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(71) Applicant *(for all designated States except US)*: **NANORIDGE MATERIALS, INCORPORATED** [—/US]; 15850 Vickery Drive, Houston, Texas TX 77032 (US).

(71) Applicant *(for ZA only)*: **LUCAS, Brian Ronald** [GB/GB]; 135 Westhall Road, Warlingham Surrey CR6 9HJ (GB).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: **KISSELL, Kyle Ryan** [US/US]; 2614 Katie Harbour Drive, Manuel, TX 77578 (US). **SIFTON, James Bruce Sinclair** [CA/CA]; 9551 Diamond Road, Richmond, British Columbia (CA). **STRINGFELLOW, William Doyle** [US/US]; 10223 Olympia Drive, Houston, TX 77042 (US). **STUART, John Bready** [US/US]; 2503 Brookdale Drive, Kingwood, TX 77339 (US).

(74) Agent: **COLE, Paul**; Lucas & Co., 133 Westhall Road, Warlingham Surrey CR6 9HJ (GB).

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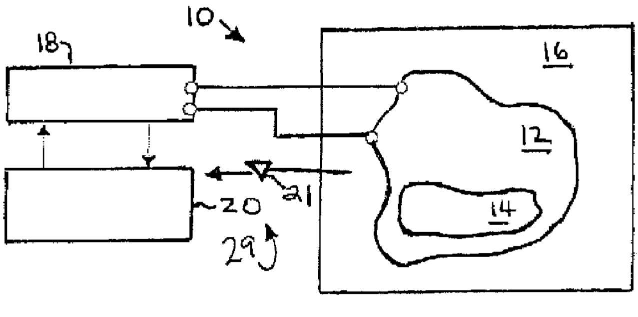
(54) Title: HEATABLE COATING WITH NANOMATERIALS

Fig. 2



(57) Abstract: Coatings and heatable coatings containing electrically conductive nanomaterial (e.g. carbon nanotubes); methods for making such a coating; items with such a coating; and methods for applying such a coating. In one aspect, such a coating is a deicing coating.

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HEATABLE COATING WITH NANOMATERIALS

FIELD OF THE INVENTION

The present invention is directed to protective coatings, to heatable coatings, to deicing coatings containing electrically conductive nanomaterials, methods for making them, methods for heating such coatings, methods for deicing, items with such coatings and, in certain aspects, to such coatings with carbon nanotubes therein.

BACKGROUND TO THE INVENTION

There is a wide variety of known approaches to heating things and surfaces with heatable coatings and to dealing with ice formation on items and on surfaces, e.g., on of wings, propellers, turbine blades, ship hulls, paved areas, bridges, runways, train tracks, pipelines, refinery equipment and apparatuses, piping, petroleum and chemical plant apparatuses and flow conduits, and power towers; as well as ice formation on equipment and machines, including, but not limited to, equipment and machines used in the exploration for, drilling of and production from oil and gas wells and the processing of recovered gas and oil. Prior patents and applications disclose a variety of articles, substances, devices, apparatuses, and methods for dealing with icing problems, including, but not limited to, those in , and those referred to in or cited in, exemplary U.S. Patents: 6,832,742; 6,790,526; 6,773,877; 6,576,115; 6,427,946; 6,303,388; 6,027,075; 4,737,618; 4,732,351; 4,685,967; 3,825,371; and 3,204,084 (all said patents incorporated fully herein for all purposes). There have long been needs, recognized by the present inventors, for a durable and effective coating, for heatable coating ;and for deicing material and methods of their use.

SUMMARY OF THE INVENTION

The present invention, in certain aspects, discloses a heatable coating with conductive nanomaterial. In certain aspects, such a coating, when heated resistively by the application of an electric current (AC or DC), heats an item or surface to which it has been applied; and, in particular circumstances, melts ice on items and on surfaces to which the coating has been applied. Such coatings can be used, among other things, to remediate paraffin wax in oil pipelines; to remediate or prevent hydrate formation or hydrate build-up in oil pipelines; and for viscosity control of heavy crude oil in storage tanks. A coating according to the present invention, any disclosed herein, may be a protective coating, a heatable coating, or a deicing coating according to the present invention, and an electrical system may be used with an event sensor or sensors which sense an event related to the item with the coating. For example, the sensed event may be a temperature increase, the formation of ice, or a change in temperature. Upon such sensing occurring, the electrical system changes the temperature of the coating or heats the coating, e.g. to deice the item.

In one aspect, such a coating has nanomaterials therein which are electrically conductive, for example, and not limited to, electrically conductive nanotubes, nanographene, nanographene ribbons, transformed nanomaterials (e.g., as in U.S. patent applications Ser. Nos. 12/657,244 (US 2011-017732); 12/657,288 (US 2011-0174701); 12/657,289 (US 2011-0174145) - all filed on Jan. 16, 2010 and co-owned with the present invention and all incorporated fully herein for all purposes) and carbon nanomaterials, e.g., but not limited to, carbon nanotubes. In certain aspects, such a coating is between 0.0001 and 1.0 inches (0.00025 – 2.5 cm) - thick.

In one aspect, such a coating includes a resin material (e.g., but not limited to: any suitable known resin system; a one-part resin; a two-part resin; a one-component resin; and a two-component resin – any, optionally, with a catalyst and/or hardener). Sufficient nanomaterials are in the resin material so that upon the application of an electric current (DC or AC) to the coating, the coating is heated. In one aspect, the nanomaterial is mixed with the backing material, e.g., a resin material using suitable known mixing techniques, e.g., but not limited to, with a Banbury mixer or a Haake mixer or by known sonication mixing methods. In one aspect, the nanomaterial is nanotubes.

In one particular embodiment, the resin material is a combination of a polyisocyanate resin and a polyester resin.

In certain aspects, an item according to the present invention includes a base or backing, e.g., a backing made of any suitable material to which the coating can be applied; including, but not limited to, glass, natural fabric, synthetic fabric, metals, elastomer, wood, plastics, composites, polymers, thermoplastics, thermosets, and in one particular aspect is HDPE (high density polyethylene) and a coating according to the present invention which includes coating material and an amount of carbon nanomaterial (nanotubes, nanoribbons, etc.) dispersed through the coating material. Any base, backing, or surface of an item according to the present invention may be prepped or prepared in any suitable known manner as is appropriate prior to the application of a coating according to the present invention. It is within the scope of the present invention for any known suitable coating material to be used to which sufficient nanomaterial can be added so that a conductivity level is reached that enables heating of the coating material. In certain aspects, the resistivity of a coating according to the present invention ranges between 1 to 100 $g*\Omega/cm^2$. Resistivity as used herein means specific resistivity which is the bulk resistivity of a material (in Ohm centimeters) multiplied by its density (in g/cm^3). The units should be $(g*Ohm)/cm^2$ as in grams (times) Ohms (divided by) centimeters squared, the symbol * being used to indicate multiplication. In certain aspects, the amount of nanomaterial is less than 5% by weight of a coating. In certain aspects, the amount of nanomaterial is, by weight, 1% or 4%, and, in other aspects, the amount of nanomaterial ranges between 5% and 32% by weight. In other aspects, this amount is as low as 0.1% and can range between 0.1% and 5% by weight or between 0.1% and 32%. The base or backing may be a surface of a thing, including, but not limited to, a surface of a substrate.

In certain aspects, a resin system, a base, a surface, and/or a backing are chosen from known engineered materials that provide moisture resistance, ultraviolet light resistance, acid resistance, and base resistance. These have low permeabilty, low surface energy, high durability and high flexibility.

It is within the scope of the present invention for a coating according to the present invention to be applied in any suitable known manner of coating application, including, but not limited to, spraying, dipping, spreading, pouring, bonding, trowelling, application with a brush or roller, electrostatic coating, and fusion bonding. In multi-component coatings, it is within the scope of the present invention to mix together the components and then to apply the mixture; or to apply one, two, or more components separately in sequence or simultaneously, e.g., but not limited to, spraying different components with separate sprayers or spraying different components with a dual, triple, or more component feed system so that the mixture is sprayed from one exit port or nozzle. It is within the scope of the present invention to use any coating herein without the application of an electrical current to it and to provide any of the items and things disclosed herein with a coating according to the present invention without any voltage application apparatus or device.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

How the invention may be put into effect will now be described, by way of example only, with reference to the accompanying drawings, in which:

Fig. 1A is a schematic perspective view - not to scale - of a coating according to the present invention on an item or surface.

Fig. 1B is a graphic view of parameters of a system according to the present invention.

Fig. 2 is a schematic view of a system according to the present invention.

Fig. 3 is a schematic view of a system according to the present invention.

Fig. 4A is a top view of a plane according to the present invention.

Fig. 4B is a cross-section view of part of a wing of the plane of Fig. 4A.

Fig. 5 is a perspective view of a helicopter according to the present invention with coating according to the present invention.

Fig. 6 is a perspective view of a boat motor and propeller according to the present invention with coating according to the present invention.

Fig. 7A is a side view of a turbine blade according to the present invention with coating according to the present invention.

Fig. 7B is a side cross-section view of a turbine blade according to the present invention with coating according to the present invention.

Fig. 8A is a side view of a tower according to the present invention with coating according to the present invention.

Fig. 8B is a side view of a tower according to the present invention with coating according to the present invention.

Fig. 9 is a front view of a propeller according to the present invention with coating according to the present invention.

Fig. 10 is a perspective view of a wind power generator system according to the present invention with coating according to the present invention.

Fig. 11A is a schematic side view of a pipeline according to the present invention with coating according to the present invention.

Fig. 11B is a schematic side view of a pipeline according to the present invention with coating according to the present invention.

Fig. 12 is a side view of a bridge according to the present invention with coating according to the present invention.

Fig. 13 is a side view of a ship according to the present invention with coating according to the present invention.

Fig. 14 is a schematic perspective view of a train according to the present invention with coating according to the present invention.

Fig. 15 is a perspective view of a rail according to the present invention with coating according to the present invention.

Fig. 16 is a side view of an automobile according to the present invention with coating according to the present invention.

Fig. 17 is a perspective view of a tractor trailer rig according to the present invention with coating according to the present invention.

Fig. 18 is a perspective view of a pick-up truck according to the present invention with coating according to the present invention.

Fig. 19 is a side view of a recreation vehicle according to the present invention with coating according to the present invention.

Fig. 20 is a side view of a travel trailer according to the present invention with coating according to the present invention.

Fig. 21 is a perspective view of a utility trailer according to the present invention with coating according to the present invention.

Fig. 22 is a schematic view of a drilling system according to the present invention with parts with coating according to the present invention.

Fig. 23 is a schematic view of a drilling system according to the present invention with parts with coating according to the present invention.

Fig. 24 is a schematic view of an offshore rig according to the present invention with parts with coating according to the present invention.

Fig. 25 is a side view of a blowout preventer system according to the present invention with parts with coating according to the present invention.

Fig. 26 is a cross-section view of a centrifuge_ according to the present invention with parts with coating according to the present invention.

Fig. 27 is a perspective view of a shale shaker according to the present invention with parts with coating according to the present invention.

Fig. 28 is a top view of a shale shaker screen according to the present invention with parts with coating according to the present invention.

Fig. 29 is a top view of a screen support according to the present invention with parts with coating according to the present invention.

Fig. 30 is a top view of a shale shaker screen according to the present invention with parts with coating according to the present invention.

Fig. 31 is a cross-section view of a shale shaker screen according to the present invention with parts with coating according to the present invention.

Fig. 32 is a perspective view of a heat exchanger according to the present invention with parts with coating according to the present invention.

Fig. 33 is a side view of a heat exchanger tube according to the present invention with parts with coating according to the present invention.

Fig. 34 is a perspective view of a jet engine according to the present invention with parts with coating according to the present invention.

Fig. 35 is a cross-section view of a tubular according to the present invention with parts with coating according to the present invention.

Fig. 36 is a cross-section view of a pipeline or conduit according to the present invention with parts with coating according to the present invention.

Fig. 37A is a partial cross-section view of a storage tank system as shown in Fig. 37B according to the present invention with parts with coating according to the present invention.

Fig. 37B is a top view partially cutaway of a storage tank system according to the present invention with parts with coating according to the present invention.

Fig. 38 is a side view partially in cross-section a pipeline pig according to the present invention with parts with coating according to the present invention.

Fig. 39 is a side cross-section view of fabric according to the present invention with parts with coating according to the present invention.

Fig. 40 is a side view of a blowuout preventer according to the present invention with parts with coating according to the present invention.

Fig. 41A is a perspective view of a tubular according to the present invention.

Fig. 41B is a cross-section view of the tubular of Fig. 41A.

Fig. 42 is a cross-section view of a tubular according to the present invention.

Fig. 43 is a perspective view of a tubular according to the present invention.

Fig. 44 is a perspective view of a tubular according to the present invention.

Fig. 45 is a cross-section view of a tubular according to the present invention.

Fig. 46 is a perspective view of an item according to the present invention.

Fig. 47 is a perspective view of an item according to the present invention.

Fig. 48 is a perspective view of an item according to the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMNENTS

Fig. 1A shows a coating A according to the present invention (not to scale) which has a base B (e.g., 1.00 to 0.04 inches, 2.5 to 0.1 cm thick). Onto the base B is applied a conductive coating C with conductive nanomaterial N therein (e.g in a thin layer; e.g. between 0.005 inches thick to 0.030 inches, 0.01 to 0.08 cm, thick). The base B may be any suitable item, surface, backing, or thing; and the conductive coating C may be any coating described or referred to herein. The nanomaterial N dispersed thoroughout (material N shown greatly exaggerated in size) may be any suitable nanomaterial whose use results in the effective heating of the coating; including, but not limited to, nanotubes and nanoribbons, and, in one aspect, carbon nanotubes and/or carbon nanoribbons. It is within the scope of the present invention for the base B and the coating C to be any desired thickness. In certain particular aspects, the base B is 0.06 inches (0.15 cm) thick and the coating C is between 0.010 and 0.020 inches (0.025 – 0.05 cm) thick.

Fig. 1B presents data for a coating according to the present invention to which seven different voltages were applied. The graph shows that as the voltage is increased (seven lines, one for each specific applied voltage, lines numbered 1-7), the temperature of the coating increases. Also, with a particular applied voltage, over time (x axis), the temperature (y axis) increases. The box with line labels 1–7 indicates the different applied voltages, from 75 VDC for line 1 to 600 VDC for line 7.

The coating of Fig. 1B includes two resins, an aliphatic polyisocyanate and a saturated polyester. These are commercially available. Fluorinated polyurethane was added (this is optional) which imparts characteristics such as low surface energy and chemical resistance for corrosive environments. This resin system (polyisocyanate, polyester, fluorinated polyurethane) was cured using an optional dibutyl tin catalyst additive. The nanomaterial used was multi-walled carbon nanotubes approximately 10nm in diameter and with lengths ranging between 1 and 10 microns to achieve an electrical conductivity that enabled resistive heating of the coating. By weight percent, the coating components were:

1. 37% Polyisocyanate
2. 50% Polyester
3. 10% Fluorinated Polyurethane
4. 0.4% Dibutyl tin catalyst
5. 4% SMW grade Multi-walled nanotubes

The components were pre-mixed using sonication and then the resulting coating was diluted with a low-boiling-point solvent, methyl ethyl ketone (MEK), and sprayed onto the base. A high-shear homogenization mixing method may also be used (as is true with any embodiment herein).

Although copper strip electrical contacts were used, any suitable electrical contacts (or leads) may be used.

Fig. 2 shows a system 20 according to the present invention which includes a heatable coating 12 which, in one aspect, is a deicing coating 12 according to the present invention (any coating according to the present invention disclosed herein) to affect ice 24 that might adhere to an item 26. The item 26 may be any item or surface subjected to icing (including, but not limited to, any item substrate, or surface disclosed hererin); for example, and not by way of limitation, the item 26 may be an airplane wing, a helicopter blade, a turbine blade, a jet inlet, a heat exchanger for kitchen and industrial equipment, a refrigerator, a road sign, machines, oil filed apparatuses, oil field devices, oil field structures, a ship hull or superstructures, any item or surface disclosed herein, or other object or surface subjected to adverse, cold, wet and/or ice conditions. More specifically, the coating 22 is applied over the item 26 to protect it, e.g., but not limited to, to protect it from ice 24. The coating 22, in one aspect, is either sprayed-on or is flexible prior to application so that it physically conforms to the shape of item 26. In operation, a voltage is applied to the coating 22 by a power supply 28 (AC or DC). In certain aspects, this voltage is between 2 volts and 1000 volts and, in one aspect, with higher voltages being applied for lower temperatures. Whether the coating 12 is a protective coating, a heatable coating, or a deicing coating according to the present invention, the electrical system 20 may be used with an event sensor 21 which senses an event related to the item with the coating. For example, the sensed event may be the formation of ice or a change in temperature. Upon such sensing occurring, the electrical system heats the coating, e.g. to change the temperature or to deice the item.

When voltage is applied, the ice 24 is heated and then melts to water and flows from the surface. Further, gases from within the ice 24 and generate pressure bubbles that exfoliate ice 24 from the coating 22 (and hence from the item 26). Optionally, a voltage regulator subsystem 29 (optionally with a temperature sensors or sensors) is connected in feedback with a power supply 28, and thereby with the circuit formed by the coating 22 and the ice 24. The subsystem 29 increases or decreases DC voltage applied to the coating 22 as required.

Fig. 3 shows a system 30 according to the present invention which has an electrical deicing coating 32 according to the present invention to affect ice 34 that might adhere to a conductive surface 36. The conductive surface 36 may be on any item subjected to icing. The coating 32 is applied over the surface 36 to protect the surface 36 from the ice 34. In one aspect, the coating 32 is flexible so as to physically conform to the shape of surface 36. In operation, a voltage is applied between the coating 32 and the surface 36 by a power supply 38. A bias voltage applied to the coating 32 may be equal and opposite to a bias voltage applied to the surface 36. If desired, an insulator 35 may be disposed between the coating 32 and the surface 36. The insulator 35 may be any known suitable insulator, insulating structure, or insulating material.

If desired, a voltage regulator subsystem 39 is connected in feedback with a power supply 38, and thereby with the circuit formed by the coating 32, the surface 36, and the ice 34, so as to increase or decrease the DC voltage applied to the coating 32.

In the embodiments that follow, any item, thing, or surface may be coated with any coating according to the present invention and any system according to the present invention may be used to apply a voltage to the coating, including, but not limited to, the coatings and systems described above in Figs. 1-3.

Fig. 4A shows a plane 40 with a body 42, a nose 42a, window 44, wings 46, engines 45, and tail 48. It is within the scope of the present invention to provide a coating according to the present invention and/or coating system according to the present invention to any part of a plane, including, and not limited to, the body, windows, wings, wing leading edge, engine inlets, engine housings, and tail, as well as any particular part, projection, or instrument which may be subjected to icing. Such parts, etc., may be entirely covered with the coating or only part thereof may be covered with the coating.

As shown in Fig. 4B, a leading edge 46a of the wings and a horizontal tail portion 47 are coated with a coating 49 according to the present invention and a system 40s (like any system disclosed herein) provides the required voltage to heat the coating. Engine inlets 43 (which engines may be any kinds of engine; e.g., jet, turbine, piston, rocket, etc.)are coated with a coating 41 according to the present invention.

Fig. 5 shows a helicopter 50 with a body 52, a nose 51, windows 54, rotors 56, engine 55, tail 58, and tail propeller 59. It is within the scope of the present invention to provide a coating according to the present invention and/or coating system according to the present invention to any part of a helicopter, including, and not limited to, the body, windows, rotors, engine inlet, engine housing, tail, and tail propeller, as well as any particular part, projection, or instrument which may be subjected to icing. Such parts, etc., may be entirely covered with the coating or only part thereof may be covered with the coating. As shown in Fig. 5, a leading edge 56a of the rotors and of a horizontal tail portion 57 are coated with a coating 59 according to the present invention and a system 50s (like any system disclosed herein) provides the required voltage to heat the coating. An engine inlet 53 (which engines may be any kinds of engine; e.g., jet) is coated with a coating 53a according to the present invention.

Fig. 6 shows a boat motor 60 with a body 62, a nose 64, a propeller 66, and a motor housing 68. It is within the scope of the present invention to provide a coating according to the present invention and/or coating system according to the present invention to any part of a boat motor, including, and not limited to, the body, nose, propeller, motor housing, and propeller, as well as any particular part, projection, or instrument which may be subjected to icing. Such parts, etc., may be entirely covered with the coating or only part thereof may be covered with the coating. Edges of the propeller 66 and the tip of the nose 64 are coated with a coating 69 according to the present invention and a system 60s is used to apply a voltage to the coating areas.

Fig. 7A shows a turbine blade 70 with a body 72 and vane portion 74. A coating 76 according to the present invention (shown partially in exaggerated size) coats the body and the vane portion. A control system 70s applies a voltage to the coating 76.

Fig. 7B shows a turbine blade 71 with a body 73, an inlet 75, and inlets 77. A coating 79 according to the present invention (shown partially in exaggerated size) coats the body and the inlets. A control system 71s applies a voltage to the coating 79.

Fig. 8A shows a power transmission tower 80 with a main structure 81, arms 82, insulators 82a, top structure 83, and interior structure 84. These parts are coated with a coating 85 according to the present invention (shown partially in exaggerated size on one of the arms 82) and a system 80s provides the voltage to be applied to the coating. It is within the scope of the present invention to delete the coating from any part of the tower 80 or to coat only one of the parts.

Fig. 8B shows a power transmission tower 86 with a main structure 87 and interior structure 88. These parts are coated with a coating 89 according to the present invention (shown partially in exaggerated size on part of the interior structure 89) and a system 86s provides the voltage to be applied to the coating. It is within the scope of the present invention to delete the coating from any part of the tower 86 or to coat only one of the parts.

Fig. 9 shows a propeller 90 according to the present invention with a coating 92 on blades 93 and on a hub 94 mounted to a support SP. A system 90s according to the present invention provides the voltage to the coating 92 to heat the coating. It is within the scope of the present invention to delete the coating from any part of the propeller 90, to coat an edge of the blades 93, to coat a leading edge of the blades 93, or to coat one of the parts of the propeller, or only one of these parts.

Fig. 10 shows a wind power generating system 100 according to the present invention with a rotatable propeller on a support 101. The propeller 109 has blades 102 and a nose 106. A power conversion system 108 converts the rotative force of the propeller into usable power. The blades 102 and/or the nose 106 are coated with a coating 103 according to the present invention (shown in exaggerated size) and a system 100s provides the voltage to heat the coating 103. Optionally, there is a coating 105 according to the present invention (shown partially in exaggerated size) on other parts of the system 100. It is within the scope of the present invention to delete the coating from any part or parts of the system 100, to coat an edge of the blades 103, to coat a leading edge of the blades 103, to coat the nose 106, and/or to coat one of the parts of the propeller, or only one of these parts.

Fig. 11A shows a pipeline 110 according to the present invention on supports ST above the earth ER with a coating 112 according to the present invention (shown partially in exaggerated size) on its exterior. A system 110s according to the present invention provides the voltage to the coating 112 to heat the coating. It is within the scope of the present invention to delete the coating from any part of the pipeline 110, to coat the bottom half of the pipeline, to coat substantially all of the exterior surface of the pipeline, or to coat a bottom strip along the entire pipeline or only along certain parts of the pipeline, or only one of these parts.

Fig. 11B shows a pipeline 114 according to the present invention within the earth ET with a coating 116 according to the present invention (shown partially in exaggerated size) on its exterior. A system 114s according to the present invention provides the voltage to the coating 116 to heat the coating. It is within the scope of the present invention to delete the coating from any part of the pipeline 114, to coat the bottom half of the pipeline, to coat substantially all of the exterior surface of the pipeline, or to coat a bottom strip along the entire pipeline or only along certain parts of the pipeline, or only one of these parts.

Fig. 12 shows a bridge 120 according to the present invention with a deck 122, supporting structure 124, cables 126, and towers 128. A coating 129 according to the present invention (shown partially in exaggerated size) coats exterior surfaces of the parts of the bridge 120. A system 120s according to the present invention provides the voltage to the coating 129 to heat the coating. It is within the scope of the present invention to delete the coating from any part of the bridge 120, to coat the deck of the bridge, to coat the cables, and/or to coat the support structure, or only one of these parts.

Fig. 13 shows a ship 130 according to the present invention with a deck 132, superstructure 133, masts 134, hull 135, cabin 136, railing 137, and drive propeller 138. A coating 139 according to the present invention (shown partially in exaggerated size) coats exterior surfaces of the parts of the ship 130. A system 130s according to the present invention provides the voltage to the coating 139 to heat the coating. It is within the scope of the present invention to delete the coating from any part of the ship 130, to coat the deck, the hull, the superstructure, the cabin, the railing and/or the masts, the bow of the ship, and/or to coat the bottom of the hull, or only one of these parts.

Fig. 14 shows a train 140 according to the present invention with a locomotive 142, car 143, and car 144. A coating 149 according to the present invention (shown partially in exaggerated size) coats exterior surfaces of the parts of the train 140. A system 140s according to the present invention provides the voltage to the coating 149 to heat the coating. It is within the scope of the present invention to delete the coating from any part of the train 140, to coat only the front of the locomotive, the tops of the locomotive and/or car(s), and/or a part or parts of the locomotive and/or cars, or only one of these parts.

Fig. 15 shows a rail 150 according to the present invention with a body 152, a base 154, and a top 156. A coating 159 according to the present invention (shown partially in exaggerated size) coats exterior surfaces of the parts of the rail 150. A system 150s according to the present invention provides the voltage to the coating 159 to heat the coating. It is within the scope of the present invention to delete the coating from any part of the rail 150, to coat the base, the body, the top of the top, and/or the top of the rail, or only one of these parts.

Fig. 16 shows an automobile 160 according to the present invention with a body 162, doors 164, windows 166, tires 168, and wheels 163. A coating 169 according to the present invention (shown partially in exaggerated size) coats exterior surfaces of the parts of the automobile 160. A system 160s according to the present invention provides the voltage to the coating 169 to heat the coating. It is within the scope of the present invention to delete the coating from any part of the automobile 160, from the tires, the body, the top of the automobile, the front of the automobile, the wheels, the top of the top, the top of the hood, and/or the windows, or only one of these parts.

Fig. 17 shows a tractor trailer rig 170 according to the present invention with a tractor 171 with a body 172, doors 174, windows 176, tires 178,and wheels 173; and with a trailer 171 with a body 171a, wheels 175, and tires 177. A coating 179 according to the present invention (shown partially in exaggerated size) coats exterior surfaces of the parts of the automobile tractor trailer rig 170. A system 170s according to the present invention provides the voltage to the coating 179 to heat the coating. It is within the scope of the present invention to delete the coating from any part of the tractor trailer rig 170, to coat the tires, the bodies, the top of the bodies, the front of the tractor, the wheels, only the top of the hood of the tractor, and/or the windows, or only one of these parts.

Fig. 18 shows a pick-up truck 180 according to the present invention with a body 182, doors 184, windows 186, tires 188, a bed 187, and wheels 183. A coating 189 according to the present invention (shown partially in exaggerated size) coats exterior surfaces of the parts of the truck 180. A system 180s according to the present invention provides the voltage to the coating 189 to heat the coating. It is within the scope of the present invention to delete the coating from any part of the truck 180, to coat the tires, the body, the top of the vehicle, the front of the vehicle, the wheels, the top of the top, and/or the windows, or only one of these parts.

Fig. 19 shows a recreational vehicle 190 according to the present invention with a body 192, windows 196, tires 198, and wheels 193. A coating 199 according to the present invention (shown partially in exaggerated size) coats exterior surfaces of the parts of the vehicle 190. A system 190s according to the present invention provides the voltage to the coating 199 to heat the coating. It is within the scope of the present invention to delete the coating from any part of the vehicle 190, to coat the tires, only the body, the top of the vehicle, the front of the vehicle, the wheels, and/or the windows or only one of these parts.

Fig. 20 shows a travel trailer 200 according to the present invention with a body 202, rear 201, roof 203, bottom 204, front 205, windows 206, tires 207, and wheels 208. A coating 209 according to the present invention (shown partially in exaggerated size) coats exterior surfaces of the parts of the trailer 200. A system 200s according to the present invention (shown schematically as are the similar systems in the figures described above) provides the voltage to the coating 209 to heat the coating. It is within the scope of the present invention to delete the coating from any part of the trailer 200, to coat the tires, the body, the top of the vehicle, the front or bottom or rear of the vehicle, the wheels, and/or the windows or only one of these parts.

Fig. 21 shows a utility trailer 210 according to the present invention with a body 212, tongue 211, fenders 215, tires 217, and wheels 218. A coating 219 according to the present invention (shown partially in exaggerated size) coats exterior surfaces of the parts of the trailer 210. A system 200s according to the present invention (shown schematically as are the similar systems in the figures described above) provides the voltage to the coating 209 to heat the coating. It is within the scope of the present invention to delete the coating from any part of the trailer 210, to coat the tires, the body, the tongue, the fenders, the wheels, the front or bottom or rear of the trailer, or only one of these parts. As is true for any embodiment herein which has an electrical system designated with a numeral followed by a lower case "s," the system 220s may be any suitable voltage applications system, apparatus, or device, including, but not limited to, those disclosed or referred to herein.

Fig 22 shows a schematic diagram of an exemplary drilling system 220 according to the present invention having a drilling assembly 221 shown conveyed in a borehole BH for drilling a wellbore. The drilling system 220 includes a conventional derrick DK having a floor FL which supports a typical rotary table RT that is rotated by a prime mover whose motor (not shown) is controlled by a motor controller (not shown). It is within the scope of the present invention to use the teachings of the present invention for known drilling methods and techniques, including, but not limited to, rotary drilling, top drive drilling, casing drilling, and coil tubing drilling. In one aspect, a drill string DR includes a drill pipe DE extending downward from the rotary table through a pressure control device PD (e.g., but not limited to, one or more BOP's) into the borehole. A drill bit 225, attached to the drill string end, disintegrates the geological formations when it is rotated to drill the borehole. The drill string is coupled to a drawworks 223 via a kelly joint KJ, swivel SW and line LN through a pulley (not shown). This description is drawn to a land rig, but the invention as disclosed herein is also equally applicable to any offshore drilling rigs or systems. Alternatives to conventional drilling rigs, such as coiled tubing systems (shown schematically as CTS), can be used to drill boreholes, and the invention disclosed herein is equally applicable to such systems. Mud pump MU pumps drilling fluid into the drill string via the kelly joint KJ and the drilling fluid is discharged at the borehole bottom through an opening in the drill bit. The drilling fluid circulates uphole through an annular space between the drill string and the borehole and returns to a mud tank MT via a solids control system SY. The solids control system may include shale shakers, centrifuges, and other known solids control equipment.

In one aspect, each, some, or substantially all of the exterior surfaces of the equipment, devices, conduits, and items described above for the system 220 is/are coated with a coating 229 according to the present invention (shown on some parts exaggerated in size) and a system 220s according to the present invention (shown schematically) provides the voltage to heat the coating. It is within the scope of the present invention to so coat only one of the pieces of equipment, etc. of the system 220 according to the present invention.

Referring now to Fig. 23, a drilling rig 230 according to the present invention is depicted schematically as a land rig, but other rigs (e.g., offshore rigs, jack-up rigs, semisubmersibles, drill ships, and the like) are within the scope of the present invention (and this is true for the embodiments of rigs and wellbore operations described below also). In conjunction with an operator interface, e.g. an interface I, a control system CS controls certain operations of the rig. The rig 230 includes a derrick 231 that is supported on the ground above a rig floor RF. The rig 230 includes lifting gear, which includes a crown block CB mounted to the derrick 231 and a traveling block TB. The crown block and the traveling block are interconnected by a cable CL that is driven by drawworks 233 to control the upward and downward movement of the traveling block. The traveling block carries a hook H from which is suspended a top drive system 237 which includes a variable frequency drive controller VD, a motor M (or motors) and a drive shaft DS. The top drive system 237 rotates a drillstring DT to which the drive shaft is connected in a wellbore W. The drillstring is coupled to the top drive system through an instrumented sub IS which can include sensors that provide information, e.g., drillstring torque information. The drillstring may be any typical drillstring and, in one aspect, includes a plurality of interconnected sections of drill pipe DP a bottom hole assembly BHA, which includes appropriate stabilizers, drill collars, and/or an apparatus or device, in one aspect, a suite of measurement while drilling (MWD) instruments including a steering tool ST to provide bit face angle information. Optionally a bent sub BS is used with a downhole or mud motor MM and a bit BT, connected to the BHA. Drilling fluid is delivered to the drillstring by mud pumps MP through a mud hose MH. During rotary drilling, the drillstring is rotated within the bore hole by the top drive system. Fluid from the well and the cuttings produced as the bit drills into the earth are carried out of bore hole by the fulid supplied by the mud pumps. The fluid expelled from the well flows to solids control equipment SC which may include one or more shale shakers SS with one or more shale shaker screens SSS; one or more centrifuges C; and/or other fluid processing equipment X (e.g., but not limited to, degassers, desilters, desanders, and hydrocyclones).

In one aspect, each, some, or substantially all of the exterior surfaces of the equipment, devices, conduits, and items described above for the rig 230 is/are coated with a coating 239 according to the present invention (shown on some parts exaggerated in size) and a system 230s according to the present invention (shown schematically) provides the voltage to heat the coating. It is within the scope of the present invention to so coat only one of the pieces of equipment, etc. of the rig 230 according to the present invention. It is also within the scope of the present invention (as is true for any part of any embodiment herein) to coat a part to heat it, for heating and/or for deicing; e.g., for heating to facilitate flow, to remediate wax build-up in a conduit or pipeline, to inhibit or reduce hydrate formation in a conduit or pipeline, to deice a well or wellbore which is cased or uncased, to control viscosity of the contents of a storage tank, to provide a conductive path or liner for a storage tank, and to improve gas permeation of a fabric.

Fig. 24 shows an offshore rig 240 according to the present invention which has legs 241 that extend down to and beneath a seafloor SF. The legs 241 support a platform 242 that has a cabin 243, a lifting apparatus 244, a derrick 245, a deck 247, and the equipment, devices, conduits, items, and apparatuses (shown schematically and all designated by the box labeled 246) necessary for operations on the rig 240.

According to the present invention, one, some, or substantially all of the equipment, devices, conduits, apparatuses, and items of the rig 240 are coated with a coating 249 according to the present invention (shown on some parts in exaggerated size) and a system 240s provides the voltage for heating the coating. In certain aspects according to the present invention, only one item, etc., or only one part, etc. has this coating; and it is within the scope of the present invention to delete the coating from any part of the rig 240.

Fig. 25 shows a blowout preventer system 250 according to the present invention. According to the present invention, one, some, or substantially all of the equipment, devices, conduits, apparatuses, parts, and items of the BOP system 250 are coated with a coating 259 according to the present invention (shown on some parts in exaggerated size). A system 250s according to the present invention provides the voltage to the coating 259 to heat the coating. It is within the scope of the present invention to delete the coating from any part of the system 250 or to coat only one of these parts.

Fig. 26 shows a centrifuge 260 according to the present invention which has the parts as labeled in Fig. 26. According to the present invention, one, some, or substantially all of the equipment, devices, conduits, apparatuses, parts, and items of the centrifuge 260 are coated with a coating 269 according to the present invention (shown on some parts in exaggerated size). A system 260s according to the present invention provides the voltage to the coating 269 to heat the coating. It is within the scope of the present invention to delete the coating from any part of the centrifuge 260 or to coat only one of these parts.

Fig. 27 shows a shale shaker 270 according to the present invention which has a screen 272 (or screens) (with screen or screening cloth or mesh as desired) mounted on vibratable screen mounting apparatus or "basket" 273 with a screen support 275. The screen(s) 272 may be any known screen or screens, but with a coating on some or all parts according to the present invention. The basket 273 is mounted on springs 274 which are supported from a frame 276. The basket 273 is vibrated a vibrating apparatus 278 which is mounted on the basket 273 for vibrating the basket and the screens. Elevator apparatus 277 provides for raising and lowering of the basket end. According to the present invention, one, some, or substantially all of the equipment, devices, conduits, apparatuses, parts, and items of the shaker 270 are coated with a coating 279 according to the present invention (shown on some parts in exaggerated size). A system

270s according to the present invention provides the voltage to the coating 279 to heat the coating. It is within the scope of the present invention to delete the coating from any part of the shaker 270 or to coat only one of these parts.

Fig. 28 shows a shale shaker screen 280 according to the present invention which has a frame 282 and screen mesh 284. According to the present invention, the frame (top, sides and/or bottom) is coated with a coating 289 according to the present invention (shown on some parts in exaggerated size); and/or the screen mesh (top and/or bottom) is so coated. A system 280s according to the present invention provides the voltage to the coating 289 to heat the coating. It is within the scope of the present invention to delete the coating from any part of the screen 280 or to coat only one of these parts.

Fig. 29 shows a shale shaker screen support 290 according to the present invention which has a sides 292, cross members 296, and mesh support grid 294. According to the present invention, sides, cross members, and/or grid are coated with a coating 299 according to the present invention (shown on some parts in exaggerated size). A system 290s according to the present invention provides the voltage to the coating 299 to heat the coating. It is within the scope of the present invention to delete the coating from any part of the screen support 290 or to coat only one of these parts.

Fig. 30 shows a shale shaker screen 300 according to the present invention which has a sides 302, screening material 306, and grid 304 (made, e.g., of metal or of epoxy). According to the present invention, the sides, screening material (top and/or bottom), and/or grid are coated with a coating 309 according to the present invention (shown on some parts in exaggerated size). A system 300s according to the present invention provides the voltage to the coating 309 to heat the coating. It is within the scope of the present invention to delete the coating from any part of the screen 300 or to coat only one of these parts.

Fig. 31 shows a shale shaker screen 310 according to the present invention which has a support 312 and three-dimensional screening material 314 (with raised portions or “hills” between lower portions or “valleys”) on the support 312. Optionally, end of the 3-D material are closed off with screening material 316 (or with a solid material).

According to the present invention, the sides, screening material (top and/or bottom), and/or grid are coated with a coating 319 according to the present invention (shown on some parts in exaggerated size). A system 310s according to the present invention provides the voltage to the coating 319 to heat the coating. It is within the scope of the present invention to delete the coating from any part of the screen 310 or to coat only one of these parts.

Fig. 32 shows a heat exchanger 320 according to the present invention which has fin plates 322 and tubes 323 extending through the plates 322. According to the present invention, the plates, and/or the tubes are coated with a coating 329 according to the present invention (shown on some parts in exaggerated size). A system 320s according to the present invention provides the voltage to the coating 309 to heat the coating. It is within the scope of the present invention to delete the coating from any part of the exchanger 320 or to coat only one of these parts.

Fig. 33 shows a finned tube 330 according to the present invention for a heat exchange. The tube 330 has a hollow tubular body 332 with a plurality of spaced-apart fins 334. According to the present invention, the body (inside and/or outside), and/or the fins (either or both sides) are coated with a coating 339 according to the present invention (shown on some parts in exaggerated size). A system 330s according to the present invention provides the voltage to the coating 339 to heat the coating. It is within the scope of the present invention to delete the coating from any part of the tube 330 or to coat only one of these parts.

Fig. 34 shows a jet engine 340 according to the present invention, e.g., for a plane. The engine 340 has a housing 342 with an inlet 344. According to the present invention, the housing (inside and/or outside), and/or the inlet (inside and/or outside) are coated with a coating 349 according to the present invention (shown on some parts in exaggerated size). A system 340s according to the present invention provides the voltage to the coating 349 to heat the coating. It is within the scope of the present invention to delete the coating from any part of the engine 340 or to coat only one of these parts.

Fig. 35 shows a tubular 350 according to the present invention. The tubular 350 has a channel 351 therethrough from one end to the other. Optionally, the tubular 350 has a pin end 354 with threading 356 and a box end 357 with threading 358. According to the present invention, the tubular 350 (inside and/or outside), and/or either end (inside and/or outside), and/or the pin end, and/or the box end, and/or the threading on either or both ends are coated with a coating 359 according to the present invention (shown on some parts in exaggerated size). A system 350s according to the present invention provides the voltage to the coating 359 to heat the coating. It is within the scope of the present invention to delete the coating from any part of the tubular 350 or to coat only one of its parts. In certain aspects, and not by way of limitation, the tubular is tubing, casing, pipe, drill pipe, drill collar, riser, or oil country tubular goods.

Fig. 36 shows a conduit 360 according to the present invention (which, in one aspect, is a pipeline for the transport of fluid, e.g., but not limited to, steam, gas, chemicals, oil, or hydrocarbons). The conduit 360 has an interior 361 coated with a coating 362 according to the present invention and/or an exterior 363 coated with a coating 364 according to the presenting invention. A system 360s according to the present invention provides the voltage to the coating(s) to heat the coating(s). Such heating can inhibit or reduce the formation of hydrates (and/or condensation) 365 within the conduit 360 and/or can inhibit or assist in removing deposits on the conduit, e.g., but not limited to, the treatment of paraffin wax 366 on the interior 361 of the conduit 360. The coatings are not shown to scale (as is true of all the drawings herein).

Figs. 37A and 37B show a storage tank system 370 according to the present invention which has tank walls 371, bottom 371b, with coatings 372 and/or 373 according to the present invention. Optional movement apparatus 374 within the tank has coating 375 on its parts. Piping 376 has coating 377 according to the present invention which includes valves 378 and exit pipe 379-any and all of which may be coated according to the present invention. A system 370s according to the present invention provides the voltage to the coating(s) to heat the coating(s). The coatings are not shown to scale (as is true of all the drawings herein). The coating(s) may be used to control the viscosity of the contents CT of the tank. In certain aspects, the exterior coating and/or the interior coating, in contact with the earth, serve as a ground for the tank system, providing a flow path for electrons impressed on the tank to the ground.

Any coating disclosed herein may be used for such grounding.

Fig. 38 shows a pipeline pig 380 according to the present invention which has a body 381, internal passageways 382, 383, and a removable disc (or discs) 384. Any or all of these parts may have a coating 385 according to the present invention partially or totally covering the part. A system 380s according to the present invention provides the voltage to the coating(s) to heat the coating(s). Suitable conductors may be provided within a pipeline, e.g., but not limited to the conductor CD shown in Fig. 36, for transmitting electricity to the pig 380, The coatings are not shown to scale (as is true of all the drawings herein).

Fig. 39 shows a fabric 390 according to the present invention which has a fabric layer (woven or unwoven) 391, an optional backing 392, and an optional wear layer 393. The fabric 390 is coated with a coating 395 according to the present invention partially or totally. A system 390s according to the present invention provides the voltage to the coating to heat the coating. The coatings are not shown to scale (as is true of all of the drawings herein).

It is within the scope of the present invention to provide a coating according to the present invention on a blowout preventer and to its internal and/or external parts and/or surfaces, including, but not limited to, its rams, actuators, seals, seal recesses, seal mount structures, and internal and external surfaces. The present invention is applicable to closing BOP's and to tubular-severing BOP's. As with other items, apparatuses, machines, and things described above according to the present invention, the provision of such a coating according to the present invention provides for, among other things, the selective heating and/or deicing of part or all of an item, etc.

Fig. 40 shows a blowout preventer 400 according to the present invention which has a body 402 with a plurality of spaced-apart rams 403 and 404 which are moved by actuators 405. According to the present invention, the body (inside and/or outside), parts, seal(s), and/or the rams are coated with a coating 339 or 340 according to the present invention (shown on some parts in exaggerated size). Any seal of any part of a blowout preventer according to the present invention may have a seal in a respective recess or mount with the seal and/or the recess coated with a coating (shown partially in exaggerated size) according to the present invention (see. e.g., the seals SS shown schematically in recesses RS to represent all seals and/or any seal of the preventer 400, seal of a ram, and/or seal of an actuator). A system 400s according to the present invention provides the voltage to the coating(s) of the blowout preventer 400 to heat the coating. It is within the scope of the present invention to delete the coating from any part of the blowout preventer 400 or to coat only one of the parts or surfaces.

Figs. 41A and 41B show a tubular 410 according to the present invention which has a coating 412 (not to scale) on its exterior (any coating according to the present invention) and leads 414 to which a voltage is applied by a system 416s. Any desired number of leads may be used, one or more. In one particular aspect, the tubular 410 is pipe which, in one aspect is rubber, PVC, or plastic “PEX” or crosslinked polyethylene and the leads are copper (e.g., copper wires or pieces of copper stock cut to size and glued to the surface of a pipe; e.g., but not limited to, a plastic pipe three-quarters of an inch in OD). The system 416s may be any system disclosed or referred to herein for applying a voltage. Any tubular according to the present invention may have its interior, exterior, or both coated with PTFE or with some other non-stick material.

In certain embodiments with copper wire leads as described above on PVC pipes and on rubber pipes, coated exteriorly with a coating having five percent multi-walled nanotubes by weight, electrical resistances of 0.632 kΩ and 1.25 kΩ were measured for PCV pipes (three quarters of an inch, 1.9 cm, OD); and electrical resistances of 0.895 kΩ and 1.155 kΩ were measured for rubber pipes (three quarters of an inch OD). The temperature of these pipes increased with heating time as current was applied to the pipe’s leads. For the PVC pipes the temperature over about fifteen minutes increased from about sixty-two degrees F (17 degrees C) to about one hundred eighteen degrees F (118 degrees C)((pipe with resistance of 0.632 kΩ) and from about sixty-two degrees F to about one hundred degrees F (pipe with resistance of 1.25 kΩ). For the rubber pipes the temperature over about fifteen minutes increased from about sixty-two degrees F to about seventy eighteen degrees F (38 degrees C) (pipe with resistance of 0.895 kΩ and from about sixty-two degrees F (17 degrees C) to about seventy degrees F (21 degrees C) (pipe with resistance of 1.15 kΩ).

As shown in Figs. 42 – 45, it is within the scope of the present invention to use one, two, three, four or more leads or electrical contacts with an embodiment of the present invention (and with any embodiment disclosed herein) and, with tubulars (e.g., pipe, tubing, casing, risers, drill collars, drill pipe) the leads may be non-straight with respect to a longitudinal axis of the tubular. Also, it is within the scope of the present invention to coat the inside of a tubular, the outside of a tubular, or both. Contacts (any leads or contacts disclosed herein) may be on top of a coating or they may be coated by the coating.

Fig. 42 shows a tubular 420 according to the present invention with an exterior coating 422 which coats a plurality of leads 424 (not to scale) which are on the exterior of the tubular 420 and are in contact with the coating 422.

Fig. 43 shows a tubular 430 according to the present invention with an exterior coating 432 (not to scale) which coats a plurality of leads 434 which are in contact with the coating 432. The leads 434 wrap partially around the tubular 430 in a helical pattern. A system 430s applies voltage to the tubular's leads.

Fig. 44 shows a tubular 440 according to the present invention with an exterior coating 442 (not to scale) which coats a plurality of leads 444 which are in contact with the coating 442. The leads 444 are slanted with respect to the tubular 440 and wrap partially around the tubular 430. A system 440s applies voltage to the leads 444.

Fig. 45 shows a tubular 450 according to the present invention with an exterior coating 452 on top of which are a plurality of leads 454 which are in contact with the coating 452 and an interior coating 456 on top of which are a plurality of leads 458. As is true for any embodiment herein in which there are multiple leads, either or both of the leads 454, 458 may be under their respective coatings; or alternating leads for one coating may be coated or on top of a coating.

Fig. 46 shows an item 460 according to the present invention with a top coating 462 which also coats leads 464 which are in contact with the coating 462. In one aspect the item 460 was a glass slide, one inch by three inches (2.5 x 7.5 cm), and the leads were aluminum with the coating containing four percent by weight multi-walled carbon nanotubes. This coating, in one aspect, due to the inclusion of the nanomaterial, was relatively viscous and was spread on the slide using a spatula, mechanical draw down film cutting device, or putty knife. This item had an electrical resistivity of about one hundred kΩ and was heated from seventy degrees F (21°C) to about one hundred and ten degrees F (43 degrees C) with five minutes of applied current at six hundred volts.

Fig. 47 shows an item 470 according to the present invention with a top coating 472 which also coats leads 474 which are in contact with the coating 472. In one aspect, an item 470 was a six-inch by six-inch (15 x 15 cm) piece of HDPE, about one eighth of an inch (0.3 cm) think, spray coated with a coating four to six mils thick. The coating was sprayed to a thickness of about 0.04 inches(0.1 cm) and was a three part resin system with four percent mutli-walled carbon nanotubes by weight. The coating three part resin system was polyisocyanate with a fluorinated polyol additive and cured with a dibutyl tin catalyst. Optionally any suitable conventional polyol, fluorinated or not, may be used. Such an embodiment heated sufficiently upon the application of an electrical current to its leads to provide de-icing. In a larger embodiment, with a piece of HDPE about twelve inches by twelve inches (30 x 30 cm), the weight percent of nanotubes in the coating was five percent and similar heating was achieved.

Fig. 48 shows a protector 480 according to the present invention which has a body 486 and an exterior coating 482. Leads 484 extend from opposite ends of the body 486. In one aspect, the body 486 operates as an anode which efficiently enables impressed current cathodic protection due to the conductivity of the conductive nanomaterial coating. The body may, according to the present invention, of any desired shape, configuration and dimensions. In certain aspects, the coating 482 is applied to a thickness of about ten mils. In one particular aspect, the coating is as the coating described above with 5% carbon nanotubes by weight. For example, a body of metal, metal alloy(s), mixed metal oxide, copper, and/or graphite may be used (and/or of any known metal used for cathodic protection). By applying electrical current (e.g., referred to as an “impressed current” or “impressed electrons”) to the leads of the body, the underlying metal is protected from corrosion due to water exposure and/or chlorine gas generation (typical byproducts of impressed current cathodic protection) which can result in prior systems in the sacrificial corrosion of unprotected metal or graphite anodes. Any coating according to the present invention may be used for the coating 482. Any coating depicted in the drawings hereof with non-straight squiggly lines and/or with a dark mass are not to scale and are understood to cover an entire surface or part unless stated otherwise. Any embodiment not shown with a current application device or apparatus may have any such device or apparatus as disclosed or referred to herein; and any coating herein, without a current application device, may be used as a protective coating.

The present invention, therefore, in at least some embodiments, provides methods for heating including: applying a heatable coating onto at least part of an item; applying electric current to the heatable coating thereby producing heat in the heatable coating and heating at least part of the item; the heatable coating having base material, nanomaterial dispersed in the base material, the nanomaterial comprising electrically conductive nanomaterial so that when the electric current is applied, if flows through and heats the nanomaterial. Such methods may include, in any possible combination, one or some (any possible number) of the following: wherein the nanomaterial is one of or a combination of two of nanotubes, nanoribbons, nanographene, transformed nanomaterial, carbon nanomaterial, and carbon nanotubes; wherein the coating on all or on at least part of the item is between 0.0001 and 1 inch thick; wherein the nanomaterial, by weight, is at least 1 % of the coating; wherein the nanomaterial, by weight, is at least between 0.1 and 32% of the coating; wherein the coating has an electrical resistivity due to the nanomaterial which is in a range which is one of between 10 to 100 g*Ω/cm and between 0.001 to 100 g*Ω/cm; wherein the base material is one of or a combination of two or more of glass, natural fabric, synthetic fabric, metal, elastomer, wood, plastic, composite, polymer, thermoplastic material, thermoset material, and high density polyethylene; wherein the coating is applied by one of dipping, spraying, spreading, trowelling, brushing, pouring, bonding, fusion bonding, and electrostatic coating; wherein the electrical current is one of direct current and alternating current; wherein the coating includes a resin material; wherein the item has a body with an outer surface and the at least part of the item is the outer surface of the body; wherein the coating further comprises two or at least two spaced-apart electrical contacts to which the electrical current is applied; wherein the nanomaterial is dispersed in the coating prior to application of the coating to the item by a method which is one of stirring, blending, mixing and sonication; wherein the item has ice thereon and the coating is heated sufficiently to melt the ice; wherein the coating (e.g., an exterior coating connected the item and to ground or an interior coating connected to the item and to ground) provides an electrical ground for the item; wherein the coating includes one of resin system, film, paint, and adhesive; wherein an electrical system provides the electrical current to the coating; wherein the electrical system includes a power supply and a voltage regulator; wherein the electrical system includes a sensor for sensing an event and a current source to apply electrical current in response to a sensed event, the event being one of ice formation and a predetermined state of temperature change; the base material is a cathodic protection material; and/or wherein the item is all or at least a portion of an airplane, an airplane part, wing, edge of a wing, propeller, part of a propeller, turbine blade, turbine blade edge, tower, wind power generator, pipeline, pipeline interior, pipeline exterior, bridge, part of a bridge, bridge deck, cable, support structure, ship, ship hull, boat, boat motor, vehicle, rail, automobile, truck, trailer, recreational vehicle, drilling system, pipe, tubular, casing, blowout preventer, seal, drilling equipment, drilling structure, drilling rig, conduit, offshore rig, centrifuge, shale shaker, screen, screen support, heat exchanger, finned tube, jet engine, tank, fabric, and cathodic protection structure.

The present invention, therefore, in at least some embodiments, provides heatable coatings for application to an item, such a heatable coating including: base material, nanomaterial dispersed in the base material, and the nanomaterial including electrically conductive nanomaterial. Such methods may include, in any possible combination, one or some (any possible number) of the following: wherein the nanomaterial is one of or a combination of two of nanotubes, nanoribbons, nanographene, transformed nanomaterial, carbon nanomaterial, and carbon nanotubes, wherein the coating is between .0001 and 1 inch thick, wherein the nanomaterial, by weight, comprises at least 1 % of the coating, wherein the coating further comprises at least two or two spaced-apart electrical contacts to which the electrical current is applied, and/or wherein the coating includes one of resin system, film, paint, and adhesive, wherein the coating has an electrical resistivity due to the nanomaterial which is in a range which is one of a range between 10 to 100 g*Ω/cm and a range between 0.001 to 100 g*Ω/cm, wherein the base material is one of or a combination of two of glass, natural fabric, synthetic fabric, metal, elastomer, wood, plastic, composite, polymer, thermoplastic material, thermoset material, and high density polyethylene, and/or wherein the coating is applied by one of dipping, spraying, spreading, trowelling, brushing, pouring, bonding, fusion bonding, and electrostatic coating, and/or wherein the coating includes a resin material, film paint or adhesive.

The present invention, therefore, in at least some embodiments, provides an item coated at least partially with a heatable coating including: base material, nanomaterial dispersed in the base material, and the nanomaterial including electrically conductive nanomaterial. Such an item may be one of or a portion of an airplane, an airplane part, wing, edge of a wing, propeller, turbine blade, turbine blade edge, tower, wind power generator, pipeline, pipeline interior, pipeline exterior, bridge, bridge deck, cable, support structure, ship, ship hull, boat, boat motor, vehicle, rail, automobile, truck, part trailer, recreational vehicle, drilling system, pipe, tubular, casing, blowout preventer, seal, drilling equipment, drilling structure, drilling rig, conduit, offshore rig, centrifuge, shale shaker, screen, screen support, heat exchanger, finned tube, jet engine, tank, fabric, and cathodic protection structure.

In conclusion, therefore, it is seen that the present invention and the embodiments disclosed herein and those covered by the appended claims are well adapted to carry out the objectives and obtain the ends set forth. Certain changes can be made in the subject matter without departing from the spirit and the scope of this invention. It is realized that changes are possible within the scope of this invention and it is further intended that each element or step recited in any of the following claims is to be understood as referring to the step literally and/or to all equivalent elements or steps. The following claims are intended to cover the invention as broadly as legally possible in whatever form it may be utilized. The invention claimed herein is new and novel in accordance with 35 U.S.C. § 102 and satisfies the conditions for patentability in § 102.

CLAIMS

1. A method for heating comprising applying a heatable coating onto at least part of an item, applying electric current to the heatable coating thereby producing heat in the heatable coating and heating at least part of the item, the heatable coating comprising base material, nanomaterial dispersed in the base material, the nanomaterial comprising electrically conductive nanomaterial.

2. The method of claim 1 wherein the nanomaterial is one of a combination of two of, or a combination of three of nanotubes, nanoribbons, nanographene, transformed nanomaterial, carbon nanomaterial, and carbon nanotubes.

3. The method of claim 1 or 2, wherein the coating on at least part of the item is between 0.0001 and 1 inch (0.00025 and 25 cm) thick.

4. The method of claim 1, 2 or 3 wherein the nanomaterial, by weight, comprises at least 1 % of the coating.

5. The method of any preceding claim, wherein the nanomaterial, by weight, comprises at least between 0.1 and 32% of the coating.

6. The method of any preceding claim, wherein the coating has an electrical resistivity due to the nanomaterial which is in a range which is one of between 10 to 100 $g^*\Omega/cm^2$ and between 0.001 to 100 $g^*\Omega/cm^2$.

7. The method of any preceding claim, wherein the base material is one of, a combination of two of, or a combination of three of glass, natural fabric, synthetic fabric, metal, elastomer, wood, plastic, composite, polymer, thermoplastic material, thermoset material, and high density polyethylene.

8. The method of any preceding claim, wherein the coating is applied by one of dipping, spraying, spreading, trowelling, brushing, pouring, bonding, fusion bonding, and electrostatic coating.

9. The method of any preceding claim, wherein the electrical current is direct current.

10. The method of any of claims 1-8, wherein the current is alternating current.

11. The method of any preceding claim, wherein the coating includes a resin material.

12. The method of any preceding claim, wherein the item has a body with an outer surface and the at least part of the item is the outer surface of the body.

13. The method of any preceding claim, wherein the coating further comprises two or more than two spaced-apart electrical contacts to which the electrical current is applied.

14. The method of any preceding claim, wherein the nanomaterial is dispersed in the coating prior to application of the coating to the item by a method which is one of stirring, blending, mixing and sonication.

15. The method of any preceding claim, wherein the item has ice thereon and the coating is heated sufficiently to melt the ice.

16. The method of any preceding claim, wherein the coating provides an electrical ground for the item.

17. The method of any preceding claim, wherein the coating includes one of resin system, film, paint, and adhesive.

18. The method of any preceding claim, wherein an electrical system provides the electrical current to the coating.

19. The method of claim 18,. wherein the electrical system includes a power supply and a voltage regulator.

20. The method of claim 18 or 19, wherein the electrical system includes a sensor for sensing an event current source to apply electrical current in response to a sensed event, the event being one of ice formation and a predetermined state of temperature change.

21. The method of any preceding claim, wherein the base material is a cathodic protection material.

22. The method of any preceding claim, wherein the item is all or at least a portion of an airplane, an airplane part, wing, edge of a wing, propeller, part of a propeller, turbine blade, turbine blade edge, tower, wind power generator, pipeline, pipeline interior, pipeline exterior, bridge, part of a bridge, bridge deck, cable, support structure, ship, ship hull, boat, boat motor, vehicle, rail, automobile, truck, trailer, recreational vehicle, drilling system, pipe, tubular, casing, blowout preventer, seal, drilling equipment, drilling structure, drilling rig, conduit, offshore rig, centrifuge, shale shaker, screen, screen support, heat exchanger, finned tube, jet engine, tank, fabric, and cathodic protection structure.

23. A heatable coating for application to an item, the heatable coating comprising base material, nanomaterial dispersed in the base material, and the nanomaterial comprising electrically conductive nanomaterial.

24. The coating of claim 23, wherein the nanomaterial is one of or a combination of two of nanotubes, nanoribbons, nanographene, transformed nanomaterial, carbon

nanomaterial, and carbon nanotubes, wherein the coating is between .0001 and 1 inch thick, wherein the nanomaterial, by weight, comprises at least 1 % of the coating, wherein the coating further comprises at least two or two spaced-apart electrical contacts to which the electrical current is applied, and wherein the coating includes one of resin system, film, paint, and adhesive, wherein the coating has an electrical resistivity due to the nanomaterial which is in a range which is one of a range between 10 to 100 g*Ω/cm and a range between 0.001 to 100 g*Ω/cm.

25. The coating of claim 23 or 24, wherein the base material is one of or a combination of two of glass, natural fabric, synthetic fabric, metal, elastomer, wood, plastic, composite, polymer, thermoplastic material, thermoset material, and high density polyethylene, wherein the coating is applied by one of dipping, spraying, spreading, trowelling, brushing, pouring, bonding, fusion bonding, and electrostatic coating.

26. The heatable coating of claim 23, 24 or 25, wherein the coating includes a resin material, film paint or adhesive.

27. An item coated at least partially with a heatable coating comprising base material, nanomaterial dispersed in the base material, and the nanomaterial comprising electrically conductive nanomaterial.

28. The item of claim 27 wherein the item is one of or a portion of an airplane, an airplane part, wing, edge of a wing, propeller, turbine blade, turbine blade edge, tower, wind power generator, pipeline, pipeline interior, pipeline exterior, bridge, bridge deck, cable, support structure, ship, ship hull, boat, boat motor, vehicle, rail, automobile, truck, part trailer, recreational vehicle, drilling system, pipe, tubular, casing, blowout preventer, seal, drilling equipment, drilling structure, drilling rig, conduit, offshore rig, centrifuge, shale shaker, screen, screen support, heat exchanger, finned tube, jet engine, tank, fabric, and cathodic protection structure.

Fig. 1A

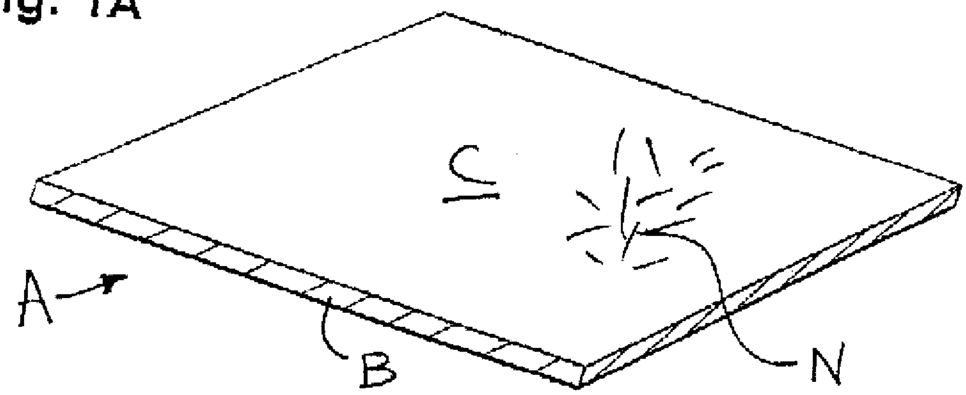


Fig. 2

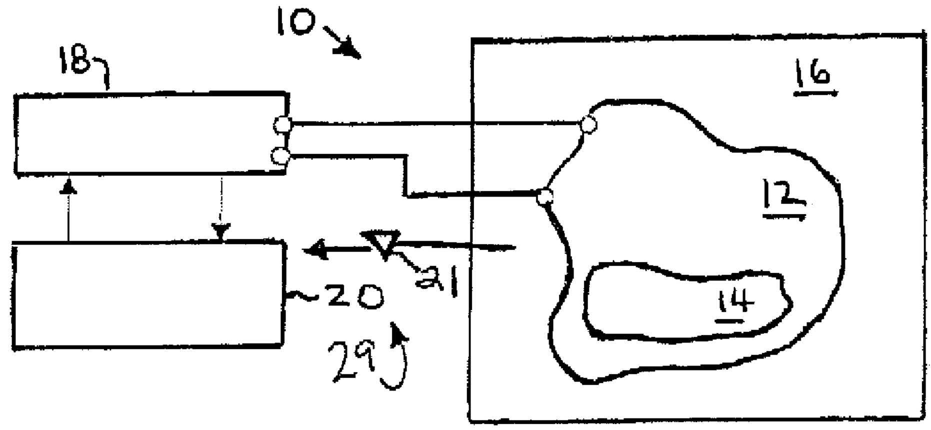


Fig. 3

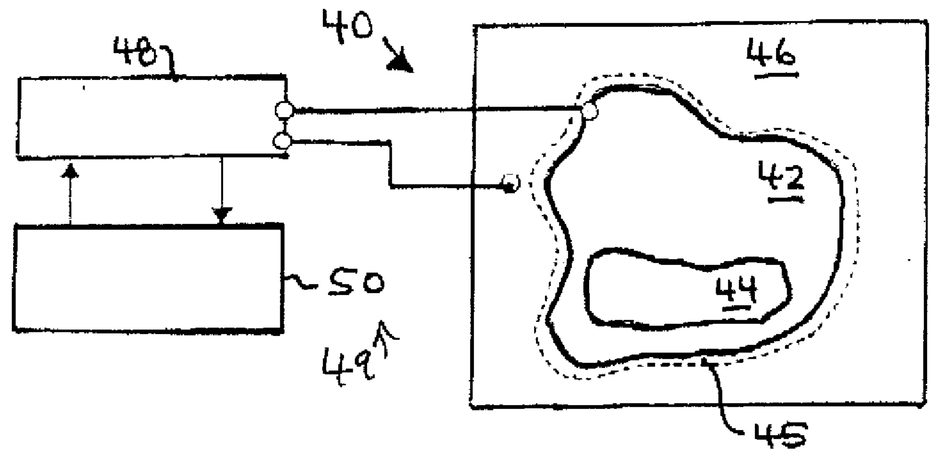
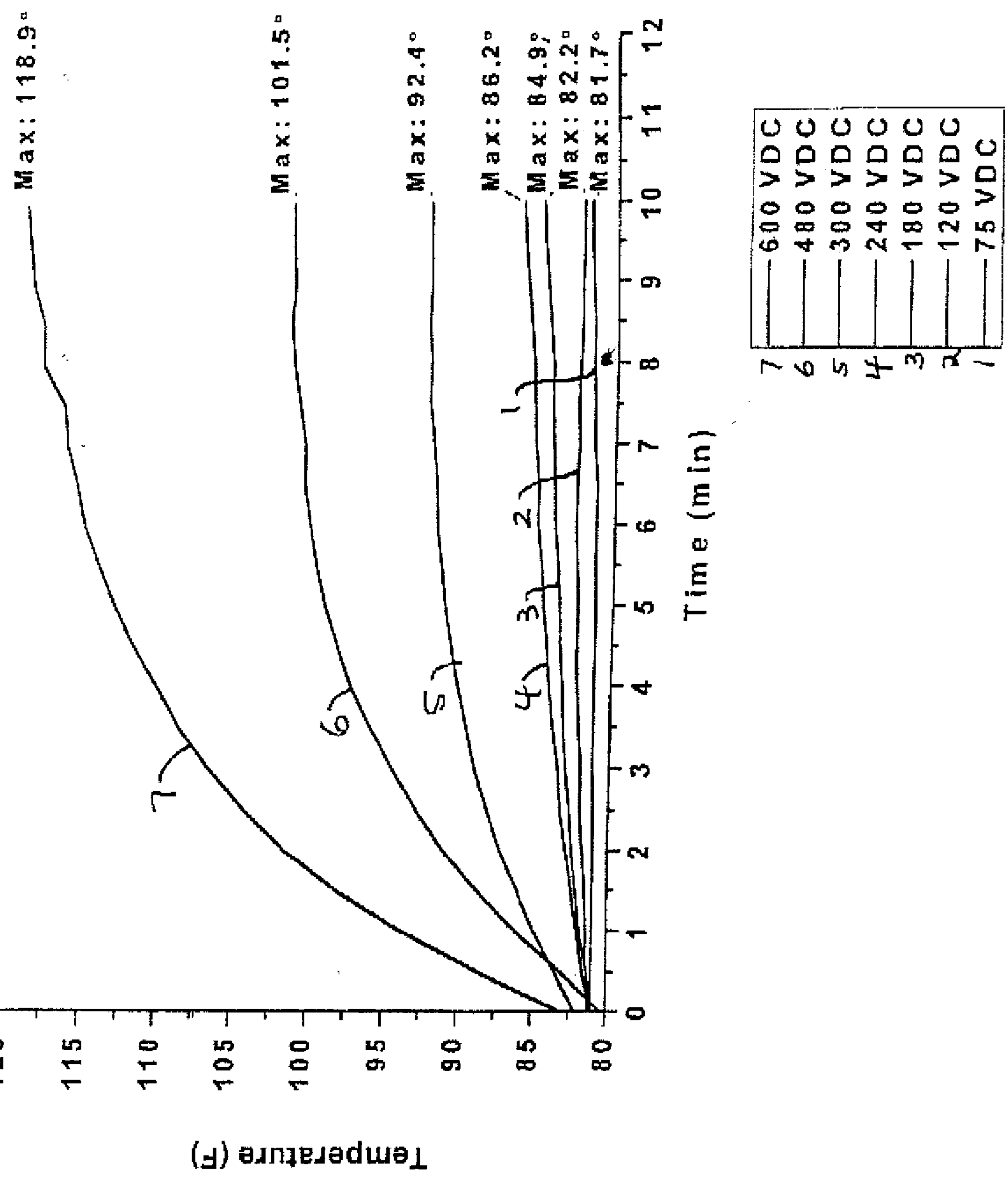


Fig. 1B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115
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105
100
95
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85
80
Time (min)
0
1
2
3
4
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6
7
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5 300 VDC
4 240 VDC
3 180 VDC
2 120 VDC
1 75 VDC

Fig. 4A

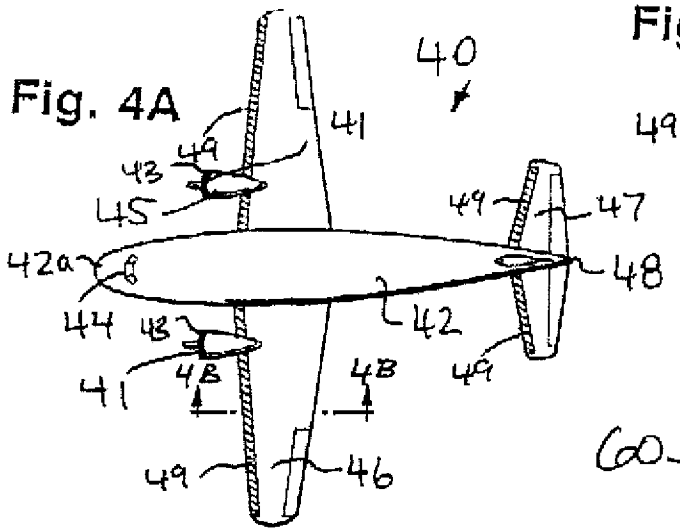


Fig. 4B

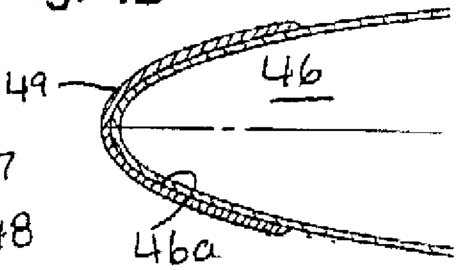


Fig. 5

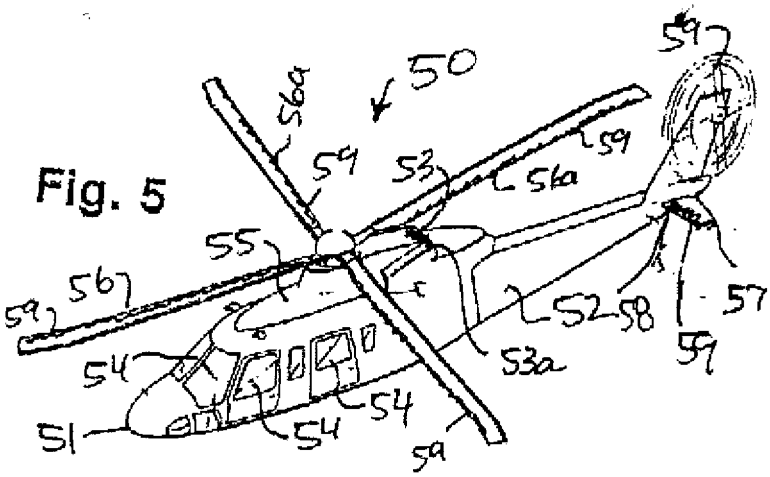


Fig. 6

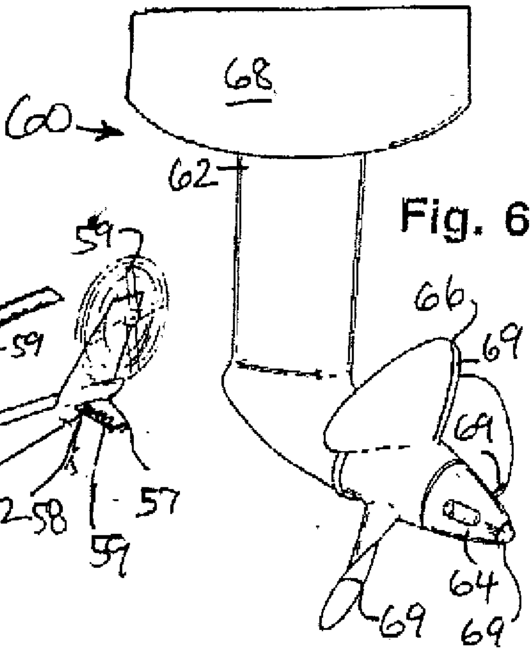


Fig. 7A

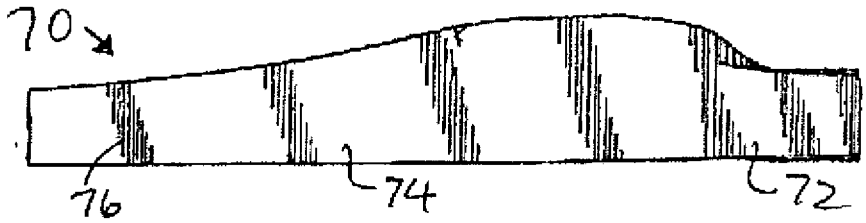


Fig. 7B

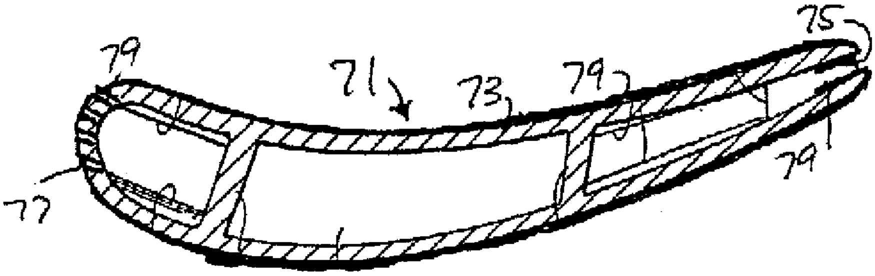


Fig. 8A

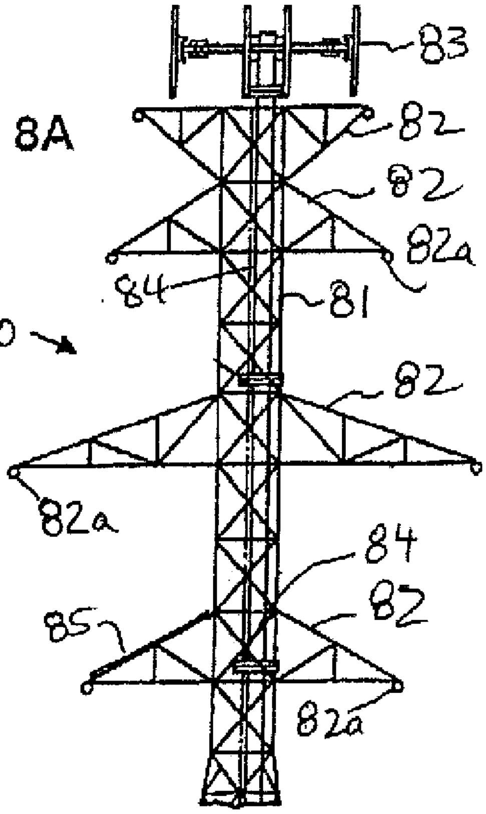
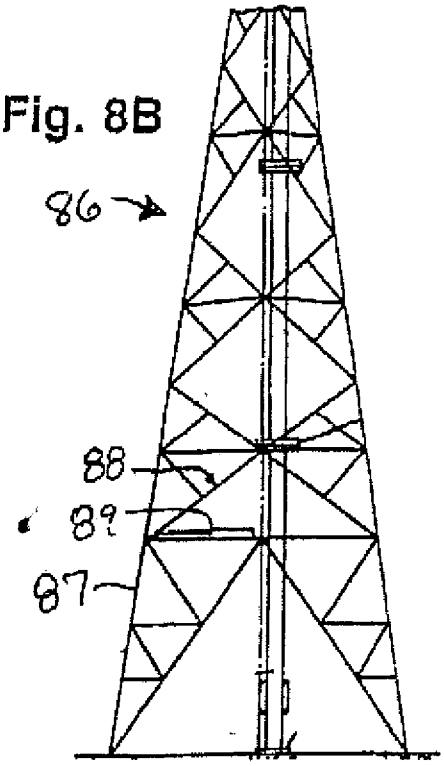


Fig. 8B



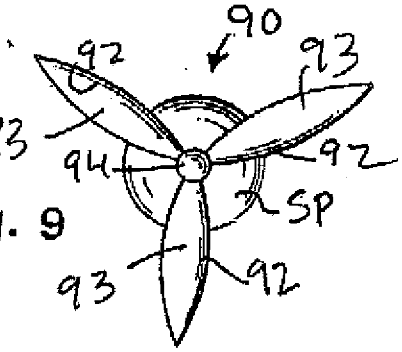


Fig. 9

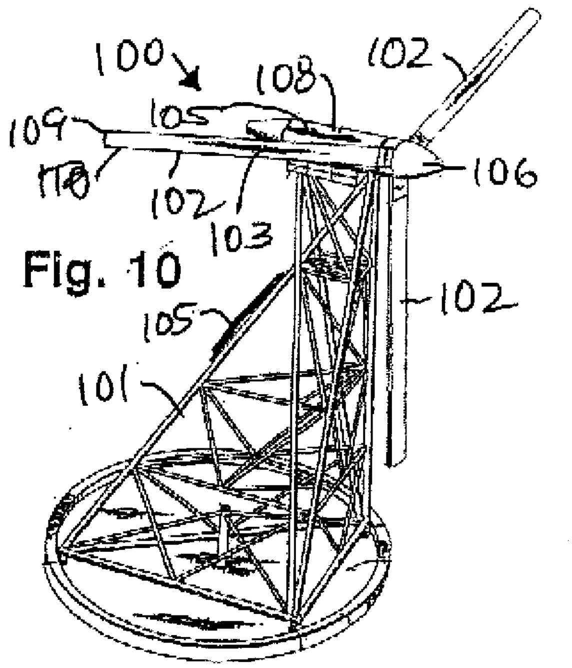


Fig. 10

Fig. 11A

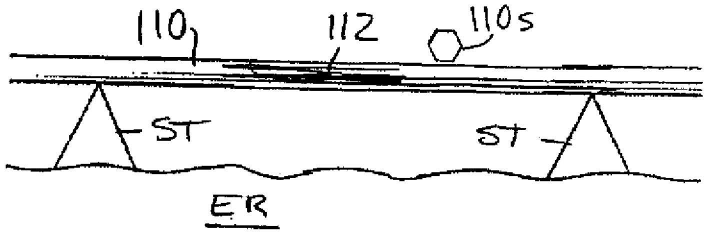


Fig. 11B

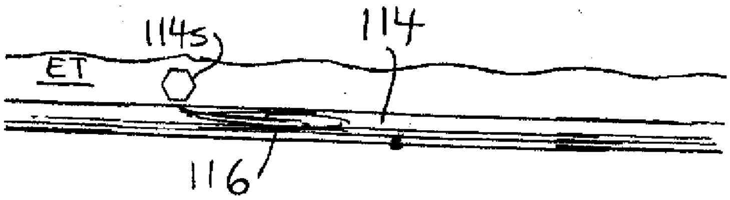


Fig. 12

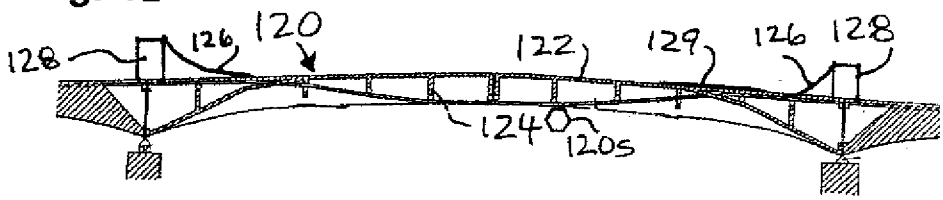


Fig. 13

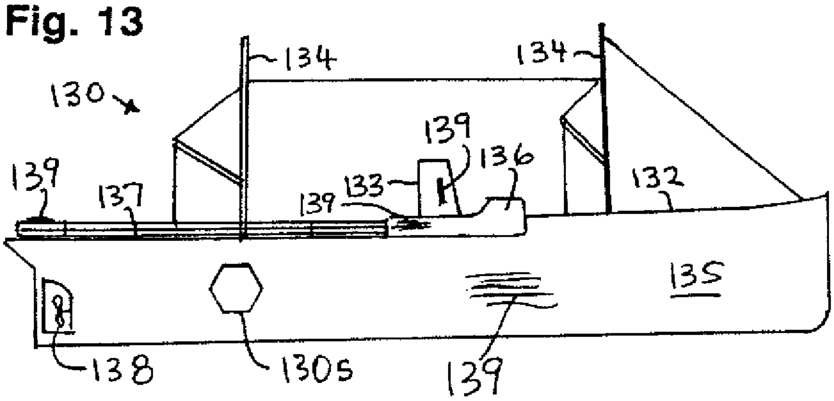


Fig. 14

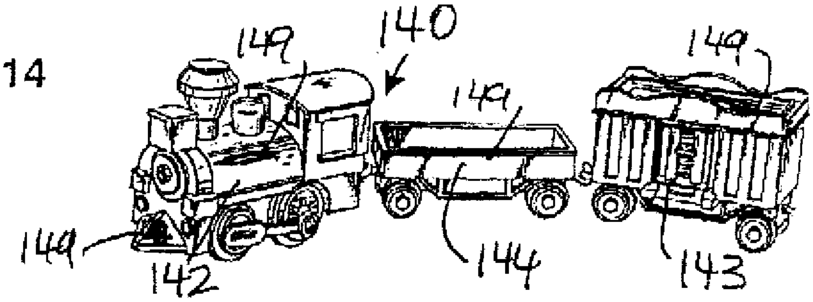


Fig. 15

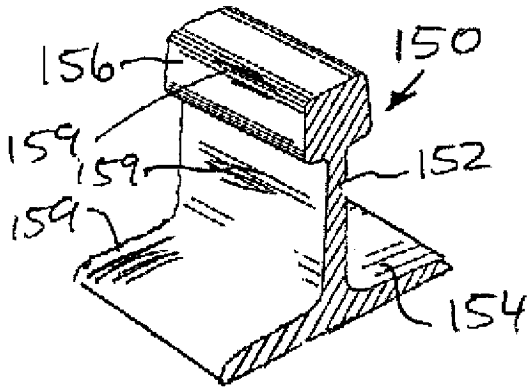
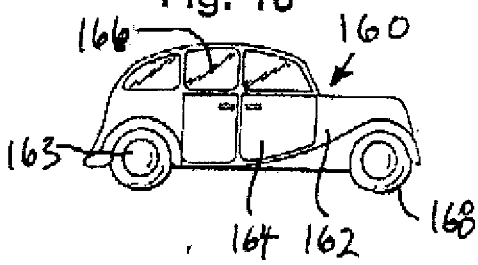
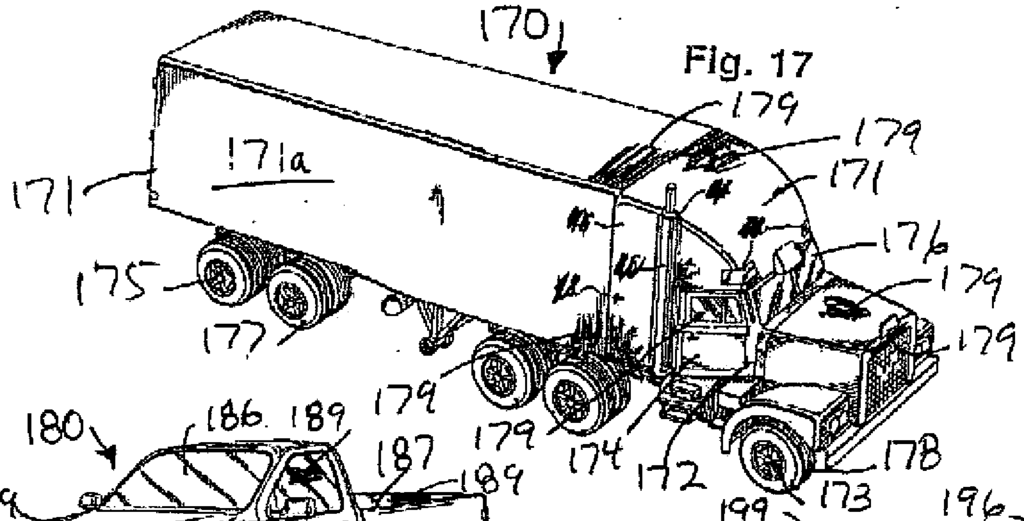


Fig. 16





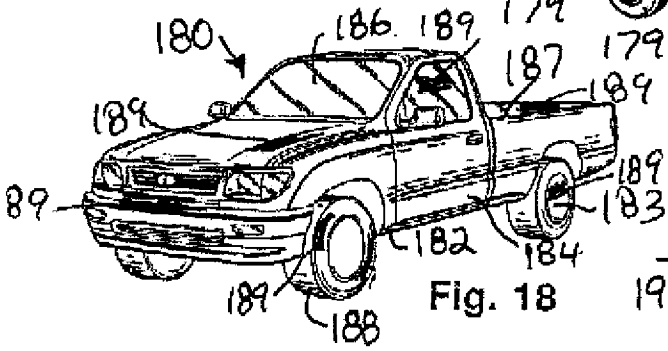


Fig. 18

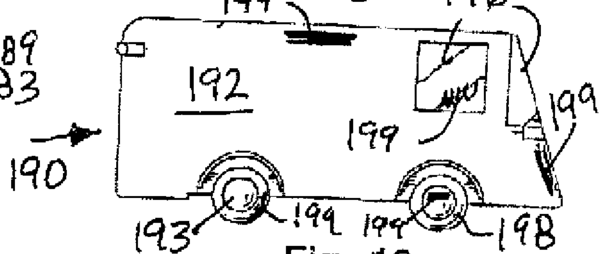


Fig. 19

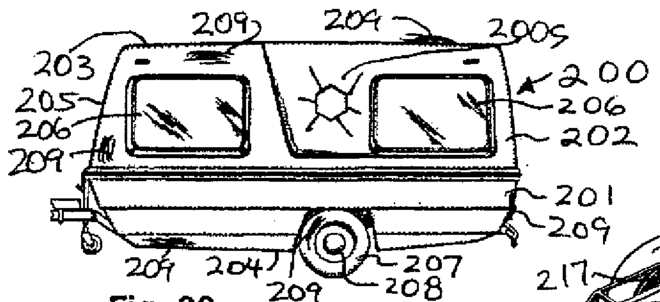


Fig. 20

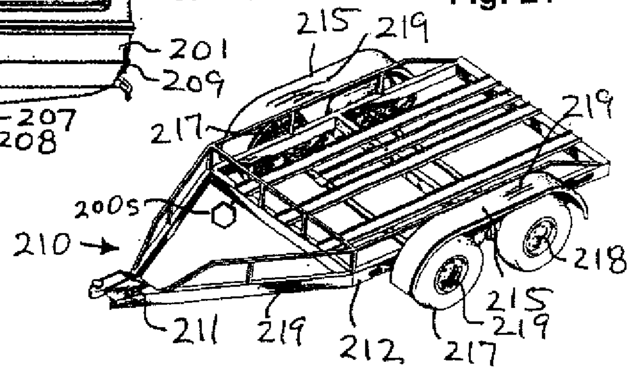


Fig. 21

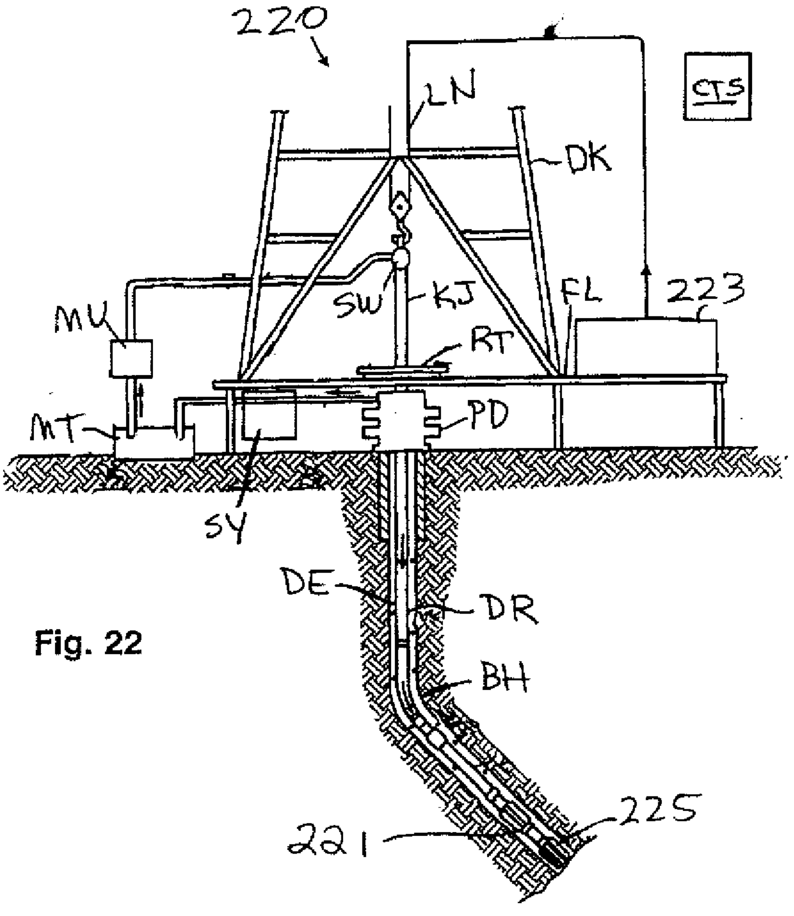


Fig. 22

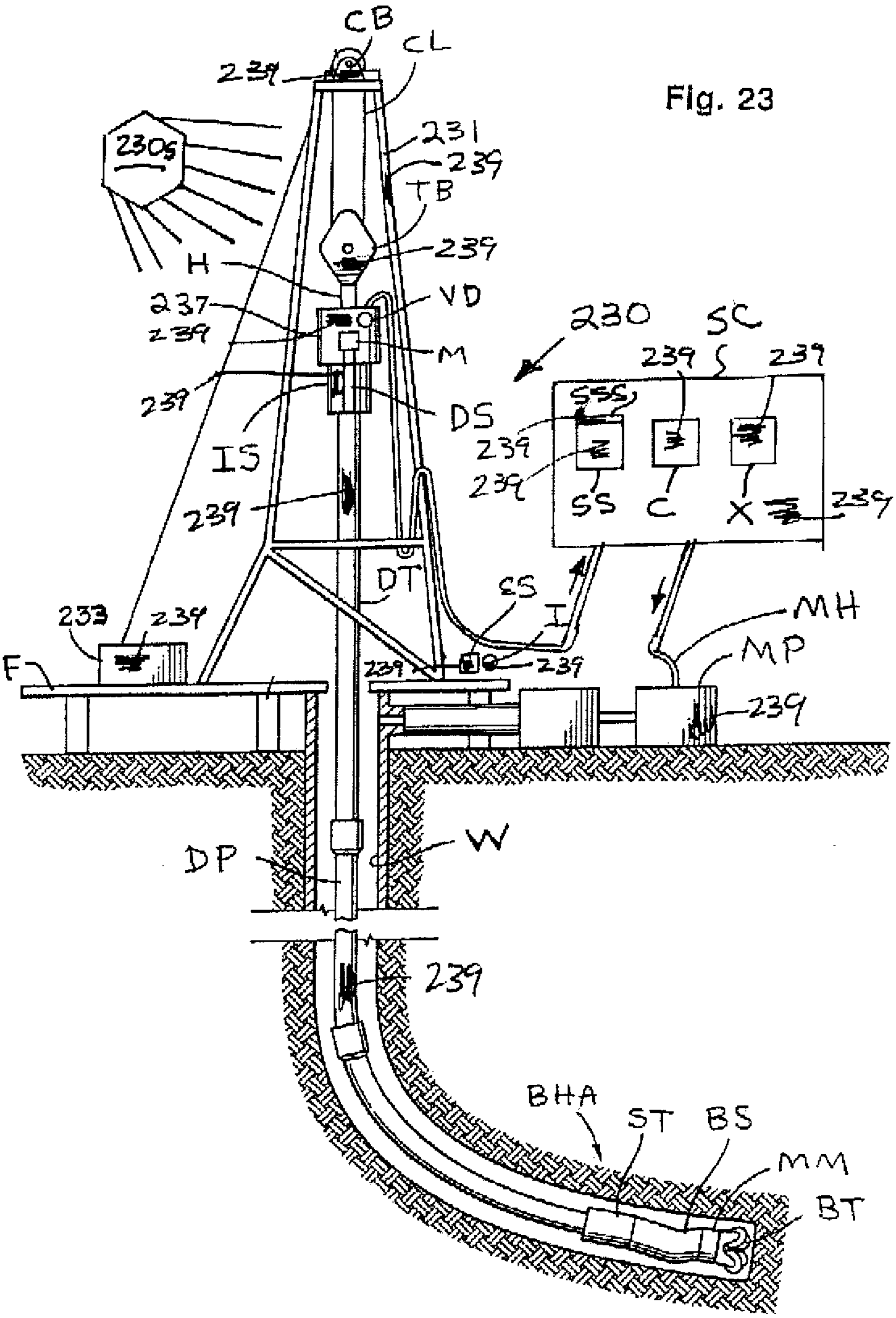

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Fig. 23

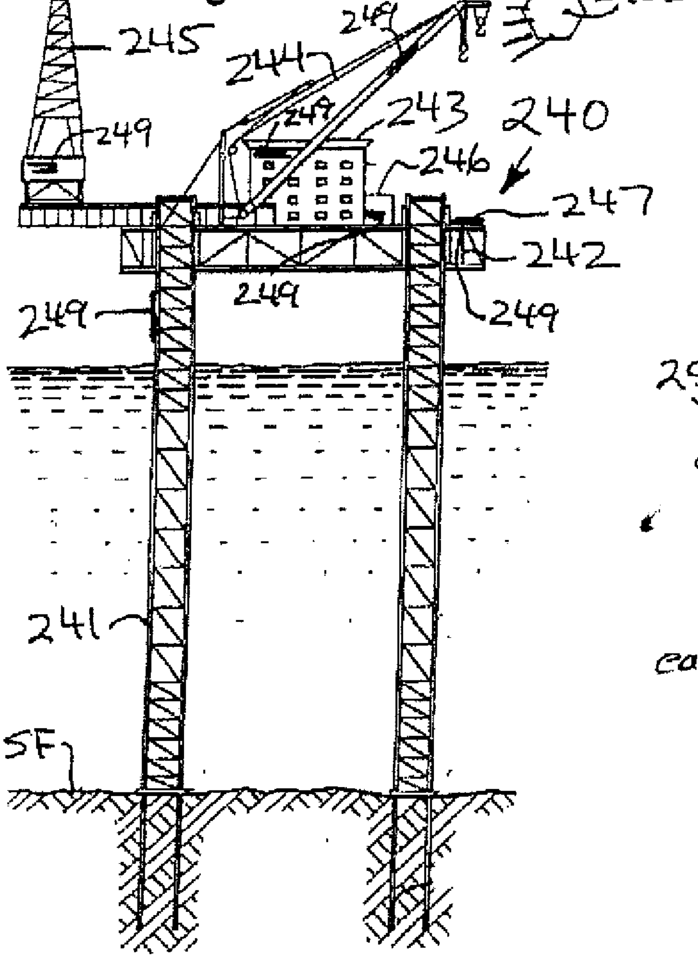


Fig. 24

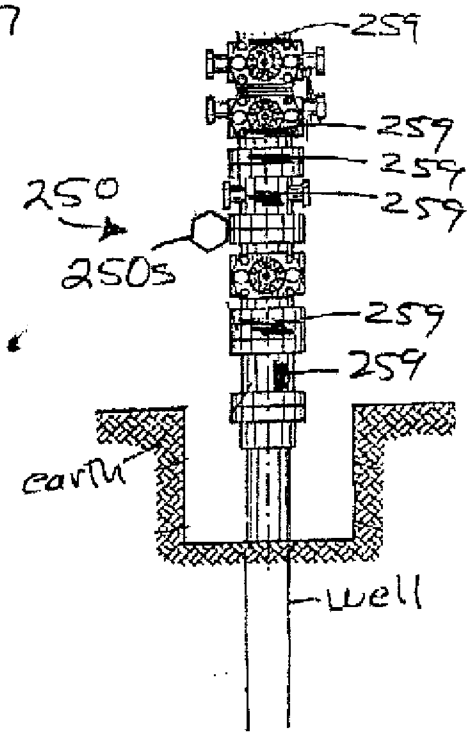


Fig. 25

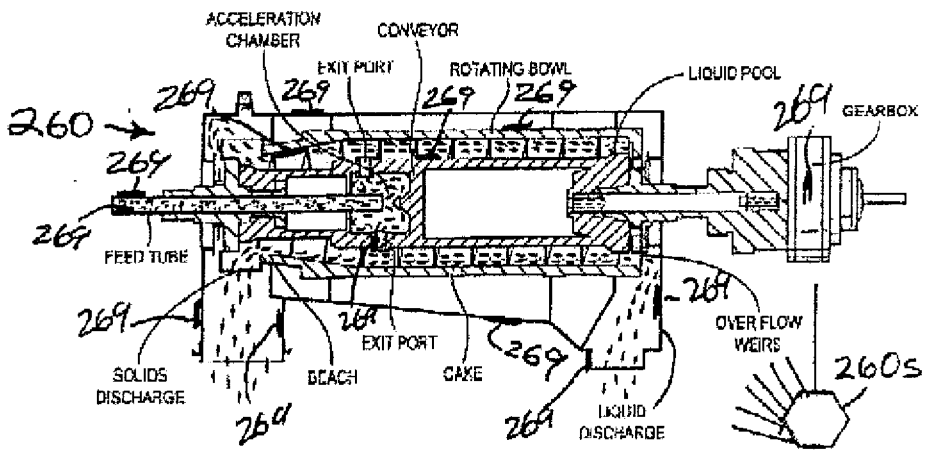


Fig. 26

Fig. 27

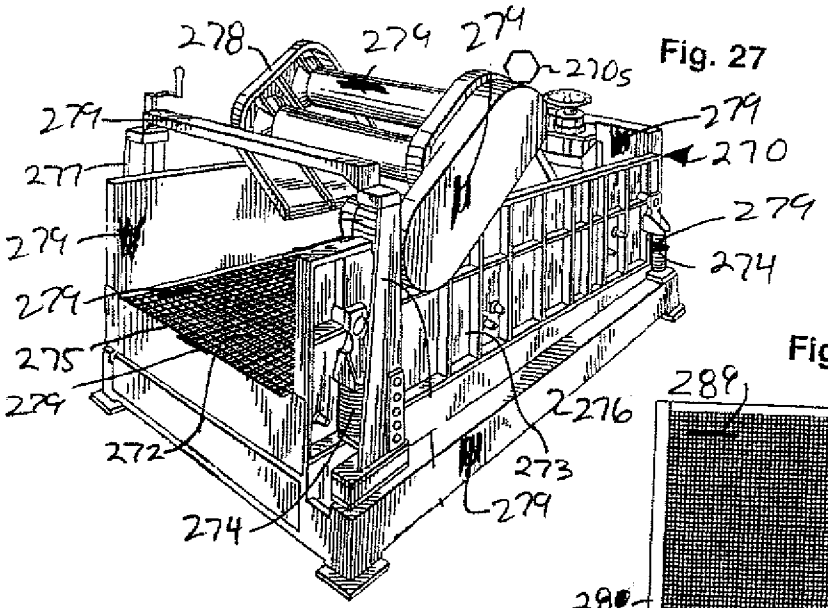


Fig. 28

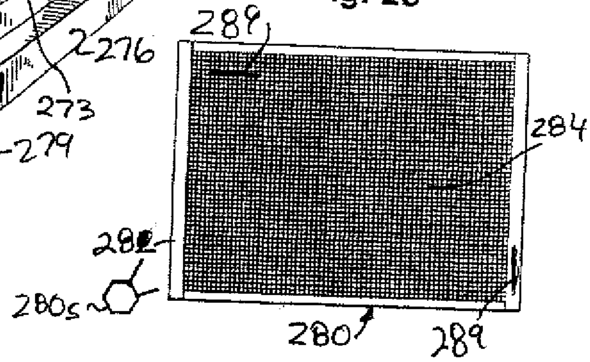


Fig. 29

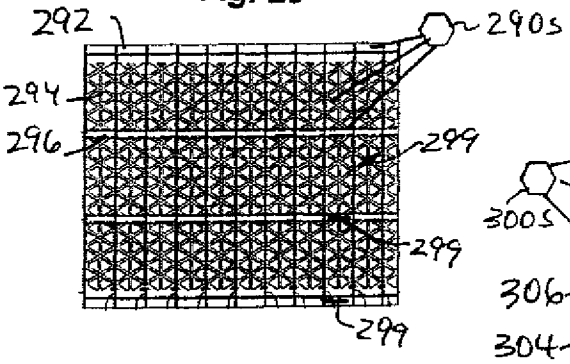


Fig. 30

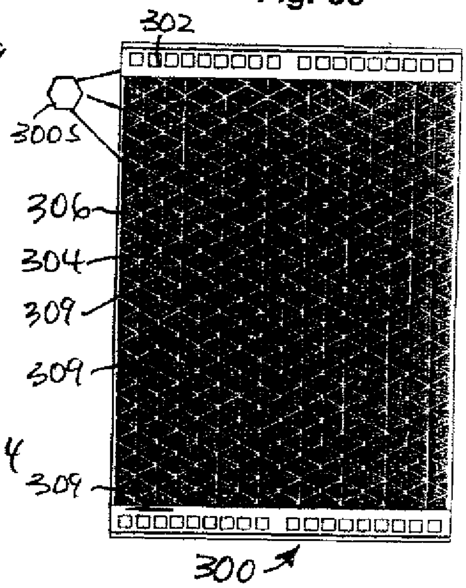
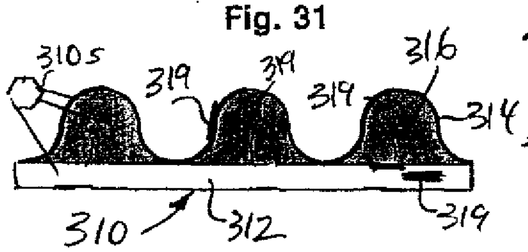


Fig. 31



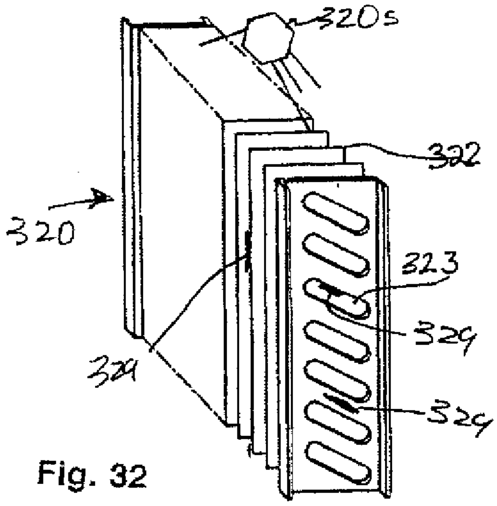


Fig. 32

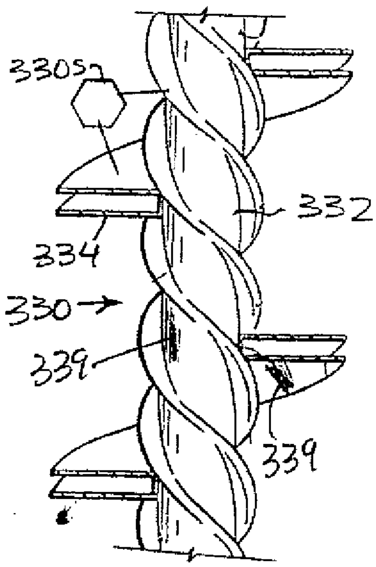
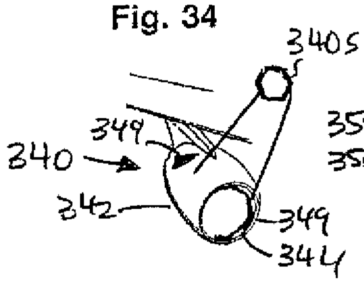


Fig. 33

Fig. 34



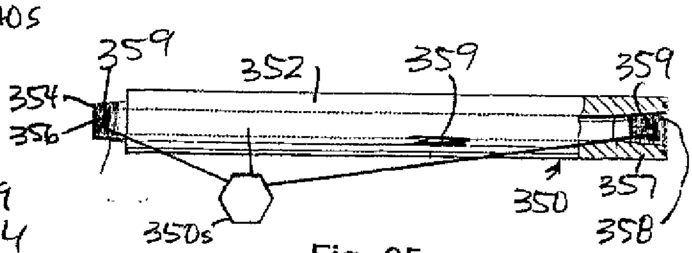


Fig. 35

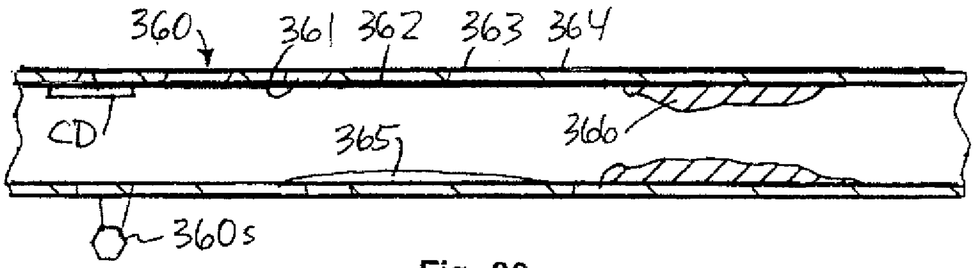
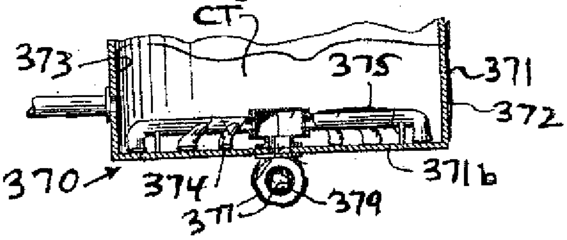


Fig. 36

Fig. 37A



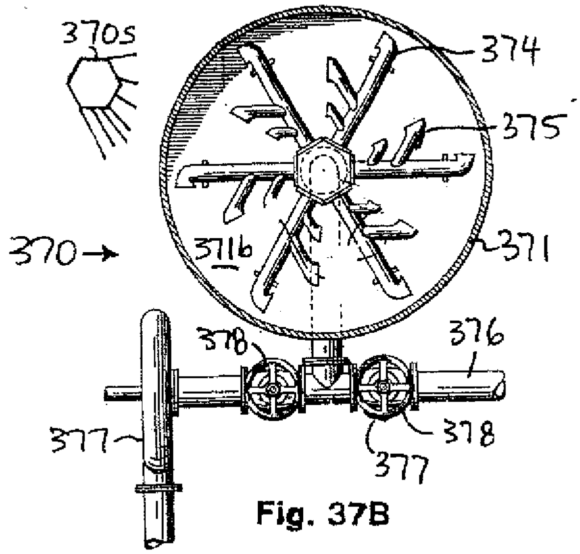


Fig. 37B

Fig. 38

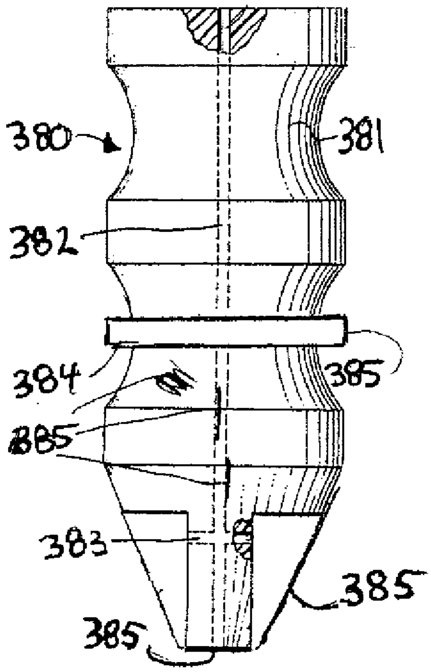


Fig. 39

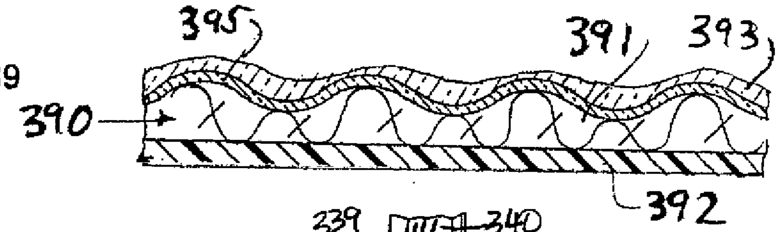


Fig. 40

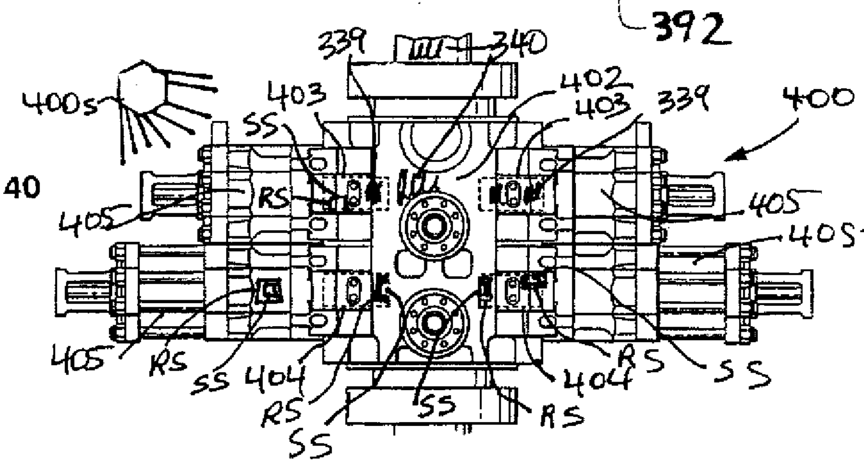


Fig. 41A

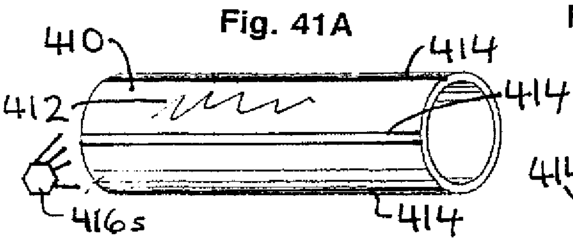


Fig. 41B

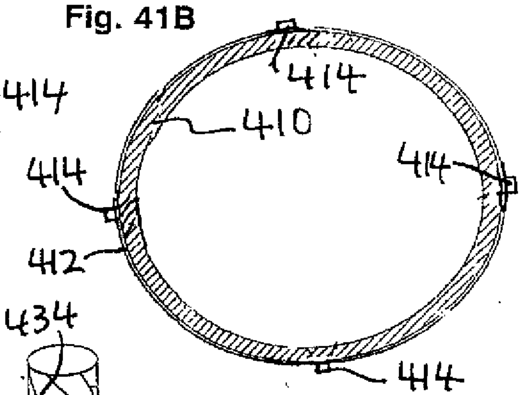
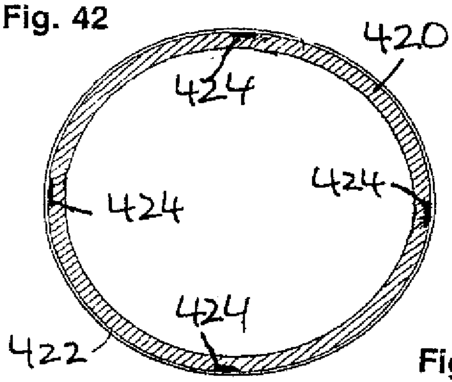


Fig. 42



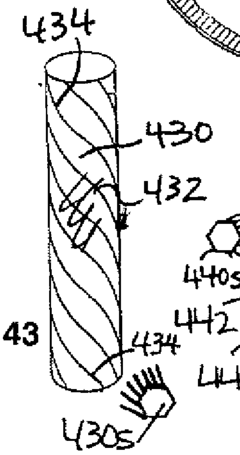


Fig. 43

Fig. 44

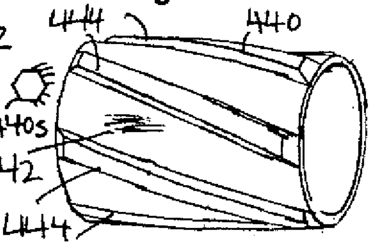


Fig. 45

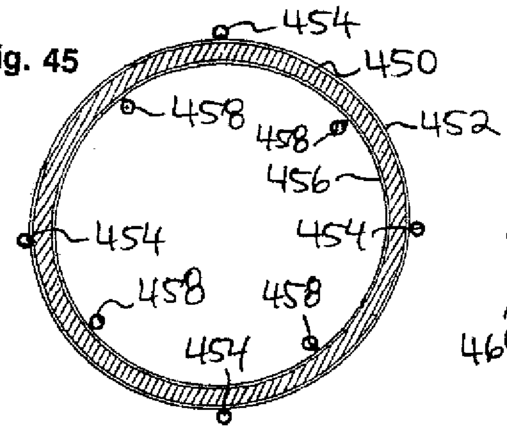
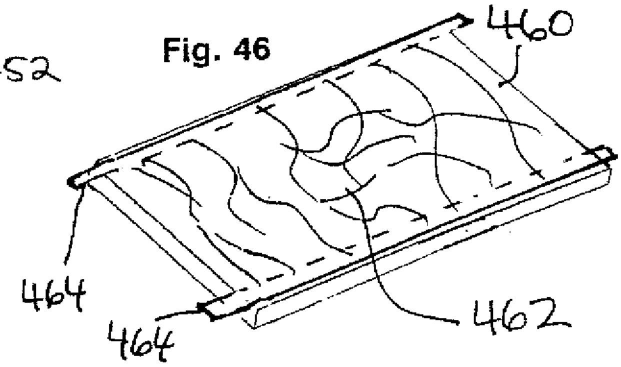


Fig. 46



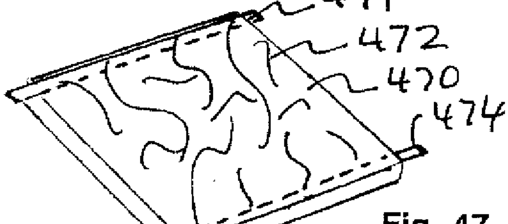


Fig. 47

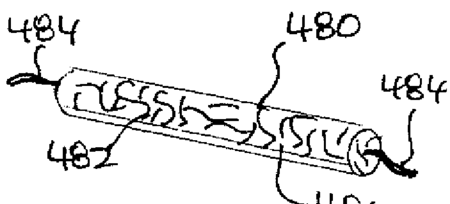


Fig. 48

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2011/051873

A. CLASSIFICATION OF SUBJECT MATTER
INV. C09D5/24 C09D7/12 H05B3/84 H05B3/14
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C09D H05B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2009/142447 A1 (KOREA MACH & MATERIALS INST [KR]; HAN CHANG-SOO [KR]; SONG JIN-WON [KR) 26 November 2009 (2009-11-26) paragraph [0004] paragraph [0056] paragraph [0061] claims 1-5 -----	1-9, 11-14, 16-20, 23-28

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
21 December 2011	29/12/2011

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Matthijssen, J-J

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2011/051873

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2010/213189 A1 (KEITE-TELGENBUESCHER KLAUS [DE] ET AL) 26 August 2010 (2010-08-26) paragraph [0049] paragraph [0108] - paragraph [0110] paragraph [0143] paragraph [0150] paragraph [0177] paragraph [0182] claims 1,11,12	1-28
X	US 2010/237055 A1 (ROUSSEAU INGRID A [US] ET AL) 23 September 2010 (2010-09-23) paragraph [0014] paragraph [0020] paragraph [0023] claims 1,7,10,17; figure 1	1-28
X	EP 2 112 868 A2 (IM KIJU [KR]) 28 October 2009 (2009-10-28) paragraph [0026] paragraph [0030] - paragraph [0032] paragraph [0037] paragraph [0040] paragraph [0045] paragraph [0067] - paragraph [0072] claims 1-5,11	1-28
X	DE 10 2007 018540 A1 (FRAUNHOFER GES FORSCHUNG [DE]) 30 October 2008 (2008-10-30) paragraph [0023] claims 1,8,9,13,17-19	1,2,4-9, 11-18, 22,23, 25-28
X	WO 2008/085550 A2 (BATTELLE MEMORIAL INSTITUTE [US]; HEINTZ AMY [US]; CHRISTIAEN ANNE-CLA) 17 July 2008 (2008-07-17) page 5, line 19 - line 21 page 6, line 16 - page 7, line 5 page 9, line 21 - line 25 page 13, line 7 - line 18 claims 1,2,6,10-14,17,19-21,34	1-28

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Information on patent family members

International application No
PCT/GB2011/051873

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