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DEBRIS-COLLECTING VACUUM MACHINE WITH GROUNDED SAFETY SYSTEM AND ASSOCIATED METHODS

FIELD OF THE INVENTION

[0001] This application relates to vacuum machines for collecting debris, and more particularly to vacuum machines equipped with safety features for facilitating debris collection within metal-processing environments.

BACKGROUND

[0002] Debris may be produced as a result of various metal processing operations in metal-processing environments. For example, during metal recycling, metal scrap (such as aluminum or aluminum alloys) are crushed, shredded, chopped, or otherwise reduced into smaller pieces of metal scrap which may be easily spilled and/or become temporarily airborne before landing on other surfaces. Debris may be at an elevated temperature and susceptible to combustion due to processing operations, and in some instances, for other reasons, e.g., due to the debris including combustibles such as metallic powder or organic compounds (such as from coatings or contaminants associated with metal work pieces). Accordingly, the presence or collection of debris in metal-processing environments may present potential safety issues.

SUMMARY

[0003] The terms “invention,” “the invention,” “this invention” and “the present invention” used in this patent are intended to refer broadly to all of the subject matter of this patent and the patent claims below. Statements containing these terms should be understood not to limit the subject matter described herein or to limit the meaning or scope of the patent claims below. Embodiments of the invention covered by this patent are defined by the claims below, not this summary. This summary is a high-level overview of various embodiments of the invention and introduces some of the concepts that are further described in the Detailed Description section below. This summary is not intended to identify key or essential features of the claimed subject matter, nor is it intended to be used in isolation to determine the scope of the claimed subject matter. The subject matter should be understood by reference to appropriate portions of the entire specification of this patent, any or all drawings and each claim.

[0004] In various examples, a debris collection machine includes a vacuum system that has a receptacle for receiving debris and a suction source operable to provide suction for pulling debris into the receptacle. The machine also includes a ground reference portion of a ground-checking circuit, a ground test portion of the ground-checking circuit, and a ground-checking module. The ground reference portion is electrically coupled with an electrically grounded reference point. The ground test portion is electrically coupled with at least a portion of the vacuum system. The ground-checking module is coupled with the vacuum system, the ground reference portion, and the ground test portion, which may permit the ground-checking module to check for grounding via the ground-checking circuit, and control the vacuum system accordingly. For example, the ground-checking module can send an electrical current through the ground-checking circuit in a completed state in which the ground-checking circuit includes the ground reference portion, the ground-checking module, the ground test portion, and a grounded object electrically coupled with the ground test portion and the ground reference portion. The ground-checking module can determine a resistance in the ground-checking circuit based on the electrical current. In response, the ground-checking module may prevent or terminate operation of the suction source of the vacuum system when a resistance exceeds a predetermined threshold value. For example, the resistance exceeding the predetermined threshold value may be indicative of at least a portion of the vacuum system being at risk of generating a spark that could provide an ignition source for material present within the receptacle.

[0005] In various examples, a debris collection machine includes a vacuum system. The vacuum system includes a receptacle for receiving debris, and the receptacle has a conductive body. The vacuum system also includes a suction source operable to provide suction for pulling debris into the receptacle. The machine also includes a chassis supporting and electrically coupled to the receptacle. Additionally, the machine includes a ground reference portion of a ground-checking circuit and a ground test portion of the ground-checking circuit. The ground reference portion is electrically coupled with an electrically grounded reference point, while the ground test portion is electrically coupled with the chassis. Other components of the machine include a lid electrically coupled to the body of the receptacle when the lid is received relative to the body of the receptacle; a suction hose interface electrically coupled to the lid; a line electrically coupled to the suction hose interface and selectively connectable to a separately grounded item; and a ground-checking module. The ground-checking module is coupled with the ground reference portion, the ground test portion, and the suction source of the vacuum system. The ground-checking module can determine a resistance between the ground reference portion of the ground-checking circuit and the ground test portion of the ground-checking circuit. The ground-checking module can prevent or terminate operation of the suction source of the vacuum system when resistance detected exceeds a predetermined threshold value corresponding to an interruption in electrical coupling through the ground test portion, chassis, body of the receptacle, lid, suction hose interface, line, and separately grounded item.

[0006] In some examples, a method includes checking a resistance of a circuit. More specifically, the circuit may be such that when completed it includes (a) a ground reference portion electrically coupled with an electrically grounded reference point and (b) a ground test portion electrically coupled with at least a portion of a vacuum system of a debris collection machine. The vacuum system can include (a) a receptacle for receiving debris, and (b) a suction source operable to provide suction for pulling debris into the receptacle. The method also includes preventing or terminating operation of the suction source of the vacuum system when the resistance exceeds a predetermined threshold value.

[0007] Various implementations described in the present disclosure can include additional systems, methods, features, and advantages, which cannot necessarily be expressly disclosed herein but will be apparent to one of ordinary skill in the art upon examination of the following detailed description and accompanying drawings. It is intended that all such systems, methods, features, and advantages be included within the present disclosure and protected by the accompanying claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] The features and components of the following figures are illustrated to emphasize the general principles of the present disclosure. Corresponding features and components throughout the figures can be designated by matching reference characters for the sake of consistency and clarity.

[0009] FIG. 1 is a perspective view depicting a debris collection machine according to various aspects of the present disclosure.

[0010] FIG. 2 is a side cutaway view depicting components relative to an interior of a receptacle of the debris collection machine of FIG. 1 according to various aspects of the present disclosure.

[0011] FIGS. 3-4 are side cutaway views of a bottom of the receptacle of FIG. 2 according to various aspects of the present disclosure.

[0012] FIGS. 5-6 are side cutaway views of a valve that may be utilized with the receptacle of FIG. 2 according to various aspects of the present disclosure.

[0013] FIG. 7 is a schematic diagram depicting the debris collection machine of FIG. 1 connected via a grounding line according to various aspects of the present disclosure.

[0014] FIG. 8 is a schematic diagram depicting an electrical panel of the debris collection machine of FIG. 1 according to various aspects of the present disclosure.

DETAILED DESCRIPTION

[0015] The subject matter of examples of the present invention is described here with specificity to meet statutory requirements, but this description is not necessarily intended to limit the scope of the claims. The claimed subject matter may be embodied in other ways, may include different elements or steps, and may be used in conjunction with other existing or future technologies. This description should not be interpreted as implying any particular order or arrangement among or between various steps or elements except when the order of individual steps or arrangement of elements is explicitly described.

[0016] FIG. 1 illustrates a debris collection machine 100. The depicted machine 100 includes a receptacle 102 supported by a chassis 104. Components of a vacuum system 106 and a safety system 108 are also shown. Generally, the vacuum system 106 can be utilized to move debris into the receptacle 102 (e.g., as explained in greater detail with reference to FIG. 2-4), and hazards or risks associated with such collection of debris in the receptacle 102 may be reduced or eliminated by features of the safety system 108 (e.g., as explained in greater detail with reference to FIGS. 5-8).

[0017] FIG. 2 is a side cutaway view depicting components relative to an interior of the receptacle 102. The vacuum system 106 can include a suction source 110 operable to provide suction for pulling debris into the receptacle 102. The suction source 110 depicted in FIG. 2 includes a venturi pump 112 that receives pressurized fluid flow (e.g., pressurized air flow) through a pressurized inlet 114, directs the pressurized fluid through a restriction 116 and out an exhaust 118, and exerts suction to pull other fluid through a suction inlet 120 as a result. For example, the pressurized inlet 114 may be coupled with a compressed air feed hose 122, and the suction inlet 120 may be arranged to provide suction relative to the receptacle 102 as a result of air flow (as at arrow 121) from the compressed air feed hose 122 through the venturi pump 112. However, the suction source 110 is not limited to the depicted venturi pump 112 and may additionally or alternatively include any other suitable components for producing suction, including, but not limited to compressors, impellers, fans, blowers, or other pressure-changing components.

[0018] The receptacle 102 may include or be coupled with any suitable structure for directing flow of fluid and/or debris. For example, a suction hose 124, a suction hose interface 126, a pipe 128, baffles 130, and a filter 132 are shown in FIG. 2. In an example operation, suction from the suction source 110 (e.g., the venturi pump 112) may pull air into the suction hose 124 (e.g., as at arrow 134), through the suction hose interface 126, and into a first end 136 of the pipe 128 (e.g., as at arrow 138). Upon exiting an opposite, second end 140 of the pipe 128 (e.g., as at arrow 142), the air may be pulled through a circuitous or tortuous path defined by the baffles 130 (e.g., as at arrows 144). The air further can be pulled (e.g., as at arrows 146) through the filter 132, which may prevent debris borne by the air from exiting the receptacle 102 along with the air. The air may exit the receptacle 102 as a result of the suction provided by the suction source 110. For example, the air may be pulled (e.g., as at arrows 148) into the suction inlet 120 (e.g., from the filter 132) and directed out through the exhaust 118 along with the air pulled in through the pressurized inlet 114 (e.g., from the compressed air feed hose 122).

[0019] The air pulled into the receptacle 102 (e.g., through the suction hose 124 etc.) may convey debris into the receptacle 102. As used herein, debris may correspond to any loose material that can be pulled off of a surface or out of the air or other fluid. Non-limiting examples of debris that may be commonly encountered when using the debris collection machine 100 in a other metal-processing environment include, but are not limited to hardware (e.g., bolts, nuts, screws, and so forth), liquids, dust, particulate, fragments of metal, organic compounds, or other material.

[0020] The receptacle 102 may be configured to hold water or other liquid 152 (hereinafter “water” for simplicity of terminology) for receiving and containing debris 150. To this end, the second end 140 of the pipe 128 may be arranged to deliver debris 150 conveyed through the pipe 128 into water 152 in the receptacle 102. For example, as shown, the pipe 128 is arranged such that the second end 140 is submerged in the water 152. Suction from the suction source 110 may lower a water level in the submerged second end of the pipe 128 sufficiently to draw air out through the second end of the pipe 128. Such air may form bubbles (e.g., illustrated adjacent arrow 142) that can rise to the surface of the water 152. Debris carried by the air may accordingly become trapped in the water 152 and ultimately settle (as at arrow 154) in the water. Alternatively, if the level of the water 152 were instead to be maintained or drop below the second end 140 of the pipe 128, air exiting the second end 140 of the pipe 128 may be pulled over the surface of the water and allow debris 150 to fall and separate out of the air. The twists and turns provided by the baffles 130 may also cause debris 150 to separate out of the air, for example, which may cause the debris 150 to collect on the baffles 130 and/or fall into the water 152 if present. The debris 150 may thus be collected by any suitable method within the water 152.

[0021] Collecting debris 150 within the water 152 may reduce chances of combustion related to the collected debris 150. For example, the water 152 may cool incoming debris 150 below temperatures at which ignition may occur. Additionally or alternatively, the water 152 may extinguish any flames on collected debris 150. Moreover, the water 152 may prevent incoming debris 150 from contacting received debris 150 with strikes that could otherwise generate combustion-triggering sparks.

[0022] Collecting debris 150 within the water 152 may also facilitate disposal of collected debris 150, for example, as described further with respect to FIGS. 3 and 4. Moreover, although the description herein focuses mainly on water 152 for the sake of simplicity, liquids other than water 152 could additionally or alternatively utilized.

[0023] FIGS. 3-4 are side cutaway views of a bottom 156 of the receptacle 102. The bottom 156 of the receptacle 102 is shown in FIG. 3 with a drainage pipe 158 having a valve 160 for selectively blocking fluid passage through the drainage pipe 158. In an example operation, the valve 160 can be opened to allow the water 152 to drain out of the receptacle 102 (e.g., as at arrow 161), for example, into a catch pan 162 that can be removed from the chassis 104 of the machine 100 to permit appropriate disposal of the water 152.

[0024] Referring to FIG. 4, the bottom of the receptacle 102 may include a cap 164 that is releasably attached to the main body of the receptacle 102 by a clamping collar 168 (FIG. 1) or other suitable mechanism. In operation as illustrated in FIG. 4, the cap 164 at the bottom 156 of the receptacle 102 may be removed, for example, to permit removal of solid debris 150 that may have accumulated within the receptacle 102, e.g., as a result of draining the water 152 as described above with reference to FIG. 3. For example, in FIG. 4, the cap 164 at the bottom of the receptacle 102 is shown received in the catch pan 162, e.g., after the catch pan 162 has been drained of water 152 and returned to its position under the receptacle 102.

[0025] Referring again to FIG. 2, the top 170 of the receptacle 102 may include a lid 172 that is releasably attached to the main body 166 of the receptacle 102. For example, the lid 172 at the top 170 and the cap 164 at the bottom 156 may both be removable to provide access through the top 170 and/or the bottom 156 of the receptacle 102 to facilitate washing the interior of the receptacle 102. The lid 172 and the cap 164 may respectively include suitable gaskets 179 or other seals to seal the receptacle 102 for operation or otherwise reduce a chance of leakage at respective junctures at the top 170 and the bottom 156 of the receptacle 102. In various examples, various elements may be mounted to the lid 172 and thus removable from the receptacle 102 by removal of the lid 172. For example, in FIG. 2, the suction hose interface 126, pipe 128, filter 132, venturi pump 112, and release valve 174 (described further below) are shown mounted to the lid.

[0026] The vacuum system 106 illustrated in FIGS. 1-4 is just one exemplary configuration for use with a debris collection machine such as machine 100. Various other arrangements and subcomponents are possible, including for receptacle 102 and suction source 110.

[0027] As previously noted, the machine 100 may include a safety system 108 to reduce or eliminate hazards or risks associated with collection of debris 150 in the receptacle 102. More specifically, various features of the safety system 108 may be associated with avoiding conditions that may lead to combustion of material within the receptacle 102. Such a risk of combustion may be present based on characteristics of debris 150 collected into the receptacle 102. For example, as mentioned above, debris 150 collected may include flammable or combustible material that may be ignited by sparks or sufficiently elevated temperatures. In some examples, the debris 150 may include organic compounds or other material that may chemically react with each other or with the water 152 to produce trace amounts of hydrogen or other flammable gasses (hereinafter collectively "hydrogen").

[0028] Referring back to FIG. 2, in various examples, air circulation during operation of the suction source 110 may flush such trace amounts of hydrogen from the receptacle 102. This may prevent hydrogen from building up to a combustible concentration level during operation of the suction source 110. The safety system 108 may also include a release valve 174, for example, to prevent hydrogen from building up to a combustible concentration level during non-operation of the suction source 110.

[0029] As illustrated in FIG. 2, the release valve 174 may be positioned at a boundary of the receptacle 102 between the interior of the receptacle 102 and the exterior of the receptacle 102. For example, the release valve in FIG. 2 is shown located in the lid 172 at the top of the receptacle 102. However, the release valve 174 additionally or alternatively may be positioned extending through the main body 166 of the receptacle 102 or in any other suitable location. Locating the release valve 174 in or near the top of the receptacle 102 may facilitate escape of hydrogen, which may tend to rise toward the top of the receptacle 102 due to a lower density relative to other gasses that may be present in the receptacle 102.

[0030] FIGS. 5-6 are side cutaway views of an example of the release valve 174. The depicted release valve 174 includes a seat 180, a stopper 182, and a biasing mechanism 184. The seat 180 includes a surface 186 defined about an aperture 188 through a boundary of the receptacle 102. The stopper 182 is movable relative to the seat 180. For example, in FIG. 5, the stopper 182 is shown in an open position in which the stopper 182 is spaced apart from the seat 180 for allowing gas flow through the aperture 188. In FIG. 6, the stopper 182 is shown in a closed position in which the stopper 182 is received on the seat 180 for preventing gas flow through the aperture 188. For example, the stopper 182 may be shaped to seal against the surface 186 defined by the seat 180.

[0031] The biasing mechanism 184 is depicted as a spring but may correspond to any other structure arranged to bias the stopper 182 toward the open position in the absence of suction from the suction source 110. The biasing mechanism 184 is shown positioned between the stopper 182 and a porous base 190 that can include one or more through-holes 192. The one or more through-holes 192 may permit gas flow through the base 190 yet still provide sufficient structure for supporting the biasing mechanism 184. For example, as depicted in FIGS. 5 and 6, the base 190 is positioned beneath the biasing mechanism 184 so that the biasing mechanism 184 will compress against the base 190 when moved downward under suction supplied by the suction source 110 and will decompress and move upward to bias the stopper 182 toward the open position in the absence of suction from the suction source 110. However, the base 190 could alternatively be positioned above the stopper 182, e.g., such that the biasing mechanism 184 would extend in response to suction from the suction source 110 to allow the stopper 182 to close against the seat 180 and would contract toward an at-rest state to bias the stopper 182 toward the open position in the absence of suction from the suction source 110.

[0032] Biasing the stopper 182 toward the open position in the absence of suction from the suction source 110 may permit the escape of hydrogen out of the receptacle 102 when the suction source 110 is not in operation. The biasing mechanism 184 may also permit the stopper 182 to move to the closed position in response to suction from the suction source 110 so as to prevent pressure loss within the receptacle 102 through the aperture 188 when the suction source 110 is in operation. As an illustrative example, the suction source 110 may be configured to generally produce about 4 PSI of vacuum during operation, and the biasing mechanism 184 may be sized and configured to push the stopper 182 apart from the seat 180 when the vacuum falls below 0.5 PSI (e.g., which may correspond to a termination or non-operation of the suction source 110).

[0033] The safety system 108 can include other features in addition to or in lieu of the release valve 174. For example, whereas the release valve 174 may mitigate a risk of a build-up of combustible material within the receptacle 102, other features may be included to reduce a chance of sparks or other sources of ignition relative to the receptacle 102. Some such features are described below with reference to FIGS. 7 and 8 and other figures herein.

[0034] FIG. 7 is a schematic diagram showing a grounding line 202 that may be included in the safety system 108. The grounding line 202 may be utilized to electrically connect the receptacle 102 and/or other components of the machine 100 to another object 204, such as another piece of equipment. In operation, if the other object 204 is grounded, the grounding line 202 may accordingly provide an electrical path for grounding a relevant portion of the machine 100. Such grounding may prevent the generation of differences in voltage potential that could otherwise result in a spark, such as may occur due to static electricity.

[0035] FIG. 8 is a schematic diagram depicting an electrical panel 206 of the debris collection machine 100 according to various aspects of the present disclosure. The electrical panel 206 in FIG. 8 is shown received within an enclosure 208. The enclosure 208 is shown in FIG. 8 in an open state to reveal components within the enclosure 208. For example, the enclosure 208 is shown in FIG. 8 with a hinged door 210 pivoted away from a housing 212 that together with the door 210 forms the enclosure 208. However, the enclosure 208 may include any other arrangement of features for providing access to components within the enclosure 208 (such as for maintenance or replacement). The enclosure 208 of FIG. 8 is also shown in FIGS. 1 and 7 (in a closed state) in relation to other components of the machine 100.

[0036] The electrical panel 206 depicted in FIG. 8 includes a checking module 214 that may form part of the safety system 108. The checking module 214 may be utilized to check for certain conditions and allow, prevent, initiate, or terminate certain operations of the machine 100 based on the conditions checked.

[0037] The functions of the checking module 214 (or any other module discussed herein) can be implemented in the form of control logic in software or hardware or a combination of both. The control logic may be stored in an information storage medium as a plurality of instructions adapted to direct an information processing device to perform a set of steps disclosed in examples of the invention. Based on the disclosure and teachings provided herein, a person of ordinary skill in the art will appreciate other ways and/or methods to implement the features associated with the corresponding modules. As an example, functions described in this application may be implemented via programming logic controllers (“PLCs”), which may use any suitable PLC programming language. In other examples, the functions described in this application may be implemented as software code to be executed by one or more processors using any suitable computer language such as, for example, Java, C++ or Perl using, for example, conventional or object-oriented techniques. The software code may be stored as a series of instructions or commands on a non-transitory computer-readable medium, such as a random access memory (“RAM”), a read-only memory (“ROM”), a magnetic medium such as a hard-drive or a floppy disk, or an optical medium such as a CD-ROM. Any such computer-readable medium may also reside on or within a single computational apparatus, and may be present on or within different computational apparatuses within a system or network. Any of the entities described herein may be embodied by a computer that performs any or all of the functions and steps disclosed.

[0038] In various examples, the checking module 214 may control the vacuum system 106 based at least in part on input received by the checking module 214. To this end, the checking module 214 in FIG. 8 includes an output 216 that is electrically coupled with the vacuum system 106. For example, the output 216 in FIG. 8 is shown in FIGS. 1 and 7 connecting to a suction source control box 220 that includes a solenoid or other electrically controllable valve (not shown) that can allow, block, or otherwise regulate airflow from a source hose 222 (e.g., connected to a pressurized air supply within a facility) to the air feed hose 122 for the venturi pump 112. However, the arrangement depicted in FIGS. 1 and 7 is only one example of implementing the output 216 of the checking module 214 in FIG. 8. For other forms of vacuum system 106, the output 216 may additionally or alternatively control other valves or power supplies to control the suction provided by the suction source 110.

[0039] In various examples, the checking module 214 may be or include a ground-checking module 224. For example, the ground-checking module 224 may control the vacuum system 106 based at least in part on input related to grounding of the machine 100. In FIG. 8, the ground-checking module 224 is electrically coupled within a ground-checking circuit that also includes a ground reference portion 226 and a ground test portion 228.

[0040] The ground reference portion 226 may be electrically coupled with an electrically grounded reference point 230. In FIG. 8, the electrically grounded reference point 230 corresponds to a grounded portion 232 of the electrical panel 206, e.g., which may be grounded for compliance with electrical codes. For example, in FIG. 8, the electrically grounded reference point 230 is electrically connected with a grounding portion 234 of a power cable 236. The power cable 236 is also shown having a power-providing portion 235 that is ultimately routed (e.g., via an on-off switch 270) to provide electrical power to the electrical panel 206 (as at 238), e.g., for providing power to the machine 100. The power cable 236 may extend through the enclosure 208. For example, referring to FIG. 7, the power cable 236 is shown exiting the enclosure 208 and extending to a plug 240 for engaging a source of grounded power such as the outlet 242 shown in FIG. 7. The depicted plug 240 includes a grounding prong 244 that may provide grounding when engaged in the outlet 242. Via the power cable 236, the ground reference portion 226 (FIG. 8) may be electrically connected with the grounding prong 244 (FIG. 7) of the power cable 236, which may provide grounding to the ground reference portion 226.

[0041] The ground test portion 228 may be electrically coupled with a relevant portion of the machine 100. This may provide input for determining whether such relevant portion of the machine 100 is appropriately grounded to reduce a chance of sparks being generated due to differences in potential of different parts of the machine 100. For example, the ground test portion 228 may be electrically connected with the grounding line 202 (e.g., via intervening components), which may allow the ground-checking module 224 to determine whether the grounding line 202 is providing appropriate grounding by connection with a grounded object 204. Although a specific series of connections between a particular set of components for establishing electrical connection with the ground test portion 228 will now be described, it should be understood that fewer, more, or other connections or components may be utilized for electrical connection between the ground test portion 228 and associated parts of the machine 100 for purposes of checking grounding of relevant portions of the machine 100.

[0042] In FIG. 8, the ground test portion 228 extends through the enclosure 208. The enclosure 208 may be formed from a non-conductive material. For example, in lieu of utilizing metal for the enclosure 208, the enclosure 208 may be formed of ceramic, plastic, or some other non-conductive material. Forming the enclosure 208 from non-conductive material may electrically isolate the electrical panel 206 from the part of the ground test portion 228 that is outside of the enclosure 208. For example, if the enclosure 208 were instead metal, the metal might adopt the electrical characteristics of the electrical panel 206 via conduction and allow the ground test portion 228 to appear to be grounded merely by being brought into contact with the metal of the enclosure 208. In contrast, a non-conductive enclosure 208 may foreclose this possibility and ensure that the ground test portion 228 will only register as being grounded when connected to a distinct grounded object 204 that is separate (e.g., thermally separate, physically separate, electrically separate, or otherwise separate in the absence of connection by the below-referenced grounding line 202 or other structure for establishing connection there between) from the portion of the machine 100 grounded by connection with grounded power (such as the outlet 242 shown in FIG. 7). Put another way, forming the enclosure 208 of non-conductive material may prevent the ground-checking module 224 from being “cheated” by bringing the ground test portion 228 into contact with the enclosure 208.

[0043] Referring to FIG. 1, upon exiting the enclosure 208, the ground test portion 228 is shown electrically coupled with the chassis 104. For example, the ground test portion 228 is shown including a cable 246 with a conductive portion 248 secured by a fastener 250 to the chassis 104. The fastener 250 may be a bolt, a weld, or any other joining technology that may permit the cable 246 to be electrically connected to the chassis 104. The chassis 104 may include metal or other conductive material.

[0044] The chassis 104 can in turn be electrically coupled with the main body 166 of the receptacle 102. For example, FIG. 1 shows bands 252 that engage the main body 166 and connect to the chassis 104 to support the receptacle 102 relative to the chassis 104. The bands and/or main body 166 of the receptacle 102 may include metal or other conductive material such that electrical signals can be conveyed through the main body 166 to the chassis 104 by direct contact between the chassis 104 and main body 166 or through indirect contact through the bands 252 between the chassis 104 and main body 166.

[0045] Referring to FIG. 2, the lid 172 can be electrically coupled to the body 166 of the receptacle 102 when the lid 172 is received relative to the body 166 of the receptacle 102. For example, in FIG. 2, a depressible plunger 254 is shown on an upper end of the body 166 of the receptacle 102. When the lid 172 is fully engaged on the body 166, the plunger 254 may press against the lid 172 and complete an electrical connection between the conductive material of the lid 172 and the body 166 of the receptacle 102. When the lid 172 is removed from the body 166, contact between the lid 172 and the plunger 254 may be broken and cause a corresponding break in electrical connection between the lid 172 and the body 166 (e.g., which may cause a disruption to the ground test portion 228 corresponding to the lid 172 being not fully seated or installed on the body 166 and indicative that the machine 100 should not be operated). Although a depressible plunger 254 may account for variations in how tightly the lid 172 is secured, in some examples, the plunger 254 may instead be a rigid structure. Providing the plunger 254 may provide electrical connection between the body 166 and the lid 172 that might otherwise be impeded by rubber or other non-conductive material that may be utilized for the gasket 179 for sealing the lid 172 to the body 166 of the receptacle 102.

[0046] The suction hose interface 126 can be electrically coupled to the lid 172. For example, both the suction hose interface 126 and the lid 172 may include electrically conductive material. In operation, grounding the suction hose interface 126 may also cause the suction hose 124 to be grounded when received relative to the suction hose interface 126.

[0047] The grounding line 202 can be electrically coupled to the suction hose interface 126 or other portion of the vacuum system 106. For example, in FIG. 2, the grounding line 202 is shown attached to the suction hose interface 126 by a conductive ring clamp 256. Referring to FIG. 7, the grounding line 202 can also be selectively connectable to a separately grounded object 204. For example, the grounding line 202 is shown terminating in an alligator clip style of clamp 258 that may allow the selective connection. However, other forms of clamps or connectors may be utilized apart from the depicted conductive ring clamp 256 and/or alligator clip style of clamp 258.

[0048] In practice, as shown in FIG. 7, the machine 100 may be made ready for operation by plugging the power cable 236 into grounded power (e.g., into the outlet 242) and connecting the grounding line 202 with the separately grounded object 204. This may fully establish or close the grounding circuit or loop. The ground-checking module 224 may be able to confirm that the grounding circuit or loop has been fully established by sending an electrical current that will travel through the completed loop, such as out through the ground test portion 228 and ultimately back in through the ground reference portion 226. Confirming that the loop is closed may confirm that one side of the checking module 224 is electrically connected to ground through the outlet 242 while another side of the checking module 224 is electrically connected to ground via the separately grounded object 204. For example, with reference to FIG. 8, the confirming current may flow out of the ground-checking module 224 and out through the ground test portion 228. The current may continue through the cable 246 (FIG. 2) that connects to the ground test portion 228 (FIG. 8). Referring to FIG. 2, the current may continue through that cable 246, through the chassis 104, through the band 252, through the body 166 of the receptacle 102, through the plunger 254, and into the lid 172. Referring to FIG. 7, the current may continue from the lid 172, through the suction hose interface 126, through the grounding line 202, and into the separately grounded object 204. The current may continue to the outlet 242 or other grounded power supply via the grounding shared with the separately grounded object 204. From the outlet 242 or other grounded power supply the current may travel onward though the grounding prong 244, and through the power cable 236 into the enclosure 208. Referring to FIG. 8, the current may continue to travel into the grounded portion 232 of the electrical panel 206 and into the ground reference portion 226 of the ground-checking module 224.

[0049] The ground-checking module 224 may determine a resistance in the completed ground-checking circuit or loop based on the current flow through the ground reference portion 226 and the ground test portion 228. If the resistance is less than a predetermined threshold value (such as 8 ohms), the ground-checking module 224 may permit power to be provided through the output 216 to enable operation of the vacuum system 106. For example, a resistance that is less than a predetermined threshold value may be indicative of the machine 100 being sufficiently grounded via connection with both the outlet 242 and the separately grounded object 204 in a manner that will reduce or eliminate a risk of a voltage difference that could otherwise lead to spark generation. Thus, based on such an indication that the machine

100 is in a condition that is safe to operate, the checking module 224 may permit power to be provided to enable operation of the vacuum system 106. In contrast, the ground-checking module 224 may prevent or terminate operation of the suction source 110 of the vacuum system 106 when resistance exceeds the predetermined threshold value. For example, the resistance exceeding the threshold value may correspond to an interruption in electrical coupling through the ground test portion 228, chassis 104, body 166 of the receptacle 102, lid 172, suction hose interface 126, line 202, and separately grounded object 204. Such interruption may indicate that relevant portions of the machine 100 are not appropriately grounded and/or connected and therefore not deemed safe to operate. Thus, the ground-checking module 224 may function to prevent operation of the machine 100 when appropriate grounding is not registered as present. Moreover, although the discussion above describes determining a resistance, it should be understood that such determination may encompass determinations tied to other corollaries or values related to resistance, including, but not limited to, conductance (e.g., one over resistance), or voltage divided by current.

[0050] In various examples, the checking module 214 additionally or alternatively may be or include a liquid level checking module 260. For example, in FIG. 2, a liquid level sensor 262 is shown. The liquid level sensor 262 may include a float sensor or any other form of sensor for determining a level of liquid in the receptacle 102. The liquid level sensor 262 may provide an additional or alternative input (e.g., as at 264 in FIG. 8) to the checking module 214. The checking module 214 may prevent or terminate operation of the vacuum system 106 in response to receiving an indication that the liquid level within the receptacle 102 is outside of a predetermined range for safe operation of the machine 100.

[0051] In various examples, the checking module 214 additionally or alternatively may be or include a temperature checking module 266. For example, in FIG. 2, the liquid level sensor 262 may be supplemented with or replaced by a thermocouple 268 or other suitable temperature sensor capable of determining a relevant temperature within the receptacle 102. Referring to FIG. 8, the checking module 214 may prevent or terminate operation of the vacuum system 106 in response to receiving an indication (e.g., via input 264 in FIG. 8, which may connect for example to the thermocouple 268 in FIG. 2 through input 264A) that the temperature within the receptacle 102 is outside of a predetermined range for safe operation of the machine 100.

[0052] In various examples, the checking module 214 additionally or alternatively may be in communication with other controls for the machine 100. For example, in FIG. 8, a path for power to the checking module 214 includes an on-off switch 270 on the door 210 of the enclosure 208. The on-off switch 270 in the on position may permit power to flow to the checking module 214, e.g., through line 235, through the switch 270, through line 237, through the power supply 238, and through line 239. In the off position, the on-off switch 270 may prevent power from flowing to the checking module 214. Operation of the vacuum system 106 accordingly may be terminated or prevented in response to the switch 270 being moved to or maintained in the off position. In contrast, even if the switch 270 is in the on position, the checking module 214 may still prevent or terminate operation of the vacuum system 106 if other inputs (such as from the ground reference portion 226, the ground test portion 228, the liquid level checking module 260, and/or the temperature checking module 266) are providing signals corresponding to unsafe operation conditions. For example, the checking module 214 may function to only permit operation of the vacuum system 106 when the switch 270 is in the on position and no other termination or prevention conditions are present based on other inputs to the checking module 214.

[0053] The above-described aspects are merely possible examples of implementations, merely set forth for a clear understanding of the principles of the present disclosure. Many variations and modifications can be made to the above-described example(s) without departing substantially from the spirit and principles of the present disclosure. All such modifications and variations are included herein within the scope of the present disclosure, and all possible claims to individual aspects or combinations of elements or steps are intended to be supported by the present disclosure. Moreover, although specific terms are employed herein, as well as in the claims that follow, they are used only in a generic and descriptive sense, and not for the purposes of limiting the described invention, nor the claims that follow.

CLAIMS

That which is claimed is:

1. A debris collection machine comprising:
a vacuum system comprising:
a receptacle for receiving debris; and
a suction source operable to provide suction for pulling debris into the receptacle;
a ground reference portion of a ground-checking circuit, the ground reference portion electrically coupled with an electrically grounded reference point;
a ground test portion of the ground-checking circuit, the ground test portion electrically coupled with a portion of the vacuum system; and
a ground-checking module coupled with the vacuum system, the ground reference portion, and the ground test portion and configured to:
send an electrical current through the ground-checking circuit in a completed state in which the ground-checking circuit comprises the ground reference portion, the ground-checking module, the ground test portion, and a grounded object electrically coupled with the ground test portion and the ground reference portion;
determine a resistance in the ground-checking circuit based on the electrical current; and
prevent or terminate operation of the suction source of the vacuum system when the resistance exceeds a predetermined threshold value.

2. The debris collection machine of claim 1, further comprising a power cable configured to provide power to the debris collection machine, wherein the ground reference portion of the ground-checking circuit is electrically connected with a grounding prong of the power cable.

3. The debris collection machine of claim 1, wherein the ground test portion of the ground-checking circuit is electrically coupled to a conductive body of the receptacle.

4. The debris collection machine of claim 3, wherein the ground test portion of the ground-checking circuit is electrically coupled to a chassis supporting the receptacle and the chassis is electrically coupled to the conductive body of the receptacle.

5. The debris collection machine of claim 3, wherein the ground test portion of the ground-checking circuit is electrically coupled via the conductive body of the receptacle to a lid of the receptacle when the lid is received relative to the body of the receptacle.

6. The debris collection machine of claim 5, further comprising:

a non-conductive gasket disposed on the lid or the conductive body of the receptacle for sealing when the lid is received relative to the conductive body of the receptacle; and

a conductive projection that extends between and contacts the lid and the conductive body of the receptacle when the lid is received relative to the conductive body of the receptacle, wherein the ground test portion of the ground-checking circuit is electrically coupled via the conductive body of the receptacle and the conductive projection to the lid of the receptacle.

7. The debris collection machine of claim 3, further comprising a suction hose interface that is electrically coupled to the ground test portion of the ground-checking circuit.

8. The debris collection machine of claim 7, wherein the suction hose interface is electrically coupled to the ground test portion of the ground-checking circuit via at least one of the conductive body of the receptacle or a lid of the receptacle.

9. The debris collection machine of claim 3, wherein the ground test portion of the ground-checking circuit is electrically coupled via at least the conductive body of the receptacle to a line that is selectively connectable to a separately grounded item.

10. The debris collection machine of claim 9, further comprising a clamp for releasably connecting the line to the separately grounded item.

11. The debris collection machine of claim 1, wherein the ground-checking module prevents or terminates operation of the suction source of the vacuum system by operating a valve that controls flow of air to a venturi nozzle of the suction source.

12. The debris collection machine of claim 1, further comprising:

a liquid level sensor configured to detect a level of liquid in the receptacle; and

a liquid level checking system configured to prevent or terminate operation of the suction source of the vacuum system when the level of liquid detected by the liquid level sensor is outside of a predetermined range.

13. The debris collection machine of claim 1, further comprising a release valve comprising:

a seat including a surface defined about an aperture through a boundary of the receptacle;

a stopper movable relative to the seat between (a) a closed position in which the stopper is received on the seat for preventing gas flow through the aperture, and (b) an open position in which the stopper is spaced apart from the seat for allowing gas flow through the aperture; and

a biasing mechanism arranged to (a) bias the stopper toward the open position in the absence of suction from the suction source so as to permit escape of hydrogen or other flammable gas out of the receptacle when the suction source is not in operation, and (b) permit the stopper to move to the closed position in response to suction from the suction source so as to prevent pressure loss within the receptacle through the aperture when the suction source is in operation.

14. The debris collection machine of claim 1, further comprising:

a suction hose interface; and

a pipe comprising:

a first end coupled with the suction hose interface for receiving debris through the suction hose interface in response to suction provided by the suction source; and

a second end arranged to deliver debris conveyed through the pipe into water in the receptacle.

15. The debris collection machine of claim 1, wherein the predetermined threshold value is 8 ohms or less.

16. The debris collection machine of claim 1, further comprising a non-conductive enclosure, wherein the ground test portion of the ground-checking circuit extends out of the non-conductive enclosure to electrically couple with the portion of the vacuum system.

17. A debris collection machine comprising:
a vacuum system comprising:
a receptacle for receiving debris, the receptacle having a conductive body; and
a suction source operable to provide suction for pulling debris into the receptacle;
a chassis supporting and electrically coupled to the receptacle;
a ground reference portion of a ground-checking circuit, the ground reference portion electrically coupled with an electrically grounded reference point;
a ground test portion of the ground-checking circuit, the ground test portion electrically coupled with the chassis;
a lid electrically coupled to the conductive body of the receptacle when the lid is received relative to the conductive body of the receptacle;
a suction hose interface electrically coupled to the lid;
a line electrically coupled to the suction hose interface and selectively connectable to a separately grounded item; and
a ground-checking module coupled with the ground reference portion of the ground-checking circuit, the ground test portion of the ground-checking circuit, and the suction source of the vacuum system, and configured to:
determine a resistance between the ground reference portion of the ground-checking circuit and the ground test portion of the ground-checking circuit; and
prevent or terminate operation of the suction source of the vacuum system when the resistance detected exceeds a predetermined threshold value corresponding to an interruption in electrical coupling through the ground test portion of the ground-checking circuit, the chassis, the conductive body of the receptacle, the lid, the suction hose interface, the line, and the separately grounded item.

18. A method comprising:
checking a resistance of a circuit configured to include (a) a ground reference portion electrically coupled with an electrically grounded reference point and (b) a ground test portion electrically coupled with a portion of a vacuum system of a debris

collection machine, the vacuum system including (a) a receptacle for receiving debris, and (b) a suction source operable to provide suction for pulling debris into the receptacle; and

preventing or terminating operation of the suction source of the vacuum system when the resistance exceeds a predetermined threshold value.

19. The method of claim 18, further comprising:

connecting the debris collection machine to grounded power so as to provide the electrically grounded reference point; and

connecting a line between a grounded item and a portion of the debris collection machine that is electrically connected to the ground test portion, wherein the grounded item is thermally separate from the debris collection machine or separate from the debris collection machine in the absence of the line.

20. The method of claim 18, wherein the predetermined threshold value is 8 ohms or less.

ABSTRACT

A debris collection machine includes a vacuum system (including a suction source operable to provide suction for pulling debris into a receptacle), a ground reference portion, a ground test portion, and a ground-checking module. The ground reference portion is electrically coupled with an electrically grounded reference point, and the ground test portion is electrically coupled with a portion of the vacuum system. The ground-checking module determines a resistance between from the ground reference portion and the ground test portion and prevents or terminates operation of the suction source of the vacuum system when the resistance exceeds a predetermined threshold value, e.g., which may correspond to a risk condition of spark generation that could ignite material in the receptacle.

FIG. 1

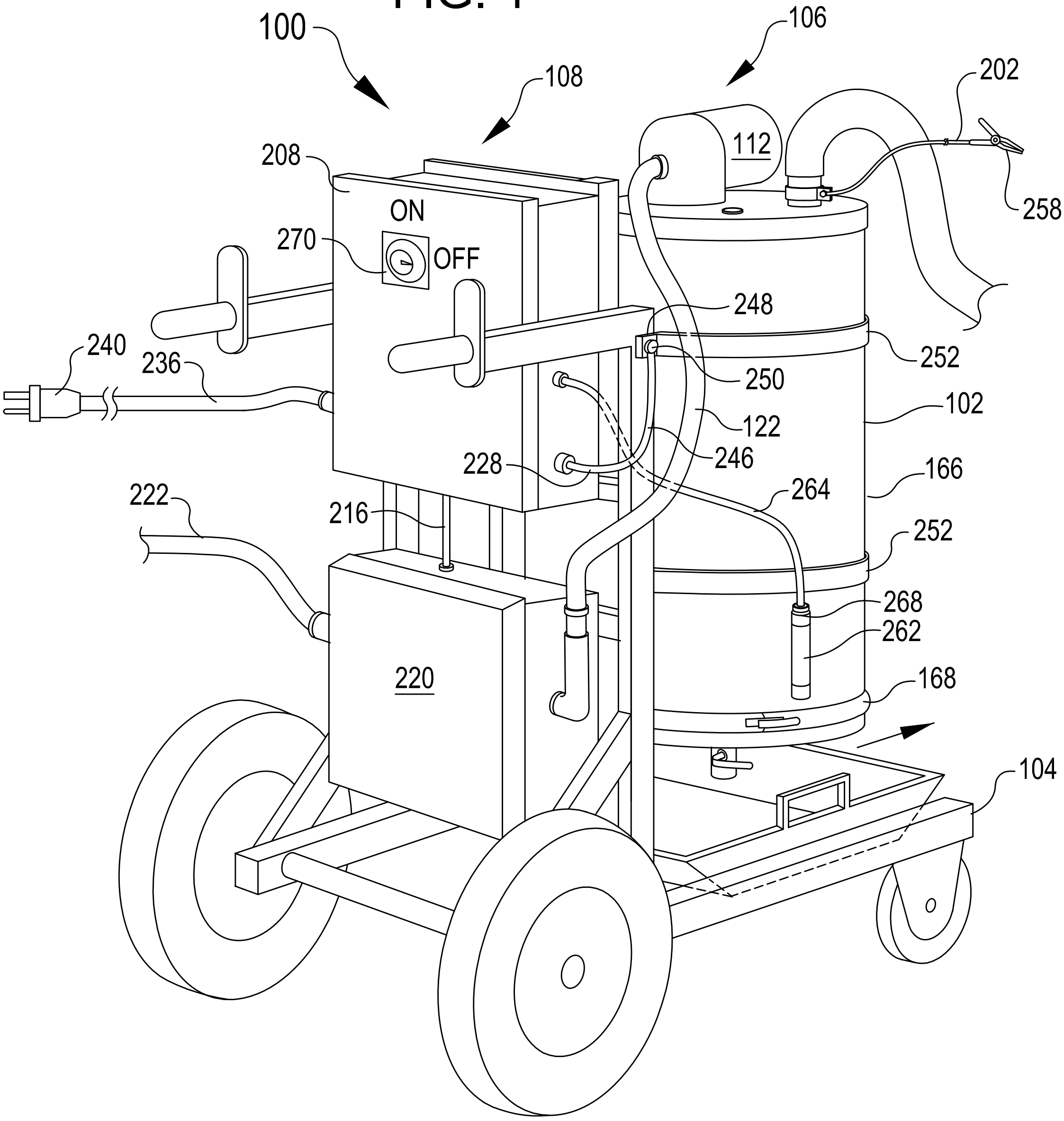
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FIG. 2

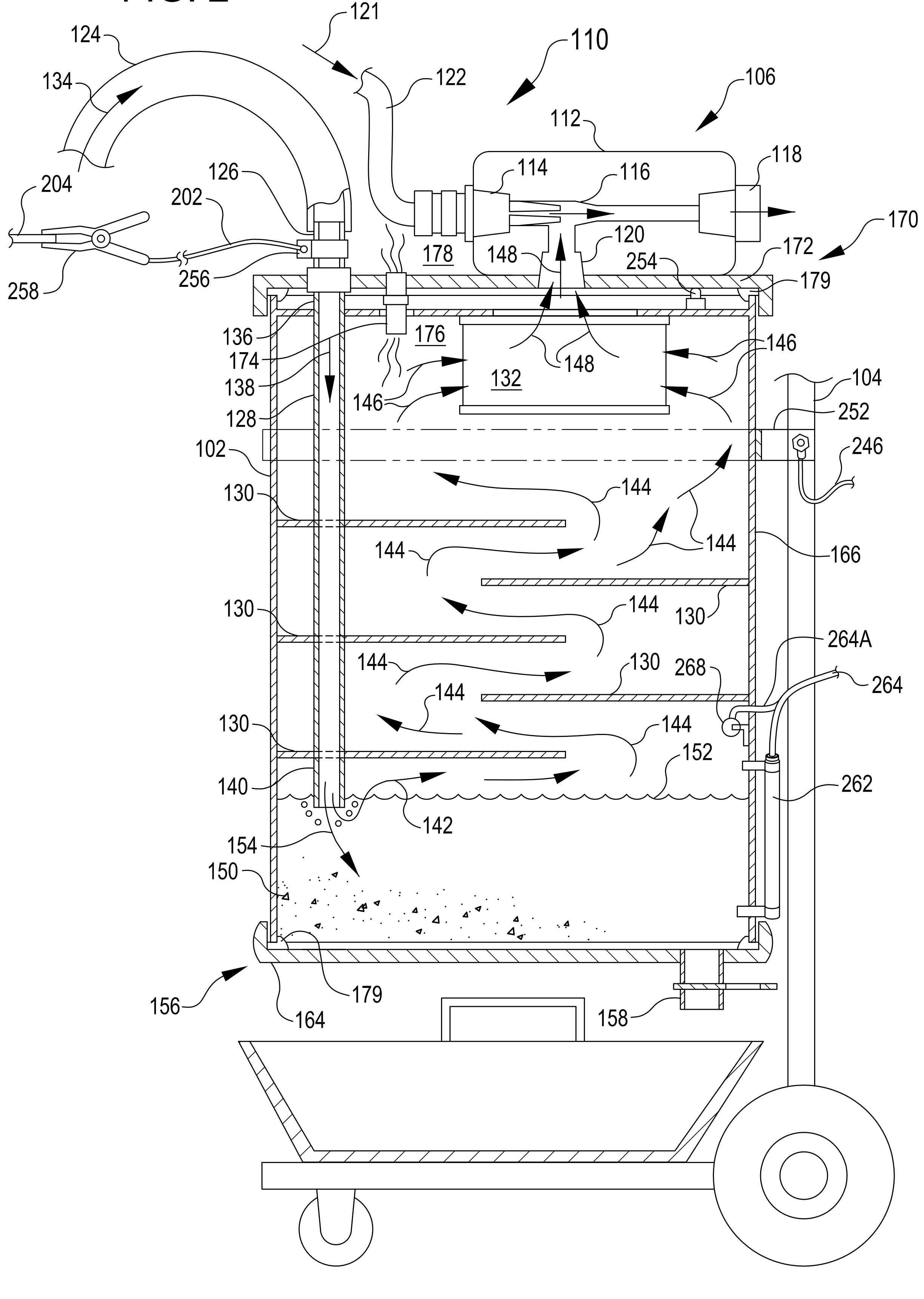
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FIG. 3

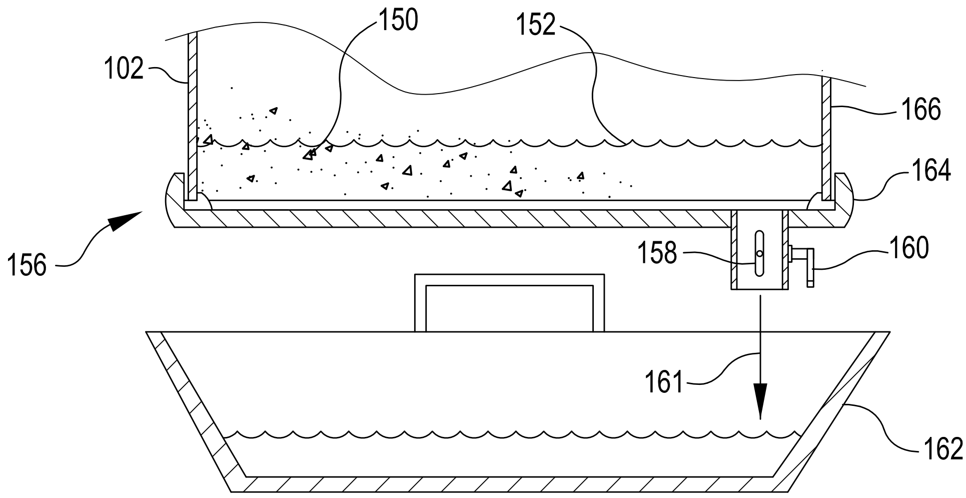
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FIG. 4

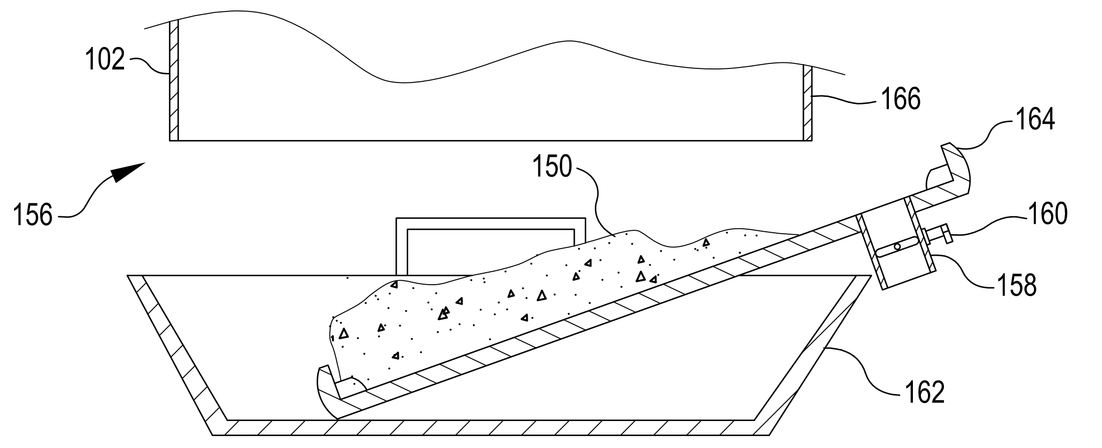
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FIG. 5

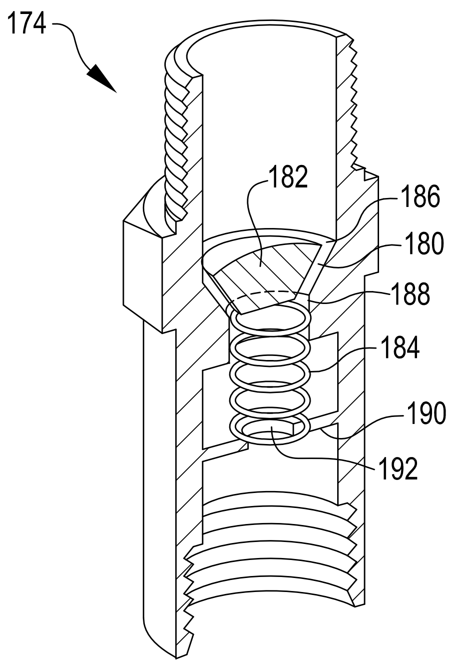

FIG. 6

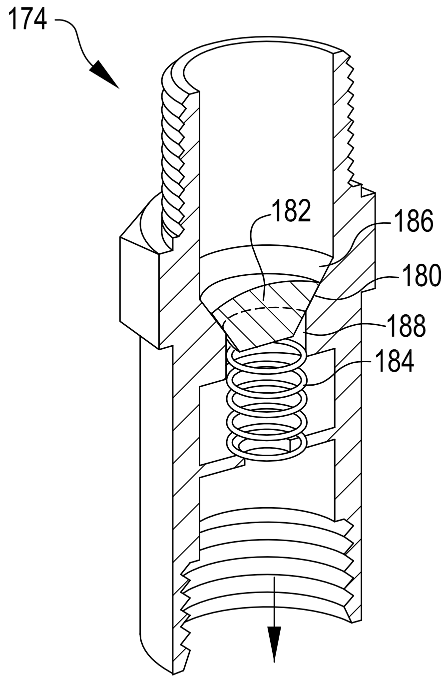

FIG. 7

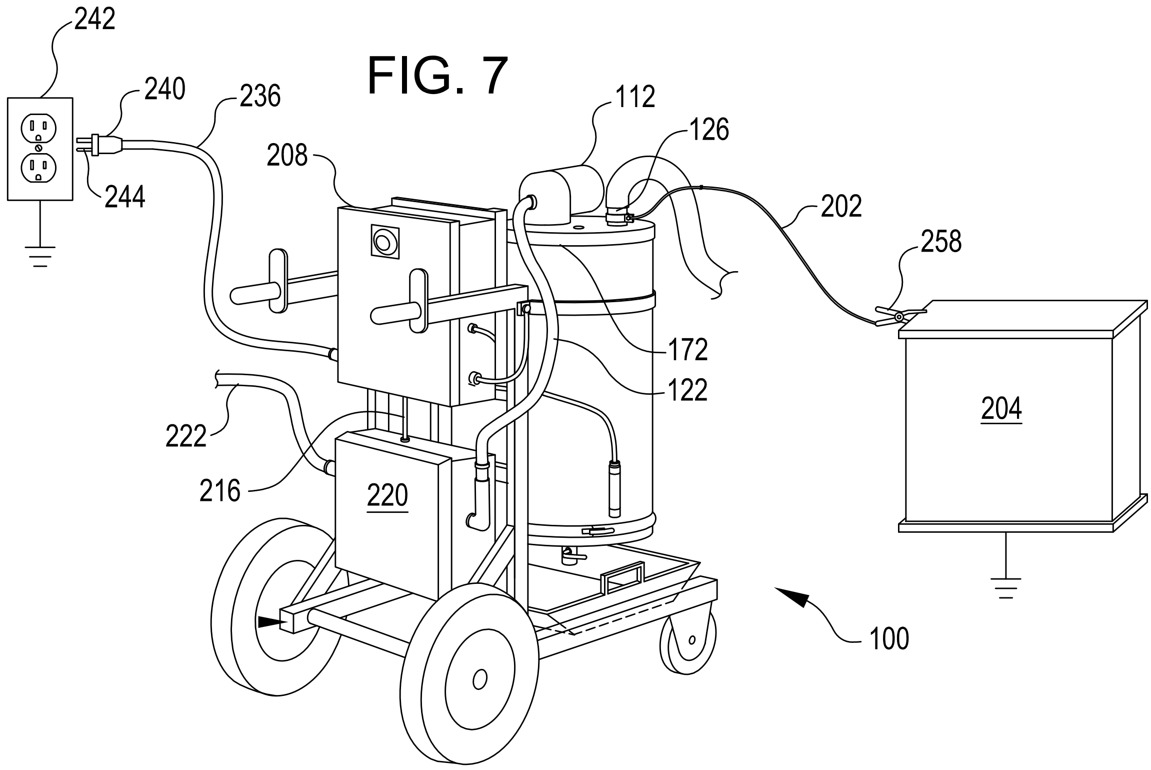
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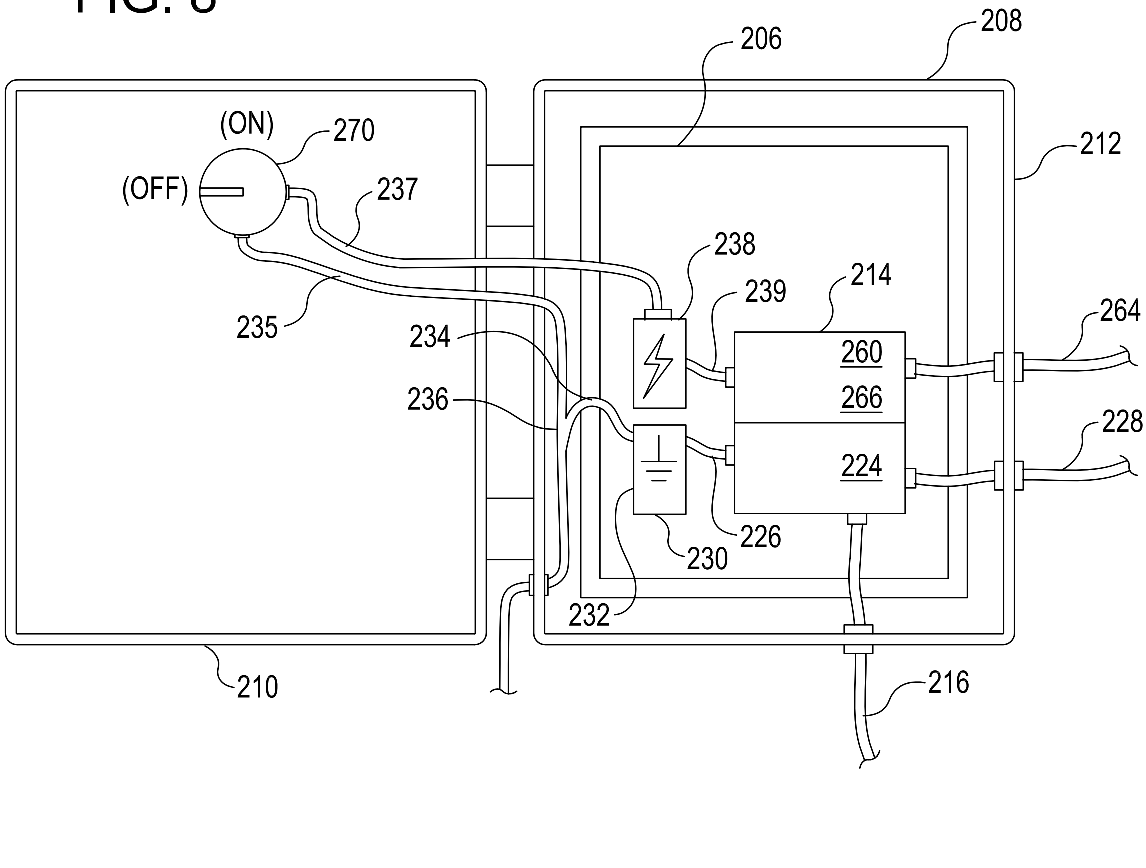
FIG. 8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