and the bottom retention piece **320**), in other embodiments there is a single piece retention component. FIG. **11** illustrates an exemplary one piece retention component according to one embodiment. The one piece retention component **1110** includes the finger members **1115**A-D. Similar to the two piece retention component **210**, in some embodiments the one piece retention component **1110** can secure the integrated snap and clamp piece **330** through the snap members **355**A-D respectively. In one embodiment the finger members **1115**A-D are lowered between the snap members **355**A-D to engagement level and rotated 45 degrees in the same plane so that the fingers rotate and slip onto the snap members **355**A-D. In another embodiment, the finger members **1115**A-D are snapped onto the snap members **355**A-D.

While embodiments have been described in relation to a multi-piece breakaway component (e.g., the breakaway component **220**), other embodiments use a single piece breakaway component. FIG. **12** illustrates an exemplary one piece breakaway component and cable gland according to one embodiment. The breakaway component **1210** includes the snap members **1215**A-D that extend from the top of the one piece breakaway component **1210**. The snap members **1215**A-D are used to couple the breakaway component **1210** with the finger members of the retention component (e.g., the finger members of the two piece retention component **210** or the one piece retention component **1010**) in a similar way as described with the snap members **355**A-D of the integrated snap and clamp piece **330**.

The single piece breakaway component **1210** is secured to the charging cable **110**, however it is secured in a different way than the multi-piece breakaway component **220**. For example, instead of clamping the charging cable **110** through use of multiple clamp pieces, the design of the single piece breakaway component **1210** squeezes the charging cable **110** through use of the cable gland **1220**. Thus, the charging cable **110** passes through the cable gland **1220**, which itself fits within the breakaway component **1210**, and the breakaway component **1210**.

While embodiments have been described in relation to using a finger and snap disengagement mechanism, other embodiments use different disengagement mechanisms. FIG. **13** illustrates a breakaway mechanism that uses a fuse pin disengagement mechanism according to one embodiment. The breakaway mechanism **1305** includes the retention component **1310**, the breakaway component **1320**, and the cable clamp pieces **1335**A-B. In one embodiment, the retention component **1310** is secured to the charging station housing. The breakaway component **1320** is secured to the charging cable **110** as the cable clamp pieces **1335**A-B are fastened by the screws **1340**. Although not illustrated, a strain relief similar to the strain relief **230** may be also be used in some embodiments.

The breakaway component **1320** is secured to the retention component **1310** by the fuse pin **1325**. The fuse pin **1325** is a double notch fuse pin that passes through one of the openings **1350**A-B of the breakaway component **1320** and the opening **1355** of the retention component **1310** and then through the other one of the openings **1350**A-B such that the notches **1330**A-B rest on the breakaway component **1320** and the pin **1325** secures the breakaway component **1320** to the retention component **1310**. The charging wires of the charging cable **110** pass through the breakaway component **1320**, but may not pass through the retention component **1310**. Upon a predetermined pull force, the fuse pin **1325** breaks in double shear causing the breakaway component **1320** to separate from the retention component **1310** (the retention component **1310** typically remains secured to the charging station), thereby causing the charging wire connectors **150** to disconnect from the charging station connectors **145**. Although not illustrated, in some embodiments the breakaway mechanism **1305** can be used in conjunction with the funnel shaped breakaway enclosure **120**.

FIG. **14** illustrates a breakaway mechanism that uses an alternative fuse pin disengagement mechanism according to one embodiment. In contrast to the fuse pin disengagement mechanism **1305** illustrated in FIG. **13** that has one degree of freedom, the disengagement mechanism **1405** has two degrees of freedom. The breakaway mechanism **1405** includes the retention component **1410**, which is similar to the retention component **1310**, and the breakaway component **1420**. In one embodiment, the retention component **1410** is secured to the charging station.

The breakaway component includes the top breakaway piece **1430** and the bottom breakaway piece **1435**. The bottom breakaway piece **1435** is secured to the charging cable **110** (e.g., through a cable clamping mechanism such as illustrated in FIG. **13**) and connects to the top breakaway piece **1430** which itself connects to the retention component **1410**. The connection between the top breakaway piece **1430** and the retention component **1410**, and the connection between the bottom breakaway piece **1435** and the top breakaway piece **1430** are substantially perpendicular. Accordingly, the top breakaway piece **1430** provides one degree of freedom and the bottom breakaway piece **1435** provides another degree of freedom. The breakaway mechanism illustrated in FIG. **14** is more tolerant to multiple directions of pull force than the breakaway mechanism illustrated in FIG. **13**.

The fuse pin **1425**A is a double notch fuse pin that secures the top breakaway piece **1430** to the retention component **1410**. For example, the fuse pin **1425**A passes through one of the openings **1450**-B of the top breakaway piece and through the opening **1455** of the retention component **1410** and then

through the other one of the openings **1450**A-B such that the pin notches rest on the top breakaway piece **1430** and secures the top breakaway piece **1430** to the retention component **1410**. The opening **1450**C that is used when securing the bottom breakaway piece **1435** to the top breakaway piece **1430** is substantially perpendicular to the openings **1450**A-B.

The fuse pin **1425**B is a double notch fuse pin that secures the bottom breakaway piece **1435** to the top breakaway piece **1430**. The fuse pin **1425**B passes through one of the openings **1440**A-B of the bottom breakaway piece **1435** and the opening **1450**C of the top breakaway piece **1430** such that the pin notches rest on the bottom breakaway piece **1435** and secures the bottom breakaway piece **1435** to the top breakaway piece **1430**. The opening **1435** of the bottom breakaway piece **1435** is used to fasten the bottom breakaway piece **1435** to the charging cable **110** (e.g., tighten a screw or other fastener in the opening **1435** to secure the bottom breakaway piece **1435** to the charging cable **110**).

While FIG. **14** illustrates that the top breakaway piece **1430** is secured to the retention component **1410** with the fuse pin **1425**A and the bottom breakaway piece **1435** is secured to the top breakaway piece with the fuse pin **1425**B, in other embodiments only one of the breakaway pieces are secured using a fuse pin. For example, the top breakaway piece **1430** may be secured to the retention component **1410** with a fuse pin while the bottom breakaway piece **1435** may be secured to the top breakaway piece **1430** using standard hinge pin that allows pivoting, but does not have breakaway capability; or the bottom breakaway piece **1435** is secured to the top breakaway piece **1430** with a fuse pin while the top breakaway piece **1430** is secured to the retention component **1410** using a standard hinge pin that allows pivoting but does not have breakaway capability.

FIG. **15** illustrates a breakaway mechanism that uses a rotating detent disengagement mechanism according to one embodiment. The breakaway mechanism **1505** includes the retention component **1510** and the breakaway component **1520**. The retention component **1510** is secured to the charging station (e.g., the funnel shaped breakaway enclosure **120**). The retention component **1510** includes the finger members **1530**A-B that are loaded by the compression springs **1515**A-B. The finger members **1530**A-B can be rotated through use of the rotation joints **1525**A-B. The finger members **1530**A-B secure the rotating detent **1540** of the breakaway component **1520**. At a predetermined pull force, the force on the rotating detent **1540** causes the compression springs **1515**A-B to deflect to such an amount to cause the finger members **1530**A-B to release the rotating detent **1540** causing the breakaway component **1520** to separate from the retention component **1510**. Although not illustrated, the breakaway component **1520** is secured to the charging cable (e.g., the breakaway component **1520** includes a two piece clamp similar to the cable clamp pieces **1335**A-B). Although not illustrated, a strain relief similar to the strain relief **230** may be also be used in the breakaway mechanism **1505** and/or a funnel shaped breakaway enclosure (e.g., the funnel shaped breakaway enclosure **120**) may be used in conjunction with the breakaway mechanism **1505**.

FIG. **16** illustrates a breakaway mechanism that uses a sliding detent disengagement mechanism according to one embodiment. The breakaway mechanism **1605** includes the retention component **1610** and the breakaway component **1620**. The retention component **1610** is secured to the charging station (e.g., the funnel shaped breakaway enclosure **120**). The retention component **1610** includes the finger members **1630**A-B that are loaded by the compression springs **1615**A-B respectively. The finger members **1630**A-B secure the detent **1640** of the breakaway component **1620**. At a predetermined pull force, the force on the rotating detent **1640** causes the compression springs **1615**A-B to deflect to such an amount to cause the finger members **1630**A-B to release the detent **1640** causing the breakaway component **1620** to separate from the retention component **1610**. Although not illustrated, the breakaway component **1620** is secured to the charging cable (e.g., the breakaway component **1620** includes a two piece clamp similar to the cable clamp pieces **1335**A-B). Although not illustrated, a strain relief similar to the strain relief **230** may be also be used in the breakaway mechanism **1605** and/or a funnel shaped breakaway enclosure (e.g., the funnel shaped breakaway enclosure **120**) may be used in conjunction with the breakaway mechanism **1605**.

While several different disengagement mechanisms have been described, other types of disengagement mechanisms may be used in other embodiments (e.g., magnets, non-permanent adhesives, latches, breakaway plates, etc).

While embodiments of the invention have been described with respect to clamping the breakaway component to the charging cable, in alternative embodiments the breakaway component is attached to the charging cable differently (e.g., magnets, adhesives, etc.).

While embodiments of the invention have been described with respect to a breakaway mechanism located near the charging station connectors, in alternative embodiments the breakaway mechanism is located in different locations (e.g., the body of the charging cable, the electric vehicle connector). For example, in some embodiments a breakaway mechanism is substantially near or integrated with the electric vehicle connector such as the connector **140**. In such a breakaway mechanism, the retention component may be secured within the electric vehicle connector and the breakaway component is secured to the charging cable. Different disengagement mechanisms may be used in different embodiments. For example, a fuse pin disengagement mechanism may be used where the retention component and the breakaway component are connected through a fuse pin that is adapted to break at a predetermined force. When a predetermined force is applied, the breakaway component separates from the retention component thereby separating the charging cable from the electric vehicle connector. In embodiments where the charging station processes control pilot signals, the wire carrying the control pilot signal may be shorter than the other wires (e.g., the wires carrying the power) such that the control pilot signal is the first signal to be interrupted thereby causing the charging station to de-energize the charging cable.

While the invention has been described in terms of several embodiments, those skilled in the art will recognize that the invention is not limited to the embodiments described, can be practiced with modification and alteration within the spirit and scope of the appended claims. The description is thus to be regarded as illustrative instead of limiting.

What is claimed is:

1. A breakaway mechanism for an electric vehicle charging station, comprising:

a retention component to be secured to the electric vehicle charging station, wherein the retention component includes a set of one or more finger members; and

a breakaway component that includes a set of one or more snap members to engage with the set of finger members to connect the breakaway component to the retention component, the breakaway component further to be secured to a charging cable that passes through the breakaway component and that includes a set of one or

more charging wires that connect to a set of one or more electric vehicle charging station connectors,

wherein the set of snap members of the breakaway component disengages from the set of finger members of the retention component at a predetermined pull force to cause the breakaway component to disengage from the retention component and to cause the set of charging wires to disconnect from the set of electric vehicle charging station connectors.

2. The breakaway mechanism of claim **1**, wherein the breakaway component includes a cable clamp piece and an integrated snap and clamp piece that includes the set of snap members, the cable clamp piece and the integrated snap and clamp piece to secure the breakaway component to the charging cable.

3. The breakaway mechanism of claim **1**, wherein the retention component includes a first retention piece that includes a first set of one or more of the set of finger members and a second retention piece that includes a second set of one or more of the set of finger members.

4. The breakaway mechanism of claim **3**, wherein the first retention piece is to slide into position such that the first set of finger members engage with a first set of one or more of the set of snap members, and wherein the second retention piece is to slide into position such that the second set of finger members engage with a second set of one or more of the set of snap members.

5. The breakaway mechanism of claim **1**, wherein the set of charging wires includes a wire carrying a pilot control signal that the electric vehicle charging station uses to ensure proper charging operation, and a set of one or more power wires, wherein the wire carrying the pilot control signal is shorter than the set of power wires such that the wire carrying the pilot control signal is disconnected first when the breakaway component disengages from the retention component.

6. The breakaway mechanism of claim **1**, further comprising:

a strain relief to be coupled with the breakaway component and to constrain the charging cable to a minimum bend radius.

7. The breakaway mechanism of claim **6**, wherein the breakaway mechanism is to be at least partially enclosed within a funnel shaped breakaway enclosure of the electric vehicle charging station that translates pull force when the charging cable is pulled in a direction that causes the strain relief to press against an inner wall of the funnel shaped breakaway enclosure to a one dimensional pull force along the line of axis of the breakaway component.

8. An apparatus, comprising:

an electric vehicle charging station including:

a set of one or more connectors to connect to a set of one or more charging wires of a charging cable; and

a breakaway mechanism including:

a retention component that is secured to housing of the electric vehicle charging station, the retention component including a set of one or more finger members, and

a breakaway component that is connected to the retention component and is secured to the charging cable, the breakaway component including:

a set of one or more snap members that engage with the set of finger members to connect the breakaway component to the retention component and disengage from the set of finger members at a predetermined pull force to disconnect the breakaway component from the retention component causing the set of charging wires to disconnect from the set of connectors, and

a set of one or more clamping pieces that secures the breakaway component to the charging cable, and

wherein the set of snap members and at least one of the set of clamping pieces are integrated in a single integrated snap and clamp piece.

9. The apparatus of claim **8**, wherein the integrated snap and clamp piece provides a portion of a clamp, wherein the breakaway component further includes a cable clamp piece that provides the remaining portion of the clamp, the integrated snap and clamp piece and the cable clamp piece to secure the breakaway component to the charging cable when fastened together by one or more fasteners.

10. The apparatus of claim **9**, wherein the breakaway mechanism further includes a strain relief that is secured to the breakaway component when the integrated snap and clamp piece and the cable clamp piece are fastened together by the one or more fasteners, the strain relief to constrain the charging cable to a minimum bend radius.

11. The apparatus of claim **10**, wherein the strain relief includes a support portion that extends from the body of the strain relief and is curved to allow the cable clamp piece to fit against the support portion.

12. The apparatus of claim **10**, wherein the electric vehicle charging station further includes a housing that includes a funnel shaped breakaway enclosure that encloses at least a portion of the breakaway mechanism including the breakaway component, wherein the retention component is secured to the funnel shaped breakaway enclosure, and wherein the funnel shaped breakaway enclosure translates pull force when the charging cable is pulled in a direction that causes the strain relief to press against an inner wall of the funnel shaped breakaway force to a one dimensional pull force along the line of axis of the breakaway component.

13. The apparatus of claim **8**, wherein the retention component includes a top retention piece and a bottom retention piece that each include one or more of the set of finger members, wherein the top retention piece and bottom retention piece each slide on the breakaway component and secure different ones of the set of snap members.

14. The apparatus of claim **8**, wherein the set of charging wires includes a wire carrying a pilot control signal that the electric vehicle charging station uses to ensure proper charging operation, and a set of one or more power wires, and wherein the wire carrying the pilot control signal is shorter than the set of power wires such that the wire carrying the pilot control signal is disconnected first when the breakaway component disengages from the retention component.

15. A breakaway mechanism for an electric vehicle charging station, comprising:

a retention component;

a breakaway component;

a means for securing the retention component to the electric vehicle charging station;

a means for securing the breakaway component to a charging cable that is connected to the electric vehicle charging station;

a means for providing strain relief for the charging cable;

a means for translating pull force in multiple directions into a one dimensional pull force along the line of axis of the breakaway component; and

a means for disengaging the breakaway component from the retention component at a predetermined pull force to cause the charging cable to disconnect from the electric vehicle charging station.

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