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Self-fitting pressure equalizing waterproof electronics enclosure

Abstract

Apparatus and associated methods relate to an electronic device enclosure having a water resistant property capable of withstanding a predetermined minimum displacement force. In an illustrative example, a pressed fit self-aligning device enclosure (PFSADE) may include a housing and a cover. The housing, for example, may include an opening configured to receive electronic components during an assembly processing. After the electronic components are installed, for example, the cover may be coupled to the housing to cover the opening. For example, the cover may include an edge surface around a perimeter of the cover and at least one self-aligning element (SAE) extending orthogonal to the edge surface. For example, the SAE may align the cover in a relative position to the housing, and to withstand a predetermined minimum displacement force threshold. Various embodiments may advantageously prevent leakage due to out of tolerance alignment between the housing and the cover.

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References Cited

U.S. PATENT DOCUMENTS

Patent No.	Issued Date	Patentee Name	U.S. Cl.	CPC
4163503	12/1978	McKinnon	220/254.3	H02G 9/10
4623753	12/1985	Feldman	174/50	H01R 4/2483
4872847	12/1988	Fennell	439/133	G01R 11/04
4896784	12/1989	Heath	174/53	H02G 3/14
5310075	12/1993	Wylar	220/731	F21V 31/00
5562222	12/1995	Jordan	220/800	H02G 3/14
5677578	12/1996	Tang	307/119	H01R 13/701
5688298	12/1996	Bosses	N/A	N/A
7291191	12/2006	Kaye	N/A	N/A
7296730	12/2006	Erdie	N/A	N/A
8591268	12/2012	Reimchen	N/A	N/A
9209554	12/2014	Wießneth	N/A	N/A
10335017	12/2018	Waagen et al.	N/A	N/A
10668263	12/2019	Ingram et al.	N/A	N/A
10934840	12/2020	Geyer et al.	N/A	N/A
2004/0123997	12/2003	Drane	174/67	H02G 3/088
2008/0083547	12/2007	Pinol Pedret	174/50	H05K 5/0204
2013/0072063	12/2012	Qiao	N/A	N/A
2015/0155696	12/2014	Coenegracht	174/564	H02G 3/14
2017/0150656	12/2016	Brodsky et al.	N/A	N/A
2021/0105917	12/2020	Vila et al.	N/A	N/A
2021/0254683	12/2020	Baumann et al.	N/A	N/A
2021/0318115	12/2020	Matsumoto et al.	N/A	N/A
2021/0318437	12/2020	Kanoda et al.	N/A	N/A
2022/0115852	12/2021	Ustianowski	N/A	H02G 3/14

FOREIGN PATENT DOCUMENTS

Patent No.	Application Date	Country	CPC
104624853	12/2015	CN	N/A
209354534	12/2018	CN	N/A
202005021092	12/2006	DE	N/A
202014103822	12/2013	DE	N/A
102018215656	12/2018	DE	N/A

2722937	12/2013	EP	N/A
3784992	12/2021	EP	N/A
2237363	12/2004	ES	N/A
2021009956	12/2020	WO	N/A

OTHER PUBLICATIONS

Erdie Industries, Twist-n-Pull Mailing Shipping Tubes: No Tape or Staples Needed, accessed Sep. 1, 2022, <https://erdie.com/pages/twist-n-pull-mailing-and-shipping-tubes>. cited by applicant

Keyence, M18 Threaded type Thrubeam M12 Connector Type, 30 m-PR-G51CBD | Keyence America, accessed Sep. 1, 2022, <https://www.keyence.com/products/sensor/photoelectric/pr-g/models/pr-g51cbd/>. cited by applicant

Sabert, Sabert 20005 14" x 9" x 16 1/4" 2 Entree Meal Cardboard Insert for Tamper-Evident Kraft Paper Delivery Bag—100/Case, accessed Sep. 1, 2022, <https://www.webrestaurantstore.com/lbp-20005-insert-for-self-sealing-delivery-entree-meal-for-2-bag-case/485TEIN20005.html>. cited by applicant

Thor Labs, Self-Centering Lens Mounts, accessed Sep. 1, 2022,

https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_ID=1488. cited by applicant

International Search Report and Written Opinion of the International Searching Authority in related International Application No. PCT/US2023/061590, dated Sep. 22, 2023, 18 pages. cited by applicant

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Background/Summary

TECHNICAL FIELD

(1) Various embodiments relate generally to design and manufacture of sealed electronic devices.

BACKGROUND

(2) A photoelectric sensor is a device used to determine the distance, absence, or presence of an object by using a light transmitter, often infrared, and a photoelectric receiver. In some examples, the photoelectric sensors may be used in industrial manufacturing. For example, the photoelectric sensors may be used to monitor a stack height of carton blanks in a magazine to ensure the stack is not empty to prevent downtime. For example, the photoelectric sensor may be used in a production line (e.g., a conveyor belt) to count a number of units traveling past a predetermined point for a predetermined time period. For example, the photoelectric sensor may be installed in a bottle processing line to reliably detect and accurately count these bottles as the bottles travel on the processing line may trigger predetermined downstream processes based on the bottle count.

(3) Photoelectric sensors are also used in food industry applications. For example, the photoelectric sensor may be used to accurately measure a fill level in a bottle. For example, a food processing line may use photoelectric sensors to accurately detect clear food trays upon their approach. For example, the photoelectric sensor may provide an accurate detection of each tray to ensure that the filling machine only fills when a tray is present, preventing spillage and wasted product.

(4) In various examples, such as in the food processing industry, the photoelectric sensors may be required to be water resistant and/or dirt resistant (e.g., with water resistant ingress protection (IP) scale ratings). In some examples, the water resistant photoelectric sensors may be made with sealed IP69K-rated stainless steel which makes them washdown ready for use in the food industry.

In some examples, because the photoelectric sensors may be required to be used in a sanitary environment (e.g., in a food processing line), the photoelectric sensor may withstand mechanical impact, over-tightening and extreme vibration. Some example housings may be made with IP69K-rated FDA-grade stainless steel enclosure to resist high-pressure, high-temperature washdown as well as chemical clean-in-place processes.

SUMMARY

(5) Apparatus and associated methods relate to an electronic device enclosure having a water resistant property capable of withstanding a predetermined minimum displacement force. In an illustrative example, a pressed fit self-aligning device enclosure (PFSADE) may include a housing and a cover. The housing, for example, may include an opening configured to receive electronic components during an assembly processing. After the electronic components are installed, for example, the cover may be coupled to the housing to cover the opening. For example, the cover may include an edge surface around a perimeter of the cover and at least one self-aligning element (SAE) extending orthogonal to the edge surface. For example, the SAE may align the cover in a relative position to the housing, and to withstand a predetermined minimum displacement force threshold. Various embodiments may advantageously prevent leakage due to out of tolerance alignment between the housing and the cover.

(6) Various embodiments may achieve one or more advantages. For example, some embodiments may advantageously include sealing members to fluidly seal the housing to the cover. Some embodiments may, for example, maintain an assembly force to couple the cover to the housing to be less than a predetermined maximum assembly force threshold. Some embodiments may, for example, include a relative position between the cover and the housing to be within a predetermined maximum displacement threshold. For example, some embodiments may advantageously provide a fluidly sealed electronic device enclosure in a connected mode.

(7) Apparatus and associated methods relate to a cable connector of an electronic device enclosure having a water resistant property. In an illustrative example, a pressed fit self-aligning device enclosure (PFSADE) may include a housing. The housing may, for example, include a cavity coupled to a cable connector. For example, the cable connector may include electrical conduits to sealingly connect electronic components in the cavity to a distant device. For example, the cable connector may include an electric potting filling to fluidly seal the electrical conduits from an exterior environment. For example, a pressure balancing channel (PBC) may provide fluid communication between the cavity to the exterior environment. In a disconnected mode, fluid pressure within the internal cavity may be released through the PBC, for example. Various embodiments may advantageously prevent a pressure differential to be generated within the internal cavity in the disconnected mode.

(8) Various embodiments may achieve one or more advantages. For example, some embodiments may, for example, advantageously prevent electric potting filling from obstructing the fluid communication of the PBC. Some embodiments may, for example, advantageously increase airflow with the PBC having non-circular cross-section.

(9) The details of various embodiments are set forth in the accompanying drawings and the description below. Other features and advantages will be apparent from the description and drawings, and from the claims.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) FIG. 1 depicts an exemplary pressed fit self-aligning device enclosure (PFSADE) employed in an illustrative use-case scenario.

(2) FIG. 2A, FIG. 2B, FIG. 2C, and FIG. 2D are schematic diagrams depicting an exemplary

PFSADE and embodiments of pressed fit side covers of the PFSADE.

(3) FIG. 3A and FIG. 3B show exemplary capability analysis of a manufacturing process of an exemplary PFSADE.

(4) FIG. 4A and FIG. 4B depict an exemplary sealing cable connector of an exemplary PFSADE.

(5) FIG. 5 is a flowchart illustrating an exemplary PFSADE assembly method.

(6) FIG. 6 is a flowchart illustrating an exemplary SAE configuration method.

(7) Like reference symbols in the various drawings indicate like elements.

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

(8) To aid understanding, this document is organized as follows. First, to help introduce discussion of various embodiments, an exemplary pressed fit self-aligning device enclosure (PFSADE) is introduced with reference to FIGS. 1-2D. Second, this disclosure turns to a review of experimental data and a discussion of configuration and placement of the PFSADE based on a capability analysis with reference to FIGS. 3A-3B. Third, with reference to FIG. 4, a pressure balancing cable connector is described in application to the PFSADE. Fourth, and with reference to FIGS. 5-6, this document describes exemplary apparatus and methods useful for manufacturing and configuring the PFSADE. Finally, the document discusses further embodiments, exemplary applications and aspects relating to PFSADE.

(9) FIG. 1 depicts an exemplary pressed fit self-aligning device enclosure (PFSADE **100**) employed in an illustrative use-case scenario. For example, the PFSADE **100** may be used as an enclosure of a water resistant (and/or dust resistant) electronic device. For example, the water resistant electronic device may be an electronic device **105** (as shown in FIG. 1). For example, the electronic device **105** may be a water resistant photoelectric distance sensor. For example, the electronic device **105** may be used in a food processing industry that requires a housing of a specific water resistant rating. For example, the PFSADE **100** may be self-aligned in an assembly process that may advantageously reduce faulty devices failing to reach the specific water resistant rating.

(10) As shown, the PFSADE **100** includes a side cover **110** and a housing **115**. For example, the side cover **110** and the housing **115** may be made of metal. For example, the side cover **110** and the housing **115** may be made of stainless steel. For example, the housing **115** may be made of water resistant stainless steel. For example, the side cover **110** and the housing **115** may be made of plastic. For example, the side cover **110** and the housing **115** may be made of a combination of metal and plastic. In some examples, the housing **115** may be an electroplated nickel housing. For example, the side cover **110** may be an electroplated aluminum cover. Various other combinations of the above and other materials may be possible.

(11) The housing **115**, in this example, includes an opening **120** that allows electronics of the electronic device **105** to be installed within the housing **115**. As shown, the housing **115** includes a mating perimeter opening **125**. For example, after the electronics are installed, the side cover **110** may be coupled to the housing **115**.

(12) In this example, the side cover **110** includes a self-aligning element (SAE **130**). In various embodiments, the SAE **130** may be one or more nubs. For example, the SAE **130** may protrude around a perimeter of the side cover **110**. The SAE **130**, for example, may interface with a press fit to the mating perimeter opening **125** of the housing **115**. As shown, the SAE **130** may extend orthogonal to an edge surface **135** of the side cover **110**. In some implementations, a size and distribution of the SAE **130** around the edge surface **135** may each advantageously provide a single point of contact around the mating perimeter opening **125**. For example, the side cover **110** may be aligned within a predetermined position threshold relative to the housing **115** based on the size and distribution of the SAE **130**.

(13) In some implementations, the PFSADE **100** may advantageously facilitate installation of the side cover **110** to the housing **115**. For example, in a cover installation assembly process, the SAE **130** may advantageously be self-aligned with the mating perimeter opening **125** to advantageously

provide a friction fit at the mating perimeter opening **125**. For example, the friction fit may maintain a relative position of the side cover **110** to the housing **115** against disturbance forces upon completion of the cover installation assembly process.

(14) In some implementations, during a cover installation assembly process, the side cover **110** to the housing **115** may be required to be physically secured. For example, a positional relationship between side cover **110** to the housing **115** may be required to be maintained to withstand a predetermined minimum displacement force.

(15) As an illustrative example shown in FIG. **1**, the electronic device **105** may be, after being assembled in a factory **140**, transported by a boat **145** to a destination (e.g., a warehouse at a destination country, a retail shop). In some implementations, the SAE **130** may be configured to be placed around the side cover **110** to advantageously result in a fit between side cover **110** to the housing **115** that may withstand displacement forces caused by transport (e.g., triggered by temperature or pressure variations during a sea freight), or manipulation of the electronic device **105**, or any residual forces or reactions in an assembly process of the electronic device **105**.

(16) In some implementations, when the SAE **130** is engaged with the mating perimeter opening **125**, the SAE **130** may be permanently deformed to be press-fitted to the mating perimeter opening **125**. For example, the SAE **130** may advantageously require a minimum assemble force to be exerted to the SAE **130** to securely install the side cover **110** to the **115**.

(17) As an illustrative example, in an assembly process of the electronic device **105**, dimensions of the opening **120** may vary (e.g., due to being produced in different manufacturing plants, different manufacturing machines, different environmental factors) for each of the housing **115**. To secure the side cover **110** to the housing **115**, for example, a smaller assembly force may be required for a larger opening **120** than a smaller opening **120**. By configuring a size of the SAE **130**, for example, the side cover **110** may be configured to require a maximum assembly force to be securely coupled to an identified smallest opening **120**. For example, sizes and dimensions of the opening **120** may be statistically determined in an industrial design process. Accordingly, the SAE **130** may advantageously ensure reliability and consistency of the cover installation assembly process.

(18) In various implementations, the PFSADE **100** may include the housing **115** coupled to the side cover **110**. For example, the SAE **130** may extend orthogonally to the edge surface **135**. For example, the SAE **130** may include a size and a distribution on the edge surface **135** configured to, upon securely coupled to the housing **115**, withstand a predetermined assembly force threshold. For example, in an assembling process, the SAE **130** is permanently deformed by a pressing force larger than a predetermined assembly force threshold. For example, the side cover **110** is aligned within a predetermined position threshold relative to the housing **115** against subsequent displacement forces.

(19) In this example, the PFSADE **100** includes a sealing cable connector **150**. In some implementations, the sealing cable connector **150** may be sealingly coupled to the PFSADE **100** to prevent fluid communication between a cavity **160** of the PFSADE **100** and an ambient environment of the PFSADE **100**. For example, the sealing cable connector **150** may ensure the PFSADE **100** to be water resistant. In some examples, during a transportation of the PFSADE **100**, temperature and pressure variances may induce a higher pressure within the cavity **160** than the ambient environment of the PFSADE **100**. The higher pressure may exert an upward force on the side cover **110**. For example, the upward force may pop the side cover **110** to create a hole on an edge between the side cover **110** and the housing **115**. In some examples, the upward force may break open the side cover **110**.

(20) In this example, the sealing cable connector **150** includes a pressure balancing channel (PBC **155**). The PBC **155** may, for example, include a lumen connecting the cavity **160** to the external environment of the PFSADE **100**. For example, when the PFSADE **100** is not coupled to other devices, the PBC **155** may relieve pressure build up within the cavity of the PFSADE **100**. In some examples, when the sealing cable connector **150** is connected to a distant device via a closed

electromagnetic conduit (e.g., a conduit **165** connecting the electronic device **105** to another device), the PBC **155** may be concealed so that the PFSADE **100** may advantageously maintain a water resistant rating in operation (e.g., in a connected state).

(21) In various implementations, the PFSADE **100** may include a body defining the cavity **160** coupled to the sealing cable connector (e.g., the sealing cable connector **150**) extending in a longitudinal axis configured to sealingly connect to a distant device via a closed electromagnetic conduit **165**, wherein the cable connector includes a pressure balancing channel including a lumen extending from the cavity to a distal end of the cable connector. In some implementations, when the cable connector is disconnected, fluid pressure within the air-tight body is released through the pressure balancing channel. For example, when the cable connector is sealingly connected to the closed electromagnetic conduit, the cavity is limited to fluid communication with an interior of the closed electromagnetic conduit. Accordingly, for example, the cavity is fluidly separated from an exterior environment.

(22) FIG. 2A, FIG. 2B, FIG. 2C, and FIG. 2D are schematic diagrams depicting exemplary PFSADEs and embodiments of pressed fit side covers of the PFSADEs. As shown in FIG. 2A, the side cover **110** includes the SAE **130** extending orthogonal to the edge surface **135**. In this example, the side cover **110** includes a flat top surface **200**. For example, the SAE **130** may extend substantially in the same plane of the flat top surface **200**. In this example, the flat top surface **200** may be on an xz-plane (e.g., a horizontal plane) orthogonal to a y-axis, and the SAE **130** may be extending along an x-axis.

(23) As shown in FIG. 2B, the side cover **110** is engaged and coupled to the housing **115**. In some implementations, the housing **115** may be applied with a sealing member (e.g., an adhesive) on a ledge **205** before coupling to the side cover **110**. For example, in an assembly process, a pressing force may be exerted on the flat top surface **200** against the ledge **205**. For example, the sealing member may, for example, seal the housing **115** to the side cover **110** fluidly. As an illustrative example, in an assembly process, the sealing member may be applied to the ledge **205** before the housing **115** engages the side cover **110**. For example, without the SAE **130** the side cover **110** may rattle around the opening without alignment.

(24) In some implementations, the housing **115** may be metal injection molded. For example, the ledge **205** may become narrow at some spots around the opening **120**. In this example, the PFSADE **100** may include a gap **210** between the side cover **110** and the housing **115**. If the gap **210** is too large or excessively wide, for example, a void without a sealing member (e.g., adhesive) may be created at a narrow position of the ledge **205**. For example, the void may create a leakage problem for the PFSADE **100**.

(25) If the gap **210** is too small, for example, the sealing member may be pressured to pop the side cover **110** up. For example, the popped up cover may create a distortion at the flat top surface **200**. In some examples, the popped up cover may render the PFSADE **100** unsealed.

(26) In some implementations, the SAE **130** may be self-fixing. For example, the side cover **110** may include a size and location of the SAE **130** determined based on measurements and/or experiments. In some examples, the size and location of the SAE **130** may advantageously reduce leaking of the PFSADE **100**. For example, the width of the gap **210** throughout the PFSADE **100** may be controlled within a predetermined maximum width to minimize fault rate of the PFSADE **100**. Accordingly, the SAE **130** may advantageously mitigate the leakage problem.

(27) As shown in FIGS. 2C-2D, a side cover **215** includes nubs **230a**, **230b**, **230c**. For example, the nubs **230a**, **230b**, **230c** may be placed around an edge surface of the side cover **215** to advantageously self-center the side cover **215** on the xz-plane of an engaging opening (e.g., the opening **120**).

(28) In some implementations, additional SAEs (the nubs **230a**, **230b**, **230c**) may advantageously distribute and/or balance an amount of force needed to install the side cover **215**. For example, with one SAE (e.g., the SAE **130**), a larger size of the SAE may be required to maintain a predetermined

minimum installation force. For example, the nubs **230a**, **230b**, **230c** may advantageously prevent wobbling of the side cover **215** after installation. For example, with spatially distributed SAEs, the PFSADE **100** may advantageously avoid a propensity to rotate, to translate, or a combination thereof.

(29) In some implementations, the nubs **230a**, **230b**, **230c** may be configured to be placed with a (e.g., statistically) most consistent reference ledge of the mating perimeter opening **125**. For example, the most consistent reference ledge may be a statistically widest ledge. For example, the statistically widest ledge may statistically be receiving more adhesive to fixedly couple the side cover **215** to the housing **115**. For example, the most consistent reference ledge may be determined by statistically observing size measurements (e.g., during manufacturing) of the housing **115**. By configuring the nubs **230a-c** to engage the most consistent reference ledge, a balanced force and relative position of the side cover **215** to the opening **120** may advantageously be controlled with a consistent contact with the ledge **205**. Accordingly, for example, the PFSADE **100** may eliminate the need for the side cover **215** and the housing **115** to be perfectly fitted around the mating perimeter opening **125**.

(30) FIG. 3A and FIG. 3B show exemplary capability analysis of a manufacturing process of an exemplary PFSADE **300** (e.g., the PFSADE **100** as shown in FIG. 1). As shown in FIG. 3A, a graph **301** may display width measurements of a housing opening along a line *x* (as shown in FIG. 3B) of the PFSADE **300**. In various implementations, based on the capability analysis shown in FIG. 3A, one or more SAEs may be configured in size and placement along an edge surface of a side cover (e.g., the edge surface **135**). For example, the size and the placement may be configured to advantageously maintain a predetermined relative position to reduce unsealed products. For example, the size and the placement may be configured to advantageously withstand a range of predetermined force (e.g., an upward force to pop up the side cover) as a result of a typical assemble and/or transportation process.

(31) As shown, the graph **301** includes a lower specification limit **305** and an upper specification limit **310**. Measurements of the widths (*x*) are represented by dots **315** in the graph **301**. A normal distribution **320** of the measurements are determined. Based on experimental data, in this example, a largest hole to self-center (as shown as a line **325**) is identified. For example, the line **325** may be determined that any hole smaller than the line **325** may have no leakage problem.

(32) In some implementations, a size of SAE may be limited by a maximum size (e.g., 1 mm in length, 1.5 mm in length). For example, an excessive sized SAE may create excessive materials during the assembly process. For example, the excessive material may damage the housing **115**. In some implementations, a larger sized SAE may require a larger assembly force. For example, the maximum size of the SAE may be determined so that the assembly force to install a side cover may not damage an engaging housing.

(33) In some implementations, a size of the SAE may be required to at least withstand a predetermined displacement force. For example, the size of the SAE may be configured to generate a frictional force to overcome 1.5 pounds of upward force.

(34) FIG. 4A and FIG. 4B depict an exemplary sealing cable connector **150** of an exemplary PFSADE. As shown in FIG. 1, the electronic device **105** may be operably coupled to a remote device via the sealing cable connector **150**. In this example, as shown in FIG. 4A, the sealing cable connector **150** includes electric potting **405** and electrical prongs **410**. For example, the electric potting **405** may be an epoxy configured to seal a joint between the electrical prongs **410** and a connecting surface of the sealing cable connector **150**. For example, electrical wirings may be coupled to electronics disposed within the PFSADE **100** via the electrical prongs **410**. For example, after the electrical wirings are coupled to the electronics in the PFSADE **100**, the electric potting **405** may seal the cavity **160** of the PFSADE **100** from outside.

(35) In this example, the sealing cable connector **150** includes the PBC **155** extending along a longitudinal axis. The PBC **155** includes a lumen **415**. For example, the lumen **415** may extend

from the cavity **160** of the housing **115** (as shown in FIG. 1) at a distal end of the sealing cable connector **150** to an exterior of the PFSADE **100** at a proximal end of the sealing cable connector **150**.

(36) The PBC **155**, as shown in this example, extends longer than the electrical prongs **410** by a height h . For example, the height may advantageously avoid accidental filling of the electric potting **405** into the PBC **155**.

(37) In some implementations, the PBC **155** may relieve pressure differential between an external pressure and an internal pressure of the cavity **160** in a disconnected state, for example, when the PFSADE **100** is disconnected from the remote device (e.g., during transportation/storage). In operation, the PBC **155** is covered by a mating cover of a remote connector of a sealing conduit connecting to the remote device, for example. Accordingly, for example, the PFSADE **100** may advantageously remain water resistant (e.g., IP65, IP67, IP69k) during operation while reducing pressure differential between the cavity **160** and an external environment in the disconnected state.

(38) As shown, the PBC **155** includes a D-shape cross-section. For example, the D-shape cross-section may advantageously increase air volume passing through the PBC **155**. In some implementations, other cross-section shapes of the PBC **155** may also be used. For example, the PBC **155** may be implemented with a round cross-section. For example, may be implemented with a square cross-section. Various shapes of the PBC **155** may advantageously be easier to be manufactured based on, for example, manufacturing capability and pre-existing equipment. In some examples, some shapes of the PBC **155** may advantageously be more durable.

(39) FIG. 4B shows a cross-section view of the PBC **155**. In this example, the lumen **415** extends along the longitudinal axis to provide a fluidly communication channel between the proximal end of the PBC **155** to the distal end of the PBC **155**. The sealing cable connector **150** includes a side wall **420** at a peripheral of the distal end. The side wall **420**, for example, may be higher than the electrical prongs **410**. For example, the side wall **420** may be filled with the electric potting **405** to fluidly seal the electrical prongs **410** from the exterior of a PFSADE. In this example, the PBC **155** may be extending towards the distal end in the longitudinal axis longer than the side wall **420**. In some implementations, the electric potting **405** may be filled at maximum to a height of the side wall **420**. For example, the electric potting **405** may advantageously be prevented from obstructing the fluid communication of the lumen **415** by the height differential h between the side wall **420** and the PBC **155**.

(40) FIG. 5 is a flowchart illustrating an exemplary PFSADE assembly method **500**. For example, the method **500** may be used to assemble the side cover **110** to the housing **115** with reference to FIGS. 1-2D. In this example, the method **500** begins when a housing is provided in step **505**. For example, the housing **115** is selected from a batch of metal molded housing from a manufacturing process. In step **510**, electronic components are installed into the housing. Next, in step **515**, adhesive is disposed on a ledge along a perimeter of the housing. For example, adhesive may be disposed along the ledge **205** of the mating perimeter opening **125**.

(41) In step **520**, a side cover is assembled to the housing with a predetermined assembly force. For example, the predetermined assembly force may be applied by a motor actuator. In a decision point **525**, it is determined whether all nubs of the side cover are deformed. For example, a sensor (e.g., optical sensor) may be used to determine whether the nubs **230a-c** are deformed (e.g., with their tips sheared). If it is determined not all of the nubs are deformed, in step **530**, the predetermined assembly force is increased, and the step **520** is repeated. If it is determined all of the nubs are deformed, the method **500** ends.

(42) FIG. 6 is a flowchart illustrating an exemplary SAE configuration method **600**. For example, an industrial engineer may design placement and size of the nubs **230a-c** on the side cover **215** based on the method **600**. In this example, SAEs are considered to be placed on both axes of a PFSADE (e.g., the PFSADE **300**). In other examples, SAEs may be required to be placed in one of the axes of the PFSADE to sufficiently maintain a self-alignment of a side cover (e.g., the side

cover **110** in an opening (e.g., the opening **120**) of a housing (e.g., the housing **115**).

(43) As shown, the method **600** begins in step **601** when a housing body (e.g., the housing **115**) and a cover (e.g., the side cover **110**) are provided. Next, in step **605**, a first axis for SAE configuration is selected. For example, the dimension x (as shown in FIG. 3B) may be selected. In step **610**, a maximum tolerance of a housing opening without a leakage problem is identified. For example, the maximum tolerance as shown in the line **325** is identified based on experimental data. For example the maximum tolerance may be identified based on simulation data. For example the maximum tolerance may be identified based on empirical calculations.

(44) Next, in step **615**, a number of SAE to be placed around an edge of the cover is determined. After the number of SAE is determined, a size of the SAE is determined based on the number of SAE and the maximum tolerance in step **620**. For example, the size of the SAE may be determined to be aligning the side cover **110** to reduce the gap **210** to advantageously mitigate the leakage problem.

(45) In a decision point **625**, it is determined whether a size of the SAE is larger than a maximum allowable size. For example, the maximum allowable size may create excessive material that may damage the housing during the assembly process. If the size of the SAE is larger than a maximum allowable size, in step **630**, the number of SAE to be placed around an edge of the cover is increased, and the step **620** is repeated. For example, a larger number of SAE may reduce the size required for the SAE. If the size of the SAE is smaller than a maximum allowable size, in a decision point **635**, it is determined whether a frictional force is larger than a predetermined displacement force. For example, the frictional force may be a resulting friction after the side cover is coupled to the housing. For example, the predetermined displacement force may be an upward force determined to be withstood by the PFSADE.

(46) If the frictional force is smaller than the predetermined displacement force, the step **630** is repeated. For example, a larger number of SAE may increase the frictional force at a contacting surface between the side cover and the housing. If the frictional force is larger than a predetermined displacement force, in a decision point **640**, it is determined whether an assembly force is larger than a predetermined maximum assembly force threshold. For example, the predetermined maximum assembly force threshold may be determined based on a design and a material of the housing and the side cover. For example, when an assembly force required to install the side cover with the determined SAEs is larger than the predetermined maximum assembly force threshold, the side cover and/or the housing may be damaged in the assembly process.

(47) If the assembly force is larger than the predetermined maximum assembly force, the step **630** is repeated. For example, a larger number of SAE may reduce a size required for the SAE to reduce the assembly force required for installing the side cover to the housing. If the assembly force is smaller than the predetermined maximum assembly force, in a decision point **645**, it is determined whether configuration for both axes of the housing are completed. If configuration for both axes of the housing are not completed, in step **650** a second axis for SAE configuration is selected, and the step **610** is repeated. For example, after configuration of SAE at an x-axis of the PFSADE **300** is completed, configuration of SAT at a y-axis of the PFSADE **300** is selected. If configuration for both axes of the housing are completed, the method **600** ends.

(48) Although various embodiments have been described with reference to the figures, other embodiments are possible. In some implementations, coupling of the side cover **110** to the housing **115** may include a laser welding process. For example, the side cover **110** may first be coupled to the housing **115**. Then, for example, a laser weld may be applied to an engagement surface between the side cover **110** and the housing **115**. For example, when a gap (e.g., the gap **210**) is wider than a predetermined width, excessive power may be required to generate heat energy required to create a bigger weld to cover the gap. In some examples, the SAE **130** may advantageously reduce the required power to weld the side cover to the housing. For example, the reduced required power may advantageously reduce a risk of component damage during the welding process.

(49) Although an exemplary system has been described with reference to FIG. 1, other implementations may be deployed in other industrial, scientific, medical, commercial, and/or residential applications. For example, the electronic device **105** may include a temperature sensor. For example, the electronic device **105** may include a vibration sensor.

(50) Some systems may be implemented as a computer system that can be used with various implementations. For example, various implementations may include digital circuitry, analog circuitry, computer hardware, firmware, software, or combinations thereof. Apparatus can be implemented in a computer program product tangibly embodied in an information carrier, e.g., in a machine-readable storage device, for execution by a programmable processor; and methods can be performed by a programmable processor executing a program of instructions to perform functions of various embodiments by operating on input data and generating an output. Various embodiments can be implemented advantageously in one or more computer programs that are executable on a programmable system including at least one programmable processor coupled to receive data and instructions from, and to transmit data and instructions to, a data storage system, at least one input device, and/or at least one output device. A computer program is a set of instructions that can be used, directly or indirectly, in a computer to perform a certain activity or bring about a certain result. A computer program can be written in any form of programming language, including compiled or interpreted languages, and it can be deployed in any form, including as a stand-alone program or as a module, component, subroutine, or other unit suitable for use in a computing environment.

(51) Various examples of modules may be implemented using circuitry, including various electronic hardware. By way of example and not limitation, the hardware may include transistors, resistors, capacitors, switches, integrated circuits, other modules, or some combination thereof. In various examples, the modules may include analog logic, digital logic, discrete components, traces and/or memory circuits fabricated on a silicon substrate including various integrated circuits (e.g., FPGAs, ASICs), or some combination thereof. In some embodiments, the module(s) may involve execution of preprogrammed instructions, software executed by a processor, or some combination thereof. For example, various modules may involve both hardware and software.

(52) In an illustrative aspect, an electronic device enclosure may include a housing. The electronic device enclosure may include an opening configured to receive electronic components through the opening. The housing may include a ledge disposed around a perimeter of the opening; The electronic device enclosure may include a cover configured to couple to the housing and cover the opening of the housing. For example, the cover may include a top surface extending on a horizontal plane. The cover may include an edge surface orthogonal to the top surface around a perimeter of the cover. The cover may include at least one self-aligning element extending orthogonal to the edge surface. For example, the at least one self-aligning element may include a size and a distribution along the edge surface configured to align the cover in a relative position to the housing, and to withstand a predetermined minimum displacement force threshold.

(53) For example, in an assembling process, a sealing member configured to fluidly seal the housing to the cover may be disposed on the ledge, and the ledge may be configured to engage the cover with an assembly force orthogonal to the top surface applied on the cover. For example, the at least one self-aligning element may be permanently deformed by the assembly force. For example, the assembly force may be less than a predetermined maximum assembly force threshold, and the relative position may be within a predetermined maximum displacement threshold.

(54) For example, the predetermined maximum displacement threshold may be determined based on experimental data to mitigate a leakage problem due to excessively wide gap between perimeter of the opening and the edge surface. For example, the cover may include at least one self-aligning element on each axis of the horizontal plane.

(55) For example, the cover may include three self-aligning elements. For example, the at least one self-aligning element may include a length of less than 1.5 mm. For example, the predetermined

minimum displacement force threshold may include 1.5 pounds.

(56) For example, may include electronics of a water resistant photoelectric distance sensor. The electronic device enclosure may include a connecting module configured to sealingly connect the water resistant photoelectric distance sensor to a remote device. For example, the connecting module may include a pressure balancing channel configured to include a fluidly communication between a cavity in the housing and an ambient environment. For example, in a disconnected mode, a pressure differential between the cavity and the ambient environment may be relieved via the pressure balancing channel. For example, in a connected mode, the connecting module receives a sealing connector such that the water resistant photoelectric distance sensor may be maintained to maintain a water resistant rating.

(57) In an illustrative aspect, an electronic device enclosure may include a housing comprising an opening configured to receive electronic components through the opening. The housing may include a cover **(110)** configured to couple to the housing and cover the opening of the housing. For example, the cover may include a top surface extending on a horizontal plane. The cover may include an edge surface orthogonal to the top surface around a perimeter of the cover. For example, the cover may include at least one self-aligning element extending orthogonal to the edge surface.

(58) For example, the at least one self-aligning element may include a size and a distribution along the edge surface configured to align the cover in a relative position to the housing, and to withstand a predetermined minimum displacement force threshold. For example, in an assembling process, the at least one self-aligning element may be permanently deformed by an assembly force less than a predetermined maximum assembly force threshold, and the relative position may be within a predetermined maximum displacement threshold.

(59) For example, the housing may include a ledge disposed around a perimeter of the opening. For example, the ledge may be configured to engage the cover when the assembly force may be applied orthogonal to the top surface. For example, the electronic device enclosure may include a sealing member disposed on the ledge. For example, the sealing member may be configured to fluidly seal the housing to the cover.

(60) For example, the predetermined maximum displacement threshold may be determined based on experimental data to mitigate a leakage problem due to excessively wide gap between perimeter of the opening and the edge surface. For example, the cover may include at least one self-aligning element on each axis of the horizontal plane. For example, the cover may include three self-aligning elements. For example, the at least one self-aligning element may include a length of less than 1.5 mm.

(61) For example, the predetermined minimum displacement force threshold may include 1.5 pounds. For example, may include electronics of a water resistant photoelectric distance sensor. For example, the electronic device enclosure may include a connecting module configured to sealingly connect the water resistant photoelectric distance sensor to a remote device. For example, the connecting module may include a pressure balancing channel configured to include a fluidly communication between a cavity in the housing and an ambient environment.

(62) For example, in a disconnected mode, a pressure differential between the cavity and the ambient environment may be relieved via the pressure balancing channel. For example, in a connected mode, the connecting module receives a sealing connector such that the water resistant photoelectric distance sensor may be maintained to maintain a water resistant rating.

(63) In an illustrative aspect, an electronic device enclosure manufacturing method may include providing a housing body and a cover to be coupled to the housing body. The method may include identifying a tolerance measurement for self-alignment of the cover relative to the housing body **(610)**. The method may include determining a number of at least one self-aligning element to be placed around an edge surface of the cover. The method may include determining a size of the at least one self-aligning element based on the tolerance measurement and the number of at least one self-aligning element.

(64) For example, the size of the at least one self-aligning element may be less than a maximum allowable size. For example, a resulting frictional force between the housing body and the cover may be higher than a predetermined displacement force. For example, an assembly force required to couple the cover to the housing body may be less than a maximum assembly force (640). For example, a leakage problem of the electronic device enclosure may be mitigated.

(65) For example, the method may include when the size of the at least one self-aligning element may be greater than the maximum allowable size, the resulting frictional force between the housing body and the cover may be higher than the predetermined displacement force, or the assembly force required to couple the cover to the housing body may be less than the maximum assembly force, increase the number of self-aligning elements to be placed around an edge of the cover.

(66) In an illustrative aspect, an electronic device enclosure may include a housing may include an internal cavity that may include electronic components. The electronic device enclosure may include a cable connector coupled to the housing. For example, the cable connector extends in a longitudinal axis and may include at least one electrical conduit configured to sealingly connect the electronic component in the internal cavity to a distant device via a closed electromagnetic conduit. The cable connector may include an electric potting filling configured to fluidly seal the at least one electrical conduit from an exterior environment.

(67) For example, a pressure balancing channel may include a lumen extending from the internal cavity to a proximal end of the cable connector. For example, in a disconnected mode, a fluid pressure within the internal cavity may be released through the pressure balancing channel. For example, in a connected mode, the at least one electrical conduit may be sealingly coupled to the closed electromagnetic conduit. For example, the internal cavity may be limited to fluid communication with an interior of the closed electromagnetic conduit such that the internal cavity may be fluidly separated from the exterior environment.

(68) For example, the pressure balancing channel may include a non-circular cross-section. For example, the pressure balancing channel may include a D-shape cross-section. For example, the electric potting filling may include epoxy.

(69) For example, the cable connector further may include a side wall at a peripheral of the proximal end of the cable connector along the longitudinal axis. For example, the pressure balancing channel extends longer than a height of the side wall along the longitudinal axis. For example, the electric potting filling may be prevented from obstructing the fluid communication of the lumen.

(70) For example, in the connected mode, the electronic device enclosure may include at least an IP65 rating. For example, the housing may include stainless steel. For example, the housing may include electroplated aluminum.

(71) In an illustrative aspect, an electronic device enclosure may include a housing may include an internal cavity. The internal cavity may include electronic components. The electronic device enclosure may include a cable connector coupled to the housing. For example, the cable connector extends in a longitudinal axis. The cable connector may include at least one electrical conduit configured to sealingly connect the electronic component in the internal cavity to a distant device via a closed electromagnetic conduit.

(72) For example, a pressure balancing channel may include a lumen extending from the internal cavity to a proximal end of the cable connector. For example, in a disconnected mode, a fluid pressure within the internal cavity may be released through the pressure balancing channel. For example, in a connected mode, the at least one electrical conduit may be sealingly coupled to the closed electromagnetic conduit. For example, the internal cavity may be limited to fluid communication with an interior of the closed electromagnetic conduit such that the internal cavity may be fluidly separated from an exterior environment.

(73) For example, the pressure balancing channel may include a non-circular cross-section. For example, the pressure balancing channel may include a D-shape cross-section. For example, the

cable connector further may include an electric potting filling configured to fluidly seal the at least one electrical conduit from the exterior environment.

(74) For example, the electric potting filling may include epoxy. For example, the cable connector further may include a side wall at a peripheral of the proximal end of the cable connector along the longitudinal axis. For example, the pressure balancing channel extends longer than a height of the side wall along the longitudinal axis. For example, the electric potting filling may be prevented from obstructing the fluid communication of the lumen.

(75) For example, in the connected mode, the electronic device enclosure may include at least an IP65 rating. For example, the housing may include stainless steel. For example, the housing may include electroplated aluminum.

(76) In an illustrative aspect, an electronic device enclosure may include a housing may include an internal cavity may include electronic components. The electronic device enclosure may include a cable connector coupled to the housing. For example, the cable connector extends in a longitudinal axis and may include means for sealingly connecting the electronic component in the internal cavity to a distant device. For example, a pressure balancing channel may include a lumen extending from the internal cavity to a proximal end of the cable connector.

(77) For example, in a disconnected mode, a fluid pressure within the internal cavity may be released through the pressure balancing channel. For example, in a connected mode, the cable connector may be sealingly coupled to the distant device. For example, the internal cavity may be fluidly separated from an exterior environment. For example, the cable connector further may include an electric potting filling configured to fluidly seal the internal cavity from the exterior environment.

(78) For example, the cable connector further may include a side wall at a peripheral of the proximal end of the cable connector along the longitudinal axis. For example, the pressure balancing channel extends longer than a height of the side wall along the longitudinal axis. For example, the electric potting filling may be prevented from obstructing a fluid communication of the lumen.

(79) A number of implementations have been described. Nevertheless, it will be understood that various modifications may be made. For example, advantageous results may be achieved if the steps of the disclosed techniques were performed in a different sequence, or if components of the disclosed systems were combined in a different manner, or if the components were supplemented with other components. Accordingly, other implementations are contemplated within the scope of the following claims.

Claims

1. An electronic device enclosure comprising: a housing comprising: an opening configured to receive electronic components through the opening; and, a ledge disposed around a perimeter of the opening; a sealing member disposed on the ledge of the housing; and, a cover configured to couple to the housing and cover the opening of the housing, wherein the cover comprises: a top surface extending on a horizontal plane, wherein, when an assembly force is applied orthogonal to the top surface, the ledge is configured to engage the cover and the sealing member is configured to fluidly seal the housing to the cover; an edge surface orthogonal to the top surface around a perimeter of the cover; and, at least one self-aligning element, each comprising a protruding nub extending from and orthogonal to the edge surface, wherein the at least one self-aligning element comprises: in an open position, a size and a distribution along the edge surface configured to align the cover in a relative position to the housing; and, in a closed position, the at least one self-aligning element is permanently deformed by the assembly force, and the relative position between the cover and the housing is within a predetermined minimum and maximum displacement threshold.

2. The electronic device enclosure of claim 1, wherein the predetermined maximum displacement

threshold is determined based on an upper width limit of a gap derived from experimental data to mitigate a leakage problem due to excessively wide gap between perimeter of the opening and the edge surface.

3. The electronic device enclosure of claim 1, wherein the at least one self-aligning element comprises a first self-aligning element and a second self-aligning element, wherein, the first and the second self-aligning elements each extends in orthogonal axes of the horizontal plane.

4. The electronic device enclosure of claim 1, wherein the cover comprises three self-aligning elements.

5. The electronic device enclosure of claim 1, wherein the at least one self-aligning element comprises a length of less than 1.5 mm.

6. The electronic device enclosure of claim 1, the predetermined minimum displacement force threshold comprises 1.5 pounds.

7. The electronic device enclosure of claim 1, further comprising electronics of a water resistant photoelectric distance sensor.

8. The electronic device enclosure of claim 7, further comprising a connecting module configured to sealingly connect the water resistant photoelectric distance sensor to a remote device, wherein the connecting module comprises a pressure balancing channel configured to comprise a fluidly communication between a cavity in the housing and an ambient environment such that, in a disconnected mode, a pressure differential between the cavity and the ambient environment is relieved via the pressure balancing channel, and, in a connected mode, the connecting module receives a sealing connector such that the water resistant photoelectric distance sensor is maintained to maintain a water resistant rating.

9. An electronic device enclosure comprising: a housing comprising an opening configured to receive electronic components through the opening; and, a cover configured to couple to the housing and cover the opening of the housing, wherein the cover comprises: a top surface extending on a horizontal plane, an edge surface orthogonal to the top surface around a perimeter of the cover, and, at least one self-aligning element, each comprising a protruding nub extending from and orthogonal to the edge surface, wherein the at least one self-aligning element comprises: in an open position, a size and a distribution along the edge surface configured to align the cover in a relative position to the housing; and in a closed position, the at least one self-aligning element is permanently deformed by an assembly force, and the relative position between the cover and the housing is within a predetermined minimum and maximum displacement threshold.

10. The electronic device enclosure of claim 9, wherein the housing further comprises a ledge disposed around a perimeter of the opening, wherein the ledge is configured to engage the cover when the assembly force is applied orthogonal to the top surface.

11. The electronic device enclosure of claim 10, further comprising a sealing member disposed on the ledge, wherein the sealing member is configured to fluidly seal the housing to the cover.

12. The electronic device enclosure of claim 10, wherein the predetermined maximum displacement threshold is determined based on an upper width limit of a gap derived from experimental data to mitigate a leakage problem due to excessively wide gap between perimeter of the opening and the edge surface.

13. The electronic device enclosure of claim 9, wherein the at least one self-aligning element comprises a first self-aligning element and a second self-aligning element, wherein, the first and the second self-aligning elements each extends in orthogonal axes of the horizontal plane.

14. The electronic device enclosure of claim 9, wherein the cover comprises three self-aligning elements.

15. The electronic device enclosure of claim 9, wherein the at least one self-aligning element comprises a length of less than 1.5 mm.

16. The electronic device enclosure of claim 9, the predetermined minimum displacement force threshold comprises 1.5 pounds.

17. The electronic device enclosure of claim 9, further comprising electronics of a water resistant photoelectric distance sensor.

18. The electronic device enclosure of claim 17, further comprising a connecting module configured to sealingly connect the water resistant photoelectric distance sensor to a remote device, wherein the connecting module comprises a pressure balancing channel configured to comprise a fluidly communication between a cavity in the housing and an ambient environment such that, in a disconnected mode, a pressure differential between the cavity and the ambient environment is relieved via the pressure balancing channel, and, in a connected mode, the connecting module receives a sealing connector such that the water resistant photoelectric distance sensor is maintained to maintain a water resistant rating.

19. An electronic device enclosure manufacturing method, comprising: provide a housing body and a cover to be coupled to the housing body; identify a tolerance width measurement for self-alignment of the cover relative to the housing body; determine a number of at least one self-aligning element to be placed around an edge surface of the cover; determine a size of the at least one self-aligning element based on the tolerance width measurement and the number of at least one self-aligning element, such that: the size of the at least one self-aligning element is less than a maximum allowable size, a resulting frictional force between the housing body and the cover is higher than a predetermined displacement force, and, an assembly force required to couple the cover to the housing body is less than a maximum assembly force, such that a leakage problem of the electronic device enclosure is mitigated.

20. The electronic device enclosure manufacturing method of claim 19, further comprising: when the size of the at least one self-aligning element is greater than the maximum allowable size, the resulting frictional force between the housing body and the cover is higher than the predetermined displacement force, or the assembly force required to couple the cover to the housing body is less than the maximum assembly force, increase the number of self-aligning elements to be placed around an edge of the cover.
